Spacecraft Mission Profile

To reach the required on-station location in geostationary orbit (station acquisition), the GOES spacecraft undergoes five distinct mission phases:

- Launch Phase: From Atlas I lift-off to spacecraft separation.
- Transfer Orbit Phase: Spacecraft separation to end of apogee maneuver firing (AMF) 1.
- Phasing Orbit Phase: End of AMF 1 to end of AMF 2.
- Trim Orbit Phase: End of AMF 2 to station acquisition.
- Synchronous Orbit Phase: Station acquisition to end of operational life.

The nominal chronological sequence of orbit raising for a nominal transfer orbit consists of AMF 1, AMF 2, AMF 3, an apogee adjust maneuver (AAM) at perigee, and one or more trim maneuver firings (TMFs), as required. During AMFs the spacecraft is maintained in a nonrotating configuration by the attitude and orbit control subsystem (AOCS) using the earth as a reference. Throughout each drift period, between firings, the spacecraft is returned to and maintained in the sun-acquisition mode, with rotation about the X-axis, to supply solar array power.

Ground Stations

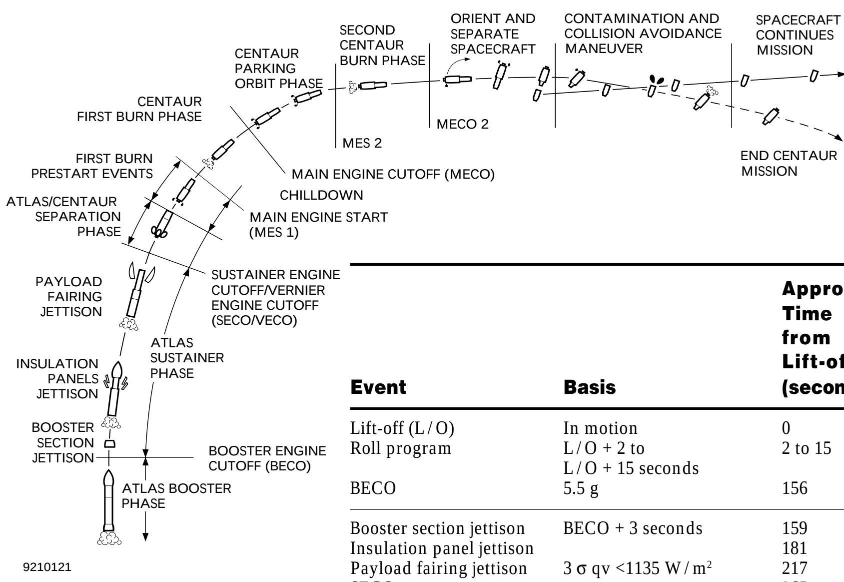
Various ground centers and tracking stations are involved throughout the mission phases:

- Deep Space Network (DSN) stations at Canberra, Australia; Madrid, Spain; and Goldstone, California, support orbit raising maneuvers with Goldstone acting as backup to the command and data acquisition (CDA) station when the spacecraft is in synchronous orbit. The NASA antenna at Wallops, Virginia, provides telemetry and command (T&C) support during orbit raising.
- Indian Ocean Station (IOS), an Air Force remote tracking station, is used for initial spacecraft T&C functions and to support the transfer orbit whenever this station is available.
- Command and Data Acquisition (CDA) station located at Wallops, Virginia, houses the telemetry and command transmission system (TACTS), portions of the operations ground equipment (OGE), and GOES I-M telemetry and command system (GIMTACS). The CDA performs spacecraft telemetry acquisition, formatting, and command transmission.
- Satellite Operations Control Center (SOCC) houses the orbit and attitude tracking system (OATS), part of the OGE, and GIMTACS. The SOCC is the prime control center for all mission phases. This station is also capable of receiving processed instrument data in GOES variable (GVAR) data format and multiuse data link (MDL) diagnostic data.

Launch and Injection

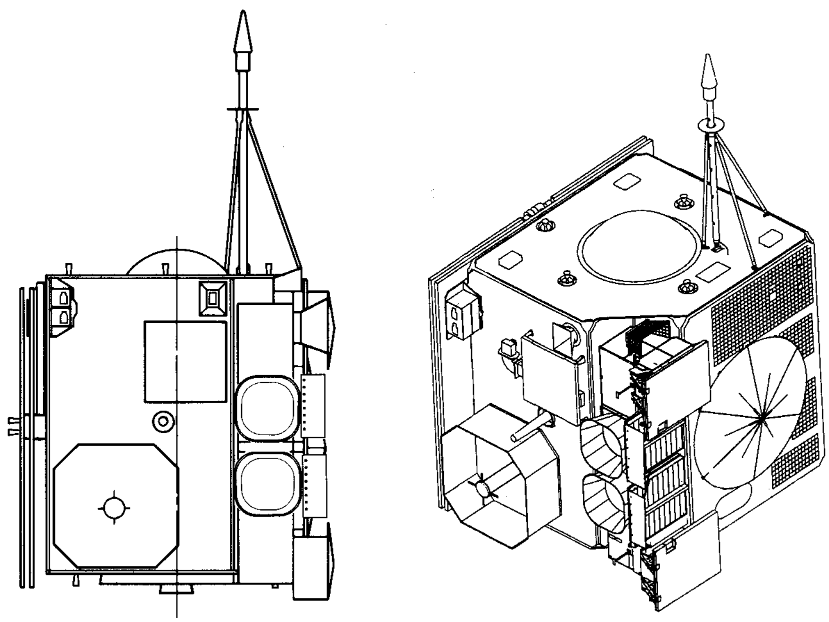
The GOES I-M spacecraft are launched from Cape Canaveral Air Force Station Launch Complex 36B by a General Dynamics Atlas I. During the launch phase the spacecraft batteries supply power to support thermal control and T&C functions, yielding a battery depth of discharge of about 8.3% at separation. The spacecraft is separated from the Centaur stage with a spin about its major moment of inertia axis (Z axis) of about 1.2 revolutions per minute (7° / s) at the time of ground station acquisition-of-signal. The +Z axis of the spacecraft is pointed generally toward earth, providing an effective T&C signal for first acquisition-of-signal. Atlas I injects the spacecraft into a highly elliptical supersynchronous orbit (48,789 kilometers (30,316 miles) apogee radius, 6545 kilometers (4067 miles) perigee) to begin the transfer orbit phase. The maximum time from lift-off to separation is about 35 minutes, nominal being about 28 minutes.

Atlas I Major Mission Events



Event	Basis	Approx Time from Lift-off (seconds)
Lift-off (L / O)	In motion	0
Roll program	L / O + 2 to L / O + 15 seconds	2 to 15
BECO	5.5 g	156
Booster section jettison	BECO + 3 seconds	159
Insulation panel jettison		181
Payload fairing jettison	3 σ qv <1135 W / m^2	217
SECO		265
Atlas / Centaur separation	SECO + 2 seconds	267
MES 1		289
MECO 1		605
MES 2	Guidance	1454
MECO 2	Hohmann apogee	1549
Spinup Option	Spacecraft separation	1551
Separation		1741

Launch Configuration

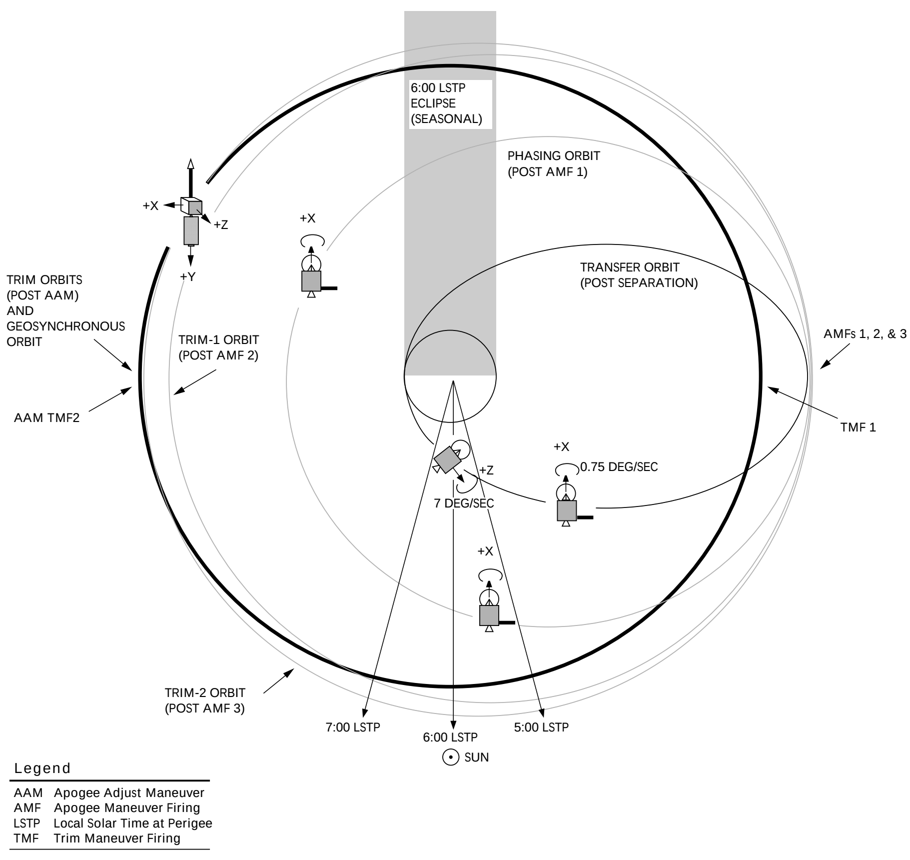


Transfer and Phasing Orbits

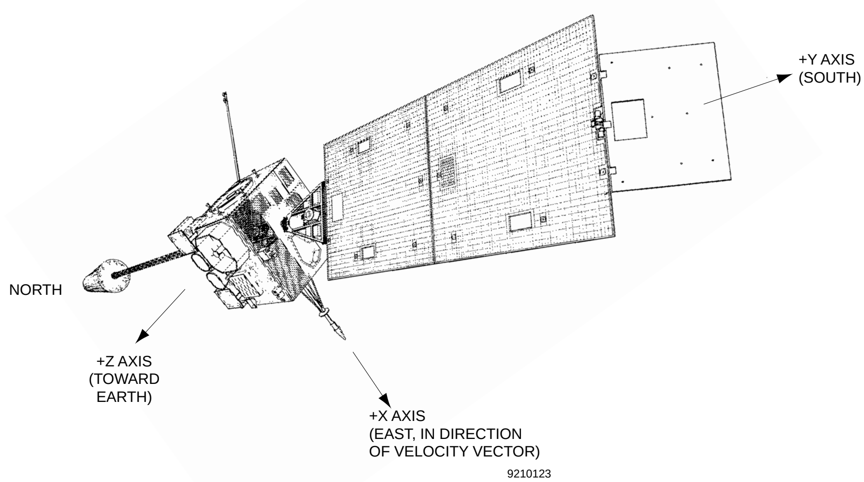
The spacecraft attitude at injection (onto the transfer orbit) is oriented so as to maximize continuous T&C coverage by both primary and backup ground stations. The effective spacecraft T&C antenna pattern is a cardioid with a maximum ±130° look angle from the +X axis. T&C visibility from the ground is obtained when the spacecraft's elevation angle with respect to the ground station local horizon is greater than 5° and the ground station is within the spacecraft T&C antenna pattern. During transfer and phasing orbits, redundant and near-continuous coverage is provided by the five T&C stations (Goldstone, Wallops, Madrid, Canberra, and Indian Ocean), except for unavoidable 1- to 2-hour outages at perigee due to the spacecraft's low altitude.

After acquisition-of-signal by the Indian Ocean Station is established and a command link verified at the beginning of the transfer orbit phase, the spacecraft is configured by ground command to prepare for initial off-axis sun-acquisition mode. Using the attitude and orbit control (AOC) thrusters, the AOCS orients the spacecraft's west face toward the sun. The outboard panel of the solar array wing is then pyrotechnically released to face the sun and provide solar power to operate the spacecraft subsystems and recharge the batteries. For a nominal timeline of 90 minutes from launch to panel deployment, the battery reaches a depth of discharge of about 20%. This level allows sufficient time for possible

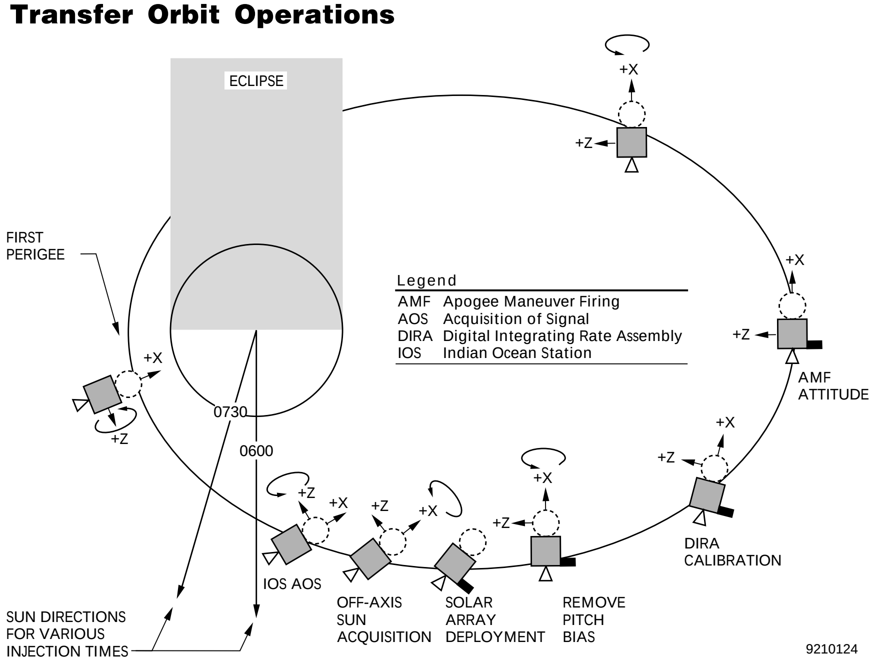
Spacecraft Orbit Geometry



Body-centered Axes of the



Transfer Orbit Operations



delays and contingencies, while remaining within the safe limit of 60% depth of discharge. If there is any delay in deploying the outer solar array panel, adequate station coverage for continuous T&C operations is provided since the spacecraft remains in view of the Indian Ocean and Canberra stations throughout this period.

The 490-N apogee thruster is used to target the spacecraft into the proper trim orbit, that is, correct apogee radius, inclination, and ascending node. The apogee motor firings minimize north/south stationkeeping (NSSK) propellant expenditures by targeting the apogee thruster for the correct ascending node and inclination that places the spacecraft on the proper NSSK schedule. Propellant consumption is minimized by using the higher specific impulse apogee thruster rather than the 22-N AOC thrusters.

Optimum targeting also involves splitting AMF into three parts. The first places the spacecraft into a high drift rate orbit, phasing the spacecraft to the on-station longitude. The second AMF corrects orbit dispersions induced by the first, placing the spacecraft into a near-synchronous trim orbit. Each AMF is retargeted before the burn to compensate for any apogee thruster dispersion or pointing errors incurred during the previous AMF. The AAM uses the apogee thruster to reduce the apogee altitude to the geosynchronous altitude. Any remaining orbit dispersions after the three AMFs and the AAM are corrected in the trim orbit using the 22-N AOC thrusters. The spacecraft arrives on station after several revolutions in the trim orbit, about 15 days after separation from the Atlas I.

The transfer orbit parameters cited here are for a nominal orbit with AMF 1 occurring at fourth apogee. The time to arrive on station is 15.2 days for the nominal transfer orbit apogee radius of 48,789 kilometers (supersynchronous). At apogee four, the spacecraft is visible to the Goldstone and Wallops stations. At the completion of AMF 1 the spacecraft is in the phasing orbit, which continues through AMF 2. Nominal AMF 2 occurs at the sixth apogee, about 38 hours after AMF 1. AMF 2 occurs two orbit revolutions after AMF 1, ensuring visibility from Madrid with Indian Ocean for backup.

Transfer orbit eclipse durations depend primarily on the launch date and launch window. Battery management, pre-eclipse and post-eclipse, is to be determined based on a firm launch date, and command sequences are to be included in the final sequence of events. During eclipse, the sun reference is lost though the spacecraft continues in the sun-oriented roll mode in the absence of the solar radiation pressure and aerodynamic perturbations. After eclipse, the sun acquisition sequence is automatically reinitiated to reacquire the sun.

Trim Orbit

The trim orbit phase begins after AMF 2 and continues until the spacecraft is on station, defined as the time when the spacecraft is in synchronous orbit positioned at 90° west longitude ready for on-orbit testing, and all launch vehicle and apogee thruster dispersions have been corrected. This phase nominally lasts for about 10.7 days. After AMF 2, the spacecraft is nominally at 13° east longitude, drifting west at 20° per day toward station location. With the spacecraft at 27° west two days later, the apogee thruster is fired (AMF 3), raising the perigee radius, increasing the drift, and also correcting any previous AMF pointing errors. One and a half revolutions later, the apogee thruster is fired at perigee to change the apogee radius (apogee adjust maneuver), and reduce drift rate. One and a half revolutions after that, near apogee six, trim maneuvers by the AOC thrusters arrest spacecraft drift. Depending upon the actual orbit parameters at this phase of the mission, additional TMFs may be required. The major operations performed during the trim orbit phase, following AAM are:

- Deploy magnetometer boom; calibrate spacecraft residual magnetic field
- Complete deployment of solar array
- Spin up momentum and reaction wheels
- Deploy solar sail and boom

On-Station/Synchronous Orbit

At this point the synchronous orbit phase begins and the spacecraft is checked for proper performance before entering service at either of two assigned locations. At the checkout station the orbit apogee and perigee radii will respectively be 155 kilometers (96.3 statute miles) above and below the geosynchronous radius of 42,164 kilometers (26,199 statute miles). By international agreement for the GOES system, two spacecraft orbital positions have been assigned: 75° and 135° west longitudes. From these two vantage points, roughly over Ecuador and the Marquesas Islands respectively, the GOES Imager and Sounder instruments are able to provide coverage of both Atlantic and Pacific Oceans. The major operations performed upon station acquisition are:

- Deploy Imager and Sounder cooler covers
- Activate space environment monitor equipment
- Start spacecraft checkout

Normal on-orbit operations entail periodic stationkeeping maneuvers that keep the spacecraft within a 0.5° inclination about the equator and within ±0.5° of the on-station longitude. These maneuvers are needed because of several forces that produce small changes over a short period of time: interactive effects of the sun’s and moon’s gravity, solar pressure variations, and the fact that the earth’s mass is distributed and does not act as a single point. Stationkeeping is performed by a particular set of the 22-N thrusters selected by ground command for manually controlled firing. The OATS software determines the needed AOC thruster combination and thruster firing durations. The AOCE maintains spacecraft attitude throughout the EWSK firing using the earth sensor and by actuating other control thrusters. (The DIRA is used for NSSK.)

Nominal Orbit Parameters

Apogee Maneuver Firing 1 at Fourth Apogee

Parameter	Orbit Type						
	Transfer	Phasing	Trim				
			Post-AMF 2	Post-AMF 3	Post-AAM	Post-Trim	Geo-Synch
Perigee, radius (km)	6,544.5	23,408	38,641	41,909	41,909	42,009	42,164
Apogee, radius (km)	48,789	48,789	48,789	48,789	42,419	42,319	42,164
Inclination (degrees)	27.0	4.4	0.25	0.5	0.5	0.5	0.5
Period (hours)	12.7	19.0	25.3	26.7	23.4	24.0	24.0
Drift (degrees/revolution east)	168.7	74.8	-20.0	-41.6	0.01	0.0	*

*Spacecraft drift induced by solar, earth and lunar gravitational effects and solar pressure corrected by stationkeeping maneuvers