Key R2E Challenges for New Space

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Outline

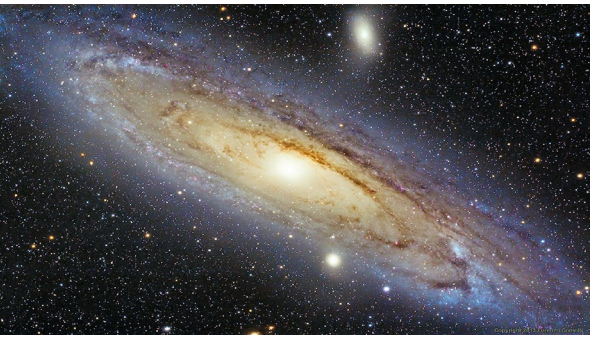
- One slide review of space rad
- What is “New Space”?
- New Space Radiation Test Challenges
- Manufacturing Variation Challenges

Replacement/Repair is (usually) NOT an Option

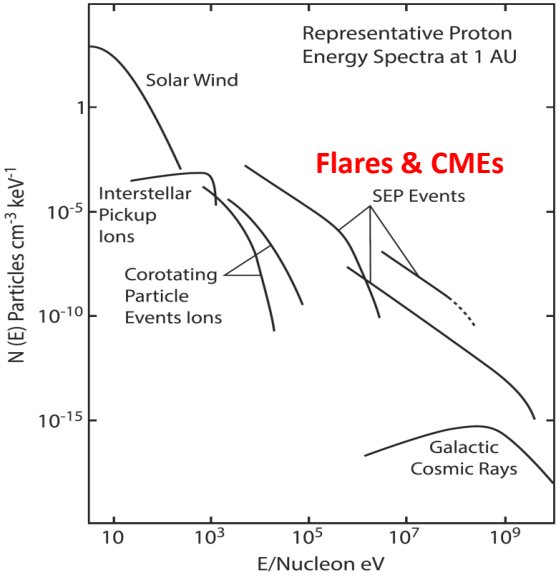
Space Radiation Environment in a Nutshell

R2E

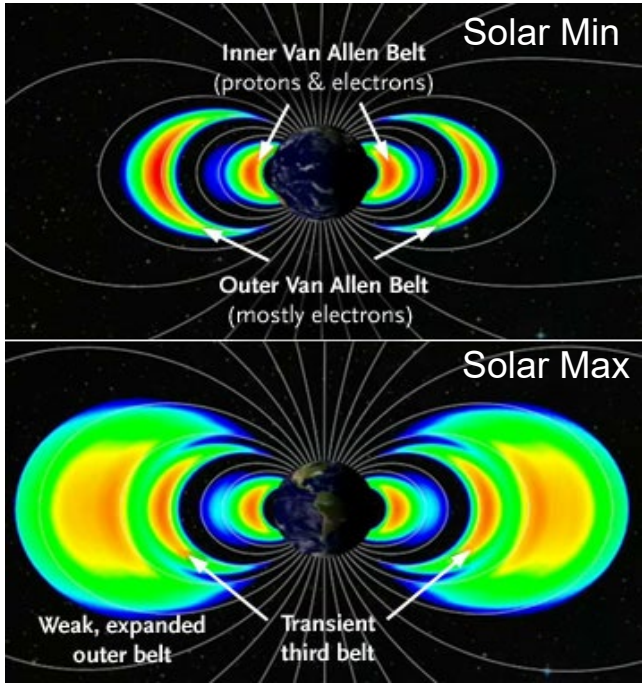
Galactic Cosmic Rays



Solar Energetic Particles



- **Lots and lots of Protons**
- **Lots of electrons (LEO/MEO)**
- **A few heavy ions**
- **(some γ-rays/neutrons)**



Trapped Particle Belts
(Geomagnetic Effects)

What is New Space (NS)?

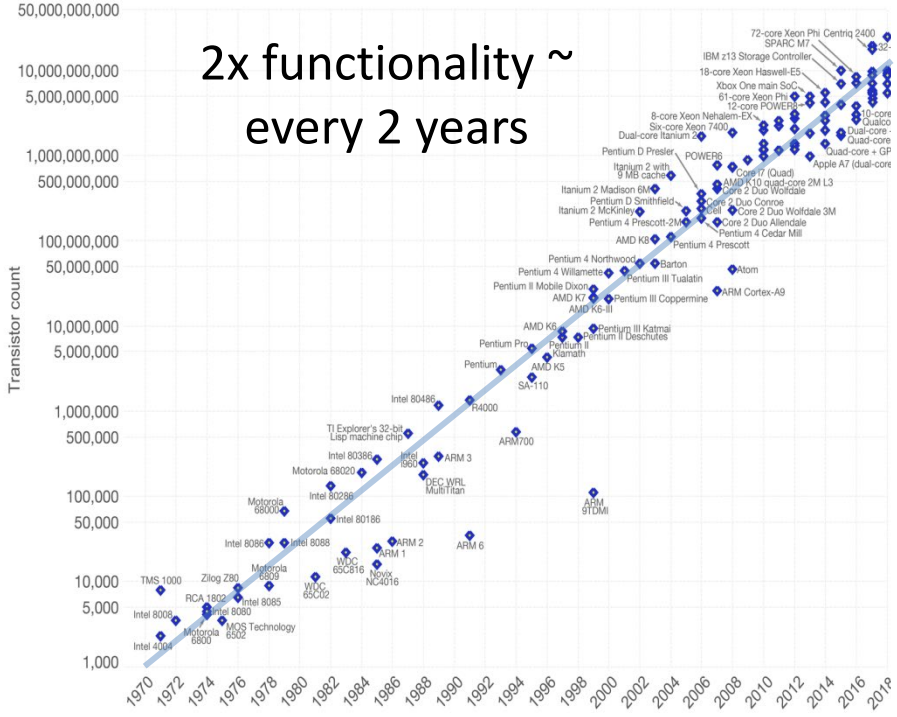
"…a global industry of private companies and entrepreneurs…backed by risk capital seeking a return, and seeking to profit from innovative products or services developed in or for space." (*newspaceglobal.com*)

"…describe approaches to space development that differ significantly from those taken by NASA and the mainstream aerospace industry." (*HobbySpace.com*)

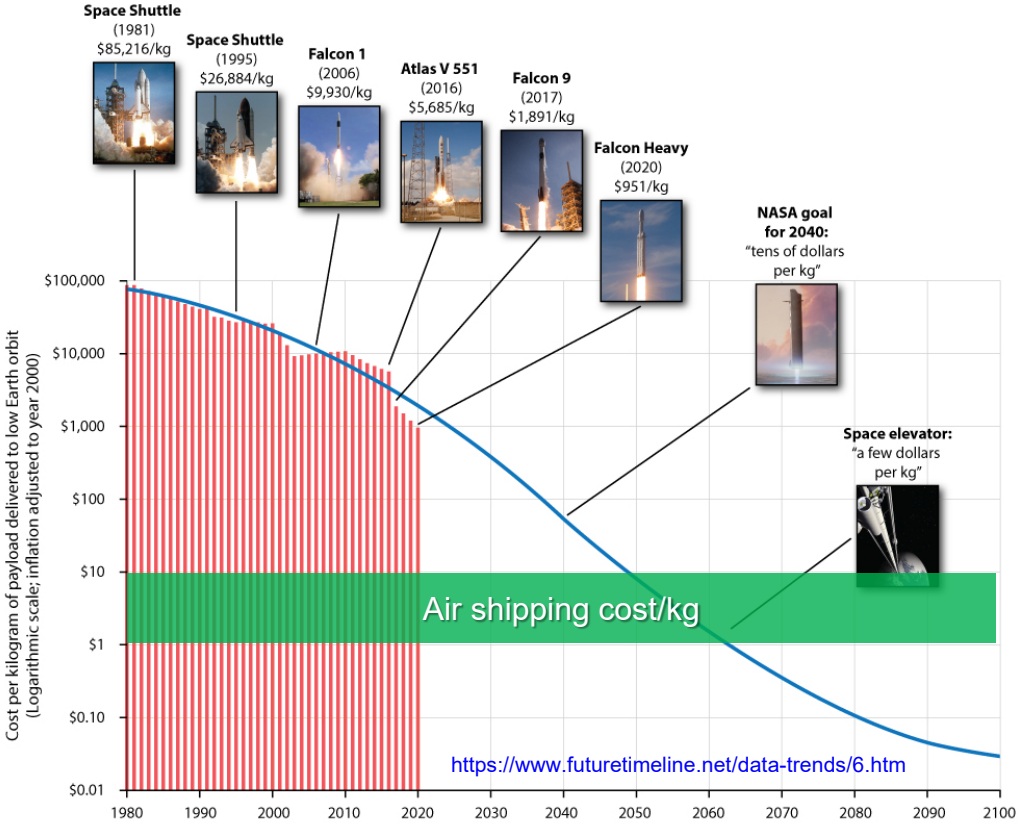
Key Differences between TS and NS

Traditional Space (TS)	*New Space (NS)*
"***Failure is not an option***"	"***Good enough for the mission***"
Large Safety Margins	Optimized Margins (just enough?)
Long Mission Lifetime (+10 yrs)	Short Mission Lifetime (< 10 years)
Established procedural heritage	Question all TS procedures
Long Development Windows	Shorter Development Windows
Radhard/Mil-grade/QML	**100% COTS or AEC grade**
Ceramic Pkg.	**Plastic Pkg.**
RLAT, RDM 2.0 or 3.0	No RLAT, RDM 1.0-1.5 ???
Large Budget	**Smaller Budget**

What is Driving New Space Growth?

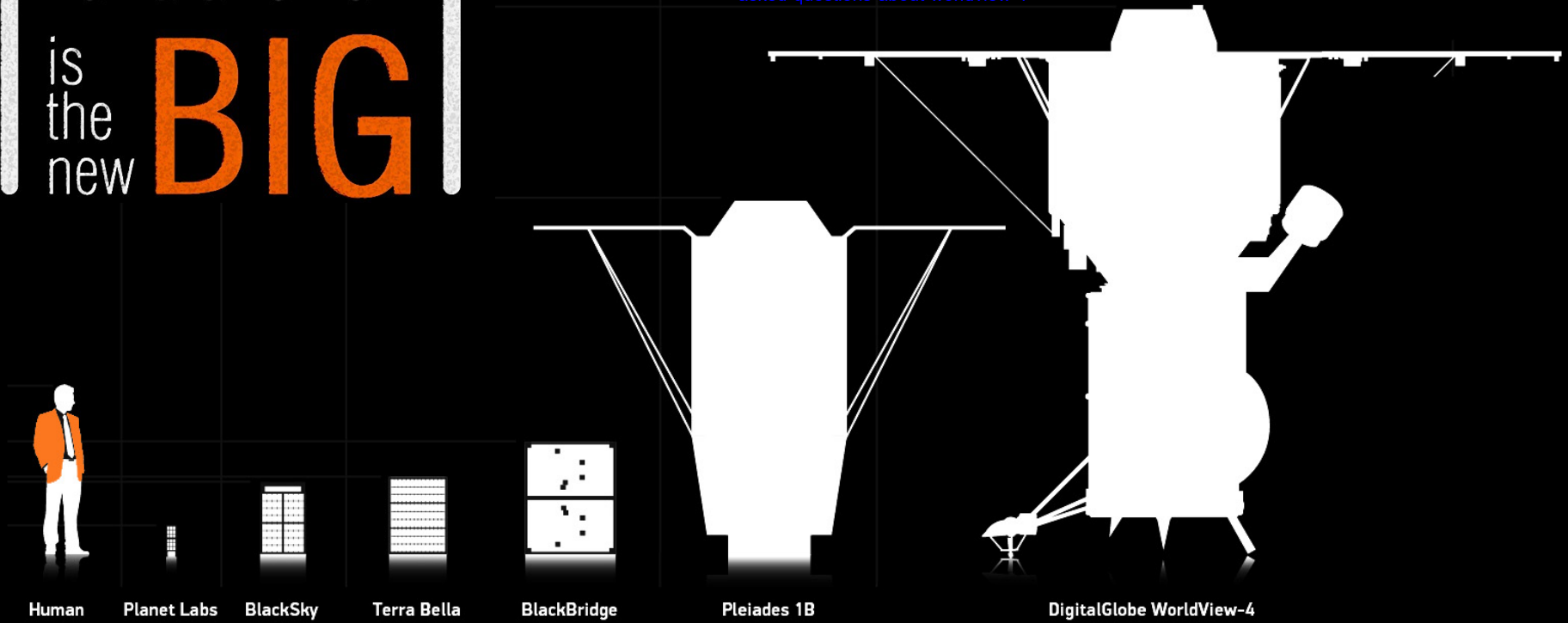


By Max Roser - https://ourworldindata.org/uploads/2019/05/Transistor-Count-over-time-to-2018.

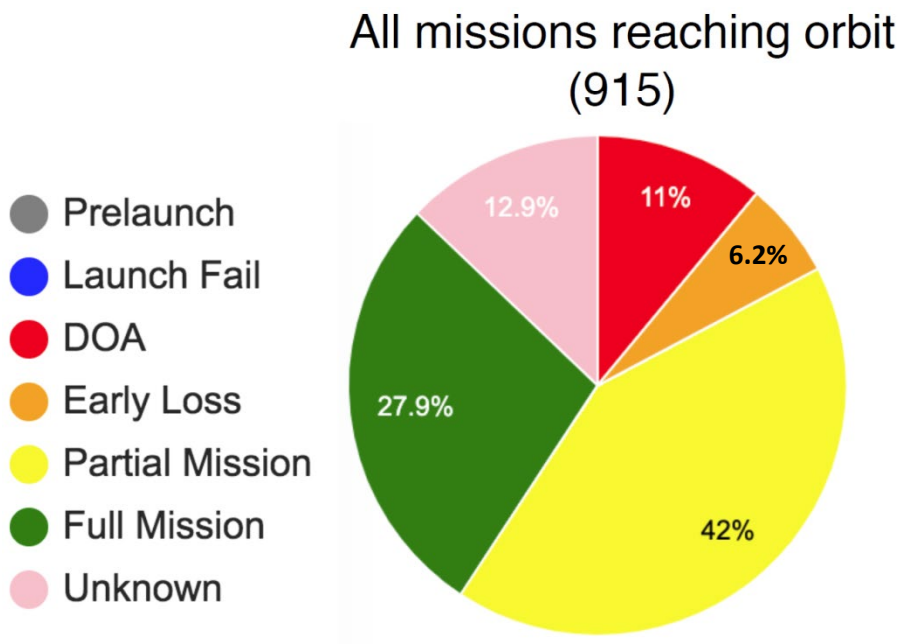


TINY is the new BIG

Adapted from https://blog.maxar.com/earth-intelligence/2016/frequently-asked-questions-about-worldview-4



“Poster Child” for New Space: Cubesats



M. Swartwout, “CubeSat Mission Success: Are We Getting Better?”, CubeSat Developers’ Workshop, April 2019

Common Characteristics of Success

“Process, Process, Process”*

Ad-hoc approach spells disaster!

Plan for success!

“Those that survive the first 90 days tend to stick around”*

Implies Quality Marginalities…

COTS needs B/I or HTOL?

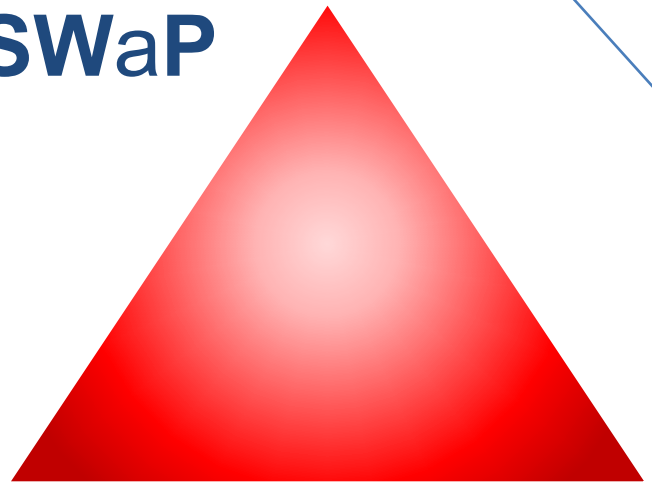
“Development schedule w significant functional test and margin”*

“You don’t know what you don’t know”

with COTS there is a lot more that you don’t know

* Adapted from M. Swartwout, “CubeSat Mission Success: Are We Getting Better?”, CubeSat Developers’ Workshop, 23 April 2019

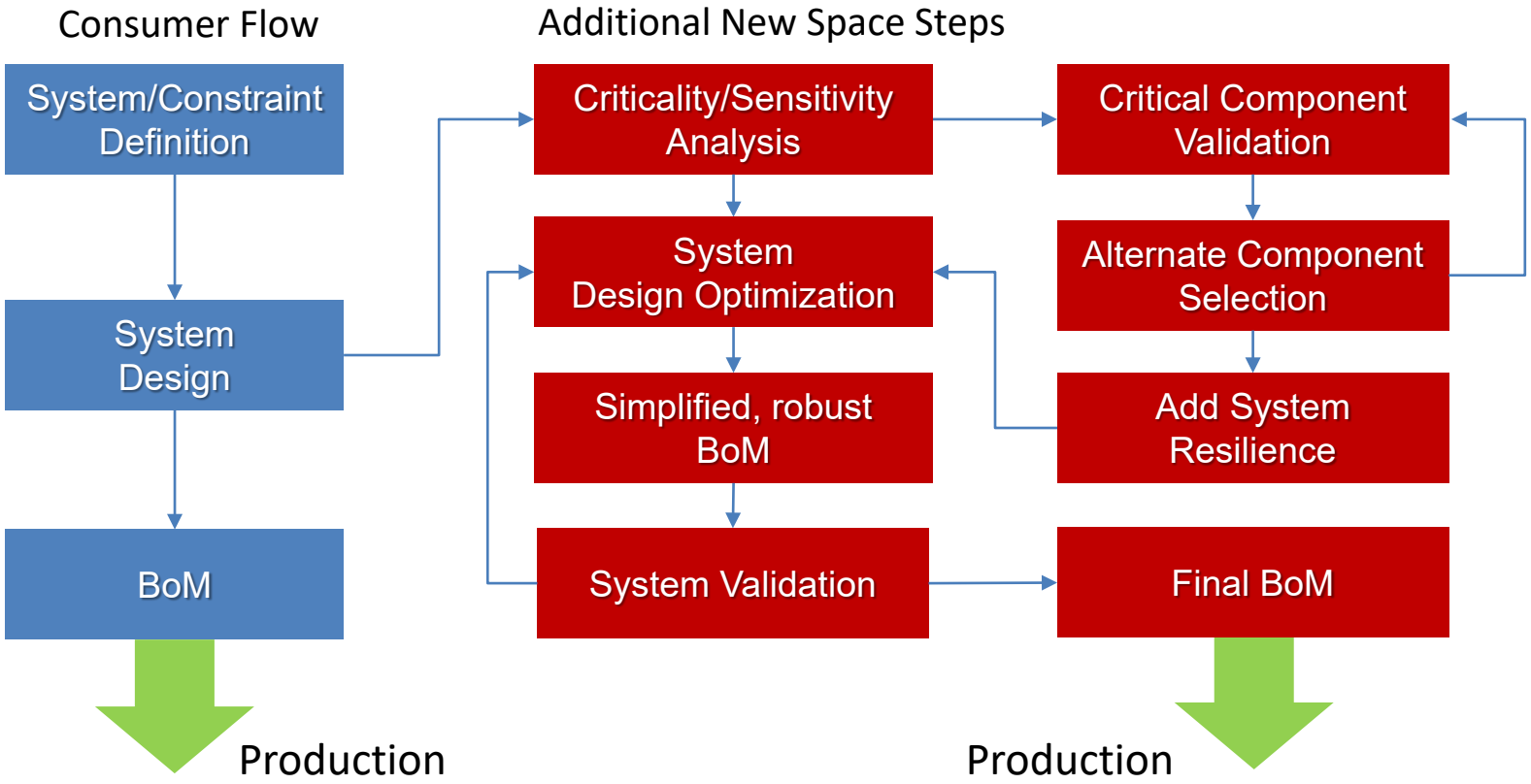
New Space is all about the TRADES!



- Functionality
- Size/weight
- Efficiency (power)
- Functional density
- Reliability
- Quality

Manufacturing variability
Test coverage
B/I, HTOL
COTS vs. RH/MIL

Managing Design/BoM for Space R2E



Specific Rad Characterization Challenges

Facilities Availability

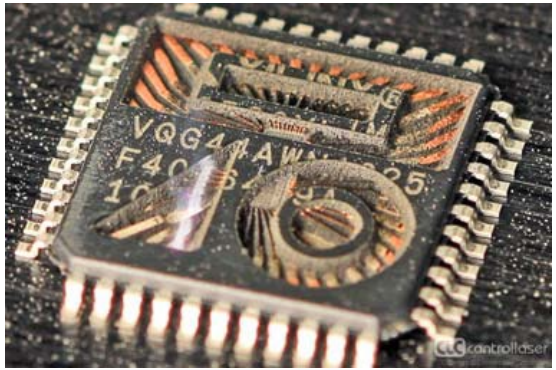
- Manage schedules/loading/down time
- Limited low LET thru plastic beams
- H.E. facilities (CERN, GSI, NSRL, NSCL, etc.)

Decapping Challenges:

- Chemical-mechanical etch (old school)
- COTS with Cu bond wire (low temp etch)
- Laser ablation

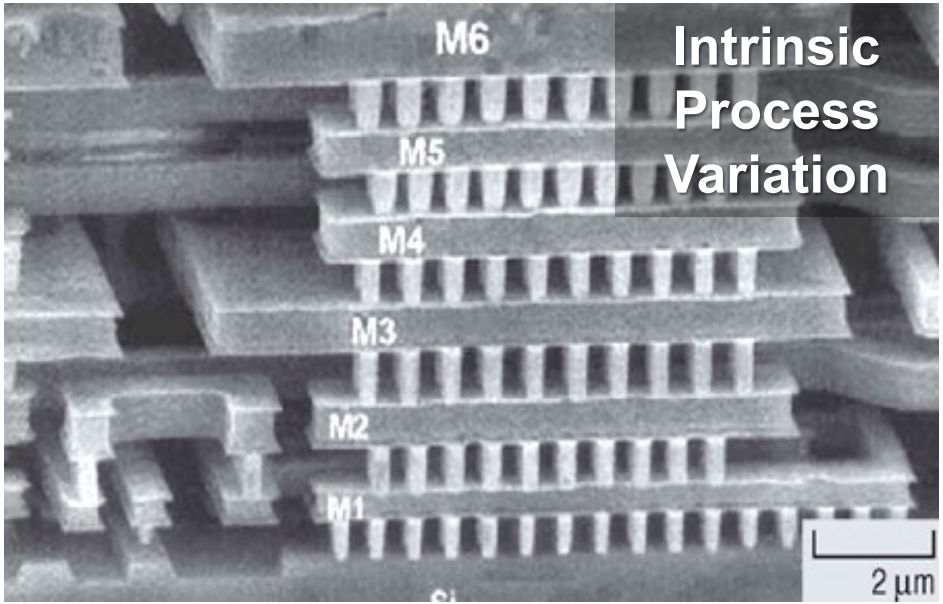
Board-Level Testing

- Commercial boards when possible
- Test boards w socketed parts
- Final product boards (w sockets)

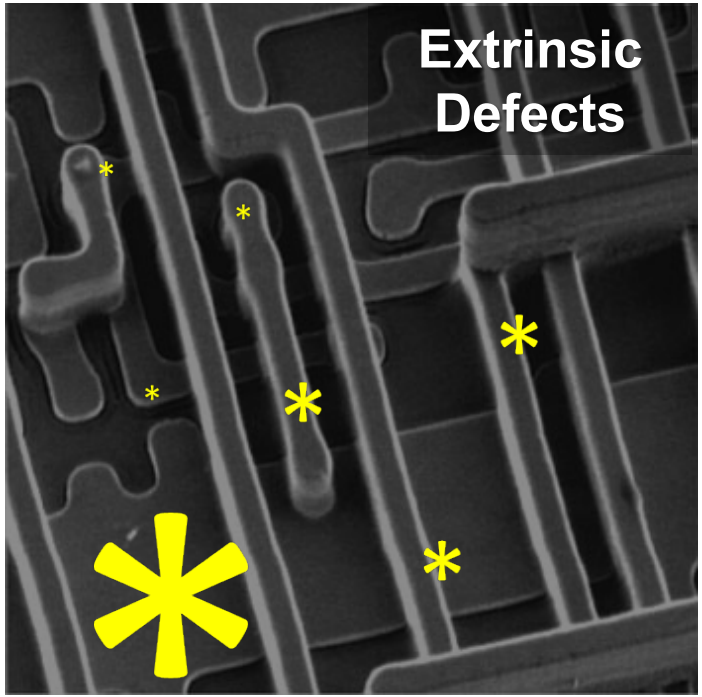


Making Manufacturable ICs

L.J. Chen, “Metal Silicides: An Integral Part of Microelectronics” J. of Materials, Vol. 57, No.9, pp. 24-31



Typical IC takes several dozen masks, with 10-20 steps/mask => Finished product = 100 – 500 steps

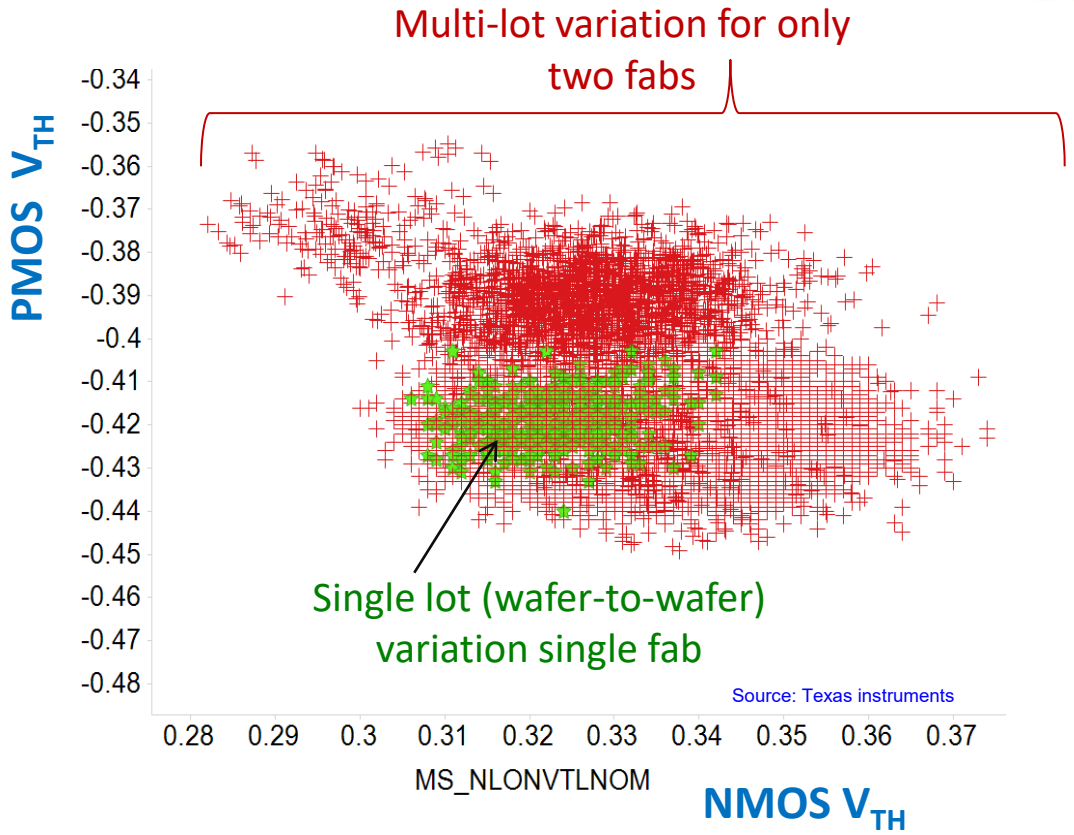


https://www.samcointl.com/featured-solutions/failure-analysis/

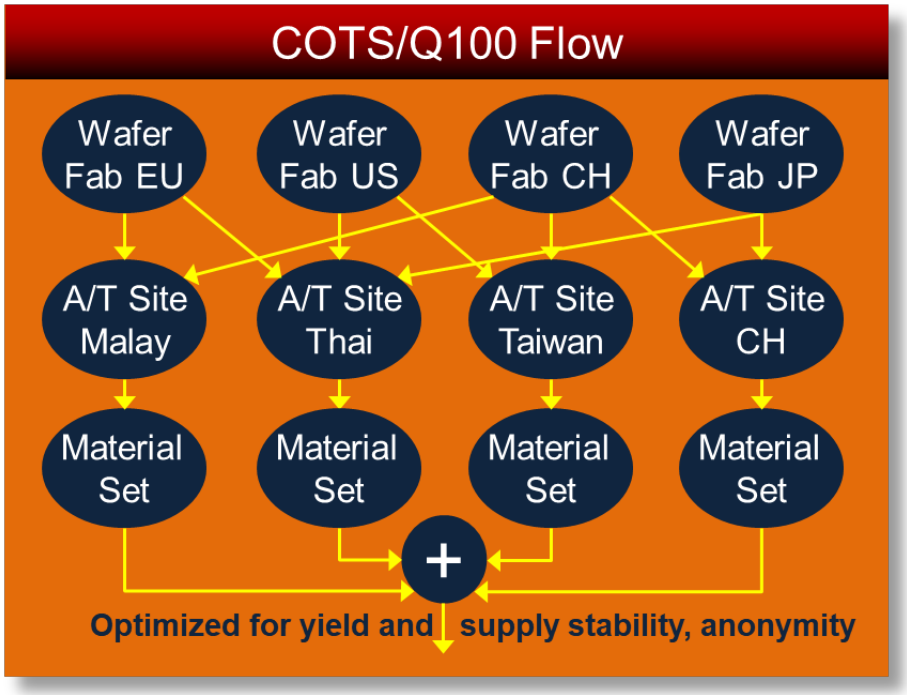
Mass-produced ≠ Identical

Multi-Fab Variability Example

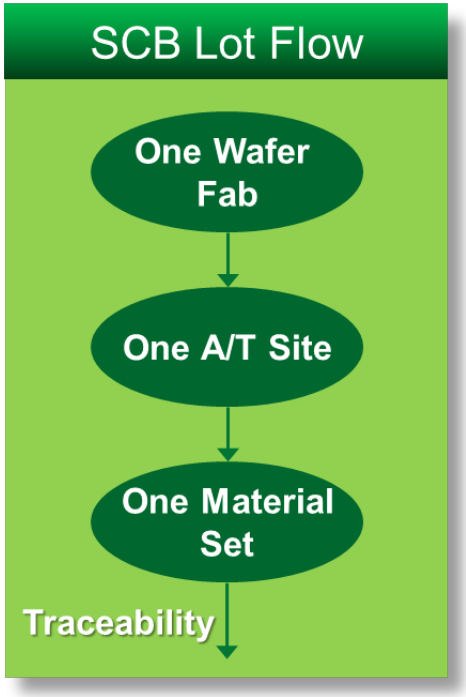
- **Fab-to-Fab**
  - Usually worse than Lot-to-Lot
  - Fab equipment set / version
  - Fab layout / cycle time
  - Fab recipe / starting material
  - Fab controls / methods
  - Revisions / shrinks
  - Design sensitivity / component choice
  - Process tweaks to boost yield
- **Lot-to-Lot**
  - Usually worse than wafer-to-wafer
  - Process has a natural variation
  - Processes / Equipment drifts over time
- **Wafer-to-Wafer**
  - Usually worse than die-to-die
  - First to last wafer variation



COTS vs. Single Controlled Baseline (Lots)



Consumer/automotive



RH/MIL/QML

Value of Single Controlled Baseline (SCB) Flow

- SCB greatly limits manufacturing variation
- Controlled manufacturing variation CRUCIAL to control rad effects

Single Fab & Assembly site

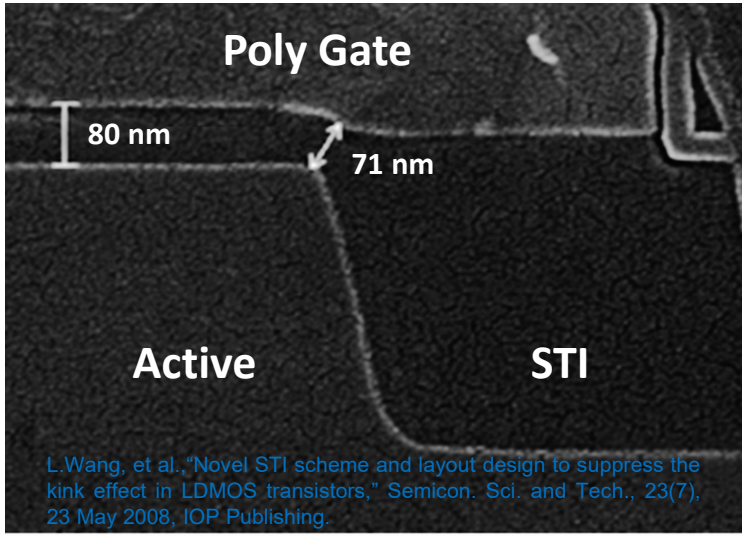
Single Controlled Baseline Lot
"SCB Lot Funnel"

Constrained variation

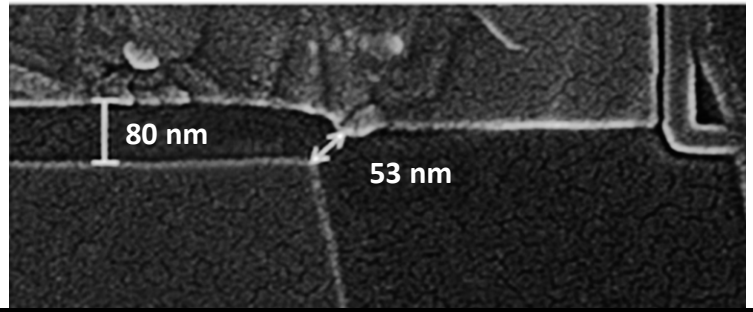
QUAL, B/I, HTOL
"Upscreening Funnel"
Less critical

Space Worthy!

TID Variability: STI Morphology Variation



L.Wang, et al.,"Novel STI scheme and layout design to suppress the kink effect in LDMOS transistors," Semicon. Sci. and Tech., 23(7), 23 May 2008, IOP Publishing.



- Morphology / uniformity
- Gate and Isolation thickness and quality
- Well, substrate, channel doping

Lot-to-Lot variation impact on HDR TID

LM108	HDR TID (krad)	Status
Lot 1	100	Pass
Lot 2	30	Pass
Lot 3	10	Fail

Source: Texas instruments

TID varies 10x over 3 lots!

Don’t be cheap with sampling!!!

Biggest COST of using COTS is the RISK you assume by using them…

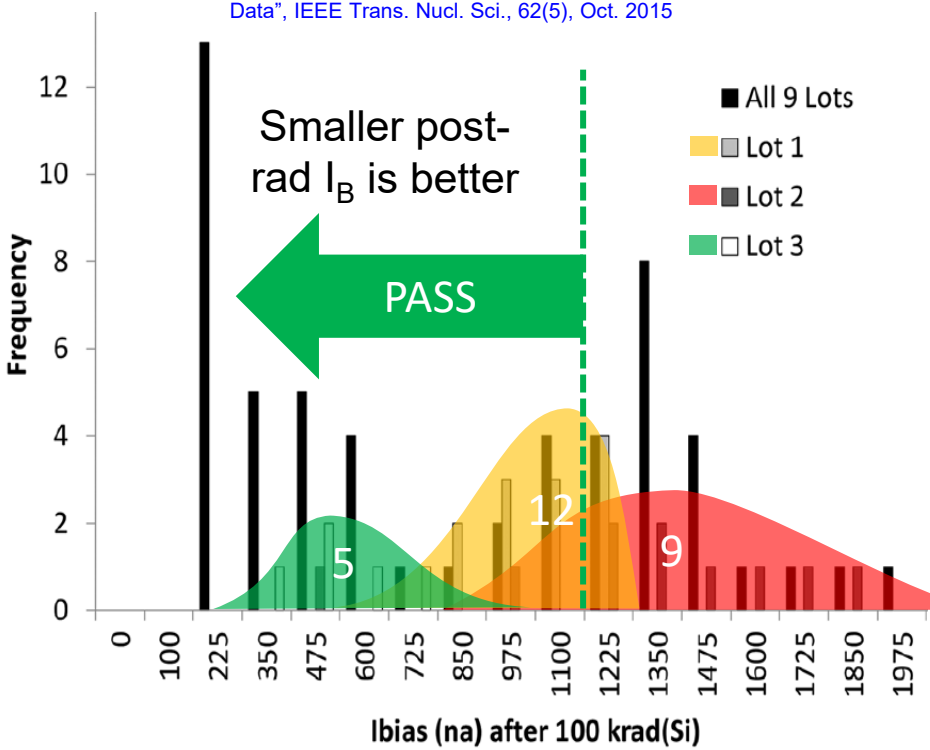
More samples allow you identify distributions = better risk assessment.

Assuming uni-modal / “normal” distribution problematic if it is actually multi-modal.

Understanding parameter distributions gives you leverage for risk management and trade-offs!

Sample early and sample often!!!

R. Ladbury and M. J. Campola, “Statistical Modeling for Radiation Hardness Assurance: Toward Bigger Data”, IEEE Trans. Nucl. Sci., 62(5), Oct. 2015



New Space is all about the TRADES!

Build "quality" organization

- BUILD cross-disciplinary systems / teams.
- INVEST in improving risk determinations.
- BUILD criticality/sensitivity methods early!!!

Limit the scope – quantify risks

- Simplify BoM (rating, type, vendor, etc.)
- PRIORITIZE parts w radiation/reliability data.
- MINIMIZE "shiny & new" syndrome - maximize reuse!!!

Manage variation (rad variation)

- WORK w distributors/manufact. => buy by lot
- SAMPLE, SAMPLE, SAMPLE!
- Build part distributions by testing MANY units.

Streamline R2E

- IDENTIFY key components early
- FILTER critical components => Adjust BOM
- DEVELOP board/system level testing
- ACCESS High Energy beams
- DEVELOP fast de-capping

Thank you for
your attention!