Electronic Design.

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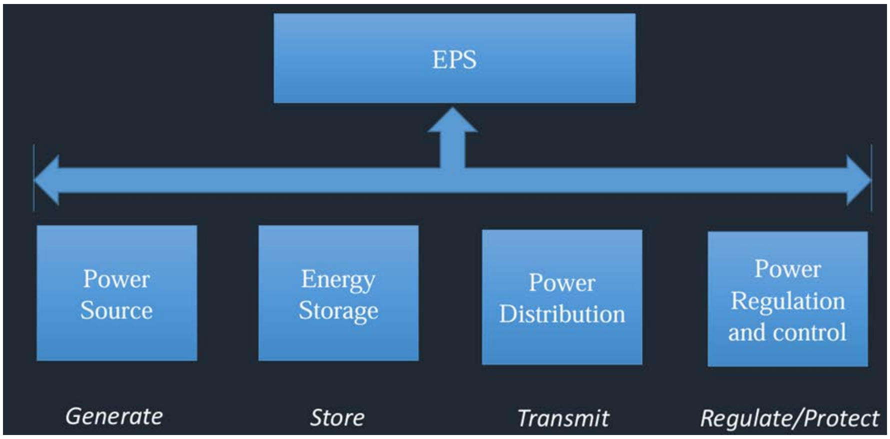
Electrical Power Systems Meet the Density Demands of Small Satellites

There's no electrical power grid in outer space, so the electrical power subsystem needs to deliver the spacecraft's requirements.

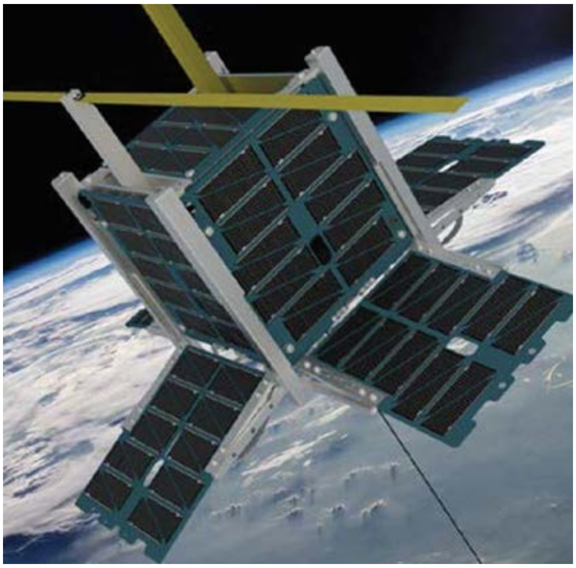
Various power-generating system methods[2] can be applied to space-based electrical power subsystems (EPS) to power spacecraft *(Fig. 1)*.

Such power sources include:

- **Solar arrays:** Photovoltaic modules can absorb sunlight in space, which generates DC electric power for satellites
- **Lithium-ion batteries:** These batteries are rechargeable (secondary) batteries. They're used as energy storage devices and are mostly connected to, and charged by, a prime energy source, delivering their energy to the load on demand. Secondary batteries are also used in applications to provide power remotely from a separate power source that they return to periodically for recharge.
- **Radioisotopes:** A radioisotope power system (RPS) can generate power by converting the heat released from the nuclear decay of radioactive isotopes, like Plutonium-238 (Pu-238), into electricity.
- **Fuel cells:** Fuel cells are used for power and energy storage. Fuel cells will support DC electrical power buses:
    - Multiple reactant types and grades (for example O_2/H_2 or O_2/CH_4)
    - Enable Commercial Lunar Payload Services (CLPS) landers to use CH_4 propellant for power



1. A typical electrical power subsystem (EPS) in space. (Image courtesy of NASA)



2. Shown is an EPS for CubeSats. (Image courtesy of NASA)

There are a variety of spacecraft and satellites, and one compact type of satellite is the **CubeSat** *(Fig. 2)*. Power requirements for CubeSat EPS[2] are a bit different when it comes to:

- Power profile
- Power margin
- Bus voltage level
- Cycling/charging
- EPS component definition:
- Size of batteries
  - Solar-array end-of-life (EOL) power
  - Other various subsystem needs (peak and steady state)

CubeSat designers need to contend with thermal design, payloads, structures, and flight control *(Fig. 3)*, and the EPS is integral to all of these.

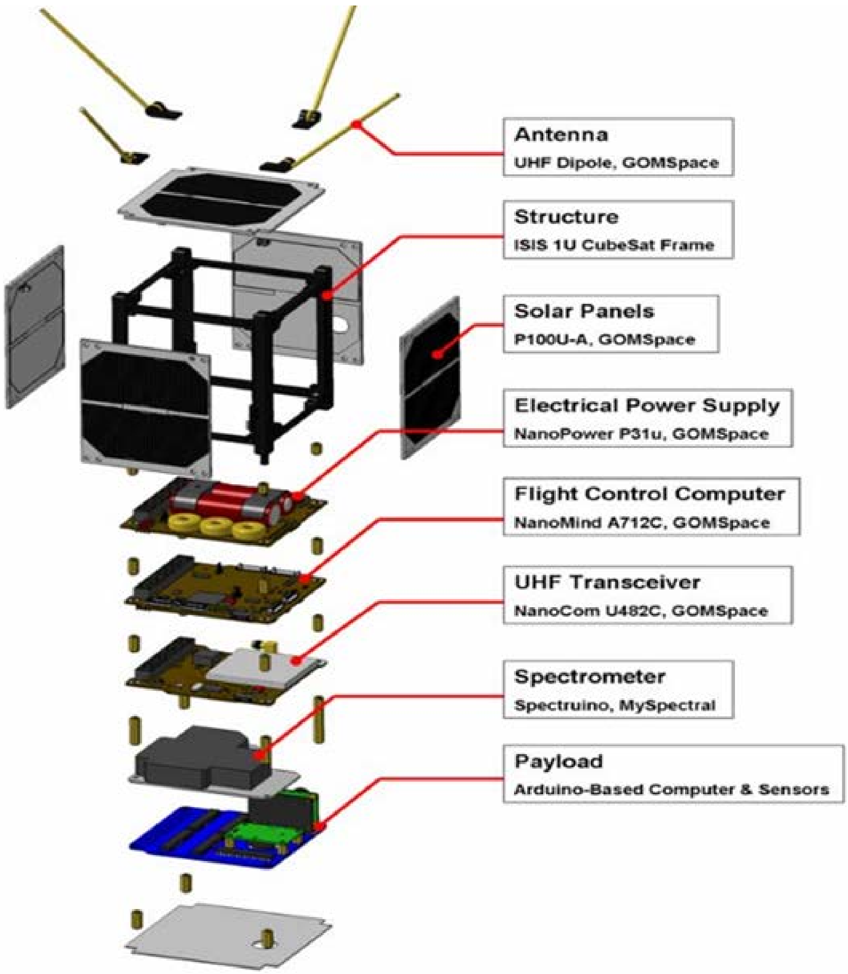
Typical EPS System Requirements

EPS designers must provide continuous electrical power to spacecraft subsystems as necessary during a spacecraft mission life that will include eclipses and nighttime. The EPS must control and distribute all onboard power safely. In addition, the system has to provide enough power, including margin, for both peak and average power loads.

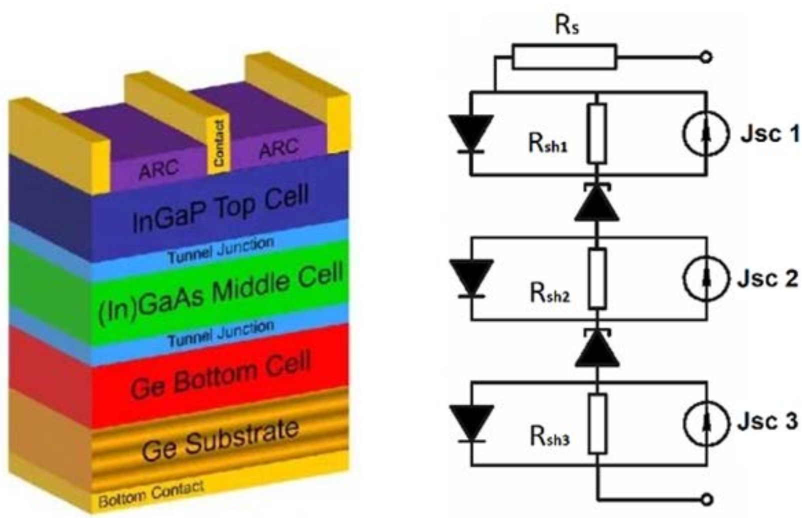
Designers need to consider that downstream power converters are able to handle required loads. Bus isolation between downstream and upstream power loads must be provided. Likewise, the logic control system needs to know the EPS status and health, including voltage, temperature, current, and more.

Furthermore, the EPS system must protect itself and other subsystems from EMI, bus faults, transients, and load faults such as overvoltage, filtering, short circuits, and more.

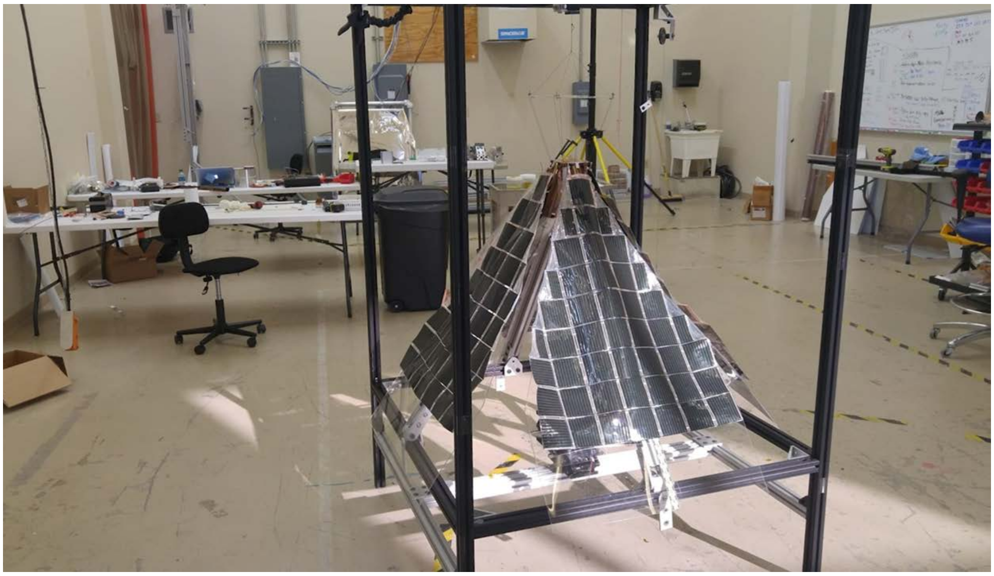
Typically, a designer needs to determine the average power from the power equipment list (PEL) that includes the other electrical subsystems. There are also the mission requirements, such as duration, to consider. This may involve evaluation of the site for fixed space applications or orbital parameters.



3. CubeSat major subsystem interactions. (Image courtesy of NASA)



4. The illustration demonstrates the equivalent structure of "InGaP/GaAs/Ge" triple-junction solar cells and electrical equivalent structure (left). The electrical equivalent circuit model of these triple-junction solar cells is shown on the right. The power provided via these cells is decided on via the I-V curve and the external resistance of the load, using the theory of conventional circuitry. (Image courtesy of Reference 4)



5. The LISA-T Tiny Solar Array delivers a significant amount of power in space. (Image courtesy of NASA Marshall Space Flight Center)

Satellite Solar Array as an EPS Source

A satellite solar-cell array design must be done early on with the development of a satellite design mission. That's because the size and deployment of the array has to be factored into the overall system design.

A high-performance satellite solar-cell array design will depend on the intensity of the incident sunlight available during the mission. The conversion efficiency of the array will also be a critical factor in determining the amount of available power.

Advances in solar array designs have led to increased efficiencies that exceed 30%. Multi-junction solar cells today provide the most efficient technology for generating electricity. Simplicity, high reliability, and relatively modest cost GaAs-based arrays are the reasons why they're often selected to supply the electrical power system for most satellites *(Fig. 4)*.

For example, the LISA-T is a very compact, stowable, thin-film solar array *(Fig. 5)*. When fully deployed in space, it offers small spacecraft power generation and communication capability.

Summary

The EPS provides electrical power to all space vehicle loads and is crucial for completing defined missions in space. The most commonly employed architectures for CubeSats are battery-only or solar-array/battery configurations. Batteries must be treated as potential hazards since they combine stored energy with caustic materials.

Mechanical and thermal are the main subsystem interfaces with the EPS because designs are developed using an iterative process. Testing is also key: "Test what you fly and fly what you test." Launch site handling is a major consideration, too.

References

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