THERMAL CONTROL AND THERMAL SENSORS OF OBSERVATION SATELLITE

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ABSTRACT:

In this study, we performed an extensive research to identify how and with what kind of facilities the observation satellites implement their thermal control. It helps observation satellite mission designers to have a good sight and overall vision about thermal control components and thermal control approaches that commonly used in this type of satellite. Also in design of thermal control subsystem, and for a rough estimate of weight and power of thermal control subsystems, thermal engineers can use pervious experiences of a similar satellite. Thermal control subsystem is one of the most important subsystems in observation satellites. It is because of the special missions of such a satellite that compel to use precision thermal control on the satellite components and subsystems. The function of the thermal control subsystem (TCS) is to preserve all spacecraft and Payload components and subsystems within their required temperature limits for each mission phase. Temperature limits include a cold temperature which the component must not go below and a hot temperature that it must not exceed. Two limits are frequently defined: operational limits that the component must remain within while operating and survival limits that the component must remain within at all times, even when not powered. Exceeding survival temperature limits can result in permanent equipment damage as opposed to out-of-tolerance performance when operational limits are exceeded. In this study we identified thermal control techniques and approaches and thermal control components that commonly used in observation and remote sensing satellites. My studies showed most observation satellites use passive control. It is because that passive thermal control is more reliable in comparison to the active thermal control. It is really interesting for designers and users, because passive thermal control is more reliable and need less power. Also it is less expensive instead of active thermal control that is expensive. Passive thermal control techniques available to the engineer consist essentially of selection of surface properties the control of conduction paths and thermal capacities and the use of insulation systems. Passive facilities include surface finishes, conduction paths, heat pipe and phase change material and two phase material and insulation systems.

1. INTRIDUCTION

Prior to the space age (conventionally dated from1957), humankind had never been able to take in the whole of a hemisphere in a single glance. In fact it had never had a global view of the world in which it lived. It was not until the first spacecraft went into orbit that our horizons expanded and we saw our planet as never before. During more than four decades of spaceflight, planet Earth has been rediscovered through the systematic collection and analysis of vast amounts of information. At the turn of the century/millennium, satellite-provided services in many fields of application (environmental monitoring, navigation, weather forecasting, communication, etc) are taken for granted. We've come to depend on the satellites in a way that would have been unimaginable a few decades ago. Earth observation covers a wide field of remote sensing as well as of other sensing methods (in-situ), it encompasses the Earth itself (in particular its outer surface) and also the Earth's environment, including the study of interactions with the outside. Thermal control techniques are broadly divided into two categories called passive thermal control and active thermal control. Passive thermal control makes use of materials, coatings, or surface finishes (such as blankets or second surface mirrors) to maintain temperature limits. Active thermal control, which is generally more complex and expensive, maintains the temperature by some active means, such as heaters or thermo-electric coolers. In general, low-cost thermal control systems are designed to keep spacecraft at the cool end of allowable temperature ranges. Cooler components generally last longer and t his allows for system power growth. Though this can require additional power, it decreases the number of expensive iterations on the thermal design and analysis (which happens anyway, of course).

Thermal control subsystem is a necessary subsystem for a satellite. Even a nanosatellite has Thermal control subsystem (SiegfriedW. Janson, Henry Helvajian,Ernest. Y. Robinson, "The Concept of "Nanosatellite" for Revolutionary Low Cost Space Systems," Proceedings of the 44th Congress of the International Astronautics Federation, Oct. 16-22, 1993, Graz, Austria, IAF-93-U.5.573). Spacecraft thermal control is a process of energy management in which environmental heating plays a major role. The principal forms of environmental heating on orbit are direct sunlight, sunlight reflected off Earth (albedo), infrared (IR) energy emitted from Earth. During launch or in exceptionally low orbits, there is also a free molecular heating effect caused by friction in the rarefied upper atmosphere.

The overall thermal control of a satellite on orbit is usually achieved by balancing energy emitted by the spacecraft as IR radiation against the energy dissipated its internal electrical components plus the energy absorbed from the environment; atmospheric convection is absent in space.

2. THERMAL CONTROL IN STATELLIE

Spacecraft thermal control techniques can be categorized as passive thermal control (PTC) or active thermal control (ATC). PTC can be achieved by control of conductive and radiative heat paths through selection of the proper geometrical configuration, insulation blankets, sun shields, radiating fins, surface thermo-optical properties, thermal coatings, heat sinks, and phase-change materials. A PTC system does not involve moving parts of fluids. The spacecraft component temperatures are maintained within the desired range by proper control of the dissipated energy between all spacecraft elements through the conductive and radiative heat paths. However, to execute a design in which the PTC techniques cannot deal with environmental extremes or to accommodate equipment dissipating high power, employment of ATC techniques may be more efficient. In such cases, designs can be executed by the use of heaters, louvers, heat pipes, thermoelectric coolers, cryogenic coolers, and pumped fluid loops (David G. Gilmore, 2002, Volume 1, Spacecraft Thermal Control Handbook, The Aerospace Press).

Establishing a thermal design for a spacecraft is usually a two-part process. The first step is to select a thermal design for the body, or basic enclosures, of the spacecraft that will serve as a thermal sink for all internal components. The second step is to select thermal designs for various components located both within and outside the spacecraft body (Wiley J. Larson, James R. Wertz, Third Edition, Space Mission Analysis and Design, Space Technology Library).

The main phases in a spacecraft projects are concept definition, validation, full-scale development, and operation. The actual activities for each vary from program to program, but the following discussion gives a general idea of the thermal engineer's role as a program matures.

2.1 Sample Satellites:

1- NEMO Satellite: The NEMO program (started in 1997) is a cooperative US government/industry satellite program, sponsored by ONR (Office of Naval Research) and DARPA as well as commercial investments, between the Navy's NRL (Naval Research Laboratory) on the government side as the program manager in partnership with commercial developers, a consortium led by STDC (Space Technology Development Corporation) of Alexandria, VA. In 1999, STDC was acquired by Earth Search Sciences Inc. (ESSI) of Kalispell, MT. 840)

The overall objective is the development/demonstration of hyperspectral technology and the collection/processing of moderate-resolution hyperspectral imagery for military and commercial use. The emphasis is on broad-area, synoptic, and unclassified hyperspectral imagery. The prime military interest is to obtain imagery of the coastal regions on a global scale (littoral modeling, shallow water bathymetry, topography, bottom type composition, detection of underwater hazards, water clarity and visibility, etc.), while the civil needs call for imagery supporting such applications as land use management, agriculture, environmental studies, and mineral exploration.

This satellite has passive thermal control with heater augmentation. Also battery and payload panels thermally isolated from bus.

2- CHAMP satellite: CHAMP is a German BMBF-funded geophysical mini-satellite mission of GFZ (GeoForschungsZentrum, Potsdam, Germany) in cooperation with DLR. The satellite was built by the German space industry with the intent to foster high-tech capabilities especially in the East-German space industry. The S/C prime contractor is DJO (Jena Optronic GmbH) in Jena, a daughter of DASA (now Astrium). The overall science objectives are in the following fields of investigation:

- Global long- to medium-wavelength recovery of the static and time variable earth gravity field from orbit perturbation analyses for use in geophysics (solid Earth), geodesy (reference surface), and oceanography (ocean currents and climate), supported by a feasibility test of GPS altimetry for ocean and ice surface monitoring
- Global Earth magnetic field recovery (solid Earth and solar-terrestrial physics)
- Atmosphere/ionosphere sounding by GPS radio occultation with applications in weather forecasting, navigation, space weather, and global climate change.

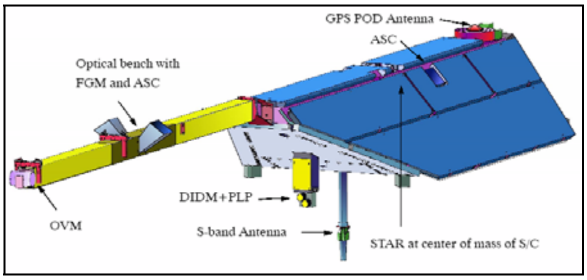

Figure1. Front view of the CHAMP spacecraft.

In this satellite passive thermal control is provided by paints and multi-layer insulation.

3- INSAT-3B satellite: This satellite is the first of the five satellites that was launched in the INSAT-3 series (built by ISRO). The satellite structure resembles a cuboid of 1.93 m x 1.7 m x 1.65 m and, with the two solar panels deployed (total area of 23m2), it measures 14.7min length. The sun tracking solar panels generate 1.7kWof power.A24AhNi-Cd battery supports the payload operations during eclipses. INSAT-3B is three-axis body-stabilized using momentum/reaction wheels, earth sensors, sun sensors, an inertial reference unit and magnetic torquers. It is equipped with unified bi-propellant thrusters. The satellite has two deployable antennas and three fixed antennas that carry out various transmit and receive functions. The antennas have a pointing accuracy of ±0.2° in pitch and roll axes, and±0.4° in yaw axis. The satellite uses a passive thermal control system. The S/Cmass is 2070 kg at launch, with 1100 kg of hydrazine propellant for orbit raising, station keeping and on-orbit attitude control. The S/C design life is 10 years.

4- ASTRO-SPAS: It is the generic name of a reusable platform, designed and built by DASA (formerly MBB, Munich, Germany) under DLR contract, which is used as a self- ontained and autonomous free-flyer service structure for special Shuttle payloads with free-flyer requirements for short-duration missions (up to the length of a Shuttle mission). The SPAS structure consists of low-weight, high-stiffness carbon fiber tubes with titanium nodes. Standardized mounting panels are provided for subsystem and payload equipment. The platform is deployed/retrieved by the Shuttle's robot arm RMS (Remote Manipulator System) for a free-flyer mission which may entail separations from the Shuttle up to 100 km. As a service structure, SPAS is particularly suited as a test bed for new science instrumentation and technology demonstrations in space. 1362) The platform overall size is 4.5mx 1.75 m, its empty mass is about 1240 kg (including service subsystems), it can accommodate a payload up to a total satellite mass of 3600 kg. The platform offers the following service subsystems:

- Electrical power: ModularLi-SO2 battery packs (up to 16), 110 kJh, with 40 kJh of energy available to the payload instruments.
- Thermal control: Passive thermal control via radiation and conduction through the platform surface and multilayer insulation blankets.
- Data management: An on-board computer provides all data management functions such as: telecommanding, storage of source data onto a recorder, telemetry data handling, attitude control, etc.
- Platform stabilization: A three-axis stabilization is provided. A precision star tracker serves as reference for pointing accuracies <3 arc seconds to astronomical targets. A GPS Tensor receiver system provides in addition orbit and attitude. Attitude control (actuator) is provided with a 12-nozzle cold gas thruster system (100 mN thrust).
- Operational modes: Two modes are provided, 'inertial pointing' and 'orbit motion.' - The inertial pointing mode serves mainly for astronomical observations. The star tracker (CCD camera) measures the position of three guide stars in its FOV of 4.5º x 6º, the gyro package senses rotations. The orbit motion mode is used for atmospheric research to point into a specific direction. One axis points into a constant, commandable altitude layer (stabilized to ±2km). The GPS Tensor instrument and the star tracker provide attitude, position and velocity of the platform.
- TT&C: A scheduled communications link via Shuttle is provided by an S-band transponder with uplink data rates of up to 2 kbit/s and downlink rates of up to 16 kbit/s.

5- NEMO: The NEMO program (started in 1997) is a cooperative US government/industry satellite program, sponsored by ONR (Office of Naval Research) and DARPA as well as commercial investments, between the Navy's NRL (Naval Research Laboratory) on the government side as the program manager in partnership with commercial developers, a consortium led by STDC (Space Technology Development Corporation) of Alexandria, VA. In 1999, STDC was acquired by Earth Search Sciences of McCall, Idaho.

The overall objective is the development/demonstration of hyperspectral technology and the collection/processing of moderate-resolution hyperspectral imagery for military and commercial use. The emphasis is on broad-area, synoptic, and unclassified hyperspectral imagery. The prime military interest is to obtain imagery of the coastal regions on a global scale (littoral modeling, shallow water bathymetry, topography, bottom type composition, detection of underwater hazards, water clarity and visibility, etc.), while the civil needs call for imagery supporting such applications as land use management, agriculture, environmental studies, and mineral exploration. Contract agreements call for STDC and its industry partners to provide the commercial satellite bus, selected flight avionics components, launch services, and long-term flight operations. NRL provides the design and integration of the NEMO sensor imaging payload with the commercial satellite bus, bus modifications, the on-board processor, ORASIS (Optical Real-time Adaptive Signature Identification System), and systems engineering. NRL has responsibility for calibration software and calibrated radiances; development of at-launch algorithms including those for atmospheric correction; on-board data compression software and related software for the ground data system; some data processing; and data archiving. The planned products of at-launch algorithms are water clarity (probably diffuse attenuation coefficient at 490 nm), concentration of chlorophyll, and absorption coefficient of colored dissolved organic matter, concentration of suspended sediments, bathymetry, and bottom characteristics. The satellite consists of eight hardware subsystems and a software subsystem that collectively accommodate the payload and meet the mission and science requirements (Table 220).The satellite platform selected is a commercial bus (LS-400) from SS/L. 1708) 1709) The satellite is three-axis stabilized and consists of a trapezoidal main body and two deployable solar arrays. STDC has responsibility for ground data processing system architecture, some data processing and merging, data archiving, and a web-based database interface. The S/C design life is five years (minimum of three year on-orbit mission life). This satellite has passive thermal control with heater augmentation. Also battery and payload panels thermally isolated from bus.

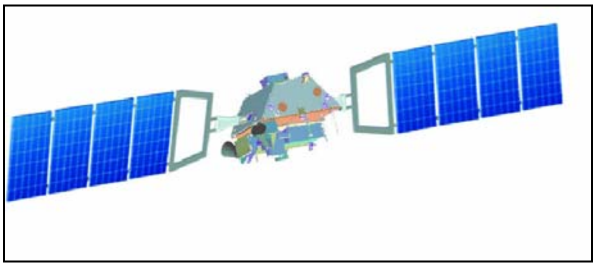

Figure2. Front view of NEMO

3. THERMAL SENSOR

Thermal sensors have extended application via commercial, industrial, spatial and remote sensing.

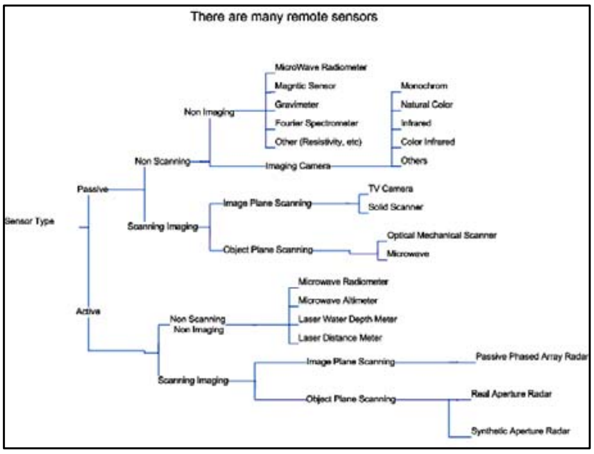

Figure 3. Different types of sensors

Wavelength (μm)	Nominal Spectral Location	Principal Applications
0.63-0.69	Red	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation. Also useful for cultural feature identification.
0.76-0.90	Near infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
155.-1.75	Mid-infrared	Indicative of vegetation moisture content and soil moisture discriminations, and thermal mapping applications.
2.08-2.35	Mid-infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

Table 1. Applications of IR waves

4. CONCLUSION

In this study we identified thermal control techniques and approaches and thermal control components that commonly used in observation and remote sensing satellites. My studied showed most observation satellite use passive control. It is because that passive thermal control is more reliable in comparison with the active thermal control. It is really interesting for designers and users, because passive thermal control is more reliable and need less power. Also it is less expensive instead of active thermal control that is expensive. Passive thermal control techniques available to the engineer consist essentially of the Selection of surface properties the control of conduction paths and thermal capacities and the use of insulation systems. Passive facilities include surface finishes, conduction paths, heat pipe and phase change material and two phase material and insulation systems.

Active thermal control systems are generally more complex than passive systems and often consume power and sometimes telemetry resources. Such systems are typically less reliable and often heavier. As a general rule, active systems should be used only when it has proved impossible to meet requirements by passive means alone. Active systems will typically be used for very temperature-sensitive equipment (telescopes scientific instruments, atomic clocks etc.), in which environmental conditions are very variable. Active facilities include heaters, variable conductance heat pipe (VCHP) and diodes, mechanically pumped two-phase loop, liquid loop and louvers and shuttle refrigerators and heat pumps.

It is clear that commonly used technique in observation satellite is passive technique but some critical subsystems and parts of this type of satellites need to be implemented by active control.

REFRENCE

David G. Gilmore, 2002, Volume 1, Spacecraft Thermal Control Handbook, The Aerospace Press

SiegfriedW. Janson, Henry Helvajian,Ernest. Y. Robinson, “The Concept of “Nanosatellite” for Revolutionary Low Cost Space Systems,” Proceedings of the 44th Congress of the International Astronautics Federation, Oct. 16-22, 1993, Graz, Austria, IAF-93-U.5.573

Wiley J. Larson, James R. Wertz, Third Edition, Space Mission Analysis and Design, Space Technology Library