THE
THOR-AGENA
STORY

draft prepared by

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ROUGH DRAFT
Chapter 1

INTRODUCTION

Since the close of the Second World War American military services have been actively interested in earth-circling satellites. Pertinent German research came to the attention of American military personnel and under the sponsorship of the Army Air Corps, the RAND Corporation undertook feasibility studies of earth satellites. In September 1947, RAND reported that a satellite was technically feasible, and in 1948 the Air Force, as an independent service, requested RAND to establish a program for the further investigation of possible satellite development.

During the next few years, RAND studied the problem under the code name "Feedback." The company reported that a space vehicle could be placed in an orbit around the earth by a rocket-powered booster.

RAND personnel recognized that numerous system component development problems existed but such hardware development would not require radically new technology or enormous costs.
About the time RAND was completing its study, the Air Force established a research and development program on an advanced reconnaissance system. Wright Air Development Center, Dayton, Ohio, was responsible for managing the program called Project III. Air Force personnel made an intensive feasibility study including such critical component development areas as satellite-born electrical power for equipment operation and component reliability in a satellite environment.

By 1955, the Air Force had obtained sufficient data to insure that the problems were surmountable, which permitted system design studies to begin that year. Consequently, in 1959, Wright center 1st design study contracts to Radio Corporation of America, Glenn L. Martin Company, and Lockheed Aircraft Corporation for the purpose of determining if a reconnaissance satellite system could be developed within a time span which would warrant a full scale development effort. These "Pied Piper" studies, submitted by all three contractors showed that the system could be developed.

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With these positive reports, the Air Force felt that it could begin hardware development under the title WS 117L.

The Air Research and Development Command believed that it would be best for Western Development Division located in the Los Angeles area to manage the program. The Los Angeles division managed the ballistic missile top national priority program, and since the WS 117L system would have to use a missile as an attempt to remove the first stage booster and several other areas presented potential military satellite areas of conflict between the two programs. During 1956, management functions passed from the Wright center to the missile division.
Personnel from both Wright center and the division combined their talents in the preparation of a WS 117L development plan. In May 1952, Washington authorities including Air Force agencies and the Secretary of the Air Force Donald Quarles, and the President's Science Advisory Committee, approved the plan.

The plan called for a two-stage vehicle which could be launched from United States territory. The booster or first stage would be an intercontinental ballistic missile which would fall away when the engine burned out at about 3,000 miles from the launch pad.

The second stage would be the orbiting vehicle, which would have a propulsion system to supply the necessary power to propel the vehicle into the speed necessary for orbit.

The vehicle would then ascend to an altitude of about 300 miles where an orbit would be assumed, and internal controls would orient the vehicle in the proper attitude.
Meanwhile in March 1956, an Air Force board convened at Wright center to study the Pied Piper designs and to recommend a contractor for hardware development. The board recommended Lockheed as the prime systems contractor and this action was subsequently approved by the Department of Defense. The Air Force formally awarded the contract to Lockheed's Missile and Space Division at Sunnyvale, California on 29 October 1956.
The usefulness of a military satellite was under consideration from the beginning. After initial flight tests in 1952, there were concerns about the possibility of political repercussions arising from the use of a military satellite. However, efforts to relieve the situation with no appreciable results.

Assistant Secretary of Defense Varney oversees the entire program. He had authorized the fabrication of mock-ups of experimental vehicles. The Western Development Division made several proposals for the West Coast in December 1955, but only in the amount of $3 million. This amount was increased to a total of $35 million. The Western Development Division then requested funds for 1957, and consequently the Senate Appropriations Committee added $35 million to the budget. The development plan included $22.5 million for fiscal 1957. However, despite the program's high national priority, there was a strong opposition to funding during the ensuing fiscal year.
space vehicle.

As a matter of policy no mock-up or environment vehicle

was to be furnished without formal permission. In this

time period the program was suspended.

The fund limitation and the defense department's general

attitude caused the 117L program activity to be channeled into component

rather than total system development. During the pre-Sputnik

Lockheed began satellite airframe design studies, investigated

sources for satellite-born auxiliary power and attitude control systems,

selected and searched for satellite propulsion systems which would be

available at an early date. Indeed some technical progress was

equal made but of less importance. A contractor team had been assembled

and a broad base established from which rapid expansion could grow.

(based largely on hist rpt, WS 117L, Jan-Dec 56; short hist & chronology


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In July 1957, the division (renamed Air Force Ballistic Missile Division) submitted new development plans for 1957. The plans were prepared by a panel of scientists and engineers who specified that if the current level of funding continued, September 1959 would be a realistic target date for the first launch. However, a more desirable level of funding—$77 million for fiscal 1958 and $112.5 million for fiscal 1959—would enable a first launch in March 1959. The Air Force Council recommended the "desirable level" of funds, but before this General approval, the Department of Defense would have to consider the political and emotional repercussions. On 4 October, the Secretary of Defense approved the "desirable level".

A few days later, Air Force secretary James H. Douglas approved the Air Force headquarters' release of a portion of the 1958 funds to the division. When the new defense secretary, Neil McElroy, was briefed on 29 October 1957, he was so enthusiastic that he directed the immediate release of the balance of the 1958 funds and that the program would proceed as rapidly as good management would permit.
Also during the crisis atmosphere following Sputnik, both RAND and the Department of the Air Force urged that Thor boosters be used in conjunction with the Lockheed 117L upperstage to provide an early space demonstration. In addition two special advisory groups created to consider steps for reviving United States prestige arrived independently at the same conclusion.

In February the Secretary of the Air Force asked for approval of a program acceleration based on the expanded use of Thor-booster satellites, but the decision was delayed pending the activation of the new Advanced Research Projects Agency. The overall management of the RS-117L program was one of the tasks of the new agency.

On 28 February, the new agency's director Roy Johnson approved the Thor-117L combination for early flight tests and as a means of conducting biomedical experiments.

The principal obstacle to RS-117L acceleration remained fund... Not until June 1958 were the various proposals and counterproposals reduced to an approved program. At that point, the Thor-RS 117L phase
received enough money to support the fabrication of the first 12
vehicles. By this time, the total 117L effort was under the new
agencys's control, the Secretary of Defense gradually making the
shift between February and June.

During December 1958, the Advanced Research Projects Agency
three

divided the original WA-117L program into specialized projects, two of
these included the Atlas as a booster and the other would retain
the

So the

Thor booster.

The Thor boosted program

involved space engineering test functions, biomedical experimentation,
of
development/recovery techniques, and associated military support activities.

Eleven months later, on 17 November 1959, the Secretary of Defense

transferred the Thor-Agana (as the second stage began to be called)
to the Air Force. However, for any program changed, Lawrence

the Air Force Ballistic Missile Division would have to receive

approval from the Department of Defense Director of Development,

Research and Engineering.

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The Thor-Agena booster-satellite combination represented an early and major Air Force achievement in that it was the first hardware combination to progress to almost routine launchings and payload recoveries. Although each stage was used with other space hardware combinations, the Air Force used the two stages together more frequently than any other combination. The original Thor-Agena flight proposal was five in January 1958, increased to 10, 13, 15, 19, and then 25 flights by 30 April 1959. Shortly after the first complete flight successes, launch, orbit, and capsule recovery—a new production growth—began in August 1960. The approved total moved upward from 35 to 41, then to 44, 60, and 65 by July 1962. Of comparable or greater importance, Director of Development, Research and Engineering in October 1961 had authorized indefinite continuation of production to provide adequate numbers of Thors and Agenas for a variety of space projects.

(based largely on USAF Space Programs, 1945-1962)
Chapter 2
THOR ADAPTATION

In November 1955 the Department of Defense assigned the development of the Thor 1,500 mile intermediate ballistic missile to the Air Force. By the end of the year the Air Force's Western Development Division had solicited Ramo-Wooldridge to perform system engineering and technical direction. They had let a letter contract with Douglas Aircraft Company to develop the airframe, assemble the various systems, and test the entire package under the technical direction of Ramo-Wooldridge. With the backlog of experience gained during the early development of the intercontinental ballistic missile, and with the decision to use components and facilities under development for the long-range missiles, the BMB Thor development time was greatly lessened. In fact, just fourteen months after the contract award, flight tests began at Cape Canaveral, and they continued until February 1960 after 48 Thors had been expended perfecting the booster as a terminal complement part.

Actually the parts of the Booster which eventually came to be used in the Thor booster had gained considerable early experience in special country vehicle tests and other satellite launches.
For the intercontinental ballistic missiles the Air Force had let two contracts for development guidance systems. AC Spark Plug Company—a subsidiary of General Motors—was developing an all-inertial system and Bendix Western Electric's Bell Telephone Laboratories was to develop a radio-inertial system. Following the decision to develop the Thor there was

After the Thor became part of the Air Force missile development program, there was no immediate decision on which guidance system to apply to the short range missile. However, after a series of program changes ending in May 1958, the Air Force Ballistic Missile Division definitely assigned the AC Spark Plug system to the Thor and the Bell system to the early Titan combat squadrons.

However, the AC Spark Plug system would not be ready until flight tests in November, while Air Force planners had scheduled some Thor development flights between June and October to carry the Bell system.
The necessary ground equipment for the radio-guidance would be ready at Cape Canaveral and, since there was no interference with the AC Spark Plug system development, the Air Force allowed the schedule to stand.

Beginning in July 1958, there was a series of three launches from Cape Canaveral using the Thor as the first stage booster, but without a guidance system. All three were failures, but primarily due to instability in the propulsion system rather than due to inadequate guidance.

In the meantime, the Air Force Ballistic Missile Division was making plans for the first Thor-117L launches from Cape Canaveral. By September 1958, the division had definitely decided not to use any of the unproven guidance systems and to rely on the Thor's autopilot and electronic programmer. (contr -65, sup 15, amend 1, 29 Sep 58)

During 1957, the development of the AC Spark Plug system continued, and after all improvements were implemented, the system weighed 1,300 pounds.
But when this decision was made, the guidance systems were still under development. Developers gradually decreased the missile-borne weight of the satellite radio-guidance system, while the inherently heavy all-inertial system gained more weight. By the end of 1959, the operationally configured Thor guidance system weighed 1,300 pounds.

Bell had reduced the systems' weight to 110 pounds for use in four successfully guided reentry vehicle tests during 1959's first half of 1959. The same configured system was used in Titan flight tests beginning in February 1960. The Bell system also contributed to the successful launch of a Thor boosted satellite from Cape Canaveral on 1 April 1960.

At Vandenberg, as part of the Titan program, the Air Force had established two installations each with one radio antenna and computer. However, by January 1960 one of these installations was abandoned and consequently, the ground guidance equipment was transferred available for other programs.

By early 1960, Bell had made additional improvements in the airborne/ground station configuration of the satellite systems weighing 80 pounds. In order to improve and increase the reliability of the Thor booster's programmed trajectory, the division decided to use these systems in the Thor.
Propulsion

For the Atlas missile, the Rocketdyne Division of North American Aviation Company was developing the booster and two vernier engines with thrusts of 150,000 pounds and higher for each booster and 1,000 pounds for each vernier.

In early 1956, the Air Force directed Rocketdyne to adapt one of the booster engines and the two vernier engines for use in the Thor missile. Rocketdyne was to deliver the required engines to Douglas, who was responsible for their installation in the missile frame.

For flight tests Douglas received the first 150,000 pound-thrust engine in January 1957. During the following year, Rocketdyne made extensive improvements including an integrated start system and made them.

Douglas received the first flight-test engine in January 1957. The final operational configuration was delivered in November 1958.

However, during previous flight tests revealed some inefficiencies, particularly in the turbopump. Rocketdyne found solutions and incorporated them into another design engine.

This was used in flight tests starting in April 1959. As part of the available Thor Missiles, both test and operational boost Agents into orbit. Although the test weapon system program was eventually cancelled.
Contractors had proposed further engine development with a goal of increasing the thrust to 165,000 pounds. Although these 150,000 pound booster engines met the requirements of the Thor weapon system program, the space program were interested in a higher thrust engine. By April 1959, the Air Force Ballistic Missile Division established a requirement for a higher 200,000 pound thrust engine. Following static tests and three successful flight tests during January and February 1960, the improved engine—LR 79-MA-11—was available for use in Thor space boosters.

The Thor engines had been calibrated to burn RP-1 fuel, but in an effort to increase the payload capacity of the Thor-Agena, the division in mid-1959 decided to switch to the RJ-1 fuel. This fuel was developed for the National ramjet engine. RJ-1 was quite similar to RP-1 except that it was denser and had higher energy qualities. Captive tests using the LR79-MA-9 engine indicated that the fuel would increase the velocity of the booster by a matter of seconds, but a study of flight data in January 1961 showed that there had been no significant advantage in using the RJ-1 fuel. Nevertheless, the Air Force continued to use the dense fuel for Thor-Agena boosters and the Rockwell LR79-MA-11 engines for RJ-1 consumption.
Just prior to Sputnik, the Air Force headquarters had authorized a total production of 175 Thor missiles at a rate of two per month. If this program had been followed, the first operationally configured missile would not have been ready before November 1960. (STL final report DTM 16 Aug 58)

However, following Sputnik, the Air Force tripled its planned production rate, reduced the number of research and development type missiles, and set a goal of June 1958 for the delivery of the first operationally configured missile. By making these revisions the Air Force cut the number of missiles to be produced back to the bare essentials for the Thor program, a total of 117. (STL final report DTM 2 Dec 57)

On 6 January 1958, General Schriber appealed to the Air Force Chief of
Staff to reinstate 24 missiles a month in order to accomplish objectives not directly related to the Thor weapon system program.  

(1st 6 Jan 58) Such objectives included tests of reentry vehicles, early demonstrations of an intercontinental ballistic missile capability and possible space launches. Under Secretary of the Air Force Malcolm A. MacIntyre approved the additional missiles and authorized an increased production rate of eight per month beginning in November 1958.

(memo 31 Jan 58; TWX, 7 Feb 58)

Within another year and half, Washington authorities had allocated had a total of 64 Thors for "special purposes" and authorized a production rate of nine missiles per month beginning in February 1959 extending through September 1959, and then tapering off to four per month from 1960 through December when the last missile beginning in February 1960. (STL final rpt)

Since February 1958, the Air Force had planned on activating four Thor squadrons of 15 missiles each in the United Kingdom.

In addition, late in 1959, Washington had directed the Air Force Ballistic Missile Division to protect the capability of activating a fifth squadron with ten missiles. On 23 February 1960, the Air Force headquarters canceled this requirement, but had already most of the missiles had started to arrive at the assembly line. The division had to allow

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a minimum of twelve months for a Thor to pass through the line.

So, the division had another ten missiles that were available for space programs.

With the termination of development phase at the end of 1959 (except for engines), the Air Research and Development Command transferred the executive management responsibility from to the Air Material Command. The Air Force Ballistic Missile Division cancelled the system engineering and technical direction role held by Space Technology Laboratories, a subsidiary of Ramo-Wooldridge, that contracted with Douglas for system engineering, and retained the technical direction for itself. (Walter Daily, 3 Sep 59, 29 Oct 59)
For these early space launches, the Air Force had Douglas take a missile off the assembly line and modify, as necessary, to meet the required program. However, beginning in November 1959, technicians established a specification for a booster called Thor, which would be used. All operational modifications were processed.

This was known as the DM-21 missile frame. The principle difference between this frame and that of the operational configuration was that the AC Spark Plug guidance system was located a foot lower. The space programmers were not using a guidance system, so a long body was not needed and it improved the aerodynamic capability of the combined launch system. Since Rocketdyne's LR79-NA-9 and LR79-NA-11 engines were interchangeable with frame from one missile frame to another, the contractor could install the 165,000 pound thrust engine to meet program requirements.
In February 1960, the Secretary of Defense approved the
fiscal year 1960 research and development program. Air Force headquarters directed the Air Force Ballistic Missile
Division to produce fourteen more Thor to boost Agenas into orbit.

(TM 27 Feb 60, justify 16 Mar 60; TM 28 Sep 60)

Consequently the division was able to contract with Douglas to
begin production of the DM-2IS. However, the authority limited the
production to two per month, so the contract specified production would begin following the last missile configured Thor
and extend through May 1961. (Conr. -24)
During 1960, space program requirements continued at

to exist perhaps in larger degree than during the previous year.

By December 1960, Washington had increased %THEAMBER junk in Agana

flight from 24 in late 1959 to 44. In the meantime, if the Air Force

production line was to continue, Washington would have to authorize

additional procurement (TWX 27 Oct 60) Indeed Washington responded

with an authorization of four more %THEAMBER junk DM-21 boosters.

(TWX 28 Nov 60) After the %THEAMBER junk the Thor office had made presentations

to %THEAMBER junk the Air Research and Development Command headquarters,

the Air Materiel Command headquarters and the Air Staff, Warner

(1tr 12 Dec 60)

asking for permission to procure 48 more missiles. Washington approved

an additional procurement of 12 at a continued production rate of two

per month. This December authorization would keep the Thor assembly

line busy through February 1962. (TWX 30 Dec 60)

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During the ensuing months there was a constant struggle

between the Space Systems Division and Washington authorities over

the extension continued production of Thor boosters. The division

At first the division objected the low production rate of boosters,

because principally because the unit cost would

be higher and the confidence that there would be a demand for the

product. The division learned to live with the low production

rate but the real difficulty lay in the obtaining approval from

early enough

Washington approval on the continued continuation so as not to have a break in the production line. Otherwise the division feared that it would be costly in time and money to have to start the production line

and to know that there was a minimum of 15 months in advance of the

first delivery when the first booster would be first delivered.

In practice however, this lead time was more nearly ten months

due to the late approval of Washington authorities.

Washington did not want to approve the procurement

of more boosters until there would be a demonstration of using.

Using Thor was often in the program office in the space division could

not obtain adequate difficulty in obtaining program approval

in Washington including funds. (TMX 11 Aug 61)
The space division usually procured the boosters with reimbursable funds; that is, the Thru booster office would have an allotted fund for direct procurement and the using program offices would pay the Thru office at an established rate. (Maj Young interview 29 Jan 63)

The net result of this continuous dialogue between Los Angeles and Washington was that upon each request for authority to continue the production line there was a minimum requisition authorization. (TMX, 31 May 1961)
After urgent requests from the Space Systems Division, on 13 March 1961, the Air Force headquarters authorized the procurement of four additional boosters, on 30 March, six more, in September, three more, in October, five more, and in December, eight more boosters at the rate of two per month. Continuing booster production well into the middle of 1963.

TWX 30 May 61;
(1tr 14 Mar 61; TWX 30 Mar 61; TWX 6 Oct 1961; 1tr 13 Nov 61; contra-55 and -80)
When the San Bruno Air Material Area assumed executive management responsibility, the material area also assumed responsibility for the configuration control board. In November 1959, during 1958 and 1959, the Air Force was pulling missiles off the Douglas assembly line and modifying them to configure to the desired requirement; a standard was not appropriate.

But there was already the beginnings of standardization with the design of the DM-21 late in 1959. In August 1961, the Air Force approved a new acceptance specification applicable to those boosters coming off the assembly line beginning in March 1962. (hist rpt 26 Feb 62; contr -887)

The advent of the acceptance specification coincided with an effort to standardize the internal subsystems of the Thor booster.

The space Systems Division felt that standardization would reduce systems production costs, and increase reliability. An example of standardized efforts was the control electronics assembly which consisted of an autopilot and a computer.

The booster control electronics assembly had essentially been a modified missile flight controller, which required assembly modifications for the various missile booster configurations. (ltr 25 May 62)
In May 1961 the division determined that the electronics assembly needed standardization. In response to the division's request, Douglas provided the Air Force with a prototype. The contractor then modified the assemblies in stock and before undertaking the manufacturing of any new ones. (ltr 20 Jul 61; contr 9887, amend 1, 24 Jul 61; contr-887-80, 5 June 62)

By mid-1962 the division had completed standardizing most of the subsystems which the division thought should be changed.

Even after these modifications were incorporated into the standard booster, some differences would continue to exist. These result from the use of various second stages which differ in their dimensions, and methods of firing and separating, and the location of the guidance systems. (First rpt 26 Feb 62)

However, the idea was to be able to support as many programs as feasible with as few changes as possible.
The Space Systems Division felt that in order to establish a standardized process, a configuration control board was necessary. In April of that year, the division established such a board consisting of representatives from the National Aeronautical and Space Administration, each Space Systems Director and having a direct interest in Thor space booster configuration, and appropriate Air Force Plant Representatives. (ltr, 2 Apr 62)
From Missiles to Boosters

Originally the Thor intermediate range ballistic missiles were no longer needed and would gradually withdrawn from England.

DDR&E directed that these SM-62 75 missiles be converted into DM-21 boosters at Douglas' inactive plant at Tulsa. Space Systems Division negotiated a contract with Douglas for the conversion of the first squadron (15 missiles) and work began in November. San Bernardino Air Material Area was responsible for the refurbishing of the RB-1 MB-3, Block I engines. The boosters were to be converted at the rate of two per month with the first completed late in February 1963. Space Systems Division estimated that the modification of each booster would be $275,000.

(Notes, FSSD program review, 14 Nov 62)

The Space Systems Division had estimated the average price of new boosters procured under the Air Force letter contracts since 1 January 1960 at $192,000 (based on letter 30 July 1962; this is the price paid to Douglas at Santa Monica, Calif. for助推器, 指挥设备, BTL guidance units, or Douglas launch services.)
This announcement was the beginning of the end of the Thor as a ballistic missile and the future use of Thor exclusively for space purposes was on the horizon. In retrospect, the transfer of executive management responsibility from Los Angeles to San Bernardino may be considered a watershed in Thor history.

Before that date, were under contract for development tests, operational squadrons, and crew training launches, while only 7 had been earmarked for use as first stage boosters for reentry vehicle tests and space launches. During this early period, the Air Force had the missiles frames modified for what was, at that time, "special purposes", but beginning in 1960, all Thors placed on contract were assembled as a booster, in most instances meeting the specifications of the DM-21, sometimes called the Standard Launch Vehicle.

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Chapter 3

AGENA DEVELOPMENT

The fact that the Air Force had designated Lockheed Aircraft Company as prime contractor for the l7L program did not mean that Lockheed was to perform research and development, design, manufacture and test of the many system components. On the contrary, the Air Force expected Lockheed to procure/produce parts including entire subsystems from capable and experienced firms who performed tests on their product before delivering it to Lockheed. These subcontractors were to deliver the tested hardware to Lockheed which in turn would integrate the components, subassemblies and subsystems into an integrated upper stage and would be responsible for the system tests together with those of the subcontractors. (ltr 23 Sep 57)

During 1957 someone conceived off the Santa Cruz Test Base, a Lockheed property for research and development vehicle, propulsion and component testing. In a fortuitous coincidence, someone conceived of the idea of acceptance firing of a missile there, thus requiring additional equipment and instrumentation. (ltr 11 Apr 60)
Eckheed produced the early flight test vehicle in various locations.

The contractor fabricated components at the Van Nuys plant, assembled the vehicle at Sunnyvale, installed and checked out subsystems at Palo Alto, before shipping the vehicle for engine firing and system checkout at Santa Cruz. (Prog rpt 31 May 58) (Mar 59 Q)

The Air Force planned that Lockheed's 600-acre tract north of Santa Cruz be used for static firing and a complete systems checkout of the entire vehicle. (Prog rpt on Santa Cruz) The Air Force completed 2400,000 in situ static firings in 1958. Workers completed the components test laboratory in April 1958 and finished the two static firing test stands and blockhouses. (Prog 3 atus rpts, 15 Apr 58, 30 Aug 58)

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Early in planning for the program, a decision was made to fabricate two propulsion test vehicles. Two failures occurred in September 1958, minor ones.
For the first flights, vehicles were sent to Sunnyvale for further checkout, then to Vandenberg where in an assembly building the vehicle went through further checks, and then still further checks on the pad prior to launch. During 1960, the Air Force Ballistic Missile Division made an effort to cut down on some of these xex checks and consequently expenses.

These procedures were not only expensive but also costly. The division attempted to reduce the need for the checkout procedures at Vandenberg assembly building and at Santa Cays.

During this period of time, the biggest obstacle in accomplishing a cut back in testing and checkout procedure was the simple fact that no two vehicles were alike. However, during this period Lockheed was able to produce a series of vehicles which were alike, therefore only the first

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of a series needed to be tested at Santa Cruz. (1ir 12 Dec 60)

In addition the extensive checkout of the vehicle at the Vandenberg assembly building was eliminated. ((16 June 1961)

The various Air Force program offices usually installed their payloads in the Agena in the assembly building.
Following the award of the 117L contract to Lockheed Aircraft Corporation, the prime contractor began making design studies for the second stage satellite vehicle, including the necessary subsystems. and casting about for possible subcontractors to develop these subsystems. Lockheed concluded that perhaps a pump-fed propulsion system would be technically the best, but稳妥/other considerations such as the availability of a particular engine and the competence of the particular firms producing the engine, should be considered.

(L 31 Jan 57, p 5-6)

The Bell Aircraft Company had been developing a turbo-pump rocket engine for the air-to-ground missile which would be carried by B-58 Hustler aircraft then under development. By March 1957, Lockheed with the concurrence of the Air Force, selected Bell's IR-51 engine as the basic propulsion unit for the 117L's second stage. (Wkly Diary, 28 Mar 1957)

Later, during the year the Air Force cancelled the missile portion of the B-58 program, a Western development project worth about $570,000

*(As part of the B-58 development program, Bell had been a subcontractor under Convair at Ft. Worth)
The **LR-81** engine consisted of a single thrust chamber, gas generator, including starting solid propellant charge (allage rockets), turbine driven pumps, propellant control valves, and auxiliary equipment to start operate and shut down. (LJ 50-59 56 pp 17-20; Two 3 Apr 57)

Without referring to the ballistic missile program, the only selected engine was the only available with a turbopump feed system and within the required thrust range. The LR-81 engine had a thrust rating of about 15,000 pounds. Engineers made sure the control system without an additional system. The engine burned JP-4 fuel when combined with the oxidizer inhibited red fuming nitric acid. (RDB Proj Card, DD Form 613 Propulsion Subsystem, 2 Apr 57)

From the B-58 design, for the B-57 engine, the engineers made only a minor change to increase the propellant burning time from 65 to 100 seconds.
During 1958 Washington changed some of the flight objectives although the principal ones, satellite vehicle and ground communications, remained the same. The development of visual reconnaissance including film recovery, was replaced with the development of a recoverable capsule and the collection of geophysical data for research purposes.

In March, the directive said that the new requirement would become effective with the fifth flight, however, before the end of the year it had been changed to be effective beginning with the third flight. In order to meet the new objectives, the satellite vehicle would have to maneuver with a heavier load than had been originally planned.

(30 Jun 58/Dic 58 Q)
Meanwhile, contractor engineers had been studying the possibility of improving the propulsion system in order to carry a heavier payload in flight. (L Jan-Mar 58, p 2-9) In March the Air Force directed Lockheed to proceed with the necessary work to change the propulsion system design and the fuel.

Lockheed engineers recommended a slightly heavier and higher energy fuel. Technically decided to use unsymmetrical dimethyl hydrazine.

In addition, the relative size of the combustion throat and injection mouth would be increased from approximately 1 to 15 to 1 to 20. (L Apr-June 58, p 2-39; Wkly Diary, 27 Mar 58) (15 Apr/rpt)

A slight increase in the size of the fluid tankage and a rearrangement of the plumbing resulted in a slight lightening of the overall airframe. (Jun 58 rpt; L Apr-Jun 58, p 2-25)

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For ground tests, Bell delivered two engines to Lockheed in March 1958. By June, technicians had mounted them on the newly completed propulsion test assemblies. The entire propulsion system composed of prototype components underwent generally successful hot firing tests. At the same time Bell was conducting a series of flight rating tests at its own plant. The tests at both locations were completed by August, but Lockheed continued testing the propulsion assembly's plumbing with the fuel and oxidizer throughout the remainder of the year.

In June 1958, Bell shipped the first two flight test engines to Lockheed at Sunnyvale. Lockheed assembled the engines within the phar, subsystems, and components, discovering the first step in flight test vehicles. Following modification and checkout, the test vehicles arrived at Santa Cruz. At the base, the two vehicles successfully passed the hot firing tests with all flight equipment installed and operating. As a result, the vehicles were deployed to Santa Cruz, and shipped to the West Coast for testing before flight, hopefully before the end of the year.
Technicians erected a prototype propulsion system and began flow tests with the new fuel. Performance was within specifications and therefore Bell completed assembling the first unsymmetrical dimethal hydrazine flight engine and delivered it to Lockheed in September 1958. Although propellant temperature variations were initially troublesome, Bell solved the difficulty and then began rating tests. The new engine designated IR81-Ba-5 was rated at 15,600 pounds of thrust compared to the J5-9 engine with 15,950.

In addition, the new engine could burn almost twice as long, 120 seconds, compared to 64 for the old. (Mar 59) By September 1959, Lockheed had incorporated the new engine into fourteen flight vehicles.

There were in turn shipped to Santa Cruz, pre-acceptance testing of satellite vehicles continued with hot engine firings, inspections, and functional component checks. After incorporating any engineering changes, the Air Force accepted the vehicle. (Sep 59)

ROUGH DRAFT
Early in 1959, developers began changing the satellite propulsion system to such a degree that the end product was known as the Agena B. 

and the previous configurations, by way of contrast, the Agena A. useless. 

Agena A engines were do/ded once the propellant was extinguished.

but technicians began working on a scheme whereby an engine could be 

restart in response to a signal from the ground. The concept originated 

consierably than the current Thor-Agena combination was capable. 

when a program needed a higher orbit capability. In addition such an 

engine would permit the change from one established orbit to one which 

is lower or higher. [AFRD ID Space Apr 61]

By the first of March 1959, the Air Force Ballistic Missile Division had set July 1960 as the goal for the new engine's first flight test. The Advanced Research Projects Agency approved the development on April 1, 1960. It also decided that the propellant capacity be increased. By August engineers had decided that tanks 

with double the Agena A capacity would be the best with both Thor and 

In order to accommodate the new capacity, designers added six feet to the length cylindrical mid-section of the Agena. When applicable 

Atlas boosted flights. Engineers used components and materials proved 

tank in the Agena A and subjected the new design to similar ground tests 

such as including vibration and centrifuge tests. In addition, Liquid 

build a new propulsion test tank at Santa Cruz incorporating the new design.
Early in the year the Air Force Ballistic Missile Division had determined that the restart engine test would be conducted at Arnold Engineering Development Center as well as at Bell's facilities. Tests at Arnold would include those in the high altitude chamber. (Jan 5)

Necessary testing on the new engine called LR-81-Ba-7 had already begun by the time the Advanced Research Projects Agency issued formal approval and in September 1959 Bell shipped one engine to Lockheed for testing at the new propulsion test assembly.

By March 1960, Lockheed had received all flight engines of the new configuration, had completed tests of the propellant tank design, and had shipped the first assembled Agena B to Santa Cruz for tests. During the Santa Cruz tests certain difficulties had to be overcome including a failure of the propellant valve. Before Air Force acceptance, technicians had to rework three engines and repeat the system tests. Under different circumstances, Bell began an extensive series of reliability tests which would have imposed, but due to the limited number of flights which would employ this particular engine model, 1960 by June the Air Force had decided to stop further testing. (Jun 60)

Nevertheless, tests had confirmed that the LR-81-Ba-7 had the same thrust as the previous Agena A model—the LR-81-Ba-5—but with twice the burn time—four minutes. (Sep Mar 60)
The limited number of flights scheduled for this radically new model was that engineers had been concurrently improving the capability of the Bell engine by another approach. The approach was to increase the relative size differences between the throat and the mouth. In July 1959, the Air Force Ballistic Missile Division authorized Lockheed to proceed with such improvements in the IR61-Ba-5; however, in March 1960, the first dual restart engine—IR61-Ba-7—was undergoing acceptance testing. At that time the Air Force directed that no further effort be expanded on improving the Agena A model, but apply that work toward improving the new restart engine.

After several months of testing, the Air Force specified:

As of the new model, the size differences, the greater the speed across the throat and the greater the force exerted against the nozzle extension.

At Bell's facilities and at the Arnold technicians tested nozzle extensions made of graphite, steel, and titanium. Titanium proved successful for the expander but the throat region. The erosion was curtailed by coating the throat with hard materials such as Zirconia. Testing and evaluation of throat coatings continued into June.
In September, technicians completed the preliminary flight rating tests without appreciable nozzle throat erosion (MSR 4 Nov 60). The new LR81-Ba-9 combined an increased thrust—16,000 pounds with the a restart capability. (AFHMD Space Apr 61)

Earlier in the year, Beal had shipped an "expanded nozzle" engine to Lockheed for testing in the propellant test assembly at Santa Cruz.

Hot firings of the Ba-9 were in progress during February and March 1960 at Santa Cruz. This series consisted of nine firings including several restarts. One of the prime objectives was the testing of a fuel-powered hydraulic system to gimbals the engine which performed satisfactorily (Feb 60; Mar 60)

In orbit the restart of a gimballed engine would propel the vehicle into another flight path.

ROUGH DRAFT
Although technicians were not completely satisfied with test results, Bell shipped the initial "expanded nozzle" engine to Lockheed (June 60).

In June 1960, after being assembled with the other airborne components and tested at Santa Cruz, the Air Force accepted the vehicle in August 1960. (Aug 60)

In order to further test the engine's reliability, technicians continued tests at Bell's facilities and at Arnold.

At Bell, the engine was tested in various positions and under unusual vibration frequencies. The use of a fuel with a high solid content tested the skin temperature of the thrust chamber.

At Arnold, tests simulated altitude and temperature conditions in which the engine would operate in orbit. The Air Force considered the reliability tests as having been completed in April 1961. The tests demonstrated an engine operational life far in excess of the specified requirements. (Apr 61; May 61)

ROUGH DRAFT
Chapter 1

LAUNCH, FLIGHT, AND RECOVERY

America's military services were using Cape Canaveral for missile flight tests and spade programs and the Air Force had originally planned to launch I17L satellites from there.

Following Sputnik, not only did the Department of Defense authorize the use of Thor as a booster in the I17L program, but also approved peacetime I17L missile launches from the West Coast at Cooke Air Force Base (later renamed Vandenberg) (TMX 23 Nov 57).

The Air Force had selected the base for the first operational intercontinental ballistic missile forces, but with permission for peacetime launches the Air Force could use the base also for complete integrated weapon system tests and combat training launches of both intermediate and intercontinental range. Also, early in 1958 the Air Force decided that Thor booster I17L satellites should be launched into polar orbit, and considering overflight hazards, a southward launch from Cooke would be the best procedure.
At Cape Canaveral, the Air Force had reserved an area near the ocean for Thor launch installations. At first, the Air Force planned for only one launch complex consisting of a launch control blockhouse and two launch emplacements or pads. As program requirements increased, the Air Force added a second complex, and then upon the "polar-orbit" decision, a third complex was added for the I17L.

The Air Force designed the first two complexes for test and training activities including the launch of missiles in a westerly direction. The third complex was designed to launch the two-stage combination southward in a direction outward.

As the Air Force's construction agent the Corps of Engineers had begun work on the first Thor launch facilities in the fall of 1957 and as decisions were made in regard to the other facilities, the Corps' activities expanded. Like the I17L program, the Thor weapon system program required a West Coast launch emplacement; one in the Cascade Range in the area of the test complex and one at the I17L complex by the needed intake and other installations. The Air Force accepted pad 4 and the blockhouse from the Corps of Engineers on August 21, 1958, and the installation was completed.
In the meantime, ground equipment for pad 4 had been arriving at the base since May and workers began deploying the equipment as soon as the area was clear. (Wkly Diary 22 May 58)

About the same time the corps had completed separate facilities. Air Force contractors began installing necessary equipment in them.

Thors, after their arrival at the base, were emplaced on the launch pad. Air Force contractors installed maintenance and checkout equipment. The first vehicle arrived from Lockheed in November 1958 and Thors began to arrive for both missile program purposes and space launches.
In the meantime, Air Force teams were wandering around the United States and the Pacific Ocean choosing sites for satellite 
data acquisition stations. The Air Force chose sites and had facilities and equipment at points in Hawaii, Alaska by August 1958 (Terhune files, installations) 22 Aug 58.

The Air Force decided that more data and tracking stations were needed in the areas of the United States, northeast, central, and north east. These stations gradually came into operation. Fort Stevens was approved for the northwest, O\textendash tussa Naval Air Station, Iowa for the central, and for the northeast at New Boston, New Hampshire.
To gain as much information as possible about the hardware behavior on each flight, the Air Force utilized one or two ships equipped with special telemetry equipment. The ships were located where the need for certain type of information was greater on some flights than on others and the ships maneuvered to the locations where the need was greatest. On the early flights the Air Force primarily was concerned about getting an Agnesa into a suitable orbit. Later the Air Force were.

After orbital injection seemed to be mastered, the Air Force became increasingly concerned over the ejection of the recovery capsule.

To gather information on orbital ascent, a ship was located downrange about 1,000 miles. To gather information on ejection and recovery procedures, ships were located between Alaska and Hawaii.
Due the many tasks that needed to be performed, contractors began preparing for a launch several days before the scheduled lift-off.

Among these tasks were the transportation of the first and second stages from their respective checkout facilities to the launch emplacement.

They were mated together in a horizontal position, but before the crew did so, they had to secure the engine(s) of the launch vehicle. At best, procedures for a launch lasted from more than seven hours. Preparations for the launch usually began in the pre-dawn hours when the crew mated the recovery capsule to the Agena and raised the Thor-Agena to an erect position. For several hours the crew frequencies, makes umbilical connections including the propellant lines, warms up electronic equipment, loads the propellant tanks with fuel, checkout guidance and flight control systems.

The last 15 minutes were devoted almost exclusively to the Thor.

When the missile automatically passes through a sequence of fueling, calibration, armament of the and miscellaneous. However, in case of a technical malfunction or an unexpected event, the procedure may be repeated. However, any case, a countdown may be held up until the the last five seconds before lift-off; the countdown may be held for technical reasons, to allow a train to pass, or due to inclement weather.
Workers had reused pad 4 for the first launch and had assembled a modified Thor and Agena for a launch on 21 January. During countdown procedures smoke began to rise while explosions occurred in the Agena.

Launch personnel cut off the power immediately. Ignition of the upper rocket's igniters and safety circuit failed.

The upper rocket had accidentally fired and triggered off internal mechanisms, causing serious damage to both the first and second stages.

Following removal of the hardware from the pad, technicians determined that the Thor could be rehabilitated but the Agena was not worth rehabilitating. Technicians investigated the accident to determine in detail the causes so corrective measures could be taken prior to the next countdown. (mc rpt Jan 59; L vol 3)

ROUGH DRAFT
Two weeks later, technicians gave the next Agena a completed systems check test in the assembly building on 4 February and then transported the vehicle to the launch pad. The launch crew mated the Agena to the Thor and conducted a practice countdown on 19 February.

The crew made an attempt to launch the combination on 25 February, but after twelve hours of countdown procedures, the managers decided to postpone the launch. So that Thor's corrections could be made in the liquid oxygen tank pressurization system. A second attempt was successful on 28 February.

When the Thor-Agena combination zoomed off into the midday sky, the Thor rolled into a southerly direction. As programmed, the Agena separated from the booster and began polar coasting in orbit. Radar at Vandenberg and Point Mugu and telemetry tracking equipment at Vandenberg received signals from the Agena for more than eight minutes after liftoff. Although ground equipment did not confirm this, Air Force observers in the Pacific area, sporadic signals acquired on later passes showed that the vehicle was in orbit. The Air Force considered this launch as a success. (sec rpt Feb 59; L vol 1)
By February, the Hawaiian Control Center was prepared for recovery operations. (Mo rpt Feb 59, vol 1)

In order to allign a flight with the current Thor-Agena Program, the Air Force decided to consider the January abortive countdown as the first flight test. Since the program specified without recovery capsules, only two JPeR-2 propelled Agenas, the next flight would include a second stage propelled which would burn unsymmetrical dimethal hydrazine/(Q rpt Mah 59). This time the crew launched an Agena into orbit at the end of the first countdown. Immediately after Agena engine burnout the satellite stabilization and guidance system operated a series of small gas jets which caused 180 degrees the vehicle to turn in a horizontal plane, and that the satellite was floating in orbit with engine in the forward position and the recovery capsule was in the rear. The new position was in preparation for the seventeenth As you turned and from the earth the satellite nose would tilt 60 degrees downward to permit the ejection of the reentry minisat capsule. Telemetry data showed that that control and station equipment operated properly.
The Air Force has established a ground-communication system after computing the orbital period around the earth so that a northern tracking station could adjust the timer to the time when the timer would activate on the seventeenth pass. The timer would react at the correct moment so that the recovery capsule would be injected in the predicted area.

However, the Agena had gone into an orbit of low velocity which caused the orbital period to much shorter than expected. There resulted some confusion in the ground tracking station and the ground command made an error in resetting the timer.

The reset error, introduced into the satellite timer from the ground, made it impossible to adjust capsule ejection to permit impact within the planned recovery area.

Automatic ejection took place. Based on the automatic ejection, technicians calculated that the capsule would impact near the Norwegian coast at the edge of a sea-ice area, northwest of both air and ground American and Norwegian forces failed to find the capsule although local observers had sighted what was thought to be descending parachute and foil chaff.
Telemetry and radar equipment installations in the
earth's atmosphere continued to operate extremely well through the twenty-fifth
pass which was about one and half days after launch. A continuous
receiver beacon emitted signals for another week and following visual
sighting reports of visual sighting continued until 25 April
when the Air Force estimated that the satellite reentered the earth's
atmosphere and burned up.

In the meantime, the Air Force took steps to prevent
an ejection from taking place above the warning geographic area. Tracking procedures were revised
beginning with the fourth flight and the vehicle timer was replaced by a more sophisticated one
manufactured by Fairchild. (Q.rpt Jun 59 no.rpt op.)
On 7 May 1959 the first and second stages were moved from their respective housing and checkout facilities to the launching pad where mating and complete systems checkout occurred.

In addition, the Air Force installed a Mark I recovery capsule on the top of the Agena. However, the combination was on the pad for several weeks due to several abortive countdown sequences. These delays were caused by technical difficulties, two in the Agena and one in the Thor.

Finally, on 3 June, the crew completed a countdown with a launch which was to end in total failure. The launch itself, ascent, vehicle separation, Agena coast, and engine boost were accomplished as planned. However, the 1801-99 engines shut down prematurely and the vehicle fell to fail to achieve the required orbital velocity.

The second stage fell into the Pacific south of the equator.

Three weeks later, the Air Force conducted a similarly configured combination without an unnecessary abortive countdown.

However, the results were as heartbreaking as the previous one. Due to two seemingly similar failures of the Agena and the result, the Air Force
Ballistic Missile Division postponed the next scheduled flight and initiated investigation of the failures. Studies showed that an increased performance could be obtained by an increase in increase in the rate of injection and thrust

Technicians had first believed that the engine had shutdown prematurely; however, this postmortem investigation revealed that in both flights the satellites had not achieved sufficient velocity at the time of second stage burnout to obtain an orbit.

The Air Force approved several actions taken in order to improve the situation.

Lockheed reduced the weight of the Agena by 46 pounds by removing desirable but not essential equipment and instrumentation.

The air speed was hoping that the Thor velocity could be improved by increasing 100 feet per second with the use of RP-1 fuel instead of the standard EJ-1. In addition, the Air Force directed that the launch azimuth be changed from 150 degrees to 170 degrees. This change in more easterly direction would take advantage of the earth's rotation and increase the Agena speed.
adjusted for the new direction. Launch emplacement number 5 had been used for the fourth flight launch, so with two pads available for space launches.

The fourth flight launch

The Thor-Agena combination had been waiting on launch pad #4 for several weeks before final launch on 13 August. There were a total of six postponements, four times due to poor weather conditions, and a fifth due to a Thor engine ignition failure. Finally on 13 August the crew launched the Thor-Agena into the sky and after separation the second stage achieved an orbit. Tracking and data acquisition at all ground stations was excellent this time.

A Thor-Agena had been installed on pad #4 and the crews did not experience such bad luck, only one of six postponements, the sixth flight, was due to separations. Agena, only six days following the order. Tracking and data acquisition was generally good at all ground stations except Point Mugu and Vandenberg where radar interference was experienced.
On both of the August flights all objectives were achieved except for Kodiak and Hawaiian capsule recovery.  On both flights data from tracking stations indicated that capsule ejection occurred between the two, therefore near the planned point.  However telemetry from the fifth flight indicated that the capsule temperature was lower than expected and a failure prevented the parachute-opening mechanism from operating.

On the sixth flight difficulties with the command-timer-adjustment sequence delayed the capsule ejection 360 miles south of the planned point.  During the flight the recovery forces were deployed properly in relation to the expected impact point.  But due to the last minute changes only aircraft were able to reach the revised impact areas.  Before the capsule would normally sink beneath the ocean waves. The forces only received scattered radar signals from the fifth flight's capsule and nothing from the sixth flight's.  (mo rpt 31 Aug 59)

ROUGH DRAFT
August

Due to the failures of these two recovery attempts, the Air Force postponed additional flight until detailed evaluation and testing of the entire recovery system could be made.

In order to allow for improved retro-rockets to be incorporated in the next flight/configuration, the Air Force delayed the
launch until 3 November. (nxmo rpt, Oct 59)

However, abortive countdowns delayed a launch for actual four days. The launch and orbit acquisition was a complete success but between that time and the first pass over Alaska, the Agena's battery auxiliary power supply failed, inactivating the guidance system.

The power failure. The operation of the guidance system, the horizon scanner and gyro stabilizers, depended on that power, so consequently crews also found it impossible to activate the vehicle began to tumble. By the second pass the recovery capsule ejection sequence was not triggered.

Two weeks later on (51), technicians successfully
placed an Agena into orbit without the
launched the eighth Transit. This attempt was not moved
proceeding because without any abortive countdowns. (MBP Q Dec 59)
However, the Agena ascended into orbit at a greater speed than
called the accelerometer-integrator
 programmed. Lockheed had installed a mechanism designed to cut the engine off when the
vehicle had reached its programmed speed. In this instance the
accelerometer failed to perform the necessary required task.

The result was an eccentric orbit and exceptionally
time to circle the earth, 165.4 minutes, to
The result was that the Agena followed an eccentric path and took
an exceptionally long time to circle the earth, 165.4 minutes, to
be exact. The 104-minute period exceeded the vehicle's timer's
possibilities to react to earth bound adjustment commands. (L vol 1)

In addition, the eccentric orbit confused the
vehicle's guidance and control system resulting in the premature
exhaustion of the control gas. The result was that the
vehicle was in an improper attitude at the time of capsule ejection.

(MSP D Dec 59)
Some improvements in the vehicle components delayed the launching of the next Agena for over a month. (NSF Q Dec 59)

The actual liftoff was delayed by several abortive pad 4 countdowns. Finally on 4 February the Thor-Agena soared upward and arced southward, but the Thor's main engine prematurely shut down resulting in the booster velocity being 1,000 feet per second less than normal at the time of Agena separation. In addition, the Agena's engine shutdown prematurely because of a malfunction in the helium pressurization system.

Neither of these mishaps would have prevented the vehicle from achieving orbit within two weeks. Undaunted, the Douglas crew launched another Thor-Agena, this time from pad 5. The countdown was smooth and the launch was made from the pad. However, immediately after lift-off the Thor began to oscillate and the range safety officer pushed the electronic destruct button. (NSF Q Feb 60; I vol 2)
Two simultaneous explosions occurred within the hardware verifying that both the Thor and the Agena destruction systems were operating. Some of the resulting debris fell close enough for recovery and examination. (NSP Q Feb 60)

The next launch had been scheduled for mid-March but the Air Force delayed the flight for a month in order to survey the situation. Again from pad 5, the Douglas crew launched a Thor-Agena combination into the sky, again at the climax of only one countdown. But this time the Agena went into a very satisfactory orbit. The battery auxiliary power supply lasted through the twenty-sixth orbit and attitude and control system functioned extremely well, resulting in excellent satellite stabilization. Telemetry indicated that the recovery capsule reached climax in the twelfth pass. But that the re-entry trajectory was probably too high since spin rocket firing was not verified. This was the first orbiting Agena to carry a dual-frequency doppler beacon and four optical tracking lights. The accuracy of the radar system could be tested.
As a result of the recovery failure, the Air Force made a greater effort in the testing of the re-entry system. The Air Force was initiated a program to test all the components. (MSP Q May 60).

An attempt to launch the Thor-Agena space system occurred the twelfth time on 29 June 1960. After some minor technical delays, the spacecraft blasted off into the afternoon sky. The Thor and then the Agena operational sequences were normal through the cutoff of the second stage engine. Nevertheless, the vehicle failed to achieve orbit. Telemetry and the vehicle investigation showed that the vehicle was in an improper attitude during engine operation causing the vehicle to reenter the atmosphere due to a malfunction in the horizon scanner. (no rpt June 60)

Subsequent investigation showed that the satellite telemetry transmitter interfered with RF and prevented the horizon scanner to perform properly. (MSP Q Aug 60)
The thirteenth liftoff from Vandenberg occurred on 10 August 1960

at the climax of one countdown attempt.

All events occurred as programmed.

Thor trajectory and speed were within the limits of toleration
and the Agena performance was very close to that which was programmed.

Following the burn out of the Agena engine, the vehicle reoriented
itself into a nose aft attitude. On the seventeenth pass
over the Pacific
orbit, 26\frac{1}{2} hours after launch, the Alaska tracking station verified
that the satellite had pitched down, and capsule had landed
that is there was a capsule ejection, spin, retro firing, capsule de-spin,
and thrust cone ejection.

ROUGH DRAFT

All aircraft and ships of the recovery force that arrived
the capsule's radar beacon began moving toward the signal.

One aircraft C-119 saw the capsule hit the water relayed
the scene.

With the help of a frogman, the helicopter was able to retrieve
the capsule from the choppy waters and returned it safely to the
mother ship. Subsequently, the capsule was delivered to Washington
for public view as a historic object, the first man-made object
recovered after a sustained period in orbit. (MRO Aug 60; SEP Q Aug 60)

After this exhilarating experience, the launch crew threw
another ** into orbit. Actually at one point the
** countdown stopped for fifteen minutes while the
vehicle passed through the projected flight area. The Thor and
Agamemnon
performance are as programmed until on the first pass over the
Alaskan station, telemetry data indicated that the satellite was
in an ** abnormal attitude. However, the satellite stabilized
itself on subsequent passes. While on the seventeenth ** orbit the
satellite programmer automatically initiated the recovery sequence
** over the North pole, and the capsule re-entered the atmosphere
over the Pacific, and deployed **. At the aircraft, one of the
recovery force's, homed in on the capsule's CW beacon signal and
visually sighted the capsule. On the third pass under the capsule as
it plumbed toward earth, the rear hooks of the special air-recovery
gear snagged the nylon line. The crew carefully re-winded in the chute and
capsules...ans stored them aboard the aircraft for return to the states.

The recovery of these capsules gave the contractor, General Electric, a chance to examine the effects of an actual reentry.

(mo rpt, Aug 50; MSP Q Aug 60)

After a month's pause, another Thor-Agena soared into the muggy mid-afternoon sky, rolled to the mouth, the Agena separated and ascended into orbit a polar orbit. This launch was the sixth consecutive one to require only a single countdown. (L vol 3)

Telemetry data on the first pass over the Pacific indicated that the vehicle was stable in the programmed attitude but that the control gas consumption was excessive. On the seventeenth pass the vehicle ejected the capsule, but because of the gas depletion, the vehicle's path downward did not coincide. As a result, the capsule reentered the earth's atmosphere and descended into the choppy waters of the Pacific about 1,000 miles south of the planned impact point. Nevertheless, recovery forces were able to reach the scene.
The Hawaiian station tracked the capsule until the atmosphere's ionization particles enveloped it.

From the satellite tracked path, the computer revised the predicted impact point toward aircraft and one recovery ship rushed to the point. The aircraft in the area picked up the capsule's radio signals and a second aircraft sighted the capsule bobbing up and down in the water. The aircraft dropped marker beacons, strobe lights, smoke bombs, and aluminum dye to mark the area. The next morning a Coast Guard amphibian arrived but did not land because of rough seas.

Because of the worsening sea and weather conditions plans were abandoned to drop paratroopers and a raft. The capsule began to list and ride low in the water. By afternoon disappeared from sight. (MHP 9 Aug 60; mo rpt Aug 60)

ROUGH DRAFT
During 1960 both Douglas and Lockheed had improved their respective products and subjected them to flight tests beginning on 26 October 1960. Prior to countdown workers had to modify some of the ground support equipment, particularly for the Agena. The Agena was six feet longer while the Thor was five feet shorter, so making the combined length a foot longer than the old combination.

The morning countdown was normal and the new combination lifted off the pad at noon and rolled into southward as programmed. The DM-21 performed but instead of separating from the Thor and ascending into orbit the Agena plunged back to earth with the booster satisfactorily except the vernier engines shut down when the main engines ignited. Normally the vernier engines began to cut in before the main engines. A malfunction in telemetry showed that the Agena timer failure prevented separation mechanisms to operate properly.
A chance to dispel the gloom cast by the ignominy fate of the first Agena B flight was at hand on 12 November. Axxequipment at the pad forced a hasty cancellation for the precarious day.

After a one day delay due to technical difficulties with pad equipment, the Dm-21-Agena B combination zoomed into the upper reaches of the atmosphere and after turning southward, reprogrammed the Agena successfully separated itself from the booster and ascended into orbit. The ascent was satisfactory except that the injection altitude was slightly lower than programmed and the orbital period was consequently 2½ minutes longer than planned. Extra batteries for auxiliary power and additional xenon gas for attitude control in the Agena B design inhibited the Air Force to make plan for delayed capsule attempts recovery operations. Previously, all recovery operations were planned within a day of launch. Now, many attempts could be considered for as long a delay as four days. Consequently, the flight plan called for a recovery on the thirty-three orbit which would occur in daylight hours over the desert.

The extended satellite period had little effect on satellite operation or the recovery except to make the next alternate pass, the thirty-first more desirable than the following one.
After nearly 51 hours in orbit, capsule ejection sequence was near normal and recovery forces were scattered in the predicted impact area. A C-119 aircraft made initial contact with the capsule's transmitter, Pelican II, and a few minutes later another craft spotted the parachute and capsule descending through the air. On the second pass under the falling apparatus, an aircraft successfully snagged the payload. (no rpt Nov 60; MSP Q Nov 60).

Although the two flights tested the new configured hardware provided by Douglas and Lockheed, neither the RBM-21 nor the Agena B had the engines. The Air Force planned flights using the higher thrust engines, following four flight tests using less advanced engines, following four flight tests with the older/models. However, by December 1960 the higher thrust configurations were available and due to payload considerations, the program director decided to intermingle the use of the higher thrust engines with the lower thrust ones. So, on 7 December the contractor's crew launched the first space mission propelled by the Rocketdyne's MB-3, Marauder III and Bell's M-114 E-1 engine.

ROUGH DRAFT
Lockheed considered the flight first high-thrust flight the most successful operation at least to date. (L vol 3)

Liftoff and booster operation was normal. The main engine cutoff when the configuration was travelling southward at 11,080 feet per second, 46 miles above the earth. The Agena engine ignited as programmed and burned for almost 295 seconds, providing a velocity of 25,900 feet per second as it went into orbit. The resulting orbit had a 380 mile apogee and 133 mile perigee and a period of almost 94 minutes.

All systems operated satisfactorily, and after a lapse of three days and on the forty-eighth orbit, the Assertix satellite successfully ejected the capsule. All elements of the recovery force were at their prescribed locations when the parachute opened, and a C-119 aircraft snagged the falling package on the first attempt.

Subsequent to capsule ejection, the ground signals reoriented the Agena to the normal orbital attitude. Telemetry recorded a stable attitude-on-orbit for the next two days when the Agena's electrical power source no longer had the energy to keep the attitude control mechanisms operating.
Both non-recoverable payload flights had successful launches on 20 December 1960 and 18 February 1961. However, on the first flight, telemetry indicated that the attitude control mechanism had lost all of its 360 degrees around before completion of the first orbit. Gas/and that the vehicles had become unstable. The contractor took action to correct the malfunction for future flights. The second non-recoverable flight was more successful.

One of the objectives of the February flight was to perform the first engine restart in orbit. Consequently, the usual 180 degrees orbital yaw turn immediately after injection was delayed until after the first pass over Alaska. The Alaska station signaled and the engine reignited, burning for about one second which increased the satellite velocity about 350 feet per second and increased the orbital period by about four minutes. (USP & FEB 60)

The non-recoverable payload flights were interspersed between two recoverable flights propelled by the higher thrust engines.
The flight was launched on 17 February 1961. It was significant not only because of the two new engines, but also because it was the first launch using a Bell Telephone Laboratories guidance system in a space launch from Vandenberg. The system was developed at the pad, technicians installed the cameras in the transition section of the Thor, and used a large radio antenna and computer installed originally for use in the Titan I testing installation at Vandenberg. Since then the Titan program personnel had abandoned the installation and Bell had improved their antenna to serve as a guide system so that it could monitor several launches several miles away as well as those within a matter of yards.

On this launch, technicians provided an open loop circuit for the radio-guidance system. A test booster trajectory had depended on the Thor's autopilot and programmer. When the technicians established the closed circuit, any slight deviation from the desired path could be corrected.

Rough Draft

This launch and flight was satisfactory through the first few days of orbit. However, technicians determined that a recovery on the sixty-third pass was more desirable.
and a **signal** tracking station sent a signal for a change. Normally, the command would be stored and halfway through the succeeding orbit, the programmer would skip an orbital cycle. However, the programmer capsule apparently malfunctioned and prevented recovery.

On 30 March 1961, technicians launched for the first time a Thor-Agena **closed-loop** combination guided by the Bell Telephone Laboratories radio-guidance system. The Thor had used an autopilot and programmer to perform trajectory movements. With the Bell guidance system a more accurate trajectory could be had. In addition the East cannister in the Thor connected by wire to the Agena which controlled the second stage engine ignition, and other mechanisms.

The booster performance and Agena separation and engine ignition performed normally, but 20 seconds prior to engine shutdown a rapid drop in hydraulic pressure caused the loss of engine control resulting in Agena velocity being less than required to attain an orbit.
A week later on September 8, a Douglas crew launched another Thor-Agena combination. The ascent was satisfactory and the Agena was injected into an orbit approximating the one programmed, and reoriented itself with the engine end in the forward position. However, by the tenth orbit the vehicle became unstable due to exhaustion of control gas. Nevertheless, the vehicle continued to receive signals from the ground stations. Ground stations were able to maintain contact.

Program managers decided to attempt a recovery during the second day in orbit rather than the fourth. Upon ground command, the vehicle ejected the capsule, but into a new and higher orbit, the vehicle's attitude.

Analysis of telemetry data indicated that temperatures beyond the Agena's experience had caused erratic operation of the gas jet control valves which resulted in the rapid expenditure of control gas.

To prevent such a recurrence, technicians were to coat the valves with a heat absorbent material and wrap them with thermostatically controlled electric blankets. (MSF 9 May 61)

(AF8M 9 Sep 61)
Exactly two months following the April launch, technicians launched another Thor-Agena. The combination appeared to soar off into the sky and curve southward in the usual pattern, but the Agena failed to attain sufficient thrust for orbit. It developed 1.7 seconds after launch.

However, far beyond the expected area on the California coast line, the Agena failed to produce sufficient thrust and plunged back to earth in a dramatic fiery collapse. Telemetry data indicated that there was a fire in the Agena's area after it reentered the atmosphere.

Taylor: After studying available data, technicians believed that the Agena's fuel leaked and caused a fire to break out in the aft section. Measures were taken to prevent this from occurring. (MSP 9-1961)
Increasing Launch Rate

During the past two and half years, all Thor-Agena combinations had blasted off from one of two launch pads. These flights were becoming more frequent and the Air Force believed that the launch rate would gradually increase in the future. The last Thor training launch occurred from Complex 1 in January 1960 and the Strategic Air Command had agreed that the Air Force Ballistic Missile Division could use the installation for space projects. However, the complex would have to be modified to accommodate the space launches and the Air Force Ballistic Missiles Committee did not approve any modification until June 1960. At that time the committee authorized the modification of the blockhouse and Pad 1. The estimated conversion cost was $2 million.

(AFBMD Elgt Mtg: Oct 60)

During the ensuing twelve months, Douglas in conjunction with Lockheed altered the equipment as necessary including the reorientation of the Pad so launches could be made in a 172 degree azimuth (contr-347, a mend 50)

(1tr 26 Jul 60)
On 16 June 1961, the Thor-Agena was launched at the Pad 1 of Cape Canaveral (MSP Q May 61).

The launch, roll and ascent occurred in the usual manner as planned. In orbit the Agena was oriented and stabilized itself in the usual programmed manner. Capsule ejection occurred as planned on the second day following the thirty-third orbit as planned, but due to a miscalculation the recovery forces were in the wrong location. Nevertheless, the capsule's electronic beacon signaled the location and aircraft rushed to the scene. Late in the afternoon the capsule floating in the water. Para-rescue men inflated their rubber-life rafts and reached the scene within a few hours. Para-rescue men jumped into the water, inflated a raft, and by nightfall the capsule was safely aboard their raft. The next morning a ship picked up the rescue team and the capsule for delivery back to the states.
Since 1959 the Agena appeared in different configurations in order to meet different program requirements. As early as September 1959, Lockheed at Sunnyvale and the Air Force in Los Angeles have discussed the feasibility of standardizing the vehicle. At the time the difficulty in establishing a standard second stage vehicle was the diversity of requirements demanded of the using programs.

In early 1960, Lockheed noted: "Six grossly dissimilar operational functions at three different altitudes on orbits varying from polar to equatorial."

Additionally, the versatile Agena must accommodate boosters of radically different capabilities and permit adaptations for widely differing control refinements." Rather than attempting to design an absolute structure, the very scope of the programs precluded the single do-all vehicle as an ideal solution, yet Lockheed agreed that the vehicle should be simplified. (1tr 4 March 60)

At first the best that seemed feasible was the fabrication of three or four identical series. By 1961 the Air Force determined that it had much to gain by a basic...
redesign of the Agena B and rigid configuration control thereafter.

So, Lockheed initiated a design study toward achieving a standard Agena vehicle for ascent entry to serve all known requirements. (ltr 6 Nov 61)

As the preliminary design (study) progressed, two salient points emerged:

It appeared feasible and desirable to design the structure so as to accept optional equipment which could be installed for specific missions. Secondly, the in order to improve reliability and maintainability as well as receive economic benefits, it appeared feasible and desirable to improve the product during the manufacture of the first few. (ltr 6 Nov 61)

In September, the Air Force staff, Under Secretary of the Air Force Chayko, and the Deputy Director of Defense Research and Engineering, Ramey, approved the standardization concept. Ramey replaced a further qualification that the concept be reviewed further after Lockheed completed the design.

(ltr 6 Nov 61)

ROUGH DRAFT
The Space Systems Division proceeded to let a contract with Lockheed for the design, development, and production of 12 Agena D vehicles which would be standard in nature and capable of being used with a minimum degree of change in the various programs. The first one was to a launch Agena D flight should be ready for flight in January 1963. (statement Aug 62)

However, this schedule was soon to change.

On 17 October 1961, Charyk appointed a four-man committee headed by Clarence L. Johnson, Vice President of Lockheed to "investigate ways and means for improving the reliability of the Agena vehicle and recommend improved procedures for getting the standard Agena D into earlier operation." A week later the committee reported its findings to Charyk. It proposed new procedures which it thought would result in a June 1962 first launch, and the possibility of starting a standard production of five per month beginning in January 1963.

The committee found the organizational methods of Sunnyvale and the acceptance testing of assembly equipment at Sunnyvale rather than at the subcontractors' plants seriously delayed against a reliable vehicle.
The committee believed that the June 1962 launch date could be met if/ten conditions...These were:

1. A high priority should be assigned to the Agena "D" program.

2. The engineering system should be similar to that of the U-2, requiring only enough drawings to tool, build and service the vehicles.

3. An early and final configuration freeze is necessary, totally adjacent to the engineering review.

4. The engineers should be located in a secure area immediately adjacent to the tooling and manufacturing areas.

5. A rapid drawing release system (24 hours maximum) from the project engineer's approval to the manufacturing group is necessary.

6. Funding should be adequate and timely.

7. Delete technical directive meetings involving large groups. Have Air Force personnel working close enough with the LMSC/Lockheed Missile and Space Company/project engineer so that formal meetings are not required. Keep extraneous visitors away.

8. Reasonable overtime should be approved. In some cases, this may come after and not prior to its use.

9. Air Force approval of vendor selection should be furnished on the spot at Sunnyvale. When single source procurement is necessary, a short written record of why this was done must be kept on file.

10. Tooling should be of the simplest type that will give interchangeability, as stated in the basic Agena "D" specification. No tool drawings or outside approval of tooling should be required.

11. Interchangeability on the first four Agena "D"s will be limited to major structural and equipment items. "Ones, for instance, may require trim to fit.

12. No engineering analysis reports should be required. Revert to the old system of using the basic engineering reports, which furnishes comparable data.

13. Another pad should be made available at Vandenberg (Pad #5 - Complex 75-1).

14. The WSC, Project Office, and LMSC should review the specification problem together and agree at the configuration conference to reduce the number of specifications involved to the minimum compatible with the Agena "D" mission. It should also be noted that many items common with the Agena "B" will be used on the "D", and have already been qualified to existing specifications.

15. The Program Director should be responsible for, and delegated authority for, all Agena "D" functions, including C&C/Communications and control/flight hardware. No C&C/"D"/Technical directives should be required.
Knowledgeable persons with the Space Systems Division were dubious about the proposed program. For one, if the Air Force was to pursue a fixed-price contract following the initial standardization, it would be necessary to have model specifications, drawings and documentation for both the vehicles themselves and any specialized tools. (Blum 6 Nov 61) The drastically compressed time schedule would make it difficult, not impossible, for the necessary documentation to be accomplished on the vehicles and according to the recommendations, formal tool design would not be required. (Evans 6 Nov 61)

Nevertheless on 7 November 1961, Charyk approved the Johnson committee proposals, which called the "skunk" procedures. (9 Nov 1961)
In pursuance to these new guidelines, the Air Force headquarters directed the Space Systems Division to prepare an Agena D program plan to be presented in Washington. The division's plan included both initial development of 12 flight vehicles and the continued production of more. The division estimated that the program would cost $48.9 million for fiscal year 1962 and $88.5 million for 1963. (Abbreviated plan, dtd 22 Dec 61) The Air Force Systems Command Headquarters approved the plan on 2 January 1962 and Charyk approved it the next day.

(Memo, 5 Jan 62)

It was the intention of the Director of Defense Research and Engineering that the Agena D program be budgeted as a separate line item. However, principally because the using programs had previously been funded for fiscal 1962 (including Agena program), it was not until 31 March 1962 that the Air Force headquarters converted funds to cover the Agena D flight development, engineering, and industrial facility requirements as a separate budgeted program. Until that time, Agena D buyers were operating on a system of reimbursable funds whereby the using program would pay the

Agena D program (TMX 8 Dec 61; ltr 19 Dec 61; ltr 2 Apr 62; ltr 11 Jan 62; ltr 30 Apr 62; TMX 1 Jun 62)

ROUGH DRAFT
The first of a matter of policy the division had not to obligate more than 60 per cent of appropriated funds on a letter contract, and the government which specified a target fee of 1/2 of total contract cost. By this time the Air Force was in process of manufacturing the LOCHHEED, and the Development Contract as a result of proposals a formula fee (Ira 22 May 62) and counter proposals revolving around incentive fee (11 July 62) negotiations dragged on between the Air Force Division and LOCHHEED. Finally in April, a definitive agreement was reached between them to charge the letter contract, or a fixed price contract, on either a fixed price contract, or a fixed price incentive fee one. 27 November 1962, chair had directed, 'Wait work proceed on a cost plus incentive fee basis with the initial 12 A.M. De 22 Dec, the remaining one be documented for the initial 12 A.M. De 22 Dec, the remaining one be documented.
The division determined it practical to issue a straight fixed price contract since the only cost data available would be derived from the first 12 standard vehicle contract, which included a large portion of non-recurring costs of design, tooling and test equipment, plus many changes in the development process. (22 Mar 62)

In April Ritland wrote to Schriver stating that a clarification was needed as to the Air Force position on whether or not the original 15 rules used to develop the first twelve A-enas D were to be continued into the production phases. Johnson and Ritland understood this, but apparently the instruction had gone through normal AF channels negating this approach. (ltr 25 Apr 62)

AF accepted first standard chassis on schedule (ltr 25 Apr 62).

Following the December 1961 issuance of the letter contract for the follow-on production of the 15 vehicles, the contractor and the government negotiated a fixed-price, nondelinable contract, a reevaluation would occur at the time of delivery of the twelfth chassis. (TMX 10 Aug 62; TMX 21 Aug 62) However, in
a fixed price incentive type contract would be best (TMX 13 Sep 62 to OSAP; TMX 13 Sep 62 to AFSC) and negotiation were completed shortly thereafter establishing [REDACTED] as the target price. (ltr 11 Nov 62)
Organization

Due to the high priority that Washington placed on the Agena D program, the entire organizational concept was to streamline procedures and to limit the number of people directly participating in the program. In November General Schriver directed General Ritland to establish within the Space Systems Division a separate Agena D program office, directly responsible to Ritland. The office should include engineering and contract administrative functions. With Schriver's approval, Ritland chose Colonel H B Kucherman to be the program director. In addition Schriver authorized direct communication between Kucherman's office and General Holmapple's office at Air Force headquarters for contact at that command level or higher.

(ltr 24 Nov 61; ltr 20 Nov 61)

Lockheed Missile and Space Company established a separate organization for the Agena D program headed by Fred O'Green and physically located apart from the rest of the Sunnyvale plant. O'Green had comprehensive authority including control over operations normally organized on a plant-wide functional basis.

(S-01A stans rpt, Aug 61)
Personnel of the Space Systems Division's program office established what amounted to temporary residence at Lockheed Agency B's fabrication facility. These officers participated with "O!Green's" and his personnel in all meetings, discussions, evaluations and decisions at the contractor's facility. In addition to the Space System Division personnel, a selected few specialists from the Air Force Plant Representatives office participated in contractual arrangements under Colonel Kuchman's direction. In this kind of relationship, the Air Force program director was actually involved in what amounted to a continuing fact finding operation with the contractor's program manager. (ltr 13 Aug 62)

Only the few people from the Space Systems Division, Air Force Plant Representatives office, and Lockheed who were had responsible roles in the day to day operation of the Agena D program had access to a restricted area adjacent to the Agena D assembly line.

In order to help Air Force and Lockheed engineers determine a suitable design, the contractor fabricated several test vehicles and mockups.
Since reliability as well as standardization were objectives of the Agena D development phase, Lockheed fabricated several test vehicles and mockups. As the propulsion test vehicle, it was used to prove test subsystems and the dual start capability of the rocket engine. The structural test vehicle was used to demonstrate the capability of the equipment rack and aft structure. The thermal test vehicle was used to verify environmental acceptability of the design. (ltr 13 Jun 62)

As the development test vehicle was completed on 31 March 1962, Lockheed performed its first hot fire at Santa Cruz on 23 May 1962. (ltr 13 Jun 62)

The development test vehicle might be used for installing, qualifying, and where necessary, hot firing, (magnesium welding and component improvement) potential improvement made available in support of all using programs. (ltr 13 Jun 62)

As part of the standardization, Air Force intended that automatic checkout equipment would be developed and could be used beginning with the nineteenth chassis. For all vehicles prior to that one, Lockheed used manual checkout equipment. However, the automatic equipment only applied to the standard...
A flyable Agena D consisted of the standard chassis plus certain optional equipment. In addition new programs would have hardware peculiar to their mission which they would add.

The objective of the development contract was to perfect one standard chassis. According to plan, Lockheed would checkout standard component parts, assemble the parts into a chassis, present checkout the entire chassis and deliver that item to Air Agena Force personnel for acceptance. Then Lockheed would move the chassis to an adjacent building and install all optional and mission insensitive equipment. The contractor would then checkout the entire vehicle for acceptance by the using program personnel. (HR 28 Dec 61)

Thus General Electric correctly observed that in order to have a usable vehicle, two checkout procedures were necessary.

(memo 25 Apr 62)
For the first twelve A-20A engines, O'Green, the Lockheed program manager, was responsible for controlling the configuration. However, Air Force managers promulgated overall guidelines. Allowing for some experimentation in design, almost all the parts of the first several chassis were not interchangeable. In April, Colonel Kuchemann asked Green to standardize the configuration beginning with the sixth chassis to be delivered to the Air Force for acceptance. (The company wanted to avoid structural changes in the design beyond the strengthening of the forward and aft equipment racks and)

(memo 18 Apr 62; prog rpt 13 Jul 62)

Lockheed had already redesigned the initial "standard" configuration at least twice, (memo 26 Feb 62) and the colonel wanted to make sure that suitable drawings, specifications, and procedures accompany the 13th chassis, which would be ready for the acceptance of the thirteenth vehicle, the first to be fabricated under the production contract.

Effective July 1962.

The Space Systems Division established a configuration control board consisting of representatives from the Air Force and...
NASA programs. and headed by an officer in the Agena program office. The board was responsible for the acceptance of all vehicles produced under the production contract and the determination of any future configuration changes.

(MAR 30, 1962)
(ltr 11 July 62; ltr 9 July 62; ltr 25 Sep 62)

The first article configuration inspection team examined the thirteenth chassis, Agena D, the first of the production contracts in September 1962. Documentation presented to the team by Lockheed was inadequate to define a configuration "baseline" but the team agreed to accept this chassis and the next five with the documentation as presented. interim specifications which the team gave in-house approval.

Lockheed took action to make the necessary corrections as recommended by the team and in November the team inspected the nineteenth chassis and determined that the documentation was adequate to now define a baseline configuration. The team then directed Air Force plant representative to began accepting the units with the approved documentation specifications. Each team inspected/optional kits were delivered to the program office. By
Since the rigid configuration control procedures were not applied before the thirteenth chassis, the Agnea office planned to modify the production package accordingly. (No prog rpt 13 Jul 62)

In the opinion of General Pitland, the final proof of the Agena D effort would be shown in the flights (1tr 25 Apr 62) according to the program plan, using programs would have flown thirteen vehicles from June through December 1962. In reality only five were used and at the end of the year there was no immediate prospect for an increase in the demand.

ROUGH DRAFT
In October 1962, the division made contractual arrangements with Lockheed to store the chassis and associated equipment while not in use. They were to be stored in a suitable environment on a first-in-first-out basis in order to mitigate against aging and weathering. (TWX 12 Oct 62; ltr 2 Nov 62; hist rpt Jul-Dec 62).

The division understood that modules were safe in storage but asked Lockheed to inform the FEC headquarters in January 1963 that storage costs were [redacted] per bird and Air Force headquarters directed the production rate be cut back to three birds per month.

(pro review 26 Jan 62)

ROUGH DRAFT
Component Improvement

One philosophy of the Agena B program was the segregation of the 32-vehicle production effort from any technical support and component improvement contract. (ltr 21 May 62) Although under the development contract provided for some product improvement the rapidity in which the design was frozen forced the division to have most of the Agena B qualified components merely in a repackaged form. (ltr 24 Jan 62)

The division believed that the components needed to be developed further in order to better serve current and future program requirements.

Following a presentation in Washington by the Space Systems Division, Charyk approved on 25 June 1962 an advanced development program as an item in the budget. The division estimated costs of $5.5 million for fiscal 1963 which the Air Force headquarters approved. (ltr 25 June 62; ltr 27 June 62)

However, the division was obligated to defend plans to improve particular components before the Air Staff. (TWX 30 Nov 62)

One of the most important advanced development requirements was for the improvement of the Bell engine for the Gemini program. (TWX 28 Sep 62)
For the Agena D configuration, engineers had adapted the 16,000 pound thrust dual-start engine which propelled Agena B in flight. Except for a change in the turbine exhaust duct, the improved Agena B and the first Agena D engines were essentially the same. However, in order to insure positive identification the Air Force designated the new model 1R61-Ba-11. (ltr, 29 Jul 62; ltr 3 Aug 62)

During 1962, the National Aeronautics and Space Administration expressed the need for a multiple-start engine in the Agena. The civilian space agency wanted to use the Agena as one of the rendezvous vehicles in the Gemini program, but in order to be able to rendezvous with another orbiting vehicle, the Agena would have to be able to make adjustments in its flight path. The Space Systems Division directed Bell through Lockheed to make the necessary improvements to meet the Gemini requirements, but at the same time design the engine to be compatible with the Agena D. After the 1963 tests, the division might adopt the multiple start engine as the standard for the Agena D.

The principal task at hand was to study the solid stage rockets and all the gas-generator valves alone. (ltr 23 Jul 62; ltr 25 Jul 62; ltr 2 Aug 62)
Chapter 6
THRUST AUGMENTED THOR

During 1959 and 1960, Douglas Aircraft Company was analyzing the basic Thor booster to determine how its capacity for lifting heavier objects into orbit and at higher altitudes might be achieved. From these studies came at least two unsolicited proposals. One involved an engine with greater thrust and propellant tankage with increased capacity. However, since the Air Force would have to develop a new engine, the pursuit of such a concept would have been relatively expensive.

In June 1961, Douglas revealed a more expedient way of increasing booster capability. This method would be by the use of the standard DM-21 booster with three solid propellant rocket motors strapped on the sides of the booster frame.

EM-33-E2 from Thiokol
These solid rocket motors were available, having been used as the second stage of the Air Force's Blue Scout launch vehicle and other programs. (D rpt, June 1961)

Flight tests had been successful, a thrust of 51,000 pounds; these three rockets combined with the DM-21 propulsion system would give about 300,000 pounds of thrust.
Agena payloads were getting heavier and heavier until it became clear that many-future program requirements would be beyond the capability of the 170,000 pound thrust of a single Thor booster. (Memo, 15 May 62 ref to ltr 4 May 62) On 27 February, a program director asked that Douglas make a two month study and in coordination with Lockheed, define more precisely the performance and design of the proposed thrust augmented Thor. (ltr 27 Feb 62) Following the detailed study, the program director felt that since additional thrust would be needed in the immediate future, the proposed approach was the only one feasible. On 26 April, he requested the Space Systems Division's the envisioned Thor booster office to provide a hardware combination ready for for the first flight seven months hence and for nine similar flights during the following year. (ltr 26 Apr 62)
The requesting program office was providing the necessary funds estimated to amount to $3.35 million. For budget purposes, the Space Systems Division estimated that after the first unit, each thrust augmented Thor would cost $700,000 or $256,000 more than the standard DM-21. (ltr 9 May 62) Launch costs would be another $700,000 or $100,000 more than the a DM-21 launch.² (hist rpt, Fests)

In early July 1962, the Thor/booster office asked Aerospace Corporation to be technical consultants for the thrust augmented Thor integration. (ltr 21 Sep 62) Operating under an extremely short lead time,
from Thiokol (contr - 146) and negotiated an agreement with Douglas.

Douglas modified the DM-21's flight control system, increased the instrumentation, and installed brackets on the aft section of the booster frame. Each set of brackets was to hold in place one of Thiokol's 75,500 pound motors. Douglas demonstrated the capacity of the Thor to support such weights and verified the suitability of the booster modifications by a series of vibrations and load tests.

In connection with the aft brackets there were a number of explosive bolts designed to sever the rockets from the booster frame upon a programmed signal. Static firings at the arsenal showed that this severance mechanism needed to be refined. In addition from scale model tests, engineers were able to improve the timing of the severance. By a minute delay, the attitude would be in a better position to miss the dropping of the empty cases as they fall away.
The Space Systems Division was also concerned about the performance of the engines and the effects of their exhausts in the new environment. In order to reduce the probability of combustion instability in the main engine, the division directed Rocketdyne to install a baffled injector in the MB-3, Block II engine. The modification had been successful in similar engines used by the Atlas booster. (TWX 1 Aug 62)
Production, Delivery and Launch

Space Systems Division planned to have Douglas produce the necessary boosters with the modified design in a normal assembly line fashion. However, the new engineering design generated from package would not be ready immediately and in order to expedite early delivery of the first three, the division directed Douglas to produce three standard DM-21 boosters and then modify them after they came off the assembly line.*

(* In addition, two Ablestar configured Thor boosters were to be similarly modified)

(11 July 62; contr. 186)

In the past, Douglas and Lockheed shipped the first and second stages from Santa Monica and Sunnyvale respectively.

Now, Thiokol was obligated to ship motors in monthly increments beginning in September 1962. (contr. 148) to be tempo rarely stored and rated with the other airborne hardware at the launching pad.

ROUGH DRAFT
Lack of a firm decision on the Class of explosives, by the Armed Forces

Explosive Safety Board precluded the completion of a storage
facilities for the solid rocket in time for the first launches.

Air Force personnel had to wait for the board to determine
whether the rockets exploded or burned. This would determine
the nature of the building in which they would be housed.

In the meantime, managers made arrangements to house
these rockets temporarily in an igloo type construction used
by the Blue Scout program.

The first of the cylindrical rockets, 2½ feet in diameter and 21 feet
long, weighing 7,300 pounds, were scheduled to arrive at Vandenberg
in September. (TWX, 1 June 62; memo 11 June 62; memo 33 Aug 62)

Finally in October the safety board ruled that these rockets would
not inadvertently explode and in February construction began on a
prefabricated metal building near the Thor launch pads.

(interview with Capt J B Rauhut, SSNF, 6 Mar 63)

Douglas provided ground equipment
to accommodate the existing Thor
launch complexes and readied Pad 5

ROUGH DRAFT
The first modified DM-2 arrived at Vandenberg in December 1962, and the program director hoped for a launch within another month. Technical difficulties caused delays including several postponements on the pad. Finally, on 28 February, the new combination booster combination rose off its pad, pushing an Agena D into the sky. However, the vehicle veered off course and the Pacific Missile Range safety officer in the Push button to destroy the flying hardware. when the Rocketdyne engine approached liftoff thrust, a current through installed circuits was designed to ignite the three solid motors. However, in this case, there was an improper connection which caused one solid motor not to ignite. Thus an Agena was inadvertently lost on what was in essence the first flight test of this particular hardware combination.

Despite the initial setback, undoubtedly the thrust augmented Thor would be used as a booster for future space flights requiring thrust ratings between that of the DM-21 and the more powerful, but (info from SSE) more expensive Atlas. These losses will be utilized only in cases utilizing a combination of liquid and propellants that did not
Chapter 7

CONCLUSIONS

During the span of seven years in the Los Angeles area, the Western Development Division, renamed the Air Force Ballistic Missile Division, and reorganized as the Space Systems Division, was responsible for the day-to-day management of the Air Force satellite development.

However, during the entire time the purse strings were held tightly in Washington and all major technical and managerial decisions were approved by the Department of Defense, or during 1958 and 1959, by the Advanced Research Projects Agency. These administrative arrangements were demonstrated in the go-slow attitude typified by Assistant Secretary of Defense Quarles in 1956 and 1957, the reams of numerical orders published by the special defense agency, during 1958 and 1959, and the continual dialogue between the Los Angeles project personnel and the Defense Director of Research and Engineering, from 1960 through 1962.

ROUGH DRAFT
Los Angeles space program managers approached the satellite components by determining what was available and what was needed to be developed. By this method, the managers could shorten overall development time and reduce costs. However, some component development was inherent in the purposes behind the early satellite concepts.

Early objectives included the establishment of ground-satellite communications and data processing techniques, and the development of a recovery system. The outer shell of the early recovery capsules were the by-products of reentry vehicle tests; but another area which had to be developed was in the satellite attitude control system.
Nevertheless, Air Force satellites owe a great debt to other programs because of the components and systems which were made available in various stages of development. Of all the systems which were available to Lockheed the most important was the satellite engine which Bell Aircraft Company had been developing for the B-50 program. This fact is not to say that many refinements had to made and that improvements were desirable. Bell redesigned the engine for a higher energy fuel, later increased the fuel burn time and established a restart capability, and then went on to increase the thrust.

Following Sputnik, the decision to use the Thor as a booster was predicated on the fact that the missile would be available before the other Air Force alternative, the Atlas. Nevertheless, space project managers were not satisfied with the Thor missile and so consequently redesigned the frame and increased the engine thrust, and selected what they thought was an improved fuel developed in the Mafaho program.

In a further effort to increase the first stage booster capacity, space program managers augmented the Thor with solid rockets used by the Air Force X-15.
program

the Air Force Blue Scout and the National Aeronautics and Space Administration and developed by the Army.

Both the airborne cannisters and the ground antennas and computers of the Bell Telephone Laboratories radio-guidance system had proven themselves before a space program manager requested, in July 1960, that the guidance system be used to provide greater trajectory accuracy on the Thor-Agena launches from Vandenberg Air Force Base. The system had successfully guided early Titan and Thor test flights and Thor boosted reentry vehicle test flights and there was available ground equipment at Vandenberg installed by the Titan program.
In very great part due to the engineering and managerial Air Force skills of space program personnel in Los Angeles, the Thor-Agena flights have become gradually more successful. At first the primary concern was for the Agena to achieve a polar orbit, later there were difficulties in the ground-satellite communications, and still later with attitude control, and recovery procedures. From February 1959 through December 1962, during the six years the Air Force had launched satellites, either 60 were Thor-Agena. Although the first or second flown stage may be used in combination with another configuration, by far the most Air Force satellite launches have been with the Thor-Agena combination. The Thor-Agena combination has proved the back bone of the Air Force space program.