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Electric power subsystems in satellites

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Contents

- Types of orbits
- Power budget
- Architecture and components
- Batteries
- Requirements for S/C equipment

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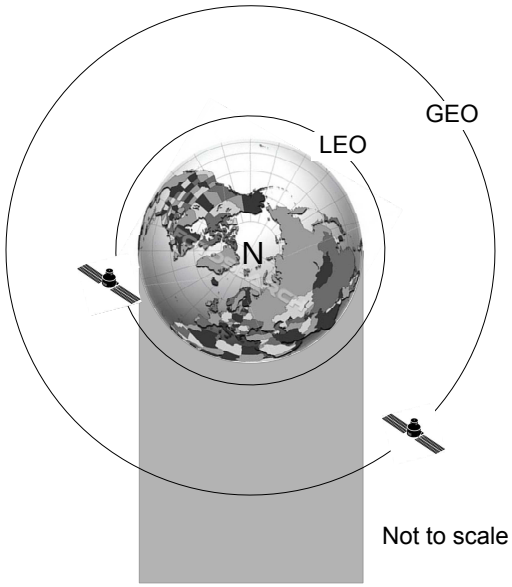
Low Earth Orbit (LEO)

- Altitude: 160 to 2000 km
- Orbit duration 88-127 minutes typical
- Eclipse duration: 20 to 35 minutes
- About 37.000 Battery charge/discharge cycles over mission lifetime of 7 years
- Battery maximum Depth of Discharge: 20%
- Often used for earth observation missions



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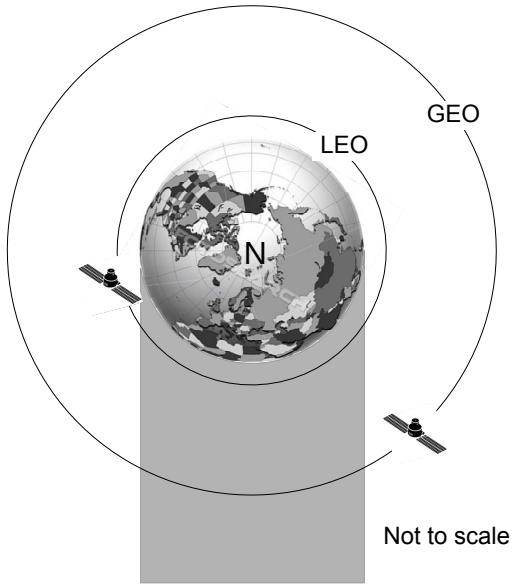
Geostationary Earth Orbit (GEO)

- Fixed location above point on equator
- Altitude: 35,786 km
- Orbit duration 24 hours
- Eclipse duration: 0 to 72 minutes
- About 1,350 Battery charge/discharge cycles over mission lifetime of 15 years
- Battery maximum Depth of Discharge: 80%
- Used for telecommunication and weather satellites



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Medium Earth Orbit (MEO)

- Altitude: 2000 to 35,786 km
- Used among others for navigation satellites:
  - GPS: 20,350 km alt.
  - GLONASS: 19,100 km alt.
  - Galileo: 23,222 km alt.

GPS

GLONASS

Galileo

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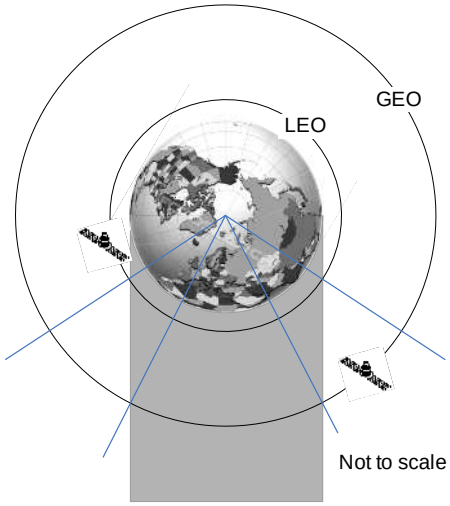
Power Budget

- Solar array sizing is determined by:
  - Orbit average power need
  - Sun/eclipse ratio
  - Losses in the system
- Battery sizing is determined by:
  - Eclipse power need
  - Eclipse duration
  - Capacity fading (due to mission lifetime and charge/disch. cycles
  - Losses in the system



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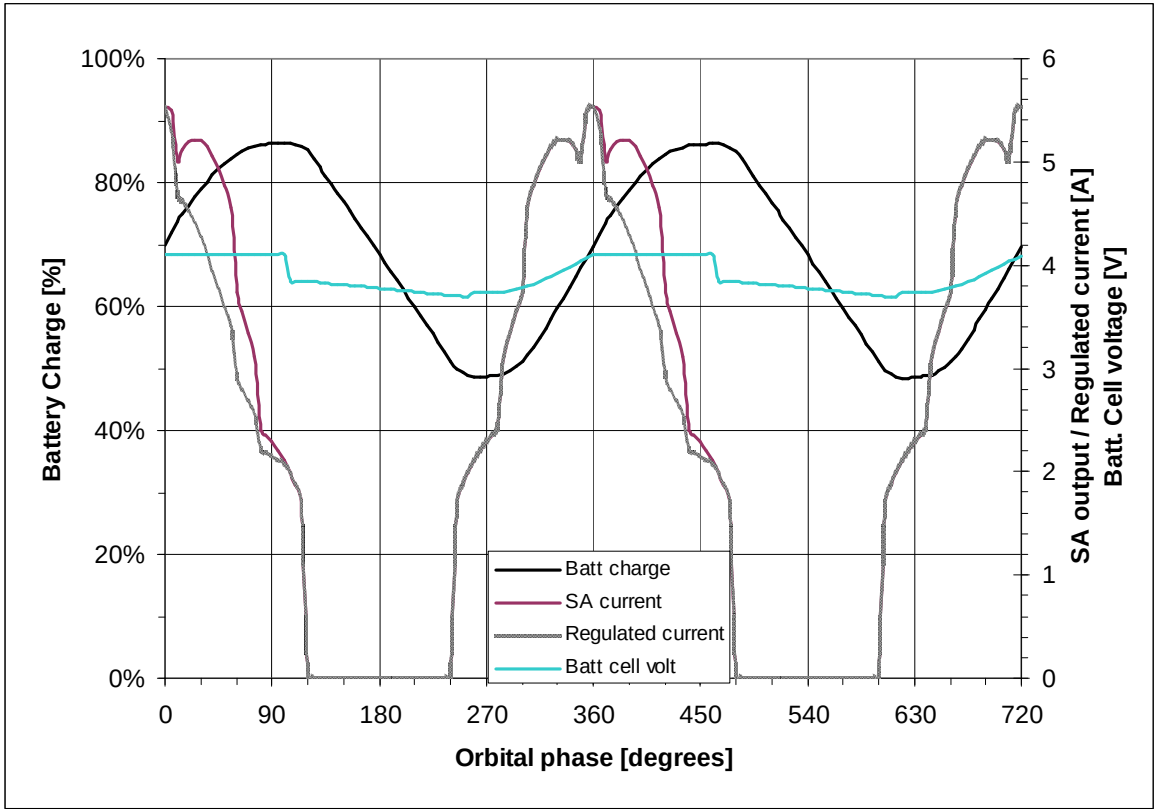
Example of simulated Power S/S behaviour (LEO)

- Body-mounted SA generates sine-shaped SA panel currents
- Battery charging strategy is CCCV (constant current, constant voltage), however the current varies to maximise efficiency



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Basic equipment and functions

- Solar Array
  - primary power generation
- BAPTA (Bearing and Power transfer assembly)
  - SA sun pointing by stepper motor, SA power transfer often via sliprings
- Battery
  - energy storage and peak power generation
- Power Control Unit
  - Solar Array power conditioning
  - Battery charge/discharge regulation
  - Communication to OBC (On-board Computer)
- Power distribution
  - Circuit protection
  - On/Off switching

Architecture

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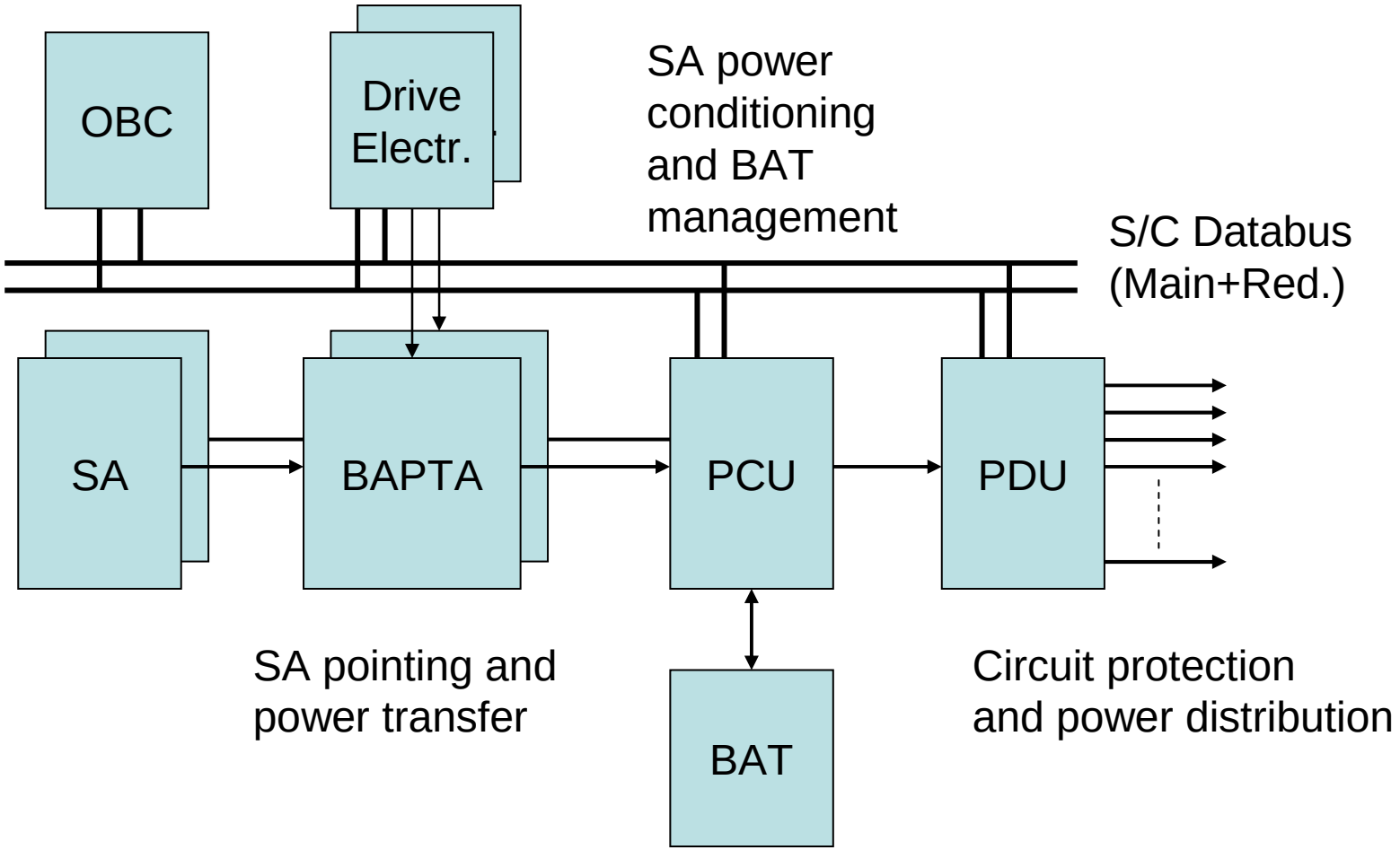

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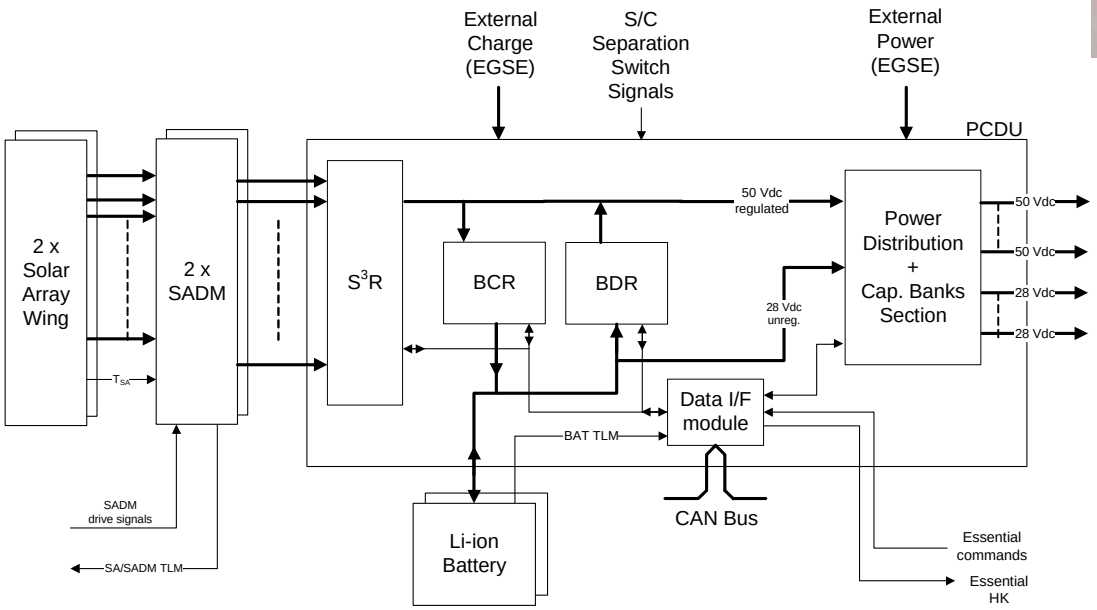
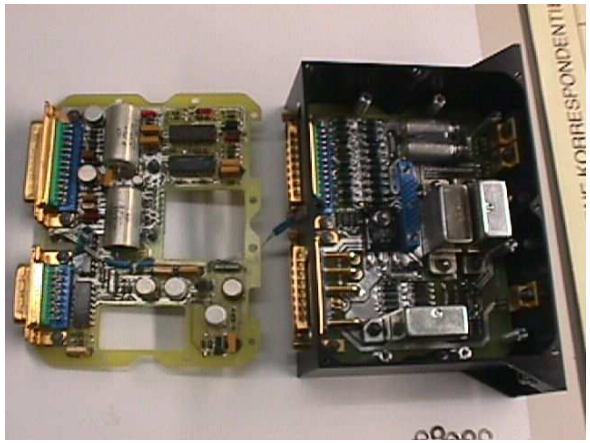
PC(D)U

- Autonomous start-up in case the S/C is un-powered during launch
- Redundant design
- Single point free design



Small PCU (70 W)



Large PCU (4000 W)

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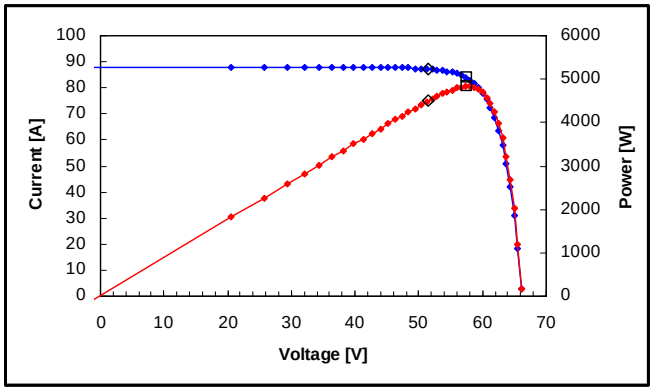
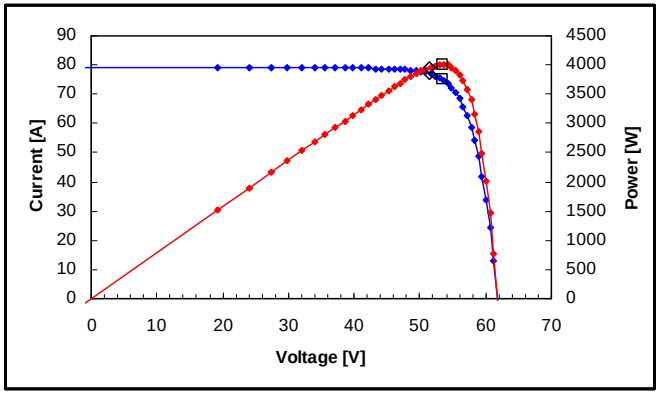
Solar Array

- SA Power efficiency determined by
  - Solar cell type
    - Silicon
    - Gallium-Arsenide
      - 1-junction
      - 2-junction
      - 3-junction (state-of-the-art), up to 30% @ 20 ℃
  - Power conditioning method
    - MPPT (Max. Power Point Tracking)
    - DET (Direct Energy Transfer)
  - Temperature
    - GEO 70 ℃
    - LEO 90 ℃
    - LEO and body-mounted panels >100 ℃
  - Cosmic radiation degradation
  - Cell lay-up efficiency
  - Typical power/area is 200 W/m^2 at EOL for GEO
  - BOL design case dimensions required wire gauge, slipring capability, etc.



Begin of Life (BOL)



End of Life (EOL)

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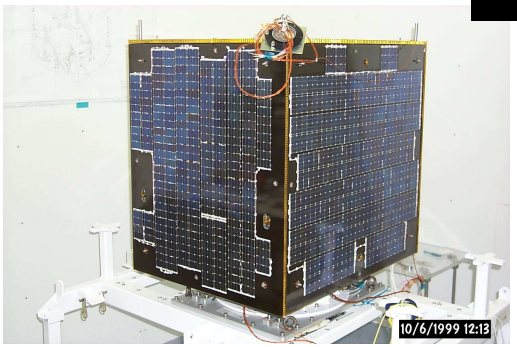
Solar Array types

- Rotating wings
  - S/C earth-pointing
- Fixed wings
  - S/C sun-pointing
- Body-mounted
  - S/C can be tumbling

Optus

SOHO



Sloshsat

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BAPTA (or SADM)

- Stepper motor to keep SA sun pointing (S/C body is normally earth pointing)
- Slipring assembly transfers the SA generated power to the PC(D)U

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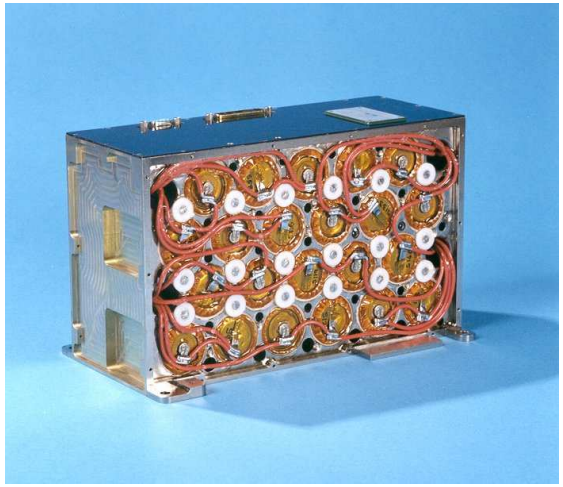
Space batteries, Ni technologies

- Nickel-Hydrogen (Ni-H_2)
  - Heritage on GEO satellites
  - No longer used for new designs

- Nickel-Cadmium (Ni-Cd)
  - Heritage on LEO satellites
  - No longer used for new designs



SLOSHSAT Battery

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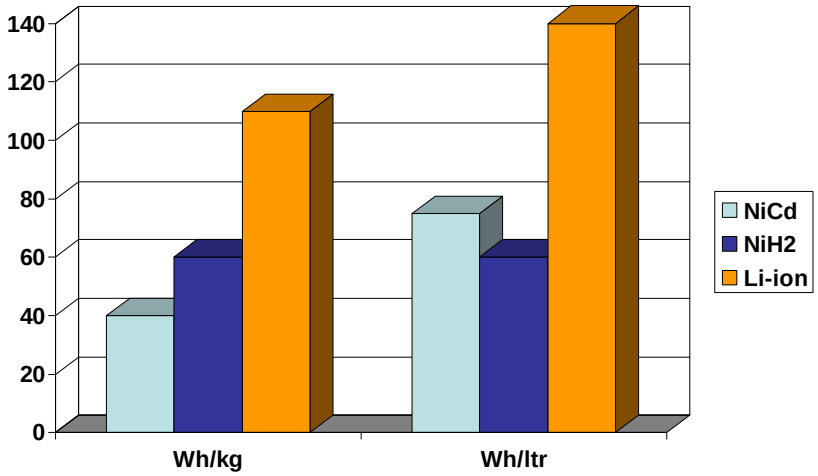
Space batteries, Li technologies

- Lithium-ion
  - Higher energy density than the Nickel-based batteries
  - Heritage on LEO and GEO satellites, widely used for new designs



- Lithium Polymer
  - Even higher energy density than Li-ion
  - Not yet qualified for use on satellite power subsystems

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European S/C Battery Manufacturers

- SAFT
  - Dedicated development for space use
  - Cells placed in parallel/series configuration
  - Large single cell: 1.1 kg
  - Battery cell balancing performed
  - Relatively low shelf-life capacity fading
- ABSL
  - Battery cells from commercial origin (Sony 18650HC)
  - Cells placed in series/parallel configuration
  - Small single cell: 42 g
  - No Battery cell balancing performed
  - Relatively high shelf-life capacity fading

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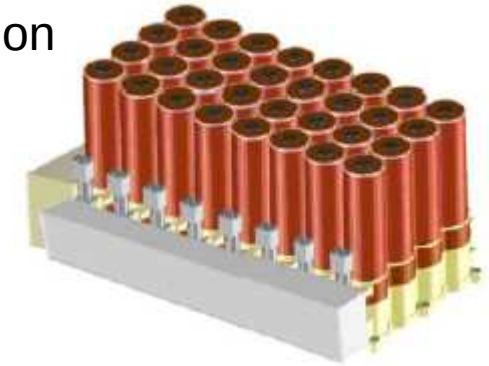
SAFT

- At the moment mainly used for GEO missions (15 years)
- Parameters for 3P9S battery:

Item	Value
Cell type	SAFT VES180
Energy capacity per cell at BOL (nominal)	171 Wh
Number of cells in parallel	3
Number of cells in series	9
Total energy capacity at BOL	4617 Wh
Capacity fading	9.3%
Total energy capacity at EOL	4188 Wh
Battery mass	42.5 kg

STENTOR Battery

4P8S configuration



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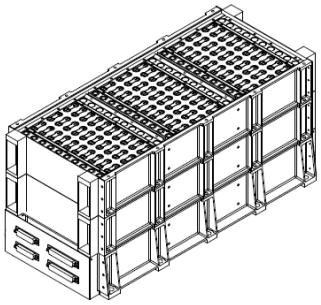
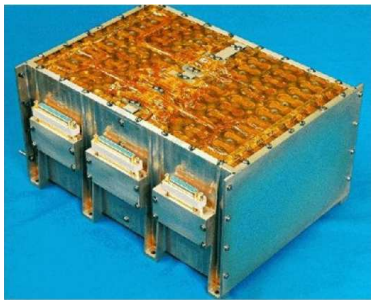
ABSL

- Mainly used for LEO and interplanetary missions (< 7 years)
- Battery parameters (for GEO):





Item	Value
Cell type	Sony 18650
Energy capacity per cell at BOL (nominal)	5.4 Wh
Number of cells in parallel	108
Number of cells in series	10
Total energy capacity at BOL	5832 Wh
Capacity fading	29%
Total energy capacity at EOL	4141 Wh
Battery mass	52 kg

General requirements for S/C equipment

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Requirement	comment	Verification method
Vibration	- dictated by launch environment	Analysis and test
Thermal	- No heat exchange by convection, only by conduction and radiation - Sun/eclipse cycles can cause large temperature range to cover, especially for exposed equipment like Solar Arrays	Analysis and test
Outgassing		Review of design
Cosmic radiation (solar particles)	- Solar cells - Materials - Electronic components	Analysis
Magnetic moment	- Residual magnetic moment will have effect on S/C Attitude Control	Analysis

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Questions???