Operational Missions in the Demanding Environment of Space

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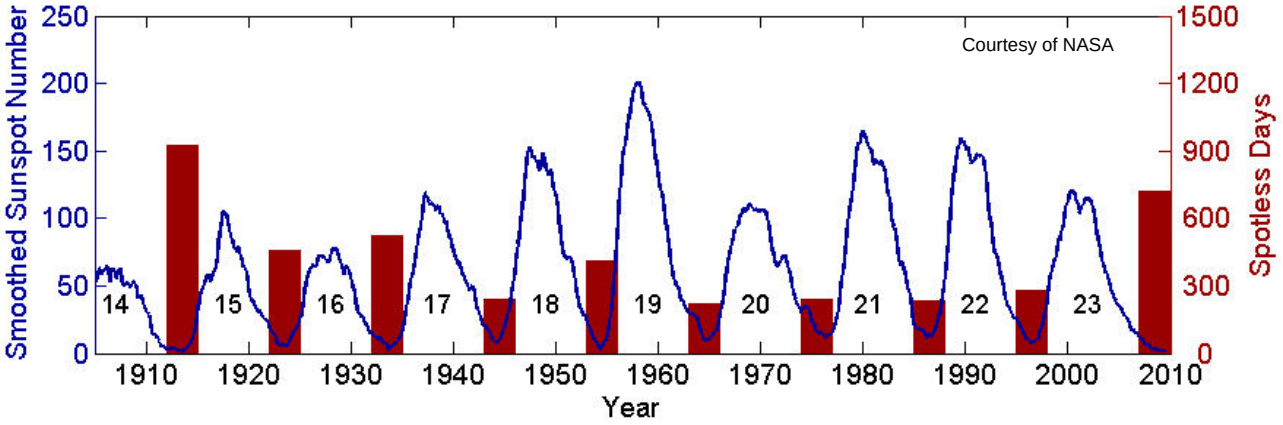
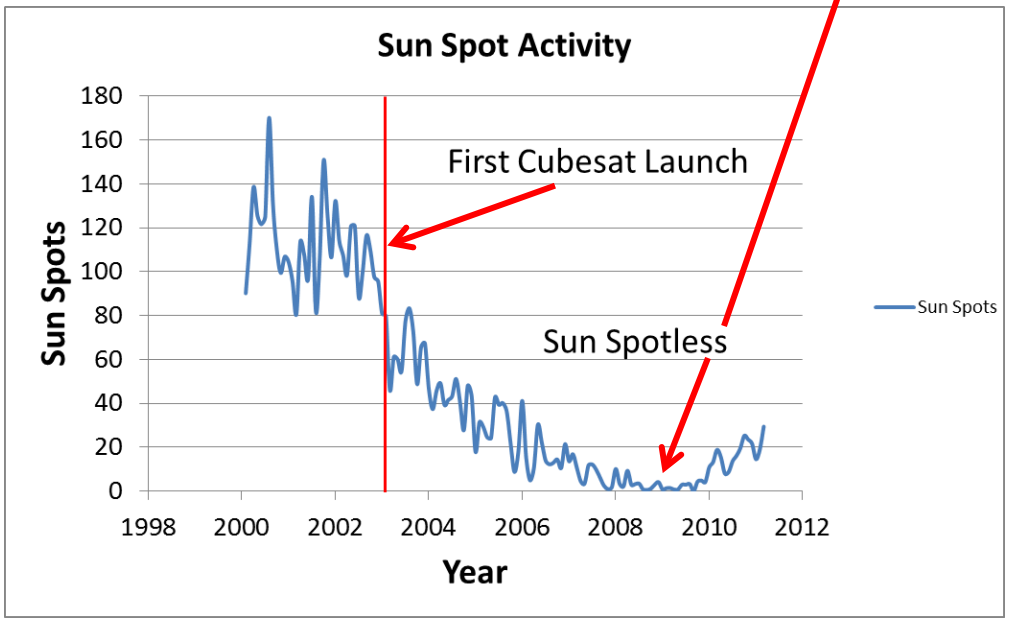
Where have all the sunspots gone?



- Sunspots almost completely disappeared in 2008-2009
  - "Blankest" of the space age
  - Hundred-year lows
- First cubesat launched 2003
- Bulk launched 2006 to present



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Why do we care?

- Sunspot activity directly relates to radiation activity and to radiation-induced electronics failure
- July 11, 2008: Stop the presses! The sun is behaving normally. So says NASA solar physicist David Hathaway. "There have been some reports lately that solar minimum is lasting longer than it should. That's not true. The ongoing lull in sunspot number is well within historic norms for the solar cycle."
- Solar activity will rise again and is already doing so
- The associated radiation damage to space electronics will also increase
- Operational missions will need to be prepared

Operational Missions

- **Different mindset**
  - **Must achieve mission (not design, not launch)**
  - **Even cubesats need reasonable assurance of success**
- **These matter:**
  - **Handling precautions (ESD, shock, contamination, etc.)**
  - **Detailed design reviews**
  - **Requirements verification (prove performance prior to launch)**
  - **Quality assurance (parts quality, traceability, certified processes and personnel, etc.)**
  - **Reliability in the space environment**

Customer View
(Paying for mission data)

Option A:
- $4.0M total program
  - $2.0M payload
  - $0.5M spacecraft
  - $1.5M mission execution
- Lower probability of success

Option B:
- $5.0M total program
  - $2.0M payload
  - $1.5M spacecraft
  - $1.5M mission execution
- Higher probability of success

25% more cost leads to higher probability of success

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EEEParts Approach for Cubesats

Balance Between cost, SWAP, and reliability

- **SDL has adopted a 5-step approach for cubesat parts selection to meet the balance**
  1. Where possible, use rad-hard-by-design parts on critical functions
  2. Spot shielding for other application-critical parts
  3. Select parts with radiation test data
  4. Select parts with known space-flight heritage
  5. Select parts that belong to radiation-tolerant families

Bus Interface Controller Overview

- **Designed to meet operational mission requirements and environments**
  - Aeroflex LEON3 Fault-tolerant Microprocessor
  - EDAC Protected Memory
    - 128 Mbytes SDRAM
    - 512 kbytes Boot PROM
    - Redundant 512 Mbytes Flash
  - I/O
    - SpaceWire
    - RS422
    - GPIO - with Interrupts
  - Ethernet and RS422 Debug Interfaces
  - PCI-104 Bus, 32-bit, Up to 33Mhz
  - RTOS Support
    - VxWorks 6.x
    - RTEMS
    - Linux

AeroFlex LEON 3FT Processor

- **System on a chip processor**
  - Aeroflex UT699RH LEON3 Fault-tolerant SPARC-V8e
    - Up to 66 MHz, 32-bit
  - Radiation-hardened-by-design process
    - 100 krad(Si) and 300 krad(Si) parts available
    - SEL Immune > 108 MeV-cm2/mg
  - Fault tolerant processor
    - On-chip RAM SEU error correction of up to 4 errors per 32-bit word
    - External memory EDAC controller
  - High-performance fully pipelined IEEE-754 FPU
  - Integrated PCI 2.2 compatible core
  - Four integrated multi-protocol SpaceWire Nodes with RMAP
  - Ethernet port for VxWorks development

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EEPROM, SDRAM & Flash Memories

- **EEPROM SuROM (Hitachi EEPROM)**
  - Tested to 100 krads(Si)
  - SEL LET > 60 MeV-cm2/mg
- **SDRAM (Micron)**
  - Tested to 50 krads(Si)
  - SEL LET > 51 MeV-cm2/mg
- **Redundant Flash Memories (Micron)**
  - Tested to 50 krads(Si)
  - SEL LET > 54 MeV-cm2/mg

Peripheral Support Electronics

- **Parts selection for other peripheral interface components follows the 5-step approach**
- **Minimum parts standards:**

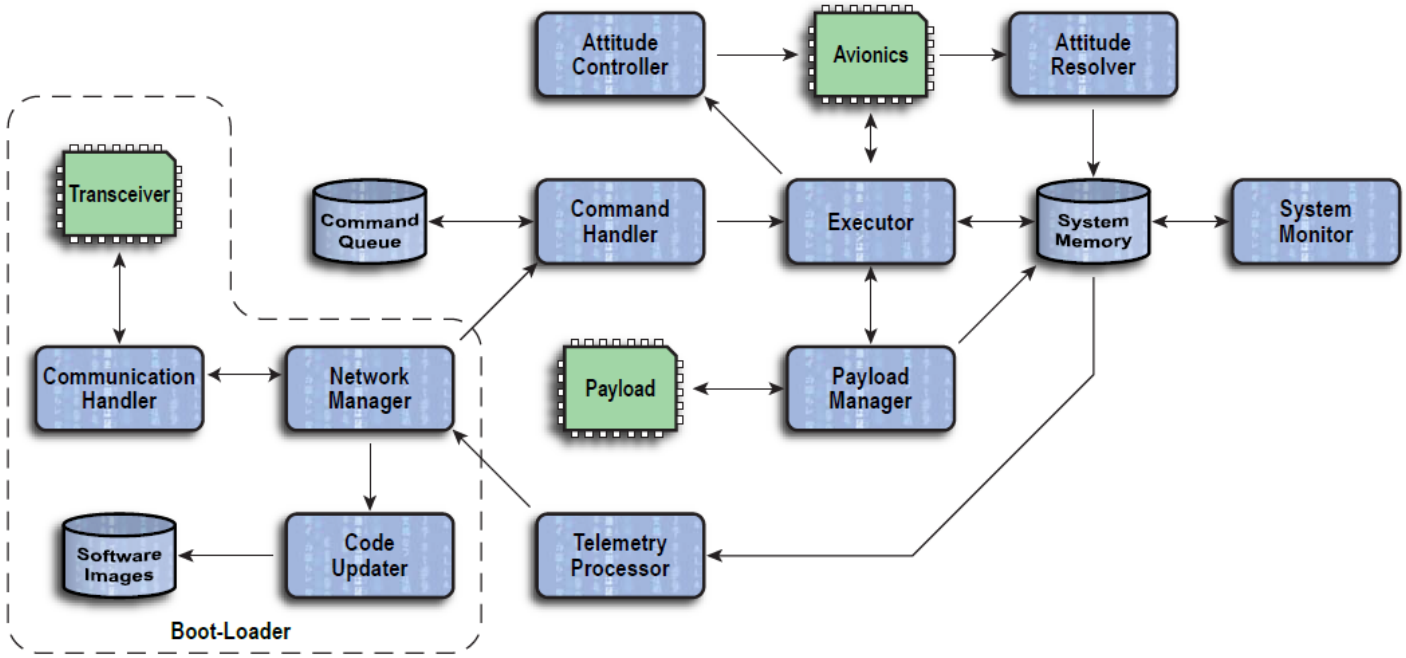
Component	Specification / Selection Criteria
Capacitors, Ceramic	Mil-PRF-55681; High-rel automotive
Capacitors, Tantalum	Preferred: Mil-PRF-55365,39006,39003; Secondary: Industrial grade
Resistors, Chip	Meets or exceeds Mil-PRF-55342 specification
Semiconductors	Meets or exceeds Mil-PRF-19500
Integrated Circuits (Microcircuits)	Industrial grade (I) Temp range -40 to +85 degrees C
Oscillator	Preferred:Mil-PRF-55310; 4-point mount, Industrial grade

Software Fault Tolerance & Mitigation

- **Start-up ROM**
  - Boot-loader
  - Additional minimal subset of functionality needed to communicate with the spacecraft and upload new code (fault/safety feature)
- **Multiple bootable images**
  - Operating System & Flight Software
  - Protects against image corruption
- **Memory scrubbing**
  - Low-priority background utility to keep bit flips from becoming a growing problem

Software Modularity

- **Software architected as individually testable and verifiable modules**



  - Individual modules can be updated or replaced without impact to other modules.

Another 50 Years Of Excellence!

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