Telemetry and Command Subsystem

The telemetry and command (T&C) subsystem provides the functional interface between the spacecraft and ground command and control. Telemetry parameters describing the status, configuration, and health of the spacecraft payload and subsystems are downlinked to the Command and Data Acquisition (CDA) Station and sent to the Satellite Operations Control Center (SOCC). Commands are received on board the spacecraft for controlling mission operations and managing expendable resources. To perform these functions, the T&C subsystem is composed of a single bicone antenna mounted on the spacecraft's east panel, two radio frequency (RF) receivers, four transmitters, redundant digital telemetry and command units, and a triplexer that allows simultaneous operation of the transmitters and receivers into the bicone antenna without interference.

The T&C subsystem primarily interfaces with the NOAA Wallops CDA Station during on-orbit operations, with the NASA Deep Space Network (DSN) available as backup. The ground interfaces during orbit raising are with DSN, Air Force Indian Ocean, and NASA Wallops CDA Stations; these stations are compatible with the interface to the spacecraft T&C subsystem.

T&C Subsystem Design Features

| Telemetry unit	Command unit
Fully redundant unit; one unit on at a time	Fully redundant unit
2000 b/s data rate	250 b/s data rate
128-word minor frame every 0.512 second	Added encryption system
Serial digital, bilevel, analog, and temperature parameters	Relay, pulse, and proportional commands

Remote multiplexer on solar array yoke (housed in XRP electronics)	Three commanding modes:
	    Store only
	    Execute and store
	    Store and execute

Simultaneous dwell and normal mode capability	Simultaneous commanding and ranging
Simultaneous ranging and telemetry capability	Secure or plain text mode operation

Telemetry

Information from the spacecraft provided via telemetry is:

- Configuration status and housekeeping data for payload instruments
- Environmental sensing data from space environment monitor (SEM) instruments
- Automatic gain control setting for each receiver

Revision 1

Telemetry and Command Subsystem Configuration
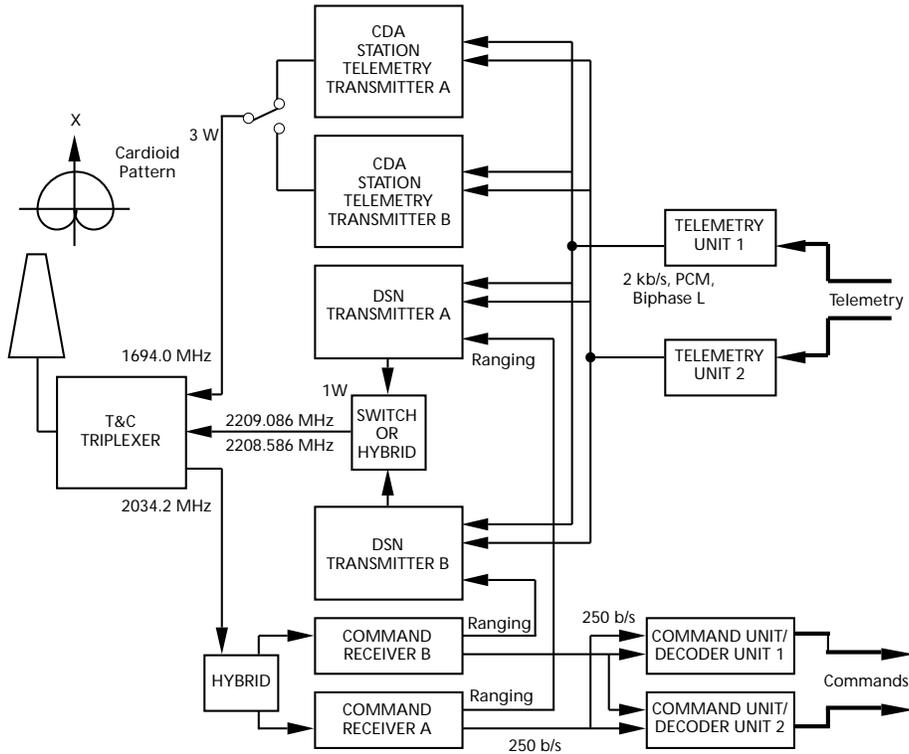
Legend

CDA	Command and Data Acquisition	PCM	Pulse Code Modulation
DSN	Deep Space Network	T&C	Telemetry and Command

9210045

- RF power output for each transmitter
- Power system parameters and voltages of critical electronic modules
- On/off status of all commandable equipment and heaters
- Temperatures of all major subassemblies
- Spacecraft attitude determination and control parameters
- Parameters of frame synchronization, spacecraft identification, command counter, secure mode operation, 16-bit error detection code, etc.

The telemetry units are "standby redundant," meaning only one unit is on and operating at a time. The operating telemetry unit collects the data, encodes, multiplexes, and formats it into two (normal and dwell) serial pulse code modulated (PCM) bit streams. Both normal and dwell PCM data are generated simultaneously by the selected telemetry unit; either normal or dwell PCM data are provided to the four telemetry transmitters. Only one of the two CDA

Revision 1

transmitters can be on at a time, but the DSN transmitters can be configured for single or dual operation. For DSN dual transmitter operation, offset frequencies are used to avoid having the two transmitters operating at the same frequency and interfering with telemetry reception. Each operating transmitter can be independently selected for either normal or dwell PCM data.

The telemetry data processed are either analog or digital. Analog data are received differentially by the telemetry unit to minimize susceptibility to noise. Each analog signal is converted into a digital signal, typically with a resolution of 8 bits. Exceptions to this resolution are measurements of the currents in the magnetic torquers of the attitude and orbit control subsystem, which are quantized into 10 bits, and the three axes of magnetic field strength as measured by the SEM magnetometers, which are digitized to 16 bits each axis. Digital inputs are both serial and parallel depending on the source. The telemetry subsystem can dwell on (that is, measure over a longer period of time) any mainframe or subframe channel, except for serial digital data sources and some fixed format channels (for example, subframe identification number, frame synchronization). During each word period (8 ms), a PCM word and a dwell word are generated, making both regular and dwell PCM available for simultaneous transmission over two RF links.

Command

The command unit features:
- Command format defined by Goddard Space Flight Center
  - 7-bit error detection code
  - Uniquely defined command decoder address
- Three command codes
- 250-b/s, phase shift keyed modulation on 16-kHz subcarrier
- Simultaneous DSN commanding and ranging
- Command override of every automatic function

The uplink signal, which can contain command and ranging data simultaneously on the same carrier, is routed to both onboard command receivers. The receivers cannot be commanded off (that is, they are "active redundant"), and once phase locked onto the carrier, they provide command data to each digital command unit/decoder, each of which is also active redundant. The command units independently switch their inputs between receivers every 320 ms until a signal is detected. Upon detection, switching is terminated and phase locking, demodulation, bit synchronization, and decoding are performed. The command units can be operated in either a clear text or encrypted/secure mode, the latter precluding unauthorized access to the spacecraft. The command decrypter can be reset to the clear text mode by an automatic timer, a power-on reset, or an automatic function provided in the event of loss of earth lock. Every command is

Barker-code checked and decoder-address checked for accuracy and, if acceptable, it is loaded and/or executed by the single command unit decoder that was selected in the command.

There are two modes of command execution: real-time and ground-command word-verify. In the real-time mode, verification of the uplinked command is performed within the command unit. If no errors are detected, the command is executed. If an error is detected, processing of the command is halted and a flag bit is telemetered to the ground station indicating that the command must be retransmitted. In the ground-command word-verify mode, the bits of the decoded command are telemetered back to the ground station for verification, and a subsequent execution message must be uplinked. The command unit outputs are completely redundant.

Ranging

Ranging is performed to determine the spacecraft orbital elements during transfer and geosynchronous orbits. Channelized to the DSN transmitter only for downlink, ranging is accomplished by ground-commanding one of the DSN transponder ranging channels on and into the coherent mode. The ground station uplinks ranging tones to the command receivers where they are routed to the selected DSN transmitter and downlinked to the ground station with the output (downlink) carrier frequency. In the coherent mode, the downlink carrier frequency is maintained at a ratio of 240 to 221 relative to the uplink carrier. With the ranging channel on, ranging and telemetry are provided simultaneously on the same downlink carrier. As with commanding, ranging can be performed only with a phase-locked receiver.