13. Thermal Control

The GOES-NOP thermal control subsystem is designed to ensure that thermal requirements are met for all mission phases from launch to end of life. The GOES-NOP spacecraft uses Boeing 601 heritage techniques such as heat pipes, mirrors, multilayer insulation (MLI) blankets, and heaters to accommodate variations in spacecraft configuration, environmental heat loads, and degradation of materials to meet these requirements. The thermal features of GOES-NOP are shown in Figure 13-1 for the stowed configuration and Figure 13-2 for the deployed operational configuration. An expanded view of the overall GOES-NOP spacecraft thermal features is shown in Figure 13-3.

Fixed conductance heat pipes, embedded in the honeycomb panels and bolted between the payload radiator and subnadir panel provide both heat transfer to the external radiators and heat spreading along the radiator panels. To provide additional heat spreading for some of the units, including the high power solid-state power amplifiers (SSPAs) and the transponder, thermal doublers are bonded under the units to the honeycomb panel interior surface. The east, west, nadir, and aft panels are blanketed to minimize daily diurnal temperature changes and maintain the spacecraft cavity within acceptable temperature ranges. The payload and bus radiator panels are oriented north and south to minimize direct solar heating. The bus radiator is also blanketed in portions to maintain internal temperatures on-orbit and during transfer orbit. All exterior radiator surfaces are covered with optical solar reflectors (OSR). Most units and all internal panels are painted black to maximize radiation heat transfer internally to the radiator panels. The integrated power controller (IPC) unit is mostly blanketed internally to thermally decouple the unit from the bus cavity to improve system thermal performance during transfer orbit conditions and minimize bus cavity environmental effects on-orbit. The reaction wheel assemblies (RWAs) are mounted external to the spacecraft near the bus panel. The RWAs dissipate heat primarily by conduction to an extension in the payload radiator panel. The subnadir shelf, which is passively coupled to the Imager/Sounder mounting plate through radiation, provides thermal control for the mounting of the Imager and Sounder electronic suites.

Active heaters (mostly controlled by the ACE) are installed for components that cannot maintain their minimum temperature requirements with only passive designs. This provides flexibility and power optimization by having multiple set points for various spacecraft configurations including transfer orbit, storage, and on-orbit. In addition, the ACE autonomously reconfigures the heaters during entry into Safehold Mode. These heaters are fully redundant and can be reprogrammed while on-orbit. In addition, there are electronically controlled heaters with fixed set points for several of the propulsion zones and all heaters on the yoke assembly. These heaters are fully redundant and are commandable on/off through mechanical relays. Most of the heaters are patch heaters, which are designed to meet the low magnetic dipole requirements of the magnetometer sensors. The heaters are mounted to the spacecraft panels or components as required. Extremely low magnetic heaters are used to maintain temperatures of the magnetometer sensors on the boom assembly.

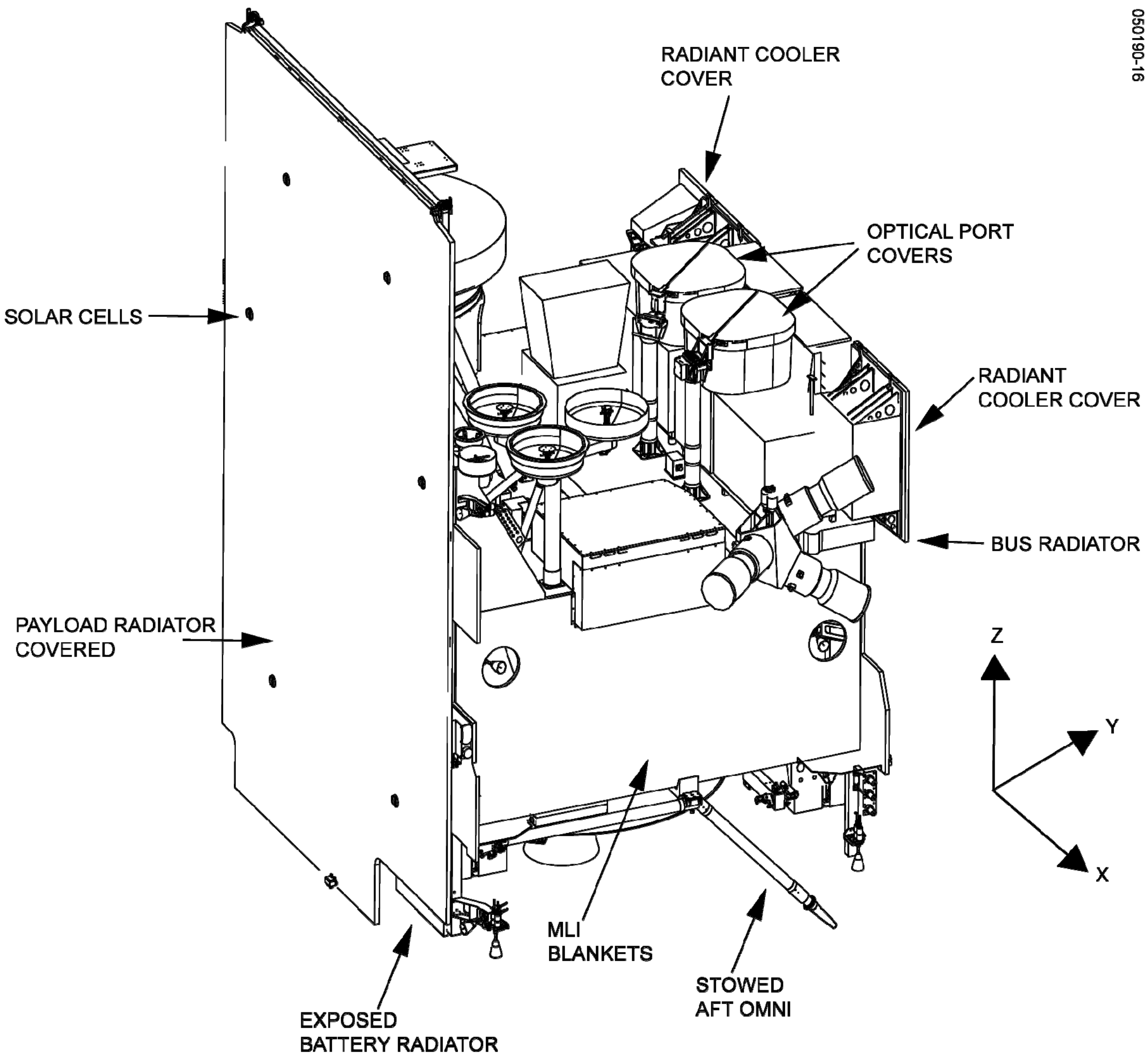

Figure 13-1. Thermal Control Features (Stowed Configuration)

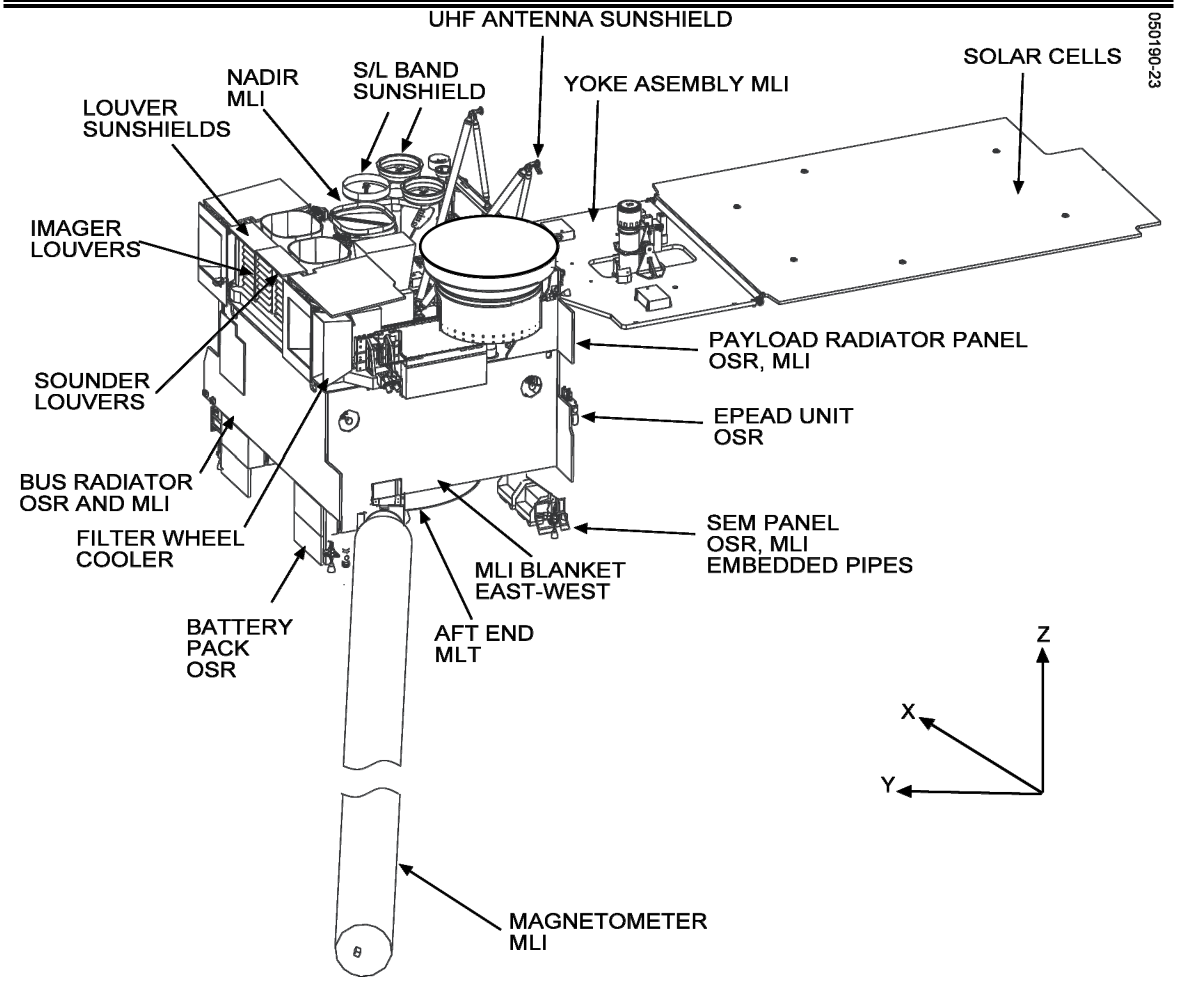

Figure 13-2. Thermal Control Features (Deployed Configuration)

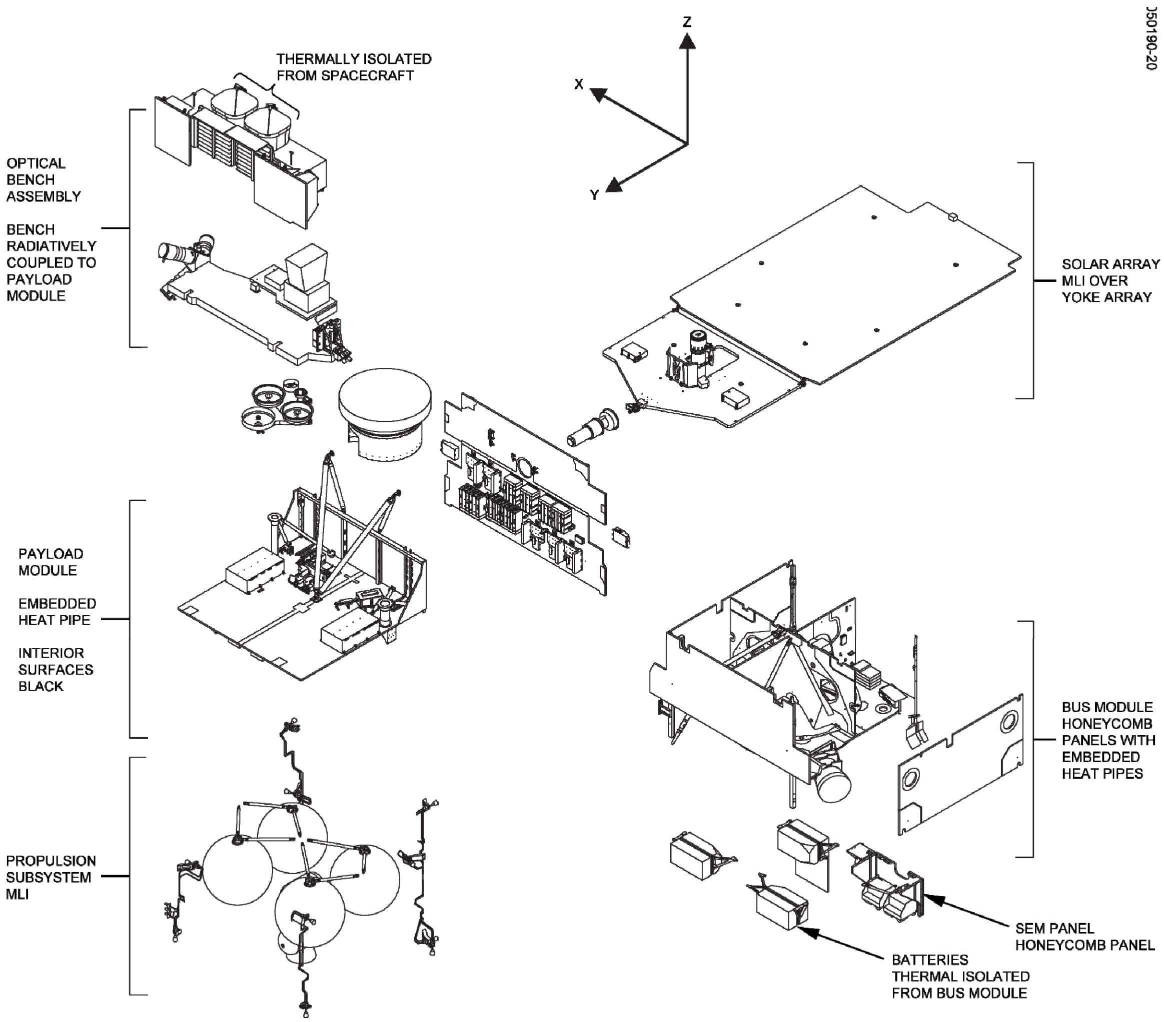

Figure 13-3. Expanded Overview of the GOES Spacecraft

Looped heat pipes are used to transport heat from the hemispherical inertial reference unit and star tracker assemblies to the external radiators. These pipes can be easily formed in multiple planes to accommodate difficult routing paths. In addition, to meet instrument requirements, the star tracker assembly is actively temperature controlled using the looped heat pipes with the ACE controlled heaters.

A majority of the space environment monitor (SEM) units are mounted external to the bus cavity and are thermally isolated from the main spacecraft cavity. These instruments use the same thermal techniques as the spacecraft bus, including mirrored radiator panels with embedded heat pipes and heaters. Both magnetometers on the boom are completely blanketed and use an active heater control system to maintain acceptable temperatures. Two SEM units—the magnetospheric electron detector (MAGED) and magnetospheric proton detector (MAGPD)—are blanketed to minimize aft solar load on the instrument through the viewing port and are supplemented with heaters during no solar load conditions.

The batteries are mounted aft of the bus panel and are thermally isolated from the bus spacecraft cavity. They maintain their own temperature environment using both a mirrored radiator and spacecraft heater control.

The yoke panel, which tracks the sun along with the solar panel, uses blankets, heaters, and radiation through the anti-sun side to maintain the unit's thermal environment. The x-ray sensor/extreme ultraviolet sensor (XRS/EUV) uses an anti-sun facing radiator connected with heat pipes to the unit to dissipate heat. The heaters are mounted on the yoke panel and the gimbal assembly to maintain temperatures for the Solar X-ray Imager suite.

The spacecraft uses temperature telemetry to monitor the spacecraft's state of health, which is downlinked, as well as to provide data onboard the ACE for heater control. Two types of temperature sensors are used—thermistors and platinum resistors. The platinum resistors are used in applications requiring a large operational range, such as the solar panel or thrusters. Thermistors are used in all other applications, which have a narrower temperature range between -40°C and 70°C. Temperature sensors are located within or on units and on the spacecraft structure as required.

Imager and Sounder Thermal Control

The Imager and Sounder instruments are mounted on flexures on a nadir facing mounting plate. As shown in Figures 13-4 and 13-5, the optical and radiometric performance of the Imager and Sounder are maintained throughout the 24-hour orbit by a combination of louver cooling and electrical heating. Thermal control is divided into two primary areas: sensor module and detector radiant cooler assembly. First is thermal control for the sensor module as defined by the scan mirror and telescope assembly along with the Imager/Sounder mounting plate or telescope baseplate and all structural sidewalls. Second is thermal design of the detector radiant cooler assembly (and the filter wheel cooler assembly for the Sounder). These are treated separately from the first in as much as these two assemblies are intended to be adiabatic (thermally isolated) from the rest of the instrument; the thermal performance of one has little or no effect on the other.

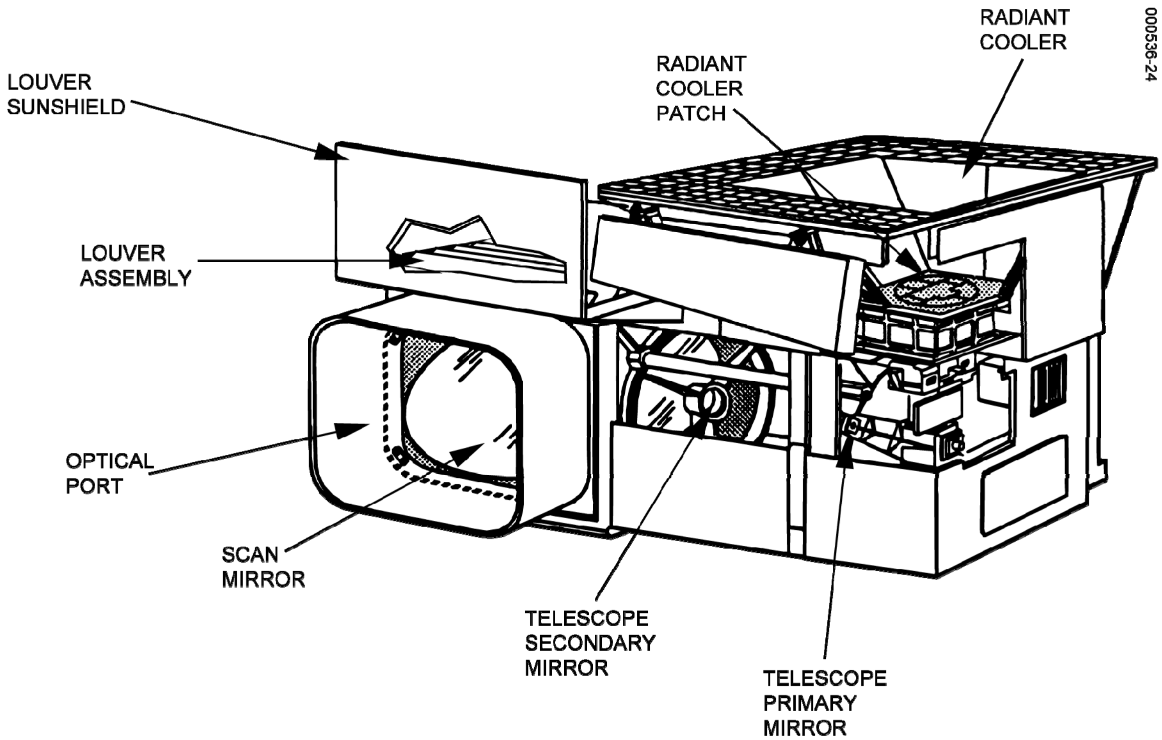

Figure 13-4. Imager Instrument Thermal Characteristics

Optical performance is maintained by restricting the total temperature range. Radiometric performance is maintained by limiting the temperature change between views of cold space (rate of change in temperature). Thermal control also contributes to channel registration and focus stability.

The basic thermal design concepts include:

- Maintaining the instrument sensor modules as adiabatic as possible from the rest of the spacecraft structure.
- Controlling the temperature during the hot part of the synchronous orbit diurnal cycle (when direct solar heating is received into the scanner aperture) with a north-facing radiator whose net energy rejection capability is controlled by a louver system.
- Providing makeup heaters within the sensor modules to replace the thermal energy lost to space through the scanner aperture during the cold portion of the diurnal cycle.

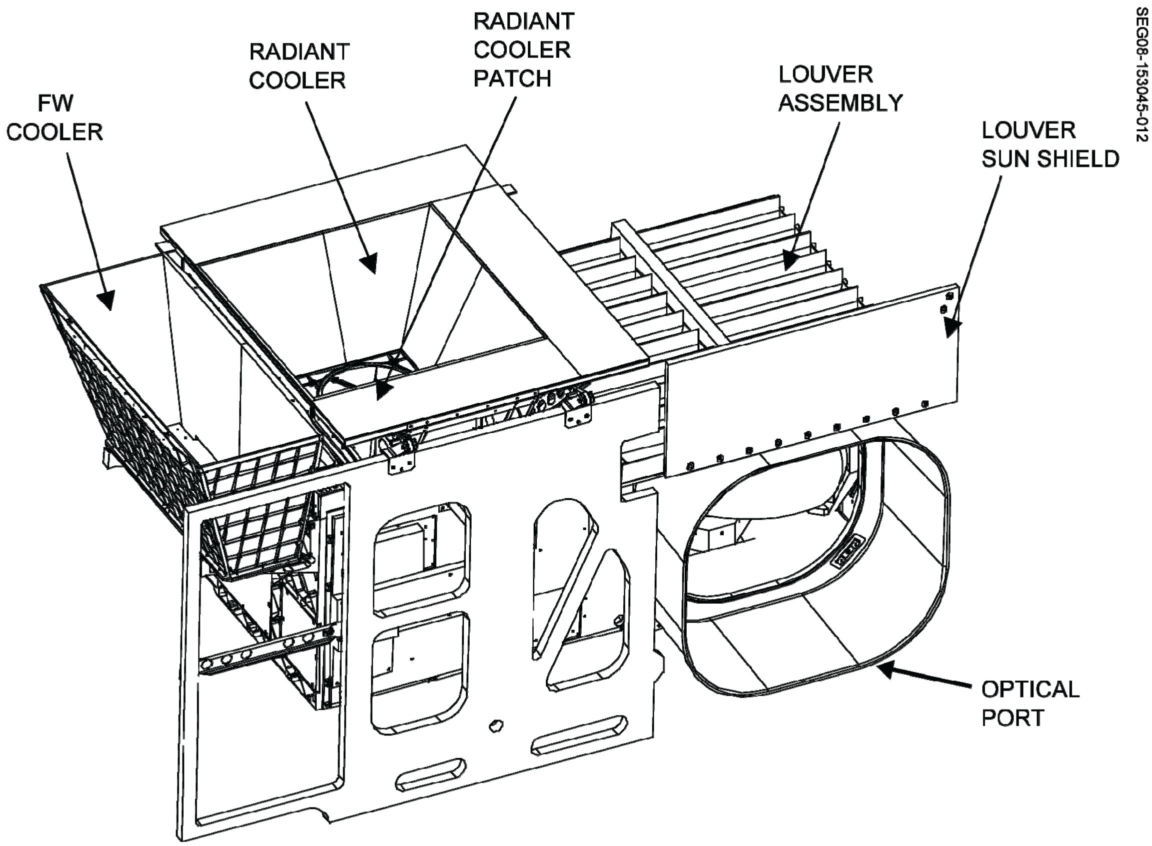

Figure 13-5. Sounder Instrument Thermal Characteristics

Additionally, a sun shield is provided around the scan aperture (just outside the instrument field of view) to block incident solar radiation into the instruments, thus limiting the time in a synchronous orbit day when the scanner can receive direct solar energy. Uncontrolled temperature variations are reduced by the sun shield around the scan cavity opening, a passive automatic louver-controlled cooling surface, and electrical heating. Electrical heat decreases temperature excursions during the cold part of the daily cycle, but increases the average temperature. To obtain lower temperature ranges, louver-controlled cooling is provided during the direct sunlight portion of the orbit. A sun shield is installed on the earth end of the louver system to reduce incident radiation.

MLI blankets are applied on the outside of all but the north side of the instruments. The covers over the radiant coolers and the optical ports are designed to provide thermal protection of the radiant cooler patch, and reduce heater power during transfer orbit. These covers have MLI blankets on both sides and are deployed onto the nadir face after reaching synchronous orbit.

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