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American Rocket Company Tests Full Scale Engines

The American Rocket Company (AMROC), Menlo Park, Calif., has begun testing a full-sized version of the company's hybrid rocket motor. Two such tests took place on December 11 and 12 at the Air Force Rocket Propulsion Laboratory at Edwards Air Force Base, Calif.

The full-sized motor is 40 inches in diameter, approximately 16 feet long, and has an operating thrust of 35,000 lbs. (earlier tests in May of 1986 involved a subscale motor with a thrust of up to 6,000 lbs.) AMROC's current launch vehicle design, the ILV-1 (Industrial Launch Vehicle One), would use a total of nineteen such engines, twelve in the first stage alone (C.S.R., Oct. 1986 pp. 2). AMROC intends to launch its first ILV-1 before the end of 1988.

Two tests were performed using the same engine. The first test scheduled was for a 20 second burn, which came off without incident. The second test burn was to last 40 seconds, but the engine had to be shut down 33 seconds into the burn due to a fire near or at the valve controlling liquid oxygen flow into the solid fuel. The fire was reportedly caused by the melting of an aluminum spacer ring in the valve assembly. The loss of control of the oxygen flow caused the injector and exhaust nozzle to blow out of the engine before it was shut down. Nevertheless, AMROC considered the tests to be successful, providing useful data for the program.

To understand the importance of AMROC's test program a little better, some background on the hybrid engine may help. The AMROC hybrid uses a liquid oxidizer and a solid fuel. The oxidizer, in this case, is liquid oxygen (LOX). The fuel is a compound primarily composed of polybutadiene (a hard black rubber similar to the material out of which hockey pucks are made). This compound is cast, in liquid form, into molds inside a metal casing where it solidifies. The casing is closed at one end and has a rocket nozzle on the other end, forming an assembly which closely resembles a standard solid-propellant rocket motor.

The schematic diagram on page 2 shows the layout of a typical AMROC-type hybrid rocket engine. In the schematic the motor has its own LOX tank, but this need not be the case--the first stage of the ILV-1 shares one large LOX tank between twelve motors.

The major difference between hybrid motors and the more familiar solid-propellant motors is that the solid motor's charge of propellant, called a "grain," (a somewhat incongruous term considering the size of some motors) contains both fuel and oxidizer chemicals mixed together in solid form. This grain requires only a source of ignition to set it burning furiously, and once ignited it is almost impossible to extinguish. In addition, throttling thrust levels is exceedingly difficult.

A hybrid motor's fuel, on the other hand, will only burn when liquid oxygen is actively applied to it. The LOX in AMROC's motor passes through a valve and into an injector at the forward end of the fuel-loaded combustion chamber. It then flows through a channel or channels formed throughout the length of the fuel (the cross-section in the diagram shows a typical arrangement of channels--a "wagon wheel" design). Burning takes place on the inside surfaces of these channels.

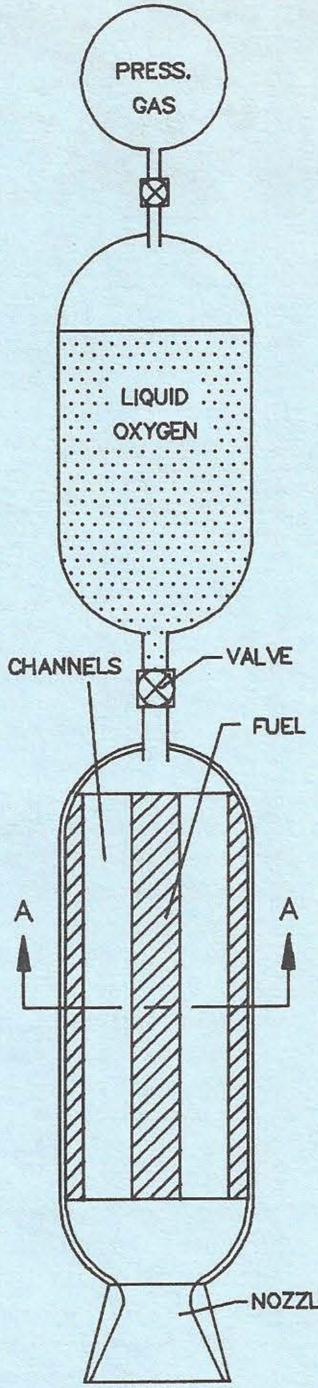
The hybrid concept has a number of advantages. The primary advantage is increased safety compared with solid-propellant rockets. Mixing and casting of the non-explosive fuel requires no extraordinary precautions, and can be done in almost any manufacturing facility at a relatively low cost. Facilities for safely casting the explosive propellants of standard solid motors are far more elaborate and expensive, involving huge vats filled with batter-like propellant in uncured form, stirred by remote-controlled mixers and located in thick-walled blockhouses far away from inhabited areas.

Additional advantages of the hybrid include ease of control--adjusting the amount of oxygen flow controls the level of thrust of the engine. When the flow of oxygen is shut off, the motor simply stops burning.

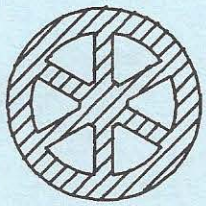
There are disadvantages to the hybrid concept too. Performance is lower than that of liquid-fueled rockets. Analysis of hybrid engines is difficult, due to the complex interaction of solids and liquids in the combustion chamber. But the chief disadvantage, in my opinion, is the current status of hybrids as a relatively unexplored technology. By comparision, the solid-propellant rocket industry is a mature one. Methods of designing, manufacturing, transporting and operating such motors have been developed over many years to the extent that, despite recent problems, solid rocket motors are considered to be highly reliable and quite safe, and are presently used for a multitude of applications. Liquid-propellant rockets too have a long history of development and testing and are used on many vehicles.

Although the concept of the hybrid is an old one, hybrids have just not been as thoroughly researched and developed as other types of propulsion methods, nor have they seen much use in flight hardware. The reasons for this neglect are not clear, but the results are: without an extensive R & D background hybrids can, for all intents and purposes, be almost considered to be a new technology. This means that a company such as AMROC must therefore cover a considerable amount of new ground in its development program in order to bring the hybrid up to its promised potential and maturity as an inexpensive and reliable method of propulsion.

There are many critical factors to be addressed in AMROC's development of the hybrid. The most important factors include assuring an even oxidizer flow over the surface of the fuel, an even burning of the fuel, and a predictable erosion of the fuel surface as it burns. In an ideal motor, the fuel would burn evenly and in such a way that useful



HYBRID SCHEMATIC



SECTION A-A

thrust is produced until the solid fuel is almost entirely gone. As mentioned earlier, analysis of the burning behavior of a hybrid is not simple. Variables such as fuel cross-sections, oxidizer flow, injector design, and others all must be addressed.

If the fuel burns unevenly, problems result. In some situations the fuel can burn through in some spots to the outer casing of the motor. This can result in casing penetration, or early shutdown of the motor with useless propellant still inside. In other situations, particularly with cross-sections such as the one shown in the diagram, the fuel could burn off large chunks of itself, which could be ejected through the nozzle, or even stick in the nozzle throat causing possible engine rupture.

These problems do not normally appear during short burns of newly-manufactured hybrid motors--the engine is shut off before serious ablation of the fuel has occurred and any burn-through problems can appear. The critical tests are, and will be, those involving full-duration burns (a full duration burn of the full-sized motor may last up to two minutes).

It is this blazing of new technological trails which makes AMROC's test program a pivotal part of its efforts to develop commercial launch vehicles, and makes the company's testing milestones of interest to the commercial space field.

Jarvis Launch Vehicle Undergoes Major Redesign

The two aerospace companies proposing development of the Jarvis launch vehicle have announced major changes of the vehicle design. The Jarvis is an expendable launch vehicle proposed by the Hughes Aircraft Company in partnership with the Boeing Aerospace Company. The vehicle was originally proposed for the Air Force's Medium Launch Vehicle (MLV) competition (C.S.R., July 1986, pp. 1-2; Aug. 1986 pp. 4-6. More on MLV later in this article).

The original design called for use of Saturn 5 propulsion technology: two F-1 engines in the first stage, burning LOX and RP-1; and a J-2 engine in the second stage, burning LOX and liquid hydrogen. The propellant tanks were sized to be built using the tooling for the Space Shuttle's External Tank.

The new concept injects a far more massive dose of Shuttle technology (see illustration on page 4). Propulsion is now provided by a Space Shuttle Main Engine (SSME) mounted below an External Tank which has been only slightly modified. And there, mounted at their accustomed place on the side of the tank, are two of the Shuttle's famous Solid Rocket Boosters.

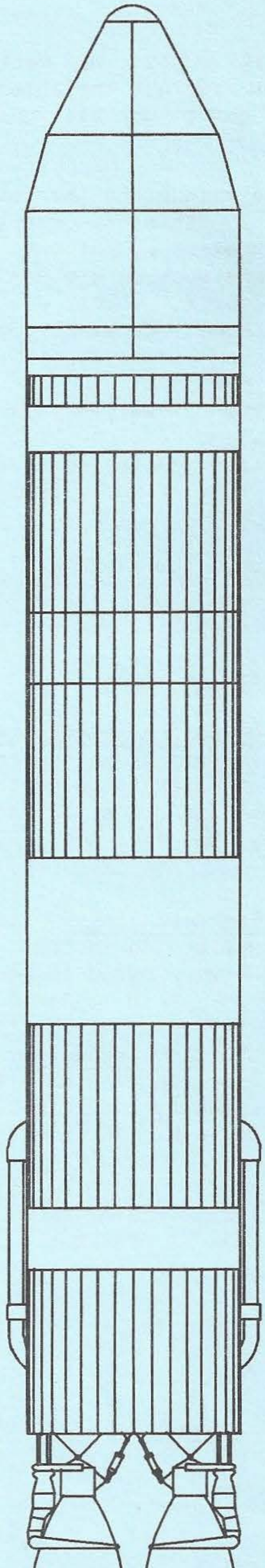
The original Jarvis design incorporated a transfer orbit stage using storable liquid fuels. The design for this upper stage, as well as the design of the payload fairing, has not undergone any major changes.

This new design provides no improvement in the Jarvis' performance. In fact, payload capacity to low earth orbit is actually slightly reduced: down to 79,800 lbs. from 85,000 lbs. The payload to geosynchronous orbit remains at 17,500 lbs.

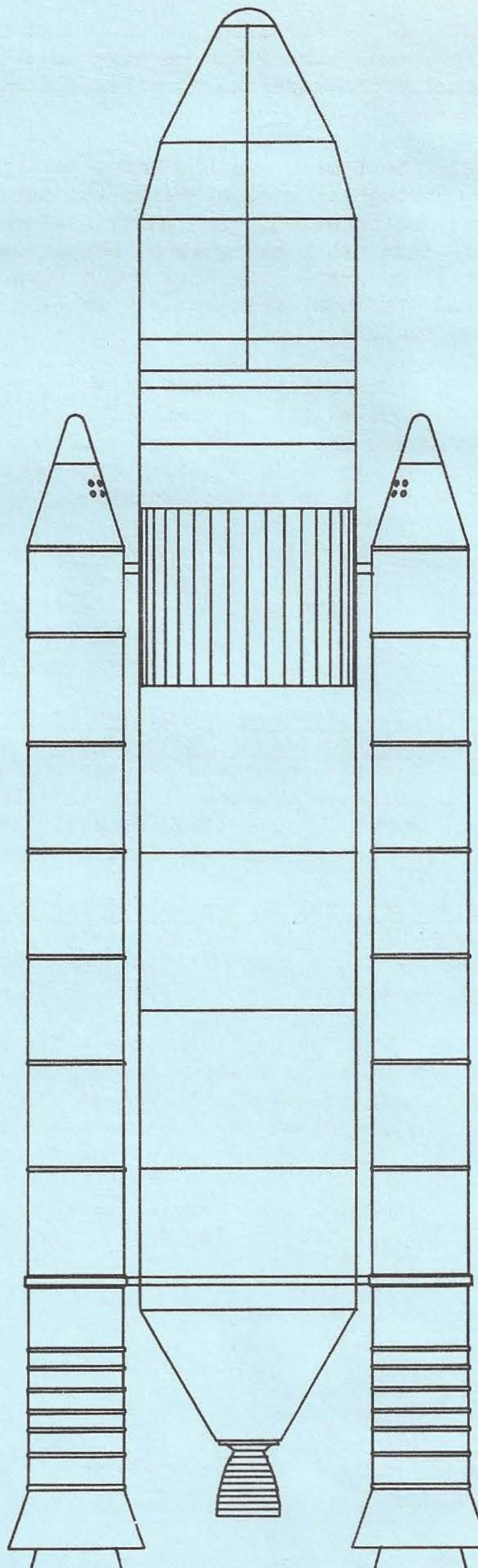
Hughes and Boeing give "lower costs" and "decreased schedule risks" as the reasons for the drastic change in design.

Unfortunately, none of their reasoning stands up to close examination.

The new design also provides no improvement in the Jarvis' costs and lead times. Estimated cost of development is still about $1 billion, while the estimated cost per flight is still about $150 million. The development time for the Jarvis



SATURN–DERIVED JARVIS



SHUTTLE–DERIVED JARVIS

was originally estimated to be about four years, and this is still the working number. Apparently the problems with the original design arose from factors that would have taken these numbers higher--enough so to warrant a major design alteration.

Hughes and Boeing claim that they ran into problems with the F-1 and J-2 engines that could have increased both costs and development time significantly.

The problem was certainly not engine reliability: Both Saturn engines have an impressive record of reliability, particularly compared with the blackened record of the Shuttle's solid and liquid propulsion systems.

The problems cited by the two companies were the costs and lead times quoted for reopening the F-1 and J-2 production lines. The Rocketdyne division of Rockwell International (which manufactured both Saturn engines) told Hughes and Boeing that the cost and lead time required to reopen the lines would be up to $300 million and 4-5 years for the F-1 alone. This is interesting, considering that another industry source was given a Rocketdyne estimate (for an unrelated project) of less than $100 million and 3-4 years. How can the discrepancy be explained?

One only needs to know that Rocketdyne is also the manufacturer of the Space Shuttle Main Engine. It seems obvious that Rocketdyne would much rather build and sell ruinously expensive SSMEs off of existing production lines instead of going to the bother of reopening old engine lines just to sell cheaper engines. Is it any wonder that they were less than cooperative, and gave Hughes and Boeing a "slightly" inflated price?

Incidentally, no mention is now being made of the F-1 and J-2 engines already built and in storage--engines that do not require reopening production lines. There are enough such engines to build three to five Jarvis vehicles in less than two years if only factory sealed engines are used. More vehicles could be built (although more lead time would be required) if engines on display or stored outdoors were renovated and used. Use of surplus engines for the startup of the Jarvis project would take a lot of the wind out of the lead time arguments for the SSME version, and the idea was certainly being considered by Hughes for the original Jarvis. Unfortunately, the contractor of choice to renovate existing engines would be Rocketdyne, and one can imagine what kind of reception this low-cost concept got in Rocketdyne's front offices.

Besides the engine problems, Hughes and Boeing have also mentioned the new Jarvis' use of existing Shuttle launch facilities for launch operations, a design feature which is also advertised as improving cost and lead time figures.

Anyone comparing the original Jarvis launch site with a typical Shuttle launch site would see this "design feature" as some kind of bizarre joke, similar to advertising concrete wings on an airplane. The original Jarvis launch site, designed to be located on a remote Pacific island, consisted of a pair of gantries, two barge-mounted propellant storage tanks, a crane and a blockhouse--all located on about 3 acres of land. Such a simple launch site could be easily constructed just about anywhere.

A typical Shuttle launch facility consists of an immense complex of buildings, tanks and structures. There are now, and there will always be, only two such launch sites: the Kennedy Space Center and Vandenberg Air Force Base. Of the two, the former will supposedly be occupied with Shuttle activities. The latter is currently doing time as the world's most expensive owl's nest. The requirement to launch from a Shuttle pad is definitely not a feature that should have inspired a change in the Jarvis design.

The root of the design change is this: Boeing has more or less taken the entire Jarvis concept away from Hughes after the latter company approached Boeing to propose a partnership. By the end of November, the "Hughes/Boeing" Jarvis has been transformed into the "Boeing/Hughes" Jarvis, a change that was reflected in press releases. Boeing's current project responsibilities include development of the core stage and booster designs, vehicle integration, and launch operations. Hughes, once the prime contractor, is now left with mission planning, payload integration, and the orbital transfer stage. With luck, perhaps Hughes will be allowed to paint the numbers on the vehicles.

It is no coincidence that the current Jarvis is now nearly identical to Boeing's earlier proposal for a Shuttle-derived Unmanned Launch Vehicle (C.S.R., July 1984, pp. 2-3). Boeing has its eye on the Strategic Defense Initiative, which is, despite talk about space stations and the like, the biggest potential market for a vehicle with an 80,000 lb. payload capacity. The company saw the MLV contract as a way to get its foot in the door with a vehicle design that until then had been languishing on the drawing boards. Boeing even magnanimously let it be known that it was willing to put up its own money to underwrite the major portion of development costs. There is only one fly in the ointment:

Soon after the announcement of the New Jarvis, the Air Force announced that the Jarvis had been eliminated from the competition for the MLV. It is not clear whether the Jarvis' design change had anything to do with the decision, but the Air Force clearly thought that the New Jarvis was too much vehicle for the MLV mission of launching Global Positioning Satellites.

Boeing is not taking this lying down. The company has announced that it will continue to support development of the Jarvis, stating that the MLV contract was "but one opportunity" for payloads. The company (oh, yes--along with Hughes) is now proceeding on a study to evaluate the market. So, it remains to be seen if Boeing will continue to see the Jarvis as an attractive investment without the added frosting of a major government contract.

Orbital Sciences Gets First NASA Contract Payment

After a long wait, Orbital Sciences Corp. (OSC) finally signed its contract to provide an upper stage for the Mars Observer probe. OSC has also received a progress payment of about $6 million on the contract which will do much to help the company keep its doors open. The actual signing of the contract, along with the payment, had been held up by large quantities of red tape and obstacles, including a protest on the contract award filed by Hughes (C.S.R. May 1986, p. 6).

Until next time,

The Commercial Space Report (C.S.R.) is published monthly, and endeavors to report and analyze developments in the field of private initiatives in space transportation and exploitation.

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