More than Moore
or More Moore: a SWOT analysis

g dan hutcheson

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More Moore v More than Moore

- Europeans popularized in 2000's
  - Sound bites "No Exponential is Forever"
  - In 90's Moore expressed doubts
- MM: who knows when it will end
- MtM: a new ontology for semiconductors
  - The new reality after MM?
  - A new business model

Moore's Law Refresher

- A doubling of components
  - in a year (1965, modified to 2 years in 1975)
  - for roughly the same manufacturing cost
  - due to lithographic shrinking
    - Shrinkonomics
  - 1st work in Innovation Economics

Moore's clock of economic innovation:

- How long it takes to
  - halve the cost
  - in a measure of user value
  - with a known innovation vector

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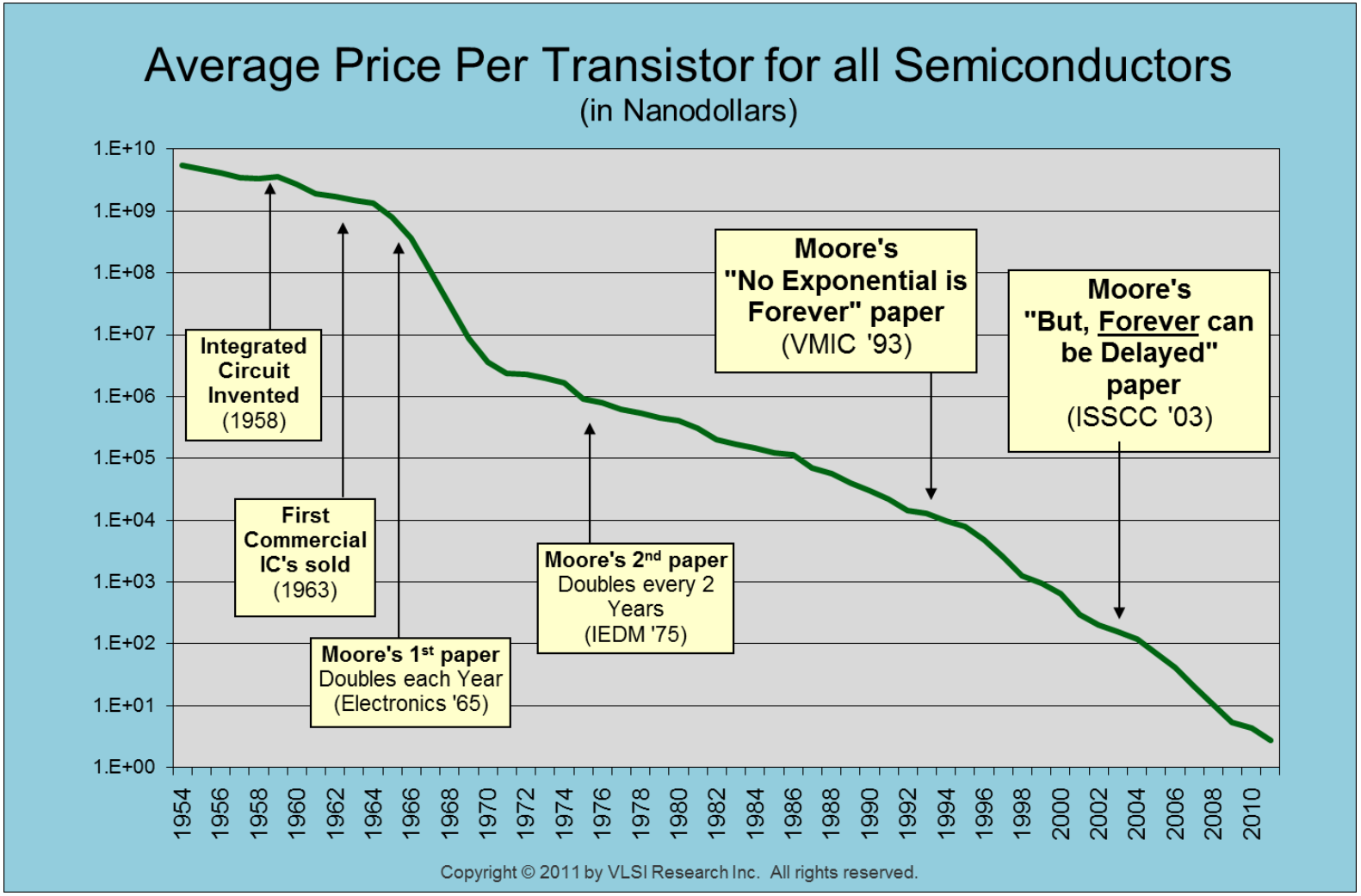
Strengths of More Moore

- Declining Cost per Function
  - Made possible by steady innovation
  - Self-fulfilling prophesy
- Bryant's corollary
  - Need less capacity = free fabs
- Social feedback loop
  - drives technologists & financiers
  - Success with each node reinforces the effort
  - Resources far larger than More Than Moore

Moore's Law and the value of Shrinkonomics



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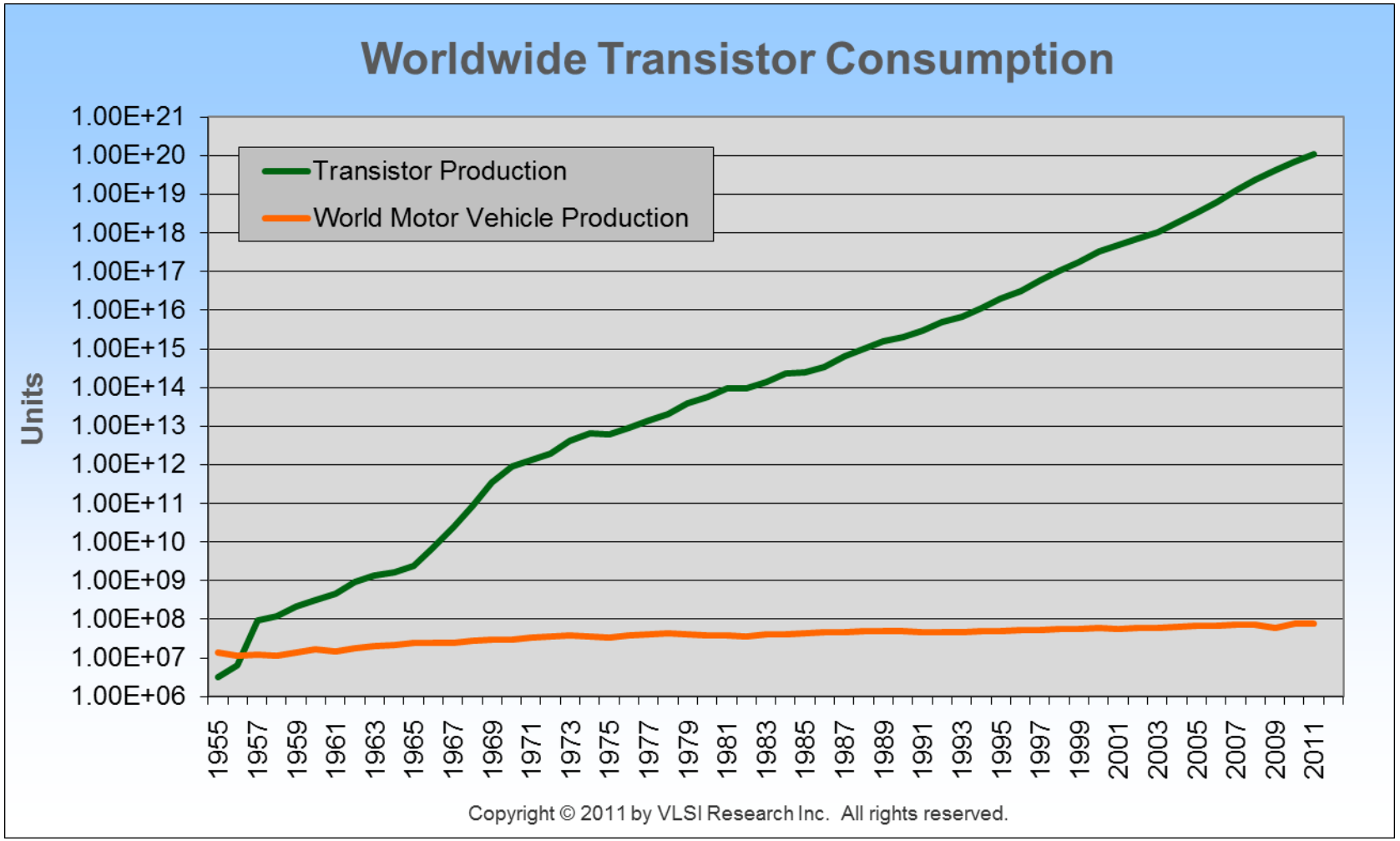
Moore's Law Drives Consumption



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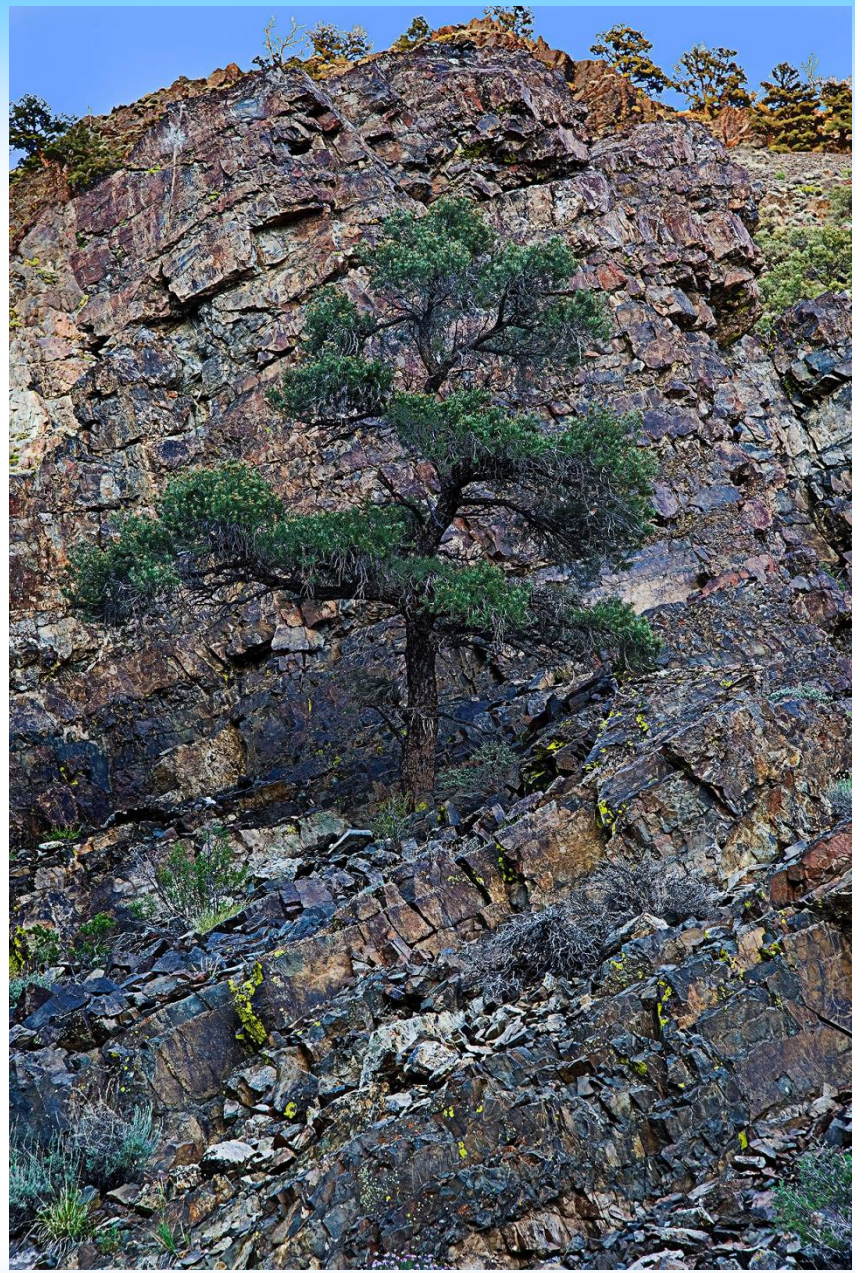
Moore's Wall is the poor vision of many a prophet

- 1968: End of Optical Lithography seen as bringing ML to a close, with multiple follow-on's throughout the 70s, 80s, and 90s, until people tired of the *death of optical* argument
- 1993: Even Moore loses faith with *No Exponential is Forever* VMIC speech
- 1996: my 1st Scientific American article published, with the commission to address growing questions about Moore's Wall.
  - the answer: Failure Mode would be Economics, not technology and not expected any time soon
  - same answer in a follow-up article in 2004
- 2003: *But, Forever can be Delayed* Moore at ISSCC



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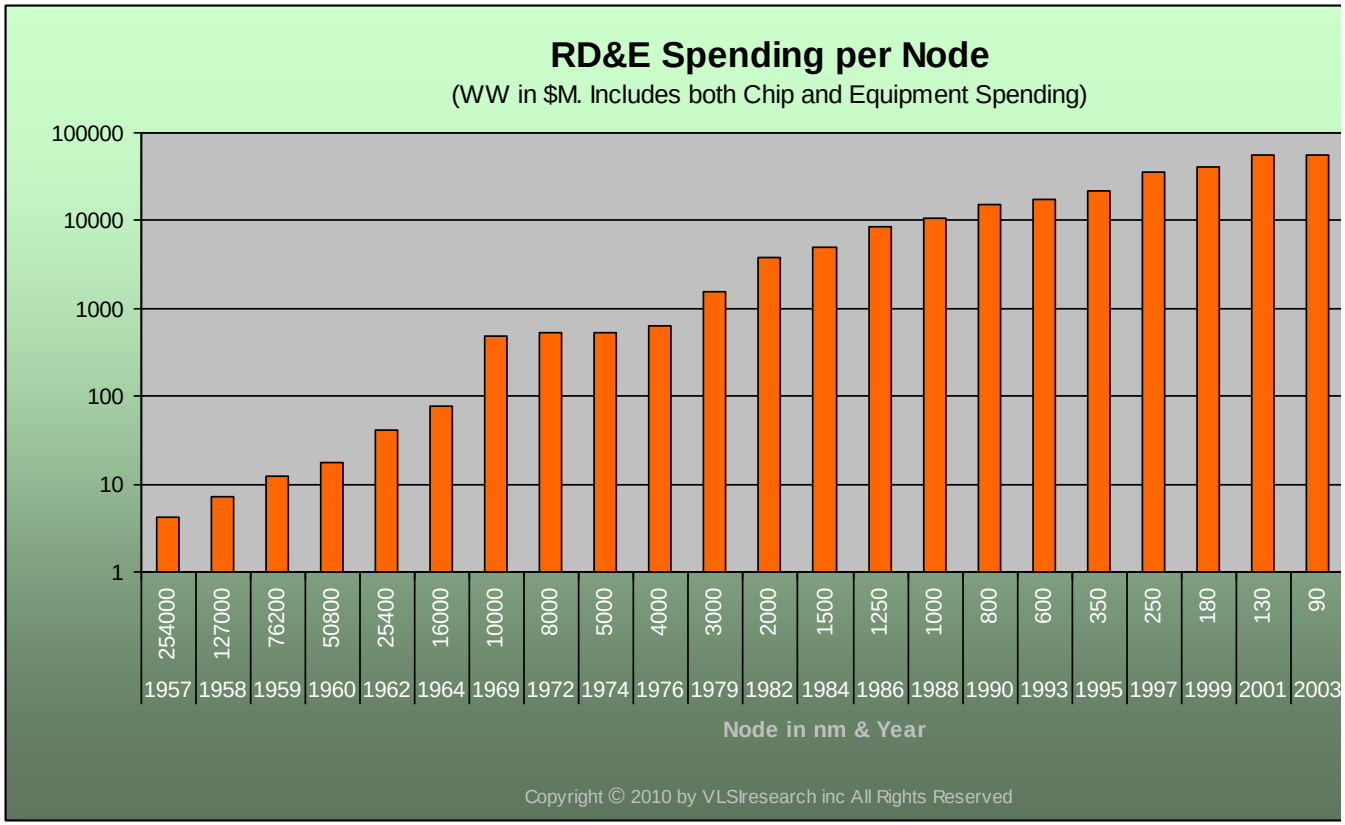
Weaknesses

2004: The R&D Crisis

First given at ISMI Manufacturing Week



- Chip sales growth
  - ~6%
  - 1995 – 2004
- R&D Spend growth
  - 12%
  - By 2020,
- if unabated,
  - R&D spend reaches 40%

Clearly unaffordable

- Either:
- Slow ML
- or up RONR

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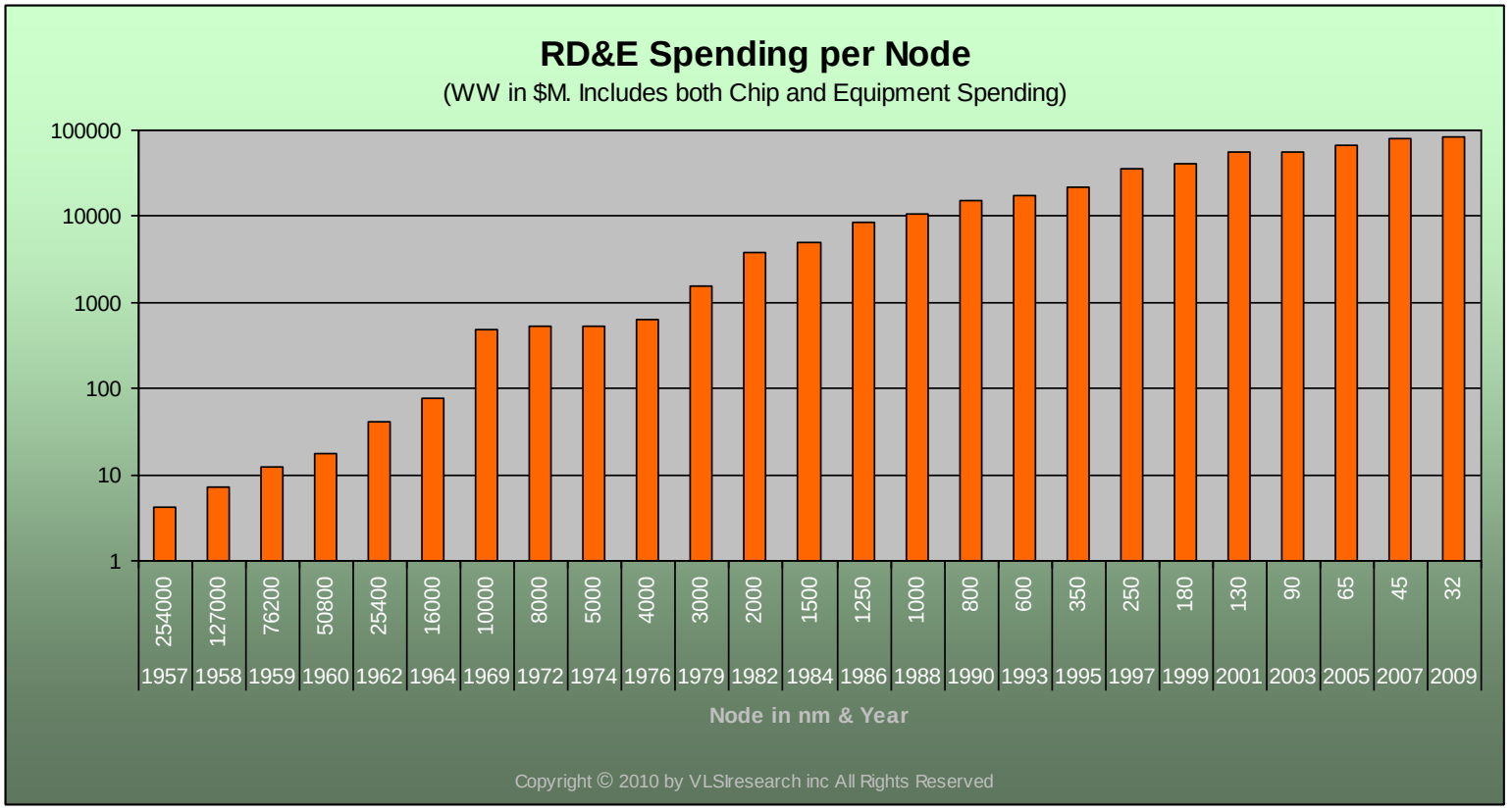
2010: The R&D Crisis Averted

First given at ISS 2010



32 nm brought to production with only a 2.2% rise in R&D cost

Proof that Coopetition & Consolidation Work

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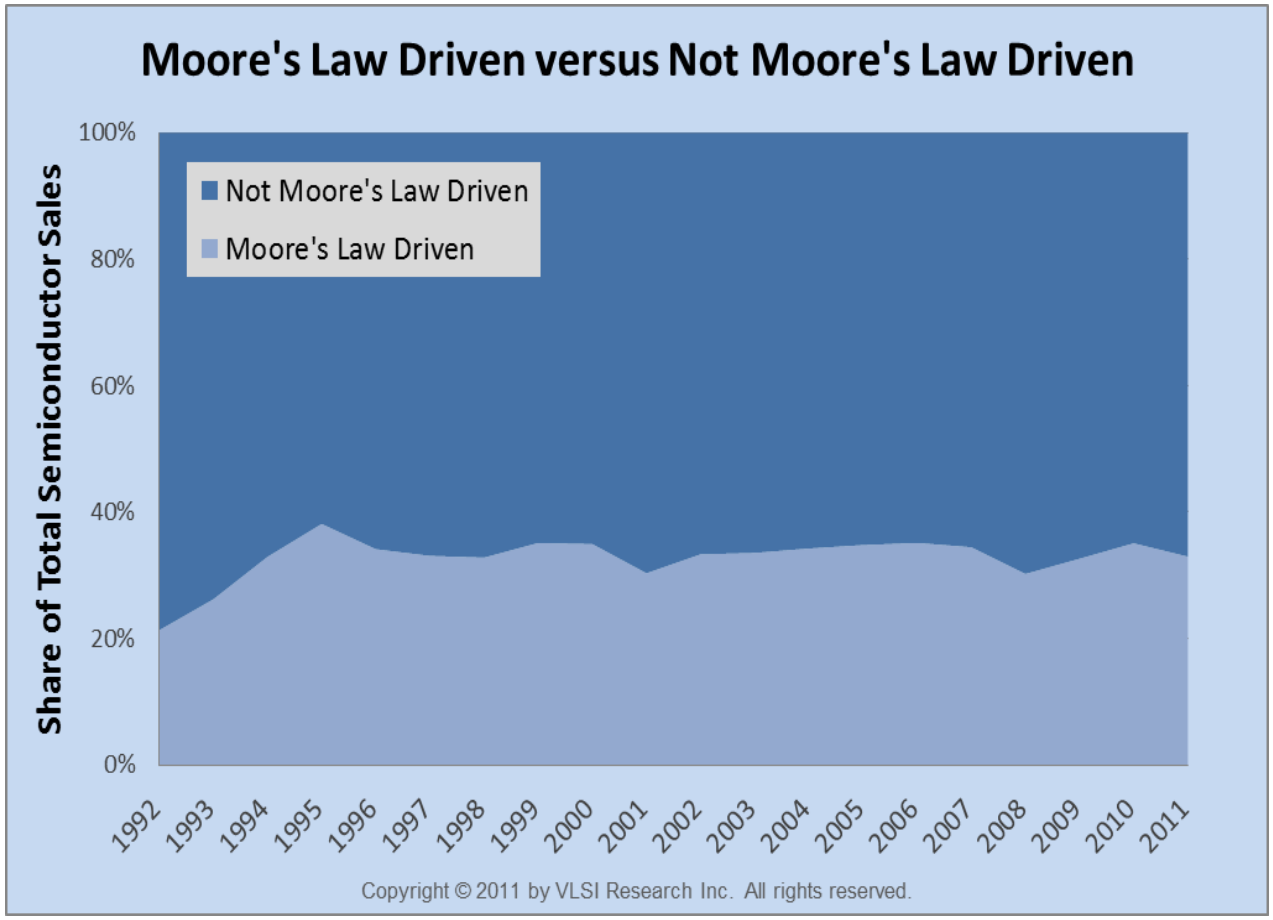
Weakness

But…Moore's Law has not driven a Revenue Growth Difference



Moore's Law Driven =

- NAND
- DRAM
- MPU

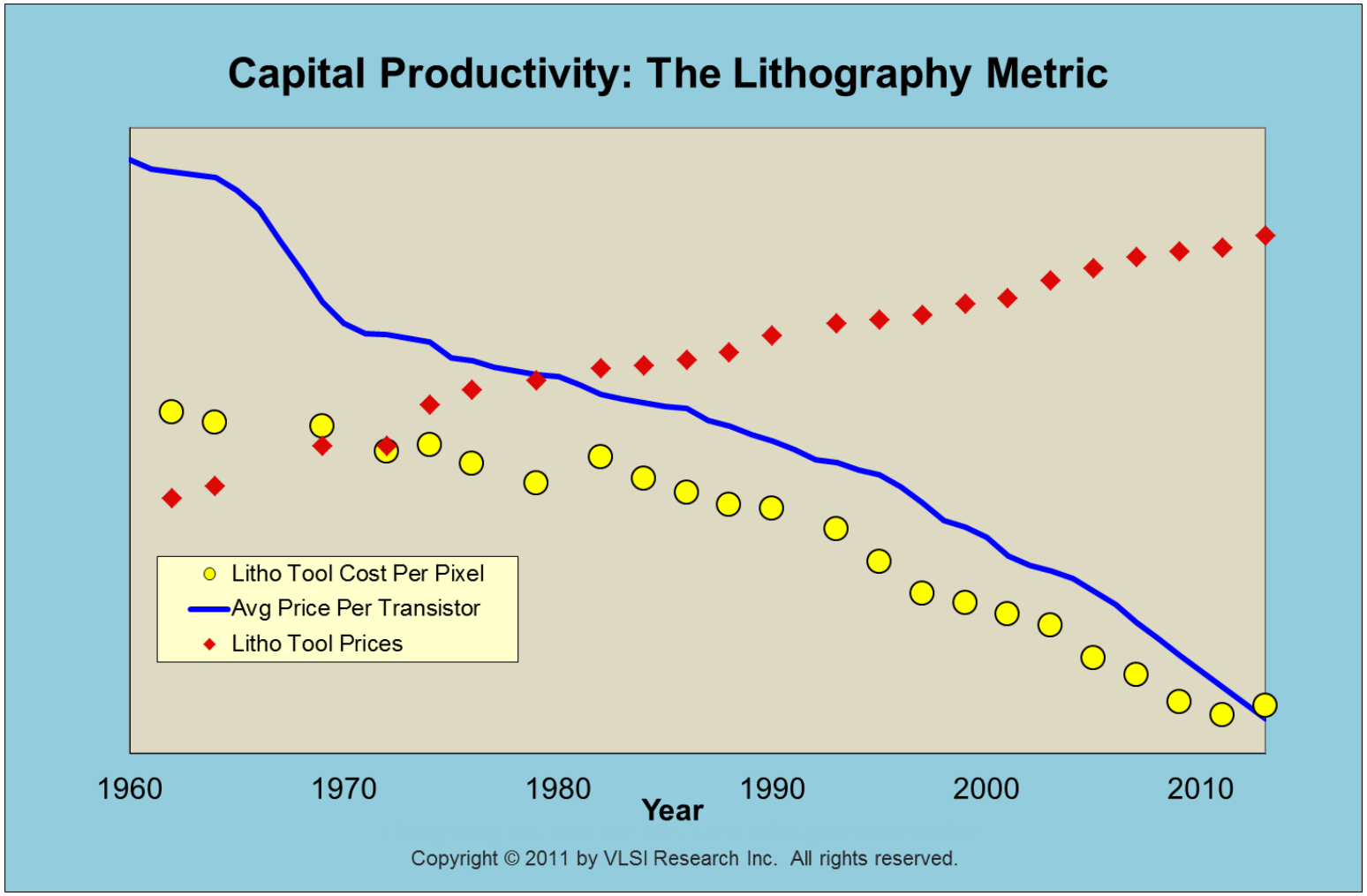
Moore's Law Laggards =

- everything else

The reason?

- Most Moore's Law Gains are Given Up in Price
  - DRAM -12%
  - NAND -16%
  - MPU -1%
  - Average -3%

Threat: Keeping Moore's Law on track will be a Bigger Challenge in this Decade



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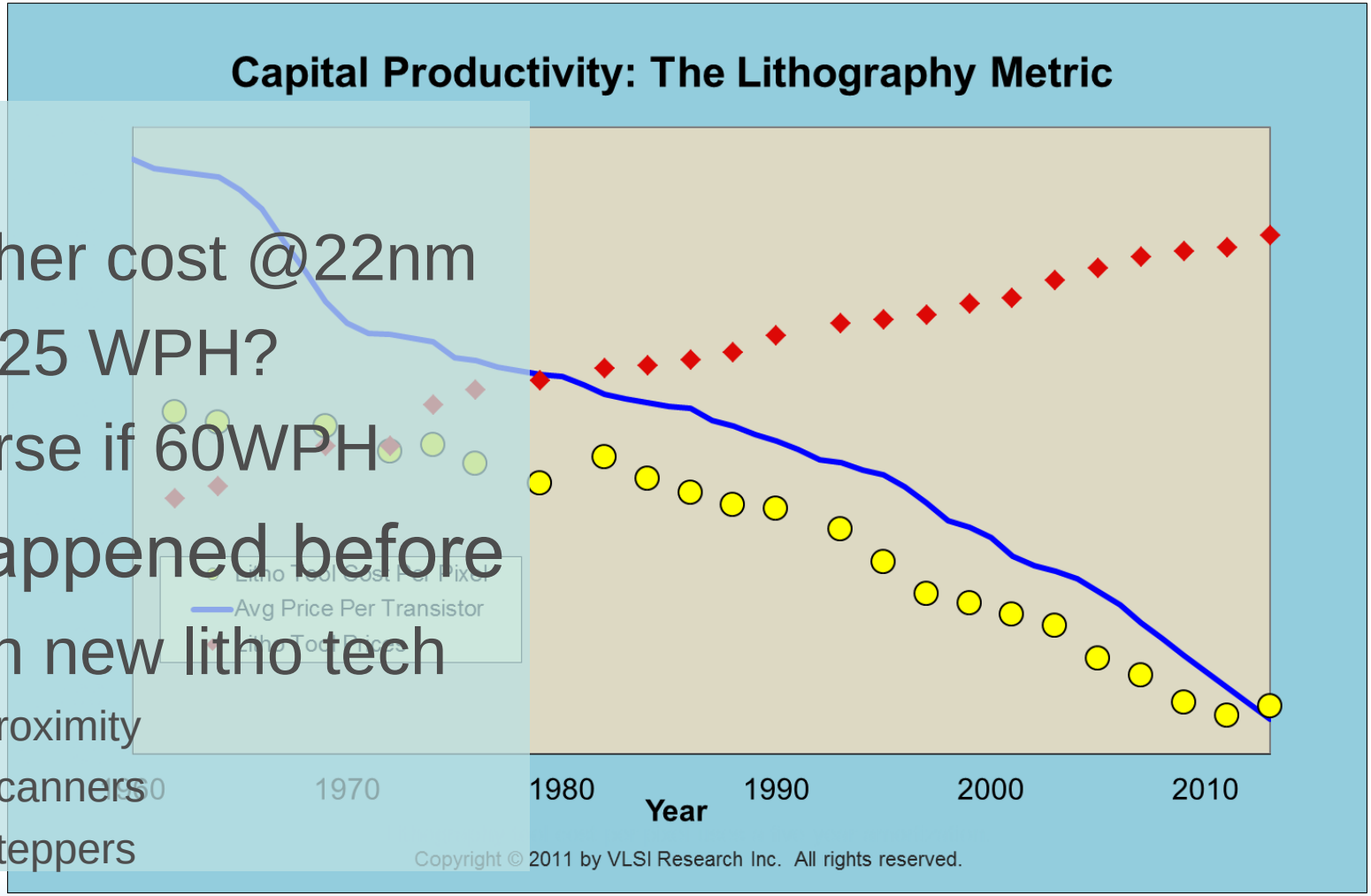
Opportunity

Litho often stalls with new generations

Hence the need for new wafer sizes

- EUV
  - Higher cost @22nm
  - @125 WPH?
  - Worse if 60WPH
- It's happened before
  - With new litho tech
    - Proximity
    - Scanners
    - Steppers



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Opportunity

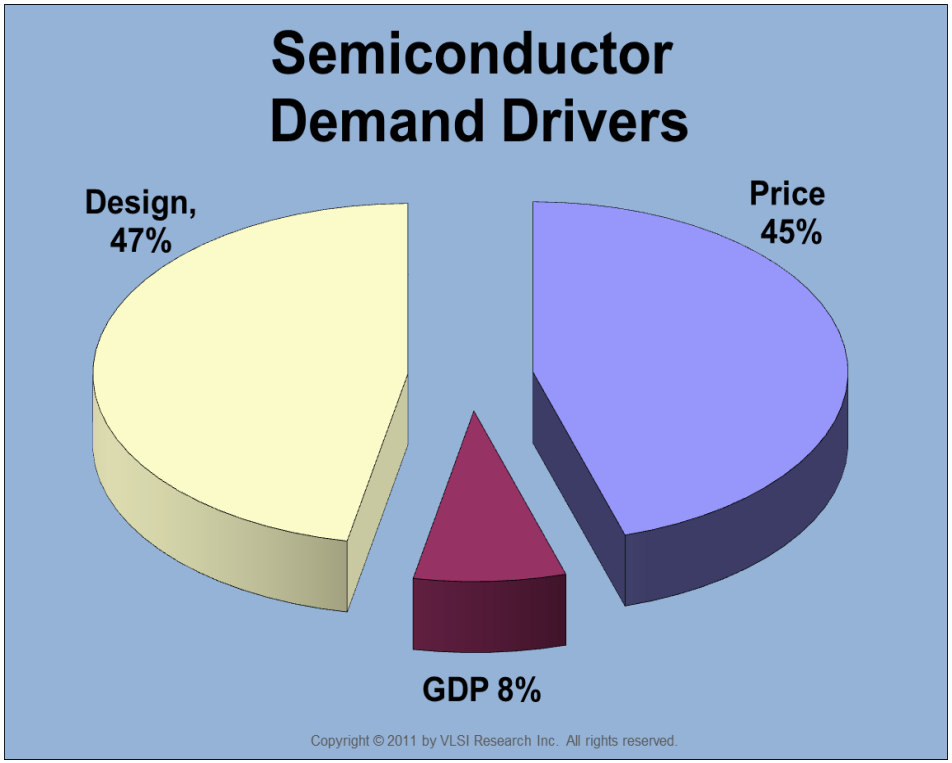
The New Era of Materials

- **1G**: Copper, Capacitor HiK – TaO2, Ru
- **2G**: LoK & Strain … Ge
- **3G**: HiKMG …Hf_xO_x
- **4G**: III-V, III-IV, Ge, Ga, GaN, TiO_2
- **Drivers: Nanochips**
  - device physics a new game <100nm
  - power for battery life & mobility
  - power for fewer losses in transmission
    - Power chips for green tech

Why Care About Moore's Law?

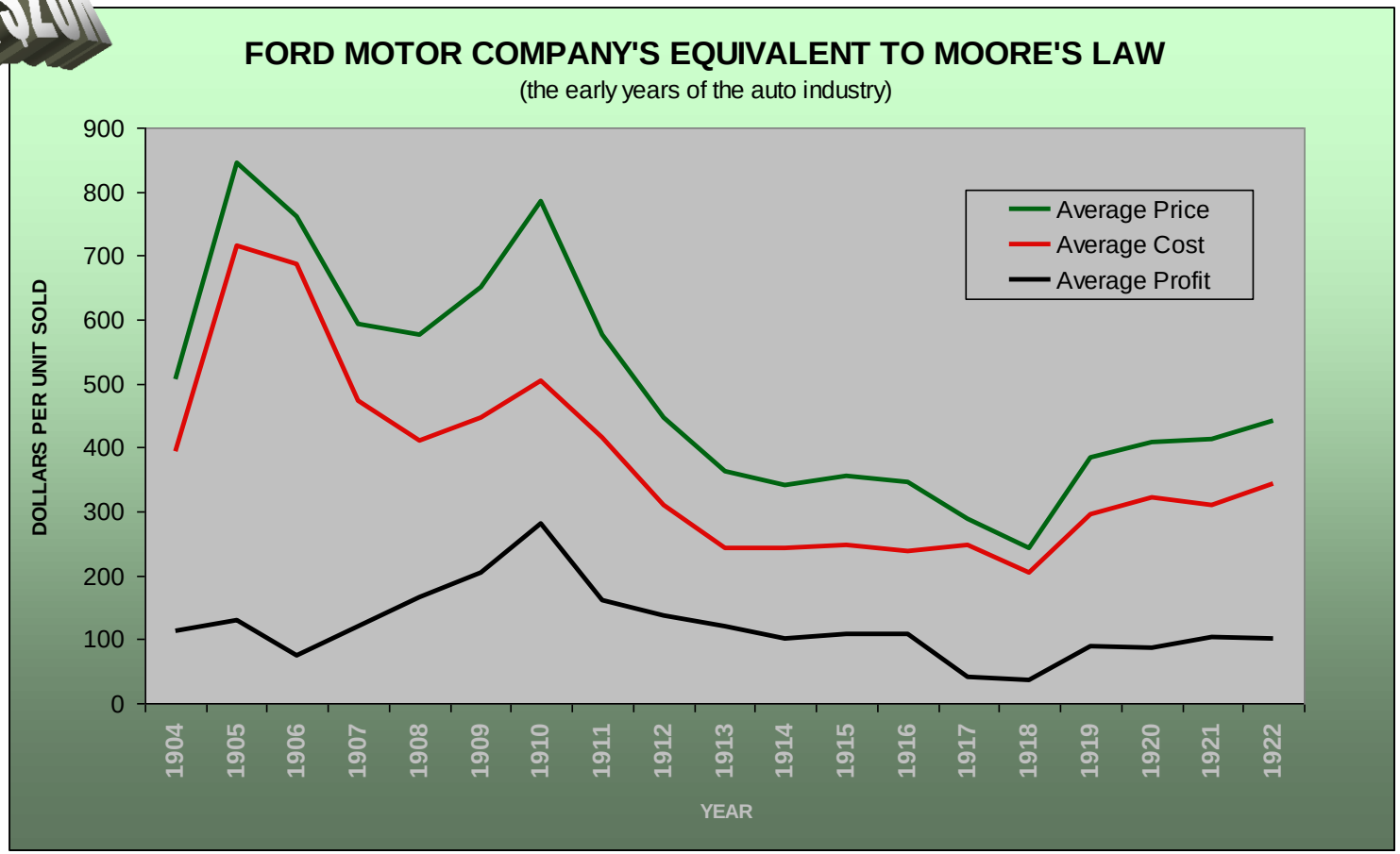
- Price is a Critical Demand Driver
- without Shrinks . . .
  - few reasons for New Designs
- Moore's Law Laggards are pulled along by Moore's Law Leaders

  Fear of the Unknown
- Electronics last for far longer than
  - we replace them
  - growth could dwindle to nothing
  - especially with technostress
    - a demand killer
    - consumer electronics slowing
    - going to dentist preferred over buying a cell phone
- Without Moore's Law there won't be *New & Improved* Supply Push



We Didn't Stop Using Cars

when manufacturing costs started to rise,
though there are more horses alive today



Moore's Clock for Autos was 2.5 years

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just imagine . . .

Where would **We** be without semiconductors?

More than Moore … *or*
Is there life after Moore's Law?

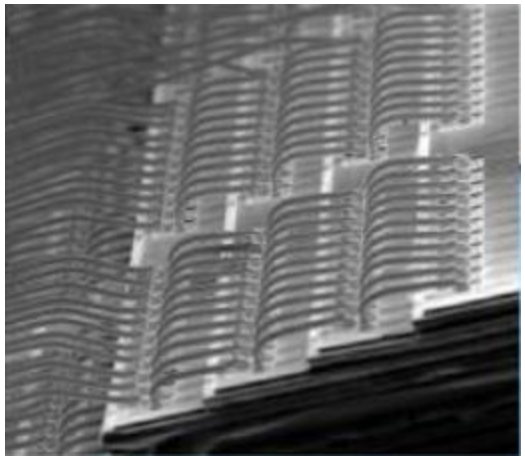
More than Moore Strengths

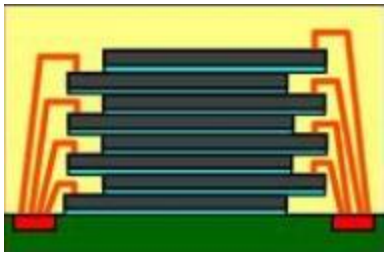
- Term popularized by Europeans in the last decade
- Sound bite: a new offshoot in semiconductor technology
  - extend the benefits of Moore's Law without scaling
    - Advanced packaging
  - Create entirely new value chains using the same technology developed for Moore's Law
- 3D Packaging
- EST: Emergent Semiconductor Technologies
  - MEMS: Micro-Electro-Mechanical-Systems
  - Solid State Lighting
  - PV Solar Cells

3D Packaging:

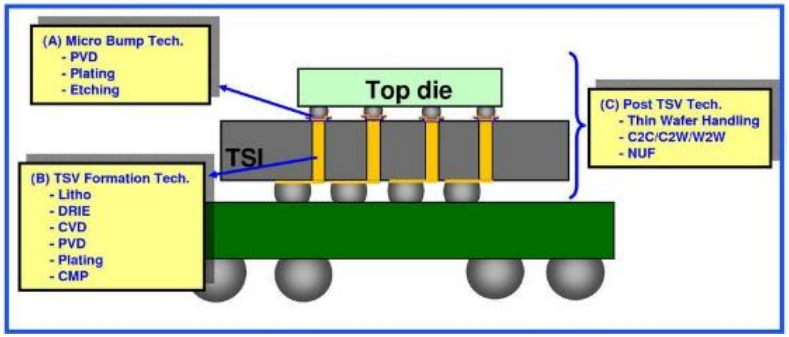
Most Common Form of MtM thinking

- Volume mostly in wire bonded stacked die
  - An evolution of 2D Hybrid/SiP
    - Kilby's IC
- TSV is mostly in cell phone camera units
  - Complex = Costly
  - Lot's of promise
  - In the Hype Cycle since the nineties





■ TSV Required 4 Technologies
(A) Micro Bump Technology
(B) TSV Formation Technology
(C) Post TSV Technology
(D) FC Assembly Technology



http://electronics.wesrch.com/paper-details/pdf-EL1SE1UN1LORM-2-5d-3d-tsv-ic-coming-of-age http://www.chiphistory.org/

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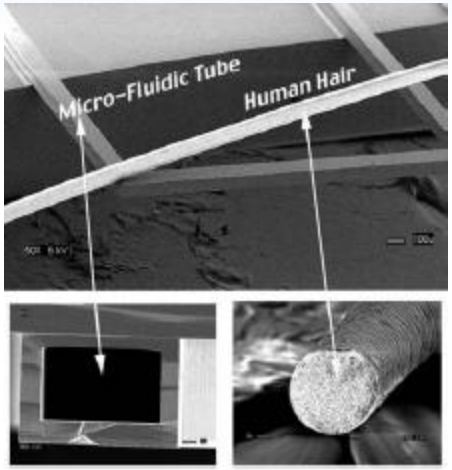
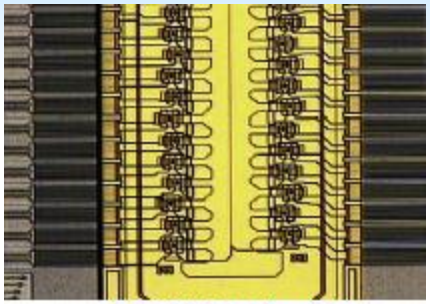
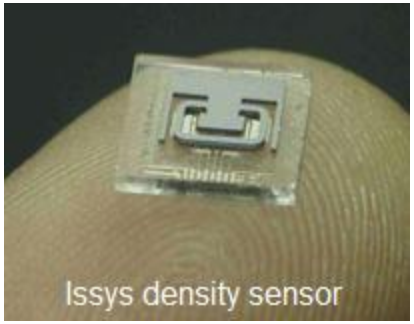
EST: Emergent Semiconductor Technologies

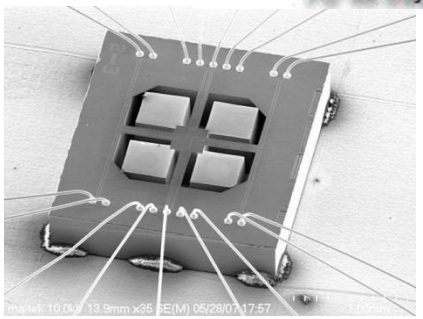
- The use of Semiconductor Manufacturing Technology to create new markets:
  - MEMS: Micro-Electro-Mechanical-Systems
    - Micromachines in Japan and Micro-Systems Technology in Europe
    - MOEMS: Micro-Opto-Electro-Mechanical-Systems
  - Nanobots/machines
  - LED Lighting and Displays
  - Solar PV
- Why Semiconductors?
  - Established tool & material supply base
  - Easy to machine and alter electrical & optical properties
  - Performs well under many different forces
- Small, high growth application focused markets

EST: MEMS



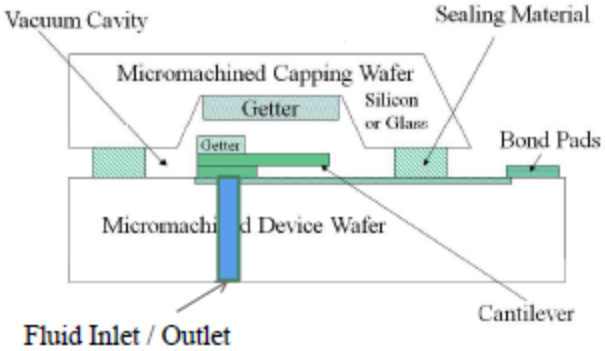

APM inkjet head


Issys density sensor

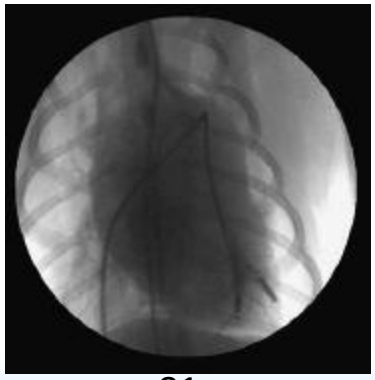


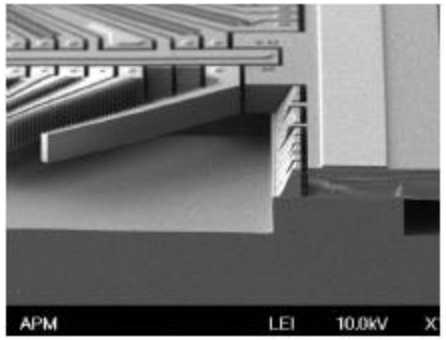
Piezoresistive Accelerometer Platform


Implantable pressure sensor



Doug Sparks
http://electronics.wesrch.com/pdfEL1SE1EZDLFIS





SOI Cavity Platform

Jerwei Hsieh
http://electronics.wesrch.com/pdfEL1SE1EZDXVWL

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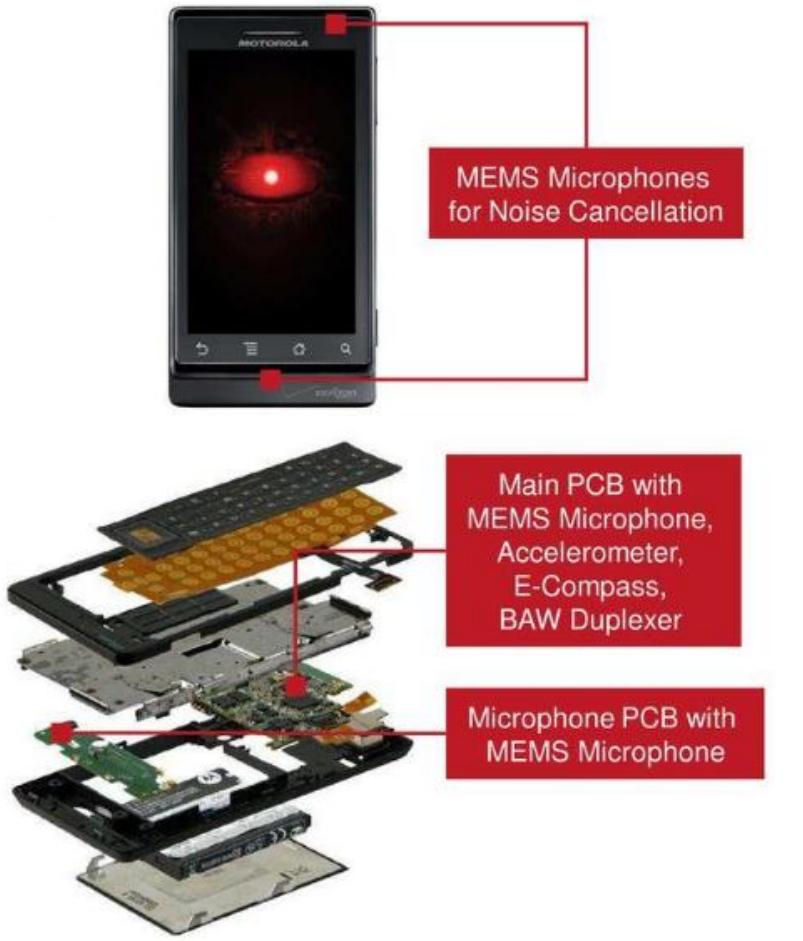
Strength: Vibrant Market

- MEMS have real applications
- Critical to all cell phones and tablets
- Critical to Autos



Source – iSuppli Corporation *Teardown Analysis – Motorola Droid Mobile Handset*

http://electronics.wesrch.com/paper-details/pdf-EL1SE1EZDIKMX-mems-back-to-double-digit-growth

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Weakness:
lots of science fiction in the science

Nanobots in Development

– Medicine

- Cancer – chemotactic sensors
- Drug Delivery
- Cell repair

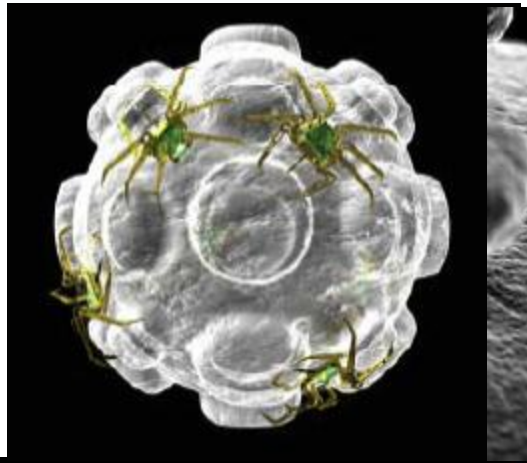
– Energy

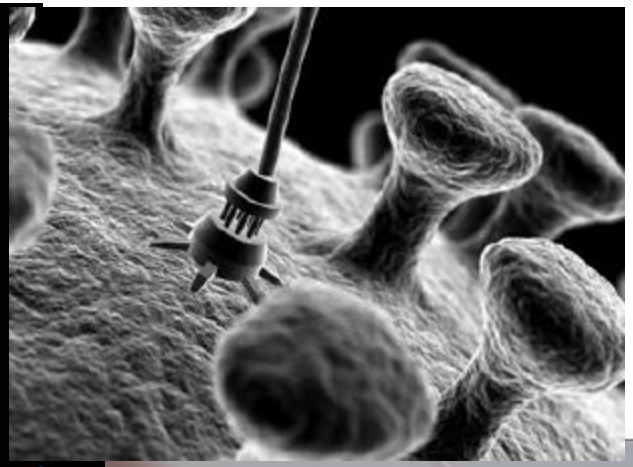
- Oil extraction nanosponges
- Oil spill clean up
- Solar power efficiency
- Ozone layer

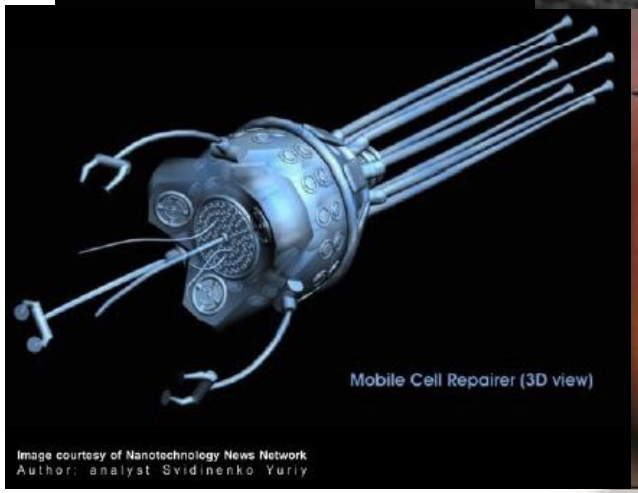
– Detection and Defense

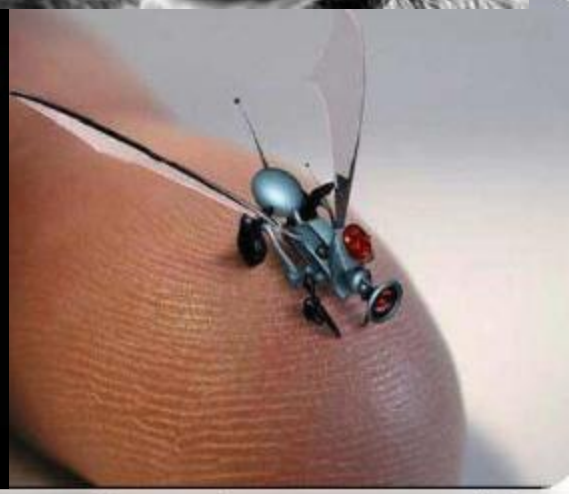
- Space exploration
- Military Defense
- Chemical Warfare Detection

- nanosensors detect <10 ppb









http://scienceblogs.com/framing-science/NanotechFly.jpg

Lindsey Armstrong, Christopher Arnold, Kamal Banjara, Ahmad Al-douah
http://electronics.wesrch.com/pdfEL1SE1EZDTSWO

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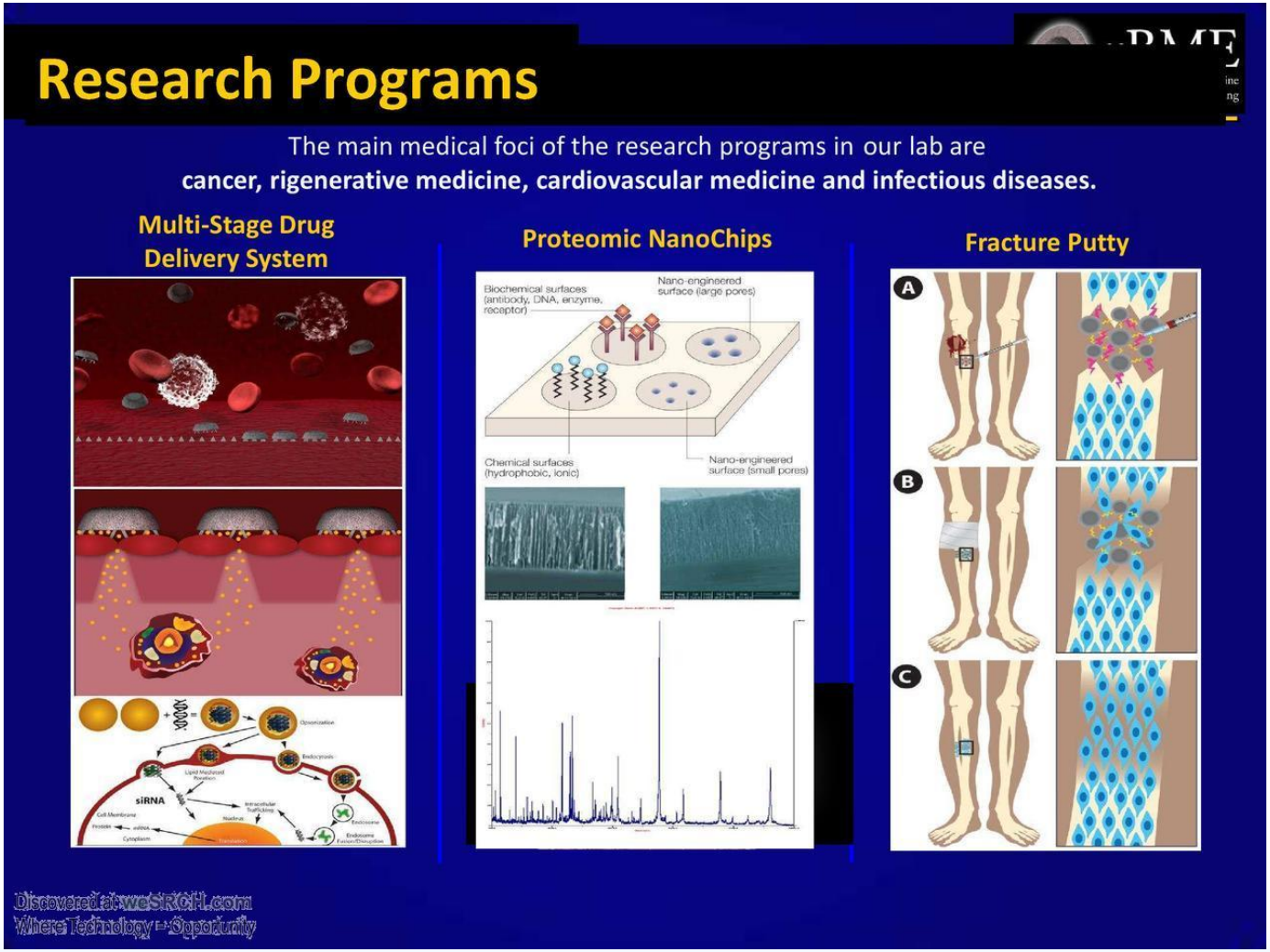
But today's science fiction is often tomorrow's science



http://medical.wesrch.com/paper-details/pdf-ME14GWMAWTHJM-nanochip-research-in-medicine-for-cancer-rigenerative-cardiovascular-and-infectious-diseases

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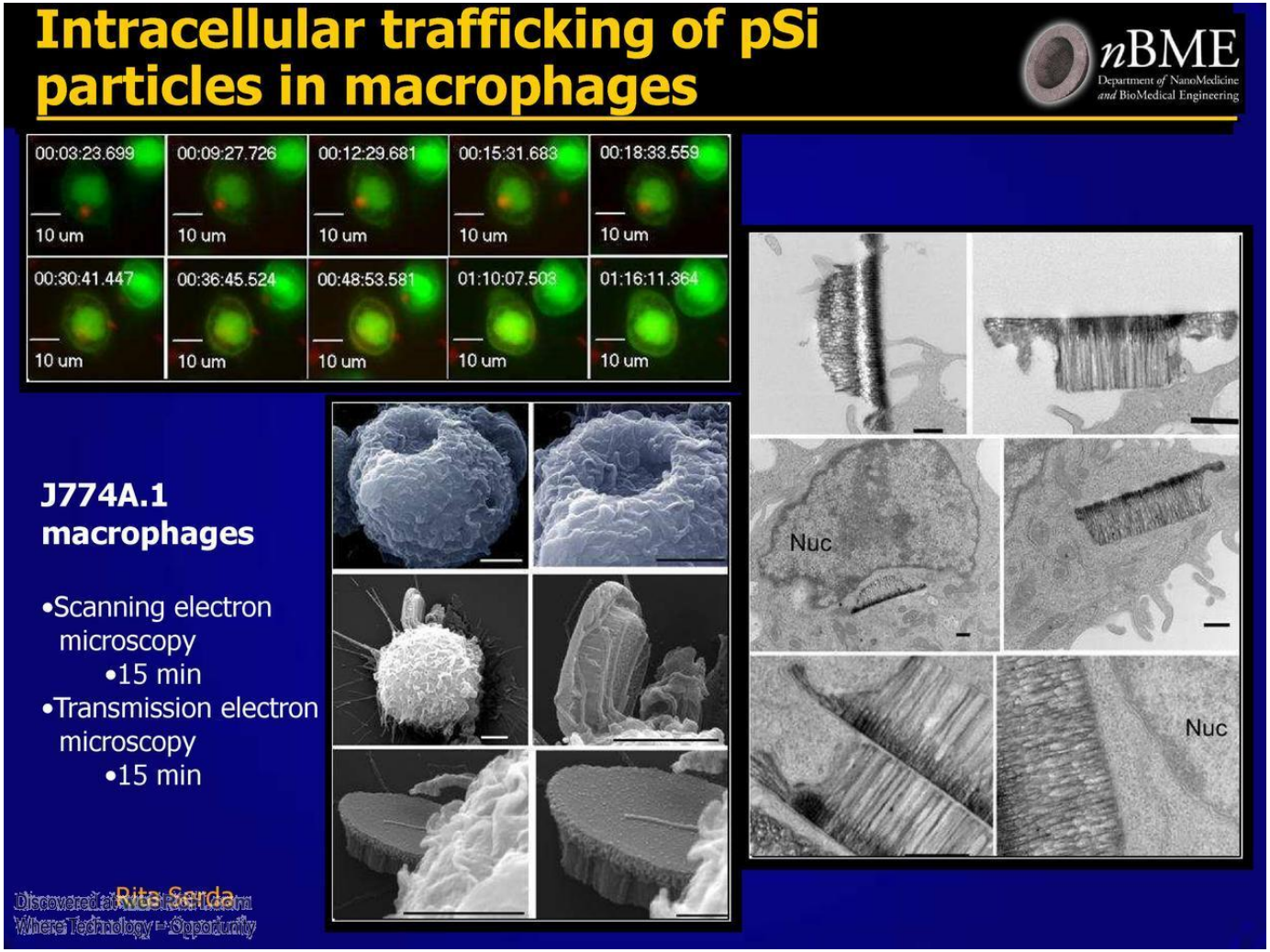
But today's science fiction is often tomorrow's science

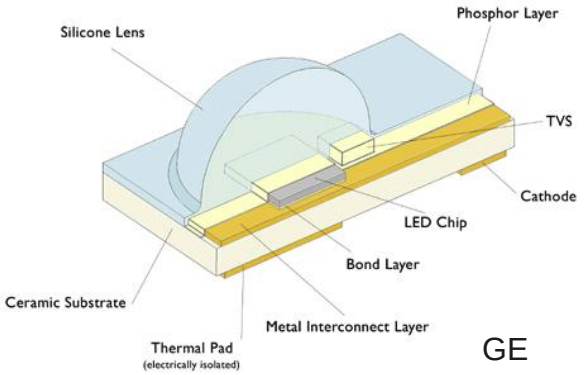


http://medical.wesrch.com/paper-details/pdf-ME14GWMAWTHJM-nanochip-research-in-medicine-for-cancer-rigenerative-cardiovascular-and-infectious-diseases

EST: LED Lighting

Rubicon Technology
Sapphire

Philips Lumileds

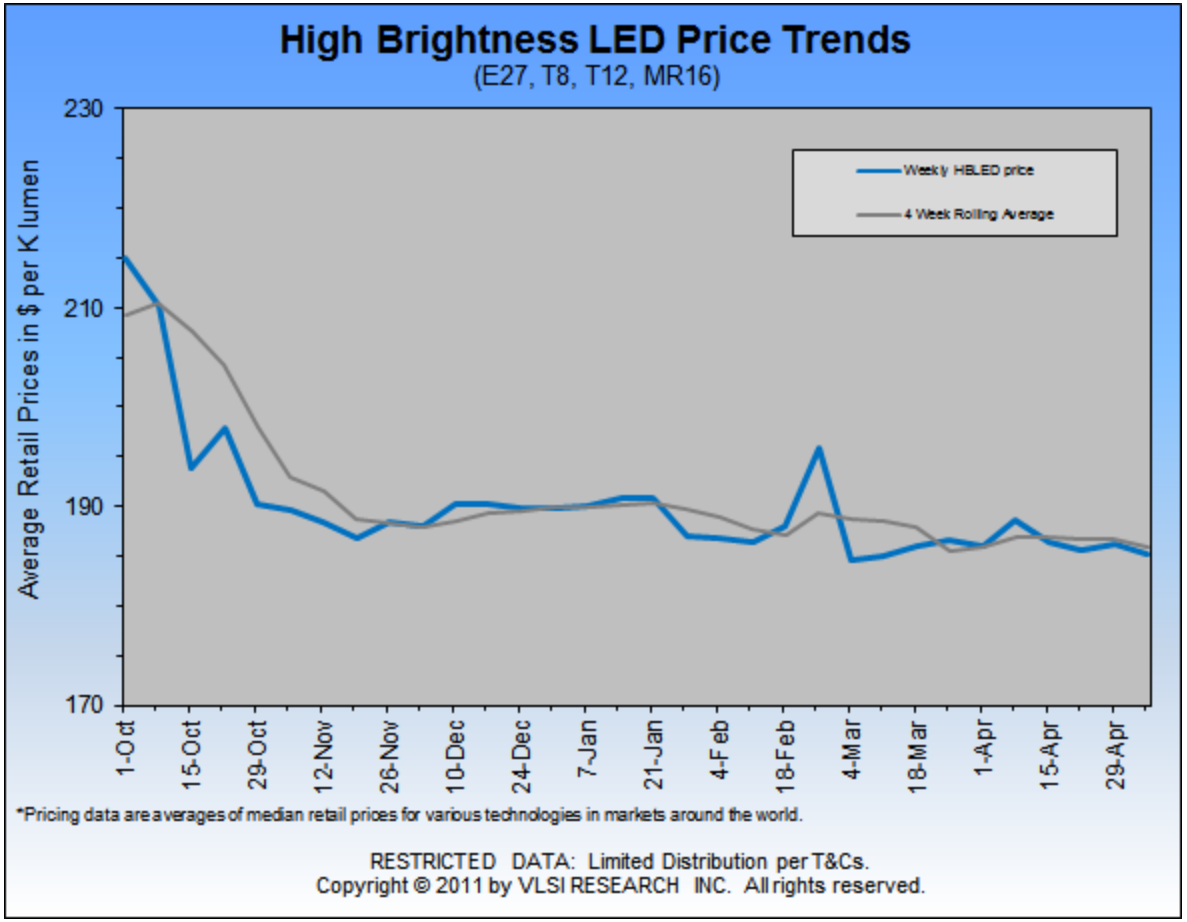


GE

Threats: LED Pricing

- LED prices have flatlined
  - < $200/Klm
  - 60W Equivalent
- CFL
  - < $6/Klm
- Incandescent
  - < $2/Klm
- *Not competitive at the consumer level*
- *Competitive at Enterprise level*
  - *Maintenance, Power & Security*

- Opportunity for Major Breakthroughs



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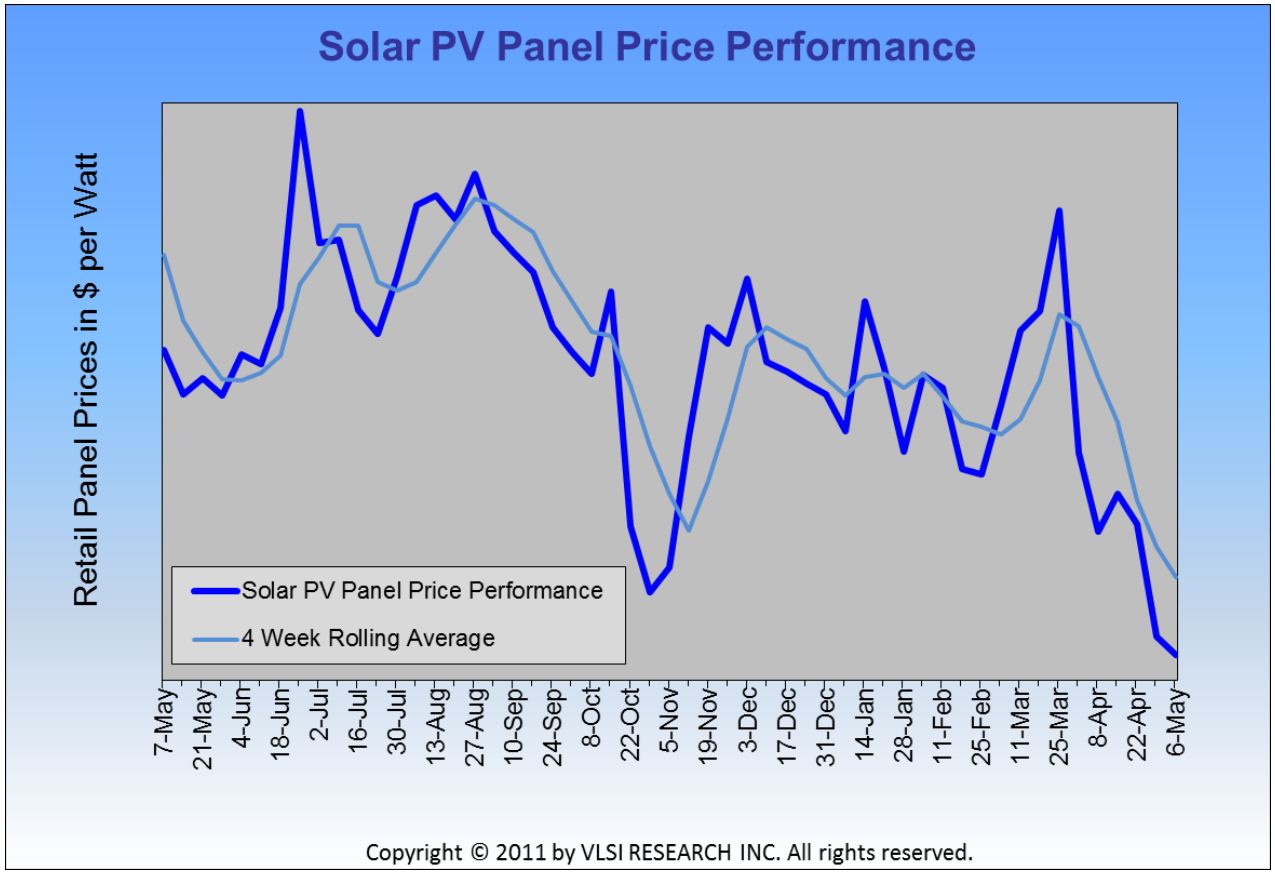
PV Solar Pricing

- PV Solar prices will soon break through $3W grid-parity barrier.
- PV solar panel prices have dropped 4.6% since beginning of the year
- Currently running at a 3-year Moore's Law rate
  - It's been accelerating



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Opportunity

MtM EST Markets

	2010 Size $B	Growth Potential	Comments
Solar PV	20.4	25-30%	Politically driven. BP disaster will help. Still relies on subsidy
MEMS	7.4	5-20%	1st Gen Mature 2nd Gen growth>40%
LED Lighting	6.2	30-40%	Power plant capital requirements are the driver
Nanobots	?	Huge	Medical and Military Apps are the Driver

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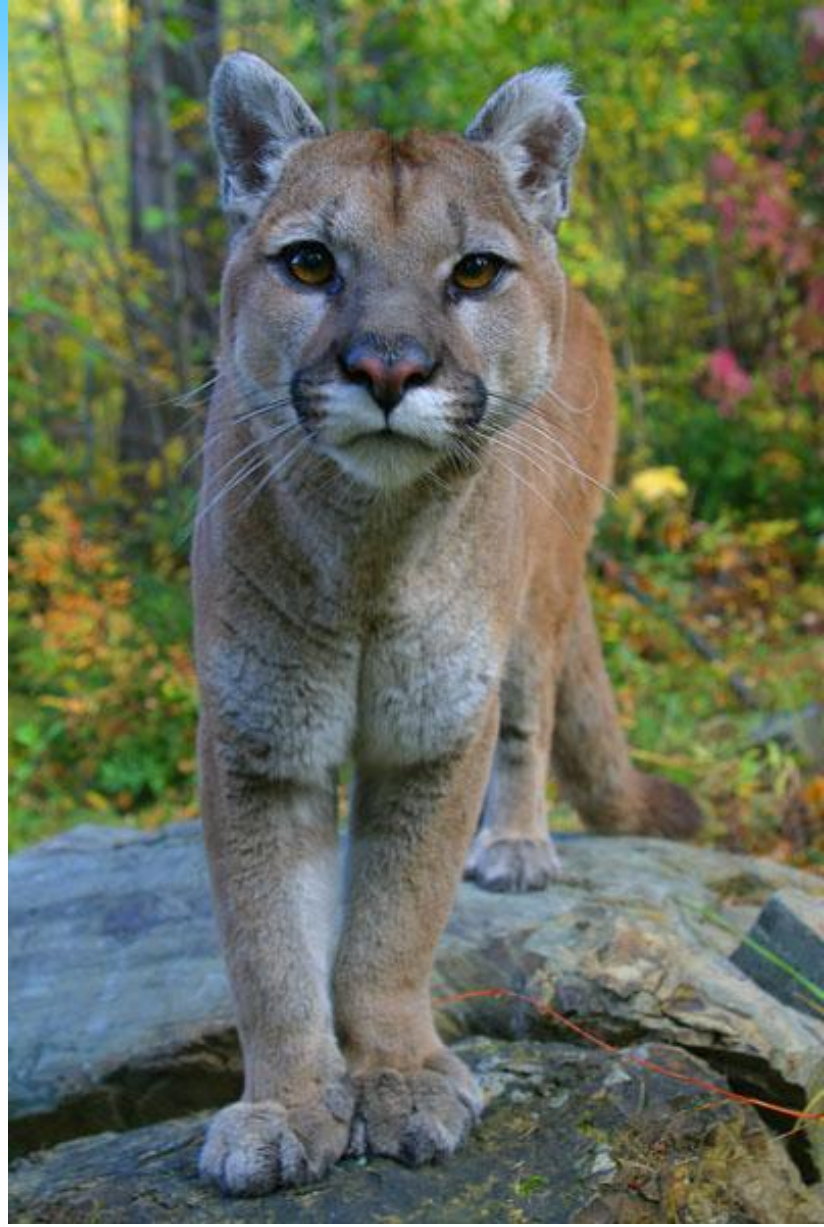

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Appendix: *Web sites*

VLSIresearch.com

- VLSI's market research page
- For research on the semiconductor supply chain

ChipHistory.org

- Education site on semiconductors
- Virtual history museum
- Based on industry donations

weSRCH.com

- Where Technology = Opportunity
- A virtual science & engineering conference
- Ads reach 200K visitors per month
  - 15-20mins & 35 page views / visit, >1 visit / week
  - High signature authority and income viewership
  - High Yield on Targets for your business

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