Work-in-Progress Draft Report of the Internet of Things (IoT) Advisory Board (IoTAB)

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Executive Summary

[this will be drafted after other sections are complete]

Introduction

The United States is undergoing a profound transformation - one that is driven by economic, societal, and cultural innovations brought about by the Internet of Things (IoT). This fourth industrial revolution intertwines connectivity and digital innovation with the opportunity to drive a revolutionary metamorphosis across all parts of our nation. By integrating the physical with the digital to interconnect devices, systems and people, we envision an Internet of Things that will enable a more resilient nation and:

Supercharge economic growth. IoT can unlock possibilities and efficiencies that were once deemed unimaginable to redefine industries, create new business models, increase competitiveness, and empower entrepreneurs to innovate. Smart manufacturing keeps American factories competitive against overseas competitors. Precision agriculture innovations increase crop yields while minimizing inputs in changing climate conditions. Businesses are supported by smart supply chains that are agile and resilient.

Increase public safety. IoT can enable agile and effective actions to prevent, protect, mitigate, respond and recover from man-made and natural disasters and hazards. Sensors embedded in roads inform engineers and planners of new ways to minimize accidents. 911 systems integrated with smart city technologies provide full situational awareness and help operators dispatch the most effective and appropriate resources. Smart buildings keep occupants safe against intruders, fires, and other hazards.

Create a more sustainable planet. IoT can revolutionize the way we use natural resources and protect the environment. Precision agriculture reduces water consumption and minimizes the use of fertilizers and pesticides. Smart grids dynamically adjust energy distribution based on demand and maximize use of renewable energy sources. Smart buildings reduce energy consumption. Smart traffic management systems optimize traffic flow while reducing congestion and emissions.

Individualize healthcare. IoT is a catalyst for redefining patient care, clinical practices, and the overall healthcare landscape. Wearable devices allow physicians to monitor patients outside traditional clinical settings, enabling early detection of health issues, personalized interventions, and a shift towards proactive, preventive care. Smart medical devices collect vast amounts of patient data which is analyzed to deliver personalized and precision medical treatments.

Facilitate equitable quality of life and well-being. IoT provides innovative ways of enabling equitable outcomes. Smart medical devices enhance telehealth capabilities, enabling patients in rural and remote communities to receive quality healthcare from doctors hundreds of miles away. Smart homes enable seniors and disabled adults to live independently. Smart mobility businesses improve accessibility for seniors, disabled individuals and residents with limited transportation options. Smart agriculture increases productivity and supports economic vitality in rural communities. Smart environmental monitoring systems help to identify and address pollution in marginalized communities. Smart classrooms provide educational access to all Americans, regardless of where they live.

In this global ecosystem, all developed nations seek these same advantages. Consequently, the adoption of IoT is not just an option; it is an imperative for the United States. It is a call to embrace a future where connectivity transcends boundaries, propelling our economy to new heights, fostering societal well-being, and ensuring that America remains at the forefront of global innovation.

Despite the unlimited potential and benefits of this transformation, a number of significant challenges and barriers stand in the way. It is imperative that we embrace the potential of IoT, acknowledge and overcome the challenges, and act with deliberation and urgency to realize its benefits for our economy and society. We must act with the same characteristics that built our nation - lead with vision and innovation, execute with passion and relentless tenacity, and persevere with unwavering commitment for the betterment of all Americans.

This report contains our findings and recommendations, based on experiences and perspectives from a cross-section of industry, local government, academia and other private-sector experts. We urge the Federal Working Group to study our recommendations, and adopt those that will best serve the needs of this nation.

Background

In January 2020, the Congress enacted the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (Public Law No. 116-283). Section 9204(b)(5) of this act established the Internet of Things Advisory Board (IoTAB) within the Department of Commerce. In accordance with the Federal Advisory Committee Act, as amended, 5 U.S.C., App., the IoT Advisory Board (IoTAB) was chartered in December 2021.

The IoTAB is chartered to provide advice to the Internet of Things Federal Working Group (IoTFWG). In support of the working group charter to develop a report to congress, the IoTAB will assist with:

- the identification of any Federal regulations, statutes, grant practices, programs, budgetary or jurisdictional challenges, and other sector-specific policies that are inhibiting, or could inhibit, the development of the Internet of Things;
- situations in which the use of the Internet of Things is likely to deliver significant and scalable economic and societal benefits to the United States, including benefits from or to—
    - smart traffic and transit technologies;
    - augmented logistics and supply chains;
    - sustainable infrastructure;
    - precision agriculture;
    - environmental monitoring;
    - public safety; and
    - health care;
- whether adequate spectrum is available to support the growing Internet of Things and what legal or regulatory barriers may exist to providing any spectrum needed in the future;
- policies, programs, or multi-stakeholder activities that—
    - promote or are related to the privacy of individuals who use or are affected by the Internet of Things;
    - may enhance the security of the Internet of Things, including the security of critical infrastructure;
    - may protect users of the Internet of Things; and
    - may encourage coordination among Federal agencies with jurisdiction over the Internet of Things;
    - the opportunities and challenges associated with the use of Internet of Things technology by small businesses; and
    - any international proceeding, international negotiation, or other international matter affecting the Internet of Things to which the United States is or should be a party.
    - The IoTAB shall submit to the IoTFWG a report that includes any findings and recommendations. The IoTFWG will be providing that report in its entirety to Congress.

The membership of the IoTAB consists of sixteen members (listed on the internal cover). The Secretary of Commerce appointed all members of the IoTAB and the Board has met on a regular schedule as necessary to complete the report.

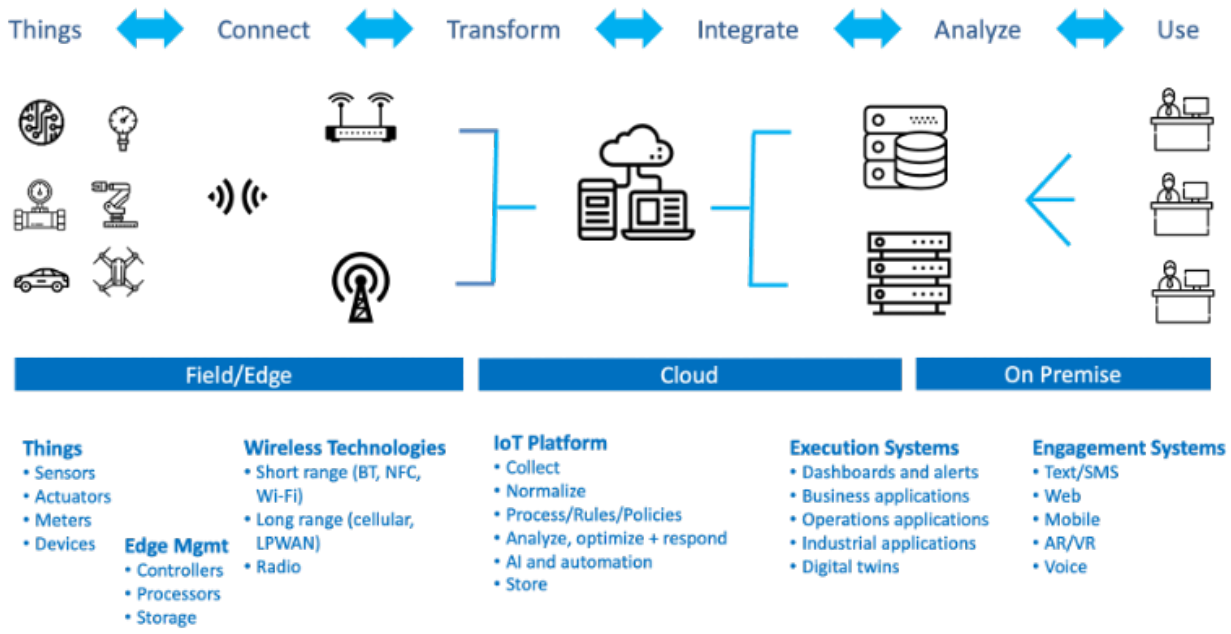
[Additional text will share the objectives of the report, and what the Board foresees as the outcome after the conclusion of its efforts. (Mention that this report is intended to highlight ways that IoT can be expanded and strengthened in ways that will bring economic prosperity and other benefits to the Nation and the World with a focus on increasing competitiveness, economic prosperity, and national security. Also highlight topics for the federal working group including ongoing efforts).]

Introduction to the Internet of Things

The Internet of Things is devices embedded with sensors and actuators and connected to the internet, enabling the internet—nominally a communications system—to react to and influence the world. As a result, the IoT is a collection of disparate technologies that work together to create innovative outcomes.

Data from IoT sensors may be used locally by an on-premises processor or sent over the internet to be handled centrally. Commands for device physical actions, such as “increase temperature” or “unlock door” may be generated locally or sent down from the central processing. The infrastructure of the internet is extended to the individual devices through various wireless technologies (e.g., Bluetooth, Wi-Fi, LoRaWAN, cellular 4G/5G, etc.)

A more detailed version of this process is shown below in Figure 1.



What can IoT do?

Adding sensors and actuators to the internet yields value from doing old things in new ways and doing new things that were not possible before. IoT drives value by creating opportunities for cost avoidance, increased efficiencies and productivity, reduced variability and waste as well as create new classes of data enabled products and services.

Figure 2 below shows an example of how this is possible with the example of a product manufacturing process enhanced by IoT.

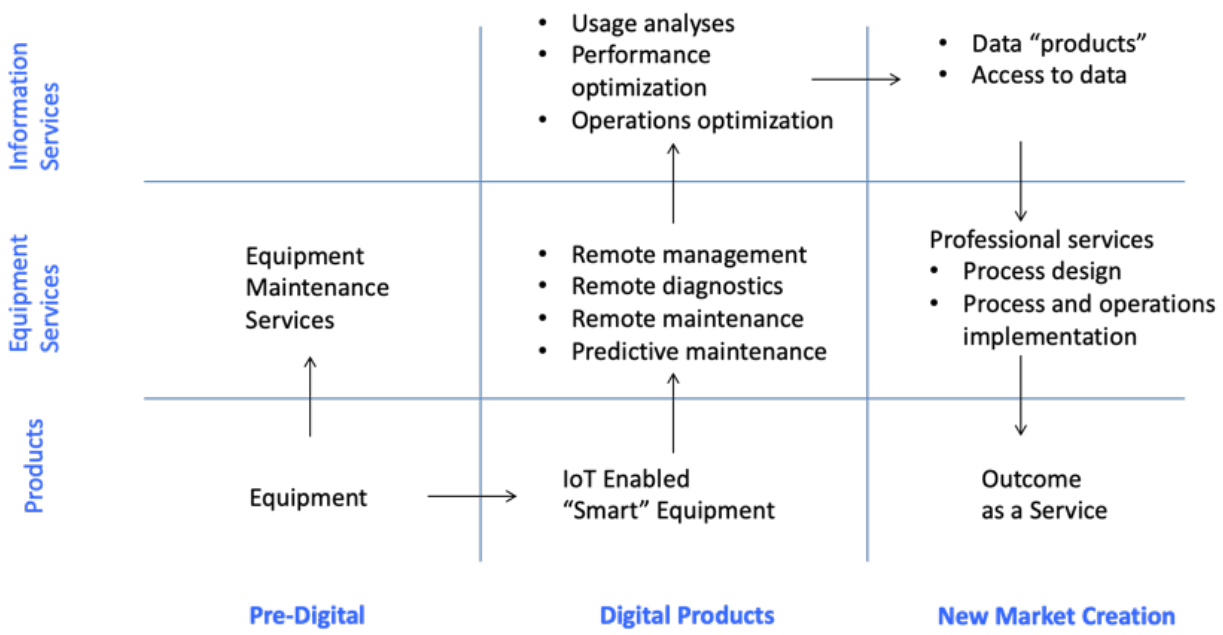


Figure 1: IoT Example: IoT-Enhanced Manufacturing Process and Resulting Opportunities

Prior to IoT, equipment dealers traditionally sold machinery, spare parts, warranties, maintenance contracts and installation and repair services.

The addition of IoT to the equipment creates new capabilities and value for both buyers and dealers. These "smart machines" allow dealers to offer new services and existing services in new ways. For example, onboard IoT sensors allow a dealer's technicians to monitor and diagnose their customers' machinery remotely and avoid an onsite visit. Predictive algorithms driven by IoT sensor data alert technicians when maintenance and repairs are needed, order a replacement part and then schedule a technician to replace the part. This helps the customer avoid unplanned machinery downtime and maintain operational productivity.

At the same time the IoT sensors collect large amounts of data, including machinery usage data from its entire customer base which is aggregated by the manufacturer to understand how their machines are used. This information is analyzed by company engineers to create new services and applications that are sold to the customers. For example, the information can be used to create performance optimization software and consulting services. Customers purchase these new information products and services because it further enhances their operational productivity, reduces inefficiencies and enables them to take on larger jobs.

For example, in a manufacturing context, the data and insights collected from "smart machines" can be aggregated, packaged and sold to lubricant vendors, who use the information to create more effective premium formulations. The data can also be purchased by insurance companies who use it in a way to minimize on-the-job accidents. Consultants use the same data to help the factories plan and implement operational process improvements.

Finally, “smart machines” provide factories with the capability to create innovative new businesses, such as “Manufacturing as a Service”. With full visibility into the actual utilization of their production equipment, factories can offer excess capacities and capabilities to customers. The “uberization” of factories turns manufacturers into “manufacturing utilities” to offer contract manufacturing at agilities, scales and efficiencies unmatched by traditional factories.

Specific Applications of IoT

[Benson has provided some thoughts on different flavors of IoT, how they are different, and what they do specifically. We need to add a sentence or two here for introduction.]

There are several specific applications of the IoT. Each application has its own unique set of use cases, benefits and challenges. This section will highlight a few in greater detail.

IoT for the Consumer

Internet of Things (IoT) technology is becoming increasingly prevalent in consumer products, from smart TVs and wearable devices (fitness trackers, smartwatches), to products that are typically not thought of as “consumer electronics”, such as refrigerators and door locks. These products connect to the internet and other devices and can gather data about their operation and about the user. IoT adoption can bring benefits to the consumer in many areas, such as:

- **Convenience:** Consumers can access data from and control devices remotely, providing convenience such as using a connected thermostat to monitor home temperatures while away on a trip, or using geofencing features to adjust the temperature when returning home. Many users enjoy the convenience of a smart speaker in the kitchen, for setting cooking timers or determining quantities.

- **Safety:** Connected baby monitors and security cameras can allow for remote monitoring and recording of video in and around the home, while smart door locks and garage doors can report their status and be controlled remotely. Increasing usage of video doorbells and other connected cameras demonstrates a consumer desire to adopt IoT for taking precautions around physical safety.

- **Maintenance/Monitoring:** Connected devices can report on their own status, such as an air purifier alerting of the need for a filter change. They can monitor conditions; for example, a smart water leak detector senses water flow through pipes and can send an alert for even small water leaks.

- **Cost Savings:** A smart water sprinkler controller can incorporate data about weather conditions and sensor inputs on soil moisture, to optimize the frequency and amount of lawn watering.

- **Health:** Wearable devices such as fitness trackers and smartwatches encourage users to track their health data and increase their physical activity, often “game-ifying” the

experience to promote regular use. Other connected devices such as body scales, blood pressure monitors, and CPAP machines allow consumers to see trends in their data, improve compliance, and can optionally report back to the health provider.

- **Entertainment:** Consumers stream a wide selection of video and audio content on their smart TVs and wireless speakers, and connected cameras inside the home can provide hours of entertainment watching and interacting with house pets remotely.

Despite these potential benefits, since IoT products gather data and connect to the internet, they present challenges for the consumer related to:

- **Cybersecurity:** The number of devices connected to a home network increases the potential cyber-attack surfaces, and as a result, the security of the home router and of all the devices connected to the network becomes a critical link. There are particular concerns around child safety, such as intruders on baby monitors or smart speakers.

- **Data Privacy:** This involves not just the possibility of personal data being accessed by a hacker, but also the collection of user data by the product manufacturers.

- **Usability:** Not all consumers are tech-savvy, and many current IoT products are difficult to set up, use, or troubleshoot without technical knowledge.

- IoT is uncharted territory for many consumers, who may not know how best to protect their network, or what is happening to their data and personal information with these types of products. With no easy way for consumers to navigate their privacy and security with IoT products, they can become paralyzed about these issues, which could slow the adoption of IoT. Addressing these challenges with certain practices during product development can result in products that are more consumer-friendly and can encourage adoption of Consumer IoT

Robust adoption of Consumer Iot will depend on consumer trust and acceptance of IoT. Proliferation of the measures listed above will improve products from a consumer perspective, and initiatives such as the U.S. Cyber Trust Mark will facilitate consumer trust of the products' security; a similar effort related to data privacy would be a welcome addition.

IoT in the Smart Home

Today's homes are becoming increasingly digital and connected. Digital networks and telecommunications systems join HVAC (heating, ventilation and air conditioning), plumbing, and electrical systems as essential infrastructure of a functioning home. Broadband Internet connects these homes with a variety of services, including news, entertainment, business and government services, education, and healthcare.

The connected home contains a variety of disparate digital systems, including audio/video (television, receivers, DVD players, media servers, etc.), security and access (alarms, cameras, electronic doorbells, digital door locks, etc.), HVAC (thermostats, fans, etc.), energy

management, and automation (lighting, windows, blinds, garage doors, irrigation, etc.). These systems operate as individual systems, and sometimes in an orchestrated fashion through a central home control and automation system.

IoT adds intelligence to this connected home in multiple ways. Sensors monitor a variety of conditions around the home, while the data collected is routed to a cloud data center and analyzed by software algorithms to create optimized responses. Homeowners can access the information and interact with the home remotely through a website or a mobile app. IoT enabled home systems provide significant improvements in energy efficiency, occupant comfort, security, and other functions.

Smart home technology is diverse. The capabilities of IoT connected products for a smart home can generally be classified into four main functions: monitor, control, optimize, and automate. Some smart home applications perform one function, while others do more.

The potential benefits include greater comfort, convenience and security with reduced energy consumption.

Monitoring

IoT connected devices monitor the condition of a home and inform the occupant of abnormal conditions or take appropriate automated responsive actions. For example, pool safety is a concern for families with young children. Connected video cameras monitor the swimming pool, alerting residents to unaccompanied children entering the restricted area. Another important smart home application is the use of IoT to monitor the health and safety of elderly residents living alone. In-room microphones detect the sound of falls or cries for help, notifying family members and caregivers. In-room proximity sensors paired with algorithms monitor resident movements throughout the home, and alert caregivers of unusual patterns of activity or inactivity. Another common smart home IoT application is an outdoor air quality monitor. These monitors detect the pollution levels of the outside air and share that information on a website. This allows the community to understand the current air quality and take the necessary precautions, such as staying indoors or refraining from heavy physical activity.

Control

The connected nature of IoT technologies allows users to remotely control and operate smart home devices and equipment. For example, a resident can unlock a smart door lock remotely to allow a guest into the home. A resident can turn house lights on and off through a control panel in the home, or remotely through a mobile phone app. Smart home applications can be controlled manually, or autonomously in response to pre-set threshold conditions or intelligent algorithms that learns from specific patterns in data. A smart irrigation system turns off the garden sprinklers when it senses rain or delays operation if soil moisture levels are high. A IoT-enabled HVAC system automatically resets to lower setpoints when it senses no occupants at home.

Optimize

The use of data collected from IoT connected devices have made homes more livable, safer, convenient, and economical to maintain. Algorithms analyze the data to optimize the use of home systems. For example, smart HVAC systems can be optimized based on patterns of use,

automatically turning on thirty minutes in the morning before first activity and turning off thirty minutes before occupants go to bed, based on historical data. Similarly, a home with a solar panel and battery system optimizes the mix of electricity stored, discharged to the grid, and used by the home users based on past data.

Automate

Home automation platforms integrate various systems together, such as lighting, energy management, blinds, audio video, IoT enabled systems (appliances, thermostats, etc.) and others. This integration enables the various systems to orchestrate and work together. Combining monitoring, control, and optimization capabilities permits home systems to operate autonomously with little human input. For example, smart home algorithms know when occupants return each day, and what rooms they used in the house. Sensors detect the resident's car entering the driveway and initiates an automated sequence to open the garage door, turn on the lights in the areas of the house used by the resident, turn on the HVAC systems, turn on the oven, and turn on the television system to the right channel. As the evening progresses, lights in the sleeping portions of the home are turned on while the common areas are turned down. Select appliances, such as the dishwasher and the laundry appliances activate at midnight when the electricity rates are the lowest.

While smart home technologies provide a variety of benefits to residents and homeowners, there are some challenges to using these technologies. These include:

Interoperability

Modern homes are comprised of a variety of mechanical and electrical systems, electronics, appliances, and other equipment. While any single system can be optimized to improve efficiency or reduce operating costs, the real value is when these individual systems are linked together, combined with sensor and external data sources, and then managed as an integrated system. The lack of interoperability between the different systems, as well as similar systems from different vendors, hinders integration and data sharing. Further complicating matters are competing smart home standards that make operating all the IoT connected devices challenging. Recent industry collaboration has resulted in the Matter standard. While the Matter 1.0 standard officially launched in 2022 and promises the potential for interoperability between various smart home devices, there are still many existing devices and systems in the market that are not interoperable and compatible.

Privacy

Smart home technologies collect a lot of information that may be private to a resident. For example, the collected data may contain both personally identifiable information (PII) as well non-PII information. While some data collection is unavoidable in order to offer personalized and relevant experiences and outcomes, smart home users are concerned with how that data is used, stored, and secured, as well as who has access to it. T

Cybersecurity

Smart home technologies create new vulnerabilities and attack surfaces in the home network. While home networks are smaller and simpler compared to their enterprise network counterparts, they are also less secure. Enterprise networks are well maintained and updated

frequently. In contrast, home networks are seldom updated, configured correctly, and maintained. The integration of IoT devices into this network greatly increases cybersecurity risks. Cybercriminals can penetrate these networks through vulnerable IoT devices and gain access to sensitive homeowner information, as well as plant malware into the devices and network. In other cases, cybercriminals can access IoT devices and intercept the data streams, such as a video feed from a camera system.

Subscription Plans

Many smart home technologies are offered as a hardware purchase and a subscription service. For example, one manufacturer sells a smart doorbell and an accompanying subscription service to access stored video. Because IoT and smart home technologies collect a lot of data, storing growing amounts of data over a period of time is expensive. Many manufacturers, especially smaller ones, are unable to “absorb” that cost and must pass it on to the consumer and homeowner. In other cases, smart home technology manufacturers offer “premium” features on a subscription basis. While there may be justification for these subscription costs, buyers are accustomed to paying once and feel that they are “nickel and dimed” by these subscription services.

User Experience

Smart home and IoT technologies offer benefits to its buyers, but those benefits may not be equally accessible to all. Complex configuration and setup processes hinder less sophisticated owners and require 3rd party installers. It may lead to improperly configured devices that function poorly. In addition, some devices are poorly designed with little thought for user experience. These poorly designed user interfaces (UI) and experiences (UX) discourage users with limited digital literacy from fully accessing and using the technology to its fullest. For example, smart home technologies that are controlled by voice commands can be challenging. The commands must follow a specified format and not in a “natural language” and have trouble accurately recognizing accents.

Maintenance and Upgrades

Smart home technologies must be maintained and updated frequently to stay current, secure and functional. However, some users are hesitant to do so because in an integrated smart home, software upgrades to one component in a system may “break” the integration with other components in the same system or other systems. Repair of this breakage may require reconfiguring of select components in the system and are beyond the capabilities of most users. These “breaks” are more likely between components from different brands. Not all upgrades are performed “over the air” as some must be done in-person. These “truck rolls” are expensive and may hinder upgrading firmware.

IoT in the Industrial Sector

IoT technologies are used in industrial applications such as energy (oil and gas, etc..), mining, chemicals, and transportation (rail, aerospace, etc.) These technologies are also prevalent in manufacturing, monitoring, process control and operations, and supply chain management. Many equipment manufacturers use Industrial Control Systems, otherwise known as ICS, that are used to control processes like manufacturing, product handling,

production, and distribution. ICS includes Supervisory Control and Data Acquisition (SCADA) systems, distributed control systems, and programmable logic controllers that incorporate IoT technologies. These technologies are often also referred to Operational Technologies (OT). OT is comprised of hardware and software that detects or causes a physical change through the direct monitoring and/or control of industrial equipment. OT devices are those that are not broadly defined as ‘consumer’ due to their usage in commercial operations and are not available or readily available for sale to the public.

IoT technologies in industrial markets together with components like sensors, data storage and integration, data analytics, and machine learning, can be applied to SCADA systems to improve interoperability and coordination among different machines. The sensors collect new data from various equipment and continuously feed the data into the analytics. This way, machine learning algorithms can learn from past data and fine-tune the settings on different machines for thousands or even millions of cycles to reach the optimal point of the entire system. Harnessing IoT in industrial markets brings several benefits:

1. **Increased efficiency in manufacturing operations**. IoT gives manufacturers and industrial operators the ability to automate and optimize their operating equipment efficiency and/or utilization. The use of robotics and automated machinery can boost productivity and help manufacturers streamline productions, reducing unplanned equipment downtime. Using sensors, manufacturers and utilities gain valuable insight into operational performance of pieces of equipment as well as entire systems.

2. **Reduction of errors**. Through digitalization, manufacturers can reduce operational and manufacturing errors generally associated with manual labor. IoT can help reduce errors in operations, even in those operations that are automated like in continuous manufacturing operations. For example, IoT sensors can detect anomalies and/or variabilities in a chemical processing operation and adjust certain parameters to reduce process waste and increase yields. AI and machine learning can do much of the required computing and data analysis and make subsequent predictive recommendations which can improve a manufacturing process.

3. **Predictive maintenance.** IoT technologies can alleviate issues and unplanned machine downtime associated with reactive maintenance. By monitoring equipment performance consistently, industrial operators are able to identify issues before they occur and allows them to schedule maintenance prior to any downtime.

4. **Improved safety**. A fully functioning manufacturing operation that incorporates sensors and other IoT technologies can use the collected data to bolster worker and product safety. Integrated systems can protect workers by providing alerts which could automatically and safely cease operations if an accident is predicted or until an incident is resolved. Safety can be improved with sensors monitoring hazardous conditions and sending alerts when necessary, such as detecting chemical leaks or equipment malfunctions, reducing the risk of accidents.

5. **Cost reduction**. The data provided to manufacturers through Industrial IoT technologies is giving them the knowledge and tools to reduce costs and increase marginal revenue. By using data-driven insights into operations, production, marketing, and sales manufacturers can steer their business into a more profitable direction.

6. **Enhanced Productivity & Quality:** IoT technologies can improve productivity by providing workers with real-time data and insights. Continuous monitoring of product quality can automatically adjust processes to maintain consistent quality levels.

7. **Data-Driven Insights, Reporting, Compliance:** The data collected by industrial devices incorporated with IoT technologies can be analyzed to gain valuable insights. This data-driven decision-making can lead to innovations, process improvements, and a better understanding of customer needs. It can also simplify regulatory compliance by automatically recording and reporting data required for compliance purposes.

The Industrial sector has many existing applicable standards and best practices., As an example, this sector utilizes the ISA/IEC 62443 series of standards and conformity assessment programs that provide a systematic, practical, and holistic approach to address cybersecurity in product development and across the overall product lifecycle, starting at its inception. It's also important to consider how the use cases of IoT technologies in the industrial sector are distinct from IoT technologies used in other sectors. There are a number of reasons for this listed below.:

- **Use/Scope**: IoT in industrial devices are used in settings for manufacturing, transportation, energy, and other critical infrastructure.

- **Utility:** IoT in industrial devices are used for enhancing productivity, improving efficiency, quality and reducing costs in industrial processes.

- **Applications:** IoT in industrial devices are used for industrial applications such as monitoring and control of machinery, inventory management, and supply chain optimization. These operations may be in harsh environments, require low latency and may operate in long time scales before replacement.

- **Impact:** Cybersecurity breaches in industrial devices with IoT technologies can cause significant damage to critical infrastructure, including production downtime, supply chain disruptions, and safety risks.

- **Life Support:** Some industrial devices with IoT technologies such as medical devices and aerospace systems may involve human safety, and their cybersecurity vulnerabilities can lead to fatal outcomes.

- **Automation:** Industrial devices with IoT technologies are often automated and may interact with other machines and systems.,

- **Reliability:** Industrial devices with IoT technologies must operate reliably and continuously in harsh environments.
- **Privacy and Confidentiality:** Industrial devices with IoT technologies may collect sensitive data, but the privacy concerns may differ based on the application. The data being transmitted and processed in Industrial IoT environments can be highly sensitive and critical to business operations. This includes manufacturing data, process control information, supply chain data, and proprietary intellectual property. Confidentiality in Industrial IoT extends beyond personal information to safeguard critical industrial processes and trade secrets.
- **Interoperability:** Industrial devices with IoT technologies are often part of larger systems and must be interoperable with other devices and systems, including legacy equipment and other operations technologies.
- **Scalability:** Industrial systems with IoT technologies often involve a large number of devices and must be scalable to accommodate growth., whereas consumer systems with IoT technologies may be smaller in scale
- **Attack Surface:** Industrial devices with IoT technologies have a larger attack surface due to their connectivity and may be vulnerable to various types of cyber threats such as hacking, malware, and ransomware.

Criticality: The cybersecurity of industrial devices with IoT technologies is critical for the operation of critical infrastructure.

The advancement of IoT technologies in industrial applications can further amplify the efficiencies of the manufacturing process, allowing for production goals and outcomes to reach levels of scale that are previously unimaginable and physically attainable. And when properly and responsibly governed and applied, these technologies can achieve these efficiencies while enhancing workers safety and privacy while fostering energy and environmental stewardship.

Update Regarding Previous IoT Initiatives

[New content proposed by Benson]

We may want to briefly discuss where we are with the Internet of Things at this point in time (e.g. adoption slow to take off, state of the marketplace, etc.). This could be some commentary on the challenges and sets up the rest of the report. Main message here is that we are exactly where we were 5 years ago when the initial green paper was drafted.

Current State of IoT

Adoption

The adoption of IoT is growing in the United States. One industry analyst estimated the value of the U.S. IoT market to be $56.3 billion in 2022, growing at 15.6% CAGR and projected to reach $270.2 billion by 2033.[1] Research published in the 2021 Microsoft IoT Signals found that 94% of business decision-makers, IT decision-makers and developers at U.S. enterprise organizations (1000+ employees) surveyed are "IoT adopters"[2], meaning that they are either learning about IoT, conducting a trial or proof of concept, purchasing IoT, or using IoT.[3] Of this, 27% have projects in the "use" phase, while 78% reported that they are planning to use IoT more within 2 years.[4]

IoT is used across a variety of industries for different reasons. For example:

- **Manufacturing.** The top three reasons for small manufacturers with less than 500 employees (which make up 98.3% of manufacturing companies in the United States), are performance improvement of operational processes, achieve production cost efficiencies and fill labor shortages.[5] A 2022 CESMII survey of manufacturers found that the top five smart manufacturing goals were better manufacturing capacity utilization (65%), lower production costs (63%), improved on-time delivery (62%), operational excellence (61%) and improved quality/reduced quality risks (60%).[6]
- **Agriculture.** IoT helps lessen the impact of labor shortages and augment existing labor resources. A 2018 study estimated 250,000 farms across the United States were using IoT solutions, with most of those in livestock and crop management. The study also found that up to half of all U.S. farms were interested in purchasing IoT solutions, representing 1.1 million farmers and a potential agricultural IoT solution market opportunity of $4 billion dollars.[7]
- **Retail.** A 2022 industry survey of 104 large American retailers (with sales of $500 million and above) by RSR Research reported that the top business challenges driving interest in IoT included competitive differentiation (43%), maintaining margins (41%), operations cost reduction (40%) and operations speed and agility (34%). The top IoT use cases deemed as "very important" centered around inventory accuracy and stock management (82%), fraud and loss prevention (80%), fulfillment center process automation (65%),

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[1] "United States IoT Market is expected to surpass revenues worth U.S.$ 270.23 billion by 2032: Persistence Market Research Report," Persistence Market Research Press Release, May 24, 2023. Link
[2] "IoT Signals - Edition 3|October 2021", Microsoft, October 2021. Exhibit 3. Link
[3] Ibid. Exhibit 2.
[4] Ibid. Exhibit 3.
[5] "The Manufacturing Institute–BKD Small and Medium-Sized Manufacturers Survey", The Manufacturing Institute, September 2021. Link.
[6] "2022 Smart Manufacturing Market Survey Executive Summary", CESMII, May 2022, Page 4. Link
[7] "Nearly 250,000 U.S. Farmers Already Using IoT Technology, Study Finds", J. Tomas, May 16, 2018. Enterprise IoT Insights. Link

supply chain process automation (63%), loyalty and personalization (62%) and brand protection and anti-counterfeiting (62%).[8]

- **Transportation and logistics.** One way IoT technologies help create a resilient supply chain is tracking the real time locations and quantities of goods and inventory across a network of warehouses and distribution centers, enabling inventory and logistics planners to draw from the most appropriate locations to minimize disruptions.[9] Approximately 95 million telematics devices have been shipped worldwide as of 2021, and is expected to grow at a CAGR of 10.9% reaching nearly 160 million units by 2026.[10] It is also estimated that there are over 130 million units of embedded car OEM telematics units in operation globally as of 2020, and 375 million embedded units by 2026.[11]

Adoption Barriers

Although IoT offers the potential for significant economic and societal benefits to the United States, its overall adoption and deeper integration into the economy and daily lives of Americans in a larger way has been slow. There are a myriad of contributing reasons, including:

- Concerns about IoT cybersecurity vulnerabilities that may lead to an intrusion of the user's network, theft of sensitive and proprietary data, unauthorized control of systems, and loss of network access.
- Concerns about privacy involving the unauthorized collection and use of information collected from IoT devices and systems. This information may be used in an adverse and discriminatory manner, limit choice, and create negative outcomes for the user.
- Shortage of workers with expertise, digital and data science skills to develop, integrate and operate IoT and IoT enabled systems.
- Limited and outdated infrastructure, such as connectivity and legacy systems, to support, operate and scale IoT systems.
- Industry barriers hinder the adoption of IoT including a lack of awareness and understanding, industry structure, processes and regulations, and organization and customer reluctance.
- Lack of interoperability hinder integration and communication with other IoT devices and existing systems and processes
- Limited technology maturity across a fragmented marketplace of hardware and software components and systems

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[8] "A Deep Dive into Retailers' Views About Rfid and the Internet of Things", B, Kilcourse and S. Rowen, Retail Systems Research Benchmark Report, April 2022. Link
[9] "How telematics and the IoT work together to improve fleet management," Verizon Connect, June 29, 2021. Link
[10] "Outlook on Vehicle Telematics Hardware Global Market to 2026…". Global Newswire, July 15, 2022, Link
[11] "Number of embedded auto telematics units n operation worldwide in 2019 and 2020…", Martin Placek, Statista, March 23, 2023. Link

Market Consolidation

There is no “one size fits all” IoT technology. The market is a fragmented ecosystem of sensors, chips and processors, modules, devices and software platforms. For example, there were 613 IoT software platforms in the market in 2021, down from 620 in 2019, but up from 450 in 2017.[12] The fragmented nature of the market has created confusion for IoT buyers who have struggled with understanding, selecting and integrating hardware and software from a vast array of technology providers to meet their specific requirements.

Today, this large and fragmented IoT market is consolidating in order to create value for buyers, scale and profitability at the current market levels. Some recent mergers in the news include:

- IoT module maker Telit acquires Thales cellular IoT products company (2022)[13]
- Semiconductor manufacturer Semtech acquires IoT technology provider Sierra Wireless[14]
- Kore acquires Twilio’s IoT business (2023)[15]
- Renesas acquires IoT chip and module provider Sequans Communications (2023)[16]
- Unabiz acquires IoT connectivity provider Sigfox (2022)[17]

Other market players have not achieved the level of success envisioned and have exited the IoT market or cut staff. Notable announcements include:

- Google exiting the IoT services business (2022)[18]
- Ericsson sells IoT business (2022)[19]
- IBM shuts down Watson IoT (2022)[20]
- SAP retires IoT platform (2022)[21]
- Cisco exits smart city market (2020)[22]
- Hologram lays off 40% of workforce (2022)[23]

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[12] “IoT platform companies landscape 2021/2022: Market consolidation has started,” P. Wegner, IoT Analytics, November 23, 2021. Link
[13] “Telit acquires Thales’ cellular IoT products to establish Telit Cinterion,” R. Daws, IoT News, August 1, 2022. Link
[14] “Semtech Corporation to acquire Sierra Wireless,” Semtech press release, August 2, 2022. Link
[15] “Twilio Sells Its IoT Business Unit to Kore,” J. Stephen, CX Today, April 3, 2023. Link
[16] “Renesas to broaden IoT offering through Sequans acquisition,” L. Redins, Edge Industry Review, September 5, 2023. Link
[17] “IoT firm Sigfox acquired by UnaBiz,” A. Wooden, Telecoms, April 22, 2022. Link.
[18] “Google to shut down its IoT Core Services from Aug 2023; users seek options,” Business Standard, August 18, 2022. Link
[19] “Ericsson quits IoT - agrees sale of loss0making IoT accelerator business to Aeris,” J. Blackman, RCR Wireless Business, December 7, 2022. Link
[20] “IBM to fire Watson IoT Platform from its cloud,” L. Clark, The Register, November 15, 2022. Link
[21] “SAP IoT Retirement and SAP Asset Performance Management,” S. Lee, SAP, October 5, 2022. Link
[22] “Cisco Systems pulls back from smart city push,” A. Tilley, Wall Street Journal, December 28, 2020. Link
[23] “Hologram lays off 40% Workforce – 80+ Employees,” Layoffs Tracker, June 9, 2022. Link

Technology Maturity

The technology enabling IoT continues to evolve. IoT is an evolving set of disparate technologies at various levels of maturity. While some are mainstream and mature, others are emerging and immature. Technologies such as cloud computing, IoT platforms, containers, supervised machine learning, IoT streaming analytics, cellular IoT and Low Power Wide Area Networks (LPWAN) have reached maturity.[24] Others are “coming up”, including edge data and app platforms, serverless/Function-as-a-Service, cloud connected sensors, edge AI chips, and low code/no code development platforms and satellite IoT connectivity.[25] Still others like data ecosystems, automated machine learning, wireless battery-free sensors, neurosynaptic chips, QRNG chips, biodegradable sensors, 6G and quantum computing are still “years out” and require continued research investments.[26]

The Future of IoT

Industry analysts estimate that the number of connected IoT devices will grow from 11.3 billion in 2020 to 27 billion by 2025.[27] As the physical environment is equipped with more and more sensors, the way those sensors and devices are used will evolve. Many of the IoT devices deployed today largely operate in isolation or “islands”. However, as IoT matures and standards and technology platforms emerge, the “islands” of devices integrate to form systems of connected devices. Driven by cross industry standards, use cases and middleware, these systems of connected devices integrate with other systems to form broader and bigger “systems of IoT systems”. For example, individual IoT applications in a factory integrate to create a smart factory. These smart factories connect with others to share data and create a network of smart factories. These smart and connected factories form a virtual factory network that offers “production as a service”. Customers find available factory capacity online and route files and orders to open factories for production. The data from these smart factory networks integrate with IoT applications across industries, such as freight and logistics providers, to coordinate the delivery of raw materials to factories and finished products to distributors and retailers. Finally, the integration of data and operations within and across industries leads to the formation of the fully autonomous factory and supply chain.

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[24] “55+ emerging IoT technologies you should have on your radar (2022 update),” S. Sinha, IoT Analytics, April 6, 2022. Link
[25] ibid.
[26] ibid.
[27] “State of IoT 2022: Number of Connected IoT Devices Growing 18% to 14.4 Billion Globally”, M. Hasan, May 18, 2022. Link

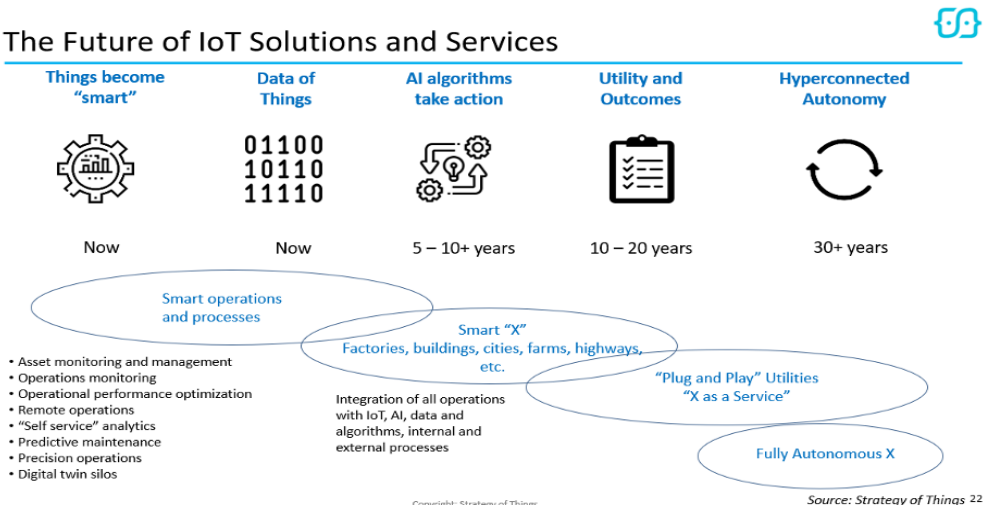

Figure 2: The Future of IoT Solutions and Services

IoT Personas

The Internet of Things (IoT) provides the potential significant economic and societal benefits to individuals, communities, businesses, and academic and government organizations across the United States. Some of these impacts provide incremental benefits, while others are more significant and transformational. The benefits offered by IoT are not uniform but vary across groups of people and organizations. The impacts range from positive outcomes from the use of IoT to creation of new jobs related to IoT and those indirectly related to IoT. This section provides a brief description of who is impacted, and in what ways.

Manufacturers

IoT in manufacturing can best be categorized via the following types: companies that design and manufacturer chips and modules (i.e., Intel, Qualcomm, Samsung), companies that assemble modules and produce branded products (i.e. Cisco), contract manufacturers that receive a chip design and deliver a packaged chip, and manufacturers who receive a design and Bill of Materials, assemble them as part of their manufacturing operations, and deliver a finished product. There are two types of manufacturers involved with the production of IoT. Component manufacturers produce the basic IoT products that are used in the development of IoT enabled "smart" products. For example, semiconductor and sensor manufacturers produce the core components used in IoT devices. Module manufacturers then purchase and assemble these semiconductors, radios, and sensors together to build modules that brand developers (see below) and device manufacturers purchase.

A second type of manufacturer produces finished IoT products for sale. These producers buy and assemble the core components and modules to create IoT products and devices. The manufacturer may offer the finished products to end user customers under their brand. Other manufacturers, known as Original Equipment Manufacturers (OEMs) may produce unbranded

products and devices with the intention of selling to other brands and brand developers to “white label” and sell as their own brand.

Manufacturers benefit from IoT in a variety of ways. The demand for IoT products creates significant direct and related revenue, jobs and business expansion opportunities in a variety of markets. IoT products generate immediate revenue for existing products, as well as pull through demand for other higher margin products, such as faster processors, storage devices, and sensors. For example, the continuing evolution of IoT demand has created the need for higher price and margin AI capable microprocessors. In addition, the buildout of IoT systems creates demand for edge servers and storage.

Manufacturers face a variety of barriers. The fragmented nature of the IoT ecosystem adds confusion and complexity in the marketplace and hinders adoption. Slower than expected market adoption of IoT hinders manufacturer investment and continuing product evolution. Overseas competition creates margin pressure on domestic suppliers and limits business expansion. Supply chain disruptions limit the ability to produce enough products and components to meet customer orders.

Developers

In the IoT ecosystem, there are various types of developers. “Brand developers” are businesses whose core product is not IoT but incorporate and integrate IoT technologies into their existing products. For example, a machine tool manufacturer incorporates IoT into their product line, to create “smart milling machines”. The brand developer buys or licenses the IoT technology from a 3rd party, or contracts with a product development firm to develop it for them.

“IoT technology developers” offer hardware, software, and cloud application development services. They contract with brand development companies to create IoT or IoT enabled products. Technology developers may also work with implementers (see below) to create custom IoT applications to support business, government and other organizations using IoT. Examples of IoT technology developers include product development firms, software development firms, and original design manufacturers (ODM).

IoT offers brand developers a variety of benefits. The addition of IoT to an existing product line creates new value, and enables the brand to charge higher prices. The IoT enabled product line may generate new revenue streams from recurring subscription based models.

In addition, the new product line may be more attractive to buyers and allows the brand to expand existing markets and enter new ones. Overall, IoT helps brand developers increase revenues, create recurring revenue opportunities and enhance profitability.

Brand developers face a number of barriers. Digital products require infrastructure and operational capabilities that are different from non-digital products. The addition of IoT and digital technologies to traditional businesses and business models brings new complexity and requirements that they may not have the expertise, skills, resources and infrastructure to

support. Adding digital capabilities to traditional product lines creates new issues and risks, such as cybersecurity, privacy and interoperability and liability that the developer is unaware of. New business and operating models enabled by IoT require significant investments that brand developers may be unwilling to commit to or may not be able to sustain for long. Despite the brand developer's reputation, customers may not be willing to adopt the new IoT enabled products because of the higher risks associated with cybersecurity and privacy vulnerabilities.

Implementers

Implementers are businesses who resell, install and set up, and maintain and service IoT and IoT enabled equipment to corporate, government, consumers and other buyers. Some businesses, such as retailers, only resell, but not install or service these IoT products, while others offer a full range of services. Typically, the more complex the IoT product is, the more services the implementers offer. Implementers may contract with IoT technology developers to build and implement custom solutions. For example, a HVAC contractor sells a smart HVAC system to a building owner. The contractor will install it, connect it to the network and the building energy management system, configure and test it for proper operation. They sell the building owner a maintenance contract, which requires them to come back on a quarterly basis to maintain the system and optimize its performance. On the other hand, a retailer may only sell a IoT solution but require the buyer to install and set up the solution or find a 3rd party to do so.

For implementer businesses, IoT provides a wide range of benefits. For example, IoT enables to sell add-ons to existing products, or new products, services, leading to a new source of revenue. IoT enables implementers to create new businesses and services on top of existing products and services. This leads to new revenues from existing customers, or new revenues from new customers. Many of the business models enabled by IoT enable implementers to shift away from "one time" transactional sales to create long lasting recurring revenue streams from subscription services.

Implementers face a number of barriers that hinder their ability to develop, operate and sustain their businesses. Their existing workforce may not be well suited to support and service these new technologies. There is a lack of a suitable and sufficient workforce with the digital skills and capabilities to install, integrate, configure and optimize these technologies. While IoT enables to create new business models, transitioning to those business models are operationally challenging because they may require business process changes and digital transformation, or a shift away from "one time" large revenues, to recurring small revenues. This requires changing operational and business models. While IoT may offer new long lasting value, customer adoption of these technologies may take longer. These long sales cycles may drive implementers to abandon these products and services in favor of traditional "tried and true" offerings that drive sales for the business now.

Administrators

Administrators are the owners and buyers of IoT and IoT equipment for business, government and other organizations. They are responsible for the overall management of these technologies

and systems, including procurement, integration, operation, maintenance and optimization within the organization. IoT technologies bring together traditional separate functions together, including information technology, operations, and the business units (marketing, technical support, finance and others). Administrators may perform some or all of these functions, or they may contract with 3rd parties, including implementers and developers, to conduct these activities. Administrators may reside in each of these organizations, or they may be centralized in a single organization.

Administrators are concerned with the benefits of IoT from an organizational perspective. The benefits of IoT depend on the application and usage, but include increased revenues, cost savings and profitability. IoT can create or enhance services and products, and lead to new revenue streams. The usage of IoT may lead to cost prevention, increased operational efficiencies, and staff and resource effectiveness. Other benefits include increased customer satisfaction, retention and loyalty.

Administrators face a number of barriers to IoT adoption in their organizations. These include cybersecurity and privacy concerns, and complexities in integrating IoT into existing information technology (IT) and operational technology (OT) or industrial processes and systems. The joining together of IT into OT and industrial operations creates resistance as it requires these separate functions and teams to break out of silos to work together. Job roles and responsibilities will change and the workforce may not have the modern digital skills, in integration, data science and programming, to fully utilize these systems.

Operators

Operators are companies that use IoT products and IoT-enabled equipment to carry out their day to day jobs in a business, government or other organization. For example, operators in a factory use sensors to monitor and control the manufacturing process to increase finished product quality and reduce scrap. Operators in a power generation facility use sensors and analytics to monitor critical turbine performance to minimize unplanned downtime. Technical support staff remotely monitor sensor data to diagnose equipment deployed in the field. Resellers monitor how customers are using their equipment and make recommendations to optimize performance and outcomes. Facilities operators monitor a building's sensors and systems to optimize comfort, energy usage and operations.

While the benefits to operators vary by operator organization, there are some common benefits. These include higher productivity and performance, reduced quality defects and customer complaints, increased proactiveness and responsiveness to customer needs, minimized operating downtimes and inefficiencies, and lower operating costs and staffing resources.

Operators face a variety of barriers hindering adoption and the full realization of benefits. Operators may require training and reskilling in digital and data skills to properly use IoT enabled equipment. While IoT increases operations visibility and leads to more transparency and accountability, it may also be perceived as “worker tracking” and is resisted by employees and their unions. Operators may resist adoption because they fear that IoT leads to operational

efficiencies, automation and less need for staff. Some operators feel that their “tried and true” experiences and intuition is more relevant and resist the use of the IoT technologies. Finally, the use of IoT may lead to changes in roles and responsibilities, which operators may not be comfortable with or suited for.

Consumers

Consumers purchase and use IoT and “smart” products for their personal or family use. For example, they use “smart watches” to monitor their health and physical activities, receive and communicate messages, and run a variety of apps. They use “tracker” devices to locate their wallets, handbags, keys, luggage and other things. They use “smart assistants” to turn on and off appliances and other devices, get information, listen to music, communicate and run “voice apps”. They use “smart thermostats” to keep the home at a comfortable temperature and save on energy bills. They also use connected cars for real-time navigation, vehicle health monitoring, Bluetooth mobile phone connectivity and personalized driving experiences.

IoT provides a variety of benefits to consumers, including saving money and time, increased convenience and peace of mind, improved awareness, health, safety and performance. The actual benefits vary by IoT devices and its intended uses.

Consumers face a variety of barriers and concerns that hinder adoption, and their ability to fully realize the benefits of IoT. Consumers are concerned about privacy, how the information collected is being used, and whether that information is used intentionally or unintentionally in a manner adverse to them. Consumers with low levels of digital literacy, as well as those with limited access to broadband service, may not be able to fully realize the utility and benefits offered by IoT. Products that are poorly designed, hard to set up and operate, result in consumers limiting their use of IoT or result in poor results. High product costs and subscription fees may preclude consumers who are on fixed incomes, or those that are on the lower end of the socio-economic scale from having these devices.

Findings of the IoT Advisory Board

[Note to readers: This is a new section proposed by Benson. It will be explained in the December 12 meeting.]

The major findings that informed the board on the development of the recommendations are listed in this section. These findings are grouped in general findings (affecting everyone) and industry-specific findings.

General findings

1. Industry adoption is slower than expected and hindered by a variety of challenges.
2. A lack of coordination at the national level is hindering IoT adoption and operation across the economy and industry sectors.
3. The adoption and operation of innovative IoT applications are hindered by various existing policies and regulations at local, state and federal levels.
4. Equity in access, opportunities, benefits and outcomes is necessary for the sustainable integration of IoT into all aspects of the national economy and civil society.
5. Small businesses can reap significant benefits from IoT, but significant barriers hinder adoption.
6. Small companies and startups are instrumental in developing many innovative and disruptive technology solutions and services but face a variety of barriers in getting adoption.
7. IoT enables new innovative business models which requires new business and technology platforms and ecosystems to support and scale it.
8. Interoperability is a key challenge for IoT across multiple industries
9. A variety of connectivity challenges is hindering IoT adoption, operation and scaling.
10. A lack of trust in IoT is a major barrier to widescale adoption.
11. Artificial Intelligence (AI) is critical to unlocking and accelerating the value of IoT.
12. There is an insufficient number of people in the current workforce with the technical, digital and analytic skills required to develop, integrate and deploy, operate and maintain IoT devices and IoT enabled systems and applications.
13. [Supply Chain findings being developed by Tom K.]

Industry findings

1. Precision Agriculture: IoT brings significant value to agriculture, but adoption is slow.

2. Smart cities and infrastructure: The development of smart cities in the United States is limited, uneven and slow to develop.

3. Transit and traffic: IoT is transforming transit systems and traffic management with real-time data analytics, intelligent traffic management, and predictive analytics to enhance efficiency, reduce congestion, increase safety, and improve overall transportation experiences.

4. Healthcare: IoT is transforming healthcare, and is poised to revolutionize it but significant challenges need to be addressed.

5. Environmental Sustainability: IoT supports environmental sustainability through real-time monitoring, optimizing resource usage, and facilitating data-driven decision-making across infrastructure and multiple sectors of the economy.

Finding: Industry adoption is slower than expected and hindered by a variety of challenges.

The adoption of IoT technologies has been growing in the United States, but that growth has been gradual and slower than expected. As a result, several major technology companies have pivoted away from IoT. Despite its potential, there are several challenges and barriers that have contributed to the slow pace of adoption across the economy and society.

- **Complexity and Integration.** IoT is a set of disparate technologies offered by a fragmented ecosystem of hardware suppliers, software platforms and connectivity service providers. It is not a “one size fits all” and components must be assembled together to create a solution that meets the specific requirements. In addition, IoT implementations often require integration with existing systems and infrastructure. Integrating IoT devices and platforms with legacy systems is a significant barrier, costly, and requires technical skills that is in short supply, especially for industries with established processes.

- **Cybersecurity Concerns.** IoT introduces a vast number of potential attack surfaces, leading to very real concerns that hinder adoption. Many industries, particularly those dealing with sensitive data or critical infrastructure, are cautious about the potential vulnerabilities associated with IoT devices. Cyberattacks may disrupt the operation of IoT devices and services, or lead to a breach of back office and enterprise systems that the IoT devices connect to.

- **Interoperability.** The inability for devices to communicate with each other or to the broader enterprise, legacy systems and operations technology systems, is a major barrier. In some cases, the lack of interoperability is caused by a lack of standards and protocols. In other cases, there are multiple competing standards as each solution provider creates “walled gardens” or “walled ecosystems”. One major challenge is the integration of IoT devices with legacy and operations technology systems, which are commonly found in many industrial and enterprise environments.

- **Data Privacy and Compliance.** Concerns related to data privacy and regulatory compliance are significant barriers to IoT adoption. Industries must navigate complex legal frameworks and ensure that IoT implementations comply with data protection regulations, which can slow down the adoption process. While privacy concerns cut across multiple markets and industries, certain markets are more sensitive to privacy issues, including smart cities, retail, insurance and healthcare.

- **High Implementation Costs.** The upfront costs associated with implementing IoT solutions, including the purchase of devices, infrastructure, and integration expenses, can be a deterrent for many potential adopters, especially for those operating on tight budgets. It is estimated that the cost of the IoT solution represents 30% of the total cost, while implementation and deployment accounts for the other 70%.

- **Lack of Skilled Workforce.** Implementing and managing IoT technologies require a skilled workforce with expertise in wide variety of areas such as cybersecurity, data analytics, application development, cloud operations, and system integration. The shortage of professionals with these skills hinder adoption, particularly in industries that have not traditionally require digital talent. In addition, the ongoing labor shortage contributes to the struggle to attract and retain such talent.

- **Uncertain ROI and Business Value.** Some industries are more hesitant to adopt IoT technologies due to uncertainty about the return on investment (ROI) and the overall business value. This is particular true for industries, such as mining, construction and agriculture, that have not traditionally incorporated digital technologies into its operations. There is a lack of clear use cases and success stories demonstrating tangible benefits are essential for convincing businesses to invest in IoT.

- **Resistance to Change.** Resistance to change within organizations is a common challenge. Many potential adopters have limited awareness and education of IoT, and what it can do. Employees and management may be accustomed to traditional processes and may resist adopting new technologies. Complexity, industry regulations and structure, and organization culture are additional barriers hindering the adoption of IoT.

- **Reliability and Stability Concerns.** IoT is still considered a new or emerging technology for many industries, particularly those in sectors like healthcare, manufacturing, energy and smart cities. In this sectors, reliability, stability and longevity

are important characteristics. The failure of a smart healthcare device may result in the death of the patient. Failure of an intelligent traffic signal may lead directly to accidents and injuries. Failure of such systems may result in the adopters incurring financial liability. In sectors like cities, maintenance and operations are a top requirement, and IoT devices are expected to last decades. In these sectors, adopters often forgo the “latest and greatest” technologies for older generation “tried and true” systems.

Finding: A lack of coordination at the national level is hindering IoT adoption and operation across the economy and industry sectors.

[dan, pete to supply content]

Finding: The adoption and operation of innovative IoT applications are hindered by various existing policies and regulations at local, state and federal levels.

Technology advancements create intended and unintended outcomes that are both positive and negative. Government policies and regulations help inform, facilitate and reduce the impact of unintended consequences. While the outcomes of regulations and policies on mature technologies have been studied and understood, new and emerging technologies often outpace the effectiveness of policies and result in unintended consequences.

While IoT offers the potential for disruptive transformation and value, there are instances where policies and regulations at various levels of government hamper the benefits it provides. Policies and regulations are generally well-intentioned and crafted to protect users and the community from harm, or to comply with standards and norms. Conflicts arise because the development and use of technology is moving and changing fast and used in ways that have never been used or studied before. These well intended policies may conflict with one another, resulting in barriers to adoption, use, compliance and commerce of IoT. Government policies and regulations play a critical role in advancing or stifling the use, the beneficial outcomes and the scaling and evolution of IoT.

Examples of policies affecting the use of IoT include

- Facial recognition algorithms running on a city’s network of video cameras helps to deter and solve crimes but may lead to privacy violations when it is used outside of its intended purpose or provide inaccurate results. Many cities have enacted laws restricting the use of video cameras and facial in smart city applications.

- Autonomous drones can perform a variety of labor-saving tasks on large farms, including monitoring plant health and crop spraying. However, FAA regulations require one operator per drone, and it must be operated within line of sight. This limits the utility and value that can be obtained from the use of drones in agriculture.

- Telematics devices generate a lot of information about a car and driver’s behaviors. This information can be used by automobile insurance companies to create personalized

insurance products and set premiums. Insurance is regulated at a state level, and each state determines what information can be used. For example, California only allows insurance companies to use mileage data.

Finding: Equity in access, opportunities, benefits and outcomes is necessary for the sustainable integration of IoT into all aspects of the national economy and civil society.

Although IoT offers the potential for significant benefit to people, communities, businesses and organizations across the United States, those benefits are not equally distributed or shared. Conversely, IoT may create adverse outcomes, with some communities disproportionately receiving more harm than others. Equity in access, opportunities, benefits and outcomes is necessary for the sustainable integration of IoT into all aspects of the national economy and civil society. Policymakers, regulators, and financiers must understand and consider equity when planning initiatives to accelerate and increase the adoption of IoT into the economy and society. Similarly, builders, developers and operators of IoT products and services should take equity in consideration to create offerings that are relevant, effective, and sustainable.

Equitable access to connectivity. Connectivity is necessary for the operation of IoT. However, many communities today do not have access to connectivity, or to service at the levels necessary to support their needs. This lack of access may be due to a lack of infrastructure, lack of access to affordable service, or insufficient infrastructure. For example, rural and remote communities lack broadband infrastructure, while lower socioeconomic communities in urban areas suffer from a lack of affordable service. Other communities may have old infrastructure that must be upgraded to support advanced IoT applications and services. Equity in connectivity is necessary to enable equity of benefits from IoT.

Equitable benefits for rural communities and economies. Rural communities face challenges that their urban counterparts do not. For example, many rural areas are “medical deserts”, a term used to describe locations with inadequate access to one or more kinds of medical services. Approximately thirty million Americans, many in rural communities, live at least a sixty-minute drive from a hospital with trauma care services.[1] In these communities, IoT-enabled telehealth services are of great benefit, especially for those with chronic health conditions requiring frequent doctor visits. However, rural regions lack not only the connectivity infrastructure, but the workforce and resources to support IoT operations. From maintaining connectivity to developing, integrating and servicing IoT applications and equipment, a lack of local expertise and trained resources is hindering the ability of rural economies to sustain and extend its benefits from IoT.

Equitable opportunities for small cities and communities. Small cities and communities lack the capital, resources and capabilities that their larger city counterparts enjoy. IoT and other innovations offer the potential of helping these smaller cities and communities “do more with less” and to do it more effectively to serve the needs of their constituents. However, these smaller cities and communities are often less aware of IoT and other innovations, lack the

budget and access to funding sources, and in-house expertise and capabilities to plan and deploy these technologies. Furthermore, the lack of innovation offerings, enablement programs, and funding sources is hindering these smaller communities from accessing the same opportunities and benefits that their larger counterparts receive.

Equitable outcomes from data. IoT devices collect vast amounts of private and non-private data to make decisions, drive actions and create outcomes. However, the use of this data may lead to negative outcomes intentionally or unintentionally. For example, the use of facial recognition on people of color has been found to have a higher probability of error and lead to inaccurate results. Because of this, people of color have been negatively impacted at higher rates than other demographic groups. Similarly, vehicle telematics data can be used by insurance companies to determine risk and set personalized premiums. However, while this leads to good drivers receiving lower premiums, bad drivers may be relegated to a class of "uninsurables" who are unable to get insurance at any premium. In the past, these drivers would have been placed into a larger risk pool, where their higher risks may be offset by others with a lower risk. Equity considerations and protections must be incorporated in using data to create beneficial outcomes for the economy and society.

Equitable access to IoT for small businesses. Small businesses are the heart of American commerce and stand to benefit from the integration of IoT into their businesses. However, these small businesses lack the staff and technical expertise, resources, and the funds to afford and buy and integrate these IoT technologies. For example, many small farming businesses have limited appetite and funds to invest in IoT technologies with an "unknown" outcome. Instead, they prefer to invest those funds into inputs (seeds, fertilizer, herbicides, etc.) which they know will lead to something tangible ("produce") even if it was produced inefficiently. Similarly, small retail businesses have limited free cash available, and prefer to invest that limited in inventory which they know will convert to profits. These day-to-day realities "trap" many small businesses into an endless cycle, and hinders their ability to buy and use IoT to obtain its associated benefits.

Equitable access to opportunities for small business and start-up IoT innovators. Start-ups and other small businesses create many of the innovations that bring disruptive new value to the economy and society and keep America strong and resilient. However, many of these companies face challenges in bringing these innovations to reality. For example, many businesses and government agencies are often unaware of these innovations and have limited funds, policies and processes ability to evaluate and validate them. Innovations often face the "valley of death" from successful completion of pilot or proof of concept to contract. Procurement policies and processes, designed for well-established mature products and services, do not work well for innovative solutions. As a result, many innovative offerings from small businesses and start-ups fail not because of their offering, but because they face access barriers to market that larger businesses don't have.

Equitable access to workforce development and employment opportunities. The integration of IoT into the economy and society creates new types of jobs and employment opportunities. Some of these jobs will require new skills, while others may be extensions to

existing skills. For example, some IoT jobs will require digital skills, such as integration, programming, cloud application development, cybersecurity and data science. At the same time, other jobs will be needed to manufacture, install, service and maintain IoT devices and IoT enabled equipment. These employment opportunities are at risk of bypassing socioeconomically challenged and rural communities, whose residents may not have the language proficiency, digital literacy, access to education and development opportunities, and broadband service, to be included. Labor shortages exist in many industries today and hinders the American economy. Similarly, the inequitable access to employment opportunities created by IoT will hinder the country's full realization of the economic and societal benefits.

Finding: Small businesses can reap significant benefits from IoT, but significant barriers hinder adoption.

IoT brings significant value and outcomes for both small and large businesses. Small business enterprises lack the resources and scales of economy that their larger counterparts have, and the adoption of IoT into their operations can have a significant and immediate impact. For example, soil moisture sensors help farmers direct irrigation to those specific areas where the soil needs watering most. Small farming operations are cash flow constrained, and the money saved on watering can be immediately redeployed to help pay for other things. In manufacturing, IoT sensors continuously monitor the condition and performance of production equipment, helping factories optimize production, reduce scrap, and minimize unplanned downtimes. This has an immediate impact on small factories, helping them to meet customer commitments, expand their business and profits, and overcome cash flow constraints.

A number of barriers hinder the adoption of IoT in small businesses. These include:

- **Financial.** The initial cost associated with purchasing and implementing IoT solutions may be beyond the means of small businesses. These businesses have limited financial resources, and many have cash flow constraints, hindering their ability to invest in IoT, hire skilled resources or contracting with service providers.

- **Skills and Expertise.** Integrating IoT technologies into existing business processes can be complex. Small businesses lack personnel with the expertise to successfully deploy and manage the integration. They face challenges in finding and retaining these employees. Training existing staff or hiring skilled workers can be difficult due to budget constraints and market competition for the same talent.

- **Infrastructure.** Small businesses often lack the infrastructure to support the integration, operation and scaling of IoT. Existing infrastructure may need to modernized. Networks may require upgrading to ensure consistent and stable connectivity for their IoT implementations. Software applications may be upgraded to integrate data from IoT sensors. Some businesses employ legacy systems, adding further complexity to integrate with IoT solutions.

- **Cybersecurity and privacy concerns.** Cybersecurity breaches are extremely disruptive to small businesses, who often lack the resources and expertise to implement and keep up with robust security measures, and mitigate the impacts of cyber-attacks. The collection of data from sensors adds further complexity. Small businesses are concerned on how their proprietary data is used and shared, as it is their source of competitive advantage. They also lack the expertise, knowledge and tools to navigate complex regulations and ensure compliance with data protection laws on customer data collected from IoT.

- **Limited Awareness.** Many small businesses have very limited to no awareness and understanding about IoT solutions. These businesses have limited time and budget for exploring and staying updated on the latest technologies. Small businesses have limited exposure to industry conferences, trade shows, or forums where IoT trends are discussed. Many IoT solution providers focus their marketing efforts on larger enterprises, leaving small businesses unaware of available solutions that could benefit them. Small businesses may have difficulty finding relevant case studies or success stories that demonstrate the practical benefits of IoT in their specific context.

- **Adoption resistance.** Small businesses, especially those in survival or growth phases, prioritize immediate operational needs over exploring new technologies. IoT may be perceived as complex and technical, especially by individuals who are not well-versed in IT. Small business owners and decision-makers may feel overwhelmed by the technicalities associated with IoT, leading to a hesitancy to explore further. Small business owners may be unfamiliar with the potential advantages of IoT technologies and may hesitate to invest without a clear understanding of the return on investment. Misperceptions about the cost of adopting IoT technologies discourage exploration and investment in IoT solutions.

Finding: Small companies and startups are instrumental in developing many innovative and disruptive technology solutions and services, but face a variety of barriers in getting adoption.

Many disruptive technology and market innovations come from small companies and start-ups. However, start-ups face a variety of challenges in developing and bringing innovative offerings to market. As a result, many promising innovations never reach commercialization. Some of these challenges include:

- **Access to Funding and Investment.** Securing funding is challenging for IoT start-ups and small businesses. Funding is necessary for the research and development of innovative offerings, but investors are risk-averse when it comes to “unproven” and emerging technologies. Customers have limited to no budgets for funding pilot and proof of concept projects. While larger and established companies can afford to fund development projects and do free pilots, smaller companies and start-ups cannot. Many more start-ups and smaller businesses fail to navigate the “Valley of Death” (the period

between initial successful pilot/prototype development and contracting) because they are unable to secure the bridging funds.

- **Customer procurement processes are not designed to purchase innovative offerings.** Existing government and enterprise procurement processes and policies are designed for sourcing established and mature products from established companies. These processes are not well-suited to buy “risky” offerings from start-ups with limited to no proof of performance, limited operating history, and innovative commercial models. Some larger companies address this by offering deep discounts or free proof of concepts to alleviate risk concerns, but small companies do not have the luxury to do so.

- **Legacy regulations and standards.** Certain industries, such as energy, healthcare and transportation, are subject to regulations and standards that were established for legacy systems and operations. The capabilities offered by IoT and other disruptive emerging technologies may deliver the desired outcomes in innovative ways, but may do it in ways that conflict with these existing industry standards and regulations. For example, drones are subject to FAA regulations specifying one drone, one operator. In addition, drones must operate within the line of sight of the operator. This prevents the development and operation of autonomous drones in farming, where drones could be used to collect imagery information of plant health, or conduct crop spraying.

- **Market incumbents.** Many start-ups offer technologies and solutions that disrupt and compete against existing incumbent legacy solutions. Incumbents are well established, and hinder market adoption of innovative solutions in a variety of ways. This includes limiting access to infrastructure and systems and creating “walled garden” ecosystems. For example, one equipment manufacturer “maliciously complies” with an industry standard for communications, but encrypts the data traffic going through it, which effectively blocks access to the data by other machines.

- **Low market awareness.** At this early stage, there is very limited market awareness of innovative IoT technologies and solutions. Start-ups often invest considerable resources and time to establish credibility and educate their target market about the technology, approach, benefits and value proposition of their innovative solutions. In addition, many start-ups lack the market credibility compared to larger and more established companies. Government adoption and use of innovative IoT solutions helps start-ups establish credibility, and more importantly, credibility of IoT.

Finding: IoT enables new innovative business models which requires new business and technology platforms and ecosystems to support and scale it.

[Under development]

Finding: Interoperability is a key challenge for IoT across multiple industries.

Interoperability allows heterogeneous devices and systems to integrate, communicate and share information with each other and automate. For example, information collected from one IoT device is used as input data by another different device, or devices from different brands may communicate and work together in a system. While interoperability is enabled by standards, it is challenging to achieve for a variety of reasons. In some areas, IoT technology is still new and rapidly evolving. There are many areas of IoT technology to be standardized and attaining agreement on a standard takes time. While open standards provide the potential for seamless interoperability, the current market is filled with products with proprietary standards, "walled garden"[28] device ecosystems and differing international standards and protocols. Some vendors believe their proprietary standard is technologically superior, some were first to market before standards developed, while others are concerned with commoditization of their offerings. For IoT to evolve, interoperability and standards across devices, industries and countries are critical. (source: NIST IoT report draft)

Here we add some stories.

Example – highlight automobile industry report highlighting lack of interoperability and value lost.

Finding: A variety of connectivity challenges is hindering IoT adoption, operation and scaling.

The availability of connectivity service coverage is a necessary prerequisite for IoT adoption and operation. The COVID-19 pandemic highlighted the impact of the digital divide and the need for connected communities. Several government and private sector initiatives offer the potential to make connectivity ubiquitous. For example, a portion of the $65 billion in the federal Bipartisan Infrastructure Law will build infrastructure in underserved areas. California is building a $6 billion middle mile fiber network to facilitate the creation of last mile services to underserved areas.[29] The FCC is considering the potential use of the frequencies in the TV white space for connecting IoT devices over wide expanses of rural areas. Several satellite operators are planning or have launched next generation Low Earth Orbit (LEO) broadband and IoT connectivity services to rural and underserved areas. These initiatives are supplemented by private enterprises establishing LTE and 5G private networks to connect campuses, factories and other facilities augment commercial telecommunications services. (source: NIST IoT research report draft)

[28] A "walled garden" ecosystem is one in which a vendor or a group of vendors together form an ecosystem where their products are compatible with each other.
[29] State of California Middle-Mile Broadband Initiative, Link

Despite these efforts, more work needs to be done to overcome the various challenges IoT adopters and operators face. These include:

- **Lack of fixed and wireless connectivity infrastructure.** While urban areas have the infrastructure to offer different connectivity service options, rural areas and remote regions lack the same. This may be manifested in the lack of fiber infrastructure, as well as a lack of sufficient wireless infrastructure. Limited infrastructure, low population and population densities, terrain challenges and poor economic returns limit industry connectivity investments in these areas.

- **Future use cases require higher bandwidth symmetric services.** Future IoT use cases, such as drone and remote machinery operation applications in agriculture, require higher bandwidth symmetric connectivity services. The FCC's current 25/3 broadband service level definition is insufficient to support those applications.

- **Insufficient spectrum to support future needs of IoT at scale.** As the number of devices and IoT enabled services continue to grow, additional wireless spectrum is needed to minimize performance issues. These issues include interference, latency, quality of service and reliability. IoT devices supporting first responder and medical applications, are especially vulnerable. Urban and metropolitan centers, having a large number of building structures, high wireless device density, are most susceptible to disruptions and issues.

- **Sunsetting of connectivity technologies.** There are millions of IoT devices that are connected through 2G and 3G networks in the United States. As 4G and 5G networks enter into service, these older networks are turned off or "sunsetted" over a period of time. For example, the various carriers started turning off their 2G networks between 2017 (AT&T) to 2022 (T-Mobile). Similarly, carriers turned off their 3G networks between 2021 and 2022.[30] In many cases, it is not possible on a practical basis to replace and update the transmitters in the devices to newer protocols, rendering the devices useless. Managing the sunset and replacement of the devices is a major task and cost burden for IoT users and owners.

Finding: A lack of trust in IoT is a major barrier to widescale adoption.

The IoT raises several cybersecurity and data privacy concerns. Cybersecurity is top of mind with developers, adopters and privacy advocates. IoT devices expose new attack surfaces that can be exploited to enter the network, steal information and disrupt operations. Data collected from IoT devices can be stolen, improperly accessed, or used for purposes outside its initial design. Algorithms can be biased or tricked to produce incorrect or unintended outcomes. While

[30] "A Complete Overview of 2G & 3G Sunsets," A. Worth, 1OT, August 29, 2019. Link

interoperability, connectivity and compute provide the technical infrastructure for IoT to scale, a trust infrastructure is necessary for IoT market adoption to evolve and scale.

[highlight stories to follow – stories from Debbie and Mike and TomKat]

Finding: Artificial Intelligence (AI) is critical to unlocking and accelerating the value of IoT.

Data collected from IoT devices is invaluable to creating insights and driving positive outcomes. For example, data from condition sensors is used to inform on the current status of an operational process or to diagnose a problem. Historical data may be used to identify trends and predict an outcome. Artificial intelligence automates the processing and analysis of vast amounts of data quickly and accurately.

Some of this data is used to train and build machine learning (ML) and artificial intelligence (AI) algorithms. Once trained, these algorithms are deployed in the cloud or on the devices where they are used to analyze newly collected sensor data to generate insights, inform on decisions and support autonomous actions. For example, cameras in fruit picking robots analyze images of fruit in a field and identify those ripe fruit for picking.

Latency, connectivity and processing requirements determine where the algorithm resides on the device, or local processing servers (“the edge”) or in the cloud. A current trend is that more and more algorithm processing is occurring on the device and the edge, instead of the cloud. Facilitating this trend is the development of AI-capable semiconductors.

As more sensors and devices are deployed, the quality of the data used to train the algorithms improve, leading to more refined models, the extension of those models to more use cases and more accurate model outcomes. Continuing advancements in algorithm development create new models that service more complex and computationally intensive applications, as well as enable more efficient processing on existing resource constrained microprocessors.

As connectivity and processing infrastructure expands, IoT will scale with new use cases that are ML/AI enabled. Continuing advancements in interoperability and development of low-cost devices will eventually lead to an environment with ubiquitous intelligence. This state, called ambient intelligence, is reached when intelligence is embedded and integrated transparently into the physical environment and human interactions. Intelligence, interoperability, connectivity and computing are interdependent. Developments in low-cost devices leads to more IoT devices, which increases the need for more connectivity service and coverage. As the number of devices scales, the amount of data collected grows. The need to process these data drives advancements in computing infrastructure and algorithms, to create outcomes. These outcomes increase the need for more devices to be integrated into the physical environment and the day-to-day interactions with humans. (source: NIST research report).

The IoT and Artificial Intelligence (AI) are two very distinct concepts that complement each other. When operational, IoT devices create and gather data. In turn AI analyzes the data to

provide insights, interpretation, and decision making that can then and improve items on the IoT device such as its efficiency and productivity. Artificial intelligence (AI) can be defined as a collection of technologies and approaches that allow a machine to perceive its environment and take actions towards a specific goal. It encompasses several different technologies that give computers human-like abilities of perception.

Most of the AI systems today are machine learning (ML)-based systems, which allow computers to learn data patterns in a supervised or unsupervised manner, and then apply these learnings to make predictions, classify data, recognize objects or images, and understand speech or text. Other techniques that are often used in AI systems include deep learning (DL), natural language processing/understanding (NLP/NLU), computer vision (CV), and machine reasoning (MR)

Within the manufacturing industry, AI is being used in a variety of environments. These range from the factory floor, where it improves the production and distribution of manufactured goods and enhances safety, to the back office, where it streamlines administrative tasks and bolsters customer service efforts. AI is also being incorporated into manufactured goods to allow others along the value chain, including distributor, retail, and service partners, to leverage the intelligence provided by the technology to provide better customer service. In addition, these partners can use AI to improve aspects of product design and lifecycle management.

IoT technologies in industrial markets together with components like sensors, data storage and integration, data analytics, and machine learning, can be applied to SCADA systems to improve interoperability and coordination among different machines. The sensors collect new data from various equipment and continuously feed the data into the analytics. This way, machine learning algorithms can learn from past data and fine-tune the settings on different machines for thousands or even millions of cycles to reach the optimal point of the entire system. The use of AI within the manufacturing sector is being driven by specific enabling market factors that include the digitization of data, the development of IoT networks, and the steady improvements in ML and DL algorithms. AI technology introduces scale and efficiency and is best applied to two types of problems:

1. Data analysis and subsequent predictive recommendations and actions: ML and DL technologies excel at analyzing massive datasets very quickly. They can complete data analysis computations much more quickly than manual human analysis or hardcoded computer analysis.

2. Routine, redundant tasks: AI technologies are successfully handling redundant, linear thought-focused tasks (clerical work, order taking, food service), freeing up human resources to focus on higher value, human-exclusive skills (creative thinking, problem solving, interpersonal skills, emotional intelligence, reasoning, negotiation, and decision-making).

Within specific vertical markets (manufacturing, health care, energy, and transportation) there are several use cases that leverage the power of AI to deliver ROI while employing ML, DL,

NLP, and CV approaches that are commonly used across vertical segments. These use cases include:

- **Digital Twins:** A digital twin is a digital representation providing the elements and the dynamics of how a device or ecosystem operates and lives throughout its lifecycle. Digital twins combine sensor data with ML and software analytics, which are then used to create spatial graphs that provide a digital simulation model that is updated and changes in real time in tandem with their physical counterparts.

- **Energy Management:** Within manufacturing, the consumption of energy remains a primary cost and concern for plant managers and the key decision makers of the company. While the cost of energy may be variable a company's energy use is fully within its control. However, in order to better assess and control energy consumption within a manufacturing environment, machines must be equipped with sensor technology. Energy usage must be tracked at a granular level in order to assess key ratios, such as energy consumption versus productivity. The use of AI can make this tedious and data-intensive process much more efficient and effective.

- **Medical Image Analysis:** Analyzing images is a strong application for DL and CV within the realm of patient data processing. DL is now being applied to automate the analysis and increase the accuracy, precision, and understanding of images down to the pixel. Some of the more common applications include 3D CV (images analyzed and rendered into detailed 3D models), auto grading of eye diseases, and detection and segmentation of radiology images.

- **Safety Enhancement in Buildings:** Employers have an incentive to ensure better compliance with safety standards and protocols. One example of how DL is being used to help ensure better compliance includes tools that allow employers to leverage photos and videos to identify workers who are missing hard hats, gloves, or other safety equipment.

- **Street Lighting:** Street lighting is an essential element for any city. In addition to providing better visibility for pedestrians and motorists, it adds a feeling of safety and security and can often deter criminal activity. Smart cities are adding AI capabilities to street lighting, which is designed to not only provide lighting, but also perform other tasks by incorporating CV, ML, and IoT connectivity. Streetlights can be equipped with an array of sensors to monitor traffic flow, as well as send signals to traffic lights and other traffic control devices.

Manufacturers that have successfully incorporated AI technology generally have been able to achieve the following:

- An understanding of how analytics and AI can work together: Data analytics can and should be used to augment and support AI.

- An understanding of the goals and benchmarks needed to assess AI use cases: AI leaders need to be able to review the output from AI use cases and ensure that proper processes are in place for confirming or overriding questionable results.

- A modicum of trust in AI: All stakeholders need to have confidence that AI can deliver benefits if properly deployed.

- A strong culture of oversight: Regular oversight over the use of AI is critical to ensure that algorithms are delivering the benefits they should, while also remaining in compliance with applicable regulations, is a major key to success. Because the technology is still relatively new, stakeholders are much more likely to stay engaged if they are confident that there is proper oversight occurring on a regular basis.

Generative AI

Traditional AI is trained on large data sets with human input, conversations, user queries and responses. Generative AI is trained on different sets of data to learn patterns to create content with predictive patterns. Generative AI can produce various types of content, including text, imagery, audio, and synthetic data. It is particularly valuable in creative fields and for novel problem solving, as it can autonomously generate many types of new outputs. ChatGPT, DALL-E, and Bard are examples of generative AIT applications that produce text of images based on user-given prompts or dialogue.

According to a recent McKinsey Global Survey (https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023-generative-ais-breakout-year), 2023 is listed as a breakout year for Generative AI. The survey describes the most commonly reported uses of Generative AI tools to be in marketing and sales, product and service development and service operations such as customer care and back-office support. Inaccuracy, cybersecurity, and intellectual property infringement are the most cited risks of generative AI adoption.

As AI continues to move forward it's important to note the distinction between traditional AI that and generative AI. Policies and regulations that are developed need to take this into account.

Finding: There is an insufficient number of people in the current workforce with the technical, digital and analytic skills required to develop, integrate and deploy, operate and maintain IoT devices and IoT enabled systems and applications.

A significant challenge in scaling IoT into the national infrastructure and economy is the development of a IoT ready workforce. The current workforce lacks many of the key digital, technical and data science skills and expertise required to support IoT. In addition, IoT involves the convergence of various disciplines, including information technology, data science, hardware development, and cybersecurity. Building an IoT-ready workforce requires a workforce with interdisciplinary knowledge who can understand the complexities of both

hardware and software components. Integrating these diverse skill sets within a single workforce is a considerable challenge.

The need for a more digital and technical skilled workforce is driven by:

- **IoT requires different skills.** Despite its connected nature, IoT is not IT. IoT is a disparate set of technologies requiring an interdisciplinary combination of existing and new technical, digital and analytic skills. The workforce must develop expertise in working with new connectivity technologies, such as LoRaWAN and 4G/5G, integration of IoT devices into internal and external networks, and the cloud. In addition, the workforce must develop skills in working with the cloud, and application development. Finally, the amount of data collected required data professionals to manage the data and analyze it to create optimal outcomes.

- **Non-digital industries and systems go digital.** Many pre-digital industries required limited technical and digital skills. For example, the installation and integration of HVAC systems into a building requires mechanical, electrical and ventilation expertise. However, smart HVAC systems incorporating IoT and other technologies now require technicians with networking skills to integrate them into the building's IT network, and systems integration skills to interoperate with building and energy automation systems. Furthermore, smart HVAC systems collect vast amounts of data that must be studied by analytics-savvy operators to optimize occupant comfort and system performance, minimize operating costs and plan maintenance activities.

- **The convergence of IT, OT and IoT systems.** Industries such as manufacturing, energy and transportation employ operations technologies (OT), including supervisory control and data acquisition (SCADA) systems and programmable logic controllers (PLC), to monitor and control physical processes. On the other hand, business operations are supported by Information Technologies (IT) systems that process data and communications. In these industries, IT and OT systems operate independently of each other and are maintained by separate organizations. The incorporation of IoT into industrial processes require OT and IT systems to come together. This convergence requires a workforce with a specific set of digital skills, including understanding of IT and OT protocols and processes, cybersecurity, systems integration, cloud computing, programming and application development, IoT integration, data analytics.

- **The value of data analytics.** IoT collects vast amounts of data that can be used to create beneficial and innovative outcomes. Unlocking that value requires a variety of skills, including data management and governance, analysis, and development of insights. In addition, there is a need for the development of algorithms and the application of machine learning and AI tools. While the value of data analytics is understood, there is a current shortage of data savvy practitioners, analysts and scientists across all industries.

- **Interdisciplinary collaboration.** IoT involves the convergence of various disciplines, including information technology, data science, hardware development, and cybersecurity. Building an IoT-ready workforce requires individuals with interdisciplinary knowledge who can understand the complexities of both hardware and software components. Integrating these diverse skill sets within a single workforce can be a considerable challenge.

Finding: something on supply chain

Industry findings

Finding: Precision Agriculture. IoT brings significant value to agriculture, but adoption is slow.

Agriculture is undergoing a transformation driven by the integration of information and digital communications technologies, the Internet of Things (IoT), data analytics, automation and robotics and other emerging technologies.[31] This transformation offers the potential to increase agricultural productivity, operational efficiency, facilitate adaptation to climate changes and enhance overall competitiveness.

Some examples of top IoT applications in agriculture include:

- **Precision Farming.** IoT sensors on tractors, drones and in the soil collect data on soil moisture, nutrient levels, and crop health. This information enables precision farming by optimizing the use of water, fertilizers, and pesticides to increase crop yields and reduce waste.

- **Smart Irrigation.** IoT-based irrigation systems monitor weather conditions and soil moisture levels, enabling automated and efficient watering. This reduces water wastage and ensures crops receive the right amount of water.

- **Livestock Monitoring.** Wearable IoT devices on livestock provide real-time data on animal health, behavior, and location. Farmers can quickly identify signs of illness, track grazing patterns, and enhance overall livestock management.

- **Crop Monitoring and Predictive Analytics.** IoT sensors in fields continuously monitor environmental conditions and provide data for predictive analytics. Farmers can anticipate disease outbreaks, pest infestations, and make informed decisions to protect their crops.

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[31] "Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming", D. Rose and J. Chilvers, Frontiers in Sustainable Food Systems, Dec 21, 2018. Link

The application of IoT to agricultural production and operations produces a variety of benefits, including increased efficiency, minimize and optimize the use of inputs (water, fertilizer, pesticides, and herbicides), improve crop and livestock production yields, reduce waste, and decrease costs and increase profitability.

- **Increased Efficiency.** IoT helps farmers and ranchers become more efficient and productive. For example, the use of IoT to monitor animal health minimizes the need for workers to physically inspect the livestock on a regular basis. Sensors mounted on drones flying over large fields check plant health and quickly identify areas needing attention. Autonomous tractors and combines facilitate row crop operations with minimal human involvement.

- **Input Optimization.** IoT devices help optimize the amounts of inputs (water, fertilizer, pesticides, and herbicides) to be used based on real-time knowledge of growing conditions, and providing insights into the exact needs and application of inputs to maximize crop growth and health.

- **Enhanced Yield and Quality.** Agriculture is a data-driven business. The ability to monitor growing conditions, animal and crop health in real-time, along analyzing the data collected, helps farmers identify and respond to issues earlier and more proactively. This facilitates crop and livestock production, leading to improved yields and less waste.

- **Cost Savings.** IoT yields cost savings by reducing and optimizing the use of inputs, minimizing livestock health issues, support automation, and reducing the number of workers needed to support operations. These cost savings increase productivity and improve profitability and cash flow.

- Story 1: IoT can help small family farms be productive and profitable

    - 2 million farms in US. 98% are family farms. Small family farms (gross income < 350K) are 90% of all farms, 48.8% of all farmland, and 21.1% of production
    - 62 - 81% of these small family farms are operating on < 10% margins
    - Production expenses have increased by 18% in 2022

- Story 2: IoT can help agricultural producers navigate around the impacts of the changing climate.

    - Changing temps and precipitation patterns affect plant lifecycles, decrease crop yields, increase livestock stress and health, reproduction and milk and egg production

    - Corn yields have declined 3.8% and wheat yields have declined 5.5% (compared to no climate trends)

- Story 3: IoT can help increase agricultural production yields to support the upcoming food shortage
    - By 2050, UN estimates there will be a global food shortage
    - Increase in half percent in yield was enough to end starvation and famine in India (Green Revolution)

IoT in agriculture suffers from a variety of challenges. The top barriers include:[32]

- **Connectivity.** Agricultural producers face three connectivity challenges. First, there is very limited broadband infrastructure and Internet service in rural areas, and many agricultural producers lack “broadband to the farmhouse”. Second, while the FCC considers 25/3 Mbps (download/upload) service to be the broadband benchmark, this asymmetric level of performance is insufficient for precision agriculture needs which send large amounts of data, such as drone imagery and mapping data, to cloud data centers for processing and analyses to support critical decision-making in a timely manner. Finally, to support agricultural activities, wireless connectivity service must be made available to the “last acre”. This is complicated by the size of farms and ranches, some of which span thousands of acres over a diverse terrains.

- **Digital skills.** As digital and emerging technologies are increasingly integrated into agricultural equipment and operations, the skills that agriculture workers need to be successful will change. For example, as smart machines increasingly automate previously manual activities, agriculture jobs will evolve from being low skill repetitive physical work to medium to high skill non-repetitive digital work. New skills include data analytics, precision agriculture, robotics and automation, networking, and systems integration.

- **Interoperability.** Farms have a variety of equipment, from the “latest and greatest” equipment with current technology to 30- to 40-year-old legacy equipment with limited technology and no connectivity. Interoperability challenges are a major barrier to IoT adoption and value realization in agriculture where old and new equipment coexist and work together. Many of the machines employ a variety of proprietary and incompatible protocols that make sharing information with each other, as well as farm operations software difficult or impossible. For example, some equipment may incorporate incompatible physical connections and require the use of adapters to communicate with other equipment. Others may have different formats (or syntaxes) for the same data, while others have different meanings for the data. Old equipment may not work with newer equipment, despite coming from the same manufacturer.

[32] Chan, B., Feller, G., Paramel, R., Reberger, C., 2022, September. *Economic Research and Analysis of the National Need for Technology Infrastructure to Support the Internet of Things (IOT*), Strategy of Things Sponsored by the National Institute of Standards and Technology

- **Adoption resistance.** Despite the benefits of IoT and precision agriculture technologies and solutions, uptake of these solutions have been uneven and may take as long as 15 years for the technology to reach a critical mass.[33] Large producers are more likely to adopt these technologies compared to smaller farms because they more education, are less wary of technology and larger economies of scale.[34] Some of these reasons, include the limited availability of broadband and connectivity in rural areas, "right to repair" concerns, trust in personal expertise over technology, and poor previous experiences with technology.

Need Ranveer and Nick content/stories here. Maybe use the story ideas I had supplied previously.

Finding: Smart cities and infrastructure. The development of smart cities in the United States is limited, uneven and slow to develop.

IoT and its adjacent technologies offer the potential to transform cities and communities to become more responsive, resilient and sustainable. For residents of these communities, smart cities offer opportunities to improve quality of life, drive economic vibrancy, and increase public safety. Despite the potential for beneficial outcomes, current smart city efforts in the United States are small in scale, limited in scope and fragmented in nature.

While the vision of a fully connected and integrated city or community is still decades away, there are examples of IoT enabled smart city applications in use today. These include:

- Smart streetlights employ LED bulbs, connected sensors and a controller to dim and brighten the streetlamps as needed. Streetlights may be dimmed late at night in order to reduce energy usage, and brightened during the evenings when people are returning home to increase safety. Smart streetlights also determine if the lamp has malfunctioned, and notifies city staff immediately so that it can be replaced.

- Smart parking employs either in-ground sensors or cameras to monitor parking space availability. Open spaces are communicated to drivers through a mobile app or digital signage on the street or garage. This helps drivers navigate to the space directly, instead of driving around looking. In addition, it also helps identify parking space violations and direct parking enforcement officers to the spot directly without having to drive around.

- Community air quality networks are deployed in select areas of the community to monitor environmental conditions and inform residents and policymakers. Air quality networks may be deployed in areas with poor air quality, or where poor air quality would

[33] "Adoption of Farming Technology, Or Precision Ag, Varies Across Generations", KTTN News, December 20, 2020. Link

[34] "Adoption of Precision Agriculture", USDA NIFA. Link

harm vulnerable populations. For example, the communities directly adjacent to freeways or industrial plants are subjected to poor air quality.

- Intelligent traffic management systems help manage the flow of traffic, minimize congestion and decrease accidents and injuries. These systems monitor traffic flow, adjust streetlight signal timing based on real time conditions, and monitor traffic and pedestrian behaviors. For example, LIDAR or camera-based traffic analytics systems monitor “near misses” at intersections, and inform traffic engineers of dangerous conditions to be addressed.

- Camera systems employing AI and facial recognition algorithms help reduce crime and aid in the identification and capture of criminals. Images are captured and analyzed in real time by facial recognition software.

Benefits of Smart Cities:

- Increase efficiency

- Increased responsiveness

-

Despite the tremendous potential offered, smart cities have been slow to develop. This is attributed to a variety of reasons. These include:

- Awareness and Vision. Many community and political leaders lack awareness of IoT and smart city technologies. Others lack the vision and the innovation culture to incorporate these technologies and capabilities into a city’s infrastructure and operations.

- Lack of funding. Funding is one of the top issues holding back smart cities. These projects, at scale, is very expensive. While larger cities may have the capabilities and some funding vehicles to support these projects, America’s small and medium size cities do have very limited capabilities. In some cases, federal, state and regional grants may be available, but securing these grants can be difficult.

- Lack of skills and resources. Many cities and communities lack the new innovation and digital skills and resources to plan, deploy, operate and support IoT applications. There is a scarcity of these resources in the market, and cities often cannot compete with the private sector for the same talent.

- Privacy Concerns. The extensive collection of data from IoT devices raises concerns about data security and privacy. Ensuring robust cybersecurity measures and transparent data handling practices is crucial to building and maintaining public trust.

- Community and political resistance: No one gets elected for building a smart city. Political leaders are re-elected if they are responsive to the needs of their constituents. Smart city initiatives that don’t align to the city’s strategic and near term priorities are liely to face resistance from both among citizens and policymakers.

Smart infrastructure

Infrastructure is essential to the functioning and resilience of the United States. For example, a nationwide network of roads, waterways, rail and airports transports freight and goods to market, and connects people with places. A regional system of natural and man-made reservoirs, aqueducts, pipes, pumping stations, and treatment plants brings fresh water to cities and farms. Electricity generated from renewable and non-renewable energy power plants travels over through a network of transmission lines and substations to power cities and communities across the country. Sewage is routed from homes and buildings through a regional network of underground pipes to wastewater treatment plants for reclamation for reuse and release.

Smart infrastructure is the integration of IoT and other digital technologies into physical infrastructure. This convergence enables new innovative capabilities for physical infrastructure and allows it to be managed, operated, and maintained in more efficient and effective ways. Sensors embedded into infrastructure, such as roads, building structures and machinery, monitor its condition in real time, notifying operators of abnormal conditions immediately so that it can be addressed before it becomes a hazard or lead to service interruptions. Data collected from the sensors are analyzed by algorithms to optimize performance and usage, predict maintenance needs, and extend infrastructure life. In addition, IoT data helps validate and improve engineering models, build high fidelity digital simulations, and facilitate managerial and operational decision-making.

The benefits enabled by smart infrastructure include:

- Increased reliability, service availability and improved delivery of services. For example, streetlights provide illumination to increase road and pedestrian safety, reduce crime and facilitate economic vibrancy. However, broken streetlights take months to be replaced because the city or utility company is unaware of the problem. IoT enabled streetlight sensors notify the city or utility company immediately of broken lights, leading to replacements in days, not months. In another example, fatal and non-fatal traffic accidents commonly occur in street intersections. “Smart intersections”, equipped with cameras employing artificial intelligence algorithms mounted on traffic signal poles, capture vehicle and pedestrian behaviors that allow traffic engineers to study and apply corrective actions before serious accidents occur.

- Optimized operations and decreased costs. For example, mechanical water pumps equipped with sensors monitor equipment conditions during operation. The sensor data is analyzed by algorithms to determine when maintenance is actually needed so that the pumps can be proactively serviced, thereby ensuring continuous system operation and

preventing cost escalation. Similarly, smart electrical grids employ sensors and two-way communications between utilities and consumers to monitor and manage power flows, and respond to changes in electricity demand. This ensures that the most appropriate energy sources, including renewable energy, batteries, and upstream generation plants, are utilized to meet demand while increasing grid resilience, reducing operational costs, and minimizing carbon emissions from upstream fossil fuel power sources.

- Facilitation and acceleration of a future autonomy-driven economy, supporting autonomous vehicles and machinery, autonomous robotic operations, and other AI-driven applications. Despite the advances in autonomous vehicle technology, they are still many years away from truly safe and reliable operation. The sensors and processors in smart infrastructure provide additional data that autonomous equipment, machines and vehicles need in order to operate safely and reliably. For example, today's autonomous vehicles operate based on the limited information collected through its on-board sensor array. Sensors embedded on roads and buildings provide an extended set of "eyes and ears" to complement the limited range of the vehicle's on-board sensors. This additional "beyond line of sight" information is shared and processed by the vehicle's algorithms and enables better decisions and safer, more reliable, and predictable operations.

Despite the many capabilities and benefits offered by smart infrastructure, there are some concerns.These include:

- American infrastructure is old and failing. It must be repaired, replaced, and upgraded before it can be digitized and made "smart". The American Society of Civil Engineers (ASCE) have given American infrastructure an overall C- grade in its 2021 report card,[1] a slight improvement from the previous report card (2017), which rated the state of American infrastructure as D+.[2] For example, the United States has over 2.2 million miles of underground pipes that deliver drinking water. There is a water main break every two minutes and an estimated 6 billion gallons of treated water are lost each day.[3] Many of America's wastewater treatment plants were built in the 1970's and have an average life span of 40-50 years.[4] This aging infrastructure and inadequate capacity leads to the discharge of 900 billion gallons of untreated sewage into U.S. waterways each year.[5] Of the four million miles of public roadways in the United States, 43% are in poor or mediocre condition.[6] The poor road infrastructure resulted in motorists paying an additional $1,000 annually in time and fuel, 36,000 road deaths annually and rising pedestrian fatalities.[7]

- Vulnerability of smart infrastructure to cybersecurity threats, cybercriminals, and malicious state actors. IoT and other smart technologies create new attack surfaces and vulnerabilities to assets and infrastructure that had traditionally not been digitized, or had been protected through "air-gaps". These cyberattacks may lead to disruption of

operations and services, compromise of control and operational capabilities, and harm to millions of Americans who rely on this infrastructure. For example, the energy sector was the third and fourth most targeted sectors in 2020 and 2021 respectively.[8] The utility industry averaged 736 cyberattacks per week and experienced a 46 per cent year-over-year increase in cyber-attacks in 2021.[9] In 2019, a renewable energy generator company, the largest private owner of operating solar assets in the United States, was subjected to a denial-of-service attack. While no loss of energy generation was reported in the attack, the company lost visibility into about 500 MW of wind and PV generation in California, Utah and Wyoming.[10] Similarly, U.S. water utilities are prime targets for cyberattacks. The March 2020 Cyberspace Solarium Commission report stated that the nation's 70,000 water utilities "remain largely ill-prepared to defend their networks from cyber-enabled disruption."[11] In 2021, an operator at a small water treatment plant in Oldsmar, Florida, thwarted an attempt by an intruder to boost the level of sodium hydroxide (lye) in the water supply to 100 times higher than normal.[12]

While the Bipartisan Infrastructure Law of 2021 provides funding to repair and update America's infrastructure, it also represents a "once in a lifetime" opportunity to build an initial set of smart infrastructure and realize the benefits that it brings.

- Some content on smart cities
- Some content on public safety

Finding: Transit and traffic: IoT is transforming transit systems and traffic management with real-time data analytics, intelligent traffic management, and predictive analytics to enhance efficiency, reduce congestion, increase safety, and improve overall transportation experiences.

According to data from the National Highway Traffic Safety Administration (NHTSA), in 2022 an estimated 42,795 people died in motor vehicle crashes. While this latest estimate shows that roadway fatalities have remained flat after two years of dramatic increases, Transportation Secretary Pete Buttigieg states that "We continue to face a national crisis of traffic deaths on our roadways, and everyone has a role to play in reversing the rise that we experienced in recent years." https://www.nhtsa.gov/press-releases/traffic-crash-death-estimates-2022. Back in January of 2022, the DOT released the comprehensive National Roadway Safety Strategy, a roadmap to address the national crisis in traffic fatalities and serious injuries. One of the key actions in that roadmap includes leveraging technology to improve the safety of motor vehicles on our roadways.

Smart traffic technologies provide an organized, integrated approach to minimizing congestion and improving safety on streets through connected technology. These technologies smooth traffic flows and prioritize traffic in response to demand in real time. They enhance pedestrian, bicycle and vehicle safety and reduce accidents that cause injuries and fatalities. Connected vehicles can alert drivers of potential hazards such as pedestrians crossing the street or other cars in the vicinity. Smart traffic lights can detect when cars are approaching and adjust their

timing accordingly, minimizing the risk of accidents. Using adaptive control, detected vehicle congestion triggers changes to traffic signal timing to optimize traffic throughput in near real-time. Traffic signal timing can be adjusted to maintain schedules of bus and rapid transit lines. A path through the city is coordinated for first responder vehicles, using congestion data and vehicle location to adapt route guidance and traffic signal timing allowing these vehicles to get to their destination sooner.

These technologies can facilitate and support multimodal transit and other innovative transportation models (including ride-share, e-scooters, drones, etc.). They also facilitate the safe testing and operation of autonomous vehicles (including cars, trucks, robotic delivery services, etc.). They can also reduce energy consumption by obviating stop-start driving that typically occurs at intersections.

There is a large and growing ecosystem of public and private sector stakeholders to deploying this technology that will redefine traffic safety. Some examples showcasing their benefits are provided below:

- A project with Audi to deploy Cellular Vehicle to Everything (C-V2X) in vehicles as part of an ongoing joint project with the Virginia Department of Transportation, the Virginia Tech Transportation Institute, and others to showcase the technology's ability to improve work zone and intersection safety.[35]
- A collaborative venture with Audi, school bus maker Blue Bird, and the Fulton County School System (Georgia) that demonstrated C-V2X's ability to protect children in and around school zones and bus stops.[36]
- A project with Audi and with bicycle safety platform maker Spoke Safety to highlight the benefits of C-V2X-powered bicycle use cases.[37]
- A project with the Tampa Hillsborough Expressway Authority (THEA) to deploy and pilot Connected Vehicle (CV) applications to demonstrate safety and mobility benefits of the technology with respect to pedestrians in and around downtown Tampa.[38]
- A project with the Florida Department of Transportation (FDOT) to test and implement connected vehicle and pedestrian/bicyclist safety applications (active or passive) at 13 signalized intersections and 8 mid–block crossings within the core of the University of Florida (UF) campus.[39]
- The New York City Department of Transportation Traffic Safety Network. a large-scale Intelligent Transportation System (ITS) upgrade, replacing their entire citywide traffic

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[35] Jacob Levin, "Virginia Tech Transportation Institute researchers to deploy smart work zone in Wise, Virginia," Virginia Tech Exponentially More (May 19, 2022), https://vtx.vt.edu/articles/2022/05/vtt-smart-work-zone.html?utm_source=cmpgn_news&utm_medium=email&utm_campaign=vtUnirelNewsDailyPublicCMP_052022-public; Audi, *Audi collaborates to deploy C-V2X communication technology on Virginia roadways* (Sept. 29, 2020), https://media.audiusa.com/en-us/releases/437.

[36] Press Release, Audi, (Mar. 30, 2021), *Blue Bird, Fulton Co. Schools join Audi, Applied Information on connected vehicle deployment to boost school bus and school zone safety*, https://media.audiusa.com/en-us/releases/465#

[37] Press Release, Audi, *Audi joins Spoke Safety, Qualcomm, Commsignia to help protect bicyclists through connected technology*, https://media.audiusa.com/en-us/releases/514.

[38] https://www.its.dot.gov/pilots/pilots_thea.htm

[39] https://teo.fdot.gov/architecture/architectures/d2/html/projects/projarch47.html

communications network with a cellular IoT system. DOT's traffic management system controls the traffic signals at 14,000 intersections, as well as a range of ITS devices including traffic cameras, variable message signs and vehicle detection devices. The new network is highly automated, secure, and achieves four 9's availability using dual concurrent cellular links.[40]

- Tri-Met in Portland, OR. The Tri-County Metropolitan Transportation District of Oregon (TriMet) serves an area of 500 square miles, operating a fleet of over 700 buses on 85 routes with thousands of stops. Smart systems maintain bus intervals and on congested corridors, prioritize bus travel over other vehicles by sensing bus arrival time then manipulating traffic signal phases[41]
- Positive Train Control- - SEPTA, LIRR, MNR, MBTA, AMTRAK. Positive Train Control (PTC) utilizes GPS, sensors and wireless communications technology to autonomously stop a train when necessary and to prevent train-to-train collisions, over-speed derailments, and unauthorized train movement. PTC helps ensures the safety of passengers by acting as a safeguard against human errors and other potential hazards.[42]

Generally speaking, these technologies include hardware, software, systems, and some type of connectivity. Hardware includes traffic signals and traffic controller assemblies, dynamic message signs, connected vehicle roadside units, cameras, sensors, LIDAR, electric vehicles (EVs) and EV charging equipment, vehicles with varying levels of autonomy (drones, delivery shuttles), and electric mobility (scooters, e-bikes). Systems include those that focus on security, intelligence, monitoring, and management. Software includes route planning and travel alerts. Connectivity includes- Cellular Vehicle to Everything (C-V2X), 5G, autonomous navigation both edge and cloud techniques.

While there are e several opportunities and benefits for personas that use these technologies primarily in the realm of safety (i.e., emergency vehicle preemption, entering school or work zone, pedestrian crossing ahead) these technologies can also provide valuable support functions such as package, food, and medicine delivery. There are also environmental benefits from congestion mitigation and providing an orderly flow of traffic (See Carnegie Melon Study for an example: https://www.cmu.edu/piper/news/archives/2012/october/smart-signals.html) as well as increased productivity (drivers spend less time stuck in traffic). Other personas may use these technologies to develop and operate innovative transportation services, such as those involving multimodal transit, ridesharing, and autonomous transportation of people and goods.

There also exist several barriers faced by personas seeking to implement these technologies. On the policy side clarity is needed with respect to data governance and privacy and what aspects of data jurisdictions can collect, retain, and subsequently use. Certain aspects of this sector still need high level policies and regulations that adequately address safety and liability concerns. The benefits of these technologies are not available in rural or undeserved areas.

[40] https://www.digi.com/resources/customer-stories/new-york-city-dot-deploys-digi-solutions
[41] https://www.digi.com/resources/customer-stories/trimet-bus-fleet-management-with-digi-connectivity
[42] https://www.digi.com/resources/customer-stories/digi-helps-septa-comply-with-federal-mandate

Interoperability and fragmentation is also a challenge when dealing with different jurisdictions and it’s important to address cybersecurity implications of all the connected devices that can be used as a gateways. Finally, there is a considerable amount of funding needed to drive adoption in this sector. The examples provided above reinforce that this technology is ready to go mainstream.

Finding: Healthcare. IoT is transforming healthcare, and is poised to revolutionize it but significant challenges need to be addressed.

The Internet of Things offers the potential to revolutionize healthcare by reshaping patient care, clinical workflows, and healthcare management. The integration of connected sensors, digital technologies, and data analytics creates a connected ecosystem of Internet of Medical Things (IoMT), medical devices, healthcare systems, and software applications that communicate with each other to streamline healthcare delivery, improve patient outcomes, and pave the way for a more efficient and patient-centric healthcare system.

IoMT devices range from wearable devices and remote patient monitoring solutions to smart medical implants. These IoMT devices encoms a vast network of sart, interconnected medical devices that collect, transmit, and analyze health data in real-time to enhance the quality of healthcare services and create a new era of personalized medicine.

IoMT devices fall into four categories:

- Wearable on-body devices, including consumer health devices (fitness watches, sleep trackers, etc.), and clinical-grade devices (regulated by health agencies, and prescribed by healthcare professionals).
- In-home devices that support telemedicine applications such as remote patient monitoring, and emergency response.
- Community IoMT systems, such as emergency response intelligence systems that connect patients and first responders, mobility services, and devices for measurement and regulation of temperature, blood pressure, etc.
- In-clinic IoMT systems that support administrative functions that allow medical workers to help patients remotely, track hospital assets and equipment, etc.

Some examples of top IoMT applications include:

- **Remote patient monitoring**. One of the most impactful applications of IoT in healthcare is the continuous monitoring of patients outside traditional healthcare settings. Wearable devices track vital signs, medication adherence, and other health metrics. This allows healthcare providers to monitor patients outside traditional clinical settings, providing timely interventions and reducing the need for frequent hospital visits. This is beneficial for individuals with chronic conditions, allowing healthcare providers to remotely track and manage patients' health, reducing hospital readmissions, and enhancing overall patient well-being.

- **Consumer health awareness**. Wearable devices, such as smartwatches and fitness trackers, have become ubiquitous. These devices play a pivotal role in promoting preventive care, tracking physical activity, monitoring sleep patterns, and even detecting early signs of health issues, fostering a proactive approach to well-being.
- **Enhanced patient care**. IoMT has propelled the development of smart medical devices, including insulin pumps, pacemakers, and continuous glucose monitors. These devices not only offer real-time monitoring but also enable healthcare professionals to adjust treatment plans based on individual patient data, leading to more personalized and effective care.
- **Asset and Inventory Management.** IoT plays a crucial role in optimizing hospital operations by monitoring the location and status of medical equipment and supplies. This ensures that resources are efficiently utilized, reduces waste, and enhances overall operational efficiency.

IoMT enables the following benefits, including:

- **Enhanced Patient Outcomes**. By enabling continuous monitoring and personalized care, IoMT contributes to improved patient outcomes. Timely access to health data allows for early detection of potential issues, better management of chronic conditions, and more proactive interventions.
- **Efficiency and Cost Savings**. The implementation of IoT in healthcare streamlines workflows, reduces manual tasks, and enhances the efficiency of healthcare delivery. This not only improves the quality of care but also contributes to cost savings by minimizing unnecessary hospitalizations, optimizing resource utilization and minimizing administrative costs.
- **Patient Engagement and Empowerment**. IoMT empowers patients to actively participate in their healthcare journey. Access to real-time health data through wearable devices fosters a sense of ownership and encourages individuals to make informed decisions about their lifestyles and treatment plans.

While IoMT offers the potential to revolutionize healthcare, there are some challenges, including:

- **Security and Privacy Concerns**. The vast amount of sensitive health data transmitted through IoT devices raises significant concerns about data security and patient privacy. Ensuring robust cybersecurity measures and compliance with privacy regulations is crucial.
- **Interoperability Issues**. The integration of diverse IoT devices and platforms poses challenges related to interoperability. Standardization efforts are essential to enable seamless communication between different systems, ensuring a cohesive and efficient healthcare ecosystem.

- **Regulatory Compliance**. The rapid pace of IoT development often outpaces regulatory frameworks, leading to challenges in ensuring compliance with healthcare regulations. Addressing these issues requires ongoing collaboration between technology developers, healthcare providers, and regulatory bodies.

The Internet of Medical Things holds immense promise for the healthcare industry, facilitating a future where patient care is personalized, efficient, and technologically advanced. However, to realize this promise, the healthcare industry ecosystem must evolve and adapt its practices, operations, policies and regulations.

Finding: Environmental Sustainability. IoT supports environmental sustainability through real-time monitoring, optimizing resource usage, and facilitating data-driven decision-making across infrastructure and multiple sectors of the economy.

IoT supports and facilitates environmental sustainability in a number of ways. IoT devices monitor environmental conditions, optimize usage of resources, and control operational processes. The data collected from IoT devices is analyzed and used to inform policymaking, enforce regulations and monitor progress and success of programs and initiatives. In other cases, IoT technologies initiate actions and control operational processes that support sustainability outcomes.

IoT is used in a variety of applications to support environmental sustainability across all aspects of infrastructure and economy. Some examples of IoT applications for environmental sustainability include:

- **Monitor air quality.** Air quality sensors measure the concentration of pollutants in the air, including particulate matter (e.g. soot or black carbon), and gas pollutants (carbon monoxide, nitrogen dioxide, etc.). This information informs residents of a community whether to go outside exercise or not. The collected data may be used by city and health officials to identify areas of poor air quality, and to devise programs to mitigate its effects (such as planting trees in the area, restricting traffic at certain hours, banning idling cars at certain hours, providing residents with respiratory healthcare information, etc.).

- **Optimize water use.** Farming consumes a lot of water. Soil moisture sensors, integrated with automatic irrigation systems, measure moisture levels and activate the irrigation systems in those spots in the field where the water is needed. This helps save water (and the corresponding expenses) by precisely directing water to those spots where it is needed. This optimizes water usage by applying water it is most needed, and reducing waste and conserving resources.

- **Reduce carbon emissions.** Intelligent traffic management systems, incorporating IoT sensors, detect heavy traffic conditions and automatically adjust traffic signals to reduce congestion. This increases the capacity of the street or freeway to handle more cars,

while reducing the time cars are idling. The overall effect is a reduction in emissions and its impact on residents of the surrounding community.

- **Reduce energy use.** Buildings are one of the largest consumers of electricity. Room occupancy sensors turn off lights in empty rooms. Smart thermostats learn the behavior of building occupants and autonomously manage ambient temperatures based on those patterns. Automated demand response systems, connected to building automation and energy management systems, automatically reduce energy use by turning things off during peak demand periods while minimizing impact on building occupants.

- **Optimize use of renewable energy sources.** IoT optimizes and maximizes the use of renewable energy sources to power communities and cities. Smart inverters in solar power systems and sensors in batteries communicate with the local electrical grid to continuously manage how much electricity is stored, discharged to the grid, and used to power loads in the home and business. This maximizes the ability of renewable energy systems to meet demand in the local grid, while delaying the use of upstream fossil fuel power generation plants to meet local community demand.

The use of IoT to support environmental sustainability offers the following benefits, including:

- **Improved and more effective outcomes.** The use of IoT enables the direct monitoring of the environment at the precise locations needed. The data collected can be used to improve and validate simulation models, and to predict likely trends and patterns. This foresight leads to more informed policies and strategies, which can then be implemented and monitored.

- **Increased resource use efficiency.** Analysis of the collected data provides insights that lead to optimization strategies. For example, a study of energy usage data helps identify patterns that may be adjusted. Automation systems may be programmed with these insights to optimize energy utilization, minimizing waste and enhancing efficiency.

- **Agile and proactive response.** Real-time monitoring of environmental conditions, such as water contamination and air quality levels, allow the community to plan and respond swiftly. This enhances the effectiveness of the response, the number of resources applied, and minimizes the extent of the adverse impacts.

- **Informed and data-driven decision making.** The vast amount of data collected by IoT devices enables informed decision-making for policymakers, businesses, and individuals in the pursuit of sustainability goals. This leads to more effective policies and strategies, more productive use of resources, and sustainable outcomes.

The use of IoT for environmental sustainability faces a number of challenges. These include:

- **Data accuracy.** Environmental monitoring is performed by many types of sensors. For example, air quality sensors range from low-cost sensors “consumer grade” to

expensive regulatory grade units. Despite measuring the same things, these sensors have different accuracy levels due to the underlying sensing technologies used. Low-cost sensors would not be suitable for use in situations where environmental monitoring is used for verification of compliance. In addition, sensors experience calibration issues, drift, or malfunctions, leading to inaccurate readings.

- **Lack of supporting infrastructure.** Environmental monitoring devices may be deployed in remote or rural areas with limited or unreliable network connectivity, affecting the real-time transmission of data. For example, many wildfires start in remote areas and early detection is critical to containing the impact. Many river monitoring stations are located upstream in remote areas. Ocean monitoring buoys are located in areas with no infrastructure. These remote areas have limited to no connectivity service, and hinders the ability to deploy IoT in these areas.

- **Initial Implementation Costs.** The upfront high costs of purchasing and deploying environmental monitoring sensors are a barrier for many agencies and communities. These costs are increased if a large network of sensors is needed. For example, in a city environment, air quality levels significantly. A street next to a freeway has poorer air quality than a street a mile away. In those applications where a dense network of sensors is needed, such as community air quality monitoring, the costs can beyond the financial means of the purchasing agency. While low-cost sensors may alleviate the financial burden, they suffer from lower accuracy and will not meet regulatory standards.

- **Data management.** Environmental monitoring sensors collect a large volume of data over time. For example, some air quality sensors collect data every 15 minutes. During a storm, sensors monitoring rising river water levels during a storm collect data more frequently than when it is not raining. Managing this data is complex and challenging. This is complicated when sensor data from different brands is combined. These sensors have different accuracy levels, different measurement methods, and different methods for how the readings are calculated. Normalizing the data is laborious and time-consuming. This data must then be stored and maintained. The challenge is magnified as the volume of data collected grows.

- **Interoperability.** Environmental monitoring is a fragmented ecosystem of diverse devices and sensors, each designed with specific communication protocols and standards. This lack of standardization hinders seamless integration and data exchange between different IoT platforms and devices, limiting the holistic view required for comprehensive environmental monitoring. The lack of standardized communication protocols hinders the ability of environmental monitoring networks to expand and scale. Without standardized interfaces, scaling up becomes a cumbersome task, leading to increased complexity in managing and maintaining diverse systems. The challenge is further exacerbated pronounced when attempting to create a unified system that aggregates data from various sources, such as air quality sensors, water quality monitors, and weather stations. Overcoming interoperability challenges is crucial for

establishing a cohesive and interconnected network of environmental monitoring devices, enabling more accurate and comprehensive assessments of environmental conditions.

Recommendations of the IoT Advisory Board

The global Internet has rapidly progressed from a simple interconnection among a few computing centers to a ubiquitous digital environment that touches every aspect of our lives. A key part of 21st Century digitization is the continued IoT implementation within public and private-sector organizations.

The IoTAB recommends that the IoTFWG consider (and where appropriate, act to implement or document the existing implementation of) the findings and recommendations below. The Board remains in place until [date] to clarify any points for the IoTFWG or to answer any questions about these recommendations.

During discussions, topics surfaced repeatedly as areas that affected a broad range of IoT topics. Because this initial set represents cross-sector needs, the Board has described recommendations on those topics first in the report. The remaining recommendations are topic-specific and follow those cross-cutting discussions.

[Ed. Note: When the recommendations are mostly stable, we will place a table here as a quick reference, with hyperlinks to each recommendation.]

Establishing a National IoT Strategy

Objective 1: Congress and the White House must work together to create and implement a coherent comprehensive coordinated national IoT strategy, as numerous federal experts have suggested over the years.

Key Recommendation 1.1: The IoTAB recommends a national strategy for taking full advantage of the opportunity presented by the IoT. [For Review by the Board]

In 2010, the President's Council of Advisors on Science and Technology (PCAST) recommended the Federal Government invest in a national, long-term, multi-agency, multi-faceted research initiative in these areas.[43] They said, "those agencies tackling problems whose solutions entail instrumenting the physical world … should conduct research to design, fabricate, and test sensors that are problem-domain specific and that are cheaper, smaller, better packaged, lower powered, and more autonomous than those available today."

In 2011, an OSTP/NSTC White Paper outlined many reasons why we needed a more comprehensive and strategic approach for taking advantage of the Cyber Physical System (IoT) opportunities over the horizon to grow our economy and help solve our national challenges.[44] They found that "Isolated efforts by mission agencies are simply not sufficient to address the underlying issues in a holistic manner." Trying to address them agency-by-agency or sector-by-sector would result in inefficiencies and insufficient progress relative to system development timetables, and we might never get to where we need to be, and the recommended the creation of a long range action plan.

They went on to say, "Without a strong, central focus on innovation and the common issues in translational research for innovation in cyber-physical systems, including standardization, manufacture, and deployment, each of the jump start activities above runs the risk of devolving into an isolated, marginally-effective effort."

Likewise, a NITRD Report from 2012 that looked at opportunity in Agriculture, smart building, defense, emergency response, energy healthcare, manufacturing and transportation, advocated for a multi-agency, multi-sector comprehensive focus on the difficult crosscutting R&D challenges in CPS.[45]

And now today, the IoT opportunities are even more pervasive, the economic stakes even more enormous, and the impacts are even more profound.

[43] The 2010 PCAST report is available from: https://www.nitrd.gov/pubs/PCAST-NITRD-report-2010.pdf
[44] The OSTP/NSTC white paper is available from: https://www.nitrd.gov/pubs/CPS-OSTP-Response-Winning-The-Future.pdf
[45] The 2012 NITRD report is available from: https://www.nitrd.gov/nitrdgroups/images/6/6a/Cyber_Physical_Systems_%28CPS%29_Vision_Statement.pdf

We need a comprehensive national IoT strategy that:

- lays out a comprehensive vision for the federal government's role in IoT;
- articulates the role that IOT can play across sectors and agencies, and within sectors, in advancing national priorities and solving social challenges – across health, transportation, manufacturing, energy etc.;
- ensures continued U.S. leadership in connected device technologies, a vibrant and innovative commercial sector, and U.S. leadership in the way the technologies are harnessed to address national challenges;
- comprehensively catalogues the game changing work the administration is already doing across many agencies in fundamental research, development, demonstration and deployments – and the important role agencies are playing in meeting our critical needs;
- identifies potential opportunities, and synergies across agencies, and identifies remaining gaps;
- outlines an R&D roadmap around the often multi-disciplinary R&D needs to push new frontiers and achieve major grand challenges.
- can ensure the continued responsible development and use of a new technologies; and
- provides a way that can help agencies, innovators, scientists, stakeholders, and commercial partners see and engage with the effort. Like nano.gov, quantum.gov, and ai.gov, stakeholders could also benefit from a one stop shop on the internet that would share the strategy and vision, demonstrate the many ways the government is tackling these issues, and that allows stakeholders to engage in meaningful ways.

As PCAST previously noted, there is a need to research ways to design, fabricate, and test sensors that are problem-domain specific. The nation requires sensors, actuators and controllers that are cheaper, smaller, better packaged, lower powered, and more autonomous than those available today. In sensors for use in extreme environments, and those that can unlock entirely new opportunities barely imagined today. Areas to consider would be the high-risk, high-reward research to advance digital sensors for example from digital noses that can detect any gas, particle or toxin; from digital eyes that for example can leverage new electro-optical technologies, photonic chips, and other sensors to help us see the world in new ways; digital tongue type technologies that can help us better sense toxins, turbidity, e-coli, pH, heavy metals in waters, and nutrients in soils; and biochemical enablers like micro-fluidic labs on a chip to advance the Internet of biochemical things. These could unlock new IoT potential across many domains;

Enabling Recommendation 1.1.1: IoT must be added back to the critical and emerging technology list. [For Review by the Board]

The U.S. National Standards strategy focuses on emerging technologies. Beyond the USNSS, the IOT is no longer included in the list of critical emerging technologies https://www.whitehouse.gov/wp-content/uploads/2022/02/02-2022-Critical-and-Emerging-Technologies-List-Update.pdf [whitehouse.gov] The U.S. National Standards strategy focuses

on crucial emerging technologies, however, beyond the USNSS, the IoT is no longer included in the critical emerging technologies list.

This as a problem since the IoT is critical to U.S. prosperity and socioeconomic success and still faces many barriers to adoption. The IoT must be added back to the CET.

Enabling Recommendation 1.1.2: Congress should further improve and elevate inter-agency coordination. [For Review by the Board]

Within the White House there is a research coordination function called the National Science and Technology Committee (NSTC). This is where coordination across the government is supposed to happen. For more than a decade, there was a Cyber-Physical System (CPS) Inter-Agency Working Group, which has made some important contributions and recommendations to advance IoT fields. But in 2019, its focus was diluted. It's important to ensure there is an NSTC IoT committee that is properly elevated, named, and empowered, just like other NSTC committees focused on AI, Quantum and Nanotechnology. This is particularly important as formerly separate disciplines of AI, Quantum and IoT begin to converge. It's also critical that an approach must be inclusive of IoT and the many different names and enablers.

The U.S. should lead in the adoption and integration of emerging technologies like the IoT into the U.S. economy and infrastructure. Currently a lack of coordination from the Executive Office of the President leads to siloed planning, policies, execution, suboptimal utilization of resources, duplicate programs, monitoring, thus limiting realization of economic, social, security and other values and benefits.

Congress should expand the mission of OSTP for additional focus on the IoT as identified by the National Standards Strategy of May 2023 or similar curated list, with additional staffing support as required for the expanded mission. OSTP has historically played a critical role in coordinating such inter-agency endeavors.

There is a need to establish new and/or leverage existing FACAs to augment knowledge and expertise gaps. The necessary coordination and integration with the NIST (FWIoT and Global City Teams Challenge (GCTC)) protocols should be in place (i.e., IoT implementations involve the integration of multiple technologies, systems, and stakeholders).

The list of Critical and Emerging Technologies (CET) is broad (AI, IoT, quantum, etc.) and some agencies may have some existing CET interagency roles. Having OSTP in a leadership role, potentially convening interagency efforts, FACAs or other whole-of-government or public-private activities, will help steer government and private sector activities.

Congress should create and fund a new National Coordination Office for IOT/CPS for advancing this strategy, like it has in the areas of Nanotechnology, Quantum, and AI, then in doing so it should also ensure that OSTP is fully resourced and funded to be able to take on these task – or risk losing focus on other critical needs.

Modernizing IoT Infrastructure

Objective 2: The U.S. should call upon and collaborate with industry to enhance and modernize the infrastructure that enables and supports IoT. Such collaboration should include the provision of clear direction and support for data sharing methods and repositories, consistent and resilient ways for communicating among devices, and improved means to connect among devices and interconnect with existing technologies.

There are three critical aspects to modernizing and expanding this infrastructure:

- Data Sharing,
- Consistent and Resilient Interoperability and,
- Enhanced Connectivity.

The U.S. Government should call for immediate attention to these needs, as it has done for other topics through strategic objectives and planning. In particular, NIST may be able to support the development of outcome-based objectives that inform industry consensus standards and may be able to offer assistance as industry collaborates and develops those standards. That partnership may also help support international success in expanding and improving IoT infrastructure and reliability.

Key Recommendation 2.1: The government should foster policies that encourage responsible IoT data sharing, and thereby drive economic growth.

Data policies can have a major impact on privacy, security, innovation, and monetization. Importantly, the lack of data policies can create uncertainty and hinder the growth of digital economies. Identifying opportunities to monetize data further enables business growth and can fuel synergistic ecosystems.

The federal government can apply policies to facilitate data protection, sharing, licensing, and analytics can minimize risk and maximize economic value.

Specifically, agencies should consider the potential impact of data policies and provide guidelines for data use and monetization. Citizens will benefit from the promotion of interoperability for data sharing, and from improved collaboration and information sharing among agencies and industry.

Implementation considerations: Implementation of this recommendation would include programs to promote the necessary infrastructure for data security and privacy, including aspects of data sharing, licensing, ownership, analytics, control, and monetization. Agencies would need to establish and maintain data policies that ensure compliance with regulatory requirements, in consultation with industry, academia, and government agencies.

Potential barriers: Lack of knowledge about the data policies and resistance to change will likely both hinder adoption. Lack of data policy would hinder growth of digital economies, and even where policies are created, any lack of clarity on how data policies on confidentiality and

security will impact stakeholders might result in reduced trust or effectiveness. There may also be challenges from costs of establishing the administrative and technical infrastructure needed.

Enabling Recommendation 2.1.1: The government should establish templates for clear and robust policies regarding data sharing, usage, and licensing among parties in the IoT ecosystem. Where practical, agencies can help foster voluntary, industry-led adoption of such policies to enhance transparency, reliability, and consistency in applying IoT.

Such templates and policies are vital due to the significant privacy and data protection risks presented by IoT's increased interconnectivity and data-sharing capabilities. Since these risks may discourage IoT adoption, clear policies safeguarding users' personal data and ensuring transparency would foster trust and expanded IoT use.

Implementation considerations: The government should create guidelines on effectively communicating third-party data sharing and data use in privacy policies, in alignment with other recommendations from this report. Those guidelines and policies would be supported by public awareness campaigns to educate users about their data rights and to share information about how to properly share and protect IoT data.

Potential barriers: Some organizations, including those who rely on third-party data sharing for business operations, may not be fully supportive of restrictions on data sharing and data usage. There may also be challenges in aligning these policies with existing privacy regulations and international data protection standards. While such challenges are not insurmountable, privacy and data protection requirements vary greatly by region and can be difficult to reconcile across cultural and geographic boundaries.

Enabling Recommendation 2.1.2: The government should partner with industry and collaborate with international allies to develop and support comprehensive data sharing policies that stimulate economic growth.

As digital threads drive growth of data among marketplaces, policies will be needed regarding data privacy, confidentiality, ownership, control, management, access, licensing, and trust for data use in applications, to minimize security risks and maximize economic value.

Monetization of data will require infrastructure for Security, Privacy, Data Sharing, Ownership plus Control Frameworks for Identity and Access management (IAM), Data Protection, Sharing and Exchange, Data Analytics and AI, to minimize supply chain risk and maximize economic value. Policies related to data can have a major impact on privacy, security, interoperability, transparency, accountability, innovation, and monetization, as they can fuel synergistic ecosystems and the future digital economies.

A lack of clear and consistent data policies can create uncertainty and hinder the growth of digital economies. The right data strategy can drive business growth and fuel synergistic ecosystems. Policy guidance from the government will support the infrastructure required for

data sharing (i.e., for security, control, trust, licensing, identity & access management (IAM), and analytics), and will also help support consistent protections, such as anonymization of collected data (an essential element of privacy, safety initiatives, and other risk management considerations).

Implementation Considerations: The government should work with industry to help establish model policies related to trusted data, including identification of areas that are critical or sensitive enough that regulatory oversight might be necessary. That process can include methods for promoting essential requirements and guidelines (such as for data privacy, confidentiality, and anonymization) and define methods for how stakeholders (e.g., industry, academia, civil society, and government agencies) might evolve the policies to keep them up to date with changing technologies and business models.

As the government works with partners to create policies that promote interoperability and data sharing across different systems and corporations, it can, in particular, consider the impact of such policies on SMBs.

Potential Implementation Barriers: As these new policies are drafted and released, the lack of familiarity with them, and any lack of clarity about how the data policies will impact stakeholders, might cause some uncertainty and, thereby, hinder the adoption by businesses and workers as well as the growth of digital economies.

The cost of establishing infrastructure for data security, privacy, sharing, and exchange, as well as data analytics with AI, may be significant, though the benefits may prove the investment worthwhile.

Secure Data Repositories

Key Recommendation 2.2: The government should establish data repositories for privately collected data.

The growth of the Internet in recent years is directly traceable to the fact that large amounts of data can be efficiently and responsibly stored, enabling significant exploration to gain insights into a myriad of information types. For more than a decade, the U.S. Government has recognized that data is a key asset that can provide valuable benefits to its citizens and other stakeholders. As with many existing datasets, there is an opportunity for the Government to help create and maintain repositories for IoT data, ensuring transparency and availability.

Some of the IoT-related data is likely to include information that may be openly shared with a broad constituency, as many thousands of existing open datasets do. There will likely also be value in helping to establish private data stores that can be licensed for particular consumer segments, bringing value to those who operate some types of IoT devices (accelerating adoption) and supporting availability of important information to those who would consume the information produced.

Federal data repositories provide transparency and the opportunity to community research to conduct analysis on the data far beyond the capabilities of a single federal agency. The growth in IoT devices portends a rapid deployment of devices. These devices have the potential to provide a strong public good, however without transparency privacy and data ownership issues may arise. Additionally, the use of different technologies and methodologies across different platforms may result in conflicting measurements, fostering misinterpretation and reducing public confidence in the monitoring process.

Implementation Considerations: There are existing examples where the federal government has provided a clearinghouse for raw data and other information. For example, the Department of Energy's EIA sharing of power plant data may provide a template and lessons learned for similar sharing.

Enabling Recommendation 2.2.1: The government should work with various organizations to facilitate interoperability through the development of a consistent data taxonomy that allows for the sharing and exchange of traffic and other data collected from IoT and non-IoT sources.

Transportation and traffic agencies have a limited ability to share and exchange data. Transportation data includes things like geographic information, asset and infrastructure information, traffic mobility history, public transportation performance, and traffic anomalies. At best, these exchanges may happen on a limited basis within each agency, but not across other agencies in other jurisdictions. This makes collaboration requiring multiple agencies difficult.

To foster data exchange and interoperability, the government should work with existing organizations such as: state transportation departments, the American Association of State Highway and Transportation Officials (AASHTO, a standards setting body), and private industry.

Implementation considerations: Projects involving multiple jurisdictions and requiring federal funding should specify the development of a data taxonomy that can be further used and developed by other jurisdictions. It's also important to engage with AASHTO as they are a standards setting body which publishes specifications, test protocols, and guidelines, that are used in highway design and construction.

Consistent and Resilient Interoperability

Key Recommendation 2.3: The government should establish methods to foster interoperability for IoT technology, including through the use of consistent models, protocols, application interfaces, and schemas.

While the Internet of Things and related technologies have made significant advancements in recent years, much of that work has been focused on the devices themselves with less focus on the interoperability, compatibility, and connectivity that converts these discrete "things" into an "Internet of Things". In some cases, while manufacturers have provided reliable interoperability

within their own product line, improved interaction among a broad range of devices from disparate producers will encourage competition and technology availability, thereby increasing adoption by enterprises and consumers.

There exist many standards today and there may be a better method for determining which standards should be used under specific conditions. In some cases, formal standards may be needed, such as those from a standards development organization or from a technical engineering organization (e.g., Institute of Electrical and Electronics Engineers (IEEE)). It is likely that wholly new standards and models will not need to be created “from scratch” but rather, industry collaboration is likely to advance existing communications and interoperability protocols that can rapidly be encouraged and adopted. The Board did not identify any single protocol that will solve the interoperability issues, since these models tend to application or domain specific. Therefore, the Board highly recommends not to mandate any formal or informal standard or protocol, but rather to encourage voluntary conformance in the interest of improved interoperability.

Discussions at board meetings indicated that concerns about getting “locked-in” to a particular vendor’s proprietary technology currently act as an impediment to IoT adoption. No company or agency wants to invest in infrastructure that will rapidly become obsolete. Quite the opposite is true – in many cases, IoT infrastructure may need to operate for many decades. Parallel examples such as Wi-Fi (supported through IEEE 802 series technical standards) and cellular industry consortium standards demonstrate that interoperability and standardization do not reduce a vendor’s ability to innovate. Quite the opposite seems to be true – the ability for products to work together has great possibilities for both established manufacturers and newcomers.

Before the government can foster specific standards, it may be helpful for one or more agencies to perform a survey of available and relevant standards, protocols, and models. Such a survey would be helpful, for example, if agencies wish to include open standards and consortium developed standards as part of the requirements for federal funded projects. Federal recommendations (or requirements) for a taxonomy or set of applicable models will promote industry adoption and foster standardization.

Enabling Recommendation 2.3.1: The government should support research and industry-led standards in areas such as telematics and sensor technologies for autonomous vehicles.

These standards should be based on high-level safety guidelines (perhaps as determined by the National Highway Traffic Safety Administration or another federal organization).

The autonomous vehicle (AVs) market in some respects is still emerging. AVs exist in states like California and Arizona, however in other areas of the country they are only found in designated geo-fenced areas like a university campus. It will be some time before these exist on current highways / streets that have vehicles with human drivers. Research is needed to determine how

AVs will interact with these vehicles, with roadside infrastructure, and with pedestrians. In addition, research is needed to show how these interactions change in times of bad weather.

Adoption of vehicle-related standards would promote improved safety and reliability through better vehicle and infrastructure communications and interoperability. Consistent communications standards will promote innovation as vendors work (and compete) to develop products and services that will work together. This increased production and adoption is expected to drive cost savings, further advancing adoption and benefits.

High-level safety guidelines will need to be finalized by the National Highway Traffic Safety Administration as there are still open liability questions particularly regarding a determination of fault in the event of an accident. Spurred by these guidelines, industry can develop appropriate performance and safety standards in a market that is still emerging while avoiding the possibility of market fragmentation. It's important that all key stakeholders in the autonomous vehicle ecosystem participate in these safety discussions and standards development activities.

Vehicle safety and data protection are key concerns in both the U.S. and international communities, so there will likely be extensive oversight and regulatory guidance needed in the short term. The benefits to be gained, including improved safety, convenience, and operational cost reduction are likely to largely offset the burden of regulatory conformance.

Implementation considerations: There should be inclusiveness to involve a diverse range of stakeholders including autonomous vehicle manufacturers, roadside infrastructure manufacturers, communication technology providers, software developers, academia, and government agencies. This ensures that the resulting standards and guidelines are comprehensive, practical, and aligned with the needs and priorities of all relevant parties.

There is a need to prioritize safety. Deaths from traffic accidents continue to increase and standards/guidelines need to address how these technologies can help to decrease these. Existing industry standards and best practices should be leveraged as a starting point. In particular there is a need for how connected vehicles that have a human driver present should interact with transportation infrastructure.

Standards and protocols need to be flexible and able to be adapt with time to accommodate new technologies, emerging threats, and evolving industry needs. There must be encouragement and incentive for widespread adoption of standards and protocols through education, outreach, and support programs. And there is a need to develop mechanisms to monitor and enforce compliance with the established standards and protocols, including certifications, audits, and penalties for non-compliance.

The existing UNECE regulatory framework for automotive security[46] is not a U.S. regulatory requirement, but it is in force in over 50 countries, making the cybersecurity requirements of WP.29 a de facto global standard. Since automakers already conform to these regulatory

[46] https://unece.org/wp29-introduction

requirements in other areas, significant consideration should be given to avoid unnecessary overlap or redundancy.

Potential barriers: The autonomous vehicle market needs to have sufficient time to develop. There are technical challenges that exist in areas such as radar interference, driving in extreme weather conditions. Developing standards and guidelines too early may hinder its growth. AVs will require certain infrastructure aspects like clear lane striping and a means to charge if they are electric.

For industry members to develop and implement protocols it is resource-intensive, requiring significant investments in time, money, and expertise. High-level guidance is needed from applicable government agencies to set the safety requirements for autonomous vehicles. The board notes there is still an open issue of liability concerns that needs resolution. There are also public concerns that warrant the need for consumer education on autonomous vehicle technology.

Enabling Recommendation 2.3.2: The government should promote and adopt industry led standards, guidelines, and protocols for minimum baseline interoperability and cybersecurity requirements for smart transportation technologies and corresponding transportation infrastructure (i.e., sensors in roads, cameras at intersections).

Industry standards and protocols ensure that devices from different manufacturers can communicate and work together seamlessly. In particular, smart transportation systems focus on safety, so standardization (especially for security and interoperability needs) is vital to ensuring that devices can communicate basic safety information to other vehicles and to/from infrastructure.

There are also cases where baseline standards, guidelines and protocols can address existing market fragmentation scenarios particularly in the global market. Some examples are provided below.

- Information Technology for Public Transport (ItxPT) is an international association with the mission to enable interoperability between IT systems in Public Transport by offering public specification of an IT architecture based on standards with open interfaces for on-board, over-the-air and back-office IT systems. By sharing standardized communication technology solutions, public transportation systems in different cities and regions can achieve interoperability, provide better passenger experience, and manage the transportation system more efficiently. Industry benefits as well, as vehicle manufacturers and integrators gain efficiencies with interoperability to reduce cost and accelerate innovation and enable better access to the global transit market. ITxPT has a growing international base of support, driven by its international members and by transit agencies around the world eager to deploy smart systems based on open standards and not proprietary solutions. If its

adoption is delayed in the USA, the transit industry could lose competitive advantage in an increasingly global market.

- Positive Train Control (PTC). There are numerous PTC systems deployed in North America, with varying features and capabilities though all designed and proven to prevent train accidents. Where train operators share tracks, especially when a mix of passenger and freight rail, multiple PTC systems are installed on rail vehicles. The 3GPP consortium has targeted certain use cases for core support within 5G, including public safety, connected vehicle and train control. In collaboration with International Union of Railways (UIC), 5G is supporting the requirements of the Future Railway Mobile Communication System (FRMCS), of which the main goal is to fully digitalize railway operations, support an increasing level of automatic train operations, and take advantage of the broader capabilities of 5G for passenger travel as well. Train control based on FRMCS has a growing international base of support. If adoption is delayed in the USA, the rail industry could lose competitive advantage in an increasingly global market.

There must be a way to address cybersecurity risks such that industry standards that describe minimum cybersecurity requirements of relevant technologies (will help to provide implementing agencies some level of assurance that these risks are mitigated. An example for this is having a unique set of keys for traffic controller cabinets (See the NEMA Standard: Cyber and Physical Security for Intelligent Transportation Systems: https://www.nema.org/standards/view/Cyber-and-Physical-Security-for-Intelligent-Transportation-Systems-ITS)

Standards and protocols can set a path forward for subsequent government regulations or policies and are particularly relevant if industry led standards are attempting to address known gaps and market fragmentation issues. This is particularly important when dealing with multiple states and local jurisdictions. The standard may propose a reference implementation which companies could extend with their own intellectual property or processes.

Standards can stimulate innovation and competition by providing a level playing field for businesses and developers as well, regardless of their size or market share. With a level baseline achieved via a multi-stakeholder process, companies can now build upon it and tailor their own solutions. Standardization can lead to cost savings for businesses by reducing the need for customized solutions and simplifying the procurement process.

Potential barriers: Cybersecurity threats are constantly evolving, so standards and guidelines could be outdated rather quickly. There is concern over organization intellectual property (IP) whereas some organizations may have their own IP different from what's described in a baseline standard and not want to participate in activities that would deviate or reveal their IP. There are also cost and resource constraints to developing and implementing industry standards.

Enabling Recommendation 2.3.3: The government should facilitate and support the adoption of smart city and sustainable infrastructure standards.

Smart city infrastructure relies upon IoT technology to consistently operate. The IoT Advisory Board recommends that the Working Group address funding and implementation considerations for smart cities. For example, municipalities may not have the budget to modernize IoT solutions that better integrate with those in other cities. Therefore, the government may need to develop creative solutions to help local, regional, and state entities to future proof their infrastructure.

Potential barriers: There could be a resistance to standardization given the current landscape and multitude that exists. There could be fragmentation of existing standards and a resistance to creating more standards given the current landscape and multitude that exists. There could be cost and resource constraints and a considerably different landscape given rapid technological advancements.

Enabling Recommendation 2.3.4: The government should promote development and adoption procedures that accelerate and streamline planning, permitting, and interconnection aspects related to energy efficient technologies within the broader electric grid.

The U.S. could benefit from improvements in decarbonization and reduction of greenhouse gas emissions. Many of the energy efficient technologies today incorporate the use of IoT (smart inverters, energy storage systems, etc.). There are improvements to be made in the deployment, permitting, and interconnection processes. Improvements to deployment of critical electric transmission to move electric power from location constrained renewables. Improvements to the installation and operation of rooftop solar panels for the permitting and interconnection process.

Implementation Considerations: Permitting legislation being discussed in Congress. Department of Energy (DOE) RFI designation of National Interest Electric Transmission Corridors (NIETCs). FERC-Back-stop siting authority. Use of existing rights of ways (i.e., railroads and highways). DOE Solar APP+.

Potential Barriers: Time consuming and resource-intensive causes developers to lose interest and cancel projects. Overcoming Resistance. Cost- accounting for them accurately and acceptably. Supply chain. Grid infrastructure requires developers to pay for upgrades to support energy sources.

Promoting Existing Methods

Key Recommendation 2.4: The government should promote the development, adoption, and implementation of interoperable standards for IoT technologies across various industries and applications to ensure seamless connectivity, data exchange, and security. [Updated]

It is likely that wholly new standards and models will not need to be created “from scratch” but rather, industry collaboration is likely to advance existing communications and interoperability protocols that can rapidly be encouraged and adopted. The Board did not identify any single protocol that will solve the interoperability issues, since these models tend to application or domain specific. Therefore, the Board highly recommends not to mandate any formal or informal standard or protocol, but rather to encourage voluntary conformance in the interest of improved interoperability.

Enabling Recommendation 2.4.1: The government should promote the collaborative development and adoption of existing industry standards activities with respect to energy efficient, clean, and renewable energy technologies that are used in sustainable infrastructure.

The federal government should consider interoperability to address the many technologies, some of which are proprietary technologies and the consideration for scalability over time. There needs to be innovation and competition, mitigation for any cybersecurity risks that exist, a way to save on costs through simplified procurement, a foundation for future policies through mechanisms of regulatory compliance, and the need to facilitate market entry.

Implementation considerations: Implementation considerations include: encouraging inclusiveness, prioritizing identified gaps, building on existing standards, encouraging flexibility and adaptability, promoting adoption, global collaboration, procurement and grants, and working with the states.

Potential barriers: Potential barriers include that it may be time consuming and resource-intensive efforts to achieve consensus, there may be technological advancements, international harmonization may create more complexity and time, fragmentation may exist, and/or states may not all agree on adoption of standards.

Enabling Recommendation 2.4.2: The government should advocate for the implementation and adoption of interoperable data standards for public safety IoT.

The proliferation of IoT devices without interoperable data will make it difficult to achieve interoperability the longer it diverges. In public safety, the interoperability of IoT device data will enhance incident responses and coordination among responder teams, providing safety benefits that would encourage the adoption of IoT. Solutions might include facilitation of

adoption by funding grants for jurisdictions/agencies for procurement of interoperable IoT solutions. Support could also include development of education/training materials to help jurisdictions/agencies apply best practices for interoperability.

Implementation considerations: Compiling guidelines and best practices for entities from what currently exists as a starting point (e.g., NISTIR 8255: Interoperability Real-Time Public Safety Data, CISA SAFECOM Interoperability Continuum, etc.), prioritizing solutions which adhere to interoperability guidelines in government contracts for public safety IoT (e.g., bulk purchase pricing a la General Services Administration (GSA) catalog). From a high level, the consideration of tax incentives that would encourage companies to implement public safety IoT with interoperable data standards and the education and promotion of interoperable data guidelines for public safety IoT across different jurisdictions (e.g., local and regional).

Potential barriers: There may be barriers to prioritizing data interoperability when procuring public safety IoT devices include limited budgets but also lack of understanding of what to require, there may be resistance from jurisdictions and public safety agencies that have already invested in an IoT solution, and there may be resistance from industry manufacturers because of concerns about their proprietary solutions.

Enabling Recommendation 2.4.3: The government should promote and, if necessary, develop a protocol for data exchange standards for IoMT (Internet of Medical Things) for interoperability, and promote the adoption of these standards.

Data exchange standards for IoMT would result in data interoperability, which would result in efficiencies and provide safety benefits that would encourage the adoption of IoT. This standardization would support coordination among relevant stakeholders, including product manufacturers and healthcare organizations, to ensure widespread adoption.

Implementation considerations: As data exchange standards for IoMT are developed and refined, agencies could prioritize the (in federal procurements and government contracts) solutions which adhere to or implement those solutions. Simply promoting the benefits (e.g., improved interoperability, potential cost reductions, avoiding vendor lock-in) to the community and education for healthcare organizations could increase adoption.

The federal government could also incentivize (e.g., through tax incentives) companies to implement the IoMT data exchange standard.

Potential barriers: There may be some resistance from healthcare organizations that have already invested in an IoT solution, or from industry manufacturers because of concerns about their proprietary solutions and captive user base.

Enabling Recommendation 2.4.4: The government should promote the development and use of standards for supply chain logistics, traceability, and assurance.

The federal government should foster the development, adoption, and use of standards and protocols for supply chain logistics, traceability, and assurance. It should collaborate with Standards Development Organizations (SDOs) and international allies to promote assured & traceable products by manufacturers for efficient, reliable, and secure supply of goods. It should incentivize suppliers to establish unique corporate IDs, product IDs, asset IDs, and part IDs linked to a digital thread of information and data, that are used to track and trace goods while improving supply chain efficiency, transparency, resilience, and security. There is value in encouraging the use of Global Identifier Standards (such as GLS of GS1) in procurement contracts and regulatory frameworks and track goods and info related to assets and data, to optimize risk, cost, benefits, and value.

The federal government should offer financial and technical support to businesses, particularly small and medium-sized enterprises, to help them adopt and comply with the established standards and protocols. There should be mechanisms to monitor and evaluate the effectiveness of the standards and protocols over time and adjust as needed to address emerging challenges and opportunities. Additionally, the federal government should also support industry-led initiatives and education campaigns to foster the development and adoption of IoT standards and protocols for supply chain management, traceability, and enablement of economic value. These standards should best enable interoperability, reliability, and security across IoT-enhanced supply chains, facilitating data exchange, decision-making and services. By creating and promoting such standards, the government can drive widespread adoption of IoT technology, minimize supply chain risk, and maximize economic value to businesses and users.

Implementation Considerations: An effective supply chain will encourage inclusiveness from a diverse range of stakeholders. Additional considerations include:

- Prioritize critical areas of supply chain management where standardization can yield significant benefits (i.e., data exchange, device interoperability, security, and privacy).
- Build on existing standards as a starting point and adapt/expand as necessary and identify where gaps exist to create new standards.
- Design standards and protocols that can accommodate new technologies, emerging threats, and evolving industry needs. Promote adoption to incentivize businesses.
- Develop mechanisms to monitor and enforce compliance to standards. Foster global collaboration to incentivize suppliers.
- Promote use of unique identifiers across the supply chain.
- Facilitate the adoption of identifiers through incentives, education, and outreach programs and promote linking Identifiers to IoT cybersecurity labeling programs for different markets.
- Create incentives to upgrade existing supply chain management systems to include global identifier standards that ensure seamless tracking and tracing.

Potential Barriers: Some challenges to implementing this solution include:

- Resistance to standardization due to potential loss of competitive advantage, customization capabilities, or intellectual property rights.
- Fragmentation challenges across supply chains with different ecosystem stakeholders.
- Cost and resource constraints.
- Rapid technological advancements make it difficult to keep standards and protocols up-to-date and relevant (and growth of AI will potentially make it even more complex).
- Technical implementation challenges by stakeholders who may view implementation of identifier infrastructure as resource intensive (e.g., time, money, and expertise).
- International harmonization challenges and creating a secure and reliable database to manage the identifiers and share across borders.

Enabling Recommendation 2.4.5: The government should promote standards and protocols for IoT technology in supply chain management to provide assurance of interoperability, reliability, and security across various IoT systems and devices.

Doing so would foster innovation and competition among all parts of the supply chain, simplify integration and maintenance for supply chain partners, examine the cybersecurity and privacy risks, scalability over time, provide cost savings, and potentially meet regulatory compliance.

By establishing a set of common standards and protocols, businesses can seamlessly integrate IoT solutions into their existing supply chain operations, facilitating data exchange, and enabling more efficient and informed decision-making processes.

Developing industry standards and protocols involves collaboration between government agencies, industry stakeholders, technology providers, and researchers to identify the key specifications for IoT systems in supply chain management. This may include addressing issues such as data formats, communication protocols, interoperability APIs, security measures, and device compatibility, among others.

In addition, the government should promote the adoption of these standards and protocols through education and awareness campaigns, providing businesses with the necessary resources and guidance to successfully implement IoT solutions in their supply chain operations. By creating industry standards and protocols, the government can help to create a stable and unified foundation for IoT technology, driving its widespread adoption, and maximizing its potential benefits for businesses and consumers alike.

Implementation considerations: The range of stakeholders should be considered from diverse persona groups including businesses, technology providers, academia, government agencies. There should be a prioritization on critical areas first (e.g., exchanging data, device interoperability, security). There should be a focus on building on existing standards ahead of creation of new ones.

Potential barriers: There could be a resistance to standardization given the current landscape and multitude that exists. There could be fragmentation of existing standards and a resistance to creating more standards given the current landscape and multitude that exists. There could be cost and resource constraints and a considerably different landscape given rapid technological advancements.

Connectivity

Key Recommendation 2.5: The federal government should expand and improve programs that ensure reliable and sufficient connectivity among and between IoT devices in all areas of the country. The government should further promote accelerated innovation to ensure improved communications by ensuring the availability of suitable and sufficient spectrum resources, the development of wide-area networking technologies, and enhancing interoperability.

By definition, IoT technology must be able to internetwork through some physical, ad hoc/mesh, or wireless capability. While communications technologies (e.g., satellite, cellular, broadband/Wi-Fi, and other traditional licensed communications technologies) have expanded in both geographic scope and capacity to accommodate higher data loads in recent years, the capabilities are not unlimited. This condition is exacerbated by the fact that, in many cases, the very places where some IoT sensors are needed, such as for remote security and environmental monitoring, are locations with limited connectivity. Scalability represents another IoT challenge: the communications infrastructure must simultaneously support hundreds of billions of digital conversations.

The rapid evolution of communications technology in recent history demonstrates the significant promise and opportunity for the nation to improve IoT connectivity. Current capabilities that were science fiction in the past are now routine in our daily lives. The U.S. must continue such advances to ensure that IoT can securely and reliably communicate and interoperate wherever devices are applied.

Enabling Recommendation 2.5.1: To promote continued U.S. leadership on spectrum policy, the government should continue to free up spectrum for licensed and unlicensed use via spectrum sharing and repurposing underutilized federal spectrum.

The government, through collaboration between the National Telecommunications and Information Administration (NTIA) and the Federal Communications Commission (FCC) has successfully identified a significant amount of under-utilized federal spectrum that could be made available for private sector use, including for IoT applications. This policy should be continued and should continue to support both licensed and unlicensed applications.

As has been noted, IoT applications are expanding and continued growth is expected.[47]1 The technology industry uses both licensed and unlicensed spectrum to enable this growth. Spectrum availability should not become a choke point in this growth.

- Licensed spectrum usage through 5G (discussion of 5G)
- Whereas unlicensed spectrum typically (discussion of unlicensed) …
- A comprehensive report on U.S. unlicensed spectrum usage is available from https://shop.cta.tech/collections/research/products/unlicensed-spectrum-and-the-us-economy-quantifying-the-market-size-and-diversity-of-unlicensed-devices

Enabling Recommendation 2.5.2: The government should consider increasing funding and accelerating implementation of broadband deployment across rural America.

A recent U.S. Department of Agriculture (USDA) report reported that 60% of U.S. farmland doesn't have good Internet connectivity. While innovative solutions have expanded in recent years, point to point solutions and satellite-based connectivity quickly become expensive and do not resolve all issues. For example, it can be difficult to maintain connectivity to all areas of a farm.

The federal government currently offers limited funding and grants (ex. Department of Agriculture – Community Connect Grant Program) to help fund broadband deployment in rural communities, however, these opportunities have not advanced quickly enough to provide broadband coverage for certain areas of rural America.

Implementation considerations: The U.S. should aggressively promote broadband infrastructure deployment across rural areas until U.S. coverage is complete. Current federal funding operates across several programs making it difficult to identify and find the opportunities available to specific areas.

In some cases, network communications equipment could be installed if power sources were adequately available. For this reason, funding might include options for supplying energy sources such as solar power, wind power, or micro-hydro power where access to reliable electricity is limited.

Other connectivity solutions that federal agencies could explore include taking advantage of modern communications technology and protocols, such as 5G mobile broadband, fixed wireless systems, and low-earth orbit (LEO) satellites.

Potential barriers: Connectivity is improving every day, yet expansion may be limited if there are few eligible service providers in certain areas. It may be helpful to better understand why

[47] *Op cit* the prior background discussion on billions of IoT devices in coming years.

some areas remain underserved, so agencies may want to review previous expansion efforts to identify lessons learned, both positive and negative.

Enabling Recommendation 2.5.3: The government should actively promote and support the adoption of satellite narrowband IoT systems for agricultural IoT, with the aim of improving connectivity, data collection, and decision-making in rural and remote agricultural areas, resulting in economic growth.

Note: While the focus for this topic by the Board relates to agricultural needs, the opportunity applies to any IoT connectivity where devices are deployed in remote areas.

Satellite IoT systems provide a reliable and efficient means of connectivity and data transfer in remote agricultural areas where traditional terrestrial connectivity options may be limited or unavailable. Encouraging the adoption of satellite IoT systems will enable farmers to optimize their operations through real-time data management, resulting in benefits for various stakeholders, including farmers, policy makers, agricultural companies, and consumers.

Encouraging the adoption of satellite IoT systems will enable adopters, such as farmers, to optimize their operations through real-time data management, resulting in benefits for various stakeholders, including farmers, policy makers, agricultural companies, and consumers.

Reliable and consistent support for such remote connectivity requires harmonization of standards for satellite narrowband IoT. The Board recommends that satellite narrowband solutions be explored and developed for specific applications such as agricultural applications and environmental monitoring needs.

Implementation Considerations:

Establish a public-private-academia partnership: This partnership should involve satellite service providers, IoT technology companies, Agriculture data-platform providers, Ag Extension Centers, research institutions, and relevant government agencies. The goal of this partnership would be to support the development, implementation, and adoption of satellite IoT systems in agriculture.

Define specific agricultural applications: Consider specific use cases for satellite IoT in agriculture, such as precision farming, crop monitoring, water management, livestock tracking, and supply chain traceability. Tailor solutions to address these specific needs to maximize the impact of satellite IoT technology in the agricultural sector.

Develop financial incentives and subsidies: Provide incentives or subsidies to facilitate the adoption and integration of satellite IoT systems by farmers and agricultural businesses. These incentives could include tax breaks, grants, or low-interest loans to help offset the upfront costs associated with implementing satellite IoT systems.

Promote education and training: Create educational programs and resources to help farmers and agricultural professionals understand the benefits of satellite IoT technology and how to effectively implement and use these systems. This can be achieved through collaborations with Ag Extension Centers, universities, and industry experts.

The role of states should be clearly defined, and funding for satellite IoT infrastructure and adoption may be allocated to states to manage and distribute. Incentives or subsidies for satellite IoT adoption and integration could be considered as part of the upcoming Farm Bill or other relevant legislation. There might be international coordination, along with spectrum considerations with the International Telecommunications Union (ITU).

Potential barriers: High upfront costs and limited expertise in satellite IoT technology may hinder widespread adoption. Additionally, effective collaboration between multiple agencies, stakeholders, and the private sector will be necessary to ensure successful implementation. Ensuring data privacy and security, as well as addressing any potential regulatory or licensing issues, will also be crucial factors to consider.

IoT Trust

Objective 3: The U.S. has an opportunity to build more trust in IoT. IoT provides powerful benefits but reaping those benefits requires placing sensors and devices in physical locations that can be highly sensitive and intrusive. While IoT promises exciting innovation and advancement opportunities, trust in that technology (and in the protection of associated data) by industrial adopters and other stakeholders is a key prerequisite. Trust considerations directly influence IoT adoption, including IoT safety, reliability, and ability to protect sensitive information stored and processed.

Data Protection Model / Framework / Roadmap

Key Recommendation 3.1: The government should facilitate/support the development of a National Data Policy Framework that clearly delineates the different aspects of data. [Integrated with former 3.1.2]

Comprehensive policy guidance will support many aspects of IoT data protection. A common framework will provide a consistent approach to data privacy and security in the IoT sector, reducing confusion and fragmentation for business, government, and consumers. The framework would also support many of the sector-specific considerations described within this report, such as smart transportation technologies.

Consistent policies will encourage innovation by providing clear guidelines and expectations for IoT device manufacturers, fostering a competitive and growth-oriented environment. The guidance can also be informed by incorporating lessons learned from existing policies and regulations, and by including measures to ensure an ongoing balance between protection challenges and technological advancements.

Framework development would require engagement with key stakeholders in relevant sectors, enabling the U.S. to lead by example through practical use cases for data usage. Some use cases might include:

- **Privacy**: Considerations for this IoT model would incorporate lessons learned from existing privacy regulations, such as the California Consumer Privacy Act (CCPA) and General Data Protection Regulation (GDPR), to create a more effective and efficient framework.
- **Smart Transportation**: Data from a Traffic Camera at an intersection could be used to determine who was responsible for an accident and allow for more efficient insurance claims. Data generated from a connected vehicle and its corresponding roadside infrastructure can be utilized to transmit basic safety information to the vehicle's driver such as entering a school or work zone. Emergency Vehicles and corresponding roadside infrastructure can generate data to preempt traffic signals so the vehicles can get to their destination sooner.
- **[Consider a third example]**

While the vast amount of data that would be provided will significantly improve safety and convenience, the criticality and sensitivity of such data requires adequate protection that can be specified through this new framework.

Implementation considerations: As part of establishing a data policy framework, the federal government should consider setting high-level policy guidelines for data ownership, retention and usage that includes specific guidance for data that has personal information. These guidelines should leverage existing legislative or regulatory language and provide incentives for state and local jurisdictions to adopt them. Creation of a model and guidelines for data ownership, retention and usage would provide states and local jurisdictions the ability to develop criteria for how long data should be retained, how personal information should be stripped from any such data, and how to effectively utilize that data in their operations.

As the framework is implemented broadly, constituents could share lessons learned from pilot projects and successful case studies, further supporting training and education on proper data retention and usage procedures.

Potential barriers: Funding and resource constraints may hinder implementation of this recommendation since some state and local jurisdictions/agencies may not have funding or staff to effectively implement these programs. Coordination across multiple jurisdictions will be challenging, since each jurisdiction has unique and challenging circumstances, and many have existing or pending data protection and privacy legislation.

Notably, it may be challenging to consistently identify and separate data that has personal or private information, or for commercial entities, confidential data and intellectual property.

Enabling Recommendation 3.1.1: The government should establish a model by which data related to the Internet of Things may be protected and used to benefit all. The model would consider a schema for describing IoT-related data and methods for both use and protection.

The model would also support privacy-related considerations. During IoTAB discussions, the Board heard that privacy concerns inhibit adoption of IoT by consumers, so resolving trust concerns from potential users is an important objective.

The model might provide states and local jurisdictions the ability to specify criteria, such as data retention or destruction standards, anonymization methods, and guidance for effective data applications.

There is general consensus that conformance to any specific set of requirements should continue to be voluntary. Market incentives continue to grow, and there is increasing interest in this program based on the participation by industry, consumer advocates and academia. Further incentives from the U.S. Government will drive more participation. On the other hand, a pivot from voluntary cooperation to obligatory mandates may diminish support. changing the focus in

industry from one of supporting development to debate over authority. Such a debate will likely stall progress despite current momentum in industry.

Enabling Recommendation 3.1.2: [Integrated with 3.1]

Enabling Recommendation 3.1.3: The government should examine opportunities to use the notional IoT Data Framework to support and document privacy considerations.

Using the framework model, the nation could create a set of "data use" basics that could be included in privacy policies for IoT devices. These could, for example, be expressed in a similar way to how security considerations are listed in NIST SP 800-60 (as referenced above). Consistent understanding of the data produced by various technologies, including example use cases that describe the data implementation, could enhance consistency of data protection. That consistency may improve confidence in IoT products and foster adoption of more trustworthy technology since adopters will have a baseline of information on which to make decisions and comparisons.

Enabling Recommendation 3.1.4: [Duplicate Removed]

Establish Guidance For Policies Related To Data Sharing

Key Recommendation 3.2: The government should enhance IoT privacy protections by implementing clear, transparent, and enforceable regulations that prioritize user control over data collection, usage, and sharing. [Updated]

[text to be provided]

Enabling Recommendation 3.2.1: The government should advocate for the of use plain language in IoT privacy policies as part of the Federal Acquisition Regulation (FAR) requirements per the Internet of Things (IoT) Cybersecurity Improvement Act of 2020.

The federal government should advocate for the simplification of IoT privacy policies, privacy notices, and data use policies in the private sector, to enhance accessibility and comprehension for users. Improved understanding of data privacy policies for users will lead to more informed decisions when adopting and using IoT devices. The creation of requirements for IoT providers will foster implementation of simplified IoT privacy policies for government contracts.

Because the expectations, requirements, and cautions will be better understood, the use of plain language may lead to increased compliance and will enhance public trust in IoT devices and related technologies.

Two areas of the Use National Cybersecurity Strategy Implementation Plan July 2023 align:

- Initiative Number: 3.2.1 Initiative Title: Implement Federal Acquisition Regulation (FAR) requirements per the Internet of Things (IoT) Cybersecurity Improvement Act of 2020

- Initiative Number: 1.1.1 Initiative Title: Establish an initiative on cyber regulatory harmonization

Implementation considerations: Develop guidelines and best practices for organizations to follow when simplifying privacy policies, establish high-level guidance for evaluating and assessing the readability of privacy policies, coordinate with relevant stakeholders, including the private sector and business, government, and consumer data advocacy groups, to ensure widespread adoption.

Potential barriers: Resistance from organizations that may perceive simplification as a limitation on their legal protections. Possible challenges in defining the appropriate level of simplification while maintaining accuracy and comprehensiveness. Monitoring and updating the simplification guidelines to account for technological advancements and emerging privacy concerns.

Enabling Recommendation 3.2.2: The government should include IoT in U.S. federal privacy regulations proposed.

Note: We need to ensure that this accurately reflects the intent of the Board. There is some question about whether the recommendation is fully correct.

Establish guidelines for manufacturers to establish clear policies on how long business, government, and consumer data is retained. This supports contemplated federal legislation (e.g., the American Data Privacy and Protection Act [ADPPA] H. R. 8152 legislation) and enhances legislation by adding language to the ADPPA related to IoT Data Retention Transparency. This ensures that IoT device manufacturers share a consistent set of privacy standards, enhancing business, government, and consumer data trust and protection. This also facilitates innovation by providing clear guidelines and expectations for IoT businesses, fostering a competitive and growth-oriented environment.

Implementation Considerations: Update contemplated federal legislation (e.g., the American Data Privacy and Protection Act [ADPPA] H. R. 8152 legislation) to address emerging data privacy challenges and technological advancements related to IoT.

Potential Barriers: Achieving consensus among stakeholders and state-level regulators on the most effective elements and practices to incorporate into the Federal Privacy legislation. Ensuring compatibility with existing national and international privacy regulations. Balancing among protecting business and government confidentiality, consumer data privacy, and innovation in the IoT sector. Providing resources, guidance, and support to businesses for the adoption and implementation of the IoT specific requirements.

Enabling Recommendation 3.2.3: The government should establish clear policies for third-party data sharing and IoT device data use.

Increased interconnectivity and data-sharing capabilities of IoT devices present significant privacy risks. Policies safeguard users' personal data and ensure transparency. Clear policies foster trust and encourage IoT adoption.

Implementation Considerations: Create guidelines on how to effectively communicate third-party data sharing and data use in privacy policies. Implement public awareness campaigns about these policies to educate users about their data rights.

Potential Barriers: Resistance from IoT companies who rely on third-party data sharing for business operations. Challenges in aligning these policies with existing privacy regulations and international data protection standards.

Enabling Recommendation 3.2.4: The government should endorse universal opt-out signals for IoT devices and companion apps.

The government should endorse adopting and recognizing Universal Opt-Out Signals for Internet of Things (IoT) devices and any associated applications. The recommendation aims to strengthen user privacy and data protection, which are growing concerns in an increasingly interconnected world. Universal Opt-Out Signals would streamline the user experience, making it easier for consumers to manage their privacy settings across multiple IoT devices and companion apps.

Implementation Considerations: The technical feasibility of implementing Universal Opt-Out Signals across a wide range of IoT devices and companion apps. The costs associated with setting up the infrastructure to recognize and enforce these Opt-Out Signals. And developing standardized guidelines or legislation to mandate the adoption of Universal Opt-Out Signals.

Potential Barriers: Resistance from IoT manufacturers and app developers who may not want to incur the cost or complexity of implementing Universal Opt-Out Signals. Technological constraints in harmonizing Opt-Out Signals across diverse platforms and devices. Potential legislative hurdles if this conflicts with existing data protection or privacy laws.

Enabling Recommendation 3.2.5: The government should add "Location Tracking Enabled" notice to U.S. E-labeled IoT devices.

Include as part of the proposed privacy transparency system for IoT devices, using the “U.S. Cyber Trust Mark”, the following statement regarding the privacy of location data, if applicable: Proposed Statement for Inclusion: "Notice: Precise location tracking is enabled by default on this device."

Consumers have a right to know if their location data is being collected and shared. This statement provides immediate and clear information regarding this aspect. For ethical data

collection and use, consumers should be aware of what data is being collected without needing to delve into complex privacy policies. This recommendation also aligns with various data protection regulations advocating transparency and informed consent.

Implementation Considerations:

Standardization: The statement's wording, visibility, and placement should be standardized across all IoT devices that receive the U.S. Cyber Trust Mark. Technical Feasibility: How will the notice be displayed? Will it be part of the physical label, on a website, or listed in an app for user awareness? Audits and Compliance: Systems need to be in place to verify that the companies adhere to the notification requirement.

Potential Barriers: Industry Resistance: Manufacturers may resist the implementation due to perceived negative impacts on sales or added complexity. Consumer Education: There is the risk that consumers may fail to understand the importance of the notice. Legal Challenges: Companies may argue that this constitutes an unfair labeling or notice burden.

Cybersecurity Improvement

Key Recommendation 3.3: The Federal Government should provide specific and consistent cybersecurity guidance for IoT providers and adopters to ensure secure operations in a whole-of-government approach.

While not the exclusive source of cybersecurity guidance, federal entities should continue to support NIST as a developer of outcome-based requirements that inform industry consensus standards, and industry as the developer of those standards.

Until now, NIST’s role has been to develop recommended baselines and outcomes for the entire IoT ecosystem. Industry subject-matter experts have participated in developing requirements for their specific sectors that align with NIST criteria. NIST’s overall cybersecurity expertise is well-known, as is that of the sector-specific experts. By tasking NIST with developing required outcomes, and industry with specific requirements to meet those outcomes, each side works in an area of strength. These roles are working and should continue.

Enabling Recommendation 3.3.1: [Moved to 3.3.6A. Will renumber]

Enabling Recommendation 3.3.2: The government should strengthen cybersecurity measures focused on IoT across supply chain networks to address concerns around data privacy, security, confidentiality, trust, and potential risks associated with increased connectivity and interdependence of IoT systems.

The recommendation to strengthen cybersecurity measures focused on IoT across supply chain networks aims to address the growing concerns around data privacy, security, and the potential risks associated with the increased connectivity and interdependence of IoT systems. By

implementing robust cybersecurity measures, the government can help ensure that businesses can confidently adopt IoT technologies in their supply chain operations without compromising the security and integrity of their networks and data.

Strengthening cybersecurity measures involves promoting the development and adoption of security best practices, guidelines, and standards specifically tailored to IoT systems in supply chain management. This includes securing data transmission, storage, and access, as well as protecting IoT devices and networks from unauthorized access, manipulation, and cyberattacks.

To implement this recommendation, the government should collaborate with industry stakeholders, cybersecurity experts, and technology providers to identify potential vulnerabilities and develop appropriate solutions that address the unique security challenges associated with IoT systems in supply chain operations. Additionally, the government should support research and development efforts aimed at advancing cybersecurity technologies and solutions tailored for IoT environments.

Training and awareness programs should also be promoted to ensure that businesses and professionals understand the importance of IoT security and are equipped with the knowledge and skills required to protect their systems and data. By strengthening cybersecurity measures focused on IoT across supply chain networks, the government can foster trust in IoT technologies and enable businesses to fully leverage their potential benefits while minimizing risks.

Implementing this recommendation will strengthen cybersecurity measures in the context of IoT adoption in supply chain management lies in the increasing reliance on interconnected systems and devices, which may expose organizations to a higher risk of cyber threats. The main reasons for this recommendation are:

1. Protecting sensitive data: IoT devices and systems in supply chains generate and transmit vast amounts of data, including sensitive information about products, inventory, and logistics. Strengthening cybersecurity measures helps protect this data from unauthorized access, theft, or manipulation.
2. Ensuring operational continuity: Cyberattacks on IoT systems can disrupt supply chain operations, leading to delays, losses, and reputational damage. Enhanced cybersecurity measures help ensure the reliability and continuity of supply chain processes.
3. Maintaining trust: Trust is a cornerstone of supply chain logistics, especially when incorporating IoT technologies which inherently involve the sharing and processing of sensitive data. Strengthening cybersecurity measures for IoT in supply chain logistics helps maintain trust between partners. This is achieved by ensuring the confidentiality, integrity, and availability of data, thereby promoting smooth and secure cooperation across various processes.
4. Compliance with regulations: As data protection and cybersecurity regulations evolve to encompass the growing use of IoT in supply chains, organizations must meet the necessary compliance requirements. By enhancing cybersecurity measures within their

IoT-enabled supply chain operations, businesses can ensure compliance with these regulations, effectively avoiding potential legal and financial penalties.

5. Enhancing competitiveness: Organizations that prioritize robust cybersecurity measures for their IoT-enabled supply chain operations are better positioned to compete in the global market. They can assure customers and partners of the safety and reliability of their operations, thus building a reputation for security and trustworthiness.
6. Addressing evolving threats: The sophistication and specificity of cyber threats are rapidly increasing, particularly in the realm of IoT in supply chain logistics. Organizations must therefore continually adapt and update their cybersecurity measures to stay ahead of potential attackers. This involves keeping abreast of the latest threats and adjusting security protocols to mitigate the risk associated with IoT devices and networks within their supply chains.
7. Fostering innovation: A secure environment enables organizations to safely experiment with new IoT technologies and solutions without the fear of exposing their systems and data to cyber risks. Strengthening cybersecurity measures, therefore, fosters innovation in supply chain management.

Implementation Considerations:

Implementation considerations for strengthening cybersecurity measures for supply chain include:

1. Develop a comprehensive supply chain cybersecurity framework: The federal government can leverage programs like the National Initiative for Improving Cybersecurity in Supply Chains (NIICS) to create a comprehensive framework that addresses various aspects of supply chain cybersecurity. This includes risk assessment, threat monitoring, incident response, and recovery plans specifically tailored for IoT in supply chain logistics.
2. Promote the adoption of best practices and standards: The government can encourage organizations to adopt industry best practices and internationally recognized standards such as the NIST Cybersecurity Framework and the ISO/IEC 27000 series. The Department of Commerce's National Institute of Standards and Technology (NIST) could play a pivotal role in this process, offering guidance and resources to streamline adoption.
3. Encourage information sharing: Facilitating the sharing of threat intelligence, vulnerabilities, and best practices among supply chain partners and industry stakeholders can significantly improve collective defense against cyber threats. The Cybersecurity and Infrastructure Security Agency's (CISA) Automated Indicator Sharing (AIS) program could be an effective platform to foster such exchange.
4. Invest in security technologies: The government can promote the adoption of advanced security technologies, such as encryption, intrusion detection systems, and AI-based solutions, to protect IoT devices and systems. The National Science Foundation (NSF) and Department of Defense (DoD) have research and development programs that could be expanded to support these technologies.
5. Implement security-by-design principles: The government should encourage organizations to adopt a security-by-design approach, integrating cybersecurity

considerations into the design and development of IoT devices and systems. Existing programs, like NIST's Secure Software Development Framework (SSDF), can provide guidelines for this approach.

6. Raise awareness and provide training: The federal government could develop programs to raise awareness of supply chain cybersecurity risks and provide training for organizations and their workforce. Programs such as the Federal Virtual Training Environment (FedVTE) can be leveraged to provide free cybersecurity training for personnel involved in managing IoT technologies within supply chains.

Potential implementation barriers:

Possible barriers to implementing this recommendation include:

1. Limited resources: Organizations may face resource constraints, including financial, technical, and human resources, which may limit their ability to strengthen cybersecurity measures.
2. Complexity of supply chains: The complexity of global supply chains, with numerous interconnected partners and systems, may make it challenging to implement comprehensive cybersecurity measures.
3. Resistance to information sharing: Organizations may be hesitant to share information about vulnerabilities or incidents due to concerns about revealing competitive information or damaging their reputation.

Evolving threats: Cyber threats are continuously evolving, which may make it difficult for organizations to stay ahead of potential attackers.

Enabling Recommendation 3.3.3: The government should consider additional ways to highlight those vulnerabilities most likely to be applicable to IoT product developers.

Provide guidance to IoT developers to help them efficiently meet requirements in standards or best practices for addressing “critical vulnerabilities” (or similar requirements for making sure known or identified vulnerabilities are addressed). This may be accomplished, for example, by providing a list of known IoT operating system vulnerabilities that developers should be aware of and address, or a means to filter an existing list for such vulnerabilities.

The government provides key guidance to the private sector in many categories. For IoT, CISA has guidance for IoT acquisition (https://www.cisa.gov/resources-tools/resources/internet-things-iot-acquisition-guidance-document), use (https://www.cisa.gov/news-events/news/securing-internet-things-iot), and for specific sectors (https://www.cisa.gov/sites/default/files/publications/CISA%20IoT%20White%20Paper_3.6.19%20-%20FINAL.pdf).

The government also maintains vulnerability lists, including the National Vulnerability Database (NVD) maintained by NIST (https://nvd.nist.gov/vuln/Vulnerability-Detail-Pages) and the Known Exploited Vulnerabilities Catalog (KEV Catalog) maintained by CISA (https://www.cisa.gov/known-exploited-vulnerabilities-catalog).

An IoT developer is encouraged or required to make sure they address any “known vulnerabilities” or “critical vulnerabilities” as part of best practices. The FCC NPRM on the U.S.

Cyber Trust Mark program (FCC 23-65 in PS docket no. 23-239) mentions “identified security vulnerabilities” @58 and “critical patches” @40.

One can already filter by “IoT” as a keyword in the National Vulnerability Database, which pulls up 1100+ hits. Those results include many product-specific hits. For example, CVE-2023-23575 is, *“Improper access control vulnerability in CONPROSYS IoT Gateway products allows a remote authenticated attacker to bypass…”* That information is useful to users of the CONPROSYS product, but not to IoT developers.

But buried in that the same set of results are items relevant to IoT developers. For example, CVE-2023-23609 is, *“Contiki-NG is an open-source, cross-platform operating system for Next-Generation IoT devices. Versions prior to and including 4.8 are vulnerable to an out-of-bounds write…”* As Contiki is an IoT operating system, this result would potentially be useful in this context.

While there is a national interest in IoT developers addressing critical vulnerabilities, there appears to be no resource in the public or private sector that can be mapped to IoT vulnerabilities.

Implementation Considerations:

- Vulnerabilities under consideration may be in developer-generated code, or in an IoT operating system or open-source library. The open-source or operating system vulnerabilities would be subject to this list.
- Vulnerabilities under consideration may be known pre-market (at the time of development) or discovered post-market. Developers should monitor the list for both pre-market and post-market vulnerabilities.
- Criteria must be established for “critical IoT source vulnerabilities”. These criteria should be based on whether the IoT vulnerability in question is applicable to a developer of a product, rather than to a specific model from a specific brand.

Potential implementation barriers:

- If the NVD is used, existing data would need to be reviewed to see if it meets the criteria and should be flagged as a critical IoT source vulnerability.

Enabling Recommendation 3.3.4: The government should accelerate the promotion and adoption of procedures and methods to make the electric grid enabled by IoT more reliable and resilient.

A more reliable and resilient grid can better accommodate the integration of renewable energy sources enabled by IoT. This is made possible through the incorporation of technologies enabled by IoT (i.e., smart inverters, energy storage systems) resulting in quicker restoration from natural and man-made threats, more efficient transmission of electricity, and potential cost reductions both for utilities and consumers.

Implementation Considerations: DOE Funding. Near-term technologies provide short-term solutions at a lower cost (e.g., Dynamic Line Ratings, Volt/Var, Power-Flow Controllers, Energy Storage, Distributed Energy Resources, and Demand Response). Microgrids that operate and function as a grid resource.

Potential Barriers: Resources including significant labor and cost implications. Moving away from the traditional process that utilities use to determine rates. Supply chain is an ongoing issue with distribution transformers.

Enabling Recommendation 3.3.5: The government should prioritize broad and active industry engagement when developing and maintaining the government-sponsored portion of the U.S. national cybersecurity label for connected devices.

As the NSC-hosted workshop (Oct. 2022) demonstrated, it is possible to establish a national label program quickly and at scale, provided existing ecosystem mechanisms are used.

Efficiently using these processes requires taking advantage of industry expertise. Continued industry engagement as the program is scoped, planned, and executed will be critical to the program's success. Existing label programs vary; the more flexible the government can be in qualifying the process rather than dictating it, the better.

Process qualification should be outcome-based rather than centrally determined. These outcomes determine the need for trust mechanisms such as meeting the NISTIR 8425 Criteria and having industry-accredited processes.

The Administration should encourage Congressional support to deploy this program, including establishing incentives for manufacturers to participate. Increasing market incentives will be enhanced by introduction of the label program, but only if manufacturers participate. There is strong interest now, but the Administration and Congress can accelerate adoption with earned safe harbors, preemption of mismatched state laws for program participants, negotiation of mutual recognition or "equivalence" opportunity across borders and coordinate agency efforts with regard to consumer education.

Incentives may require legislation. However, there are a range of other options. Authorities of the responsible agencies may need adjustment.

Implementation considerations: Existing label programs vary; the more flexible the government can be in qualifying the process rather than dictating it, the better. Process qualification should be outcome-based rather than centrally determined. These outcomes determine the need for trust mechanisms such as meeting the NISTIR 8425 criteria and having industry-accredited processes.

Potential barriers: There may be a perceived advantage in defining a uniform U.S. government scheme rather than defining the necessary outcomes from various industry schemes.

Enabling Recommendation 3.3.6: The government should encourage congressional support to deploy IoT cybersecurity certification initiatives, including establishing incentives for manufacturers to participate.

Successful deployment of sector-specific IoT cybersecurity certification programs will require assistance from Congress. For example, interest in the consumer-oriented U.S. Cyber Trust Mark program is currently very strong, but manufacturers have the expectation that certain issues would be addressed over time.

Manufacturers cite concerns over perceived new liabilities incurred by adding the label to the product, as well as concerns over the existing possibility of enforcement action by relevant agencies in the event of a device hack. Relief from this concern could be via an earned safe harbor provision. Other potential incentives include relief from a patchwork of state requirements via a federal preempt and a successful negotiation of mutual recognition of U.S. marks with other nations and the EU. Coordinating agency messaging to ensure “one voice” on these label and certification programs to the private sector is also important.

Increasing market incentives will be enhanced by introduction of the label program, but only if manufacturers participate.

There is strong interest now but the Administration and Congress can accelerate adoption with earned safe harbors, preemption of mismatched state laws for program participants, negotiation of mutual recognition or “equivalence” opportunity across borders and coordinate agency efforts with regard to consumer education.

Going forward, the government can use lessons learned from the U.S. Cyber Trust Mark incentive and adoption process to accelerate other IoT cybersecurity certification initiatives.

Implementation considerations: Existing label programs vary; the more flexible the government can be in qualifying the process rather than dictating it, the better.

Process qualification should be outcome-based rather than centrally determined. These outcomes determine the need for trust mechanisms such as meeting the NISTIR 8425 Criteria and having industry-accredited processes.

Potential barriers: There may be a perceived advantage in defining a uniform U.S. government scheme rather than defining the necessary outcomes from various industry schemes.

Enabling Recommendation 3.3.6A: The government should promote the U.S. Cyber Trust Mark and similar programs on the international stage, promoting the U.S. vision and seeking mutual recognition in other areas. [Moved from 3.3.1]

The U.S. Department of State must prioritize supporting the Mark program owner, NIST and stakeholders in the relevant private sector for each of the various U.S. cybersecurity trust certification programs, in conjunction with the Department of Homeland Security and relevant

other agencies, the IoT Federal Working Group, to engage allies and partners toward harmonizing standards and pursuing mutual recognition of the U.S. Cyber Trust Mark and similar labeling efforts.

Enabling Recommendation 3.3.7: The government should facilitate cybersecurity in IoT applications for smart retail. [For Board Review - Proposed by Benson]

- Expand cybersecurity trust mark program to include IoT devices and modules used for smart retail
- Facilitate workforce development programs to increase pool of IoT cybersecurity trained resources to support the digital transformation of retail

IoTAB Themes: Trust, Workforce

The evolution of retail requires heavy use of digital technologies, from back office systems to IoT. The incorporation of IoT in the retail environment creates vulnerabilities and new attack surfaces that must be mitigated. Retailers lack the critical cybersecurity and digital skills to address these risks.

Enabling Recommendation 3.3.8: The government should adopt and promote existing standards, and conformity assessment schemes that facilitate cybersecurity in IoT applications for smart manufacturing. [For Board Review - Proposed by Benson]

- Existing standards and conformity assessment schemes can demonstrate cybersecurity compliance by a number of methods based on a risk assessment. These can include a manufacturer self-attestation that the product or device complies to a certain cybersecurity standard, documentation that the product or device uses a Secure Development Life Cycle that places security front and center during the product development, or third-party testing compliance via a Nationally Recognized Testing Laboratory.
- International harmonization and alignment should be pursued to the greatest extent possible
- Facilitate workforce development programs to increase pool of IoT cybersecurity trained resources in smart manufacturing.
- Support existing legislation (H.R. 4502, Modernizing the Acquisition of Cybersecurity Experts) in Congress that would eliminate certain educational minimums for federal cybersecurity workforce positions to provide agencies the flexibility to attract qualified talent based on an individual's skills and ability to perform the tasks demanded of the job versus relying on degree requirements that often do not relate to the position.

IoTAB Themes: Trust (cybersecurity)

Justification/challenges

- Manufacturing industry was #1 industry targeted in 2021.
- Creation of new attack surfaces into a former “protection by air gap” environment
- Integration of resource constrained IoT devices with limited cybersecurity capabilities
- Exposure of air gapped legacy equipment, industrial control systems and OT infrastructure vulnerabilities

Privacy

Key Recommendation 3.4: The government should promote holistic IoT privacy-related practices that help to safeguard user data and promote responsible IoT development and deployment. [Secretariat drafted – should be strengthened]

The widespread adoption of IoT is contingent upon building a strong foundation of trust among various stakeholders including organizations, governmental agencies, and individual consumers. IoT offers transformative advantages, but to fully realize these benefits, it often necessitates deploying sensors and devices in locations that could seems sensitive or intrusive. Consequently, the assurance of robust data protection mechanisms is imperative. Stakeholder trust hinges not only on the safety and reliability of IoT but also on their capability to secure sensitive information they collect and process. Therefore, establishing this trust is a critical precondition for the successful proliferation and utilization of IoT technology.

This overarching recommendation emphasizes the need for a holistic approach to IoT privacy that addresses various aspects of the IoT ecosystem, including device design, data collection, usage, and sharing. By implementing such practices (e.g., transparency, privacy-enhancing technologies, and data minimization principles), the government can create a trustworthy and privacy-protective IoT environment.

Enabling Recommendation 3.4.1: The government should develop and implement a privacy transparency system for IoT devices, using the “U.S. Cyber Trust Mark” for business, government, and consumer data for Connected Devices and other transparency programs as a guide.

Implementation Considerations: Empowering businesses, governments, and consumers to make informed decisions about IoT devices based on their privacy features and practices. Encouraging IoT device manufacturers to prioritize privacy, fostering competition and innovation in privacy-enhancing technologies. Enhancing overall Cybersecurity and data protection by promoting greater business, government, and consumer data awareness of privacy practices. Considering input from privacy experts, industry stakeholders, and business, government, and consumer data advocacy groups to develop privacy transparency, including content and design. Developing guidelines and standards for privacy transparency, including recommended information, format, and or product information. And encouraging IoT device manufacturers to adopt privacy transparency and provide resources to help them align with the new recommendations.

Potential Barriers: Ensuring broad adoption and compliance with the privacy transparency system across different industries and sectors. Incentivizing IoT device manufacturers who may perceive privacy transparency as burdensome, costly, or restrictive. Balancing the need for comprehensive privacy information with simplicity and ease of understanding for businesses, the government, and consumers.

Enabling Recommendation 3.4.2: The government should promote the implementation of Privacy-Enhancing Technologies (PETs) in IoT systems.

PETs support broader U.S. goals of leveraging technology for societal benefits and protect privacy while extracting valuable insights from the vast IoT data. The use of PETs fosters trust and promotes acceptance of IoT solutions. There is an alignment to responsible data use without compromising user privacy. The implementation of PETs can be used to prevent data breaches and associated legal issues.

Also, there is alignment in existing proposals through the White House in the White House's Advancing a Vision for Privacy-Enhancing Technologies proposal (June 2022) and the National Cybersecurity Strategy Implementation Plan from July 2023 on Initiative Number: 1.2.1 Initiative Title: Scale public-private partnerships to drive development and adoption of secure-by-design and secure-by-default technology.

Implementation Considerations: There are measures to ensure that there are robust security measures for PETs to prevent unauthorized data access. Conducting comprehensive technical and ethical evaluations of PETs before their adoption. There is a need to enhance public understanding and trust in PETs, encourage interoperability between different PET systems, and potentially establish a framework for monitoring the effectiveness and impacts of PETs in IoT technology.

Potential Barriers: Limited technical expertise to understand, implement, and manage PETs, possible resistance from private sectors due to perceived risks or costs, and the complexity of developing universally accepted privacy standards for IoT.

Enabling Recommendation 3.4.3: The government should facilitate the use and development of privacy enhancing technologies. [For Board Review - Proposed by Benson]

- Support research in privacy enhancing technologies
- Facilitate industry integration and use of PETs
- Consider the usage of PETs on IoT technologies and retail systems used in retail outlets on federal properties (including BXs on military bases, federally own and managed facilities)

[Some linkage with Privacy team recommendation on PETs, above]

IoTAB Themes: Trust (privacy)

Consumers want personalized experiences and are likely to become repeat buyers. IoT helps retailers understand and offer personalized experiences, which helps revenues and profitability. The use of IoT technologies and the data it collects enable retailers to understand their customers better. Privacy issues hinder the use of IoT technologies in retail and other consumer facing environments.

Enabling Recommendation 3.4.4: The government should promote "Privacy by Design" in IoT device development, deployment, and implementation

The U.S. government should support the implementation of Privacy-Enhancing Technologies (PETs) in IoT systems by investing in research, standardizing privacy protection, and fostering public-private collaboration for widespread adoption. PETs align with the U.S. National Strategy To Advance Privacy-Preserving Data Sharing and Analytics (March 2023) from the National Science and Technology Council and the National Cybersecurity Strategy Implementation Plan in supporting broader U.S. goals of leveraging technology for societal benefits. PETs foster trust and promote widespread acceptance of IoT solutions while minimizing data privacy risk and minimizes associated legal ramifications. Privacy-By-Design is also a concept aligned with international standards, notably the EU GDPR and ISO standards.

Implementation Considerations: Coordination among various agencies and departments is critical for a unified approach. Enhancing public understanding through education and awareness initiatives and promoting trust in PETs and balancing the economic implications of implementation with the public benefit. Ensuring robust security measures for PETs to improve data security and encouraging interoperability between different PETs systems.

Potential Barriers: The need for more funding, research, and development to ensure PETs are reliable and secure. Possible resistance from private sectors due to perceived risks or costs. The complexity of developing universally accepted privacy standards for IoT.

Enabling Recommendation 3.4.5: The government should include IoT Privacy information on new car automobile “Monroney Stickers”

Monroney Stickers already offer crucial information like fuel efficiency and safety ratings, making them a logical platform for additional disclosures. Providing IoT privacy information helps consumers make informed decisions regarding their personally identifiable information, including 1) data collection, 2) data retention, and 3) data sale. This aligns with broader initiatives to enhance consumer protection and data privacy and addresses growing public concern about how personal data is used and shared by IoT devices in automobiles.

Implementation Considerations: Standardization Privacy Information: The language used for IoT privacy statements should be clear, concise, and standardized to prevent confusion; Regulatory Alignment: Existing privacy laws must be reviewed to ensure that the sticker amendments align with current legal frameworks; Periodic Updates: As IoT technologies evolve, the criteria for what must be disclosed should also be updated periodically.

Potential Barriers: Resistance from Automakers: Automakers may resist this change due to the costs of modifying Monroney Stickers; Consumer Education: There's a possibility that consumers may not fully understand the added IoT information; Complex Regulatory Environment: The landscape of IoT and privacy is complex, making standardization challenging.

Enabling Recommendation 3.4.6: The government should follow NIST sanitization standards for government automobiles before resale.

The government should require that car seller organizations adhere to NIST's media sanitization guidelines prior to reselling a previously-owned vehicle. This recommendation aligns with the e-Stewards Standard, supported by the Environmental Protection Agency (EPA) Recycling Program. Proper data sanitization can protect consumer privacy and prevent unauthorized access to sensitive information stored in modern vehicle systems.

The current version of NIST media sanitization guidelines is *Guidelines for Media Sanitization*, NIST Special Publication 800-88 revision 1 (NIST SP 800-88r1)[1]. The document specifies different types of media and multiple levels of security associated with different sanitization processes. Vehicle electronics represent “electronic media” as in section 2.2, which should be sanitized as per “clean” processes defined, as appropriate for the specific media type, in Appendix A of 800-88r1.

[1] Available at https://dx.doi.org/10.6028/NIST.SP.800-88r1

Connected IoT Value Chains

Note: IoT for Supply Chain is grouped into two segments: 1) the actual logistics of producing, transporting, and storing products (and providing services), and 2) the reliability and security of that chain of goods and services. Those segments are illustrated as “logistics” and “transparency” throughout Recommendation 9.

Objective 4: Maintain efficient and transparent value chains by tracking the movement of goods and materials (i.e., international supply chains) to ensure appropriate levels of availability of products. Augmented logistics will help track materials throughout production, warehousing, and distribution. [Updated but needs refinement]

Key Recommendation 4.1: The government should provide an intentional process to monitor and evaluate progress to provide assurance that IoT adoption efforts in supply chain logistics are on track, effectively addressing identified challenges and opportunities, and delivering desired outcomes.

By regularly monitoring and evaluating the progress of IoT implementation, the government can identify areas of improvement, assess the impact of its policies and initiatives, and make informed decisions to optimize its strategies and investments in the future. Monitoring and evaluating progress involves establishing a set of measurable indicators and targets that reflect the key objectives and desired outcomes of IoT adoption in supply chain management. These indicators may include the level of IoT technology adoption, efficiency gains, cost reductions, improvements in transparency and traceability, and advancements in cybersecurity, among others.

To implement this recommendation, the government should develop a comprehensive framework for data collection, analysis, and reporting, which includes input from industry stakeholders, technology providers, and relevant government agencies. Regular assessments should be conducted to track the progress of IoT adoption against the established targets, identify any gaps or challenges, and evaluate the effectiveness of the implemented policies and initiatives. Based on the findings of these assessments, the government should adapt its strategies and actions to address the identified issues, optimize resource allocation, and maximize the impact of its efforts. By monitoring and evaluating progress, the government can ensure that its approach to driving IoT adoption in supply chain management remains agile, responsive, and results-oriented, ultimately contributing to the long-term success and competitiveness of the industry.

The need to monitor and evaluate progress in IoT adoption for supply chain management stems from the need to ensure the effectiveness of implemented strategies, measure their impact, and identify areas for improvement. Regular monitoring and evaluation are crucial for several reasons:

- Assess effectiveness: Monitoring and evaluation help determine whether the implemented strategies and policies are achieving their intended goals and objectives.

- Measure impact: Assessing the impact of IoT adoption in supply chain management is essential to understand the benefits, such as efficiency improvements, cost savings, and enhanced resilience.
- Identify areas for improvement: By evaluating progress, the government can identify weaknesses or gaps in the implementation of IoT adoption strategies, enabling targeted improvements and adjustments to ensure better outcomes.
- Allocate resources efficiently: Monitoring and evaluation provide insights into the effectiveness of various initiatives, helping the government make informed decisions on resource allocation and prioritize investments in areas with the most significant potential impact.
- Enhance accountability: Regular assessment of progress helps ensure transparency and countability for the government and other stakeholders involved in IoT adoption and supply chain management.
- Facilitate knowledge sharing: Monitoring and evaluating progress can generate valuable knowledge and insights that can be shared with other stakeholders, helping to improve practices and drive further innovation in the field.
- Inform future strategies: The insights gained from monitoring and evaluating progress can inform the development of future policies and strategies, ensuring they are more effective and better aligned with the evolving needs of supply chain management.

Implementation Considerations: Implementation considerations for monitoring and evaluating progress for supply chain include:

- Establish clear goals and objectives: Define specific, measurable, and time-bound goals and objectives for IoT adoption in supply chain management to enable effective monitoring and evaluation.
- Develop relevant performance indicators: Identify key performance indicators (KPIs) that reflect the desired outcomes of IoT adoption and can be used to measure progress and impact.
- Implement data collection and reporting mechanisms: Set up systems and processes for collecting, storing, and analyzing data related to IoT adoption and supply chain performance.
- Conduct periodic assessments: Schedule regular evaluations of progress and impact, using the collected data and KPIs to assess the effectiveness of IoT initiatives in supply chain management.
- Foster a culture of continuous improvement: Encourage feedback and learning from monitoring and evaluation results, using the insights to improve and refine policies and initiatives.
- Collaborate with stakeholders: Engage with industry, academia, and other relevant stakeholders to gather their insights and perspectives, ensuring a comprehensive understanding of progress and challenges.
- Assign responsibility: Designate a lead federal agency or interagency group responsible for overseeing the monitoring and evaluation process for IoT adoption in supply chain management.
- Develop a monitoring and evaluation plan: Create a detailed plan outlining the goals, objectives, KPIs, data collection methods, and evaluation schedule.

- Allocate resources: Ensure adequate financial, human, and technical resources are allocated to support monitoring and evaluation activities.

Potential barriers: Possible barriers to implementing this recommendation include:

- Lack of clear goals and objectives: Ambiguous or poorly defined goals can make it difficult to assess progress and impact.
- Inadequate data collection and reporting mechanisms: Ineffective systems for collecting, storing, and analyzing data can hinder accurate and reliable monitoring and evaluation.
- Resource constraints: Limited resources can impede the government's ability to conduct thorough and consistent monitoring and evaluation.
- Resistance to change: Stakeholders may resist sharing information or adopting new practices based on evaluation results, limiting the impact of monitoring and evaluation efforts.

Public and Private Partnership

Key Recommendation 4.2: The government should help establish and foster public-private partnerships (PPPs) focused on IoT adoption to facilitate collaboration and knowledge sharing between government agencies, businesses, technology providers, and academia.

The federal government should consider leading the formation of public-private partnerships (PPPs) to accelerate the adoption of Internet of Things (IoT) technologies within supply chain logistics operations. These partnerships would bring together a diverse array of stakeholders, including government agencies such as the Department of Commerce, logistics providers, IoT technology companies, and academic institutions such as MIT's Center for Transportation & Logistics. The resultant platform would foster collaboration and knowledge exchange, stimulating the development, deployment, and wider adoption of IoT technologies in supply chain management.

PPPs can also address common barriers to IoT adoption, including infrastructure gaps, limited technical knowledge, and financial constraints. By aligning efforts and pooling resources, these partnerships can drive the innovation of IoT solutions, initiate pilot projects, and roll out proof-of-concept initiatives that demonstrate the value and benefits of IoT in supply chain operations. Additionally, they can contribute to workforce development by creating and supporting training programs, potentially in collaboration with technical colleges and universities.

PPPs can also play a role in establishing industry standards and regulatory frameworks conducive to IoT adoption across the supply chain industry. This would involve close collaboration with regulatory bodies like the Federal Communications Commission (FCC) and standard-setting institutions like the National Institute of Standards and Technology (NIST). By fostering such partnerships, the government can nurture a thriving ecosystem that drives innovation and competitiveness in the supply chain sector, maximizing the potential of IoT technologies.

In today's competitive and technologically advanced environment, no single entity possesses all the resources and expertise necessary to fully drive adoption of IoT solutions across global supply chains. Establishing public-private partnerships provides benefits realized through collaboration between the government and the private sector in promoting IoT adoption in supply chain management. Public-private partnerships can help overcome barriers to IoT implementation and unlock the full potential of this technology. The main reasons for this recommendation are:

1. Leveraging resources and expertise: Public-private partnerships serve as a conduit for governmental entities and private organizations to effectively combine their resources, insights, and proficiencies. This partnership can elevate the efficiency and efficacy of IoT implementation across supply chains. For instance, the knowledge base of technology companies, when combined with resources from government agencies such as the Department of Commerce, can tailor solutions to specific supply chain challenges.
2. Risk sharing: IoT adoption in supply chain management may involve significant investments and risks for businesses. Public-private partnerships can help share these risks, providing businesses with the confidence to invest in IoT technology and reducing potential financial burdens.
3. Accelerating technology adoption: With the government's collaboration with the private sector, the deployment pace of IoT solutions in supply chains can be accelerated. PPPs can stimulate the development and execution of pilot projects, thereby expediting the testing and scaling of groundbreaking IoT solutions.
4. Addressing regulatory challenges: Public-private partnerships can help address regulatory and policy challenges associated with IoT technology. By involving private sector stakeholders in the decision-making process, the government can develop more informed and targeted regulations that support IoT adoption while addressing potential risks.
5. Fostering innovation: Collaborative efforts between the public and private sectors can create a fertile environment for innovation in IoT and supply chain management. Public-private partnerships can help identify and address gaps in the market, support research and development initiatives, and encourage the exchange of ideas and best practices.
6. Enhancing global competitiveness: Public-private partnerships can strengthen the competitiveness of the manufacturing sector on a global scale. By working together, the government and private sector can accelerate the development and deployment of IoT technology, enabling businesses to compete more effectively with international rivals.
7. Building trust and cooperation: Fostering public-private partnerships can help build trust and cooperation between the government and the private sector, which is essential for addressing complex challenges in supply chain management. A strong partnership can facilitate dialogue and encourage collaborative problem-solving, ensuring that the interests of all stakeholders are considered in the development and implementation of IoT solutions.

Implementation Considerations:

Implementation considerations for fostering public-private partnerships for supply chain IoT adoption include:

1. Identifying key stakeholders: The federal government should identify relevant private sector stakeholders, including businesses, industry associations, research institutions, and technology providers, who can contribute to the development and implementation of IoT solutions in supply chain management.
2. Establishing a collaborative framework: A formal framework should be established to facilitate collaboration between the public and private sectors. This may include creating joint working groups, industry forums, or innovation hubs, where stakeholders can share ideas, knowledge, and resources.
3. Defining clear goals and objectives: Public-private partnerships should have well-defined goals and objectives that align with the overall strategy for promoting IoT adoption in supply chain management. This will help ensure that all stakeholders are working towards a common vision and can measure their progress.
4. Developing joint projects and initiatives: The federal government and private sector stakeholders should collaborate on joint projects and initiatives that address specific challenges or opportunities in supply chain management. These could include pilot projects, research and development programs, or the development of new IoT standards and protocols.
5. Ensuring effective communication and coordination: Open and transparent communication between the public and private sectors is critical for successful collaboration. Regular meetings, progress reports, and information sharing mechanisms should be established to facilitate coordination and maintain momentum.
6. Monitoring and evaluation: The federal government should establish a system for monitoring and evaluating the effectiveness of public-private partnerships in promoting IoT adoption in supply chain management. This may involve tracking key performance indicators, such as the number of joint projects implemented, the amount of private investment leveraged, and the impact on supply chain efficiency and resilience.

Potential implementation barriers:

Possible barriers to implementing this recommendation include:

1. Mistrust between public and private sectors: A lack of trust between the government and private sector stakeholders can hinder collaboration and limit the effectiveness of public-private partnerships.
2. Differing priorities and objectives: Public and private sector stakeholders may have different priorities, objectives, and timelines, which can create challenges in aligning their efforts.
3. Intellectual property and data confidentiality concerns: Private sector stakeholders may be hesitant to share proprietary information or data with the government, hindering collaboration and knowledge sharing.

4. Limited resources: Both the government and private sector organizations may face resource constraints that limit their ability to participate in public-private partnerships.

Enabling Recommendation 4.2.1: The government should subsidize initiatives for digital infrastructure supporting the digital transformation of enterprise business processes including design, production, procurement, distribution.

The digitalization of all business functions (design, production, marketing, procurement, distribution, etc.) enables more efficient IoT product management, greater visibility, and transparency over supply chains to track products, monitor quality, and fix issues or defects. By using cryptographic methods, digitalization can have a major impart in improving the security, reliability, integrity, and trust of data for the digital economy. By providing incentives for businesses to adopt digital tools, the federal government can help promote ecosystems that create opportunities for businesses and workers in any value chains which will drive economic growth. Furthermore, digitalization enables digital transformation whereby IoT device suppliers become connected to their customers which enables sustainability and circular economy.

Justification

1. Digitalization of business functions leads to greater management, efficiency, and visibility in supply chains.

2. Cryptographic methods for digitalization, especially hand-offs in value chains, improve security, reliability, and integrity of digital data, especially in hand-offs.

3. Digitalization, including creation of trusted digital threads, enables secure ecosystems, opportunities for businesses/workers and economic growth.

4. Financing a common digitalization infrastructure for various vertical markets can increase adoption among stakeholders in IoT value chains.

5. Digitalization of value chains enhances security, reliability, and integrity of data used to fuel the digital economy.

Implementation Considerations

1. Develop and communicate clear guidelines and criteria for eligibility for the subsidies.

2. Incentivize Orchestrated PPPs to work on Proof of Concept (PoC) projects to assess the economic value before investing in solutions to deploy at scale.

3. Create a streamlined application process for businesses to apply for subsidies. Ensure that the funds are accessible to businesses of all sizes and types in the IoT value chain.

4. Monitor the effectiveness of the funds allocated to PPPs to ensure that they are achieving the intended outcomes.

5. Provide incentives for businesses to invest in digitalization and adopt digital technologies and tools. Encourage knowledge sharing among businesses to promote best practices.

Potential Implementation Barriers

1. SMBs lack the resources or expertise to effectively implement digital technologies and tools. The cost of implementing digital technologies and tools may be a barrier.

2. Resistance to change or adoption of new technologies, or lack of technical expertise and resources.

3. Concerns over the security and confidentiality of digital data may discourage some businesses from adopting digital technologies and tools.

Federal Considerations

1. Ensure that any funds for digitalization align with broader federal priorities and goals, such as promoting economic growth and national security.

2. Coordinate with other federal agencies to ensure that the subsidies do not conflict with other federal programs or initiatives to promote consistency and avoid redundancy.

3. Monitor and evaluate the impact of the subsidies in IoT value chains and digital economies.

4. Encourage equitable access to digital technologies and tools across different regions and industries. Ensure that digitalization efforts prioritize security and privacy matters.

Enabling Recommendation 4.2.2: The government should incentivize the enablement and use of trusted digital marketplaces and platform-based business ecosystems.

As digital threads and digital platforms emerge, the government should incentivize the enablement and use of digital marketplaces to drive economic growth with trusted data exchange and licensing while protecting proprietary IP of enterprises in the value chain.

Description

The government should incentivize the enablement and use of trusted digital marketplaces where producers and consumers query and share information about assets and related data, enabling better visibility, traceability, and monetization while protecting proprietary IP and PII. Trusted digital marketplaces can be enabled through incentives such as tax credits or subsidies for companies that develop platforms for data exchange, or IoT services that establish market preference or regulated market access & use of goods. Platforms facilitate adoption of digital marketplaces can enable producers and consumers reduce costs, improve efficiency by streamlining processes and eliminate redundancies, especially in complex supply chains where

information flows are often fragmented or disconnected. Furthermore, trusted digital marketplaces driven by digital threads enable participating stakeholders to evolve new business models and revenue streams. When these are combined with business platforms that maximize network effects, it will fuel the growth of ecosystems and future digital economies.

Justification

1. Establish market preference and market access with better visibility, transparency and traceability across IoT value chains.
2. Reduce costs of data sharing and licensing across the value chain for related services among producers and consumers.
3. Improve efficiency by streamlining processes to locate and license relevant data across connected value chains.
4. Reduce redundancies and simplify logistics in complex value chains for access and use of goods, data and services related to them.
5. Increase visibility, transparency and trust across value chains to enable growth of marketplaces that will fuel digital economies.

Implementation Considerations

1. Identify suitable marketplaces to incentivize and support (e.g., EV charging and monetization). Develop guidelines and incentives for access and use of data.
2. Promote the benefits of data marketplaces to potential participants and provide tax credits and subsidies to encourage participation.
3. Ensure data security and confidentiality measures are in place. Monitor and evaluate the effectiveness of the data marketplaces. Use analytics to improve visibility, traceability, efficiency, and cost.

Potential Implementation Barriers

1. Lack of awareness about the benefits of marketplace platforms. Concerns and resistance over data security and confidentiality
2. Difficulty in regulating and monitoring access and use of data in the marketplace. Unwillingness to share proprietary data without a license.
3. Lack of open and participatory business platforms for data marketplaces that can evolve over time as more business discover the value of digitalization.

Federal Considerations

1. Implement data privacy and confidentiality regulations based on experience (GDPR, CDPP, etc.). Develop policies to prevent monopolies in the data marketplace.

2. Provide education and resources to help organizations participate in data marketplaces. Ensure that the marketplace is accessible to SMBs and not just large corporations.

3. Balance incentives for participation with data security, and confidentiality concerns so that enterprises are incentivized to join data marketplaces and grow their business.

4. Coordinate with other federal agencies and international allies to ensure a cohesive approach. Align with broader government efforts to promote open innovation platforms.

Enabling Recommendation 4.2.3: The government should promote and regulate trusted AIoT platforms across circular value chains and ecosystems to improve transparency and sustainability and drive economic growth.

The government should promote and regulate trusted AIoT platforms within circular value chain ecosystems. This will ensure transparency, sustainability, and economic growth by fostering innovation and efficiency which will benefit businesses, the environment and digital economy.

Description

Promoting and regulating trusted AIoT platforms within circular value chain ecosystems is imperative for ensuring transparency, sustainability, and economic growth. This initiative not only fosters innovation but also enhances efficiency, benefiting businesses, the environment, and the future digital economy. By strategically integrating AIoT into circular value chains, the government can create a foundation for responsible and sustainable technological advancement, positioning the nation as a leader for the global digital economies.

1. Innovation Hubs: Promoting AIoT platforms will drive innovation, enabling the development of cutting-edge technologies and solutions.

2. Efficiency Boost: AIoT can optimize resource utilization, reducing waste and energy consumption within circular value chains.

3. Environmental Benefits: Sustainable practices fostered by this initiative can help combat climate change and promote eco-friendliness.

4. Economic Growth: The growth of AIoT-driven industries will create jobs and stimulate economic development.

5. Competitive Advantage: By embracing AIoT, the nation can establish itself as a pioneer in the digital economy, attracting global investments.

Implementation Considerations:

1. Regulatory Framework: Develop comprehensive regulations to ensure the ethical and secure use of AIoT technology.
2. Public-Private Partnerships: Encourage collaboration between government, businesses, and research institutions to drive innovation.
3. Sustainability Standards: Establish clear sustainability guidelines for AIoT projects within circular value chains.
4. Data Governance: Develop robust data governance policies to protect privacy and promote transparency.
5. Education and Training: Invest in workforce development and educational programs to prepare individuals for AIoT-related jobs.

Barriers:

1. Privacy Concerns: Balancing data sharing with privacy protection can be challenging.
2. Resource Allocation: Ensuring sufficient funding and resources for AIoT development and regulation.
3. Security Risks: Rapid AIoT growth increases the risk of cybersecurity threats.
4. Resistance to Change: Some stakeholders may be resistant to adopting AIoT due to fear or uncertainty.

Federal Considerations:

1. Regulatory Oversight: Establish a regulatory body responsible for overseeing AIoT platforms and ensuring compliance with ethical standards.
2. Investment: Allocate funding for AIoT research, development, and infrastructure.
3. Incentives: Create incentives such as tax benefits and grants to motivate businesses to adopt sustainable AIoT practices.
4. International Collaboration: Collaborate with other nations to create global AIoT standards and ensure interoperability and security.

Promoting and regulating trusted AIoT platforms within circular value chain ecosystems is a strategic investment in a sustainable and innovative future. By embracing this initiative, the federal government can foster responsible AIoT development, protect the environment, and bolster the nation's position in the global digital economy.

Key Recommendation 4.3: The government should support trusted architectures and conduct a limited pilot to assess the value of trusted digital threads for provenance and traceability across the value chain.

Support creation of cryptographically strong architectures and infrastructure that enable supply chain provenance, traceability, and lifecycle management by linking hardware and software bill of materials to the design and manufacturing processes delivering trusted assets and data.

The federal government should incentivize suppliers to develop trusted architectures for supply chain provenance, traceability, assurance of supply and IoT product lifecycle management. By cryptographically linking trusted SBOM[48] to trusted HBOM[49] in any IoT device or system, industries can help mitigate the risks associated with supply chain security, compromised components, and ensure the security and reliability of critical systems. This will strengthen national security, public safety, and economic stability, making it a valuable investment for the government and society.

Justification

1. The use of trusted architectures for supply chain provenance and traceability can help mitigate the risks associated with vulnerabilities or compromised components.

2. Trusted architectures for supply chain provenance and traceability can increase the trustworthiness of critical IoT systems, which is key for national security, public safety, and economic stability.

3. Trusted architectures linked to Cyber Trust Mark[50] can increase consumer confidence in the products they purchase and prevent supply chain attacks and data breaches leading to greater economic benefits for businesses.

4. Cryptographic linking of SBOM to trusted HBOM enhances supply chain security, visibility, chain of custody and product lifecycle management. (and overall user confidence).

5. Trusted HBOM and SBOM assets and related data can form the basis of trusted digital threads which also enable trusted IoT applications and data for AI based digital twins.

Implementation Considerations

1. Educate stakeholders in the value chain on the benefits of using trusted architectures for supply chain provenance and traceability.

[48] Software Bill of Materials for Electronic parts and Software modules used in the assembly of a device or complex system.
[49] Hardware Bill of Materials must include a Root of Trust with a source of Entropy such for security and unique ID (fingerprint).
[50] The US Cyber Trust Mark all you need to know https://www.iotforall.com/u-s-cyber-trust-mark-all-you-need-to-know

2. Promote industry adoption of trusted architectures through education and outreach. Incentivize hardware suppliers to develop trusted architectures that enable supply chain provenance and traceability and promote them with the Cyber Trust Mark.

3. Develop guidelines for how the trusted architectures should be implemented by linking HBOM and SBOM with DBOM[51] to facilitate provenance and traceability and encourage the adoption of standards and best practices.

4. Foster collaboration between government agencies and industry stakeholders (Private-Public Partnerships) to develop and promote trusted architectures that support secure protocols for provisioning and market access.

Potential Implementation Barriers

1. Lack of awareness or understanding of the benefits of trusted architectures.

2. Resistance from industry stakeholders who are not interested in investing in new technologies. (or are considering competing technologies).

3. Implementation costs associated with developing and deploying trusted systems.

4. Technical challenges associated with integrating trusted systems with existing legacy infrastructure.

5. Complexities involved in developing and deploying trusted architectures at scale.

Enabling Recommendation 4.3.1: The government should incentivize multi-stakeholder alliances and collaboration for trusted end-to-end solutions across value chains.

Establish incentives for industries to adopt capabilities for tracing design, manufacturing, and enterprise workflows that cryptographically link parts, personas, and data to deliver traceable products and IoT systems that function and perform as originally intended.

Description

The federal government should implement incentives to promote collaboration for trusted end to end solutions, including enterprise business processes and workflows cryptographically linking tasks, personas, and handoffs of acids and data and we're participating stakeholders. This would help enhance cybersecurity, reduce operational risk, foster innovation, and establish the US as a global leader of trusted IoT solutions. The term “trusted” means that IoT parts, systems, applications, and value chains operate as intended and produce data that is not compromised

[51] Digital Bill of Materials consisting of HBOM, SBOM plus info on quality, reliability, and workflow process.

or tampered with. By encouraging industries to pursue trusted digitalization solutions, the government can strengthen national security and accelerate adoption and growth.

Justification

1. Ensure the confidentiality and integrity of IoT electronics supply chains to prevent cyber-attacks in critical infrastructure and protect against human and economic losses.
2. Accelerate IT/OT convergence with adoption of trusted traceability methods for the electronics value chain that enhance the effectiveness of critical infrastructure services.
3. Enable companies and businesses to foster innovation, create a competitive advantage with smart-connected IoT Systems to become smart-connected-secure suppliers.
4. Enable the creation of trusted ecosystems that accelerate end-to-end innovation, monetization, and growth of IoT-enabled digital economies.

Implementation Considerations

1. Offer tax credits, grants, or other financial incentives to companies that market electronics products with traceable parts Country of Diffusion and Country of Origin[52], provenance, and journey in the supply chain.
2. Require contractors and suppliers to adhere to specific security and traceability standards when bidding on government contracts, particularly for critical infrastructure.
3. Establish a certification process for electronics and IoT products that meet security and traceability standards to improve trust in value chains, linked to cybersecurity labels.
4. Engage industry associations and other stakeholders to develop best practices and guidelines for trusted electronics and IoT systems development and supply chain.

Barriers

1. Lack of awareness or expertise: Some companies may not be aware of traceability benefits and risks. SMBs may lack the expertise to implement traceability methods.
2. Limited supply chain visibility: In some cases, it may be difficult to trace components back to their original source due to limited information or visibility into the supply chain.
3. Data confidentiality concerns: Collecting and storing data for traceability purposes may raise concerns about data trust and potential risks of using it for various applications.

[52] Country of Diffusion where a part is fabricated and Country of Origin where the product made of parts is assembled.

4. Cost of implementation: Companies may be resistant to investing in trusted traceability methods due to limited budgets, or lack of expertise or lack of standardized security and traceability protocols.

Federal Considerations

1. Provide financial incentives to companies to encourage the adoption of trusted traceability methods aligned with executive orders and broader government priorities.

2. Work with industry stakeholders to offer tax credits, grants, or other financial incentives to companies that offer traceable connected electronics products.

3. Incentivize contractors and suppliers to adhere to specific security and traceability standards when bidding on government contracts for critical infrastructure.

4. Promote partnerships of industry associations and stakeholders to identify potential gaps in the electronics supply chain and develop targeted solutions to address them.

Incentivizing IoT value chains to adopt trusted digitalization solutions with cryptographic tracing capabilities is a strategic to enhance national security, stimulate economic growth, and position the US as a global leader in IoT technology. The federal government's active role in promoting these capabilities can contribute to more resilient supply chains and valuable end-to-end solutions, that benefit societies and industry ecosystems.

Enabling Recommendation 4.3.2: The government should support collaborative IoT solutions platforms that align stakeholder business incentives.

The government should support collaborative IoT solutions platforms that align the business incentives of stakeholders to foster innovation, enable orchestration and while harnessing the power of network effects to enhance security, user experience and drive economic growth.

Description

The recommendation to support collaborative IoT solutions platforms that align business incentives of stakeholders by enabling orchestration, governance and network effects is essential to accelerate adoption and growth of IoT. This approach will significantly benefit the nation by enhancing security, improving the user experience, and driving economic growth. It provides a powerful framework for IoT development, bringing together diverse stakeholders to create robust and secure ecosystems that will shape the future of digital economy.

Justification:

1. Innovation Catalyst: Collaborative IoT platforms encourage industry-wide innovation, leading to the development of cutting-edge technologies and solutions.

2. Efficient Orchestration: These platforms streamline device management, data exchange, and interoperability, reducing operational complexities.
3. Enhanced Security: By aligning business incentives, stakeholders are motivated to prioritize cybersecurity, resulting in safer IoT environments.
4. Economic Growth: IoT-driven industries will experience substantial growth, creating jobs and contributing to economic prosperity.

Implementation Considerations:

1. Standardization: Define industry standards to ensure compatibility and interoperability across IoT platforms.
2. Public-Private Partnerships: Foster collaboration between government agencies, businesses, and academia to drive innovation.
3. Data Privacy and Confidentiality: Establish robust data protection regulations to build trust and protect user data.
4. Incentive Mechanisms: Create incentives like tax benefits and grants to motivate businesses to align their incentives with IoT platform goals.
5. Monitoring and Evaluation: Implement a monitoring system to track progress, security, and the impact on economic growth.

Barriers:

1. Privacy Concerns: Balancing data sharing with privacy protection can be challenging.
2. Fragmentation: Lack of standardization and coordination among stakeholders may hinder platform adoption.
3. Cybersecurity Risks: Rapid IoT growth increases the risk of cyber threats.
4. Resource Allocation: Ensuring adequate funding and resources for IoT platform development and governance.

Federal Considerations:

1. Regulatory Framework: Develop and enforce regulations that promote secure and collaborative IoT solutions.
2. Investment and Partnerships: Allocate funding for IoT research, development, and infrastructure. Encourage PPPs that leverage diverse expertise and resources.

3. Educational Initiatives: Promote IoT education and workforce development to meet industry demands.

4. International Collaboration: Collaborate with other nations to create global IoT standards and ensure security and interoperability.

Supporting collaborative IoT solutions platforms aligning business incentives is a strategic move that will drive innovation, enhance security, and boost economic growth

Enabling Recommendation 4.3.3: The government should encourage the use of digital threads for connected value chains.

Promote the use of digital threads[53] among enterprises in disaggregated supply chains, to enable the creation of connected IoT value chains. Leverage digital threads of data across value chains to enable marketplaces of trusted data producers and data consumers.

Description

The government should support the development of digital threads across value chains by incentivizing companies to digitalize their workflows, link their internal data IDs and Bills of Materials to identifiers and data to create trusted (certified) digital threads that can enable trusted digital marketplaces of producers, consumers, and platform-based business ecosystems. Business platforms for data exchange can have a significant impact on improving supply chain visibility, efficiency, security, and growth. Digital threads may extend from supply chains to the field use of IoT devices and connected ecosystems of data marketplaces.

Justification

1. Increase end-to-end visibility of a product's lifecycle, supply chain transparency security and which can help reduce risk of cyberattacks, counterfeiting, and product recalls.

2. Companies that adopt a digital thread can improve supply chain efficiency, reduce costs, manage vulnerabilities, increase differentiation, and promote innovation.

3. Digital threads enable marketplaces of data producers and data consumers, creating new business opportunities for revenue streams that will fuel the digital economies.

4. Accelerate adoption by linking digital threads for HBOM, SBOM, DBOM across value chains in ways that protect proprietary IP while enabling new digital marketplaces.

Implementation Considerations

[53] Digital flow of data connecting business processes products assets and bill of materials in a value chain. For the electronics value chain the digital threat includesof HBOM, SBOM and other Digital Bill of Materials (DBOM)

1. Develop educational and training programs to help businesses implement digital threads. Establish guidelines for creating a digital thread, including standards.

2. Incentivize companies to digitalize their workflows through tax credits, grants, or subsidies for investing in digital technologies. Encourage PPP collaboration.

3. Leverage the Cybersecurity labeling program to create a digital trail for BOM (DBOM, HBOM, SBOM, Security keys, certificates etc.) for IoT systems by vertical market.

4. Provide funding for research and development of methods and standards to facilitate development of best practices and guidelines for implementing digital threads.

Potential Implementation Barriers

1. Resistance from businesses to adopt new digital technologies and workflows. Upfront costs of digitalization may be prohibitive for SMBs, even if the ROI justifies them.

2. Reluctance to share data due to concerns about intellectual property and competitive advantage. The digital thread should allow sharing of metadata information and data at the producer's discretion.

3. Different industries may have varying requirements for digital threads, making it challenging to establish common standards and overcome concerns around data privacy, security, and interoperability.

Federal Considerations

1. Provide financial incentives to companies to encourage the adoption of digitalization and the creation of a digital thread for both SMBs as well as large enterprises.

2. Work with industry stakeholders to develop guidelines for creating a trusted digital thread and how to comply with regulatory requirements for data privacy and security.

3. Promote the adoption of digital threads in procurement contracts (e.g., DBOM linked to assets) and foster PPPs that enable and promote trusted value chain traceability.

Enabling Recommendation 4.3.4: The government should promote orchestrated Public-Private Partnerships (PPPs) promoting network effects among connected enterprises and across value chains

To speed up the creation of connected value chains the government should promote PPPs that promote network effects to speed the adoption of end-to-end digital threads using consistent digitalization methods capturing receivables, processes, and certified deliverables.

Description

The federal government can accelerate the creation of traceable supply chains by encouraging orchestration of connected Private-Public Partnerships (PPPs) promoting network effects among stakeholders across complex value chains who maintain Trust through collaboration by digitalizing portions of supply chains piecemeal using consistent methods of “receivables-process-deliverables”. Digitalization across value chains of PPPs collaborating in parallel can help accelerate adoption of digital threads and become more efficient which will help businesses to grow digital revenue streams on top of IoT products and services that drive economic growth.

Justification

1. Orchestrated PPPs can accelerate the adoption of end-to-end digital thread and traceability in complex supply chains, by digitalizing portions of solutions value chains or supply chains piecemeal in parallel using consistent methods.

2. Collaboration and accountability among enterprises in IoT value chains can create resilient and secure supply chains that can help businesses drive economic growth.

3. Traceability can help businesses reduce risk, increase resilience, and protect against supply chain risks of vulnerabilities, intrusions, and adversaries, which can lead to business and economic growth.

4. Trustworthiness across IoT value chain with secure infrastructure can drive shared monetization among stakeholders leveraging fintech to enable scalable economics.

Implementation Considerations

1. Encourage orchestration of connected Private-Public Partnerships (PPPs) across complex value chains, by providing incentives for businesses to adopt transparent workflow practices and engage in pilot projects to prove the value.

2. Promote consistent digitalization methods for "receivables-process-deliverables" across supply chains by digitalizing portions of supply chains piecemeal to facilitate parallel collaboration among stakeholders. Network effects can accelerate adoption and growth.

3. Fund the development of digital infrastructure, training programs, and other resources necessary for successful partnership implementation. All requirements are shared responsibility among all PPP stakeholders.

4. Create taxonomy of entities in market-specific supply chains that can be orchestrated to maintain trust through orchestration, collaboration, guidelines, and standards among stakeholders in connected value chains.

Potential Implementation Barriers

1. Resistance to change from supply chain stakeholders who are accustomed to traditional methods and may be hesitant to share or exchange data with competitors in the value chain. Trusted digital threads of metadata can alleviate this issue.

2. Limited awareness about the benefits, or lack of technical expertise, or capacity to join PPPs, or costs associated with implementing digitalization methods across enterprises in the supply chain.

3. Lack of awareness about the importance of trustworthy and secure supply chains and resource constraints for smaller businesses that may not have the capacity to participate in partnerships.

4. Difficulty in creating a taxonomy of enterprises in supply chains orchestrating and coordinating multiple stakeholders across fragmented supply chains.

Federal Considerations

1. Prioritize PPPs that promote transparency, efficiency, security and network effects ensuring that any incentives align with established guidelines and standards and not unfairly disadvantage SMBs or create monopolies.

2. Foster collaboration among federal agencies, industries, and value chains to accelerate adoption with a unified approach to IoT supply chain security and transparency.

Consider the potential impact on domestic and international trade policies and the importance of ensuring that any subsidies are distributed equitably across various stakeholders.

Enabling Recommendation 4.3.5: The government should facilitate the creation of business ecosystems that enable new business models and revenue streams

As data produced in connected value chains and during field or IoT devices and becomes the "*new gold*", the government should raise awareness about the value of digital or data business ecosystems and trusted data-driven digital threads the will enable new business models.

Description

The federal government should raise awareness about the *New Gold*, Data Monetization Strategies, Data Analytics for Insights, Trusted Data Marketplaces, Platform-based Business Ecosystems, Network effects, Digital Thread of Data in connected value chains, Data Regulations, and tools for Monitoring and Managing Data Marketplaces. Digital networks of interconnected businesses, technologies, and platforms can leverage synergies to enhance existing products, enable digital twins and drive growth through XaaS[54] business models.

[54] XaaS Everything as a Service, Hardware, Software, Network, Applications, etc.

Justification

1. Data-driven ecosystems can create new revenue streams and enhance existing products and services among Interconnected businesses, technologies, and platforms that can leverage synergies in the value chain.

2. Data analytics can provide insights that drive innovation, improve decision-making, and enable data monetization strategies. This can lead to significant benefits across value chains and drive economic growth.

3. Trusted digital marketplaces can promote data sharing and collaboration and business ecosystems can lead to new revenue streams and enhanced products and services.

4. Platform-based ecosystems made of connected businesses can collaborate and innovate more effectively. They can also scale rapidly through network effects and can drive sustainable growth for businesses and value chains.

5. Data regulations can provide a framework for businesses to manage and use data responsibly and using tools for monitoring and managing trusted digital marketplaces that ensure transparency and accountability.

Implementation Considerations

1. Develop educational programs for businesses and individuals. Raise awareness about business ecosystems through public campaigns, conferences, and workshops.

2. Provide funding and incentives for data-driven ecosystem and solutions PPPs with industry leaders, innovative startups, and academic institutions.

3. Foster the development of orchestrated platform-based business ecosystems supporting networks effects by providing incentives and resources to businesses.

4. Encourage collaboration and innovation by promoting the value network effects. Provide tools and resources for monitoring and managing data marketplaces.

Potential Implementation Barriers

1. Lack of awareness and understanding about digital business ecosystems and platforms.

2. Limited resources and expertise for implementing data monetization strategies from data analytics.

3. Lack of national strategy to enable the creation of platform-based ecosystems and balance the benefits of data-driven businesses and marketplaces with data privacy and security concerns.

Federal Considerations

1. Ensure fair competition and prevent monopolies. Balance the need for data confidentiality and security with the benefits and value of data-driven business ecosystems for data management and sharing.

2. Encourage the private sector to invest in data-driven economic growth. Promote collaboration between government, industry, and academia. Promote collaboration businesses while ensuring fair competition.

3. Ensure transparency and visibility in data marketplaces by encouraging the use of data analytics to improve government operations and services.

4. Address the digital divide to ensure that all businesses have access to the resources and tools needed to participate in data-driven business ecosystems.

Enabling Recommendation 4.3.6: The government should promote consistent levels of IoT device hardware and software identity documentation information included in trusted digital threads for Software IoT value chains.

Establish a centralized IoT Device Registry to standardize due diligence, enhancing IoT device validation, security, and maintenance. This promotes transparency, sustainability, and economic growth by fostering accountability, efficient IoT management and new business models.

Description:
The Federal government should initiate the development of a centralized IoT Device Registry to standardize due diligence processes for IoT devices, capturing vital data points necessary for their validation, security, and maintenance. This comprehensive approach aims to enhance transparency, sustainability, and economic growth by fostering innovation, accountability, and efficient management within the IoT ecosystem. The proposed registry would facilitate collaboration, risk mitigation, and timely vulnerability notifications, benefitting businesses, the environment, and the broader digital economy.

Justification:

1. Fragmented IoT Ecosystem: The current IoT landscape lacks transparency, accountability, and standardized practices for supply chain management and vulnerability mitigation.

2. Lack of Traceability: The fragmented ecosystem results in limited traceability across different IoT ecosystem segments, leaving device management, support, and security responsibilities unclear.

3. Integration for Visibility: The registry offers a solution to integrate fragmented IoT module and device ecosystems, providing end-to-end visibility, accountability, and clear lines of responsibility for risk management, mitigation, and remediation.

4. Identity Fragmentation: IoT devices have diverse identities (physical, network, service) that are not correlated in one place, leaving vulnerabilities unaddressed and creating extensive attack surfaces.

5. Security Concerns: A significant number of companies report IoT-related breaches, but lack of device identity and patch information hinders effective mitigation.

Implementation Considerations:

1. Regulatory Framework: Develop regulations to mandate IoT device manufacturers to provide comprehensive Software Bills of Materials (SBOMs) during firmware and OS updates.

2. Centralized Database: Create a centralized database to correlate vulnerable software and hardware components with IoT modules and devices, updated regularly.

3. Device Management Systems: Implement reporting mechanisms for device management systems, over-the-air updates, and remote monitoring services.

4. Subscription Model: Enterprises would pay a subscription fee to register their devices, ensuring continued access to registry information.

1. **Potential** Cost-Effectiveness Perception: Some industries may question the cost-effectiveness of securing IoT devices, but the reality is that these devices are prime targets for botnets, which contribute to denial-of-service attacks and provide entry points for infiltrators into enterprise networks.

2. Regulatory Mandates: High-risk industries, including critical infrastructure and healthcare, are already experiencing negative effects from IoT-related issues and are subject to new regulatory mandates. Encouraging these sectors to adopt comprehensive documentation can be challenging but is essential for security.

3. Standardization Challenges: Coordinating with various stakeholders and IoT manufacturers to adhere to standardized practices and SBOM requirements may encounter resistance.

The establishment of a centralized IoT Device Registry is a critical step towards addressing the current fragmentation, security risks, and accountability issues within the IoT ecosystem. This initiative will foster transparency, sustainability, and economic growth while reducing risks associated with IoT devices and promoting the adoption of secure IoT practices across various industries.

IoT Leadership / Government capabilities

Objective 5: The United States is recognized as a global leader in the promotion, adoption, and innovation of advanced IoT technologies. [Updated]

Establish Government Capabilities

Key Recommendation 5.1: The government should prioritize the advancement and integration of emerging technologies, including IoT, across federal agencies, and provide leadership for effective and responsible IoT adoption globally. [Updated]

Enabling Recommendation 5.1.1: The government should consider upgrading legacy federal owned or operated buildings that have inadequate security in their connected systems.

By upgrading these buildings, they can set an example for private industry to follow. They could then promote conversion in other market segments such as industrial factories or power plants. Credibility and assurance can also be provided to the private sector when the Federal Government leads by example.

Many government buildings are reliant on building control systems which provide the functional, operational, and safety needs of a building. These can serve as gateways for malicious actors who can take control of critical applications (including life and safety-related services) within a building (i.e., heating, air conditioning, physical access).

While such upgrades may be costly, it is possible that some of those costs could be offset by reduced cybersecurity insurance premiums and other fiscal benefits.

It is also notable that a great deal of data in an unprotected building control system may contain significant amounts of personal and confidential information.

Implementation considerations: The Environmental Protection Agency (EPA) has a program for Energy Star Building Certifications and there could be a similar program that addresses cybersecurity within a building. There are some efforts already underway within the commercial real estate sector that could be leveraged (). There are also parallels that could be explored such as the National Cyber Labeling Program for Consumer IoT versus Energy Star on appliances.

Implementation could occur through updated acquisition requirements, such as in the GSA Federal Acquisition Regulation (FAR) and Defense Federal Acquisition Regulation (DFAR).

Owners of buildings used by federal organizations should, at a minimum, use basic cyber hygiene best practices (i.e., changing default passwords, segmentation of networks by using

items such as firewalls, installing patches) as directed within requirements. NEMA has developed a cyber hygiene best practice document for end users that is available at the following URL (https://www.nema.org/standards/view/cyber-hygiene-best-practices-part-2)

Potential barriers: Funding to upgrade the existing legacy base could be considerable. Also, if additional validation/certifications are needed for a particular building there is an additional upfront cost.

Building owners and managers may have limited knowledge of how to protect against cybersecurity attacks, especially in today's fast-moving technical environments, so lack of knowledge (or insufficient training) may be a barrier to such updates. These considerations would also be quite different depending upon the facility in question. For example, a medical building may have different needs and associated risks from a commercial office building.

Due to the evolving threat landscape, there may be frustration with changing requirements. As the threat landscape is constantly evolving, concerns may exist if a building has been updated with cybersecurity systems and malicious actors can still gain access to it. This condition is often the case, though, and should not impede whatever improvements can be made.

Enabling Recommendation 5.1.2A: The government should establish an Emerging Technology (EmT) office within each of the federal agencies.

[Note: This recommendation was earlier proposed; subsequently there was language proposed that significantly changed it. The Board will need to discuss these A and B recommendations, select how to proceed, and then we can adjust the text to match.]

EmT is rapidly evolving, with transformational value, and unexplored opportunities. The topic of emerging technology (including AI, IoT, quantum) is broad and some agencies may have some existing EmT interagency roles. Agencies consider participating in a Community of Practice, like the Federal CIO Council format, which, in turn, will serve to convene EmT officials across all agencies. This recommendation is in parallel to the supporting recommendation (below 6.4) on establishing a National Emerging Technologies (EmT) Office. The aim should be to establish new and/or leverage existing FACAs to augment knowledge and expertise gaps and a process for defining what EmT is and a list of EmT should do.

Implementation considerations: Establish specialized capabilities (e.g., IoT, smart cities, AI, quantum, etc.), in each office. Use language specified in the Oversee Emerging Technology Act (S.1577, 5/11/2023) on advising on responsible use of emerging technologies; providing expertise on responsible policies and practices, collaborate with officials and coordinating bodies across the Federal government, and offer input for responsible procurement policies; and the identification of the official and provide a description of the official's authorities and responsibilities to Congress.

Potential barriers: Agencies lack expertise on EmTs and the resources/capacity to implement an agency strategy, develop policy or other associated support, practices, programs and

actions. There is limited EmT coordination between agencies that lead to uneven treatment, policies and siloed execution.

Supporting Recommendation 5.1.2B: The government should expand the mission of OSTP for additional focus on the Critical and Emerging Technologies as identified by the National Standards Strategy of May 2023 or similar curated list, with additional staffing support as required for the expanded mission.

The U.S. should lead in the adoption and integration of emerging technologies into the U.S. economy and infrastructure. Currently a lack of coordination from the Executive Office leads to siloed planning, policies, execution, suboptimal utilization of resources, duplicate programs, monitoring, thus limiting realization of economic, social, security and other values and benefits.

There is a need to establish new and/or leverage existing FACAs to augment knowledge and expertise gaps. The necessary coordination and integration with the NIST (FWIoT and Global City Teams Challenge (GCTC)) protocols should be in place (i.e., IoT implementations involve the integration of multiple technologies, systems, and stakeholders).

CET is rapidly evolving, with transformational value, and unexplored opportunities. The list of Critical and Emerging Technologies is broad (AI, IoT, quantum, etc.) and some agencies may have some existing CET interagency roles. Having OSTP in a leadership role, potentially convening interagency efforts, FACAs or other whole-of-government or public-private activities, will help steer government and private sector activities.

Implementation considerations: Establish specialized capabilities (e.g., IoT, smart cities, AI, quantum, etc.), in OSTP, as required.

Potential barriers: Primary expertise in CET is in industry rather than government. Government lacks expertise on CET and the resources/capacity to develop and implement a public-sector strategy, develop policy or other associated support, practices, programs and actions. There is limited CET coordination between agencies that leads to uneven treatment, policies and siloed execution.

Enabling Recommendation 5.1.3: The government should establish a national Emerging Technologies Program Office within the Executive Office of the President to ensure that the federal government, state, and local government entities can effectively plan, implement, and manage emerging technology initiatives across the United States.

[This recommendation has been recommended for removal, but the record is not clear whether the Board has agreed to do so. There needs to be a final decision at the next Board meeting.]

The U.S. should lead in the adoption and integration of emerging technologies into the U.S. economy and infrastructure. Currently a lack of coordination from the Executive Office leads to

siloed planning, policies, execution, suboptimal utilization of resources, duplicate programs, monitoring, thus limiting realization of economic, social, security and other values and benefits.

This office should be aligned with the Office of Science and Technology Policy to: 1) work with federal departments and agencies and with Congress to create bold visions, unified strategies, clear plans, wise policies, and effective, equitable programs for IoT and Smart Cities modernization; 2) engage with external partners, including industry, academia, philanthropic organizations, and civil society; state, local, Tribal and territorial governments; and other nations; and 3) ensure equity, inclusion, and integrity in all aspects of IoT implementations.

The specific roles, responsibilities and interactions with the EmT function in the federal agencies and with states should be identified. There is a need to establish new and/or leverage existing FACAs to augment knowledge and expertise gaps. The necessary coordination and integration with the NIST (FWIoT and Global City Teams Challenge (GCTC)) protocols should be in place (i.e., IoT implementations involve the integration of multiple technologies, systems, and stakeholders).

Implementation considerations: Establish specialized capabilities (e.g., IoT, smart cities, AI, quantum, etc.), in each office. Consider alignment with the U.S. Chief Technology Officer role. Consider language specified in the Global Technology Leadership Act (S.__, 6/8/2023) for some of the functions, including: the identification of technologies that matter most to U.S. economic and national security; assess U.S. capacity with each, including manufacturing, workforce, supply chain, capital access and R&D; evaluate technology leadership relative to other countries; and determine appropriate policy response.

Potential Barriers: Siloed execution and Lack of coordination from the Executive Office, minimal support from designated agency leadership, lack of branding, lack of coordination, stakeholder engagement, resource allocation, and performance monitoring.

Enabling Recommendation 5.1.4: The government should consider the development of Smart City and Sustainability Extension Partnerships (SCSEP).

IoT can bring great economic and societal benefits to our cities, but specific smart city and sustainable infrastructure expertise in industry is limited, unevenly distributed, and fragmented. Some cities and agencies also lack the tools and resources, and even smaller cities and agencies may be even more constrained. Municipalities and agencies may not have the budget, the empowerment, or the ability to engage the necessary resources.

A different way to engage these resources is needed. The public procurement processes to engage private sector resources are burdensome. A SCSEP similar to existing partnerships (e.g., MEP, USDA) would be a worthwhile investment, and would provide an improved model over the current public procurement process to engage private sector resources.

SCSEP should be put in place and operational to support sustainable infrastructure projects funded through the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA).

The role of states should be defined. In particular, some BIL and IRA funding may be given to states to manage and allocate. Consideration should be given as to whether some of these activities can be performed through the existing extension offices and infrastructure, or through partnerships with regional consortiums or states.

Implementation Considerations: Smart cities, sustainable infrastructure and IoT are broad in scope and discipline. A SCSEP should be a multidisciplinary center with spanning expertise (technical, operations, cybersecurity, etc.). The expertise lies across a variety of areas and could be implemented through partnerships with public (state, local) agencies, industry, and universities. There are a small number of regional “smart city” type consortiums across the country. Consider establishing partnerships or collaboration with these consortiums to support or enable these capabilities. For example, the USDA agriculture extension offices and the U.S. Department of Commerce manufacturing extension partnerships model as starting points. They have built infrastructure and processes. In some rural areas, perhaps this is how these capabilities of the SCSEP should be delivered.

Potential barriers: Limited expertise in the market and industry; resources and expertise may be difficult to secure. Establishing a new extension office infrastructure will take time and resources. There is not a clear or obvious federal agency owner for this.

Enabling Recommendation 5.1.5: The government should fully fund existing IoT research, development, deployment and demonstrations.

We recommend Congress complete the funding procedure for vital IoT related R&D and deployment work already approved and taking place throughout the federal government. That means fully funding the critical investments that a bipartisan Congress has supported through the bipartisan Chips and Science Act, and through the bipartisan Infrastructure Act, and that these be fully funded at the levels Congress authorized. These research investments span multiple areas, including semiconductors and sensors, to the connectivity and interoperability methods that connect them, to the infrastructure and systems that allows them to operate, automate and sustain itself at scale.

In addition, the U.S. Government should fully fund the science agencies’ work in these areas, including:

- ARPA–E, which is advancing its SENSOR program, and PANDA programs
- ARPA-H and its connected health work;
- DOE and its smart building, smart manufacturing technology programs and other initiatives;
- DOE Office of Science;
- EERE’s work for energy efficiency and climate gains;
- NSF – the NSF Engines, NSF’s Smart and Connected Communities program, and various other programs – that are advancing smart cities, smart manufacturing, and the new IoT smart agriculture program created under the CHIPS & Science Act

- DOT's – fledging new ARPA-I, SMART grants program, and Sensor programs
- At Commerce, fully fund NIST and the vital work it does, the Global Cities Team Challenge (GCTC), and the Regional Tech Hubs created by the Chips and Science Act, continue to invest in the important IoT working being done at DoD, EPA, NIOSH, USDA/NIFA (and its Sensor Technologies Program)
- And lastly, but importantly – make sure OSTP is adequately resourced to be able to take on a bigger role.

Anything less will slow down these efforts and cut our IoT opportunity short.

Leading by Example: Improved Use of IoT in Federally Funded Projects

Key Recommendation 5.2: The government should expand and improve integration of efficient, sustainable technologies into federally subsidized or funded infrastructure projects. [Secretariat drafted]

[Need additional text]

Enabling Recommendation 5.2.1: The government should specify and utilize energy efficient and sustainable technologies into infrastructure and other projects that are funded in full, or partially, with federal funding.

The U.S. lags behind other nations in reducing environmental impact, such as by reducing carbon footprint and greenhouse gas emissions. By requiring increased use of energy efficient technologies, the U.S. can make progress toward environmental goals.

Implementation might include adoption of building and energy codes that include language like automated demand response technologies, EV Ready, EV Capable, etc. Also look at incorporating energy savings through energy performance contracts and examination of building energy use benchmarking. The GSA FAR specifies energy efficiency requirements for procurement in federal owned and operated buildings.

Potential barriers: Funds such as high costs to scale conversion to energy efficiency. Supply chain issues (e.g., in distribution transformers, mining limitations for batteries, etc.) that manufacturing is trying to overcome. Legacy equipment and existing equipment (e.g., boilers, furnaces, etc.) that have a long lifetime.

Enabling Recommendation 5.2.2: The government should consider the specification and utilization of IoT and “smart” technologies into infrastructure and other projects that are funded in full, or partially, with federal funding.

The federal government should consider the specification and utilization of IoT and “smart” technologies into infrastructure and other projects that are funded in full, or partially, with federal funding. Every year, the federal government, through its many agencies, supports and funds billions of dollars of infrastructure planning, construction and operation projects. These projects include projects owned by non-federal stakeholders (municipalities, utilities, agencies, states, etc.) and federal stakeholders (federal facilities, infrastructure, etc.).

The federal government should take this opportunity to specify and incorporate IoT and smart technologies into infrastructure projects spanning the project lifecycle from design, construction, to commissioning and operation. For example, IoT technologies can be specified and used during the construction phase of infrastructure projects. Air quality sensors can be specified to monitor vehicle emissions and dust and particulate matter generated during construction in

order to comply with local air quality regulations. When air quality levels reach certain levels, mitigation measures can be implemented to minimize impacts to worker and community health. IoT sensors and intelligent traffic solutions can be specified into roadway projects to support future intelligent highway and autonomous vehicle projects. Remodeling or construction of new federal facilities, including airports, military bases and buildings can specify the use of various IoT solutions, such as smart building sensors and energy management systems, smart parking, and other technologies.

The federal government, through its procurement and funding activities, can influence and facilitate action. For example, the GSA and the U.S. Army Corps of Engineers specified the use of Building Information Modeling (BIM) in its projects. As a result, contractors had to comply with the requirement and used BIM tools, which enabled both the government and the contractor to reduce construction and project risks. A similar approach was used to accelerate the utilization of small and disadvantaged businesses (SB and SB8a) in federally funded transportation projects.

Implementation Considerations: While it is easy to say, “you shall incorporate IoT technologies”, it is more difficult to specify what IoT technologies should be acceptable to be used. Some concrete and specific IoT applications should be defined for inclusion in the project and funding requirements, based on project types. Without this list, the contractors will be left on their own to interpret what is meant by IoT, and in some cases, will do the minimum possible just to comply or comply with things that meet the definition but not make any sense. Additionally, a broader vision and understanding of how IoT is to be incorporated, used and operated is needed by project owners, governments and operators in order to develop the requirements and specifications.

Potential Barriers: Project owners may have limited to no IoT awareness of knowledge. Limited expertise and resources in government and marketplace to support IoT in the projects. Specification of IoT may add complexity and cost to the project, the requirements, and to the timeline. No pre-defined acceptable or allowable IoT is be considered and specified for the different types of projects.

Leverage Federal Grants And Programs To Improve IoT Technology Use

Key Recommendation 5.3: The government should consider new models for sustaining and support in considering IoT project feasibility.

Grants offset acquisition and build, but many organizations lack financial means and resources to sustain IoT operations and maintenance. Because of this constraint, projects either shut down after funds run out or some entities are discouraged from applying. IoT requires additional levels of support and resources that buyers may not have accounted for – software licenses, data maintenance, data analysis, for example.

IoT enables new business and operating models. Economic service models to assist could include extended funding for O&M for select applicants (i.e., rural, tribal, small towns, etc.), encourage regional cost sharing for multiple cities in a region to apply as one, and encourage innovative models (i.e., corporate, sponsorships).

Implementation considerations: There are types of models - 1) Extended Funding – extending funding for O&M for select applicants (rural, tribal, small towns, etc.). 2) Regional cost sharing – encourage multiple cities in a region to apply as one. 3) Innovative – encourage innovative models (corporate, sponsorships).

Potential barriers: Non-traditional and innovative models may be difficult to evaluate and track. IoT funding may be embedded into a broader funding package and not easy to separate the two.

Enabling Recommendation 5.3.1: The government should encourage other models to help select adopting organizations sustain and support in evaluating IoT project feasibility.

The federal government should consider models to help select adopting organizations sustain and support beyond the initial acquisition and building of new projects incorporating IoT technologies. While grants for projects help offset the initial cost of capital procurement, integration and development, the cost of operating the asset or system is left to the organization, municipality or agency. Some select organizations have the resources, funding models, or mechanisms to find the resources to sustain the operation and maintenance of this asset or system. However, many other organizations, especially the smaller ones, or those in rural and tribal areas, that benefit from these technologies the most, do not have these mechanisms (budget, taxes, etc.), and may forgo these types of projects, or only operate the IoT applications short term until the funds run out. Similarly, current agency grant application evaluation criteria may screen out those that don’t meet the financial requirements for sustaining operations.

Implementation considerations: Extended Funding: For existing grant programs, consider extending funding for operations from one to two years for applicants that meet specific criteria of those that can benefit from IoT but could not otherwise sustain it (rural areas, tribal areas,

small cities and towns, etc.) Regional models: Incorporate models that encourage regional partnerships. For example, one small community may not have the means to sustain a small IoT application. But if multiple adjacent communities apply for a grant together, they may be able to leverage some economies of scale to purchase and set up the application but may be able to employ synergies and cost sharing to maintain the application together. Innovative partnerships: Incorporate criteria that encourage and reward innovative approaches to sustaining operations. For example, one city was able to sustain operations by implementing a “support a AQ node” and getting corporate sponsors in the business community to support the maintenance and operation of the network.

Potential barriers: IoT funding may be embedded into a broader funding or project package, and it may not be easy to separate the two. Non-traditional and innovative funding models may be challenging to track and evaluate. All federal agencies that provide grants and funding for projects where IoT may be incorporated.

Enabling Recommendation 5.3.2: The government should consider “student loan forgiveness” programs in exchange for providing critical emerging technology (IoT, data science, cybersecurity, etc.) skills to municipalities and agencies.

The federal government should consider “student loan forgiveness” programs in exchange for providing critical emerging technology (IoT, data science, cybersecurity, etc.) skills to municipalities and agencies. These programs, analogous to the National Health Science Corps, provide expertise to municipalities, agencies and utilities, especially smaller ones, that can help them to adopt, and accelerate the implementation and execution of these “smart solutions”.

Many cities lack the type of digital talent that is critically needed to implement and operate advanced technology. Moreover, many small cities and rural areas face an exodus (or “brain drain”) of workers. Cities, in general, often find it difficult to attract sufficient digital talent at a scale that will have an impact. Federal agencies can help cities to leverage a similar model to that used by the National Health Science Corps. They can seek opportunities to partner with non-profit organizations (e.g., FUSE Corps) to find, attract, and hire talent.

Implementation considerations: Leverage the model used by the National Health Science Corps. These resources can work with non-profit organizations that support government agencies (e.g., FUSE Corps). Identification of specified work roles/skills needs (cybersecurity, data analytics, software development.

Potential barriers: For critical skills like cybersecurity and data science, it may still be hard to attract someone to this program since there is fierce competition from the private sector. There is a lack of sufficient numbers of certain skills, especially working with cybersecurity, AI, ML, etc. There may not be enough of these skill sets

Enabling Recommendation 5.3.3: The government should develop and facilitate programs and grants to reskill existing workers, train future workers across manufacturing, construction, and clean technology / renewable industries.

IoT is a critical technology in renewable energy systems. This recommendation would leverage existing initiatives and programs that address workforce development. Federal considerations include the need to consider integration with existing workforce development programs and infrastructure.

Implementation considerations: Leverage existing initiatives and programs that address workforce development.

Potential barriers: Labor shortage in renewable and adjacent industries (manufacturing, construction) and lower wages in renewables than in other industries

Enabling Recommendation 5.3.4: The government should consider developing programs and grants to allow underserved and less developed communities as well as rural areas to adopt smart transportation technologies.

Doing so would help improve national accessibility to benefits from the adoption of IoT technologies that are not currently available to all citizens and municipalities. Government grants and programs targeted towards these areas could spur private investment and growth in these areas, as well, further amplifying the economic and societal benefits that would result from such funding.

Funding opportunities for these underserved and rural communities will create jobs and promote economic growth. As digital technologies are adopted in these areas, they will require skilled workers to develop, implement, and maintain these systems. Financial incentives can help stimulate this job growth and support the development of a skilled workforce in the IoT sector. to adopt smart transportation technologies.

Implementation Considerations: The government will need to Identify appropriate tactics and methods, such as ADA-compliant EV Charging stations, adding EV-Ready language into building codes, small- disadvantaged business set asides, or Department of Transportation (DOT) Grand challenges as programs/grants are developed. Clear eligibility criteria should be established to ensure that these grants/incentives are targeted only at these types of communities and areas. The federal government should establish a system for monitoring and evaluating the effectiveness of these grants/incentives.

Potential Barriers: Individuals that reside in these areas may not be fully aware of all the potential benefits that smart transportation technologies provide. Connectivity might be an issue in rural areas. Initial efforts may need to focus on those rural areas that already have some base level of connectivity. Other barriers include budget constraints, lack of political support, or concerns about market distortion. The federal government should address these concerns by demonstrating the potential economic and environmental benefits of IoT adoption in supply

chains, leveraging public-private partnerships to share costs, and ensuring that the financial incentives are designed to minimize market distortions.

Leading the Way for IoT Adoption in Agriculture

Key Recommendation 5.4: The government should implement sector-specific actions to further promote IoT adoption in the Agriculture sector.

[text needed]

Enabling Recommendation 5.4.1: The government should develop a comprehensive strategy for agricultural IoT.

As IoT technologies continue to advance, their adoption in agriculture can significantly enhance productivity, resource efficiency, and environmental sustainability. However, without a cohesive national strategy, the potential benefits of agricultural IoT may be hindered by fragmented initiatives, limited interoperability, and a lack of clear direction. This strategy should be developed in collaboration with stakeholders, such as farmers, technology providers, industry experts, and research institutions, to ensure broad consensus and commitment to its implementation.

The Federal government should identify and prioritize the most pressing challenges faced by the agricultural sector that can be addressed using IoT technologies, such as water management, pest control, and labor shortages. The government should develop specific goals, timelines, and milestones for the integration of IoT in agriculture, ensuring alignment with broader national objectives related to food security, environmental sustainability, and economic growth. This could be accomplished by establishing an interagency task force to oversee the development and implementation of the national strategy, involving relevant agencies such as the USDA, FCC, and DOE.

The federal government should consider programs to help growers and producers adopt IoT technologies. This should include subsidies around connectivity, sensors, and digital applications. The programs could be similar to other subsidies that the USDA has for farmers around agricultural inputs or climate smart agriculture. The use of IoT in agriculture will benefit all stakeholders, including the farmer, the policy makers, the agricultural companies, and the consumer.

The upfront cost of IoT typically limits the adoption of data-driven agriculture, and the farmers who may have the most need may be the ones least likely to take advantage of digital technology. Federal subsidies can help scale the technology, which will drive down costs for all, and could help marginalized farmers and smallholder farmers who might need more help to leverage technology.

Implementation Considerations: Developing an approach to IoT subsidization could involve a public / private / academic partnership and leveraging the knowledge and capabilities of

Agricultural Extension centers. Particular attention should be paid to defining approaches that will enable marginalized and smallholder farmers to leverage available subsidies to deploy and benefit from IoT technology.

Potential Barriers: There is limited expertise in the market and industry, meaning resources and expertise may be difficult to secure.

Enabling Recommendation 5.4.2: The government should consider fully funding the deployment of a “farm of the future” setup in every land grant university nationwide. This nationwide test-farm IoT network should span different forms of agriculture, including, but not limited to broadacre, horticulture, livestock, and aquaculture.

The proposed initiative advocates for the federal government to allocate sufficient funding to implement a "farm of the future" setup in all land grant universities across the United States, providing a showcase for farmers in the region on how to collect and analyze data from their farms.

The data collected by the IoT network could be used to develop and refine machine learning algorithms, which could help farmers predict future crop yields and identify potential issues before they occur. (Note: That data might also be housed and shared through data repositories described in other recommendations.)

The nationwide "farm of the future" IoT network would enable universities to share data and insights with each other more easily, fostering a collaborative approach to agriculture.

The implementation of a nationwide IoT network in land grant universities could help to advance research and development in agriculture, leading to the creation of new technologies and practices that could benefit farmers and consumers alike.

It is difficult to specify what IoT technologies should be acceptable to be used. Some concrete and specific IoT applications should be defined for inclusion in the project and funding requirements, based on project types.

Implementation Considerations: “Farm of the Future” efforts should look to assist in determining what IoT technologies should be acceptable to be used. Some concrete and specific IT applications should be defined for inclusion in the project and funding requirements, based on project types. This may require coordination with other federal agencies in alignment with their objectives. Different land grant universities might pose different challenges with respect to implementation, including connectivity, tech readiness, etc. It is important to include every university, including the HBCUs.

Potential Barriers: Project owners may have limited IoT awareness and knowledge, and there may be limited expertise and resources available in the marketplace to support IoT in the

projects. Given the large number of land grant universities and the cost of agricultural equipment (e.g., connected combines, aquaculture systems), significant funding will be needed.

Enabling Recommendation 5.4.3: The government should actively promote and support the adoption of Generative AI applications for agricultural IoT, with the aim of improving decision-making, optimizing resource utilization, and enhancing productivity in the agricultural sector through innovative and data-driven solutions.

Generative AI applications have the potential to revolutionize the way farmers analyze and use the data collected from IoT devices in agriculture. By leveraging advanced algorithms and machine learning techniques, Generative AI can enable farmers to identify patterns, optimize resource allocation, and make better informed decisions. This will result in benefits for various stakeholders, including farmers, policy makers, agricultural companies, and consumers.

Federal stakeholders could establish a public-private-academia partnership that would define specific agriculture applications (e.g., yield prediction, pest and disease management, irrigation scheduling, supply chain optimization) that might benefit from AI. Agencies could support the partnership through financial incentives and subsidies, and through formal promotion of education and training opportunities (perhaps in concert with other workforce efforts described.)

Implementation Considerations: Define specific agricultural applications: Consider specific use cases for Generative AI in agriculture, such as

- **Yield prediction:** Generative AI can analyze historical and real-time data from IoT devices to predict crop yields more accurately, helping farmers to make better informed decisions regarding planting, harvesting, and marketing.
- **Pest and disease management:** Generative AI can use data collected from IoT sensors to identify patterns in pest and disease occurrences, enabling farmers to adopt targeted and timely interventions for prevention and control
- **Irrigation scheduling:** Generative AI can optimize irrigation schedules by analyzing data from IoT devices such as soil moisture sensors, weather stations, and satellite imagery, ensuring efficient water use and reducing water waste.
- **Supply chain optimization:** Generative AI can analyze data from IoT devices throughout the supply chain to optimize logistics, reduce food waste, and increase overall efficiency.

Provide incentives or subsidies to facilitate the adoption and integration of Generative AI applications by farmers and agricultural businesses. These incentives could include tax breaks, grants, or low-interest loans to help offset the upfront costs associated with implementing Generative AI solutions.

Create educational programs and resources to help farmers and agricultural professionals understand the benefits of Generative AI technology and how to effectively implement and use these applications. This can be achieved through collaborations with Ag Extension Centers, universities, and industry experts. Offer workshops, webinars, and online courses to ensure widespread access to knowledge and training opportunities.

Potential Barriers: Limited expertise and understanding of Generative AI technology may hinder widespread adoption. Additionally, effective collaboration between multiple agencies, stakeholders, and the private sector will be necessary to ensure successful implementation. Ensuring data privacy and security, as well as addressing any potential ethical concerns related to the use of AI in agriculture, will also be crucial factors to consider. Furthermore, the integration of Generative AI applications with existing agricultural IoT systems may require significant technical and operational adjustments.

Enabling Recommendation 5.4.4: The government should provide overarching regulatory guidance for the drone industry. The Federal Government should also provide funding for the drone industry for additional research in order that existing technical obstacles can be overcome.

[Note that the use of drones was primarily discussed for use in an agricultural context, although it could be used for many of the topics described including sustainability, transportation and environmental monitoring. We should add that to the prose herein.]

There are conflicting regulations that govern drones for recreational pilots versus those that govern drones for commercial pilots. The regulations that govern drones for commercial pilots are put forth by the Federal Aviation Administration (FAA) as they regulate that section of the airspace. Sometimes these regulations are mistakenly applied to recreational pilots. In some jurisdictions there is uncertainty over who regulates the airspace for recreational pilots (FAA versus Local Police).

In addition, there are commercial drone pilots that fly large aircraft in sections of the airspace that fall under Advanced Air Mobility (AAM) jurisdiction. Another issue facing the drone industry is Remote ID — a requirement for a drone to have an internal signal broadcasting the drone’s location, latitude, longitude and heading. Not all drones currently meet this requirement.

Implementation Considerations: It will be necessary to involve all stakeholders: drone equipment manufacturers, communications providers, among others need to be involved. This should be accompanied by expanding access to education and training: particularly on safety aspects related to drones.

Potential Barriers: Limited resources may constrain the government's ability to fund drone research. The drone industry is facing supply chain challenges. Drones approved by the Department of Defense (DoD) need to be on the Blue UAS Cleared Drone List. Drones on this list are validated as cyber-secure and safe to fly and are available for government purchase and operation.

Enabling Recommendation 5.4.5: The government should facilitate development of connectivity policies and programs. [For Board Review - Proposed by Benson]

Needs include:

- Broadband service at the farmhouse greater than 25/3 Mbps
- Symmetric connectivity of at least 100/100 Mbps that supports high bandwidth precision agriculture use cases (video, imagery, automation and control, etc.)
- Last acre IoT connectivity service that addresses coverage, terrain diversity, evolving use cases, and foliage/canopy interference

Today's broadband and connectivity infrastructure and capabilities are insufficient to support current and future precision agriculture needs for a variety of reasons.

- While many agriculture IoT use cases are low bandwidth, intermittent communications applications (e.g., soil moisture, animal health monitoring, etc.), future farming required the processing of low latency, real time data, support automation applications, and high bandwidth applications. Examples are drone imagery and remote viewing/monitoring and remote operation of automated farm machinery.
- Some farming applications, such as imagery and video, require high upload speeds from device to the cloud data center. For example, drone imagery needs to be uploaded to the cloud for analysis and processing. These files are very large and need a high bandwidth connection.

Implementation Considerations

- Existing broadband infrastructure grant programs for rural areas (BIL, USDA) should account for more high bandwidth, symmetric connections. These types of connections support other non-agriculture applications, such as telehealth, remote education, and manufacturing (factories) in rural communities.
- There is no one size fits all approach due to the large areas of coverage, terrain diversity and application types. Addressing this requires multiple technologies to be considered and used, including satellite service, terrestrial wireless (licensed and unlicensed), fiber, and other approaches like TV white space, etc.

Barriers

- Unfavorable economics and ROI may preclude terrestrial mobile operators from establishing services in rural communities
- Signal blockage due to foliage and tree/plant canopies from some plants may make some types of connectivity services less feasible
- Terrain diversity and wide areas of coverage may make last acre connectivity challenging
- FCC definition of broadband as 25/3 needs to be updated for modern and future applications and services

Enabling Recommendation 5.4.6: The government should support and promote industry and SDO efforts to address interoperability of agricultural systems and machinery [For Board Review - Proposed by Benson]

Farms have a variety of equipment and machinery from different manufacturers that can't communicate or exchange data with each other, each with their own data formats and languages. The agriculture industry model is to develop s/w and devices in proprietary formats.[1] This lack of interoperability hinders data sharing, automation of processes, and timely diagnosis and analysis of problems to create positive outcomes. In addition, costly manual labor is required to extract the data for use.

Implementation considerations
There are a variety of SDOs and industry associations that are addressing small parts of this much broader problem. However, broader efforts involving the major equipment manufacturers is needed

Barriers
The industry model is to build their own ecosystem. Equipment manufacturers have limited incentives to fully address interoperability, or they may form their own "walled garden" ecosystem.

Enabling Recommendation 5.4.7: The government should facilitate small farm/ranch adoption of IoT technologies. [For Board Review - Proposed by Benson]

Small farms **(< $350,000 GCFI)**[2] are 90% of all U.S. farms (~1.8 million farms), own 49% of farmland, but represent 20% of production. They operate with <10% margins. Because of their small scale and low margins, they are cash flow constrained and do not have the capability to buy IoT or smart equipment, even if they want to.

Implementation considerations:

- Offer grants and subsidies for purchase. Since these small farms operate on low margins, they have limited upfront cash available for investment is a critical barrier to adoption.
- Tax credits offer another way to incentivize purchase, but may not be a viable option for those small farms that do not have the upfront cash to purchase and use.
- Use of Cooperative Extension Offices and resources for IoT data analytics and other technical support. In order to ensure that IoT is being used, additional support (beyond what the IoT vendor provides) is necessary to help the agriculture producers get the value out of the data collected so they can optimize outcomes.
- Need to define and specify what subset of IoT devices and solutions would be addressed by this.

Barriers

- Not all of these small farms may have the proper infrastructure (connectivity, etc.) to take advantage of IoT, even if this program was to be offered
- Small farms may not have any awareness of IoT and may not take advantage of this program if offered.

Enabling Recommendation 5.4.8: The government should facilitate policies and programs that support the key education and digital skills development for the current and future agriculture workforce. [For Board Review - Proposed by Benson]

Needs include:

Data analytics and management

- IoT technologies
- Machine vision and robotics
- Networking and systems integration
- Cybersecurity
- Installation, maintenance and servicing of IoT systems

Agricultural workers lack the needed skills required to support and succeed in an increasingly digital agriculture environment. Technology will automate manual activities and low skill repetitive work will shift to work requiring technical, cognitive and people skills. In addition, as machinery gets more digitized and IoT enabled, digital skills are required to support, service and operate these devices and equipment. At the heart of precision agriculture is data and the ability to analyze that data to create beneficial outcomes.

In addition to workers on the agricultural production side, machinery and equipment manufacturers also need workers with digital and engineering skills to develop the IoT and IoT enabled precision agriculture products and solutions. This may range from engineering to technicians and mechanics, as well as data analysts and scientists.

Implementation considerations:

- Integrate any specialized precision agricultural needs and gaps into the National Cyber Workforce and Education strategy
- Workforce development is needed for a variety of workers, including the engineers who design the technology and products, the technicians that install and service the equipment and machinery, the data scientists and analysts that drive the outcomes of the technology, as well as other disciplines.
- Workforce development includes reskilling of existing workforce in industry, reskilling of workforce entering industry from other industry, and development of skills for new workers

- Workforce development partners could vocational schools, community colleges and four year universities, as well as professional associations, private educational institutes, and others

Barriers

- Labor shortage in agriculture and competition from non-agriculture industries

Enabling Recommendation 5.4.9: The government should support enactment of federal "right to repair" legislation to address the inability of agricultural producers to service their smart equipment. [For Board Review - Proposed by Benson]

Smart equipment cannot be fixed by farmers. In many cases, it required servicing by the equipment dealer technicians. These repairs are expensive and may take a long time to get fixed. These may occur at sensitive times for farmers who can't afford the wait, such as during harvest season. Today, farmers are getting around this by purchasing "hacked" software from Eastern Europe or buying older non-smart equipment that they can maintain and repair themselves.[3]

Implementation considerations

- Current legislation has been introduced - the Agricultural Right to Repair Act[4] - review to ensure that precision agriculture and IoT needs has been addressed in legislation

Barriers

- Manufacturer resistance
- Individual states are enacting state level "right to repair" laws

Enabling Recommendation 5.4.10: The government should facilitate development of IoT data confidentiality guidelines for agricultural IoT systems, and manufacturers of "smart" and IoT enabled agricultural machinery and systems [Linkage to privacy recommendations] [For Board Review - Proposed by Benson]

Producers are concerned with who and how their data is used. 77% of producers are concerned about who accesses data, 67% will consider how their data is used when making purchase decisions, and 61% are concerned that companies use their data to influence market decisions.[5]

Implementation Considerations:

Integrate with privacy framework and regulations being considered

Barriers:

- Each IoT solution provider may have their own privacy and data usage policies and guidelines, which may be conflicting
- Manufacturer and solution provider resistance

Enabling Recommendation 5.4.11: The government should increase awareness and education of agricultural IoT technologies through government funded programs, cooperative extension programs, publications, and other means. [linkage to Ranveer university demo centers] [For Board Review - Proposed by Benson]

Implementation Considerations

- Leverage existing USDA infrastructure (ag extension offices, etc.)

Leading the Way for IoT Adoption in Manufacturing

Key Recommendation 5.5: [Preliminary Text: The government should implement specific actions to further promote IoT adoption in the manufacturing and construction industries.] [For Board Review - Proposed by Benson]

The U.S. government should consider addressing the following factors to support IoT adoption in manufacturing.

Enabling Recommendation 5.5.1: The government should facilitate and prioritize the rollout of broadband infrastructure in rural parts of the country with manufacturing facilities. [For Board Review - Proposed by Benson]

Justification/Challenges Addressed

Lack of broadband threatens rural based manufacturing companies to compete against others using Industry 4.0 technologies.[6]

Implementation Considerations

Existing USDA and BIL programs may or may not have manufacturing as a consideration criteria

Barriers

- Unfavorable economics and ROI may preclude terrestrial mobile operators from establishing services in rural communities
- Terrain diversity and wide areas of coverage may make last acre connectivity challenging
- FCC definition of broadband as 25/3 is outdated and insufficient for modern and future applications and services

Enabling Recommendation 5.5.2: The government should Support and promote industry and SDO efforts to address interoperability of manufacturing systems and machinery [For Board Review - Proposed by Benson]

IoTAB Themes: Infrastructure (Interoperability), Manufacturing

Justification/challenges addressed
Interoperability challenges are a major barrier to IoT adoption and value realization in manufacturing. Factories have a variety of equipment, from new industrial equipment with current technology to legacy equipment with limited technology and connectivity. Many of the machines employ a variety of proprietary and incompatible protocols that make sharing information from MES, ERP systems, and SCADA and DCS difficult or impossible.

Implementation Considerations
There are a variety of SDOs and industry associations that are addressing small parts of this much broader problem. However, broader efforts involving the major equipment manufacturers is needed

Barriers
Equipment manufacturers have limited incentives to fully address interoperability, or they may form their own “walled garden” ecosystem.

Enabling Recommendation 5.5.3: The government should facilitate small manufacturer adoption of “smart manufacturing”. [For Board Review - Proposed by Benson]

- Grants, subsidies and tax credits for purchase
- Expand Manufacturing Extension Partnership and CESMII and resources for IoT data analytics, technical support, promote “smart manufacturing” benefits and successes, change resistance and cultural issues
- Increase awareness and education of smart manufacturing technologies through government funded programs, cooperative extension programs, publications, and other means.
- Facilitate workforce development to support smart manufacturing

IoTAB Themes: Small Business

Justification/challenges
- Labor productivity fell 4% (2010-19) compared to 41% increase (2001-10)
- Small manufacturers < 500 people are 98.3% of all U.S. manufacturers. 74.3% are < 20 people.
- ROI skepticism
- Change resistance issues (IT/OT silos, culture)

Enabling Recommendation 5.5.4: The government should facilitate policies and programs that support the key education and digital skills development across community colleges and four year universities for the current and future manufacturing workforce. [For Board Review - Proposed by Benson]

Considerations include:

- Technology and computer skills
- Digital skills (analytics, cybersecurity, IT, networking, etc.)
- Robotics and automation programming
- Working with tools and technology
- Critical thinking

IoTAB Themes: Workforce Development

Justification/challenges

- Manufacturing industry was #1 industry targeted in 2021.
- Creation of new attack surfaces into a former “protection by air gap” environment
- Integration of resource constrained IoT devices with limited cybersecurity capabilities
- Exposure of air gapped legacy equipment, industrial control systems and OT infrastructure vulnerabilities
- Security operations, such as updates and patches, limited to machine downtime periods

Leading the Way for IoT Adoption in the Construction Sector

Key Recommendation 5.6: [Preliminary Text: The government should implement specific actions to further promote IoT adoption in the construction industry.] [For Board Review - Proposed by Benson]

[To be developed]

Enabling Recommendation 5.6.1: The government should specify the use of IoT and other technologies (e.g., BIM, etc.). [For Board Review - Proposed by Benson]

- In the design, construction and maintenance of federally owned, leased and operated properties, buildings and facilities.
- In the design of construction projects funded fully or partially by federal grants and funds (e.g. state and local highway projects, infrastructure projects, etc.)

IoTAB Themes: Construction, U.S. Leadership

Justification/Challenges addressed:
Contractors will not add IoT or other technologies unless the customer (federal government) specifies the use of it. No contractor will add anything on their own without a customer requirement.

Enabling Recommendation 5.6.2: The government should support and promote industry and SDO efforts to address interoperability of data from IoT sources with other construction and asset sources. [some linkage to transportation recommendation on interoperability] [For Board Review - Proposed by Benson]

IoTAB Themes: Construction, Infrastructure (Interoperability)

Justification/Challenges addressed:
Data from IoT devices do not integrate with BIM software, nor do they integrate with the data sets in that software.

Enabling Recommendation 5.6.3: The government should facilitate small contractor adoption of "smart construction" tools and technologies. [For Board Review - Proposed by Benson]

Considerations include:

- Subsidies and tax credits for purchase for tools and machinery
- Increase awareness and education of smart construction technologies through government funded programs (e.g., SBA), cooperative extension programs, publications, and other means.
- Facilitate workforce development to support smart construction

IoTAB Themes: Small Business

Justification/Challenges Addressed
- Industry labor productivity is flat from 2007-2020
- Small contractor firms < 5 people are two-thirds of all U.S. contractors. Half the workforce is in firms between 20-250 people.
- Low profit margins
- Adoption resistance of IoT due to status quo, risk aversion, workforce readiness

Enabling Recommendation 5.6.4: The government should facilitate cybersecurity in IoT in smart construction. [For Board Review - Proposed by Benson]

Expand cybersecurity trust mark program to include IoT devices and modules used for smart construction and industrial and construction operations, and in IoT equipped construction machinery and equipment

Facilitate workforce development programs to increase pool of IoT cybersecurity trained resources in smart construction

IoTAB Themes: Trust (cybersecurity)

Justification/Challenges Addressed
Construction systems do not have the same level of digital sophistication as other industries. Construction IoT technologies need to be secure if they are to be integrated into construction monitoring, operations platforms, BIM and other software tools.

Leading the Way for IoT Adoption in the Insurance Sector

Key Recommendation 5.7 [Preliminary Text: The government should implement specific actions to further promote IoT adoption in the construction industry.] [For Board Review - Proposed by Benson]

[To be developed]

Enabling Recommendation 5.7.1: The Federal Insurance Office should undertake a study of the impacts of IoT and adjacent technologies like AI, in order to understand its potential impact on the insurance industry, the products produced, and its impact on the markets served, and the role of the FIO. [For Board Review - Proposed by Benson]

IoTAB Themes: U.S. Leadership

With few exceptions, insurance is regulated at the state level. However, each state has a different treatment, policies and regulations of IoT. This inconsistent treatment limits the development of IoT-enabled products, the benefits realized and the growth of the industry. Data collected from IoT enabled products and services may be used to discriminate at a personal levelt to create a class of “uninsurables” whose members are unable to get coverage or have limited coverage.

Enabling Recommendation 5.7.2: The government should study and take into consideration the data privacy challenges of IoT enabled insurance products in its development of data and privacy frameworks, policies and regulations. [For Board Review - Proposed by Benson]

IoTAB Themes: Trust (privacy)

Justification:
IoT enabled insurance products offer the potential for personalized policies that reduce underwriting risk, align policies and premiums to customer needs, and create new value and revenues. However, these products collect data that could be used for other purposes now or in the future. In addition, the data collected from IoT enabled products and services may be used to discriminate at a personal level to create a class of “uninsurables” whose members are unable to get coverage or have limited coverage.

Enabling Recommendation 5.7.3: The government should facilitate the adoption of AI in IoT in insurance. [For Board Review - Proposed by Benson]

- Support research in the development of trustworthy AI algorithms and tools, including AI explainability

- Facilitate the development of IoT data usage and privacy policies that support the development of AI algorithms [linkage with Debbie recommendation]
- Support workforce development efforts to increase the pool of workers trained in data analytics and AI

IoTAB Themes: Insurance, U.S. Leadership

Justification
While AI can help automate the analysis of massive amounts of IoT data, and other data collected from insurance companies, its ability to create beneficial outcomes that are fair, equitable, ethical, and explainable is a challenge.

Leading the Way for IoT Adoption in the Retail Sector

Key Recommendation 5.8: [Preliminary Text: The government should implement specific actions to further promote IoT adoption in the retail sector.] [For Board Review - Proposed by Benson]

Enabling Recommendation 5.8.1: The government should support research for the development of low cost sensor technologies. [For Board Review - Proposed by Benson]

IoTAB Themes: U.S. Leadership, Retail

Justification:
Low retail industry profitability margins limit the cost of adoption of IoT solutions. New lower cost sensing technologies at lower price points are needed. Costs need to be on the order of RFID chips.

Enabling Recommendation 5.8.2: The government should facilitate the adoption of AI in IoT in retail. [For Board Review - Proposed by Benson]

- Support research in the development of trustworthy AI algorithms and tools, including AI explainability
- Support workforce development efforts to increase the pool of workers trained in data analytics and AI

IoTAB Themes: Retail, U.S. Leadership

Justification
IoT is one of many sources that will provide a “tsunami of data” for retailers. Artificial intelligence (AI) technologies are poised to transform the industry by helping retailers make sense of data, create insights and act on those insights, with some in real time and autonomously. There is strong interest in AI by retailers. However, trustworthiness of the data, and explainability of the outcomes are major concerns.

Enabling Recommendation 5.8.3: The government should facilitate small retailer adoption of IoT. [For Board Review - Proposed by Benson]

- Subsidies and tax credits for purchase of IoT technologies
- Increase awareness and education of smart retail technologies through SBA programs, publications, and other means.

IoTAB Themes: Small Business

Justification:
98.5% of retail businesses in U.S. < 50 people. Retail businesses operate with 4% margins, and small retailers have limited to no ability to invest in IoT technology.

Leading the Way for IoT Adoption Through Smart Cities

Key Recommendation 5.9: [Preliminary Text: The government should implement specific actions to further promote IoT adoption through smart cities.] [For Board Review - Proposed by Benson]

Enabling Recommendation 5.9.1: The government should facilitate and support the development and use of smart city and sustainable infrastructure reference models.

The federal government should facilitate and support the development and use of smart city and sustainable infrastructure reference models that capture and document the ecosystem. Smart cities are complex ecosystems of communities, neighborhoods, districts, buildings, other cities, utilities, and businesses that co-exist, collaborate occasionally and interoperate with each other. Reference models capture the various components of the ecosystem and provide a blueprint for design and planning, collaboration, coordination and communication in smart city efforts, sharing and economies of scale.

These reference models include technical and operations frameworks and architectures, operational concepts, and draft requirements and reference standards. The reference models serve as a template that planners can use to plan, design and build their smart city projects, and if followed, provides a path for interoperability, scalability, integration and security. Furthermore, these models incorporate best practices and facilitate collaboration between various stakeholders, accelerate adoption and scaling, and are replicable. A broader reference model/architecture helps to identify use cases, potential areas of collaboration between entities, as well as identify areas of “sharing” and economies of scale.

Implementation considerations: The NIST GCTC has already established a structure and model to create, engage and support industry/academia/government partnerships. This effort

should consider inclusion of public entities such as counties, states, and other regional agencies and utilities. There is not a one size fits all “reference model and architecture”. There is one for small cities, large cities, as well as “smart regions”, utilities, buildings, etc. Key participants in developing the reference model include government (states), federal, industry (and industry and standards bodies), and academia. There are various efforts around models and standards. Consider projects that are funded using federal money to incorporate the use of these reference models. NIST has developed the Smart City Framework v1.0 (https://pages.nist.gov/smartcitiesarchitecture/) and that is a starting point for building on something that may be more usable to city planners.

Potential barriers: Complexity of coordinating various stakeholders together to define a reference model or Architecture. There may be work in these models undertaken by consortiums or industry. Integrating and aligning existing parts of models may be challenging.

Enabling Recommendation 5.9.2: The government should facilitate opportunities for adoption and equity of benefits of IoT and smart city technologies for local governments (cities, counties), regional entities (water districts, sanitation districts, air quality districts, etc.) and utility companies. [For Board Review - Proposed by Benson]

This may include:

- Funding regional or state programs that support municipalities and local governments in strategy and roadmap development and integration of smart city technologies into city vision, infrastructure and operations.
- Project grants for smart city and related innovations pilot projects and deployment projects
- Consideration and specification of IoT applications into the design, construction and operation of federally funded infrastructure projects (e.g. highway projects, street improvements, etc.)
- Facilitate smart city grants for communities that have received broadband grants to build on new connectivity infrastructure

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, U.S. Leadership

Justification

While cities, regional entities, and utilities may want to do smart city projects, a number of factors is hindering this, including:

- the lack of funding for pilots and projects
- a lack of leadership awareness, vision and planning for these innovations
- A lack of project owner specification for IoT

Enabling Recommendation 5.9.3: The government should facilitate smart community opportunities and adoption of IoT for those rural communities that have broadband infrastructure, have received broadband infrastructure funding or have completed broadband infrastructure build outs. [For Board Review - Proposed by Benson]

Examples of smart community IoT opportunities include home healthcare monitoring, agriculture, natural resources and environmental monitoring, home energy monitoring, etc. Examples of approaches include:

- Coordination with federal agencies to drive community awareness of IoT opportunities, and support programs that encourage industry participation
- Project grants for community related IoT projects and deployment projects (e.g. environmental monitoring, etc.)
- Consideration and specification of IoT applications into the design, construction and operation of federally funded rural infrastructure projects (e.g. highway projects, street improvements, energy transmission lines, etc.)

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, U.S. Leadership

Justification

Rural communities lack many of the same resources, services and amenities that residents in urban areas benefit from. The lack of infrastructure, low population densities, private sector investment and other factors contribute to the urban/rural divide. For example, many rural areas are considered medical deserts with limited number of healthcare providers and facilities. As a result, healthcare access inequities exist. Telehealth and home healthcare monitoring are IoT enabled services that can alleviate some of these inequities.

Enabling Recommendation 5.9.4: The government should facilitate federal adoption of IoT and smart city technologies within its facilities, including government buildings, military bases, campuses and other facilities. [For Board Review - Proposed by Benson] [This could also go in 5.2]

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, U.S. Leadership (adoption)

Justification

The federal government is the largest landlord and owner of properties across the United States. These facilities do not incorporate IoT technologies which could provide a variety of benefits, including energy savings, safety, resilience, etc.

Enabling Recommendation 5.9.5: The government should support and promote industry and SDO efforts to address interoperability of smart cities (including smart buildings, energy and utilities, traffic, etc.). [For Board Review - Proposed by Benson]

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, Infrastructure (interoperability)

Justification: Interoperability challenges are a major barrier to maximizing the value of IoT and smart city technologies. Disparate IoT devices and smart city systems have limited to no ability to communicate with each other and other city systems. This limits the ability of the city to monitor conditions, automate operations, respond quickly, effectively and efficiently.

Enabling Recommendation 5.9.6: The government should facilitate small to medium city adoption of smart city technologies. [For Board Review - Proposed by Benson]

Considerations include:

- Develop smart city grants targeted for smaller communities and rural communities [linkage to existing recommendation]
- Develop smart city grants for communities that receive broadband infrastructure funding (BIL, USDA, etc.), to encourage them to build on their infrastructure investments
- Consider program grants that allow these communities to sustain the operation and maintenance of smart city technologies beyond the initial project funding (for initial acquisition, installation and operation). [linkage to existing recommendation in smart cities/sustainable infrastructure]
- Consider creating smart city innovation extension partnerships (modeled after MEP and agriculture extension offices) to provide the smaller cities with the technical and innovation expertise, resources and capabilities to design, operate and innovate with smart city technologies [linkage to existing recommendation in smart cities]
- Facilitate workforce development to support innovation, IoT and digital technologies in smaller cities (including municipalities, regional entities, and utilities)

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, U.S. Leadership

Justification

There are 1300 cities that have less than 250,000 people. These cities lack the funding, expertise and resources to implement, operate and maintain smart city technologies. At the same time, these smaller cities have needs that are different from their larger city counterparts and may require grants that are more aligned to their needs.

Enabling Recommendation 5.9.7: The government should facilitate cybersecurity in IoT in smart cities. [Could move to Trust – Cyber] [For Board Review - Proposed by Benson]

Considerations include:

- Expand cybersecurity trust mark program to include IoT devices and modules used in a variety of smart city and utility applications (including public safety, public health, energy and sustainability, facilities, economic development, traffic, mobility, water/wastewater, public infrastructure, and others)
- Facilitate workforce development programs to increase pool of IoT cybersecurity trained resources for smart city and utility on both the solution provider side and city/utility (buyer) side

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, Trust (cybersecurity)

Justification:

City and utility infrastructure are attractive targets for cyberattacks. The number of ransomware attacks on cities has been steadily growing. Similarly, the introduction of IoT into utility OT infrastructure creates new attack surfaces and vulnerabilities to formerly air gapped systems. Cities and utilities lack the resources and capabilities to defend and mitigate.

Enabling Recommendation 5.9.8: The government should facilitate the research into smart city privacy concerns. [For Board Review - Proposed by Benson]

- Support research in privacy enhancing technologies
- Consider the usage of PETs on IoT technologies used in small city applications on federal government facilities and properties
- Consider the usage of PETs on IoT technologies and retail systems used in retail outlets on federal properties (including BXs on military bases, federally own and managed facilities)
- Increase industry awareness of privacy by design in developing smart city solutions and services
- Incorporate considerations for “smart cities” in the development of a national privacy framework and regulations

[Some linkage with Debbie recommendation on PETs]

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, Trust (privacy)

Justification

Privacy concerns are hindering the adoption and use of IoT technologies. Concerns about the information collected and how it is used, as well as the accuracy of the data collected and the ability of the technology to create the correct outcomes.

Enabling Recommendation 5.9.10: The government should continue and expand GCTC efforts to foster collaboration between municipalities and the broader smart city ecosystem (utilities, regional agencies), industry and academia. [For Board Review - Proposed by Benson]

Build clusters and superclusters around select topic and collaboration areas

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure

Justification

Limited opportunities for cities to collaborate, exchange knowledge, and learn from each other. GCTC has moved away from clusters and superclusters.

Enabling Recommendation 5.9.11: The government should facilitate equity in realization of smart city benefits. [For Board Review - Proposed by Benson]

This may include:

- Smart city project grants for underserved and rural communities, including those applications where underserved communities are disproportionately impacted (e.g. environmental monitoring, healthcare, public safety, etc.)
- Increase access to broadband services and affordability
- Workforce development opportunities for residents of underserved and rural communities for the new IoT and digital jobs to be created

IoTAB Themes: Sustainable Infrastructure, Smart Cities, U.S. Leadership

Justification

Benefits of IoT and smart city technologies are not available to all members of a community. Socioeconomically challenged and rural communities may not have the broadband infrastructure, or have limited resources to implement and operate smart city technologies. The new jobs created by IoT, smart cities and digital transformation require skills and education that members of underserved communities may not be able to develop. Some services enabled by these technologies require smart phones and Internet service to access, which some community members may not have, while others are offered in ways that cannot be accessed by residents due to language barriers, digital literacy skills, etc.

Enabling Recommendation 5.9.12: The government should develop a national smart city strategy. [For Board Review - Proposed by Benson] [Integrate with 1.1?]

IoTAB Themes: Smart Cities/Sustainable Infrastructure, U.S. Leadership

Justification:

Smart cities bring significant benefits to residents, businesses and visitors of those communities. For example, smart city technologies help reduce energy usage of homes and buildings. Other smart city technologies facilitate transportation and mobility, leading to increased accessibility, and economic vibrancy while reducing traffic congestion and accidents. Different smart city technologies lead to increased public safety, enhanced quality of life, government responsiveness, and community resilience.

While there are pockets of “smart city” activity within the United States, these efforts are disparate and smart cities have not really scaled as compared to other countries such as Singapore, Netherlands, India, among others. No current strategy exists and progress toward smart city development is slow, siloed, and inconsistent. Many federal agencies are involved in different aspects of smart city development (energy, transportation, traffic, healthcare, etc.), with limited coordination. For smart cities to get traction in the United States in any meaningful way, a coordinated approach between federal, state and local governments is required.

Implementation Considerations

- The strategy should take into account the broader ecosystem of stakeholders involved in the design, building and operation of smarter cities (local government, regional agencies and authorities, states, utilities, industry, communities), the vision, opportunities, federal/state/local coordination, equity of benefits, funding, etc.

- The strategy should take into account the various desired areas of outcomes, including resilience, economic vibrancy, public safety, mobility, quality of life, sustainability, health and wellness, and government/community responsiveness.

Barriers

- Limited collaboration between cities, states and federal agencies

- Limited coordination and collaboration between federal agencies, who each own parts of “smart city and sustainable infrastructure” programs and initiatives

Leading the Way for IoT Adoption for Public Safety

Key Recommendation 5.10: [Preliminary Text: The government should implement specific actions to promote IoT adoption that will improve public safety.]

Enabling Recommendation 5.10.1: The government should create a stockpile of public safety IoT devices that is available for immediate access.

The federal government should create a stockpile of public safety IoT devices that are finite in type and need but contains a medley of manufacturers to choose from rather than a single or a couple of manufacturers from which stockpiles are sourced. Stewards could refresh the stockpile per labeling requirements and best use-by date.

The safety and wellbeing of each and every citizen, including their ability to live in safe environments and conditions, is paramount and vital. Having a stockpile of certified and approved devices to be used by law enforcement, EMS, fire, and rescue will enable public safety officials to arrive at scenes of crime and disasters armed with devices that interoperate, can be shared/exchanged while on duty, and enable ease-of-use.

Implementation Considerations: Similar to the Department of Health and Human Services (DHHS) stockpiles of vaccines, personal protective equipment (PPE), etc., we recommend the U.S. government add public safety devices to their procurement list. Initial and ongoing funding is needed along with cooperation from manufacturers who wish to participate in the stockpile program develop APIs and interoperability to other competing and complementary devices.

Potential Barriers: Lack of funding and resources needed to manage an additional set of assets found in stockpile.

Leading the Way for IoT Adoption for Health Care

Key Recommendation 5.10: [Preliminary Text: The government should implement specific actions to promote IoT adoption in the health care industry.]

Enabling Recommendation 5.10.1: The government should remind Healthcare Facilities' Executive Leadership Teams to ensure that IoMT be an enterprise priority.

IoMT should be equivalent in priority for all healthcare stakeholders as is IT infrastructure, cybersecurity posture, or applications. IoMTs monitor, detect, inform, and deliver therapies to patients, therefore, they deserve just as much attention and call out as cloud services, for example. Currently IoMTs are ignored by healthcare IT organizations, as the responsibility to make decisions and/or purchase the devices is owned by the biomedical engineering

department. IoMTs may not undergo strict infrastructure, privacy, and security guidelines as to large capital equipment investments such as MRI scanners.

Implementation Considerations: None identified.

Potential Barriers: None Identified.

Enabling Recommendation 5.10.2: The government should enact HIPAA-like protection for users' medical data in mobile applications and IoT devices. Consider medical data as a category for defined data protections.

Many consumer-grade IoT devices and mobile apps collect users' sensitive medical data. Consumers tend to believe that this data is protected similarly to medical data in a healthcare facility, but it is not.

Implementation: Extend HIPAA protections to these classes of devices and mobile apps or enact a similar type of protection.

Barriers: Possible resistance from industry manufacturers to restricting the sharing of user data.

Federal Considerations: Enact HIPAA-like regulations to protect user PHI in consumer IoT devices and mobile apps.

Enabling Recommendation 5.10.x: The government should support and promote industry and SDO efforts to address interoperability of medical and healthcare devices and systems. [For Board Review - Proposed by Benson]

Interoperability challenges are a major barrier to maximizing the value of IoT in healthcare. One of the primary challenges in achieving interoperability in healthcare IoT and IoMT is the inherent fragmentation of the ecosystem. Healthcare facilities often deploy a variety of devices and systems from different manufacturers, each operating on proprietary protocols and standards. In addition, consumer wearable health trackers have limited interoperability, depending on the device, standards and integration capabilities. This lack of uniformity creates silos of data, with disparate IoT devices and systems having limited to no ability to communicate with each other. Besides hindering the free flow of information between devices and systems, this lack of interoperability limits the ability of the systems with multiple devices to monitor patient conditions, inform and support diagnoses, and provide effective and accurate individualized treatment. The lack of interoperability among these devices poses a significant challenge to the seamless integration of IoT in healthcare.

The lack of interoperability is manifested in many forms, including:

- Diverse communication protocols

- Disparate data formats and structures. Diverse coding systems, data models, and terminology standards are prevalent across healthcare organizations, making it challenging to ensure consistency in data interpretation and exchange.
- Legacy systems that may not be inherently compatible with IoT and IoMT technologies.
- Inability to integrate and interoperate with electronic health record systems

Enabling Recommendation 5.10.3: The government should facilitate cybersecurity in IoT in smart medical devices and equipment, including wearables, in-home devices, community IoMT systems, and in-clinic systems. [For Board Review - Proposed by Benson]

In addition to the trust considerations described in section 3, the government has an opportunity to specifically ensure improved cybersecurity for health IT devices. Some ways in which the U.S. could lead cybersecurity improvement include:

- Expand cybersecurity trust mark program to include IoT devices and modules used in a variety of healthcare systems and applications.
- Facilitate workforce development programs to increase pool of IoT cybersecurity trained resources for healthcare industry on both the solution provider side and care provider (buyer) side.
- Consider development of programs, resources and incentives to help healthcare providers migrate away from those vulnerable legacy equipment and devices that cannot be patched, or upgradeable, or were not subject to compliance with section 524B of the Federal Food, Drug, and Cosmetic Act (FD&C Act).
- Develop a plan to audit, inspect and update healthcare and medical IoT devices, and the networks they operate in used in federally owned or funded health facilities (e.g. VA medical facilities, military medical facilities, etc.). Replace those legacy devices and equipment that cannot be patched or upgradeable or not subject to compliance with section 524B of the Federal Food, Drug, and Cosmetic Act (FD&C Act). Verify devices and systems, and practices meet IoT cybersecurity guidance and best practices.

Healthcare and medical IoT devices and systems are susceptible to cyberattacks. These cyberattacks not only expose sensitive and personal health data and information, but they could lead to disruption to the operation of the devices and systems, leading to potential injury and loss of life. Areas of healthcare and medical device IoT cybersecurity concerns include:

- Vast attack surface due to the interconnected nature of IoT and IoMT devices. Each connected device represents a potential entry point for malicious actors seeking to exploit vulnerabilities.
- Protecting data in transit and at rest is of concern because the data generated by IoT and IoMT devices in healthcare include sensitive patient information. Encryption is critical to preventing unauthorized access.

- Unauthorized access to healthcare data can have severe consequences, ranging from identity theft to compromised patient care. Robust authentication and access control mechanisms is essential to restrict data access to authorized personnel only.
- Patching millions of IoT and IoMT devices is logistically and operationally challenging. These devices often have a longer life cycle than traditional IT devices, and some lack the capability for regular software updates. Not all device and system owners apply patches and firmware updates.
- Legacy systems and devices that cannot be patched or updated with the latest software to address known vulnerabilities
- Compliance with regulatory frameworks (e.g. HIPAA) can be challenging due to the dynamic and evolving nature of IoT and IoMT technologies.
- Securing endpoints (devices) and gateways against unauthorized access and breaches is critical as they act as crucial points in the data transmission process for IoT and IoMT devices.

Enabling Recommendation 5.10.4: The government should facilitate government-based adoption and use of medical and healthcare IoT technologies. [For Board Review - Proposed by Benson]

Adoption considerations could include the following:

- Increased use of healthcare IoT by federal healthcare providers in federally owned or funded health facilities (e.g. VA medical facilities, military medical facilities, Indian Health Service, federal prisons medical centers, etc.).
- Programs for healthcare payers (HMOs, PPOs, etc.) that support federal employees to adopt these technologies in the treatment of their patients.
- Initiatives by federal healthcare programs (Medicare, Medicaid, the Children's Health Insurance Program, Affordable Care Act) that support qualifying patients to adopt these technologies in the treatment of their patients.
- Guidance that supports and integrates the use of IoT devices in existing medical services, procedures and supplies codes in Medicare (HCPCS, ICD-10-CM).

The federal government has a major influence in facilitating the adoption of IoT in healthcare. Directly, and indirectly, the federal government programs provide and support the health of millions of Americans. For example, a number of major healthcare insurance companies (payers) support its 2.951 million federal civilian employees (October 2023). Approximately 1.3 million active duty military in 2022 receive government sponsored healthcare insurance (Tricare). Nearly 45%, or 143.3 million persons are enrolled in, or heavily subsidized by, the big federal health programs: Medicare, Medicaid, the Children's Health Insurance Program (CHIP), and the Affordable Care Act health insurance exchange plans.

Because of the number of people it supports, the government can use its significant influence and scale to use innovation to help improve delivery of services, quality of services, and health outcomes in a way no private insurer can.

Enabling Recommendation 5.10.5: The government should facilitate the resolution of privacy concerns in healthcare and medical IoT. [For Board Review - Proposed by Benson]

In addition to the privacy considerations described in section 3, the government has an opportunity to specifically ensure improved privacy protections for health IT devices. Some ways in which the U.S. could lead this improvement include:

- Supporting research in privacy enhancing technologies specific to the needs of the healthcare industry.
- Considering the incorporation of PETs on IoT technologies used in the treatment of patients in federal government owned medical facilities, and federal supported healthcare programs (Medicare, etc.).
- Incorporating considerations for healthcare in the development of a national privacy framework and regulations.

Privacy matters are a cause of concern and can potentially hinder the adoption and use of IoT technologies in healthcare. Concerns about the information collected and how it is used, as well as the accuracy of the data collected and the ability of the technology to create the correct outcomes. These concerns are wide-ranging and include:

- **Securing data from unauthorized access**. Personal health data can come from a variety of sources, including clinical medical devices, as well as consumer wearable devices.
- **Ownership and consent to use of patient data**. The interconnected nature of healthcare IoT devices raises questions about data ownership and the extent to which patients have control over their health information. Obtaining informed consent from patients for the collection, use, and sharing of their data (outside of patient treatment) is a complex process, especially when considering the numerous devices involved in IoMT and the number of people who could have access to the data (e.g., insurance companies, researchers, etc.).
- **Ethical use of data**. The extensive data collected by IoT and IoMT devices provide valuable insights into patient health and behavior. However, the ethical use of this data is a concern. Ensuring that data is used responsibly, without enabling discrimination or exploitation, requires robust ethical frameworks and regulations.

Enabling Recommendation 5.10.6: The government should facilitate and support the use and adoption of healthcare IoT in rural communities. [For Board Review - Proposed by Benson]

Rural communities lack many of the same resources, services and amenities that residents in urban areas benefit from. Many rural areas are considered medical deserts with limited number of healthcare providers and facilities. In addition, residents in rural areas tend to be sicker than their urban counterparts, as well as older and more likely to suffer from chronic conditions. In addition, many have limited transit options to go see a doctor on a regular basis.

As a result, healthcare access inequities exist. Telehealth, home healthcare monitoring and consumer health tracking are IoT enabled services that can alleviate some of these inequities by providing access to healthcare and improving their health outcomes.

The U.S. should facilitate grants to drive IoT adoption among healthcare providers in those communities that have received broadband grants to build on new connectivity infrastructure. Actions could include coordination with federal agencies to drive physician and patient awareness of IoT in healthcare for treatment. Other implementation considerations include:

- Coding IoT enabled services in Medicare to support senior population in rural areas.
- Facilitating support from private payers (insurance companies).
- Focusing on chronic disease management that may benefit from ongoing monitoring and treatment options.

Barriers to implementation include the cost of connectivity services, since rural residents may have affordability issues, and other issues limiting wireless and fixed broadband connectivity.

Enabling Recommendation 5.10.7: The government should facilitate adoption of IoT among small practices of less than 50 physicians. [For Board Review - Proposed by Benson]

- Consider programs by healthcare payers (HMOs, PPOs, etc.) that support federal employees to adopt these technologies in the treatment of their non-federal employee patients

- Consider programs by federal healthcare programs (Medicare, Medicaid, the Children's Health Insurance Program, Affordable Care Act) that support qualifying patients to adopt these technologies in the treatment of their patients

- Coordination with federal agencies to drive physician and patient awareness of IoT in healthcare for treatment

Small physician practices make up the majority of physician practices in the United States. However, these practices tend to be less likely to use electronic information than those physician offices with 50 people or more.

Enabling Recommendation 5.10.8: The government should facilitate policies and programs that support the key education and digital skills development for the current and future healthcare workforce. [For Board Review - Proposed by Benson]

IoTAB Themes: Healthcare, Workforce

The healthcare industry is undergoing a major digital and technology transformation towards revolutionizing healthcare, including the potential for data led individualized care and treatment. The integration of IoT and digital technologies in healthcare will provide more effective

treatment, reduce the impact of a shortage of healthcare labor, and reduce healthcare expenditures. However, a lack of the relevant digital skills and workforce is hindering this transformation of healthcare across all levels, from device development and use, integration into hospital and healthcare systems, to analysis of patient data and development of AI algorithms for treatment and diagnosis.

Areas of focus would include:

- Data analytics and management
- Artificial intelligence
- IoT technologies
- Networking and systems integration
- Cybersecurity
- Installation, maintenance and servicing of IoT systems

Implementers could integrate the needs for the development of digital skills and workforce in the National Cyber Workforce and Education Strategy.

Enabling Recommendation 5.10.9: The government should facilitate the adoption of AI in IoT in healthcare. [For Board Review - Proposed by Benson]

Initiatives would include additional research in the development of trustworthy AI algorithms and tools (including AI explainability), development of IoT data usage and privacy policies that support the development of AI algorithms [linkage with Debbie recommendation], and workforce development efforts to increase the pool of workers trained in data analytics and AI.

IoTAB Themes: Healthcare, Workforce

While AI can help automate the analysis of massive amounts of IoMT data, and other data collected from health records, its ability to create explainable, beneficial and personalized outcomes specific to the patient that are clinically appropriate, reliable and accurate is a major challenge.

AI algorithms review and analyze data, and make recommendations and in cases requiring autonomous operations, take action. Diagnosing people and identifying treatments for people is complex. Diseases such as cancer are complex, and there is still much to be learned. Furthermore, each person has a different reaction to treatments and what works for one person may not work for another. AI generated recommendations may yield treatment recommendations that lead to adverse outcomes, including injury and death. There are a variety of reasons AI may lead to negative or unintended outcomes, including data that may be outdated, contains bias, or incomplete. The source of the data may be unknown for privacy reasons. While the AI algorithms have been trained on this data, the reasons it led to a specific recommendation may not be explainable and transparent. This leads to a loss of confidence in the AI's ability to analyze the data accurately and reliably.

Implementation barriers

- Data privacy regulations and policies limit what data can be collected, and how it is used
- Lack of workforce trained to develop, test and refine data and AI algorithms

Sustainability / Environmental Monitoring

Key Recommendation 5.11: [Preliminary Text: The government should implement specific actions to promote IoT adoption that will improve sustainability and environmental monitoring.]

[text needed]

Enabling Recommendation 5.11.1: The government should establish or encourage IoT environmental data repositories in support of open, available data.

Promoting the open availability of data would promote research, improve transparency, and encourage proactive improvement by industry participants. As described in other recommendations throughout this report, improved interoperability and competitiveness will help benefit all IoT adopters, and an open model for shared and consistent data will help take strides toward those objectives.

Enabling Recommendation 5.11.2: The government should facilitate and support the research, development and deployment of low cost Air Quality sensors. (Could we expand to additional types of monitoring?)

The Board observed that there is a need to shift from expensive (i.e., highly sensitive regulatory grade) sensors that limit deployment by organizations and municipalities. While such sensors are vital for particular monitoring purposes, large scale deployment of these types of monitoring equipment would be expensive and difficult.

Encouraging development and implementation of local, scalable air quality monitoring would support a variety of use cases, including:

- Increasing public awareness of air quality conditions;
- Informing environment and public policy, including through real time testing and demonstration of policy impacts;
- Environmental justice work;
- Supplementing regulatory grade sensing with IoT commercial sensors;
- Public health research;
- Construction site emissions monitoring; and,
- Rapid or emergency air quality monitoring for particular circumstances.

Currently, regulatory monitoring is often limited to a few pollutants; the government can encourage expanded coverage of other emerging chemicals of concern (including greenhouse gasses) in monitoring and sensing systems.

Agencies should encourage automated and consistent measurement and can facilitate research in low-cost sensing technologies for criterial pollutants, such as optical particle scanning for particulate matter and M0x elements for gases and detection of other emerging chemicals of concern.

IoT sensing allows for the effortless collection of data from multiple devices and technical innovation in IoT has emerged in research communities worldwide, which together provide new opportunities for low-cost, high resolution, environmental monitoring. However, wider implementation of such devices in the United States will require the approval and encouragement of the federal government.

Additional reasons for this recommendation are listed below:

- Regulatory grade sensors are expensive, limiting the number that can be deployed. Their purpose is specific to looking at broad air quality of an area and compare against EPA levels to protect health and welfare (epidemiological reasons). This limits the scaling of AQ monitors
- Metal Oxide (MOx) devices are not as accurate as PID instruments; however, are excellent for the purpose of initial reconnaissance of VOC levels;
- Optical particle scanning for particulate matter and M0x testing for VCs are economical IoT technologies which could augment federal FRM FEM monitoring for NAAQS and NESHAP air pollutants;
- Gap in local (community) scalable air quality monitoring to support a variety of use cases, including
    - Increasing public awareness of AQ
    - Informing environment and public policy; real time testing of policy impacts
    - Environmental justice work
    - Supplementing regulatory grade sensing with com sensors
    - Public health research
    - Construction site emissions monitoring
    - Rapid or emergency AQ monitoring

Implementation Considerations:

The EPA should consider amendments to the Code of Federal Regulations 40 Part 50, to encourage implementation of IoT AQ sensing devices to augment regulatory FRM and FEM Methods for air quality monitoring.

- Need top down demonstration by EPA, as well as concrete policy methods, by which to improve implementation of IoT devices and incorporate this data into government data.

- Facilitate research in low-cost sensing technologies for criterial pollutants, such optical particle scanning for particulate matter and M0x elements for gases, as well as detection of emerging pollutants of concern.
- Facility the use of space at federal infrastructure (e.g., post office buildings) and federal assets (e.g., post office delivery vehicles) for locating academic and private sector air quality monitors.
- Facilitate and support research and a program in correlating regulatory grade data with low cost AQ data
- Push state/city to facilitate the expansion of wireless connectivity to support remote monitoring and sensing in areas not serviced by traditional connectivity (TV white space, satellite, etc.)

Potential implementation barriers:

- Different federal agencies (e.g., EPA, BLM, U.S. Forestry Service) have adopted IoT monitors and different ways and can have different protocols for interpreting the same raw data. Consistent standards for interpreting IoT monitoring data will be needed

- Federal policies take time to be implemented at a state and local level. Funding must accompany IT device related policy statements.

The Code of Federal Regulations is changed by request of regulatory agencies. The EPA changes slowly by its nature;

Enabling Recommendation 5.11.3: The government should facilitate the expansion of wireless connectivity to support remote monitoring and sensing in areas not serviced by traditional connectivity.

The effortless collection of sensing data from IoT devices creates opportunity to provide monitoring in locations and at scale where direct data collection would be cost and labor prohibitive. However, the lack of data transmission in areas not currently serviceable to internet or cellular limits implementation in areas where sensing could be beneficial.

The federal government oversees communication policy (e.g., the Federal Communications Commission) and influences the expansion of communication infrastructure.

Implementation Considerations:

- Consider lower cost and precision opportunities, such TV white space for rural regions

Enabling Recommendation 5.11.4: The government should consider establishing stockpile reserves of IoT monitoring equipment for quick short-term deployment during emergency and catastrophic event scenarios

IoT devices are being develop for mid to long term monitoring of various environment conditions, but the low barriers to cost and deployment create new opportunities to use IoT

monitors for assessing environmental conditions after emergency events, such as after fires, floods, industrial accidents.

Justification:

IoT device deployment can help quickly assess safety concerns through quick deployment with relatively minimal time and effort

Implementation Considerations:

- Consider sharing stockpile across agencies
- IoT devices should be updatable during storage for quick deployment

Potential implementation barriers:

Purchase, storage, and use represent new agency costs

Enabling Recommendation 5.11.5: The government should implement a nationwide IoT-based Water Monitoring Infrastructure

Develop a comprehensive, nationwide water monitoring infrastructure that leverages IoT technology for real-time, accurate, and cost-effective water quality and quantity data collection. This infrastructure should support data-driven decision-making, address the challenges of water scarcity, contamination, and climate change, and integrate with existing NOAA water models for enhanced forecasting and management capabilities.

Current water monitoring systems are often fragmented, inefficient, and insufficient to address the growing challenges of water management.

IoT technology enables real-time, remote, and continuous data collection, allowing for proactive responses to water-related issues.

Integration with NOAA water models can enhance forecasting and management capabilities, leading to more effective water resource planning and allocation.

Efficient water management is crucial for consumption, agriculture, and industry, ultimately contributing to environmental and economic sustainability.

Implementation Considerations:

Develop a standardized, nationwide framework for water monitoring, including protocols for data collection, transmission, storage, and analysis.

Encourage the adoption of open data standards and APIs to ensure interoperability among different IoT devices, platforms, and NOAA water models.

Allocate resources for research and development of advanced IoT sensors, data analytics tools, and communication networks that can seamlessly integrate with NOAA's existing water modeling systems.

Support pilot projects that demonstrate the potential of IoT in water monitoring and management, as well as the successful integration with NOAA water models, and scale up successful models through federal and state programs, grants, and incentives.

Potential Implementation Barriers:

Diverse geographical, environmental, and regulatory factors may present challenges in the implementation of a nationwide water monitoring infrastructure.

Ensuring data privacy and security in IoT-based systems may require significant investments in cybersecurity measures.

Achieving widespread adoption and integration of IoT-based water monitoring systems with NOAA water models may be met with resistance from stakeholders who are accustomed to traditional monitoring methods.

Enabling Recommendation 5.11.6: The government should utilize IoT Technologies to facilitate carbon transparency across economic sectors.

Promote the adoption of IoT-based solutions across multiple economic sectors to accurately estimate and manage indirect carbon emissions associated with goods and services. By leveraging IoT technologies, greenhouse gas emissions associated with upstream and downstream supply chains (scope 3 emissions) can be measured, collected, and compiled for the manufacturing, transportation, agriculture production, and end-of-life practices for economic activity. Great transparency of scope 3 emission with enable the implementation of effective mitigation strategies and contribute to national and global efforts to reduce carbon emissions.

Additional factors include:

- Greenhouse gas reporting protocols are recently experiencing increased adoption and many of these reporting protocols include greenhouse gas emissions beyond those associated emitted at the company’s site (scope 1) and emissions associated with the generation electricity that the company consumes (scope 2). These indirect, “scope 3” emissions can be challenging to monitor since they are distributed across supply chains of products and services a company uses (e.g., the transportation of the company’s product)

- Accurate monitoring and estimation of scope 3 carbon emissions across economic sectors can help identify indirect but significant emission hotspots and develop targeted mitigation strategies.

- IoT technologies enable real-time, remote, and continuous data collection, allowing for systematic management of carbon emissions at reduced cost and effort.

- Combining IoT-based monitoring with other estimation methods can improve the accuracy and reliability of scope 3 emissions data.

Implementation Considerations:

- Develop a standardized framework for the integration of IoT technologies in scope 3 carbon emissions monitoring, including protocols for data collection, transmission, storage, and analysis.
- Encourage research and development of advanced IoT sensors and data analytics tools specifically designed for estimating greenhouse gas emissions across supply chains.
- Support pilot projects that demonstrate the potential of IoT in estimating and mitigating carbon emissions across sectors and scale up successful models through federal and state programs, grants, and incentives.
- Provide training and technical assistance to stakeholders in the implementation and maintenance of IoT-based carbon emissions monitoring systems.
- Facilitate collaboration and data sharing among stakeholders, researchers, and policymakers to promote informed decision-making and the development of best practices for emissions reduction.
- Include the use of IoT technologies in grants for carbon emissions monitoring

Potential Implementation Barriers:
The diverse nature of different economic practices and environmental conditions across supply chains may present challenges in the development and implementation of standardized IoT-based solutions for carbon emissions monitoring.

- Achieving widespread adoption of IoT technologies across sectors may be met with resistance from stakeholders who are accustomed to traditional monitoring methods.
- Ensuring data privacy and security in IoT-based systems may require significant investments in cybersecurity measures.

Enabling Recommendation 5.11.7: The government should facilitate and promote the use and integration of IoT technologies to complement and support wide area environmental situational awareness capabilities to monitor and inform on a variety of environmental conditions and hazards in environmentally sensitive areas.

The use of proprietary technologies and systems are common in systems used to monitor various environmental conditions for first responder, scientific research, and safety applications.

The federal government should facilitate and promote the use and integration of IoT technologies to complement and support wide area environmental situational awareness capabilities to monitor and inform on a variety of environmental conditions and hazards in

environmentally sensitive areas. Examples of opportunities where IoT technologies should be incorporated include forest monitoring, wildfire monitoring, earthquake detection, flood, air quality, etc.

Many existing environmental monitoring platforms today use proprietary technologies. One example are the stream gauges used by various federal and state agencies, local governments and private water rights owners to monitor water flow conditions to determine river health and warn on flooding situations. Data collected from proprietary systems are not easily shared nor integrated with data from other sources, thus limiting timely analysis and responsive actions.

Environmental situational awareness monitoring is critical to ecological health, public safety and disaster recovery. For example, a dense network of low cost IoT enabled gas sensors can be used in conjunction with a network of cameras to detect and pinpoint wildfires. Early detection of wildfires in remote forests allows firefighters to direct resources to the initial location, increasing the odds of combating the fire before it becomes widespread. A network of IoT enabled air quality, earthquake, and other sensors integrated together allow state and regional agencies to build real time situational awareness capabilities to support and plan activities that preserve ecologically sensitive areas, mitigate, respond and recover from natural and man-made hazards.

Implementation considerations

- Specification of IoT technologies into grants and federal procurements for environmental monitoring and situational awareness
- Collaboration with federal, state and regional agencies to define missions and requirements
- Monitoring of wide areas, especially in areas not monitored before or remote areas, may require new connectivity methods, such as satellite and other approaches

Implementation barriers

- Wide area monitoring may span multiple jurisdictions and owners who may have different missions, requirements and goals for monitoring that may not be easily met.
- IoT based sensors may be based on different technologies, which may not meet the users application scenarios, performance requirements, and integration needs.
- Owners/jurisdictions may lack the new skills to support, maintain and operate IoT technologies. Skills include integration, data science, cybersecurity, cloud, etc.

Smart Transportation

Key Recommendation 5.12: [Preliminary Text: The government should implement specific actions to promote IoT adoption in Smart Transit and Transportation.]

Smart transit and transportation technologies provide an organized, integrated approach to minimizing congestion and improving safety on streets through connected technology. These

technologies smooth traffic flows and prioritize traffic in response to demand in real time. They enhance pedestrian, bicycle and vehicle safety and reduce accidents that cause injuries and fatalities]

Enabling Recommendation 5.12.1: The government should promote the development and adoption of policies, procedures and funding methods that can accelerate the adoption of smart, connected, and electrified transportation technologies.

Many of these transportation technologies incorporate the use of IoT. Federal funding can also serve to increase private sector investment.

Greater adoption of smart, connected, and electrified transportation technologies could help in the following examples:

- Incorporation of technologies enabled by IoT: Opportunities for IoT technologies in smart, connected transportation include sensors, cameras, and edge computing devices that can improve safety in things such as vulnerable road users (i.e., pedestrians at crosswalks), traffic intersections, school and work zones. Opportunities for IoT technologies in electrified transportation include in car systems or mobile apps that can locate charging stations, as well sensors that manage charging stations to gather data about usage and performance, to anticipate maintenance needs, and troubleshoot problems.

- Improving overall traffic safety: Vehicles that have technologies such as Cellular Vehicle to Everything (C-V2X) can communicate basic safety messages and information to corresponding infrastructure and other road users thereby reducing traffic and pedestrian fatalities.

- Reduction in greenhouse gas emissions: The transportation sector generates the largest share of greenhouse gas emissions a big contributor to climate change. Electrification of transportation away from traditional fossil fuels are a viable option for transportation. Also smart, connected transportation can improve traffic flow and reduce congestion which is also better for the environment.

Implementation considerations:

- With the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA) the Federal Government is already taking steps to electrify the transportation sector. Funds are being directed to the states to deploy electric vehicle charging stations via the NEVI Formula Program (https://afdc.energy.gov/laws/12744). Under the IRA tax credits are available for EVs that are primarily assembled in North America. Its important that this legislation stays in effect throughout its designated time period.

- While the BIL and the IRA are significant pieces of legislation, additional legislation is probably needed to focus on rural communities.

- The Federal Government could set aside easily and readily tappable funding pools year-round for innovation and next-generation technologies. Grants could be set aside for categories that the government deems high importance.

- The Federal Government can leverage innovative procurement technologies like outcomes-based contracting in surface transportation. (https://www.nema.org/docs/default-source/nema-documents-libraries/whitepaper-on-outcomes-based-contracting.pdf?sfvrsn=f3ad2716_2)

- Earlier this year ITS America published the National V2X Deployment Plan which includes a call to action for the federal government, as well as state and local transportation agencies, automotive OEMs, and other stakeholders to install V2X systems for public safety – beginning with signalized intersections, other road users and selected production vehicles (https://itsa.org/advocacy-material/its-america-national-v2x-deployment-plan/)

Potential implementation barriers:

- Time and Cost: The time and cost for this transformation could be considerable. Its important that these initial investments are focused and targeted.
- Education: There is an overarching need to educate local governments and consumers on these new types of technologies (particularly those related to Electric Vehicles) which could be hard and time consuming.
- Supply Chain: The manufacturing industry recognizes the goal from the Administration of Buy America, Build America (BABA) however, there are current constraints meeting domestic content requirements and there needs to be an appropriate ramp-up, phase in period to get to full production. There is also a lack of consistent Buy America, Build America across federal and state government agencies.
- The Electric Grid: States with the most EVs today are already struggling to accommodate large scale charging loads on congested grids, and these constraints will only become a bigger problem as the number of EVs grow. Charging for heavy-duty EVs like trucks and busses is even more challenging to accommodate on the distribution grid since they require far more power in concentrated locations.

Enabling Recommendation 5.12.2: Road Safety and Ultra-Wideband (UWB)-the government should direct the FCC to revisit the regulation that prohibits the use of Ultra-Wideband (UWB) technology from outdoor fixed infrastructure.

The FCC should revisit the regulation, working with industry to determine an architecture that enables outdoor UWB deployment with adequate performance for envisioned use cases including Cellular Vehicle-to-Everything (C-V2X). UWB is a proven technology for highly

accurate location estimation between connected vehicles and vulnerable road users (i.e., pedestrians, bicyclists).

An important considerations comes from a core tenant of Vision Zero (https://visionzeronetwork.org/) in that “people will sometimes make mistakes, so the road system and related policies should be designed to ensure those inevitable mistakes do not result in severe injuries or fatalities.”

Many of the smart systems developed for road safety, both for vehicles and vulnerable road users (e.g., pedestrians, bicyclists) are only as good as their location accuracy. For example, to avoid a collision between a vehicle and a pedestrian, the location, speed and heading of both must be know with good accuracy. However surprisingly today that is not possible, especially in urban areas where the need is greatest. GPS suffers from multipath, RTK is better suited for open areas, smart cameras have limited field-of-view, and inertial sensors cannot recover from an errant starting location estimate.

A proven technology for highly accurate location estimation is available today in smartphones – ultra wideband (UWB). A popular use case today is for a digital key for a vehicle, whereby the vehicle knows the precise location of the UWB-equipped smartphone, and after authentication the car door is unlocked. There are many potential use cases, for example enabling the vision-impaired to navigate crosswalks or subway stations. The technology enables precise location measurement within around 10 centimeters in less than a second with very little power consumption.

UWB supports several modes of operation however the most efficient for smart city and especially connected vehicle is infrastructure mode, where many “anchor” nodes (on streetlights for example) transmit timing information received by mobile “tags”. The tags, installed in vehicles, bicycles and already in phones, calculate their own position, speed and heading constantly as a receiver only. Then communicate that using the method in the application, for example cellular in a C-V2X environment.

Implementation Barriers:

- There are concerns with interference from UWB devices with other licensed devices in the cellular network.
- Until the regulation is revisited the only way for UWB devices to operate would be a waiver granted on a case-by-case basis, that process can be very time consuming.

Supply Chain

Key Recommendation 5.13: [Preliminary Text: The government should implement specific actions to promote IoT for supply chain logistics.]

[Text needed]

Enabling Recommendation 5.13.1: The government should establish a comprehensive national IoT strategy that outlines clear goals and objectives for IoT adoption in supply chain management. [Add to 1.1?]

This federal IoT strategy would outline clear goals and objectives for IoT adoption in supply chain management and would encompass regulatory frameworks, infrastructure development, education, and incentives for implementation.

The justification for developing a national IoT strategy lies in the numerous benefits that IoT can bring to various industries, including supply chain management, as well as the overall economy and society. A comprehensive and coordinated national IoT strategy can help ensure that these benefits are fully realized and that potential challenges and risks are adequately addressed. Key benefits of an IoT supply chain logistics strategy include:

- **Economic growth and competitiveness**: A national IoT strategy for adoption in supply chain management can foster innovation, drive economic growth, and enhance the competitiveness of industries by promoting the widespread adoption and integration of IoT technologies. This can lead to increased productivity, reduced operational costs, and new business opportunities across various sectors.

- **Enhanced efficiency and resilience of supply chains**: IoT technologies can significantly improve supply chain efficiency, transparency, and resilience by enabling real-time monitoring, data-driven decision-making, and automation of processes. A national IoT strategy can provide guidance and support for businesses to adopt and integrate IoT solutions within their supply chains, thereby enhancing overall supply chain performance.

- **Job creation and workforce development**: The widespread adoption of IoT technologies will lead to the creation of new jobs and the need for skilled workers in areas such as data analytics, IoT device development, and cybersecurity. A national IoT strategy for adoption in supply chain management can help guide investments in education and workforce development to ensure that citizens are equipped with the necessary skills for the future IoT-driven job market.

- **Addressing cybersecurity and privacy concerns**: As IoT devices generate and process large amounts of data, there are inherent risks related to cybersecurity and data privacy. A national IoT strategy for supply chain management can help establish guidelines, standards, and best practices for IoT security and data protection, ensuring that the risks are adequately addressed and managed.

- **Encouraging collaboration and standardization**: A national IoT strategy can promote collaboration among businesses, academia, and government agencies, fostering innovation and knowledge sharing. Furthermore, it can help drive the development and adoption of IoT standards for supply chain management, which are essential for interoperability, security, and scalability of IoT solutions.

- **Ensuring equitable access and benefits**: A national IoT strategy can ensure that the benefits of IoT technologies are distributed equitably across enterprises engaged in supply chain management, addressing potential digital divides and promoting inclusive growth.

Implementation Considerations: A comprehensive strategy should begin with engaging with key stakeholders, including businesses, academia, and government agencies, to identify priorities, needs, and challenges related to IoT adoption in supply chain management. This collaboration will ensure the strategy is comprehensive, practical, and aligned with industry requirements.

Additional considerations include:

- **Focusing on key areas**: Prioritize areas within the supply chain where IoT can provide the most significant benefits and address the most pressing challenges, such as inventory management, transportation and logistics, and quality control.

- **Supporting innovation and R&D**: Foster innovation and R&D in IoT technologies by providing funding, incentives, and resources to businesses and research institutions. This will accelerate the development and commercialization of advanced IoT solutions tailored to supply chain management.

- **Developing standards and guidelines**: Establish standards and guidelines for IoT implementation in supply chain management, focusing on interoperability, security, and data privacy. This will facilitate seamless integration and adoption of IoT technologies across supply chains while addressing potential risks.

- **Promoting workforce development**: Invest in education and workforce development programs to ensure that workers have the necessary skills and expertise to thrive in an IoT-driven supply chain environment.

- **Encouraging public-private partnerships**: Foster collaboration between public and private sectors to promote IoT adoption in supply chain management, share knowledge, and address common challenges.

- **Monitoring progress and adapt**: Establish mechanisms to monitor and evaluate the progress of IoT adoption in supply chain management, and adapt the national strategy as needed based on emerging trends, technologies, and challenges.

Potential barriers: The following considerations represent barriers that would need to be addressed by those creating a supply chain logistics strategy:

- **Funding constraints**: Allocating sufficient funds to support IoT infrastructure, research and development, and workforce development initiatives can be a challenge, especially when competing with other national priorities.

- **Interagency coordination**: Developing a national IoT strategy requires close coordination among various federal agencies, which may have different goals, agendas, and regulatory frameworks. Ensuring a cohesive and consistent approach across agencies can be challenging.

- **Resistance to change**: Some stakeholders within the supply chain ecosystem may resist adopting IoT technologies due to concerns about job displacement, technological complexity, or fear of change. Overcoming this resistance requires effective communication, education, and change management strategies.

- **Cybersecurity and data privacy concerns**: Ensuring the security and privacy of the vast amounts of data generated by IoT devices is a significant challenge. Addressing these concerns requires investment in robust security measures and the development of comprehensive data protection policies and regulations.

- **Standardization and interoperability**: The IoT ecosystem consists of a wide variety of devices, platforms, and communication protocols. Developing and enforcing standards for interoperability can be a complex and time-consuming process, which may slow down the implementation of a national IoT strategy.

- **Skilled workforce shortage**: The rapid growth of IoT technologies and applications may outpace the availability of a skilled workforce in fields such as data analytics, IoT device development, and cybersecurity. Addressing this talent gap requires investments in education and workforce development programs.

- **Legal and regulatory barriers**: Existing laws and regulations may not adequately address the unique challenges posed by IoT technologies in supply chain management. Updating and harmonizing these legal and regulatory frameworks can be a complex and time-consuming process.

- **Balancing innovation and regulation**: Striking the right balance between promoting innovation and ensuring consumer protection, security, and privacy can be challenging. The federal government must carefully consider the potential trade-offs and unintended consequences of new regulations on IoT adoption and innovation.

Enabling Recommendation 5.13.2: The government should select the most appropriate mix of policies, incentives, and requirements to support sustainable and scalable growth in the domestic IoT manufacturing supply chain.

These policies, incentives, and requirements are particularly relevant in the transportation sector as that becomes increasingly connected, electric, shared, integrated, seamless, and ultimately autonomous. Rapid advances in transportation technologies are already occurring that are further augmented by several communication and information technologies, including the Internet of Things (IoT). In addition, the sector is becoming increasingly electrified.

The recommendations in this section can apply to all aspects of domestic IoT manufacturing. American manufacturers share the goal of fostering and strengthening domestic manufacturing and supply chain capabilities. With the recent influx of federal funding and executive orders in this sector, there is an increasing trend to support the “Buy American” concept.

The justification for an appropriate mix of policies, incentives, and requirements to support sustainable and scalable growth in the domestic manufacturing supply chain market is provided below:

- Absent significant time to build new manufacturing capacity, develop new supply chains, and train workers, tighter domestic preference requirements could create supply constraints and prevent the manufacturers from meeting even modest deployment goals.

- In some cases, U.S. manufacturing capacity cannot meet increased demand that would be sparked by anticipated federal investment/incentives let alone current domestic demand.

- In some cases, there are no domestic alternatives for components and subcomponents, limiting the ability of equipment providers to control their domestic content. U.S. Manufacturers cannot force their component and subcomponent suppliers to relocate facilities to the U.S.

- Compliance with federal domestic preference requirements is time consuming and costly particularly when it comes to the country of origin of components and subcomponents. This burden will increase as subcomponents become smaller and more integrated.

Implementation Considerations: Methods for fostering and strengthening domestic manufacturing and supply chain capabilities include:

- Phasing in domestic contact requirements. An extended phase in period is necessary in order to avoid supply shortages and provide domestic manufacturers and their suppliers with sufficient time to develop domestic manufacturing capabilities, build up supply chains, and train their workforce.

- Accelerate domestic manufacturing with an investment tax credit for associated capital costs.

- Provide clear rules governing domestic content requirements, including guidelines on how they apply across all funding and procurement programs. Further, this guidance should also be provided to implementing state agencies.

- Avoid any rules that require determining the country of origin of subcomponents integrated into larger domestically manufactured components.

- The component test should include all costs associated with the manufacturing of a product, such as labor, transportation, allocable overhead, and material. And clearly

designate that the domestic labor used in the final assembly of a product is included in the component test.

- Allow 100% of manufacture value added (MVA) or substantial transformation to be classified as domestic content in component tests.

- Countries should be designated outside of the U.S. from which materials and components can be procured and the component test for products substantially transformed in one of these acceptable countries can be waived. These could be countries that the U.S. already has established trade agreements with such as: USMCA (United States-Mexico-Canada Agreement) countries, European Union member states, The United Kingdom, and Indo-Pacific

Potential barriers: Impediments to implementing this recommendation include:

- Current Supply Chain constraints meeting domestic content requirements - while there are a number of North American manufacturing plants for EV components particularly batteries being developed and constructed, there is a ramp up time to get to full production.

- Funding constraints: There is a huge initial capital cost investment to build up new domestic manufacturing plants.

- Resource constraints: There will need to be an influx of skilled engineers and technicians to support this domestic buildup.

Enabling Recommendation 5.13.3: The government should establish and provide financial incentives to encourage businesses to adopt IoT technologies in their supply chain operations by reducing the initial investment costs and perceived risks associated with the implementation of IoT solutions.

The recommendation to establish and provide financial incentives aims to encourage businesses to adopt IoT technologies in their supply chain operations by reducing the initial investment costs and perceived risks associated with the implementation of IoT solutions. Financial incentives, such as tax breaks, grants, subsidies, or low-interest loans, can help lower the financial barriers for companies to experiment with and deploy IoT systems, leading to more widespread adoption and innovation in the sector.

By offering financial support, the government can promote the development and integration of IoT solutions into supply chain management, enabling businesses to capitalize on the various benefits IoT offers, such as improved efficiency, transparency, and resilience. Financial incentives can stimulate private sector investment, drive the growth of IoT technology providers, and foster an ecosystem that encourages collaboration and innovation within the industry.

It is crucial, however, for the government to carefully design and target these financial incentives, ensuring that they align with strategic objectives and deliver measurable impact. By doing so, the federal government can effectively drive IoT adoption in supply chain management, unlocking its full potential to transform the industry and strengthen national competitiveness.

The justification for providing financial incentives as a recommendation is to accelerate the adoption of IoT technology in supply chain management, particularly within the manufacturing sector. Financial incentives can lower the initial barriers to entry, making IoT adoption more feasible and attractive for businesses. The main reasons for this recommendation are:

1. Encouraging investment: Financial incentives, such as tax credits, grants, or low-interest loans, can help businesses offset the costs associated with implementing IoT solutions in their supply chains. This financial support can encourage companies to invest in IoT technology, even if they are initially hesitant due to the perceived risks or costs involved.
2. Stimulating innovation: Financial incentives can spur innovation in the IoT space for supply chain management by providing companies with the resources they need to experiment with new technologies and solutions. This can lead to the development of new IoT applications and the refinement of existing ones, ultimately contributing to the overall competitiveness of the manufacturing sector.
3. Enhancing competitiveness: By lowering the barriers to IoT adoption, financial incentives can help businesses in the manufacturing sector become more competitive on a global scale. Companies that leverage IoT technology can improve their supply chain efficiency, responsiveness, and resilience, allowing them to better compete with international rivals.
4. Creating jobs and economic growth: The implementation of IoT technology in supply chains can lead to job creation and contribute to economic growth. As companies adopt IoT solutions, they will require skilled workers to develop, implement, and maintain these systems. Financial incentives can help stimulate this job growth and support the development of a skilled workforce in the IoT sector.
5. Promoting sustainability: IoT technology can contribute to more sustainable supply chain practices, such as reducing waste, conserving resources, and minimizing emissions. Financial incentives can encourage businesses to adopt IoT solutions that support these goals, ultimately promoting environmental sustainability and corporate social responsibility.

Implementation Considerations:

Implementation considerations for providing financial incentives for supply chain IoT adoption include the following:

1. Identifying appropriate incentives: The federal government could explore the most efficient financial incentives to promote IoT adoption in supply chains. These incentives might include grants, tax credits, low-interest loans, or subsidies. This exploration could

involve engaging with industry experts, conducting cost-benefit analyses, and evaluating the success of similar programs globally or in other sectors. For instance, the Technology Modernization Fund (TMF) has been used to drive technological innovation in the federal government and could potentially be leveraged or expanded to promote IoT in supply chain logistics.

2. Defining eligibility criteria: Clear eligibility criteria could be established to ensure that the incentives are targeted at companies poised to gain the most from IoT adoption. These might include small and medium-sized businesses or those in key industries. Criteria could encompass company size, revenue, sector, or proposed IoT projects. The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are examples of federal initiatives that have defined eligibility criteria to stimulate technological innovation.
3. Coordinating among federal agencies: Federal agencies that may be impacted by this recommendation include the Department of Commerce, the Small Business Administration, and the Department of Energy. These agencies should coordinate their efforts to ensure efficient and effective implementation of the financial incentives program. Collaboration with state and local governments may also be necessary to align initiatives and maximize the impact.
4. Monitoring and evaluation: The federal government should establish a system for monitoring and evaluating the effectiveness of the financial incentives program. This may include tracking key performance indicators, such as the number of IoT projects funded, the amount of private investment leveraged, and the impact on supply chain efficiency and sustainability. Periodic reviews should be conducted to assess the program's success and identify areas for improvement.
5. Addressing potential barriers: Possible barriers to implementing this recommendation may include budget constraints, lack of political support, or concerns about market distortion. The federal government should address these concerns by demonstrating the potential economic and environmental benefits of IoT adoption in supply chains, leveraging public-private partnerships to share costs, and ensuring that the financial incentives are designed to minimize market distortions.
6. Raising awareness and providing technical assistance: The federal government should consider launching outreach campaigns to inform companies about the available incentives and the benefits of IoT adoption in supply chain management. Additionally, offering technical assistance to businesses in identifying, developing, and implementing IoT projects can ensure successful technology deployment and optimize the impact of the incentive program. The Manufacturing Extension Partnership (MEP) at the National Institute of Standards and Technology (NIST) is an example of a program that could be utilized to provide this type of support.

Potential implementation barriers:

1. Budget constraints: Limited budgetary resources can restrict the federal government's ability to allocate sufficient funds for financial incentives. This may result in a smaller or less comprehensive program, reducing its overall impact on IoT adoption.

2. Political opposition: Financial incentives may face opposition from certain political groups or stakeholders who argue against government intervention in the market or perceive the incentives as favoring specific industries or companies.
3. Bureaucratic hurdles: The implementation of financial incentives may require collaboration and coordination among multiple federal agencies, which can introduce bureaucratic challenges and delays in rolling out the program.
4. Inefficient allocation of resources: There is a risk that financial incentives may be allocated to businesses that do not use the funds effectively or do not fully commit to IoT adoption, leading to an inefficient use of government resources.
5. Market distortion: Financial incentives may inadvertently create market distortions if they disproportionately benefit certain companies or industries, leading to an uneven playing field and potential resistance from competitors.
6. Difficulty in measuring impact: Assessing the direct impact of financial incentives on IoT adoption in supply chains can be challenging, as multiple factors contribute to a company's decision to invest in new technologies. This may make it difficult for the federal government to demonstrate the effectiveness of the incentives program and justify its continued funding.
7. Lack of awareness: Companies may not be aware of the available financial incentives or may not understand the potential benefits of IoT adoption in their supply chains, limiting the program's effectiveness in driving change.

International Leadership

Key Recommendation 5.14: The government should lead international efforts related to the adoption, implementation, and promotion of IoT. [Secretariat draft]

[Note: These are very specific to supply chain and privacy. Does the board wish to make this topic more general or OK as is?]

Enabling Recommendation 5.14.1: The government should promote international collaboration in IoT adoption across global supply chains to share knowledge, best practices, and resources between countries & regions, driving innovation & accelerating widespread adoption of IoT technologies in supply chain operations worldwide.

Promoting international collaboration in the drive to adopt IoT technologies across global supply chains presents a unique opportunity to foster the sharing of knowledge, best practices, and resources between countries and regions. The goal is to spur innovation and accelerate the widespread adoption of IoT technologies in supply chain operations on a global scale. Stakeholders like the United States Federal Government, European Union Commission, and Asian Development Bank can form a global ecosystem that supports the development and deployment of IoT solutions, thereby tackling challenges related to interoperability, standardization, and regulatory compliance.

This international collaboration necessitates the creation of platforms and forums that allow policymakers, industry stakeholders, technology providers, and researchers from different countries to come together. Such platforms could include international bodies like the World Economic Forum, United Nations Industrial Development Organization, and International Telecommunication Union. These stakeholders can engage in a productive exchange of ideas, address common challenges, and explore opportunities for joint projects and initiatives. The outcome of these collaborations could be the development of harmonized regulations, standards, and guidelines that enable seamless integration of IoT systems across borders. This harmonization can foster efficient and resilient global supply chain networks.

International collaboration can facilitate the pooling of resources and expertise to support research and development efforts, pilot projects, and capacity-building initiatives aimed at promoting IoT adoption in supply chain management. Organizations like the World Bank and World Trade Organization can help bridge the digital divide between developed and developing countries, ensuring that businesses worldwide have access to the tools and technologies needed to harness the potential of IoT in their supply chain operations. This collective effort, led by governments actively engaging with international partners and participating in relevant forums and organizations, can contribute to the development of a connected and resilient global supply chain ecosystem that benefits businesses and consumers alike.

The justification for the recommendation to promote international collaboration in the context of IoT adoption in supply chain management lies in the inherently global nature of supply chains and the need for a coordinated approach to address common challenges. The main reasons for promoting international collaboration are:

1. Global nature of supply chains: Modern supply chains often involve multiple countries, making it essential for governments and organizations to collaborate across borders to ensure seamless, efficient, and secure operations.
2. Harmonization of standards and regulations: International collaboration can help develop and promote the adoption of common standards, protocols, and regulations, which can reduce inconsistencies and friction between countries, making it easier for organizations to operate globally.
3. Addressing global cyber threats: Cyber threats are not limited by geographical boundaries; therefore, international collaboration can enable the sharing of threat intelligence, best practices, and resources, improving collective defense against cyber attacks.
4. Leveraging global expertise: Collaborating with international partners allows countries to benefit from the expertise, technologies, and best practices developed by others, leading to more effective and efficient IoT adoption in supply chain management.
5. Fostering innovation: International collaboration can stimulate innovation by enabling the exchange of ideas, knowledge, and technologies among countries, research institutions, and businesses.

6. Building trust: Working together on common challenges can help build trust between countries, which is crucial for the smooth functioning of global supply chains.
7. Addressing social and environmental challenges: International collaboration can help address global social and environmental issues related to supply chain management, such as labor rights, environmental sustainability, and resource management.

Implementation Considerations:

Implementation considerations for promoting international collaboration for supply chain include:

1. Establish bilateral and multilateral agreements: The United States should form strategic partnerships with key countries, particularly those with a strong presence in IoT and supply chain sectors. These partnerships can be facilitated through existing programs like the Technology Collaboration Programme, which supports work of international groups of experts to advance the research, development, and commercialization of energy technologies.
2. Participate in international forums and organizations: U.S. should actively participate in existing forums and organizations dedicated to supply chain management, IoT, and cybersecurity. This could include leveraging the Department of Energy (DOE) Office of International Science and Technology Collaboration's programs such as "Net Zero World" and "Mission Innovation", which allow for global collaborative efforts on clean energy research and technology innovations.
3. Share information and best practices: The U.S. should encourage the exchange of information, threat intelligence, and best practices related to IoT adoption and supply chain security among international partners. The Global Innovation through Science and Technology (GIST) Network, an initiative by the Department of State, provides a platform for such exchange, connecting entrepreneurs globally and providing access to international angel investors and venture capitalists.
4. Collaborate on research and development: The U.S. should engage in joint research and development projects with international partners, harnessing the expertise of the Technology Collaboration Program to advance the research, development and commercialization of IoT technologies in the supply chain.
5. Promote capacity building: Federal programs like the GIST Initiative can support capacity-building initiatives and programs to help countries strengthen their IoT infrastructure, develop relevant skills, and improve supply chain management practices. These programs assist entrepreneurs in emerging economies through a combination of in-country training, online programming, and access to U.S. experts.
6. Identify key international partners: The U.S. should assess which countries are critical for collaboration based on their role in global supply chains, technological capabilities, and mutual strategic interests. The DOE International Science & Technology Collaboration office could potentially play a significant role in this assessment, given its expertise in coordinating international science and technology strategies and programs.

7. Leverage existing diplomatic channels: Existing diplomatic relationships should be utilized to initiate dialogue and cooperation on IoT adoption in supply chain management. Programs like "Mission Innovation", led by the Department of Energy, already foster international collaboration and could be leveraged to promote IoT-related discussions.

Potential implementation barriers:

Possible barriers to implementing this recommendation:

1. Differing priorities and interests: Different countries may have varying priorities and interests, which could make it challenging to align objectives and collaborate effectively.
2. Trust and data privacy concerns: Sharing sensitive information and best practices may be hindered by trust and data privacy concerns among collaborating countries.
3. Regulatory and legal barriers: Differences in regulations, standards, and legal frameworks may impede collaboration efforts and create challenges in harmonizing policies.

Enabling Recommendation 5.14.2: The government should create internationally compatible data minimization guidance related to IoT devices, aligning with the NIST Privacy Framework and NIST Cybersecurity Framework principles.

Data minimization processes (related to both collection and retention of sensitive data) reduce potential harm from data breaches or unauthorized access. Data minimization is inherently supportive of Privacy By Design. Implementation of these processes, and reduced risk that would result, may boost consumer trust by ensuring data is only used for necessary purposes. Consistent processes (supported by international agreement) would also help establish uniform data privacy standards globally.

The government should collaborate with public sector, private sector, and international counterparts to develop universally acceptable guidance on data minimization that would be tailored to various IoT applications.

Implementation considerations: Those working to foster international agreement on data minimization should recognize that the resulting processes should not hinder innovation or competitiveness in the IoT industry. This will be a delicate balance that may require a long-term commitment to advocacy since international agreements often require considerable time and negotiation. Principles of this guidance would be considered in future international agreements.

Potential barriers: Differences in privacy laws and cultural attitudes towards privacy in different countries will represent a challenge to achieving international agreements. There may also be significant resistance from companies that rely on extensive data collection.

Small Business Leadership

Key Recommendation 5.15: The government should accelerate the manufacturing of IoT technology by small businesses and startup organizations and promote adoption of IoT created by small-business entities. [Updated]

This can be done via policies, procedures, and funding methods that specifically target them. Small businesses and startup organizations who are looking to adopt or manufacture IoT technologies may find it challenging to know where to start or have the resources and knowledge to do so. Federal funding mechanisms and procurements targeted to them can aid these companies by giving them a resource to help speed and incentivize their adoption.

Enabling Recommendation 5.15.1: The government should accelerate the adoption of IoT technologies manufactured by small business and startup organizations through targeted Federal Government programs, policies, procedures, and funding methods.

The federal government should accelerate the adoption of IoT technologies manufacturers by small business and startup organizations. This can be done via policies, procedures, and funding methods that specifically target them. It is particularly challenging for small businesses and startup companies in this sector that have to provide upfront capital and full understanding in successfully navigating opportunities both within the federal government and with federal government support to market externally. The process for these projects can also take many years to bring them from proposal to commercial operation and these companies may not have patient resources.

Small businesses have the primary option of using a channel with existing relationships to cities to make sales which is also unpredictable and not very scalable. This makes it challenging for small businesses and startups. Federal funding mechanisms and procurements targeted to them can aid these companies so they can more effectively compete with larger organizations on RFPs relevant to their business. There are many existing Federal Government programs and policies that support small businesses and startup organizations. Rather than create from scratch, this recommendation advises tapping into these existing programs and have a dedicated IoT technologies track for related small businesses and startups in this space.

Implementation Considerations: The Federal Government could set aside readily tappable funding pools year-round for innovation and next-generation technologies. Grants could also be set aside for categories that the government deems high importance. The Federal Government could fast-track programs for startups and small companies to deploy this technology in pilots. There should be consideration to set up a system to make it easier for startups and small companies to find relevant funding sources like grants and SBIR awards. The Federal Government should encourage local governments to leverage its local startup accelerator network to develop technology and fast-track it to local adoption on successes.

The Federal Government can modify guidelines for grant programs and funding mechanisms already in existence for small businesses to allow for greater incorporation of IoT technologies, examples include:

- The U.S. Department of Commerce, Minority Business Development Agency (MBDA) (https://www.mbda.gov/who-we-are/overview)
- DOE Office of Small and Disadvantaged Business (https://www.energy.gov/osdbu/office-small-and-disadvantaged-business-utilization)
- National Science Foundation Program for Small Business (https://www.nsf.gov/funding/smallbusiness.jsp)

Potential barriers: The time and cost for this transformation could be considerable and small companies or startups may find it hard to continue the process. That is why targeted Federal Government programs and policies could provide greater incentive. There is an overarching need to educate local governments and consumers on these new types of technologies which could be hard and time consuming, especially relevant for small businesses and startups. The manufacturing industry recognizes the goal from the Administration of Buy America, Build America (BABA) however, there are current constraints meeting domestic content requirements and there needs to be an appropriate ramp-up, phase in period to get to full production. Again, this could be particularly relevant for small businesses and startups.

Enabling Recommendation 5.15.2: The government should accelerate the adoption of IoT technologies manufactured by small business and startup organizations.

This can be done via policies, procedures, and funding methods that specifically target them.

The federal government should accelerate the adoption of IoT technologies manufactured by small business and startup organizations. This can be done via policies, procedures, and funding methods that specifically target them. It is particularly challenging for these types of manufacturers in this sector that have to provide upfront capital, access, and knowhow, before hopefully being selected as a result of an RFP. The process for these projects can also take many years to bring them from proposal to commercial operation and these companies may lose both funding, ability, and interest in that time frame.

Small businesses IoT technology manufacturers have the primary option of using a channel with existing relationships to local governments to make sales which is also unpredictable and not very scalable. Federal funding mechanisms and procurements targeted to them can aid these companies so they can more effectively compete with larger organizations on RFPs relevant to their business.

Greater adoption of IoT technologies manufactured by small businesses and startups could help in the following examples:

- Incorporation of technologies enabled by IoT: Opportunities for IoT technologies are manufacturers by small business and startups across the IoT. For example, in smart, connected transportation these technologies include sensors, cameras, and edge computing devices that can improve safety in things such as vulnerable road users (i.e., pedestrians at crosswalks), traffic intersections, school, and work zones. Opportunities for IoT technologies in electrified transportation manufactured by small businesses and startups include in car systems or mobile apps that can locate charging stations, as well sensors that manage charging stations to gather data about usage and performance, to anticipate maintenance needs, and troubleshoot problems.
- Greater competition across IoT markets: Incentivizing small businesses and startups to bid on projects and deploy their technology will increase their market penetration and provide end-users more technology options. This would lead to greater competition in selected markets providing end-users the ability to select manufacturers based on several factors such as cost, quality of products manufactured, service, and innovation.

Implementation considerations:

- The Federal Government should set aside fast-track programs for startups and small companies to deploy this technology in pilots.
- The Federal Government should set up a system to make it easier for startups and small companies to find relevant funding sources like grants and SBIR awards and RFP opportunities.
- The Federal Government should encourage local governments to leverage its local startup accelerator network to develop technology and fast-track it to local adoption on successes.
- The Federal Government can work with the national chamber of commerce, rotary clubs, small business associations, start-up accelerators/incubators, state partnership programs to help identify relevant IoT manufacturers to support and get input on the programs.
- The Federal Government can modify guidelines for grant programs and funding mechanisms already in existence for small businesses to allow for greater incorporation of IoT technologies. Examples include the following:
  - The U.S. Department of Commerce, Minority Business Development Agency (MBDA) (https://www.mbda.gov/who-we-are/overview)
  - DOE Office of Small and Disadvantaged Business (https://www.energy.gov/osdbu/office-small-and-disadvantaged-business-utilization)
  - National Science Foundation Program for Small Business (https://www.nsf.gov/funding/smallbusiness.jsp)

Potential implementation barriers:

- Time and Cost: The time and cost for this transformation could be considerable and small companies or startups may lose funding and/or interest and cancel a project.

- Education: There is an overarching need to educate local governments and consumers on these new types of technologies which could be hard and time consuming, especially relevant for small businesses and startup manufacturers who have limited personnel.
- Supply Chain: The manufacturing industry recognizes the goal from the Administration of Buy America, Build America (BABA) however, there are current constraints meeting domestic content requirements and there needs to be an appropriate ramp-up, phase in period to get to full production. Again, this could be particularly relevant for small businesses and startup manufacturers who may have fewer sources to purchase needed components.

Research to Support the Future State Of IoT

Key Recommendation 5.16: The government should prioritize research into enhanced IoT capabilities and resilient infrastructure to drive innovation and shape the future of IoT. [For Board Review - Proposed by Benson]

[Text needed]

Enabling Recommendation 5.16.1: The government should research increased capabilities of IoT devices. [For Board Review - Proposed by Benson]

- Device processing capabilities
- Decreasing microprocessor power consumption
- Energy harvesting technologies
- Low cost sensors

IoT AB Themes: U.S. Leadership

Justification:

- As more IoT applications shift to the edge, the complexity and intensity of the workloads processed is expected to increase.
- Smarter IoT devices incorporate more capable microprocessors and microcontrollers. However, more capable processors consume more power.
- Battery powered IoT devices have a limited lifetime. With billions of IoT devices to be deployed, replacing those batteries is not realistic nor practical. Disposal of billions of batteries is a looming environmental waste issue.

Enabling Recommendation 5.16.2: The government should research enabling robust infrastructure to support increasingly large number of IoT devices and systems. [For Board Review - Proposed by Benson]

- Management of distributed IoT networks (at scale)
- Optimization and maintenance of performance and Quality of Service under continuously varying conditions

- Improving system fault tolerance and resilience
- Improving middleware to support scaling

IoT AB Themes: U.S. Leadership

Justification:

- With billions of devices, routers and servers of all types soon operating in a multi-layer architectural environment, the ability to monitor, manage, operate and support this infrastructure over its life cycle is a complex undertaking.
- The ability to detect workload demand and allocate appropriate resources to collect, process and store the data, whether on a scheduled or dynamic basis, is crucial to IoT performance. This is made more complex by the addition of new devices of varying capabilities to the environment which consumes existing resources, devices that drop in and out of the network (e.g., mobile devices, etc.), devices with varying resource demands and availability of resources.
- IoT applications and its enabling systems may sometimes fail to work properly. These failures affect the operations that the IoT application is managing and could potentially spread to other processes through a chain of cascading failures. Even if detected immediately, it is not always possible to repair the fault or to do so in a timely manner.
- As more IoT devices are added to the network in the future, the ability of these devices to be integrated into the network and interoperate with existing and older devices and systems is critical to scaling. Middleware, the software that sits between increasingly diverse and heterogeneous devices and applications and allows them to communicate with each other, is essential to integration and scaling of IoT networks. However, middleware must also evolve to support future IoT infrastructure needs.

Enabling Recommendation 5.16.3: The government should research methods to enable Usable AI for IoT. [For Board Review - Proposed by Benson]

- Ethical AI development
- Explainable AI tools and operations
- Collective intelligence IoT
- Human-AI collaboration

IoT AB Themes: U.S. Leadership

Justification

- the use of AI in IoT raises questions of fairness, privacy, ethics, maleficence, accountability and transparency
- For AI controlled operations to be trusted and adopted at scale, its users must be able to understand and assess the AI algorithm’s decision-making processes, its alignment and precision to target outcomes under a variety of planned and unplanned conditions and its consistency in creating and acting on the outcomes.

- As IoT adoption scales and the number of devices grow, IoT will transition from devices working individually to create individual outcomes to a collection of IoT devices working together to create an overall greater outcome. Collective intelligence is relatively new and the technology is still immature.
- Human-AI collaboration requires both to “work together as partners to achieve a common goal, sharing a mutual understanding of the abilities and respective roles of each other”. Successful collaboration requires the development of new techniques, methods and components to enable a tightly coupled perception-action integration.

Enabling Recommendation 5.16.4: The government should conduct research in the development of hyperconnected communications networks. [For Board Review - Proposed by Benson]

- Spectrum sharing and management
- Network infrastructure to support AI and complex IoT applications
- Fault tolerant and resilient network infrastructure
- Self-defending adaptive network security

IoT AB Themes: U.S. Leadership

Justification:

- There is a finite amount of wireless spectrum available for IoT applications. In dense urban environments, this can become problematic as the number of IoT devices scale up and data traffic volumes grow, leading to network congestion and radio frequency interference.
- AI and autonomous IoT applications impose high performance requirements for communications networks. Further research and innovation are necessary to develop the network to meet these needs.
- As additional IoT devices with varying levels of quality and performance levels are integrated into the network, they introduce faults that could disrupt operations. During operation, some devices may be capable of tolerating errors, while others propagate errors. Some devices are operating with the latest firmware updates, while others are running outdated versions or cannot be patched. Finally, the IoT devices may be operating in networks that may be outdated, misconfigured or incompatible.
- IoT devices introduce new attack surfaces that can be exploited to breach the network. To be successful, self-defending and adaptive networks must “be effective in an unstructured, unstable, rapidly changing, chaotic, adversarial environments; able to learn in real-time and under extreme time constraints, using only a few observations that are potentially erroneous, of uncertain accuracy and meaning, or even intentionally misleading and deceptive.”

Enabling Recommendation 5.16.5: The government should research methods to enable the development of Human centric ambient IoT. [For Board Review - Proposed by Benson]

- Design for human-AI interaction
- Trust in human-AI interactions
- Accessibility and inclusion

IoT AB Themes: U.S. Leadership

Justification

- For replicable and successful collaboration with humans and AI systems, continued research is necessary to understand how humans can most effectively augment AI systems, how AI systems can enhance what humans do best and how to redesign operations and algorithms to support the collaboration.
- Human-AI collaboration breaks down or becomes less productive if one or both sides do not execute as expected. Humans may not trust the outputs of AI or its ability to execute.
- To be inclusive and accessible to as many people as possible, a connected society must develop interaction models and user interfaces that are intuitive, easy to use and program and consistent with the way people expect to interact with human-AI and IoT systems.

Fostering an IoT-Ready Workforce

Objective 6: The U.S. should invest in and promote initiatives that will improve the knowledge, skills, and abilities of those who develop, implement, and operate IoT devices.

Key Recommendation 6.1: The government should invest in and promote education and workforce.

Workforce and education are broad topics. Specialized training programs could start as early as high school and include cybersecurity topics. Inclusion of yearly certifications is encouraged.

When discussing IoT worker capabilities, there are many roles that are relevant, from designers to implementers to operations staff. For each role to be filled, the government can help foster collaboration about the necessary skills in each role and the knowledge needed to fulfill relevant tasks.

The federal government can help to develop targeted criteria and encourage expanded access to education and training opportunities. Agencies could help provide (or at least coordinate) means to assist learners through financial aid, scholarships, and online learning options. The U.S. can also encourage industry/academia partnerships as it has in other areas. This would help provide a focus on opportunities for existing workforce to adapt and better support digital transformation.

Enabling Recommendation 6.1.1: The government promote continuing education, professional development, and vocational training for IoT integration in supply chain management.

The recommendation to focus on education and workforce development, specifically geared toward the Internet of Things (IoT), is a response to the growing need for professionals adept in the design, implementation, and management of IoT systems within supply chain operations. This involves not just building knowledge in areas such as data science, analytics, data integration, and software development, but also developing a robust framework of continuing education, professional development, and vocational training. Such initiatives aim to equip businesses with a workforce capable of unlocking the full potential of IoT technologies.

The focus of these efforts should be a commitment to lifelong learning and continuous skills upgrade. This can be facilitated through various professional development opportunities such as workshops, online courses, and certification programs. These initiatives should be designed to help professionals stay current with the latest IoT trends and innovations, thereby promoting the adoption of new technologies in the supply chain sector. Vocational training programs, for instance, could provide hands-on experience in areas such as IoT device management, data analytics, and software development, thereby fostering technical proficiency.

Partnerships with industry stakeholders and technology providers are crucial. These partnerships can lead to internships, apprenticeships, and real-world projects, offering practical experience in IoT implementation. By focusing on these aspects of education and development, the government can create a pool of professionals who are not just knowledgeable but are also adaptable and up to date. This will ensure the workforce is well-equipped to navigate the complexities of IoT adoption, ultimately driving growth and competitiveness in the supply chain industry.

The justification for the recommendation to invest in education and workforce development in the context of IoT adoption in supply chain management lies in the need to prepare the workforce for the technological advancements and skills required in the rapidly evolving industry. The main reasons for this recommendation are:

- Addressing Skills Gap: The surge in IoT utilization in supply chain management will necessitate a workforce proficient in specialized areas such as data analytics, software development, and data integration. Investments in continuing education, professional development, and vocational training can bridge this gap, ensuring businesses have the skilled talent for effective IoT implementation.
- Enhancing Competitiveness: The competitiveness of the manufacturing sector hinges on a well-equipped workforce. Government investment in lifelong learning and skills development can bolster businesses' competitiveness, enabling them to maintain a robust global standing.
- Fostering Innovation: A workforce with deep-rooted IoT knowledge can spark innovation in supply chain management. Government-led educational and training programs can cultivate this innovative spirit, supporting the creation of avant-garde solutions.
- Supporting Digital Transformation: As the manufacturing sector undergoes digital transformation, there is a need to adapt operations to accommodate IoT and similar technologies. Education and workforce development investments can empower workers with the skills needed to support this transition, facilitating seamless integration of IoT in supply chains.
- Encouraging Job Creation: The integration of IoT in supply chain management can open new job avenues in areas like data analysis, software development, and cybersecurity. Government investment in education and workforce development can prepare workers for these opportunities, stimulating economic growth and job creation.
- Promoting Social Inclusion: Education and workforce development programs can enhance social inclusion, providing underrepresented groups with the necessary skills and training for the IoT-centric job market. This includes opportunities for professional development, vocational training, and continuous learning.
- Ensuring Long-term Sustainability: As the manufacturing sector evolves, businesses need to adapt to emerging technologies and industry trends. Government investment in education and workforce development can support the sector's long-term sustainability, assisting businesses in their ongoing IoT adoption and integration efforts.

Implementation Considerations: Agencies should consider the following implementation considerations for investing in education and workforce development for supply chain IoT adoption including:

- Identifying Skill Requirements: Carry out an exhaustive analysis to identify the specific skills and expertise required to support IoT integration in supply chain management. This includes technical proficiencies in data analytics, software development, and data integration, and managerial competencies.
- Developing Targeted Curricula: Partner with training providers, industry stakeholders, and educational institutions to create curricula and training programs that cater to these identified skills. These programs should focus on professional development and vocational training, promoting lifelong learning and adaptability in the IoT domain.
- Expanding Access to Education and Training: Implement policies and programs that ensure extensive access to continuing education and training focused on IoT. This should involve financial assistance, scholarships, and online learning options, making these resources accessible to a broad audience, including underserved communities.
- Encouraging Industry-Academia Partnerships: Foster relationships between industry and educational institutions that facilitate real-world learning experiences, internships, and collaborative research projects. These initiatives can enhance practical skills development and provide valuable industry exposure.
- Focusing on Reskilling and Upskilling: Launch initiatives to reskill and upskill the existing workforce, ensuring they can adapt to the evolving demands of IoT-driven supply chain management. This reinforces the importance of continuous professional development and staying current with the latest trends and innovations.
- Promoting Vocational Training: Encourage interest in vocational training in the fields of science, technology, engineering, and mathematics (STEM), focusing on the development of IoT competencies within the existing workforce. This will lay the groundwork for future workforce development in the IoT field.
- Establishing Performance Metrics: Develop performance indicators and evaluation methods to assess the effectiveness of continuing education and professional development initiatives. This will enable data-driven improvements, ensuring these programs remain relevant and effective in meeting the demands of the IoT-centric job market.

Potential barriers: Impediments to implementing this recommendation include:

- Insufficient Funding: Limited resources may restrict the government's capacity to invest in continuing education, professional development, and vocational training programs at the necessary scale. This could impact the availability and accessibility of these programs for the workforce.
- Resistance to Change: Some industry stakeholders may be hesitant to invest in new training and professional development initiatives due to concerns about costs, time commitments, or disruption to existing workflows. This resistance could slow the pace of upskilling and reskilling efforts in the IoT field.

- Difficulty in Identifying Skill Requirements: The rapid evolution of technologies and market dynamics can pose challenges in accurately identifying the specific skills needed for successful IoT adoption in supply chain management. This could impact the design and relevance of continuing education and professional development programs.
- Skills Mismatch: A disparity between the skills imparted through vocational training and professional development programs and the skills demanded by the industry can limit the effectiveness of these initiatives. This mismatch could result in a workforce that is not fully equipped to navigate the complexities of IoT integration in supply chain operations.

Enabling Recommendation 6.1.2: (proposed) The government should invest and promote education and workforce development in smart transportation technologies.

The federal government can also promote the concept of outcomes-based contracting in surface transportation for those entities and jurisdictions who have an existing workforce that are not familiar with these types of smart transportation technologies. When the focus of the contract is on results and outcomes, procurement officers and agency leaders can better design contracts that drive innovative, cost-effective services, reasonable risk-sharing, and measurable results.

While workforce development and education are a broader topic across the IoT, there are specialized training/apprenticeship programs needed in the area of smart transportation. They could start as early as high school (and could also be summer intern programs) and need to include cybersecurity topics. The inclusion of yearly certifications on these is also encouraged.

Implementation considerations: For investing in education and workforce development include:

- Identifying skill requirements: Conduct a thorough analysis of the specific skills and expertise needed.
- Developing targeted curricula: Collaborate with educational institutions, industry stakeholders, and training providers to develop targeted curricula and training programs unique to the transportation sector.
- Expanding access to education and training: Implement policies and programs that ensure broad access to this and training, including financial aid, scholarships, and online learning options to reach underserved communities.
- Encouraging industry-academia partnerships: Promote partnerships between industry and educational institutions to facilitate real-world learning experiences, internships, and collaborative research projects.
- Focusing on reskilling and upskilling: Implement programs to reskill and upskill the existing workforce, enabling them to adapt to the changing requirements of the transportation sector.

- Establishing performance metrics: Develop performance metrics and evaluation methods to assess the effectiveness of education and workforce development initiatives and make data-driven improvements as needed.
- Outcomes-based Contracting: Outcomes-based Contracting is a form of contracting comprised of four discrete characteristics: Identification, Alignment, Measurement, and Adjustment... NEMA has published a whitepaper on this topic (https://www.nema.org/docs/default-source/nema-documents-libraries/whitepaper-on-outcomes-based-contracting.pdf?sfvrsn=f3ad2716_2).

Potential barriers: Possible barriers to implementing this recommendation include:

- Insufficient funding and resources: Limited resources may constrain the government's ability to invest in education and workforce development programs at the desired scale. Also, some state and local agencies may not have enough staff on hand.
- Resistance to change: Some industry stakeholders may resist investing in new training and education programs due to concerns about costs, time constraints, or disruption to existing processes. This is particularly relevant to those traffic engineers who have spent their entire career on replacing concrete and asphalt on roads and bridges.
- Difficulty in identifying skill requirements: Rapidly evolving technologies and market dynamics may make it challenging to accurately identify the specific skills needed. As these technologies become smarter and more digitized it will require more than one core skill set to operate and maintain installed transportation equipment.
- Skills mismatch: A mismatch between the skills taught in educational institutions and the skills required by industry can limit the effectiveness of education and workforce development initiatives.

Enabling Recommendation 6.1.3: The government should develop educational initiatives that include IoT, targeting workforce development, and enhancing business, government, and consumer data privacy and trust.

Education and training are needed to enhance the U.S. workforce. There are increases in the understanding and safe use of IoT technologies. There is demand for a highly skilled workforce capable of addressing IoT privacy challenges. And boosting business, government, and consumer data trust will forge the adoption of IoT devices and services.

Implementation considerations: Defining the scope and content of educational initiatives, identifying key target audiences (schools, universities, businesses, general public), collaborating with educational institutions and industry leaders, ensuring the relevancy and practicality of the educational content, regularly updating the initiatives to keep pace with technological changes, and workforce development to encompass personas, including manufacturers, implementers, service providers, and workers.

Potential Barriers: Difficulty in keeping up with the fast-paced advancements in IoT, challenges in reaching and engaging the targeted audiences, securing sufficient funding and resources.

Enabling Recommendation 6.1.4: The government should facilitate policies and programs that support the key education and digital skills development across vocational schools, community colleges and four year universities for the current and future construction workforce. [For Board Review - Proposed by Benson]

Considerations include:

- Technology and computer skills
- Digital skills (analytics, cybersecurity, IT, networking, etc.)
- Software tools - BIM
- Working with tools and technology
- Critical thinking

IoTAB Themes: Workforce Development

Justification/Challenges Addressed
The construction industry is behind the curve in digitalization. 43% of U.S. civil engineers and contractors reported the use of digital tools and innovations, compared with 66% of non-U.S. counterparts. 43% of U.S. civil contractors had low digital capabilities, compared with only 23% of non-U.S. construction companies. In contrast, 45% of non-U.S. construction and engineering companies reported high digital capabilities, compared with just 20% for U.S. companies.

Enabling Recommendation 6.1.5: The government should facilitate policies and programs that support the key education and digital skills development across community colleges and four year universities for the current and future insurance workforce. [For Board Review - Proposed by Benson]

Considerations include:

- Technology and computer skills
- Digital skills (analytics, cybersecurity, IT, networking, etc.)
- Data analytics
- AI and Machine Learning
- Privacy engineering

IoTAB Themes: Workforce

Justification
Digital innovation is transforming the insurance industry. A shortage of digital skills and talent, however, is hindering the ability of the insurance companies to innovate and deliver new products and experiences, execute and operate new business models and to re-engineer existing processes and digitize operations.

Enabling Recommendation 6.1.6: The government should facilitate policies and programs that support the key education and digital skills development across community colleges and four year universities for the current and future retail workforce. [For Board Review - Proposed by Benson]

- Software development and engineering
- IT (Networking, systems integration, cybersecurity)
- IoT (architecture and design, sensor and device integration, etc.)
- Cloud management and operations
- Data integration and analytics
- Artificial intelligence and machine learning
- Privacy engineering

IoTAB Themes: Workforce

Justification
The retail industry is undergoing a long running technology transformation towards omni-channel retail. This is necessary for retailers to be relevant, operationally efficient, profitable and resilient. A lack of the relevant digital skills and workforce is hindering this transformation.

Enabling Recommendation 6.1.7: The government should facilitate policies and programs that support the key education and digital skills development across community colleges and four year universities for the current and future city and utility workforce. [For Board Review - Proposed by Benson]

Considerations include:

- Technology and computer skills
- Digital skills (analytics, cybersecurity, IT, networking, etc.)
- Cloud and other architectures
- Working with tools and technology
- Critical thinking

IoT AB Themes: U.S. Leadership, Smart Cities, Sustainable Infrastructure, Workforce Development

Justification

Manufacturing jobs are no longer low skilled jobs but require new skills. Automation will require people to work alongside robots and machines. A labor shortage and skills shortage will leave 2.4 million unfilled jobs between 2018-2028. This leads to a loss of $454 B of manufacturing value by 2028 and makes the U.S. less competitive in manufacturing.[7]

Compliance Matrix

[this matrix will be provide upon completion of the recommendation list.]

The IoTAB fulfills the role of the ‘‘steering committee’’ as established under subsection (b)(5)(A) of the NDAA Section. It supports the IoTFWG which is the working group convened under subsection (b)(1).

The IoTAB herein advises working group in the following areas:

Advisory Topic	Relevant Report Sections
(i) the identification of any Federal regulations, statutes, grant practices, programs, budgetary or jurisdictional challenges, and other sector-specific policies that are inhibiting, or could inhibit, the development of the Internet of Things;	
(ii) situations in which the use of the Internet of Things is likely to deliver significant and scalable economic and societal benefits to the United States, including benefits from or to	
(I) smart traffic and transit technologies;	
(II) augmented logistics and supply chains;	
(III) sustainable infrastructure;	
(IV) precision agriculture;	
(V) environmental monitoring;	
(VI) public safety; and	
(VII) health care;	
(iii) whether adequate spectrum is available to support the growing Internet of Things and what legal or regulatory barriers may exist to providing any spectrum needed in the future;	
(iv) policies, programs, or multi-stakeholder activities that—	
(I) promote or are related to the privacy of individuals who use or are affected by the Internet of Things;	

Advisory Topic	Relevant Report Sections
(II) may enhance the security of the Internet of Things, including the security of critical infrastructure;	
(III) may protect users of the Internet of Things; and	
(IV) may encourage coordination among Federal agencies with jurisdiction over the Internet of Things;	
(v) the opportunities and challenges associated with the use of Internet of Things technology by small businesses; and	
(vi) any international proceeding, international negotiation, or other international matter affecting the Internet of Things to which the United States is or should be a party.	

[To be added before submission: The IoTAB is pleased to provide this report within the one year timeframe specified within the section. It represents independent advice (as specified in the NDAA) and represents the independent judgement of the steering committee, each member of which is acting as a stakeholder outside of the Federal Government with expertise relating to the Internet of Things.]

Adjacent and Complementary Technology and Considerations

[Need to draft an introductory paragraph describing the purpose and content of this section. These generally describe concepts that have an important relationship to IoT but are not necessarily elements of IoT in themselves.]

Quantum Computing

Quantum technology has been prominent in research and development centers, in funding of new ventures, in planning for future consequences, and in the news. Quantum information technologies is specifically named as a Critical and Emerging Technology in the National Standards Strategy. So, while this is still an emerging technology, it is appropriate to look at the intersection of quantum and IoT for future considerations.

There are currently several main categories of quantum technologies, including quantum sensors, quantum simulators, quantum computing and quantum key distribution. Of these, the closest to the IoT space is quantum computing.

Quantum computing (“QC”) uses “qubits” which are structures fundamentally operating via quantum mechanics. A physical qubit can suffer from errors, so groups of physical qubits may be combined to make “logical qubits”. Requirements for usable QC algorithms are often described in terms of the number of (logical) qubits required.

Although breakthroughs are announced regularly, the emergence of practical and useful QC is still in the future. When there are usable QC systems with 1000’s of qubits, however, popular public-key encryption systems are at risk. Worse, exchanges (sessions of protocol handshakes, key exchanges and encrypted data) that happen today may be captured, stored, and decrypted a decade or so from now, using future QC capability.

Organizations are strongly encouraged by governments, industry, and professional and trade associations to inventory their use of such encryption today and begin planning for conversion to “post quantum computing” (“PQC”) safe algorithms. Many enterprises are working through such processes, even as NIST works through the process of selecting and standardizing PQC algorithms.

Missing in this picture is IoT. Current research on PQC algorithms does not take into account low-power, low-complexity, low-compute-footprint devices that are common in IoT. The risk profile is greatest for enterprises. However, IoT installations present a known attack surface, as evidenced by the infamous “WiFi fish tank thermometer hack”, where an IoT device was used as an entry point to a casino’s private data. [https://www.businessinsider.in/Hackers-stole-a-casinos-high-roller-database-through-a-thermometer-in-the-lobby-fish-tank/articleshow/63769685.cms [businessinsider.in]]

This report does not have a specific recommendation on “quantum IoT”, but it would be prudent to study the challenge of future-proofing IoT encryption in the run-up to the PQC era.

Conclusion

- A concluding statement from the report that summarizes the work and the findings and that encourages continued progress from the Board.
- A cordial invitation for follow-up questions, if needed and as permitted by the FACA process.
- Thank you to the IoT Advisory Board members for their contributions and support.

References

Specific documents cited in the report (end notes) (standards, guidelines, policies) (with hyperlinks).

The following **international** data transfer agreements may have an impact on IoT:

Global Asia-Pacific Economic Cooperation (APEC) Cross-Border Privacy Rules (CBPR)

Canada, Japan, the Republic of Korea, the Philippines, Singapore, Chinese Taipei, and the United States of America are current economies participating in the APEC CBPR System

https://www.commerce.gov/news/press-releases/2022/04/statement-commerce-secretary-raimondo-establishment-global-cross-border [commerce.gov]

EU-U.S. Data Privacy Framework (EU-U.S. DPF) - Privacy Shield Replacement

https://www.commerce.gov/news/press-releases/2023/07/statement-us-secretary-commerce-gina-raimondo-european-union-us-data [commerce.gov]

U.S. & UK Data Bridge (Added to the Privacy Shield Replacement)

https://www.commerce.gov/news/press-releases/2023/06/us-uk-joint-statement-us-uk-data-bridge [commerce.gov]

Acknowledgements

This section will acknowledge the work of groups or individuals (outside of the Board itself, which is listed elsewhere) who have contributed to the project. Such contributions include support for meetings, useful discussions, or extensive copy-editing of the publication.

Include speakers with links to meeting materials

Appendices

- Other selected industry references (standards, guidelines, corporate reports) considered during discussions and for recommendations.
- Other Federal regulations and statutes affecting IoT
- Summaries of other federal reports supporting IoT improvement / actions
- Glossary of Selected Terms
- Abbreviations / Acronyms
- Other ideas?

Appendix x: Detailed Privacy Considerations

[Note – this represents a very detailed storyboard regarding the privacy components of trust, as they relate to IoT adoption. It represents good information but likely too much for the opening chapters, so we propose to include one or two such appendices to provide more information.]

Additional information below

Regulation: Support Comprehensive Federal Data Privacy Regulation

To address the growing complexities and uncertainties surrounding data privacy in the United States, a key recommendation has been proposed to the U.S. government: the support of a comprehensive Federal Data Privacy Regulation. This initiative seeks to support the establishment of uniform standards for data privacy across the nation, aiming to harmonize the existing patchwork of State privacy regulations. The primary motivation behind this recommendation is to reduce the complexity and legal uncertainty currently faced by businesses, which often have to navigate a labyrinth of varied State laws regarding data collection, storage, use, and sharing.

Consider the scenario of Laura, a small business owner who operates online and in multiple States. She constantly grapples with the complexities of adhering to different State data privacy laws, which consumes considerable time and resources that could be better spent on growing her business. Introducing a Federal Data Privacy Regulation would streamline Laura's operations by providing a clear set of rules regarding data collection, storage, use, and sharing in the U.S. This uniformity would significantly reduce her legal uncertainties and compliance costs.

To effectively implement this regulation, several considerations need to be considered. These include addressing four key aspects of data privacy - collection, storage, use, and sharing - and carefully considering the costs associated with implementing and enforcing the new regulation. Additionally, there needs to be a well-thought-out transition period and set compliance deadlines for businesses presently operating under various State laws.

However, implementing this Federal Data Privacy Regulation is not without challenges. The U.S. government is likely to face legislative gridlock and potential opposition from various interest groups. Managing preemption and the private right of action will be crucial, along with the need for inter-agency cooperation. Several agencies could be pivotal in championing this recommendation, including Congress, the Federal Trade Commission (FTC), the Department of Commerce, and the House Committee on Energy and Commerce.

In pursuing this course of action, it is recommended that the U.S. government support efforts like those proposed by the House Committee on Energy and Commerce on National Data Privacy Regulation. Moreover, leveraging the National Cybersecurity Strategy Implementation Plan of July 2013, particularly the initiative on cyber regulatory harmonization, could provide a solid foundation for establishing a cohesive and effective Federal data privacy framework.

Regulation: Federal IoT Privacy Policy Framework

To address the unique challenges posed by the Internet of Things (IoT), a recommendation has been made to the U.S. government to develop a Federal IoT Privacy Policy Framework. This framework, designed to balance the need for data privacy and security with fostering innovation in the IoT sector, aims to serve as a voluntary guideline applicable across various sectors involved in developing or implementing IoT technologies.

The justification for this recommendation stems from the need for a consistent and unified approach to data privacy and security within the IoT sector. This move will reduce confusion and fragmentation for businesses, government entities, and consumers. Acknowledging the advancements in privacy legislation by several U.S. States, this framework also seeks to encourage innovation by providing clear guidelines and expectations for IoT device manufacturers, thus fostering a competitive and growth-oriented environment.

The story of Sarah, an administrator at a healthcare facility, perfectly encapsulates the challenges faced in the absence of such a framework. Sarah struggles with integrating IoT devices in her facility due to the lack of a unified privacy policy framework. With health being a highly regulated industry, Sara is concerned about running afoul of any privacy regulations by utilizing IoT devices.

The development of a Federal IoT Privacy Policy Framework would be instrumental in guiding Sarah in safely implementing IoT technologies, ensuring both the protection of patient data and operational efficiency in a healthcare setting.

However, implementing such a framework comes with its considerations and challenges. The U.S. government is advised to draw lessons from existing privacy regulations to create an effective and efficient framework. This framework must remain adaptable and scalable to keep pace with the rapidly evolving nature of IoT technology and the data privacy landscape.

One of the key challenges in implementing this framework is balancing the protection of data privacy for businesses, government, and consumers while simultaneously fostering innovation in the IoT sector. Additionally, the government needs to provide adequate resources, guidance, and support to businesses to adopt and implement this framework. Regular review and framework updates are essential to ensure its relevance and effectiveness in addressing emerging data privacy challenges and technological advancements.

Congress is identified as a possible participating body that could assist or champion this recommendation. For successful implementation, the U.S. Federal government should consider working closely with States that have already embraced privacy frameworks or are advancing regulations. This collaboration is vital for regulatory alignment. The government is also encouraged to utilize strategies from the National Cybersecurity Strategy Implementation Plan of July 2013, particularly initiatives focused on cyber regulatory harmonization and increasing agency use of frameworks and international standards for regulatory alignment.

Regulation: Inclusion of IoT in Federal Privacy Regulation

To enhance privacy standards and foster innovation in the rapidly evolving realm of the Internet of Things (IoT), a recommendation has been proposed to the U.S. government to include IoT considerations in any future Federal Privacy Regulation Proposal. This recommendation focuses on adding specific provisions regarding IoT Data Retention and Transparency. It aims to establish clear guidelines for manufacturers on the duration of data retention for business, government, and consumer data. This move is intended to align with existing or future Federal privacy legislation by integrating IoT-specific language related to data retention.

The rationale behind this recommendation ensures that IoT device manufacturers adhere to a consistent set of privacy standards. This consistency is pivotal in enhancing the trust and protection of data across business, government, and consumer sectors. Moreover, the recommendation aims to stimulate innovation by providing IoT businesses with clear guidelines and expectations, fostering a competitive and growth-oriented environment.

Alex, a tech-savvy consumer currently hesitant to purchase IoT devices due to privacy concerns, stands to benefit significantly from this development. Including IoT in the Federal Privacy Regulation would provide Alex with a much-needed sense of security, offering a clear legal framework that assures personal data protection. This move could alleviate his concerns and encourage him to engage confidently with IoT technologies.

For successful implementation, the U.S. government must consider privacy legislation to address the unique challenges and technological advancements in the IoT sector. However, this initiative faces several potential barriers. These include achieving consensus among stakeholders and State-level regulators on incorporating effective elements and practices into the Federal privacy legislation. Additionally, there's a need to ensure that these new IoT-specific requirements are compatible with existing national and international privacy regulations. Balancing data privacy protection with promoting innovation in the IoT sector is another critical consideration. Moreover, providing adequate resources, guidance, and support to businesses for adopting and implementing these IoT-specific requirements is essential.

Several bodies within the U.S. government could play a significant role in championing this recommendation, including Congress, the Department of Commerce (DoC), the National Institute of Standards and Technology (NIST), and the Federal Trade Commission (FTC). The overarching goal is to support the inclusion of IoT in the contemplated Federal Data Privacy legislation, ensuring a comprehensive and future-proof privacy framework in the age of IoT.

Policy: Plain Language in Privacy Policies

In IoT and privacy, a crucial recommendation for the U.S. government is adopting plain language in privacy policies. This recommendation, stemming from the Internet of Things (IoT) Cybersecurity Improvement Act of 2020, focuses on integrating plain language into privacy policies as part of the Federal Acquisition Regulation (FAR) requirements. The goal is to simplify privacy policies, notices, and data use policies, making them more accessible and

understandable to users. This initiative aligns with the "Plain Writing Act of 2010" (Public Law 111-274), which the government can use to model this recommendation on organizations providing IoT technology to the government.

The justification for this recommendation lies in its potential to improve user understanding of data privacy policies, thereby leading to more informed decisions regarding IoT device usage. Additionally, it aims to enhance public trust in IoT devices and related technologies, and simplified policies could result in increased compliance and fewer legal disputes.

Implementing this recommendation requires the U.S. government to develop guidelines and best practices for organizations on simplifying privacy policies. It involves establishing criteria for evaluating the readability of these policies and coordinating with various stakeholders, including the private sector, business, government, and consumer data advocacy groups, to ensure widespread adoption.

This recommendation resonates with consumers like Emily, who often finds the complex language in IoT device privacy policies confusing, leading to her reluctance to adopt smart home technologies. The U.S. government's move to mandate plain language in these policies would significantly aid Emily, enhancing her confidence in her understanding of how her data is used and decreasing her hesitation to engage with these technologies.

However, potential barriers exist. Organizations might resist simplification, fearing it could limit their legal protections. There are also challenges in defining the appropriate level of simplification while ensuring policies remain accurate and comprehensive. Moreover, monitoring and updating these guidelines in response to technological advancements and emerging privacy concerns is crucial.

Agencies within the U.S. government that could play a key role in championing this recommendation include the National Institute of Standards and Technology (NIST), the Department of Commerce (DoC), the Office of Management and Budget (OMB), which oversees the Act's implementation, and the Office of the National Cyber Director (ONCD).

For effective implementation, the U.S. Federal government should consider creating requirements for IoT providers to implement simplified privacy policies in government contracts. This can be achieved by utilizing the National Cybersecurity Strategy Implementation Plan of July 2013, particularly Initiative Number 3.2.1, related to the IoT Cybersecurity Improvement Act of 2020, and Initiative Number 1.1.1, focused on cyber regulatory harmonization. The Plain Writing Act of 2010 is also a foundation for this recommendation.

Policy: Third-Party Data Sharing Policies

In response to IoT devices' growing interconnectivity and data-sharing capabilities, which pose significant privacy risks, the U.S. government is recommended to establish clear policies for third-party data sharing and IoT device data use. This recommendation includes outlining IoT

manufacturers' and service providers' responsibilities and obligations when dealing with third-party entities, emphasizing the importance of user consent and secure data practices.

The rationale for this recommendation stems from the need to safeguard consumers'' personal data and ensure transparency in how this data is shared and used. By establishing clear policies, the government can foster trust among users and encourage wider adoption of IoT technologies. These policies are expected to communicate third-party data sharing and usage in privacy policies and be supported by public awareness campaigns to educate users about their data rights.

Consider the case of John, a small business owner, who experiences firsthand the challenges posed by the current ambiguity in third-party data sharing. John is apprehensive about how the IoT devices in his store handle data sharing with third-party entities. The lack of transparency has made him wary of fully integrating IoT solutions into his business operations. Establishing clear, government-led third-party data-sharing policies would significantly alleviate John's concerns. It would provide him with much-needed assurance about the security and use of his business's data, thus fostering his confidence in adopting IoT technologies more extensively in his business.

However, implementing these policies faces potential barriers, including resistance from IoT companies who rely on third-party data sharing for their business revenue and challenges in aligning these new policies with existing privacy regulations and international data protection standards.

To overcome these barriers and effectively implement these policies, the U.S. government should consider working with industry leaders to establish data use guidelines, leveraging the National Cybersecurity Strategy Implementation Plans from July 2013. These include Initiative Number 1.1.1, focusing on cyber regulatory harmonization, and Initiative Number 1.1.3, which aims to increase agency use of frameworks and international standards for regulatory alignment.

Agencies within the U.S. government, including the National Institute of Standards and Technology (NIST), the Federal Trade Commission (FTC), the Department of Energy (DOE), the United States Department of Agriculture (USDA), and the Office of the National Cyber Director (ONCD), are identified as key players who could assist or champion the recommendation, contributing to the establishment of a more secure and transparent IoT ecosystem.

Trust and Transparency: Privacy Transparency for IoT

In the evolving landscape of IoT and privacy, the U.S. government is poised to take a significant step forward with the recommendation of establishing a comprehensive privacy transparency system for IoT devices. This initiative, drawing inspiration from the “U.S. Cyber Trust Mark” and other transparency frameworks, is designed to significantly empower various stakeholders – businesses, governments, and consumers – by providing them with detailed insights into the

privacy features and practices of IoT devices. This move is anticipated to enhance general awareness and stimulate IoT manufacturers to prioritize privacy, thereby fostering innovation and competition in the development of privacy-enhancing technologies.

Consider the case of Mia, an operator in a manufacturing plant. She regularly interacts with IoT sensors on the production floor but feels uneasy due to her uncertainty about how her data is being used and protected. Implementing a privacy transparency system, as recommended by the U.S. government, could be a game-changer for Mia and many others like her. With clear and understandable privacy information readily available, Mia would better understand the privacy implications of the IoT sensors she works with. This knowledge would alleviate her concerns and likely lead to greater acceptance and utilization of these technologies in her work environment.

For the successful deployment of this system, the government needs to consider the perspectives of privacy experts, industry stakeholders, and advocacy groups. It is essential to develop clear guidelines and standards for privacy transparency, including what information should be included, its format, and how it should be presented. It is also crucial to motivate IoT device manufacturers to adopt this system, supporting them in aligning with these new recommendations.

However, challenges such as ensuring widespread adoption and compliance across different industries, motivating manufacturers, and balancing comprehensive information with simplicity and understandability need to be addressed. Key agencies like the Department of Commerce, the National Institute of Standards and Technology, and the Federal Trade Commission could play instrumental roles in driving this initiative forward.

Additionally, the government's strategy should promote the benefits of IoT privacy transparency, forging partnerships with industry leaders to develop this system and leveraging existing initiatives under the National Cybersecurity Strategy Implementation Plan. These steps would establish a robust framework for IoT privacy and significantly contribute to enhancing cybersecurity and data protection in the digital era.

Trust and Transparency: IoT Privacy on Automobile Monroney Stickers

In the landscape of connected automobiles, where privacy concerns are mounting, a crucial recommendation has been presented to the U.S. government: including IoT Privacy Information on "Monroney Stickers" for new and used cars. This recommendation aims to leverage the traditional role of Monroney Stickers – known for detailing fuel efficiency and safety ratings – to now also disclose vital information about IoT privacy. This encompasses data collection, retention, sale, and the availability of a universal opt-out feature.

Consider Anne, a consumer in the market for a new car. Like many, she is largely unaware of the privacy implications tied to the connected features in modern vehicles. The U.S. government's proposed addition of IoT privacy information on Monroney Stickers could

significantly aid consumers like Anne by clarifying each vehicle's data collection practices, informing her purchase decision.

This initiative is primarily driven by the need to enhance consumer protection and address growing concerns over personal data use and sharing by IoT devices in automobiles. The urgency of this issue is highlighted by findings from the Mozilla Foundation's Automobile Privacy Report in 2023, which reveals that all 25 car brands reviewed in this report collect personal data, with most sharing or selling this information. The report further indicates that most brands offer limited control over drivers' data, and many have concerning records regarding privacy breaches. Notably, the report notes that none of the car brands reviewed that participate under the Alliance for Automotive Innovation adhere to voluntary consumer protection principles focusing on data privacy.

However, the path to implementing this recommendation involves overcoming several hurdles. It requires a standardized, straightforward, and concise method to present IoT privacy information, ensuring compliance with existing privacy laws and adaptability to future technological developments. The U.S. government must also prepare for possible resistance from automakers concerned about cost implications, the task of educating consumers about the importance of this information, and the complexity of the regulatory landscape governing IoT and privacy.

A united effort from various U.S. government agencies is imperative to successfully implement this recommendation. Agencies such as the Federal Trade Commission (FTC), National Highway Traffic Safety Administration (NHTSA), Federal Communications Commission (FCC), Department of Transportation (DOT), and the Cybersecurity and Infrastructure Security Agency (CISA) could play critical roles. Their involvement would uphold the principles of the Automobile Information Disclosure Act of 1958 and significantly bolster consumer rights in an era increasingly defined by connected technology.

Trust and Transparency: Location Tracking Notice in IoT e-Labeling

In a move to enhance consumer awareness and data privacy in the IoT sphere, a pivotal recommendation has been proposed to the U.S. government. It focuses on incorporating a clear and upfront notification within the U.S. e-labeling program for IoT devices, specifically stating, "Notice: Precise location tracking is enabled by default on this device." This recommendation emerged from a deep-seated belief in transparency and informed consent. Consumers, often unknowingly, have their location data collected and shared by various IoT devices. This straightforward Statement aims to inform consumers about this data collection practice immediately.

For example, consider Joan, a consumer who is apprehensive about the location-tracking features of her IoT devices but struggles to find clear information about them. Implementing this straightforward e-labeling notice would greatly assist Joan in understanding and managing her privacy. It would empower her to make more informed decisions about using her IoT

technology, ensuring she knows when and how her location data is being tracked and what action she needs to take to stop tracking.

The justification for this recommendation is threefold. Firstly, it upholds the consumer's right to know if and how their location data is tracked. Secondly, it emphasizes the ethical imperative of informed consent in data collection, ensuring that consumers know these practices without navigating complex privacy policies. Lastly, this recommendation aligns with various data protection regulations advocating transparency and informed consent.

However, implementing this recommendation poses several challenges and considerations. The U.S. government needs to standardize the Statement's wording, visibility, and placement across all IoT devices as part of the U.S. e-labeling program. It is crucial to assess the technical feasibility of how and where this notice will be displayed—be it on the physical device, a website, or an associated app—for effective consumer awareness. Moreover, robust systems for audits and compliance must be established to ensure adherence to this notification requirement.

Potential barriers to this implementation include resistance from the industry, which might perceive this as a negative impact on sales or an added complexity to product design. Consumer education also presents a hurdle, as there is a risk that all users might not fully understand the importance of this notice. Legal challenges are another concern, as companies might view this requirement as an unfair labeling burden.

To champion this recommendation, collaboration among various U.S. government agencies, including the Federal Trade Commission (FTC), the National Institute of Standards and Technology (NIST), and the Federal Communications Commission (FCC), is essential. Furthermore, the U.S. government should consider leveraging strategies from the National Cybersecurity Strategy Implementation Plan of July 2013, specifically, Initiative Number 4.6.1, titled "Publish a National Cyber Workforce and Education Strategy", to foster a comprehensive approach to this privacy-enhancing initiative.

Security and Compliance: Universal Opt-Out Signals for IoT

In an initiative to bolster privacy and data protection in the Internet of Things (IoT) realm, the U.S. government is recommended to endorse Universal Opt-Out Signals for IoT devices and their companion apps. This proposal is driven by the growing need to safeguard user privacy in an increasingly interconnected digital world. Adopting Universal Opt-Out Signals would simplify the process for consumers, enabling them to easily manage their privacy settings across various IoT devices and applications.

Consider Nina, a tech enthusiast who finds managing privacy settings across multiple IoT devices cumbersome. The U.S. government's endorsement of Universal Opt-Out Signals for IoT devices would simplify Nina's experience, allowing her to easily control her privacy settings, leading to greater adoption and trust in IoT technologies.

However, implementing this recommendation is not without its challenges. The government must consider the technical feasibility of applying these universal opt-out signals across various devices and apps and the associated costs of establishing and enforcing such a system. Standardized guidelines or legislation may be necessary to ensure uniform adoption of the Universal Opt-Out Signals.

Resistance from IoT manufacturers and app developers is anticipated, primarily due to the potential costs and complexities of implementing these signals. Additionally, the technological constraints of harmonizing these signals across different platforms and devices pose a significant challenge. Another crucial aspect is effectively communicating to consumers how Universal Opt-Out Signals can facilitate easier management of their privacy rights.

Several agencies within the U.S. government could play pivotal roles in championing this initiative, including the Federal Trade Commission (FTC), the National Institute of Standards and Technology (NIST), the Federal Communications Commission (FCC), and the Department of Commerce.

In formulating the implementation strategy, the government should consider leveraging existing frameworks and regulations. This includes the National Cybersecurity Strategy Implementation Plan of July 2013, which suggests initiating a U.S. Government IoT security labeling program. Furthermore, existing privacy laws like the California Consumer Privacy Act (CCPA) and its amendment, the California Privacy Rights Act (CPRA), along with the Colorado Privacy Act (CPA) and the Connecticut Data Privacy Act (CTDPA), provide valuable precedents for enforcing privacy provisions starting from 2024. These laws and initiatives could serve as models for developing a comprehensive and effective system of Universal Opt-Out Signals in the IoT space.

Security and Compliance: NIST Sanitization Standards for Used Automobiles

In enhancing privacy and security in the used automobile sector, the U.S. government faces a crucial recommendation: to mandate that car seller organizations adhere to the National Institute of Standards and Technology's (NIST) media sanitization guidelines before reselling vehicles. This recommendation aligns with the e-Stewards Standard, supported by the Environmental Protection Agency (EPA) Recycling Program. The core objective is to protect consumer privacy and prevent unauthorized access to sensitive data that modern vehicle systems often store.

The implementation of this recommendation, however, is not without its challenges and considerations. The U.S. government must account for the financial implications for car sellers, who would bear the cost of implementing these sanitization standards. Additionally, there's a need for comprehensive training and awareness programs to familiarize car sellers with the NIST guidelines. The technological infrastructure to support these sanitization processes is another vital consideration, along with robust mechanisms for monitoring and ensuring compliance.

Consider Mark, an automobile reseller who faces challenges ensuring the privacy of previous owners' data in used IoT-enabled cars. Adopting NIST's sanitization standards for used automobiles as recommended by the U.S. government could provide Mark with clear guidelines, ensuring customer data privacy and boosting consumer trust.

Yet, the path to implementation is beset with potential barriers. Car-selling organizations might resist these changes due to the perceived increase in operational costs. Older vehicle models might present technological limitations that complicate compliance with the guidelines. Furthermore, potential legal challenges related to data privacy and compliance need to be navigated.

To champion this initiative, several U.S. government agencies could play pivotal roles. The National Institute of Standards and Technology (NIST) and the Department of Transportation (DOT) are key players, along with the Federal Trade Commission (FTC) and the Environmental Protection Agency (EPA).

These leverage existing frameworks and standards for a successful implementation. This includes utilizing the National Cybersecurity Strategy Implementation Plan, specifically Initiative Number: 1.1.3, which focuses on increasing agency use of frameworks and international standards for regulatory alignment. The NIST Cybersecurity Framework provides a solid foundation, particularly the 'PROTECT - Secure Data - 800-88 Rev. 1 - Guidelines for Media Sanitization', provides a solid foundation. Additionally, aligning with the EPA’s implementation of Electronics Recycling Standards, particularly R2, and e-Stewards, will ensure a comprehensive approach to the sanitization and reselling of used automobiles.

Security and Compliance: NIST Standards for Government Automobiles Resell

In response to the emerging privacy and security challenges associated with the resale of government automobiles equipped with IoT technologies, a significant recommendation has been proposed: Mandating NIST Sanitization Standards for Government Automobiles Before Resell. This narrative encapsulates the key aspects of this recommendation.

The U.S. government is advised to ensure that before reselling, all agencies adhere strictly to the media sanitization guidelines set forth by the National Institute of Standards and Technology (NIST) before reselling. This requirement is not just a procedural formality; it is a critical step to safeguard consumer privacy and prevent unauthorized access to sensitive information that might be stored in modern vehicle systems. Such an approach is in alignment with the e-Stewards Standard, which is supported by the Environmental Protection Agency (EPA) as part of its Recycling Program.

In her role, Sara faces the pressing task of ensuring that sensitive data in government vehicles is fully erased before they are transferred or sold. Adopting NIST sanitization standards, as recommended by the U.S. government, would provide her with the necessary procedures to ensure that no residual data remains. This implementation would address her concerns about data security and play a significant role in maintaining public trust.

However, implementing these standards is not without its challenges. The government must consider the financial implications, including the costs associated with procuring and deploying data sanitization tools across its entire fleet of vehicles. Additionally, ensuring that these sanitization solutions are compatible with a diverse range of vehicle models and embedded systems is crucial.

Another significant aspect of this recommendation involves the human element – training and awareness. Government staff and contractors need comprehensive training in new data sanitization procedures, which could be resource-intensive. To facilitate this, the development of awareness programs about these guidelines is essential.

For effective implementation and monitoring, the government should leverage existing frameworks and international standards to align regulations. This includes utilizing resources such as the National Cybersecurity Strategy Implementation Plan and the NIST Cybersecurity Framework, specifically focusing on securing data and adhering to guidelines for media sanitization.

Collaboration across various agencies will be pivotal in the successful implementation of this recommendation. Agencies like the NIST, Department of Transportation (DOT), and EPA are poised to play crucial roles, each bringing their unique expertise and resources to the table.

The proposal to mandate NIST sanitization standards for government automobiles before reselling represents a comprehensive approach that combines regulatory alignment, technological solutions, and human resource training. It is a concerted effort to enhance data security, align with environmental standards, and ultimately protect consumer privacy in the age of IoT.

Security and Compliance: Privacy By Design for IoT

In the realm of IoT (Internet of Things), the U.S. government is recommended to adopt and promote the "Privacy by Design" (PbD) approach in the development, deployment, and implementation of IoT devices. This recommendation is in line with the U.S. National Strategy to Advance Privacy-Preserving Data Sharing and Analytics (PPDSA) as of March 2023 and the National Cybersecurity Strategy Implementation Plan of July 2013. The latter particularly emphasizes scaling public-private partnerships to develop and adopt technologies that are secure by design and default.

The rationale behind this recommendation is multifaceted. Firstly, it aims to minimize data privacy risks and the ensuing legal complications, thereby aligning IoT privacy practices with international data protection standards. Additionally, the approach serves to educate both businesses and consumers about privacy in IoT, providing incentives to companies that comply with PbD guidelines.

Consider the case of Raj, a developer at an IoT firm, who encounters challenges in embedding privacy at every developmental stage of IoT devices. The U.S. government's endorsement of

'Privacy by Design' for IoT offers a solution, providing Raj with a comprehensive framework and resources. This support is crucial in facilitating the creation of inherently safer and privacy-conscious products, significantly enhancing the security and trustworthiness of IoT technologies.

Implementing this recommendation, however, comes with its own set of challenges. These include the difficulty in monitoring a diverse and constantly evolving range of IoT applications and potential resistance from the private sector, which might perceive PbD implementation as risky or costly. Another significant challenge is developing universally accepted privacy standards for IoT.

For the successful execution of this recommendation, the involvement of key U.S. government agencies is essential. The Office of Science and Technology Policy (OSTP), the National Institute of Standards and Technology (NIST), and the Federal Trade Commission (FTC) are identified as critical players in championing this recommendation.

To effectively implement PbD in IoT, the U.S. government needs to consider several factors. These include the development of clear PbD guidelines and the provision of incentives to companies that comply. It's also important to ensure the adaptability of these principles across various IoT devices and to align them with international privacy standards. Support for small and medium enterprises (SMEs) in adhering to these principles is crucial, as is the regular evaluation and refinement of guidelines and incentives. The government should also consider leveraging the National Cybersecurity Strategy Implementation Plan to drive the development of secure-by-design technology through public-private partnerships.

Security and Compliance: Promotion of Privacy-Enhancing Technologies (PETs)

In the realm of IoT, the U.S. government is recommended to champion the implementation of Privacy-Enhancing Technologies (PETs). These technologies are vital in safeguarding privacy while still harnessing valuable insights from the expansive IoT data. PETs align with responsible data use principles and bolster trust and acceptance of IoT solutions across society. Their adoption is crucial for preventing data breaches and the ensuing legal complications.

However, the path to implementing PETs is not without challenges. The government needs to ensure robust security measures are in place to avert unauthorized data access and conduct thorough technical and ethical evaluations before adopting these technologies. It's also essential to enhance public understanding and trust in PETs and encourage interoperability among different PET systems is also essential. Developing a framework to monitor PETs' effectiveness and impacts in the IoT environment.

The implementation journey may encounter hurdles such as limited technical expertise for understanding, implementing, and managing PETs. Resistance from the private sector, often due to perceived risks or costs, and the complexity of developing universally accepted privacy standards for IoT are other potential barriers.

One of the primary hurdles in this endeavor is the resistance from the private sector, often stemming from perceived risks or costs associated with PET integration. This is exemplified by Linda, a manufacturer of IoT devices, who is apprehensive about the cost and complexity of integrating PETs into her products. A U.S. government initiative that not only promotes PETs but also offers guidelines and support could be instrumental in helping manufacturers like Linda overcome these barriers. Such an initiative would facilitate the production of more privacy-conscious IoT devices, thereby reinforcing the security and trustworthiness of IoT systems in the eyes of users and manufacturers alike.

To effectively implement this recommendation, several agencies within the U.S. government could play pivotal roles, including the Office of Science and Technology Policy (OSTP) and the National Institute of Standards and Technology (NIST). The government should consider leveraging existing frameworks and initiatives, such as the IoT Cybersecurity Improvement Act of 2020, The White House's proposal for Advancing a Vision for Privacy-Enhancing Technologies (June 2022), and the National Cybersecurity Strategy Implementation Plan (July 2013), particularly the initiative focused on scaling public-private partnerships for secure technology development and adoption. This approach ensures a comprehensive and collaborative effort towards integrating PETs into IoT systems, aligning with the broader goal of leveraging technology for societal benefits while maintaining user privacy.

Education and Innovation: Enhancing Workforce

In response to the rapidly evolving landscape of the Internet of Things (IoT), the U.S. government has been recommended to develop targeted educational initiatives. These initiatives are not just focused on workforce development but also aim to enhance data privacy and trust among businesses, government entities, and consumers. The rationale behind this recommendation hinges on several key benefits: increasing the understanding and safe use of IoT technologies, cultivating a skilled workforce adept at navigating IoT privacy challenges, and bolstering trust and adoption of IoT devices and services across various sectors.

To effectively implement these educational initiatives the government needs to undertake a comprehensive approach to effectively implement these educational initiatives. This includes defining the scope and content of the initiatives, identifying and reaching key target audiences like schools, universities, businesses, and the general public, and ensuring that the workforce development encompasses a broad range of personas, including manufacturers, implementors, service providers, and workers. Collaboration with educational institutions and industry leaders is vital, as is the need to ensure that the educational content remains relevant and practical. An essential aspect of this initiative is the regular update of these programs to align with ongoing technological advancements and evaluate their effectiveness through consistent assessments and feedback.

These educational initiatives could be transformative for someone like Carlos, an IoT implementer. Carlos frequently faces challenges staying abreast of the latest IoT technologies and privacy practices. Government-led educational programs targeting the IoT workforce would provide him with crucial training, empowering him to install and maintain IoT systems with up-to-

date privacy standards. This direct impact on professionals like Carlos underscores the broader significance of these initiatives in building a capable and privacy-conscious IoT workforce.

However, there are notable challenges in this endeavor. Some potential hurdles are keeping pace with the fast advancements in IoT technology, reaching and engaging diverse audiences effectively, and securing adequate funding and resources. To overcome these, involvement from agencies like the National Institute of Standards and Technology (NIST) and the Office of the National Cyber Director (ONCD) is crucial. They can assist in promoting the importance of IoT education and advocate for adopting educational programs aimed at workforce development.

In implementing these recommendations, the U.S. government should consider utilizing frameworks such as the National Cybersecurity Strategy Implementation Plan, specifically Initiative 4.6.1, which focuses on publishing and tracking a National Cyber Workforce and Education Strategy. This strategy could be a cornerstone in achieving the broader goals of enhancing understanding, skill development, and trust in IoT technologies.

Hold: Theme Based Overview and Commentary

[This section provides the overarching vision and rationale for the forthcoming recommendations. Note that many of these have only recently provided and are being reviewed by the Board for the first time. The final level of detail will be more consistent from topic-to-topic.]

The remainder of this report is structured around a set of organizing themes:

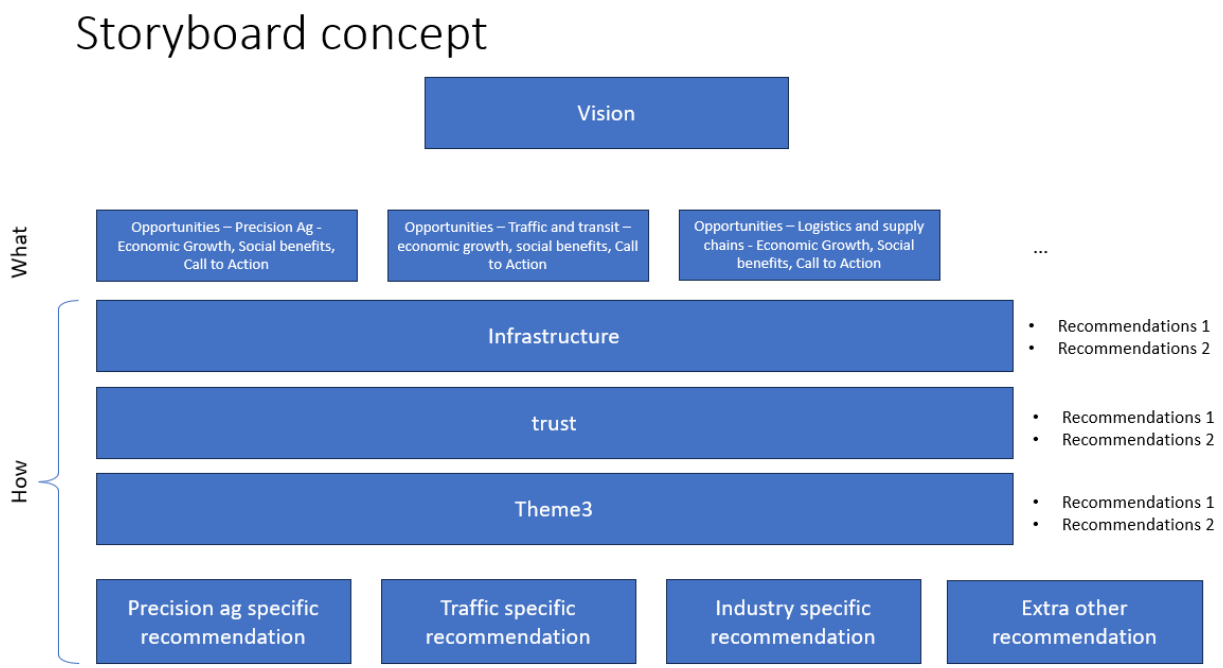
- Establishing A National Strategy for Taking Full Advantage of the Opportunity Presented by IoT – expanding and improving interagency coordination to help national and international initiatives be more successful.
- Orchestrated platform-based business ecosystems for next generation smart cities, critical infrastructure and value chains, to drive trillions of value for digital economies.
- Modernizing IoT Infrastructure - Enhance and modernize infrastructure supporting IoT including resilience considerations, improved interoperability and connectivity needs.
- IoT Trust – Enhance adoption by improving trust in IoT through specific data protection, cybersecurity, privacy, and facilitated usage and management of IoT-related data.
- IoT Supply Chain - Ensure IoT supply chain integrity and resilience including augmented logistics & and improved reliability on the developers, manufacturers, and suppliers.
- Leveraging the CHIPS Acts and IoT technology to create digital thread from chip design and manufacturing to strengthen national security and fuel global economic growth.
- IoT Leadership / Government capabilities - Develop government capabilities to support and sustain a IoT-connected economy and facilitate U.S. IoT technology leadership. Support research and development and technology transfer while addressing challenges of IoT in a global ecosystem.
- Fostering an IoT-Ready Workforce - Develop, grow, and maintain a workforce to support the IoT economy from farms to factories to freeways.

[This page is a placeholder for describing the themes by which the stories and recommendations are structured. As the stories and illustrations are finalized, this page will be updated as an introduction to those.]

[Note that this will be the primary place for graphics and illustrations. As reviewers read this section, please consider and comment regarding graphics that would be helpful in telling these stories.]

Overall model for storyboards:

- Address the needs and requirements in the legislation
- Create understanding of the key impacts, opportunities, challenges of IoT from an industry perspective
- Create a sense of “urgency” to act faster and in a bigger way



Orchestrated platform-based business ecosystems for smart cities, critical infrastructure and value chains driving trillions for global digital economies.

This section describes a strategy to operationalize certain recommendations of the IoT Advisory Board for IoT and Adjacent Technologies (5G+, AI, Quantum, etc.) IoT in this context means any network-based (Internet or Intranet) connected electronic device or system that consumes or produces data. Connectivity plus data drives economic growth. Key takeaways:

1. IoT will explode in ways that are transformative for our society. It will enable connected value chains and digital marketplaces that will drive 10s of trillions in economic value.

2. IoT adoption and growth is hindered by major factors, legacy infrastructure, value chain silos and limited digitalization affecting scalability IoT services and revenue streams.

3. The US must lead globally by promoting orchestrated PPPs and trusted platform-based business ecosystems that enable XaaS[55] revenue streams and digital marketplaces.

The U.S. can leverage the unique knowhow of trillion-dollar platform companies to encourage the development of orchestrated IoT business ecosystems across value chains and digital marketplaces. Such ecosystems powered by trusted data will give rise to new IoT services, AI applications and digital twins that accelerate adoption of IoT and fuel global digital economies.

Factors Affecting IoT Adoption and Growth

Connectivity Changes the Value Chain Economics

Connectivity Changes Products to Platform Businesses

Commercial IoT Platforms and Partnerships

IoT Solutions Require Orchestrated Ecosystem Partnerships

Evolution of Scalable Platform-based Business Ecosystems

Enterprise Digitalization Accelerates IoT Value Chains

Trusted Digital Transformation for IoT Edge Applications

Scaling the Value and Growth with Industry Ecosystems

Convergence of Trusted AIoT and Circular Value Chains

Strategy to Accelerate Adoption and Growth

Recommendations Referenced [List Titles]

Summary

- The US must lead globally in promoting orchestrated PPPs, platform-based business ecosystems and digital threads enabling XaaS revenue streams across value chains.

- The U.S. can leverage its unique strengths from the experience of trillion-dollar platform companies to encourage orchestrated business ecosystems and digital marketplaces.

[55] XaaS - Everything as a Service

- Such ecosystems powered by trusted data will give rise to new IoT services, AI apps and digital twins. Regulation will be key to managing risks and driving economic growth.

Leveraging the CHIPS Acts and IoT technology to start digital thread from design and manufacturing to strengthen national security and fuel economic growth.

This section describes a strategy to operationalize certain recommendations of the IoT Advisory Board for IoT and Adjacent Technologies (5G+, AI, Quantum, etc.) IoT in this context means any network-based (Internet or Intranet) connected electronic device or system that consumes or produces data. Connectivity plus data enable economic growth. Key takeaways:

1. IoT will explode in ways that are transformative for our society. It will enable connected value chains and digital marketplaces that will drive 10s of trillions in economic value.

2. IoT adoption and growth is hindered by global supply chain imbalances, fragmentation and vulnerabilities impacting the security of IoT services and the trust of data used by AI.

3. The US must lead the EU and allied nations in developing trusted supply chain networks and collaborative ecosystems that align incentives on cybersecurity and economic value.

The U.S. and EU CHIPS Acts and similar investments by allied nations worldwide present a historic opportunity to invest in creating a trusted digital thread for supply chain provenance and traceability from chip design and manufacturing to IoT Edge. Such investment coupled with cybersecurity labeling and digital product passports programs will accelerate evolution of trusted IoT value chains and fuel the global digital economies.

IoT Opportunity for National and Economic Security

Global Electronics Value Chains and IoT Landscape

IoT Supply Chain Vulnerabilities, Risks and Opportunities

Supply Chain Provenance Starts from Trusted Chips

Digitalization Across the Electronics and IoT Value Chain

Digital Thread Enables Data and Apps Monetization

Digital Thread Use Cases, Benefits and Value Proposition

Accelerating Supply Chain Resilience and Economic Growth

U.S. Cyber Trust Mark and EU Digital Product Passport

Expanding Digital Thread Global Impact Beyond Borders

Strategy to Accelerate Adoption by Leveraging CHIPS Acts

Recommendations Referenced [List Titles]

Summary

- The US must lead the EU and allied nations in developing trusted supply chain networks and collaborative ecosystems that align incentives on cybersecurity and economic value.

- The U.S. and EU CHIPS Acts and similar investments by allied nations provide a historic opportunity to invest in creating trusted digital threads from chip design & manufacturing.

- Such investment along with programs for cybersecurity labeling and digital product passports will accelerate trusted IoT value chains, marketplaces, and digital economies.

Other Story

Other Story

Introductory text explaining the importance of the cross market and development topic areas. (Section 8.1 serves as an example to be iterated throughout the remaining subsections)

- Enhance and modernize the infrastructure for IoT (this can be related to things like connectivity, computing, power, legacy infrastructure, etc.)
- Create trust in IoT (security, privacy, transparency, data ownership, etc.)
- Increase supply chain integrity and resilience (in this case, Tom's version of supply chain, and not Robby's. We can put Robby's into the industry-specific section).
- Develop, grow, and maintain a workforce to support the IoT economy.
- Address challenges of IoT in a global ecosystem and economy
- Develop government capability to support and sustain a IoT economy (this is where the emerging technology office recommendations come in. We could also put in the recommendations from sustainable infrastructure
- about government procuring IoT for its own use in its facilities, etc.).
- Facilitate adoption (including govt, small business adoption and value realization of IoT. this theme can be moved to the topic specific section, if we think it is appropriate).
- Facilitate IoT technology leadership (R&D, etc.). This one could potentially be combined with 6 although 6 is about govt leadership. whereas this one is about facilitating industry R&D…

Current topics in this section are a bit disjointed since we have a variety of disparate topics.

Theme: Convergence with adjacent technologies

Quantum + IoT? [we sort of have this, but it talks about cryptography]

IoT + OT (or rather IT + OT) - [we don't have this content, but this would be a good one to have.. Tom would be all over this. Worst case, I will extract some of this content from our research report as we have something on this topic]

IoT + infrastructure [smart infrastructure writeup that was submitted last week]

[suggested] Commentary write-up on key themes enabling the realization of an IoT economy (here we discuss briefly the themes that we had organized the recommendations around and why - modernizing infrastructure, establishing trust, workforce development, etc.). This gives good context on why these areas are important and it sets up the themes/recommendations in the later sections

[suggested] Equity considerations around IoT (availability, distribution of benefits, etc.)

- We have a number of recommendations that touch upon various aspects of this. It may be a good idea to highlight the equity aspect and considerations of our recommendations, its importance, etc. For example, we have recommendations for
- Rural areas - connectivity, transportation, ag, manufacturing
- Small businesses - startups offering technology, small businesses buying IoT, small farms, manufacturers, retail, etc.
- Small cities and rural communities (vs. bigger cities and urban communities)
- Workforce considerations (e.g. IoT creates opportunities and jobs for communities that may have been underrepresented)
- Privacy (some communities are more concerned about privacy, especially in underrepresented areas where there is an inherent trust of government)
- Environmental (certain communities live and work in areas that are not great, but IoT makes that much more transparent, and top of mind)

[suggested] Policy considerations

We have a number of recommendations that are policy related. We may want to discuss some assumptions or thoughts [industry plays a bigger role to figure it out, but there are areas where government should take a more active role, etc.]

Trust, Privacy, Security, and Resilience in the Internet of Things

In the evolving landscape of the Internet of Things (IoT), trust, privacy, security, and resilience form the cornerstone of its sustainable development and deployment. This report examines various aspects of IoT, highlighting federal regulations, potential economic and societal benefits, spectrum availability, privacy and security policies, small business implications, and international considerations.

Federal Regulations and Sector-Specific Policies

The proliferation of IoT technologies intersects significantly with some existing regulations and sector-specific policies. However, regulatory gaps exist, particularly in standardizing protocols and ensuring interoperability among IoT technology across different sectors. A comprehensive policy framework that addresses these challenges is imperative for IoT to reach its full potential.

Economic and Societal Benefits

IoT promises transformative benefits across various sectors:

- Smart Traffic and Transit Technologies: IoT can optimize traffic flow, reduce congestion, and enhance public transportation systems, leading to considerable economic savings and environmental benefits.
- Augmented Logistics and Supply Chains: IoT applications in logistics can lead to efficient supply chain management, reducing operational costs and improving customer satisfaction.
- Sustainable Infrastructure: IoT technologies can be pivotal in creating sustainable urban environments through intelligent energy management and infrastructure monitoring.
- Precision Agriculture: By leveraging IoT, precision agriculture can increase crop yields and sustainable farming practices.
- Environmental Monitoring: IoT devices can provide real-time data for environmental monitoring, helping in disaster prediction and climate change mitigation.
- Public Safety: IoT applications can enhance public safety through improved emergency response systems and public health monitoring.
- Healthcare: IoT in healthcare promises improved patient monitoring, telemedicine, and personalized healthcare services.

Spectrum Availability

The growing demand for IoT devices raises questions about the adequacy of the available spectrum. Legal and regulatory barriers, such as licensing regimes and allocation of frequency bands, need re-evaluation to ensure sufficient spectrum availability for IoT. This is crucial for maintaining the functionality and efficiency of IoT networks.

Privacy and Security Policies

IoT poses significant challenges to privacy and security:

- Privacy Concerns: IoT devices often collect vast amounts of personal data, necessitating robust privacy protection frameworks to ensure user trust.

- Security of IoT: With the increasing prevalence of IoT in critical infrastructure, its security is paramount. Policies must focus on standardizing security protocols and ensuring regular updates to IoT devices.
- User Protection: Protecting users from potential misuse of IoT data while still allowing legitimate usage is vital. This includes implementing consent mechanisms and transparent data usage policies.
- Federal Coordination: Encouraging coordination among federal agencies overseeing IoT will ensure a unified approach to tackling privacy and security challenges.

Opportunities and Challenges for Small Businesses

IoT technology presents both opportunities and challenges for small businesses. While IoT can drive innovation and efficiency, small businesses may face hurdles in terms of cost, technical expertise, and cybersecurity risks. Supportive policies and programs are needed to help small businesses overcome these challenges and leverage IoT technology effectively.

International Proceedings and Negotiations

The global nature of IoT necessitates the active participation of the United States in international proceedings and negotiations. This includes standard-setting, privacy and security norms, and spectrum management. Ensuring a harmonized international IoT framework is critical for global interoperability and security.

The Internet of Things holds immense potential for societal and economic benefits. However, this potential can only be fully realized through a concerted effort to address regulatory challenges, ensuring adequate spectrum, safeguarding privacy and security, supporting small businesses, and engaging in international collaborations. A balanced, forward-looking approach is essential for nurturing an environment where trust, privacy, security, and resilience in IoT can flourish, ultimately contributing to a more connected, efficient, and innovative society.

Envisioning Privacy in the Internet of Things (IoT) Era

As we delve deeper into the digital age, the Internet of Things (IoT) 's impact on privacy brings exciting opportunities and significant challenges. A comprehensive vision to address privacy in the IoT realm is critical, encompassing various aspects such as regulation, policy, trust and transparency, security, compliance, and education and innovation.

Regulation

As an example, theDeveloping a Federal IoT Privacy Policy Framework is crucial to provide specific guidance for IoT technologies. Equally important is the inclusion of IoT in Federal Privacy Regulations, ensuring comprehensive consumer protection under privacy laws.

Policy

Policies form the foundation of privacy in IoT. Implementing Plain Language in Privacy Policies is essential to make privacy terms understandable for consumers. Additionally, well-defined

Third-Party Data Sharing Policies are necessary to regulate the sharing and use of IoT data, thus protecting user privacy.

Trust and Transparency

Building trust and transparency is imperative in the IoT ecosystem. Initiatives like Privacy Transparency for IoT aim to make privacy practices more visible and understandable to consumers. In specific applications such as automobiles, introducing IoT Privacy information on Automobile Monroney Stickers and Location Tracking Notice in IoT e-labeling are key measures to inform consumers about the privacy features of IoT-enabled vehicles.

Security and Compliance

Security and compliance in IoT require a multifaceted approach. Universal Opt-Out Signals for IoT offer consumers a simple method to control their privacy settings. Promoting Privacy-Enhancing Technologies (PETs) is crucial for advancing secure IoT solutions. Adhering to NIST Sanitization Standards for Used Automobiles and Government Automobiles Resell also ensures proper data erasure before vehicle resale. Under this umbrella, 'Privacy by Design' for IoT is essential. This approach integrates privacy considerations into every stage of IoT product development, ensuring that privacy safeguards are built into IoT technologies from the ground up.

Education and Innovation

Finally, Educational Initiatives for the IoT-savvy Workforce are key to providing professionals with the skills and knowledge necessary to navigate and influence the future of IoT and privacy. This education will drive innovation, ensuring privacy considerations evolve alongside technological advancements.

This vision for privacy in the IoT era aims to establish a balanced ecosystem where innovation thrives alongside robust consumer privacy protection, achieved through comprehensive regulation, effective policies, enhanced trust and transparency, stringent security measures, and continuous education and innovation.

Smart Infrastructure

Infrastructure is essential to the functioning and resilience of the United States. For example, a nationwide network of roads, waterways, rail and airports transports freight and goods to market, and connects people with places. A regional system of natural and man-made reservoirs, aqueducts, pipes, pumping stations, and treatment plants brings fresh water to cities and farms. Electricity generated from renewable and non-renewable energy power plants travels over through a network of transmission lines and substations to power cities and communities across the country. Sewage is routed from homes and buildings through a regional network of underground pipes to wastewater treatment plants for reclamation for reuse and release.

Smart infrastructure is the integration of IoT and other digital technologies into physical infrastructure. This convergence enables new innovative capabilities for physical infrastructure and allows it to be managed, operated, and maintained in more efficient and effective ways. Sensors embedded into infrastructure, such as roads, building structures and machinery, monitor its condition in real time, notifying operators of abnormal conditions immediately so that it can be addressed before it becomes a hazard or lead to service interruptions. Data collected from the sensors are analyzed by algorithms to optimize performance and usage, predict maintenance needs, and extend infrastructure life. In addition, IoT data helps validate and improve engineering models, build high fidelity digital simulations, and facilitate managerial and operational decision-making.

The benefits enabled by smart infrastructure include increased reliability, service availability and improved delivery of services. For example, streetlights provide illumination to increase road and pedestrian safety, reduce crime and facilitate economic vibrancy. However, broken streetlights take months to be replaced because the city or utility company is unaware of the problem. IoT enabled streetlight sensors notify the city or utility company immediately of broken lights, leading to replacements in days, not months. In another example, fatal and non-fatal traffic accidents commonly occur in street intersections. “Smart intersections”, equipped with cameras employing artificial intelligence algorithms mounted on traffic signal poles, capture vehicle and pedestrian behaviors that allow traffic engineers to study and apply corrective actions before serious accidents occur.

Other benefits of smart infrastructure included optimized operations and decreased costs. For example, mechanical water pumps equipped with sensors monitor equipment conditions during operation. The sensor data is analyzed by algorithms to determine when maintenance is actually needed so that the pumps can be proactively serviced, thereby ensuring continuous system operation and preventing cost escalation. Similarly, smart electrical grids employ sensors and two-way communications between utilities and consumers to monitor and manage power flows, and respond to changes in electricity demand. This ensures that the most appropriate energy sources, including renewable energy, batteries, and upstream generation plants, are utilized to meet demand while increasing grid resilience, reducing operational costs, and minimizing carbon emissions from upstream fossil fuel power sources.

A third benefit of smart infrastructure is its facilitation and acceleration of a future autonomy-driven economy, supporting autonomous vehicles and machinery, autonomous robotic operations, and other AI-driven applications. Despite the advances in autonomous vehicle technology, they are still many years away from truly safe and reliable operation. The sensors and processors in smart infrastructure provide additional data that autonomous equipment, machines and vehicles need in order to operate safely and reliably. For example, today's autonomous vehicles operate based on the limited information collected through its on-board sensor array. Sensors embedded on roads and buildings provide an extended set of "eyes and ears" to complement the limited range of the vehicle's on-board sensors. This additional "beyond line of sight" information is shared and processed by the vehicle's algorithms and enables better decisions and safer, more reliable, and predictable operations.

Despite the many capabilities and benefits offered by smart infrastructure, American infrastructure is old and failing. It must be repaired, replaced, and upgraded before it can be digitized and made "smart". The American Society of Civil Engineers (ASCE) have given American infrastructure an overall C- grade in its 2021 report card,[1] a slight improvement from the previous report card (2017), which rated the state of American infrastructure as D+.[2] For example, the United States has over 2.2 million miles of underground pipes that deliver drinking water. There is a water main break every two minutes and an estimated 6 billion gallons of treated water are lost each day.[3] Many of America's wastewater treatment plants were built in the 1970's and have an average life span of 40-50 years.[4] This aging infrastructure and inadequate capacity leads to the discharge of 900 billion gallons of untreated sewage into U.S. waterways each year.[5] Of the four million miles of public roadways in the United States, 43% are in poor or mediocre condition.[6] The poor road infrastructure resulted in motorists paying an additional $1,000 annually in time and fuel, 36,000 road deaths annually and rising pedestrian fatalities.[7]

Another concern is the vulnerability of smart infrastructure to cybersecurity threats, cybercriminals, and malicious state actors. IoT and other smart technologies create new attack surfaces and vulnerabilities to assets and infrastructure that had traditionally not been digitized, or had been protected through "air-gaps". These cyberattacks may lead to disruption of operations and services, compromise of control and operational capabilities, and harm to millions of Americans who rely on this infrastructure. For example, the energy sector was the third and fourth most targeted sectors in 2020 and 2021 respectively.[8] The utility industry averaged 736 cyberattacks per week and experienced a 46 per cent year-over-year increase in cyber-attacks in 2021.[9] In 2019, a renewable energy generator company, the largest private owner of operating solar assets in the United States, was subjected to a denial-of-service attack. While no loss of energy generation was reported in the attack, the company lost visibility into about 500 MW of wind and PV generation in California, Utah and Wyoming.[10] Similarly, U.S. water utilities are prime targets for cyberattacks. The March 2020 Cyberspace Solarium Commission report stated that the nation's 70,000 water utilities "remain largely ill-prepared to defend their networks from cyber-enabled disruption."[11] In 2021, an operator at a small water treatment plant in Oldsmar, Florida, thwarted an attempt by an intruder to boost the level of sodium hydroxide (lye) in the water supply to 100 times higher than normal.[12]

While the Bipartisan Infrastructure Law of 2021 provides funding to repair and update America's infrastructure, it also represents a "once in a lifetime" opportunity to build an initial set of smart infrastructure and realize the benefits that it brings.

Smart Traffic and Transit Technologies

According to data from the National Highway Traffic Safety Administration (NHTSA), in 2022 an estimated 42,795 people died in motor vehicle crashes. While this latest estimate shows that roadway fatalities have remained flat after two years of dramatic increases, Transportation Secretary Pete Buttigieg states that "We continue to face a national crisis of traffic deaths on our roadways, and everyone has a role to play in reversing the rise that we experienced in recent years." https://www.nhtsa.gov/press-releases/traffic-crash-death-estimates-2022. Back in January of 2022, the DOT released the comprehensive National Roadway Safety Strategy, a roadmap to address the national crisis in traffic fatalities and serious injuries. One of the key actions in that roadmap includes leveraging technology to improve the safety of motor vehicles on our roadways.

Smart traffic technologies provide an organized, integrated approach to minimizing congestion and improving safety on streets through connected technology. These technologies smooth traffic flows and prioritize traffic in response to demand in real time. They enhance pedestrian, bicycle and vehicle safety and reduce accidents that cause injuries and fatalities. Connected vehicles can alert drivers of potential hazards such as pedestrians crossing the street or other cars in the vicinity. Smart traffic lights can detect when cars are approaching and adjust their timing accordingly, minimizing the risk of accidents. Using adaptive control, detected vehicle congestion triggers changes to traffic signal timing to optimize traffic throughput in near real-time. Traffic signal timing can be adjusted to maintain schedules of bus and rapid transit lines. A path through the city is coordinated for first responder vehicles, using congestion data and vehicle location to adapt route guidance and traffic signal timing allowing these vehicles to get to their destination sooner.

These technologies can facilitate and support multimodal transit and other innovative transportation models (including ride-share, e-scooters, drones, etc.). They also facilitate the safe testing and operation of autonomous vehicles (including cars, trucks, robotic delivery services, etc.). They can also reduce energy consumption by obviating stop-start driving that typically occurs at intersections.

There is a large and growing ecosystem of public and private sector stakeholders to deploying this technology that will redefine traffic safety. Some examples showcasing their benefits are provided below.

- A project with Audi to deploy Cellular Vehicle to Everything (C-V2X) in vehicles as part of an ongoing joint project with the Virginia Department of Transportation, the Virginia Tech

Transportation Institute, and others to showcase the technology's ability to improve work zone and intersection safety.[56]

- A collaborative venture with Audi, school bus maker Blue Bird, and the Fulton County School System (Georgia) that demonstrated C-V2X's ability to protect children in and around school zones and bus stops.[57]
- A project with Audi and with bicycle safety platform maker Spoke Safety to highlight the benefits of C-V2X-powered bicycle use cases.[58]
- A project with the Tampa Hillsborough Expressway Authority (THEA) to deploy and pilot Connected Vehicle (CV) applications to demonstrate safety and mobility benefits of the technology with respect to pedestrians in and around downtown Tampa.[59]
- A project with the Florida Department of Transportation (FDOT) to test and implement connected vehicle and pedestrian/bicyclist safety applications (active or passive) at 13 signalized intersections and 8 mid–block crossings within the core of the University of Florida (UF) campus.[60]
- The New York City Department of Transportation Traffic Safety Network. a large-scale Intelligent Transportation System (ITS) upgrade, replacing their entire citywide traffic communications network with a cellular IoT system. DOT's traffic management system controls the traffic signals at 14,000 intersections, as well as a range of ITS devices including traffic cameras, variable message signs and vehicle detection devices. The new network is highly automated, secure, and achieves four 9's availability using dual concurrent cellular links.[61]
- Tri-Met in Portland, OR. The Tri-County Metropolitan Transportation District of Oregon (TriMet) serves an area of 500 square miles, operating a fleet of over 700 buses on 85 routes with thousands of stops. Smart systems maintain bus intervals and on congested corridors, prioritize bus travel over other vehicles by sensing bus arrival time then manipulating traffic signal phases[62]
- Positive Train Control- - SEPTA, LIRR, MNR, MBTA, AMTRAK. Positive Train Control (PTC) utilizes GPS, sensors and wireless communications technology to autonomously stop a train when necessary and to prevent train-to-train collisions, over-speed derailments, and unauthorized train movement. PTC helps ensures the safety of passengers by acting as a safeguard against human errors and other potential hazards.[63]

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[56] Jacob Levin, "Virginia Tech Transportation Institute researchers to deploy smart work zone in Wise, Virginia," Virginia Tech Exponentially More (May 19, 2022), https://vtx.vt.edu/articles/2022/05/vtt-smart-work-zone.html?utm_source=cmpgn_news&utm_medium=email&utm_campaign=vtUnirelNewsDailyPublicCMP_052022-public; Audi, *Audi collaborates to deploy C-V2X communication technology on Virginia roadways* (Sept. 29, 2020), https://media.audiusa.com/en-us/releases/437.

[57] Press Release, Audi, (Mar. 30, 2021), *Blue Bird, Fulton Co. Schools join Audi, Applied Information on connected vehicle deployment to boost school bus and school zone safety*, https://media.audiusa.com/en-us/releases/465#

[58] Press Release, Audi, *Audi joins Spoke Safety, Qualcomm, Commsignia to help protect bicyclists through connected technology*, https://media.audiusa.com/en-us/releases/514.

[59] https://www.its.dot.gov/pilots/pilots_thea.htm
[60] https://teo.fdot.gov/architecture/architectures/d2/html/projects/projarch47.html
[61] https://www.digi.com/resources/customer-stories/new-york-city-dot-deploys-digi-solutions
[62] https://www.digi.com/resources/customer-stories/trimet-bus-fleet-management-with-digi-connectivity
[63] https://www.digi.com/resources/customer-stories/digi-helps-septa-comply-with-federal-mandate

Generally speaking, these technologies include hardware, software, systems, and some type of connectivity. Hardware includes traffic signals and traffic controller assemblies, dynamic message signs, connected vehicle roadside units, cameras, sensors, LIDAR, electric vehicles (EVs) and EV charging equipment, vehicles with varying levels of autonomy (drones, delivery shuttles), and electric mobility (scooters, e-bikes). Systems include those that focus on security, intelligence, monitoring, and management. Software includes route planning and travel alerts. Connectivity includes- Cellular Vehicle to Everything (C-V2X), 5G, autonomous navigation both edge and cloud techniques.

While there are e several opportunities and benefits for personas that use these technologies primarily in the realm of safety (i.e., emergency vehicle preemption, entering school or work zone, pedestrian crossing ahead) these technologies can also provide valuable support functions such as package, food, and medicine delivery. There are also environmental benefits from congestion mitigation and providing an orderly flow of traffic (See Carnegie Melon Study for an example: https://www.cmu.edu/piper/news/archives/2012/october/smart-signals.html) as well as increased productivity (drivers spend less time stuck in traffic). Other personas may use these technologies to develop and operate innovative transportation services, such as those involving multimodal transit, ridesharing, and autonomous transportation of people and goods.

There also exist several barriers faced by personas seeking to implement these technologies. On the policy side clarity is needed with respect to data governance and privacy and what aspects of data jurisdictions can collect, retain, and subsequently use. Certain aspects of this sector still need high level policies and regulations that adequately address safety and liability concerns. The benefits of these technologies are not available in rural or undeserved areas. Interoperability and fragmentation is also a challenge when dealing with different jurisdictions and it's important to address cybersecurity implications of all the connected devices that can be used as a gateways. Finally, there is a considerable amount of funding needed to drive adoption in this sector. The examples provided above reinforce that this technology is ready to go mainstream.

Augmented Logistics And Supply Chains

[to be developed]

Sustainable infrastructure

- [Idea] IoT technologies can be used to manage demand and reduce energy usage in factories, buildings and other facilities.
- [Idea] IoT technologies facilitate the ability of cities and communities to become resilient. This includes energy resilience, water resilience, environmental, weather and disaster resilience.
- [Idea] IoT technologies facilitate the distribution and usage of energy generated from local sustainable and renewable sources (distributed energy resources) to supplement

local demand loads, while reducing the use of electricity generated from fossil fuel power plants.

Precision Agriculture

- [Idea] IoT can help small family farms be productive and profitable
    - 2 million farms in U.S.. 98% are family farms. Small family farms (gross income < 350K) are 90% of all farms, 48.8% of all farmland, and 21.1% of production
    - 62 - 81% of these small family farms are operating on < 10% margins
    - Production expenses have increased by 18% in 2022
- [Idea] IoT can help agricultural producers navigate around the impacts of the changing climate.
    - Changing temps and precipitation patterns affect plant lifecycles, decrease crop yields, increase livestock stress and health, reproduction and milk and egg production
    - Corn yields have declined 3.8% and wheat yields have declined 5.5% (compared to no climate trends)
- [Idea] IoT can help increase agricultural production yields to support the upcoming food shortage
    - By 2050, UN estimates there will be a global food shortage
    - Increase in half percent in yield was enough to end starvation and famine in India (Green Revolution)

Environmental monitoring

- [Idea] IoT technologies enable the different parties in the supply chain to monitor, understand, and report on their carbon emissions generated from their activities. This will allow them to plan strategies and initiatives, and utilize options that will optimize and minimize carbon emissions.
- [Idea] IoT technologies enable underserved and socioeconomically challenged communities deploy low-cost community AQ networks to measure, monitor and address environmental issues that cause health problems (e.g. respiratory, etc.)

Public Safety

- [Proposed Story 1]: IoT technologies help 911 operators determine which calls to prioritize and send first responders to. IoT technologies integrated to smart city platforms or next gen 911 systems helps first responders with an understanding of the situation before and at the scene for more effective response.
    - 911 response times have been rising due to increasing call volumes, a shortage of operators and first responders.
    - In New Orleans, average response time went from 15.3 min in 2019 to 32.4 min in 2021

- LAPD police union propose police stop responding to 28 types of 911 calls in order to transfer officers to more serious crimes

Healthcare / Internet of Medical Things

The Internet of Things offers the potential to revolutionize healthcare by reshaping patient care, clinical workflows, and healthcare management. The integration of connected sensors, digital technologies, and data analytics creates a connected ecosystem of Internet of Medical Things (IoMT), medical devices, healthcare systems, and software applications that communicate with each other to streamline healthcare delivery, improve patient outcomes, and pave the way for a more efficient and patient-centric healthcare system.

IoMT devices range from wearable devices and remote patient monitoring solutions to smart medical implants. These IoMT devices encoms a vast network of sart, interconnected medical devices that collect, transmit, and analyze health data in real-time to enhance the quality of healthcare services and create a new era of personalized medicine.

IoMT devices fall into four categories:

- Wearable on-body devices, including consumer health devices (fitness watches, sleep trackers, etc.), and clinical-grade devices (regulated by health agencies, and prescribed by healthcare professionals).
- In-home devices that support telemedicine applications such as remote patient monitoring, and emergency response.
- Community IoMT systems, such as emergency response intelligence systems that connect patients and first responders, mobility services, and devices for measurement and regulation of temperature, blood pressure, etc.
- In-clinic IoMT systems that support administrative functions that allow medical workers to help patients remotely, track hospital assets and equipment, etc.

Some examples of top IoMT applications include:

- **Remote patient monitoring**. One of the most impactful applications of IoT in healthcare is the continuous monitoring of patients outside traditional healthcare settings. Wearable devices track vital signs, medication adherence, and other health metrics. This allows healthcare providers to monitor patients outside traditional clinical settings, providing timely interventions and reducing the need for frequent hospital visits. This is beneficial for individuals with chronic conditions, allowing healthcare providers to remotely track and manage patients' health, reducing hospital readmissions, and enhancing overall patient well-being.
- **Consumer health awareness**. Wearable devices, such as smartwatches and fitness trackers, have become ubiquitous. These devices play a pivotal role in promoting preventive care, tracking physical activity, monitoring sleep patterns, and even detecting early signs of health issues, fostering a proactive approach to well-being.

- **Enhanced patient care**. IoMT has propelled the development of smart medical devices, including insulin pumps, pacemakers, and continuous glucose monitors. These devices not only offer real-time monitoring but also enable healthcare professionals to adjust treatment plans based on individual patient data, leading to more personalized and effective care.
- **Asset and Inventory Management.** IoT plays a crucial role in optimizing hospital operations by monitoring the location and status of medical equipment and supplies. This ensures that resources are efficiently utilized, reduces waste, and enhances overall operational efficiency.

IoMT enables the following benefits, including:

- **Enhanced Patient Outcomes**. By enabling continuous monitoring and personalized care, IoMT contributes to improved patient outcomes. Timely access to health data allows for early detection of potential issues, better management of chronic conditions, and more proactive interventions.
- **Efficiency and Cost Savings**. The implementation of IoT in healthcare streamlines workflows, reduces manual tasks, and enhances the efficiency of healthcare delivery. This not only improves the quality of care but also contributes to cost savings by minimizing unnecessary hospitalizations, optimizing resource utilization and minimizing administrative costs.
- **Patient Engagement and Empowerment**. IoMT empowers patients to actively participate in their healthcare journey. Access to real-time health data through wearable devices fosters a sense of ownership and encourages individuals to make informed decisions about their lifestyles and treatment plans.

While IoMT offers the potential to revolutionize healthcare, there are some challenges, including:

- **Security and Privacy Concerns**. The vast amount of sensitive health data transmitted through IoT devices raises significant concerns about data security and patient privacy. Ensuring robust cybersecurity measures and compliance with privacy regulations is crucial.
- **Interoperability Issues**. The integration of diverse IoT devices and platforms poses challenges related to interoperability. Standardization efforts are essential to enable seamless communication between different systems, ensuring a cohesive and efficient healthcare ecosystem.
- **Regulatory Compliance**. The rapid pace of IoT development often outpaces regulatory frameworks, leading to challenges in ensuring compliance with healthcare regulations. Addressing these issues requires ongoing collaboration between technology developers, healthcare providers, and regulatory bodies.

The Internet of Medical Things holds immense promise for the healthcare industry, facilitating a future where patient care is personalized, efficient, and technologically advanced. However, to realize this promise, the healthcare industry ecosystem must evolve and adapt its practices, operations, policies and regulations.

Workforce

[to be developed]

Compliance Matrix

The IoTAB fulfills the role of the ‘‘steering committee’’ as established under subsection (b)(5)(A) of the NDAA Section. It supports the IoTFWG which is the working group convened under subsection (b)(1).

The IoTAB herein advises working group in the following areas:

Advisory Topic	Relevant Report Sections
(i) the identification of any Federal regulations, statutes, grant practices, programs, budgetary or jurisdictional challenges, and other sector-specific policies that are inhibiting, or could inhibit, the development of the Internet of Things;	
(ii) situations in which the use of the Internet of Things is likely to deliver significant and scalable economic and societal benefits to the United States, including benefits from or to	
(I) smart traffic and transit technologies;	
(II) augmented logistics and supply chains;	
(III) sustainable infrastructure;	
(IV) precision agriculture;	
(V) environmental monitoring;	
(VI) public safety; and	
(VII) health care;	
(iii) whether adequate spectrum is available to support the growing Internet of Things and what legal or regulatory barriers may exist to providing any spectrum needed in the future;	
(iv) policies, programs, or multi-stakeholder activities that—	
(I) promote or are related to the privacy of individuals who use or are affected by the Internet of Things;	

Advisory Topic	Relevant Report Sections
(II) may enhance the security of the Internet of Things, including the security of critical infrastructure;	
(III) may protect users of the Internet of Things; and	
(IV) may encourage coordination among Federal agencies with jurisdiction over the Internet of Things;	
(v) the opportunities and challenges associated with the use of Internet of Things technology by small businesses; and	
(vi) any international proceeding, international negotiation, or other international matter affecting the Internet of Things to which the United States is or should be a party.	

[To be added before submission: The IoTAB is pleased to provide this report within the one year timeframe specified within the section. It represents independent advice (as specified in the NDAA) and represents the independent judgement of the steering committee, each member of which is acting as a stakeholder outside of the Federal Government with expertise relating to the Internet of Things.]