DEVELOPMENT OF THE SATURN SPACE VEHICLE

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The Saturn launch vehicle program has become a major element in our national space effort within little more than 3 years. At the beginning of the program, in 1958, various Saturn configurations were planned to lift instrumented payloads of 20,000 to 40,000 lb into Earth orbit. As research and development progressed, it became apparent that the vehicle design approach had far more potential than anticipated - that it was, in fact, a breakthrough into a new class of heavy launch vehicles.

Thus, within the space of a few years, it was possible to consider even more advanced missions. In addition to placing multiton payloads in orbit, we can seriously conceive sending over 90,000 lb of instruments on escape missions, using advanced Saturn-class vehicles. With these vehicles, we plan to accomplish lunar reconnaissance and manned lunar landings scheduled for the latter part of this decade. Likewise, these vehicles will permit flight tests of advanced nuclear power plants and stages.

The increased performance of these advanced launch vehicles is a direct result of the first (C-1) Saturn development program. The advanced vehicles are to be considerably larger than the present Saturn while not requiring designs or concepts greatly beyond the present state of the art. Basically, they are extensions of the present program, the summation of research and development activities, and long range planning making up the C-1 program.

To understand present trends in vehicle development, we must turn to the C-1 development program. In this paper we will review some of the major decisions and activities made during the C-1 development. These link together, step by step, from the concept of a multistage carrier vehicle to vehicles that will support advanced missions in space.

During 1957, the Department of Defense considered certain advanced missions using space devices for communication. Clear need was also seen for other scientific payloads, including weather satellites and heavily instrumented space probes. The weight of these satellites, however, virtually precluded the use of available military missiles. To orbit 20,000 to 40,000 lb of payload or to escape with 6000 to 12,000 lb required a booster stage generating about 1,500,000 lb of thrust.

A heavy payload capability was urgently needed. In consequence, development of a high-thrust booster with associated equipment had to be accomplished within an exceedingly short time. Moreover, the development had to be performed within strict budgetary limitations.

In terms of design simplicity, a booster stage using a single engine was preferable. In 1957, no such engine existed, although feasibility studies of a rocket engine producing about 1,000,000 lb of thrust were being performed under an Air Force program. Full-scale tests of this engine were still 2 years away, a delay too long for the accelerated booster program.

For this reason, our designers considered several clustered booster concepts, securing the required thrust by grouping a number of engines and off-the-shelf tankage into a single stage. One of these early concepts proposed clustering four Rocketdyne E-1 engines, each providing 360,000 lb of thrust. The E-1 was still early in development; however much time and cost were required to make it operational. The proposal was dropped for these reasons, and preliminary design work continued on other concepts.

What would become the Saturn program was formally initiated on August 15, 1958. On that date, the Advanced Research Projects Agency (ARPA) of the Department of Defense authorized development of a 1,500,000 lb thrust booster using a cluster of available rocket engines. The design of the Thor/Jupiter S-3D engine was selected for this application. Besides being flight tested and of proven reliability, the design was straightforward and adaptable to the booster at relatively low cost.

On September 11, 1958, Rocketdyne was selected to modify the S-3D engine design. Engine packaging was improved and the lubrication system was simplified. Engine starting was simplified to use a solid propellant drive turbine spinner and hypergolic ignition. The turbopump, mounted on the swivel-suspended combustion chamber, was deflected along with the chamber, so that the flex lines carried only the low-intake pressure of the pumps. Using LOX and RP-1 propellants, the engine would initially produce 165,000 lb of thrust; additional development would give up to 188,000 lb of thrust. Eight of these H-1 engines were clustered to produce the total thrust needed.

Engine redesign had just begun when, in October 1958, the ARPA program objectives were expanded. The booster to be developed would serve as the first stage of a multistage carrier vehicle, capable of performing advanced space missions. Four flight vehicles were authorized. A static firing test to demonstrate the feasibility of the clustering concept was scheduled by the end of 1959, with the first flight test planned for late in 1960.

The final two flight vehicles would use unsophisticated upper stages to provide a payload capability as rapidly as possible. While design of the booster continued, parallel studies were carried out to define the upper stages and identify staging problems. Concurrently with this activity, work began in December 1958 to determine design requirements of the launch facility and the required static test facilities.

A series of studies indicated that already proven IRBM and ICBM components could be adapted for use as upper stages of the new vehicle. These off-the-shelf components would permit rapid development with a minimum expenditure of funds. As a result of these studies, in May 1959 a modified Titan missile with a 120-in. diameter was selected as the second stage.

The Centaur vehicle, under development by Convair, was selected as the third stage. This selection was guided by the necessity to choose components capable of satisfying current needs and of being easily adapted to future requirements.

The choice of Centaur had far-reaching effects on the Saturn development program. At this time, Pratt & Whitney, in association with Convair, was developing a new rocket engine. A major breakthrough, this engine burned liquid hydrogen and liquid oxygen, providing approximately 50 per cent more specific impulse than conventional hydrocarbon fuels. To take full advantage of this development, it was decided that the new engine would become the propulsion unit for the third Saturn stage. By the time second-stage testing was complete, the engine would be sufficiently developed for use with the third stage.

While speeding development of the immediate vehicle, use of the Titan-type second stage did not provide the desired performance. On July 29, 1959, ARPA ordered that effort be redirected from the Titan to development of larger-diameter upper stages to support certain spacecraft projects. Authorization was given to consider components other than those available from ICBM programs.

A series of studies began of upper stage configurations for the Saturn vehicle. Late in October, four upper-stage combinations were proposed. The most feasible of these was identified as the Saturn B-1. Offering the best growth potential and mission flexibility, plus the best cost to payload-weight ratio, the B-1 included a second and third stage 220 in. in diameter, both using liquid hydrogen engines. The principal disadvantage was that the B-1 required either a high initial cost in the first two years of development or a longer development schedule, with corresponding delays in operational availability.

As a result, a further series of studies was performed, culminating in December 1959, with a recommendation by a NASA appointed team, headed by Dr. A. Silverstein, that the present C-1 vehicle configuration be adopted.

The Silverstein Report marked a major milestone in the Saturn program. A long-range vehicle development program was recommended, beginning with the C-1 Saturn. Advanced configurations, the C-2 and C-3, would evolve by adding advanced, high-thrust stages to the initial configuration.

The C-1, based on a first stage clustered booster, would use liquid hydrogen as fuel for the upper stages. Ten R&D vehicle flights were planned. In addition, a high-thrust liquid hydrogen engine, generating 200,000 lb, would be developed for use on advanced vehicle configurations, beginning with the C-2.

The three-stage C-1 configuration evolving from these plans offered distinct advantages in terms of payload capability at an early date in addition to a final configuration that would fully exploit the performance of the booster stages. The vehicle itself would be about 185 ft high and weigh over 1,000,000 lb when fully fueled. About 750,000 lb of this weight would be propellants.

The booster, or S-I stage, used in the first portion of the present R&D flight test program, is substantially the same as that first proposed (Fig. 1.1). The stage is 82 ft long and 21.5 ft in diameter. It is powered by eight H-1 engines, each producing 165,000 lb of thrust; later in the R&D program, these engines will be rated at their full 188,000 lb of thrust.

The engines are attached to a thrust frame on the aft end of the stage. The four inboard engines are rigidly fixed at a 3 deg cant to the vehicle centerline. The four outboard engines, canted at 6 deg and mounted to alternate outriggers, are mounted on gimbals that permit them to be turned $\pm$ 10 deg. This permits vehicle roll and attitude control during the first phase of flight, which lasts about 120 sec.

The general booster structure consists of nine tanks, an upper-stage adapter, tail section, and shrouding. The tail section, composed largely of 7075-T6 aluminum, includes a corrugated central barrel, eight outriggers, firewall, heat shield, shrouding, and associated members. The tail section also provides support and holddown points.

SYSTEMS AND OPERATIONS

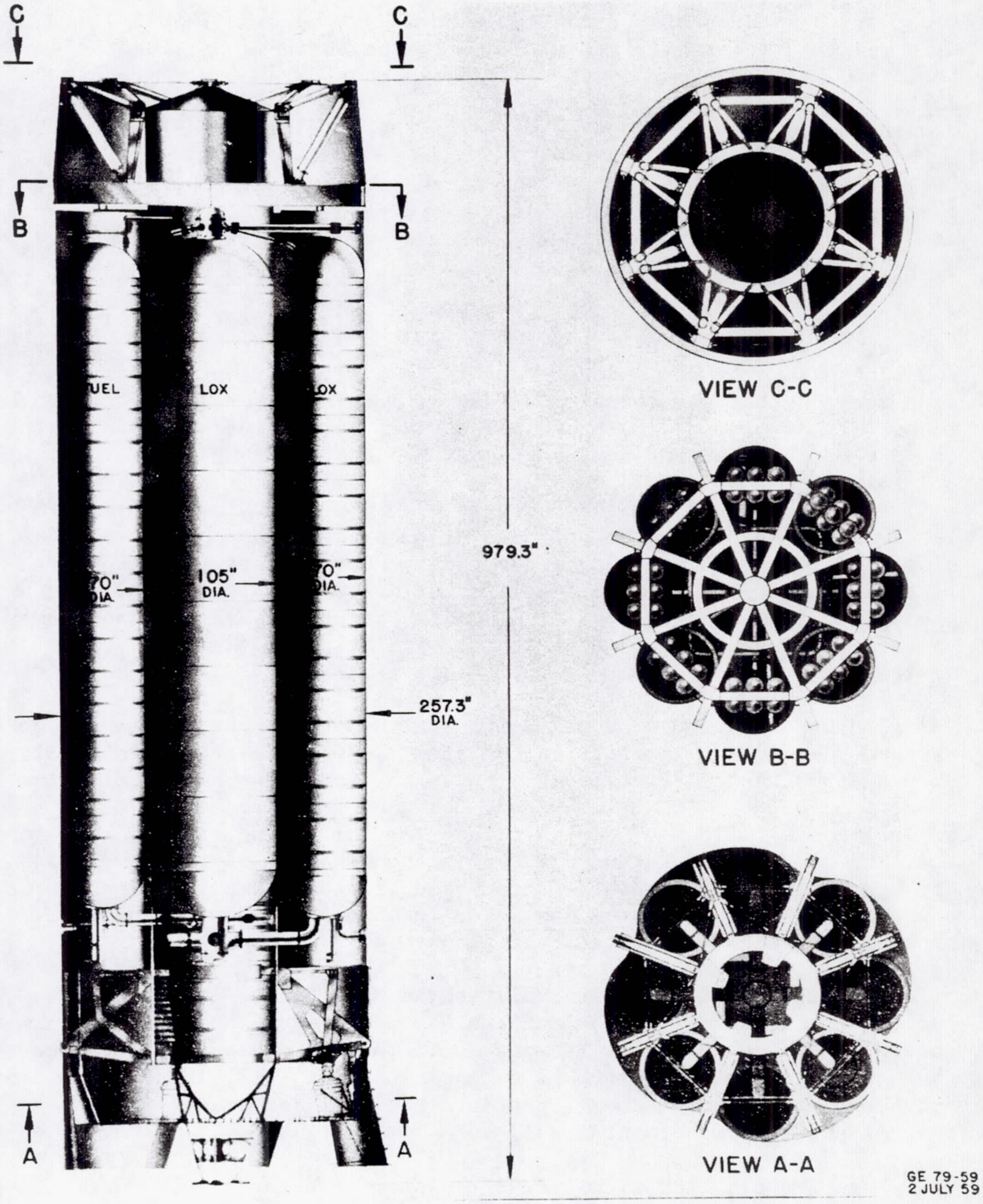

Fig. 1.1 Saturn booster structure.

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Eight 70-in. propellant containers, four fuel and four oxidizer, are clustered alternately around a central 105-in. oxidizer tank. All tanks are of semimonocoque construction, built up from 5456-343 aluminum skin segments. The oxidizer tanks carry the entire axial loading from the upper stages. Four other containers contribute only to lateral stiffness, since they must have a slip joint on their upper end to compensate for the 2.5 in. shrinkage of the oxidizer tanks after filling.

Each of the container systems is interconnected to permit equalizing the liquid level during propellant loading and flight. The total capacity of the containers is 750,000 lb. Sloshing is suppressed by fixed baffles running accordion-like down the interior of the tanks.

The oxidizer tanks are pressurized by gaseous oxygen, obtained by passing a small portion of the liquid oxygen flow through heat exchangers and channeling the gas through a manifold system at the top of the booster. In this way, equal pressure is furnished for all oxidizer tanks. The fuel containers are pressurized by gaseous nitrogen, carried in 48 Fiberglas spheres at the top of the booster.

The upper-stage adapter and spider beam assembly consists of an I-beam and tube truss combination, which holds the upper ends of the clustered tanks and provides support for the upper stage. For this latter purpose, a 220-in. diameter mounting ring is located 90 in. above the spider beam. Eight 7075-T6 aluminum extruded I-beams compose the spider. The beams attach to each outboard oxidizer tank. Lateral restraint is provided for the fuel containers.

The upper shroud provides a transition between the 257-in. diameter S-I and the 220-in. diameter second stage S-IV. The stainless steel shroud supports the telemetry antennas and a power supply umbilical connection point. The tail shroud, designed to minimize the effects of inflight air flow and high-altitude jet ballooning, is attached to the tank section and extends to a point somewhat below the level of the heat shield. The shroud is composed of aluminum alloy skin for the upper panels, with stainless steel used for the lower panels because of the higher temperatures encountered.

Protection against heat radiation is provided by a heat shield located at the levels of the throats of the engines. A separate flame shield to prevent backflow is mounted in the diamond-shaped area between the nozzles of the four inboard engines. A fire wall, located immediately above the engine compartment, protects the fuel and oxidizer tanks in case of engine compartment fires.

The on-board electrical network system integrates all vehicle electrical, electro-mechanical, and electronic equipment in a single functional system. A major design parameter of this system was the provision for checkout and countdown procedures. The vehicle network consists of about 500 electrical cables, interconnecting a group of distributor boxes, which, in turn, combine junction and relay patch boards in single units.

For the initial boosters, four instrument canisters are located in the upper-stage adapter. These canisters contain the telemetry and tracking transmitters, power distribution functions, guidance and control units, and related instrumentation. On later vehicles, this equipment will be contained in an instrument unit, located between the payload and last stage.

The S-I stage control system uses thrust vectoring to achieve the control torques required to stabilize the vehicle. Control forces are obtained by engine gimbaling in response to signals from the flight control computer, activating the two hydraulic actuators for each engine. Certain Jupiter system components have been adapted for use in this system. Rate gyros are used as sensing elements, an application dictated by structural bending of the large and relatively flexible vehicle. A shaping network separates structural bending from the synthetic control mode.

In carrying out the general development philosophy at MSFC, it was decided that the guidance system would be standarized as far as possible (Fig. 1.2). This assures maximum use of proven components, eliminates considerable development expense, and allows the vehicle to support readily a variety of missions. This concept is termed the adaptive guidance mode and is sufficiently comprehensive to include all forseeable guidance schemes. The fundamental principle of the adaptive guidance mode is that any specific guidance scheme derived from the general mathematical structure will cause the vehicle to fly an optimum trajectory. The assigned mission dictates the features for optimum development.

The guidance system includes an inertial reference subsystem comprising a stabilized platform and accelerometers, platform electronics, and associated ground support equipment. The guidance computer subsystem consists of a guidance computer, guidance signal processor, and a body-fixed accelerometer. A number of Jupiter and Juno 2 components (including the ST-90 stabilized platform) have been selected for the very early flights, since they have the accuracy, size, and weight suitable for the Saturn.

The second stage of the Saturn launch vehicle (S-IV) is under development by the Douglas Aircraft Corporation (DAC). The S-IV stage represents the second application of liquid hydrogen technology to a space vehicle (Centaur was the first); as a result, the stage includes many design innovations. Formal procurement of the S-IV began in July 1960 when DAC was requested to design, develop, and test a four-engine stage. Later, in March 1961, the number of engines was increased to six, providing better inflight control and increased payload capability.

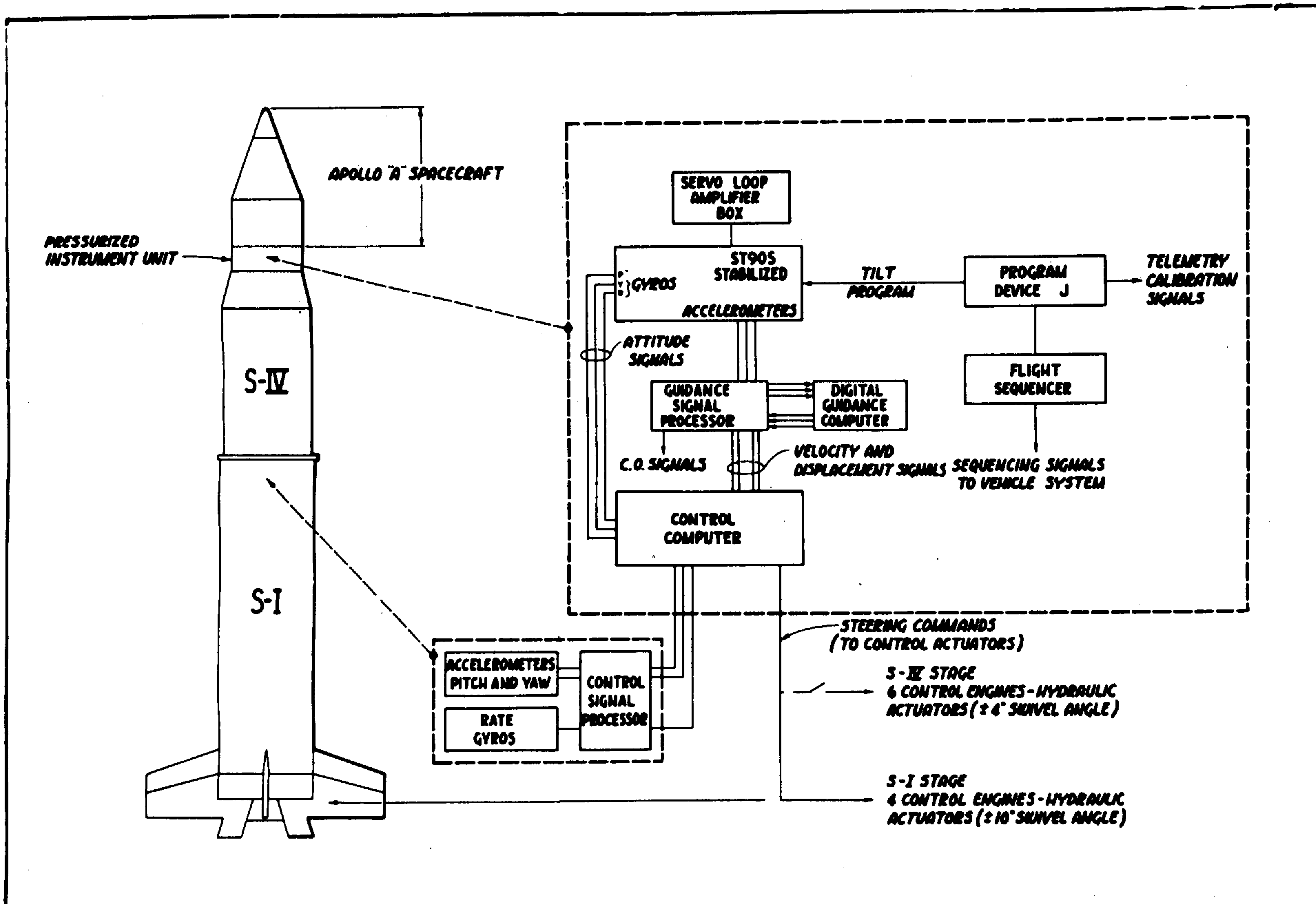

Fig. 1.2 Guidance and control system, C-1 Saturn (block II).

The present S-IV stage is about 41 ft in length, with a diameter of 220 in. (Fig. 1.3). The stage is powered by six liquid hydrogen RL10A-3 engines (also used on the Centaur vehicle) being developed by Pratt & Whitney. Each engine will provide 15,000 lb of thrust for a total stage thrust of 90,000 lb.

The stage is a self-supporting structure containing two propellant tanks fabricated of 2014-T6 aluminum alloy. The liquid oxygen tank, located aft, is separated from the liquid hydrogen tank by a common insulated bulkhead made of a Fiberglas, honeycomb core between aluminum faces. The bulkhead is designed to withstand reverse pressures that may result from maximum pressure in the liquid hydrogen tank and ambient pressure in the oxidizer tank while the vehicle is on the launch pedestal.

The cylindrical portion of the tank consists of three segments of machine-milled waffle skin, longitudinally welded. End bulkheads, fabricated from six segments, are welded to form a hemisphere. All welds are made in sections thickened to keep tresses well below the yield point in the "as welded" condition.

The entire inner surface of the hydrogen tank, excepting only the common bulkhead, is insulated. Slosh baffles are included in both tanks.

The engine thrust structure, a truncated cone of conventional skin and stringer construction, is bolted to the aft bulkhead. A base head shield is installed behind the gimbal plane; the shield, constructed of an insulated honeycomb sandwich, is supported from the thrust structure. Additional thermal protection is afforded the structure and components located forward of the base heat shield.

The forward interstage structure and aft skirt are constructed of aluminum honeycomb core between aluminum faces. The aft end of the skirt forms the forward face of the S-I and S-IV inflight separation plane.

The S-IV vehicle is steered by gimbaling the six engines in response to signals contained in the vehicle instrument unit, located forward of the stage. The S-IV mounted control hardware is capable of providing engine deflection rates proportional to the pitch, yaw, and roll control signals, furnished by the MSFC guidance and control computer. The engines, mounted with an outboard cant of 6 deg, can be gimbaled $\pm$ 4 deg. The engines are attached to the conical aluminum thrust structure joined to the aft bulkhead. Propellants are supplied to the engines through individual, low-pressure ducting from pressurized propellant tanks.

Separation of the S-I and S-IV stages takes place at the time when an electrical signal triggers explosive bolts installed at the aft separation plane. Separation is accomplished by retrorockets on the S-I stage and

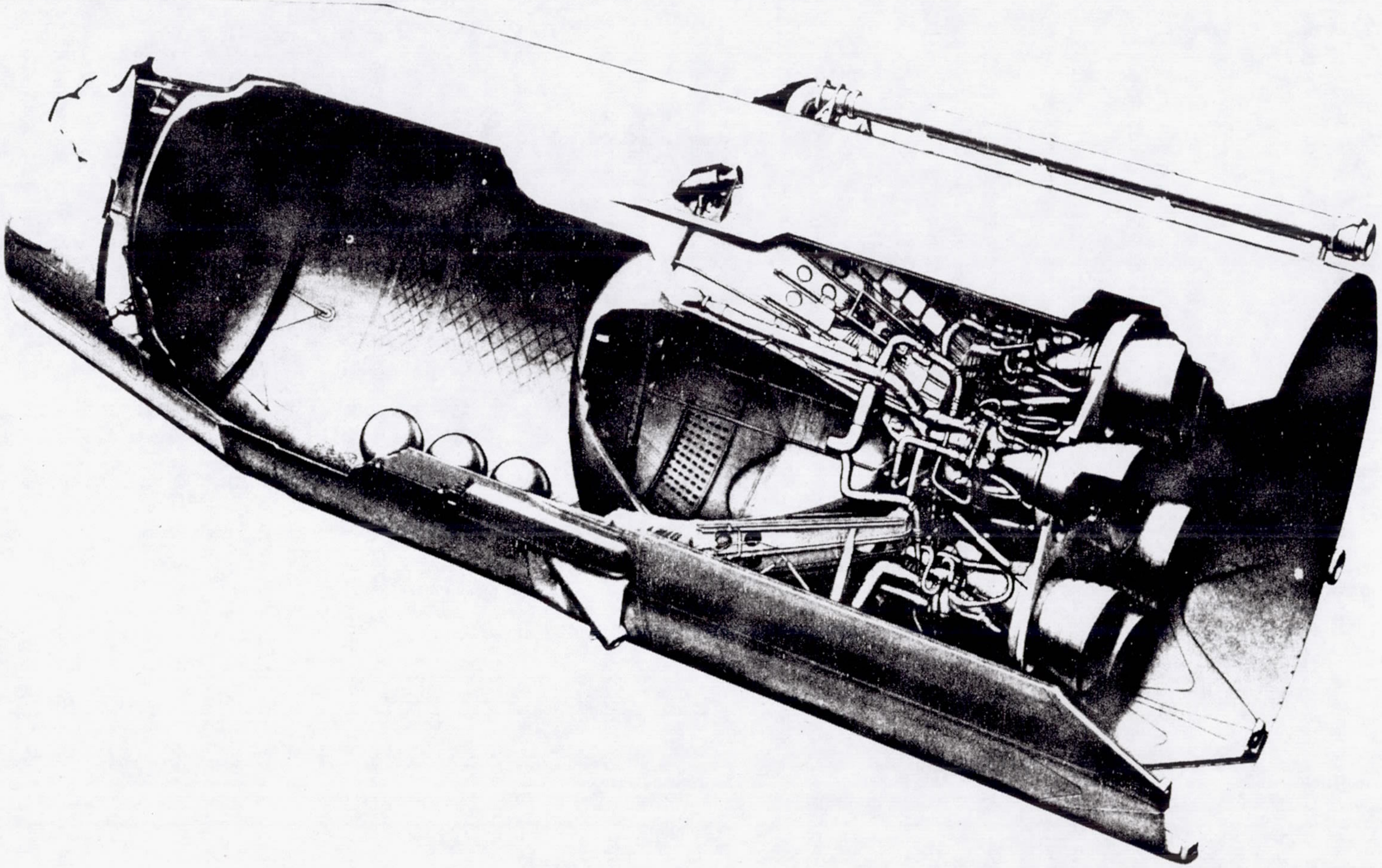

Fig. 1.3 Saturn S-IV stage.

ullage rockets on the S-IV vehicles. The ullage rockets give sufficient forward movement to the S-IV to position the propellants before engine ignition. A short period of uncontrolled coast occurs between separation and stage ignition to make sure that the stages are a sufficient distance apart.

Inflight control of the succession of events in the S-IV stage is provided by the S-IV sequencer, a separate unipackaged subsystem that receives signals from the S-I stage, the guidance and control package, and other S-IV subsystems. The sequencer provides sequential commands to initiate S-IV functions and stage separation, and is mounted, with other operational components, in the engine compartment.

NASA policy is to base programs on the use of a few multipurpose vehicles, thus achieving high reliability through many flights. In keeping this policy, the third stage of the C-1 configuration (the S-V stage) was to be the Centaur vehicle, the upper stage of the Atlas-Centaur launch vehicle. Powered by two liquid hydrogen engines, the Centaur vehicle would be slightly modified by increasing the skin thickness to accommodate the heavier Saturn payloads. The vehicle was intended to perform escape and deep space missions.

All of these stages would be used on the proposed C-2 vehicle configuration, differing from the C-1 only in having a new high-energy stage inserted immediately above the booster (Fig. 1.4). Later to be identified as the S-II, this stage was first conceived as using two advanced liquid hydrogen engines, generating a total thrust of 400,000 lb. Being the third application of liquid hydrogen technology to a space vehicle, the stage development program would benefit from the experience gained in the Centaur and S-IV programs.

By the early part of 1960, the Saturn program had taken great strides toward developing an operational launch vehicle. The first eight prototype engines were initially tested on a single engine test stand. Then, on March 28, two engines were fired together; on April 6, four engines were fired; and, finally, on April 29, all 8 engines of the booster were fired in demonstration of the clustered booster concept. On May 26, 1960, assembly of the S-I stage began for the first flight vehicle. In the same month, Rocketdyne was awarded a contract for the development of an advanced high-thrust liquid hydrogen engine, the J-2, the type defined by the Silverstein Committee in December, 1959.

These varied development programs of stages and engines were paralleled by the F-1 development program, formally initiated as a NASA project in January 1959. The F-1, an engine of simplified conventional design, incorporates proven concepts of liquid propellant technology. Liquid oxygen and RP-1 are burned to generate 1,500,000 lb of thrust. Basic components of the engine are a tubular wall, regeneratively cooled thrust chamber assembly, and direct drive turbopumps, and gas generator.

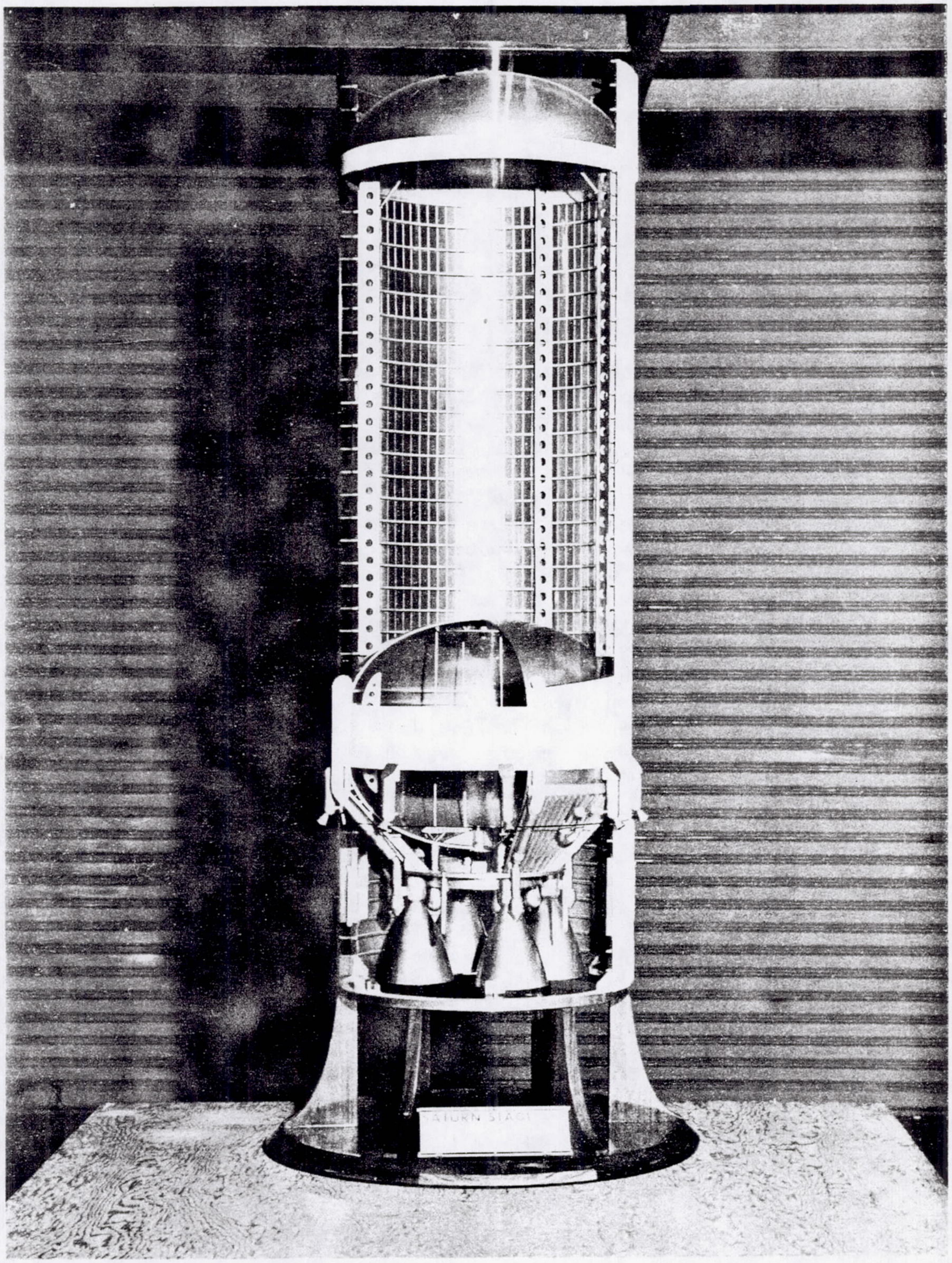

Fig. 1.4 Saturn S-II stage.

To summarize the status of the program at the end of 1960, the S-I and S-IV stage development programs were underway, preliminary design studies of the S-V (modified Centaur) stage had begun; and detailed performance studies of the C-1 configuration were continuing. Static firing of the test booster, modified to the configuration of the SA-1 flight booster, had been completed. Assembly of the first flight booster was almost complete, and assembly of the SA-2 booster was about to begin.

Four individual engine development programs were underway: two liquid hydrogen engines for the Centaur vehicle and the advanced S-II stage, respectively, and the H-1 and the F-1 engines. Studies were also being completed on the C-2 configuration of the Saturn launch vehicle. Concurrently with this activity, construction continued of the launch facilities at Launch Complex 34, Cape Canaveral, and test facilities (including a dynamic test tower) at MSFC in Huntsville.

In May 1961, President Kennedy, in his State of the Union address to the Congress, emphasized that major effort be directed toward circumlunar flights and manned landings on the Moon. Because of the high priority of this effort, MSFC thoroughly reviewed the Saturn program. This review showed that low orbital missions in support of the Apollo porgram were of primary importance. A two-stage Saturn would provide the performance needed to orbit an Apollo spacecraft and posses the safety requirements required for a manned mission.

Further, it was found that, as lunar mission weight requirements had increased, a vehicle configuration of even greater performance than the C-2 was desirable. These findings were followed on June 23, 1961, by redirection of design effort on the C-2 clarifying concepts of the C-3 and Nova configurations.

While these configuration studies were proceeding, the C-1 ten-vehicle R&D program was being revised. Because of the prime importance of the Apollo project, the mission required for Saturn was reoriented toward the injection of unmanned and manned Apollo spacecraft into earth orbits. As a result of this redirection, development of the S-V stage was deferred because it had been planned for other missions and was not required for the Apollo flights.

Essentially, the present Saturn program will develop a two-stage vehicle capable of supporting the manned mission. The flights will secure experience in the development of multiple-engine stages, launching equipment, procedures, and facilities. This experience will provide the technical basis for design data required for later members of the heavy launch vehicle family.

The C-1 R&D program has been divided into two blocks of vehicles (Fig. 1.5). In Block I, four vehicles (SA-1 through SA-4) will be flown. These will be composed of a live S-I stage, with inert S-IV and S-V stages. Such tests will define flight operation of the booster and explore control and environmental conditions, rf and tracking problems, and procedures for the operation of large vehicles.

The Block II Saturn vehicles (SA-5 through SA-10) will contain design modifications to support the Apollo mission more effectively. Tanks will be lengthened to accommodate a greater volume of propellants. Fins will be added to provide increased vehicle stability. For an extra measure of control, a more flexible and universal guidance and control system is being readied to support the manned mission.

The Block II vehicle will consist of a live, modified S-I stage, a live S-IV stage, a new instrument unit, and payload. Initial flight tests will be designed to study S-I and S-IV staging, S-IV operation, and system guidance and control. Operational procedures will be proved out for the new liquid hydrogen loading facilities at the launch site. Additional flight experience will be secured with the booster and associated facilities and tracking networks.

During the latter portion of Block II testing, Apollo "boiler plate" spacecraft will be tested under actual flight and reentry conditions. Apollo-Saturn interface events or compatibility and detail requirements of reentry heat shielding will be studied.

All these elements represent the evolution of MSFC's basic approach to vehicle development. Each stage is flight tested and thoroughly proved out before proceeding to flight tests of the next higher stage. As a result, desirable design changes can be fully defined and incorporated at a specific cutoff point. Mandatory changes are introduced as required.

Because of the complexity of the Saturn program, its unique development characteristics, and the large costs involved, the stages and associated components must be qualified and tested to a greater extent than in previous programs. Vehicle components must have the same high quality as the first items received for qualification testing. This need illustrates one of industry's main contributions to the program, for industry has played a responsible role not only in S-I component fabrication but in the design and development of stages and engines.

This responsibility is increased many times when the development program puts into practice such innovations as liquid hydrogen technology. A constant effort must be maintained to secure reliable, high quality components produced in response to the latest research developments. To assist the contractor, MSFC has established lines of intraprogram coordination between similar R&D efforts. For instance, details of

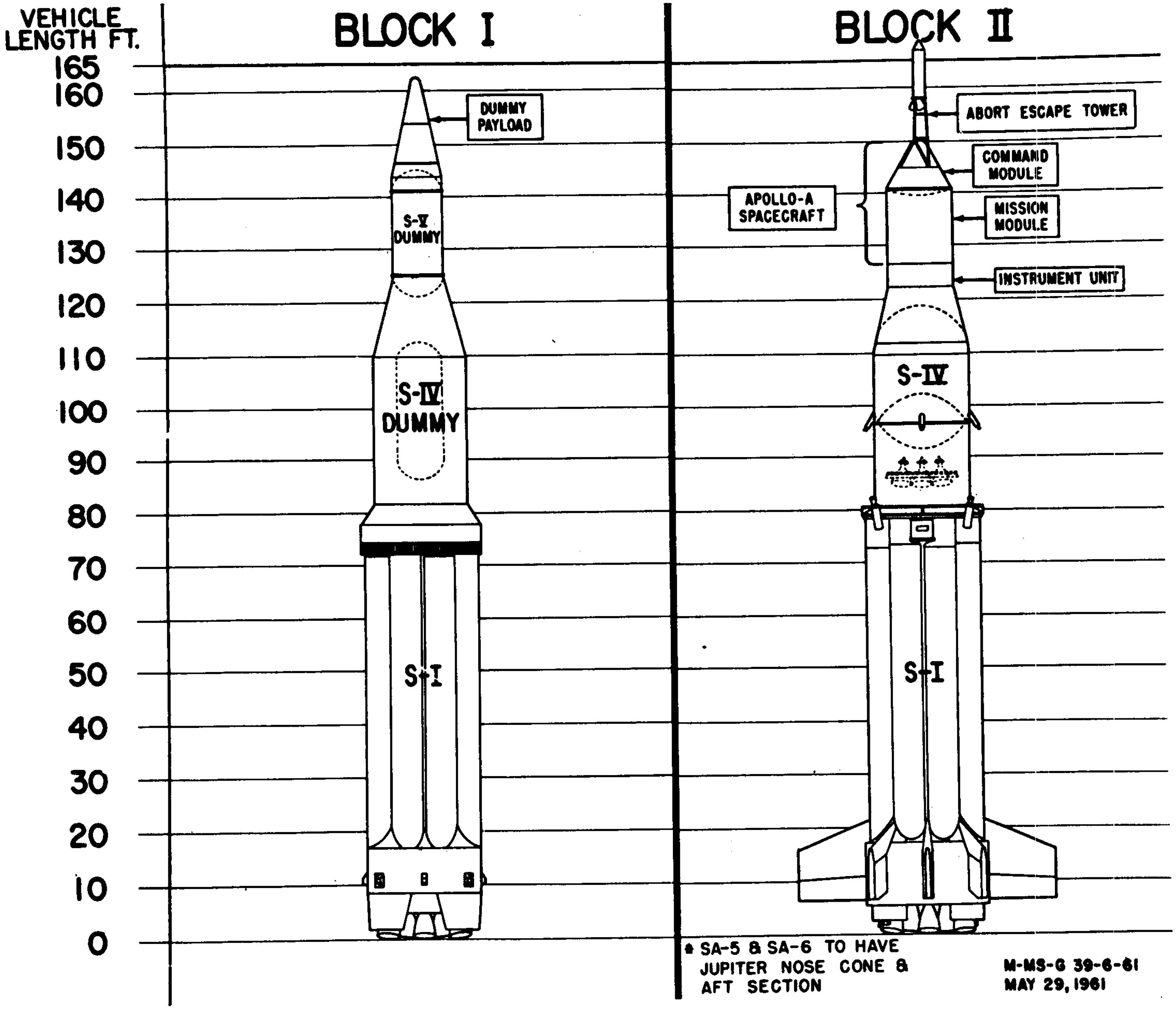

Fig. 1.5 C-1 development vehicle configurations, blocks I and II.

rapidly advancing liquid hydrogen technology were shared by Convair and DAC. In the same way, coordination has been established between DAC and North American Aviation, the latter contractor having been selected in September 1961 to develop and build a four-engine S-II stage for an advanced launch vehicle.

As the C-1 configuration moves toward operational status, industry's participation is secured not only for the research and development phase, but for production. The government-owned Michoud Plant was secured for this purpose early in September 1961. At this plant, operated by industry under the technical direction of MSFC, the C-1 vehicle first stage will be produced along with the F-1 powered booster for an advanced Saturn configuration.

Support for booster static testing, an essential part of the production program, led NASA to announce in October 1961 that a test site would be developed near the plant. Facilities included at this site will permit static firing qualification tests of both the C-1 and the advanced vehicle boosters before release to Cape Canaveral.

NASA Headquarters announced in September, 1961, the selection of Cape Canaveral as the base for all manned lunar flights and other advanced space vehicle missions. Approximately 80,000 acres north of Cape Canaveral will be secured for the development of these sites. This expansion was required because of the excessive vibration and noise anticipated with these vehicles.

Throughout 1961 planning of industrial booster production continued, S-II stage development was initiated, and investigations of advanced vehicle configurations to support the lunar missions proceeded. During the same period, preparations were completed for the launch of the first Saturn vehicle.

Static testing of the SA-1 flight booster was concluded in May. 1961. Booster checkout was completed in August, at about the same time when the second flight booster was transferred from the assembly area to checkout. The SA-1 booster, the inert S-IV stages, and the inert payload body were then transferred to Launch Complex 34. (The inert S-V stage had been delivered in April.) In the latter part of August, assembly of the SA-1 flight vehicle began at the launch site.

Between completion of assembly and actual launch, an exhaustive series of checkout tests were performed to assure that every required operation and function could be performed. Specifically, checkout consists of the application of a series of operational and calibration tests performed in a certain sequence. The response to each of these tests must be within a predetermined tolerance.

The checkout includes continuity testing, to assure that circuits have not been interrupted; component tests, to determine the satisfactory operation of individual parts; and overall testing, to evaluate power plant cutoff and other functions associated with the general vehicle network. Steering testing verifies the gimbaling response, attitude control, guidance, and special device systems of the vehicle. During calibration, the various vehicle measuring devices are adjusted. All of these tests are performed to check the sequences of operations required to bring the vehicle through the point of liftoff.

On October 27, 1961, the Saturn program reached its first major milestone with the successful SA-1 flight test (Fig. 1.6). The 162-ft tall vehicle weighed about 460 tons, with both inert upper stages filled with water to simulate fuel loading. Automatic fueling and sequencing processes were satisfactorily carried out. The 600-min countdown was uninterrupted by holds for technical reasons, although two holds were called because of weather.

The booster produced the 1,300,000 lb of thrust intended for the first four vehicle flights. (Later vehicles, using more powerful engines, will generate 1,500,000 lb of thrust.) Overall performance of the booster during flight was highly satisfactory. Structural integrity was maintained throughout powered flight. Wind shear, encountered near the region of maximum dynamic pressure, resulted in a 4.5-deg engine deflection, which was handled by the control system without difficulty.

Inboard engine cutoff occurred after 109 sec of burning, slightly earlier than anticipated. Analysis of telemetry data indicates the cause was propellant sloshing amplitudes, rather than performance deviations of the engines. Outboard engine cutoff occurred at about 115 sec. All engine thrust decays appeared smooth. The vehicle experienced practically no disturbance torques at cutoff and flew without pronounced tumbling motion through loss of the uprange signal.

During its trajectory, the SA-1 reached a height of about 137 km (85 statute miles). The vehicle flew for approximately 8 min, attaining a speed of almost 5800 km/hr (3600 statute mph), and impacted 345 km (185 nautical miles) downrange. Throughout the flight, more than 500 telemetry measurements were transmitted back to the ground station.

The flight of any vehicle is followed by an exhaustive evaluation of telemetry records. From these evaluations come the design improvements to be made on the next flight vehicle. As a result of the SA-1 flight findings, certain modifications are being made to the Block I vehicles, including additional slosh baffles in the propellant tanks to improve vehicle controllability in the latter phase of flight.

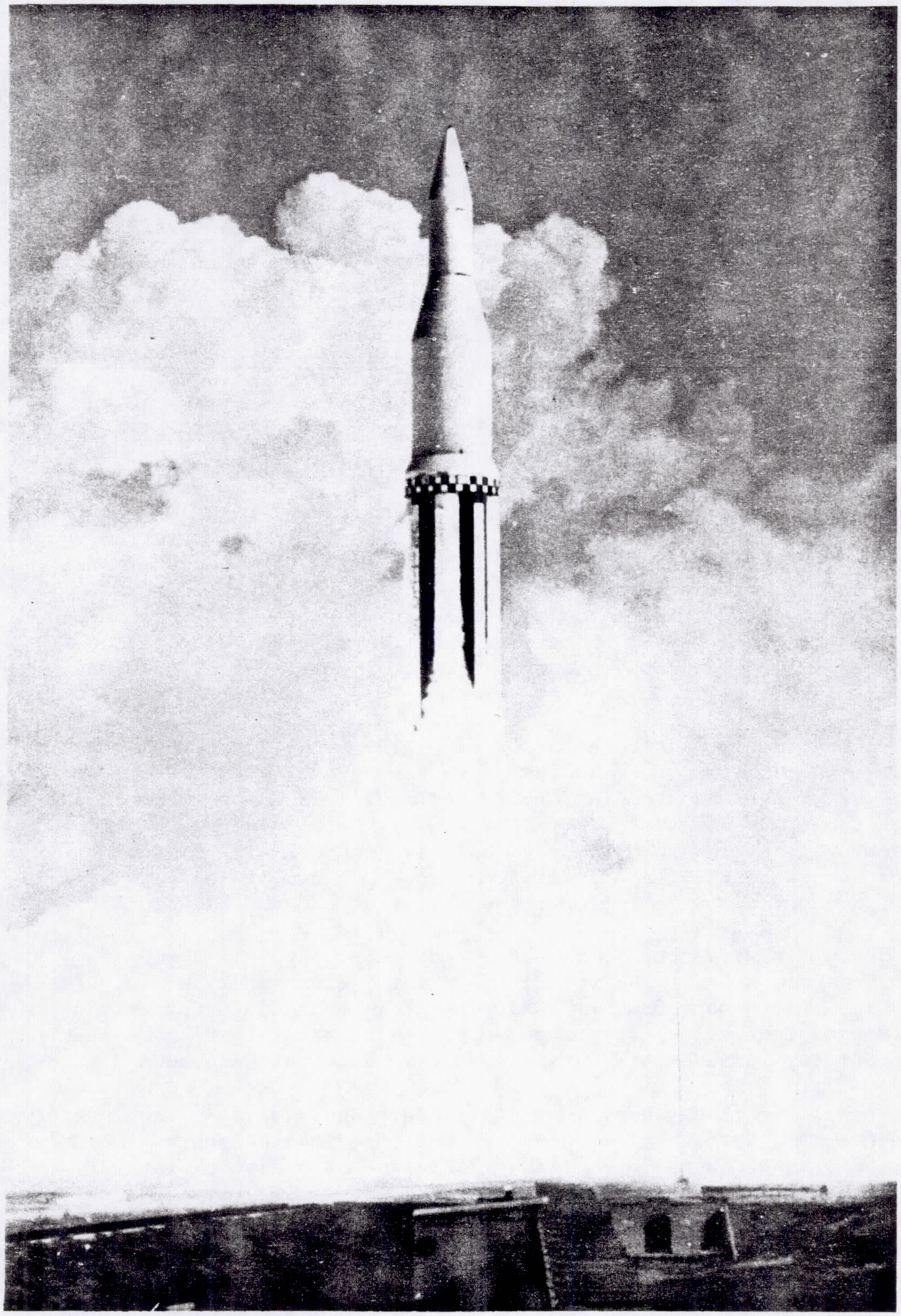

Fig. 1.6 Liftoff of the SA-1.

The flight disclosed that all major vehicle subsystems performed satisfactorily - structure, propulsion, control instrumentation, and heat protection. Ground equipment also performed satisfactorily, both during launch preparation and during the automatic sequence prior to liftoff.

The first milestone in Saturn history has been passed, leading to other steps in the development of the Saturn system. As testing and design improvement continue at MSFC for the Block I and Block II vehicles, parallel planning is also carried on to define the advanced vehicle, a step up from the C-1.

The advances in technology, methods, and procedures secured during the C-1 program provide a solid basis for the advanced configuration. Technical gains have already been realized in many fields: metals, instrumentation, facilities, handling and fabrication techniques. A large portion of advanced vehicle manufacturing can be accomplished in existing facilities with available tooling. Improved methods of handling the thicker metals of the advanced stages can be developed from fabrication methods defined during the C-1 program. C-1 assembly and checkout methods will be revised to meet new needs. Automated checkout, performed at the production plant, the test site, and the launch area, can be extended to meet the more comprehensive needs of the advanced vehicle program.

The C-1 and the advanced vehicle research and development programs merge inseparably, a continuity of effort based on and extending our present knowledge. Aerodynamic studies of advanced designs logically follow those studies performed on the C-1 vehicle. Liquid hydrogen technology, developed during the C-1 upper-stage programs, is extended in a logical development sequence through the S-II stage program.

In the same way, the high-thrust F-1 engine, developed during the course of the initial Saturn program, provides the foundation for developing a booster of greatly increased performance. In lieu of a booster providing 1,500,000 lb of thrust, future boosters are expected to provide thrust to magnititudes of 3,000,000 to 7,5000,000 lb.

The advanced launch vehicles with the mature results of past plans and advances in research and development will directly support the manned lunar missions late in this decade. They will be capable of orbiting over 250,000 lb around Earth or sending 90,000 lb of payload on escape missions for lunar and interplanetary flights.

Of equal importance, the vehicles will be able to support essential R&D testing of spacecraft within flight and space environments. They provide the means for developing orbital rendezvous and mating techniques and for carrying payloads to the Moon for exploration of it prior to manned landings. Furthermore, the vehicles can carry nuclear upper stages, developed during the Rift program, for required flight testing in space.

The history of Saturn development to date illustrates some often unseen factors governing final vehicle design. In response to progressively more demanding missions and the steady advancement of scientific and technical knowledge, vehicle capabilities have constantly increased along with increasing performance.

In the space of little more than 3 years, we have progressed from the concept of a vehicle using relatively small clustered engines and ICBM-adapted hardware to the immense four- or five-stage vehicles, with F-1 clustered engines, upper stages using the most advanced liquid technology known, and capped with nuclear stages.

These programs have demanded the full measure of ingenuity and skills. Advanced programs, carrying men into still unexplored environments, demand that we provide even more; the history of Saturn development is still in the process of being created.