GENERAL DYNAMICS
Convair Aerospace Division

CENTAUR

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Imagination has been the hallmark of the Centaur program since its inception. Centaur was the vehicle selected to satisfy man's quest for knowledge in space. Already it has sent Surveyor to probe the moon's surface. Mariner to chart the planet Mars, the Orbiting Astronomical Observatory to scan the stars without interference from the earth's atmosphere, and Pioneer to Jupiter and beyond. Centaur will also be called upon to launch other spacecraft to continue to unlock the secrets of the planets, such as Mariner for Venus and Mercury in 1973, Viking Orbiter/Lander spacecraft to Mars in 1975, and advanced Mariners to Jupiter and Saturn in 1977.

Centaur has not only flown scientific missions but also ones with application for solving more tangible problems, such as Applications Technology Satellites and the Intelsat communications satellite. Centaur has also been chosen to deliver domestic and military communication satellites to synchronous orbit beginning in 1975.

Because man's curiosity will never be satisfied, Convair Aerospace stands ready to respond to the challenges of tomorrow with the same imaginative design and quality craftsmanship embodied in Centaur.

K. E. Newton
Vice President & Program Director
Launch Vehicle Programs

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INTRODUCTION

A little over a decade ago, Centaur began the first evolutionary steps from conventional rocketry to the high-energy-fueled vehicles of oxygen/hydrogen. Centaur faced numerous problems, many of them demanding solutions beyond the then current state of the art. Centaur's liquid hydrogen fuel required special tank construction and materials that would not freeze, become brittle, or fail under the stresses of space flight. Even the behavior of the liquid hydrogen under weightless conditions was unknown, but a vital question . . .

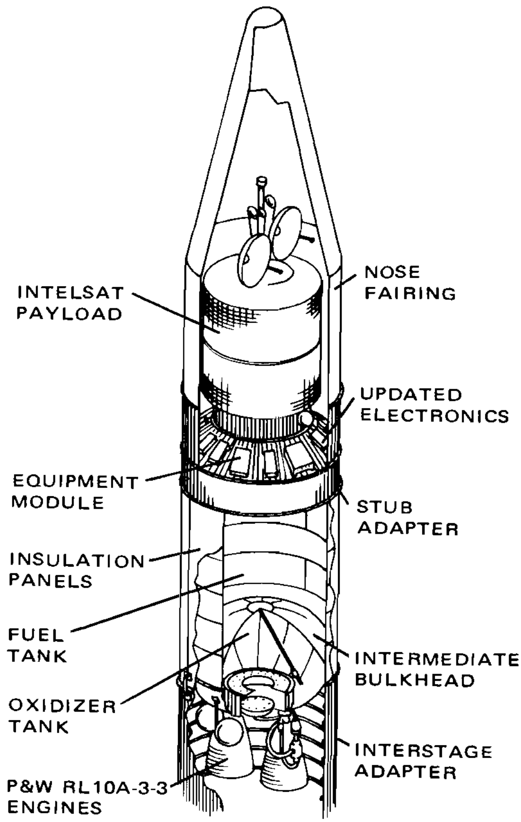
Centaur met all challenges and, on its first operational flight, placed the Surveyor spacecraft on its historic journey to the moon. A perfect record of seven successful Surveyor flights was followed by the Orbiting Astronomical Observatory (OAO), Applications Technology Satellite (ATS), Mariner Mars programs in 1969 and 71, Pioneers 10 and 11 to Jupiter in 1972 and 1973, and a continuing Intelsat program for COMSAT Corporation, which has four straight successful launches to date.

Centaur has been selected by the Navy for the Fleet Satellite Communications program and by COMSAT Corporation to launch the American Telephone & Telegraph Corp. communication satellites – both programs beginning in 1975. The Atlas/Centaur combination will also be sending spacecraft to the planets in search of knowledge relating to the origin of life. A Mariner Venus/Mercury spacecraft is scheduled for launch by Atlas/Centaur in October of 1973 for a journey to the inner planets and will become the first satellite to investigate the planet Mercury.

Centaur is also being integrated with the Titan IIIE launch vehicle for launches in 1975 of the Viking Orbiter/Lander for man's most detailed examination of the planet Mars. The U.S. and West German governments have selected this same combination to launch Helios solar probes to 0.25 AU in 1974 and 1975. These spacecraft will fly closer to the sun than any previous mission to date.

CENTAUR STRUCTURE AND MAJOR SYSTEMS

The overall length of Centaur from the forward end of the fuel tank to the aft-most position of the main engines is 30 feet. Fully fueled, the vehicle weighs about 35,000 pounds. The tank structure is fabricated from thin stainless steel. The cylindrical portion of the tank is 0.014 inch thick.



Centaur D-1A Intelsat configuration.

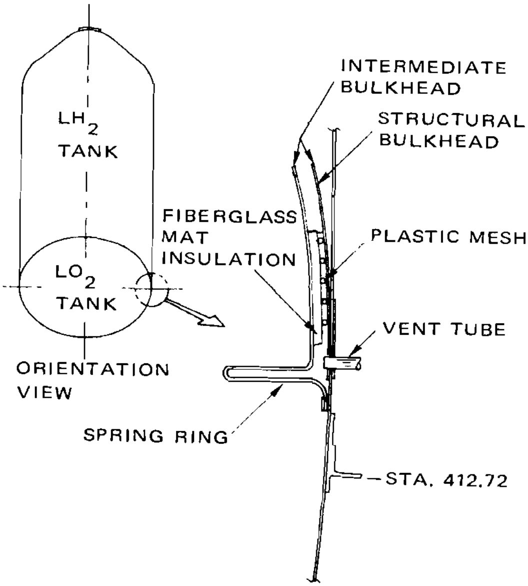
STRUCTURE

The tank is separated into two propellent compartments by a double-walled intermediate bulkhead. The bulkhead not only separates the propellants but, equally important, it also serves as a heat barrier. Without such a barrier, liquid oxygen, at -297°F, which is relatively "hot" compared to the -423°F temperature of liquid hydrogen, would vaporize the hydrogen and cause it to vent from the vehicle.

Vacuum between the double-walled bulkheads increases its effectiveness as a heat barrier. The double-walled bulkhead consists of two hemispherical thin-steel bulkheads positioned together, one fitting into the other. The vacuum is created in the space between them by a method called "cryogenic pumping." In cryogenic pumping, the supercold propellants in the vehicle literally freeze the oxygen and nitrogen from the air in the bulkhead's inner space, causing the gases to solidify and creating a vacuum. Heat transfer across the bulkhead is greatly reduced as a result of the vacuum.

On Centaur D-1A the liquid hydrogen tank is insulated by lightweight fiberglass insulation panels. The four panels enclose the cylindrical portion of the vehicle, thus shielding the hydrogen from aerodynamic heating as the vehicle rises through the atmosphere, minimizing fuel boiloff. The panels are jettisoned inflight when no longer required.

Centaur D-1T uses thermal radiation shielding consisting of layers of aluminized Mylar to insulate the hydrogen tank sidewall and forward bulkhead.



Intermediate bulkhead installation.

PROPULSION

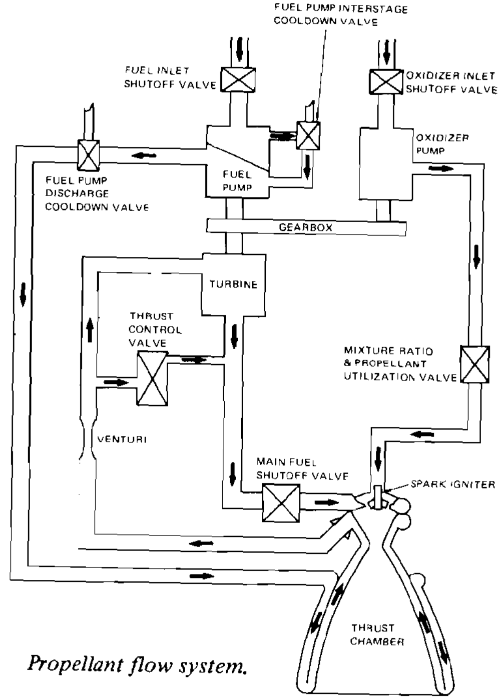
Centaur's main engines use liquid hydrogen and liquid oxygen as propellants. Each engine generates 15,000 pounds of thrust, for a total of 30,000 pounds. Externally, the RL-10A-3-3 does not look like an evolutionary step in engine design. But the advances in internal engine design are considerable. One such advance is multiple use of the fuel. Most rocket engines use a portion of the burning propellant to drive gas generators. These generators, in turn, drive the pumps to move the propellant to the thrust chamber. The RL-10A-3-3 eliminates this cycle.

Liquid hydrogen at -423°F enters the cooling jacket around the thrust chamber. Inside the thrust chamber, hydrogen and oxygen are burning at temperatures around 6,000°F. The hydrogen in the outer jacket cools the engine wall, protecting it from the destructive heat of the mixture burning inside. As it absorbs heat from the engine, the liquid hydrogen becomes a gas. This gas, still cold at -100°F is expanded through a turbine to furnish the mechanical power needed to pump more liquid hydrogen into the combustion chamber. Thus, hydrogen serves two purposes before it is burned: it cools the thrust chamber, and drives the pumps. It is burned only in the thrust chamber where it produces useful thrust.

REACTION CONTROL

Centaur D-1A has a reaction control system that positions the vehicle when it is in orbit and the main engines are not firing. It also keeps propellants settled against the bulkheads for engine start.

The system consists of a hydrogen peroxide supply bottle, lines, valves, and 14 small motors located around the airframe. There are four 50-pound thrust vernier motors, four 3-pound thrust propellant-settling motors, and two thrust clus-

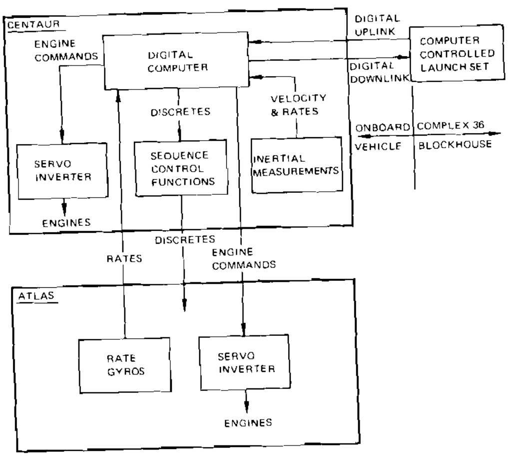


Propellant flow system.

ters, each containing one 6-pound thrust pitch motor and two 3.5-pound thrust roll/yaw motors. There are 12 motors on Centaur D-1T with six pounds thrust each.

GUIDANCE

The Centaur guidance and flight control system integrates autopilot, attitude control, and sequencing functions into the airborne computer software. This system also provides steering and sequencing commands for both Atlas and Titan booster operations. The combination of a serial digital command link from the ground-installed Computer Controlled Launch Set (CCLS) and Pulse Code Modulation (PCM) telemetry system down-link data provides automatic checkout while reducing the need for umbilical lines. The CCLS is a ground computer capable of loading test subroutines and commands into the airborne computer over a serial digital data link.



Atlas/Centaur guidance and flight control block diagram.

System flexibility is achieved by locating all mission-peculiar parameters within the software. Autopilot gains; filter characteristics; pitch, yaw, and roll programs; event time; attitude control thresholds; and logic as well as guidance parameters are software-controlled. This feature enables a wide spectrum of missions to be flown with identical hardware. The hardware consists of five major hardware units: (1) the Servo-Inverter Unit, (2) Sequence Control Unit, (3) Digital Computer Unit, (4) System Electronics Unit, and (5) Inertial Reference Unit.

The Teledyne Digital Computer Unit (DCU) is a general-purpose, stored-program, binary, two's complement unit with a self-contained 16,000-word random access memory, arithmetic section, timing and control section, input/output section, and power supply. The DCU provides discretes to the Sequence Control Unit (SCU) and engine commands to the Servo-Inverter Unit (SIU).

The SCU provides a-c and d-c on/off power controls, relay closures, flight event commands, attitude control engine commands, power changeover, and safe and arm switches.

The SIU contains the servoamplifiers that drive the Centaur engine position servovalves and a 120-va single-phase, 400-Hz inverter. It provides proper voltages for the engine position feedback transducers and propellant utilization system.

The Honeywell Inertial Reference Unit (IRU) contains a four-gimbal, all-attitude, gyro-stabilized platform that supports three orthogonal pulse rebalanced accelerometers and a prism for alignment. Mounted on the gimbals are resolvers that transform inertial vectors into the vehicle coordinate system. The IRU also contains all pulse rebalance, gimbal stabilization, gyro torquing, and resolver chain electronics.

The System Electronics Unit provides filter, power supplies, and mode control relays for the IRU.

When Centaur D-1 flies on Atlas, Centaur provides both stabilization and steering. Titan IIID, however, maintains its own autopilot function and therefore requires only guidance steering signals from Centaur.

HYDRAULICS

Two identical and separate hydraulic power supply systems provide the force to gimbal Centaur engines – one system for each engine. Main components of each system are a power-package assembly and two actuators. Each power package contains a miniature pump that supplies pressure to the actuators. One pump, coupled to the engine turbine drive, operates while the engines are firing. During coast phase, when the rocket engines and main pumps are not operating, another electrically powered and thermostatically controlled pump circulates the hydraulic fluid through the system. This is done whenever the hydraulic temperature falls below a predetermined level, thus maintaining the system at a nearly uniform temperature.

TANK PRESSURIZATION

The airborne tank pressurization system consist of the helium storage bottle, valves, and lines t deliver pressurized helium from the storage bot tle to the propellant tanks. Vent valves on th tanks prevent overpressurization.

Before tanking, propellant tanks are pressurize directly from ground-supplied helium. Durin and after tanking, pressurization is maintained b hydrogen and oxygen boiloff and regulated b vent valves on each tank. Fuel tank pressure i nominally 21 psia and the oxidizer tank pressur is 30 psia. The fuel tank has a secondary ven valve set to relieve at 5 psia above the primar valve. This valve prevents over-pressurizatio whenever the primary vent valve is locked close

Propellant tank pressurization is increased befor each main engine start to prevent boost pum cavitation. Helium is the working gas used i this operation.

ELECTRICAL

The Centaur main electrical system consists of silver oxide-zinc battery and the harnessing t distribute 28-volt d-c power and electrical signal to vehicle systems. Single-point grounding i used and nonessential systems are fused to ensur reliable Centaur operation. Alternating curren power, both 26- and 115-volt, single-phase, 40 Hz, is supplied by the servo-inverter unit.

The Centaur and its boost vehicle are electrically independent in that each has its own primary a-c and d-c power sources.

Pyrotechnic electrical systems provide conditioned initiation current for each vehicle pyrotechnic system. Electrical power for Centaur payload pyrotechnic functions is furnished by pyrotechnic batteries or the Centaur main power battery through pyrotechnic control units on the Centaur vehicle.

Two identical batteries furnish power for the Centaur range safety command system. One battery supplies each redundant half of the system. Circuit isolation makes each battery and its associated equipment completely independent of any possible failure of the other battery and its associated circuitry.

PROPELLANT UTILIZATION

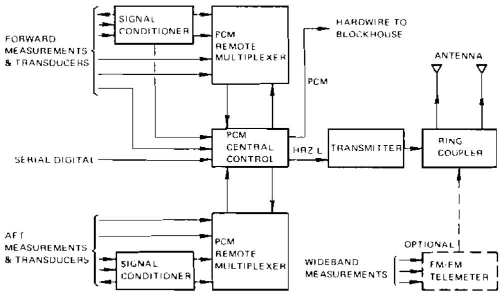
A propellant utilization system is used to improve vehicle performance by regulating the flow of propellants so that both tanks are emptied at the same time. The system continuously compares the amount of propellants remaining in each tank and meters the flow of oxygen to the engines. Flow is regulated by valves in the main oxidizer feed system. These valves move in response to signals from a computer that receives information on the amount of propellants remaining in the tanks.

INSTRUMENTATION AND TELEMETRY

The instrumentation and telemetry system monitors Centaur vehicle and subsystem performance and environment during flight and ground operations.

The instrumentation subsystem senses such physical parameters as pressure, temperature, position, strain, and acceleration. This information is converted by transducers and signal conditioning to electrical analogs suitable for the PCM telemeter unit.

The telemetry subsystem accepts the outputs of the instrumentation subsystem, encodes the data, and transmits to ground recording and monitoring equipment. At the request of payload contractors, some spacecraft measurements may be transmitted over the Centaur telemeter as backup for payload telemeter systems.



Instrumentation and telemetry subsystem block diagram.

TRACKING AND RANGE SAFETY

Centaur is carefully tracked during powered portions of its flight to obtain information about its trajectory. Initial tracking down the Atlantic Missile Range is performed by stations at Cape Kennedy, Grand Bahama, Grand Turk, Antigua, and Bermuda Islands.

This tracking data is used to determine orbital parameters and to permit real-time impact prediction for range safety displays. The data also will be a measure of vehicle performance.

Atlas/Centaur and Titan/Centaur are each equipped with a redundant range safety command system. With this system, the range safety officer at Cape Kennedy can shut off the engines and/or destroy the vehicle in case of a malfunction. The system is disabled by the range safety officer when Centaur reaches a point in its trajectory where a malfunction would no longer be dangerous.

CENTAUR ON ATLAS

Atlas and Centaur each have a constant 10-foot diameter and are made of thin, lightweight, stainless steel. Each vehicle keeps its shape through pressurization; excess weight is avoided by eliminating internal framework. All main engines are gimbaled for directional control. Gross weight of the 131-foot vehicle is about 323,000 pounds at launch.

ATLAS – THE FIRST STAGE

Developed as a weapon system for the U.S. Air Force, Atlas evolved to serve as a versatile space launch vehicle.

Atlas operational space boosters are the most advanced versions of a long line of successful launch vehicles. Based on simplicity and quality of design, the Atlas continues to prove that the lightweight, pressure-stabilized steel structure is the most efficient airframe in use today, without a single structural failure in 406 flights. Atlas has performed a variety of missions, including ballistic, earth orbit, lunar, and planetary. It recently amassed a record of 53 consecutive successful space launches between June 1966 and December 1971.

For use with Centaur, the tapered nose section of the Atlas has been enlarged to a constant 10-foot diameter. Eight 500-pound-thrust retrorockets have been added to the aft section of the Atlas to increase the rate of separation from Centaur. This configuration is called Space Launch Vehicle – 3D (SLV-3D).

Atlas, like Centaur, has no internal bracing; it maintains its cylindrical shape through internal pressurization. This concept can be likened to a football – lightweight, but rugged.

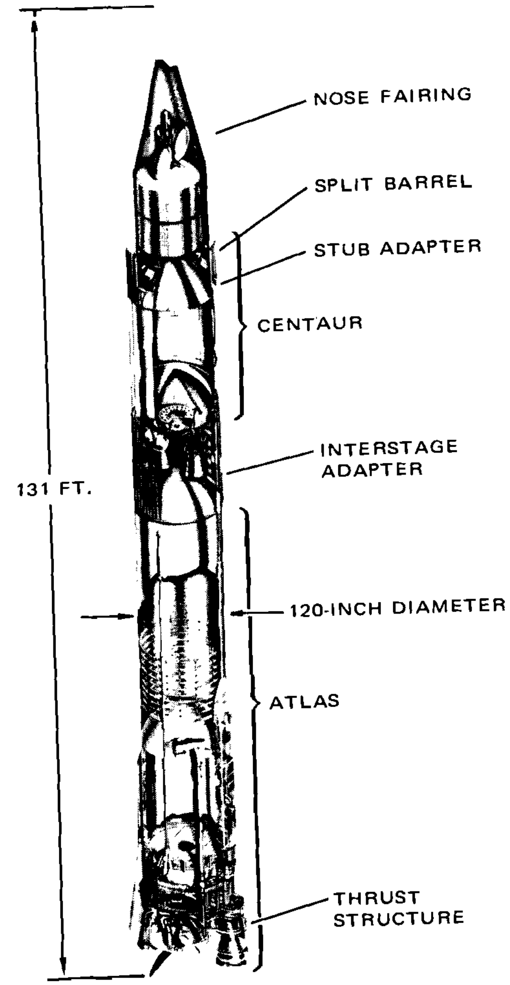
The Atlas first stage, which weighs about 284,000 pounds at launch, consists of a jettisonable booster section, the sustainer and propellant tank section, and the interstage adapter section. Its MA-5 propulsion system, produced by the Rocketdyne Division of North American Rockwell, includes two booster engines, a sustainer engine, and two small vernier rockets. These five engines produce a takeoff thrust of approximately 431,000 pounds at launch. All engines gimbal for directional control.

The Atlas launch vehicle and the Centaur are joined by an aluminum alloy interstage adapter – a hollow, cylindrical structure fixed to the top of the Atlas. Centaur is seated on the adapter, secured by bolts. At separation, the adapter remains with the Atlas. Separation is accomplished by an explosive charge that concentrates its energy into a cutting action. The charge is encased in a 1/16-inch lead tube that encircles the adapter. On signal, the charge detonates and slices through the adapter to free Centaur from Atlas.

CENTAUR – THE UPPER STAGE

The second stage, a high-energy space vehicle, is powered by two Pratt & Whitney RL-10A-3-3

ATLAS/CENTAUR COMBINATION USED TO LAUNCH INTELSAT IV SERIES OF COMMUNICATION SATELLITES



engines. Each generates 15,000 pounds of thrust, gimbals for directional control, and can be stopped and restarted in flight. The engines burn a liquid hydrogen-liquid oxygen mixture that delivers more power per pound than conventional propellants.

The hydrogen turbopumps in Centaur engines are chilled before ignition because liquid hydrogen vaporizes to a gas if "heated" above -423°F. If the pumps were not prechilled, the hydrogen would form a gas upon contact with the relatively warm metal and the engines would not operate properly. Although Centaur's engines are chilled to liquid helium temperatures on the ground, they "heat up" to an estimated -280°F by the time the space vehicle separates from Atlas. To return the pumps to operating temperatures, liquid hydrogen and liquid oxygen flow through them for approximately eight seconds before the engines are started the first time. Due to space heating, about 20 seconds of flow are required to chilldown the engines before the restart of a second burn.

Hydrogen peroxide is used by Centaur's reaction control system to provide attitude control and propellant management during coast periods between main engine firings. The amount of hydrogen peroxide carried is mission dependent, with ample volume available for long-duration coasts to synchronous altitude.

Centaur takes advantage of the high-energy characteristics of hydrogen as a fuel to perform more complex deep-space missions for NASA than have been attempted heretofore. It provides about a 35% increase in capability over conventional hydrocarbon fuels.

With its high-energy capability, Centaur is playing a key role in launching U.S. and international payloads to expand man's knowledge of the universe in which he lives and to improve long-distance communication on earth.

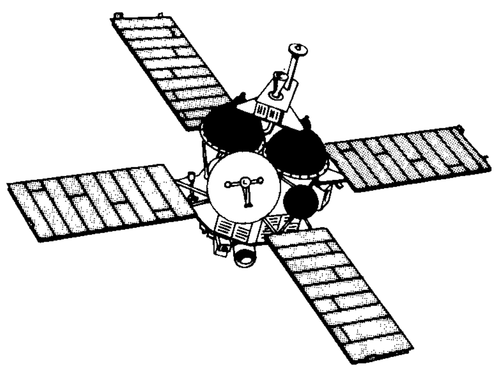
ATLAS/CENTAUR VITAL STATISTICS

ATLAS (SLV-3D)	
Length	70 ft.
Diameter	10 ft.
Guidance	by upper stage
Propulsion	Rocketdyne MA-5
Rated Thrust:	
Booster	370,000 lb.
Sustainer	60,000 lb.
Rated I_{sp} (sea level):	
Booster	257 sec.
Sustainer	221 sec.
Rated I_{sp} (vacuum):	
Booster	292 sec.
Sustainer	312 sec.
Propellants	LO_2/RP-1
Booster Jettison Wt.	7,500 lb.
Sustainer Jettison Wt.	8,200 lb.
Booster Staging	5.7g
Flt. Performance Reserve	0
CENTAUR D-1A	
Length	30 ft. (without fairing)
Diameter	10 ft.
Guidance	Inertial
Propulsion	P&W RL10A-3-3
Rated Thrust	30,000 lb.
Rated I_{sp} (vacuum)	444 sec.
Propellants	LO_2/LH_2
Centaur Jettison Wt.	4,240 lb.
Flt. Performance Reserve	1% ΔV
Centaur Payload Fairing	2,960 lb.

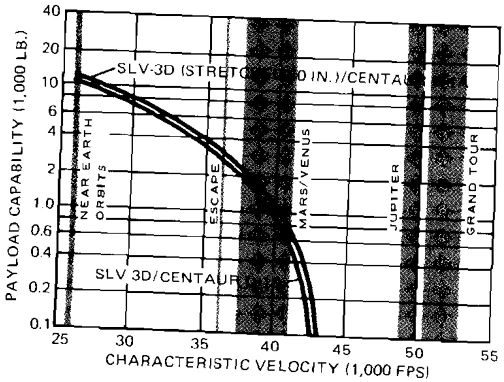
PERFORMANCE

The Atlas/Centaur launch vehicle is capable of placing 4,100 to 4,500 pounds of payload into synchronous transfer orbit, depending upon the version of the Atlas used; and from 2,140 to 2,300 pounds, including an Apogee Kick Motor (AKM) case, into synchronous equatorial orbit when an optimum AKM is used for the final circularizing burn.

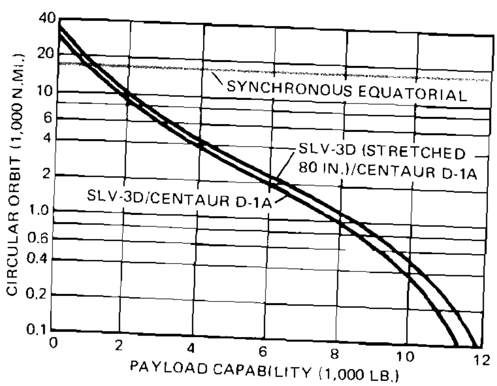
The payload capability of Atlas/Centaur for a range of characteristic velocities and launch from ETR is presented for both the current Atlas configuration and a stretched version. The longer Atlas is stretched approximately 80 inches to carry additional propellants and maintain a thrust-to-weight ratio at liftoff of 1.2:1. In addition, the payload capability has been determined for a range of circular-orbit altitudes for launch from ETR. The circular orbit performance cap-



ability is based on a Hohmann transfer technique with a 100-nautical-mile perigee.

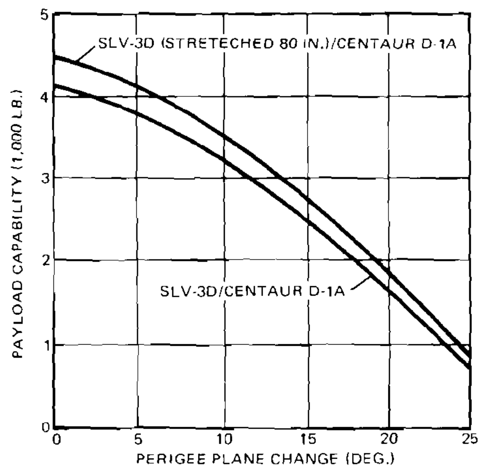


Atlas/Centaur D-1A generalized performance capability.



Atlas/Centaur D-1A circular orbit payload capability.

The payload capability for the synchronous transfer orbit (100 X 19,300 n.mi.) as a function of perigee plane change is presented for synchronous missions. For this mission, the Centaur second burn occurs at the first nodal crossing. For missions requiring the second burn to occur at the second nodal crossing, additional attitude control propellant must be carried for the longer coast. As a result, 140 pounds of payload capability will be lost. Note that zero perigee plane change conforms to a synchronous transfer orbit inclination of 28.3°.



Atlas/Centaur D-1A payload capability for synchronous transfer perigee plane change angle.

ATLAS/CENTAUR VITAL STATISTICS

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Rated Thrust:	
Booster	370,000 lb.
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Rated Thrust	30,000 lb.
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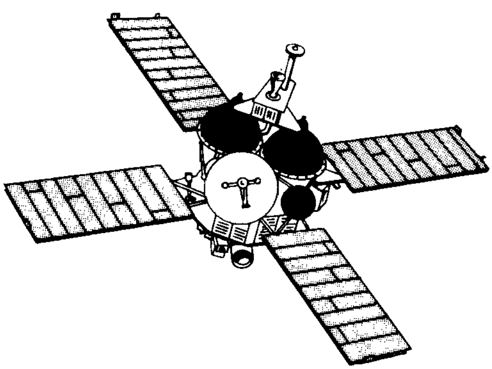

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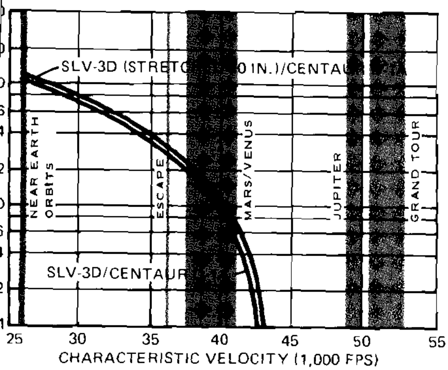

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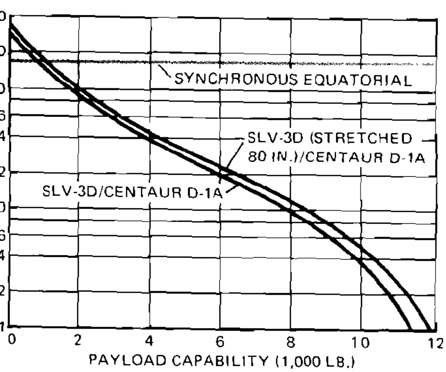

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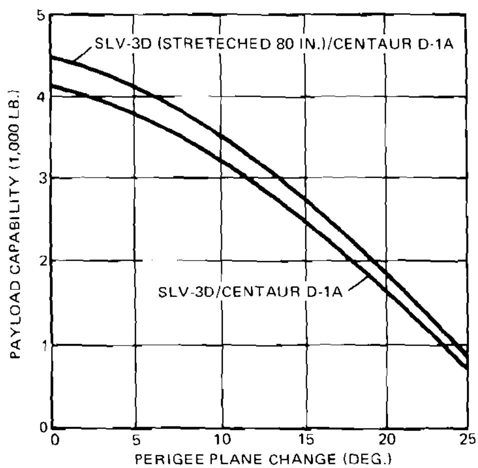


Atlas/Centaur D-1A payload capability for synchronous transfer perigee plane change angle.

CENTAUR ON TITAN IIIE

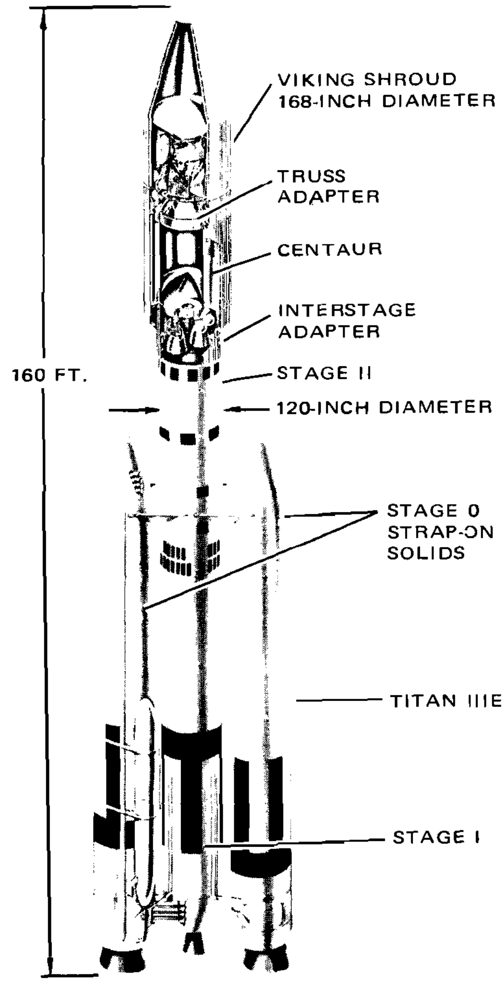
The Centaur used with Titan (D-1T) is essentially the same as the Centaur used with Atlas (D-1A). One difference is that D-1T uses a thermal radiation shield to reduce the amount of heat transferred to the supercold liquid hydrogen during long coast periods in space, whereas D-1A has jettisonable insulation panels to perform a similar function during the ascent portion of flight.

Thermal radiation shielding consists of layers of aluminized Mylar to insulate the hydrogen tank sidewall and forward bulkhead. The gaseous hydrogen boiloff is reduced by a factor of 10. As a result, vent cycles will only be required at two-hour intervals on long coasts. Since each vent cycle requires thrusting with the auxiliary propulsion system to settle propellants, performance is improved by reduced auxiliary propellant requirements as well as reduced boiloff.

A new 14-foot diameter shroud, under development for the Viking program, provides a large payload envelope. It encloses the Centaur as well as the payload, insulating the helium-blanketed Centaur on the ground, and protecting the thermal radiation shield during launch.

The payload support structure on Centaur is designed for 12,000-pound payloads, carrying them on a truss structure with a 10-foot interface diameter. Payloads weighing less than 4,000 pounds can be carried on the equipment module with a 59-inch diameter bolt circle.

TITAN IIIE/CENTAUR COMBINATION USED TO LAUNCH VIKING MARS LANDER/ORBITER



TITAN IIIE/CENTAUR VITAL STATISTICS

TITAN IIIE	
Length	96 ft.
Diameter	10 ft.
Guidance	by upper stage
Rated Thrust (lb.)	
Stage 0 (sea level)	2,341,000
Stage I (vacuum)	523,000
Stage II (vacuum)	102,300
Rated I_{sp} (vacuum):	
Stage 0	266 sec.
Stage I	301 sec.
Stage II	317 sec.
Propellants:	
Core	N_2O_4/AZ-50
Stage 0	Solid propellant
Jettison Weights:	
Step 0	145,000 lb.
Step I	16,900 lb.
Step II	7,700 lb.
Shroud Jettison Wt.	6,100 lb.
Flt. Performance Reserve	0
CENTAUR D-1T	
Length	30 ft.
Diameter	10 ft.
Guidance	Inertial
Propulsion	P&W RL10A-3-3
Rated Thrust	30,000 lb.
Rated I_{sp} (vacuum)	444 sec.
Propellants	LO_2/LH_2
Centaur Jettison Wt.	4,500 lb.
Flt. Performance Reserve	1.435% ΔV

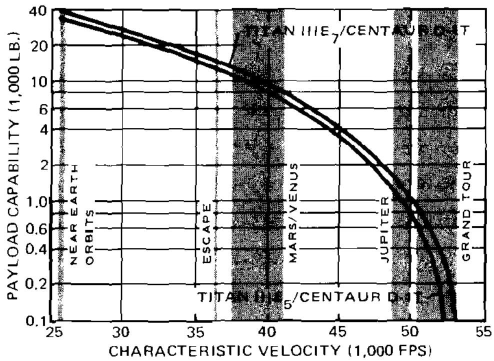
The Titan IIIE weighs about 1.36 million pounds at launch and consists of two five-segment solid rocket motors, a two-stage liquid propellant core section, and an interstage adapter section. The United Technology Center solid motors develop a combined thrust of more than 2.3 million pounds at liftoff.

PERFORMANCE

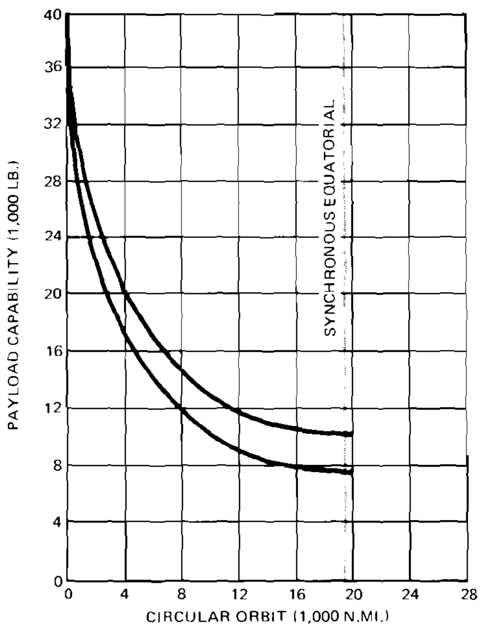
The payload capability of the Titan IIIE/Centaur to synchronous equatorial orbit from a due-east launch from the Eastern Test Range (ETR) is 7,400 pounds for a three-burn Centaur mission, and 7,900 pounds, including AKM case weight, for the two-burn mission with an optimized apogee kick motor.

The payload capability of Titan IIIE/Centaur for a range of mission characteristic velocities, for an ETR launch is presented for both the current Titan IIIE five-segment solid motor and the Titan IIIE seven-segment solid motor.

Payload capability has also been determined for a range of circular-orbit altitudes for launch from ETR. The circular orbit performance capability is based on a Hohmann transfer technique with 100-nautical mile perigee. The payload capability for the synchronous transfer orbit (100 X 19,330 n.mi.) as a function of perigee plane change is presented for synchronous missions.

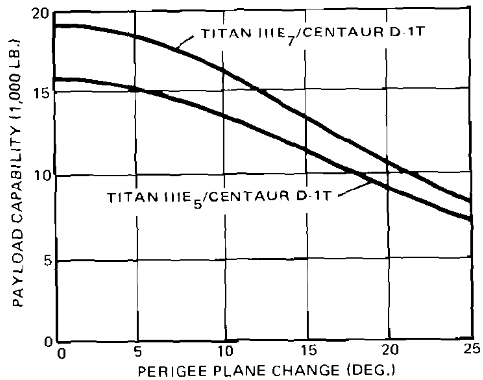


Titan/Centaur D-1T generalized performance capability.



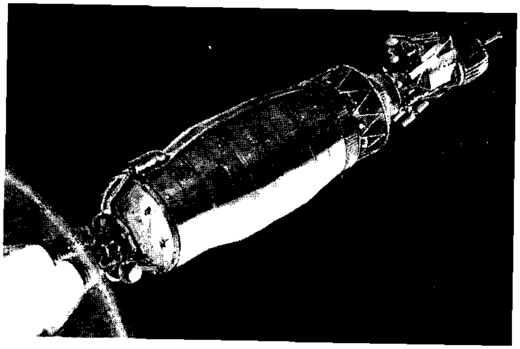
Titan/Centaur D-1T circular orbit payload capability.

For this mission, the Centaur second burn occurs at either the first or second nodal crossing, and a zero perigee plane change conforms to a synchronous transfer orbit inclination of 28.3°.



Titan/Centaur D-1T payload capability for synchronous transfer perigee plane change angle.

CENTAUR EXTENSIONS AND GROWTH

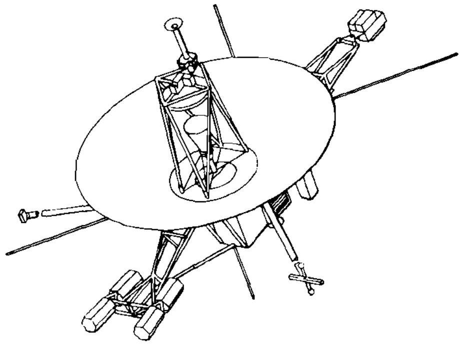


Improvements in Centaur and Atlas have been the subject of numerous studies. Today's vehicles incorporate many of these improvements – modern astrionics coupled with a high-capacity digital computer, redundancy in mechanical and fluid systems, tank extensions, engine thrust uprates, increased payload weight and volume capability, improved launch available in high winds, and improved thermal insulation. Other improvements are currently being considered to further extend Centaur's capacity to meet new and demanding mission requirements.

CENTAUR GROWTH TANK

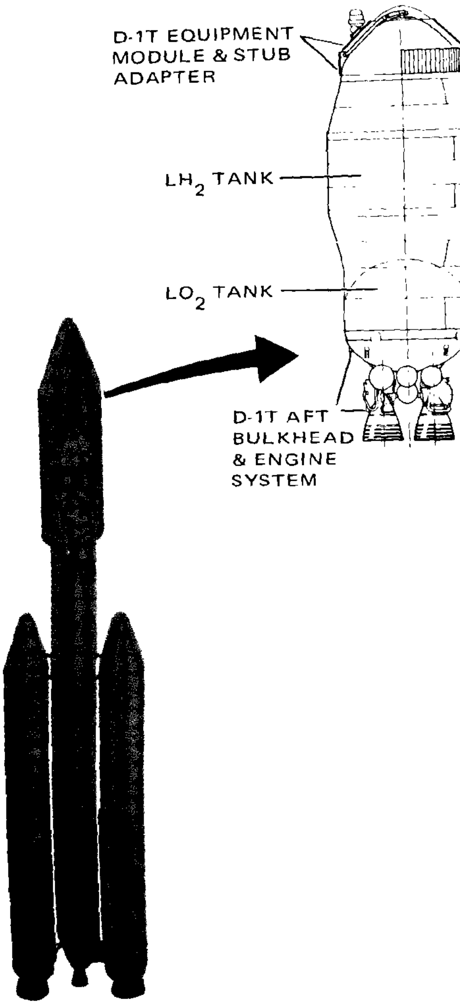
The Centaur Growth Tank (GT) offers a cost-effective performance improvement with Titan IIIE by increasing propellant capacity 50% with only a 58.5-inch length increase of

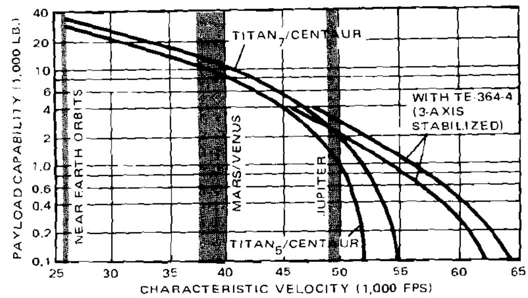
Centaur and its 14-foot diameter shroud. This is accomplished with a 28.6-inch cylindrical extension of the ten-foot-diameter oxidizer tank, and by increasing the fuel tank diameter to 146 inches. The payload support, forward equipment module, stub adapter, intermediate bulkhead, aft bulkhead, and propulsion system are left essentially unchanged to minimize costs.



TITAN IIIE/CENTAUR GT PERFORMANCE

Centaur GT with 45,000 pounds of propellants will increase Titan/Centaur payload capability by 200 to 300 pounds for outer planet missions to Jupiter and beyond (with TE-M-364-4), and by approximately 900 pounds for three-burn synchronous equatorial missions. The performance curve presents payload weight as a function of characteristic velocity for the Titan IIIE/Centaur GT combination with the stretched Centaur Standard Shroud.





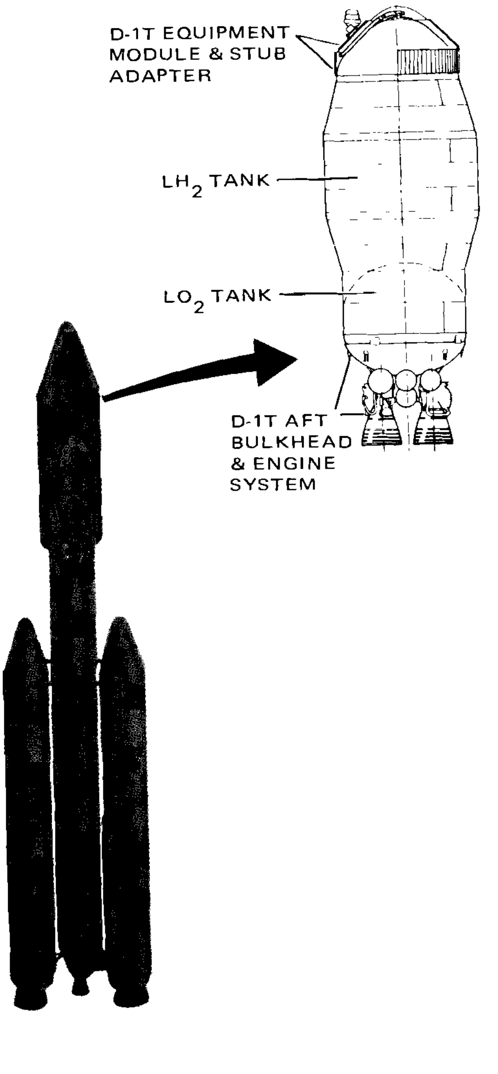
Titan IIIE/Centaur GT generalized performance.

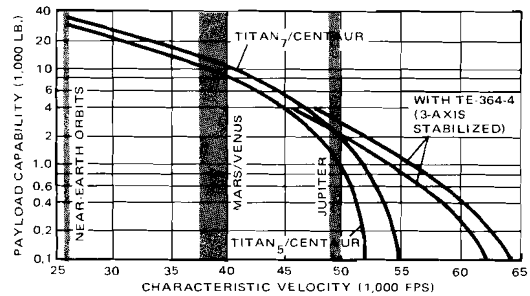
LONGER SPACE RESIDENCY

Although the Centaur D-1T is capable of long coast duration in parking orbit, the current Centaur D-1A configuration is presently limited to approximately 30 minutes. Some performance loss will be incurred for longer coast periods with Centaur D-1A due to added battery weight, control propellant, and propellant boiloff. The exact loss depends on payload weight, coast duration, and propellant management techniques.

Studies are under way to improve insulating methods, propellant management, and electrical power to extend both Centaur D-1A and D-1T space residency to days or even weeks. With these improvements, Centaur will be capable of making multiple payload placements, provide velocity increments for orbit changes or station-keeping, and furnish payload data processing, power, and ground command capability.

TITAN IIIE/CENTAUR GT COMBINATION





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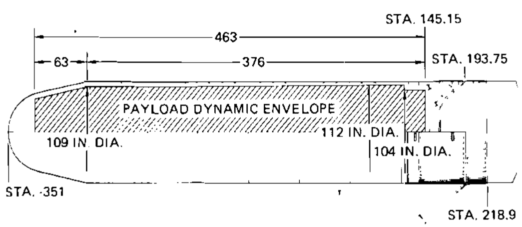
REDUNDANCY AND RELIABILITY IMPROVEMENTS

Additional increases in redundancy and reliability are being studied for Centaur D-1T and D-1A. The most promising, in terms of appreciable improvement with minimum cost and weight effects, are redundant strapdown guidance platforms and cross-connected hydraulic systems.

EXTENDED NOSE FAIRING

If a greater payload envelope than that offered by a five-foot extension of the standard fairing is required, integration of the McDonnell Douglas Universal Payload Fairing (UPLF), now used on Titan IIIC, can be accomplished on Centaur D-1A. This fairing has been analyzed for use with Atlas/Centaur and found to be within adequate control and structural margins. Use of the UPLF requires only strengthening of the Centaur fairing support structure and a 4 psi increase in the Atlas LO_2 tank pressure regulator setting.

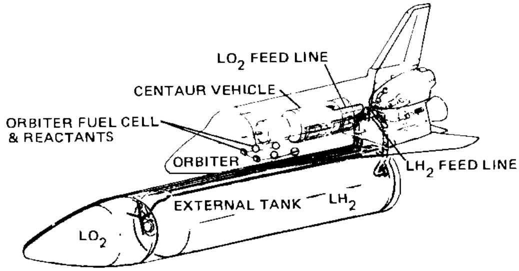


Extended nose fairing

CENTAUR IN THE SHUTTLE ERA

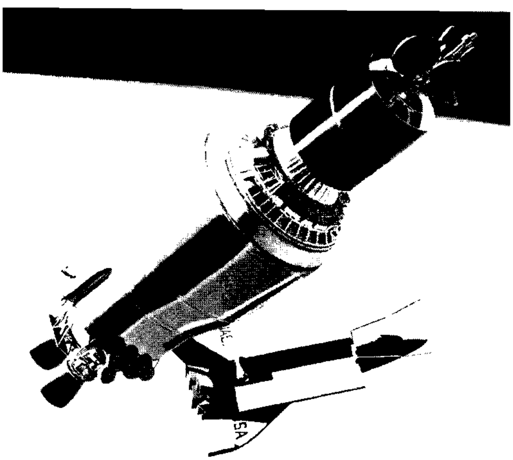
Convair Aerospace is currently involved in a NASA/DOD-funded systems study for the Space Tug as both an evolutionary (extension of Centaur) and a direct development vehicle. As the third stage of the Space Transportation System (STS), Centaur would be carried into a low earth orbit within the protective confines of the reusable Orbiter stage's cargo bay. After reaching this low orbit, the Centaur and its attached payload are extracted from the Orbiter. Centaur will then provide the propulsion and guidance necessary to place the payload into a higher energy orbit.

Centaur can accomplish all high-energy placement missions with relatively small adaptive changes to its present configuration. The advantage of known and proven hardware being available for STS use will greatly reduce the complexity and risk for its initial operations.



Centaur in the Shuttle Orbiter.

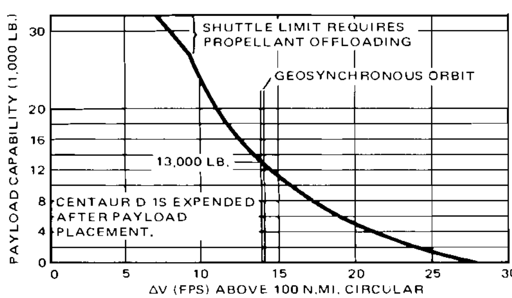
As usage rate of the STS increases, the economics of expending Centaur with each payload placement becomes an increasingly larger portion of STS operational costs. To offset this effect, a potential evolutionary step will be to increase the propellant-carrying capacity of Centaur to provide it with sufficient energy to enable it to place a payload in orbit and return to the Orbiter stage for reuse. Reusable Large Tank Centaur (RLTC) will require additional astrionics to provide the new guidance and navigation capability of returning. The RLTC is a way of evolving a current vehicle into a reusable third stage. It can be developed concurrently with the shuttle and have a minimum impact on total program development cost and risk.



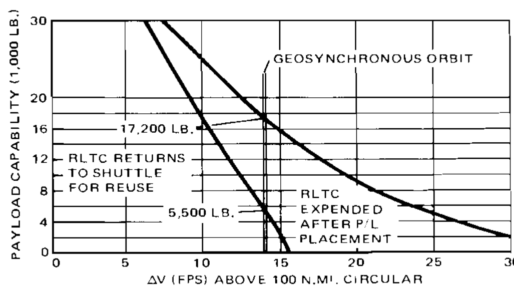
Reusable Large Tank Centaur

CENTAUR PERFORMANCE FROM THE SPACE SHUTTLE

Centaur performance from the shuttle is presented as a function of placement from 100 n.mi. altitude. Centaur D-1S performance is shown in expendable mode only, while the RLTC performance chart shows the capability for both expendable and reusable modes of operation. Expendable placement indicates that the Centaur third stage is not recovered after placing its payload in the proper orbit. The RLTC can be flown back to the Orbiter stage after payload delivery and returned to earth for minor refurbishment and reuse.



Centaur D-1S performance.



Reusable large tank Centaur performance.

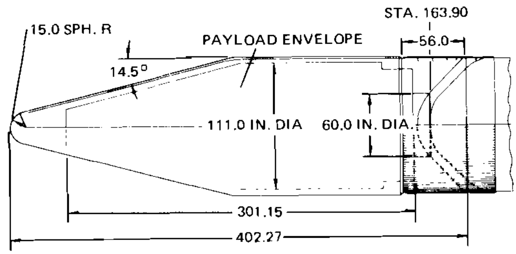
PAYLOAD FAIRINGS

An increasing number of space probes require large, low-density fairing systems for spacecraft protection. To meet this need, Convair Aerospace has developed a standard 120-inch diameter fairing for Centaur. In addition, a 168-inch diameter shroud is being developed for flight in 1974.

ATLAS/CENTAUR STANDARD FAIRING

The Atlas/Centaur standard fairing has a 10-foot inside diameter and is 31.5 feet long. It is supported by a 25-inch stub adapter on the forward end of the fuel tank and provides a payload envelope of approximately 111 inches diameter by 25.5 feet long. The front 29 feet is a split cone-cylinder with a spherical end cap. The 0.31-inch thick end cap is a solid laminate of phenolic and high-silica fiberglass. Main cone-cylinder shells are of sandwich construction with laminated phenolic outer skins, epoxy inner skins, and a 1.82-inch thick phenolic cellular core. It is constructed of fiberglass to provide RF transparency and thermal insulation. The remaining five feet is an aluminum barrel section. This configuration may be lengthened up to an additional 60 inches by inserting an aluminum barrel section between the two standard sections. This modification can accommodate a payload length on the order of 30 feet.

The complete length is staged in two halves. Separation force for staging is provided by two compressed springs located at the nose. Jettison tests have shown that either spring alone provides enough force for jettisoning.



Centaur payload fairing for Intelsat IV.

The payload cavity is separated from the liquid hydrogen tank by the equipment module and protected by insulation on the forward bulkhead. A thermal bulkhead in the top of the equipment module completes the isolation of the payload envelope from the liquid hydrogen tank. Conditioned air is supplied to the cavity until the start of propellant tanking, at which time the gas is switched to conditioned nitrogen.

CENTAUR STANDARD SHROUD

The Centaur Standard Shroud is 14 feet in external diameter and 58 feet long. It is attached to the Titan IIIE/Centaur interstage adapter and surrounds both the payload and Centaur stage. Up to 28 feet of length is available for payload above the truss adapter, depending on the forward payload configuration.

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