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FLIGHT DATA REPORT

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TC-6 FLIGHT DATA REPORT

VOYAGER I

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I SUMMARY

I SUMMARY

by R. P. Geye

Titan/Centaur TC-6 was launched from the Eastern Test Range, Complex 41, at 8:56:01 a.m. EDT, on Monday, September 5, 1977. This was the sixth (last scheduled) operational flight of the newest NASA expendable launch vehicle. The spacecraft was the Voyager I, the second of two flyby missions to Jupiter and Saturn planned for the 1977 Jupiter/Saturn launch opportunity.

The objective of the launch phase of the mission for the launch vehicle was to inject the Voyager spacecraft onto the proper orbit, with the proper inertial attitude, so that with the firing of the Voyager Propulsion Module, the Voyager Mission Module would be injected onto the planned transfer orbit to Jupiter. This objective was successfully accomplished.

II INTRODUCTION

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by R. P. Geye

The Voyager Mission to Jupiter and Saturn is one of NASA's principal plane-tary efforts of this decade. On the basis of flight time and Jupiter flyby distance, the 1977 launch opportunity was the most attractive for reaching Saturn via a gravity-assisted swingby of Jupiter. During this 1977 launch opportunity, two Titan IIIE/Centaur D-1T launch vehicles, each augmented by a Voyager solid propellant Propulsion Module, were used to launch identical Voyager Mission Modules on similar dual-planet flyby missions to Jupiter and Saturn from the AFETR Launch Complex 41, Cape Canaveral, Florida.

The two flybys of Jupiter will occur in March and July 1979. The two flybys of Saturn will occur in November 1980 and August 1981. The second Voyager Mission Module (Voyager 2) to arrive at Saturn may be targeted to fly on to Uranus using a gravity-assist from Saturn. If exercised, this option would result in a flyby of Uranus in early 1986.

Launch Phase of the Voyager Mission

The 1977 Jupiter/Saturn launch opportunity spanned an approximate 1 month period beginning August 20, 1977. The launch windows opened as late as 1425 GMT (10:25 EDT) on August 20 and as early as 1108 GMT (7:08 EDT) at the end of the launch opportunity. On each launch day, the launch window was about 1 hour long. The launch azimuth sector used for the mission was from 92° to 108° , with trajectories being yawed from 108° southward to the greater equivalent azimuths required on the early days of the launch opportunity.

The launch phase of the Voyager I mission was accomplished on September 5, 1977, using the TC-6 Titan/Centaur launch vehicle, augmented by the Voyager I Propulsion Module.

The flight profile for Titan Stage 0 phase of flight consisted basically of a short vertical rise with roll to the required flight azimuth (between 920 and 1080), followed by an initial pitch/yaw maneuver and subsequent near zero total angle-of-attack. The required steering, referred to as wind biased steering, was determined on launch day and implemented by the Centaur digital computer unit (DCU) in an open loop mode. Burnout of the Stage 0 solid rocket motors activated the Titan Step 0 staging timer (1.5g decreasing axial acceleration) which initiates Titan Stage I engine start, heat shield jettison/Stage I ignition and Titan Step 0 jettison.

During Titan Stages I and II phases of flight, the flight profile was primarily determined by the steering required to achieve a 90 n. mi. parking orbit at the end of the first Centaur burn. The required steering was implemented by combining incremental pitch and yaw rates, derived from the Centaur guidance steering vector, with a rate vs. time pitch program that was stored in Titan. Titan Step I jettison/Stage II ignition was initiated by Stage I propellant depletion. The Centaur standard shroud was jettisoned 10 seconds after Stage I shutdown, as sensed by the Centaur DCU. Titan Stage II also burned to propellant depletion which then initiated Titan Step 2 jettison, the Centaur prestart sequence, and Centaur Main Engine Start.

The Centaur first burn phase was about 110 seconds in duration and terminated at injection into a 90-nautical mile circular parking orbit. The 90-nautical mile orbit is standard for parking orbit ascent missions on the Titan/Centaur. Steering commands were provided by the Centaur digital computer unit (DCU) based on the guidance steering vector. Main engine cutoff (MECO) was commanded by guidance when the desired parking orbit is achieved.

Due to the relatively long coast times (37 to 50 minutes) required for Voyager, continuous propellant settling throughout the coast (which has been used on all previous Centaur parking orbit missions) was deleted. Only 10 minutes of prestart settling thrust by the Centaur hydrogen peroxide engines prior to Centaur second burn was retained. This "zero-g" mode of coast was selected to provide maximum Centaur performance to the Voyager missions. Successfully proven in flight during numerous "zero-g" coast tests on TC-2 and TC-5, Voyager marks its first application in the launching of operational payloads.

Throughout most of the parking orbit coast phase the vehicle was stabilized and aligned along the velocity vector. However, toward the end of the coast period, the Centaur will realign itself to the proper attitude required for the second burn. In succession, the Centaur then initiated propellant settling, Centaur chilldown, and Centaur second main engine start (MES2).

The Centaur second burn lasted about 335 seconds to accelerate the combined Centaur/spacecraft vehicle from parking orbit to beyond Earth-escape velocity conditions. (Nominally, Earth escape energy is reached after about 260 seconds into the burn.) The or bit at the end of the Centaur second burn was hyperbolic with respect to Earth, with a perigee altitude of approximately 110 nautical miles. Centaur second main engine cutoff (MECO2) was commanded by Centaur guidance when predicted cutoff conditions (when added to the velocity increase to be contributed by the spacecraft Propulsion Module) satisfy the Voyager mission requirements for the Jupiter transfer orbit.

Following MECO2, a short coast was performed during which Centaur aligned the spacecraft to the attitude vector required for the subsequent Propulsion Module burn and provided a redundant set of arming signals to the spacecraft. The Mission Module computer then initiated a sequence which resulted in spacecraft separation from Centaur and activation of spacecraft attitude control 15

seconds prior to the end of the coast. Fifteen seconds after spacecraft separation from Centaur, the Propulsion Module TE-M-364-4 solid rocket motor was ignited to provide the final velocity increment necessary for injection into the Jupiter transfer orbit. The 45 second Propulsion Module burn was performed at a constant attitude, adding approximately the final 6200 ft/sec of the 46,000 to 48,500 ft/sec velocity required at spacecraft injection.

Voyager Mission Objectives

The primary objective of the NASA Voyager Project is to extend the exploration of the solar system to the neighborhood of Jupiter and Saturn with a spacecraft that can conduct significant scientific experiments at both planetary systems and pave the way for later missions to the outer planets.

The major science objectives of the basic mission are to conduct comparative studies of the Jupiter and Saturn systems and to perform investigations in the interplanetary and interstellar media. In addition, the science objectives for an extended mission are to extend interplanetary and interstellar media investigations well beyond the orbit of Saturn and to add an investigation of the Uranus system if conditions should permit implementation of a Uranus targeting option.

Planetary Objectives - Specific objectives for the planets and their satellites include comparative studies of:

- 1. Physical properties, dynamics, and compositions of atmospheres
- 2. Surface features
- 3. Thermal regimes and energy balances
- 4. Charged particles and electromagnetic environments
- 5. Periods of rotation, radii figures, and other body properties
- 6. Gravitational fields

Items of special interest that are included in the objectives above are Jupiter's great red spot, the question of lo's anomalous brightening and the phenomena associated with its electromagnetic behavior (modulation of Jupiter's decameter radiation), the nature of Saturn's rings, and Titan's atmosphere (perhaps unique among satellites).

For Jupiter and Saturn, the initial experiments will provide the elements of knowledge that will block out a fundamental model of each planet, offering a * major step in understanding, and providing a basis for designing the more penetrating experiments to be performed by follow-on or biters and probes. Data from the satellites, notably pictures that reveal their surface topography, may provide considerable insight into solar system history.

Interplanetary Objectives - Specific interplanetary objectives include studies of the variations with time and heliocentric distance of the solar-wind plasma, magnetic fields, cosmic ray particles, and solar energetic particles.

The science experiments carried on each Voyager Mission Module are listed in Table 2-1.

TABLE 2-1 - VOYAGER SCIENCE EXPERIMENTS

| Experiment | Primary Experiment Objectives |
|------------------------------|---|
| | Target Body Oriented |
| IMAGING SCIENCE | Imaging of planets and satellites at resolutions and phase angles not possible from earth. Atmospheric dynamics and surface structure. |
| INFRARED RADIATION | Energy balance of planets. Atmospheric composition and temperature fields. Composition and physical characteristics of satellite surfaces and Saturn rings. |
| PHOTOPOLARIMETRY | Methane, ammonia, molecular hydrogen, and aerosols in atmospheres. Composition and physical characteristics of satellite surfaces and Saturn rings. |
| ULTRAVIOLET SPECTROSCOPY | Atmospheric composition including the hydrogen to helium ratio. Thermal structure of upper atmospheres. Hydrogen and helium in interplanetary and interstellar space. |
| RADIO SCIENCE | Physical properties of atmospheres and ionospheres planet and satellite masses, densities, and gravity fields. Structure of Saturn rings. |
| | Fields and Particles |
| COSMIC RAY PARTICLES | Energy spectra and isotopic composition of cosmic ray particles and trapped planetary energetic particles. |
| LOW ENERGY CHARGED PARTICLES | Energy spectra and isotopic composition of low energy charged particles in planetary magnetospheres and interplanetary space. |
| MAGNETIC FIELDS | Planetary and interplanetary magnetic fields. |
| PLANETARY RADIO ASTRONOMY | Planetary radio emissions and plasma resonances in planetary magnetospheres. |
| PLASMA PARTICLES | Energy spectra of solar-wind electrons and ions, low energy charged particles in planetary environments, and ionized interstellar hydrogen. |
| PLASMA WAVES | Electron densities and local plasma wave-charged particle interactions in planetary magnetospheres. |

III SPACE VEHICLE DESCRIPTION

III SPACE VEHICLE DESCRIPTION

Voyager Spacecraft

by R. P. Geye

The Voyager spacecraft is composed of a Mission Module (MM) and a Propulsion Module (PM). In Figure 3-1, the MM and PM are shown in the launch configuration mated to the Centaur stage within the Centaur Standard Shroud (CSS). The MM is the primary element of the spacecraft, containing the science instruments, the communication and data handling capability, the command and control capability, the electrical power capability, and the attitude control and trajectory correction capability required to attain the science objectives of the mission. The PM is the element of the spacecraft which provides the final injection velocity and is jettisoned from the MM shortly after PM burnout during the launch phase. Total weight of the assembled MM and PM is approximately 4470 pounds. Weight of the MM following MM/PM separation is approximately 1780 pounds.

Mission Module - The general arrangement of the Voyager Mission Module in the flight configuration is shown in Figure 3-2.

The MM design is based on previous Mariner (especially Mariner Mars 1971 and Mariner Venus/Mercury 1973) and Viking Orbiter (V075) experience, with modifications to satisfy specific Voyager mission re-requirements for long-range communications, precision navigation, solar-independent power, and science instrumentation support. In order to operate for the extremely long duration required for the missions, the Mission Module subsystems have been designed with high reliability components and extensive redundancy. In addition, an on-board computer will provide for selected fault detection and corrective action to place the Mission Module in a safe state for ground-based follow-Because of the distance of the outer planets from the Sun, radioisotope thermoelectric generators (RTGs) in lieu of solar panels will be used to supply spacecraft electrical power. Each stack of three RTG units will generate about 425 watts of electrical power at launch, decreasing gradually to about 384 watts at Saturn encounter 4 years later. During cruise, Mission Module attitude control electronics will utilize Sun and star tracker error signals to maintain three-axis orientation by firing small thrusters. An integrated hydrazine propulsion subsystem with 16 small thrusters (redundant sets of eight thrusters) will be used for both attitude control and trajectory correction maneuvers. In addition, precision pointing of the science instruments scan platform will be possible under both the celestial and inertial control modes. Finally, very high telemetry data rates of 115,000 v bits/second from Jupiter and 30,000 bits/second from Saturn will be provided by transmitting at X-band radio frequency over the Mission Module's 3.7 meter parabolic antenna.

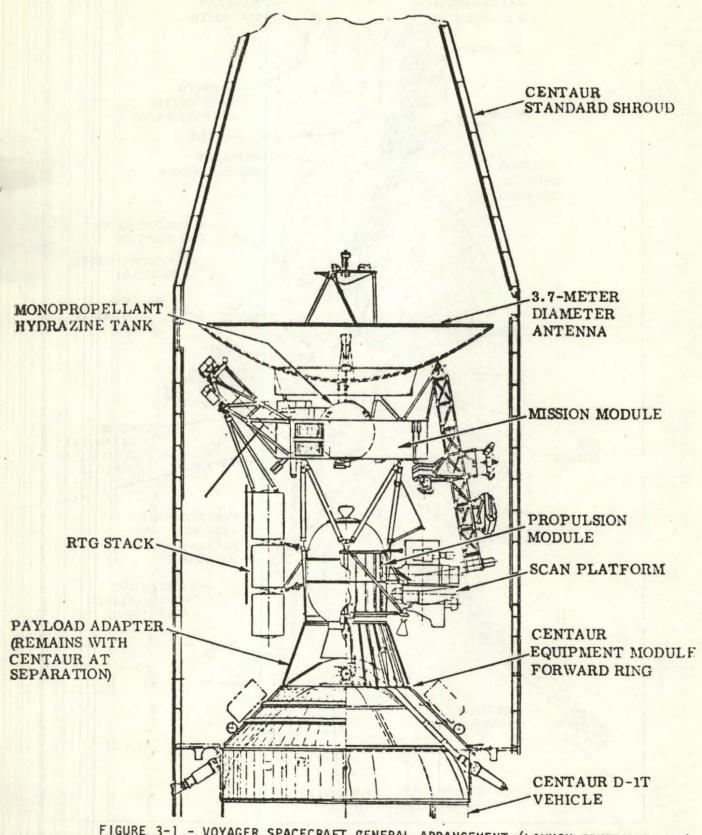


FIGURE 3-1 - VOYAGER SPACECRAFT GENERAL ARRANGEMENT (LAUNCH CONFIGURATION)

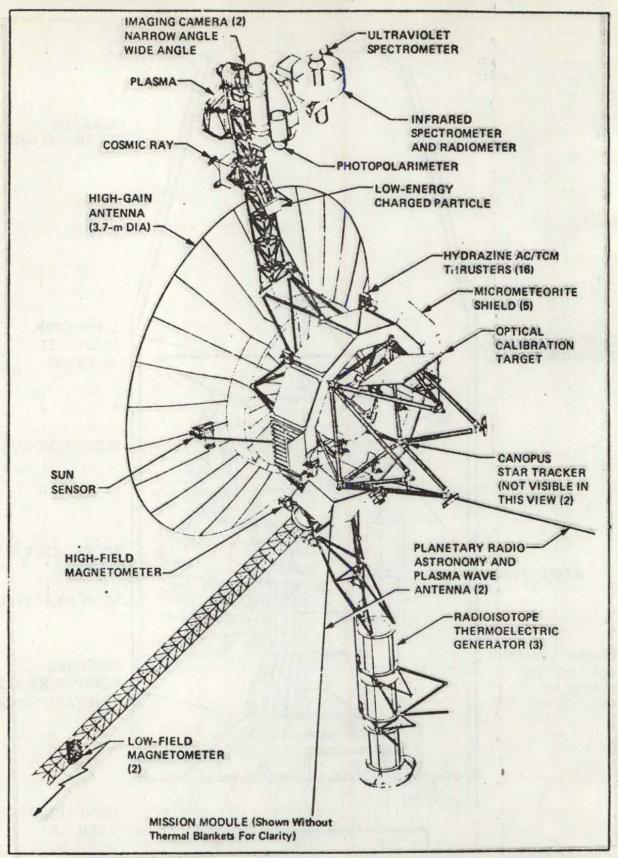


FIGURE 3-2 - VOYAGER MISSION MODULE GENERAL ARRANGEMENT (FLIGHT CONFIGURATION)

The central structure of the MM (called bus structure) consists of a hollow 10-sided compartment approximately 18.5 inches in height and 74 inches in diameter. The structure is divided into 10 bays, all of which are used to house MM electronic subsystems. Variable emittance louvers in conjunction with electric and radioisotope heaters provide required thermal control within the electric bays. Attached to the top of the bus structure is the dominant feature of the MM--a 12-foot (3.7 meter) diameter parabolic high gain antenna which is used for both S-band and X-band communications.

Mounted on opposite sides of the bus structure are two deployable booms for (1) the science instruments scan platform and (2) three tandem-mounted multi-hundred-watt radioisotope thermoelectric generators (RTG's) which provide electrical power for the MM. Mounting these items on diametrically-opposed booms provides physical displacement for reducing the science instruments exposure to RTG radiation as well as taking advantage of the shielding effect of the bus structure interposed between them. Other MM appendages include two 10-meter long extendalbe monopole antennas for the Planetary Radio Astronomy and Plasma Wave experiments, and a 13-meter long extendable boom to deply two magnetometers away from the MM-generated magnetic field.

A single, spherical, self-pressurized propellant tank containing approximately 230 pounds of hydrazine is mounted in the center of the MM bus structure. This tank supplies propellant for the Injection Propulsion Unit (IPU) engines (used for spacecraft attitude control from spacecraft/Centaur separation through MM/PM separation) and the Trajectory Correction Auxiliary Propulsion Unit (TCAPU) engines (used for MM attitude control and trajectory correction maneuvers).

The Voyager is attitude stabilized in three axes using the Sun and Canopus as primary reference objects while maintaining communications with the Earth. The MM has two-way communications equipment which permit the transmission of science data to the Earth, receipt of command transmissions from the Earth, two-way doppler tracking, and range measurements. The MM is capable of executing on-board stored sequenced for trajectory correction maneuvers, antennas pointing, science instrument pointing, science and engineering data acquisition, and data formatting.

Propulsion Module - The PM consists primarily of the Injection Propulsion Unit (IPU) and a semimonocoque cylinder which serves as the primary monitoring structure. The IPU is made up of (1) a TE-M-364-4 solid rocket motor which provides an average 14,346 pounds of thrust for approximately 45 seconds to supply the final injection velocity increment of more than 6,200 ft/sec to the MM; (2) four thrust vector control engines to provide pitch-yaw moments during the solid motor burn; and (3) four attitude control engines to provide roll control during the solid motor burn and roll, pitch and yaw control at other tunes from spacecraft/Centaur separation through MM/PM separation.

The structural cylinder surrounds the TE-M-364-4 motor casing. At the aft end of the cylinder there is a pyrotechnic joint for separation of the space-craft from the launch vehicle. At the forward end of the structural cylinder, there are four attach fittings for the MM-to-PM truss members. These fittings are fitted with pyrotechnic devices for separation of the MM from the PM.

Launch Vehicle Configuration

by R. P. Geye

The launch vehicle for Voyager I was the four-stage Titan IIIE/Centaur D-1T configuration. This was the sixth operational flight of this combination of stages.

The overall vehicle configuration is shown in Figure 3-3. The Titan vehicle consists of a two-stage liquid propulsion core vehicle manufactured by the Martin Marietta Corporation and two solid rocket motors (Stage 0) manufactured by the United Technology Center. The Titan vehicle integrator is Martin Marietta Corporation. The upper stage is the Centaur D-IT manufactured by General Dynamics Convair Division.

The payload fairing for this configuration is the Centaur Standard Shroud (CSS) manufactured by Lockheed Missiles and Space Company, Inc. Figure 3-4 shows the Centaur/CSS/Viking spacecraft general arrangement.

The following sections of the report give a summary description of the vehicle stage and CSS configurations. Detailed subsystem descriptions can be found in the Flight Data Report for Titan/Centaur TC-1 Proof Flight (NASA TM X-71692). Only configuration differences from TC-1 and/or TC-2 will be addressed in this report.

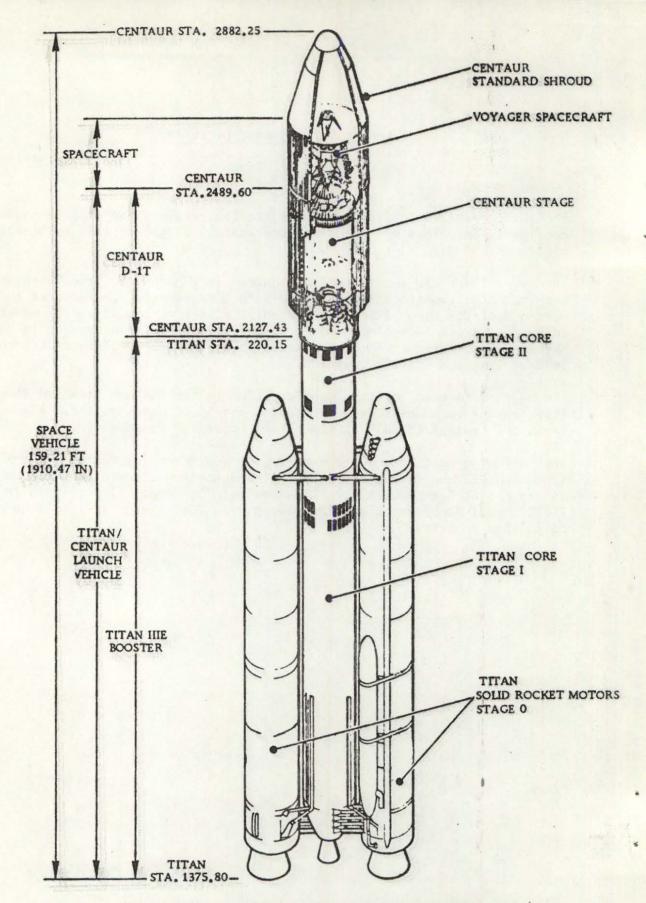


FIGURE 3-3 - OVERALL TC-6, -7 VEHICLE CONFIGURATION

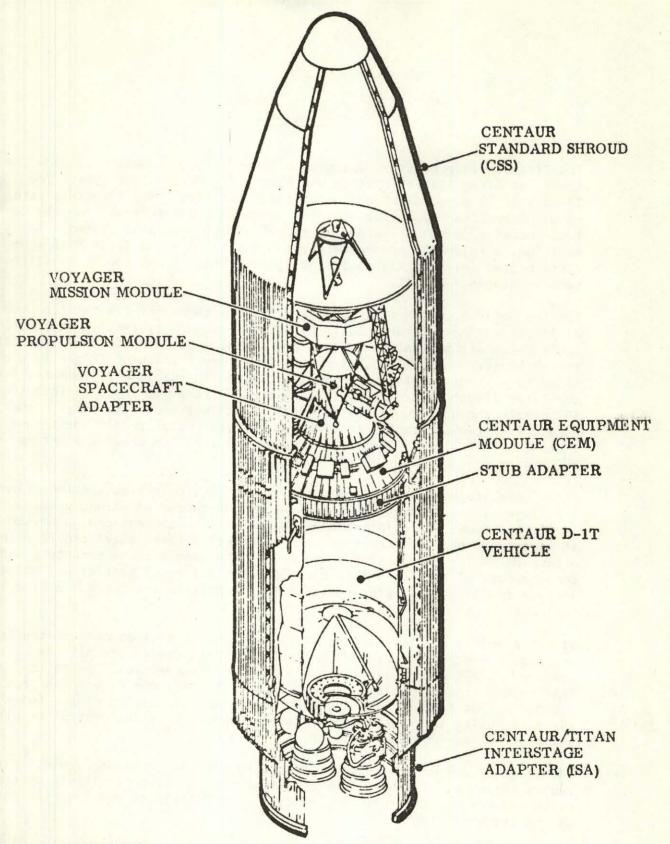


FIGURE 3-4 - CENTAUR/CSS/VOYAGER SPACECRAFT GENERAL ARRANGEMENT

Titan IIIE

The Titan/Centaur booster, designated Titan IIIE, was developed from the family of Titan III vehicles in use by the Air Force since 1964. The Titan IIIE is a modified version of the Titan IIID. Modifications were made to the Titan to accept steering commands and discretes from the Centaur inertial guidance system instead of a radio guidance system. In addition, a redundant programmer system was added. The Titan IIIE consists of two solid rocket motors designated Stage 0 and the Titan III core vehicle Stages I and II.

The two Solid Rocket Motors (SRM's) provide a thrust of 2.4 million pounds at liftoff. These motors, built by United Technology Center, use propellants which are basically aluminum and ammonium perchlorate in a synethetic rubber binder. Flight control during the Stage O phase of flight is provided by a Thrust Vector Control (TVC) system in response to commands from the Titan flight control computer. Nitrogen tetroxide injected into the SRM nozzle through TVC valves deflects the thrust vector to provide control. Pressurized tanks attached to each solid rocket motor supply the thrust vector control fluid. Electrical systems on each SRM provide power for the TVC system.

Titan core Stages I and II are built by the Martin Marrietta Corporation. The Stages I and II propellant tanks are constructed of welded aluminum panels and domes while interconnecting skirts use conventional aluminum sheet and stringer construction. The Stage II forward skirt provides the attach point for the Centaur stage and also houses a truss structure supporting most of the Titan IIIE electronics. A thermal barrier was added to isolate the Titan IIIE electronics compartment from the Centaur engine compartment.

Stages I and II are both powered by liquid rocket engines made by the Aero-jet Liquid Rocket Company. Propellants for both stages are nitrogen tetroxide and a 50/50 combination of hydrazine and unsymmetrical dimethylhydrazine. The Stage I engine consists of dual thrust chambers and turbopumps producing 520,000 pounds thrust at altitude. Independent gimballing of the two thrust chambers, using a conventional hydraulic system, provides control in pitch, yaw and roll during Stage I flight.

The Stage II engine is a single thrust chamber and turbopump producing 100,000 pounds thrust at altitude. The thrust chamber gimbals for flight control in pitch and yaw and the turbopump exhaust duct rotates to provide roll control during Stage II flight.

To preclude longitudinal oscillations which were encountered during Stage I operation on TC-1 and TC-2, accumulators are installed in the oxidizer feed lines to each of the Stage I thrust chambers on this Titan vehicle.

The Stage I oxidizer autogenous pressurization system consists of two superheaters as flown on TC-1 (only one superheater was flown on TC-2). This pressurization system provides tank ullage pressure during Stage I burn time.

The Titan flight control computer provides pitch, yaw and roll commands to the solid rocket motor's thrust vector control system and the Stages I and II hydraulic actuators. The flight control computer receives attitude signals from the three-axis reference system which contains three displacement gyros.

Vehicle attitude rates in pitch and yaw are provided by the rate gyro system located in Stage I. In addition, the flight control computer generates preprogrammed pitch and yaw signals, provides signal conditioning, filtering and gain changes, and controls the dump of excess thrust vector control fluid. A roll axis control change was added to proide a variable flight azimuth capability for planetary launches. The Centaur computer provides steering programs for Stage O wind load relief and guidance steering for Titan Stages I and II.

A flight programmer provides timing for flight control programs, gain changes and other discrete events. A staging timer provides acceleration-dependent discretes for Stage I ignition and timed discretes for other events keyed to staging events. The flight programmer and staging timer, operating in conjunction with a relay package and enable-disable circuits, comprise the electrical sequencing system. On Titan IIIE a second programmer, relay packages and other circuits were added to provide redundancy. Also, capability for transmitting backup commands was added to the Titan systems for staging of the Centaur Standard Shroud and the Centaur.

The standard Titan uses three batteries: one for flight control and sequencing, one for telemetry and instrumentation, and one for ordnance. On Titan IIIE additional separate redundant Range Safety Command system batteries were added to satisfy Range requirements.

The Titan telemetry system is an S-band frequency, pulse code modulation/ frequency modulation (PCM/FM) system consisting of one control converter and remote multiplexer units. The PCM format is reprogrammable.

Many of the modifications to the Titan for Titan/Centaur were made to incorporate redundancy and reliability improvements. In addition to those modifications previously mentioned, a fourth retrorocket was added to Stage II in order to ensure proper Titan/Centaur separation if one motor does not fire. All redundancy modifications to Titan IIIE utilized Titan flight proven components.

Centaur D-IT

The Centaur tank is a pressure-stabilized structure made from stainless steel (0.014 inches thick in cylindrical section). A double-walled, vacuum-insulated intermediate bulkhead separates the liquid oxygen tank from the liquid hydrogen tank.

The entire cylindrical section of the Centaur LH₂ tank is covered by a radiation shield. This shield consists of three separate layers of an aluminized Mylar-dacron net sandwich. The forward tank bulkhead and tank access door are insulated with a multilayer aluminized Mylar. The aft bulkhead is covered with a membrane which is in contact with the tank bulkhead and a rigid radiation shield supported on brackets. The membrane is a layer of dacron-reinforced aluminized Mylar. The radiation shield is made of laminated nylon fabric with aluminized Mylar on its inner surface and white polyvinyl fluoride on its outer surface. This Centaur vehicle has no thermal control shielding on components in the thrust section.

The forward equipment module, an aluminum conical structure, attaches to the tank by a short cylindrical stub adapter.

Two modes of tank pressurization are used. Before propellant tanking, a helium system maintains pressure. With propellants in the tank, pressure is maintained by propellant boiloff. During flight, the airborne helium system provides supplementary pressure when required. This system also provides pressure for the H₂O₂ and engine controls system. This Centaur vehicle has one large helium storage tank.

Primary thrust is provided by two Pratt & Whitney RL10A3-3 engines, which develop 15,000 pounds total thrust each. The engines are fed by hydrogen peroxide fuel boost pumps. This Centaur vehicle has a boost pump cold gas spinup system used for ground checkout of the boost pumps. Engine gimballing is provided by a separate hydraulic system on each engine.

During coast flight, attitude control is provided by four H₂0₂ engine cluster manifold assemblies mounted on the tank aft bulkhead on the peripheral center of each quadrant. Each assembly consists of two 6-pound lateral thrust engines manifolded together.

A propellant utilization system controls the engine mixture ratio to ensure that both propellant tanks will be emptied simultaneously. Quantity measurement probes are mounted within the fuel and oxidizer tanks.

The Centaur D-1T astrionics system's Teledyne Digital Computer Unit (DCU) is an advanced, high speed computer with a 16,384 word random access memory.

From the DCU discretes are provided to the Sequence Control Unit (SCU). Engine commands go to the Servo-Inverter Unit (SIU) through six digital-to-analog (D/A) channels.

The Honeywell Inertial Reference Unit (IRU) contains a four-gimbal, all-attitude stable platform. Three gros stabilize this platform, on which are mounted three pulse-balanced accelerometers. A prism and window allow for optical azimuth alignment. Resolvers on the platform gimbals transform vector components from inertial to vehicle coordinates. A crystal oscillator, which is the primary timing reference, is also contained in the IRU.

The System Electronic Unit (SEU) provides conditioned power and sequencing for the IRU. Communication from the IRU to the DCU is through three analog-to-digital channels (for attitude and rate signals) and three incremental velocity channels. The SEU and IRU combination forms the inertial Measuring Group (IMG).

The Centaur D-1T system also provides guidance for Titan, with the stabilization function performed by the Titan.

The central controllr for the Centaur pulse code modulation PCM telemetry system is housed in the DCU. System capacity is 267,000 bits per second. The central controller services two Teledyne remote-multiplexer units on the Centaur D-1T.

The C-band tracking system provides ground tracking of the vehicle during flight. The airborne transponder returns an amplified radio-frequency signal when it detects a tracking radar's interrogation.

This Centaur vehicle uses a basic d-c power system, with power supplied by one 150 ampere-hour battery and distributed via harnessing. The servo-inverter provides a-c power, 26 and 115 volts, single phase, 400 Hz.

Centaur Standard Shroud

The Centaur Standard Shroud is a jettisonable fairing designed to protect the Centaur vehicle and its payloads for a variety of space missions. The Centaur Standard Shroud, as shown in Figure 3-5 consists of three major segments: a payload section, a tank section and a boattail section. The 14-foot diameter of the shroud was selected to accommodate Viking space-craft requirements. The separation joints sever the shroud into clamshell halves.

The shroud basic structure is a ring stiffened aluminum and magnesium shell. The cylindrical sections are constructed of two light gage aluminum sheets. The outer sheet is longtudinally corrugated for stiffness. The sheets are joined by spot welding through an epoxy adhesive bond. Sheet splices, ring attachments and field joints employ conventional rivet and bolted construction. The bi-conic nose is a semi-monocoque magnesium-thorium single skin shell. The nose dome is stainless steel. The boattail section accomplishes the transition form the 14-foot shourd diameter to the 10-foot Centaur interstage adapter. The boattail is constructed of a ring stiffened aluminum sheet conical shell having external riveted hat section stiffeners.

The Centaur Standard Shroud modular concept permits installation of the tank section around the Centaur independent of the payload section. The payload section is installed around the spacecraft in a special clean room, after which the encapsulated spacecraft is transported to the launch pad for installation on the Centaur.

The lower section of the shroud provides insulation for the Centaur liquid hydrogen tank during propellant tanking and prelaunch ground hold operations. This section has seals at each end which close off the volume between the Centaur tanks and the shroud. A helium purge is required to prevent formation of ice in this volume.

The shroud is separated from the Titan/Centaur during Titan Stage II flight. Jettison is accomplished when an electrical command from the Centaur initiates the Super-Zip separation system detonation. Redundant dual explosive cords are confined in a flattened steel tube which lies between two notched plates around the circumference of the shroud near the base and up the sides of the shroud to the nose dome. The pressure produced by the explosive cord detonation expands the flattened tubes, breaking the two notched plates and separating the shroud into two halves.

To ensure reliability, two completely redundant electrical and explosive systems are used. If the first system should fail to function, the second is automatically activated as a backup within one-half second.

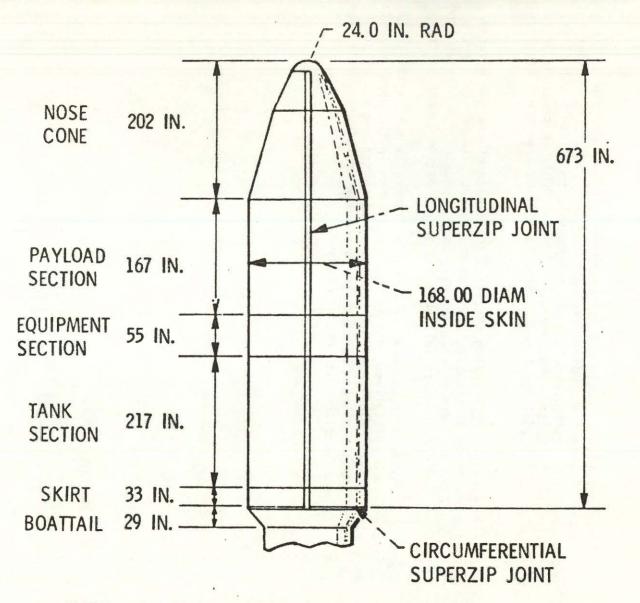


FIGURE 3-5 - CENTAUR STANDARD SHROUD CONFIGURATION

The Titan pyrotechnic battery supplies the electrical power to initiate the Centaur Standard Shroud electric pyrotechnic detonators. Primary and backup jettison discrete signals are sent to the Titan squib firing circuitry by the Centaur Sequence Control Unit (SCU). A tertiary jettison signal, for additional redundancy, is derived from the Titan staging timer.

Four base-mounted, coil-spring thrusters force each of the two severed shroud sections to pivot about hinge points at the base of the shroud. After rotating approximately 60 degrees, each shroud half separates from its hinges and continues to fall back and away from the launch vehicle.

Two additional sets of springs are installed laterally across the Centaur Standard Shroud split lines; one set of two springs in the upper nose cone to assist in overcoming nose dome rubbing friction and one set of two springs at the top of the tank section to provide additional impulse during Centaur/shroud jettison disconnect breakaway.

IV TRAJECTORY AND PERFORMANCE SUMMARY

IV TRAJECTORY AND PERFORMANCE SUMMARY

by G. D. Sagerman

The Titan IIIE/Centaur D-1T vehicle, TC-6, was successfully launched from Complex 41 at ETR on September 5, 1977, at 12:56:00.958 GMT (08:56:00.958 EDT). The vehicle placed the Voyager I spacecraft onto a highly accurate trajectory to Jupiter. A comparison of the predicted and actual times for the major flight events is shown in Table 4-1.

Performance of Titan Stages 0 and I was below the predicted level, but within the extremes which have been observed on previous Titan flights. The Titan solid rocket motors (SRM's) were ignited at 12:56:00.958 GMT, with lift-off occurring approximately 0.26 seconds later when the thrust of the SRM's exceeded the total weight of the vehicle. Beginning 6.6 seconds after SRM ignition, the launch vehicle was rolled from the launch pad azimuth of 100.20 east of North to the required flight azimuth of 920 east of North. The trajectory profile through the SRM portion of the flight was slightly below nominal, with Stage I ignition occurring at 112.1 seconds into the flight. The SRM's were jettisoned at 123.2 seconds. At SRM jettison the vehicle was about 2600 feet below the predicted altitude and the inertial velocity was about 50 feet per second slower than that predicted by the preflight actual launch time trajectory (PALTT).

The Stage I burn was about 1 second longer than predicted. Performance of the stage, while well within specification limits, was somewhat lower than predicted. At Step I jettison, velocity was 105 feet per second slow and altitude was 6200 feet low.

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TABLE 4-1

TC-6/VOYAGER I; SEPTEMBER 5, 1977

SEQUENCE OF EVENTS

| FLIGHT EVENTS | Time (T+: | Sec) ACTUAL |
|--|-----------|--------------------------|
| Go Inertial | T-6.0 | T-6.004 |
| SRM Ignition | T=0.0 | T=0.0 (12:56:00.958 GMT) |
| Forward Bearing Reactor Separation | 100.0 | 100.1 |
| Stage Ignition | 110.5 | 112.1 |
| Step 0 (SRM's) Jettison | 121.8 | 123.2 |
| Stage Shutdown | 259.5 | 262.2 |
| Step Jettison/Stage Ignition | 260.3 | 262.2 |
| Centaur Standard Shroud Jettison | 271.0 | 272.2 |
| Stage II Shutdown | 469.9 | 469.9 |
| Step II Jettison | 476.0 | 474.1 |
| Centaur MES-1 | 486.5 | 484.6 |
| Centaur MECO-1 | 578.2 | 594.0 |
| Centaur MES-2 | 3181.3 | 3199.8 |
| Centaur MECO-2 | 3534.4 | 3535.3 |
| Start Alignment to Spacecraft Separation Attitude | 3536.4 | 3537.4 |
| Spacecraft Arm | 3635.5 | 3636.2 |
| Spacecraft Separation | 3704.4 | 3705.2 |
| Spacecraft TVC On | 3706.4 | 3707.2 |
| Propulsion Module Ignition | 3719.4 | 3722.2 |
| Propulsion Module Burnout | 3764.4 | 3767.3 |

TABLE 4-1 (Cont.)

| | Time (T+Sec) | | |
|---------------------------|--------------|--------|--|
| FLIGHT EVENTS | NOMINAL (1) | ACTUAL | |
| Start Spacecraft Turndown | 3779.4 | 3788.3 | |
| End Spacecraft Turndown | 3827.4 | 3896.3 | |
| PM/MM Separation | 4441.4 | 4445.0 | |

⁽¹⁾ GDC Preflight Actual Launch Time Trajectory (PALTT)

The Stage II engine was ignited at 262.2 seconds into the flight. An anomaly during the Stage II burn (as described in other sectionns of this report) caused a reduction in the oxidizer flow rate and hence a significant change in the mixture ratio at which the Stage II propellants were burned. The duration of the Stage II burn was very close to the predicted duration. However, the anomaly caused a 1.8 percent reduction in thrust and also resulted in an oxidizer outage of nearly 2000 pounds at Stage II shutdown. As a result, velocity at Stage II jettison was 544 feet per second below that predicted. The vehicle was 3000 feet below the predicted altitude at that point.

The Centaur was separated from the Titan at 474.1 seconds into the flight, and the Centaur engines were ignited for the first time at 484.6 seconds. The Centaur burned 17.7 seconds longer than predicted to make up the energy deficiency accumulated throughout the Titan portion of the flight. This burn placed the vehicle into a near-nominal parking orbit at MECO1. Table 4-2 compares selected actual parking orbit parameters with predicted values from the PALTT.

After a 43.4 minute coast in parking orbit, the Centaur engines ignited for the second time at 3199.8 seconds into the flight. The second burn was 335.5 seconds in duration, 17.6 seconds shorter than originally predicted. The long Centaur first burn resulted in a lighter-than-nominal vehicle at MES2, and based on the lighter weight, a second burn duration on the order of 341 seconds was estimated. The fact that the total Centaur burn time was about 5 seconds shorter than the revised prediction is consistent with recent Centaur flights. The second Centaur burn placed the spacecraft on a hyperbolic trajectory with a C3 of approximately 51.0 km²/sec². A summary of the orbit parameters after the second burn is presented in Table 4-3.

The Centaur was reoriented to point the spacecraft in the proper direction for the fixed-attitude burn of the spacecraft propulsion module. After the Centaur was jettisoned, the TE364-4 solid rocket motor, which was integrated into the propulsion module, burned to provide the final energy required to attain the desired trajectory to Jupiter. The accuracy of the final injection, as illustrated by the comparison of actual and predicted final orbit parameters in Table 4-4, attests to the accuracy of the Centaur pointing and the propulsion module performance prediction.

Table 4-5 compares the injection orbit parameters mapped at Jupiter to the targeted conditions. The guidance solution is based on DCU telemetry data and assumed a nominal propulsion module. The tracking solution is based on about 48 hours of DSN tracking data. The midcourse correction requirements (MCR's) shown are those required at 6 days after launch to achieve the target parameters specified in the final targeting specification. Comparison with the predicted 3-sigma MCR indicates that about a 1-sigma flight was achieved.

TABLE 4-2 - VOYAGER I (TC-6) PARKING ORBIT

| | | Actual | |
|-------------------------|--------------|--------------------|------------------|
| | Expected (1) | Guidance Telemetry | Antigua Tracking |
| Epoch (sec) | 578.7 | 596.03 | 572.0 |
| Semi-Major Axis (n.mi.) | 3534.01 | 3533.81 | 3532.05 |
| Eccentricity | .000023 | .000038 | .000412 |
| Inclination (deg) | 28.5227 | 28.5201 | 28.519 |
| Perigee Alt. (n.mi.) | 90.0015 | 89.75 | 86.66 |
| Apogee Alt. (n.mi.) | 90.1616 | 90.01 | 89.57 |
| $C_3 (km^2/sec^2)$ | -60.9017 | -60.90520 | -60.9347 |

⁽¹⁾ GDC Preflight Actual Launch Time Trajectory (PALTT)

TABLE 4-3 - VOYAGER I (TC-6) CENTAUR POST-MECO2 ORBIT

| | w . | Expected (1) | Guidance Telemetry | Vanguard |
|----|-----------------------------------|--------------|--------------------|----------|
| | Epoch (sec) | 3534.9 | 3600.03 | 3529.0 |
| | Semi-Major Axis (n.mi.) | -4216.31 | -4220.43 | -4225.75 |
| | Eccentricity | 1.84238 | 1.84171 | 1.84043 |
| 31 | Inclination (deg) | 28.5041 | 28.5165 | 28.5360 |
| | Perigee Alt. (n.mi.) | 107.803 | 108.46 | 109.09 |
| | Longitude of Ascending Node (deg) | 170.466 | 170.237 | - |
| | $C_3 (km^2/sec^2)$ | 51.0464 | 50.9966 | 50.9324 |

⁽¹⁾ GDC Preflight Actual Launch Time Trajectory (PALTT)

TABLE 4-4 - VOYAGER I (TC-6) SPACECRAFT ORBIT

| | Expected (1) | DCU (2) | Vanguard ⁽²⁾ Tracking | DSS-12 Tracking |
|----------------------|--------------|---------|-------------------------------------|--------------------|
| Epoch (sec) | 3779.4 | 3751.2 | 3755.0 | 3755.0 |
| Eccentricity | 2.77356 | 2.77298 | 2.78598 | 2.77099 |
| Inclination (deg) | 28.5064 | 28.5241 | 28.5349 | 28.4944 |
| $C_3 (km^2/sec^2)$ | 105.447 | 105.430 | 106.277 | 105.239 |
| Perigee Alt. (n.mi.) | 176.061 | 176.07 | 172.95 | 177.98 |

⁽¹⁾ GDC Preflight Actual launch Time Trajectory (PALTT)

⁽²⁾ Assumes Nominal Propulsion Module Impulse

TABLE 4-5 - VOYAGER I (TC-6)

JUPITER B-PLANE MAP OF INJECTION PARAMETERS

| | | Targeted (1) | Guidance (2) | Tracking (3) |
|-----|-------------------|---------------------------|-------------------------|-------------------------|
| В•Т | (km) | 9.39550×10 ⁵ | 9.76042×10 ⁵ | 5.10900×10 ⁵ |
| B•R | (km) | 6.1970×10 ⁴ | 4.8362×10 ⁴ | 3.1913x10 ⁴ |
| TCA | (MO/DA/YR HR:MIN) | 3/5/79 12:05 | 3/5/79 13:04 | 3/6/79 16:21 |
| w | | | | |
| MCR | (m/sec) | 40.3 (3-sigma prediction) | 2.06 | 12.7 |

V VEHICLE DYNAMICS

V VEHICLE DYNAMICS

by J. C. Estes and R. P. Miller

The Titan/Centaur receives dynamic loading from two major sources: (1) aero-dynamic and acoustic sources, and (2) transient loads from launch, starting and stopping engines, and various separation systems.

Aerodynamic Loads - The ADDJUST system was used to design flight steering programs P1A 3800*TC06 and Y1A3800 for the wind profile measured by a Windsonde balloon released at 1031Z, September 5, 1977. The pitch and yaw components of this wind are shown in Figure 5-1. During prelaunch verification of the flight steering programs, peak response to the 1031Z wind was calculated to be 82 percent of the weakest structural allowable. This response was calculated to occur at an altitude of 22913 feet. It should be noted that this percentage includes a combination of nominal wind responses with allowances for such unmeasured and/or non-nominal quantities as gust, buffeting, trajectory dispersions, and two-hour wind changes. At the time of peak response, the calculated product of dynamic pressure, Q, and total angle of attack was 286 degree-pounds per square foot.

A wind sounding was initiated 30 minutes before launch with a Windsonde balloon released at 1226Z, September 5, 1977. The pitch and yaw components of this wind are shown in Figure 5-2. The 1226Z sounding reached 25000 feet about 5 minutes before lift-off of TC-6. Peak calculated response from this sounding was 81 percent of the weakest structural allowable at 25663 feet altitude. This percentage includes all of the same allowances for extreme conditions described above for prelaunch verification. The peak response was based on a calculated Q-alpha total of 433 degree-pounds per square foot. As may be seen in the discussion of measured TVC usage (Section VII) and Titan flight controls (Section VII), all of the measured flight wind responses were well below allowables.

Transient Loads - Transient loads on Voyager I, TC-6, were assessed with data acquired from 12 flight accelerometers located on the spacecraft, Centaur and Titan. The location, orientation and range of each accelerometer are shown in Figures 5-3 and 5-4.

Loads evaluation was made by comparison of flight accelerometer response to predicted levels and previous experience. A tabular summary of TC-6 response compared to TC-7, at significant flight events, is presented in TAble 5-1.

The spacecraft axial response at lift-off was similar to TC-7. The lateral response at this time was approximately 70 percent higher on TC-6 but was well within the maximum expected. The maximum buffet response, occurring at transonic, was similar in both amplitude and frequency to that observed on TC-7.



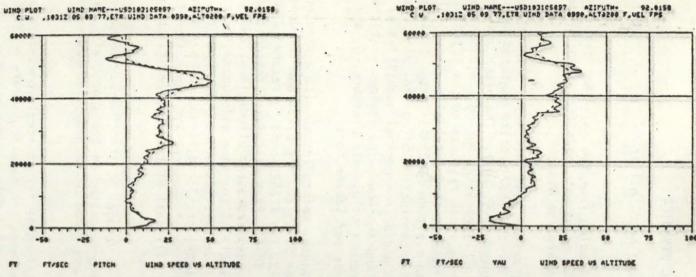


FIGURE 5-1 - WINDSONDE PITCH AND YAW COMPONENTS OF WIND VELOCITY, 1031Z, 9/5/77

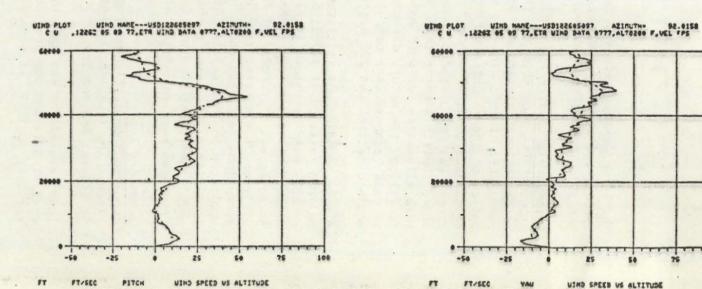
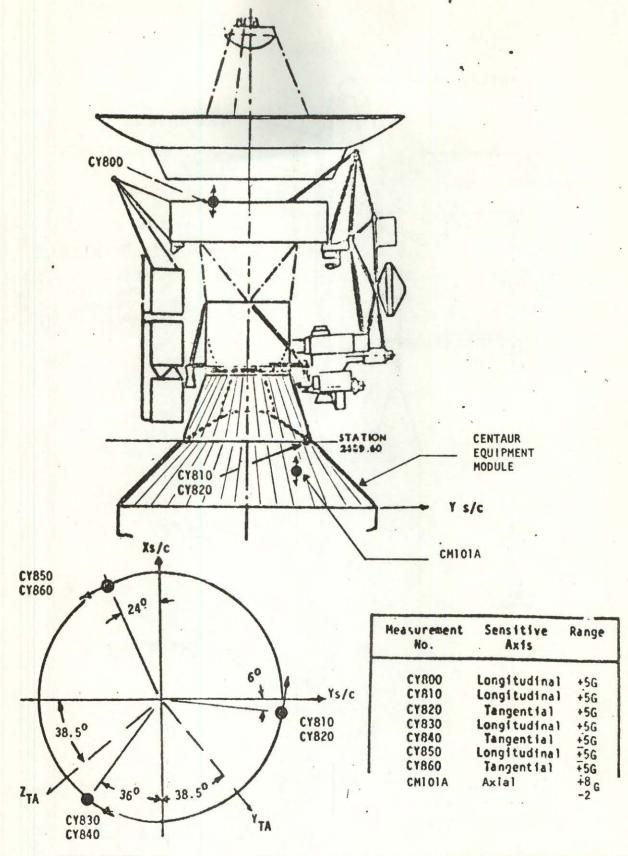


FIGURE 5-2 - WINDSONDE PITCH AND YAW COMPONENTS OF WIND VELOCITY, 1226Z, 9/5/77

MAY

WIND SPEED US ALTITUDE



VIEW LOOKING AFT

FIGURE 5-3 - ACCELEROMETER LOCATIONS ON VOYAGER & CENTAUR

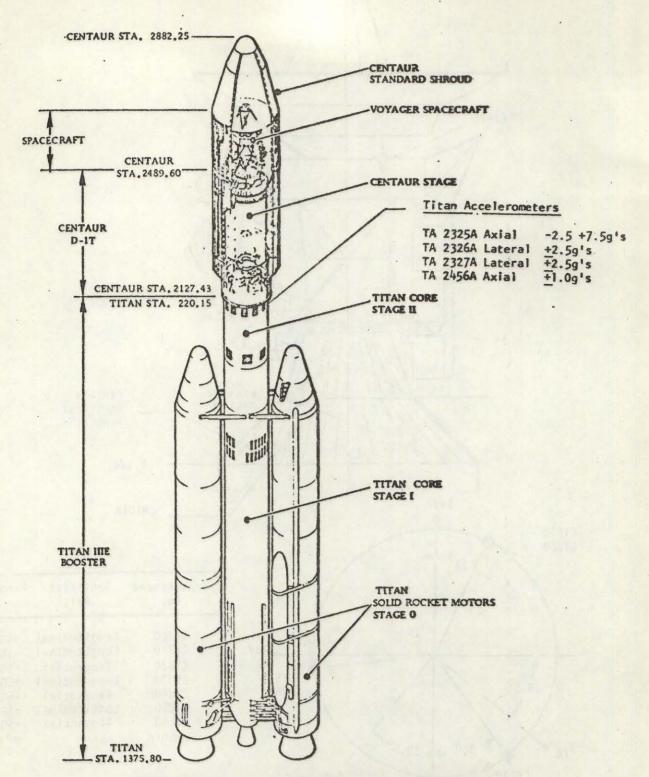


FIGURE 5-4 - ACCELEROMETER LOCATIONS ON TITAN

Significantly higher response was observed on TC-6 at Stage I and II burnout than was seen on TC-7. (See Table 5-1). However, the amplitudes were well within the maximum expected values for these events.

First longitudinal mode noise (FLMN) occurred during the second half of Stage 1 flight. The amplitude was similar to that seen on TC-7. However, at approximately 43 seconds before Stage 1 burnout the FLMN oscillations reached an amplitude of .6 g's peak to peak at 12HZ that was sustained for approximately 6 seconds. The duration of the response at a single frequency is considered outside previous experience.

The response during Centaur flight events was similar to TC-7 and within the maximum expected levels.

TABLE 5-1 - ACCELERATION RESPONSE SUMMARY FOR TC-6

| Flight Event | Flight | CM101A | Axial CY810 | Accelerate CY830 | CY850 | CY800 | Latera CY820 | Accele CY840 | ration* CY860 |
|--|--------------|--------------|----------------|------------------|-------|-------|-----------------|-----------------|------------------|
| Lift-off | TC-6 TC-7 | 1.0 | .8 | 1.0 | 1.1 | 2.2 | 1.3 | 1.2 | 2.2 |
| Transonic | TC-6 TC-7 | .3 | .3 | .3 | .3 | 2.2 | 1.7 | 1.2 | 2.4 |
| Stage Start | TC-6 TC-7 | 1.0 | 1.1 | 1.1 | 1.1 | 1.2 | >.1 | >.1 | >.1 |
| Stage FLMN (Lift-off + 219 Sec.) | TC-6 TC-7 | .6(12 | 2HZ).5 | .5 | .5 | .8 | >.1 | >.1 | >.1 |
| Stage FLMN (near Stg B.O.) | TC-6 TC-7 | .8(20 1.0 | 0HZ).9 1.0 | 1.1 | 1.2 | 1.7 | >.1 >.1 | >.1 >.1 | >.1 >.1 |
| Stage I Burnout | TC-6 TC-7 | 1.5 | 2.0 | 2.4 | 2.6 | 3.0 | >.1 >.1 | >.1 >.1 | >.1 >.1 |
| Stage II Burnout | TC-6 TC-7 | 1.3 | 1.2 | 1.4 | 1.2 | 2.2 | 1.0 | 1.1 | 1.2 |
| Stage II Jettison | TC-6 TC-7 | 1.2 | 1.2 | 1.2 | 1.0 | 1.2 | 1.2 | .8 | .8 |
| MESI | TC-6 TC-7 | .5 | .6 | :4:7 | .4 | .5 | .4 | .4 .6 | .4 |
| MECO I | TC-6 TC-7 | 1.4 | 1.2 | 1.0 | 1.4 | 1.4 | .2 | .3 | .3 |
| MES II | TC-6 TC-7 | | .6 1.1 | 1.1 | 1.2 | 1.8 | .4 | .3 | .2 |
| MECO II | TC-6 TC-7 | | 1.4 | 1.2 | 1.8 | 3.6 | 1.2 | 1.0 | .8 |

^{*} Acceleration is in Peak to Peak g's

VI SOFTWARE PERFORMANCE

VI SOFTWARE PERFORMANCE

Airborne

by J. L. Feagan

All available DCU flight telemetry data for the flight of TC-6 was thoroughly reviewed to verify that the flight software performed as designed. The data reviewed included analog plots of the DCU inputs (A/D's) and outputs (D/A's) and digital listings of the SCU switch commands and the software internal sequencing. The digital data was also used to verify the proper operation of each module of the flight program as well as the transfer of data between the various modules. The details of the software performance are elaborated upon in the descriptions of the various flight systems; e.g., PU, flight control, guidance, CCVAPS and trajectory.

COMPUTER CONTROLLED LAUNCH SET (CCLS)

by C. F. Weegmann

During the prelaunch countdown of TC-6, the performance of the CCLS software and hardware was nominal with the exception of a minor anomaly that occurred early in the count. A Disc Monitor System (DMS) software abort occurred on the prime computer during a vulnerable data transfer from the prime to back-up computer. An approved procedure was executed at the time of the abort, and the prime and back-up computers were on-line and supporting countdown operations within 5 minutes of the DMS abort. The remainder of the preflight CCLS tasks were completed within the specified timelines with no anomalies.

VII TITAN IIIE SYSTEMS ANALYSIS

VII TITAN IIIE SYSTEMS ANALYSIS

Mechanical Systems

Airframe Structures

by R. C. Edwards

Summary

The Titan E6 vehicle airframe configuration remained unchanged from the E5 configuration. The Titan vehicle maintained structural integrity throughout all phases of booster ascent flight. Data from flight instrumentation agreed well with predicted flight values.

Discussion

Response of the vehicle airframe to steady-state loads and transient events was nominal with peaks at expected levels.

The ullage pressures within the oxidizer and fuel tanks of both Stage I and Stage II were within prelaunch limits (Table 7-2) and remained sufficient to maintain structural integrity throughout flight. The pressures did not exceed the design limits of the vehicle.

Compartment IIA internal pressure vented as expected and achieved essentially zero psi at approximately 125 seconds after lift-off (Figure 9-9).

SRM separation and Stage I/Stage II separation occurred within predicted three sigma event times (Table 4-1). Flight data indicates Titan ordnance for these events performed as expected.

Titan Propulsion Systems

by R. J. Salmi

Summary

The Titan Stage 0 SRM performance and the core Stage I performance for the TC-6 flight were within the expected ranges and exhibited no significant operating anomalies. The Stage II propulsion exhibited a decrease in the engine mixture ratio which resulted in a fuel depletion shutdown and an oxidizer outage of about 2000 pounds. The resultant loss in velocity at Titan/Centaur separation was greater than the amount normally allowed for in the Centaur stage propellant margin. Fortunately, the Centaur stage carried an additional propellant margin to allow for launch delay, which became available for Titan margin because the launch occurred at the opening of the launch window.

Discussion

Stage 0 Solid Rocket Motors (SRMs) - The Stage 0 propulsion system was comprised of CSD/UTC solid rocket motors number 67 and 68. The flight propulsion performance parameters as summarized in Table 7-1 were within the specification limits or in the expected range based on normal flight experience. No system anomalies were detected.

The measured Web Action Times (WAT) for SRM's 67 and 68 were 105.8 and 105.3 seconds respectively. Correcting the web action times for the effects of temperature, from 80°F to the nominal 60°F, increased the WAT's to 108.7 and 108.0 seconds respectively, both of which are within the nominal specification values of 106.9 + 2.16 percent seconds at 60°F. The maximum pressure peaks were below specification values for both SRM's. This has been observed for all Titan/Centaur SRM's and was expected. Except for the maximum ignition peaks, the head-end chamber pressures were well within the specification limits as shown by Figures 7-1 and 7-2. The ignition transients were normal and the delay times were within 5 msec of each other for the two motors, as shown in Figure 7-3. The thrust differentials at ignition and shutdown were relatively low.

Stage I and II Prelaunch Operations - The Stage I and II propellant loadings are summarized in Table 7-2a. The loadings were all about 0.1 percent, high which is well within the required limits. The tank pressures (Table 7-2b) at T-20 seconds were all close to the middle of the prelaunch limits for both stages. Stage I propellant temperatures were 81°F and 79°F respectively for the oxidizer and fuel. The target load center temperature was 82.5 ± 7.5 °F. Stage II temperatures were very close to the expected values, being 75.0°F and 79.5°F for oxidizer and fuel respectively. The expected values

were 75°F and 80°F. The prevalve opening times during the countdown were normal and in family for both stages. For Stage II subassemblies 1 and 2 and for Stage II the oxidizer prevalve opening times were 6.96, 6.88 and 7.02 seconds respectively and the fuel prevalve times were 7.44, 7.22 and 7.37 seconds respectively.

TABLE 7-1 - SOLID ROCKET MOTOR PERFORMANCE SUMMARY FOR TC-6

| 1 | | Rocket Mo | tor Specs | | SRM | 67 | | SRM 68 | |
|-----|---|--------------------------------------|------------------------|------------|------------|------------|------------|------------|------------|
| | Parameter | Nominal or Maximum Allowable | Allowable Deviation | Measured | Corrected | Deviation | Measured | Corrected | Deviation |
| | Nominal Data Condition, OF | 60 | | \Diamond | 60 | \Diamond | \Diamond | 60 | \Diamond |
| | Firing Condition, OF | \Diamond | \Diamond | 80 | \Diamond | \Diamond | 80 | \Diamond | \Diamond |
| | Web Action Time, seconds | 106.9 | +2.16% | 105.8 | 108.7 | +1.68% | 105.3 | 108.0 | +1.03% |
| | Action Time, seconds | 116.8 | +3.43% | 116.2 | 119.2 | +2.05% | 116.5 | 119.5 | +2.31% |
| 2,1 | Maximum Forward End Chamber Pressure, psia | 791 | +3.76% | 775 | 755.4 | -4.5% | 760 | 740.7 | -6.36% |
| | N ₂ 0 ₄ Loaded, pounds | 8424 | +42 | 8418 | \Diamond | -6 | 8419 | \Diamond | -5 |
| | Manifold Pressure at Ignition, psia | 1 041 | <u>+</u> 77 | 1084 | \Diamond | +43 | 1070 | \Diamond | +29 |
| | Manifold Pressure at Separation, psia min | 450 | \Diamond | 607 | \Diamond | +157 | 600 | \Diamond | +150 |
| | Thrust Differential During Ignition Transient, lbs max | 168,000 @ 0.17 sec | 54,440 | | | | | | |
| | Thrust Differential During Tail-off, lbs max | 290,000 | 17,700 | | | | 27 10 | | |
| | Time of Separation, sec | \Diamond | 123.3 | | | | | | |
| | Ignition Delay, msec | 150 - | 300 | | 220 | | | 225 | |

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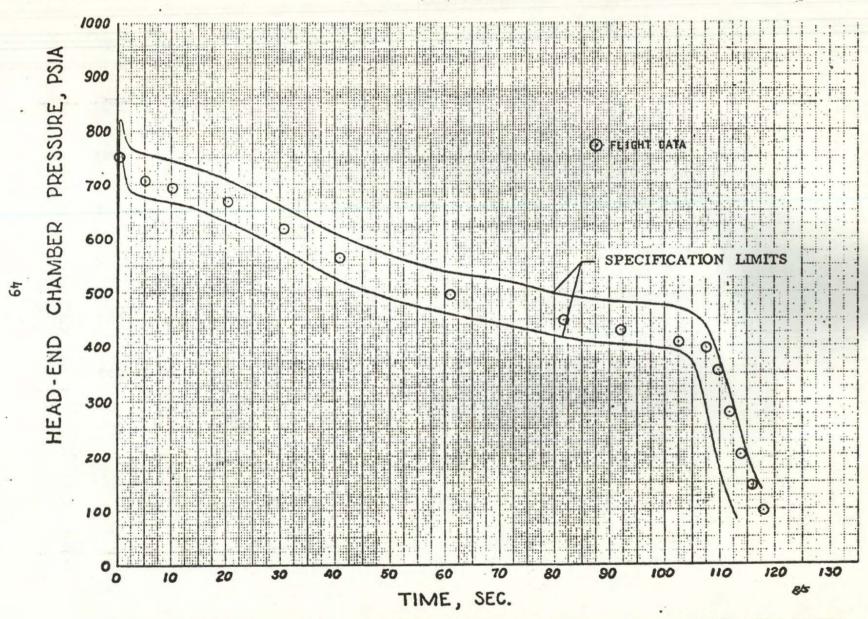


FIGURE 7-1- COMPARISON OF HEAD-END CHAMBER PRESSURE WITH SPECIFICATION LIMITS.
- SRM No.67, TITAN III E - 6. DATA CORRECTED TO 60° F.

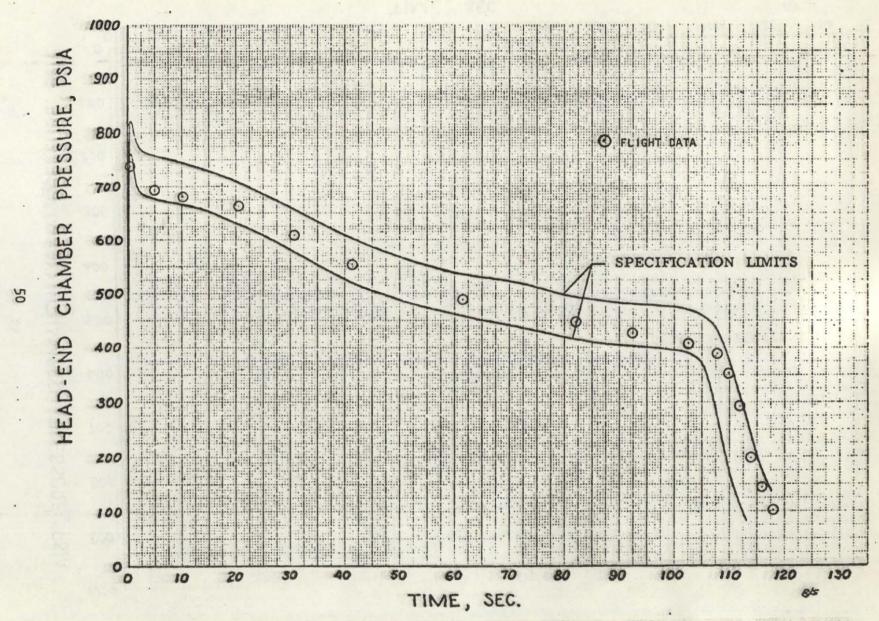


FIGURE 7-2- COMPARISON OF HEAD-END CHAMBER PRESSURE WITH SPECIFICATION LIMITS.

SRM No.68, TITAN III E - 6. DATA CORRECTED TO 60° F.

FIGURE 7-3 - SRM HEAD-END CHAMBER PRESSURE IGNITION TRANSIENTS

TABLE 7-2 - T/C-6 LIQUID PROPULSION SYSTEM DATA

(a) Loaded Propellant Weights

| TITAN | PROPELLANT | UNITS | EXPECTED LOADING | ACTUAL LOADING |
|-------|------------|-------|------------------|----------------|
| | 0xidizer | lbs. | 168353 | 168446 |
| | Fuel | lbs. | 89367 | 89438 |
| | Oxidizer | lbs. | 43013 | 43064 |
| 11 | Fuel | 1bs. | 23864 | 23883 |

(b) Propellant Tank Pressures

| | PROPELLANT TANK | UNITS | PRELA | UNCH | ENGINE OPERATION | | |
|-------|--------------------|-------|-----------------|-----------------------|------------------|--------|--|
| TITAN | | | L IMIT RANGE | VALUE at T-20 Sec. | EXPECTED VALUE | ACTUAL | |
| | 0xidizer | psia | 33.6 - 45.0 | 40.0 | 34.64 | 33.5 | |
| | Fuel | psia | 24.0 - 32.0 | 29.5 | 26.67 | 26.0 | |
| 11 | 0xidizer | psia | 45.0 - 57.0 | 51.0 | 50.55 | 35.8 | |
| | Fuel | psia | 50.0 - 56.0 | 54 | 56.27 | 56.0 | |

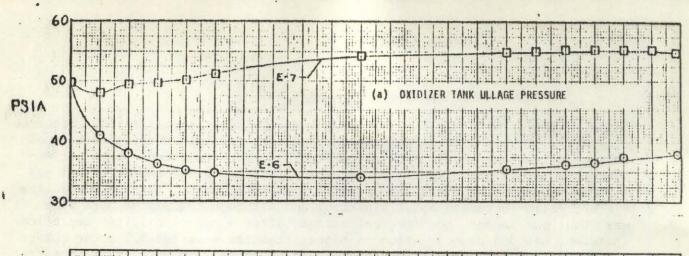
(c) Engine Performane Parameters

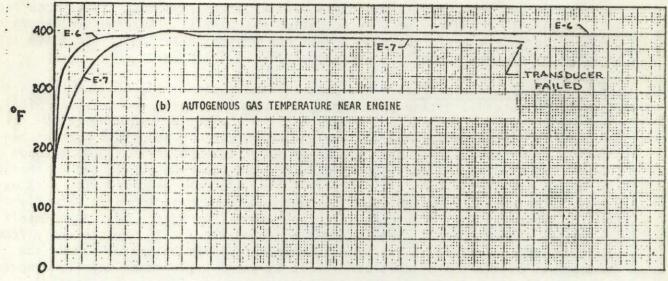
| | | STAGE I | | STAGE 11 | | |
|--|---|--|--|---|--|--|
| PARAMETER | UNITS | EXPECTED VALUE (MMC) | ACTUAL | EXPECTED VALUE (MMC) | ACTUAL | |
| Total thrust Specific impulse Mixture ratio Oxidizer flow rate Fuel flow rate Outage (Fuel) Oxidizer temp. Fuel temperature FS1 to FS2 | lbs. sec. lb/sec. lb/sec. lbs. oF oF sec. | 516528 301.16 1.89 1122 593 472 82.5 82.5 | 519484 301.49 1.91 1125 589 898 81 79 150.09 | 100415 315.38 1.810 204.05 112.72 98 75 80 210.72 | 99622 319.46 1.700 195.46 115.00 2331 (ox.) 75.0 79.5 208.46 | |

Stage I Engine Performance - The Stage I engine start signal (87FS1) occurred at T + 111.33 seconds. Normal start transients for both subassemblies indicated satisfactory jettison of the exit closures. The steady-state performance was smooth and slightly higher than predicted. The engine thrust was about 0.6 percent high and the specific impulse about 0.1 percent high. The mixture ratio increased about 1 percent and although the engine burn time was about one second long the fuel outage, after a normal oxidizer depletion shutdown, was 898 pounds, which is higher than the expected 472 pound outage but much lower than the 3-sigma maximum value of 1923 pounds. 87FS2 occurred at T + 261.42 seconds. The tCPS actuation was normal. There were no anomalies noted in the performance of any of the engine subsystems. The Stage I engine performance parameters are summarized in Table 7-2c.

Stage II Engine Performance - The Stage II start signal (91FS1) occurred at T + 261.42 seconds. Stage I/II separation occurred 0.36 seconds after 91FS1. The engine start transient was normal and the chamber pressure appeared smooth. As shown by Table 7-2c, the engine thrust was about 0.8 percent below the predicted value. The calculated specific impulse of 319.46 seconds was higher than normal and is much greater than could be attributed to changes in the mixture ratio. As indicated in Table 7-2c, the oxidizer flow rate was about 4.2 percent low which would allow the turbopump to speed us slightly and increase the fuel flow rate which was about 2 percent high. As a result of the flow rate changes, the shutdown occurred about 2.26 seconds early from fuel depletion instead of the planned oxidizer depletion shutdown, and the outage was over a ton of oxidizer. This Stage II performance anomaly dropped the overall Titan performance lower than the amount of Centaur propellant margin allowed for this purpose. Fortunately, the Centaur propellant margin was greater than this due to the amount allowed for launch day postponement, and the mission velocity was achieved.

Figure 7-4 shows some of the oxidizer system operating parameters compared with data from TC-7, which was a nearly nominal flight. As can be seen from Figure 7-4a, the oxidizer tank ullage pressure dropped during the first 80 seconds of flight reaching a minimum of about 34 psia. The temperature of the autogenous gas at the MMC/ALRC interface (Figure 7-4b) indicates that the gas temperature was normal and that there was, therefore, no anomalous performance in the autogenous system to this point. The oxidizer temperature measured near the prevalue, as shown in Figure 7-4c, indicates that a rise in the oxidizer temperature started at about 150 seconds into the burn and increased rapidly; whereas the TC-7 data, which is typical of the other E flights, indicates the normal rise in temperature which occurs at about 200 seconds. This temperature phenomena remains to be explained if an ullage gas leak between the interface point and the tank is assumed as the cause for the lower ullage pressures. Failure analysis by MMC also indicated that the ullage pressure drop was not sufficient to reduce the oxidizer flow to its low value. An additional pressure drop of about 15 psi in the oxidizer flow was required. The only failure mode which can account for all of the measured





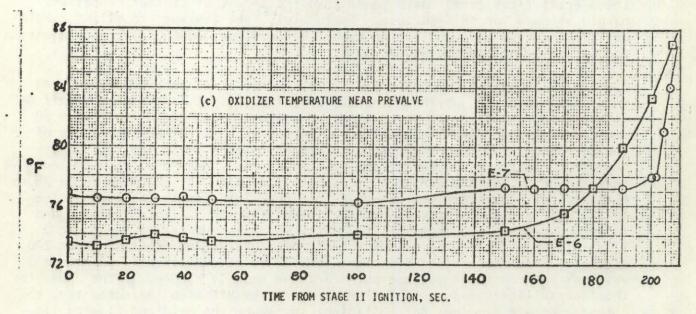


FIGURE 7-4 - VARIATION OF TC-6 STAGE II OXIDIZER PARAMETERS DURING STAGE II BURN

results was determined by MMC to be a loss of the autogenous gas diffuser from the top of the ullage space. If the diffuser drops into the oxidizer line and rests in a certain position on top of the prevalve, the addition pressure drop to reduce the flow rate can be achieved. The direct impingement of the autogenous gas on the oxidizer would also increase condensation of the pressurant and reduce the ullage pressure. Thermodynamic calculations by MMC showed that the amount of heat transferred to heating the Stage II oxidizer, as determined from the temperature data, is equivalent to that which would be required to reduce the ullage pressure by condensation to the observed values. It is interesting to note that the oxidizer outage sensor indication occurred 0.44 seconds after 91FS2, which occurred at T + 469.88 seconds. No other operating anomalies in the Stage II performance were observed.

Titan Hydraulic System

by E. J. Fourney

Summary

Performance of the hydraulic systems on Stage I and Stage II was normal during preflight checkout and the boost phases of TC-6 flight. No anomalies were noted.

Discussion

Performance data for the Titan hydraulic systems are summarized in Table 7-3. All system parameters were nominal and within specification limits. The electric motor driven pumps in each stage supplied normal hydraulic pressure for the flight control system tests performed during launch countdown. Hydraulic reservoir levels were within limits throughout the countdown and flight. Both Stage I and Stage II hydraulic pressure was normal during main pump operation.

Stage I and Stage II actuator peak loads at engine start were nominal and well within the family of Titan data experience (See Table 7-3b).

TABLE 7-3 - TITAN HYDRAULIC SYSTEM DATA FOR TC-6

(a) System Pressure and Reservoir Levels

| | Expected | | Flight Results | | |
|--------------------------|---|--|--|---|--|
| arameters | Units | Values | Stage I | Stage II | |
| Maximum at pump start | psig | 4500 (1) | 3375 | 3915 | |
| Average steady stage | psig | 2900 - 3000 | 2970 | 2957 | |
| Prior to pump start | 8 | 47 - 62 | 49 | 49 | |
| At maximum start press. | 8 | 22 - 47 | 34 | 35 | |
| Average steady stage | 8 | 22 - 47 | 34 | 37.5 | |
| Shutdown minus 5 seconds | 8 | 22 - 47 | 37.5 | 40 | |
| | Maximum at pump start Average steady stage Prior to pump start At maximum start press. Average steady stage | Maximum at pump start psig Average steady stage psig Prior to pump start % At maximum start press. % Average steady stage % | Maximum at pump start psig 4500 (1) Average steady stage psig 2900 - 3000 Prior to pump start % 47 - 62 At maximum start press. % 22 - 47 Average steady stage % 22 - 47 | Maximum at pump start psig 4500 (1) 3375 Average steady stage psig 2900 - 3000 2970 Prior to pump start % 47 - 62 49 At maximum start press. % 22 - 47 34 Average steady stage % 22 - 47 34 | |

(1) proof pressure limit

(b) Actuator Loads

| | St | age Actua | Stage II Ac | tuator Loads | | |
|---------------------|--------------------|--------------------|--------------------|--------------------|-------------------|-------------------|
| Loading | Subasse | mbly #1 | Subassemb | ly #2 | Subass | embly #3 |
| | pitch 1-1 | yaw-roll 2-1 | yaw-roll 3-1 | pitch 4-1 | pitch | yaw-roll |
| TC-6 (E-6) | +11,900 | + 4,200 - 4,200 | +14,000 - 5,600 | + 2,800 | + 1,000 - 750 | + 750 - 1,000 |
| TC-1 to TC-5 max | +10,600 | +12,449 | 12,450 - 6,916 | +12,800 -18,780 | 9,700 - 1,530 | 9,750 - 7,900 |
| Titan Famil | y 14,100 15,400 | 12,500 - 8,151 | 15,400 - 6,920 | +13,030 | 14,400 - 8,750 | 9,750 - 11,184 |

Flight Controls and Sequencing System AAT

by E. S. Jeris

Summary

The flight control system maintained vehicle stability throughout the TC-6 powered flight. All open loop pitch rates and the preprogrammed events were issued as planned. No system or component anomalies occurred. Dump programming of TVC injectant fluid was satisfactory.

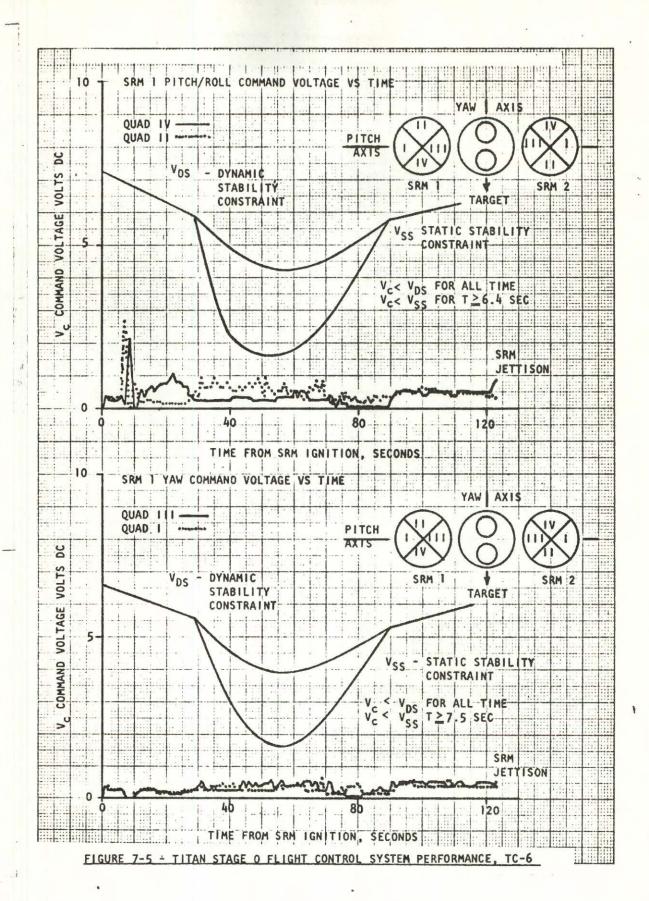
Discussion

Command voltage to each SRM quadrant and the dynamic and static capability limits are shown in Figures 7-5 and 7-6. The stability limits represent the TIIIE-6 side force constraint in terms of TVC system quadrant voltage. This constraint is used in conjunction with launch day wind synthetic vehicle simulations as a go/no-go criterion with respect to vehicle stability and control authority. Simulation responses satisfying the constraint assures a three-sigma probability of acceptable control authority and vehicle stability. Maximum command during Stage O flight was 2.8 volts which is 28 percent of the control system capability and 40 percent of the dynamic stability limit. The peak command occurred at T + 7 seconds for the roll program.

For Stages I and II, the control system limit is the maximum gimbal angle associated with the actuator stop. During Stage I flight, the peak gimbal angle required for control was 7.4 degrees which is 17.8 percent of the maximum gimbal angle. The peak angle was required at T + 130.6 seconds for pitch rate #7 steering command. During Stage II, 4.27 degrees or 12.5 percent of peak gimbal angle was the maximum gimbal angle required at T + 275 seconds, and was used to correct a roll attitude error at shroud jettison.

The control system response to vehicle dynamics was evaluated for each significant flight event. The amplitude, frequency and duration of vehicle transients, and the control system command capability required is shown in Table 7-4.

Both flight programmers and the staging timer issued all preprogrammed discretes at the proper times. The Centaur sent four discretes to the Titan at the proper times. The complete sequence of events with actual and nominal times from SRM ignition is shown in Table 7-5.



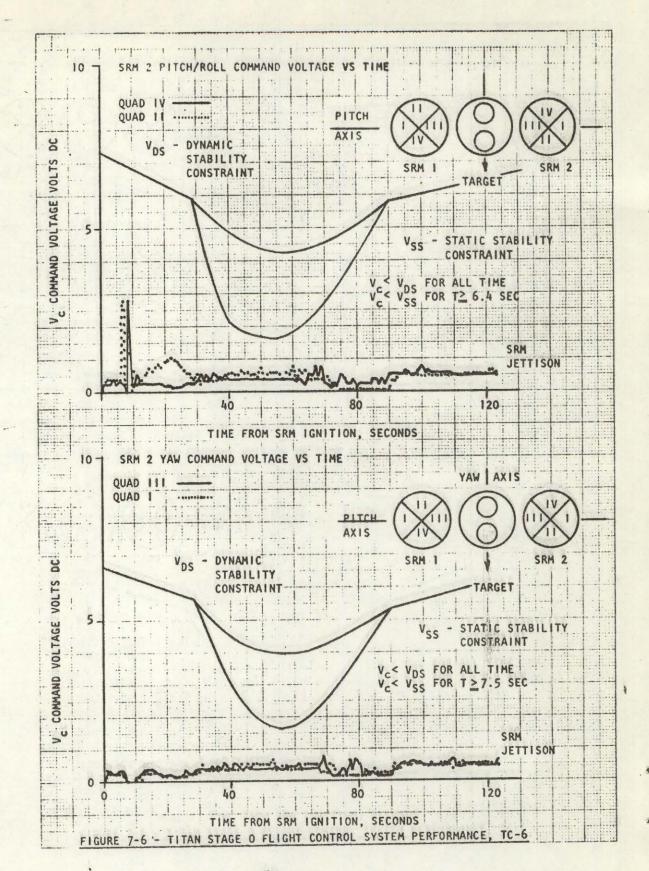


TABLE 7-4 - VEHICLE DYNAMIC RESPONSE FOR TC-6

| EVENT | TIME SEC. | AXIS | ZERO TO PEAK AMPLITUDE DEG./SEC. | TRANSIENT FREQUENCY HZ. | TRANSIENT DURATION SEC. |
|-------------------------------------|--|-------------|--|-------------------------------|-------------------------------|
| Roll Maneuver | T+8 | R | 9.8 | .3 | 5 |
| SRM Jettison Transient | T+123 | R | 6.0 | .33 | 4 |
| Start of PR 7 (Pitch Up Program) | T+130 | Р | 1.08 | Pulse | 2 |
| CSS Jettison | T+272.2 T+272.2 T+272.6 T+275.2 | P R R | .96 2.16 .48 .70 | 10 10 2.5-4 Pulse | .4 |

TABLE 7-5 E-6 FLIGHT SEQUENCE OF EVENTS

T-0 = 12:56:00.958 (SRM Ignition Command)

| Event | Predicted | F/P A | F/P B | S/T | DCU | Other | Delta |
|-----------------------------|-----------|--------|--------|--------|--------|--------|-------|
| Start Roll Program | 6.50 | | | | 6.57 | | +0.07 |
| Stop Roll Program | - | | | | 7.40 | | |
| Pitch Rate 1 | 10.00 | 10.00 | 10.00 | | | | 0.00 |
| Pitch Rate 2 | 20.00 | 19.99 | 19.99 | | | | -0.01 |
| Gain Change 1 | 29.00 | 28.99 | 28.99 | | | | -0.01 |
| Pitch Rate 3 | 30.00 | 29.99 | 29.99 | | | | -0.01 |
| Pitch Rate 4 | 62.00 | 61.99 | 61.99 | | | | -0.01 |
| Gain Change 2 | 70.00 | 69.99 | 69.99 | | | | -0.01 |
| Pitch Rate 5 | 75.00 | 74.98 | 74.99 | | | | -0.02 |
| Gain Change 3 | 90.00 | 89.98 | 89.98 | | | | -0.02 |
| S Pitch Rate 6 | 95.00 | 94.98 | 94.98 | | | | -0.02 |
| Enable F/P B | 96.00 | | 95.98 | | | | -0.02 |
| Stage Start CMD | 109.92 | | 111.30 | 111.36 | | | +1.38 |
| Stage ISDS Safe En | 115.92 | | 117.38 | | | | +1.38 |
| O/I Separation CMD | 121.92 | | 123.31 | 123.32 | | | +1.39 |
| Stage ISDS Safe En | 121.92 | 123.38 | | | | | +1.45 |
| Pitch Rate 7 | 130.00 | 129.98 | 131.11 | | | | -0.02 |
| Pitch Rate 9 | 140.00 | 139.97 | 141.10 | | | | -0.03 |
| Gain Change 5 | 192.00 | 191.96 | 193.30 | | | | -0.04 |
| Gain Change 6 | 232.00 | 231.96 | 233.29 | | | | -0.04 |
| Stage I S/D En | 245.00 | 244.96 | 246.29 | | | | -0.04 |
| Stage S/D/Stage Start | | | | | | 261.43 | +2.39 |
| I/II Separation | 259.83 | | | | | 262.18 | +2.35 |
| CSS Sep Prim | 269.04 | | | | 272.24 | | +3.20 |
| CSS Sep Sec | 269.54 | | | | 272.74 | | +3.20 |
| CSS Sep B/U | 288.83 | | | 291.23 | | | +2.40 |
| Remove GC7, PR10 | 310.00 | 309.95 | 311.09 | | | | -0.05 |
| Gain Change 8 | 340.00 | 339.94 | 341.28 | | | | -0.06 |
| Gain Change 9 | 400.00 | 399.93 | 401.27 | | | | -0.07 |
| Stage II S/D En | 448.00 | 447.92 | 448.37 | | | | -0.08 |
| Stage II S/D | 470.73 | 470.21 | | | 469.87 | | -0.52 |
| Stage II/Cen Sep | 475.86 | 477.61 | | | 474.99 | | -0.87 |
| | | | | | | | |

Titan Electrical/Electronic Systems

Solid Rocket Motor Electrical System

by B. L. Beaton

Summary

For TC-6, the Solid Rocket Motor (SRM) electrical system was identical to that flown on all previous TC vehicles. The SRM electrical system performance was satisfactory with no anomalies. All power requirements of the SRM electrical system were satisfied.

Discussion

The SRM electrical system supplied the requirements of the dependent systems at normal voltage levels. The SRM electrical system performance is summarized in Table 7-6.

The Titan core transfer shunt indicated 0.6 amps for approximately 400 ms at SRM ignition. This condition was experienced on all previous TC vehicles. It is caused by a short from an SRM igniter bridgewire positive to structure and simultaneous shorting from the transient return to readiness return within the igniter safe and arm device. The transfer current dropped to zero simultaneous with the removal of the current path when the SRM umbilicals were ejected. This condition had no adverse effect on any airborne system.

TABLE 7-6 - SRM ELECTRICAL SYSTEM PERFORMANCE SUMMARY

| | | | POWER ON INTERNAL | LIFT-OFF | SRM JETTISON |
|---|---------------------------|-------|-------------------|----------|-----------------|
| | TVC VOLTAGE | SRM-1 | 31.4 | 32.0 | 31.6 |
| | | SRM-2 | 31.2 | 31.6 | 31.2 |
| | AIPS VOLTAGE | SRM-1 | 29.0 | 29.4 | 29.4 |
| 2 | | SRM-2 | 28.6 | 29.2 | 29.6 |
| | INSTRUMENTATION REGULATED | SRM-1 | 10.0 | 10.0 | 10.0 |
| | BUS VOLTAGE | SRM-2 | 9.9 | 9.9 | 9.9 |
| | BUS VOLTAGE | SRM-2 | 9.9 | 9.9 | 9.9 |

9

Titan Core Electrical System

by B. L. Beaton

Summary

For TC-6, the Titan electrical system was identical to that flown on all previous TC vehicles. The core electrical system performance was satisfactory with no anomalies. All power requirements of the core electrical system were satisfied. All voltage and current measurements indicated expected values. Some bridgewire shorting (after initiation) was observed at every ordnance event.

Discussion

The Titan core electrical system supplied the requirements of the dependent systems at normal voltage and current levels. The Titan core electrical system performance is summarized in Table 7-7.

The 800 Hz squarewave output of the static inverter was 37.9 volts during the entire flight.

The TPS bus voltage was 34.4 volts d-c at TPS bus enable and 35.3 volts d-c at Titan/Centaur staging.

The TPS bus voltage and pyrotechnic firing currents during ordnance events are summarized in Table 7-8.

The transfer current indicated 0.6 amps at T-O as previously discussed under SRM electrical system performance. The transfer current indicated that during short periods of high current demand on the APS bus the IPS battery provided load sharing.

TABLE 7-7 - TITAN CORE VEHICLE ELECTRICAL SYSTEM PERFORMANCE SUMMARY

| | | POWER ON INTERNAL | LIFT-OFF | ENABLE TPS | STAGE I START | STG 0/1 SEP | STG 1/11 SEP | CSS JETTISON | STG II | T/C STAGING |
|----|------------------|----------------------|----------|------------|------------------|----------------|-----------------|-----------------|--------|----------------|
| | APS VOLTAGE | 28.7 | 28.7 | 28.6 | 28.0 | 28.1 | 27.8 | 28.3 | 28.4 | 28.0 |
| | APS CURRENT | 7.5 | 7.6 | 8.0 | 9.5 | 10.0 | 12.5 | 7.7 | 9.0 | 9.2 |
| 66 | IPS VOLTAGE | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.0 | 29.1 | 29.1 | 29.1 |
| | IPS CURRENT | 8.5 | 8.3 | 8.4 | 8.4 | 8.4 | 8.5 | 7.7 | 7.7 | 7.7 |
| | TRANSFER CURRENT | 0 | 0.6 | 0 | 0.3 | 0 | 0.5 | 0 | 0 | 0 |
| | TPS VOLTAGE | 0 | 0 | 34.4 | 34.4 | 34.4 | 34.6 | 34.7 | 35.3 | 35.3 |

TABLE 7-8 - TITAN CORE VEHICLE PYROTECHNIC SYSTEM

| | STAGE I START | STG 0/1 SEP | STAGING MOTORS | STG 1/11 SEP | JETTISON | T/C STAG. & RETROROCKETS | T/C STAGING |
|---------------|------------------|----------------|-------------------|-----------------|----------|--------------------------|----------------|
| 5 TPS VOLTAGE | 28.4 | 27.4 | 27.4 | 26.2 | 29.9 | 29.6 | 29.6 |
| TPS CURRENT | 26.3 | 174.8 | 244.3 | 246.7 | 27.7 | 57.4 | 28.1 |

Titan Instrumentation

by J. Bulloch

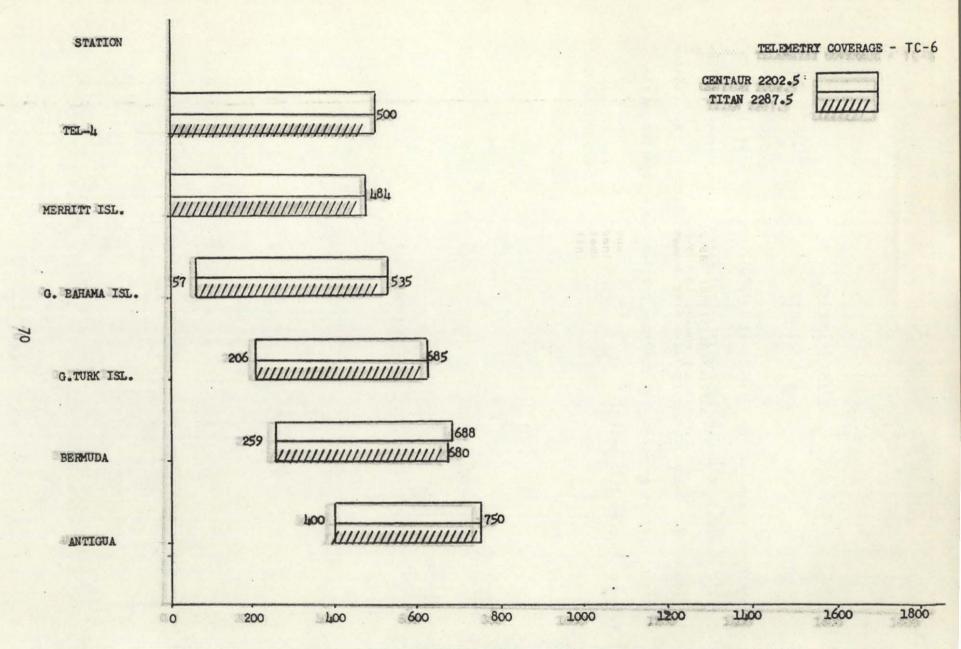
During the TC-6 flight, a total of 197 measurements were telemetered by the Titan Remote Multiplexed Instrumentation System. Only the following measurement exhibited data anomalies during the flight.

1. TP3029P (Stage II Oxidizer Discharge Pressure 0 to 2000 psia) and TP3030P (Stage II Fuel Discharge Pressure 0 to 2000 psia) appear to be interchanged. The most probable cause is miswiring at the transducer. No data was lost because of the anomaly.

Titan Telemetry

by T. J. Hill

Telemetry coverage for the Titan E6 vehicle was provided from liftoff to T + 750 seconds. A summary of the Titan Telemetry link coverage is given in Figure 7-7. Operation of the Titan S-Band Transmitter and R.F. System components was as expected. No coverage problems were reported by the Telemetry Ground Stations.



FLIGHT TIME - SECONDS
FIGURE 7-7 - TC-6 TELEMETRY COVERAGE

Titan Flight Termination System

by T. J. Hill

The Titan E6 Flight Termination System performance was nominal throughout the flight. Receiver Automatic Gain Control (AGC) voltages, monitored by Telemetry, indicated that sufficient signal was present throughout the powered flight to assure that any engine shutdown or distruct command would have been properly executed. A SAFE command was sent by Antigua at T + 600 seconds.

The Range Safety Command battery voltages were nominal at liftoff, and remained steady throughout the flight. The commands from the Flight Programmer to SAFE the stage I and stage II SRM Inadvertant Separation Destruct System (ISDS) were issued at their expected times. The Flight Programmer also issued the command to SAFE the Destruct Initiator on stage II prior to the Titan/Centaur separation.

VIII CENTAUR D-1 SYSTEMS ANALYSIS

VIII CENTAUR D-1T SYSTEMS ANALYSIS

Mechanical Systems

Airframe Structures

By T. L. Seehoizer and R. C. Edwards

Summary

The Centaur D-1T structural configuration for the TC-6 vehicle was similar to the TC-5 vehicle. The ISA satisfactorily transferred all Centaur and CSS loadings onto the Titan skirt structure. The ISA forward ring was completely severed at Titan/Centaur staging and the vehicles separated at a constant acceleration.

The ullage pressures in the Centaur propellant compartments were with in prescribed limits. Sufficient pressure was maintained to prevent buckling and maximum pressures did not exceed burst limits of the tank structure.

Discussion

Interstage Adapter - Titan/Centaur separation occurred at T + 474.10 seconds. Initial motion was at approximately T + 474.34 seconds. The interstage adapter cleared the Centaur vehicle 1.66 seconds after separation. The 15-foot extensiometer (yo-yo) between the ISA and the Centaur indicated a smooth normal separation (Figure 8-1).

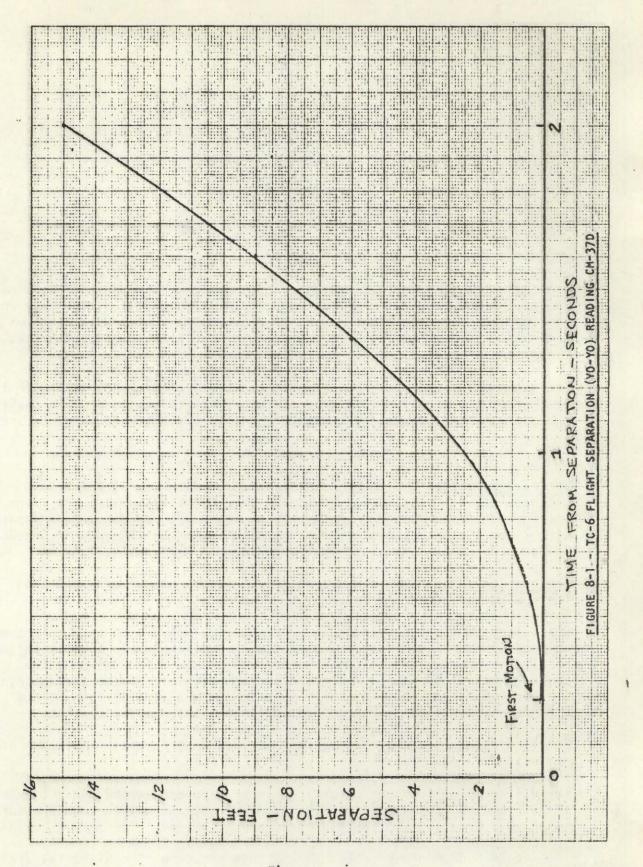
Centaur Tank - The liquid hydrogen tank pressure was always less than the maximum allowable pressure of 29.2 psid.

Sufficient pressure was maintained in the liquid hydrogen tank to prevent compressive buckling of the pressure stabilized tank skin for all periods of flight. During the critical compressive loading at lift-off, the pressure was 24.45 psia. The hydrogen tank pressure during the aerodynamic phase of flight (T + 10 to T + 90 seconds) was similar to previous Titan/Centaur flights and provided sufficient compressive strength.

The liquid oxygen tank pressure was within the structural limits for all periods of flight.

The differential pressure across the intermediate bulkhead did not exceed the structural limit of 23.0 psi. As required, the oxygen tank pressure was always greater than the hydrogen tank pressure.

The liquid hydrogen and oxygen tank ullage pressure time histories are listed in the Centaur D-1T pneumatics section of this report. See Figures 8-7.1 through 8-7.6.



CENTAUR MAIN PROPULSION

by W. K. Tabata

Summary

The Centaur main engines consisting of P&WA RL10A-3-3 engines S/N P641995 performed satisfactorily during the prelaunch operations and inflight for TC-6.

Discussion

<u>Liquid Helium Prechill</u> - Liquid helium prechill of the engine fuel pumps was satisfactory. There was no difficulty in maintaining the fuel pump housing temperatures below the 100°R redline value during the launch countdown. The C-1 and C-2 engine fuel and oxidizer pump housing temperatures and the fuel turbine inlet temperatures at liftoff are listed in Table 8-1. All temperatures were within the experience of previous Centaur launches.

Prestart for MES #1 - The first-burn engine cooldown was satisfactory. The C-1 and C-2 engine fuel and oxidizer pump housing temperatures and the fuel turbine inlet temperatures at the beginning of the first-burn prestart are listed in Table 8-1. All the temperatures were within the range of previous Centaur launches.

The fuel and oxidizer pump housing temperature probes exhibited good response. The temperature transients during the first-burn prestart are shown in Figure 8-2. The difference between C-1 and C-2 engine fuel pump housing temperature transient is probably due to variations in the application of "Silver Goop" thermal grease. This type of variation has been observed on previous flights. The response of the engine pump housing temperature probes agree well with TC-7 flight data.

The 7^oR temperature rise indicated by the C-2 engine fuel pump housing temperature probe at engine start signal plus 2 seconds is due to the temperature rise across the first-stage of the fuel pump at steady state operation.

Prestart for MES #2 - Engine cooldown prior to second-burn on the Voyager missions consisted of a new operational sequence demonstrated on the TC-5 Helios-B post-mission experiments. The sequence consisted of duct prechill for 10 seconds at MES #2 minus 47 seconds and then a normal engine prestart for 9 seconds prior to engine start. Duct prechill consisted of flowing from the Centaur propellant tanks through the RL10A-3-3 engines without tank pressurization or boost pumps operating. The 9 seconds of prestart was a reduction from the 17 seconds normally used for second-burn because the duct prechill does cooldown the engine pumps as well as the ducts.

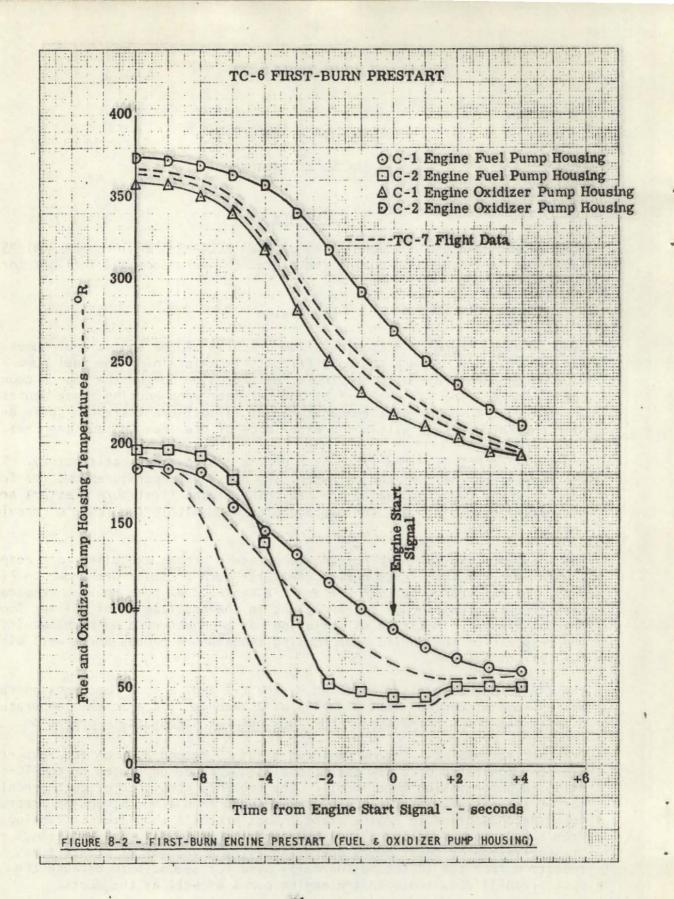


TABLE 8-1 - RL10 ENGINE TEMPERATURES FOR TC-6

| | AT LIF | TOFF(T-0) | AT PRES | TART #1 | AT PRESTA | RT #2 (a) |
|----------------------------|----------|-----------|----------|-----------|-----------|-----------|
| MEASUREMENT | MEASURED | EXPECTED | MEASURED | EXPECTED | MEASURED | EXPECTED |
| C-1 Fuel Pump Hsg, OR | 64 | 60 - 100 | 186 | 180 - 210 | 256 / 146 | 200 - 283 |
| C-1 Fuel Pump Hsg (B/U) | 70 | 60 - 100 | 186 | 180 - 210 | NAV / NAV | 200 - 283 |
| C-2 Fuel Pump Hsg, OR | 74 | 60 - 100 | 198 | 180 - 210 | 261 / 149 | 200 - 283 |
| C-2 Fuel Pump Hsg (B/U) | 70 | 60 - 100 | 194 | 180 - 210 | 257 / 151 | 200 - 283 |
| C-1 Ox Pump Hsg, OR | 388 | 380 - 430 | 357 | 350 - 400 | 343 / 334 | 253 - 350 |
| C-2 Ox Pump Hsg, OR | 413 | 380 - 430 | 374 | 350 - 400 | 349 / 337 | 253 - 350 |
| C-1 Fuel Turbine Inlet, OR | 350 | 315 - 420 | 355 | 350 - 400 | 295 / 299 | 300 - 360 |
| C-2 Fuel Turbine Inlet, OR | 381 | 315 - 420 | 388 | 350 - 400 | 307 / 310 | 300 - 360 |

NOTE: (a) Two temperatures are quoted. The first value is at start of duct prechill (MES #2 minus 47 seconds) and the second value is at beginning of engine prestart (MES #2 minus 9 seconds).

The new second-burn engine cooldown sequence was satisfactory. The C-1 and C-2 engine fuel and oxidizer pump housing temperatures and the fuel turbine inlet temperatures at the beginning of the duct prechill and at the beginning of second-burn engine prestart are listed in Table 8-1. All temperatures were within the expected ranges.

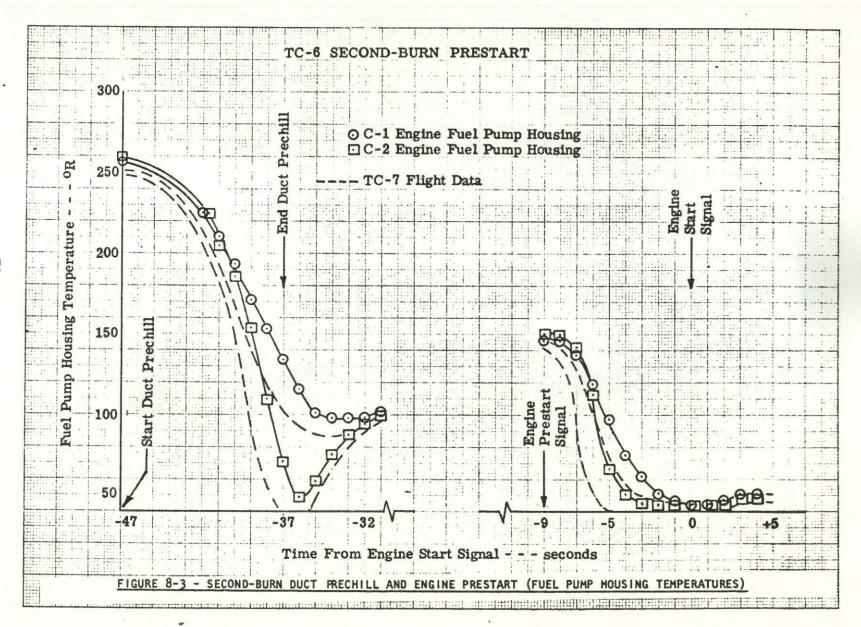
The fuel and oxidizer pump housing temperature and the fuel turbine inlet temperature transients during the duct prechill and engine prestart are shown in Figures 8-3, 8-4, and 8-5, respectively. All temperature transients were as expected and agreed well with the TC-7 flight data.

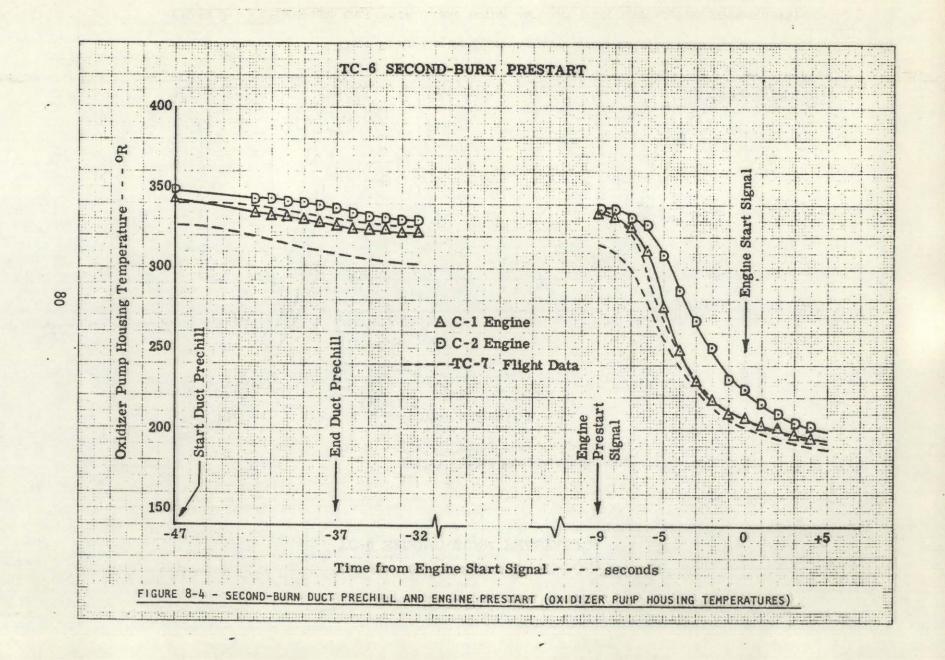
Engine Start Transients - Engine ignition and start transients were normal for both burns with no unusual characteristics observed. Engine acceleration times to 90 percent rated thrust and start total impulses for both engines and for both burns are listed in Table 8-2.

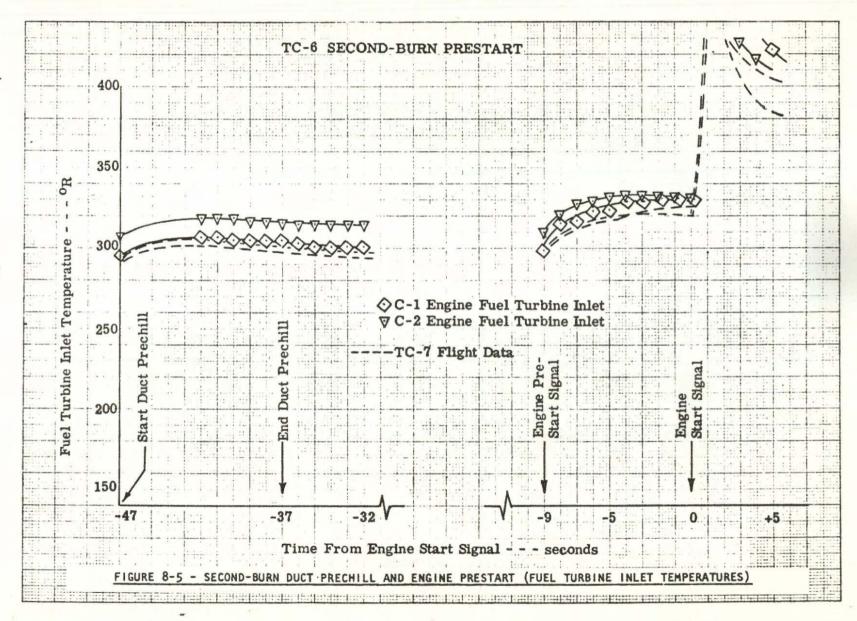
Steady State Operation - Steady state engine operation was normal for both burns. Engine parameters measured inflight compare well with engine acceptance test values (Table 8-3). Steady state engine performance values as calculated by Pratt & Whitney Aircraft Group are tabulated in Table 8-4.

First-burn was 17.8 seconds longer than predicted and second-burn was 17.4 seconds shorter than predicted. The reasons for these burn times were due to the Titan Stage II problem and are discussed in more details in the Performance Section IV of this report.

Shutdown Transients - Engine shutdown transients for both engines were normal for both burns. There were no unusual characteristics observed.







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⁽a) Values are from Pratt & Whitney Aircraft analyses

TABLE 8-3 - RL10 ENGINE STEADY-STATE PERFORMANCE FOR TC-6

| MEASUREMENT | MECO #1 | MECO #2 | ACCEPTANCE TEST | MEASUREMENT ACCURACY |
|--------------------------|---------|---------|--------------------|-------------------------|
| C-1 Chamber Press., psia | 390 | 390 | 392.5 | + 10 |
| C-2 Chamber Press., psia | 398 | 398 | 397.0 | <u>+</u> 10 |
| C-1 Ox Pump Speed, rpm | 12,525 | 12,375 | 12,477 | + 600 |
| C-2 0x Pump Speed, rpm | 12,300 | 12,150 | 12,421 | <u>+</u> 600 |
| C-1 Venturi Press., psia | 765 | 765 | 750 | <u>+</u> 30 |
| C-2 Venturi Press., psia | 750 | 755 | 747 | <u>+</u> 30 |
| C-1 Turbine Temp., R | 393 | 385 | 387.0 | <u>+</u> 16 |
| C-2 Turbine Temp., OR | 389 | 375 | 381.5 | <u>+</u> 16 |
| C-1 Ox Pump Disch., psia | 612 | 608 | 620 | <u>+</u> 16 |
| C-2 Ox Pump Disch., psia | 604 | 596 | 610 | + 16 |

TABLE 8-4 - RL10 ENGINE CALCULATED STEADY-STATE PERFORMANCE FOR TC-6

| PARAMETER | MECO #1 | MECO #2 | ACCEPTANCE TEST |
|------------------------|---------|---------|--------------------|
| C-1 Engine | | | |
| Thrust, 1bs. | 14,807 | 14,883 | 14,974 |
| Specific Impulse, sec. | 441.5 | 441.7 | 441.3 |
| Mixture Ratio | 4.90 | 4.86 | 5.01 |
| C-2 Engine | | | |
| Thrust, 1bs. | 15,073 | 15,242 | 15,091 |
| Specific Impulse, sec. | 441.1 | 441.3 | 441.3 |
| Mixture Ratio | 5.03 | 4.97 | 4.99 |

⁽a) Values are from Pratt & Whitney Aircraft analyses (C* Iteration).

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Centaur Hydraulic System

by E. J. Fourney

Summary

Centaur hydraulic system performance was normal throughout the TC-6 flight. The recirculation pumps functioned properly prior to engine starts. Main system performance was satisfactory. No anomalies were noted.

Discussion

Prior to main engine start, MES #1 and #2, pressure and flow to null the engines was supplied by the airborne electric driven recirculation pumps. At main engine start for both burns the engine driven pumps furnished the pressure and flow required to properly position the engines.

At MES #1 and #2, the start up transients were normal. At MECO #1 and MECO #2 the shutdown transients were normal. System operation was normal during the engine firing times and there were no anomalies.

A summary of flight performance data for selected discrete flight times is contained in Table 8-5.

TABLE 8-5 - CENTAUR HYDRAULIC SYSTEM TC-6 FLIGHT PERFORMANCE

| | | Hydraul | ic Press, | psia | Manifo | ld Temp, | °F |
|--------------------|------------------|--------------------------------|------------------------|------------------------|--------------------|------------------------|------------------------|
| Flight Sequence | Parameters | Expected Values (approx) | CH 1P C-1 Engine | CH 3P C-2 Engine | Expected Values | CH 5T C-1 Engine | CH 6T C-2 Engine |
| | Recirc motors on | 100- 140 | 127 | 135 | 180 max | 60° | 580 |
| First Burn | MES - 1 | 1110-1150 | 1140 | 1140 | 180 max | 58° | 58° |
| Burn | MECO - 1 | 1110-1150 | 1140 | 1125 | 180 max | 58° | 58° |
| | Recirc motors on | 100- 140 | 127 | 135 | 180 max | 87° | 72° |
| Second | MES - 2 | 1110-1150 | 1133 | 1140 | 180 max | 82° | 72° |
| Burn | MECO - 2 | 1110-1150 | 1140 | 1125 | 180 max | 153° | 153° |

Centaur Pneumatics

by R. A. Corso and R. F. Lacovic

Summary

The pneumatic system performed satisfactory throughout the TC-6 flight. The tank pressures and propulsion pneumatic control pressures were within predicted values.

Discussion

Configuration - The Centaur pneumatic system which is shown schematically in Figure 8-6 was the same as TC-3 except a smaller helium bottle was used. Its nominal volume was 4350 cubic inches versus the standard 7365 cubic inch bottle. The smaller bottle was used to save weight, 29 pounds.

Propellant Tank Pressurization and Venting - Performance data for the pneumatic system during the flight are summarized in Tables 8-6, 8-7, and 8-8; and a time history of the propellant tank ullage pressures during the flight is shown in Figures 8-7.1 through 8-7.6.

The hydrogen tank pressure, as regulated by the primary vent valve, prior to lockup at T-27 seconds was 21.21 psia. The primary hydrogen vent valve was locked to allow the tank pressure to rise in order to satisfy the tank structural strength requirements during liftoff and during the subsonic portion of the flight.

At liftoff, the LH2 tank pressure requirement was 23.5 to 25.1 psia. Tank pressure after vent valve lockup was monitored by the computer controlled vent and pressurization system (CCVAPS). A final liftoff pressure check by CCVAPS at T-8 seconds projected a 24.5 psia pressure at T-0. The actual liftoff tank pressure was 24.55 psia.

The tank pressure profiles during the boost phase are shown in Figures 8-7.1 and 8-7.2. The LH2 tank pressure increased to a maximum of only 25.3 psia, which was less than the minimum cracking pressure of the secondary vent valve. At T + 90 seconds, the primary hydrogen vent valve was unlocked allowing the tank pressure to vent down to the primary vent valve operating range of 19 to 21.5 psia. The tank pressure was then controlled within this range until the start of tank pressurization for the first main engine start. At this time both vent valves were locked. Operation of the vent valve was satisfactory throughout flight.

The oxygen tank pressure at liftoff was 30.4 psia. During the boost phase, the oxygen tank vent valve maintained the tank pressure between 29 and 32

FIGURE 8-6 - CENTAUR PNEUMATIC SYSTEM

TABLE 8-6 - PNEUMATIC SYSTEM DATA SUMMARY FOR TC-6

| | Units | Control Range | T-0 | Start PRTZN #1 | MES #1 | MECO #1 | Start PRTZN # | MES #2 #2 | MECC #2 | |
|-----------------------------|---|--|--|--|---|--|---|--|---|--|
| LO2 Tank Ullage Pressure | psia | 29-32 | 30.4 | 31.2 | 39.1 | 29.9 | 32.1 | 36.0 | 24.8 | |
| LO2 Tank Ullage Temperature | °F | Ref. Data | -283.4 | -283.2 | -282.2 | -282.2 | -284.2 | -280.7 | -288.1 | |
| LH2 Tank Ullage Pressure | psia | 19-21.5 | 24.45 | 20.6 | 27.6 | 26.6 | 20.2 | 23.5 | 12.8 | |
| LH2 Tank Ullage Temperature | °F | Ref. Data | -404.4 | -420.8 | -276.4 | -276.4 | -420.8 | -291.4 | -374-2 | |
| Eng.Ctl. Reg. Outlet Press. | psig | 440-475 | 451.2 | 449.6 | 453.8 | 453.8 | 461.7 | 462.9 | 462.9 | |
| Att.Ctl. Reg. Outlet Press. | psig | 297-315 | 310.6 | 311.4 | 311.0 | 311.4 | 310.6 | 310.6 | 311-4 | |
| Helium Bottle Pressure | psia | * | 3308 | 3272 | 2590 | 2590 | 2485 | 1610 | 1732 | |
| Helium Bottle Temperature | °F | * | 79 | 75 | 48 | 47 | 57 | 33 | 22 | |
| Aft Pneumatic Panel | ° _F | Ref. Data | 57 | 47 | 47 | 47 | 72 | 72 | 85 | |
| | LO2 Tank Ullage Temperature LH2 Tank Ullage Pressure LH2 Tank Ullage Temperature Eng.Ctl. Reg. Outlet Press. Att.Ctl. Reg. Outlet Press. Helium Bottle Pressure Helium Bottle Temperature | LO2 Tank Ullage Temperature OF LH2 Tank Ullage Pressure psia LH2 Tank Ullage Temperature OF Eng.Ctl. Reg. Outlet Press. psig Att.Ctl. Reg. Outlet Press. psig Helium Bottle Pressure psia Helium Bottle Temperature OF | LO2 Tank Ullage Temperature OF Ref. Data LH2 Tank Ullage Pressure psia 19-21.5 LH2 Tank Ullage Temperature OF Ref. Data Eng.Ctl. Reg. Outlet Press. psig 440-475 Att.Ctl. Reg. Outlet Press. psig 297-315 Helium Bottle Pressure psia * Helium Bottle Temperature OF * | LO2 Tank Ullage Temperature OF Ref. Data -283.4 LH2 Tank Ullage Pressure psia 19-21.5 24.45 LH2 Tank Ullage Temperature OF Ref. Data -404.4 Eng.Ctl. Reg. Outlet Press. psig 440-475 451.2 Att.Ctl. Reg. Outlet Press. psig 297-315 310.6 Helium Bottle Pressure psia * 3308 Helium Bottle Temperature OF * 79 | LO2 Tank Ullage Temperature OF Ref. Data -283.4 -283.2 LH2 Tank Ullage Pressure psia 19-21.5 24.45 20.6 LH2 Tank Ullage Temperature OF Ref. Data -404.4 -420.8 Eng.Ctl. Reg. Outlet Press. psig 440-475 451.2 449.6 Att.Ctl. Reg. Outlet Press. psig 297-315 310.6 311.4 Helium Bottle Pressure psia * 3308 3272 Helium Bottle Temperature OF * 79 75 | LO2 Tank Ullage Temperature OF Ref. Data -283.4 -283.2 -282.2 LH2 Tank Ullage Pressure psia 19-21.5 24.45 20.6 27.6 LH2 Tank Ullage Temperature OF Ref. Data -404.4 -420.8 -276.4 Eng.Ctl. Reg. Outlet Press. psig 440-475 451.2 449.6 453.8 Att.Ctl. Reg. Outlet Press. psig 297-315 310.6 311.4 311.0 Helium Bottle Pressure psia * 3308 3272 2590 Helium Bottle Temperature OF * 79 75 48 | LO2 Tank Ullage Temperature OF Ref. Data -283.4 -283.2 -282.2 -282.2 LH2 Tank Ullage Pressure psia 19-21.5 24.45 20.6 27.6 26.6 LH2 Tank Ullage Temperature OF Ref. Data -404.4 -420.8 -276.4 -276.4 Eng.Ctl. Reg. Outlet Press. psig 440-475 451.2 449.6 453.8 453.8 Att.Ctl. Reg. Outlet Press. psig 297-315 310.6 311.4 311.0 311.4 Helium Bottle Pressure psia * 3308 3272 2590 2590 Helium Bottle Temperature OF * 79 75 48 47 | LO2 Tank Ullage Temperature OF Ref. Data -283.4 -283.2 -282.2 -282.2 -284.2 LH2 Tank Ullage Pressure psia 19-21.5 24.45 20.6 27.6 26.6 20.2 LH2 Tank Ullage Temperature OF Ref. Data -404.4 -420.8 -276.4 -276.4 -420.8 Eng.Ctl. Reg. Outlet Press. psig 440-475 451.2 449.6 453.8 453.8 461.7 Att.Ctl. Reg. Outlet Press. psig 297-315 310.6 311.4 311.0 311.4 310.6 Helium Bottle Pressure psia * 3308 3272 2590 2590 2485 Helium Bottle Temperature OF * 79 75 48 47 57 | LO2 Tank Ullage Temperature OF Ref. Data -283.4 -283.2 -282.2 -282.2 -284.2 -280.7 LH2 Tank Ullage Pressure psia 19-21.5 24.45 20.6 27.6 26.6 20.2 23.5 LH2 Tank Ullage Temperature OF Ref. Data -404.4 -420.8 -276.4 -276.4 -420.8 -291.4 Eng.Ctl. Reg. Outlet Press. psig 440-475 451.2 449.6 453.8 453.8 461.7 462.9 Att.Ctl. Reg. Outlet Press. psig 297-315 310.6 311.4 311.0 311.4 310.6 310.6 Helium Bottle Pressure psia * 3308 3272 2590 2590 2485 1610 Helium Bottle Temperature OF * 79 75 48 47 57 33 | LO2 Tank Ullage Temperature OF Ref. Data -283.4 -283.2 -282.2 -282.2 -284.2 -280.7 -288.1 LH2 Tank Ullage Pressure psia 19-21.5 24.45 20.6 27.6 26.6 20.2 23.5 12.3 LH2 Tank Ullage Temperature OF Ref. Data -404.4 -420.8 -276.4 -276.4 -420.8 -291.4 -374.2 Eng.Ctl. Reg. Outlet Press. psig 440-475 451.2 449.6 453.8 453.8 461.7 462.9 462.9 Att.Ctl. Reg. Outlet Press. psig 297-315 310.6 311.4 311.0 311.4 310.6 310.6 311.4 Helium Bottle Pressure psia * 3308 3272 2590 2590 2485 1610 1732 Helium Bottle Temperature OF * 79 75 48 47 57 33 22 |

^{*} Not Applicable

| Pressurization Control Constant | Units | LH2 Ta | ank | | LO2 Tank |
|----------------------------------|-------|--------------------|------------|------------|------------|
| AND VANDICADIE | | Pre MES #1 | Pre MES #2 | Pre MES #1 | Pre MES #2 |
| Initial Pressure | psia | 20.74 | 20.17 | 31.1 | 32.15 |
| Closing Pressure | psia | (1) 26.74/27.7 (2) | 23.73 (3) | 39.30(4) | 36.11 (5) |
| Tank Pressure Increase | psi | 6.00 | 3.56 | 8.10 | 3.96 |
| CCVAPS Closing Pressure Criteria | | Pmax | Pclose | Pmax | Pclose |
| Maximum Overshoot, Pos | psi | 0.74 | 0.35 | 0.45 | 0.32 |
| Maximum Undershoot, Pus | psi | 0.90 | 0 | 0.25 | 0.02 |

TABLE 8-8 - CCVAPS TANK VENTING PARAMETER FOR TC-6

| Vent Control Pressures, 1st Coast | Units | Time Period | LH2 Tank | LO2 Tank |
|--|-------|-------------------|----------|----------|
| Pressure at Vent Control Initiation | psia | MECO #1 + 30 sec. | 19.5 | 31.3 |
| Pressure at start of propellant settling | psia | MES #2 - 600 sec. | 21.1 | 33.0 |
| Pressure at Vent Initiation | psia | MES #2 - 120 sec. | 20.3 | 32.2 |
| Pressure at end of Vent Control | psia | MES #2 - 96 sec. | 20.3 | 32.2 |

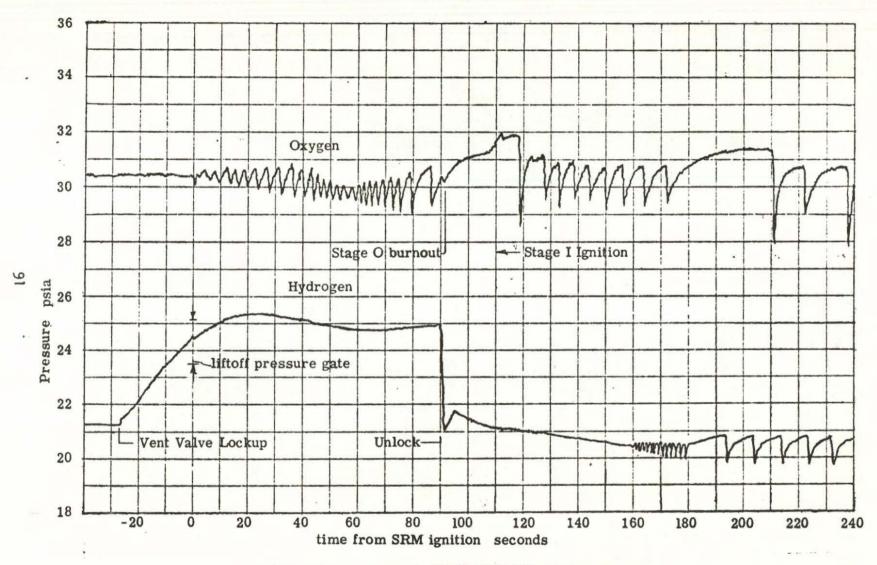


FIGURE 8-7.1 - CENTAUR PROPELLANT TANK ULLAGE PRESSURES

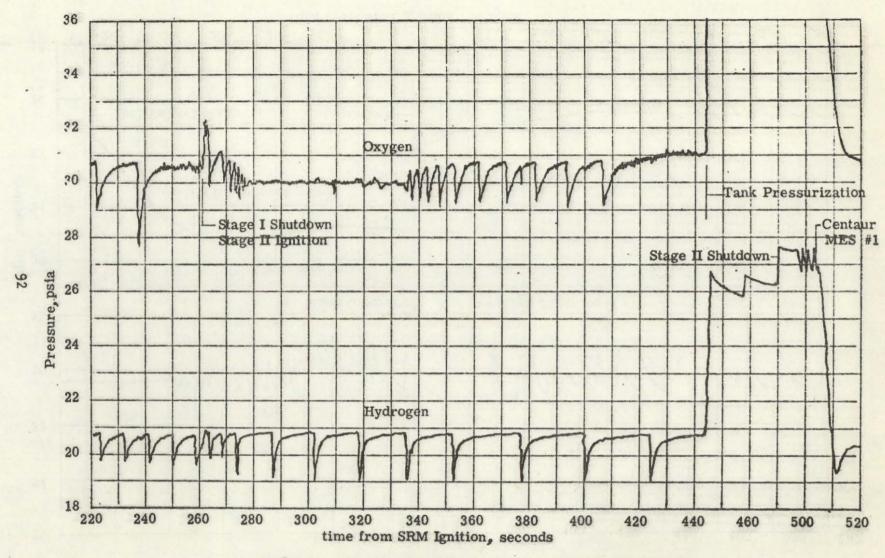


FIGURE 8-7.2 - CENTAUR PROPELLANT TANK ULLAGE PRESSURE (CONTINUED)

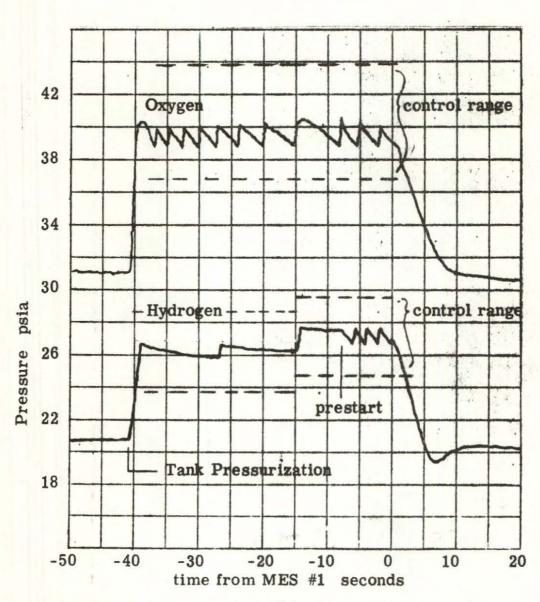


FIGURE 8-7.3 - CENTAUR PROPELLANT TANK ULLAGE PRESSURE (CONTINUED)

FIGURE 8-7.4 - CENTAUR PROPELLANT TANK ULLAGE PRESSURE (CONTINUED)

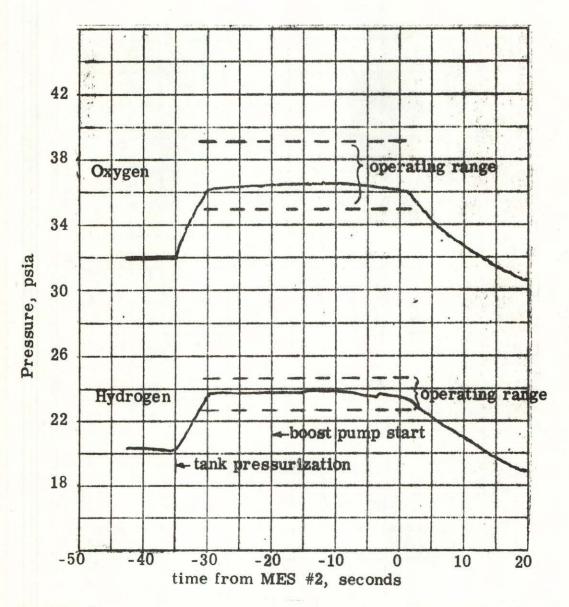


FIGURE 8-7.5 - CENTAUR PROPELLANT TANK ULLAGE PRESSURE (CONTINUED)

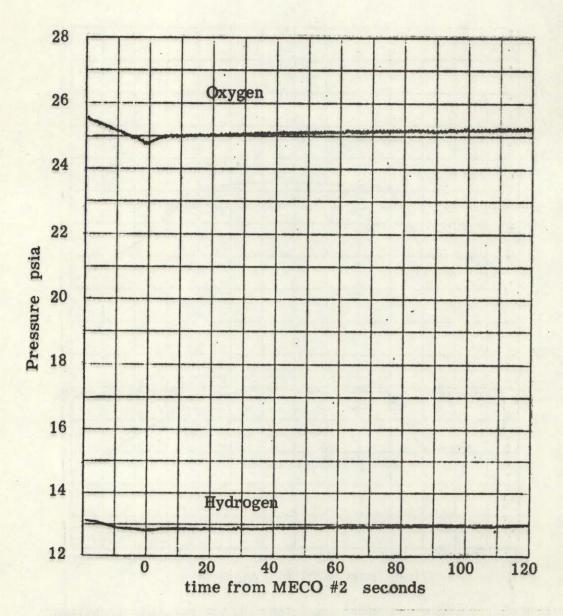


FIGURE 8-7.6 - CENTAUR PROPELLANT TANK ULLAGE PRESSURE (CONCLUDED)

psia; although the tank pressure momentarily dipped below 29 psia on three separate occasions. This phenomenon has been seen on prior Titan/Centaur flights and may be attributed to effects of liquid entrainment and vent valve response time in a hard vacuum.

At T + 443.9 seconds, both hydrogen vent valves and the oxygen vent valve were activated to the locked mode, and the tanks were pressurized for the first main engine start sequence. The tank pressures as tabulated in Table 8-7 and as shown in Figure 8-7.3 were increased to predetermined levels, based upon tank structural limits and boost pump net positive suction pressure requirements.

The hydrogen tank pressure was increased from 20.7 to a nominal 26.0 psia prior to Titan Stage II shutdown and then to a nominal 26.7 psia after Stage II shutdown. The oxygen tank pressure was increased from 31.2 to a nominal 39.3 psia. The tank pressure at main engine start (MES-1) was 26.8 psia in the LH2 tank and 39.1 psia in the LO2 tank. Tank pressurization was then terminated at MES-1.

Centaur MES-1 was initiated at T + 484.8 seconds. The pressures in both tanks initially dropped down rapidly to the saturation pressure; and then decayed slowly through first main engine cutoff (MECO-1) at T + 534.1 seconds. The pressure in the hydrogen tank at MECO-1 was 19.0 psia while that in the oxygen tank was 29.9 psia.

Tank pressures during the 2606 second parking orbit are shown in Table 8-8 and Figure 8-7.4. The pressures in the oxygen tank and hydrogen tank increased to a maximum of 33.0 and 21.1 psia, respectively. As a result of the small pressure increase, no tank venting was enabled by CCVAPS during the coast.

After the start of propellant settling at MES #2 - 600 seconds the LO2 tank pressure decreased 1.0 psi and the LH2 tank pressure decreased by 0.9 psi as a result of the tank ullage moving through the liquid bulk during the propellant process.

Tank pressurization for MES-2 was initiated at T + 3164.9 seconds. As shown in Figure 8-7.5, the hydrogen tank pressure was increased from 20.17 to a nominal 23.73 psia. The oxygen tank pressure was increased from 21.15 to a nominal 36.11 psia. Again the tank pressures dropped rapidly right after MES-2 and then more gradually until MECO-2, at which time the LOX tank pressure was 24.8 psia and the LH2 tank pressure was 12.8 psia (See Figure 8-7.6).

The helium stored in one 4650 cubic inch bottle was used to pressurize the propellant tanks during engine start sequences, to operate the engine control valves, to pressurize the H202 bottle and to provide purges to various components on the Centaur. Bottle pressure at liftoff was 3308 psia and at MECO-2 the pressure was 1732 psia. Minimum allowable pressure at MECO #2 was 500 psia.

<u>Propulsion Pneumatics</u> - The engine control and attitude control regulators maintained proper system pressure levels from pressurization of the helium bottles through retromaneuver. The engine control regulator output pressure at liftoff was 451.2 psig (allowable limits are 440 to 479 psig). The H202 bottle pressure regulator was 310.6 psig (allowable limits are 297 - 316 psig).

Helium Purge - Throughout the launch countdown, the ground system supplied a helium gas purge to the forward and aft ends of the vehicle. The gas was used to purge the hydrogen tank/shroud annulous, the district package and several propulsion system components. The purge was required to maintain enough pressure differential across the shroud after cryogenic tanking to prevent ground wind inflow. The minimum differential pressure required was .045 psid. The minimum pressure experienced was a momentary dip to .05 psid. At liftoff, the pressure was .23 psid.

Centaur Propellant Feed and Reaction Control Systems

by R. W. Heath

Summary

The performance of the Centaur propellant feed and reaction control systems was normal throughout the flight of TC-6. There were no anomalies.

Discussion

Propellant Feed System - The propellant feed system operated satisfactorily during the flight. The boost pumps operated normally throughout both Centaur engine burns. A summary of the performance data is given in Table 8-9.

Within two seconds of the issuance of the pump start command, indications were seen of turbine rotation. The pumps did go into overspeed at engine shutdown, but this is a normal condition. The overspeeding results from residual peroxide in feed lines being purged out into the catalyst beds, and pump cavitation due to a lack of liquid heat during zero gravity conditions. The 02 turbine did not overspeed at MECO #1, but at MECO #2 it accelerated to a peak of 61,000 rpm before slowing down. The H2 turbine accelerated to 52,000 rpm at MECO #1 and to 63,700 rpm at MECO #2. The overspeed was well below the allowable of 70,000 rpm.

A tabulation of the propellant feed system temperature data is given in Table 8-10. All of the temperatures were within the expected ranges.

Reaction Control System - Component temperatures were within expected ranges during the countdown and flight. The temperature data is summarized in Table 8-11.

The S2A, Y1 and Y2 thrusters were programmed for a 20 second operation during the boost phase to prime the H2O2 lines. Thruster firing was verified by the temperature measurements on the engines, and by current traces. A 20 second warming firing of all the P, Y, and S thrusters at MECO #1-20 seconds was similarly verified.

The Centaur entered a zero gravity parking orbit after its first burn and there was no thrust requirement to maintain settling of the propellants during this time period. At MES #2 - 600 seconds a propellant settling sequence was started by firing two six-pound thrusters in a "2S on" mode. Then, at MES #2 - 120 seconds, the thrust level was increased by going to a "4S on" mode for the balance of the MES #2 prestart sequence. All of the H202 engines fired normally and there were no anomalies.

TABLE 8-9 - CENTAUR BOOST PUMP PERFORMANCE DATA SUMMARY FOR TC-6

| | Meas. | Units | Fi | rst Burn | | Second Burn | | |
|------------------------|----------|-------|----------|----------|-------|-------------|-------|-------|
| Parameter | Number | | Prestart | MES | MECO | Prestart | MES | MECO |
| LO2 Boost Pump | | | | | | | | |
| pump headrise ΔP | CPT 120P | psid | 86 | 82 | 36 | 63 | 81 | 34 |
| turbine speed | CPT 15B | rpm | 39000 | 39000 | 35100 | 34400 | 39000 | 35100 |
| turbine inlet pressure | CPT 26P | psid | 96 | 96 | 98 | 93 | 93 | 99 |
| LH2 Boost Pump | | | | | | | | |
| pump headrise ΔP | CPT 121P | psid | 23 | 20 | 10 | 15 | 20 | 11 |
| turbine speed | CPT 16B | rpm | 43900 | 41600 | 40600 | 35800 | 41900 | 41000 |
| Turbine inlet pressure | CPT 28P | psid | 92 | 92 | 93 | 90 | 90 | 93 |
| | | 200 | | | | | | |

TABLE 8-10 - CENTAUR PROPELLANT FEED SYSTEM TEMPERATURE DATA FOR TC-6

| Parameter | Meas. Number | Units | T-0 | BPS-1 | MES-1 | MECO-1 | BPS-2 | MES-2 | MECO-2 | P/L |
|------------------------------|-----------------|--------|------|--------|--------|--------|--------|-------|--------|------|
| , arameter | Number | OIIIES | 1 0 | Br 3-1 | INCS-1 | MECO-1 | DF 3-2 | HE3-2 | MECO-2 | F/L |
| Propellant Feed System | | | | | | | | | | |
| LH2 boost pump inlet | CP 32T | DGF | -420 | -419 | -419 | -422 | -421 | -421 | -424 | -424 |
| LO2 boost pump inlet | CP 33T | DGF | -283 | -283 | -282 | -283 | -285 | -282 | -287 | -288 |
| C-1 LO2 duct surface | CP 55T | DGF | -276 | -259 | -266 | -263 | -267 | -269 | -273 | -270 |
| C-1 LH2 duct surface | CP 56T | DGF | -402 | OSH | -394 | -400 | OSH | OSH | -394 | -OSH |
| C-2 LO2 duct surface | CP 57T | DGF | -276 | -273 | -274 | -277 | -279 | -278 | -273 | -274 |
| C-2 LH2 duct surface | CP 58T | DGF | -405 | -378 | -398 | -409 | OSH | OSH | -408 | -397 |
| C-1 LO2 pump inlet | CP 59T | DGF | -282 | -280 | -281 | -293 | -280 | -282 | -287 | -287 |
| C-1 LH2 pump inlet | CP 60T | DGF | -421 | -421 | -421 | -421 | -420 | -420 | -423 | -423 |
| C-2 LO2 pump inlet | CP 61T | DGF | -281 | -280 | -281 | -283 | -283 | -281 | -286 | -287 |
| C-2 LH2 pump inlet | CP 62T | DGF | -421 | -421 | -421 | -422 | -419 | -420 | -423 | -423 |
| .02 Boost Pump Turbine | | | | | | | | | | |
| rotor lower bearing | CPT 36T | DGF | 83 | 77 | 88 | 119 | 279 | 279 | 368 | 422 |
| gearcase surface (output) | CP 176T | DGF | 62 | 62 | 62 | 83 | 181 | 184 | OSH | OSH |
| catalyst bed surface | CP 186T | DGF | 118 | 144 | OSH | OSH | 492 | OSH | OSH | OSH |
| H2 Boost Pump Turbine | | | | | | | | | | |
| rotor lower bearing | CPT127T | DGF | 83 | 94 | 94 | 184 | 270 | 273 | 380 | 416 |
| gearcase surface (output) | CP 177T | DGF | 67 | 67 | 67 | 147 | 232 | 232 | оѕн | OSH |
| catalyst bed surface | CP 187T | DGF | 110 | 136 | OSH | OSH | 464 | OSH | OSH | OSH |

TABLE 8-11 - CENTAUR H202 SUPPLY AND REACTION CONTROL SYSTEM TEMPERATURES FOR TC-6

| | Parameters | Meas. | | | | | Event and | Event Tir | nes | | |
|-----|--|--|-------------------|----------------------|------------------------|------------------------|---------------------------|------------------------------|------------------------------|--------------------------|----------------------------|
| | rarameters | Number | Units | T-0 | BPS-1 | MES-1 | MECO-1 | BPS-2 | MES-2 | MECO-2 | P/L-SEP |
| H20 | 2 Bulk | | | - 31 jul | | | | | | | |
| | RCS Bottle | CP 93T | DGF | 90 | 90 | 90 | 90 | 95 | 95 | 93 | 91 |
| Thr | uster Chamber Surfaces | | | | | | | | | | |
| 102 | Y1 P3 S2A S4B | CP 148T CP 375T CP 691T CP 836T | DGF DGF DGF | 90 68 68 68 | 567 68 585 68 | 514 68 550 68 | 959 976 1110 976 | 1110 1144 1246 1279 | 1060 1110 1246 1279 | 740 585 585 567 | 1110 1178 532 497 |
| H20 | 2 Lines to Thruster | | | | | | | | | | |
| | Quad 2/3 Quad 1/4 Quad 1/2 | CP 152T CP 155T CP 100T | DGF DGF DGF | 72 80 66 | 92 96 82 | 92 96 84 | 92 96 80 | 92 96 92 | 92 96 90 | 84 96 82 | 90 96 80 |
| H20 | 2 Lines to Boost Pumps | | | | | | | | | | |
| | LH2 orifice inlet LO2 orifice inlet | CP 361T CP 714T | | 75 64 | 64 64 | 98 98 | 112 | 216 131 | 112 | 138 112 | 168 |

H202 Supply - He H202 bottle was loaded with 241.6 pounds. The required peroxide for a three sigma mission was only 198 pounds, but a full bottle was loaded for additional reserve. This additional reserve was made possible by giving up some propellant FPR. The actual peroxide usage for the mission was 119.1 pounds as compared to a predicted usage of 129 pounds.

Centaur Thermodynamics

by R. F. Lacovic

Summary

For TC-5 all of the vehicle airframe and component temperatures were normal and well within previous Titan/Centaur flight and prelaunch experience. There were no anomalies.

Discussion

A summary of the vehicle airframe and component temperature data are given in Table 8-12. All structural and component temperature measurements were normal and in good agreement with previous Titan Centaur flight data.

The maximum temperature on the interstage adapter was 128° F. The maximum temperature on the CSS skin was 315° F. The stagnation point temperature reached a maximum of 561° F.

As noted, all equipment and component temperatures remained well within operational limits through spacecraft separation. After spacecraft separation the Centaur forward end component temperatures increased considerably as a result of exhaust plume impingement from the TE 364 engine firing. This trend, however, was not unexpected and the component temperatures still remained within their operational limits.

TABLE 8-12 - AIRFRAME AND COMPONENT TEMPERATURES FOR TC-6

| | MEAS. | T-O TEMP. | MAX. TEM | MPERATURE | MIN. TE | MPERATURE |
|--------------------------------|---------|-----------|----------|-----------|---------|-----------|
| PARAMETER | NUMBER | °F | °F | T + SEC. | °F | T + SEC. |
| Airframe & Insulation: | | | | | | |
| Stagnation Point | CA 80T | 66 | 561 | 220 | 66 | 0 |
| ISA Station 2144 | CA167T | 71 | 160 | 128 | 71 | 0 |
| ISA Station 2159 | CA168T | 71 | 151 | 128 | 71 | 0 |
| CSS Skin Station 2812 | CA169T | 82 | 311 | 220 | 82 | 0 |
| CSS Skin Station 2688 | CA170T | 89 | 227 | 220 | 89 | 0 |
| CSS Ins'tn. Inner Sta. 2816 | CA192T | 72 | 72 | 0 | 32 | 116 |
| CSS Ins'tn. Inner Sta. 2696 | CA193T | 72 | 72 | 0 | 22 | 124 |
| CSS Frame Inner Sta. 2422 | CA198T | 53 | 111 | 240 | 53 | 0 |
| CSS Diaphragm Inner Sta. 2242 | CA199T | - 42 | - 28 | 40 | - 66 | 265 |
| CSS Ins'tn. Inner Sta. 2452 | CA204T | - 64 | - 49 | 220 | - 64 | 0 |
| CSS Ins'tn. Inner Sta. 2422 | CA205T | -137 | -137 | 0 | -155 | 60 |
| CSS Ins'tn. Inner Sta. 2279 | CA209T | -340 | -262 | 186 | -340 | 0 |
| Equipment Module Skin +Z* | CA914T | 61 | 72 | 3722 | 39 | MECO1 |
| LH2 Radiation Shield 2279/03 | CA963T | -381 | - 95 | MES2 | -418 | 160 |
| Component Temperatures:** | | | | | | |
| RSC Battery #1 | CET56T | 78 | 78 | 0 | 75 | S/CSEP |
| RSC Battery #2 | CET57T | 90 | 90 | 0 | 77 | S/CSEP |
| Main Battery | CET108T | 94 | 134 | S/CSEP | 94 | 0 |
| Aft Pneumatic Panel | CF134T | 61 | 75 | 3160 | 47 | MECO1 |
| IRU Skin Internal* | C1300T | 90 | 113 | 3722 | 90 | 0 |
| DCU Skin* | CK30T | 98 | 137 | 3722 | 93 | 0 |
| Engine Compartment Ambient | CP144T | 90 | 90 | 0 | - 70 | 128 |
| Spacecraft Compartment Ambient | CY26T | 85 | 85 | 0 | 78 | 128 |

^{*} Large temperature increase during third stage firing.

^{**} Data not available during some periods of the mission.

TABLE 8-12 - AIRFRAME AND COMPONENT TEMPERATURES FOR TC-6 (CONT'D.)

| PARAMETER | MEAS. | T-O TEMP. | MAX. TEM | PERATURE T + SEC. | MIN. TI | EMPERATURE T + SEC |
|------------------------------|--------|-----------|----------|----------------------|---------|-----------------------|
| THANKE LEW | | | | | | |
| Hydraulic System Components: | ** | | | | | |
| C-1 Hydraulic Manifold | CH5T | 58 | 157 | MECO2 | 58 | 0 |
| C-2 Hydraulic Manifold | сн6т | 54 | 164 | MECO2 | 54 | 0 |
| H202 System Lines & Supply: | * | | | | 200 | |
| H202 Bottle | CP 93T | 90 | 95 | 3180 | 90 | 0 |
| Quad 2-3 A/C Line | CP152T | 72 | 92 | 3180 | 72 | 0 |
| Quad 1-4 A/C Line | CP155T | 80 | 96 | 3180 | 80 | 0 |
| Quad 1-2 A/C Line | CP160T | 66 | 92 | 3180 | 66 | 0 |

^{*} Large temperature increase during third stage firing.

** Data not available during some periods of the mission.

Electrical/Electronic Systems

Electrical Power System

by J. B. Nechvatal

Summary

Performance of the Centaur electrical system on TC-6 was satisfactory throughout the countdown and flight until the end of useful telemetered data at approximately 3900 seconds.

Discussion

Configuration: The electrical power system, Figure 8-8 consists of a power changeover switch (integral part of the Sequence Control Unit), a main battery, two independent Range Safety Command (vehicle destruct) batteries and a single phase, 400 Hertz inverter. (Inverter is an integral part of the Servo-Inverter Unit.)

System Performance: Transfer of the Centaur electrical loads from external power to the internal battery was accomplished at minus 108.9 seconds by the changeover switch.

The main battery voltage was 28.7 volts at liftoff (Table 8-13). A low of 27.9 volts was recorded during main engine first start sequence and 28.1 volts at main engine second start sequence. The voltage recovered to 28.7 volts after spacecraft separation, reaching a peak of 28.8 volts at 3900 seconds (Table 8-14).

Main battery current was 36.3 amperes at liftoff. It peaked at 56.2 amperes at main engine first start and 55.6 amperes at main engine second start. The flight current profile was consistent with values recorded during preflight tests. The individual bus and package currents also indicated normal operating profile. Battery current values with respect to flight programmed events are shown in Table 8-15.

Performance of the two range safety command system batteries was satisfactory. At liftoff, the battery voltages were 32.8 and 32.7 volts, (Table 8-13) and remain steady to first main engine cutoff, when the RF disable was initiated.

Vehicle AC power was supplied by the Servo Inverter Unit. The voltage output of the inverter remained steady at 26.0 volts AC throughout the programmed flight.

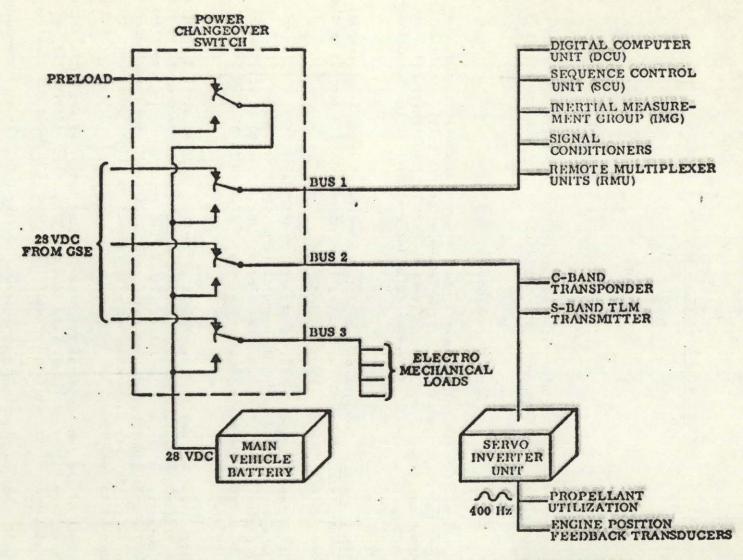


FIGURE 8-8 - TC-6/-7 CENTAUR ELECTRICAL SYSTEM SCHEMATIC DIAGRAM

TABLE 8-13 - TC-6 CENTAUR BATTERY DATA

| | OPEN CIRCUIT | T-0 LIFT-OFF | LOAD TEST |
|-------------------------|-----------------|-----------------|--------------|
| MAIN BATTERY VOLTS | 35.1 | 28.8 | 27.9 @ 6 4 |
| RSC NO. 1 BATTERY VOLTS | 33.9 | 32.8 | 28.7 @ 10A |
| RSC NO. 2 BATTERY VOLTS | 33.8 | 32.7 | 28.6 @ 10A |

| | MEAS. NO. | DESCRIPTION | UNITS | T-0 | SHROUD SEP. | T/C SEP. | MES NO.1 | MECO NO.1 | MES NO.2 | MECO No.2 | S/C SEP. | |
|---|--------------|---------------------------|-------|------|----------------|-------------|-------------|--------------|-------------|------------------------|-----------------------------|---|
| | CE 1C | Main Battery Current | AMPS | 36.3 | 33.6 | 47.8 | 56.2 | 37.8 | 55.6 | 36.7 | 36.4 | |
| | CD 28V | Bus No. 1 Volts | VDC | 28.5 | 28.4 | 27.9 | 27.7 | 28.2 | 28.0 | 28.5 | 28.6 | |
| | CE600V | Main Battery Volts | VDC | 28.7 | 28.6 | 28.1 | 27.9 | 28.5 | 28.1 | 28.6 | 28.7 | |
| = | CE142C | Bus No. 1 Current | AMPS | 9.9 | 10.1 | 10.1 | 10.2 | 10.1 | 10.0 | 10.0 | 9.9 | - |
| 0 | CE143C | Bus No. 2 Current | AMPS | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.7 | |
| | CE144C | Bus No. 3 Current | AMPS | 5.7 | 3.7 | 11.1 | 16.3 | 8.3 | 8.4 | 7.5 | 7.5 | 1 |
| | CE 97C | Bus No. 3 Partial Current | AMPS | 8.4 | 7.4 | 9.2 | 8.2 | 7.3 | 15.4 | 7.3 | 7.4 | - |
| | cs844v | Inverter Output Volts | VAC | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | |
| | CE 21V | RSC No. 1 Battery Volts | VDC | 32.8 | 32.8 | 32.9 | 32.9 | 32.9 | 33.5 | 33.6 | 33.6 | |
| | CE 22V | RSC No. 2 Battery Volts | VDC | 32.7 | 32.7 | 32.7 | 32.7 | 32.7 | 33.4 | 33.4 | 33.4 | |
| - | | | 1 | | | 1 | 1 | | | A commence of the same | and the same of the same of | 1 |

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TABLE 8-15 - TC-6 CENTAUR BATTERY CURRENT PROFILE

| EVENT | EXPE | CTED | | |
|---|---------|---------|--------|--------------|
| LVLINI | NOMINAL | MAXIMUM | ACTUAL | TIME SECONDS |
| Centaur to Internal | 35.4 | 39.9 | 34.0 | Т - 108.9 |
| Lock LH2 Vent Valve | 37.0 | 41.9 | 36.0 | T - 26.9 |
| Lift-Off (T-0) | 36.8 | 41.6 | 36.3 | T - 0 |
| Unlock LH2 Vent Valve | 35.2 | 39.7 | 35.0 | T + 90 |
| Fwd. Bearing Reaction Separation | 35.4 | 40.1 | 35.4 | T + 100 |
| Fwd. Bearing Reaction Reset | 35.2 | 39.7 | 35.0 | T + 102 |
| Fwd. Seal Release | 35.5 | 40.0 | 35.3 | T + 211.5 |
| Fwd. Seal Release Reset | 35.2 | 39.7 | 34.9 | T + 214.5 |
| Shroud Coax Switches Off | 34.0 | 38.1 | 33.6 | T + 273.8 |
| H202 Engines - S2A On | 34.4 | 38.6 | 34.1 | T + 277.3 |
| H202 Engines - S2A Off; Y1 On | 34.4 | 38.6 | 34.1 | T + 297-3 |
| H202 Engines - Y1 Off; Y2 On | 34.4 | 38.6 | 34.1 | T + 317-3 |
| H202 Engines - Y2 Off | 34.0 | 38.1 | 33.8 | T + 337-3 |
| Lock All Vent Valves | 38.3 | 43.5 | 39.3 | T + 441.8 |
| LO2 & LH2 Tank Pressurization | 40.7 | 46.5 | 41.8 | T + 443.8 |
| and Control Valve On | | | | |
| Boost Pumps - Primary and Back | 44.0 | 50.5 | 45.5 | T + 443.9 |
| Up On; H202 Purge Valve On | | | | |
| End LO2 Tank Pressurization | 43.2 | 48.1 | 44.6 | T + 444.8 |
| End LH2 Tank Pressurization | 42.4 | 47.2 | 43.7 | T + 445.4 |
| Hydraulic Circ. Pumps On | 47.5 | 54.7 | 47.8 | T + 470.0 |
| Open Prestart Valves | 50.4 | 57.9 | 50.8 | T + 476.6 |
| Control Valve Off | 49.6 | 57.0 | 49.7 | T + 484.3 |
| MES: Igniters Off; Open Start Valves | 56.1 | 65.1 | 56.2 | T + 484.6 |
| Igniters Off | 52.3 | 60.1 | 52.6 | T + 488.6 |
| Hydraulic Circ. Pumps Off | 47.2 | 53.8 | 47.3 | T + 496.6 |
| H202 Engines - S, P, & Y's On | 52.8 | 60.3 | 52.0 | T + 574.0 |
| H202 Engines - S, P, & Y's Off | 47.2 | 53.8 | 46.3 | T + 584.0 |
| MECO: Boost Pumps - Primary & | 38.3 | 43.5 | 37.8 | T + 594.0 |
| Backup Off; H202 Purge Valve Off; Close Start & Prestart Valves | ,,,, | 7,7,7 | 37.0 | |

TABLE 8-15 - TC-6 CENTAUR BATTERY CURRENT PROFILE

| | EXPECTED | | | |
|--|----------|---------|--------------|--------------|
| EVENT | NOMINAL | MAXIMUM | ACTUAL | TIME SECONDS |
| H202 Engines; S2A & S4A On | 39.3 | 44.5 | 37.8 | T + 2599.8 |
| H202 Engines; S2B & S4B On; S2A & S4A Off | 39.3 | 44.5 | 37.8 | T + 3039.8 |
| H202 Engines; All "S" On Mode | 40.2 | 45.6 | 38.7 | T + 3079.8 |
| Hydraulic Circ. Pumps On | 45.3 | 51.8 | 38.7 43.0 | T + 3109.8 |
| Open Prestart Valves | 48.1 | 55.0 | 45.7 | T + 3152.8 |
| Close Prestart Valves | 45.3 | 51.8 | 43.0 | T + 3162.8 |
| LO2 & LH2 Tank Pressurization & Control Valve On | 47.6 | 54.8 | 45.5 | T + 3164.8 |
| End LO2 Tank Pressurization | 46.8 | 53.8 | 44.5 | T + 3169.8 |
| End LH2 Tank Pressurization | 46.0 | 52.8 | 43.7 | T + 3170.0 |
| Boost Pumps - Primary & Back-Up On; H202 Purge Valve On | 49.4 | 56.8 | 47.0 | T + 3179.9 |
| Open Prestart Valves | 52.2 | 60.0 | 49.8 | T + 3190.9 |
| | | | | |

Centaur Digital Computer Unit

by E. R. Ziemba

Performance of the DCU throughout the TC-6 flight was nominal. Comparison of the DCU word and analog outputs telemetered data indicate all the Analog Converter Module conversions were satisfactory.

The DCU software performance was nominal throughout the flight and no anomalies were found. The DCU functions which include navigation, guidance and steering interface performed flawlessly. Inertial guidance system time and velocity accumulation were nominal.

The DCU sequencing function operated as planned and all discrete outputs were generated at the nominal times. The DCU temperature was $92^{\circ}F$ at liftoff and rose to $136^{\circ}F$ after spacecraft separation. These temperatures are within the operating range of the DCU.

Centaur Inertial Measurement Group

by P. W. Kuebeler

The Inertial Measurement Group (IMG) performance during the flight of TC-6 was satisfactory as evidenced by the accuracy of the trajectory, which is described in the Trajectory and Performance Section, and telemetered data which is considered below.

The IMG consisted of IRU S/N 22, P/N GG8065B4, and SEU S/N 22, P/N EG8076B1. Gimbal. Gimbal loop performance was excellent. The maximum gimbal error observed was approximately 6 arcseconds as compared to a specification of 60 arcseconds. The IMG current was normal throughout the flight. The IRU temperature was 91° at lift-off, reached a peak of 105°, and was 103° at spacecraft separation. These temperatures were within the operating range of the IRU.

Flight Control System

by D. W. Bitler

The Digital Computer Unit (DCU) and the Sequence Control Unit (SCU) performed satisfactorily in issuing the flight control system commands to other vehicle systems during the flight of TC-6. The SCU receives its input from the DCU and converts this input into switch commands usable by other vehicle systems. The DCU commands were issued at the expected times and for the expected duration of time.

Table 8-16 lists the planned switching sequence and actual flight events. The column headed "Sequence" shows the time of the event from the start of each phase of flight. The column headed "Planned Time" shows the time after lift-off for each event based upon preflight actual launch time trajectory with launch day winds. The "Actual Time" column shows the time after lift-off that the DCU command was issued to the SCU. Other functions programmed by the DCU software are shown in the table to help in clarifying the flight sequence.

TABLE 8-16 - TC-6 FLIGHT SEQUENCE OF EVENTS

| SCU SWITCH | EVENT | SEQUENCE | PLANNED TIME-SEC | ACTUAL TIME-SEC |
|-----------------|--|--------------|---------------------|--------------------|
| 84,85,86 Reset | Go Inertial (1) | T-6.0 | T-6.0 | T-6.0 |
| | Liftoff (2) | SRM + 0.0 | 0.0 | T+0.0 |
| 57, Set 58 | Begin Roll Program | SRM + 6.5 | 6.5 | T+6.6 |
| 57, Reset 58 | End Roll Program | (3) | | |
| | (4) Begin DCU Pitch, Yaw Program | SRM + 10.0 | 10.0 | T+10.1 |
| 28 Reset | Unlock LH ₂ Vent Valve 1 | SRM + 90.0 | 90.0 | T+90.0 |
| 34 Set | Sep Fwd Brg Reactor | SRM + 100.0 | 100.0 | T+100.0 |
| 34 Reset | Reset Fwd Brg Reactor | SRM + 102.0 | 102.0 | T+102.0 |
| | (5) Stg O Shutdown Detected by DCU | STG 0 + 0 | (6)110.0 | T+111.4 |
| - Ing Your 1895 | End Pitch, Yaw Program | STG 0 + 0 | (6)110.0 | T+111.1 |
| | Enable Titan Steering | STG 0 + 32 | 142.0 | T+148.3 |
| 9 Set | Release Fwd Seal | STG 0 + 100 | 210.0 | T+211.4 |
| 9 Reset | Reset Fwd Seal | STG 0 + 103 | 213.0 | T+214.4 |
| - | Inhibit Titan Steering | STG 0 + 122 | 232.0 | T+228.3 |
| • • | (7) STG 1 Shutdown Detected by DCU | STG 1 + 0 | (6)259.5 | T+262.2 |
| SI Set | Unlatch Shroud CMD 1 | STG 1 + 10 | 269.5 | T+272.2 |
| 62 Set | Unlatch Shroud CMD 2 | STG 1 + 10.5 | 270.0 | T+272.7 |

⁽¹⁾ Go Inertial occurs 25 seconds after the control monitor group sends a command to start the DCU count.

(2) Liftoff - Defined as start of Rocket Motor Ignition (DRS 496).

(3) End Roll Program - Time is launch azimuth dependent.

(4) Pitch Yaw Steering - Enabled when altitude exceeds 1050 feet and time exceeds 10 seconds from SRM ignition.

(5) STG O Shutdown - Noted by DCU when computing a decreasing acceleration of less than 1.5 g's.

(6) Expected time from preflight actual launch time trajectory dated September 6, 1977.

(7) STG 1 Shutdown - Noted by DCU when computing a decreasing acceleration of less than 1.5 g's.

TABLE 8-16 - TC-6 FLIGHT SEQUENCE OF EVENTS (CONT.)

| SCU SWITCH | EVENT | SEQUENCE | PLANNED TIME-SEC | ACTUAL TIME-SEC |
|----------------|---------------------------------------|---------------|---------------------|--------------------|
| 61 Reset | Reset Shroud CMD 1 | STG 1 + 11.5 | 271.0 | T+273.7 |
| 62 Reset | Reset Shroud CMD 2 | STG 1 + 11.5 | 271.0 | T+273.7 |
| 8 Set | S2A On | STG 1 + 15.0 | 274.5 | T+277.2 |
| 8 Reset | S2A Off | STG 1 + 35.0 | 294.5 | T+297.2 |
| 1 Set | Y1 On | STG 1 + 35.0 | 294.5 | T+297.2 |
| | Enable Titan Steering | STG 1 + 35.0 | 294.5 | T+297.2 |
| i Reset | Y1 Off | STG 1 + 55.0 | 314.5 | T+317.3 |
| 2 Set | Y2 On | STG 1 + 55.0 | 314.5 | T+317.3 |
| 2 Reset | Y2 Off | STG 1 + 75.0 | 334.5 | T+337.0 |
| 4 Set | Lock LO2 Vent Valve | STG 2 - 30.5 | 439.4 | T+441.8 |
| 8 Set | Lock LH ₂ Vent Valve | STG 2 - 30.5 | 439.4 | T+441.8 |
| SI Set | Lock LH ₂ Vent Valve | STG 2 - 30.5 | 439.4 | T+441.8 |
| | Inhibit Titan Steering | STG 2 - 30.0 | 439.9 | T+436.3 |
| 7 Set | Open Control Valve | STG 2 - 28.56 | 441.34 | T+443.8 |
| 9 Set | Press LO ₂ Tank | STG 2 - 28.56 | 441.34 | T+443.8 |
| 2 Set | Press LH2 Tank | STG 2 - 28.56 | 441.34 | T+443.8 |
| 3 Set | Primary- Boost Pumps On | STG 2 - 28.4 | 441.5 | T+443.9 |
| 8 Set | B/U Boost Pumps On | STG 2 - 28.4 | 441.5 | T+443. |
| | (8) STG 2 Shutdown Detected by DCU | STG 2 + 0 | (6)469.9 | T+469.9 |
| 5 Set | STG 2 S/D B/U | STG 2 + 0 | (6)469.9 | T+469.9 |
| 7 Set | Cl Circ Pump On | STG 2 + .1 | 470.0 | T+470.0 |
| 1 Set | C2 Circ Pump On | STG 2 + .1 | 470.0 | T+470.0 |
| 3 Set 4 Set | (9) T/C Separation | Sep + 0 | (6) 476.0 | T+474. |
| 9 Set | Open Prestart Valves | Sep + 2.5 | 478.5 | T+476.6 |
| 7 Reset | Close Control Valve | Sep + 10.22 | 486.2 | T+484. |
| | | | | |

⁽⁸⁾ Stage II Shutdown - Noted by DCU when observed acceleration is less than lg.

⁽⁹⁾ T/C Separation - Commanded by DCU when computed acceleration is less than 0.01g.

⁽⁶⁾ Expected time from preflight actual launch trajectory, dated September 6, 1977.

TABLE 8-16 - TC-6 FLIGHT SEQUENCE OF EVENTS (CONT.)

| SCU SWITCH | EVENT | SEQUENCE | PLANNED TIME-SEC | ACTUAL TIME-SEC |
|-----------------------|----------------------------|--------------|---------------------|--------------------|
| | MES 1 (10) | SEP + 10.5 | (6)486.5 | T+484.6 |
| 22 Set | Igniters On | SEP + 10.5 | (6) 486.5 | T+484.6 |
| 20 Set | Open Start Valves | SEP + 10.5 | (6) 486.5 | T+484.6 |
| 22 Reset | Igniters Off | MES1+4 | 490.5 | T+488.6 |
| THE THE | Start Guidance Steering | MES1+7 | 493.5 | T+491.6 |
| 17 Reset | Cl Circ Pump Off | MES1+12 | 498.5 | T+496.6 |
| 21 Reset | C2 Circ Pump Off | MES1+12 | 498.5 | T+496.6 |
| 1-4 Set | Yaw Engines On | (13)Meco1-20 | 558.2 | T+573.9 |
| 5,6 Set 15,16 Set | Pitch Engines On | MEC01-20 | 558.2 | T+573.9 |
| 8,10 Set 12,14 Set | "S" Engines On | MEC01-20 | 558.2 | T+573.9 |
| 1,4 Reset | Yaw Engines Off | MEC01-10 | 568.2 | T+584.0 |
| 5,6 Reset 15,16 | Pitch Engines Off | MEC01-10 | 568.2 | T+584.0 |
| 8,10 Reset 12,14 | "S" Engines Off | MEC01-10 | 568.2 | T+584.0 |
| ++ | MECO 1 (11) | MECO1+0 | 578.2 | T+594.0 |
| 23 Reset | Primary Boost Pumps Off | MECO1+0 | 578.2 | T+594.0 |
| 18 Reset | B/U Boost Pumps Off | MECO1+0 | 578.2 | T+594.0 |
| 20 Reset | Close Start Valves | MECO1+0 | 578.2 | T+594.0 |
| 19 Reset | Close Prestart Valves | MECO1+0 | 578.2 | T+594.0 |
| 68,72 Reset | Reset PU Switches | MEC01+1.0 | 579.2 | T+595.0 |
| 76,80 Reset | и и и | MECO1+1.0 | 579.2 | T+595.0 |
| | "2S" On Settled | MES2-600 | 2581.3 | (12) |
| 8 Set | S2A On | MES2-600 | 2581.3 | (12) |
| 10 Set | S4A On | MES2-600 | 2581.3 | (12) |
| | Change "S" Engine Pairs | MES2-160 | 3021.3 | (12) |
| 8,10 Reset | S2A, S4A Off | MES2-160 | 3021.3 | (12) |
| 12,14 Set | S2B, S4B On | MES2-160 | 3021.3 | (12) |

⁽¹⁰⁾ MES 1 - Commanded by the DCU 10.5 seconds after T/C Separation.

(12) No telemetry data.

⁽¹¹⁾ MECO 1 - Commanded by the DCU based on guidance computed time.

⁽¹³⁾ MECO 1-20 - Time used here is the guidance predicted time at that particular instant.

⁽⁶⁾ Expected time from preflight actual launch time trajectory, dated September 6, 1977.

TABLE 8-16 - TC-6 FLIGHT SEQUENCE OF EVENTS (CONT.)

| SCU SWITCH | EVENT | SEQUENCE | PLANNED TIME-SEC | ACTUAL TIME-SEC |
|---|---|--|----------------------------|--|
| 8,10 Set | Increase to 4S Engines On S2A, S4A On | MES2-120 | 3061.3 | T+3079.85 |
| 17 Set 21 Set | Cl Circ Pump On C2 Circ Pump On | MES2-90 MES2-90 | 3091.3 3091.3 | (12) (12) |
| 19 Set | Open Prestart Valves | MES2-47 | 3134.3 | (12) |
| 19 Reset | Close Prestart Valves | MES2-37 | 3144.3 | T+3162.8 |
| 27 Set 29 Set 32 Set | Open Control Valve Press LO ₂ Tank Press LH ₂ Tank | MES2-35.06 MES2-35.06 MES2-35.06 | 3146.2 3146.2 3146.2 | T+3164.8 T+3164.8 T+3164.8 |
| 23 Set | Primary Boost Pumps | MES2-20.0 | 3161.3 | T+3179.8 |
| 18 Set | On B/U Boost Pumps On | MES2-20.0 | 3161.3 | T+3179.8 |
| 19 Set | Open Prestart Valves | MES2-9 | 3172.3 | T+3190.8 |
| 27 Reset 29 Reset 32 Reset | Close Control Valve Press LO ₂ Tank Press LH ₂ Tank | MES2-0.28 | 3181.0 3181.0 3181.0 | T+3199.6 T+3199.6 T+3199.6 |
| 20 Set 22 Set | MES 2 (14) Open Start Valves Igniters On | MES2+0 MES2+0 MES2+0 | 3181.3 3181.3 3181.3 | T+3199.8 T+3199.8 T+3199.8 |
| 1-4 Reset 5,6 Reset 15,16 | Yaw Engines Off Pitch Engines Off | MES2+.2 MES2+.2 | 3181.5 3181.5 | T+3200.0 T+3200.0 |
| 22 Reset | Igniters Off | MES2+4 | 3185.3 | T+3203.8 |
| 8 Reset 10 Reset 12 Reset 14 Reset | End 4S Settled Thrust | MES2+5 MES2+5 MES2+5 MES2+5 | 3186.3 3186.3 3186.3 | T+3204.8 T+3204.8 T+3204.8 T+3204.8 |
| | Start Guidance Steer- | MES2+7 | 3188.3 | T+3206.8 |
| 17 Reset 21 Reset | ing Cl Circ Pump Off C2 Circ Pump Off | MES2+12 MES2+12 | 3193.3 3193.3 | T+3211.8 T+3211.8 |

⁽¹⁴⁾ MES2 - Command by the DCU based on guidance computed time.

⁽⁶⁾ Expected time from preflight actual launch time trajectory dated September 6, 1977.

⁽¹²⁾ No telemetry data.

TABLE 8-16 - TC-6 FLIGHT SEQUENCE OF EVENTS (CONT.)

| SCU SWITCH | EVENT | SEQUENCE | PLANNED TIME-SEC | ACTUAL TIME-SEC |
|----------------------------------|--|-------------------------------|-------------------------------------|----------------------------------|
| 23 Reset | (15) MECO 2 Primary Boost Pumps Off | MEC02+0 MEC02+0 | (6)3534.4 (6)3534.4 | T+3535.3 T+3535.3 |
| 19 Reset 20 Reset 18 Reset | Close Prestart Valves Close Start Valves B/U Boost Pumps Off | MEC02+0 MEC02+0 MEC02+0 | (6)3534.4 (6)3534.4 (6)3534.4 | T+3535.3 T+3535.3 T+3535.3 |
| 68,72 Reset 76,80 Reset | Reset PU Switches | MEC02+1.0 | 3535.4 | T+3536.2 |
| 69,70 Set | Pyro/TCAPU/CCS | S/C SEP-69 | 3635.4 | T+3636.2 |
| 77,78 Set | ARM "A" Pyro/TCAPU/CCS ARM "B" | S/C SEP-69 | 3635.4 | T+3636.2 |
| 69,70 Reset 77,78 Reset | ARM "A" ARM "B" | S/C SEP-1 S/C SEP-1 | 3703.4 | T+3704.2 |
| | Separate Voyager | MEC02+J(20)-15 | 3704.4 | T+3705.2 |
| 69,70 Set | Pyro/TCAPU/CCS | S/C+20 | 3724.4 | T+3725.2 |
| 77,78 Set | Pyro/TCAPU/CCS Arm ''B'' | S/C+20 | 3724.4 | T+3725.2 |
| 24 | Unlock LO ₂ Vent | S/C+3599 | 7303.4 | (12) |
| 28 | Valve Unlock LH ₂ Vent | s/c+3599 | 7303.4 | (12) |
| 31 | Valve Unlock LH ₂ Vent Valve | S/C+3599 | 7303.4 | (12) |
| 69,70 Reset 77,78 Reset | Reset Arm "A" Reset Arm "B" | S/C+3600 S/C+3600 | 7304.4 7304.4 | (12) (12) |

⁽¹⁵⁾ MECO 2 - Commanded by the DCU based on guidance computed time.

⁽⁶⁾ Expected time from preflight actual launch time trajectory, dated September, 1977.

⁽¹²⁾ No telemetry data.

Propellant Loading and Propellant Utilization Systems

by K. Semenchuk

Propellant Level Indicating System - The Centaur propellant level indicating system operated satisfactorily during the countdown. The total propellant tanked was approximately 5292 pounds of liquid hydrogen and 25781 pounds of liquid oxygen.

Propellant Utilization (PU) System - The TC-6 propellant utilization system operated satisfactorily throughout the flight. PU valve angle measurements for C1 and C2 engines responded properly. PU valves were properly locked in a null position until 5 seconds after MES-1, when they were properly commanded to the fixed angle positions of 3.8 degrees for C1 and 1.9 degrees for C2 engines. PU valves are to remain in their fixed position for 110 seconds after MES-1, before they are brought into control.

The LO2 level passed the probe top at MES-1 + 93 seconds, and the LH2 level passed the probe top sometime during first coast period.

DCU enabled the valves to begin controlling at MES-2 + 5 seconds. The valves then moved to the plus stop angles and remained there for 45 seconds, then gradually moved to the nominal and remained around the nominal for the remainder of the second burn.

The propellant residuals remaining at the Centaur Main Engine Cutoff were calculated by using the times when the propellant levels passed the bottom of the probes as reference points.

Liquid propellant residuals are shown below:

| | Actual | Predicted | |
|-----------------|----------|-----------|--|
| LO2 | 276 lbs. | 545 lbs. | |
| LH ₂ | 36 lbs. | 131 lbs. | |

The burning time remaining to depletion was calculated to be approximately 3.2 seconds at which time the liquid propellant outage was determined to be 97 pounds of LO2. The expected outage is 13 ± 32 pounds of LH2. PU outage is defined as the usable propellant remaining at the theoretical depletion of the other propellant. The investigation has concluded that the large LO2 outage was the result a wrong LH2 gas mass used in the PU error bias calculation. (See memo TC-6/TC-7 PU LO2 outage L. White to A. L. Yankee dated December 6, 1977). The above problem appears to be isolated to the Titan/Centaur missions and no corrective action is required for the future Atlas/Centaur flights.

Centaur Instrumentation

by J. Bulloch

For the TC-6 flight, a total of 319 measurements were instrumented, 296 PCM measurements, and 23 twenty-four bit DCU words via the PCM system. The following measurements exhibited data anomalies during the flight.

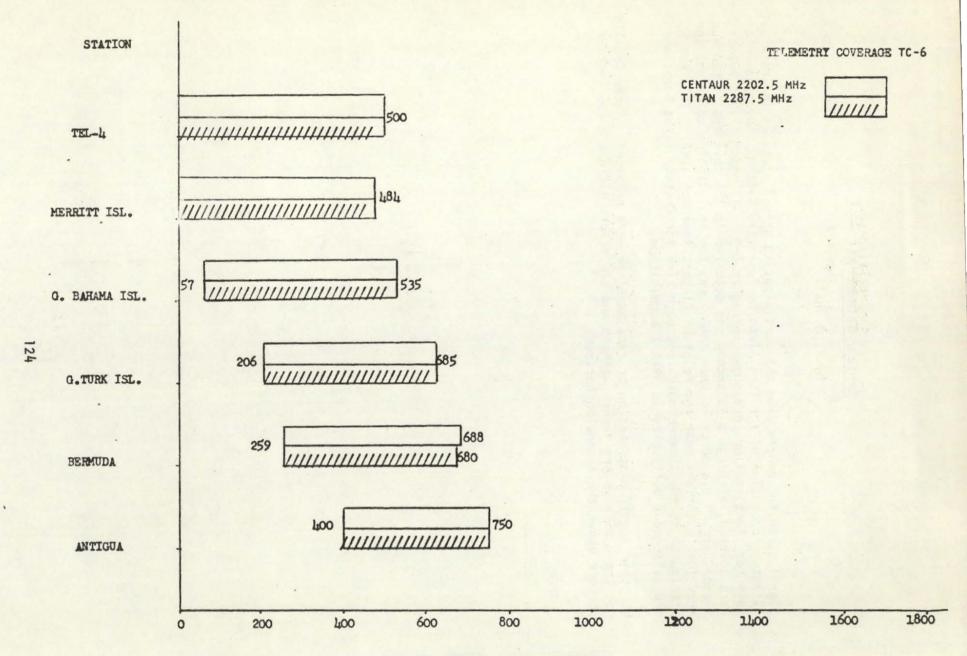
- 1. CA337X (FBR Struct No. 1 Breakwire On-Off) indicated an off condition for four data samples (approximately 57 milliseconds) at FBR separation (T + 99.6 seconds). It then came back on and went off again at T + 156.1 seconds. The most likely cause for the failure mechanism is that the broken ends of the breakwire made contact again following the initial separation.
- 2. Measurement CM242X, H_2 Liquid/Vapor Sensor, Station 2473/340, remained off scale high throughout the flight. No data was obtained from this measurement. This anomaly was first observed during the TCD test on this vehicle. It was decided to fly with this measurement inoperative.

Centaur Telemetry

by T. J. Hill

Signal strength reports from the participating ground stations indicate satisfactory operation of the TC-6 Airborne Telemetry System. Coverage intervals for these stations are shown in Figure 8-9. All major flight events were covered, although a 58 second gap occurred in the coverage of Centaur second burn. This occurred when ARIA 2 was the only station covering, and they lost Autotrack near the Point of Closest Approach (PCA). This was attributed to the unexpectedly long burn time for Centaur first burn, and the subsequent difficulty in ARIA 2 acquisition.

No other significant station or data problems were reported. Ascension did not track because the launch azimuth and trajectory did not allow Centaur to come above the Ascension horizon.



FLIGHT TIME - SECONDS
FIGURE 8-9 - TC-6 TELEMETRY COVERAGE

FIGURE 8-9 - TC-6 TELEMETRY COVERAGE (CONTINUED)

Centaur C-Band Tracking System

by T. J. Hill

The Centaur C-Band Tracking System on TC-6 performed satisfactorily. The tracking intervals for the participating Ground Radar Stations are shown in Figure 8-10.

Merritt Island (19.14) lost their computer program at T+221, and had to reboot. They reacquired at T+242 and covered to their normal range limit at T+497. No other significant problems were reported.

Ascension Ground Stations (12.15 and 12.16) did not cover TC-6 because the launch azimuth caused the TC-6 track to be below the Ascension horizon.

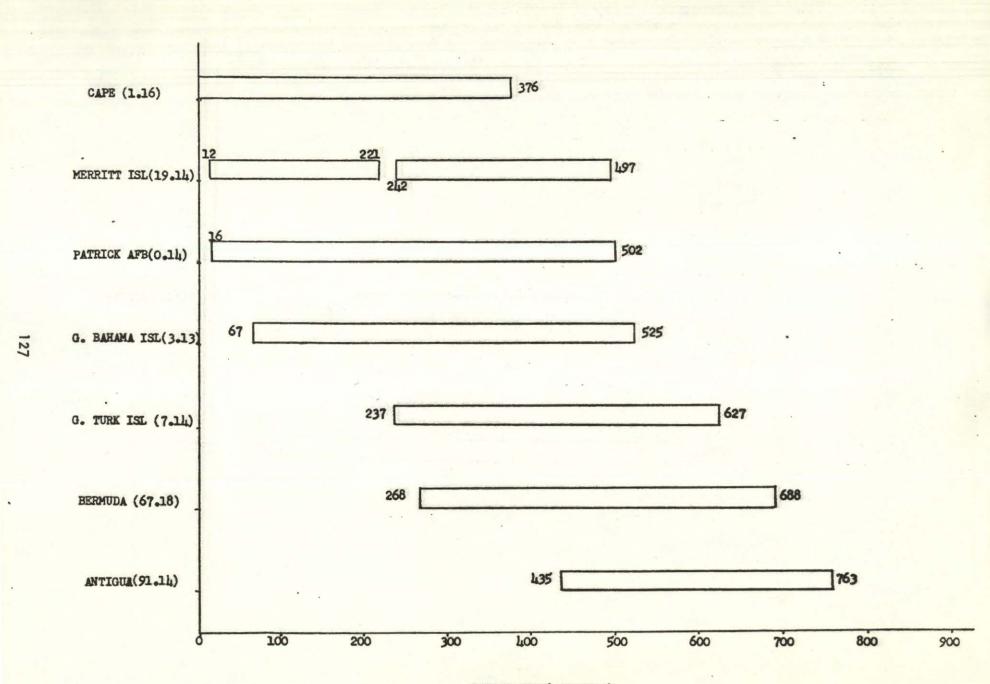
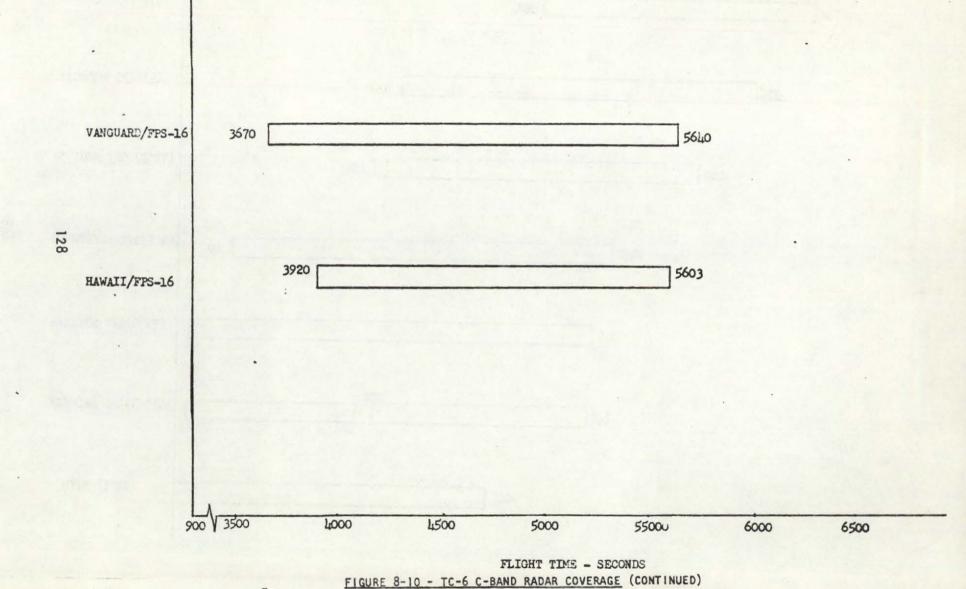


FIGURE 8-10 - TC-6 C-BAND RADAR COVERAGE



Centaur Range Safety System

by T. J. Hill

Range Safety Receiver signal strength data (AGC), received via Telemetry, indicated satisfactory operation of the Range Safety Command System throughout the TC-6 flight. System control was maintained as the vehicle flew downrange by switching to downrange transmitters. Switching times for the stations involved are presented in the following table.

| Station | Carrier On (Seconds) | Carrier Off (Seconds) |
|---------------------|----------------------|-----------------------|
| Cape Canaveral | T-2297 | T+172 |
| Grand Bahama Island | T+ 170 | T+467 |
| Antigua | T+ 466 | T+663 |

The Antigua station sent the R.S.C. R.F. Disable (SAFE) command at T+600 seconds, resulting in the shutdown of the Centaur R.S.C. receivers.

IX CENTAUR STANDARD SHROUD (CSS)

IX CENTAUR STANDARD SHROUD (CSS)

Liftoff/In-flight Functions

by T. L. Seeholzer

CSS Disconnects and Door Closures - The CSS disconnects and door closures located as shown in Figure 9-1 functioned normally on the TC-6 flight. The CSS disconnects and door closures were equivalent to the systems used on the TC-5 flight.

Movie and television coverage verified proper disconnect of the umbilicals and the closing of the T-O and T-4 CSS doors on the primary latches.

CSS In-flight Events and Jettison - All CSS in-flight events and jettison were normal on the TC-6 flight. These events included forward bearing reaction separation, forward seal release, shroud separation and jettison as shown in Figures 9-2 through 9-6. These systems were equivalent to those on the TC-5 flight.

Discussion

All six forward bearing reaction struts were separated at T + 100.11 seconds as verified by breakwires on the explosive bolts. Nominal separation time was T + 100 seconds. There was an instrumentation anomaly on one forward bearing reactor breakwire. This is discussed under Centaur Instrumentation (Section VIII).

Forward seal release occurred at T + 211.60 seconds as verified by breakwires on the explosive bolts. Nominal separation time was T + 210 seconds.

The CSS Super Zip primary system separated the shroud at T \pm 272.20 seconds. Separation by the primary system was verified by the fact that the CSS rotated over 3° prior to secondary system command. The secondary command was issued .50 seconds after primary system command. The secondary system is deactivated by electrical disconnect after 1° rotation.

Shroud rotation times comparing TC-4, TC-5, TC-6, and TC-7 are given in Table 9-1.

FIGURE 9-1 - CENTAUR STANDARD SHROUD DISCONNECTS AND DOOR CLOSURES

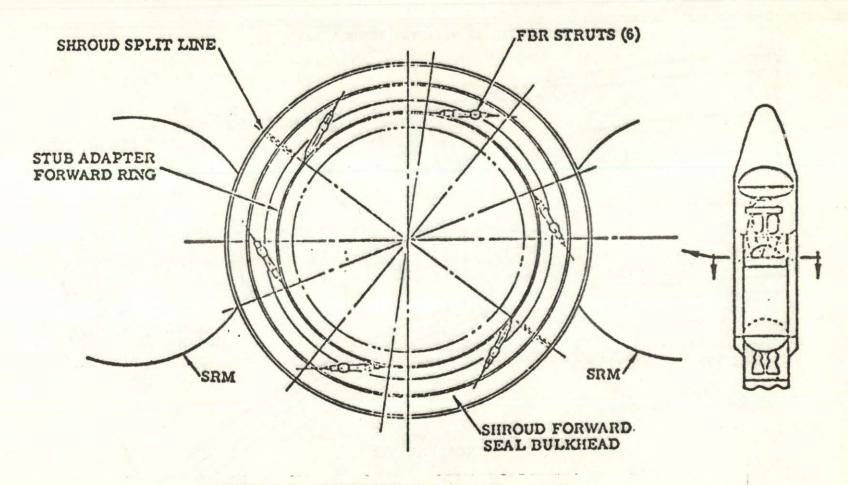


FIGURE 9-2 - FORWARD BEARING REACTION SYSTEM

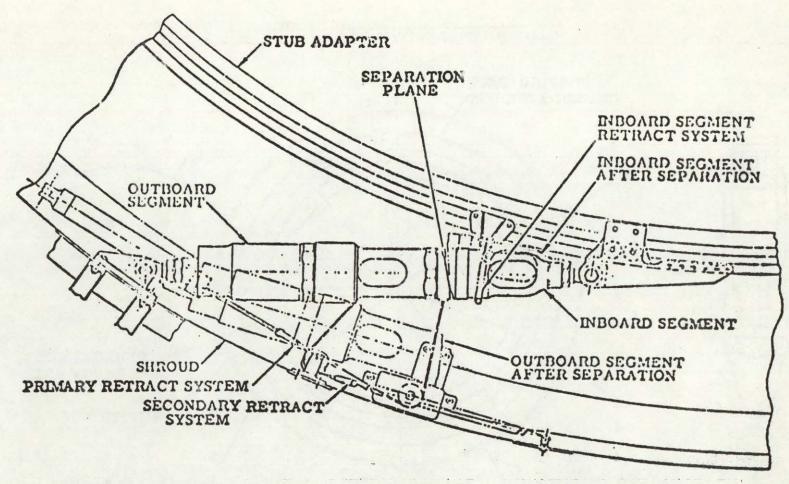


FIGURE 9-3 - FORWARD BEARING REACTION STRUT INSTALLATION

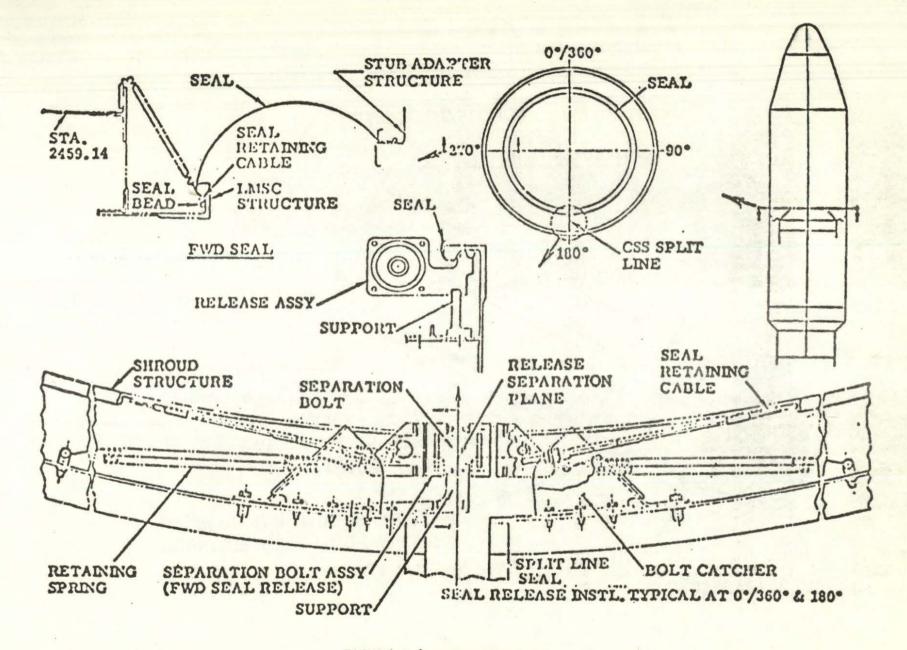


FIGURE 9-4 - FORWARD SEAL

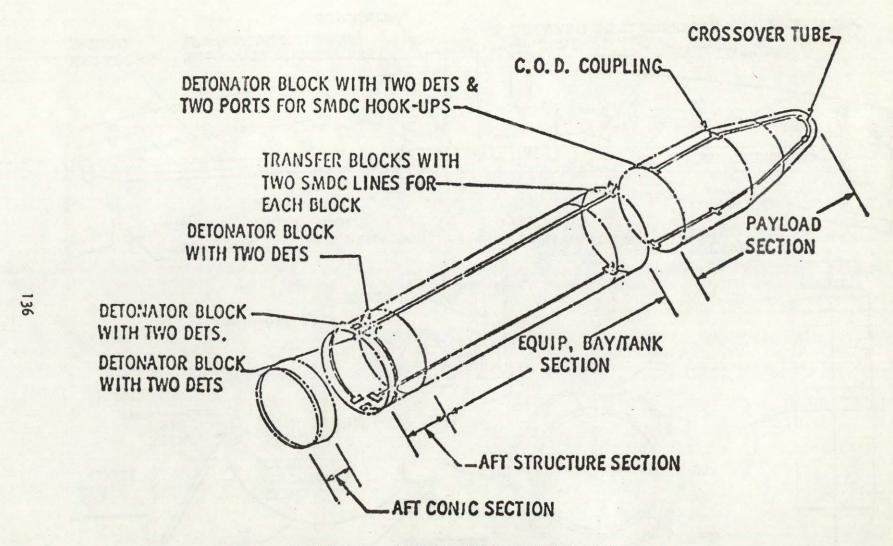


FIGURE 9-5 - SUPER * ZIP SEPARATION SYSTEM

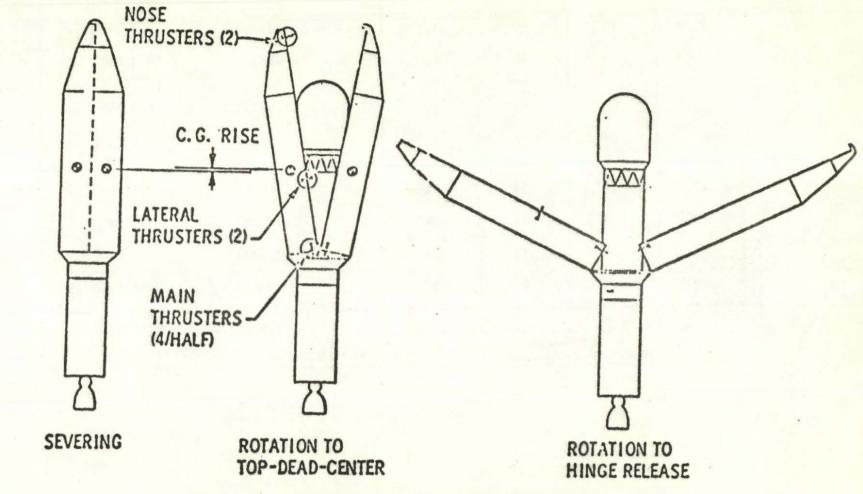


FIGURE 9-6 - JETTISON SEQUENCE AND SPRING LOCATION

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TABLE 9-1 - CSS BREAKWIRE SUMMARY

| BREAKWIRE | | TIME FROM PRIMARY COMMAND (SECONDS) | | | | |
|-------------------|----------|-------------------------------------|------|------|------|--|
| (ROTATION AND L | OCATION) | TC-4 | TC-5 | TC-6 | TC-7 | |
| 3º QUAD I | CAPPED | .36 | .41 | .42 | .41 | |
| 3º QUAD II | CAPPED | .36 | .41 | .42 | .41 | |
| 3º QUAD III | UNCAPPED | .36 | .41 | .41 | .41 | |
| 3º QUAD IV | UNCAPPED | .36 | .41 | .40 | .41 | |
| 8º QUAD 1 - 11 | CAPPED | .69 | .75 | .72 | .75 | |
| 8º QUAD III - IV | UNCAPPED | .70 | .75 | .69 | .71 | |
| 32° QUAD 1 - 11 | CAPPED | 1.89 | 1.91 | 1.95 | 1.96 | |
| 32° QUAD 111 - 1V | UNCAPPED | 1.75 | 1.86 | 1.83 | 1.85 | |

CSS Ascent Vent System

by W. K. Tabata

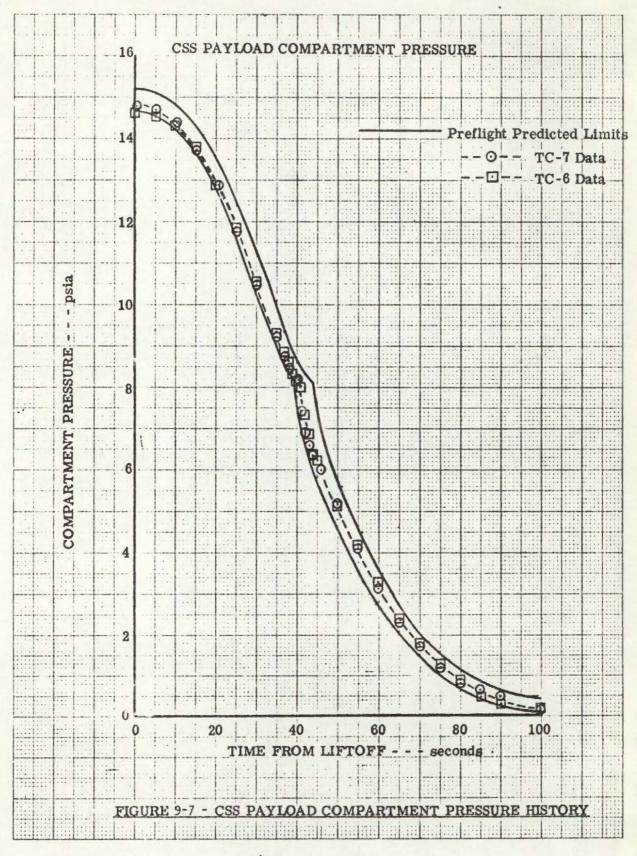
Summary

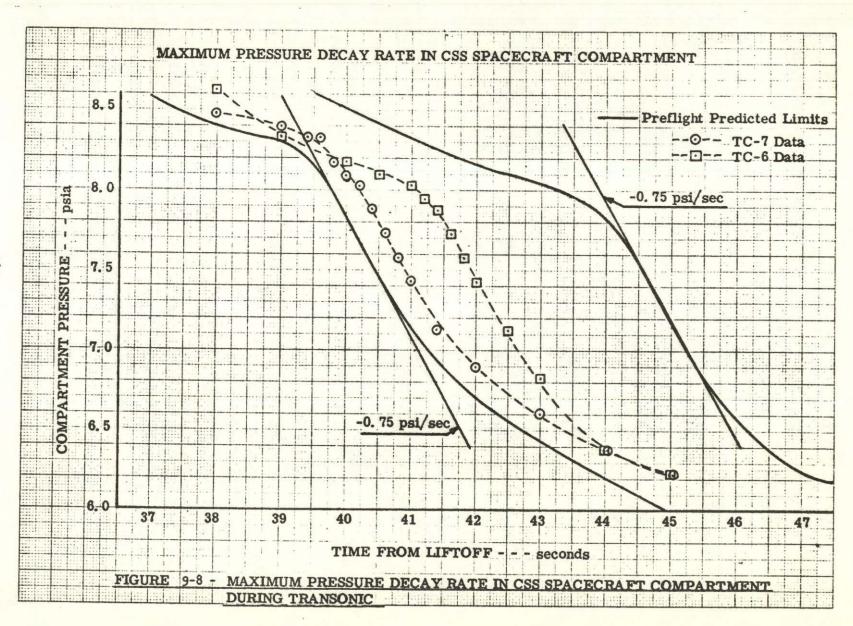
The CSS ascent vent system configuration for TC-6 was inspected on launch day by the Vent Team and found to be proper. The inflight operation of the system was satisfactory.

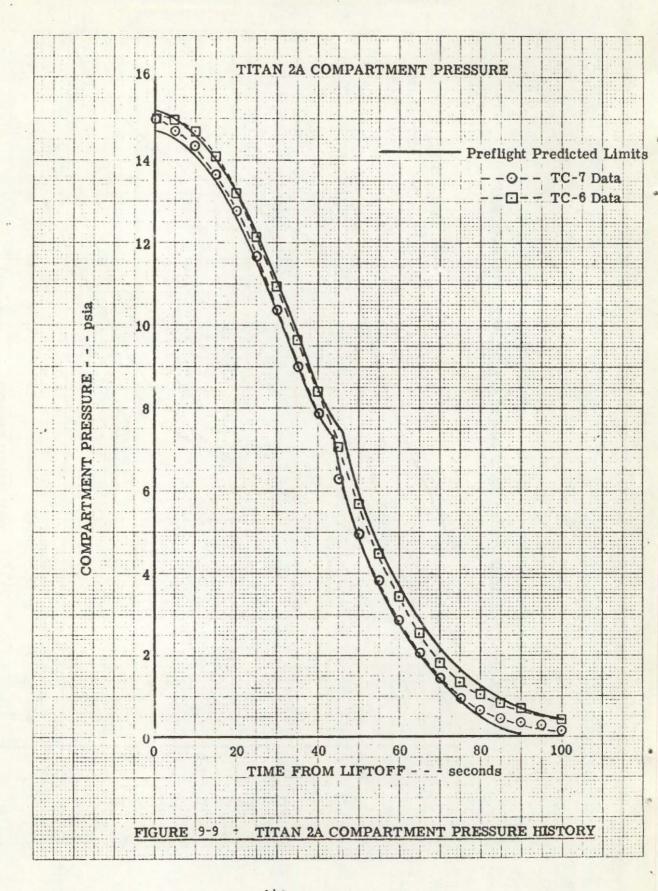
Discussion

<u>Spacecraft Compartment</u> - The time pressure history of the spacecraft compartment is shown in Figure 9-7. The data agree well with the preflight predicted limits which were based on analyses and flight data from TC-1 through TC-5 and agree well with TC-7 flight data. The maximum dp/dt during transonic was approximately -0.75 psi/sec. The time pressure history during transonic is shown in Figure 9-8 with similar data from TC-7.

<u>Titan 2A Compartment</u> - Venting of the Titan 2A compartment was normal. The time pressure history of the 2A compartment is shown in Figure 9-9. The data agree well with the preflight predicted limits and flight data from TC-7. There were no unusual pressure characteristics.







X TITAN/CENTAUR GROUND SYSTEMS

X TITAN/CENTAUR GROUND SYSTEMS

Mechanical Ground Support Equipment

by A. C. Hahn and M. Crnobrnja

Summary

The overall operation of the Complex 41 mechanical ground support equipment was satisfactory during the launch countdown for the TC-6 vehicle. System data are summarized in the following discussion and tables.

Discussion

Environment Control - The gas conditioning supply systems for the Centaur interstage adapter, the equipment module and payload compartment all performed properly. As shown in Table 10-1, the supply flow rates and gas temperatures for environmental control within these compartments were all within specification.

For the payload compartment, the inlet temperature, flow rate and dew point requirements had been maintained within parameters from time of erection on August 31, 1977, through launch.

The payload inlet cleanliness was well within class 100 clean room requirements from erection to disconnection of the Royco counter about three hours before MST removal. Maximum readings during this period were 30 particles greater than 0.5 microns, and 0 particles greater than 5 microns. The outlet readings were well within the Class 1000 clean room requirements.

A bolt in the actuator on the main shutoff valve in the 5800 psig header of GN2 system broke when the technician was opening the valve during countdown preparations. The broken bolt hit a nearby retaining wall like a shot. KSC Safety is processing a NASA "red alert" on the actuator.

The 500 kW diesel generator output voltage was cycling between 472 and 488 volts every 10 minutes. The reason was that the spare voltage regulator installed on R-2 day was single phase sensing instead of three phase sensing. The cycling did not affect system performance.

Pneumatics - All Centaur pneumatic systems performed normal. System pressure data is shown in Table 10-2.

Propellant Loading - Titan oxidizer and fuel tanking were performed satisfactorily on F-4 and F-3 days respectively.

TABLE 10-1 - GSE ENVIRONMENTAL CONTROL SYSTEMS FOR TC-6

| | | | | Countdown Time, Minutes | | | | | | | |
|---|--|-------------------------------------|---|---|---|---|---|---|---|---|---|
| Parameter | Meas. No. | V014-62 04-37-214-01 | Expected Range | T-115C | T-110 | T-95 | T-73 | T-60 | T-20 | T-10¢ | T-0 |
| | | | | 1051Z | 1056Z Start LO2 Chill | 1111Z Start LH2 Chill | 1133Z Start LH2 Tank | 1146Z | 1226Z Start LHe Chill | 1246Z | 1256Z |
| GN2 Supply: High Pressure Supply Supply Pressure Htr. Disch. Press. Inlet Press. Inlet Temperature | COS13P COS17P COS15P COS16P COS10T | psig psig psig psig DGF | 5500 max. 2200 max. 105-110 50+ 5 Amb+ 10 | 4296 2232 107.2 52.4 84.2 | 4284 2232 107.2 52.4 84.2 | 4068 2232 107.2 52.4 84.2 | 3846 2232 107.2 52.4 84.4 | 3696 2232 107.2 52.4 84.4 | 3360 2232 107.2 52.4 85.4 | 3180 2232 107.2 52.4 86.4 | 3108 2232 107.2 52.4 87.2 |
| Centaur Interstage Adapter: Supply temperature Flow Rate Inlet Temp. Duct Pressure Evap. Disch. Temp. | COS36T COS23R COS 9T COS 6P COS19T | DGF LBM DGF INW DGF | 130± 5 118+7-3 32.5 45 max. | 124.8 126.3 118.3 30.7 35.6 | 124.8 126.3 118.2 30.7 35.6 |
| Centaur Equipment Module: Supply temperature Flow Rate Inlet Temp. | COS35T COS22R COS 8T | DGF LBM DGF | 90 <u>+</u> 5 70+ 5-0 | 73.6 90.55 72.5 |
| Duct Pressure Evap. Disch Temp. | COS 7P COS2OT | I NW DGF | 17 45 max. | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 |
| Payload Compartment: Supply Temp. Flow Rate Inlet Temp. Duct Pressure Evap. Disch. Temp. | COS34T COS24R COS 5T COS14P COS18T | DGF LBM DGF INW DGF | 160± 5 64± 2 40 max. | 64.0 161.5 64.2 30.1 32.2 | 64.0 161.5 64.2 30.1 32.2 | 64.0 161.5 64.2 30.1 32.2 | 64.0 161.5 64.2 30.1 32.26 | 64.0 162.5 64.2 30.1 32.3 | 64.0 162.5 64.2 30.1 32.4 | 64.0 162.5 64.2 30.1 32.5 | 64.0 162.5 64.2 30.1 32.5 |
| Backup Unit Evap. Disch. Temp. | COS21T | DGF | 40 max. | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 |

TABLE 10-2 - GSE PNEUMATICS AND UMBILICAL RETRACT SYSTEMS FOR TC-6

| | Cou | | | | Countdo | Countdown Time, Minutes | | | | | |
|--------------------|--------------|-------|-------------------|--------|-----------------------------|-----------------------------|----------------------------|--------|--|--------------|--------------|
| Parameter | Meas. No. | Units | Expected Range | T-115C | T-110 | T-95 | T-73 | т-60 | T-20 | T-10C | T-0 |
| | | | 10 | 1051Z | 1056Z Start LO2 Chill | 1111Z Start LH2 Chill | 1133Z Start LH2 Tank | 1146Z | 1226Z Start LHe Chill | 1246Z | 1256 |
| Pneumatics: | | | | | | | | | | | |
| _He purge supply | CFS 62P | | 1200-5000 | 5286 | 5274 | 5178 | 5076 | 4950 | 4734 | 4632 | 4572 |
| 5Normal GN2 supply | CFS 63P | | 2200-5000 | 5430 | 5418 | 5418 | 5418 | 5418 | 5418 | 5382 | 5382 |
| Primary H3 supply | CFS 64P | | 2200-5000 | 5370 | 5358 | 5292 | 5190 | 5130 | 4956 | 4956 | 4950 5478 |
| Emerg. He supply | CFS 65P | | 3500-5000 | 5520 | 5520 | 5508 | 5508 | 5508 | 5490 2160 | 5484 2160 | 2160 |
| BPSC Inlet Press. | CFS122P | psig | 2200+ 100 | 2160 | 2160 | 2160 | 2160 | 2160 | 2100 | 2100 | 2100 |
| Umbilical Retract: | The state | | | | -300 | | | | | | 1005 |
| Aft T-4 Cyl press. | CLS450P | | 1200+ 25 | 1205.9 | 1205.9 | 1205.9 | 1205.9 | 1205.9 | The second secon | 1205.9 | 1205. |
| Aft T-4 Cyl vent | CLS451P | | 1200+ 25 | 1213.3 | 1213.3 | 1213.3 | 1213.3 | 1213.3 | | 1213.3 | 1213. |
| LO2 T5 Cyl press. | | | 2000+ 25 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055. |
| LO2 T5 Cyl vent | CLS453P | | 2000+ 25 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055.0 | 2055. |
| FWD T-4 Cyl press. | CLS454P | | 1800+ 25 | 1801.9 | 1801.9 | 1801.9 | 1801.9 | 1801.9 | | 1801.9 | 1816. |
| FWD T-4 Cyl vent | CLS455P | | 1800+ 25 | 1816.8 | 1816.8 | 1816.8 | 1816.8 | 1816.8 | 1816.8 | | 1995. |
| LH2 T1 Cyl press. | | | 2000+ 25 | 1995.5 | 1995.5 | 1995.5 | 1995.5 | 1995.5 | 1995.5 | 1995.5 | 2010. |
| LH2 T5 Cyl vent | CLS457P | psig | 2000+ 25 | 2010.4 | 2010.4 | 2010.4 | 2010.4 | 2010.4 | 2010.4 | 2010.4 | 2010. |

<u>Umbilicals</u> - All Centaur umbilical systems performed normally. System loads and pressure data are summarized in Tables 10-2 and 10-3.

The LO2 T-0.5 second cylinder and vent pressure readouts during countdown were slightly higher than expected but were acceptable.

The lanyard load for pulling the T-4 aft plate was 330 pounds, the highest ever. The addition of the hydraulic accumulator in the retract system resulted in a good fast time of 1.36 seconds from command signal to door closure even with the high load. Post launch checks showed that the lanyard reaving block had separated from the cylinder rod during or after disconnect. Attempts are being made to understand the reason for the separation.

TABLE 10-3 - GSE UMBILICAL RETRACT SYSTEMS FOR TC-6

| | Parameter | | Units | Maximum Allowable | |
|-----|------------------------------|-------------|-------|----------------------|-------------|
| | Forward T-4 Disconnect | | | | |
| | Time to disconnect | P-1 | sec | 3.0 | 1.35 |
| | | P-2 | sec | 3.0 | 1.10 |
| | | P-3 | sec | 3.0 | 0.86 |
| | Lanyard Load | P-1 | lbs | 1100 | 131 |
| | | P-2 | 1bs | 1100 | unavailable |
| | | P-3 | lbs | 1100 | unavaitable |
| | T-4 Aft Plate | | | | |
| | Time from cmd to door clos | ire | sec | 3.0 | 1.36 |
| - | Time from cmd to aft plate | | sec | | 1.31 |
| 148 | Lanyard Load | 4136 | 1 bs | 600 | 330 |
| | LO2 F&D | | | | |
| | Time from cmd to disconnec | | sec | | .46 |
| | Lanyard Load | | 1bs | 1200 | 569 |
| | LH2 F&D | | | | |
| | Time from cmd to disconnec | | sec | | .68 |
| | Lanyard Load | | lbs | | 576 |
| | Fwd T-0 Electrical Disconnec | ts | | | |
| | Time from SRM ign to disc | P-4 | sec | | 0.65 |
| | | P-5 | sec | - 1 | 0.75 |
| | Disconnect times are based o | n DRS data. | | | |
| | | | | | |

Electrical Ground Support Equipment

by H. E. Timmons

The countdown for the launch of TC-6 began at 9:21 p.m. (EDST) on September 4, 1977, at T-625 minutes. Launch took place at 08:56:00.958 a.m. (EDST) on September 5, 1977, at the opening of the launch window. The electrical and mechanical umbilical disconnect times were as shown in Tables 10-4 and 10-5, respectively. Table 10-6 shows the opening times for the six Titan prevalves. Subassemblies (S/A) 1 and 2 are associated with the Stage 1 engines while Subassembly 3 is for the Stage 2 engine. During the entire countdown, all launch control, ground instrumentation, and power systems operated normally. There were no anomalies reported during the countdown period.

TABLE 10-4 - TC-6 ELECTRICAL UMBILICAL DATA

CMG T-0 (DRS channel 295 off) - 12:56:00.916

Ignite SRM command (DRS 739) - 12:56:00.937

SRM ignition relay closed (DRS 496) - (Official T-0) - 12:56:00.958

| | Titan Umbilicals | Time Disconnected | Time from Official T-0 |
|----|--|-------------------|------------------------|
| | LB1E (DRS 048) | 12:56:01.315 | T+0.357 |
| | RBIE (DRS 049) | 12:56:01.321 | T+0.363 |
| _ | ICIE (DRS 499) | 12:56:01.372 | T+0.414 |
| 50 | 2A2E (DRS 015) | 12:56:01.372 | T+0.414 |
| | 2A1E (DRS 035) | 12:56:01.387 | T+0.429 |
| | 2C1E (DRS 505) | 12:56:01.450 | T+0.492 |
| | Centaur Umbilicals (All Breakwire Indications) | | |
| | B600P3 (DRS 050) | 12:55:57.799 | T-3.159 |
| | B600P2 (DRS 042) | 12:55:58.036 | T-2.922 |
| | B600P1 (DRS 098) | 12:55:58.291 | T-2.667 |
| | B600P4 (DRS 099) | 12:56:01.582 | T+0.624 |
| | B600P5 (DRS 103) | 12:56:01.690 | T+0.732 |

TABLE 10-5 - TC-6 MECHANICAL UMBILICAL DATA

Centaur

| Event | Time | Time from CMG T-0 |
|--|---------------|-------------------|
| Aft Plate Eject Command from CMG (DRS 718) | 12:55:56:.938 | T-3.978 |
| Aft Plate & T-4 Command from MTR (DRS 443 & 459) | 12:55:56.953 | T-3.963 |
| Aft Door Closed (DRS 051) (Microswitch Indication) | 12:55:58.246 | T-2.670 |
| Vent Door Closed (DRS 330) (Breakwire Indication) | 12:55:58.297 | T-2.619 |
| T-4 Events Complete (DRS 091) | 12:55:58.300 | T-2.616 |
| Fill & Drain Valve Eject CMD from CMG (DRS 716, 719(| 12:56:00.436 | T-0.480 |
| LH2 & LO2 Fill & Drain Valve Eject Command from MTR (DRS 359, 360, 361, 362) | 12:56:00.454 | T-0.462 |
| LO2 Fill & Drain Valve Dis- connected (DRS 018) (Loss of Valve Closed Indication) | 12:56:00.898 | T-0.018 |
| LH2 Fill & Drain Valve Disconnected (DRS 030) (Loss of Valve Closed Indication) | 12:56:01.117 | T+0.201 |
| Air-Conditioning Duct Dis- connect Command from CMG (DRS 715) | 12:56:00.937 | T+0.021 |
| Air-Conditioning Duct Dis- connect Command from MTR (DRS 461) | 12:56:00.955 | T+0.039 |

TABLE 10-6 - TC-6 TITAN PRE-VALVE OPERATE DATA

PRE-VALVE OPEN COMMAND FROM CMG (DRS 548) = 12:56:43.456

| PRE-VALVE | TIME VALVE FULL OPEN | OPERATE TIME (SECONDS) |
|----------------------------|----------------------|------------------------|
| FUEL S/A-1 (DRS 079) | 12:56:50.893 | 7.437 |
| FUEL S/A-2 (DRS 080) | 12:56:50.680 | 7.224 |
| FUEL S/A-3 (DRS 081) | 12:56:50.821 | 7.365 |
| OXIDIZER - S/A-1 (DRS 082) | 12:56:50.404 | 6.948 |
| OXIDIZER - S/A-2 (DRS 083) | 12:56:50.332 | 6.876 |
| OXIDIZER - S/A-3 (DRS 084) | 12:56:50.479 | 7.023 |