Prop M-1 Eng

Flight of M-1 Delayed Three Years

New-look Aerojet engine will have increased thrust, new cooling; more ambitious missions envisioned

by Hal Taylor

A NEW NASA development schedule will delay actual flights of Aerojet-General's M-1 engine until 1969 or later.

Other program goals call for component testing over the next 18 months; first engine test late next year; and completion of its Preliminary Flight Rating Test by a 1967 target date.

The stretchout, however, will not lower the program's total pricetag. Instead, the contract between NASA and Aerojet will be worth about $230 million, compared with the original estimate of $90 million.

Prime cause for the sharp price boost is a major design change which uprates the liquid-hydrogen engine's thrust from 1.2 million to 1.5 million lbs. Design features providing for even greater thrust and performance and a longer testing schedule also added to the cost.

• **New look**—The new program was revealed to MISSILES AND ROCKETS by A. O. Tishler, NASA's liquid propulsion chief.

"It will produce a more reliable booster," he declared, adding that the M-1 is now a far different engine from the one proposed by Aerojet in early 1962. In addition to its increased thrust, he said, the new M-1 boasts a completely new cooling system. The fuel pump also will have a increased capability through use of a two-stage turbine delivering higher flow and pressure.

Tishler said the program is now on a minimum-cost schedule, under which space agency funding will be spread out over a much longer period than was originally planned.

Currently, much of the NASA/Aerojet effort is focused on development of facilities and initiation of component testing. Tests already have begun on the gas generator. The liquid-oxygen pump will be tested in late 1963, and tests on the thrust chamber and hydrogen pump are set for early 1964.

When the program was announced in April, 1962, NASA's plans called for delivery of the first M-1 engines in 1965, with flights in 1967. Under the new schedule, delivery will not begin until about 1968, and actual flights could easily slip into the 1970's.

The decision to slow the program's pace followed selection of lunar orbit rendezvous, using the *Saturn V* booster, for Project *Apollo* missions. This permitted NASA to delay work on the *Nova* booster, for which the M-1 originally was designed.

• **Future jobs**—NASA now plans to use the M-1 as an upper-stage powerplant in post-*Saturn* launch vehicles. Contemplated missions include orbital space stations, manned interplanetary flights and deep-space flights.

The mission would require low-orbit payloads ranging from 500,000 to 2 million lbs., with launches in the 1970-1980 period—well within the M-1's development schedule.

In addition to providing for better performance and more reliability, the new M-1 program expanded the range of its potential uses.

Two Aerojet officials, Dr. J. C. Moise and D. E. Price, declared in a paper presented to a meeting of the Society of Automotive Engineers in Washington, D.C., that M-1 could be converted for use as a first-stage powerplant for future space boosters.

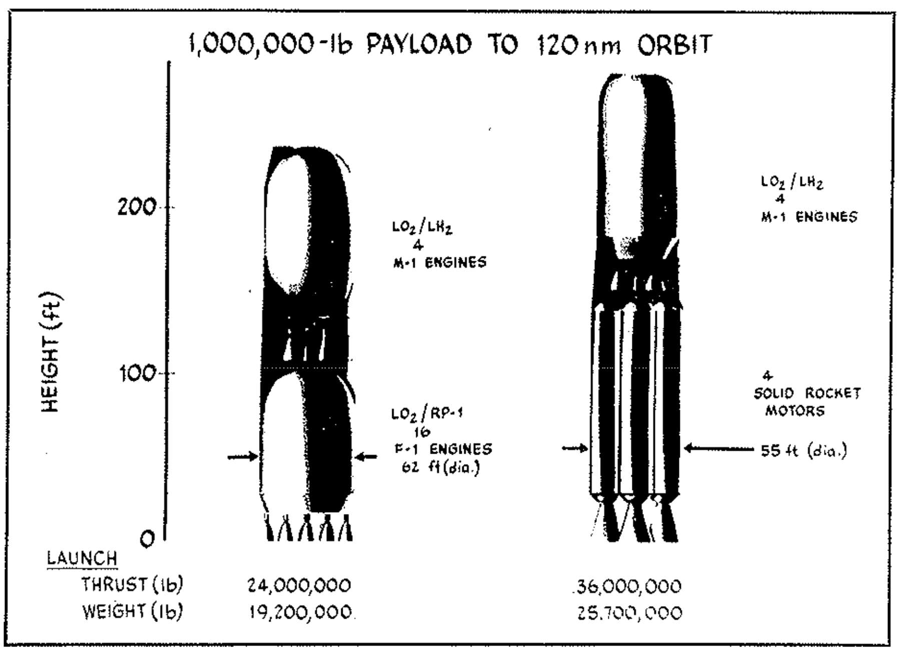
The first-stage M-1, they predicted, would develop 1.2 million lbs. of sea-level thrust, with a potentional uprating to 1.5 million lbs. of thrust. The converter engine would require a thrust chamber with a smaller nozzle expansion ratio.

The launch vehicle would have 14 M-1 engines in the first stage, and only one M-1 in the second stage. If the higher-rated engine were used, only 12 engines would be needed for the first stage.

With a maximum diameter of 73 ft., the vehicle would be able to put a 1-million-lb. payload into a 120-n.-mi. orbit. The launch vehicle would have a total thrust of 17 million lbs., weighing only 13.6 million lbs.

The major advantages of such a vehicle, the Aerojet officials said, are the single-engine second stage; low sea-level thrust; use of the same propellant in all stages; and low liftoff weight.

The main use of the M-1 continues to be as a second-stage powerplant, pro-



BOOSTER CANDIDATES for U.S. space missions during post-Saturn period.

radiographic and hydrotest procedures used in solid rocket production, as well as high-strength steels and other special metals involved in case fabrication.

Both Aerojet's Dade County facility and the Thiokol site in Camden, Ga., are on waterways and cover considerable acreage—Aerojet's is 75,000 acres and Thiokol's 50,000 acres.

Lockheed expects to use a 9100-acre site at Potrero, near its Redlands, Calif., headquarters, for the Phase 4 work under Program 623A.

• **Facility squeeze**—The prospect that all large solid rocket work will be done in company-owned facilities has put the squeeze on propulsion companies to develop their own facilities—with more than the usual risk.

This development—caused by lack of funding for any government-financed plants—puts industry in the position of building required facilities as a prerequisite to bidding on the contract, with no guarantee of getting the award (M/R, Dec. 24, p. 19). The Air Force wants maximum use to be made of existing facilities such as propellant plants, personnel and hardware.

Those firms having maximum transportability built into the fabrication site, such as those on waterways or the ocean, will be ahead of the game throughout the development period of large solid rockets, unless a drastic solution is found to the transportability problem (M/R, Mar. 4, p. 16). This will be particularly true during the later phases of the program, involving the full-scale 260-in. motors.

• **AF is coy**—Despite the obvious import of the program, the Air Force has refused to describe it as a new breed of booster, and shies away from the term *Nova*. It says the program is to demonstrate the feasibility of huge solid rockets. Simultaneously, the Air Force will benefit from the *Titan III* effort.

Technical progress realized during the program probably will determine how many future full-scale 260-in. firings will be carried out before feasibility is considered fully demonstrated and further work is contracted for. AF and NASA officials have said the potential now exists for design and fabrication of 300-to-325-in.-dia. motors.

• **Management**—The large solid rocket program grew out of the November, 1962, DOD/NASA agreement on large space boosters. Program direction will be handled by the Air Force Systems Command's Space Systems Division, Inglewood, Calif., and NASA requirements will be cranked into the management aspects. NASA's needs to date have been generalized, but they nominally call for a unit of six to seven million lbs. thrust and a final vehicle made up of a cluster of four motors.

Subcontracting in the program may be handled largely by the main contractors, but the Air Force probably will break out major portions for separate contracting. If this pattern is followed, it will parallel the method used in the 100-in.-dia. program during the past 18 months.

• **Impact**—Aerojet-General, somewhat disappointed over its assigned role in the program, is determined to prove that large solid rockets have a definite role in the nation's space program. The company's program manager says engineering work will be done in Sacramento, heavy fabrication will be subcontracted, and the completed chamber will be barged to Dade County for propellant loading, final assembly and test firing.

"We haven't waited idly for these contract awards," he said, "We spent our own funds to build a rocket chamber 280 inches in diameter to prove the shipbuilding industry can fabricate these giant chambers to the precise tolerances of the Space Age. This same chamber, now at Sun Shipyard in Chester, Pa., will be shipped by barge to Florida to prove our transportation theories. I figure we're six months ahead of schedule because of this investment."

He said all construction necessary for commencing the just-contracted work on the big solid rockets will be finished by November, while all work the company now plans for the Dade County site will be finished by May, 1964. The new plant site will represent a $10-million investment and will employ 250 people within the next year. Of these, 25 will be transferred from Sacramento and the remainder hired locally. The contract award will have no significant effect on the Sacramento employment.

Similarly, Thiokol expects to have a $10.5-million investment in its plant, will have most of its work complete by next spring, and will have 450 employes within a year. Thiokol is expected to become one of Georgia's largest industrial employers. The exact location of the site, more fitting for its Utah operations, is Horse Pen Bluff.

Lockheed's Potrero facility, one of three company locations near Redlands, is equipped with a 2-million-lb.-thrust test stand, a non-destructive test facility, a conditioning oven complex, and supporting personnel and instrumentation bunkers.

LPC is planning construction of a 300-gallon vertical propellant mixer and other facilities for the 156-in.-dia. motor work.

The 600-employee company, located 65 miles east of Los Angeles, is a wholly owned subsidiary of Lockheed Aircraft Corp. Its previous large booster work includes last year's firing of a segmented 120-in.-dia. solid rocket, 34 ft. long, which developed 400,000 lbs. of thrust during its 130-sec. burning time. ■

Titan II Expected to Overcome 'Pogo-Stick' Trouble

VIBRATION PROBLEMS causing a pogo-stick effect during flight of the *Titan II* booster are expected to be solved through continuing effort in the development program.

It will be "well within tolerable limits" by the time *Gemini* flights are scheduled to use the vehicle, a program spokesman told M/R.

"The problem is not so bad as it looks," the spokesman said, "but the fix is always harder than the diagnosis." He explained that the booster's natural frequency is 11 cps, which offers no problem until the lower portion of the bird "decides to sing harmony." The "harmony" then causes elastic motion along the longitudinal axis.

The anticipated fix of the problem includes increasing pressure within the propellant tanks, thus damping out the vibrations. Every large booster has the same problem, the source said, and various fixes have been used. The *Titan II* propellant tankage is now pressurized far below its maximum capability, and boosting it a few psi is expected to achieve the desired effect.

"If we had our choice, this is the kind of problem we'd prefer to have, rather than some major catastrophe like structural weaknesses," the *Titan II* spokesman claimed.

The problem stems from a combination of factors, including pump vibration, pressure in the propellant system, and flow rates, as well as the volume of fluids within the tanks. Engine combustion instability has been ruled out as a cause. The overall combination of factors thus introduces the resonance problems.

The *Titan II*, which normally "flies like a javelin," eventually develops a slack/taut movement about one minute after liftoff. This condition continues for 10 to 20 seconds, but not at the point of maximum aerodynamic stress.

viding more than 45% more payload capability than upper stages powered by conventional liquid-oxygen/kerosene stages.

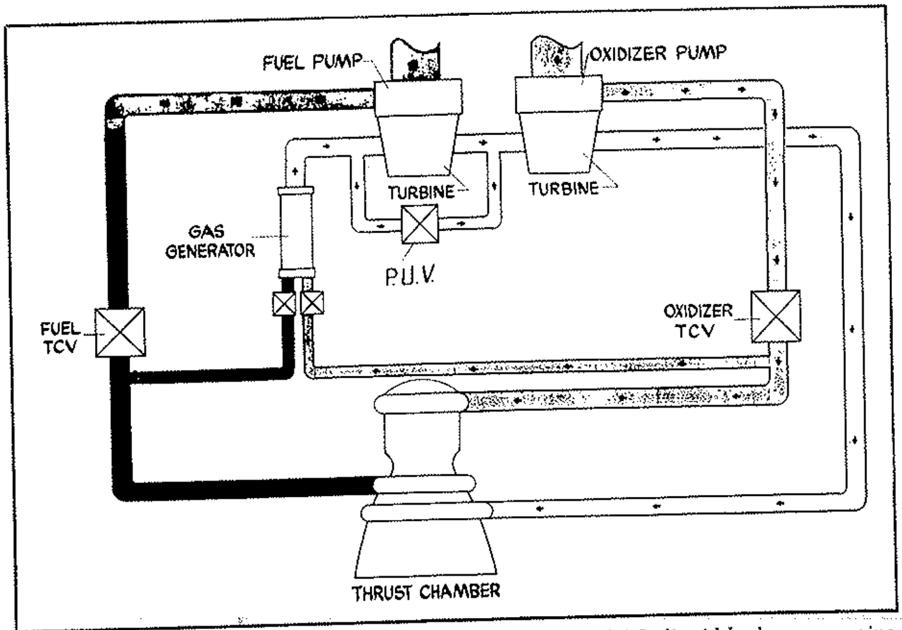
A four-M-1-engine second stage, coupled with a first stage powered either by 16 F-1 liquid-oxygen/kerosene engines or four solid-fuel motors, would again be able to place a million-lb. payload into a 120-mile orbit. The escape payload for lunar or planetary flights would be 400,000 lbs.

● **Operation**—The Moise-Price paper also provides the first details of the engine's design and operating characteristics.

Propellants are supplied to the thrust chamber by separate fuel and oxidizer turbopump assemblies. The fuel pump is a multi-stage axial flow pump and the oxidizer pump a single-stage centrifugal pump. Both pumps are mounted on the regeneratively cooled thrust chamber and each pump is driven by its own gas turbine.

A fuel-rich fluid-hydrogen/liquid-oxygen gas generator supplies the turbine drive gases in series: first to the fuel pump turbine; then to the oxidizer pump turbine. More than 100,000 shaft hp is delivered by the turbopump assemblies. The liquid-hydrogen pump is said to have about three times as much shaft horsepower as any other liquid rocket engine turbopump under development.

In addition to providing turbine power, the gases are utilized for two other purposes: to cool the thrust chamber nozzle skirt, and to provide additional thrust as it is exhausted through small nozzles at the main nozzle exit plane. The regenerative coolant tubes extend along the DeLaval-contoured nozzle to the point at which the nozzle is cooled by turbine exhaust gases. The engine is gimbaled to provide thrust-vector-control capability.



SCHEMATIC SHOWS fluid flow of Aerojet-General's M-1 liquid-hydrogen engine.

The engine-starting sequence is initiated electrically. At the start signal, the thrust-chamber and the gas-generator spark igniters are energized. High-pressure helium opens the main propellant thrust chamber valves. As the turbines accelerate, the pumps supply fuel and oxidizer to the gas generator and the thrust chamber. Propellants entering the thrust chamber are ignited by the previously energized ignition system. Gas generator exhaust gases accelerate the turbines to their steady-state operating condition. More than 1½ tons of propellant per second are consumed during this steady-state operation. Engine shutdown is effected by venting the gas generator valve and the thrust chamber valve actuators. This allows valve spring forces to close the propellant valves to both units, shutting off the flow of propellants and terminating engine operation. ■