# SATURN

DESIGNATION — Saturn 1; Uprated Saturn (1B); Saturn 5

NASA PROGRAM — Research and Development, Space Science and Applications

EXECUTIVE — Marshall Space Flight Center, Huntsville, Ala.

PRIME — See SATURN CONTRACTORS report for major prime and subcontractors.

STATUS — Saturn 1 program completed; Uprated Saturn 1 (formerly Saturn 1B in mid-production); Saturn 5 is operational

MISSION — Standard launch vehicle for NASA's heaviest payloads with major emphasis on Project Apollo

TYPE — Liquid-fueled space booster

FUNDING

| ($ millions) | | FY69 | FY68 | FY67 | FY61-FY66 |
|---|---|---|---|---|---|
| RDT&E | $ | 8,87.0 | 1,164.2 | 1,373.58 | 4,900.0 |

(See FORECAST for future requirements)

A review of Saturn funding including FY69 requests, plus a breakdown of appropriations for engine development follows:

SATURN 1 totals ( including S-1 stage, S-4 stage, instrument unit, ground support, H-1 procurement, RL-10 procurement and support)

| ($ millions) | | FY69 | FY68 | FY67 | FY61-FY66 |
|---|---|---|---|---|---|
| Funding | $ | 0 | 0 | 0 | 780.3 |

UPRATED SATURN 1 (formerly 1B)

| ($ millions) | FY69 | FY68 | FY67 | FY61-FY66 |
|---|---|---|---|---|
| S-1B stage | $20.0 | 30.5 | 56.2 | 187.0 |
| S-4B stage | $12.5 | 37.1 | 52.6 | 152.9 |
| Instrument unit | $11.0 | 22.6 | 36.1 | 88.7 |
| Ground support | $ 4.9 | 6.5 | 7.4 | 88.8 |
| H-1 procurement | $ 2.0 | 5.2 | 4.0 | 27.6 |
| J-2 procurement | $ 0.4 | 0.9 | 7.7 | 32.5 |
| Vehicle support | $18.3 | 53.4 | 52.4 | 105.3 |
| Totals | $69.1 | 156.2 | 216.4 | 682.7 |

SATURN 5

| ($ millions) | FY69 | FY68 | FY67 | FY64-FY66 |
|---|---|---|---|---|
| S-1C stage | $137.6 | 174.7 | 215.6 | 727.4 |
| S-2 stage | $174.0 | 245.9 | 257.7 | 611.2 |
| S-4B stage | $117.1 | 151.2 | 160.4 | 428.8 |

| ($ millions) | FY69 | FY68 | FY67 | FY64-FY66 |
|---|---|---|---|---|
| Instrument unit | $ 67.6 | 75.1 | 73.6 | 201.9 |
| Ground support | $ 29.3 | 35.8 | 73.8 | 184.0 |
| F-1 procurement | $ 42.7 | 105.3 | 85.8 | 176.5 |
| J-2 procurement | $ 41.9 | 78.5 | 75.2 | 109.7 |
| Vehicle support | $208.0 | 242.0 | 248.9 | 414.5 |
| Totals | $818.2 | 1,108.5* | 1,191.0 | 2,688.4 |

ENGINE DEVELOPMENT

| ($ millions) | FY69 | FY68 | FY67 | FY64-FY66 |
|---|---|---|---|---|
| H-1 engine** | $ 0 | -- | 5.5 | 42.4 |
| RL-10 engine*** | $ -- | -- | -- | 78.4 |
| F-1 engine | $ -- | -- | 41.0 | 303.0 |
| J-2 engine | $ -- | -- | 37.9 | 221.2 |
| Propellants and related engine support | $ -- | -- | 26.6 | 139.7 |
| Totals | $ -- | 24.5 | 111.0 | 784.7 |

*The total Saturn 5 and Uprated Saturn 1 FY68 funding was cut from $1,289.2 million listed in the table to $1,164.2 million but specific details by item of where the cuts were made are not available except that engine development went from the requested $24.5 million to $18.7 million for FY68.

**H-1 engine production halted in August due to budget cuts.
***Initially, the Saturn 1 consisted of six RL-10 engines which were later replaced by a single 205,000 lb thrust J-2 engine produced by Rocketdyne.

| DESCRIPTION | Height (ft) | Diam (ft) | Engine No/Type | Thrust (M lbs) |
|---|---|---|---|---|
| SATURN 1 | | | | |
| S-1 booster | 80.2 | 21.4 | 8/H-1 | 1,500 |
| S-1VB 2nd stage | 41.4 | 18.3 | 6/RL-10 | .90 |
| Instrument unit | 4.8 | 12.8 | -- | -- |
| UPRATED SATURN 1 | | | | |
| S-1B booster | 80.2 | 21.7 | 8/H-1 | 1,600 |
| S-1VB 2nd stage | 58.4 | 21.7 | 1/J-2 | .200 |
| Instrument unit | 3.0 | 21.7 | -- | -- |
| SATURN 5 | | | | |
| S-1C booster | 138.0 | 33.0 | 5/F-1 | 7,500 |
| S-11 2nd stage | 81.0 | 33.0 | 5/J-2 | 1,000 |
| S-1VB 3rd stage | 58.4 | 21.7 | 1/J-2 | .200 |
| Instrument unit | 3.0 | 21.7 | -- | -- |

(Earlier configurations called Saturn C-2, C-3, and C-4, were all cancelled and replaced by Saturn 5. Uprated Saturn 1 was called Saturn 1B throughout its pre-flight development.

TIMETABLE

| | |
|---|---|
| ARPA program approved: | 1957 |
| Transferred to NASA: | 1959 |
| Saturn 1 development began: | 1961 |
| Saturn 1 development complete: | 1965 |
| Uprated Saturn 1 flight test began: | 1966 |
| First unmanned Saturn 5 mission: | 1967 |
| First manned Uprated Saturn 1 mission: | 1968 |
| Last Uprated Saturn 1 mission: | 1968* |
| First manned Saturn 5 mission: | 1968 |
| First manned circumlunar Saturn 5 mission: | 1968 |
| Lunar landing Attempt: | 1969-70 |
| Program to end: | 1970* |
| Follow-on system: | Apollo Applications* |

(*Current development schedule. For post-1970 projections, see COMMENT and FORECAST)

QUANTITY

Ten-vehicle Saturn 1 project complete; 12 Uprated Saturn 1 and 15 Saturn 5 launch vehicles ordered; three launches using Uprated Saturn 1 vehicles were made in 1966 and two in 1968; six of the remaining seven Uprated Saturn 1 launch vehicles had been tentatively scheduled for use in 1969 but will not be needed--although they are in hand--due to the success of Apollo 7; the first Saturn 5, AS-501, an unmanned earth-orbital test of Command and Service Modules, Spacecraft Lunar Module Adapter and Lunar Module Test Article (Block 1) was successfully launched November 9, 1967; the latter mission, Apollo 4, was followed on April 4, 1968 by an unsuccessful Saturn 5 flight, Apollo 6, in which two second stage engines cut out and the third stage engine refused to start; one other Saturn 5 flight is scheduled for December 1968, five more in 1969 at 10-week intervals with one backup launch vehicle and a schedule of two launches a year over the following three years.

GENERAL

The Saturn program has evolved during the past eleven years to the point where today it ranks as the most important vehicle in the immediate future of U.S. space exploration. The program was originated in 1957 under the technical direction of ARPA to investigate the possibility of achieving high thrust by clustering existing rocket engines. NASA took over Saturn in 1959 and assigned to it the mission of boosting a manned Apollo spacecraft to a lunar landing in 1970.

## SATURN 1

Saturn 1 completed a remarkable 10-for-10 success record with the launch of SA-10 in July 1965. From the program's official beginning in January 1960 evolved the first four tests (Block 1). Consisting of live first stages and dummy second stages, the Block 1 tests proved the feasibility of the clustered-engine concept. The

first flight with a live upper stage, on Jan. 27, 1964, placed 37,700 lbs in low earth orbit. Subsequent flights, SA-6 through SA-10, proved the orbital capacity of the configuration, with the last three flights used also to launch the Pegasus micrometeoroid detection satellite.

Housed in the boilerplate Apollo service module during launch, the 3400 pound Pegasus remained attached to the S-1V upper stage after the module was released. Two large wings, each 15 feet wide and with a 100-foot span, covered with thin sheets of aluminum and separated by Mylar, were deployed. Meteoroids which impact against the metal skin generate electrical pulses which are stored for transmission on command. Results of the data gathered by the Fairchild Hiller-built spacecraft have tended to indicate that meteoroids will not be unduly hazardous to manned spacecraft orbiting Earth for short periods. With the Saturn 1 program complete, attention is focused on Uprated Saturn 1 as the major launch vehicle for testing and proving the Apollo spacecraft prior to a lunar landing attempt with the Saturn 5.

## UPRATED SATURN 1

The Uprated Saturn 1 program, formerly designated Saturn 1B, is nearing completion with the exception of two flights in 1970 for the Apollo Applications program in connection with the Saturn 1 workshop which uses the empty hydrogen tank of the spent second S-4B stage after the stage is used as a launch vehicle to set up an orbital workshop. The mission requires the launch to two Uprated Saturn 1 launch vehicles. Long lead time items for these two launch vehicles are being ordered but no further orders for the Uprated Saturn 1 are imminent. The Uprated Saturn 1 initially had been programmed for Voyager, but increased payload requirements impelled NASA to transfer that mission then to Saturn 5.

The Uprated Saturn 1 program consisted of 12 flight vehicles. Three were flown in 1966 and two in 1968. Six of the remaining seven were tentatively scheduled for use in 1969 in case the Apollo program faltered during the transition to the Saturn 5.

The tasks set for the Uprated Saturn 1 initially were to include testing of the IBM Instrument Unit and the S-4B second stage, which also are part of the Saturn 5 launch vehicle, and of testing Block 1 and 2 Apollo Command and Service Modules, Lunar Modules and many other major subsystems in manned and unmanned flights that are necessary for man-rating systems for the eventual lunar landing mission in 1969.

The Chrysler-built first stage (S-1B) is a modified version of the first stage of Saturn 1. Eight uprated H-1 engines, built by Rocketdyne, power the first stage with 1.64 million pounds of

thrust. The second stage (S-4B), built by McDonnell Douglas, is similar to the S-4 stage of Saturn 1. However, Saturn 1's cluster of six RL-10 engines has been replaced with a single 205,000 pound-thrust J-2 engine produced by Rocketdyne.

Development of the first Uprated Saturn was started in FY63. Battleship testing of the second stage began a year later. The first launch, (AS-201) on February 26, 1966, was a ballistic "lob" flight to test the Apollo heat shield. Following this successful launch, AS-203 was flown on July 5, 1966. This flight did not carry an Apollo craft, but was designed to prove liquid propellant handling techniques in the second stage. The test succeeded, and the stage was allowed to destroy itself two days after launch. Uprated Saturn scored its third straight success on August 25 when AS-202 accomplished the second re-entry test of the Apollo heat shield.

NASA had intended to launch AS-204, the first manned Saturn mission in January 1967. As the initial result of the January 1967 Apollo fire that killed three astronauts, the spacecraft designs, materials and test procedures were comprehensively reevaluated. Changes were defined and their implementation continued throughout the year. A revised Apollo launch schedule was established in November 1967. The new schedule provided for two more Uprated Saturn 1 and three more Saturn 5 flights in 1968. First of the two Saturn 1s was successfully flown January 22, 1968. It was flown to demonstrate the capability of major Lunar Module subsystems such as: verifying the operation of the descent and ascent propulsion systems including engine restart; evaluating LM staging and determining structural worthiness. The second Uprated Saturn 1, Apollo 7, boosted three astronauts into earth orbit for 11 days to successfully check out and test the Block 2 Command and Service Modules during the first manned Apollo flight from October 11-22, 1968.

## SATURN 5

Saturn 5, the most powerful launch vehicle developed by the U.S., was successfully launched November 9, 1967, for the first time. The unmanned mission used Block 1 (earth-orbit) Apollo Command and Service Modules, a Lunar Module Adapter and Test Article. The flight, designated Apollo 4, lifted a 278,699 pound payload into earth orbit. The current Saturn 5 can lift a 285,000 pound payload into a 105 naut. mi. earth orbit. The second Saturn 5 launch, designated SA-502, was unsuccessful. Shortly after its launch April 4, 1968 the second stage cut out and the third stage engine refused to restart. Later investigations showed that longitudinal oscillations, the pogo effect, resulted in the spacecraft exceeding design limits.

Saturn 5 consists of three stages. The first, S-1C, is a cluster of

five Rocketdyne F-1 engines which together develop 7.57 million pounds of thrust. Directing S-1C construction is Marshall Space Flight Center. Boeing, the prime, is in turn directing more than 2200 subcontractors. The work is divided into ground and flight test stages. The first two ground stages and first two flight stages were built at Marshall, while Boeing was building other ground stages at Michoud. Initial captive fire testing was accomplished in April and June 1965, and on August 5 of that year the entire S-1C-T was fired for the required 2.5 second burn. Boeing delivered the first ground test stage early in 1966 from Michoud. At about the same time, the first flight test stage was checked out at Marshall and delivered to Cape Kennedy.

Development of the second stage (S-2), built by North American Rockwell, was set back on May 28, 1966, when the cluster of five J-2 engines exploded. The initial test, in August 1965, had accomplished a 6.5 minute burn. NASA completed the program with the S-2-1 stage which was fired in August 1966. Rocketdyne, the J-2 developer, received an order in November 1965 for enough engines, 48, to complete the 102-engine Uprated Saturn 1 and Saturn 5 programs.

The total J-2 contract exceeds $600 million through FY69 if engine development funding costs are included. Meanwhile, Rocketdyne was uprating the J-2 engine from a thrust range of 200,000-175,000 pounds to the present 225,000-205,000 pounds thrust. Early in 1966, Rocketdyne received $7.5 million for modification of its H-1 engine program to supply 22 more engines to complete Uprated Saturn 1 engine procurement. Production of the H-1 engine was halted in August due to budget cuts. Total H-1 contract value through FY69 is $38.8 million with an additional $47.9 million for engine development during the life of the program. Of the 60 engines being produced, Rocketdyne has delivered 32 engines to NASA's Marshall Space Flight Center. Of the remaining 28 engines to be delivered, one will be complete, one will be complete without firing, six will be assembled and the hardware for the other 20 will be delivered in the present production state. The 205,000 pound thrust H-1 engine is used in the booster stage of the Uprated Saturn 1 launch vehicle. This purchase of H-1 engines was originally intended for use in post-Apollo missions planned under Apollo Applications (see Report).

The remaining components of Saturn 5, with the S-1C and S-2 stages, are the S-4 stage and the IBM-built Instrument Unit. Both underwent tests in the Uprated Saturn program. NASA then successfully completed tests with the Saturn 5 5500F facilities checkout vehicle at Cape Kennedy and the agency proceeded with initial assembly of AS-501, which was successfully flown November 9, 1967. NASA announced in late October 1966 that it

would award a $37 million-plus-fixed-fee contract to North American Rockwell for launch preparation and checkout of 10 second (S-1C) stages of Saturn 5. The contract supplemented NAR's development pact. Another late-October 1966 award provided a $4.5 million modification for design and procurement of first (S-1C) stages. The agreement increased Boeing's contract value to more than $855 million overall.

In September 1968 Boeing got three Saturn 5 research and development contracts for modifications totaling $4,652,364. One contract totaling $1,100,443 is for installation of more than 4,000 instrumentation and data acquisition items in a special second stage structural test verification program. The work relates to ground tests to confirm the design of a lighter weight, but more powerful second stage that will fly as part of the fourth Apollo/Saturn 5 and subsequent vehicles.

In the second modification, Marshall Space Flight Center, the awarding agency, asked Boeing to perform abort and alternate mission analyses for Apollo/Saturn vehicles 503 and 510. Under the $2,237,268 contract, Boeing will study mission objectives and propose various alternate missions that may be taken by each flight based on various failures that could develop during the powered flight phase. This would be in order to obtain at least a partial mission success despite certain failures that could occur.

In the third proposal, Boeing is being asked to perform a reliability, quality and component qualification program, special pre-launch analyses, telemetry systems and a Saturn 5 Apollo operations system safety program. The contract totals $1,314,653. Cumulative value of the Boeing Saturn 5 Systems Engineering and Integration contract is now $213,443,238.

The success of AS-205, Apollo 7, in its 11-day, earth-orbital mission on October 11-22, 1968, with Block 2 Command and Service Modules and a three-man crew, served to increase NASA confidence in attaining the lunar landing goal by 1970. The Apollo 7, however, did not use the complete Saturn 5 three-stage launch vehicle. Utilization of the full Saturn 5 configuration in a manned mission is tentatively scheduled for December 1968. The mission will be either another earth-orbital mission or a manned flight around the moon-a circumlunar mission. The latter is designated A/S 503 or in current NASA terminology, Mission D. Initial schedule for a circumlunar flight was two launches later or Mission F with a lunar landing being Mission G.

## INTERMEDIATE SATURN

NASA is currently looking into a launch vehicle that would have a payload capability intermediate between the Uprated Saturn 1 and the Saturn 5. The Intermediate Saturn is also called Saturn Jr.

NASA identities two possible Intermediate Saturn as Intermediate 20 and 21. First of the two-stage launch vehicles would have a S-1C first stage and the S-4B upper stage to place 135,000 pounds of payload into earth orbit. The Intermediate 21 would use the S-1C first stage and North American Rockwell S-2 stage of the Saturn 5 to put 250,000 pounds into earth orbit. Both Boeing and McDonnell Douglas Corp. have proposed launch vehicles which would bridge the Saturn 5-Uprated Saturn 1 gap. McDonnell Douglas Corp. is proposing a two-stage vehicle with the S-4B as second stage. The McDonnell Douglas Corp. launch vehicle , designated MLV-SAT-1B-27 would use a cluster of four 156-in diameter solid motors to produce a total lift-off thrust of 7,280,000 pounds. This would enable the vehicle to put 108,300 pounds into a 105-naut. mi. orbit. The MLV-SAT-1B-27 would be about 265 ft. long, with a lift-off weight of 5,248,762 lb. The S-4B second stage would require some structural modifications to adapt it to the proposed new first stage. Each of the four 156-in. in diameter motors in the first stage would consist of three center segments and contain 1.118 million pounds of propellant. The Lockheed-designed solid propellant motors under subcontract to McDonnell Douglas would use polycarbutene-N propellant and a 18 pc. nickel maraging steel as case material. A flexible-seal, movable nozzle system developed by Lockheed would provide vehicle pitch, yaw and roll control. The flexible seal or bearing, located between the nozzle and motor case, consists of alternate layers of low modulus rubber and concentric steel reinforcements vulcanized into a single unit. Two hydraulic actuators similar to those used on the F-1 engine are mounted 90 degrees apart on each motor and can deflect each nozzle up to 5.5 degrees. Mission performance for the McDonnell Douglas-proposed launch vehicle could be reduced to about 66,800 pounds of payload into a 105 nautical mile orbit by using two solid motors instead of four. Alternatives to increase the proposed launch vehicle payload are: adding 156 in. in diameter motors to the first stage; increasing propellant tank capacity for the S-4B second stage; by using a higher-thrust second stage motor such as the Rocketdyne J-2S or by adding a third stage to the launch vehicle. Suggested third stages include: the Apollo service module, the Centaur and the Centaur plus a kick stage. The latter third stages would increase the 22,200 pound payload of the basic launch vehicle for a lunar flyby to 24,800 , 36,700 or 40,600 pounds, respectively. In the case of a Jupiter-Mercury mission, the proposed three upper stages provide a payload capability that did not exist in the basic vehicle.

Purpose behind an intermediate Saturn besides filling a payload capability void is also cost savings associated with hardware already developed. There is some thinking opposed to the latter

contention. Adherents to this contending view hold that taking a different design approach such as the one proposed by McDonnell Douglas might entail higher development costs but lower production costs. Before the end of the year NASA's Marshall Space Flight Center is expected to award a study contract for further definition of an Intermediate 20 launch vehicle as further evidence of continuing interest in the program.

Contracting activities relating to the two-stage Intermediate Saturn include a $250,000 contract award to Boeing from NASA's Marshall Space Flight Center in October for a 10-month study of a two-stage Saturn derivative launch vehicle using a S-1C booster with an S-4B upper stage. Boeing also got an eight-month $95,850 contract from NASA Kennedy for study of the Saturn Jr. or Intermediate 20 launch vehicle.

COMMENT

NASA points out that the Saturn program involves more than 100,000 persons representing 12,500 companies in 47 states. More than $17 billion already has been poured into the Saturn/Apollo program, with a lunar landing still six months to a year away at the least, barring any more technical problems. Within this huge space effort, with its thicket of opportunities for error and slippage, such as occurred after the Apollo 204 fire that killed three astronauts, Apollo/Saturn has made remarkable headway. While meeting most of its deadlines for the lunar effort, NASA is pressing ahead for development of a launch vehicle which would fill the payload capability gap that exists between the Uprated Saturn 1 and Saturn 5 because the enormous cost of these launch vehicles and their unsuitability for most Apollo Applications and advanced manned missions envisaged for the future. Only two Uprated Saturn 1 spacecraft are being procured for two flights in 1970 for the Apollo Applications program where the launch vehicle's spent S-4B second stage is to be used as an orbital workshop. A series of studies is being conducted in NASA of the configuration and utilization of a Saturn 5 orbital workshop. The workshop would be a natural progression from the Uprated Saturn 1 workshop. However, the severe budget cuts in which Apollo Applications suffered a cut from a requested $439.6 million to $150 million will undoubtedly cloud post-Apollo development of an intermediate Saturn. Saturn will face severe competition from follow-on Titan 3 (see Report) programs. A Titan 3G under development by Martin with a 15 ft. in diameter liquid core and equipped with 156 in. in diameter solid strap-on motors could have a 80,000 pound payload capability for earth orbit. For missions with under 100,000 pound payloads, Titan 3 variants fulfill the need. However, for payloads substantially greater than 100,000 pounds in earth-orbit an Intermediate Saturn alone at this time can fulfill the booster needed. Without definition of or approval of advanced manned missions for the mid-1970s

further Saturn launch vehicle development will remain on a study contract low-key level until NASA-DOD arrive at some requirements which will enable them to carry on some kind of joint development program. Chances are that DOD requirements will prevail.

**FORECAST** **With no mission requirements having been approved for the forseeable future no forecast is possible. Production lines for all Saturn stages appears nearing an end with the halting of the H-1 production line in August.**