Power Electronics for the Next Generation

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Where We Have Been

So You Need Power?

- Who Gives a Watt?
  - And what does that Watt Cost you?

Workhorse of a Spacecraft Power System

- NiCad Battery
  - 22 Watt Hour / kg
    - TRMM Spacecraft 2 batteries with total weight of 278 Pounds (126 kg)
- Nickel Hydrogen
  - 30 to 40 Watt Hour / kg
    - HST 6 Batteries with a total weight of 930 Pounds (421 kg)
- Lithium Ion
  - 80 Watt Hour / kg
    - SDO 1 Battery with a total weight of 97 Pounds (44 kg)

Note: Mixing of Units

Battery Weight Does Not Include

- Solar Arrays
- Power Handling Electronics
- Harness
- Spacecraft Structure to Handle the Weight of the Batteries
- Cooling Equipment

Crude Voltage Estimates for Batteries Over One Orbit

- NiCad Battery
  - End of Day: 33V End of Eclipse: 26.4V ΔV = 6.6V
- Nickel Hydrogen
  - End of Day: 33v End of Eclipse: 26.4V ΔV = 6.6V
- Lithium Ion
  - End of Day: 32v End of Eclipse: 28.8V ΔV = 3.2V

Allowed Voltage Variation on Electronic Logic

- Neon Logic
  - 95v to 500v allowed ripple: 15 volts – 20 volts
- CD4000 Logic
  - 5v to 20v allowed ripple: 1 volt at 5 volt input.
- 74HC Logic
  - 2v to 7v Allowed ripple: 0.5 volt at 4 volt input.
- FPGA's
  - 3.14v to 3.45 and 1.43v to 1.57v Allowed ripple: 0.015 volt input.

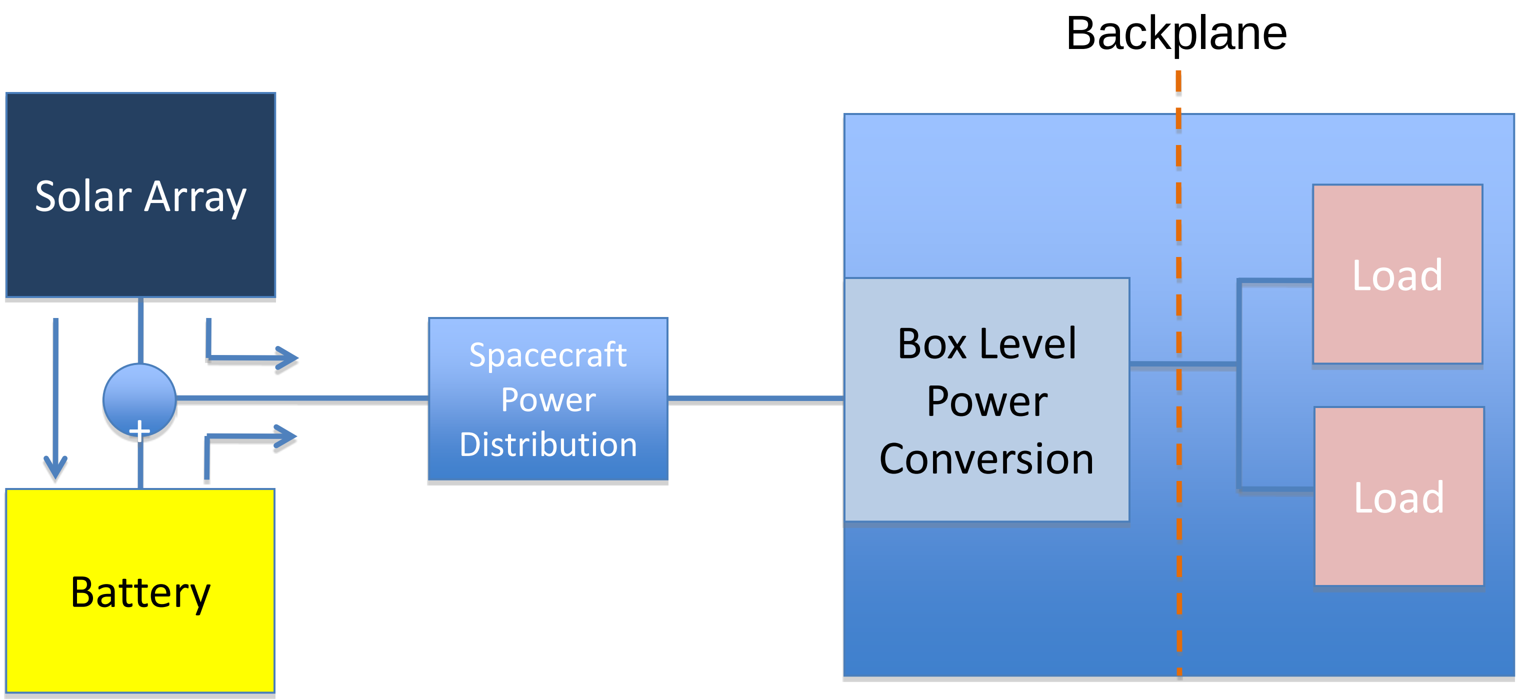
Problems in Developing What We Have.

Top 5 Problems

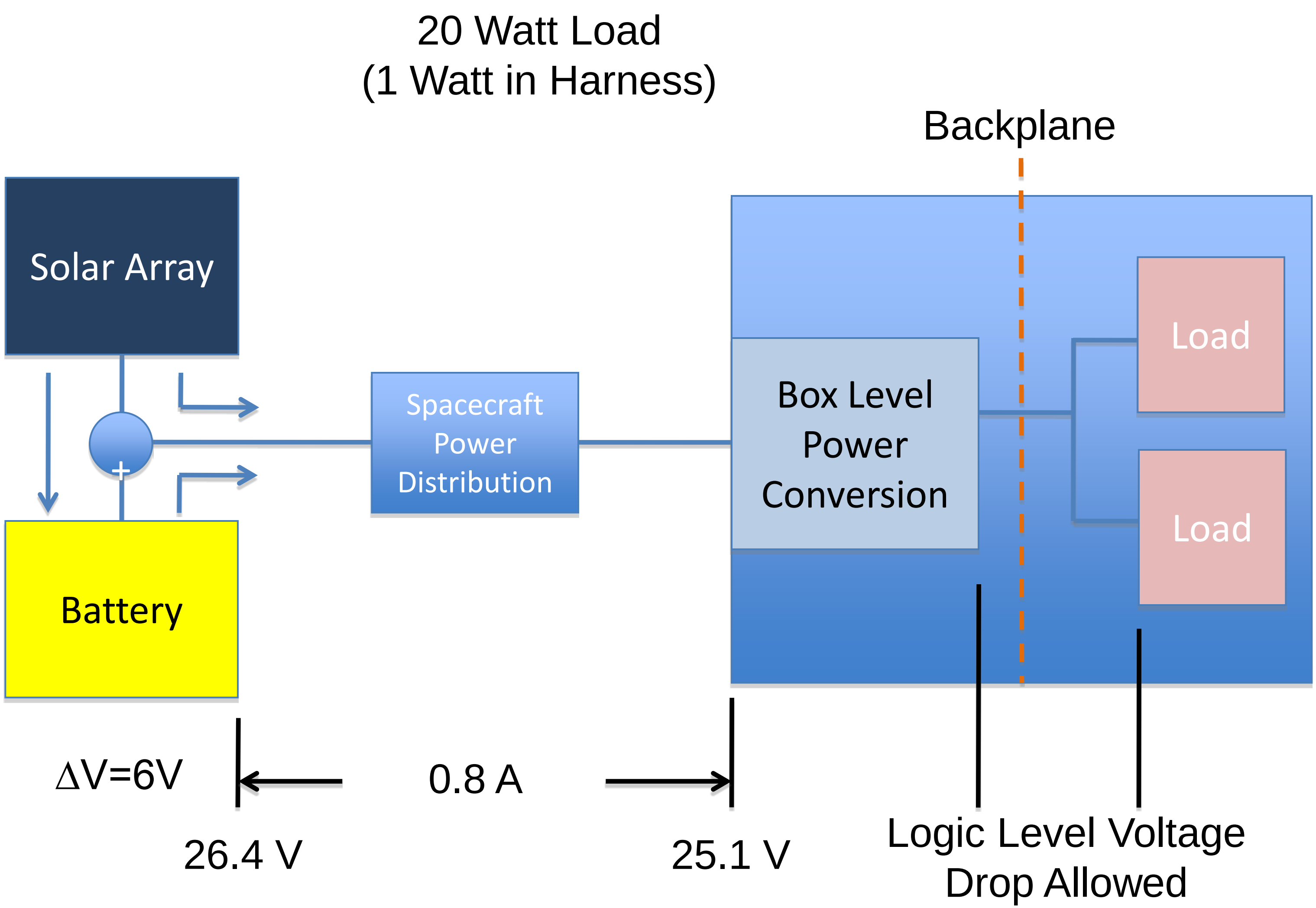
- Lack of Requirements / Requirements Creep.
- Overloading and UNDERLOADING : Both are bad, underloading is less understood.
- Thermal
- Robustness (Distinct from Redundancy)
- Parts Design Changes and Thermal Instability Issues

Where We are Going

Getting Power to Your Parts



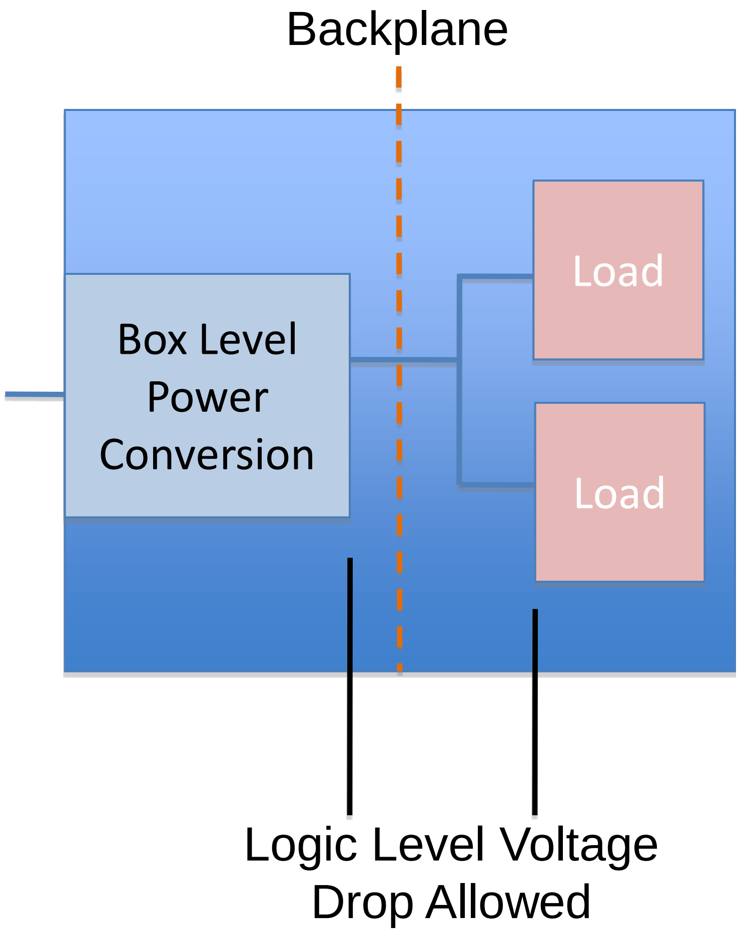
Getting Power to Your Parts
Harness Drop and Voltage Variations.



Resistances Needed to Remain in Specification Due to Logic.

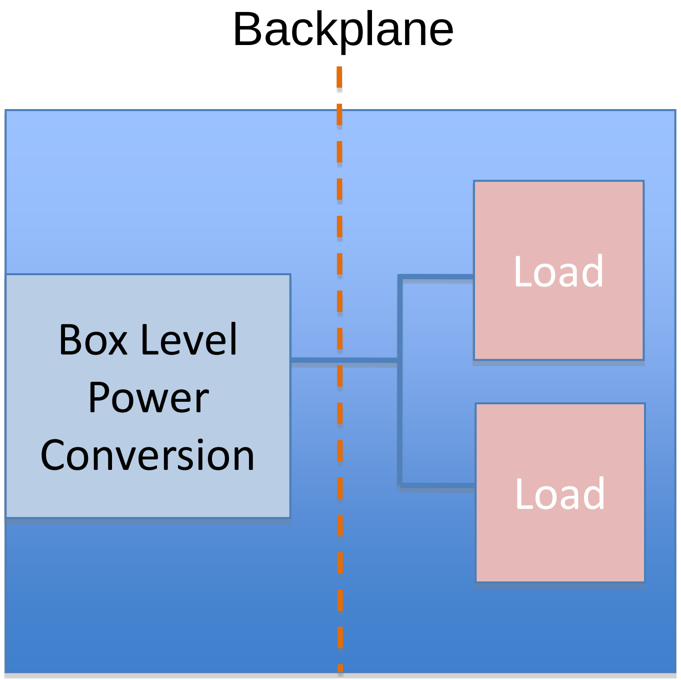
20 Watt Load

Logic Family	Volts	Ripple	Current	Resistance
Neon Bulb	150.0	20.0	0.1	150.0
CD4000	5.0	1.0	4.0	0.3
54HC	4.0	0.5	5.0	0.1
FPGA	3.3	0.04	6.1	0.007
Core FPGA	1.5	0.015	13.3	0.001



Power Delivery Internal to a Box

Logic Family	Resistance	
Neon Bulb	150.0	Lay out the board
CD4000	0.3	Be careful in board layout
54HC	0.1	Ground Plains, Extra Pins, Filtering
FPGA	0.007	?
Core FPGA	0.001	?

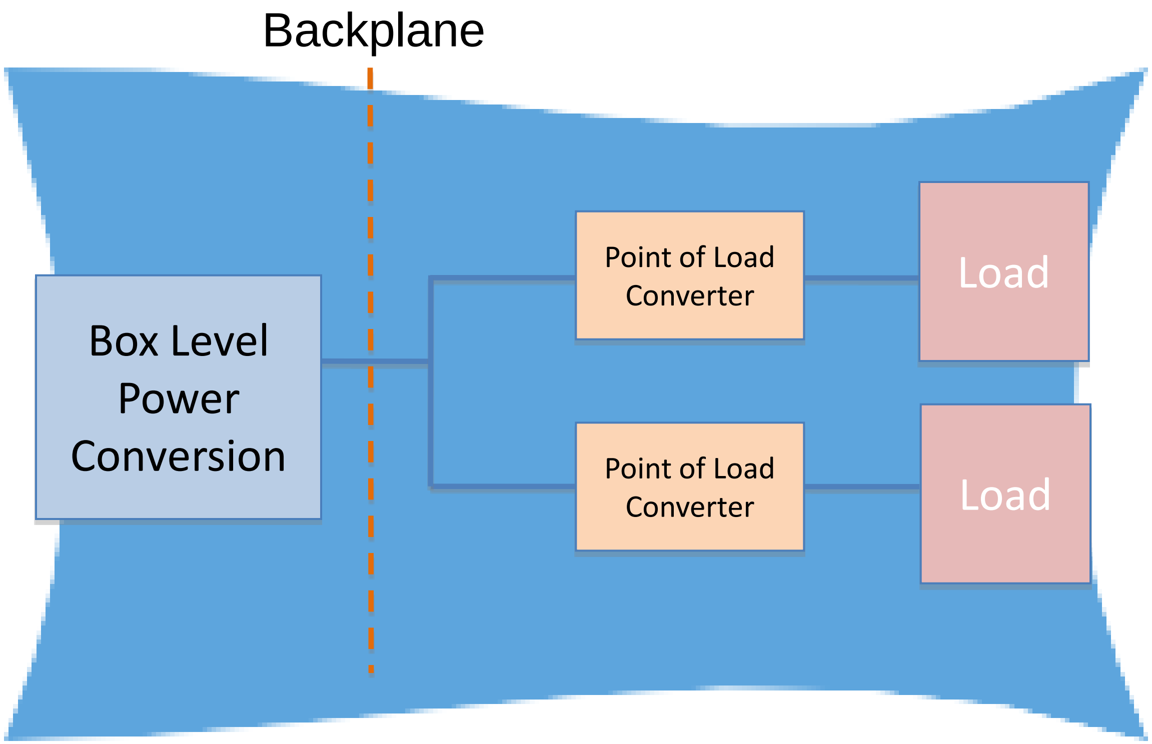


If you can not get there from here…..

Power Delivery Internal to a Box

If you can not get there from here…..

Go somewhere else first!



Point of Load Converters
The JWST ICDH Approach

- James Webb Space Telescope's Instrument Command and Data Handling Box has 20 FPGA's.
- The Approach was to use Low Drop-out Linear regulators near each FPGA.

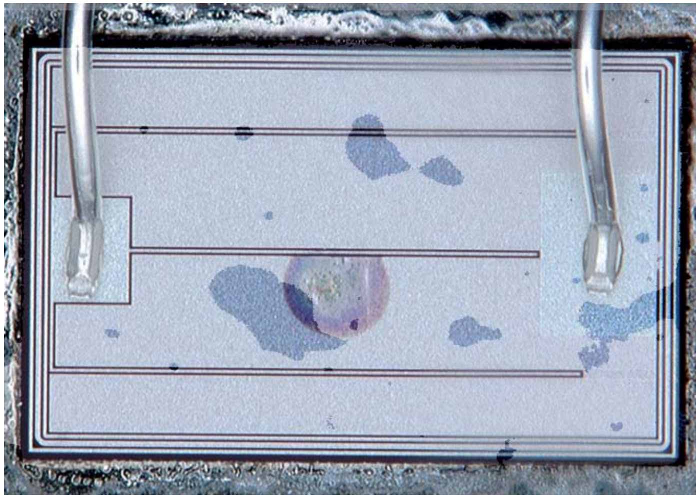
Point of Load Converters
The JWST ICDH Approach

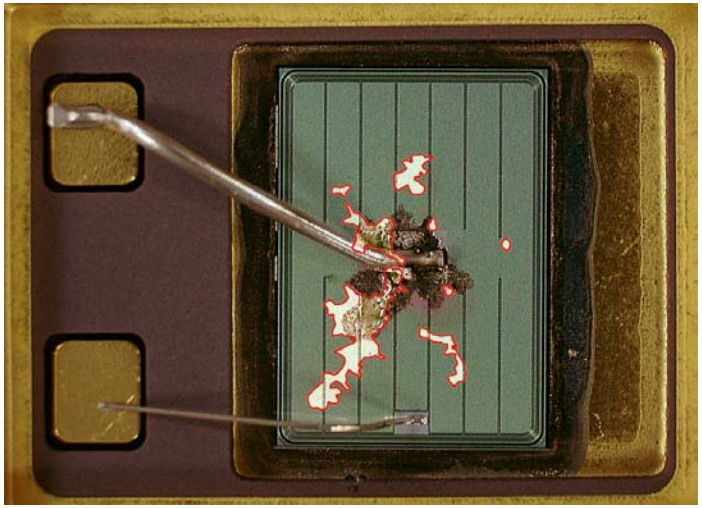
- Low Drop-out Linear Regulators had problems with Radiation.
- Changed for Homemade Linear Regulator, which took up too much space and was complex.
- Final Approach was to use “Standard” Linear regulators. (5.0 Volt to 1.5 Volt) With over all efficiency of 30%.

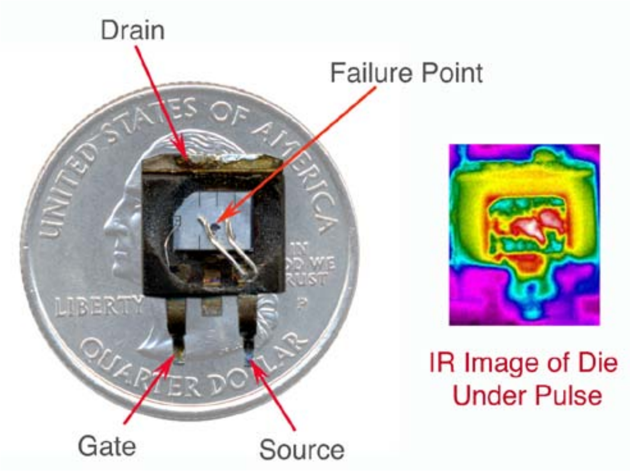
Note on Homemade Linear Regulator.

- Late in the development cycle on JWST it was learned at GSFC that there is a **Thermal Instability** with MOSFETs when Vgs is below ~ 7 volts (Linear Region).
  - As manufactures work to make their MOSFETs faster and lower in On-Resistance, the problem is already causing failures and is becoming worse.

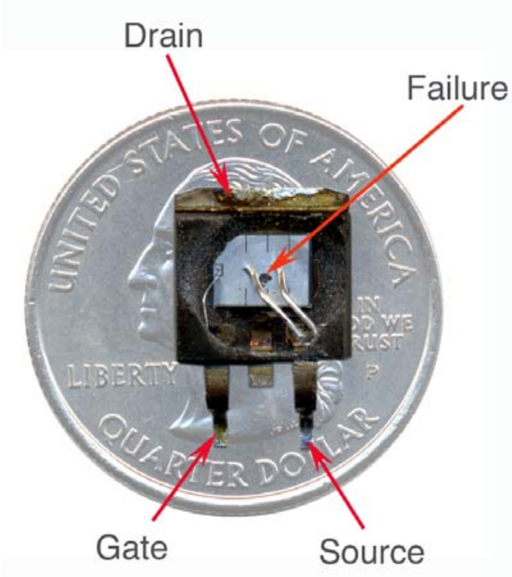
Thermal Instability

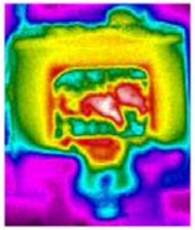






The MOSFET Technical Bulletin (10-01)





IR Image of Die Under Pulse

The MOSFET Technical Bulletin (10-01) has been reviewed by Export Control and deemed Non-ITAR. This document is now available on the NRB PBMA at http://secureworkgroups.grc.nasa.gov/nesc-review-board?go=396207.

http://ntrs.nasa.gov/search.jsp?R=699181&id=1&as=false&or=false&qs=Ntt%3Dmosfet%26Ntk%3Dall%26Ntx%3Dmode%2Bmatchall%26Ns%3DHarvestDate%257c1%26N%3D0

Point of Load
The Next Step

- With the drive for MORE Current, Smaller Input Voltages, and Higher Efficiencies.

- The Next Step is a Switching Regulator

Point of Load
Switching Converters

- Non-isolation Converters (Input & Output Grounds are Common)
- High Efficiency (80% to 97%)
- Small (1.5 inches square)

- Commercial Vendors are starting to be interested in manufacturing Point of Load Converters. **<u>These are Hybrid Converters</u>**

Plans to Qualify Point of Load's

- Obtaining Point of Load's from several vendors.
- Test converters to determine what they can / can not do.
- Bring Manufacturing up to Flight Standard's
- Testing will be done according to the NESC paper on DC – DC Converters. http://standards.nasa.gov/
- Keyword -or- Document Number search on "**DC/DC Converter**"

Plans to Qualify Point of Load's Key Tests

- Performance under low loads and high loads
  - Stability
  - Efficiency
- Performance with dynamic loading on input as well as output.
- EMI