# Improving Mass and Efficiency in Space Power Systems for Enhanced Science Return

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**Primary Applications:** ASTROLAB, Endurance A, Mars access missions, Uranus Orbiter and Probe, Titan Orbiter, Enceladus Orbilander, Enceladus Multiple Flyby, Saturn Probe, Triton Ocean World Surveyor, various deep-space mission concepts

Although exploration platforms are evolving for increasingly challenging deep-space targets and terrains, heritage power architectures used in most NASA missions are large, bulky, and inefficient, requiring large resource allocations to support complex harnessing schemes and overcome system power losses. Through the implementation of a distributed architecture, the mass and volume of large power system elements like batteries, solar arrays, and power harnessing can be significantly reduced and the overall efficiency increased in order to divert valuable spacecraft resources to instruments for enhanced science return. On small-scale rotorcraft, harnessing mass can by reduced by up to 36%, with this improvement expected to scale much better on larger missions like Europa.

The Breakthrough Distributed Power Architecture (BDPA) task was recently funded by NASA to push the development of a new type of power architecture to meet the needs of upcoming missions. Combining extremely high efficiency power converters (>95%) with digitally-controlled heaters, switches, pyros, and bus controls, the BDPA provides future planetary missions with the architectural pieces required to support next-generation exploration platforms for challenging environments. These elements are connected by a single, distributed power bus with modular interfaces to reduce lifted mass and improve energy capture at greater AU distances. With outer planetary missions experiencing a surge in attention, distributed power systems provide key advantages that allow limited spacecraft resources to be better utilized in support of mission science goals.

The BDPA was developed with the following objectives:

- Complies with the finding of the SMAP Power Converter Failure Report to provide telemetry access even if the power converter were to fail
- Common power and communication busses for all units, enabled through distributed digital control
- Distributed bus converters for >90-95% efficiency to loads with localized digital control/telemetry
- Distributed load switches & linear heater controls to maximize thermal system efficiency
- Common modules that can be used throughout rover, orbiter, or base power distribution systems

The BDPA is built through several architectural elements that target holistic power system improvements:

- Distributed heater control provides autonomous, closed-loop heater control to reduce communication bus traffic, reduce harness mass, and reduce spacecraft power consumption during critical power modes (such as during eclipse), which reduces the size of the battery and enables longer mission operations
- High efficiency power conversion utilized across the spacecraft minimizes power losses from loads and reduces the size of the battery and solar array

- Distributed load switching and pyro switching significantly reduces harness mass across the spacecraft
- Maximum power point tracker for peak power out of the solar array, including in the presence of dynamic or partially shaded/obstructed conditions (i.e., dust accumulation, partial shadow across panel due to antenna, etc). The solar array can be significantly reduced in size

Combining the above improvements into a cohesive power architecture results in a lighter, more compact spacecraft. This NASA STMD sponsored effort has supported designs for each of the above architectural elements, with some at a higher level of maturity (with tested hardware assessed at TRL4) and part selection performed to support a path to TRL6.

The BDPA's mass and power density reduction and efficiency enhancements relative to state-of-the-art space power systems can benefit a variety of future mission concepts, including planetary surface missions that require compact form factors and large flagship missions that will have to overcome challenging mass and volume constraints at further distances from the sun.