Addressing the SWaP-C Revolution by Aggregating Power System Command and Control

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Space Power Workshop

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Agenda

- Satellite Industry Snapshot
- Implementation Priorities by Satellite Class
- Sources of Electronic Failures in Satellite Applications
- Consider SWaP-C Opportunities in Satellite Power Systems
- Evaluate Where/How PMBus™ Fits in the Satellite Power System
- Mention Next Steps Toward PMBus™ Adoption in Satellites
- Questions

Satellite Industry Metrics at a Glance

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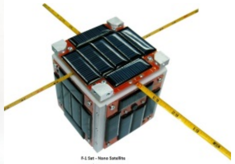
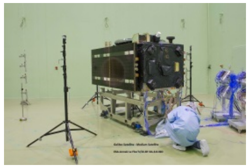
Most Growth is in 30W-400W Class





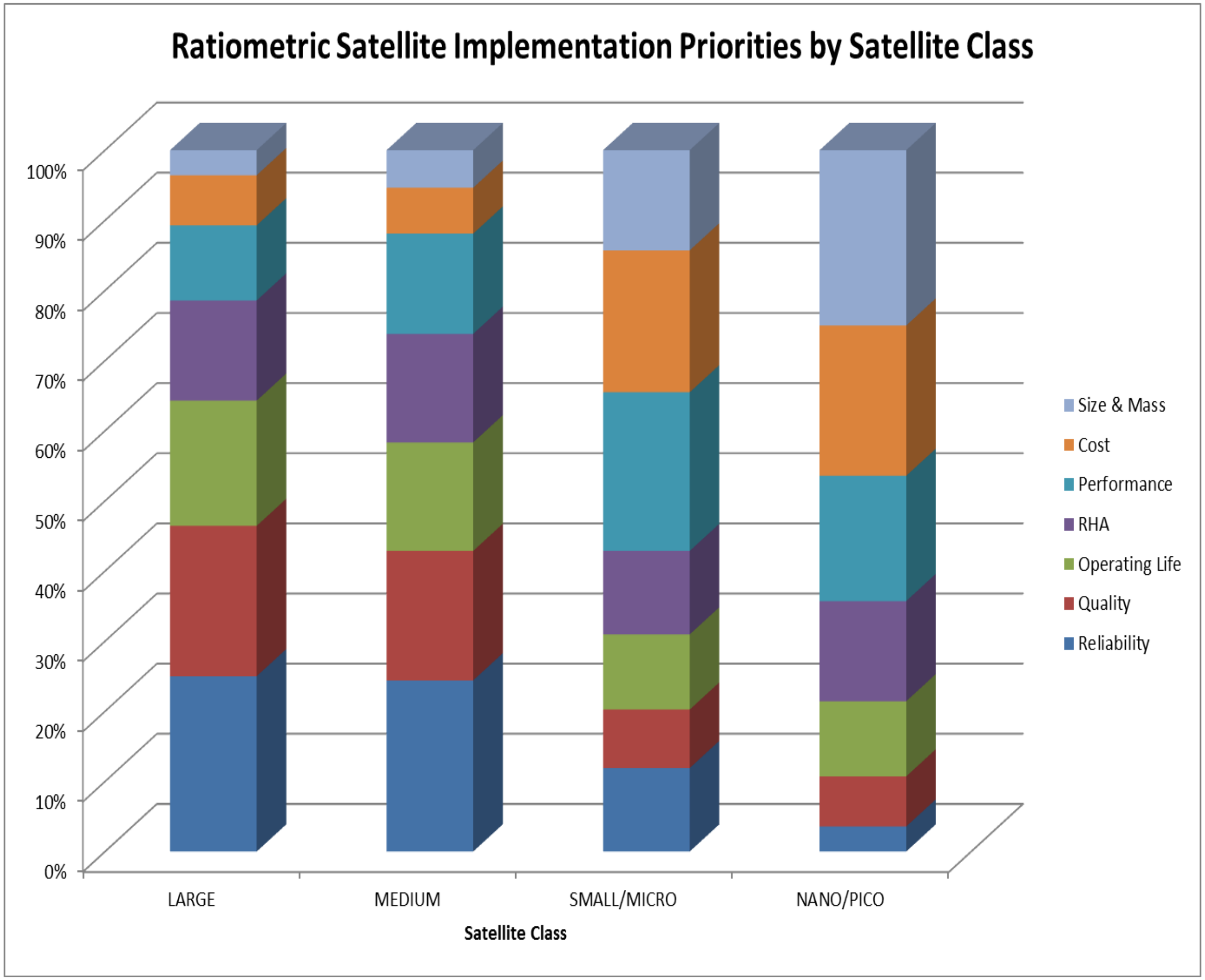

	PICO	NANO	MICRO	SMALL	MEDIUM	LARGE
Mass (kg)	<1	1-10	10-100	100-500	500-1000	>1000
Power (W)	<20	10-30	25-100	75-400	350-5k	5k-15k
Max Volume	125 in^3	750 in^3	18K in^3	45K in^3	284K in^3	1M in^3
Mission Life	1 Yr	3 Yrs	5 Yrs	7 Yrs	7+ Yrs	15+ Yrs
Top Satellite Price (USD)	< $500k	$2M	$10M	$25M	$50M	$100M+
Growth (CAGR)	ND	16.2%	16.2%	11%	6.8%	4.96%
2018 Deploy Expected	ND	185	51	43	32	35
Example	PocketQube	F1-CubeSat	FalconSat-1	FASTSAT	Galileo	TDRS-K

High growth rate driven by Mega Constellation Initiatives and Space Industry's Trend to prioritize Size-Weight-Power-Performance-Cost over Reliability and Space Assured Devices

- *Data Sources: Forecast International Satellite Production Database; Space Works Launch Demand Database; Teal Group; Euroconsult Report*
- *Graphics from: NASA; ESA; Wikimedia Commons*

Satellite Implementation Priorities

- Large & Medium Sats focus on mission assurance
- Small Sats seek maximize performance size & weight, with the best assurance practical
- NANO/PICO sats are driven by cost and size, settling with whatever performance and reliability is achievable



Environment Induced Failure Modes

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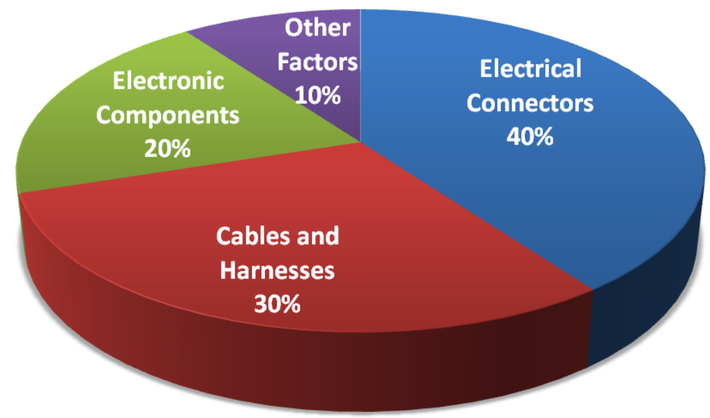
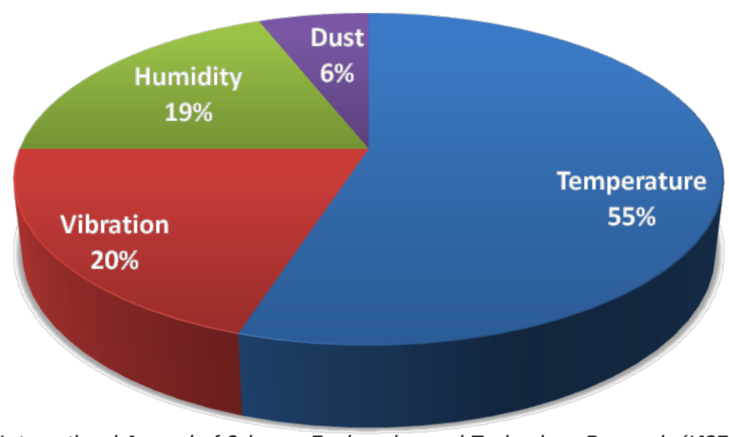
- Examples of Environmental Stress Failures in Spacecraft Electronic Assemblies:
  - Connector contact corrosions
  - Contact fractures
  - Loose hardware
  - Wire/harness breakage
  - Solder Fatigue
  - Cracked IC packages
  - Lead and lead frame fractures
  - De-lamination
  - Radiation induced failures...

Failure Trends in Spaceborne Electronic Systems

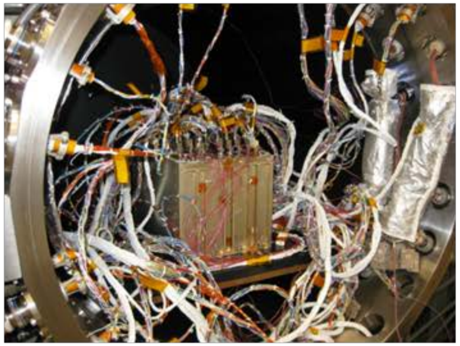


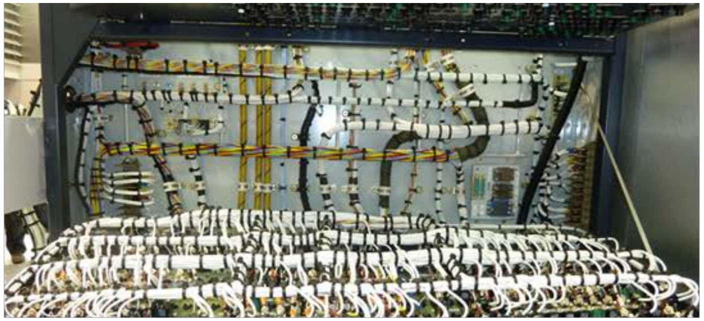
Failure Source Distribution

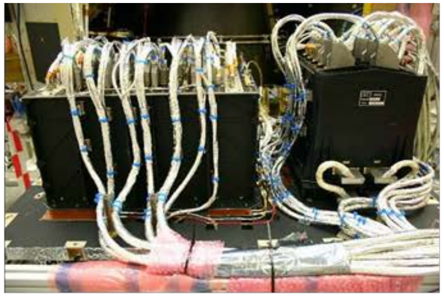


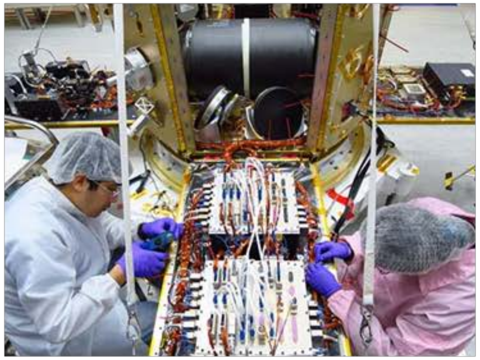
Source: International Journal of Science, Engineering and Technology Research (IJSETR), Volume 3, Issue 3, March 2014, K.P. Subramanya, et al., "Vibration Analysis Study of Spacecraft Electronic Package: A Review" pgs. 503-04.

Harnessing, Connectors and Cables Oh My!!!







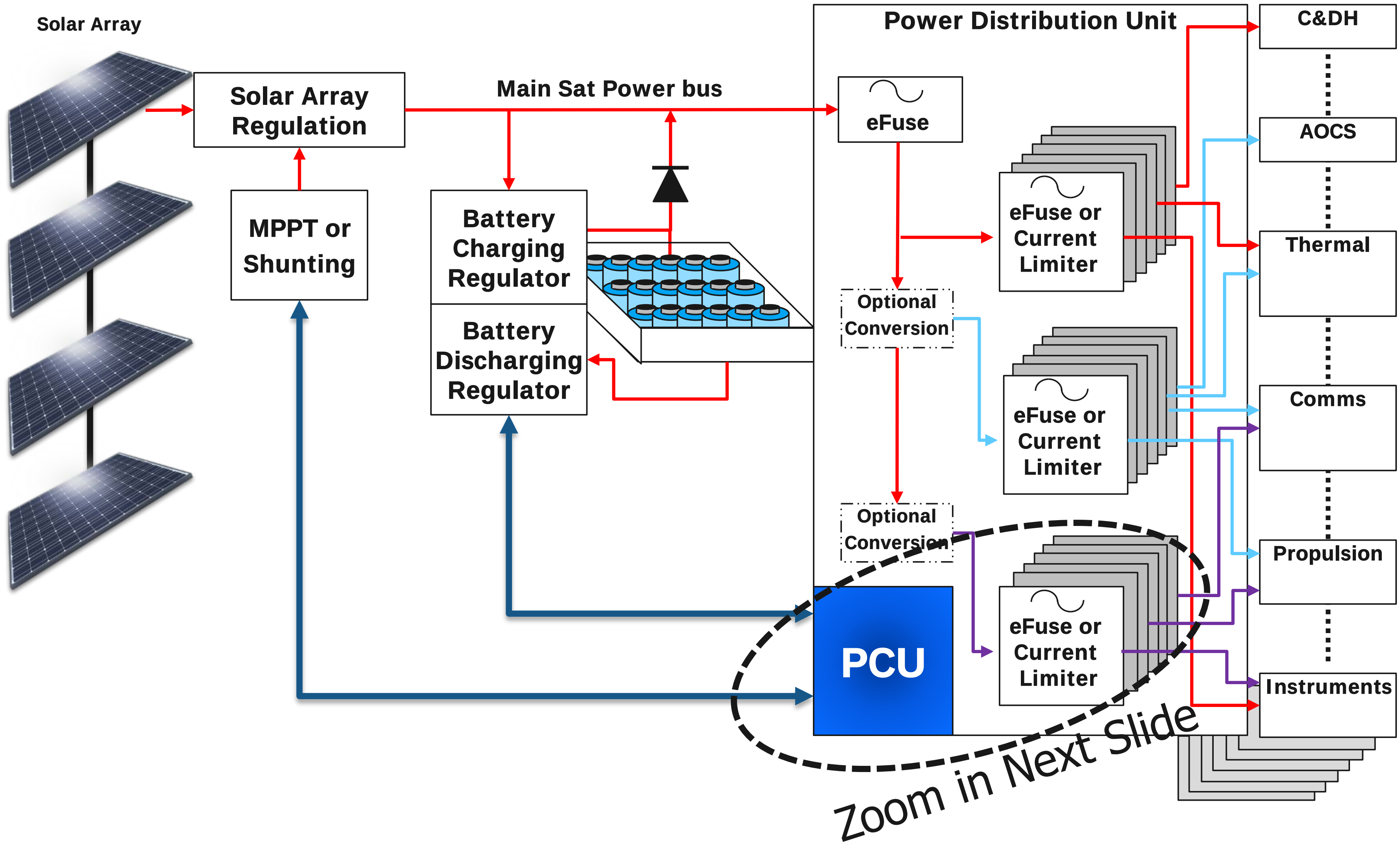


What's the point?

- Addressing Size, Weight, and Power is not only a play for cost effectiveness, it can actually improve overall satellite reliability, as well!

- So, let's look at one approach to addressing SWaP-C in the Satellite power-system...

Typical Satellite Electrical Power System



Traditional Power System Control

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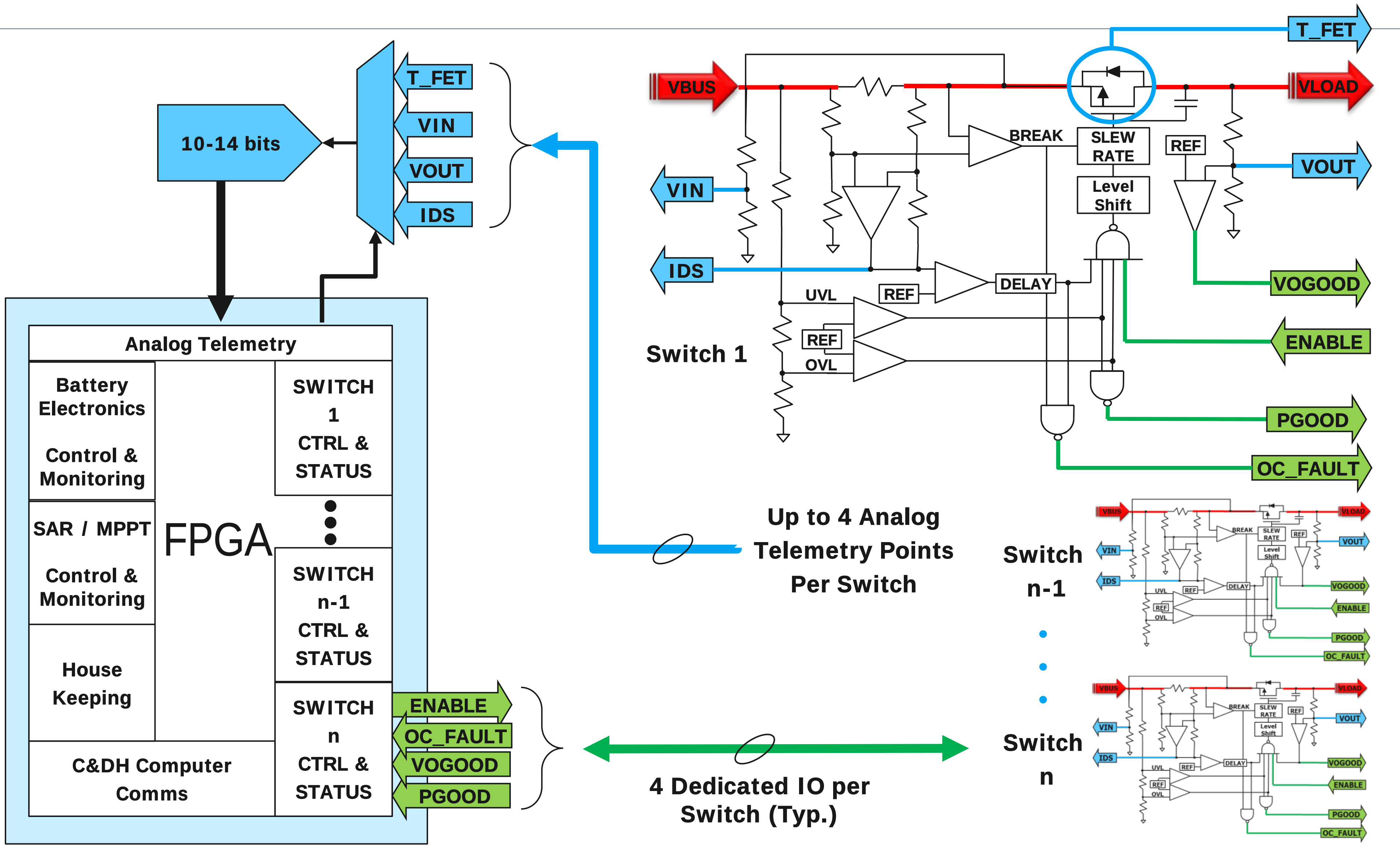

Today's Power Distribution Architecture Isn't SWaP-C Friendly

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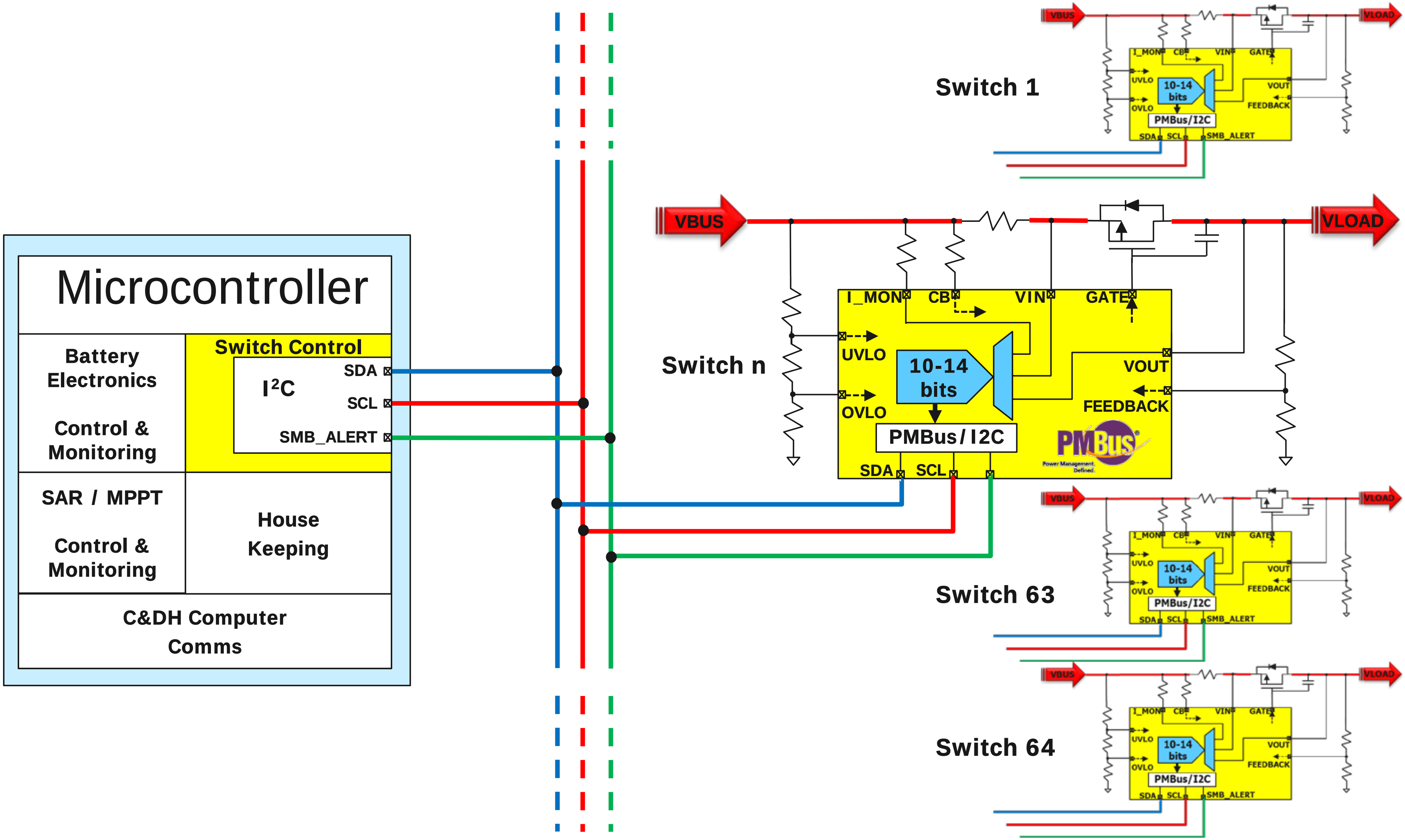
- Large BOM
  - Per Switch:
    - PowerFET, Schottky Diode, Quad Comparator, 1-2 OpAmps, Voltage Reference, Gate Driver, Level Shifters, Logic, plus Passives
  - Analog Mux:
    - One 16-Channel Mux per 4 Switches
  - A2D Converter:
    - One 10-to-14-bit A2D per 64 analog channels, typ.
  - FPGA or ASIC:
    - ~4 IO/switch, plus IO and logic for A2D telemetry processing, housekeeping and interfacing to other systems (e.g. C&DH, BEU, and Solar Array Regulation)
- Not very scalable
  - Large amount of signal routing

Estimate for 64-Channel non-Isolated PDU

Device	QTY	Area (mm^2)	Cost
FPGA (484-CCGA)	1	780	~$15K
ADC (28-CFP)	4	240	~$1.5K
AMUX (28-CFP)	16	280	~$0.8K
Quad Comp (16-SOIC)	64	105	~$0.7K
Quad OpAmp (16-SOIC)	64	105	~$0.7K
VREF (SMD-0.5)	8	75	~$0.5K
Total	157	20.3K	~$127.4K

- **Represents major components required to implement a conventional power switch control architecture**

New "Smart" Power System Control



Smart Power Distribution Architecture SWaP-C Friendly

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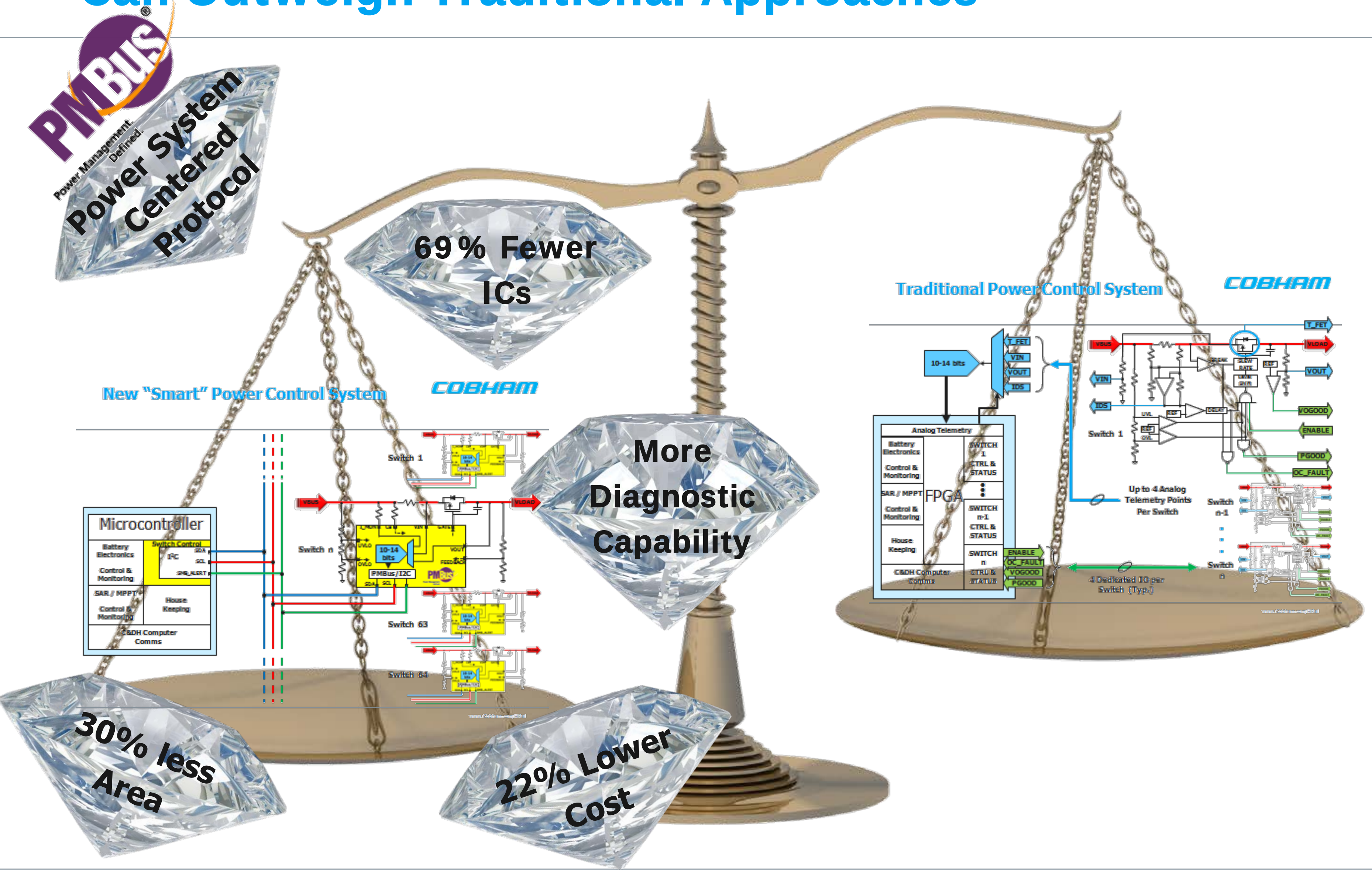
- Significant BOM reduction
  - Per Switch:
    - One integrated "Smart" eFUSE controller
  - No Analog Muxes
  - No A2D Converters
  - No Voltage Refs
  - No Comparators
  - No OpAmps
  - One Microcontroller with I^2C:
    - Full featured uC with I2C, GPIO, Analog Mux, A2D, Precision Current Source, D2A, MIL-STD-1553 can control all Power System Control functions
- Scalable to ~64 switches per I2C bus
  - Only 3-wires required per bus

Estimate for 64-Channel non-Isolated PDU

Device	QTY	Area (mm^2)	Cost
uController (144-CCGA)	1	210	~$3.5K
Power Switch Controller with PMBus (48-CFP)	64	230	~$1.5K
~~ADC (28-CFP)~~	~~4~~	~~240~~	~~~$1.5K~~
~~AMUX (28-CFP)~~	~~16~~	~~280~~	~~~$0.8K~~
~~Quad Comp (16-SOIC)~~	~~64~~	~~105~~	~~~$0.7K~~
~~Quad OpAmp (16-SOIC)~~	~~64~~	~~105~~	~~~$0.7K~~
~~VREF (SMD-0.5)~~	~~8~~	~~75~~	~~~$0.5K~~
Total	65	14.3K	~$99.5K

- **Excludes consideration of elements common to power switch architecture, e.g. PowerFET, Schottky Diodes, Connectors, Passives, etc.**

Smart Power System Control Benefits Can Outweigh Traditional Approaches



HOWEVER...

- I^2C is best implemented on PCB and up to ~1m bus length
  - Running I2C over a wire harness raises concerns about
    * Common mode, Isolation, Voltage Fault Tolerance Noise immunity, etc.
- I^2C is an open-drain, multi-drop, AND'd serial bus
  - Bus faults can render the bus uncommunicable
    - This can be addressed with a redundant I^2C bus, which is common for Microcontrollers and is supported in Cobham's Smart Power Switch Controller
- That said...
- **Cobham is working with the PMBus Standards Committee to define PMBus on a different physical layer (like CAN)**
- **We are seeking participation from Space Power System implementers to help define this Satellite optimized variant of the PMBus standard**
- **If interested, please contact Tim Meade (info on next slide)**

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