Operations Ground Equipment

The GOES ground segment consists of three parts: ground station radio frequency (RF) equipment, telemetry and command system, and the payload processing and spacecraft operations system. The ground station RF equipment is located at the SOCC and CDA facilities. Telemetry and command are provided by the GOES I-M telemetry and command system (GIMTACS), also located at the SOCC and CDA. Payload processing and spacecraft operations support is provided by the operations ground equipment (OGE).

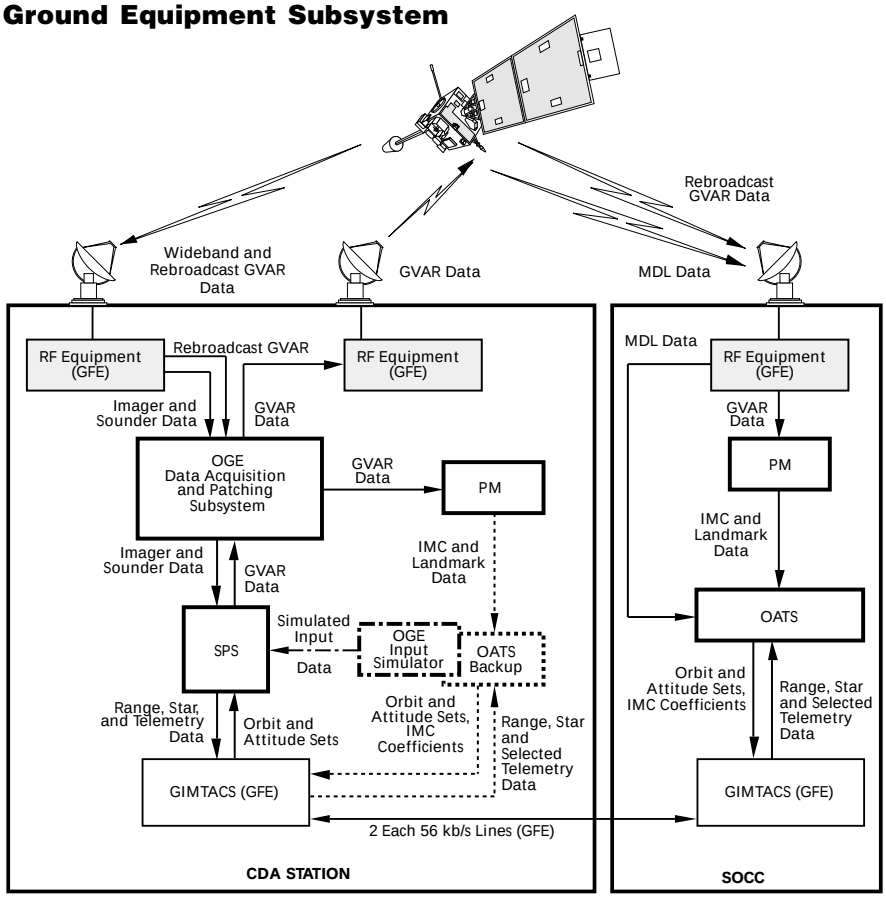
The OGE performs several important functions that support on-orbit operations of the GOES spacecraft:

- Radiometric calibration, visible data normalization
- Earth location and gridding
- Range, star location, and landmark measurements
- GVAR data product monitoring
- Calibration database management
- Orbit and attitude determination
- Image motion compensation (IMC) coefficient generation
- Star command generation, scan frame command generation
- Raw instrument data simulation
- Diagnostic telemetry data processing
- Stationkeeping maneuver planning and command generation
- On-board propellant remaining estimation
- Daily trim tab angle prediction

Five major functional elements perform the above activities: OGE data acquisition and patching subsystem (ODAPS), sensor processing system (SPS), product monitor (PM), orbit and attitude tracking system (OATS), and OGE input simulator (OIS). These elements are located at the Command and Data Acquisition (CDA) Station, Wallops, Virginia, and the Satellite Operations Control Center (SOCC) at Suitland, Maryland. Communications among several of these functional elements are provided by the GOES I-M telemetry and command system (GIMTACS), which is part of the OGE network and provided as Government-furnished equipment (GFE).

Primary inputs to the OGE are the Imager and Sounder sensor data streams and the multiuse data link (MDL). Primary outputs are the processed data relays for the Imager and Sounder data streams in the GOES variable data format (GVAR), one GVAR-formatted output data stream being generated for each instrument downlink data stream. The GVAR data stream is transmitted to its corresponding spacecraft for relay to principal users, as well as to the CDA Station and SOCC for OGE internal purposes. Internal OGE uses of GVAR data are primarily for monitoring the quality of the processed data (CDA Station and SOCC), determining spacecraft range for use in orbit and attitude determination (CDA),

Ground Equipment Subsystem



Legend

CDA	Command and Data Acquisition	OGE	Operations Ground Equipment
GFE	Government-Furnished Equipment	PM	Product Monitor
GIMTACS	GOES I-M Telemetry and Command System	RF	Radio Frequency
GVAR	GOES Variable Data Format	SOCC	Satellite Operations Control Center
IMC	Image Motion Compensation	SPS	Sensor Processing System
MDL	Multiuse Data Link		Existing Site Equipment
OATS	Orbit and Attitude Tracking System		

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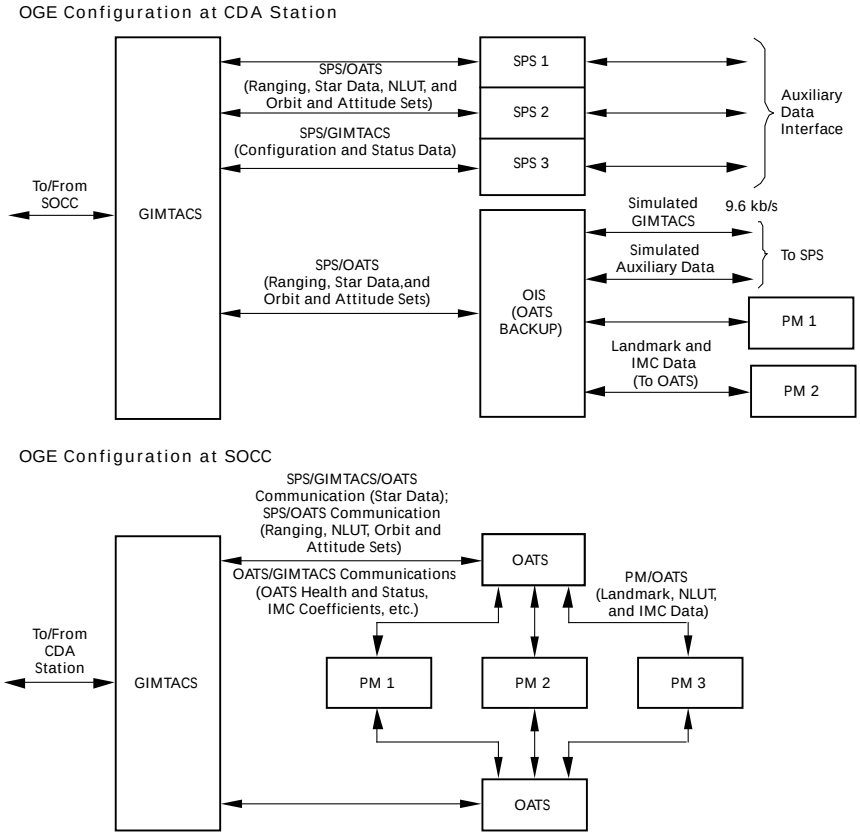
and extracting landmark images as part of the orbit and attitude determination (CDA and SOCC).

Data from the MDL are received at the SOCC and processed by the OGE. The MDL is received as an independent data link, containing angular displacement sensor (ADS) and digital integrating rate assembly (DIRA) data from the spacecraft attitude control subsystem. These data are ingested and processed by the OGE to diagnose dynamic interactions between the Imager and Sounder instruments and the spacecraft.

The OGE at the CDA Station consists of three SPSs, two PMs, and an OIS which may be switched to the backup OATS. Communications among the three SPSs and the two SOCC OATS computers or the CDA OATS backup (OIS) are via GIMTACS. Message traffic between the SPSs and the OATS computers consists primarily of ranging data, star measurement transmissions to the OATS, and orbit and attitude data from the OATS. GIMTACS receives spacecraft orbit and attitude related data, such as IMC coefficients, from the OATS. The OATS receives selected spacecraft telemetry (for example, DIRA data) to support spacecraft stationkeeping functions by GIMTACS. In addition, each SPS receives configuration messages from the GIMTACS, and both the SPS and OATS transmit status to the GIMTACS.

Operations Ground Equipment Subsystem Configuration



Legend

CDA	Command and Data Acquisition	OGE	Operations Ground Equipment
GIMTACS	GOES I-M Telemetry and Command System	OIS	OGE Input Simulator
IMC	Image Motion Compensation	PM	Product Monitor
NLUT	Normalization Look-Up Table	SOCC	Satellite Operations Control Center
OATS	Orbit and Attitude Tracking System	SPS	Sensor Processing System

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Communications from the PM to OATS consist of landmark measurements, IMC and servo error messages, and normalization look-up table (NLUT) data sent to SPS via OATS and GIMTACS. In the SOCC configuration, each PM provides synchronous data communication interface to each OATS. In the CDA Station configuration, synchronous communication interfaces are provided from each PM to the OIS to support the OATS backup function.

Operations Ground Equipment

GVAR Transmission Format

The GVAR data transmission format was developed to allow full use of the capabilities of the advanced, three-axis-stabilized spacecraft while retaining as much commonality as possible with receiving equipment presently in use from earlier spin-stabilized GOES spacecraft. The GVAR format is based on the operational visible and infrared spin scan radiometer atmospheric sounder (VAS) mode AAA format, which consists of a repeating sequence of 12 fixed-length equal size blocks. The transmission of these blocks is synchronized with the spin rate of the earlier GOES spacecraft; that is, one complete 12-block sequence per rotation of the satellite.

The GVAR transmission sequence consists of 12 distinct blocks numbered 0 through 11. Blocks 0 through 10 are transmitted when an Imager scan line is completed. Block 10 is followed by a variable number of block 11s, according to what data are available for transmission.

GOES I-M Variable (GVAR) Data Transmission Format

GVAR Data Block Type

	Doc-ument	IR 1	IR 2	Visible 1	Visible 2	Visible 3	Visible 4	Visible 5	Visible 6	Visible 7	Visible 8	Sounder and Auxiliary Data
GVAR Block Number	0	1	2	3	4	5	6	7	8	9	10	11
Word Size, Bits	8	10	10	10	10	10	10	10	10	10	10	6, 8, 10
Field Length, Words	8,040	68 – 21,008	51 – 15,756	20 – 20,960	20 – 20,960	20 – 20,960	20 – 20,960	20 – 20,960	20 – 20,960	20 – 20,960	20 – 20,960	10,720/ 8,040/ 6,432
Number of Records	—	4/block	3/block	1/block	1/block	1/block	1/block	1/block	1/block	1block	1/block	1 – 8
IR Detector Data, Words	—	5,236	1 – 5,236	4 – 20,944	4 – 20,944	4 – 20,944	4 – 20,944	4 – 20,944	4 – 20,944	4 – 20,944	4 – 20,944	–

Each GVAR block has
- 10,032-bit synchronization code
- 720-bit header
- N-bit information field
- 16-bit cyclic redundancy check

Block Characteristics
- Period 15.25 – 104.6 ms
- Synch Length 10,032 bits
- Header Word Length 8 bits/word
- Header Length 90 words (720 bits) (Triple Redundant)

Scan Characteristics
- Period Variable
- Block/Imager scan 11
- Bit Rate 2,111,360 b/s

- Blocks 0 and 11 have fixed length information field of 64,320 bits
- Blocks 1 through 10 have variable length information fields directly dependent on width of scan, with minimum information field of 21,440 bits
- A single Imager scan generates blocks 0 through 10 in sequence
- Blocks 0 through 10 may be followed by any number of block 11s (0–N) depending on data available; in priority order, the next block(s) transmitted will be:

1. Next Imager scan	Blocks 0 through 10
2. Imager compensation and servo errors	One block 11
3. Sounder compensation and servo errors	One block 11
4. Imager telemetry statistics	One block 11
5. Imager spacelook statistics and data	Six block 11s
6. Imager calibration coefficients and limits	One block 11
7. Imager electronic calibration statistics and data	Two block 11s
8. Imager blackbody statistics and data	Two block 11s
9. Imager visible NLUT	Two block 11s
10. Imager star sense data	Nine block 11s
11. Sounder scan data	2 to 523 block 11s
12. Sounder telemetry statistics	One block 11
13. Sounder spacelook statistics and data	Five block 11s
14. Sounder calibration coefficients and limits	Two block 11s
15. Sounder electronic calibration statistics and data	Three block 11s
16. Sounder blackbody statistics and data	Five block 11s
17. Sounder visible NLUT	Nine block 11s
18. Sounder star sense data	Nine block 11s
19. GIMTACS text messages	One to two block 11s
20. SPS text messages	One block 11
21. Auxiliary data	One to N block 11s
22. Fill data	One block 11

Block 0 and all varieties of block 11s are fixed, equal-length structures. Blocks 1 through 10 vary in length according to the length of the Imager scan line. The smallest possible block size (blocks 1 through 10 for scan widths less than 1.9°) has a total length of 32,208 bits, while the largest block size (block 1 for a 23°-wide scan) is 262,288 bits. The maximum values for blocks 1 through 10 correspond to the specified maximum scan width of 19.2°. Scan widths up to 23° are possible with either instrument, although radiometric and pointing accuracies degrade at widths above 19.2°. The GVAR format handles scans wider than 19.2° in order to support special tests that may be desired following spacecraft launch. During normal operations, the 19.2° specified limit represents the upper boundary.

OGE Data Acquisition and Patching Subsystem

The ODAPS provides intermediate frequency (IF) level processing and routing/patching of data streams to/from the CDA Station equipment for two operational spacecraft. The OGE also utilizes the VAS interface electronics (VIE), currently in use at the CDA Station, to provide reception of one GVAR data stream used as a backup. The VIE also provides redundant switching necessary to select GVAR data streams from the three available for routing to the PMs. ODAPS also provides IF demodulation and bit synchronization functions.

Operations Ground Equipment Data Acquisition and Patching Subsystem

Data Handling Summary

ODAPS Data	Sensor Data	GOES Variable Data Uplink	GOES Variable Data Downlink
Source	CDA Station equipment; SPS intermediate frequency switch	SPS/uplink interface output	CDA Station receive equipment/intermediate frequency splitter
Source format	Unbalanced asynchronous quadraphase shift keying modulated, 64.4 MHz intermediate frequency; Q Ch Imager data at 2.6208 Mb/s; I Ch Sounder data at 40 kb/s	Biphase shift keying modulated; 67.7 MHz intermediate frequency; 2.11136 Mb/s	Biphase shift keying modulated; 65.7 MHz intermediate frequency 2.11136 Mb/s
ODAPS processing	Demodulate; bit synchronize	None	Demodulate; bit synchronize; frame synchronize into GOES BUS format
Destination	SPS/SD interface input	CDA Station transmit equipment/intermediate frequency switch	VAS interface electronics selector unit input, SPS/uplink interface ranging input

Sensor Processing System

The SPS, the functional element responsible for real-time processing of Imager and Sounder data, receives auxiliary data products from the GFE, combining them with processed data. The combined data in GVAR format are transmitted to users via the corresponding GOES spacecraft. GVAR data, organized in user friendly segments, are calibrated, earth-located, and gridded (Imager only). OIS to SPS serial communications interfaces that allow simulation of GIMTACS communications and auxiliary data products, are provided for OGE system testing.

To accomplish its tasks the SPS performs:

- Data ingest, including frame synchronization, decommutation by channel, detector scan alignment, and alternate scan line reversal.
- Infrared calibration for conversion of raw data to engineering units.
- Computation of Imager and Sounder space look, blackbody, electronic calibration and instrument telemetry statisitcs for inclusion in GVAR data stream.
- Visible sensor normalization for stripping the visible data.
- Coregistration function which applies correction factors (computed by PM) to Imager visible sensor data to ensure visible and IR data alignment.
- Imager gridding to convert geopolitical latitude and longitude grid points to scan line and pixel coordinates as a function of spacecraft orbit and Imager attitude.
- Earth location to convert Imager and Sounder instrument coordinates to latitude and longitude as a function of spacecraft orbit and instrument attitudes.
- Data formatting to create the GVAR data stream.

To support the orbit and attitude determination function of the OATS subsystem, the SPS:

- Performs spacecraft range measurements using the GVAR data stream round trip propagation time; these measurements are sent via GIMTACS to OATS for orbit determination.
- Performs star crossing event measurements by processing Imager and Sounder star view data; these are also sent to OATS via GIMTACS for attitude determination.
- Extracts periodic IMC and servo error data from the sensor data for use in the IMC quality check function performed by OATS; formatted messages of these data are periodically sent to OATS via the GVAR through the PM subsystem.

Further, SPS sends wideband telemetry data, including command register echo information extracted from the Imager and Sounder data streams and scan position to GIMTACS every 10 seconds, as long as valid telemetry is being processed in the SPS. The telemetry message data consists of the latest values received for the telemetry words extracted from the telemetry blocks of the Imager turn-around sequence and telemetry words extracted from the Sounder block.

Product Monitor

PMs are located at the CDA and the SOCC. Under normal operational circumstances, the PMs at the CDA Station perform only the monitoring function while the PMs at the SOCC perform the OATS support functions as well as the monitoring functions. In the backup operational configuration, with the OATS resident at the CDA Station, the PM roles at the CDA Station and SOCC are reversed. The PM also supports processed data quality monitoring and system troubleshooting, and the orbit and attitude determination function performed by the OATS.

In support of the orbit and attitude determination function, the PM provides landmark identification by storing, displaying, and registering small areas of visible Imager data (visible Sounder and infrared Imager as backup) defined as landmark sectors. Landmark registration is performed by a semiautomatic correlation of selected landmark sectors to previously stored landmark sectors referred to in landmark correlation chips. Once correlated, landmark measurement data in the form of earth location coordinates are sent to the OATS. The PM also captures the IMC and servo error data included in the GVAR data by the SPS and passes it to OATS, which provides quality checks of the image navigation and registration function performed on board the spacecraft.

Product Monitor

Orbit and Attitude Tracking System

The OATS performs three major functions in support of mission operations. The primary function is to provide daily computational support for implementing the INR process. This support consists of a closed-loop sequence that:

- Ingests star, range, and landmark observations
- Determines spacecraft orbit and Imager and Sounder attitudes
- Determines station and sensor intrusions; predicts eclipses
- Computes image motion compensation
- Determines star observation coordinates

The second major function of OATS is to provide the capability to plan, generate command data, and evaluate stationkeeping and repositioning maneuvers. The evaluation utilizes processes to estimate the onboard propellant remaining and to calibrate the propulsion system.

Finally, OATS requests, accepts, and processes telemetry data to support other functions such as determination of command data for daily operations of the trim tab, evaluation of AOCE data to verify and calibrate IMC, verification and calibration of MMC, DIRA calibration for stationkeeping and reacquisition support, and evaluation of thruster firing data.

The outputs generated by OATS are:

- Orbit and Imager/Sounder attitude coefficients for the SPS
- IMC coefficients uplinked to the spacecraft via GIMTACS
- Star view command data to support Imager and Sounder star sense and sequence operation
- Maneuver planning information and spacecraft stationkeeping command data
- Estimates of onboard propellant remaining
- Command data for daily operation of the trim tab
- Orbit and station events prediction
- Sensor intrusion predictions
- Scan frame coordinates conversion
- IMC calibration factors
- MMC calibration factors

Not a part of OATS, though resident in its computer, is the dynamic interaction diagnostic (DID) function. This function processes and displays telemetry data contained in the MDL for analyzing possible dynamic interactions between the Imager and Sounder instruments and the spacecraft. Telemetry ingested for diagnostic purposes includes ADS and DIRA angular data (roll, pitch, and yaw), instrument servo error, and solar array and instrument events. These spacecraft data are available on GOES I and one other spacecraft to be identified later in the program.

OGE Input Simulator

The OIS provides simulated Imager and Sounder data streams and outputs OGE message communications and auxiliary products in support of OGE integration and test. In addition, the OIS serves as a diagnostic tool and a backup computer for the OATS at the SOCC during the operational phase. The OIS provides the ODAPS with Imager and Sounder data, which may be manually patched into any one of three SPS inputs.

The GVAR simulator outputs a simulated GVAR data stream in support of OGE and GOES user system integration and testing. The outputs are in both NRZ-S serial baseband and GOES bus frame synchronized serial data. The latter output allows a direct interface to the PMs and does not require ODAPS to provide GVAR frame synchronization.