5 More Subsystems Onboard

Until now, we’ve looked into telecommunications, attitude control, and propulsion systems from a general point of view encompassing their components in flight as well as their components on Earth. The systems of telecommunications and navigation encompass parts of both the spacecraft and the Deep Space Network facilities worldwide. The propulsion system spans launch vehicle, upper stage or injection propulsion unit, and mission module. In this chapter our focus shifts to view flight components as subsystems on a spacecraft, which is seen as a flight system. For this purpose we define the spacecraft as the “mission module” part that operates in the vicinity of a target of interest after having jettisoned any ancillary modules.

5.0.1 Hierarchy

The spacecraft’s operation and engineering team members speak, for example, of an attitude-control subsystem or a propulsion subsystem aboard the spacecraft (flight system). This hierarchy generally spans the following levels, although there may be considerable overlap in nomenclature between the two lowest levels:

1. System, e.g. flight system.
2. Subsystem, e.g. propulsion subsystem, telecommunications subsystem.
3. Assembly, e.g. propellant tank assembly, high-gain antenna assembly.
4. Subassembly, e.g. tank temperature sensor, X-band waveguide.

5.0.2 Spacecraft Bus

The core of an interplanetary spacecraft is usually called a bus. It is a mechanical housing including all vehicle subsystems mounted within or attached to it. Its purpose is to support a payload of scientific instruments reliably with everything they need:

- Mechanical load bearing and alignment.
- Delivery to target. This encompasses tracking, course corrections, and flybys or atmospheric entry, descent, and landing as applicable.
- Electrical power generation, storage if applicable, conditioning, and distribution.
- Aperture pointing. This is the attitude and articulation control subsystem’s job.
Uplinked command data, and
Telemetry downlink. Both of these are provided by the telecommunications subsystem.
Data storage, processing, and redundant backup as applicable.
Protection from such threats as thermal extremes, dust, radio-frequency noise, stray electrical potentials, sunlight in camera, excessive accelerations, and galactic cosmic rays.

Engineers responsible for the spacecraft bus work on loosely aggregated teams in specific disciplines and interests. These may be the same people who designed, and tested pre-launch, the very subsystems they watch flying in interplanetary space. Generally one manager and one secretary provide leadership and support to the whole team, perhaps up to forty women and men. Often these engineers are also working on the design, assembly, and/or testing of different vehicles which are yet to launch, although they will always put aside their other projects when it comes time for a launch or a landing. Other teams on the project, or shared by many projects, handle navigation, planning, command preparation, real-time operations, and data management.

The people responsible for the instruments, for which the bus exists, are usually teams of scientists, typically led by a world-leading expert Principal Investigator (PI) working with graduate students and support staff. Many a PI may be found flying similar instruments on several spacecraft and perhaps carrying university-level teaching responsibilities at the same time.

The relationship between the engineers and their spacecraft bus on the one hand, and scientists and their instruments on the other, is not unlike the crew and passengers participating together on the voyage of an oceangoing research vessel. The vessel provides a platform, electrical power, data communications, and protection for the scientists’ instrumentation, and carries them to targets they selected where they can carry out experiments and observations. And if one of the passengers were to suffer problems with an instrument, everyone aboard the ship would do their best to help work around the difficulty.

5.1 Electrical Power Subsystem

There are only three practical sources of electrical power in use today to run the computers, radios, motors, and other such devices on an interplanetary spacecraft: solar panels, batteries, and radioisotope thermoelectric generators. We’ll visit each of these. Note that batteries can serve either as a pre-charged primary source of power for a spacecraft, or as a temporary storage device for a subsystem that generates power by using solar panels.

5.1.1 Voltage and Current

The *voltage* in an electric circuit is a measure of the difference in electrical potential between two points in a circuit.\(^1\) It can be visualized by analogy as the water *pressure* in a residential plumbing system. Its SI unit, the “volt,” is named after