INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

Karlsruhe Institute of Technology

Measurements and Standards to Characterize Nano-Enabled Applications of Electronics: Perspectives from IEC

2011 International Conference on Frontiers of Characterization and Metrology for Nanoelectronics

Grenoble, France, May 23-27, 2011

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Karlsruhe Institute of Technology

Secretary IEC/TC 113
Secretary CLC/SR 113
Obmann DKE/K 141

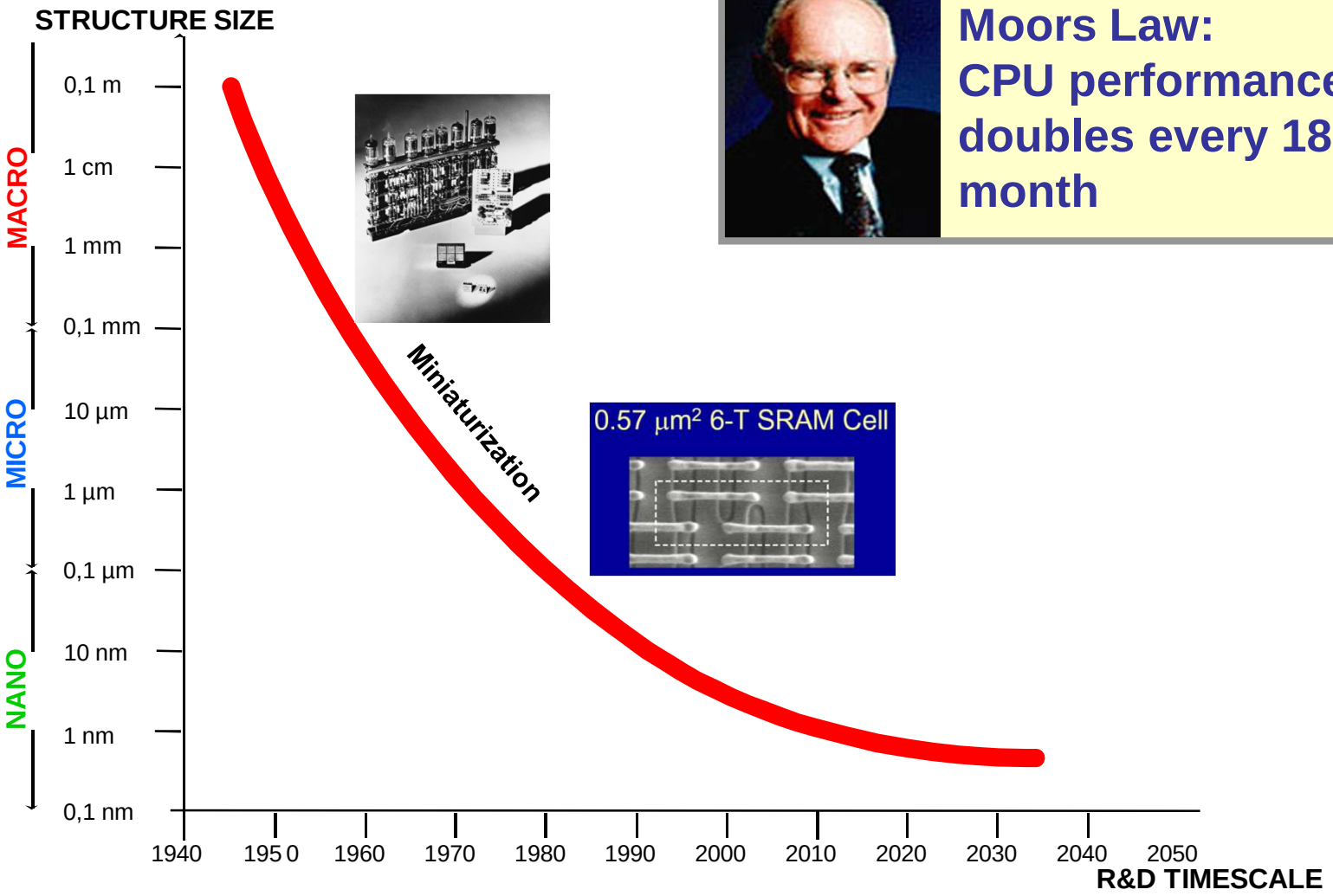
IEC/TC 113: NANOTECHNOLOGY STANDARDIZATION FOR ELECTRICAL AND ELECTRONIC PRODUCTS AND SYSTEMS

Outline

- More than Moore versus nano-enabled
- IEC technical committee on nano-electrotechnologies
- Framework of standards for nanofabrication
  - Key control characteristics
  - Blank detail specifications
- Programme of work of IEC/TC 113
- Active participation in the standardization process

Nanoelectronics

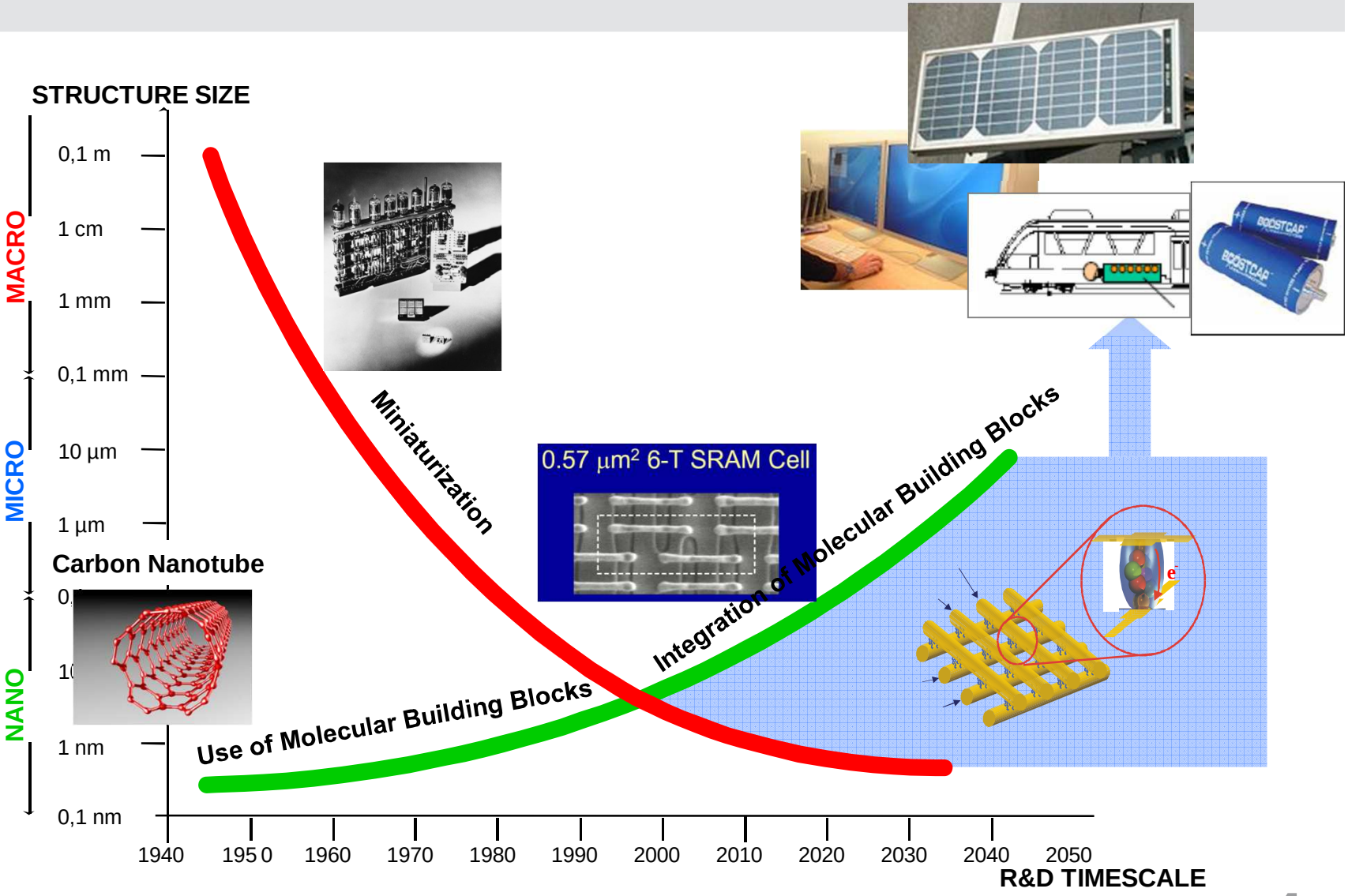
Top Down



Moors Law:
CPU performance doubles every 18 month

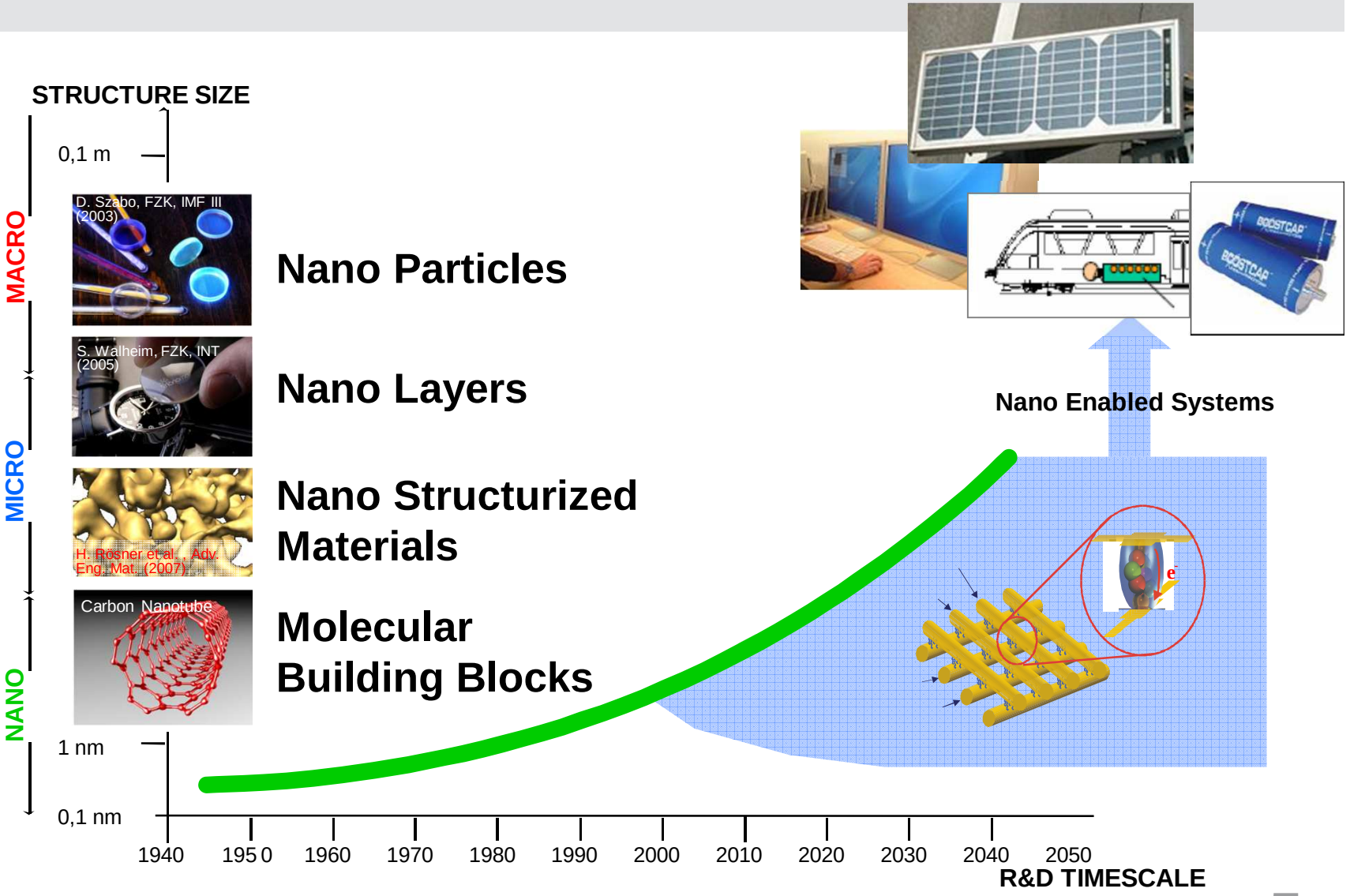
Nanoelectronics

Bottom Up

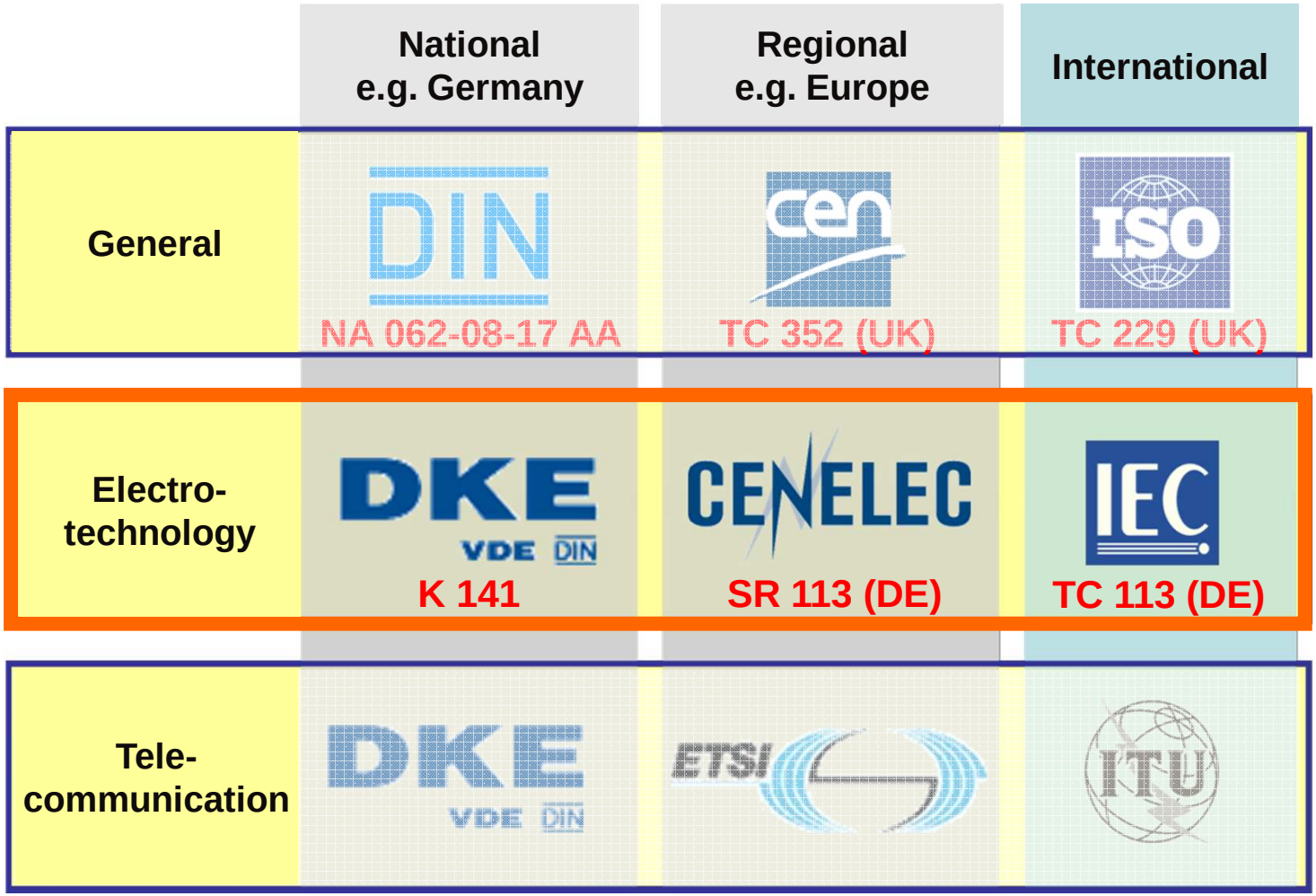


Nanoelectronics

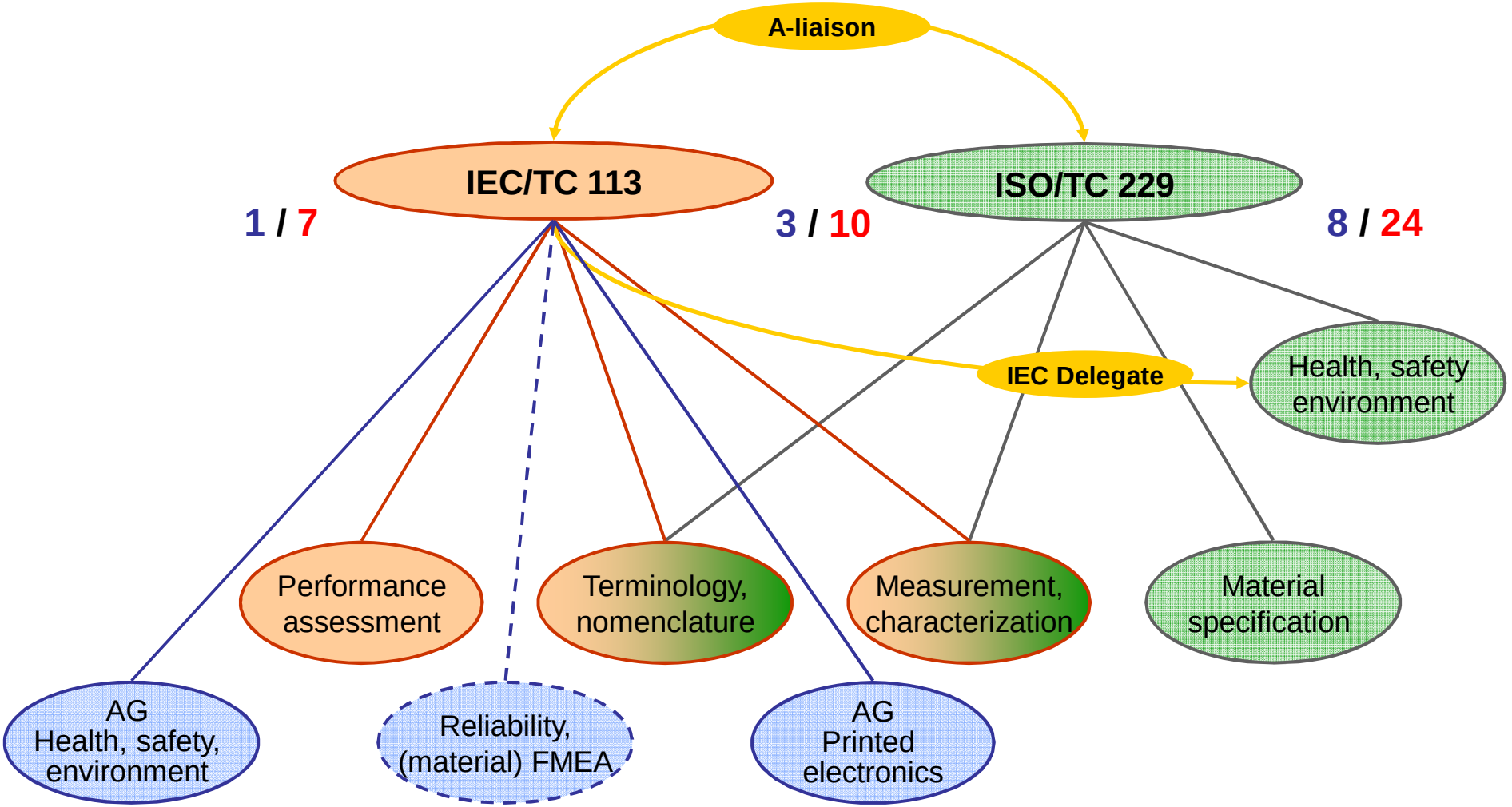
Bottom Up



National and International Nanotechnology Standardization

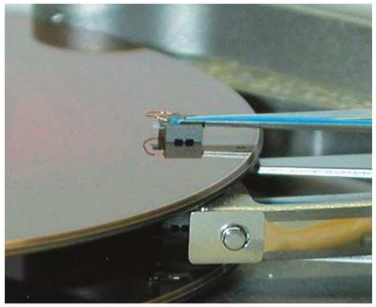


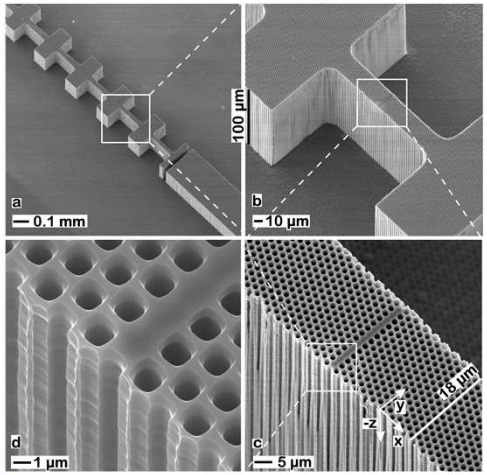
Overview nano-standardization within IEC and ISO

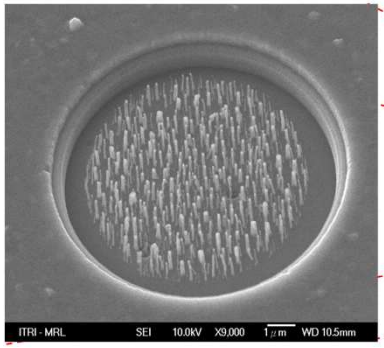


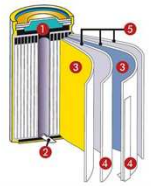
2010-11: published / unpublished

Nano-enabled electrotechnical products (IEC/TC 113)

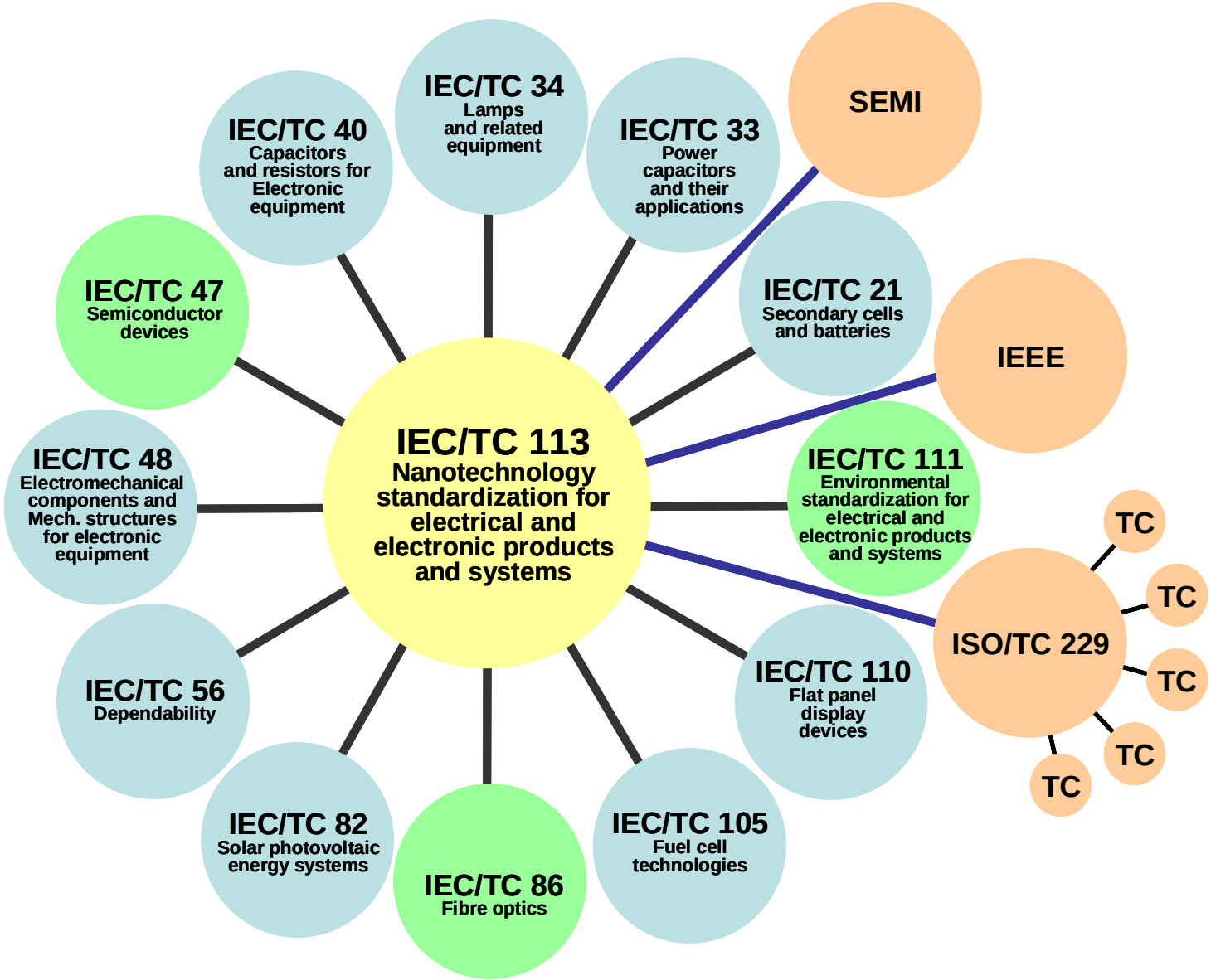




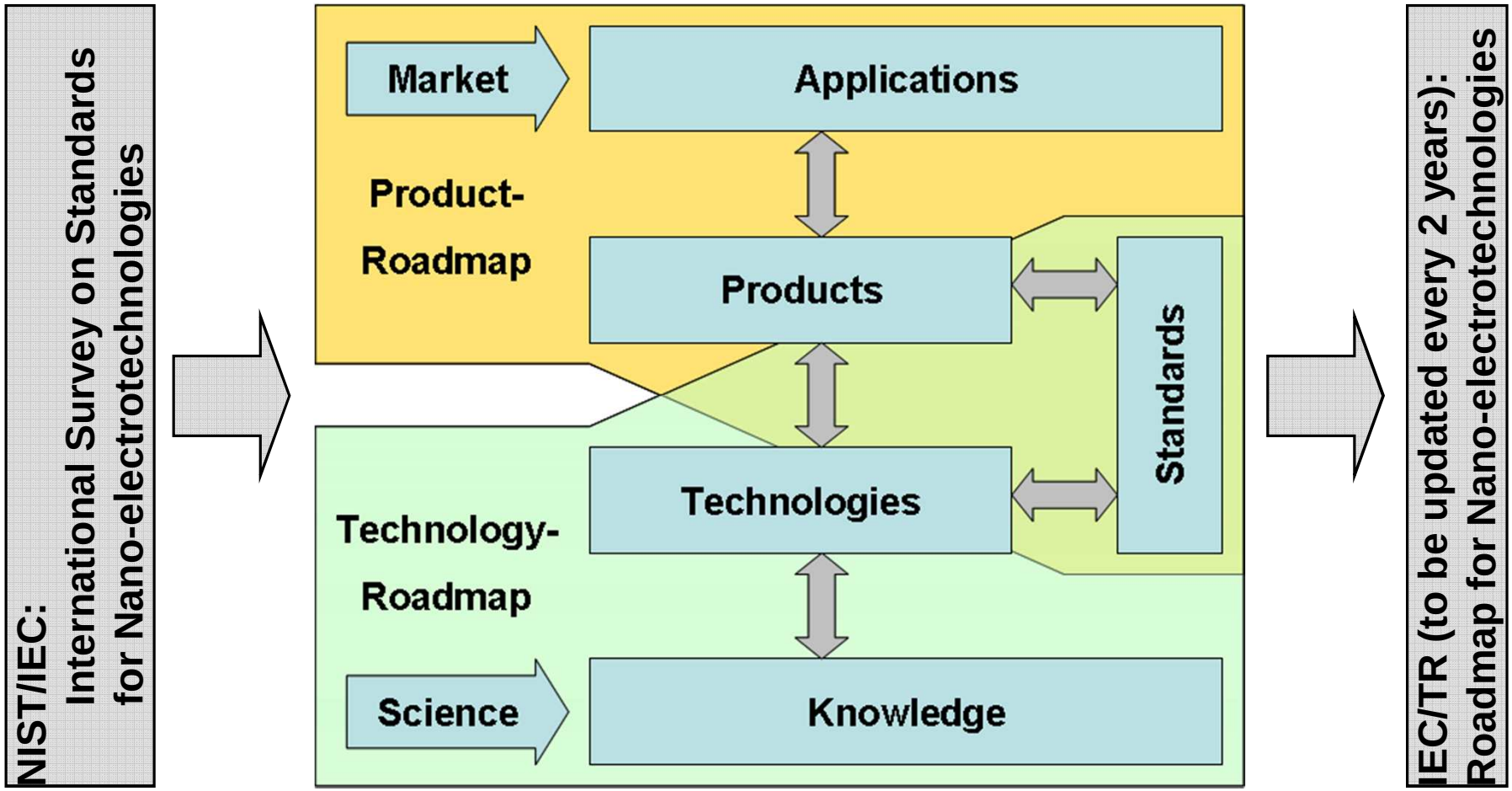




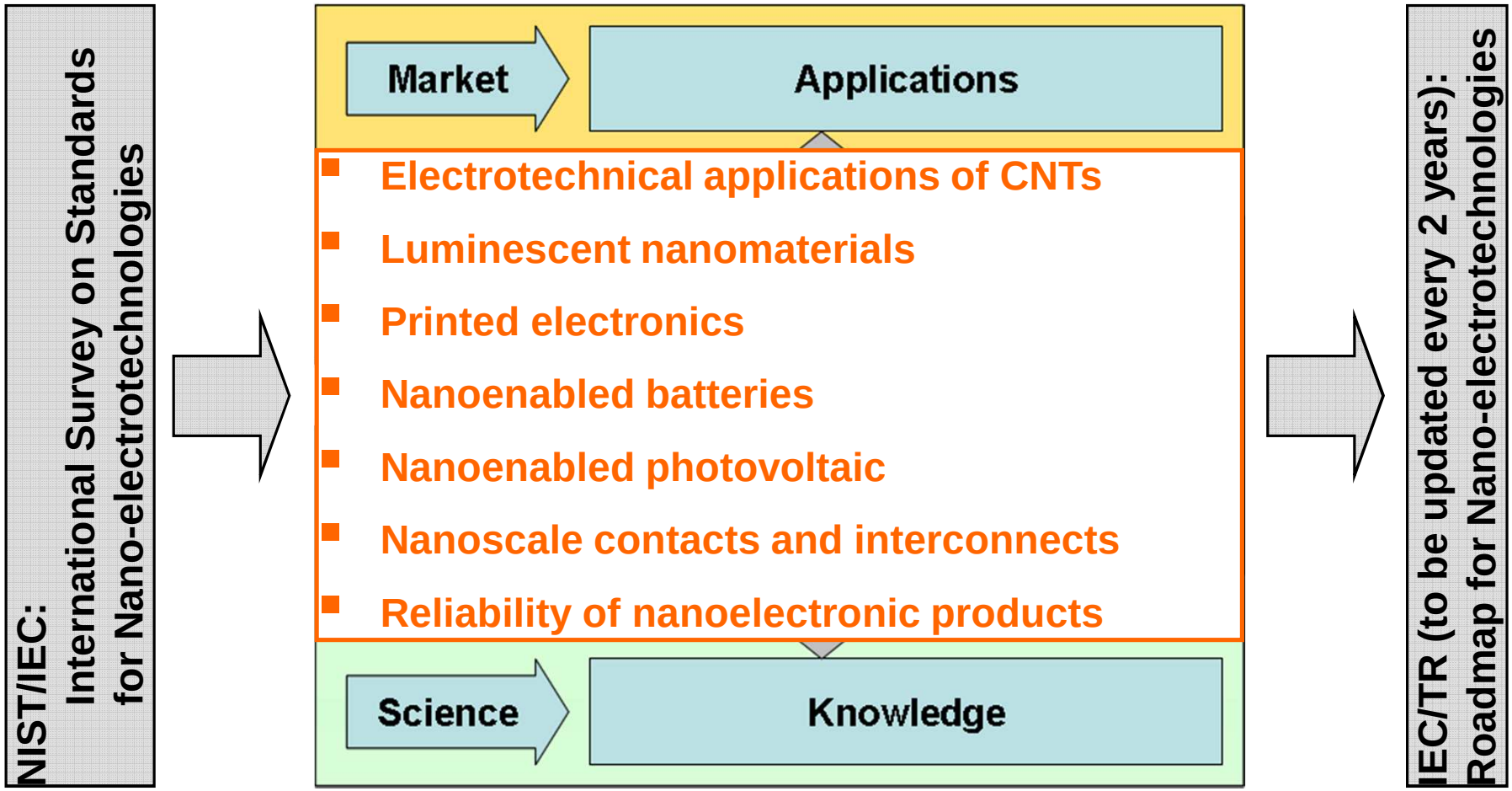
Current and potential liaisons for IEC/TC 113



IEC Nanoelectronic Standards Roadmap

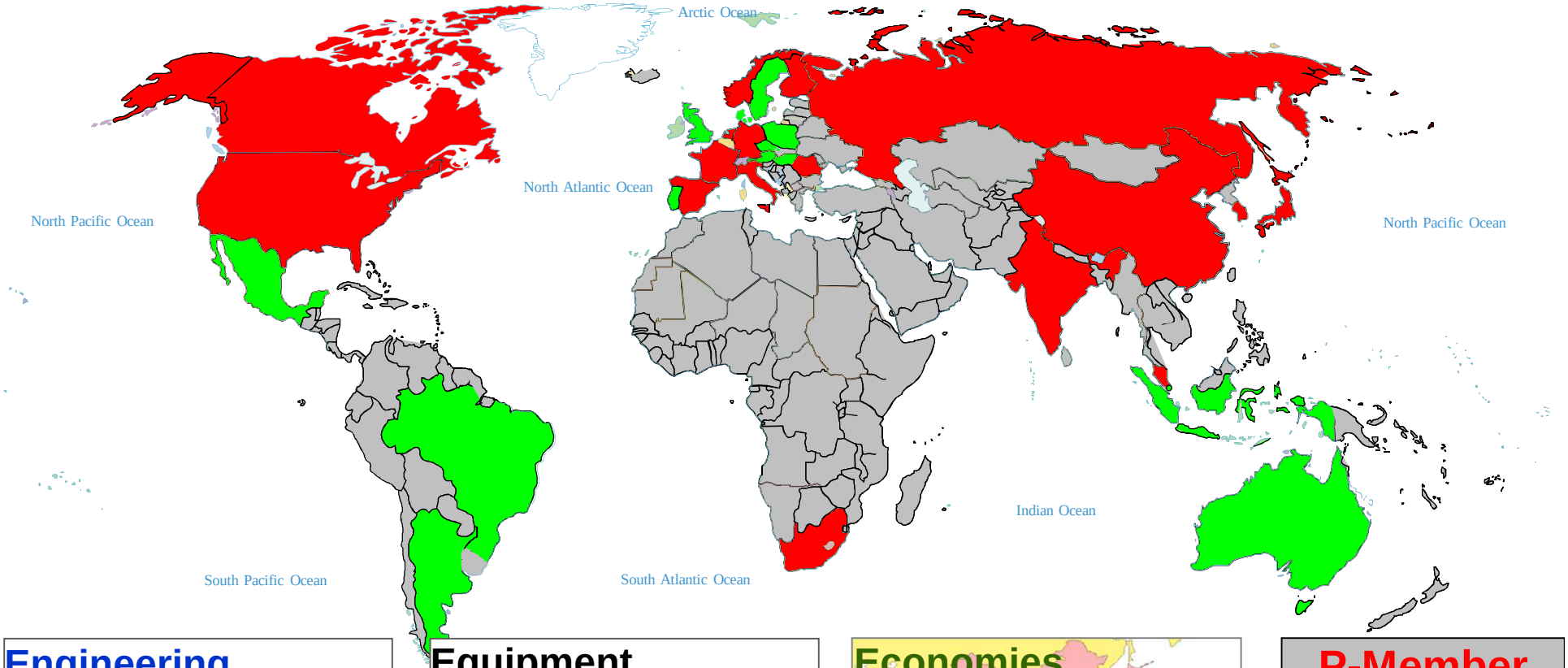


IEC Nanoelectronic Standards Roadmap



Standardization = Global Consensus Achievement

Example IEC/TC 113



Engineering

IEEE Nanotechnology Council

Equipment

semi

Economies

ANF

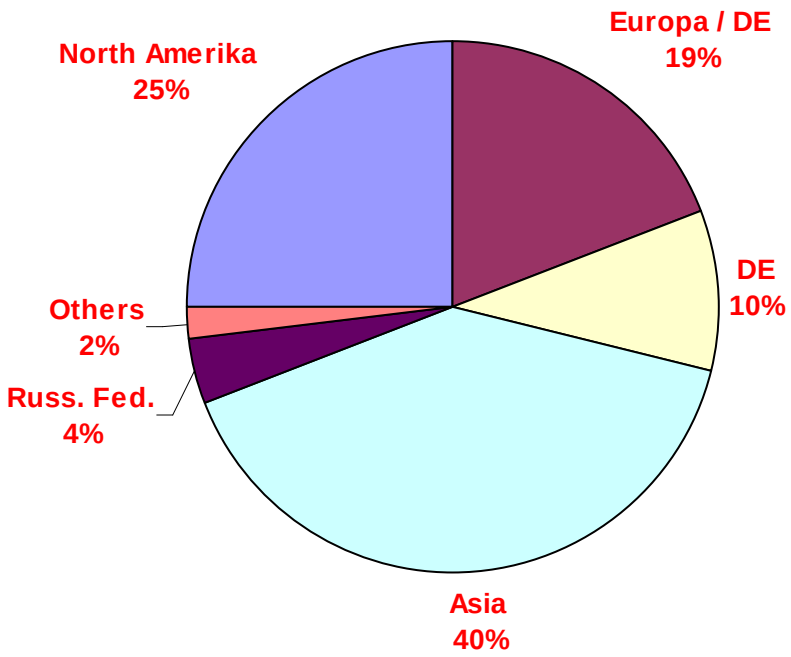
Hongkong
Taiwan

P-Member

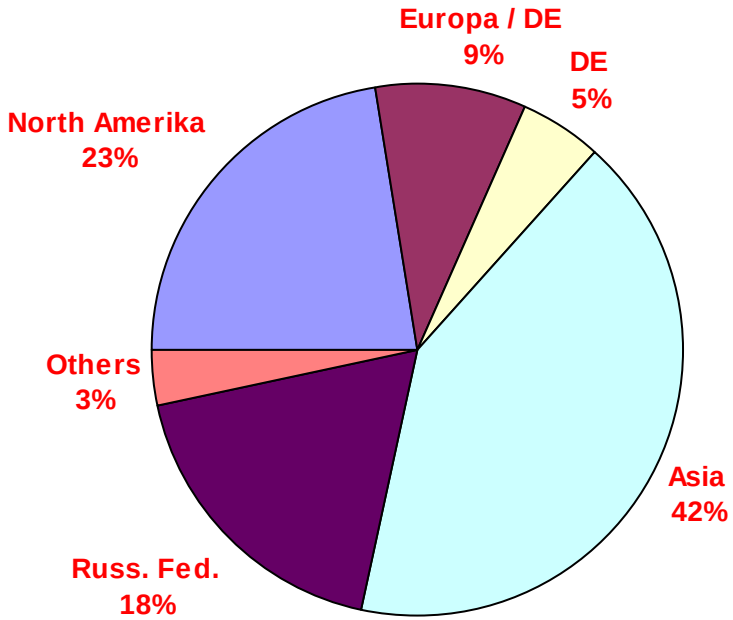
O-Member

National participation in IEC/TC 113

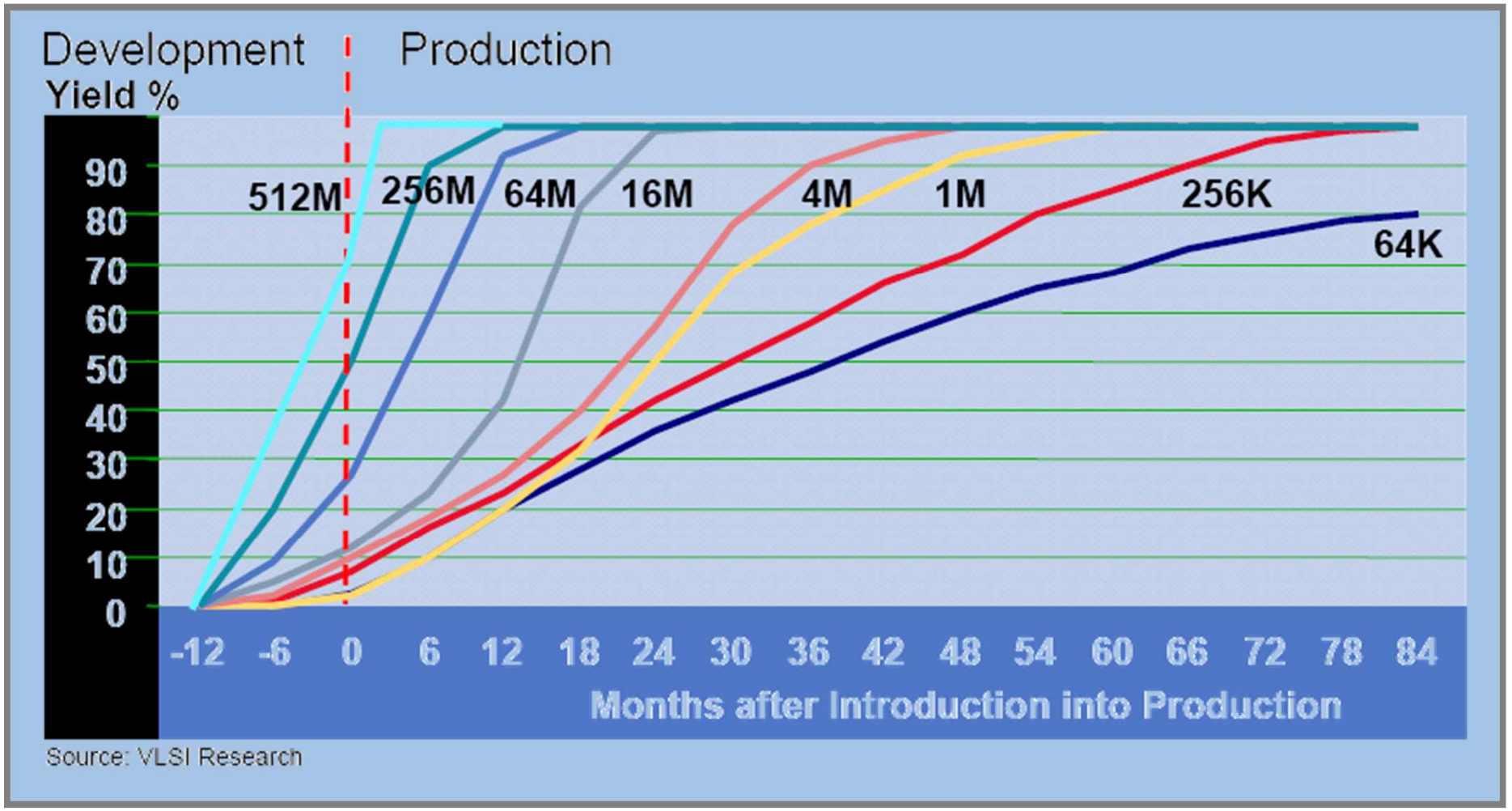
12/2008
52 Experts



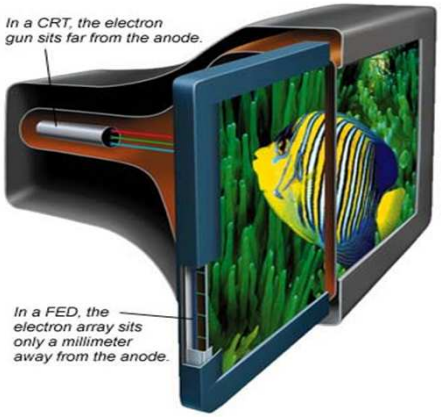
12/2010
154 Experts



Progress by QM / Material and Process Control:
Ramp up for DRAMs faster and faster



Value Adding Chain for Nano-Electronics

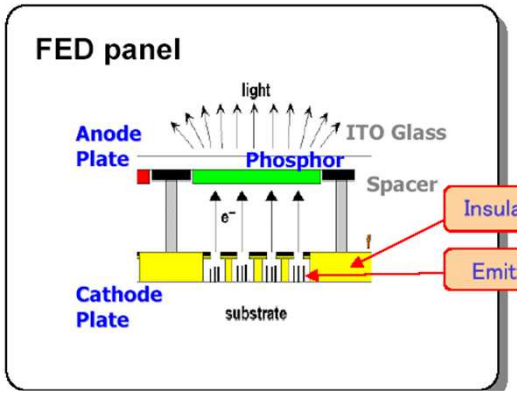


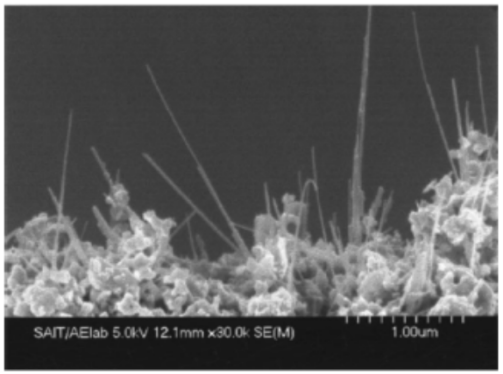
Nano Enabled Product

Example:

Flat Panel Displays made from CNT

Value Adding Chain for Nano-Electronics





Nano Enabled Product

System Integration

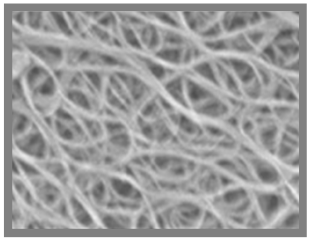
Nano Subassembly

Subassembly #1

Subassembly #N

Nano Materials & Processes

Nano Science

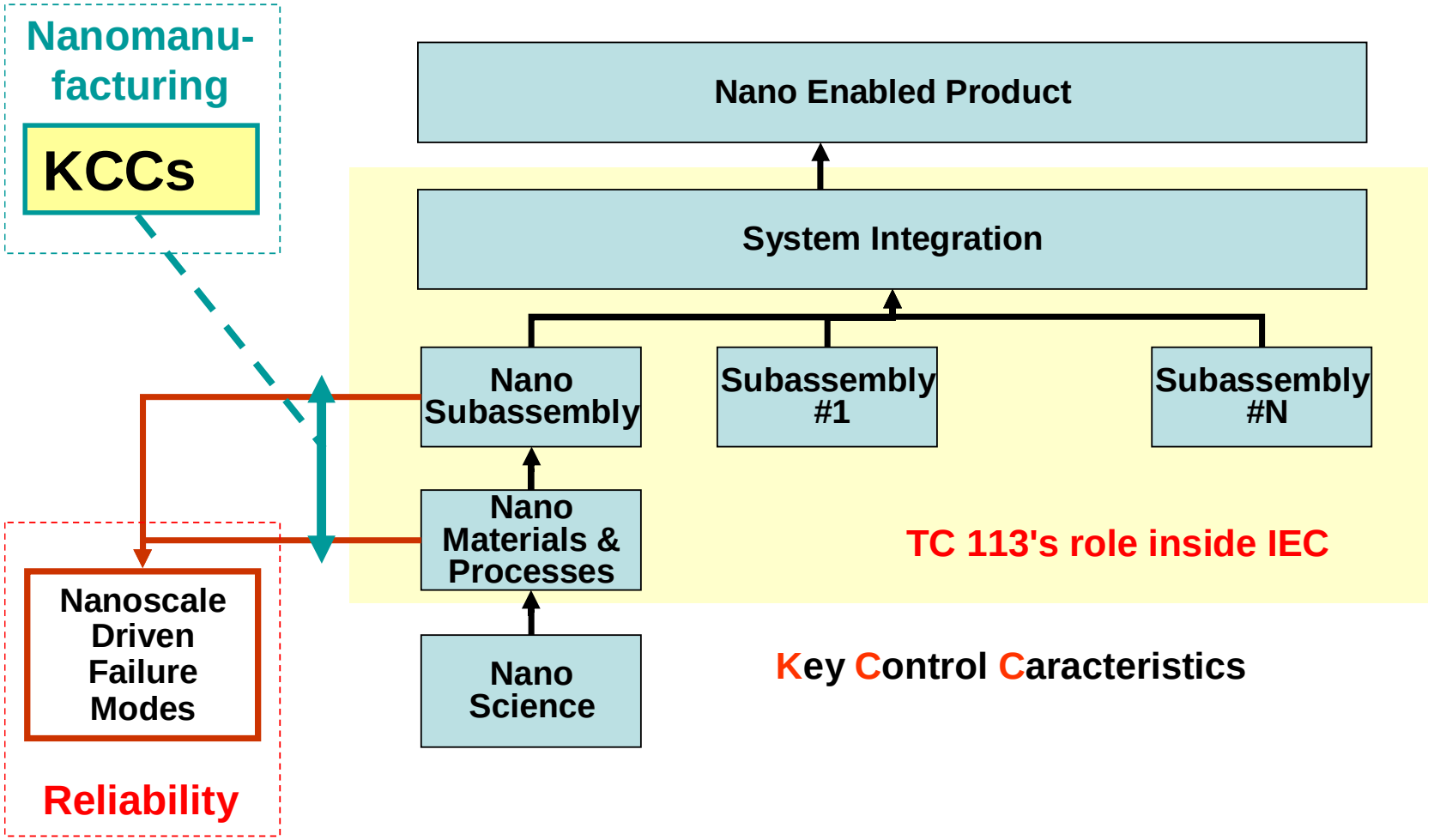


Key Control Caracteristic:

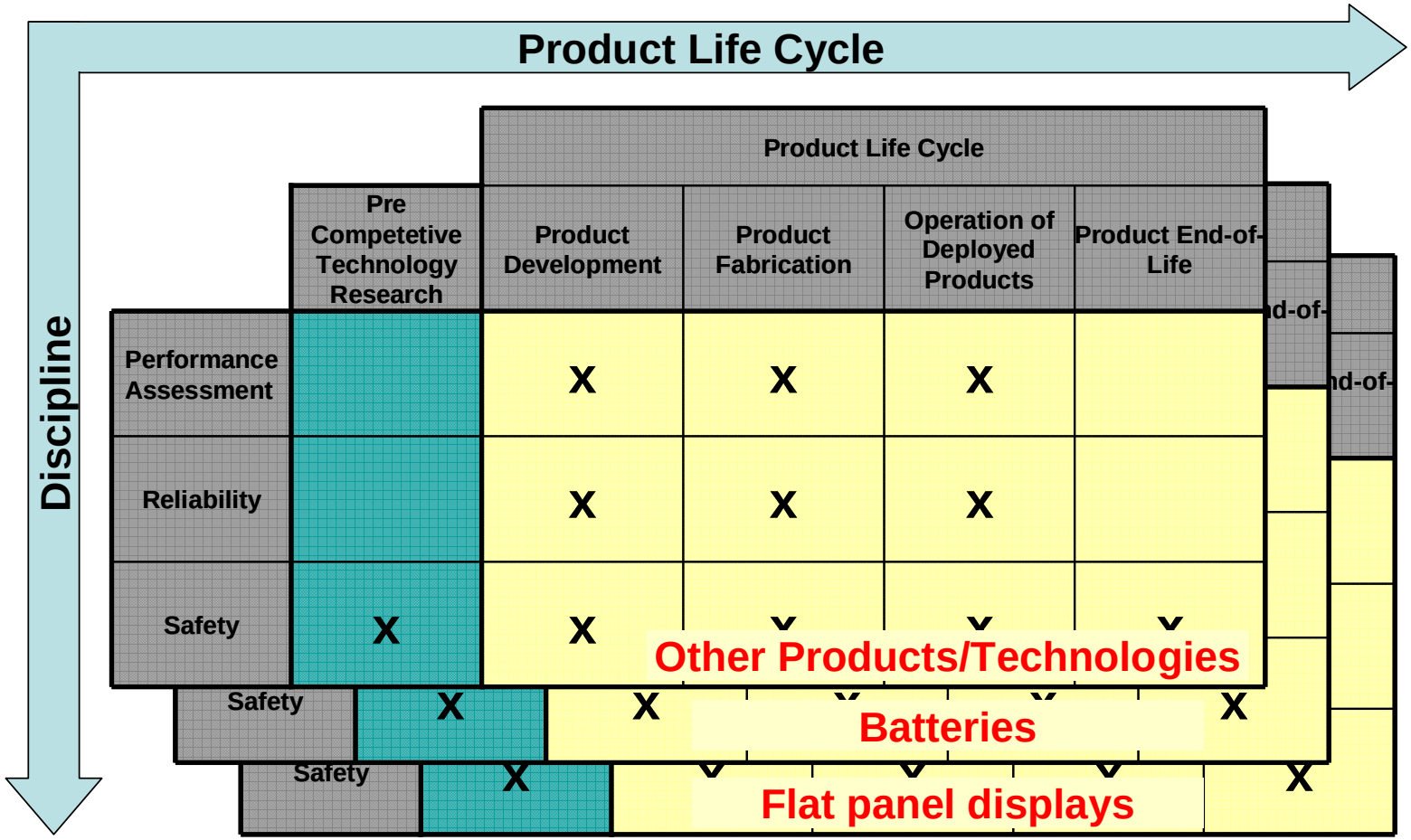
An electrical property describing the CNT raw material for this application

Prof. Young Hee Lee, Sungkyunkwan University, KO
Samsung

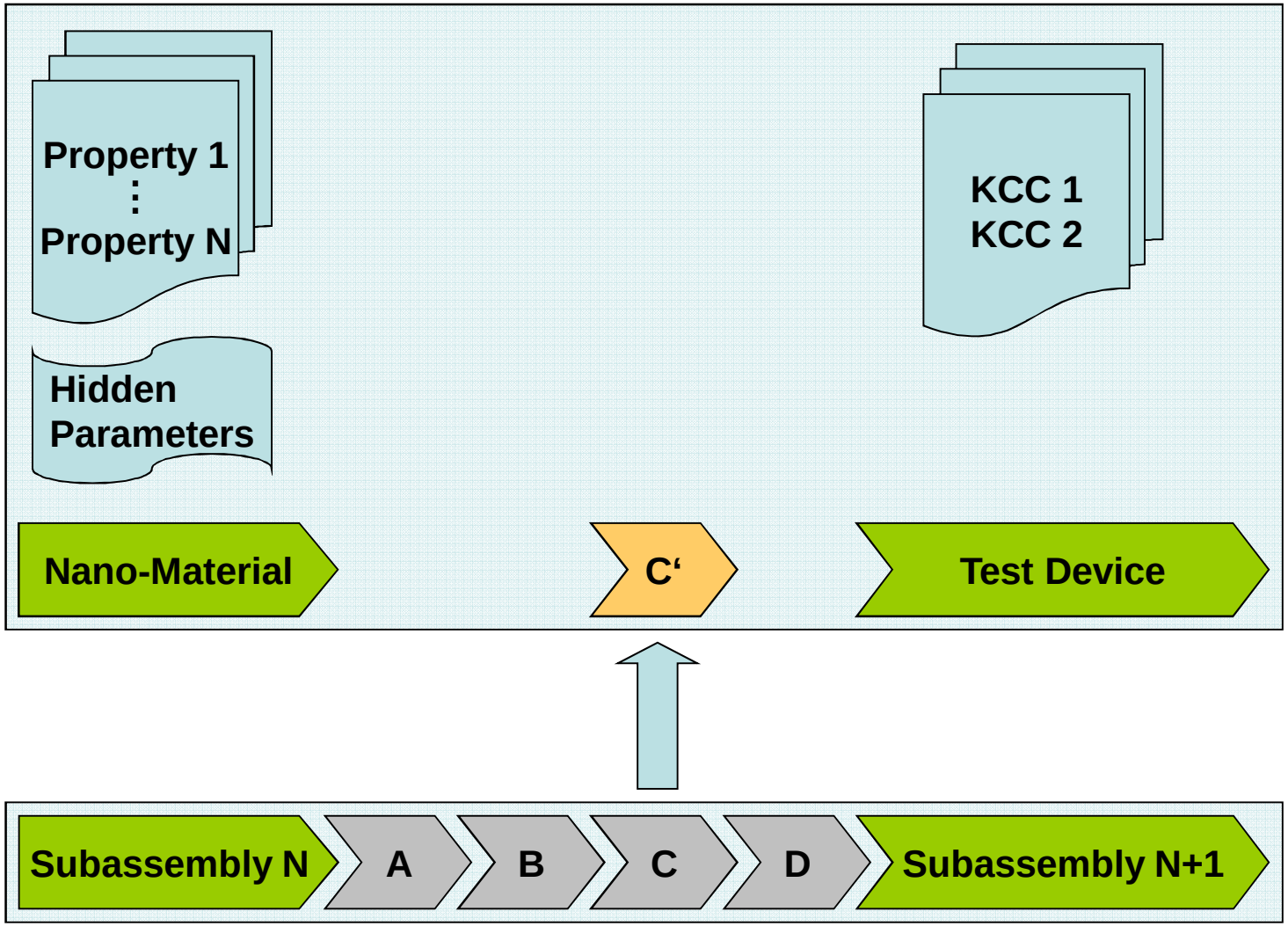
The Value Adding Chain



Standardization for the whole Product Life Cicle

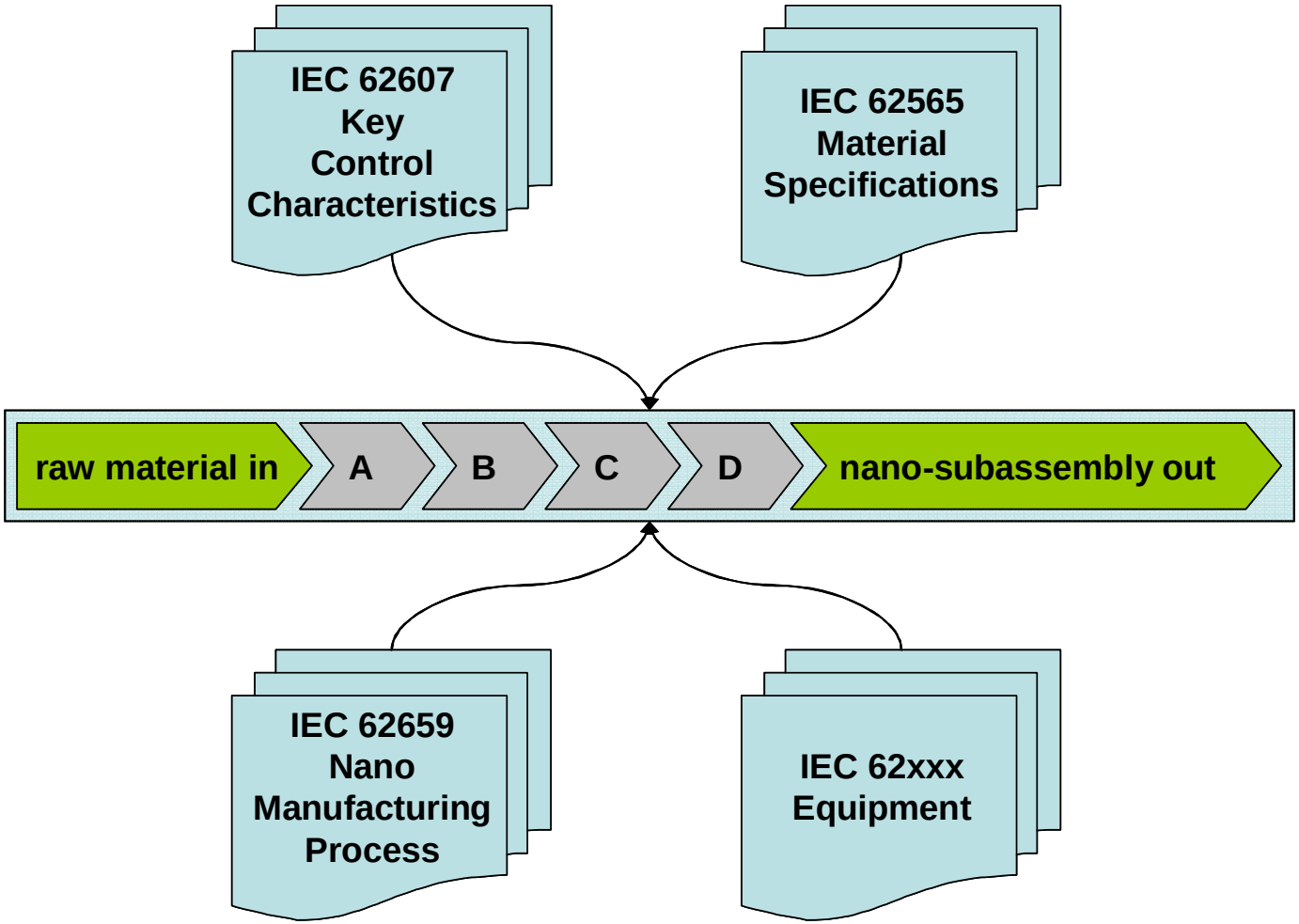


Material Specifications and Key Control Characteristics

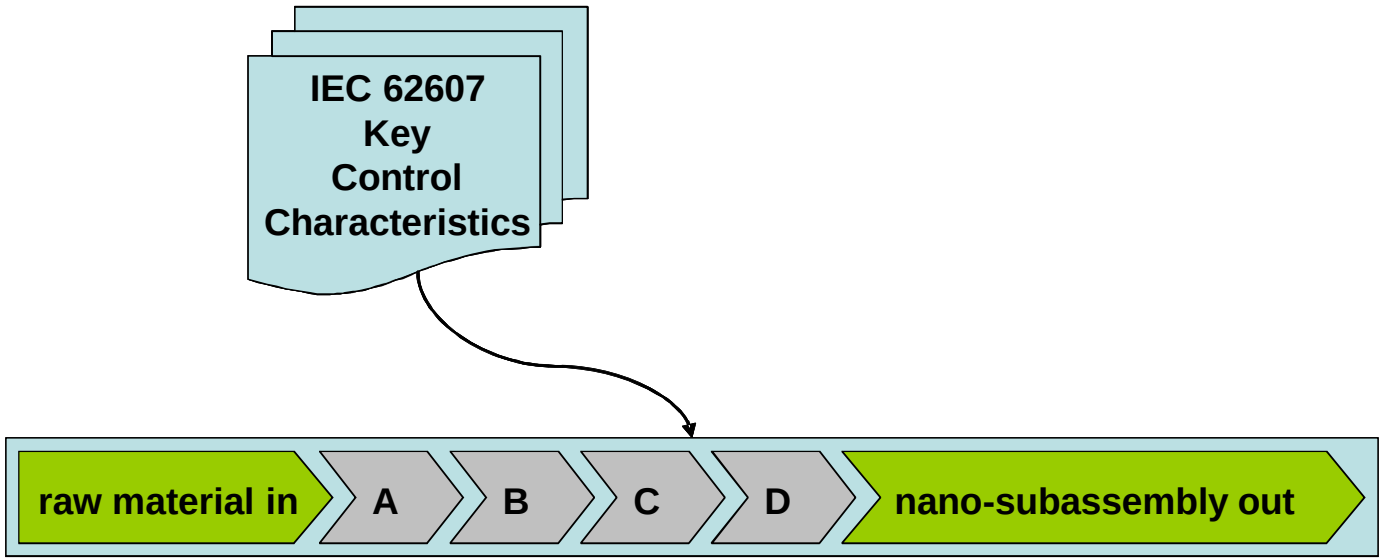


Process C‘ = Control Process C

Standards for Nanofabrication



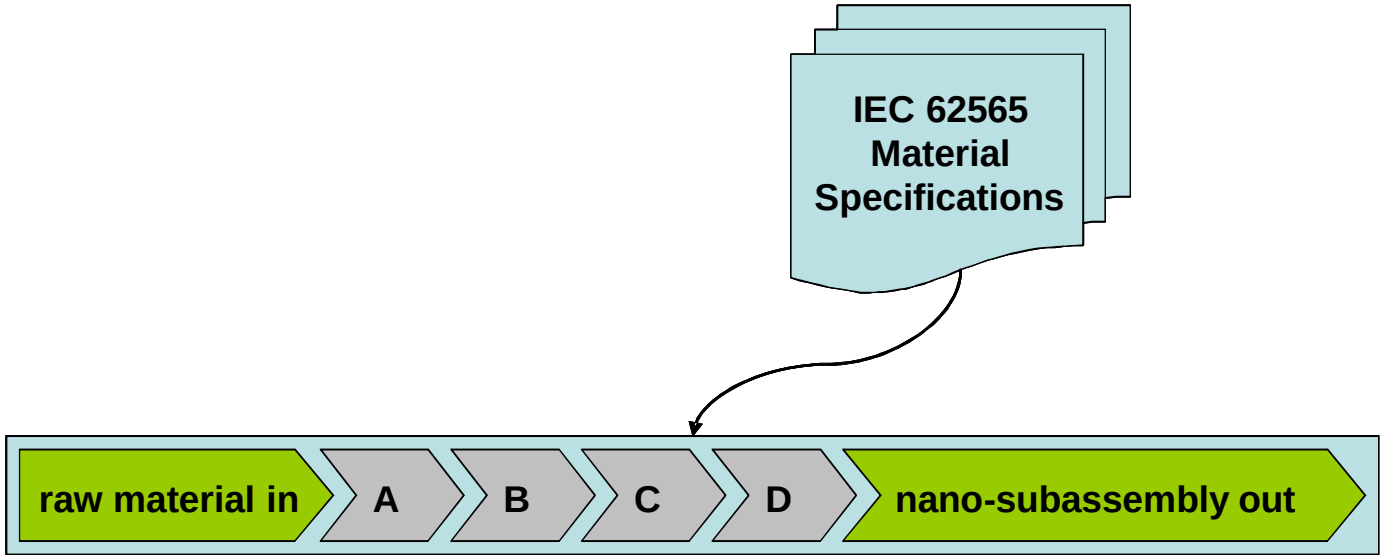
Standards for Nanofabrication: Key Control Characteristics



IEC 62607: Nanomanufacturing – Key control characteristics

- **Part 2-1: Carbon nanotube materials - Film resistance**
- **Part 3-1: Luminescent nanoparticles - Quantum efficiency**

Standards for Nanofabrication: Blank Detail Specifications



IEC 62565: Nanomanufacturing - Material specifications

- **Part 1: Basic concept**
- **Part 2-1: Single-wall carbon nanotubes - Blank detail specification**

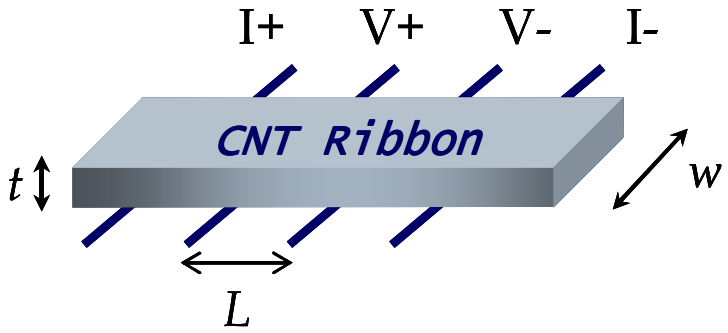
Standards for Nanofabrication: Blank Detail Specifications

IEC 62565: Nanomanufacturing - Material specifications

- **Part 1: Basic concept**
- **Part 2-1: Single-wall carbon nanotubes - Blank detail specification**
- **Part 3-1: Multiwall carbon nanotubes - Blank detail specification**
- **Part 4-1: Graphene - Blank detail specification**
- **Part 5-1: Quantum dots- Blank detail specification**
- **Part 6-1: Nano-inks for printed electronics - Blank detail specification**

Key Control Characteristics: IEC/TS 62607

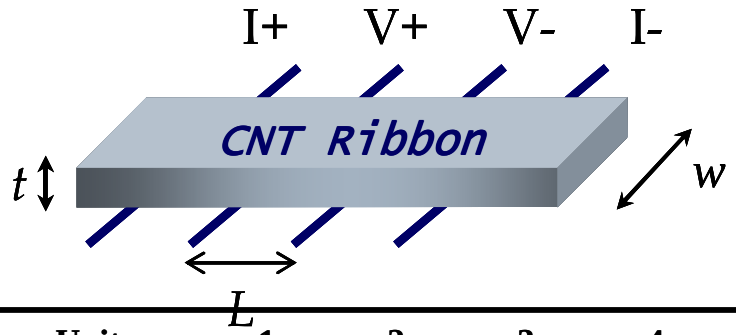
- **IEC 62607-2-1: Nanomanufacturing – Key control characteristics Part 2-1 Carbon nanotube materials - Film resistance**



- **Method to prepare a "ribbon" made from Carbon Nano Tubes and perform measurement and report results:**
  - **Description of the properties measured by the method**
  - **Recommendation for sample preparation**
  - **Outline of the experimental procedures**
  - **Interpretation on results and discussions on data analysis**
  - **Case studies**

Key Control Characteristics: IEC/TS 62607

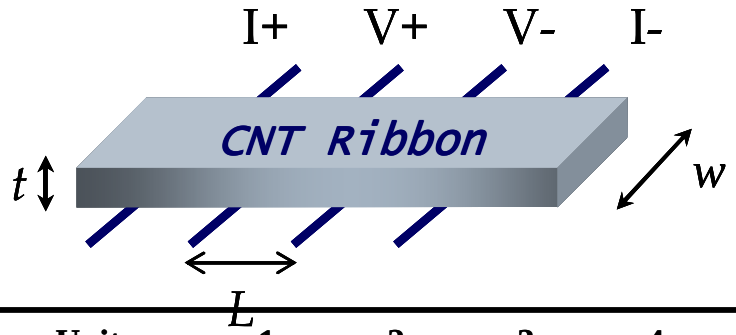
- **IEC 62607-2-1: Nanomanufacturing – Key control characteristics**
  Part 2-1 Carbon nanotube materials - Film resistance



CNT	Units	1	2	3	4	5	Av
MWNT (A)	R (Ω)	19.03	27.27	27.04	20.83	20.38	
	ρs (Ω/sq.)	5.45	5.45	5.41	5.42	5.43	5.43±0.02
MWNT (B)	R (Ω)	2080	1920	1860	1680	1310	
	ρs (Ω/sq.)	693.3	672.0	620.0	616.0	679.5	656.17±35.7
MWNT (C)	R (Ω)	226.8	185.6	210.3	225.4	202.6	
	ρs (Ω/sq.)	83.92	89.09	92.53	78.89	83.07	85.50±5.35
SWNT (D)	R (Ω)	9.55	7	7.4	7.6	6.4	
	ρs (Ω/sq.)	1.43	1.40	1.53	1.52	1.79	1.53±0.15
SWNT (E)	R (Ω)	38.9	36.0	52.1	38.2	36.1	
	ρs (Ω/sq.)	14.00	12.60	18.24	16.43	14.44	15.1±2.21

Key Control Characteristics: IEC/TS 62607

- **IEC 62607-2-1: Nanomanufacturing – Key control characteristics Part 2-1 Carbon nanotube materials - Film resistance**



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Risk Management for Nanotechnology

Companies needs standardized, clear and easy to implement risk management processes!

Excerpt from the work programme

- PWI/TR 62565: Nanomanufacturing - Material specifications
  - Part 1 - Basic concept
  - Part 2-1: Single-wall carbon nanotubes - Blank detail specification
- IEC/TS 62607-2-1: Nanomanufacturing - Key control characteristics
  - Part 2-1: Carbon nanotube materials - Film resistance
  - Part 3-1: Luminescent nanoparticles - Quantum efficency
- IEC/IEEE 62659 Large scale manufacturing of nanoelectronics
- PWI/TR 113-70: IEC nano-electronics standards roadmap
- PWI/TR 113-69: Nanoscale electrical contacts
- PWI 113-91: Guidelines of quality assessment for surface engineered nano electrotechnical products

TABLE 1. IEC/TC 113 Program of work: Published standards

IEC or ISO Number	Title
IEC/PAS 62565-2-1	Nanomanufacturing - Material specifications - Part 2-1: Single-wall carbon nanotubes - Blank detail specification
IEC/IEEE 62624	Test methods for measurement of electrical properties of carbon nanotubes
ISO/IEC/TS 80004-1	Nanotechnologies - Vocabulary - Part 1: Core terms
ISO/IEC/TS 80004-3	Nanotechnologies - Vocabulary - Part 3: Carbon nano-objects

TABLE 2. IEC/TC 113 Program of work: Projects in progress, JWG 1: Terminology and nomenclature

IEC or ISO Number	Title
ISO/IEC/TR 12802	Nanotechnologies - Model Taxonomic Framework for Use in Developing Vocabularies - Core Concepts
ISO/IEC/TR 14786	Nanotechnologies - Framework for nomenclature models for nano-objects
ISO/IEC/TS 80004-4	Nanotechnologies - Vocabulary - Part 4: Nanostructured materials
ISO/IEC/TS 80004-5	Nanotechnologies - Vocabulary - Part 5: Nano-bio interface
ISO/IEC/TS 80004-6	Nanotechnologies - Vocabulary - Part 6: Nanoscale measurement and instrumentation
ISO/IEC/TS 80004-7	Nanotechnologies - Vocabulary - Part 7: Healthcare - Diagnostics and therapeutics
ISO/IEC/TS 80004-8	Nanotechnologies - Vocabulary - Part 8: Nanomanufacturing processes
IEC/ISO/TS 80004-9	Nanotechnologies - Vocabulary - Part 9: Electrotechnical products and systems
IEC/ISO/TS 80004-10	Nanotechnologies - Vocabulary - Part 10: Photonics components and systems

TABLE 3. IEC/TC 113 Program of work: Projects in progress, JWG 2: Measurement and characterization

IEC or ISO Number	Title
ISO/IEC/TS 10797	Nanotechnologies - Characterization of single-wall carbon nanotubes using transmission electron microscopy
ISO/IEC/TS 13278	Nanotechnologies - Determination of elemental impurities in samples of carbon nanotubes using inductively coupled plasma mass spectrometry
IEC/ISO/TS 62622	Nanotechnologies - Description, measurement and dimensional quality parameters of artificial gratings

TABLE 4. IEC/TC 113 Program of work: Projects in progress, WG 3: Performance assessment

IEC or ISO Number	Title
PWI/TR 113-69	Nanoscale electrical contacts and interconnects
PWI/TR 113-70	IEC nanoelectronics standards roadmap
PWI 113-91	Guidelines of quality assessment for surface engineered nano-electrotechnical products
IEC/TR 62565-1	Nanomanufacturing - Material specifications - Part 1: Basic concept
IEC 62565-2-1	Nanomanufacturing - Material specifications - Part 2-1: Single-wall carbon nanotubes - Blank detail specification
IEC/TS 62607-2-1	Nanomanufacturing - Key control characteristics - Part 2-1: Carbon nanotube materials - Film resistance
IEC/TS 62607-3-1	Nanomanufacturing - Key control characteristics - Part 3-1: Luminescent nanoparticles - Quantum efficiency
IEC/IEEE 62659	Large scale manufacturing of nanoelectronics

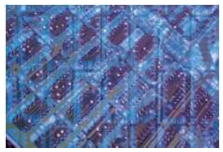
Participation on the Standardization Process

To Support:

Global Market

- **Members of the IEC technical committees …**

  reduce international barriers for global trade. Companies which send their employees into committees knows about upcomming standards early.



Innovation

- **Members of the IEC technical committees …**

  meet other technical experts and exchange up-to-date technical information. It's proven that companies which are active in standardization are typically well positioned in the market.

Efficiency

- **Members of the IEC technical committees …**

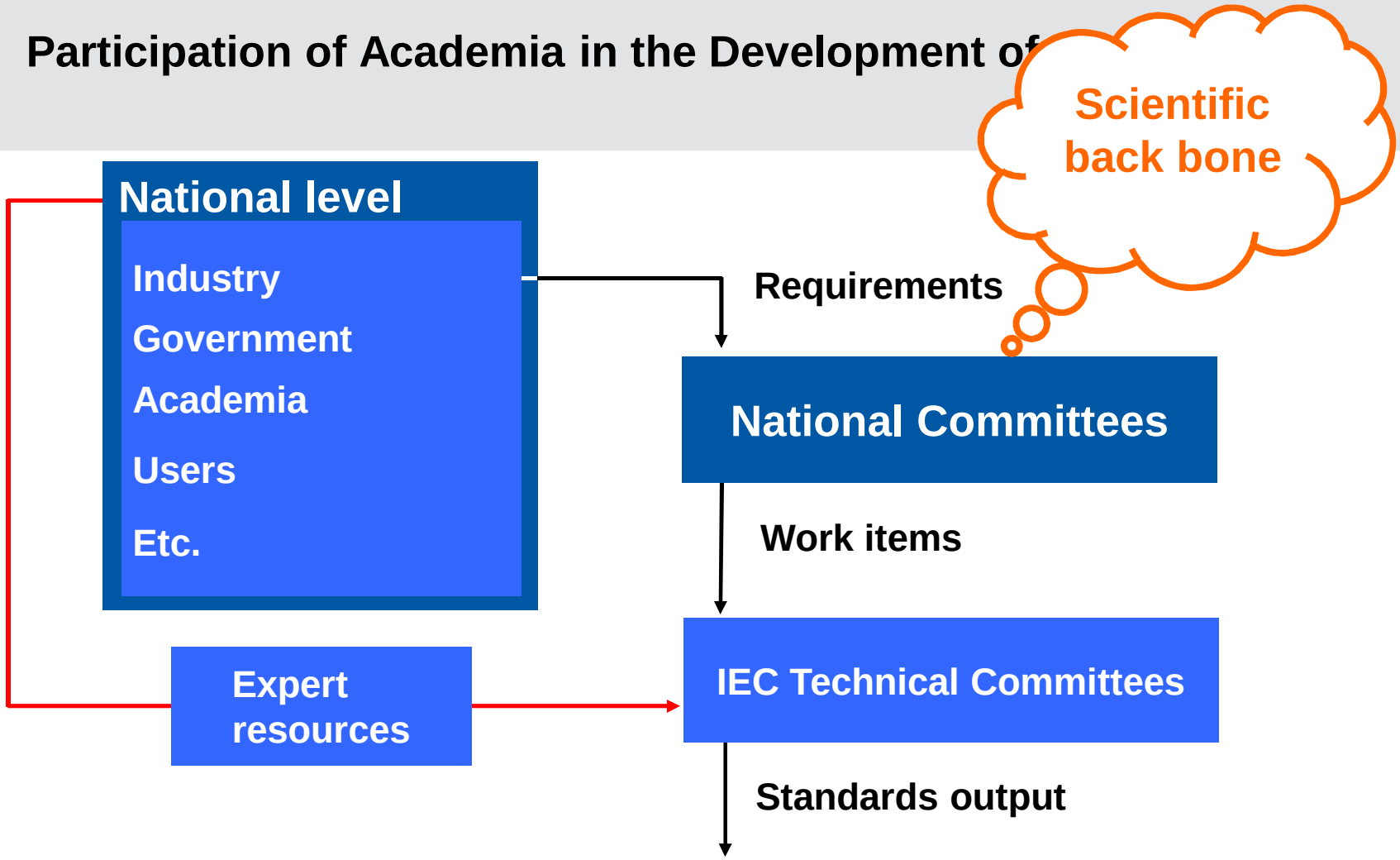
  helps to increase efficency in fabrication and business processes. Companies can concetrate on product design if the dayly working processes are supported by standards.

Regulation

- **Members of the IEC technical committees …**

  defines the state-of-the-art in a technology and supports regulation processes. Companies active in standardization feed in their stakeholder know-how before regulation takes place.

Participation of Academia in the Development of



Increase the participation of academia in the standardization process

- Mandatory evaluation of research projects regarding their impact on standardization
- Benefit of participation in standardization for the academic career
- Founding of travelling cost to international standardization meetings

Importance of Nanotechnology Standardization in the Chinese Scientific Community

"Summary" or "is there any Benefit from Standardization" ?