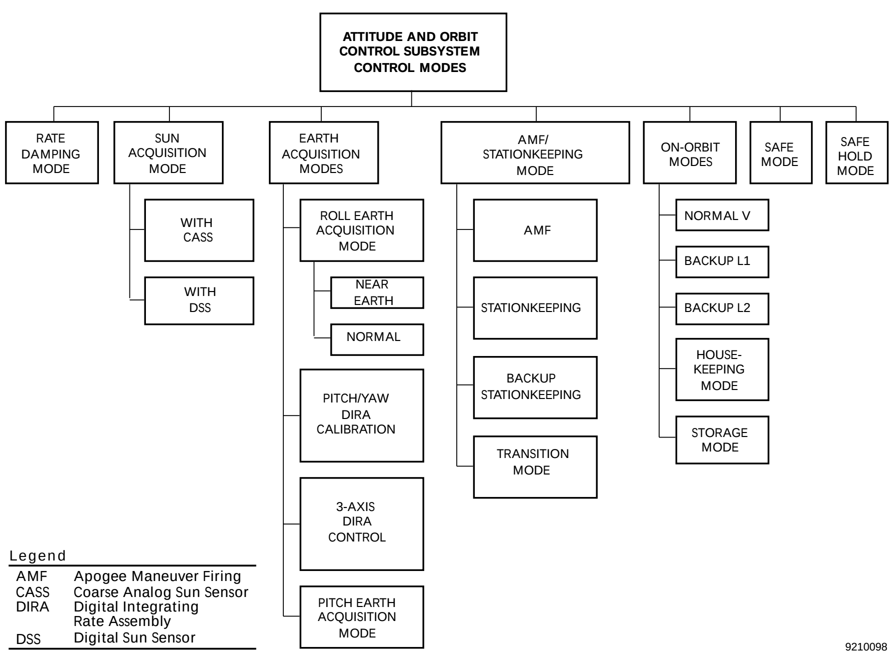
Attitude and Orbit Control Subsystem

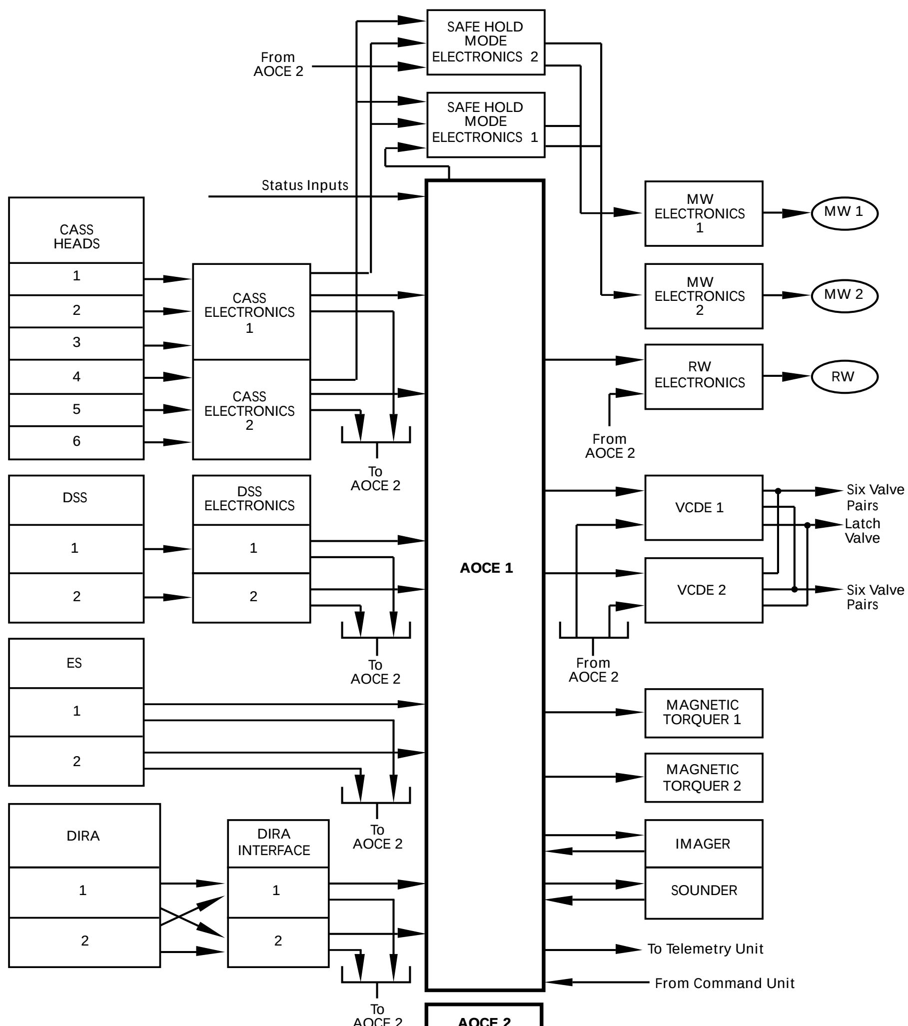
The attitude and orbit control subsystem (AOCS) provides attitude information and maintains the required spacecraft attitude during all phases of the mission, starting at spacecraft separation from the launch vehicle and throughout its operational lifetime. The subsystem consists of redundant microprocessor-based control electronics, sun and earth sensors, gyros, momentum wheels (MWs), a reaction wheel (RW), magnetic torquers, thrusters, and solar array and trim tab positioners.

Normal on-orbit attitude control operations are based on a momentum bias concept that provides precise pointing of the Imager and Sounder, communications service equipment, and scientific instruments. Control is accomplished by applying torque to internal MWs and the RW or by modulating the current applied to roll and / or yaw magnetic torquing coils. Attitude control during orbit maneuvers is provided by twelve 22-N bipropellant thrusters. Control during transfer orbit uses thrusters only, without momentum bias.

AOCS Control Modes



AOCS Functional Block Diagram



Legend

AOCE	Attitude and Orbit Control Electronics	DIRA	Digital Integrating Rate Assembly	MW	Momentum Wheel
		DSS	Digital Sun Sensor	RW	Reaction Wheel
CASS	Coarse Analog Sun Sensor	ES	Earth Sensor	VCDE	Valve Coil Drive Electronics

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Attitude and Orbit Control Electronics

The attitude and orbit control electronics (AOCE) contain electronic circuitry and software to collect attitude data from a variety of sensors and to control the attitude of the spacecraft. The AOCE includes a microprocessor that performs attitude data processing and control algorithm calculations to close the loop between the sensors and the actuators. With the exception of the solar array drive electronics, the AOCE receives all commands to the subsystem as derived from the command unit, processes them, and coordinates related hardware functions. The various AOCE control modes are selected by ground command. Most telemetry signals from the AOCS are formatted in the AOCE.

The interface electronics portion of the AOCE provides appropriate gates and clocks, analog-to-digital and digital-to-analog conversion, magnetic torquer control, thruster control, and MW speed regulation. Sensors interfaced to the AOCS include coarse analog sun sensors (CASSs), digital sun sensors (DSSs), digital integrating rate assemblies (DIRAs), and infrared earth sensors (ESs). The sensors provide attitude data in the form of absolute attitude, attitude error, and rates for processing by the AOCE. These data are also formatted and telemetered to the ground to be used for mission operation checks of attitude determination.

Momentum and Reaction Wheels

Three wheels are associated with the AOCE: two 51-newton-meter-second (N·m·s) MWs and one 2.1-N·m·s yaw-axis RW. Nominal on-orbit operation uses the two MWs to provide gyroscopic stiffness and pointing control about the spacecraft pitch and roll axis. The yaw RW can be used as a redundant backup in conjunction with either MW. The two MWs are mounted with their spin axes skewed ±1.66° off the spacecraft pitch axis in the spacecraft pitch/yaw plane. In addition to pitch control, this configuration (V-mode) allows the wheels to be used to control spacecraft yaw momentum by differentially modulating the wheel speeds. Similarly, in the backup, or L-mode, modulation of the yaw RW speed is used to control yaw momentum.

Solar Array and Trim Tab Positioning

The positioning mechanisms used on orbit, as a part of the AOCS and included within its functional responsibilities but not involved in attitude determination, are the solar array drive assembly (SADA) and the solar array trim tab drive electronics (SATTDE). The SADA structurally supports the solar array wing;

rotates the wing about the spacecraft pitch axis to maintain sun pointing; and transfers power, control, and telemetry signals across slip rings at the rotary interface. Two SATTDE units are provided for redundancy.

The SATTDE: (1) processes array and trim tab encoder analog signals to derive position telemetry; (2) provides power to drive the redundantly wound stepper motor that rotates the array; and (3) drives the redundant motors that position the trim tab assembly. The trim tab compensates for the large, seasonally varying, inertial roll, solar pressure torque unbalance between the solar array and solar sail. The tab position is varied in a slow sinusoidal sequence over a year's span to also compensate for small changes in torque due to the solar flux and sun declination. A higher slew rate can be selected, by ground command, to help set the desired initial trim tab position. Magnetic torquer coils, in conjunction with the momentum bias system, provide desaturation of the angular momentum caused by slowly varying roll/yaw torques due to higher order solar radiation pressure.

Image and Mirror Motion Compensation Support

The AOCE also provides mirror motion compensation (MMC) and image motion compensation (IMC) signals to the Imager and Sounder. It accepts ground command-selected coefficients that the AOCE processor uses to determine the magnitude and timing of the servo signals for the image navigation and registration (INR) function.

Space Environment Monitor Support

The AOCS also supports the space environment monitor (SEM) payload. The X-ray positioner (XRP), a single-axis gimballed platform located on the solar array yoke, supports SEM equipment dedicated to solar studies. To maintain sun pointing throughout the seasons, the XRP contains a yoke-mounted electronics unit and a sun analog sensor that generate closed-loop drive signals to a stepper motor which in turn moves the XRP in a north/south (declination) direction to track the sun. By ground command, small east/west (azimuth) adjustments can be performed, with no effect on output power, by slewing the solar array slightly east or west of its nominal position.

Upon ground command, the XRP electronics can slew the platform to any declination position ±25° of the sun to facilitate instrument calibrations and/or background measurements. For solar X-ray imaging or other SEM tasks requiring higher azimuthal pointing accuracy, the electronics design incorporates the ability to accept control signals derived from a high-accuracy analog sun sensor, providing closed-loop sun pointing in both axes. The XRP electronics is also able to multiplex telemetry parameters of the yoke-mounted SEM equipment, housekeeping, and position data, routing it to the spacecraft telemetry and command subsystem via slip rings in the SADA.

Safe Hold Mode

A major operational safety feature of the GOES I-M spacecraft is a backup control mode that is manually commanded should loss-of-earth lock occur during normal on-orbit operations or if the interrupt safety system (ISS) is tripped. This "safe hold mode" (SHM) is designed to allow flight controllers to place the spacecraft in a safe state without the use of thrusters. Implemented via analog electronics, SHM electronics (SHME) are independent of the attitude and orbit control electronics (AOCE). SHM ensures spacecraft health and safety for long periods of time (more than 24 hours under nominal conditions, if needed) by providing sufficient solar array power and a stable thermal environment. Such extended periods allow time for technical experts to resolve spacecraft anomalies. Further, by not using thrusters to control attitude, the stored bias momentum is preserved, contributing to an enhanced level of safety and a more efficient return to normal operations.

Safe Hold may be invoked when the spacecraft loses attitude control in any wheel control mode with pitch rates within specified limits. Commanded by a ground operator (it is not automatic), SHM is capable of controlling the spacecraft to attain and hold a sun-pointing attitude starting from any orientation in pitch. Using the output of the coarse analog sun sensor electronics (CASSE) in conjunction with control wheels, SHM orients the spacecraft -X axis (or +X axis) toward the sun. After the spacecraft is brought to a stable sun-pointing mode, the solar array is slewed to face the sun and the SHME is then commanded for long-term stability. In steady-state operation, the SHM provides thermal, power and attitude safety, as well as continuous telemetry and command access except for a predictable 4-hour null per day.

As a backup mode, SHM safes the spacecraft differently than the *safe mode* which does not provide continuous solar array power or a stable thermal environment for the spacecraft. In contrast, the purpose of Safe Mode is to ensure that a continuous telemetry and command null does not occur by disabling all actuator torques and changing the commanded wheel speed bias to induce a spacecraft pitch rate of -1°/s. And because of insufficient power and intermittent telemetry, the spacecraft cannot be held in Safe Mode for long time periods. Whereas SHM is always manually commanded, the Safe Mode can be either manually commanded or automatically activated by the AOCE when certain anomalies are detected (e.g., earth sensor out of limits, processor cycle time too long). Moreover, because Safe Mode control is internal to the AOCE there is no protection against any AOCE failure.