

# Design considerations in predicting energy needs of spacecraft

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## Abstract

Multiple modes of power are available to spacecraft ranging from solar to nuclear thermoelectric. But, how do we select between the different power sources for reliability and long duration power? To this end, understanding the amount of solar energy available at the designated locale for the mission on a per unit surface area basis is critical for designing the power management function of the spacecraft. Specifically, once the amount of solar power available at the designated orbit is estimated, and together with the amount of energy required for the various instrument package onboard the spacecraft, estimates of the surface area of the solar panels could be calculated. If the required surface area is larger than that supportable by the spacecraft structure as well as launch constraints, nuclear thermoelectric power source would be needed instead of solar power. More importantly, integrated power management is required to titrate the amount of energy generated against that required by the spacecraft and instruments; thereby, presenting scenarios where the engineers at mission control would need to switch off specific instruments for conserving power to maintain safe flight control of the spacecraft. Hence, energy management of spacecraft runs through the design phase of the mission through to daily operation of the spacecraft, for example, in orbit around another planet, and is critically important to the overall success of the mission. While solar energy is desirable for most missions, lack of insolation at distances far away from the Sun meant that either the mission is deficient in science payload or a nuclear thermoelectric power source is required for powering all necessary scientific instruments onboard.

**Keywords:** nuclear thermoelectric generator, solar energy, solar arrays, power requirement, target destination, science instruments,

**Subject areas:** astronomy,

Modern science mission spacecraft carries a raft of instruments, all requiring energy to carry out essential functions; thus, energy management is a critical issue that impacts on mission success, especially for large spacecrafts on long duration missions to faraway Solar System objects such as Jupiter, Saturn, and Kuiper Belt Objects.

In spacecraft design, knowledge of its target and anticipated destinations are important criteria for framing the energy question important to selecting the correct power source for the spacecraft. Specifically, mission extension cannot be excluded from the mission designers' calculus given that many contemporary spacecraft survives long after the initial science missions, the most important examples of which are NASA's Voyager 1 and 2, , which are all on their way out of our Solar System.

Knowledge of the anticipated and target destinations will give mission planners an idea of the amount of solar energy available to the spacecraft at the designated position. This, together with the energy capture efficiency with contemporary space mission ready solar panels, will help spacecraft designers decide on the appropriate size of the solar arrays necessary as well as their design.

Size of solar panels is, however, also constrained by the power requirement of the various instruments onboard, as well as the size and mass of the spacecraft. Specifically, a small spacecraft such as NASA's CubeSat would not be able to structurally accommodate a large solar panel array compared to the case for NASA's MAVEN mission (Mars atmosphere volatile evolution experiment). Additionally, primary science missions of the spacecraft set the boundary for the energy requirement of the spacecraft. Note that energy required to manoeuvre the spacecraft into various orbital positions comes not from the solar panels, but its store of fuel propellant that, upon firing, provides the thrust necessary to position the spacecraft in a position ideal for fulfilling its science missions.

Hence, knowing the amount of solar energy that could be harvested at a given location together with the energy requirement of the spacecraft for powering its science instruments, would allow mission designers to select the correct power source for the mission. If the target speed of the spacecraft is high, such as New Horizons, who had a high speed flyby of Pluto in July 2015, solar energy panels is not an option given the possibility of structural disintegration of the solar panels at high speeds. Thus, New Horizons is equipped with a nuclear thermoelectric power source, which is a hazard on launch, as any launch failure would mean contamination of the atmosphere with nuclear materials, which through atmospheric circulation, would spread around the world.

In the case of low solar energy available for harvesting at the target destination of the mission, mission designers may have to opt for a combined solar energy cum nuclear thermoelectric generator power option for providing the spacecraft with sufficient energy to perform its designed science mission experiments.

Hence, taken together, understanding the amount of solar energy available for harvesting by the best solar panel arrays is important to calculating whether the energy captured is sufficient to fulfil the power requirement necessary for running all the designated science instruments of the mission. If the answer is no, a nuclear thermoelectric power source, with high levels of shielding to protect the science instruments, would be required. But, having a nuclear thermoelectric power source adds to possibility of nuclear contamination at the point of launch failure; thus, launch preparations and details should judiciously be reviewed to avoid a nuclear contamination disaster.

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