TEST TELEMETRY AND COMMAND SYSTEM (TTACS)

Alvin J. Fogel
Jet Propulsion Laboratory
4800 Oak Grove Drive, M/S 525-3970
Pasadena, California 91109-8099

Abstract - The Jet Propulsion Laboratory has developed a multimission Test Telemetry and Command System (TTACS) which provides a multimission telemetry and command data system in a spacecraft test environment. TTACS reuses, in the spacecraft test environment, components of the same data system used for flight operations; no new software is developed for the spacecraft test environment. Additionally, the TTACS is transportable to any spacecraft test site, including the launch site. The TTACS currently supports projects at the Jet Propulsion Laboratory involved in the unmanned exploration of deep space. The TTACS is currently operational in the Galileo spacecraft testbed; it is also being provided to support the Cassini and Mars Surveyor Program projects.

TTACS usage results in lower cost planetary missions since no new software is developed for the spacecraft test environment. Also, minimal personnel data system training is required in the transition from pre-launch spacecraft test to post-launch flight operations since test personnel are already familiar with the data system's operation. Additionally, data system components, e.g. data display, can be reused to support spacecraft software development; and the same data system components will again be reused during the spacecraft integration and system test phases. TTACS usage also results in early availability of spacecraft data to data system development and, as a result, early data system development feedback to spacecraft system developers.

The TTACS consists of a multimission spacecraft support equipment interface and components of the multimission telemetry and command software adapted for a specific project. The TTACS interfaces to the spacecraft, e.g., Command Data System (CDS), support equipment. The TTACS telemetry interface to the CDS support equipment performs serial (RS-422)-to-ethernet conversion at rates between 1 bps and 1 mbps, telemetry data blocking and header generation, guaranteed data transmission to the telemetry data system, and graphical downlink routing summary and control. The TTACS command interface to the CDS support equipment is nominally a command file transferred in non-real-time via ethernet. The CDS support equipment is responsible for metering the commands to the CDS; additionally for Galileo, TTACS includes a real-time-interface to the CDS support equipment.

The TTACS provides the basic functionality of the multimission telemetry and command data system used during flight operations. TTACS telemetry capabilities include frame synchronization, Reed-Solomon decoding, packet extraction and channelization, and data storage/query. Multimission data display capabilities are also available. TTACS command capabilities include command generation, verification, and storage.

TTACS CAPABILITIES

TTACS provides the operational interface between the spacecraft support equipment and the end-user workstation in the spacecraft system test environment. The TTACS, together with the end-user workstation, provide the primary system test visibility. Figure 1 describes TTACS functions in the context of the spacecraft testbed data flow. For spacecraft subsystem test, TTACS has limited functionality; subsystem personnel determine which TTACS functions are appropriate for that subsystem test.

A basic supporting element of the TTACS concept is the existence of multimission software which can be adapted as necessary for each project. This allows the early availability of ground data system (GDS) software in support of spacecraft development, which in turn supports early availability of spacecraft data for ground system development. The multimission infrastructure which supports each project's TTACS is provided through the Multimission Operations System Office (MOSO). MOSO was established at JPL to provide those operational capabilities, services, and tools that are common to all missions/projects thereby realizing a cost avoidance to the projects and a cost savings to NASA HQ.

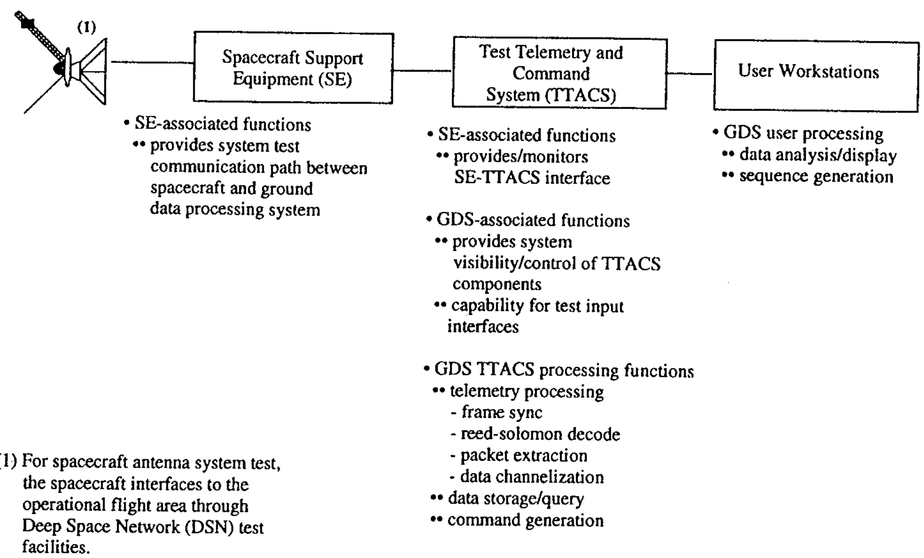


Figure 1 - TTACS Functions Within the Spacecraft Testbed Data Flow

TTACS COST BENEFIT SUMMARY

TTACS results in lower cost planetary missions as summarized below:

- Minimize software costs through software reuse
  - TTACS based on reusable multimission infrastructure
  - TTACS reuses project flight operations software to support spacecraft system test and spacecraft simulator development/operations
  - TTACS reuses multimission SE-TTACS interface

- Enhance spacecraft-GDS system test through early/continued use of GDS in spacecraft development/test
  - GDS test with actual spacecraft data
  - GDS test in operational environment
  - Spacecraft test in GDS operational environment
  - Spacecraft subsystem test use of multimission display software

- Minimize post-launch ground system training by using ground system pre-launch in spacecraft system test

- Support the extension of commercial, low-cost products, e.g., UconX Communique[1]; share functionality growth of those products as fostered by other customers.

- Maximize support of testbed/launch sites by enhancing transportability, e.g., TTACS is sized to fit customer-specific needs

TTACS ARCHITECTURE/COMPONENT DETAILED DESCRIPTION

The TTACS detailed data flow/component description is presented in Figure 2. Key points include:

- TTACS interfaces only with spacecraft support equipment, not spacecraft (which has extensive interface requirements).

- TTACS downlink processing includes a support equipment - TTACS interface which optionally can provide electrical isolation, biphase clock reduction, and true/complement polarity.

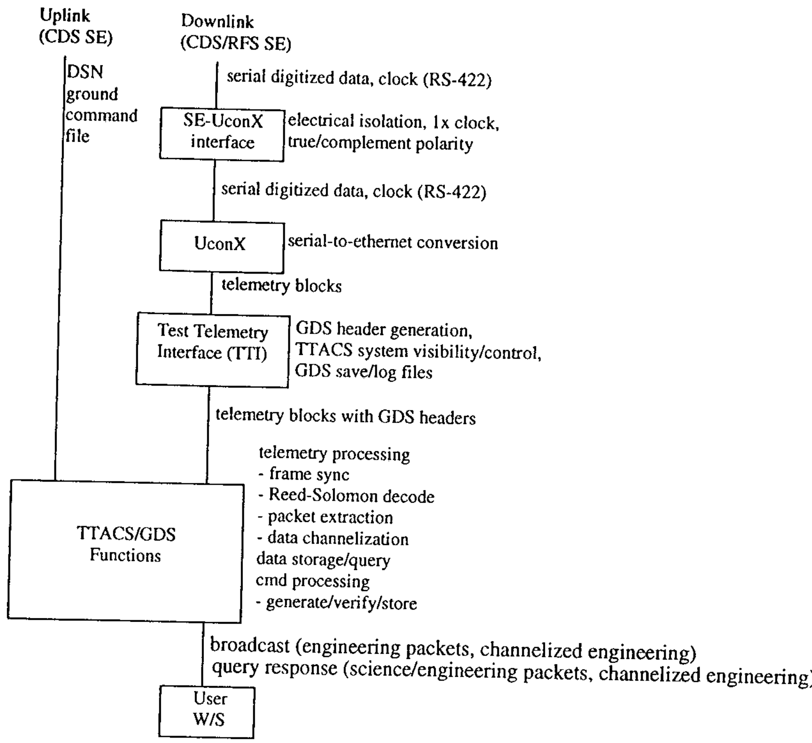
- TTACS downlink processing also includes a serial-to-ethernet conversion function. This function resides in the UconX Communique, a multi-protocol communication server for LANs. UconX developed, in coordination with JPL, a Synchronous Bit Stream Interface (SBSI) protocol to process the RS-422 NRZ-L stream.

- TTACS uplink processing provides DSN ground command files to spacecraft support equipment. The support equipment is responsible for extracting the included command bits and metering those bits to the spacecraft.

- The opportunity also exists for TTACS to transmit only command bits to the spacecraft support equipment. This architecture would utilize the newly developed transmit protocol.

---

[1] UconX is a trademark of UconX Corporation, San Diego, CA



Where

CDS	Command and Data System
DSN	Deep Space Network
RFS	Radio Frequency System
SE	Support equipment
TTACS/GDS	TTACS Ground Data System functions
TTI	Test Telemetry Interface
UconX	Serial-to-ethernet converter

Figure 2 - TTACS Detailed Data Flow/ Component Description

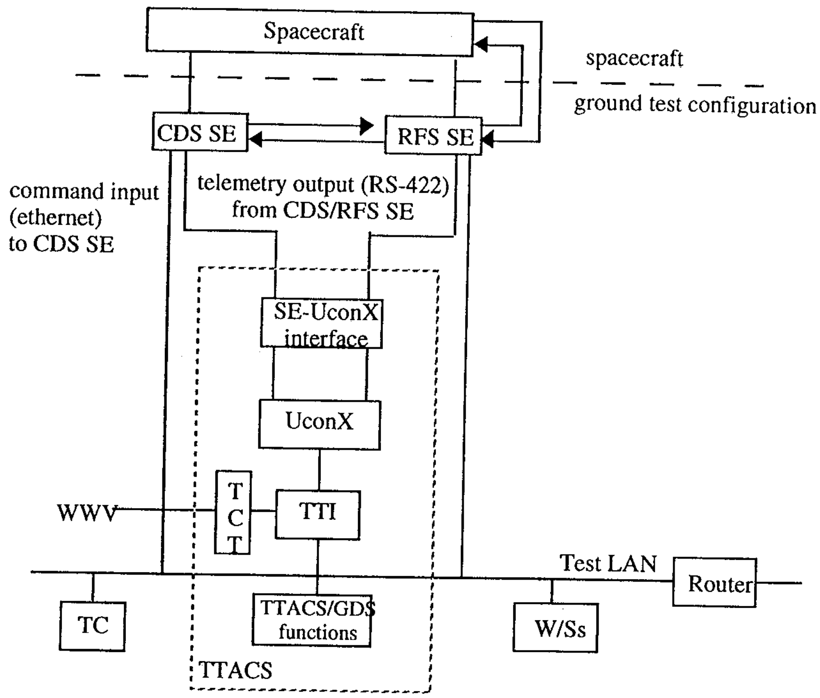
The TTACS generic testbed architecture is presented in Figure 3. Key points include:

- The ground test configuration which supports spacecraft system test is interconnected via a test LAN. A router provides external security/connectivity for the ground test configuration.

- TTACS provides computer clock synchronization via Network Time Protocol (NTP) on the test LAN. The master NTP server resides on the TTI node and utilizes a DATUM[2] Time Code Translator (TCT). DATUM support is now a standard feature of the freely available NTP code; JPL provided the DATUM support code to the NTP maintainers.

- The UconX Communique is configured to provide four serial (RS-422) input ports; serial-to-ethernet conversion may be performed concurrently on any of these input ports. The SE-UconX interface also provides four input/output ports to match the UconX capability.

[2] DATUM is a trademark of DATUM INC., Anaheim, CA



Where

CDS	Command and Data System
RFS	Radio Frequency System
SE	Support equipment
TC	Test conductor w/s
TCT	Time Code Translator
TTACS/GDS	TTACS Ground Data System functions
TTI	Test Telemetry Interface
UconX	Serial-to-ethernet converter
W/S	User workstation
WWV	Standard time broadcast

Figure 3 - Spacecraft Generic Testbed Configuration

PROJECT-SPECIFIC TTACS EXAMPLES

Projects may implement TTACS in its entirety, (i.e., SE hardware interface, GDS compatibility/visibility/control, TTACS GDS functions), or a subset of TTACS functionality. Projects which currently plan/implement the total TTACS functionality include Cassini, Galileo, and Mars Global Surveyor. Projects which currently plan/implement partial TTACS functionality include High-Speed Spacecraft Simulation, Mars Pathfinder, and Disaster Recovery Facility (DRF).

Cassini plans to use TTACS for both spacecraft integration and spacecraft system test. Key points follow:

- Figure 3 is the architecture for Cassini spacecraft system test. The TTACS/GDS component of Figure 3 becomes two computers to process the high input data rate; one computer performs telemetry/command processing, the other performs data load/query.

- Cassini TTACS will process test rates, i.e., up to 249 kbps, which are higher than flight rates, i.e., up to 140 kbps.

Galileo has implemented TTACS in their spacecraft testbed which is used for spacecraft integration and sequence checkout. Key points follow:

- Figure 4 is the architecture for the Galileo TTACS. This architecture accomodates the Galileo testbed which predates TTACS, e.g., multiple concurrent spacecraft outputs, pre-existing support equipment configuration.

- Galileo TTACS provides multiple (1 data, 2 test) concurrent telemetry data streams (RS-422) from spacecraft support equipment to the end-user.

- Galileo TTACS provides real-time (RS-232) DSN ground command file transmission to the spacecraft support equipment which, in turn, meters the commands to the spacecraft.

- Galileo TTACS processes test rates, i.e., up to 134 kbps, which are much higher than flight rates, i.e., up to 160 bps.

Mars Global Surveyor plans to use TTACS; details will be a function of spacecraft contractor discussions. TTACS downlink capability has been demonstrated using the Mars Observer Verification Test Lab (VTL).

The High-Speed Spacecraft Simulation project has implemented TTACS partial functionality to support the development and operation of its spacecraft bit simulation. Multimission simulations are planned; the Galileo simulation is currently being implemented. Key points follow:

- Figure 5 is the architecture for the High-Speed Spacecraft Simulation TTACS. Since the output of the simulation is a TCP/IP stream on an ethernet LAN, the TTI test input interface is used instead of the UconX (RS-422) interface.

- The High-Speed Spacecraft Simulation TTACS processes simulated rates higher than flight rates. The current Galileo simulation uses one computer as both TTACS and its user workstation.

The Mars Pathfinder project plans to implement partial TTACS capability. Key points follow:

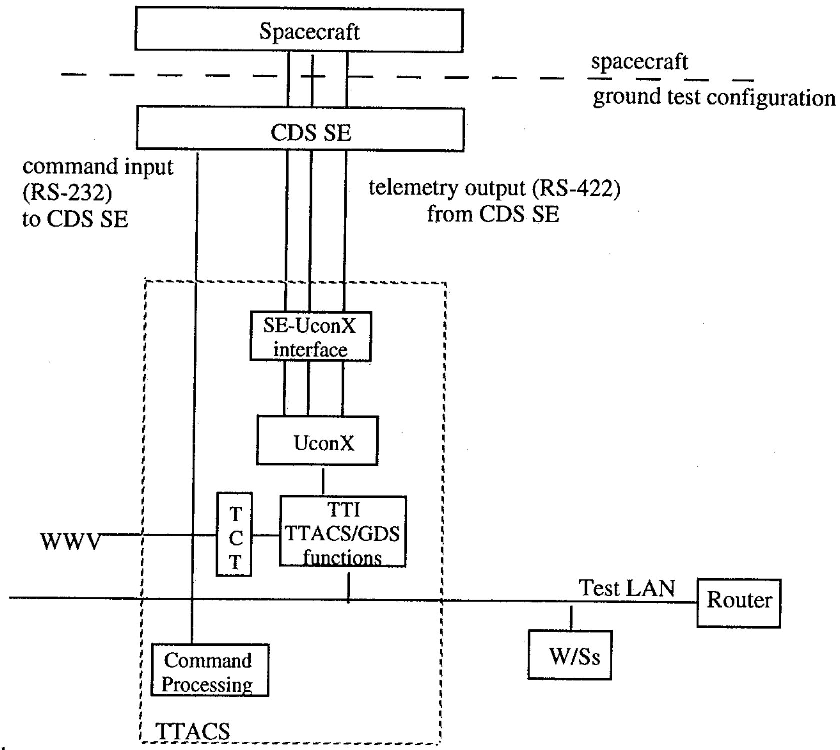
- Figure 6 is the architecture for the Mars Pathfinder TTACS. The project will closely integrate the support equipment and the GDS via a TCP/IP stream on an ethernet LAN. Additionally, the SE will generate GDS headers for output telemetry blocks. In this architecture, the SE replaces the UconX/TTI function.

- The AIM SE is the single TTACS interface, i.e., RFS SE downlink is provided to TTACS via the AIM SE.

The Disaster Recovery Facility (DRF) project plans to implement partial TTACS capability for a disaster recovery operational facility which supports all projects. Key points follow:

- Figure 7 is the architecture for the Disaster Recovery Facility TTACS. The facility will interface to the Deep Space Network (DSN) via an IP endpoint; additionally,DSNI must process DSN telemetry/command protocols. In this architecture, DSNI replaces the UconX/TTI function.

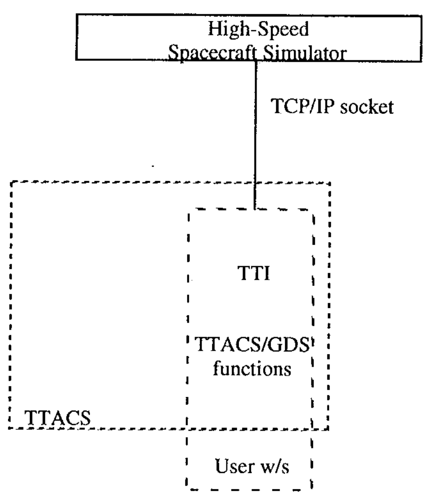
- The Disaster Recovery Facility will support one spacecraft at a time, performing housekeeping/safing via real-time low rate (1200 bps maximum) telemetry reception and smaller command file transmission. Science data is processed after JPL comes back on-line (six months maximum) using DSN station recordings.



Where

CDS SE	Command and Data System support equipment
TCT	Time Code Translator
TTACS/GDS	TTACS Ground Data System functions
TTI	Test Telemetry Interface
UconX	Serial-to-ethernet converter
W/S	User workstation
WWV	Standard time broadcast

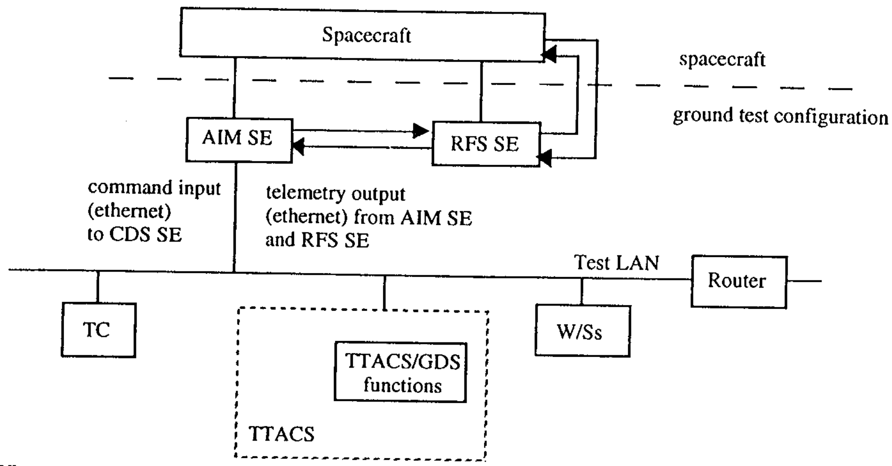
Figure 4 - Galileo Spacecraft Testbed Configuration



Where

TCP/IP	Transmission Control Protocol/Internet Protocol
TTI	Test Telemetry Interface
TTACS/GDS	TTACS Ground Data System functions

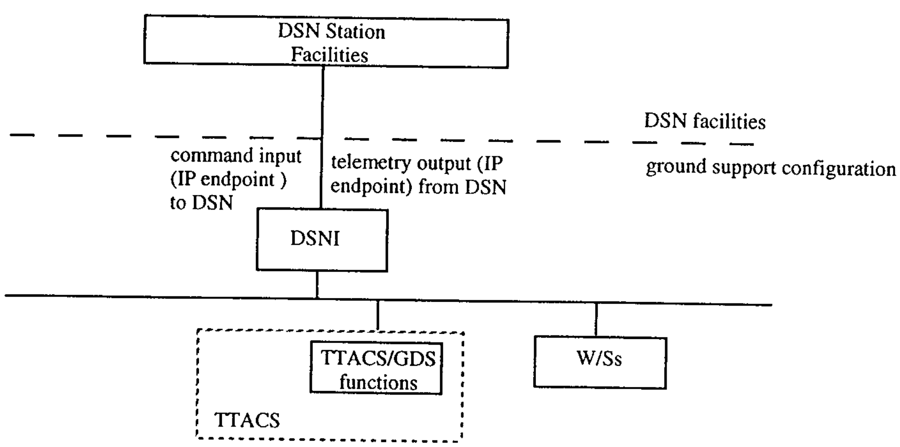
Figure 5 - High-Speed Spacecraft Simulation Test Configuration



Where

AIM	Attitude Information System
RFS	Radio Frequency System
SE	Support equipment
TC	Test conductor w/s
TTACS/GDS	TTACS Ground Data System functions
W/S	User workstation

Figure 6 - Mars Pathfinder Spacecraft Testbed Configuration



Where

DSN	Deep Space Network
DSNI	Deep Space Network Interface
IP	Internet Protocol
TTACS/GDS	TTACS Ground Data System functions
W/S	User workstation

Figure 7 - Disaster Recovery Facility (DRF) Operational Configuration