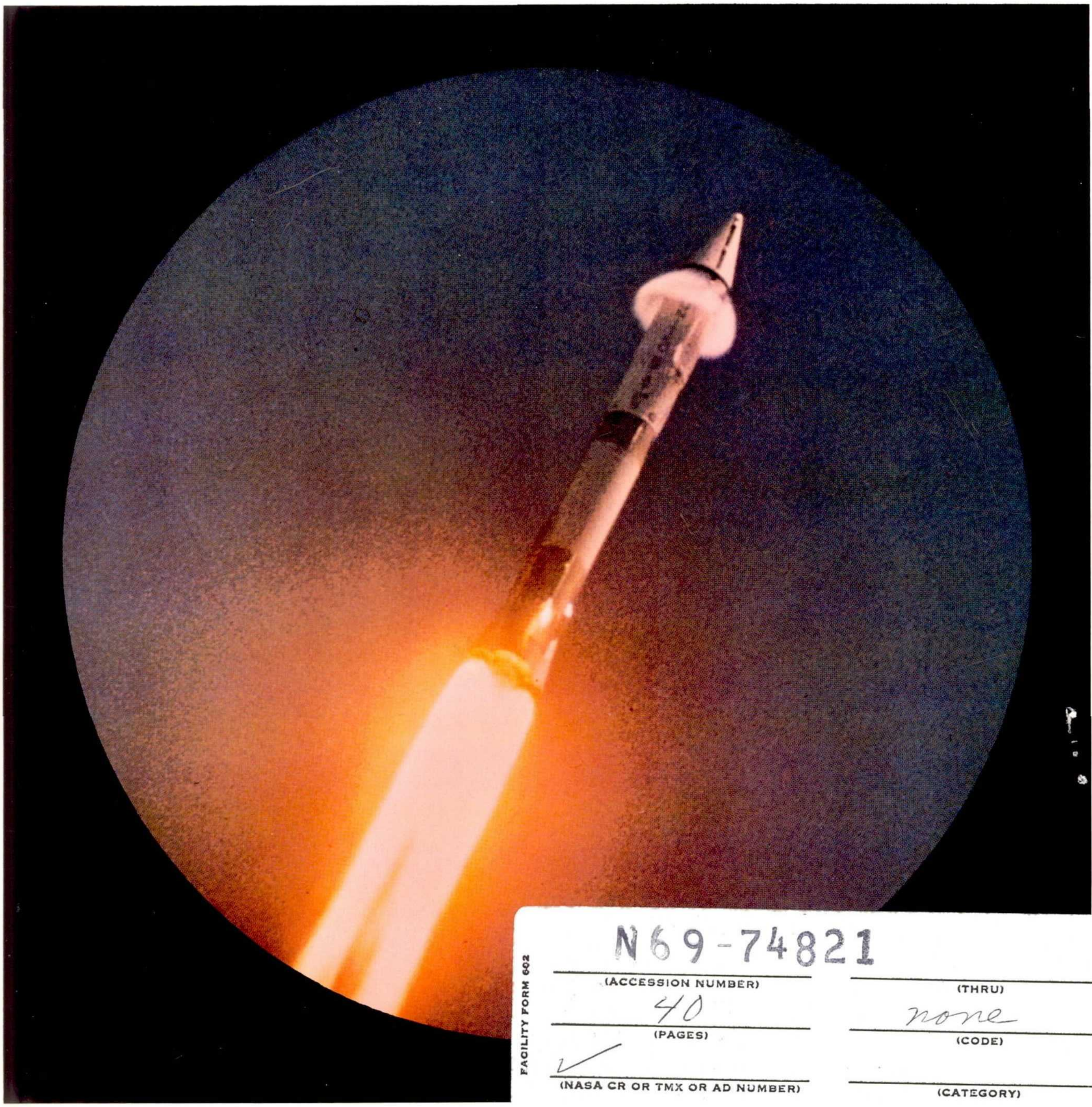
Advanced Atlas Launch Vehicle **DIGEST**

CONVAIR DIVISION OF GENERAL DYNAMICS

Issue No. 2



This Digest is compiled to aid mission program managers in determining the vehicle combination best suited to support each of their advanced or extended mission requirements. Changes resulting from continuing advancements at Convair division are included in this issue.

Since each individual mission has different requirements, the information submitted in this Digest is intentionally conservative to allow for mission peculiarities. With specific mission data, considerably more payload capability may be realized from these combinations. Cost information and more detailed performance and interface data will be supplied upon request; other documentation in the series covering the Convair division space products is listed below.

Atlas Launch Vehicle Family for Spacecraft Contractor Planning	GDC-BGJ67-002
Software and Integrating Contractor Capability	GDC-BGJ67-004
Atlas E/F Boosters and ABRES-A Criteria for Payload Designers	GDC-ANR67-005
Atlas Launch Vehicle Systems Summary	GDC-BGJ67-001
Centaur Systems Summary	GDC-BGJ67-003
Centaur Technical Handbook	GDC-BPM64-001-2
Convair Fairing Systems Brochure	October 1966
Advanced Fairing Systems	GDC-BGJ66-016
Orbital Vehicle One (OV1) Brochure	April 1967
OV1 Applications Guidebook	GDC-AAX65-015A

ABOUT THE COVER ✦ An unusual halo appeared aft of the Surveyor fairing 50 seconds after the launch of AC-6 on 11 August 1965. The halo was visible for ten seconds while the vehicle climbed from 16,000 to 25,000 feet and accelerated from Mach 0.76 to Mach 1.07. The effect was apparently caused by local expansion of air aft of the fairing during the transonic period. This expansion reduces the temperature; when humidity is high, the resultant condensation of ambient water vapor appears as a halo.

The phenomenon was recorded from the ROTI (recording optical tracking instrument) at Melbourne Beach, Florida, through a 500-inch optical system incorporating automatic focus and exposure control. The ROTI is a tracking telescope, domed like an observatory and using the mount from a 5-inch naval gun to provide azimuth rotation. A 70-mm Photosonic sequence camera operating at 20 exposures per second with daylight color film (ASA 160) was used to obtain this photograph.

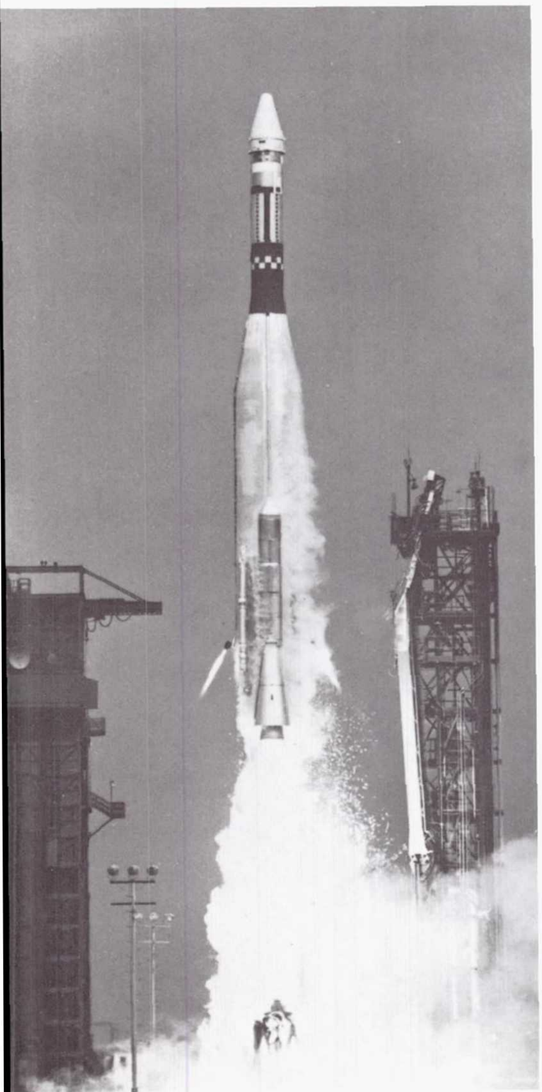
ADVANCED ATLAS LAUNCH VEHICLE DIGEST

Issue No. 2

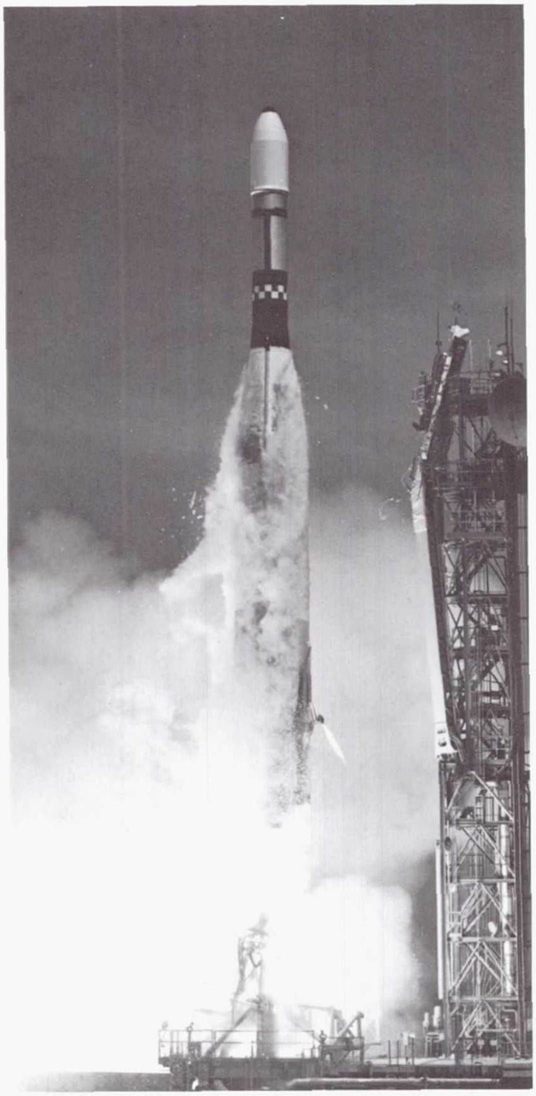
APRIL 1967

CONVAIR DIVISION OF GENERAL DYNAMICS
San Diego, California

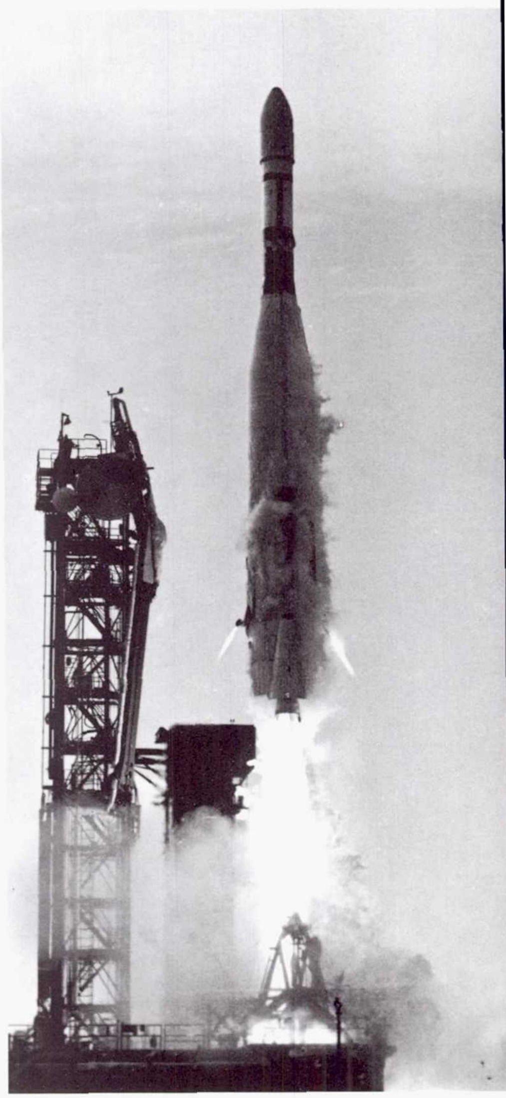
CONTENTS



Earth | Gemini Target



Moon | Lunar Orbiter



Mars | Project Mariner

UNDER the leadership of the United States Air Force and NASA, advanced Atlas and Centaur vehicles are being provided for space missions programmed far into the next decade. The Convair division of General Dynamics is proud of its participation in these programs and welcomes the opportunity of working with its customers in developing the most cost-effective launch vehicles for future missions.

Convair division is continually evolving more powerful versions of the Atlas. Two uprated configurations, the SLV-3A and SLV-3C, will soon join America's launch vehicle inventory. Studies are being performed to provide advanced Atlas vehicles with still higher performance – the SLV-3X series. All versions retain the flight-proven reliability of the SLV-3.

A variety of operational upper stages, including the high-energy Centaur vehicle, is available for use with future payloads. Payload velocity can also be increased by using kick stages. Further performance increases can be obtained by attaching existing solid-propellant motors to any member of the Atlas launch vehicle family. Under evaluation is a sustainer-tank apogee kick technique capable of injecting payloads directly into orbits at altitudes which would normally require an upper stage.

Both ballistic and powered passenger pods have been used to capitalize on performance capability above primary mission payload requirements, performing two missions for the cost of a single launch. This concept has been expanded to include multiple OV1 satellite systems housed in a single fairing and a multiple-mission "bus" to deliver several payloads to various orbits from a single launch.

With the phase-out of the Series E and F Atlas Weapon System as an operational strategic deterrent, 135 missiles are being programmed for a variety of missions. The low cost of these boosters is of extreme interest to many program managers with reduced budgets.

The dependability and economy of the Atlas and Centaur vehicles are unmatched in their classes. To maintain this leadership, Convair division will continue to stress maximum reliability and cost effectiveness in its entire family of space products.

ACCOMPLISHMENTS

Since 1958, the Atlas launch vehicle family has been the primary intermediate booster for the National Space Program. Significant contributions of America's first major space booster include:

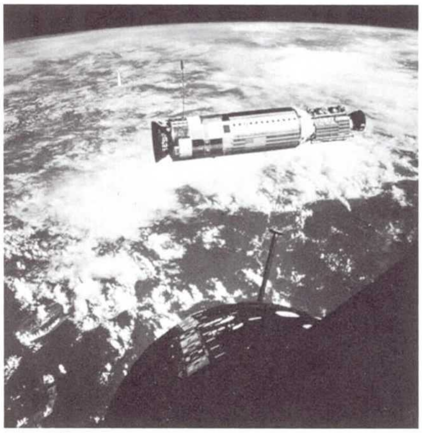
1st communications satellite
(Project Score, December 1958)
1st manned orbital flight
(Mercury, February 1962)
1st lunar impact by an American spacecraft
(Ranger 4, April 1962)
1st interplanetary fly-by
(Mariner 2 to Venus, August 1962)
1st launch of a hydrogen-powered upper stage
(Centaur, November 1963)
1st televised pictures of the moon
(Ranger 7, July 1964)
1st close-up pictures of Mars
(Mariner 4, November 1964)
1st nuclear reactor in space
(Snapshot, April 1965)
1st lunar soft landing by an American spacecraft
(Surveyor I, June 1966)
1st lunar-orbiting spacecraft
(Lunar Orbiter 1, October 1966)

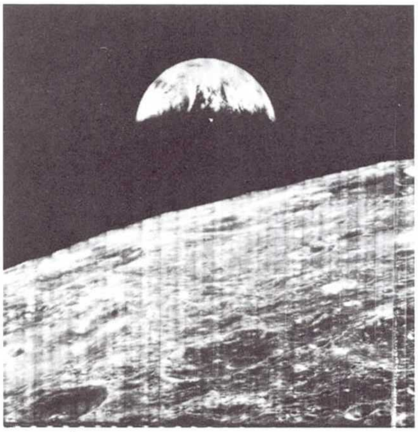
Surveyor I was soft-landed within 8 n.mi. of the selected target, requiring only 3.5 of the 50 meters/second mid-course correction capability. It was injected into lunar-intercept trajectory by the AC-10 Atlas/Centaur combination with such accuracy that it would have successfully landed within 216.3 n.mi. of the prelaunch target (247,420 miles from earth) even without mid-course correction.

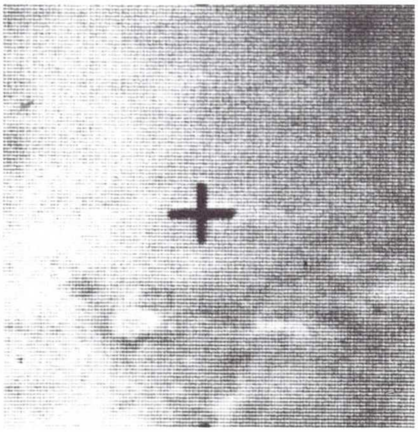
Dependability reaps results in savings. According to two communications from Air Force Major General Ben I. Funk, the series of 28 consecutive successful Atlas space launch vehicle flights beginning in June 1963 resulted in over $140 million of reduced expenditures for the national space effort. The 80 Atlas space launches since June 1963 have a cumulative reliability of over 96 percent; a second series of consecutive successes beginning May 1966 is now at 28. A total of 327 Atlas vehicles were launched as of 19 April 1967.

The total cost for a launched Atlas SLV-3 is quoted by the Air Force Space Systems Division as $3.5 million, including Convair division and Associate Contractor costs, propellants, payload integration, range, AGE, and all other associated costs.

This cost, which provides the lowest price per launched pound of payload in its range, is made even more meaningful by the types of contracts between Convair division and the using agency. Fee on current Atlas production and launch services contracts (FPIF, CPIF) is directly related to demonstrated performance in meeting specific incentive objectives: countdown and flight reliability, cost and schedule. Experience to date confirms that these objectives are being met; on the production and launch services contract for 35 SLV-3 vehicles recently completed, overall objectives were exceeded. Convair division is confident that future contractual obligations will also be met — not only within costs and on schedule, but with countdown and flight reliability assured.


Earth | Gemini Target

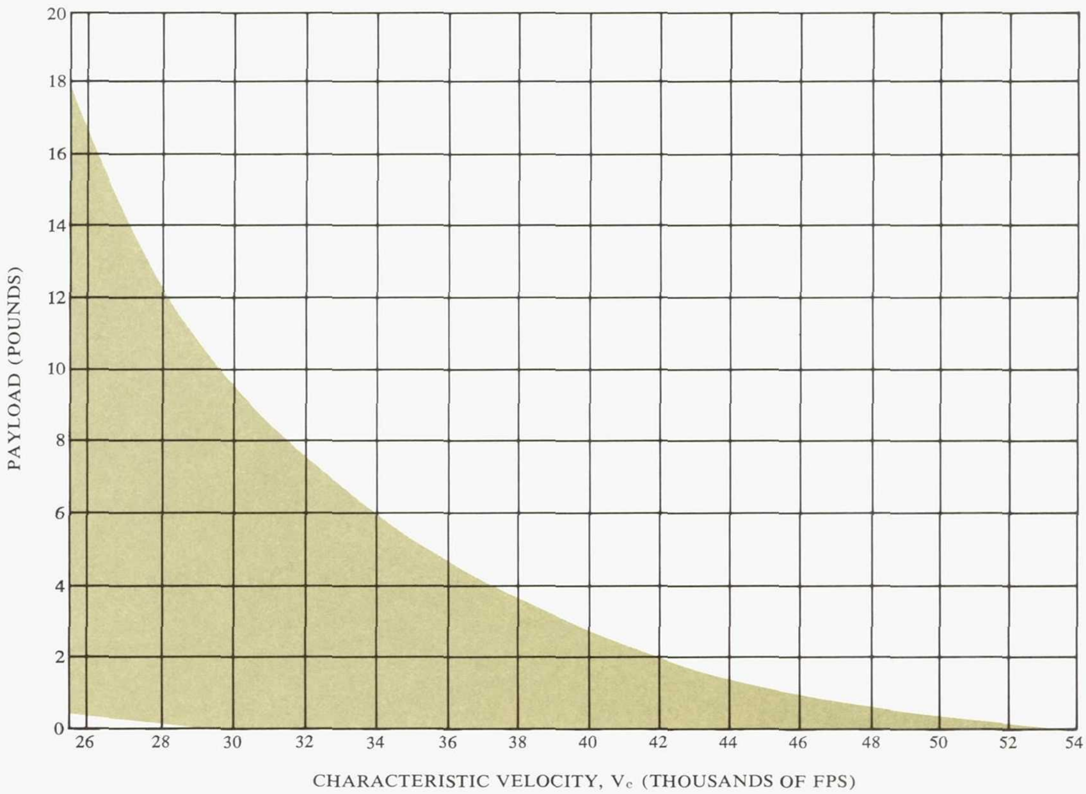

Moon | Lunar Orbiter

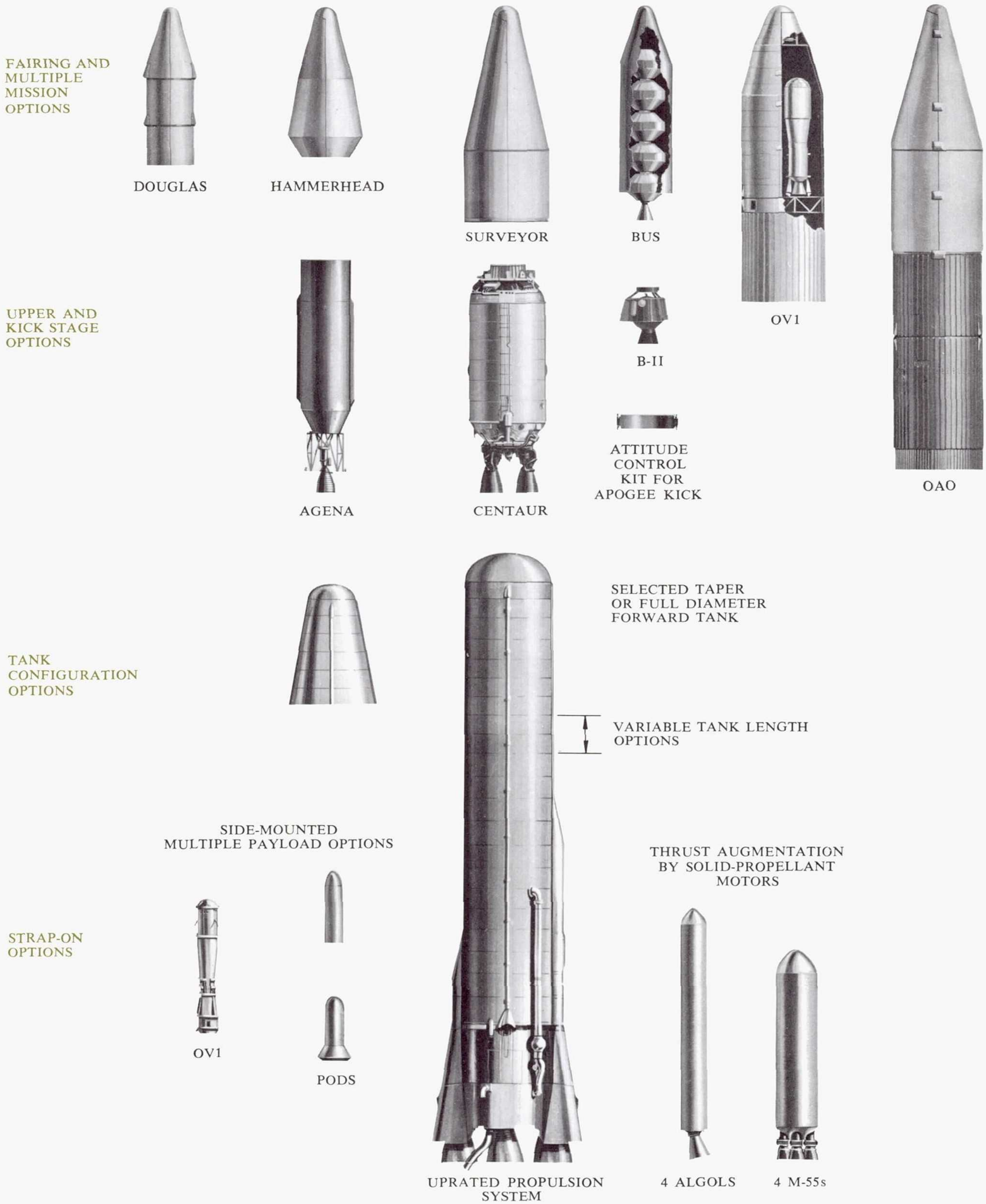

Mars | Project Mariner

Payload capabilities formerly considered to be beyond the range of Atlas are now in planning and development stages at Convair division. The feasibility of these designs has been well documented, and the advanced Atlas family (using existing upper stages) is capable of performing any mission contained in the range below. To deliver the 18,000-pound payload to 100-n.mi. circular orbit, thrust augmentation may be attached to an Atlas/Centaur; by also adding a solid-propellant kick stage, over 53,000 feet per second characteristic velocity can be achieved.

Mission requirements considered for the advanced Atlas launch vehicle family range from low earth orbit to hypervelocity deep-space probes. More than high thrust levels will be needed for the space efforts of the future; sophistication, reliability, and accuracy — as were demonstrated by Atlas/Centaur on the Surveyor mission — will be needed for these complex programs. Today, Centaur is the outstanding vehicle candidate for such high-energy applications as lunar and interplanetary excursions, solar probes, and synchronous missions.

By retaining the proven and reliable concepts of SLV-3 and Centaur, the Atlas family offers a variety of options to accomplish the higher performance missions of the next decade — within schedule and with assured reliability and maximum benefit/cost ratio.




FAIRING AND MULTIPLE MISSION OPTIONS
DOUGLAS
HAMMERHEAD
SURVEYOR
BUS
OV1
OAO
UPPER AND KICK STAGE OPTIONS
AGENA
CENTAUR
B-II
ATTITUDE CONTROL KIT FOR APOGEE KICK
TANK CONFIGURATION OPTIONS
SELECTED TAPER OR FULL DIAMETER FORWARD TANK
VARIABLE TANK LENGTH OPTIONS
SIDE-MOUNTED MULTIPLE PAYLOAD OPTIONS
STRAP-ON OPTIONS
OV1
PODS
UPRATED PROPULSION SYSTEM
THRUST AUGMENTATION BY SOLID-PROPELLANT MOTORS
4 ALGOLS
4 M-55s

To meet the increased needs of the next decade with maximum dependability and cost effectiveness, payload capability is increased by

UPRATING THE SLV-3

The advanced Atlas family vehicles (described in detail on pages 6 through 9), are improved-capability versions of the flight-proven SLV-3, uprated by techniques well within the current state-of-the-art. Modifications consist primarily of lengthening the tanks to provide additional propellant capacity and uprating the Rocketdyne MA-5 propulsion system; each retains the original Atlas concepts and proven reliability. Thrust can be augmented by attaching flight-proven solid motors with an existing attachment and jettison system.

A sustainer-tank apogee-kick technique can be used to greatly increase the orbital altitude of payloads without the cost, error source, and reliability loss associated with an upper stage.

A variety of kits, including a high-precision advanced autopilot, is used with the uprated Atlas configurations to further increase reliability and accuracy and to standardize and simplify payload or upper stage interface.

✦

USING MISSION-COMPATIBLE UPPER STAGES

Several existing upper stages are considered for use with Atlas, the largest being the operational one- and two-burn Centaur described on pages 12 through 15. Burner II is considered as a separate upper stage and as a kick stage with Centaur.

The flight-proven Atlas/Agena combination is also considered; payload performance with the standard two- and three-burn Agena and with the improved (N_2O_4) Agena are shown.

✦

USING RELIABLE LOW-DENSITY FAIRING SYSTEMS

A variety of fairing systems have flown successfully with Atlas, ranging from the 5-foot-diameter Ogive and Agena (long and short) to the 10-foot-diameter Surveyor and OAO fairing systems. Other fairings based on the OAO fairing system components are under contract, including an all-metal version. Fairing systems are further discussed on pages 14 and 15.

✦

PERFORMING MULTIPLE MISSIONS

Multiple missions may be flown with any Atlas configuration (including refurbished Series E/F missiles). A selected configuration with more payload capability than that required to accomplish the primary mission can carry a secondary payload. Cost sharing between the primary and secondary programs can result in substantially lower costs than would be incurred by using a separate launch vehicle for each program. This "piggyback" principle has already been used successfully on many Atlas launches. Dual OV1 satellite systems have already been launched by Atlas; a multiple-mission "bus" under investigation will house several payloads containing small injection motors in a single fairing. These and other multiple-mission concepts are discussed on pages 28 and 29.

ATLAS CHARACTERISTICS

The Atlas space launch vehicle has performed successfully on every type of mission in the current space program. Successful missions range from low earth orbit (Mercury, Gemini Target and ATDA) to lunar and interplanetary (Surveyor 1, Lunar Orbiter, Mariner to Venus and Mars). General features of the various Atlas configurations are discussed on the following pages.

All Atlas space launch vehicles have pressurized propellant tanks, with all loads reacted by the skin instead of by conventional stringers and frames. Tanks are fabricated as a series of stainless steel rings welded together to form a cylinder, an approach which lends itself to simplified tank lengthening by merely adding rings and allows simple change of skin thicknesses. Increased propellant quantity for added performance capability is accommodated by this added tank volume.

Skin gages are determined by the composite effects and interrelationship of aerodynamic heating, flight bending, axial load, ground winds, and tank pressures expected for planned Atlas missions. Skin thickness of each ring is selected to meet the most critical condition.

Atlas vehicles burn RP-1 fuel with liquid oxygen (LO_2). Propellants are separated by a hemispherical intermediate bulkhead (convex upward). To maintain bulkhead integrity, pressure in the lower tank is always positive relative to the combination of LO_2 (upper) tank pressure, LO_2 head, and acceleration loads.

Because the tanks have no stringers, they must be supported at all times or positive pressures must be maintained within the tanks to prevent collapse. During transport, erection, and prior to propellant tanking, Atlas vehicles are kept under low pressure and supported by stretch slings. After the vehicle is erected, fuel is tanked and the fuel tank pressure is raised to the flight-pressure level. Before engine ignition, LO_2 tank pressure is increased to Phase III (flight) level and pressurization is switched to internal supply.

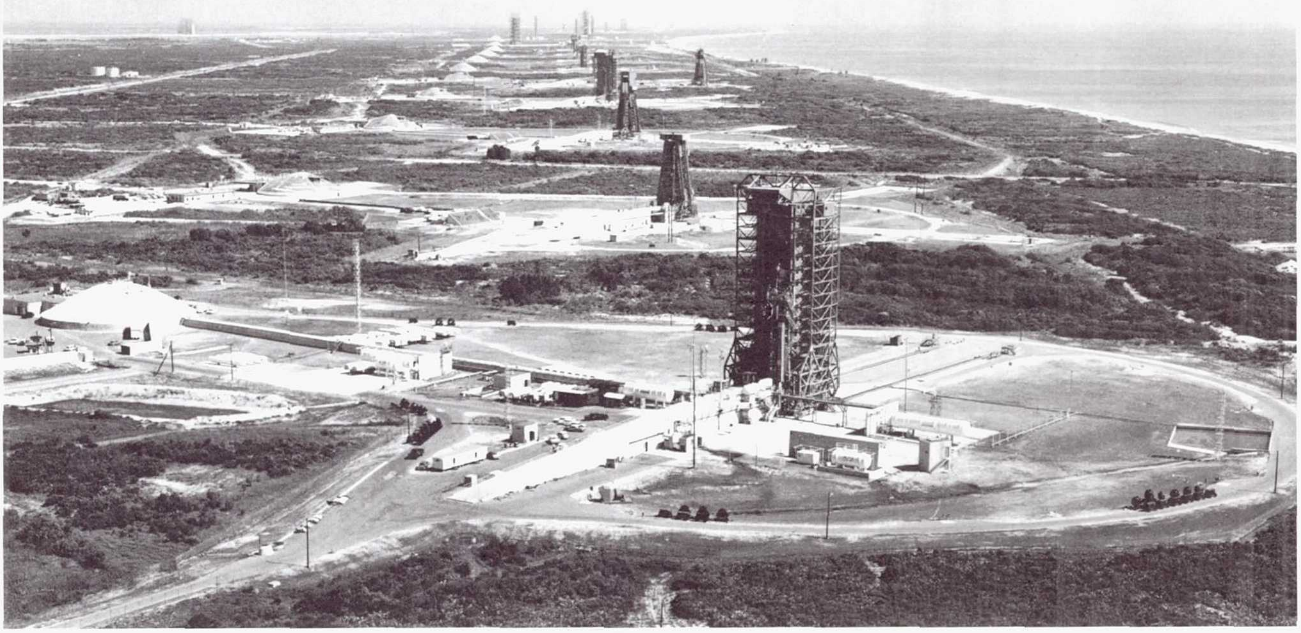
With the exception of SLV-3, Atlas space launch vehicles use programmed Phase III LO_2 tank pressure. Because of launch transient loads and the initially large LO_2 head, the first 5 to 10 seconds of flight are the most critical to integrity of the intermediate bulkhead.

Therefore, Phase III LO_2 tank pressure is programmed low for the first 20 seconds of flight and then increased to react maximum flight bending loads. This concept permits a reduction in the fuel tank design pressure and a consequent decrease in fuel tank skin gages (and overall vehicle weight).

Another unique Atlas feature is the stage-and-a-half concept with all three main engines and both verniers ignited on the ground, allowing comprehensive assessment of vehicle operation prior to committing to launch. The stage-and-a-half concept also allows broad variations in engine-burning and booster-staging times by changing only the autopilot programmer. This flexibility permits a single vehicle structure to efficiently accommodate the varying weight and trajectory requirements of many missions, as well as the capability for orbital missions without the use of an upper stage.

Approximately 1.2 seconds after main engine ignition, all engines achieve 90 percent of full thrust and the vehicle is released by the launcher. (Mission hold can be initiated at any time prior to actual release.) The autopilot, through the hydraulic servo system, gimbals the thrust chambers as required to maintain a vertical attitude during liftoff. During the first 15 seconds of flight, the autopilot commands the vehicle to roll from its fixed launch orientation to align the pitch plane with the desired trajectory azimuth. The preselected pitch program then bends the flight path over to meet mission requirements.

About 130 to 150 seconds after liftoff (determined by mission parameters and governed by axial acceleration), the booster engines are shut down (BECO) by a guidance discrete and the entire booster section is jettisoned. Vehicle acceleration is continued by the thrust of the sustainer and vernier engines until the specified mission velocity is attained. The sustainer engine is then shut down (SECO) by guidance command. If desired, a vernier solo phase may be used to damp out SECO transients and to provide final velocity and attitude trim corrections prior to releasing the payload or upper stage. Retrorockets are fired to assure positive separation at staging.



Cape Kennedy launch site, Florida

Rocketdyne LO_2/RP-1 engines are used on all Atlas vehicles. LV-3C and SLV-3 vehicles use the MA-5 engine system, developing 330,000 pounds of thrust in the booster engine and 57,000 pounds of thrust in the sustainer engine. This same system is uprated for use on SLV-3A and SLV-3C vehicles, developing 336,000 and 58,000 pounds of thrust for the booster and sustainer engines, respectively. Further uprated engine systems are being considered for the SLV-3X. The two vernier engines develop a total of 1,000 pounds of axial thrust in all cases.

A propellant utilization (PU) system ensures use of propellants at the appropriate mixture ratio so there is minimum residual at the end of powered flight. Either an analog, manometer type (Convair division) or a digital, sensor type (Acoustica) may be used.

General Electric radio guidance (Mod IIIG at ETR, Mark II at WTR) is used on all Atlas launch vehicles except those with a Centaur upper stage. Atlas/Centaur vehicles use the all-inertial Honeywell guidance system contained in the Centaur stage. Either guidance system calculates the required vehicle position and velocity and commands the flight correction necessary to satisfy the mission trajectory objectives. The guidance system senses dispersions due to atmospheric disturbances or vehicle performance (by measuring the position and velocity vectors) and issues steering commands—from the ground station for the GE system. Normally, the guidance system is in control of the vehicle only during sustainer phase; with a change in guidance equations, however, the vehicle can accept guidance steering commands during booster phase.

The flight control system provides stabilization and attitude control to Atlas vehicles during powered flight. During booster phase, the flight control system senses pitch, yaw, and roll displacements and rates and commands the required position of the booster engine thrust chambers and of the vernier engines. During sustainer phase, the flight control system commands sustainer engine displacement for pitch and yaw control, and vernier engine displacement for roll control. During booster staging and vernier-solo phase (if used), vernier displacement provides control about all three axes at WTR and roll-only at ETR (all three after SECO).

The Atlas flight control/guidance system has demonstrated the highest injection accuracies in the National Space Program. In accomplishing 32 classified Air Force missions with Convair division as guidance equation contractor, Atlas injected the Agena second stage with an average velocity error of less than 0.7 fps. (The largest error in the series was 2.7 fps.) Complete GE guidance system accuracy is classified but may be obtained upon request after establishment of "need to know."

The Convair division advanced autopilot (which is under development) may be used on later Atlas launch vehicles. This autopilot, incorporating high reliability parts throughout, was designed with several advanced features. The most interesting feature is the on-the-pad retargeting capability which allows remote retargeting from the blockhouse. Used in conjunction with Convair division's AGARTS (Automated Guidance and Reference Trajectory Service), mission parameters can be changed in less than six hours; if the new parameters are known in advance, the mission can be changed in less than one hour. This feature also serves to increase launch availability—the effects of adverse wind conditions can be offset by on-the-pad reprogramming to vary the pitch program at the critical altitudes.

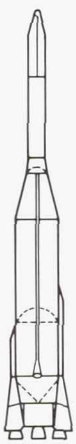
The increased accuracy of the advanced autopilot, coupled with an optional velocity cutoff meter, allows over-the-horizon control, decreasing the radio-guidance elevation-angle constraint.

Atlas vehicles use a PAM/FM/FM telemetry system with an 18-channel capacity. Five of these channels are normally commutated to supply 26 measurements each. Approximately ten percent of the total telemetry system is available for mission-peculiar measurements; mounting provisions allow installation of an additional 18-channel telemetry package if needed.

Currently, four launch sites are available for Atlas space launch vehicles at ETR and two at WTR. Two of the ETR sites are configured for Atlas/Centaur launches; all others are configured for Atlas/Agena but will accommodate other Atlas configurations by performing minor platform and upper stage umbilical tower modifications. Five additional VAFB sites, configured for refurbished Atlas missiles, are operational.

The Atlas launch vehicle was derived from the Series D Atlas Weapon System. Designated the LV-3, it was America's first intermediate-class launch vehicle. A constant 10-foot diameter version called LV-3C was developed for use with Centaur.

SLV-3



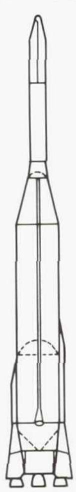
The SLV-3 standardized Atlas launch vehicle eliminated the custom-tailored approach. Standardization was achieved by designing a single configuration capable of supporting any of the missions then planned for the Atlas.

Standardized vehicles result in increased reliability, lower cost, standardized upper-stage interface, reduced manufacturing and site-turnaround time, and ease of incorporating late changes of mission parameters.

SLV-3 and later vehicles use the end-item kit concept. Because the kits are interchangeable between vehicles, mission effectivity can be changed by replacing kits with those required for the new mission. Kits include:

- Basic Booster
- Autopilot
- Telemetry
- Electrical Distribution Box
- Guidance
  (Mod IIIG for ETR or Mark II for WTR)
- Range Safety Command (ETR or WTR)

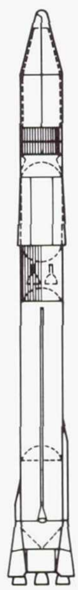
SLV-3A



SLV-3A is an uprated version of the dependable SLV-3 vehicle. Designed primarily for use with the Agena upper stage, it is also effective as a direct-ascent vehicle or in conjunction with other upper stages.

The tapered forward tank (5-foot mating ring) of the SLV-3A contains standardized interface equipment and the propulsion system is uprated to 395,000 pounds of thrust. Total tank length is 117 inches longer than that of SLV-3, increasing usable propellants by approximately 48,000 pounds. Additional helium supply, necessitated by the increased tank volume, is supplied by adding two helium storage bottles (total of eight).

SLV-3C



The SLV-3C is an uprated and standardized version of the LV-3C vehicle, and will replace it after the next two Atlas/Centaur launches.

The constant 10-foot-diameter tank of the SLV-3C contains standardized interface equipment and the propulsion system is uprated to 395,000 pounds of thrust. Total tank length is 51 inches longer than that of LV-3C, increasing usable propellants by approximately 21,000 pounds. Like the SLV-3A, it requires eight helium storage bottles for tank pressurization. SLV-3C guidance is provided by the Centaur vehicle.

Characteristics of the SLV-3A and the SLV-3C can be combined to form a new version of Atlas – the SLV-3B. This configuration eliminates the five-foot-diameter payload constraint associated with the Agena upper stage by encapsulating both the payload and the Agena within the OAO fairing system.

SLV-3B

Although the SLV-3B is not under contract *per se,* it can be provided within normal vehicle lead times since it uses existing SLV-3A guidance system and interface wiring with the existing SLV-3C stub tank.

SLV-3X ✦ Even more powerful Atlas launch vehicles have been proposed to the Department of Defense and NASA, and are under consideration. Designated the SLV-3X series, these vehicles further increase performance capability of the standardized Atlas launch vehicle family, while retaining the proven Atlas reliability. Increased performance is attained primarily by further increasing tank volume along with additional engine uprating.

REFURBISHED ATLAS MISSILES

The Atlas Weapon System, America's first ICBM, is available for aerospace research missions. All but three Series D missiles have already been flown, and the 135 Series E/F missiles have been transferred to the launch vehicle inventory and made available for these types of missions. Launches are planned into the 1970's.

Series E/F missiles are similar to the LV-3 space boosters except that all-inertial rather than radio-inertial guidance is used and the skin gages are thinner. Each surplus Atlas is cycled through a refurbishment program at Convair division prior to delivery to the launch site. During refurbishment, short-life components are replaced, all systems are thoroughly tested, and the missiles are delivered in like-new condition. Because of the unique Atlas annular ring construction, skin thickness can be easily changed if required to meet specific mission dynamic and heating constraints. General Electric radio guidance can be substituted for the all-inertial system using small bolt-on and plug-in hardware changes to the Atlas subsystems.

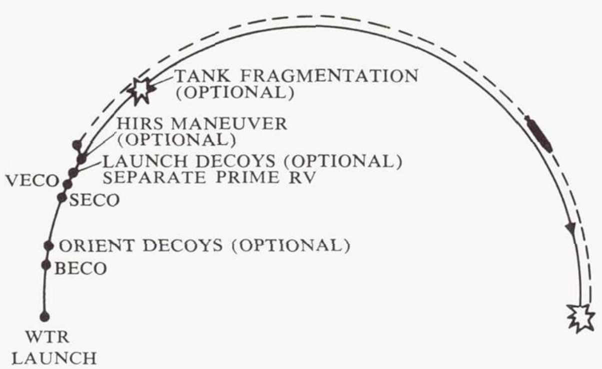
Refurbished E/F vehicles are used extensively to provide targets for NIKE anti-missile missiles and for performing ABRES (advanced ballistic re-entry system) experiments.

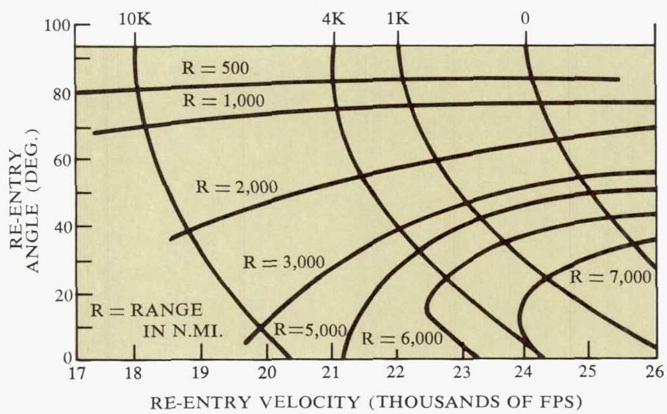
Two mission options are currently in use: 1) decoy pods to provide multiple targets for NIKE training and 2) a HIRS (high impulse retro system) to increase separation distance so that ABRES can be studied without interference from the sustainer tank and so that valid radar signature is obtained for NIKE missions.

A typical mission profile for these suborbital flights is shown in the following illustration.

Precision injection trajectories can be flown to inject maneuverable re-entry vehicles at hypersonic velocities. Re-entry velocities and downrange distances to be expected at a 400,000-foot test altitude for various payload weights and re-entry angle combinations are shown in the following graph.

Series E/F vehicles are also used to launch the OV1 system, with multiple OV1's nose-mounted in the Convair 84-inch-diameter fairing system described on page 17. Two dual OV1 missions have been completed; a dual and a triple arrangement are contracted for launch during 1967.





The OV1 is an economical, multipurpose orbital vehicle designed to accommodate a wide variety of scientific experiments in orbit. It consists of a propulsion module and a completely self-contained satellite, each available separately for other applications. For example, the OV1 propulsion module (containing an FW-4S motor) can easily be adapted as an upper stage on Minuteman; the OV1 satellite will fit within the Scout 34-inch-diameter fairing.

The OV1 propulsion module contains guidance and attitude control systems. The guidance system comprises an inertial-reference unit (gyro reference package), the required system logic electronics (flight control package), and a flight-sequence controller (programmer package). Attitude control is maintained by use of H_2O_2 jets. The propulsion module contains its own electrical power (battery) and 10-channel PAM/FM/FM telemetry system.

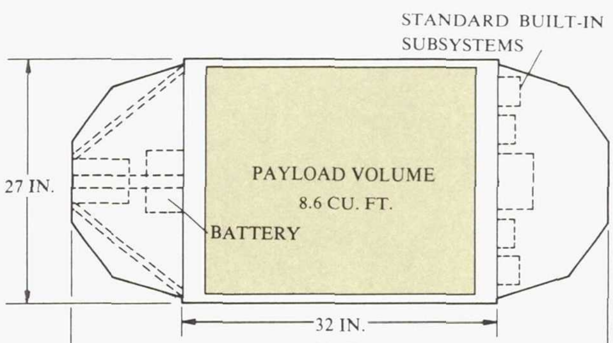
Payload experiments are contained in the 30-inch-long, 25.2-inch-diameter cylindrical section of the satellite, giving an interference-free volume of 8.6 cubic feet. Electrical power is supplied by solar cells mounted on faceted domes at either end of the satellite.

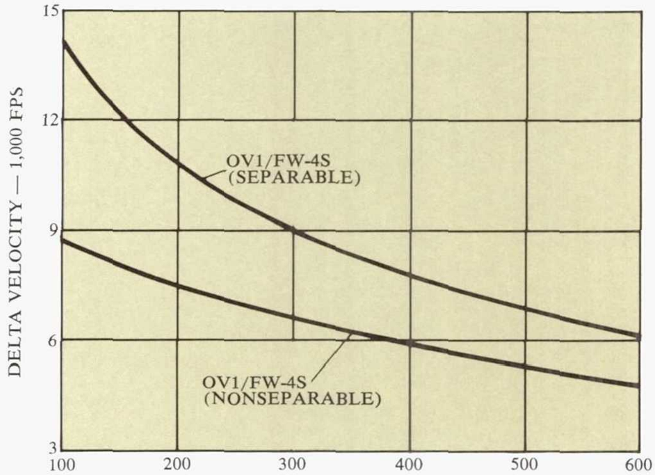
A non-magnetic silver-cadmium battery, mounted on the aft bulkhead, is charged by the solar cells and operates through a voltage booster to provide a nominal 28 watts at a regulated 28 vdc. The battery is designed to a nominal 40-percent depth of drain. All other electrical equipment (power, command, and telemetry systems) is mounted on the forward bulkhead. A PCM/FM telemetry system relays experiment and housekeeping data.

If attitude stabilization relative to the earth is required, the Convair Vertistat three-axis, gravity-gradient system may be employed. Magnetic and spin-stabilization systems have also been used successfully.

Satellite design weight is 330 pounds, of which 220 pounds are available as experiment payload. Since housekeeping functions are provided, payload weight includes only the experiments, mounting shelves and bracketry, and experiment-peculiar harnesses. On a typical mission, the shelves and bracketry weigh 12 pounds and the harness 8 pounds, leaving about 200 pounds available for actual experiments.

Since the OV1 solid-fuel motor is a constant-impulse system, performance is a direct function of launch vehicle trajectory and OV1 incremental velocity. OV1 velocity increment available for various total satellite weights is shown in the following graph.

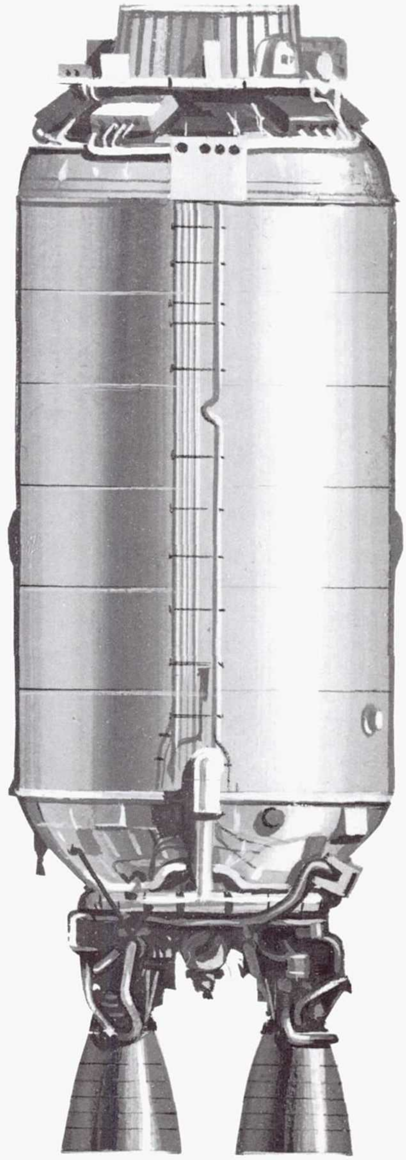




CENTAUR CHARACTERISTICS

Centaur is a pressure-stabilized vehicle with one of the highest mass fractions of any current upper stage. This lightweight structure, combined with the high specific impulse of the liquid hydrogen/liquid oxygen main engines, makes it an extremely efficient vehicle for high-energy missions. General features of the Centaur vehicle are shown below and discussed on the following pages.

Monocoque Structure – High Mass Fraction (0.88)
High Specific Impulse (444 seconds)
Main Engine Restart Capability
Coast-Phase Attitude Control
Coast-Phase Propellant Management
Jettisonable Insulation Panels
Precision Guidance System:
All-Attitude-Stable, Four-Gimbal Inertial Platform
General-Purpose Reprogrammable Digital Computer
Launch-On-Time Capability
Over 2-Hour Hold Capability at T–5 Minutes
Less-Than-One-Day Turnaround for Next Launch Window
Payload Electrical Interface for:
Ground Checkout
Telemetry
Programmer Commands
Available Within 18 Months from Contractual Go-Ahead



STRUCTURE ✦ The 10-foot-diameter tank structure is a thin-walled, 301 stainless steel, monocoque cylinder whose ends are capped with semi-ellipsoidal, stainless-steel bulkheads. A double-walled intermediate bulkhead separates the propellants. Tank weldments support systems and subsystems. Steel rings near the forward and aft ends provide mating surfaces for the nose fairing and interstage adapter. Overall length is 30.5 feet.

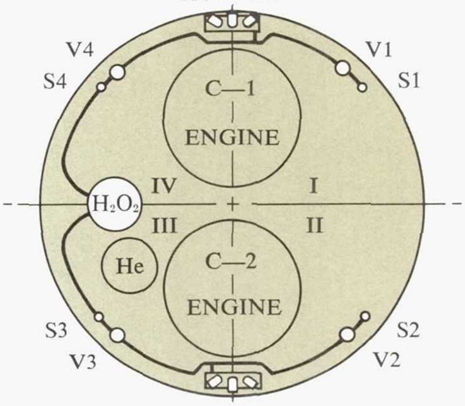
Insulation reduces propellant boiloff and protects externally mounted equipment from the cryogenic temperatures of the propellants. The forward bulkhead is insulated with polyurethane foam panels bonded to the skin surface. Between the double walls of the intermediate bulkhead is an insulation blanket filled with fiberglass matting. Fiberglass radiation shielding covers the exposed portion of the aft bulkhead.

Four insulation panel sections of one-inch-thick fiberglass sandwich construction surround the cylindrical portion of the tank. The honeycomb core is filled with closed-cell polyurethane foam. The panels also serve as an aerodynamic shroud for the structure and tank-mounted equipment, and are jettisoned after the vehicle leaves the earth's atmosphere.

PROPULSION ✦ Primary thrust is provided by two Pratt & Whitney RL10A-3-3 engines that develop a total thrust of 30,000 pounds (vacuum) at a specific impulse of 444 seconds. These engines, which can be shut off and restarted during flight, are regeneratively cooled and turbopump-fed. Prior to launch, the turbopumps are prechilled to −310°F with liquid helium from a ground source, minimizing usage of main-impulse propellants for in-flight chilldown.

A propellant utilization system maintains the consumption mixture ratio between 4.4:1 and 5.6:1 by varying liquid oxygen flow to the engines as a function of propellant mass remaining in the tanks. This ensures minimum propellant residuals after final burn.

The main engines are gimbal-mounted to allow a nominal square gimbal pattern of ±3.09 degrees for thrust vector control. Hydrogen peroxide reaction-control engines provide coast-phase attitude control and propellant settling. These engines are mounted on the aft bulkhead as shown (view looking forward).



Yaw and roll control is provided by the four 3.5-pound-thrust *A* engines, and pitch control by the two 6-pound thrust *P* engines. Primary thrust for propellant settling is provided by the four 50-pound-thrust *V* engines. The four 3-pound-thrust *S* engines added to the two-burn configuration supplement the *V* engines by maintaining propellant position control throughout the coast period; they also aid the *A* and *P* engines in controlling vehicle attitude.

GUIDANCE AND FLIGHT CONTROL ✦ Precision guidance is provided by a four-gimbal, all-attitude, inertial-platform system using a general-purpose reprogrammable digital computer. The computer can store 2816 permanent and 256 temporary words. The guidance program stored in the computer is a basic program capable of handling a wide range of missions. Special tapes are employed to change temporary-storage constants from mission to mission, ensuring fast reaction time to mission changes, mission flexibility, and a minimum of guidance program changes between missions. Primary control functions are provided by a flight control (autopilot) system that gimbals the engines.

Some pertinent features of the guidance system are:

a. All-Attitude Capability ✦ The four-gimbal system allows the vehicle to be oriented in any attitude during powered and coast phases of flight.

b. Launch-on-Time ✦ Existing ground support equipment references the spacecraft computer to real time, establishing earth-to-target geometry as a function of launch time.

c. Remote Load and Read ✦ The remote load-and-read unit provides communication with the computer until launch time.

d. Discrete Commands ✦ The guidance computer can generate 28 discrete commands; approximately 8 can be made available for payload use.

e. Targeting ✦ Detailed computer simulations for powered flight of Atlas/Centaur and for intercept trajectories to geocentric or heliocentric targets provide all guidance constants necessary for closed-loop flight. An operational, fully automated, closed-loop targeting program for either direct-ascent or parking-orbit boost mode is readily adaptable to the desired missions.

The guidance system measures accelerations in a launch-point-based inertial system, solves the velocity-to-be-gained guidance equations, and provides pitch and yaw steering signals to the flight control system. Typical Atlas/Centaur 3σ injection errors (based on 20-minute coast) are shown in the following table:

100 N.MI. CIRCULAR VELOCITY EXCESS (FPS)	POSITION DEVIATION (FT)	VELOCITY DEVIATION (FPS)	FLIGHT PATH DEVIATION (MILLIRADIANS)
0	4,723	11.02	0.87
10,500	13,638	16.72	1.49
13,400	13,658	16.72	1.50
16,500	12,349	15.15	1.69

During powered flight, Centaur attitude and steering are thrust-vector-controlled by gimbaling the main engines. During coast periods, attitude is controlled by on-off operation of the attitude control engines. The autopilot system detects either rate or position errors. Roll-attitude reference is obtained by integrating roll rate. The system reacts when the rate error detected exceeds 0.2 degree per second. Vehicle position is controlled during coast to within ±1.6 degrees of misalignment from the reference vector. When a particular mission requires greater alignment control during coast, the ±1.6-degree threshold can be reduced considerably by changing system gains.

Uneven main-engine shutdown can result in vehicle 3σ transient rates approaching 2.0 deg/sec; the attitude control system returns these rates to the limit-cycle value of 0.2 deg/sec in less than 35 seconds. Coast-phase reorientation maneuvers, if required, are commanded by guidance system steering signals. A 180-degree maneuver can be accomplished in 120 seconds.

ELECTRICAL SYSTEM ✦ Direct current at 28 volts is supplied from a ground source during prelaunch operations and from an airborne battery during flight. A vehicleborne inverter converts the 28-volt direct current to 115-volt, 3-phase, 400-cycle alternating current for operation of guidance, autopilot, and propellant utilization systems during prelaunch operations and flight. The inverter provides an output power of 650 volt-amperes at a power factor from 0.8 lagging to unity. It can operate for 12 hours at full load and can accommodate a 25-percent overload for up to 60 seconds. Separate, redundant 28-volt batteries supply power for the range safety system and for fairing separation.

Electrical interface between Centaur and Surveyor is provided through a 52-pin electrical connector; suitable electrical interface for other payloads can be provided. This interface permits prelaunch checkout of the payload through the electrical umbilicals. During flight, it allows transmission of payload data through the Centaur telemetry and of commands from the Centaur programmer to the payload. A separation command from the programmer disconnects the electrical connector prior to payload separation.

INSTRUMENTATION AND TELEMETRY ✦ The telemetry system relays the outputs of the instrumentation system to ground recording and monitoring equipment through a PAM/FM/FM transmitter. The system consists of one telemetry antenna and one 18-channel telepak, powered by the main battery. The 18 channels comprise 8 continuous, 7 commutated, 1 direct, and 2 digital input channels. Suitable allocation of telemetry channels can be made when a potential payload and its telemetry requirements have been established. Currently, there are three data channels available for the payload instrumentation, and supplemental telepaks can be readily added as required by specific missions.

Data received from the instrumentation system are accurate to within ±5 percent in final reduced form. Where greater accuracy is required, special high-accuracy transducers are used. The system operates from launch until battery power depletion.

HOLD AND TURNAROUND CAPABILITY ✦ Present AFETR General Range Safety Plan limits the total time to launch, after completion of range safety command system destruct tests, to a maximum of 10 hours. This constraint allows a contingency delay period of 6 hours in the terminal countdown of Atlas/Centaur.

Centaur hold time capability at T−5 minutes is limited only by the 10-hour range safety constraint and by the quantities of fluids and gases available from GSE/facility systems. The T−5 hold point is based on the current Atlas/Centaur countdown, and could be changed to as late as T−2 minutes. Existing Complex 36 fluid systems provide hold capability in excess of two hours at T−5 minutes.

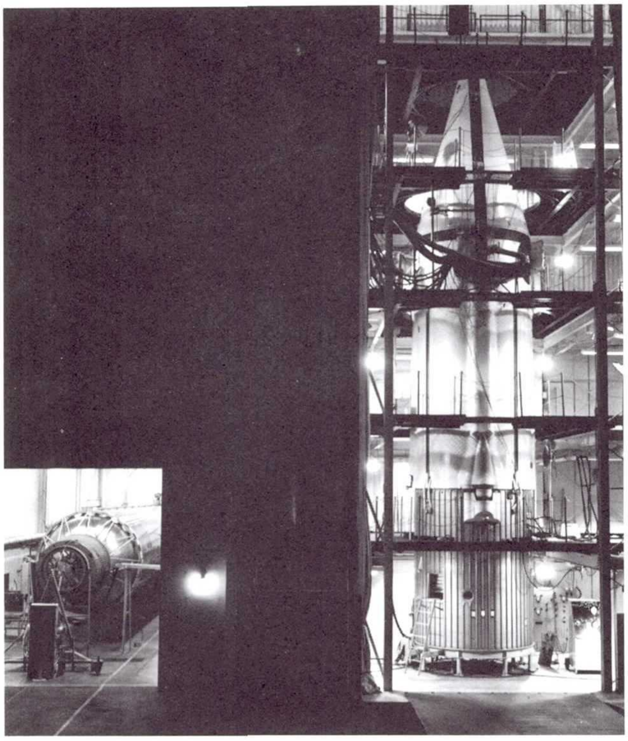
Centaur has a one-day turnaround capability for meeting the next launch window. Atlas/Centaur launch crews have demonstrated turnaround capability to meet a launch window on the following day.

COAST CAPABILITY ✦ The Centaur stage, as currently configured, can coast for 25 minutes in a parking orbit and then restart to accelerate its payload to the required velocity. To support existing missions, coast capability will be increased to 65 minutes by mid 1968. Analyses have determined that the modifications to attain extended coast periods and additional engine restarts are within the current state-of-the-art.

TRACKING ✦ A C-band transponder on Centaur provides position and velocity data at distances greater than radar tracking alone can provide. Vehicle position and velocity data received by ground stations are fed into computers to derive trajectory performance. Range safety control determines that the vehicle trajectory is within predetermined limits and that the impact prediction remains within desired bounds.

FACILITIES ✦ Extensive Centaur test and checkout facilities in the San Diego area include the static-firing facility at Sycamore Test Site, tanking and structural testing facilities at Point Loma Test Site, and the Combined Systems Test Stand (CSTS). The CSTS facility is used for integrated launch-vehicle/payload matchmate and electrical systems tests similar to those at ETR Complex 36. CSTS electronically links all elements of the launch vehicle/Centaur/payload to a central control and display. The Atlas launch vehicle is mounted horizontally in a test bay; the mated interstage adapter/Centaur/payload/nose fairing is erect in an adjacent 90-foot tower. Complete flight routines are simulated: propellant and propulsion are checked electronically; all other operations are exercised mechanically and electronically exactly as they will operate in orbital or deep space flights, providing a significantly higher level of confidence than is possible through individual checkout of the stages and payload.

Complexes 36A and 36B at ETR provide Atlas/Centaur launch capability. The two launch sites share a common blockhouse with independent launch-control and instrumentation equipment. Downrange facilities for tracking and telemetry are available.



Combined Systems Test Stand

FAIRING SYSTEMS

Two types of 10-foot-diameter fairing systems are currently in production at Convair division: Surveyor and OAO. The OAO fairing system was developed to completely enclose an Agena upper stage and the Orbiting Astronomical Observatory (OAO). This development drew heavily from the experience gained during Surveyor fairing development and resulted in a flexible system readily adaptable to a variety of missions. These two systems and some of the advanced OAO-type fairing systems under development at Convair division are discussed in the following paragraphs.

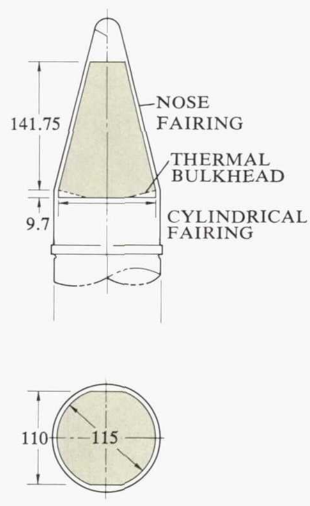
SURVEYOR FAIRING SYSTEM ✦ The Surveyor fairing system consists of a nose cone bolted to a cylindrical section. Sandwich construction (laminated phenolic outer skins, laminated epoxy inner skins, and a phenolic cellular core) is used in each section. Insulation against aerodynamic heating is provided by spraying Thermolag T-230 on external surfaces to the required thickness. Sublimation of the Thermolag coating during flight reduces the outer surface temperature experienced by about 500°F.

Both sections are fabricated in longitudinal halves and are jettisoned using reaction impulse from two 3,000-psi gaseous nitrogen bottles, either of which is capable of successfully jettisoning the fairing at up to 10g of vehicle acceleration. A deflector bulkhead prevents gas from entering the payload cavity; a thermal bulkhead isolates the payload from Centaur.

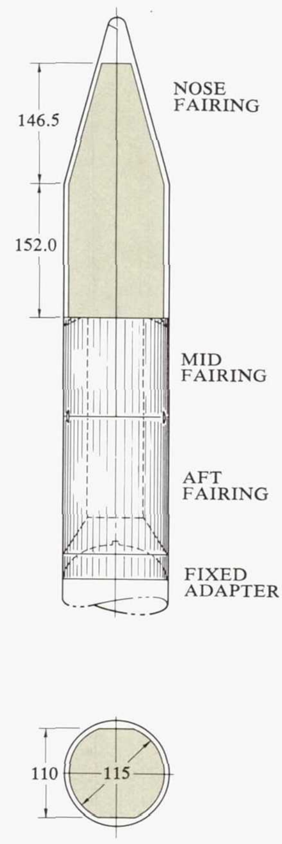
OAO FAIRING SYSTEM ✦ The OAO fairing system consists of a fiberglass sandwich-construction nose fairing similar to the Surveyor fairing, aluminum skin/stringer mid and aft fairings, and a stainless steel fixed adapter. The nose fairing may be further insulated against excessive aerodynamic heating by sheet cork bonded to the outer skin, then coated with a layer of abrasion- and moisture-resistance enamel. The mid fairing is permanently bolted to the nose fairing; both are fabricated as longitudinal halves. The aft fairing is permanently bolted to the fixed adapter.

Only the nose and mid fairings are separated; the aft fairing and fixed adapter remain attached to the Atlas. Separation occurs along the longitudinal plane, using 2500 pounds of force generated by two springs enclosed in telescoping actuators. The actuators extend automatically when the separation latches are released by explosive nuts. Each fairing half rotates about a two-point hinge, restricting motion to the jettison plane.

Since it was originally designed to meet the stringent temperature and cleanliness requirements of the OAO mission, the OAO fairing system has the following additional features. For normal trajectories, inside skin temperature never exceeds 150°F; on the OAO flight using the optional cork external insulation, inside temperature rise was only about 10°F from the initial air-



Surveyor Fairing Payload Envelope



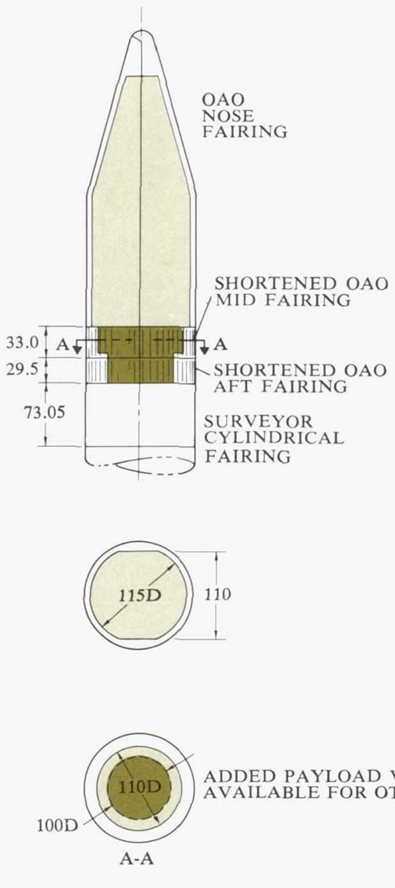
OAO Fairing Payload Envelope

conditioning temperature. An epoxy wash coat on the inside skin allows very little outgassing. The jettison actuator springs are completely enclosed so there is no possibility of payload contamination or damage. An encapsulation bulkhead separates the Agena and spacecraft cavities and allows the spacecraft to be completely encapsulated in the fairing before installation on the launch vehicle. The current configuration can be jettisoned at a vehicle acceleration of 3.5g, although this value can be easily raised by using stiffer springs.

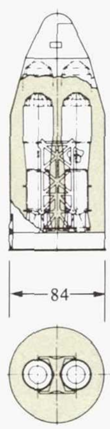
CENTAUR / OAO FAIRING SYSTEM ✦ Since the OAO mission has recently been assigned to the Atlas/Centaur vehicle, the OAO fairing system is being modified for use with Centaur. The Centaur/OAO fairing system follows the Atlas family building block concept of combining flight-qualified components to form practical configurations at the lowest possible cost.

Basically, it consists of the existing OAO nose fairing (including the encapsulation bulkhead), shortened mid and aft fairings, and the existing cylindrical portion of the Surveyor fairing system. The aft fairing is permanently bolted to the Surveyor portion; neither is jettisoned. By using this approach, there is only one new interface: OAO aft fairing/Surveyor fairing cylindrical section. The new system functions like the existing OAO fairing system and will retain all its features.

The first Atlas/Centaur/OAO will be launched in 1968. Because of its low weight per cubic foot of usable payload volume, this fairing system can be used for many other Atlas/Centaur missions.



Centaur OAO Fairing Payload Envelope



OV1 Fairing Payload Envelope

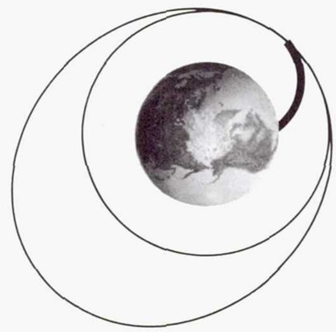
MULTIPLE OV1 FAIRING SYSTEM ✦ Currently in production under Air Force contract, this 84-inch-diameter fairing system makes extensive use of OAO fairing system concepts. The nose fairing is made of welded aluminum skins riveted to sheet metal and machined internal frames. It has single curvature, double cone/cylinder geometry and will encapsulate up to four OV1's and their dispenser. Adequate room is provided to allow for payload growth.

A fixed adapter is attached to an 84-inch-diameter ring at Station 541 on the tapered Atlas propellant tank. A spacer module containing the aft halves of the dual hinges is bolted permanently to the adapter. The dual-hinge arrangement restricts motion to the jettison plane, causing the fairing halves to jettison along a highly predictable trajectory.

FIVE-FOOT-DIAMETER FAIRINGS ✦ Many five-foot-diameter fairings are flight qualified with Atlas family combinations. These include the Agena fairing system (classified Air Force missions, FIRE, EGO, ATDA, Gemini Target), Ogive fairing system (Vela), and other special purpose fairing systems (classified Air Force missions, Mariner, Ranger, Snapshot).

A one-stage vehicle orbits a payload by burning continuously to the desired altitude and velocity. Missions requiring high circular orbital altitudes or high velocity are performed much more efficiently with upper stages, because the heavy-duty engines and equipment required to overcome initial inertia are jettisoned (staged). If more than one upper stage is used (or if the second stage has multiple burn capability), certain techniques can be used to greatly extend the mission range. There are many ways to achieve the desired mission end conditions; the techniques discussed here are those commonly in use with existing vehicles.

DIRECT ASCENT (NO UPPER STAGE) ✦ Without an upper stage, current launch vehicles are limited to low earth orbital missions. Payloads can be placed in circular orbits only by burning all the way to desired altitude, shaping the trajectory to inject the payload tangential to the earth's surface. Elliptical orbits are achieved by lofting the payload to injection perigee at high velocity along the proper trajectory to achieve desired orbital eccentricity. Because of its unique stage-and-a-half concept, Atlas is more efficient than other launch vehicles in its class. This is the basis for the apogee kick technique discussed on page 25.

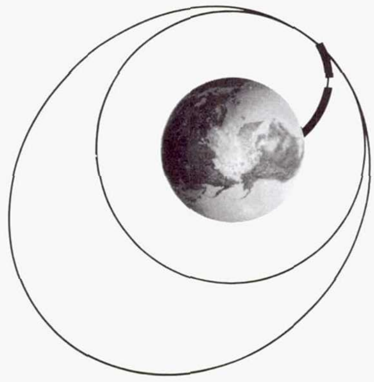


Direct Asscent (no upper stage)

ONE-BURN SECOND STAGE ✦ To orbit heavier payloads, a second stage may be required. These vehicles are ignited almost immediately after separation and effectively increase the burn time of the launch vehicle. The one-burn second stage mission mode is used for heavier payloads in relatively low circular or elliptical earth orbits (including lunar and interplanetary missions, under certain unique geometry conditions).

For a circular orbit, the second stage burns all the way to the desired circular altitude, injecting the payload tangentially to the earth's surface with the required circular-orbit velocity.

For an elliptical orbit, the second stage injects the payload (usually at perigee) with sufficient supercircular velocity to achieve desired orbital apogee. Lunar and interplanetary missions are of this type.



One-Burn Upper Stage

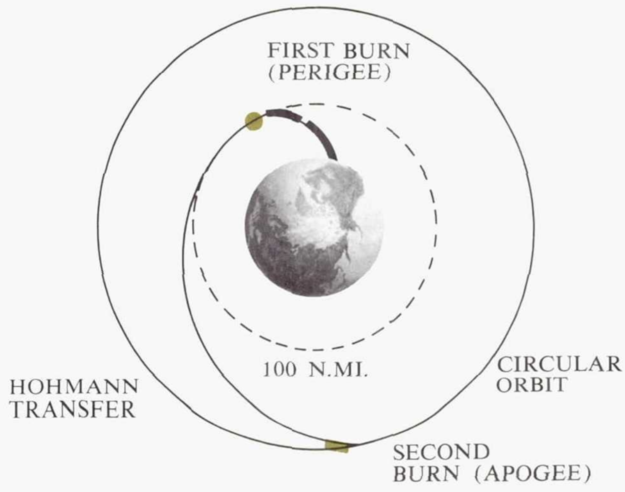
TWO-BURN SECOND STAGES ✦ Two-burn second stages provide additional payload capability at high circular orbit altitudes and increase the length and frequency of interplanetary and lunar launch windows.

Using the Hohmann transfer ellipse for circular orbital missions, the first second-stage burn is used to acquire enough velocity to coast to desired apogee altitude. The second stage and payload then coast along the minimum-energy (Hohmann transfer) ellipse to the desired apogee, where the second burn applies the apogee velocity increment to circularize the orbit.

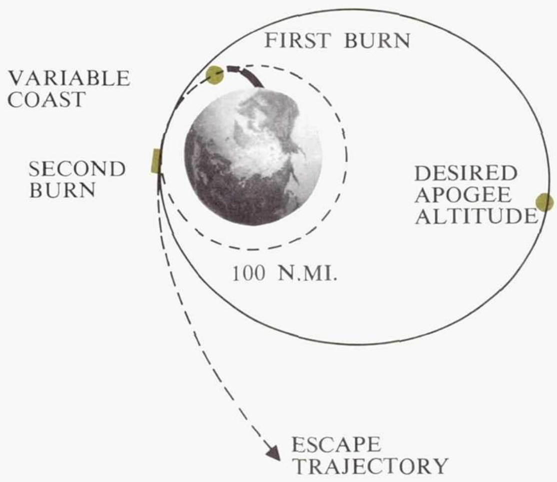
The parking orbit coast mode allows shifting of the perigee to different points in space. The first burn injects the second stage and payload into the circular parking orbit, where they coast to the desired final injection point (aligned with the proper escape trajectory for interplanetary missions or crossing the equator at the desired longitude for synchronous apogee missions). The second burn provides the perigee velocity increment (with or without plane change) to achieve the desired apogee altitude, transfer orbit, or escape trajectory.

SYNCHRONOUS EQUATORIAL ORBIT ✦ The synchronous equatorial orbit is normally achieved by special application of the parking orbit coast mode. After suborbital burning into parking orbit, the second stage and payload coast until the desired nodal (equatorial) crossing is approached (180 degrees of longitude from the desired stationary orbit point over the equator, minus earth rotational effect). The second burn then provides the perigee velocity increment required to reach the required apogee altitude for a stationary orbit (about 19,300 n.mi.). Some of the second-burn impulse may be used for plane change to remove a portion of the orbital inclination. This establishes an inclined elliptical orbit with apogee at synchronous altitude, requiring only a plane change and circularization velocity to become synchronous equatorial.

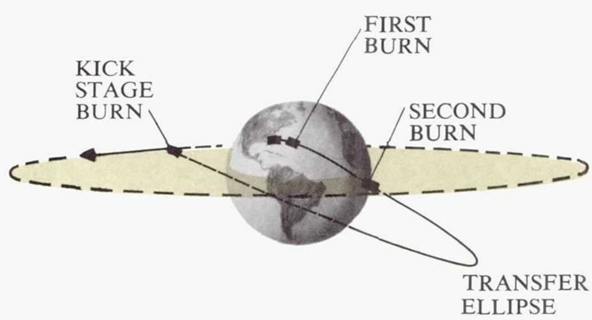
The required velocity may be provided by a small injection motor as part of the payload or by a separate kick stage like Burner II. A three-burn second stage can eliminate the requirement for the small injection motor or kick stage, but is a less efficient method because no staging is involved. Small propulsion units (normally used for attitude control) may be used to "drift" the payload to new positions.



Hohmann Transfer Mode



Parking Orbit Coast Mode

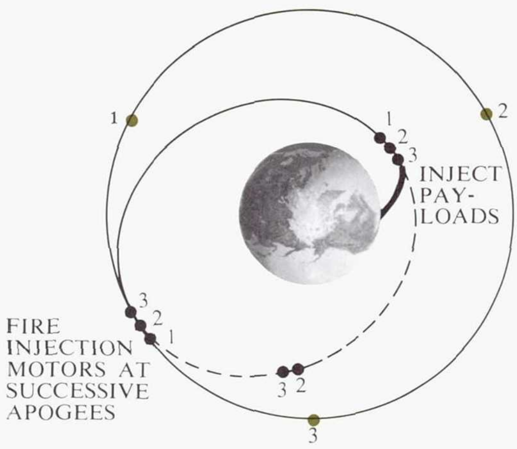


Synchronous Equatorial Orbit

Mission sharing ensures that using agencies obtain maximum benefits from their launch vehicle investment. Several methods of performing multiple missions are currently contracted or under evaluation by Convair division.

Payload Integration into a Single Satellite ✦ For several years, Convair division has worked with the Air Force Office of Aerospace Research (OAR) in integrating scientific experiments into the OV1 Program. OAR processes requests for experimentation from various research agencies; they are then categorized according to mission orbital parameters. After allocation of a sufficient number of experiments into a specific category, an OV1 is assigned and Convair division performs the necessary experiment integration tasks.

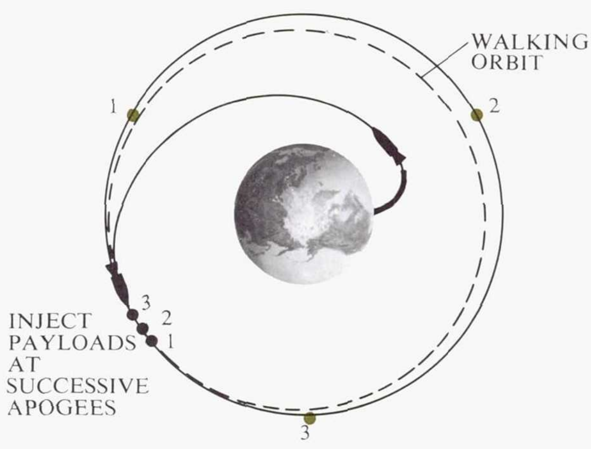
All experiments are delivered to Convair division, where they are tested prior to installation. After assembly into the satellite, a check of the entire satellite/payload assembly and the propulsion module is performed prior to delivery to the launch site. A similar approach is followed in integrating ballistic experiments into the Scientific Passenger Pods.



Random Spacing with Payload Injection Motors

Multiple Payloads into Similar Orbits ✦ If a number of satellites are planned for delivery to the same orbital altitude, they may be launched by a single Atlas, with or without an upper stage. Atlas family combinations performed missions of this type as early as 9 May 1963, when a classified Air Force payload and two Environmental Research Satellites (ERS 5 and 6) were injected simultaneously into a 2250-n.mi. circular orbit. More than 10 Atlas multiple missions have been flown since that time.

If phasing between satellites is a requirement, a small injection motor can be incorporated into each satellite. The satellites are then injected simultaneously into elliptical orbits, with the first injection motor firing at apogee and the second injection motor firing during a later apogee to provide the desired spacing. This technique was used with Atlas/Agena vehicles in launching the Vela nuclear detection satellites plus a small environmental research satellite to monitor background radiation in the Van Allen belt.



Precision Injection from Walking Orbit

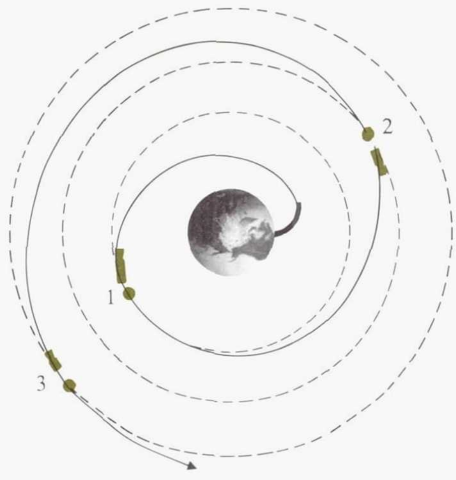
The advantage of combining an injection motor into each satellite is the increased performance resulting from jettison of the second stage.

Precision injection utilizing upper-stage guidance can be obtained by circularizing at the desired altitude with the second burn of the upper stage. The first satellite is separated at a slight relative velocity. A secondary propulsion system (added as a self-contained module on the upper stage) flips the upper stage and remaining satellite(s) and provides a slight retro force, placing them into an eccentric orbit with a period slightly less than the circular orbit of the first satellite. This is termed a *walking orbit:* each subsequent apogee occurs at a different angular separation from the first satellite.

The walking orbit is maintained until desired angular separation from the first satellite is achieved. The upper stage is then flipped to its original attitude and accelerated into the circular orbit of the first satellite and the second satellite is injected. If sufficient payload capability exists, any number of satellites can be injected in this manner by again decelerating the upper stage and re-entering the walking orbit. Upper stage orbital stay-time is not a function of propellant storability, because the main engines are not used after initial injection into circular orbit.

Multiple Payloads into Dissimilar Orbits ✦ Two basic approaches are in use or under development at Convair division: attachments and the "bus" system.

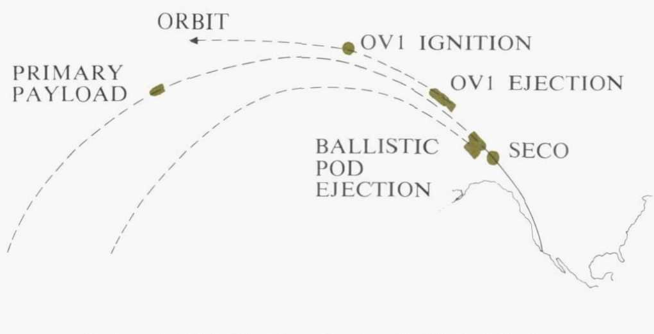
Attaching secondary satellites (with or without injection motors) to the Atlas or to an upper stage is a simple and economical way to capitalize on vehicle excess capability. (Pods attached directly to the Atlas are currently used for secondary ballistic and orbital payloads for a number of important projects, as previously discussed.) Satellite systems attached to the upper stage can be ejected from aft rails or from the primary payload adapter during second stage flight. The ideal ejection time is at the end of first burn, because acceleration is not a constraint at that time. The satellite then fires an injection motor to circularize at that point or follows an elliptical orbit (Hohmann transfer) until desired altitude is reached and then fires its injection motor.



Multiple Burn Upper Stage (Bus)

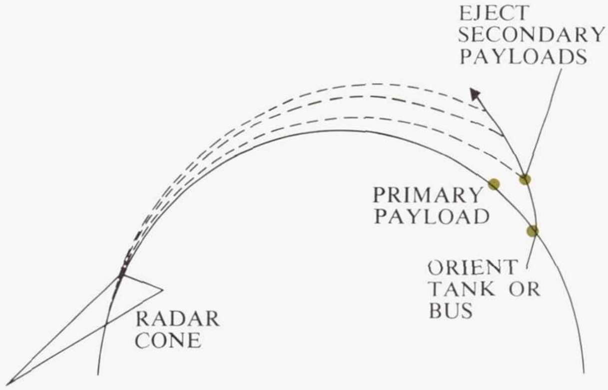
The bus concept uses a multiple burn upper stage and "nested" payloads. It achieves a circular orbit at the desired altitude and ejects the first satellite with a slight separation velocity. After sufficient separation, the bus burns to follow a Hohmann transfer ellipse until the second desired altitude is reached (approximately 180 degrees away from bus first burn). The sequence is repeated for each remaining satellite.

Secondary Payloads on Ballistic Missions ✦ The Scientific Passenger Pod (SPP) concept has been used at Convair division since 1960. These pods are launched side mounted on Atlas and are ejected at a programmed



Pod and OV1 Ejection During Ballistic Mission point of the Atlas trajectory. Both recoverable and non-recoverable pods have been flown, as well as OV1's in the side-mounted configuration.

Re-entry payloads can be made to arrive at approximately the same point and time after following different trajectories. This may be accomplished using a pitch maneuver near the end of Atlas burn or a bus concept to add velocity and altitude to secondary re-entry vehicles along a constant range trajectory ($dR/dt = 0$), while the primary payload follows a conventional ballistic path. The HIRS can be used to prevent the spent Atlas tank from entering the test area.



Multiple Re-entry Payloads

✦ ✦ ✦

UPPER STAGE VEHICLE DATA

	CENTAUR 1 AND 2 BURN	AGENA D 2 BURN	N_2O_4 AGENA 2 BURN	BURNER II	OV 1 PROPULSION MODULE
THRUST (POUNDS)	30,000	16,140	18,000	9,250	5,330
SPECIFIC IMPULSE, I_{SP} (SECONDS)	444			290	283.8
MAIN IMPULSE PROPELLANTS (POUNDS)	29,911	13,450	13,000	1,440	612
INCLUDING FPR OF (POUNDS)	††	(60)	(60)	—	—
LAUNCH WEIGHT (POUNDS)	37,632	14,833	14,510	1,769	874
JETTISON WEIGHT (POUNDS)	4,005	1,277	1,380	307	256

ATLAS VEHICLE DATA

	SLV-3*	SLV-3A*	SLV-3A	SLV-3B	SLV-3C
THRUST (POUNDS)	388,000	← 395,000 →			
SPECIFIC IMPULSE, I_{SP}					
SEA LEVEL/VACUUM (SECONDS)**					
BOOSTER	252.5 (S.L.)	← 258.9/296.8 →			
SUSTAINER	214.2 (S.L.)	← 215.3/308.9 →			
VERNIER	190.9/237.7	← 190.9/237.7 →			
MAIN IMPULSE PROPELLANTS (POUNDS)	246,549	295,356	295,356	268,930	268,102
INCLUDING FPR OF (POUNDS)	(684)	(800)	(1000)	(1000)	†
LAUNCH WEIGHT (POUNDS)	260,928	310,073	310,998	287,984	283,960
BOOSTER JETTISON WEIGHT (POUNDS)	7,368	7,464	7,464	7,456	7,467
SUSTAINER JETTISON WEIGHT (POUNDS)	6,569	6,805	7,185	7,536	8,208

*NO UPPER STAGE
**ROCKETDYNE SPECIFICATION VALUES
†INCLUDED IN CENTAUR
††ONE PERCENT OF IDEAL VELOCITY REQUIREMENT

The advanced Atlas space launch vehicle can be used with a number of flight-proven upper stages. Performance shown on the following pages can be increased by attaching solid-propellant, thrust-augmentation motors to the Atlas tank. Side-mounted pods and satellites may be carried if there is vehicle capability in excess of primary payload requirements, allowing two or more programs to share mission costs. Actual performance characteristics for any vehicle depend upon mission requirements. To allow for mission differences, the curves conservatively represent typical three sigma rather than maximum payload capability. To permit direct comparison of configurations, all performance data in this Digest are based on the following ground rules.

Secondary Scales on Payload Curves ✦ Characteristic velocity (V_c) values quoted in this Digest are based on minimum velocity requirements. Altitude tic marks on the secondary scales, therefore, are not always at the same V_c because of flight mode limitations.

100-N.Mi. Altitude Parking Orbit ✦ This is the departure orbit for the coplanar cotangential (Hohmann) transfer to the terminal altitude. Although 100 n.mi. is the usual parking orbit selected for payload quotation, significant performance improvements can be achieved by injecting into lower parking orbits. Curves shown in this Digest, therefore, are conservative.

Launch Due East from ETR and Due South from WTR ✦ For consistency, all payload capability reflected in this Digest assumes a due east launch from Cape Kennedy along the Eastern Test Range (ETR) and a due south launch from Vandenberg Air Force Base (VAFB) along the Western Test Range (WTR).

3σ Minimum Performance ✦ An appropriate flight performance propellant reserve has been retained aboard the booster and/or upper stage to compensate for 3σ dispersions in numerous parameters. These dispersions include engine thrust and specific impulse, weight of tanked propellants, autopilot pitch program, gyro drift, and propellant utilization system operation, as well as many other parameters. Payloads quoted, therefore, are conservative and represent 3σ minimum capability rather than nominal performance.

Fairing Jettison at Sustainer Engine Cutoff (SECO) ✦ Fairings may be jettisoned as soon as the vehicle leaves the atmosphere. This is not always possible, however, because of mission trajectory and payload characteristics. To allow for special mission requirements, fairings are assumed to be jettisoned at SECO (unless otherwise noted), even though this reduces the payload capability reflected in the curves.

Payload Defined as Spacecraft plus Spacecraft Supports ✦ Payload weight is defined generally as gross weight of the spacecraft and its supporting airborne systems and hardware. For Centaur combinations, this includes everything forward of the field splice. Fairing weight, however, is not considered as payload.

Coast Period ✦ Unless otherwise noted, all curves are based on a coast period of 11.5 seconds after SECO for Centaur and 43 seconds for other upper stages.

ATLAS DIRECT ASCENT (NO UPPER STAGE)

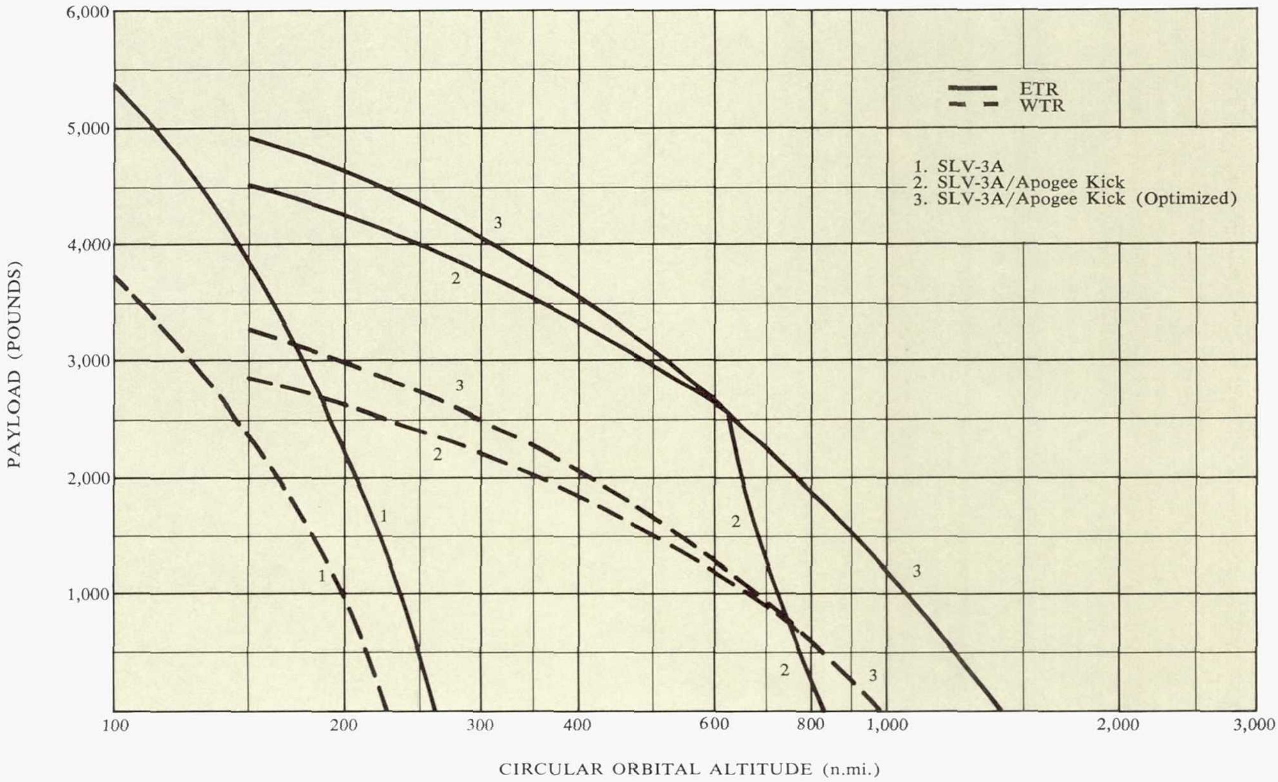
Project Score in 1958 demonstrated that the Atlas is capable of injecting its entire sustainer tank into orbit. As shown on the facing graph, the SLV-3A can deliver a 5000-pound payload into a 100-n.mi. circular orbit. Direct-ascent missions which have been performed by the Atlas launch vehicle include projects Score, Mercury, and ATDA.

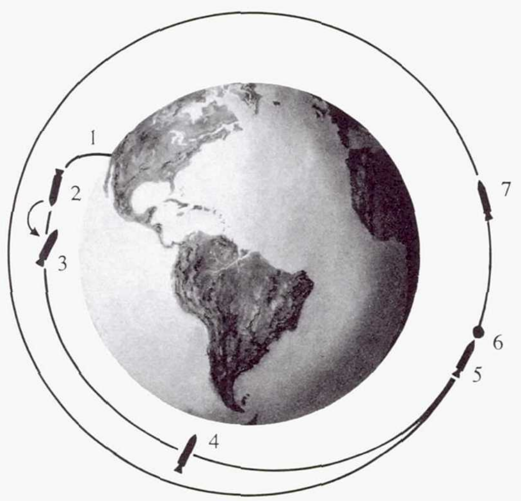
Payload capability falls off rapidly with increasing circular-orbit altitudes, however, because the launch vehicle must burn all the way to the desired altitude. To increase the number of missions which can be performed without the cost, error source, and reliability loss associated with upper stages, Convair division has designed a sustainer-tank apogee kick technique. This is done by deleting the vernier engines, replacing their function with an attitude control unit, and adding small storable-propellant rockets to the Atlas tank.

Curve 1 on the facing graph shows that maximum SLV-3A circular orbital altitude from ETR is 260 n.mi. Curves 2 and 3 show the extended altitude capability using the apogee-kick technique. Performance shown in Curve 2 represents the basic approach, which has been completely predesigned. As shown in Curve 3, much greater capability can be realized by optimizing the system for a specific mission.

Atlas direct ascent vehicles use the GE radio guidance system. With the apogee-kick technique, attitude control during coast is provided by an H_2O_2 reaction jet module. Since injection into high circular orbital altitudes occurs out of radio guidance range, an extremely accurate, low-drift-gyro unit like the Convair division advanced autopilot will be used for apogee-kick missions. A velocity meter provides the apogee-kick engine cutoff discrete.

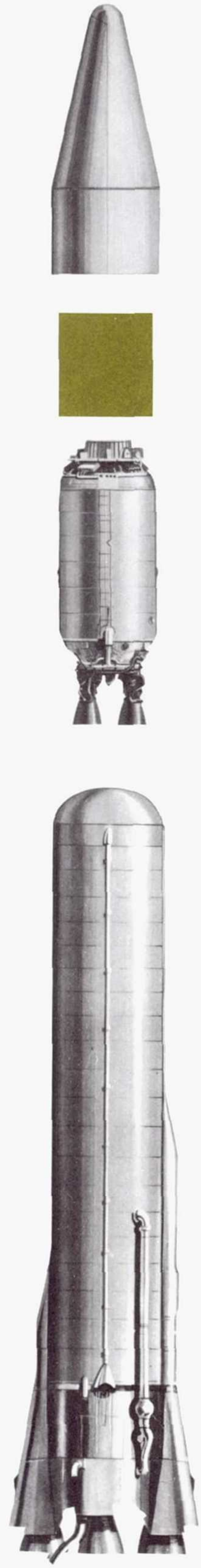
Atlas direct ascent vehicles can perform multiple-payload missions with the OV1 satellite system or can carry scientific passenger pods in addition to the primary mission payload. Even heavier payloads can be launched by using thrust augmentation.





1. *Booster- and sustainer-powered ascent.*
2. *Sustainer engine cutoff and perigee injection of sustainer tank and payload with supercircular velocity at 90 n.mi.*
3. *Pitchover maneuver to position sustainer tank to the desired apogee attitude.*
4. *Coast along Hohmann transfer ellipse.* H_2O_2 *attitude control during coast, advanced autopilot guidance.*
5. *Apogee-kick engine ignition to provide velocity increment to circularize orbit.*
6. *Payload (or payload and sustainer tank) injected into circular orbit.*
7. *Orbital housekeeping by Atlas systems if desired.*

ATLAS/CENTAUR



Centaur is America's first high-energy liquid-hydrogen upper stage, and is operational in both one-burn and two-burn modes. Atlas/Centaur combinations are applicable to a variety of missions, from large payloads in earth orbit to lunar and interplanetary missions. To further increase mission capability, a Burner II vehicle can be used as a kick stage. A 162-pound adapter mates the Burner II to Centaur.

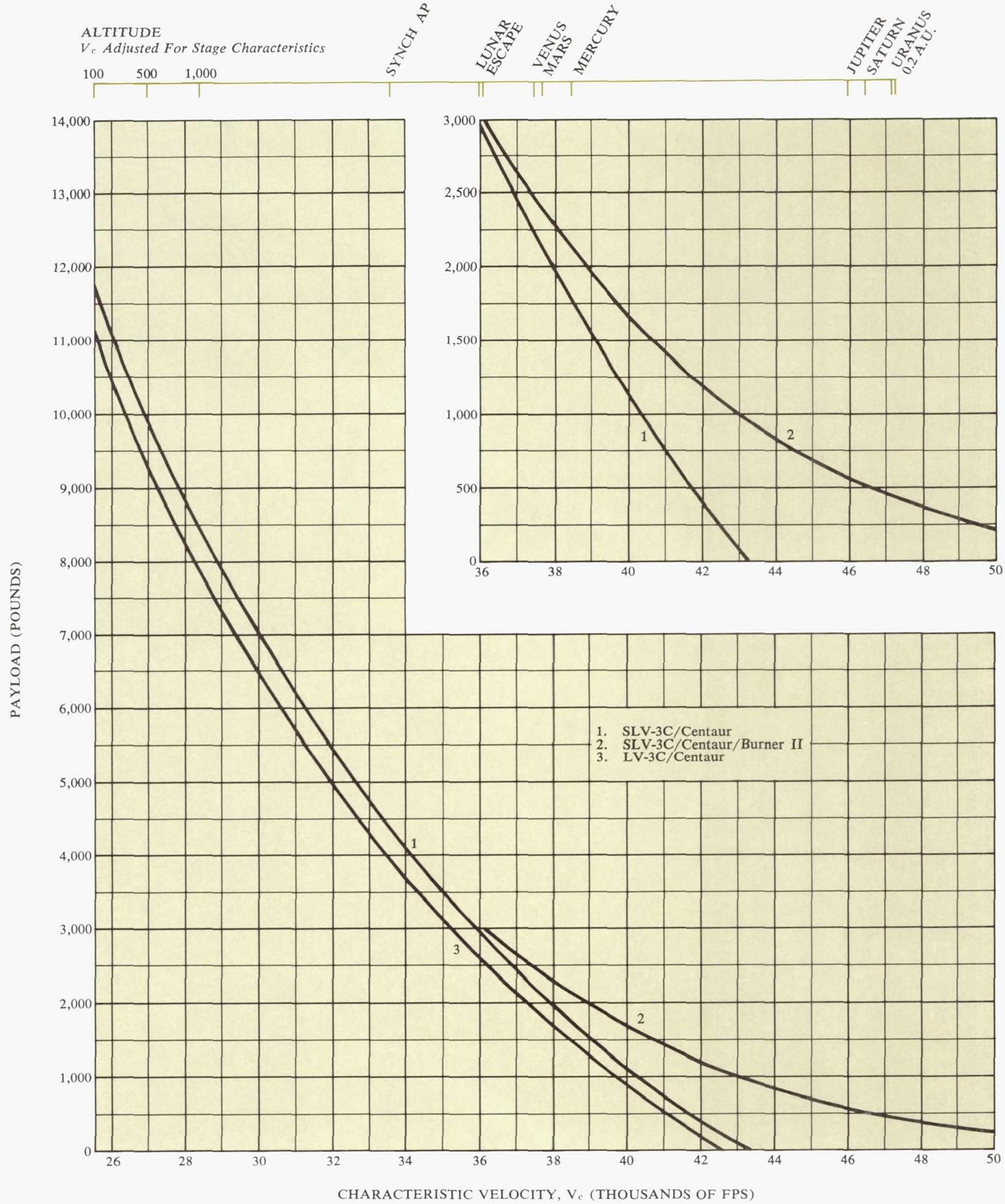
The most notable Atlas/Centaur mission to date was the highly successful Surveyor I. Missions scheduled for Atlas/Centaur in the near future include additional Surveyor missions, OAO, Advanced Technology Satellites, and Mariner 69. Other planned missions include OGO, TV and FM satellites, and Voyager.

The facing graph shows payload capability of the SLV-3C/Centaur, with and without a Burner II kick stage. Although the LV-3C/Centaur used to launch the Surveyor is no longer in production, its capability is indicated as a reference for the more advanced SLV-3C/Centaur. Centaur weights are based on the AC-15 configuration; residuals and vent losses were adjusted for mission differences (e.g., engine firing times, transfer coast periods).

A parking-orbit coast is assumed, with two 50-pound-thrust propellant settling engines operating for 100 seconds after first Centaur engine shutdown and for 45 seconds prior to the second engine start. Two 3-pound-thrust propellant position control engines operate from 100 seconds after the first engine shutdown until 45 seconds prior to the second engine start.

Missions requiring three upper-stage burns may be accomplished with a two-burn Centaur and a small kick stage. For example, an SLV-3C/Centaur plus a Burner II kick stage with optimized propellant loading can provide the final plane change and circularization impulse for a 1710-pound synchronous equatorial payload. Using an injection motor in the payload, 2010-pounds of usable payload can be placed in synchronous equatorial orbit by SLV-3C/Centaur.

With the increasing number of missions being assigned to Atlas/Centaur combinations, some excess payload capability will result. This excess capability can be utilized by the multiple-mission techniques described on page 20.


ALTITUDE
Vc Adjusted For Stage Characteristics
100
500
1,000
SYNCH AP
LUNAR ESCAPE
VENUS
MARS
MERCURY
JUPITER
SATURN
URANUS
0.2 A.U.
PAYLOAD (POUNDS)
CHARACTERISTIC VELOCITY, Vc (THOUSANDS OF FPS)
1. SLV-3C/Centaur
2. SLV-3C/Centaur/Burner II
3. LV-3C/Centaur

ATLAS/AGENA

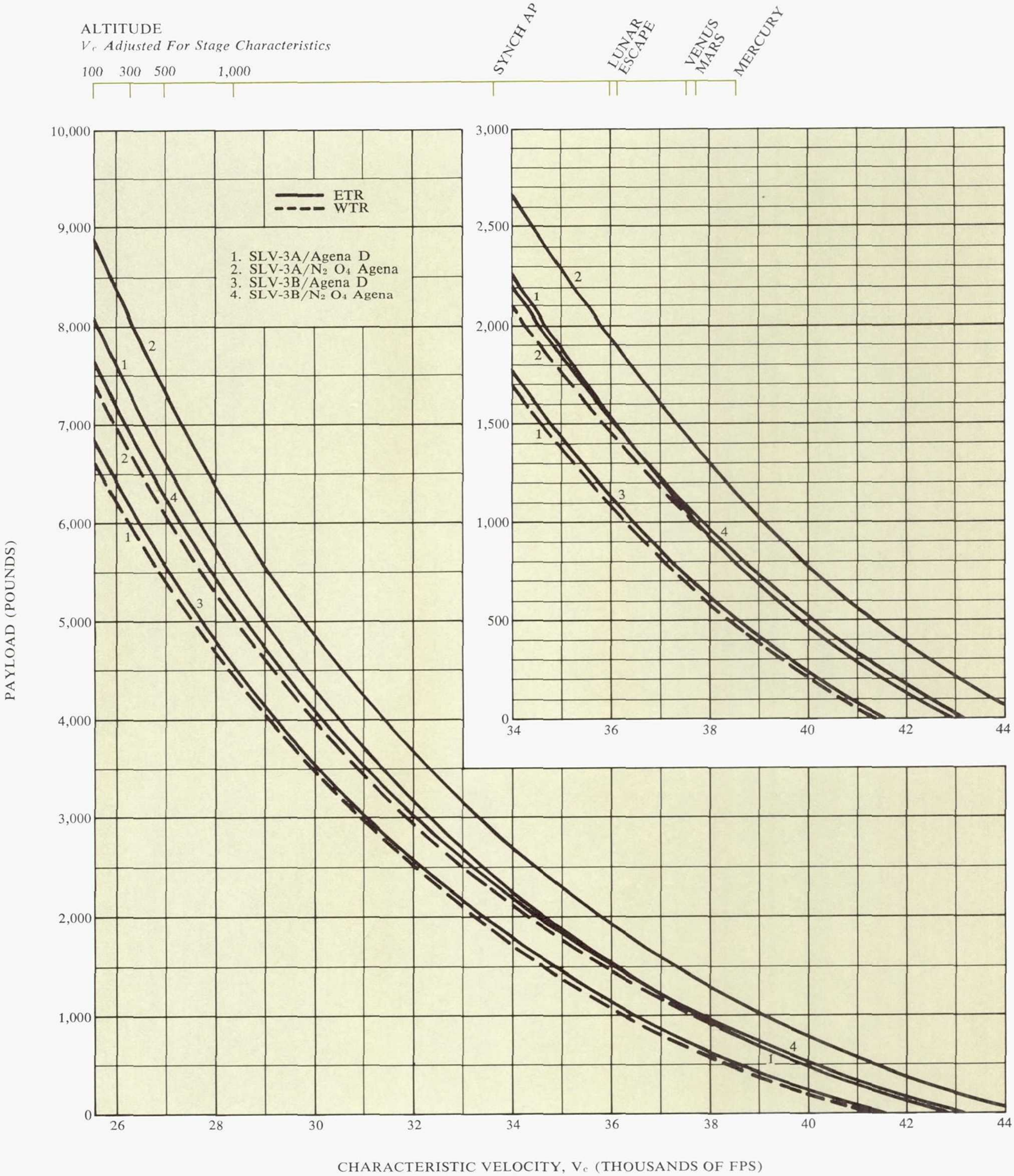
Atlas/Agena (SS01B) combinations have successfully performed many space missions, ranging from earth orbital to interplanetary. These missions include Ranger, Gemini Target, OAO, EGO, Vela, Mariner, Snapshot, Lunar Orbiter, ATS, and a large number of classified Air Force missions. Over 60 standardized Atlas/Agena vehicles have been launched since June 1963, with an ascent success of over 95 percent.

The Agena vehicle is capable of multiple restarts in space, and may remain attached to the payload to provide orbital housekeeping functions (power supply, orbital changes/corrections, attitude control, de-orbit).

SLV-3A/Agena curves on the facing page are based on use of a 5-foot-diameter fairing jettisoned at VECO. SLV-3B/Agena curves are based on use of a 10-foot-diameter OAO fairing system completely enclosing the Agena and payload, with the nose and mid fairings jettisoned at 300,000 feet and the remainder at SECO. To avoid further crowding of the graph, SLV-3B/Agena payload capability is shown for ETR only.

The Atlas portion of flight uses the GE radio guidance system. After separating from Atlas, the Agena uses an all-inertial guidance system to generate attitude error signals whenever the vehicle deviates from the prescribed attitude references. These error signals are applied to the control system, which utilizes pneumatic and hydraulic control forces to effect attitude corrections. Attitude is sensed by a three-axis, body-mounted gyro reference system and a pair of horizon scanners; attitude during coast phase is controlled by jets ejecting gaseous nitrogen/Freon 14. The guidance and control system can be programmed to accomplish various trajectory/orbital maneuvers.

An improved Agena under development will use nitrogen tetroxide (N_2O_4) instead of IRFNA as oxidizer, and A-50 (50 percent N_2H_4 and 50 percent UDMH) fuel to increase performance capability. Requests for additional Agena information should be directed to Lockheed Missiles and Space Company, Sunnyvale, California.

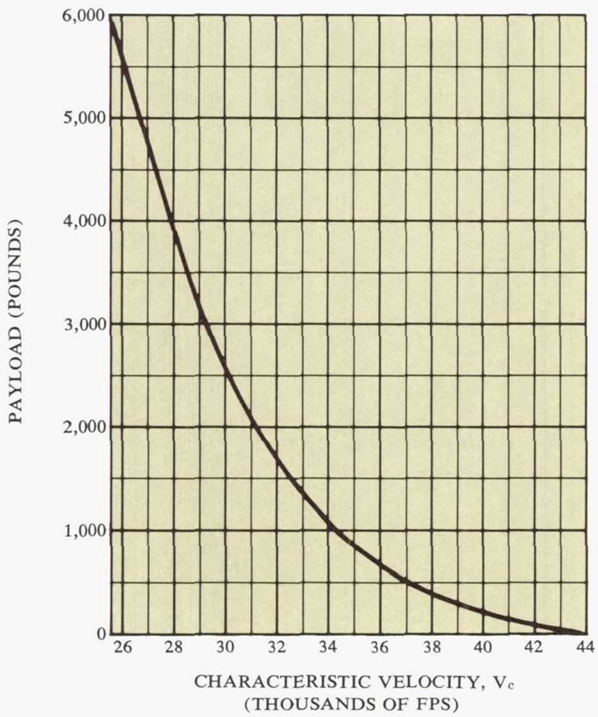

ALTITUDE
V_c Adjusted For Stage Characteristics
100 300 500 1,000
SYNCH AP
LUNAR ESCAPE
VENUS MARS
MERCURY
ETR
WTR
1. SLV-3A/Agena D
2. SLV-3A/N_2O_4 Agena
3. SLV-3B/Agena D
4. SLV-3B/N_2O_4 Agena
PAYLOAD (POUNDS)
CHARACTERISTIC VELOCITY, V_c (THOUSANDS OF FPS)

ATLAS/BURNER II

Burner II is a self-contained upper stage powered by a spherical solid-propellant rocket engine. Although Burner II is operational for other uses, no Atlas/Burner II flights are currently contracted. The combination would be particularly useful for earth orbital missions and lightweight planetary probes, with payload capability falling between the Atlas direct ascent/apogee kick and the Atlas/Agena combination.

The Atlas portion of flight would use the G E radio guidance system. Burner II stage guidance is furnished by precision strap-down gyros and a velocity meter carried aboard the stage; directional control during engine firing is provided by H_2O_2 reaction engines. The H_2O_2 engines also provide thrust for separation from the lower stage and velocity vernier thrust after main engine firing. Gaseous nitrogen jets provide attitude control during coast, optional spacecraft spinup, and retro-thrust at spacecraft separation.

Requests for additional Burner II information should be directed to the Aerospace Group of the Boeing Company, Seattle, Washington.



As a further aid to mission planning, Atlas family payload capability is shown in the following matrices for representative earth-orbital and interplanetary missions. Knowing the approximate payload weight requirement, a quick scan of the appropriate mission column will indicate which Atlas family combination should be considered.

Payload as presented is a function of characteristic velocity, V_C, using a 100-n.mi. circular parking orbit. Characteristic velocity is the sum of the parking orbit circular velocity (25,572 feet per second for 100 n.mi.) and the excess velocity capability, ΔV, at that orbit for a given payload; in other words, it is the burnout velocity capability of the launch vehicle configuration.

This capability may also be expressed as twice orbital energy per unit mass, C_3. Characteristic velocity and C_3 are related in the following manner:

$$V_C^2 - V_P^2 = C_3$$

where V_P = local parabolic velocity
= 36,164 ft/sec for 100-n.mi. orbit

Since C_3 is customarily specified in units of $(km/sec)^2$, a conversion factor is necessary. Thus,

$$C_3 = \frac{V_C^2 - (36{,}164)^2}{(3280.84)^2}$$

At escape velocity ($V_C = 36{,}164$ ft/sec), $C_3 = 0$. The following values of V_C, ΔV, and C_3 based on transfer from 100 n.mi. orbit were used in payload tabulations presented in this Digest.

It is recognized that the energy required to perform a specific interplanetary mission is a function of desired transit time and desired launch period; the value of V_C shown for each of the tabulated missions is the minimum energy requirement except for Uranus, Neptune, and Pluto (based on a 10-year transit time).

Payload capabilities shown in the matrices are taken from the performance curves on the configuration data sheets. Values are conservative, and comply with the specific conditions listed for that particular curve.

MISSION VELOCITY/ENERGY REQUIREMENTS

MISSION	CHARACTERISTIC VELOCITY, V_C (FT/SEC)	CIRCULAR VELOCITY EXCESS, ΔV (FT/SEC)	C_3 ENERGY $(KM/SEC)^2$
100-N.MI. CIRCULAR ORBIT	25,572	0	
300-N.MI. CIRCULAR ORBIT	26,262	690	
500-N.MI. CIRCULAR ORBIT	26,900	1,328	
SYNCHRONOUS APOGEE	33,652	8,080	
LUNAR IMPACT	36,035	10,463	
ESCAPE	36,164	10,592	0
INCLINED SYNCHRONOUS	38,503	12,931	16.0
SYNCHRONOUS EQUATORIAL	39,611	14,039	24.0
VENUS	37,572	12,000	9.6
MARS	37,772	12,200	11.0
MERCURY (VIA VENUS FLYBY)	38,572	13,000	16.7
JUPITER	46,072	20,500	75.7
SATURN (VIA JUPITER FLYBY)	46,572	21,000	80.0
URANUS (VIA JUPITER FLYBY)	47,272	21,700	86.1
0.2 A.U. (VIA VENUS FLYBY)	47,372	21,800	86.9
NEPTUNE (VIA JUPITER FLYBY)	50,072	24,500	111.4
PLUTO (VIA JUPITER FLYBY)	54,272	28,700	152.1

CHARACTERISTIC VELOCITY, V_C (FPS × 1,000)

ATLAS CONFIGURATION	CENTAUR	N_2O_4 AGENA	AGENA D	BURNER II	NO UPPER STAGE	100 N.MI. CIRCULAR $V_c \simeq 25.6$		500 N.MI. CIRCULAR $V_c \simeq 26.9$		1000 N.MI. CIRCULAR $V_c \simeq 28.3$		SYNCH AP	SYNCH EQ	LUNAR IMPACT
						DUE EAST (ETR)	DUE SOUTH (WTR)	DUE EAST (ETR)	DUE SOUTH (WTR)	DUE EAST (ETR)	DUE SOUTH (WTR)	$V_c \simeq 33.7$	$V_c \simeq 39.6$	$V_c \simeq 36.0$
SLV-3 (REFERENCE)					•	4,160	2,670							
			•			6,850	5,550	5,650	4,630	4,630	3,730	1,940	285	1,170
		•				7,500	6,250	6,300	5,250	5,250	4,330	2,350	540	1,480
LV-3C (REFERENCE)	•					11,100	9,400	9,200	7,900	7,800	6,500	4,000	240	2,620
SLV-3A					•	5,350	3,700							
		(APOGEE KICK)			•			3,070	1,630	1,150				
				•		6,000	4,700	3,700	2,600	2,200	1,500	1,170		670
			•			8,050	6,620	6,650	5,500	5,450	4,500	2,410	485	1,500
		•				8,800	7,400	7,410	6,150	6,130	5,080	2,820	800	1,900
			•	•									816	1,760
		•		•										2,040
SLV-3B			•			6,850	5,550	5,620	4,600	4,600	3,700	1,920	260	1,130
		•				7,600	6,300	6,330	5,240	5,200	4,280	2,320	530	1,500
SLV-3C	•					11,800	10,100	9,900	8,500	8,400	7,200	4,300	590	2,920
	•			•									1,710*	

*Replace TE-364-2 Motor with TE-364-4 Motor.

CHARACTERISTIC VELOCITY, V_C (FPS $\times$ 1,000)

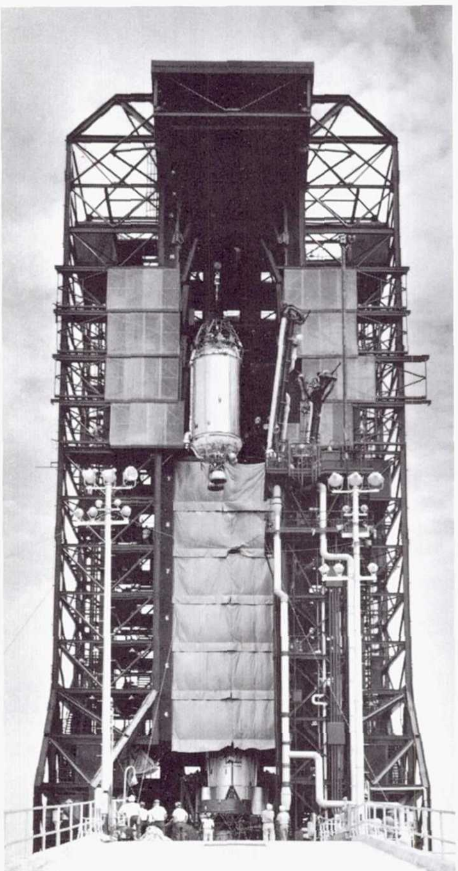
ATLAS CONFIGURATION	CENTAUR	N_2O_4 AGENA	AGENA D	BURNER II	ESCAPE $V_c \simeq 36.2$	☿ MERCURY $V_c \simeq 38.6$	♀ VENUS $V_c \simeq 37.6$	♂ MARS $V_c \simeq 37.8$	♃ JUPITER $V_c \simeq 46.1$	♄ SATURN $V_c \simeq 46.6$	⛢ URANUS $V_c \simeq 47.3$	♆ NEPTUNE $V_c \simeq 50.1$	♇ PLUTO $V_c \simeq 54.3$	☉ 0.2 A.U. $V_c \simeq 47.4$
SLV-3 (REFERENCE)			●		1,150	540	790	740						
		●			1,440	780	1,030	980						
LV-3C (REFERENCE)	●				2,600	1,500	1,920	1,820						
SLV-3A				●	650	350	450	430						
			●		1,470	800	1,050	1,000						
		●			1,860	1,130	1,420	1,380						
			●	●	1,730	1,160	1,380	1,330	250	210	170	40		170
		●		●	2,000	1,380	1,610	1,560	330	300	250	90		240
SLV-3B			●		1,090	500	720	670						
		●			1,460	830	1,070	1,020						
SLV-3C	●				2,880	1,750	2,200	2,100						
	●			●	2,960	2,090	2,435	2,370	560	500	430	205		420

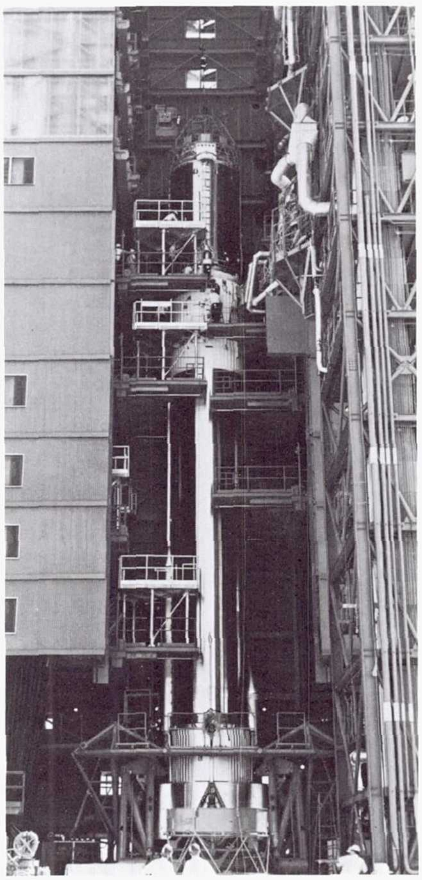
SUMMARY

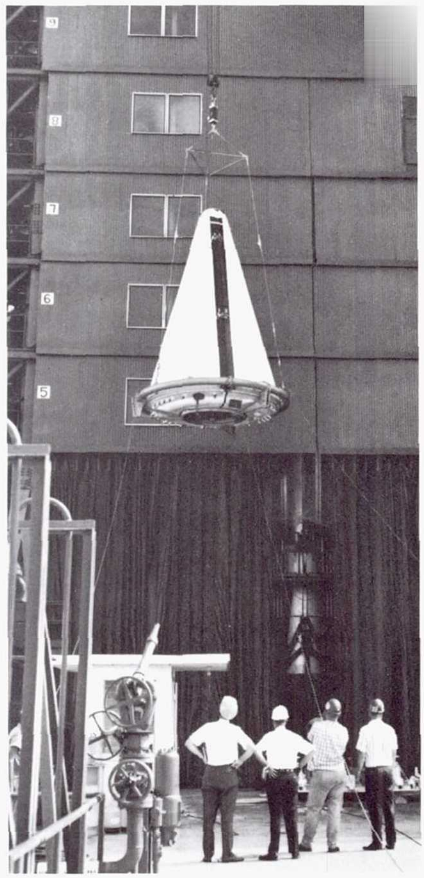
Based on nine years of actual flight history, the Atlas family is the most dependable and flexible launch vehicle system in operation today. With its uprated configurations and with the extended payload capability of the operational Centaur upper stage, even greater accomplishments are expected in the future.

The Atlas family concept is one of flexibility and cost effectiveness. Starting with a flight-proven and dependable launch vehicle, additional payload capability is attained by applying technology well within the current state-of-the-art. Performance is increased by uprating the propulsion system, increasing propellant tank volume, augmenting thrust, and employing techniques such as sustainer-tank apogee kick. Multiple mission capability, already a proven fact with Atlas, is an excellent example of cost effectiveness. Use of existing Series E and F missiles reduces launch costs of smaller experiments still further.

Convair has extensive integrating and software contractor experience to support all missions involving any part of the Atlas launch vehicle family.







More detailed information is readily available in the documents listed on the inside front cover. Cost and exact performance data will be provided to any using agency with a mission requirement in the payload/velocity range supported by the advanced Atlas family. Inquiries should be directed to any of the General Dynamics Field Offices listed below or to:

R. J. VOTH
Advanced Program Development
Phone (714) 277-8900, Extension 711
CONVAIR DIVISION OF GENERAL DYNAMICS
San Diego, California

W. J. GEUDTNER
Suite 1, Office Center
16501 Brookpark Road
Cleveland, Ohio 44142
Phone (216) 267-1245

J. O. KIRBY
Suite 525, Cape Royal Bldg.
1980 N. Atlantic Ave.
P. O. Box 459
Cocoa Beach, Fla. 32931
Phone (305) 783-4901

H. T. ALNESS
Suite 1024, Medalion Bldg.
Bijou at Union Blvd.
Colorado Springs, Colo. 80909
Phone (303) 634-4824

F. F. de FRANCE
Suite 236, 333 West 1st St.
Dayton, Ohio 45402
Phone (513) 223-9923

J. H. MASON
Suite 606
650 N. Sepulveda Blvd.
El Segundo, Calif. 90245
Phone (213) 772-3361

J. O. KIRBY
P. O. Box 1447
Fort Walton Beach, Fla. 32548
Phone (904) 651-2061

J. J. KING
830 Black River Blvd.
P. O. Box 390
Rome, New York 13441
Phone (315) 336-7400

B. A. ROBERTS
1208 Tower Life Bldg.
310 S. St. Mary's Street
San Antonio, Texas 78205
Phone (512) 226-2203

C. C. BREWER
456 N. Arrowhead Ave.
San Bernardino, Calif. 92401
Phone (714) 884-1191

J. M. FITZPATRICK
Ninth Floor
1710 H Street, N.W.
Washington, D.C. 20006
Phone (202) 298-6600

R. F. CONLEY
48 rue de Bassano
Paris 8e, France
Phone BALZac 13-82/87-97
ELYsees 30-98

H. B. HENDERSON
Suite 210, 1120 W. Mercury Blvd.
Hampton, Virginia 23366
Phone (703) 838-1300

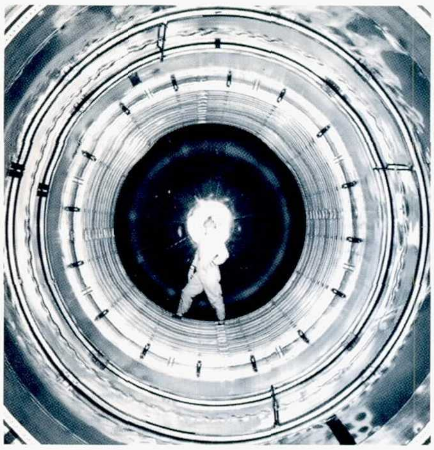
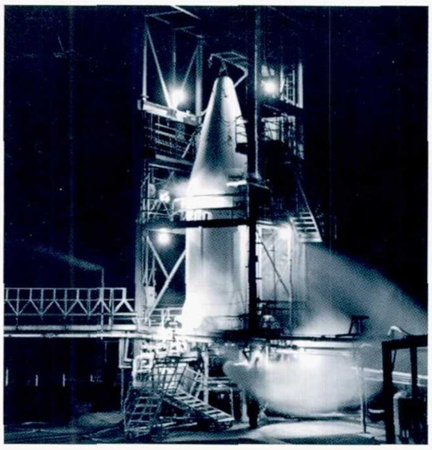
B. A. ROBERTS
Suite 204, 1730 NASA Blvd.
Houston, Texas 77058
Phone (713) 488-2281

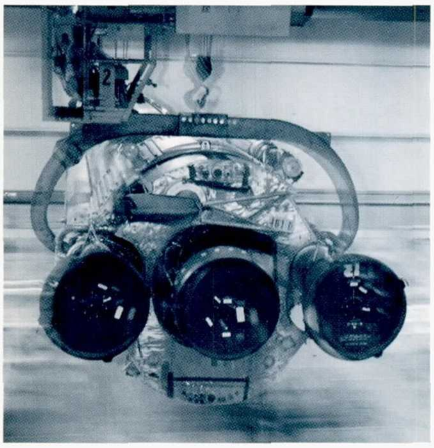
G. C. HOLT
Suite 42, Holiday Office Center
South Memorial Parkway, S.W.
Huntsville, Alabama 35801
Phone (205) 881-2021

F. R. HEYNER
442 Marrett Road, Suite 8
Lexington, Mass. 02173
Phone (617) 862-7550

E. A. REYNOLDS
1445 Kiewit Plaza
Farnam at 36th Street
Omaha, Neb. 68131
Phone (402) 341-3293

P. E. BRANDT
25 Reckless Place
P. O. Box 829
Red Bank, N.J. 07701
Phone (201) 741-7064



GENERAL DYNAMICS

Convair Division

San Diego, California