Sabertooth: Integrated Avionics for Small Spacecraft Missions

2022 GR740 User Day Webinar

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Jet Propulsion Laboratory
California Institute of Technology

Advanced Computer Systems and Technologies Group

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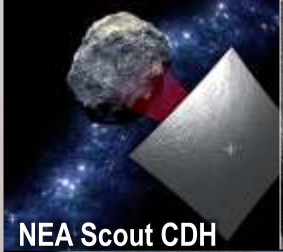
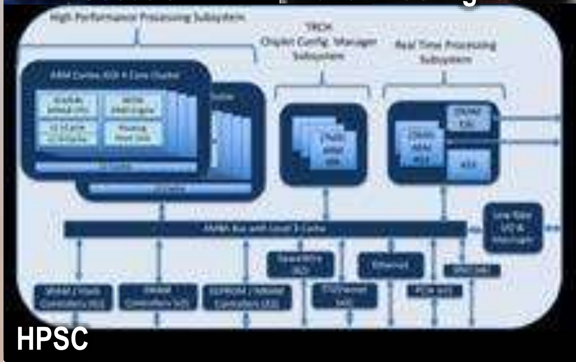
Avionics development for Sabertooth is being led out of the Advanced Computer Systems and Technologies Group at the *Jet Propulsion laboratory*, which develops computing and avionics platforms for future spacecraft and specialized missions.


NEA Scout CDH


Lunar Flashlight CDH


HPSC


49-Core Computer for Autonomous Landing


Heterogeneous Processing for Fast Mobility


Mars Helicopter Avionics


Sabertooth integrated Processor and Avionics

Sabertooth Integrated Avionics

Introduction

Sabertooth is an integrated high-reliability deep space avionics platform

- Designed to support a variety of deep-space missions
- Combines key avionics functions onto a single slice
- Aggressive improvement in Size, Weight, Power, and Cost (SWaP-C)
- Exclusively high-rel parts
- Natively configurable from flight processor to single and dual-string avionics
  - Modular solution which scales to mission needs

Sabertooth Integrated Avionics
background and Goals

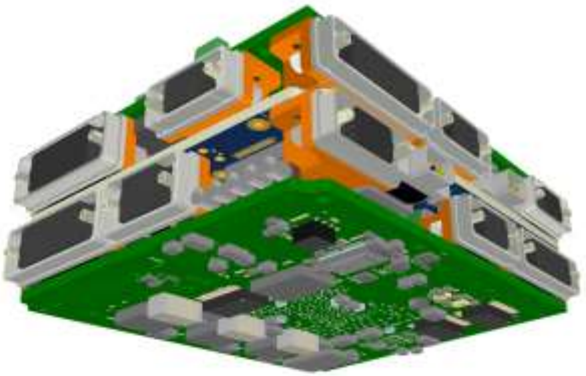
Sabertooth is the follow-on to the Sphinx deep-space cubesat single-board C&DH

2014
Sphinx

2017
Sabertooth

Goals:

- 8-10x improvement in SWaP-C over state of practice Avionics
  - Reduction in Size, Weight, Power, Cost
  - Increase in performance
- Integrate subsystems
  - Eliminate subsystem cabling
  - Reduce Warm Electronics Box volume
- Flagship-class capability and reliability



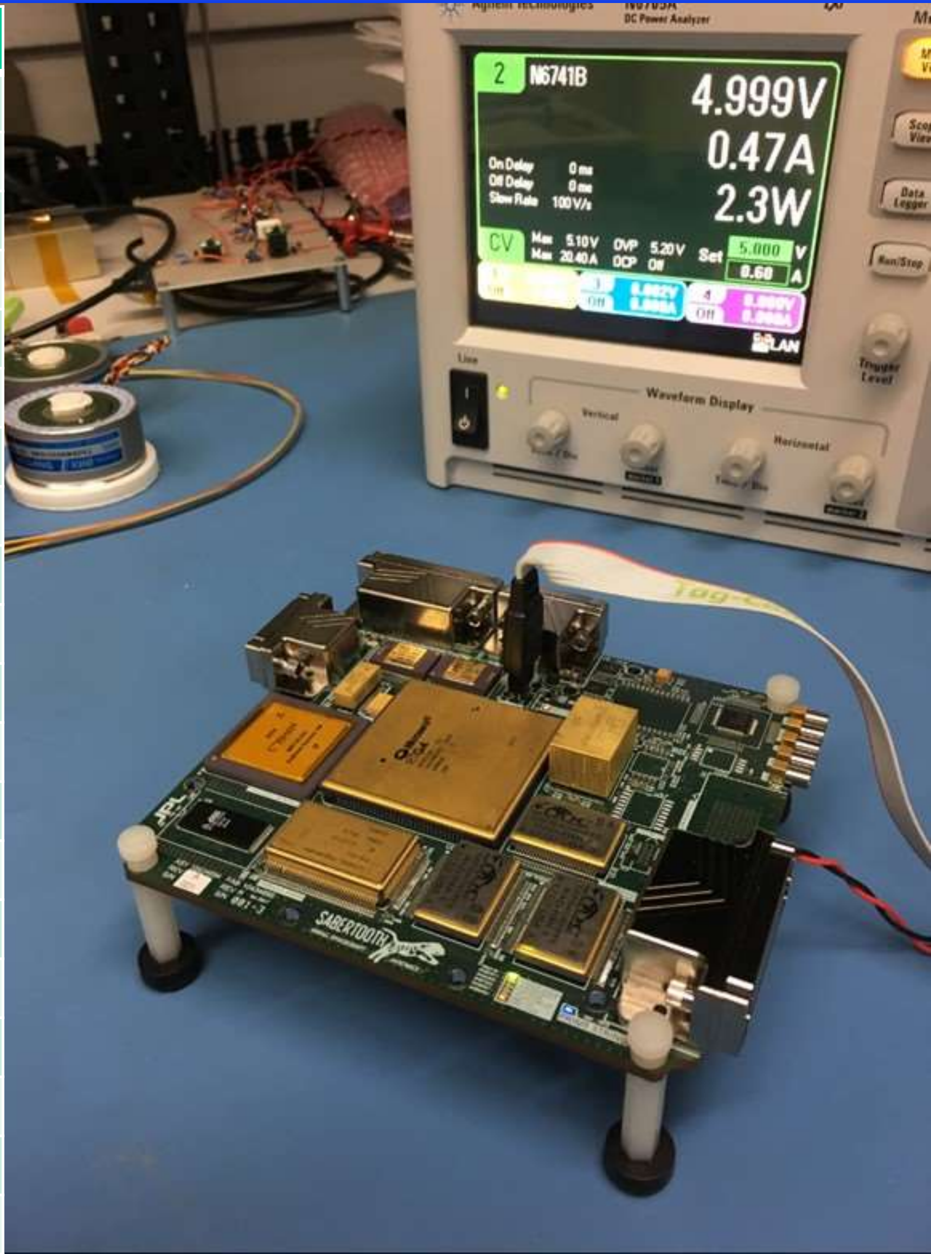
2 Sabertooth Processors + Fault Management Unit Stack-up

Attribute	Class B Sphinx	Sabertooth	State of Practice
Cores:	Dual Core	Quad Core	Single
CPU Performance:	160 MIPS	~1200 MIPS	266 MIPS
Power:	1-3W	currently 4.8W	10+W
Mass:	0.55kg	currently ~3kg	10+kg
Size:	10cm x 10cm x 1.5cm	11cm x 12cm x 4.5cm	cPCI-based subsystems
Radiation (CPU):	300krad	300krad	1Mrad

Sabertooth Integrated Avionics

Key Specifications

Feature	Target
Processor	**GR740 SPARC V8 Processor**
Processor performance	**1200MIPS**
Processor cores	Quad-Core
Power	**5W**
Mass	3kg
Size	**11cm x 12cm**
Radiation (Overall)	100krad
Radiation (CPU)	300krad
FPGA Device	**Microsemi RTG4 FPGA**
Board Supply Voltage	5V
Data Storage	**8 GBytes NAND**
Flight Software Storage	**6 X 32 Mbytes NOR**
Start-up ROM Size	4 x 64 kBytes with EDAC
RAM	256MBytes PC100 SDRAM with EDAC
SpaceWire	**8 Channels**
Motor Control	64 channels
GNC	7 channels
Time distribution	64 channels
Telecom	Full Iris transceiver signal processor + DAC/ADC
Packaging	Slice-based, Serial interconnect

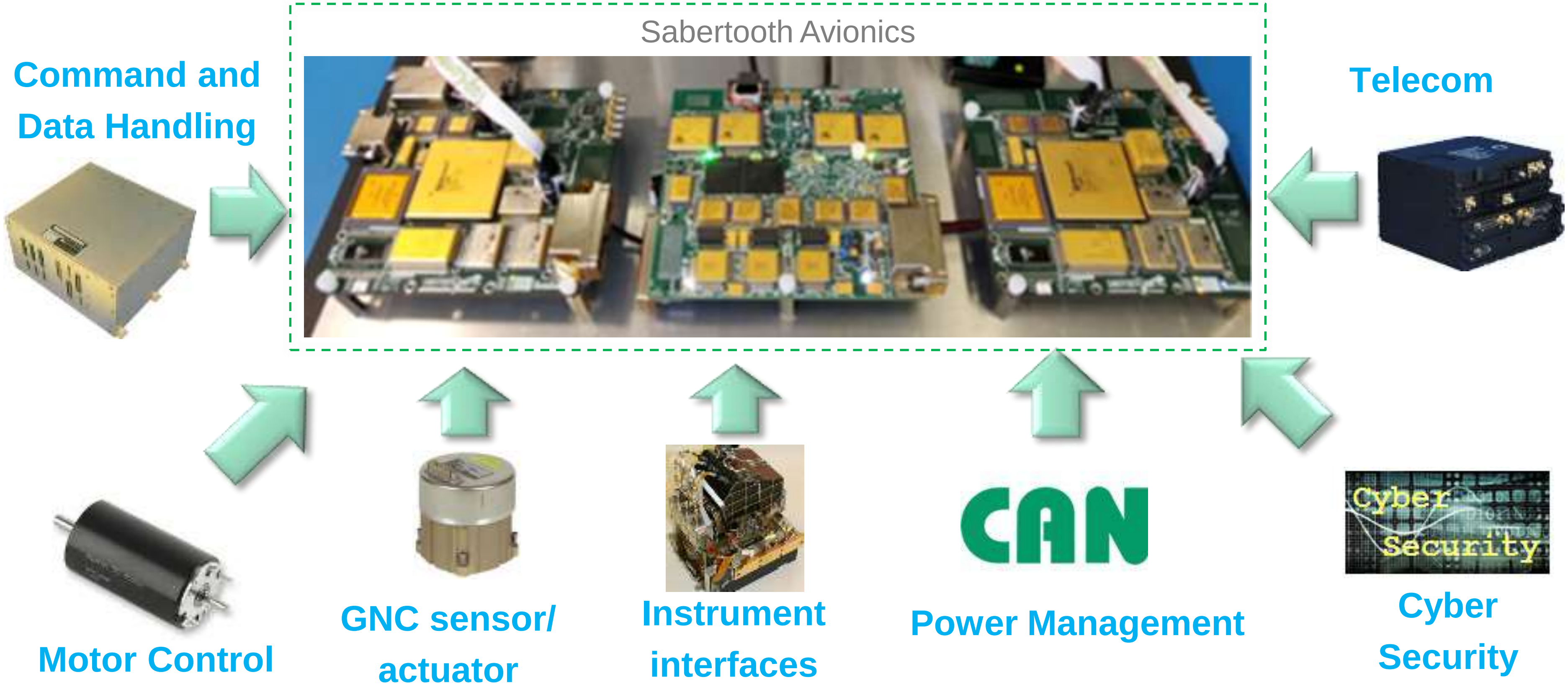


Sabertooth Integrated Avionics

Integration of Key Avionics Subsystems

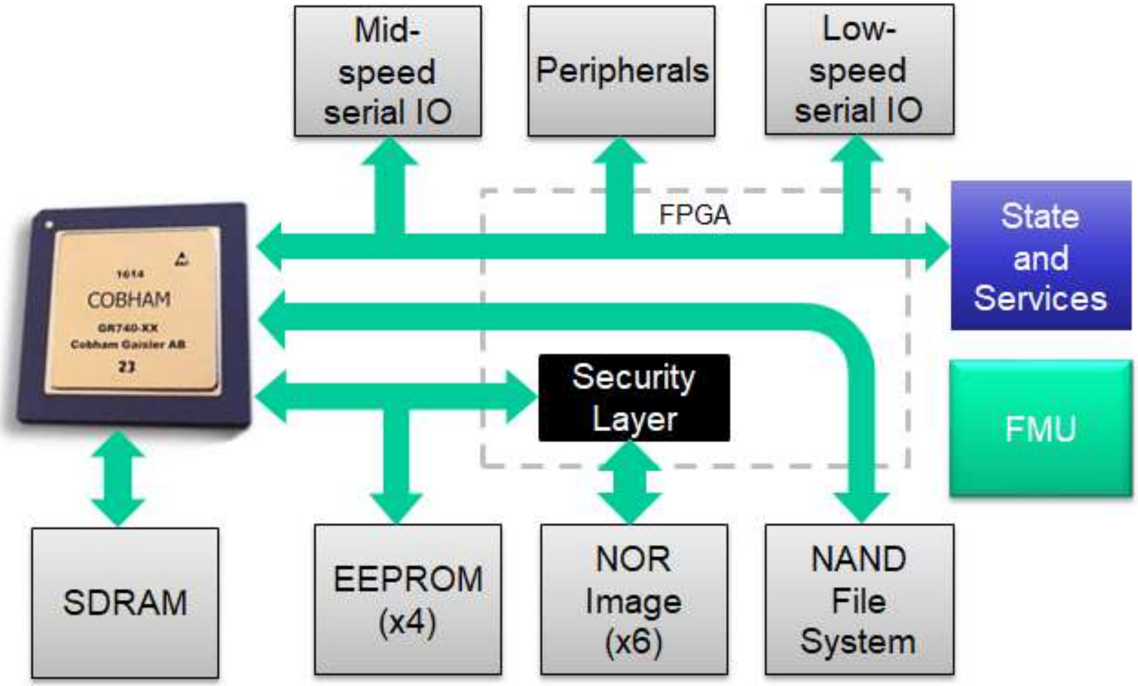
Sabertooth Avionics integrates multiple subsystems into a compact assembly

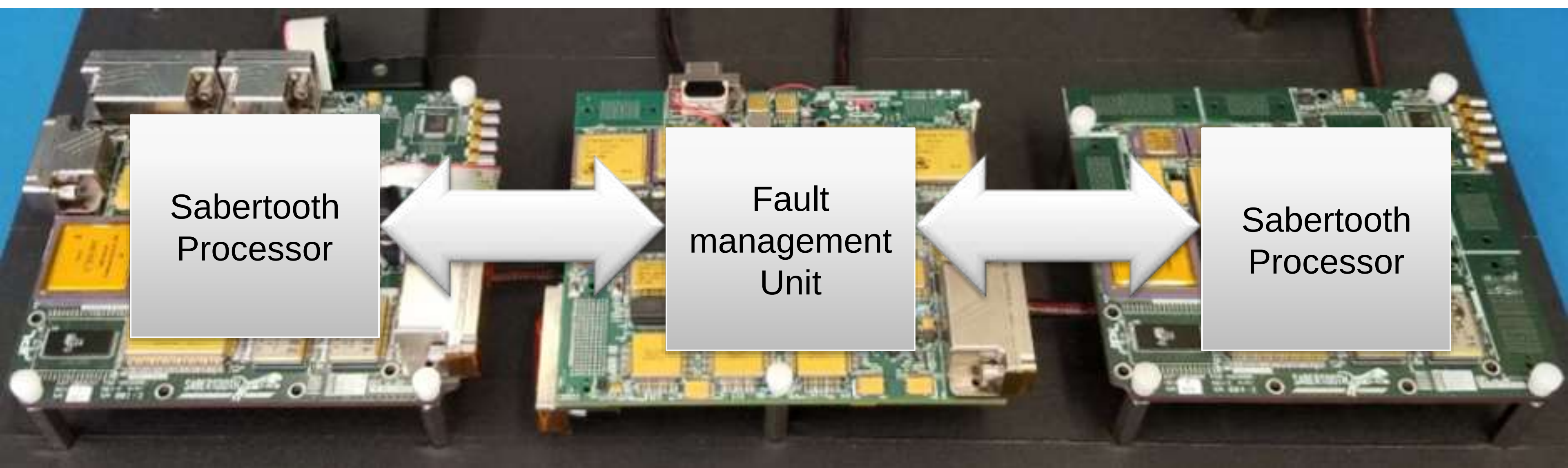
- Combine traditionally individual subsystems
  - CDH, telecom, Motor Control, GNC, power regulation/switch/housekeeping
- Integrate the functions of consistently-required support cards



Sabertooth Compute Layer

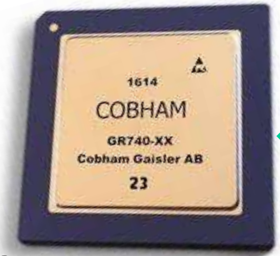
- GR740 Processor
- Spacewire for payload and interconnect
- Low-speed serial
  - SPI / UART / LVDS
- EEPROM bootloader
- FSW image memory
  - Cybersecurity protected
- NAND-based file system

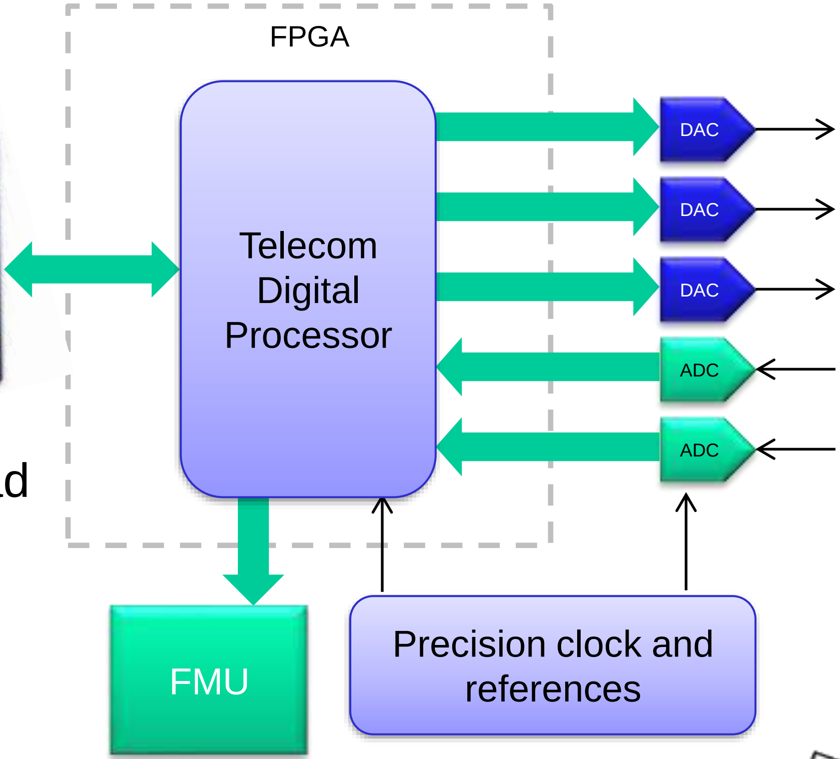


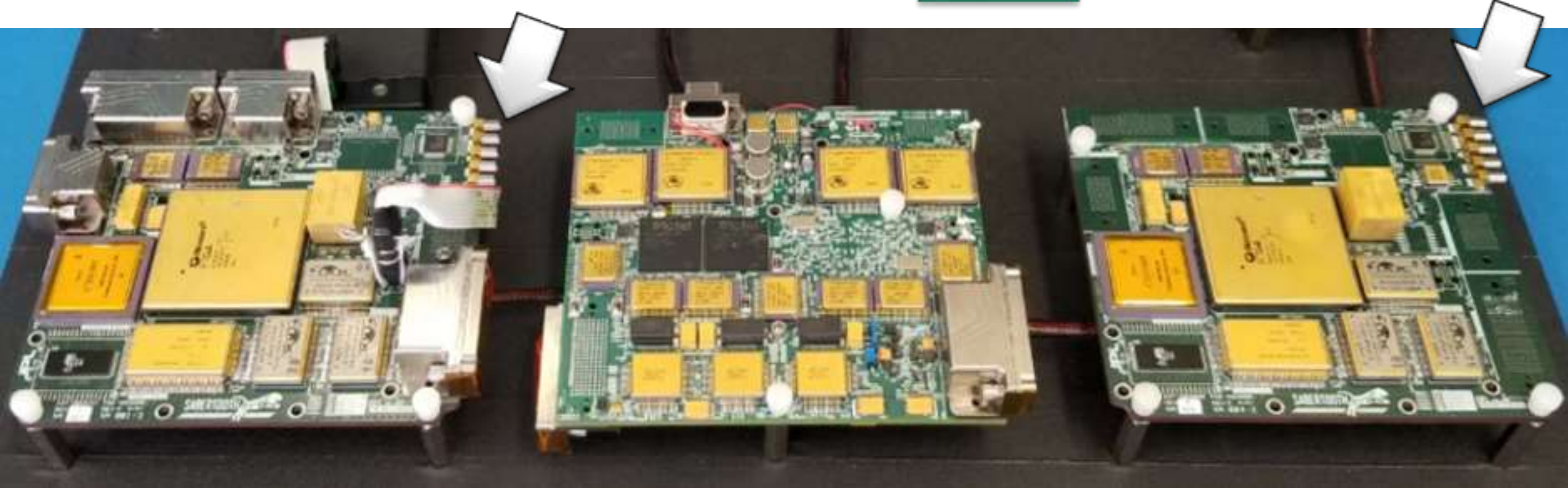


Sabertooth Telecom Layer

- Integrated Iris deep-space radio
  - Signal Processing
  - ADC/DACs
  - EMI doghouse in frame
- Radio FSW runs on GR740
  - Radio-CDH interface is thread-to-thread
- Radio firecode interface to FMU
- Supports UHF/X/S/Ka-band RF slice

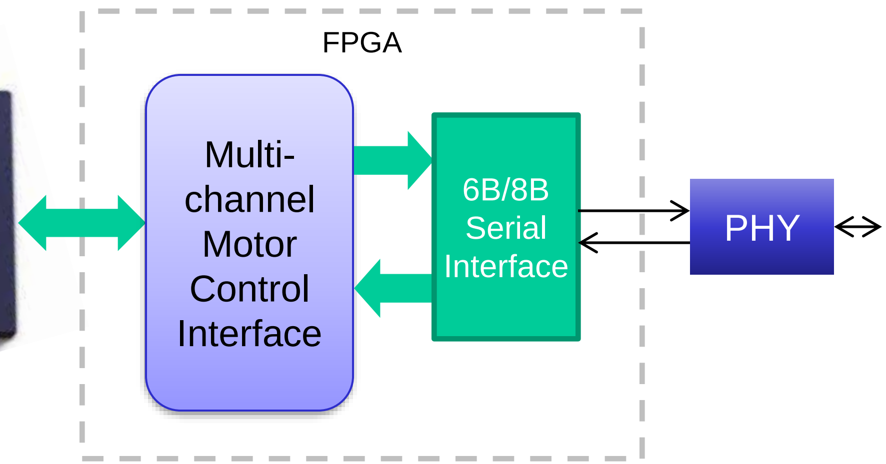


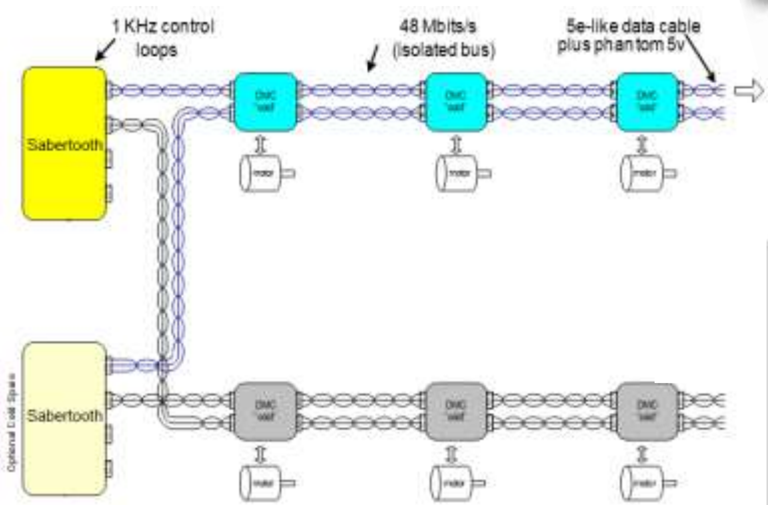


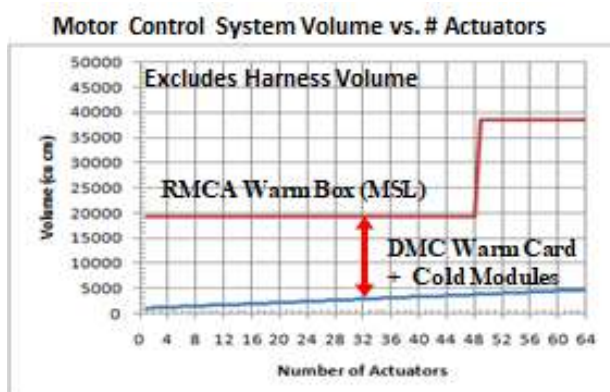


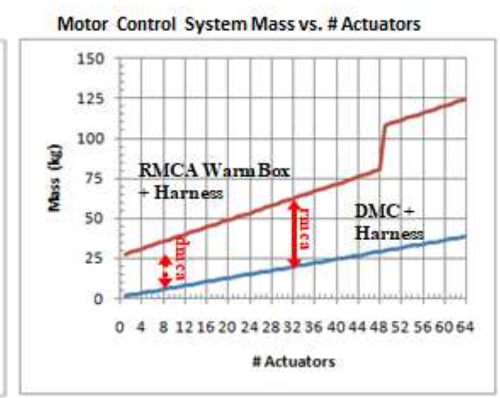
Sabertooth Motor Control Layer

- Distributed Motor Control Architecture
- Design inheritance from M2020 and Mars Helicopter
- All motors connect via a single CAT5 cable
- Improvement in performance while reducing overhead
  - Reduce SWaP
  - Reduce Cable complexity
- HW and SW loop control



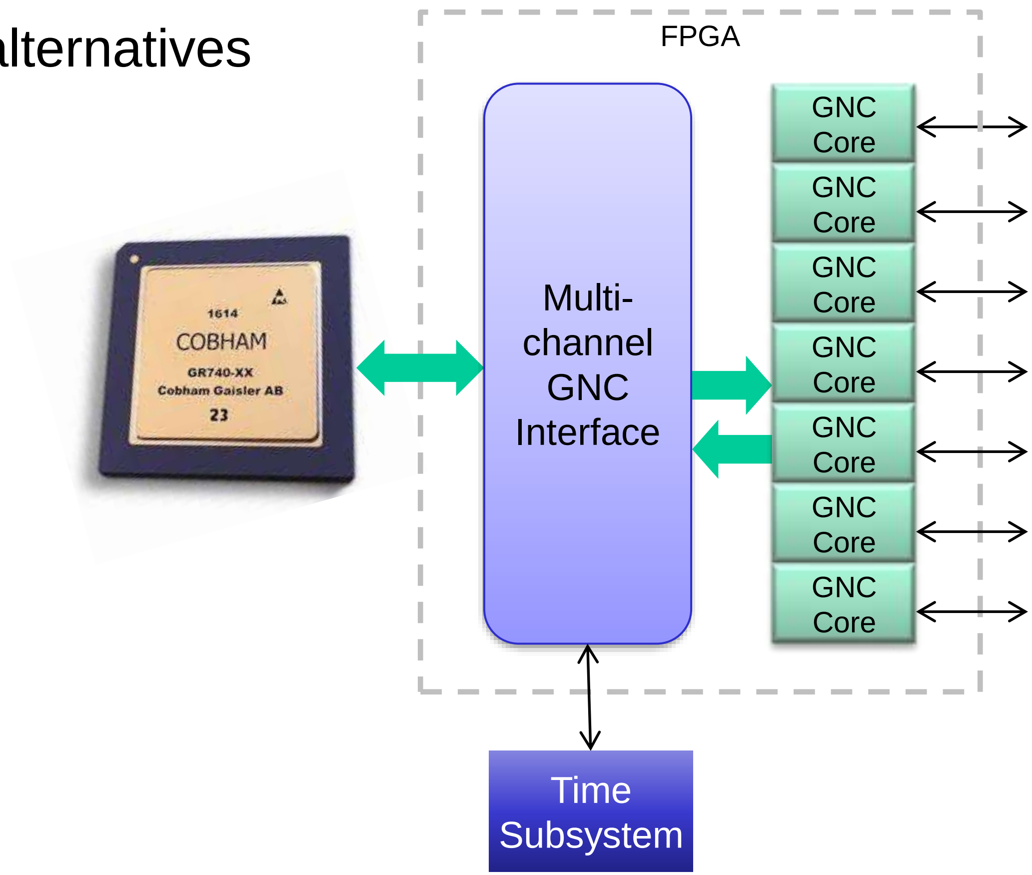






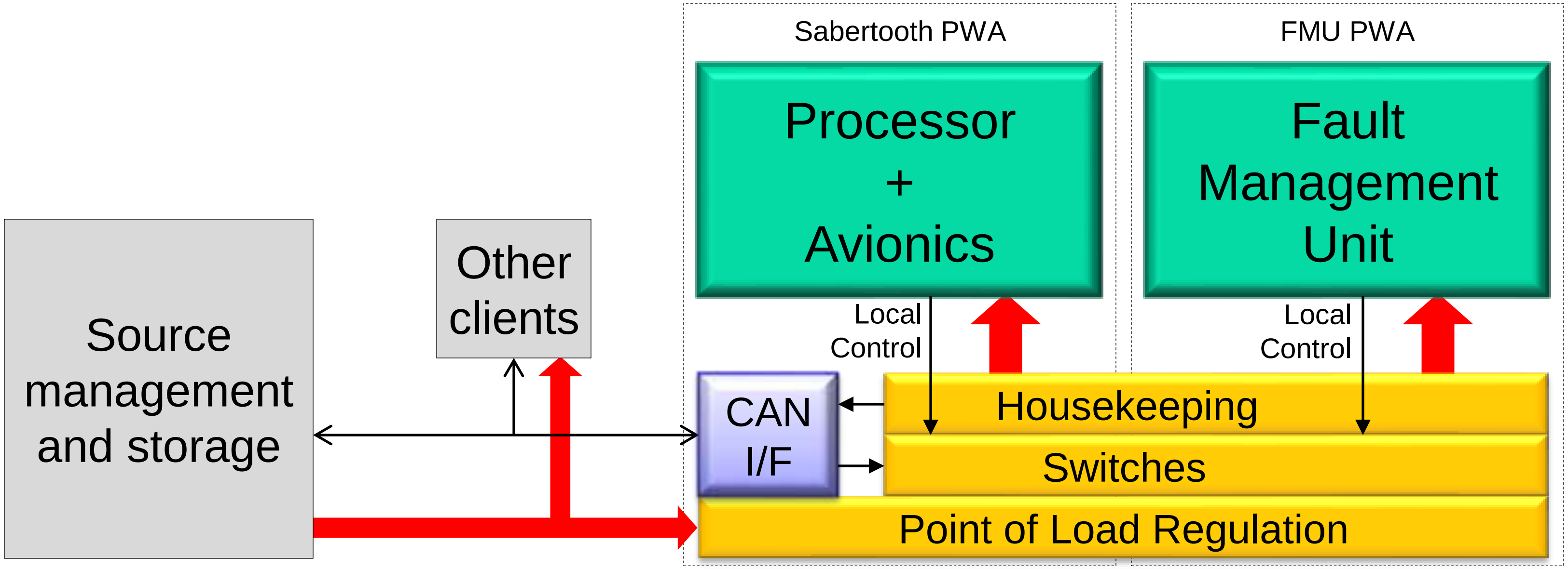
Sabertooth GNC Layer

- Integrated programmable GNC interfaces
  - Programmable GNC devices
  - Provides interface, data strobes/enables/valids
  - Integrated timestamping
- Increase variety and combinations of GNC devices
- No native 1553 support, use alternatives
  - Spacewire
  - LVDS / 422



Sabertooth Power Layer

- Sabertooth supports a distributed power architecture (DPA)
  - Control and housekeeping via CAN Bus
- DPA is a key element in the significant reduction in power
  - Increased efficiency from source to load
  - Enable fine-grain power management
  - GaN devices
  - Complemented with the low-power-focused architecture and Sabertooth design
  - Supported by efficient flight parts at the load



Sabertooth Integrated Avionics

Challenges

***Integrating historically separate subsystems*:**

Order of magnitude improvement in SWaP requires attention from the system-level down to the components

- Focusing multi-disciplinary team to develop an integrated assembly
- Impact on the whole as important as the optimization of a subsystem
- Adapting to the blurring of subsystem boundaries
- Maintaining reliability while altering traditional fault containment regions

***Maintaining a low-SWaP focus*:**

There is a huge desire for unbounded increases in features which must be managed

- Features are always traded against SWaP impact
- Prioritizing mission-enabling capability
- Containing feature creep with the 80% rule:
  - "support of 100% of the requirements for 80% of the application in the target space"
  - Don't allow the outliers to drive up the SWaP-C for the majority customer

Sabertooth Integrated Avionics
Challenges

Flight Component Limitations:

Sabertooth is a significant increase in function density and modern flight parts are very capable…

…but flight parts lag behind in some critical areas

- Need reliable rugged high-density connectors
- Need a better selection of instrumentation amps, sense amps, op amps, flight passives (02-01s)
- Flight memories are always a need: high-rel, long life, high density, and low power

Sabertooth is designed to support a new generation solar system exploration missions with improved SWaP, performance, and cost

- Enable new spacecraft and spacecraft configurations
- Explore new destinations
- Gather new science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GR740-XX
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SN 001-3
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