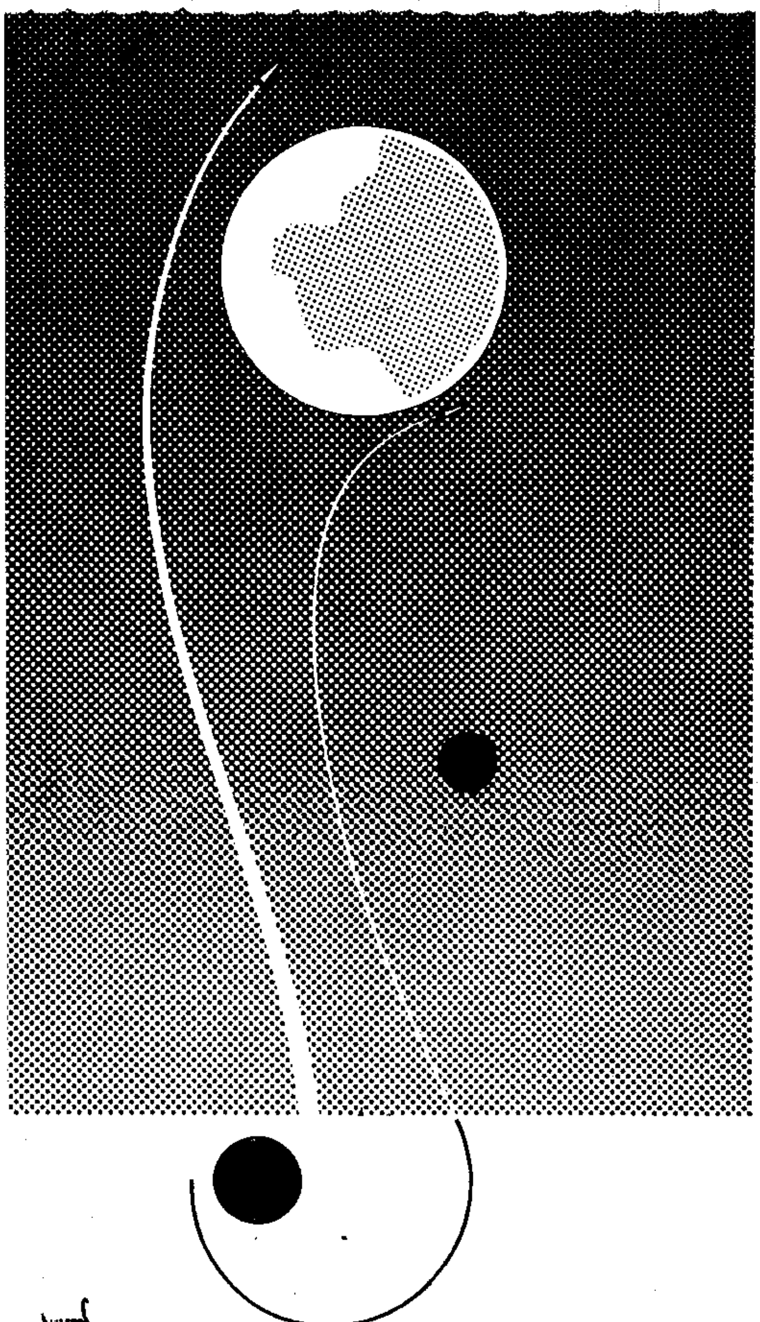

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(TITLE UNCLASSIFIED)

THE LIQUID ROCKET PLANT IN-SPACE ENGINE PROGRAMS AND RELATED EFFORTS

Revision A

61#120a

Aerojet-General® CORPORATION

LIQUID ROCKET PLANT SACRAMENTO, CALIFORNIA

DEP-R&D

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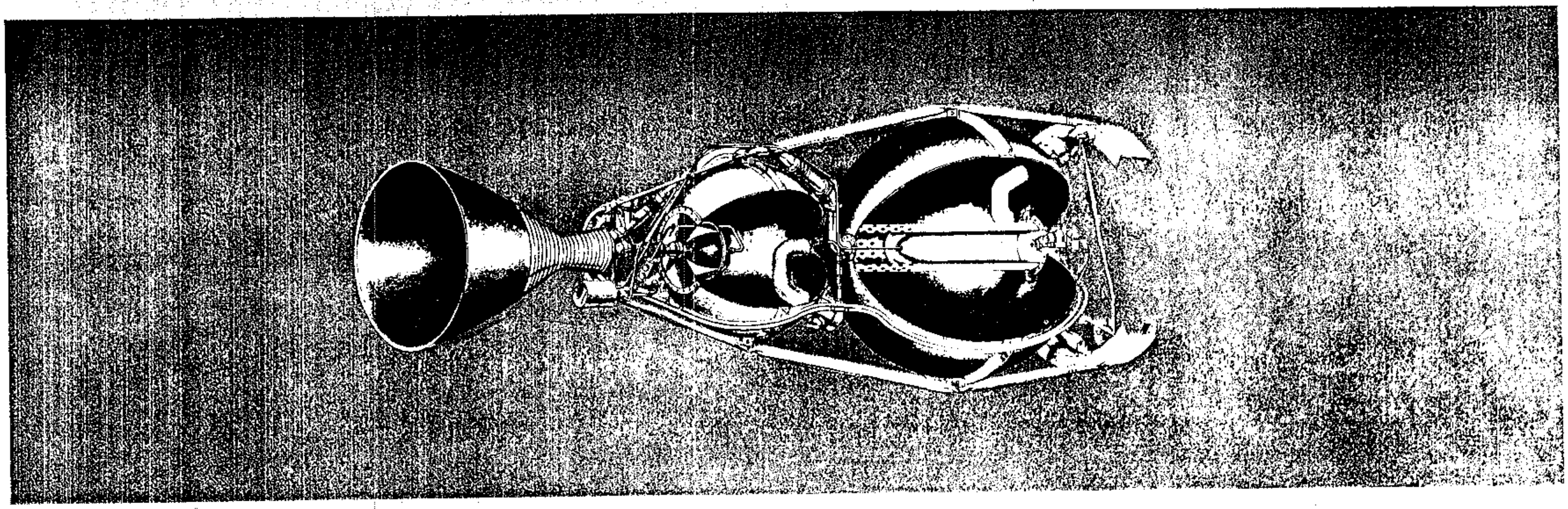
HYLAS



GROSS WEIGHT, lb — 5,000
THRUST, lb — 6,000
CHAMBER PRESSURE, psia — 40
SPECIFIC IMPULSE, sec — 433
TOTAL IMPULSE, lb-sec — 1.80×10^6

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Figure 47

HYLAS

A performance survey of the space vehicles currently in use and under development by the National Aeronautics and Space Administration has been conducted. The purpose of this study was to evaluate the concept of extending the range, payload capabilities, and, therefore, the period of usefulness of these vehicles through the addition of a small high-performance third stage using liquid oxygen and liquid hydrogen as propellants.

In order to achieve maximum utilization of the upper-stage vehicle considered - called Hylas - it was felt that versatility should be the keynote of the design selected. The stage was sized to be optimum, or near optimum, for all of the existing booster second-stage combinations and also for later use as a terminal or lunar return stage for the more advanced Saturn program. It incorporates provisions for a space restart capability, and is so designed as to provide the potential for the later development of a long-term, space-storage capability.

In addition to versatility and high performance, the Hylas studies have emphasized design simplicity through the use of a pressure-fed system and an uncooled ablative thrust chamber. This provides the opportunity to develop a high degree of reliability for a minimum expenditure of development time and money. Low cost, high reliability, and early availability are the primary objectives of the proposed development program.

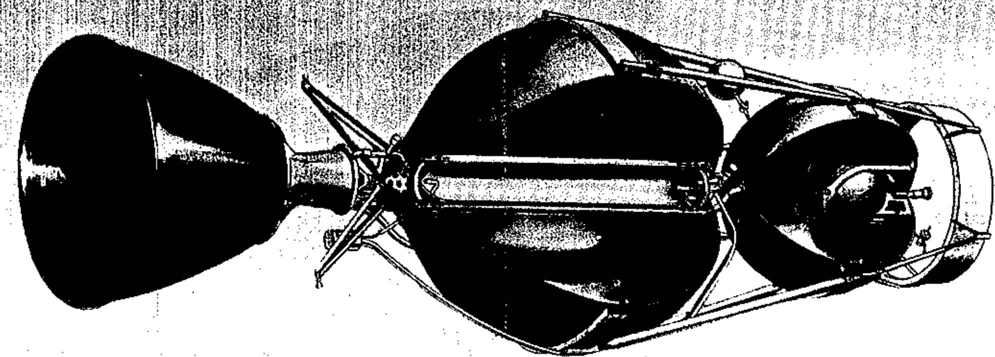
It is 89.5 in. in diameter, 251 in. long and has a 0.85 propellant mass ratio.

Aerojet is currently engaged in the development of components for a larger Hylas-type system under the Air Force-sponsored Hydra program (Contract No. AF 04(611)-5170). This contract called for the fabrication and firing of 12 ablative flight thrust chambers of 20,000 lb

Hylas (cont.)

thrust using LOX/LH_2, the development of pressurization system, and a detailed stage design study for an advanced Titan third stage. The work related to this contract, together with other test programs involving several hundred hot firings of high-energy propellants and ablative thrust chambers, has provided the basic design data used in the Hylas stage. Hylas, therefore, requires no advances in the state-of-the-art of rocketry. It is a sound, conservative design based upon actual test data, and a broad background of successful Aerojet upper stages. It can be developed immediately using existing technology, materials, and techniques.

HYLAS STAR



GROSS WEIGHT, lb	12,315
THRUST, lb	13,000
CHAMBER PRESSURE, psia	40
SPECIFIC IMPULSE, sec	433
TOTAL IMPULSE, lb-sec	4.63×10^6

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Figure 48

HYLAS STAR

Hylas Star is an advanced high-energy upper-stage vehicle, using liquid oxygen and liquid hydrogen as propellants. Emphasis was placed on simplicity, reliability, low cost, and early availability. Hylas Star is designed to accommodate the existing IRBM and ICBM boosters.

The Hylas Star vehicle is a simple gas-pressurized propulsion system utilizing the high energy liquid oxygen and liquid hydrogen propellant combinations. It incorporates an uncooled ablative thrust chamber and has a restart capability. It provides a total impulse of 4.34 million lb/sec at a thrust of 13,000 lb. The nominal tank pressures are 65 psia with a corresponding chamber pressure of 40 psia. It is 97 in. in diameter, 329 in. long, weighs approximately 12,900 lb at liftoff, and has a 0.87 propellant mass ratio.

Recent efforts were feasibility testing of the uncooled ablative-type thrust chamber, the development of a pressurization system, and a detailed design study of the propulsion system and its components.

HYLAS STAR ACCOMPLISHMENTS

- **ABLATIVE THRUST CHAMBER**
  - MAXIMUM DURATION: 300 sec at $P_c = 40$ psia
  - MULTIPLE TESTS PER CHAMBER
  - ESTABLISHED DESIGN CRITERIA
- **LOX & LH_2 PRESSURIZATION SYSTEM**
  - DURATION: 200 sec
  - CONTROLLED STABLE OPERATION
  - ESTABLISHED DESIGN CRITERIA
- **SYSTEM DESIGN STUDY**

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Figure 49

HYLAS/HYLAS STAR PROGRAM ACCOMPLISHMENTS

The two key elements of the propulsion system - the ablative thrust chamber and the pressurization system - have been proven and initial development completed on Contract AF 04(611)-5170.

This work included the following:

- Testing of eight development-type thrust chambers at conditions of:
  - Chamber pressure 65 psia
  - Durations*up to 207 sec (6.5 M.R.)
    165 sec (5.0 M.R.)
  - Mixture ratios up to 12
  - Multiple runs up to 4 on 1 chamber
- Testing of 5 flight weight chambers:
  - Chamber pressures of 65 and 40 psia
  - Durations*of 301 sec (40 psia)
    165 sec (65 psia)
  - Two multiple runs on one chamber totaling 215 sec (65 psia)
- Demonstration expulsion tests with a breadboard pressurization system in which simultaneous expulsion of liquid-hydrogen and liquid-oxygen was achieved for long duration (200 sec) and with controlled, stable operation.

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*Capacity of tank

Hylas/Hylas Star Program Accomplishments (cont.)

-Expulsion of liquid hydrogen in a series of development tests under conditions of:

Tank pressure	90 psia
Durations	200 sec
Inlet gas temperature	150° - 500°R
Sloshing	1 c.p.s.

The major results on this contract are as follows:

Thrust Chamber

Excellent correlation between experimental and theoretical char depth. Ablation essentially zero at nozzle throat for durations up to 200 sec at 165 psia chamber pressure and for 300 sec at 40 psia.

Design and fabrication techniques established.

Multiple tests on one chamber indicate no deleterious effect on structural character of chamber.

Operation at high mixture ratio with no apparent sacrifice in life.

Operation at low fuel injector pressure drop.

High performance at low chamber pressure.

Hylas/Hylas Star Program Accomplishments (cont.)

Pressurization System

Performed dynamic analysis of pressurizing system.

Experimentally determined major design parameters

Amount of pressurant is essentially independent of gas temperature

Varying ullage had no apparent effect on amount of pressurant

No change in system behavior with sloshing

Demonstrated that pressurant requirements can be predicted and are compatible with flight operation

Demonstrated expulsion of both liquid hydrogen and liquid oxygen

HYLAS/HYLAS STAR NET PAYLOAD CAPABILITY

	CENTAUR HYLAS	TITAN II HYLAS STAR
24 hr ORBIT	2,540	2,300
LUNAR IMPACT	3,370	3,480
INTERPLANETARY		
VENUS	2,900	3,020
MARS	2,770	2,880
JUPITER	670	480

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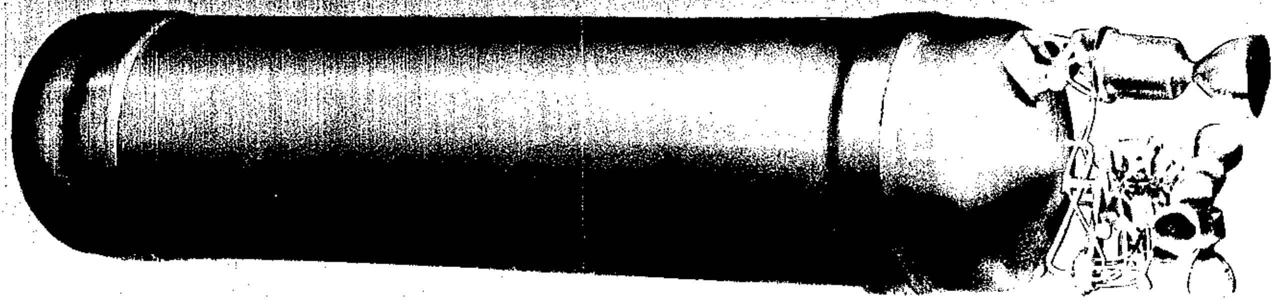
Figure 50

HYLAS/HYLAS STAR NET PAYLOAD CAPABILITY

As part of the effort to determine the optimum thrust level for high energy upper-stage use with the Centaur and Titan II booster vehicles--the thrust levels of 6,000 lb (Hylas) and 13,000 lb (Hylas Star) resulted--the payload capabilities for a variety of missions have been determined. In order to accommodate the Hylas stage, it was necessary to off-load the Centaur by approximately 15% (5,000 lb). This restriction was not required in applying Hylas Star to Titan II. Based on the above studies, the Hylas/Hylas Star stages are representative of the small, high-energy vehicles which may be used to extend the usefulness of current boost systems.

AGENA ATTITUDE AND ORBIT-CONTROL SYSTEM



• FEATURES

- STORABLE PROPELLANTS
- RADIATION - COOLED THRUST CHAMBER
- PULSE-OPERATION CAPABILITY
- POSITIVE-EXPULSION PROPELLANT TANKS
- RESTART CAPABILITY

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Figure 52

AGENA ATTITUDE AND ORBIT-CONTROL SYSTEM

The proposed control system for the Agena vehicle was designed to a package concept with two package units per system. The five package units differ only in that a single pressurization system is utilized for the complete attitude and orbit-control system. With this single deviation, each package is identical to the model above. Each package has an oxidizer compartment, a fuel compartment, a high pressure nitrogen-gas compartment, a set of three 1/2-lb-thrust motors, a set of three 10-lb-thrust motors, and one 20-lb-thrust motor, complete with associated valves and controls. The propellants used are MON-10/UDMH. Positive propellant expulsion is accomplished with a titanium bellows system. Each thrust chamber is coupled to a bipropellant valve and is considered to be an individual rocket engine assembly. The individual thrust chambers operate at 60 psia nominal chamber pressure and are designed to be cooled by radiation only. The two package system delivers a total impulse of 72,800-lb/sec and weighs 372 lb.