Development and Operation of the STPSat-5 Small Satellite Power Subsystem

Space Power Workshop
Torrance, CA

April 1, 2019 – April 4, 2019

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DEVELOPMENT AND OPERATION OF THE STPSAT-5 SMALL SATELLITE POWER SUBSYSTEM

Space Power Workshop – Torrance, CA

April 1, 2019

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- Pat Remias, John Eterno, Clyde O'Quinn – Sierra Nevada Corporation – Louisville, CO
- Clifford Graham, Mark Barrera – The Aerospace Corporation – Albuquerque, NM and El Segundo, CA

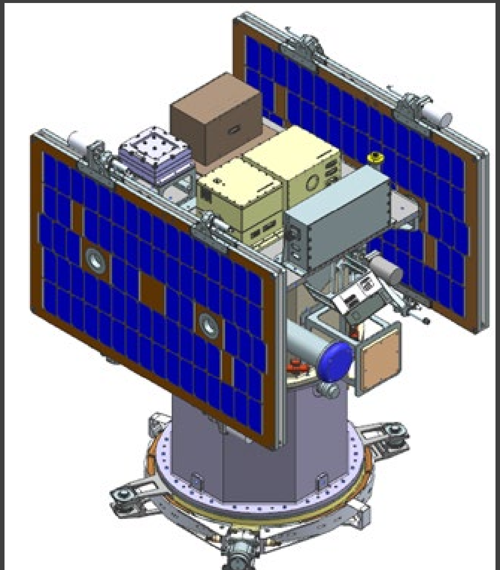

Image courtesy of Sierra Nevada Corporation

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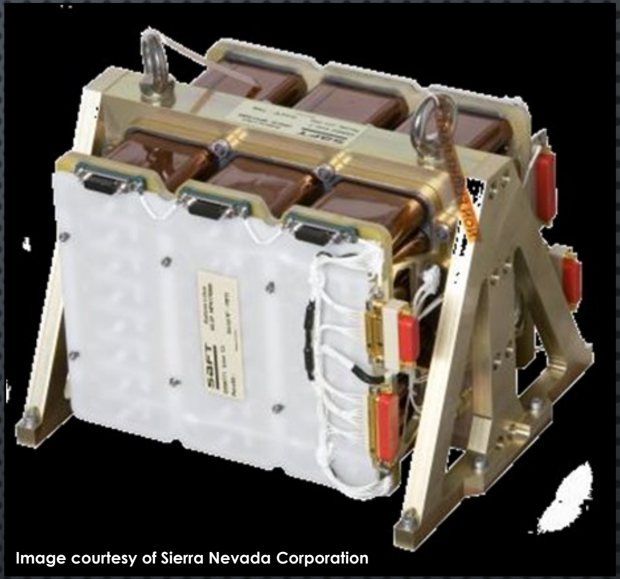
STPSAT-5 Power Subsystem Development and Operation

- Mission Overview
- Driving Power Requirements
- Spacecraft Overview
- Power Subsystem Overview
- Power Subsystem Development and Analysis
- Mission status
- Power Subsystem Performance on orbit
- Lessons Learned



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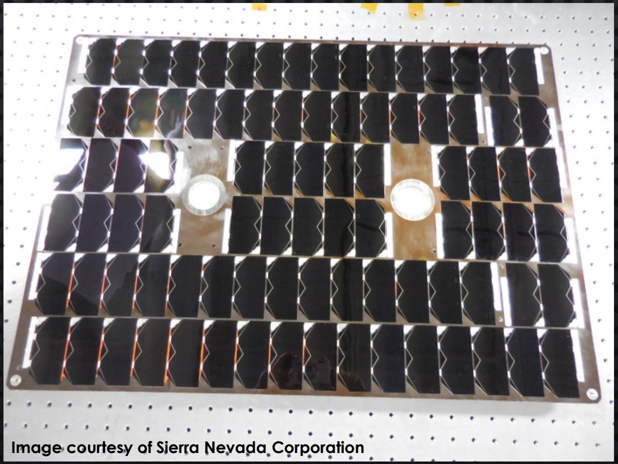

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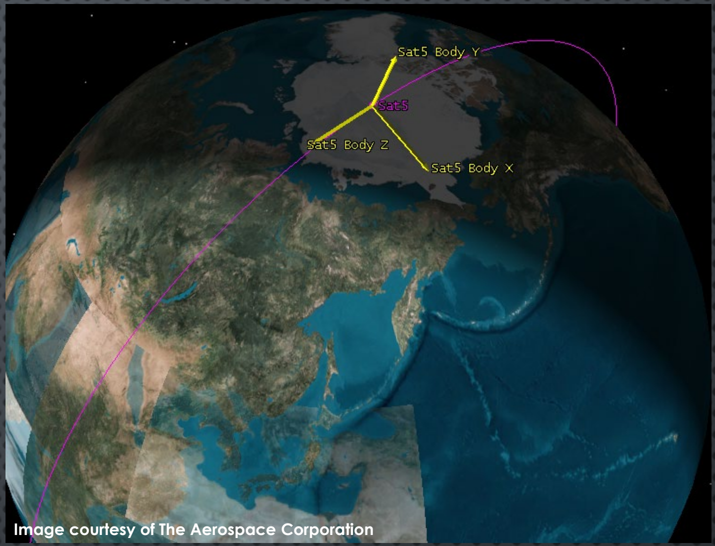
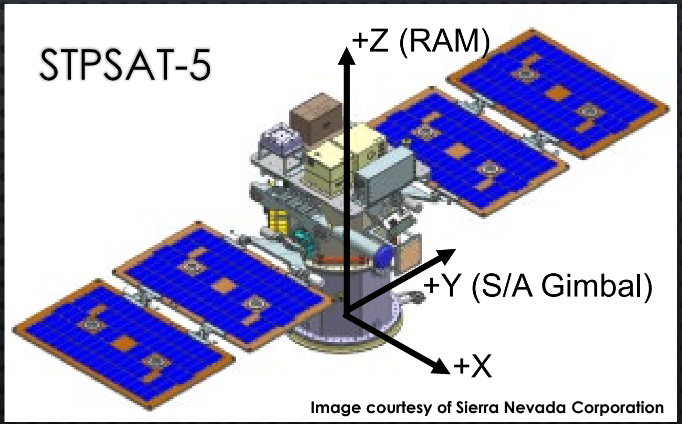
STPSAT-5 MISSION OVERVIEW

- Hosting 5 DoD space experiments
  - Radiation-Hardened Electronic Memory Experiment (RHEME)
  - High-bandwidth Anti-jam Laser Optical NETwork (HALO-NET) – Laser communications experiment
  - Ram Angle Magnetic field Sensor (RAMS)
  - Strontium Iodide Radiation Instrumentation (SIRI) – Gamma radiation sensor
  - Integrated Miniaturized Electrostatic Analyzer-Reflight (iMESA-R) – Space weather sensor
- One year mission life
- Goal to utilize CubeSat-class hardware where practical to advance maturity and reduce cost
- 450 km x 550 km, 97.8 deg inclined orbit, ~10:30 AM descending node
- Launch mass: ~ 115 kg
- Launched on SSO-A (SmallSat Express) Falcon 9 Rideshare: December 3, 2018 at 10:34 AM PST



STPSat-5 Orbit



STPSat-5 Deployed Configuration

STPSAT-5 Driving Requirements for Power Subsystem

- Minimum design life: 1 year
- Mission modes
  - Mode A: Spacecraft velocity oriented with sun-constrained roll
  - Mode B: HALO-Net boresight ground tracking – short duration (< 10 min)
  - Safe sun track
- Provide power for payload and spacecraft bus
  - Payload power – 30 W orbit average (Mode A & B)
  - Spacecraft Bus Power – 75 W orbit average
- Bus voltage: 22 – 34 VDC
- Battery depth of discharge: < 30% (State of charge > 70%)

STPSAT-5 SPACE VEHICLE OVERVIEW

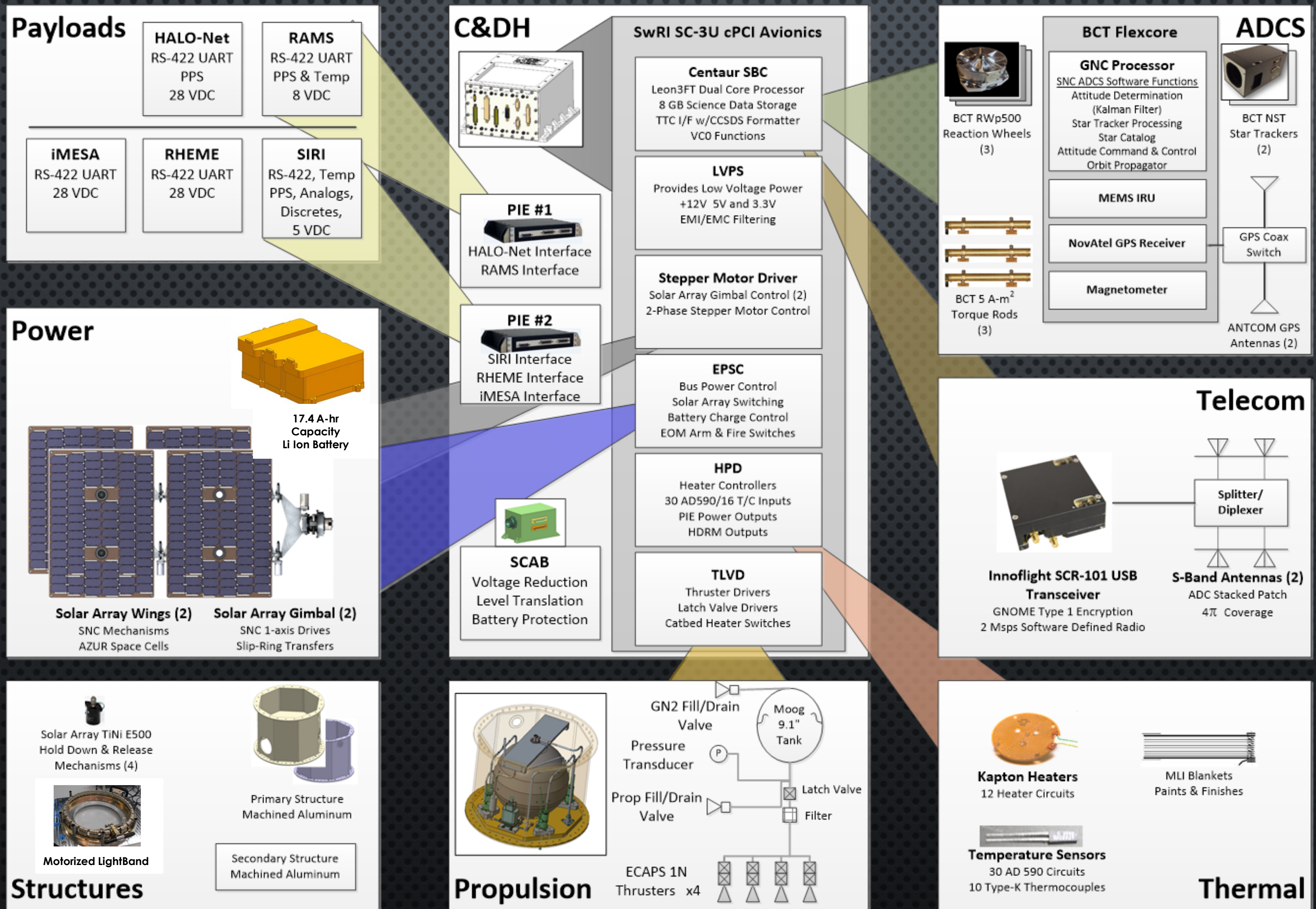


Image courtesy of Sierra Nevada Corporation

STPSAT-5 Electrical Power Subsystem

- Solar Array
  - Azur space Multi-junction solar cells (29.3% efficiency)
  - 2 wings of 2 panels each
  - 20 solar cell strings, each producing up to 0.5A
  - Single-axis solar array drive
  - New solar array design developed under internal research and development at Sierra Nevada Corporation
- Power Control and Distribution
  - Flight software charge controller configures string switch state to get between 5 – 20 active strings
  - Switch state is adjusted to maintain battery charge within voltage and current limits
- Battery
  - SAFT Lithium ion cells
  - 17.4 A-hr battery capacity
  - 32 V nominal at full charge
  - Heritage battery from OG-2 mission

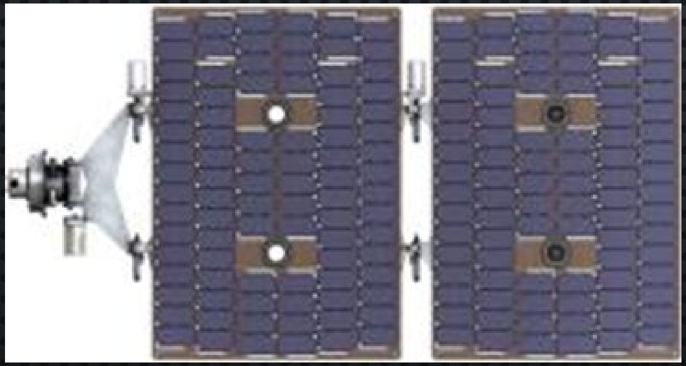


Image courtesy of Sierra Nevada Corporation

Solar Array Wing


Image courtesy of Sierra Nevada Corporation

Single-Axis Gimbal

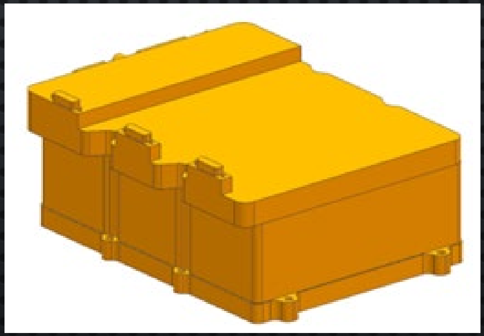


Image courtesy of Sierra Nevada Corporation

Battery

Solar Array Development

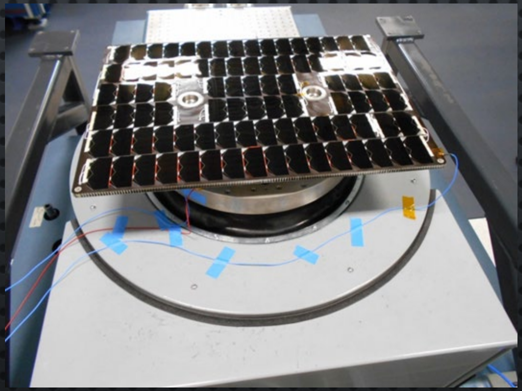
- Solar array process development included testing of 10x19" and 16x19" coupon panels
  - LAPSS testing
  - Thermal vacuum
  - Ambient thermal cycling
- Flight-like STPSat-5 panel was tested for qualification
  - LAPSS testing
  - Vibration
  - Thermal vacuum

Image courtesy of Sierra Nevada Corporation

Solar Array Coupon

Image courtesy of Sierra Nevada Corporation

Thermal Cycling



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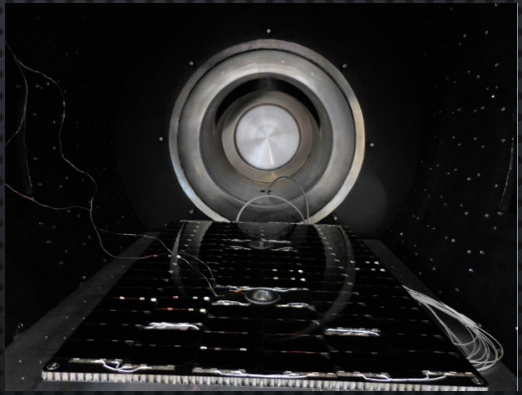
Vibration Test



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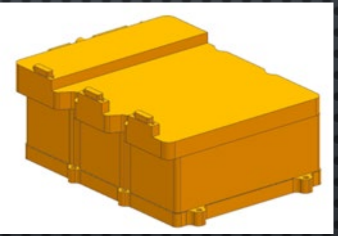
Thermal Vacuum

BATTERY DEVELOPMENT

- Original plan was to use a new development battery, however, issues were experienced during qualification
- New plan was to use existing surplus battery from OG-2 program and repurpose for STPSat-5
  - One OG-2 battery yielded 2 batteries for STPSat-5 (1 for test and 1 for flight)
- Minor mechanical mounting modifications were required to provide adequate clearance between battery and deployable solar array

Image courtesy of Sierra Nevada Corporation

OG-2 Battery (2 modules)



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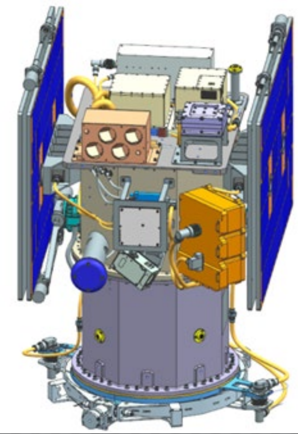
STPSat-5 Battery (1 module)



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STPSat-5 Stowed Configuration (Battery in orange)

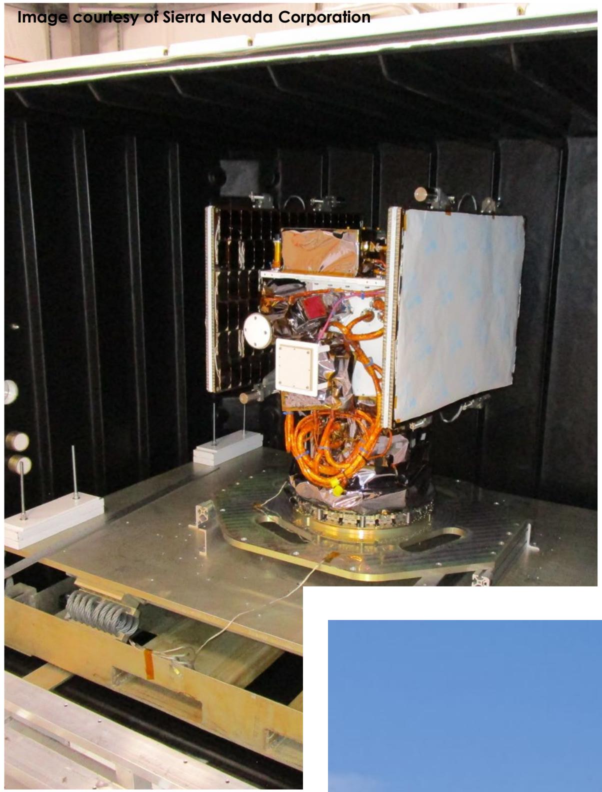
Power Analysis

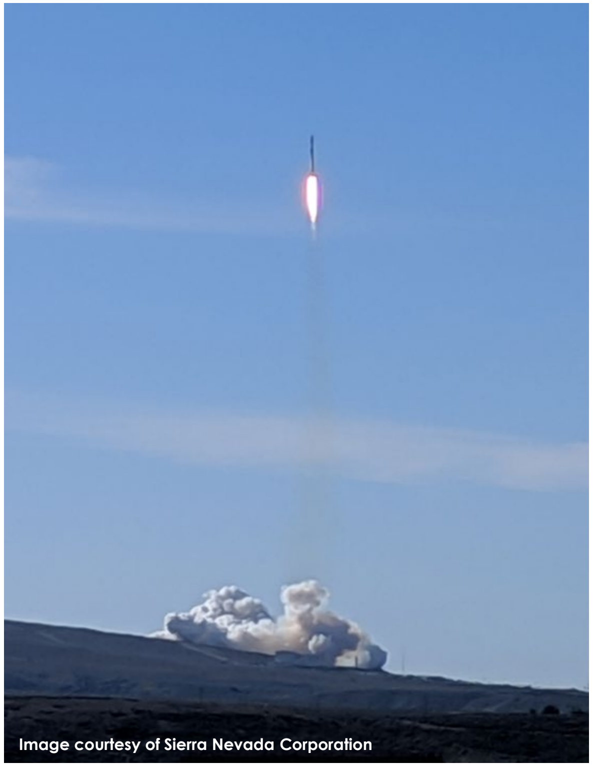
Mission Mode	Payload Orbit Average Power (W)	Bus Orbit Average Power (W)	Battery SOC (%)	Satellite Pointing	Array Gimbal
Mode A	20	95	> 70%	Velocity oriented, solar constrained	Gimballed solar arrays (single-axis)
Safe	0	100	> 70%	Sun tracking	Fixed

- Maximum solar array power ~ 320 W

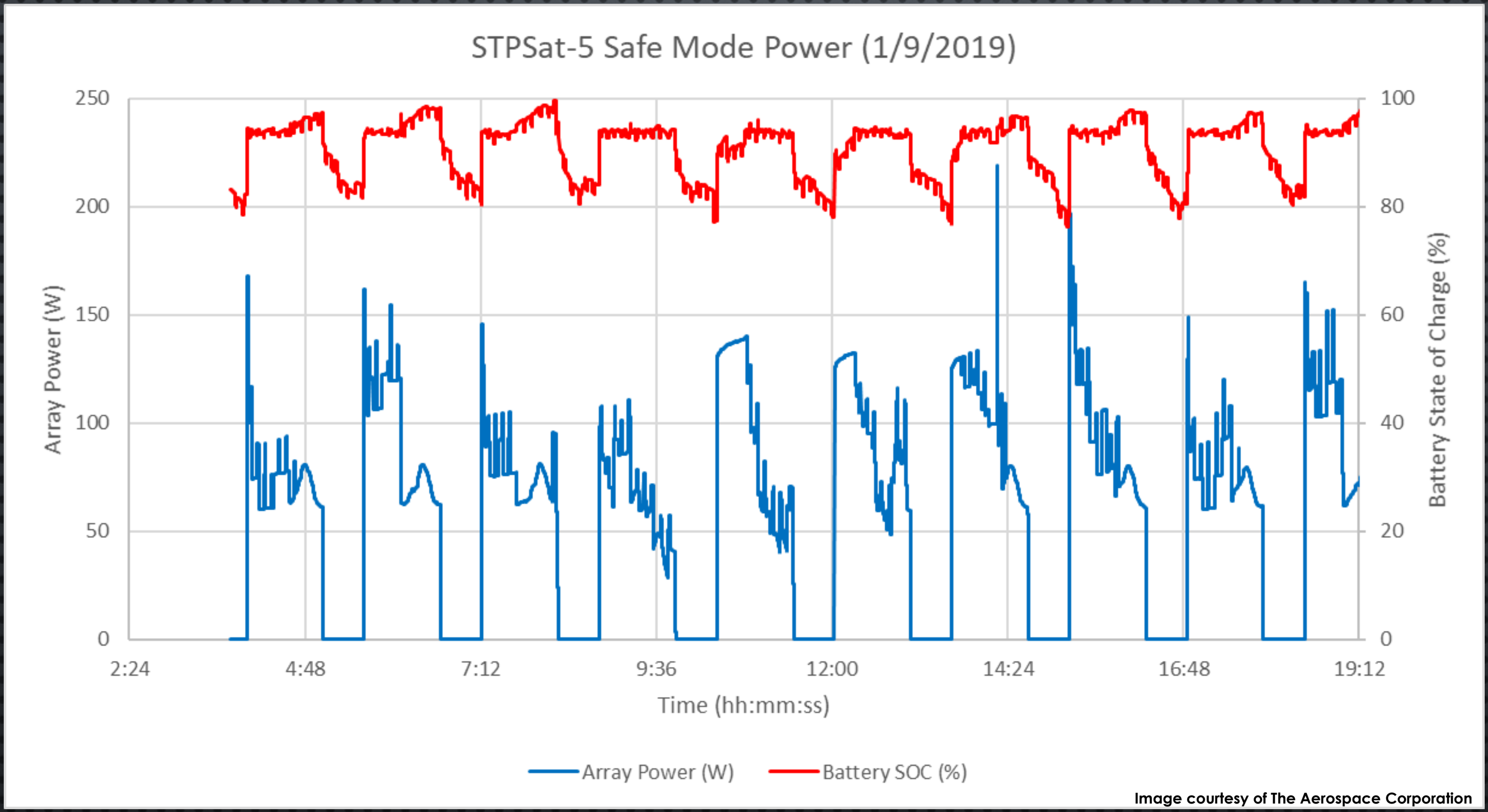
Mission Status

- Launch: December 3, 2018 from Vandenberg AFB, CA
- Experiment data collection in progress



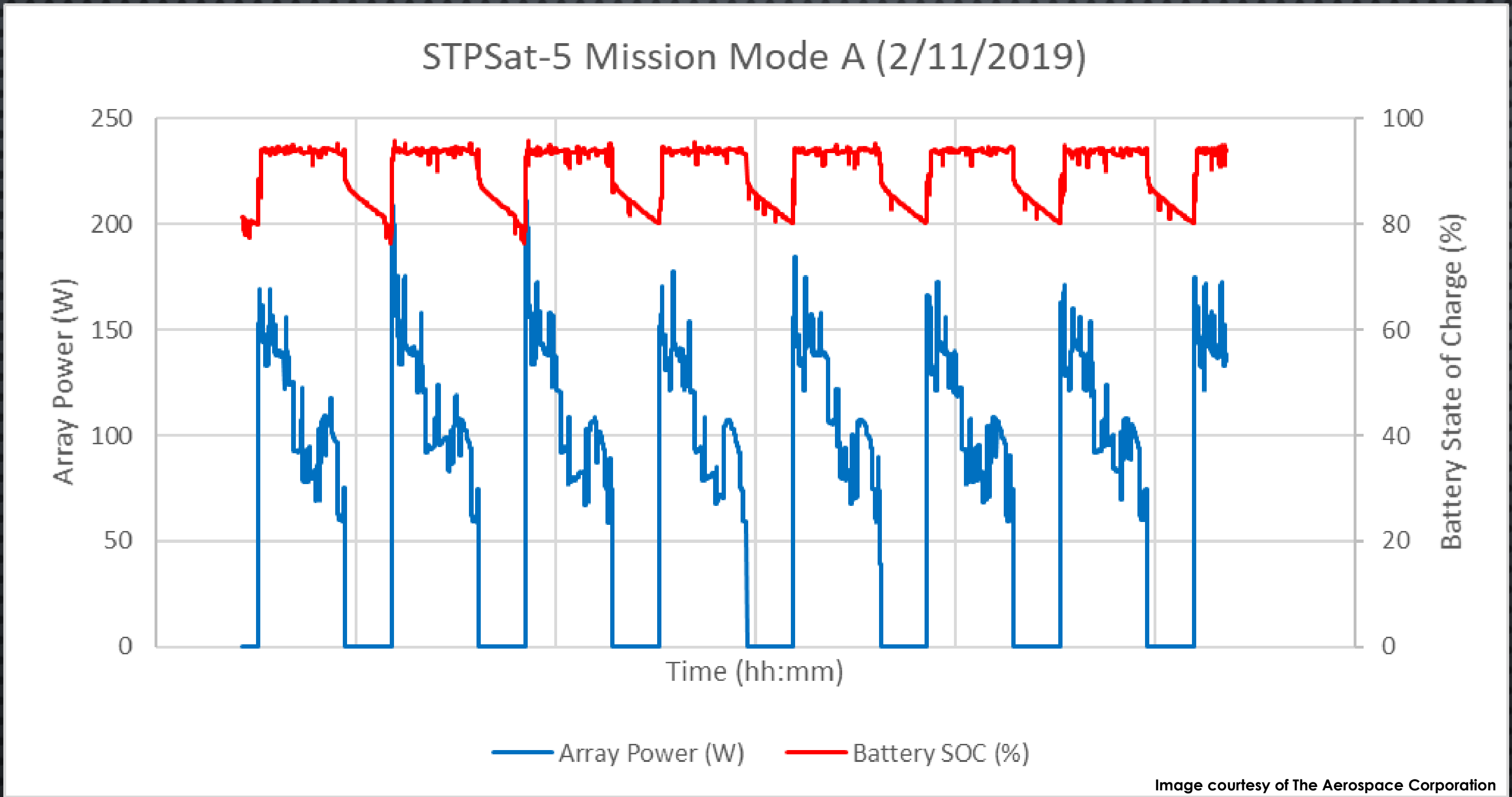


SAFE SUN-TRACK ON-ORBIT PERFORMANCE



- Array sunlit average power ~ 75-95 W – max capability of 320 W limited by flight software switching
- Typically < 10 out of 20 circuits total needed to be switched on to maintain battery within limits
- Minimum battery state of charge > 76%

MISSION MODE A
ON-ORBIT PERFORMANCE



- Array sunlit average power ~ 110 W – max capability of 320W limited by flight software switching
- Typically < 12 out of 20 circuits total needed to be switched on to maintain battery within limits
- Minimum battery state of charge > 76%

Lessons Learned

- Gimballed solar arrays on Microsat-class vehicles are a practical means to achieve more capable systems, however …
  - Always look for low-cost alternatives where possible
  - Have an "off-ramp" for new development items
- A robust power subsystem provides critical resources to …
  - Address on-orbit issues/anomalies
  - Exceed mission expectations