Communications Subsystem

The spacecraft communications subsystem provides the conditioning, transmission, reception, and routing of attitude telemetry and mission data signals for the GOES space segment. It consists of six major component groups that provide a variety of functions:

- Sensor data (SD) and multiuse data link (MDL) transmitters
- Data collection platform interrogate (DCPI) transponder
- Data collection platform report (DCPR) transponder
- Processed data relay (PDR) and transponders
- Weather facsimile (WEFAX) transmission
- Search and rescue (SAR) transponder

Four antennas, each with full earth coverage beamwidth, are used to provide communications with the ground segment:

- S-band receive horn: receives uplink DCPI, PDR, and WEFAX signals
- S-band slotted array: transmits SD, MDL, DCPR, and PDR signals
- UHF cavity backed dipole: receives DCPR and SAR signals; transmits DCPI signal
- L-band helix: transmits SAR downlink signal

Multiplexers are used to interface multiple signals with low RF loss into and/or out of an antenna. The S-band output multiplexer filters and combines the SD, MDL, DCPR, PDR, and WEFAX signals and a UHF diplexer multiplexes the downlink DCPI, uplink DCPR, and SAR signals. Stand-alone filters reject unwanted signals and band limit desired signals; filters after the S-band receivers separate the PDR, DCPI, and WEFAX signals for later hard-limiting amplification in their respective sections. Transponders and receivers are used for low-noise amplification and frequency conversion, while transmitters provide carrier modulation and power amplification.

Space-Ground Communications Interfaces

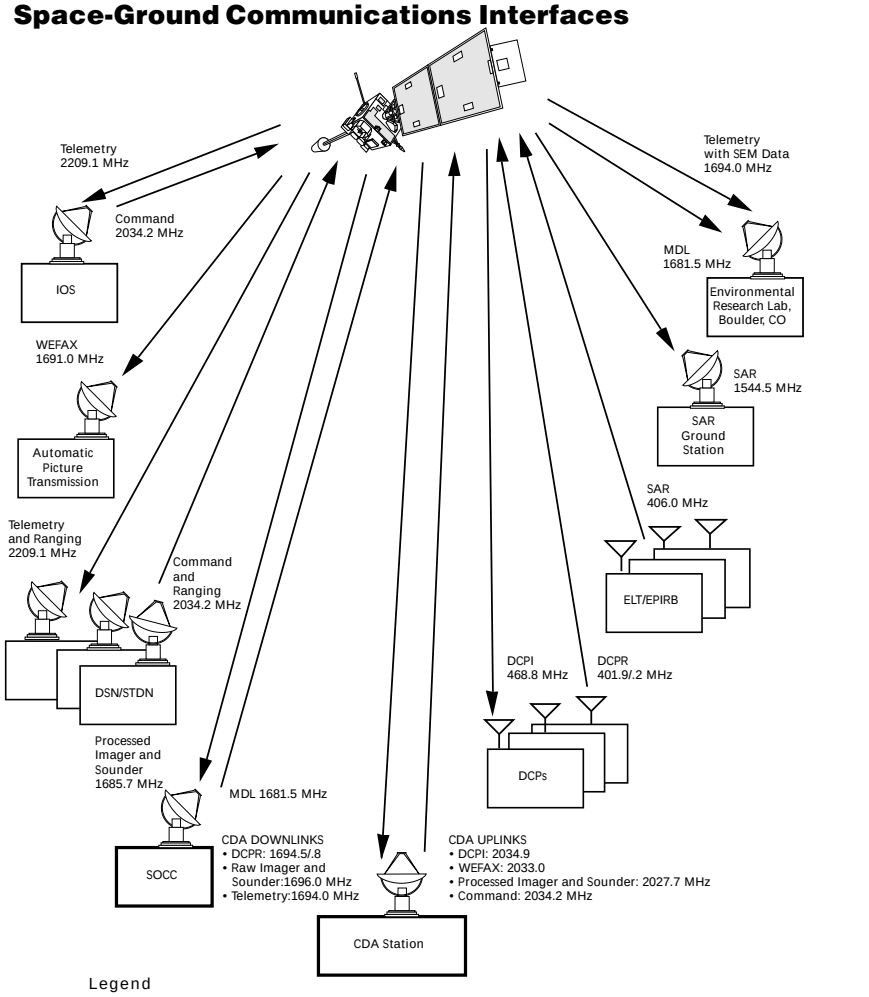
The flexibility and multitude of services provided by the GOES spacecraft are illustrated by the communication interfaces between the spacecraft and ground. The major system interfaces are those linking the GOES I-M to the command and control ground stations, end user equipment, and communications service terminals. The principal interfaces are those between the spacecraft and the Command and Data Acquisition (CDA) Station:

GOES Communications Performance Summary

Communications Parameter	Performance
Bit rate stability	±0.03%
Bit error rate	1 x 10^{-5} with 3.9 dB margin
Command receiver G/T	–39.2 dB/K
Command link margin	13.9 dB CDA Station 22.2 dB Deep Space Network (DSN)
Simultaneous ranging margin	12.5 dB DSN
Telemetry EIRP	28.9 dBm CDA Station Telemetry link margin 18.5 dB 17.0 dBm DSN Telemetry link margin 5.1 dB
Sensor data EIRP	47.3 dBm
Imager link margin	4.4 dB
Sounder link margin	16.6 dB
Processed data relay	
EIRP	54.9 dBm; link margin 3.9 dB
G/T	–15.3 dB/K
MDL EIRP	45.2 dBm; link margin 11.9 dB
Data collection platform	
Interrogate EIRP	46.2 dBm; link margin 11.0 dB
Interrogate G/T	–15.3 dB/K
Report EIRP	34.9 dBm; link margin 9.2 dB
Report G/T	–18.6 dB/K
WEFAX G/T	–15.3 dB/K
SAR	
EIRP	46.0 dBm; link margin 3.4 dB
G/T	–16.3 dB/K

- CDA downlinks:
  - Data collection platform report
  - Raw Imager and Sounder data
  - Spacecraft telemetry
- CDA uplinks:
  - Data collection platform interrogation
  - Weather facsimile transmission
  - Processed Imager and Sounder data
  - Spacecraft commands

Space-Ground Communications Interfaces



Legend

CDA	Command and Data Acquisition	IOS	Indian Ocean Station
DCP	Data Collection Platform	MDL	Multiuse Data Link
DCPI	Data Collection Platform Interrogate	SAR	Search and Rescue
DCPR	Data Collection Platform Report	SEM	Space Environment Monitor
DSN	Deep Space Network	SOCC	Satellite Operations Control Center
ELT	Emergency Locator Transmitter	STDN	Satellite Tracking Data Network
EPIRB	Emergency Position Indicator Response Beacon	WEFAX	Weather Facsimile

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Data Links

Telemetry containing space environment data is downlinked to the end user at the Environmental Research Laboratory in Boulder, Colorado. Also, processed Imager and Sounder (calibrated, earth-located) data are downlinked to the Satellite Operations Control Center (SOCC) at Suitland, Maryland, then to the World Weather Building for subsequent distribution to end users, which are typically satellite field service stations located throughout the United States. The SOCC also receives diagnostic data from the MDL for further analysis.

Center Frequency Assignments

Downlink Center Frequency	MHz
UHF	
Data collection platform interrogation	
Frequency 1	468.8250
Frequency 2	468.8375
S-Band	
SAR	1544.500
WEFAX	1691.000
DCP report	
Pilot	1694.450
Frequency band 1	1694.500
Frequency band 2	1694.800
Telemetry	
CDA Station	1694.000
DSN*	2209.085
Tracking	2209.085
Raw imaging and sounding data	1676.000
Processed imaging and sounding data	1685.700
Multiuse data	1681.480

* DSN telemetry data is modulated on a 1.024 MHz subcarrier, then used to phase modulate the DSN telemetry carrier frequency.

Uplink Center Frequency	MHz
UHF	
Data collection platform report	
Pilot	401.850
Frequency band 1	401.900
Frequency band 2	402.200
SAR	
Normal mode	406.050
Narrowband mode	406.025
S-Band	
WEFAX	2033.000
DCP interrogation	
Frequency 1	2034.9000
Frequency 2	2034.9125
DSN ranging	2034.200
CDA Station and DSN spacecraft command frequency	2034.200
Processed imaging and sounding data	2027.700

Telemetry, Command and Ranging

Telemetry, command, and ranging (TC&R) data are downlinked and uplinked among a network of stations, including the Indian Ocean Remote Tracking Station, the NASA Deep Space Network (DSN), and Satellite Tracking and Data Network (STDN), with the CDA Station as the center for the origin of commands and reception of spacecraft telemetry (refer to Telemetry and Command Subsystem).

Search and Rescue

The Search and Rescue (SAR) subsystem onboard each GOES satellite is a dedicated transponder that detects the presence of distress signals broadcast by Emergency Locator Transmitters (ELTs) carried on general aviation aircraft and by Emergency Position Indicating Radio Beacons (EPIRBs) aboard some classes of marine vessels. The SAR mission is performed by relaying the distress signals emitted from the ELT/EPIRBs via the GOES satellite to a Search and Rescue Satellite-Aided Tracking (SARSAT) ground station located within the field-of-view

of the spacecraft. Through a Rescue Coordination Center, help is dispatched to the downed aircraft or ship in distress.

Data Collection System

The GOES Data Collection System (DCS) collects near real-time environmental data from data collection platforms (DCPs) located in remote areas where normal monitoring is not practical. The DCS receives data from DCPs on aircraft, ships, balloons, and fixed sites in a region from Antartica to Greenland and from the west coast of Africa to just east of the Hawaiian Islands, an area covered by the GOES satellites. The system encompasses almost every level of the atmosphere, land, and ocean. It is used to monitor seismic events, volcanoes, tsunami, snow conditions, rivers, lakes, reservoirs, ice cover, ocean data, forest fire control, meteorological and upper air parameters, and to provide ground truth information.

Weather Facsimile Transmission

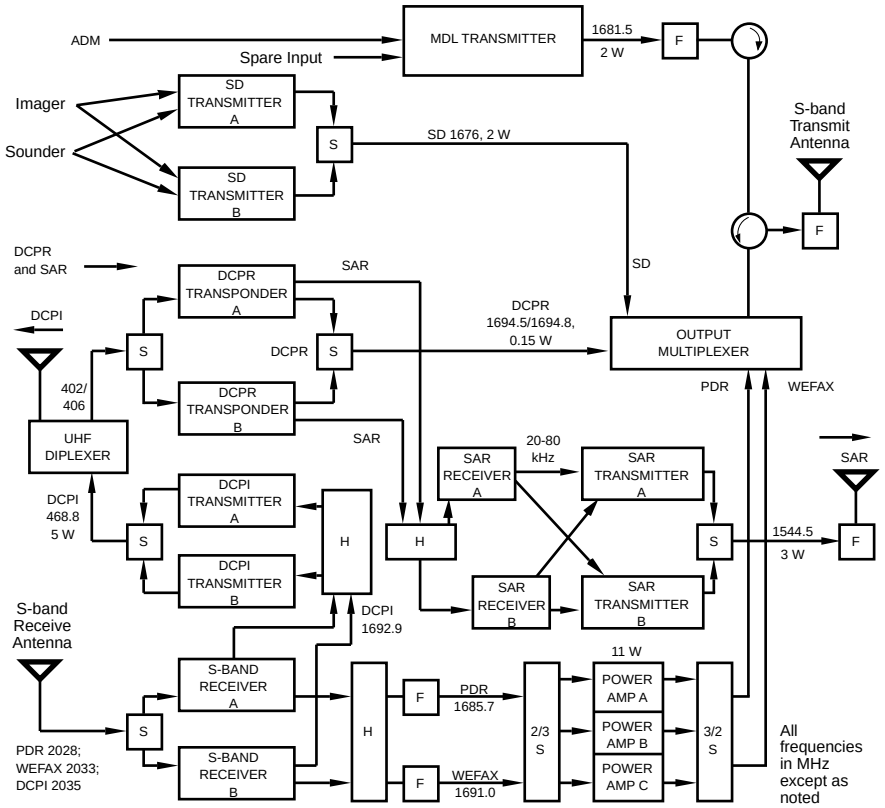
The Weather Facsimile (WEFAX) transmission is a communication service provided through a transponder on board the GOES satellite. Low resolution satellite imagery and meteorological charts from GOES and polar orbiting satellites are uplinked by the CDA ground station. The GOES transponder provides for continuous WEFAX transmissions, except during eclipse periods, relaying the data to small, local user ground terminals in the Western Hemisphere. Information distributed by this transmission service provides the only satellite imagery for many countries as well as standard meteorological charts from the World Meteorological Center, Washington, D.C. The WEFAX transmission frequency is common with that used by the European Space Agancy's METEOSAT and Japan's GMS spacecraft, enabling near-global access to WEFAX service. This global availability is especially important to commercial shipping and U.S. military operations.

Sensor Data and Multiuse Data Link Transmitters (GOES-I & K)

Both the SD transmitter and MDL transmitter can accept two asynchronous baseband data streams and simultaneously modulate them onto the downlink carrier in quadrature with 6-dB amplitude unbalance. The two-for-one redundant SD transmitters each receive a 2.62-Mb/s signal from the Imager and a 40-kb/s signal from the Sounder. Two ground-commandable switches allow either of the Imager's or Sounder's two output signals to be routed to either SD transmitter. The Imager signal is provided to the modulator at a 6-dB higher level than the Sounder, producing an unbalanced, asynchronous, quadraphase shift-keyed signal amplified to 2 watts.

For GOES I, and one other spacecraft to be identified later in the program, the single MDL transmitter receives only the 32-kb/s signal from the attitude data multiplexer (ADM). In this configuration the modulator produces a biphase shift-keyed signal amplified to 2 watts. Both the SD and MDL signals are band-limited by filters and multiplexed into the S-band transmit antenna. The 3-dB bandwidths of SD and MDL filters are 6 and 4 MHz, respectively.

Communications Subsystem Configuration



Legend

ADM	Attitude Data Multiplexer	PDR	Processed Data Relay
DCPI	Data Collection Platform Interrogate	S	Switch
DCPR	Data Collection Platform Report	SAR	Search and Rescue
F	Filter	SD	Sensor Data
H	Hybrid	UHF	Ultra High Frequency
MDL	Multiuse Data Link (GOES I & K)	WEFAX	Weather Facsimile

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Data Collection Platform Interrogate Transponder

The two DCPI uplink carriers are digitally phase modulated at 100 b/s at center frequencies of 2034.9 and 2034.9125 MHz; both signals may be transmitted simultaneously. The signals share the same receive antenna and receiver with the PDR and WEFAX signals, although the desired DCPI signal exits the selected receiver from a coupled port. The coupled output from each receiver is combined

in a hybrid and provided to both DCPI transmitters; in the selected transmitter the signals are downconverted to UHF and bandpass filtered. The 3-dB bandwidth of the filter is about 200 kHz. The signal is then hard-limited and amplified to 5 watts. The operating transmitter output is provided to the UHF diplexer and UHF antenna for transmission to the ground platforms.

Data Collection Platform Report Transponder

Up to 233 DCPR signals may be accommodated in one of the two frequency bands: 401.9 and 402.2 MHz. These signals, digitally phase modulated at 100 b/s, are received by the UHF antenna and routed via the diplexer to one of two DCPR transponders, where they are amplified (using low-noise amplifiers) and provided 400-kHz, 3-dB bandwidth filtering in one of two selectable bands. The signals are then upconverted in frequency and amplified with automatic gain control to 150 milliwatts. The output of the selected transponder is filtered (2-MHz, 3-dB bandwidth), combined with the other S-band downlink signals by the output multiplexer, then transmitted to the ground via the S-band transmit antenna.

Processed Data Relay and Weather Facsimile Transponders

The PDR and WEFAX signals are received by the S-band receive antenna and amplified (using low-noise amplifiers) and downconverted in frequency in one of two S-band receivers. The receiver outputs are combined in a hybrid and provided to independent PDR and WEFAX channel filters. The PDR signal is 2.1-Mb/s biphase shift keyed and is band limited by the PDR filter, which has a 3-dB bandwidth of about 5 MHz. The WEFAX signal is FM with an approximate 30-kHz bandwidth and a 1-MHz wide filter. The filters reject the adjacent channels (including the DCPI and command signals) and send their outputs to a three-to-two switch. The signals are sent to two of the three S-band power amplifiers. Power amplifier A is dedicated to the PDR channel, power amplifier C is dedicated to the WEFAX channel, and power amplifier B can be switched to either PDR or WEFAX.

The power amplifiers hard-limit the signals, amplify them to 12 watts, and provide them to an output three-to-two switch. The input and output three-to-two switches are controlled by the same commands. The signals are then bandpass filtered and multiplexed for transmission to the ground via the S-band transmit antenna. The 3-dB bandwidths of the PDR and WEFAX are 5 MHz.

Search and Rescue Transponder

The uplink SAR signals, digitally phase modulated at 400 b/s in the frequency band of 406.01 to 406.9 MHz, are received by the UHF antenna and amplified, using low-noise amplifiers, by one of two DCPR transponders. The signal is then coupled out to a hybrid that combines both DCPR preamplifiers and drives both SAR receivers. The operating SAR receiver filters out the DCPR band, downconverts the signal frequency, performs bandpass filtering in one of two bands (20 or 80 kHz, 3-dB bandwidth), then further downconverts the signal to near baseband. The SAR receiver can be commanded into a fixed gain or automatic level control mode.

The output of each SAR receiver is routed to both SAR transmitters. The selected SAR transmitter phase modulates a UHF carrier with the signals, multiplies the frequency to L-band, then filters and amplifies the modulated carrier to 3 watts. The nominal modulation index is one radian; a baseband limiter in the transmitter ensures the index does not exceed two radians. The output of the selected transmitter is passed through a harmonic filter (100-MHz, 3-dB bandwidth) and finally transmitted by the helical antenna.

Attitude Data Multiplexer (GOES-I & K)

The attitude data multiplexer (ADM) provides diagnostic data used to determine the dynamic interaction among spacecraft components with mechanical motion. The data are provided to the ADM at 32 kb/s where they are multiplexed and the output routed to the MDL transmitter for downlinking to the SOCC. The sources and types of data provided to the ADM are:

- Angular displacement sensor (ADS): roll, pitch, yaw and ADS temperature
- Digital integrating rate assembly (DIRA): roll, pitch, and yaw
- Solar array: step and slew events
- Imager and Sounder: slew events, north/south and east/west servo error

Emergency Locator Transmitter and Emergency Position Indicating Radio Beacon Performance Characteristics

ELT/EPIRB Parameter	Performance
RF Signal	
Frequency	406.025 ±0.001 MHz
Stability	1 in 10^9 in 100 ms 2 kHz in 5 years
Phase jitter	10° RMS measured in 50 Hz bandwidth
Power output	3 W +1 dB; –2 dB into 50 Ω
Spurious	50 dB below carrier; harmonics, 30 dB below carrier
Data encoding	Biphase L
Modulation	Phase modulation 1.1 ±0.1 radians peak referenced to unmodulated carrier
Modulation rise time	Rise and fall times of modulation wave forms must be less than 0.25 ms
Digital message	
Repetition rate	50 s ±5%
Transmission time	440 ms ±1%, short message 520 ms ±1%, long message
CW preamble	160 ±1%
Digital message	280 ms ±1%, short message 360 ms ±1%, long message
Bit rate	400 ±5 b/s
Bit synchronization	All ones (fifteen ones)
Frame synchronization	000101111
Continuous emission	Not to exceed 45 seconds