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HISTORY OF TITAN III
1961–1963

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NARRATIVE

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HISTORY OF TITAN III
1961-1963

by

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June 1964

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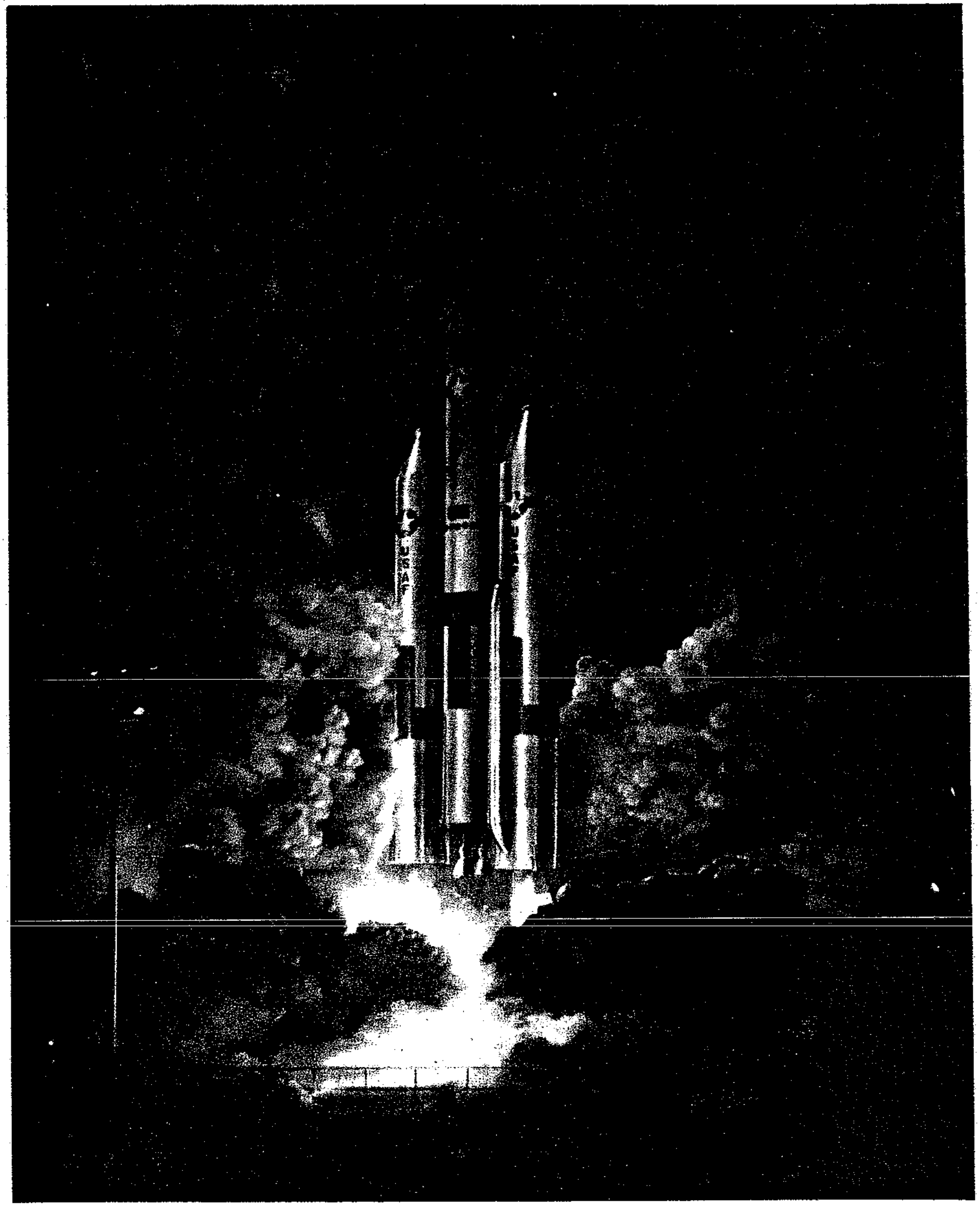

USAF TITAN III

Space Systems Division
Air Force Systems Command
Los Angeles, California

USAF TITAN III

Standard Launch Vehicle V

Titan III is a standardized space launch system capable of performing a variety of manned and unmanned booster missions during this decade.

The Titan III system is based upon technology and hardware developed in the liquid and solid ICBM programs. It will provide the first launch vehicles to be developed for the Department of Defense from the outset as a space booster. Current military space boosters all are intermediate range or intercontinental ballistic missiles with minimum modifications combined with upper stages developed separately.

The Titan III system will be marked by greater payload capability and versatility on the part of the booster, increased launch rate, and long-range dollar savings achieved by simplified characteristics of the vehicle and associated launch facilities.

In addition to the launch vehicles, the program calls for the development of associated aerospace ground equipment and an integrate-transfer-launch complex (ITL). The ITL concept provides for the Titan III to be completely assembled and checked out in a controlled factory-like environment on its launcher; then moved intact on rails to a simplified launch pad. This will reduce substantially the time-on-launch pad and the number of pads required.

A part of the National Launch Vehicle Program, the Titan III will meet requirements in the 5,000 to 25,000 pound payload range for relatively low altitude orbits, accommodating payload capabilities ranging from placing 10 tons in a 100-nautical-mile orbit to orbiting 13,000 pounds at 1,000 nautical miles.

CONFIGURATIONS:

Designed as a versatile launch system, Titan III, depending upon the job to be performed, may be used in either of two standard configurations: (1) The Titan III A configuration consisting of a modified Titan II "core" with a new upper stage and control module mounted on top; or (2) the Titan III C, a complete Titan III A with two five-segment strap-on solid motors attached.

BUILDING BLOCKS:

Core: A liquid, storable propellant Titan II, structurally modified to accept a new third stage, control module and payload. First stage thrust – 430,000 pounds. Second stage thrust – 100,000 pounds.

Upper Stage: A new liquid-fueled stage called a transtage (for transfer stage) designed to provide a multiple re-start capability to facilitate changing orbits and achieving deep space trajectories. Thrust – 16,000 pounds.

Control Module: Structurally a part of the transtage, this module contains all control and guidance equipment for all stages.

Solid Motors: Two five-segment, 120-inch diameter, solid rocket motors, each producing over a million pounds of thrust, "strapped on" for missions requiring additional thrust.

MANAGEMENT:

The Space Systems Division, Air Force Systems Command, is the executive manager for the development of the Titan III standardized space launch system.

Under contract to SSD, Aerospace Corporation will provide systems engineering and technical direction.

Associate Prime Contractors: Martin-Marietta Corporation – airframe, assembly, test and system integration; Aerojet General Corporation – liquid propulsion systems for the first and second stages of the core and the transtage; United Technology Center – 120 inch, segmented solid rocket motors; A. C. Spark Plug Division, General Motors Corporation – inertial guidance; Ralph M. Parsons Company – architectural engineering and design of ITL.

1 April 1963

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AUTHOR'S FOREWORD

This history of Titan III deals first with the main events and forces which resulted in the decision to develop a standardized space launching system with a significant military value. Thereafter, for reasons sometimes obscure, the course of Titan III development tended to fluctuate in response to the emergence of new dimensions in the complex process of defense management. The Titan III program marks a turning point in the management of research and development. Thus this historical study not only records the course of development but also identifies those evolutionary changes in the institutional environment which had a major effect on the methods by which the Air Force carries out its mission.

The narrative of events was based primarily on sources in the Titan III System Program Office and in the Space Systems Division historical office files. Basic documents supporting the text, some cited in the footnotes, have been reproduced in two supplementary volumes; copies are on file in the Space Systems Division historical office, the office of the Air Force Systems Command Historian and the Air Force Historical Division archives at the Air University. The author also drew on Titan III information contained in files at Headquarters, Air Force Systems Command and Headquarters, United States Air Force.

Everyone contacted in the Titan III Program Office, at systems command headquarters, and in Air Force headquarters was cooperative; many were enthusiastic contributors. Without such aid, the historian's task would have been impossibly difficult. The author's grateful acknowledgments are also due his associates in the historical office, not only for their close critical review of the manuscript but also for their many valuable suggestions during the research process.

And finally, for those errors and imperfections that often appear so startlingly obvious after a manscript is published, however careful the proofreading and final editing, the author assumes responsibility.

R. F. P.
June 1964

AN INTRODUCTION

The Titan III program, or that much of it which had become history by January 1964, is the concern of this monograph. It is a subject of extraordinary significance to the future of the United States Air Force, and particularly to research, development, and general technology within that service. Through a fog of contradictions there has become apparent a pattern which, at the time this introduction is written, seems to stand an excellent chance of dominating the Air Force. It deserves more attention than it has received. The Titan III program has been complimented for specific technical achievements which, though performed with exceptional skill, probably have much less long term signifance than certain management actions which even in retrospect are indifferently appreciated.

Titan III differed from contemporary programs from the conception stage onward. The first and greatest distinction, and that which has received least acknowledgment, was that the early proposals never satisfied a basic requirement of Air Force policy--that no major development program should be undertaken unless in support of an approved weapon system program. Even though that rule carried within itself the seeds of technological frustration, and often seemed to be honored more in the breach than the observance, it was a rule. A meticulous examination of the course of program approvals in the years 1961-1963 discloses nothing similar to Titan III. All others which received significant funding support had weaponry applications. Titan III did not.

A second circumstance, and one the Air Force generally tried to ignore, was that even at the end of 1963 there still was no specific role for the military in space, and certainly none for Titan III. The only mission that had both coherence and logic was reconnaissance--identified at least a decade earlier and being separately handled. Some other military mission in space was often declared, but not very convincingly. Apart from Dyna Soar, which in ten years of trying never quite became believable, there was then no known payload for Titan III. The Manned Orbiting Laboratory (MOL) became a candidate in December 1963. For political and prestige reasons the National Aeronautics and Space Administration preferred some other booster to that supported by the Air Force. In essence, therefore, Titan III could not demonstrate a specific reason for being, and the mere suggestion that they might not be needed had been enough to kill several other systems.

A third situation, derived from the second, was that Titan III seemed to be threatened more dangerously, and more often, than virtually any other major development entrusted to the Air Force. It competed for funds and priorities with systems which had influential and vocal supporters both in Congress and in the press corps. But during the period of Titan III's approval and early development several of these "vital" systems were resoundingly "terminated"--in the vernacular of the time.* Included were such glamorous entries as Skybolt, Dyna Soar, Advent, and the nuclear powered bomber project. In that context Titan III takes on an unaccustomed aura of stability, though that aura remained strangely invisible to most.

Acknowledged more frequently than other program peculiarities, perhaps because it was so prominent it could not be ignored, was the use of Titan III as a culture medium for experiments in management. Program definition, a usefully ambigious phrase that identified a period of exhaustive justification and rejustification, certainly was the most obvious experiment. Others included attempts to fix in advance the price of a research and development program and the effort to commit contractors to an incentive payment philosophy. None of these notions was in great favor with the Air Force. The adaptability of Titan III's managers and their willingness to accept harsh reality indisputably kept the Titan III alive and vital through a period when the inability of Skybolt management to operate effectively under similar handicaps presaged the cancellation of that program.

The reality of the need for Titan III was an article of faith for program personnel. But at those levels of government where budgets were approved and programs endorsed, faith was a singularly suspect commodity. For a variety of reasons, policy makers in the Department of Defense displayed little confidence in the ability of the Air Force to select new programs or to manage them properly. Successfully coping with that outlook certainly was one of the more remarkable of program office achievements.

In a unique way, the Titan III program had more than a passing likeness to the original Atlas ballistic missile program. Folklore to the contrary, the Atlas effort of 1954-1957 was firmly based on the application of contemporary technology to a pressing requirement.

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* System programs apparently never "began" or "ended," but invariably were "initiated" and "terminated." It is impossible to avoid a comparison with "deceased" for "dead," or that 16th Century favorite, "shortened" for beheaded.

The Atlas was a development program, never critically dependent on invention. The same was true of Titan III. In the case of Atlas, disagreements over which of several possible technical solutions offered the best hope for program success frequently were resolved by resorting to parallel developments, money being used to buy time.* For Titan III the same problems of choice existed, but Titan III was not a vital element of national survival; time could be deliberately expended in an effort to reduce costs. That process, the antithesis of ballistic missile practice, was thoroughly frustrating to managers conditioned to the frantic pace of ballistic missile programs. Brigadier General J. S. Bleymaier and the staff of the Titan III program office were--happily--able to appreciate and to accommodate to the fact that Titan III was not a ballistic missile and to the reality that it could not be treated as if it were. Their greatest achievement, therefore, may well have been pushing stubbornly toward realistic goals by realistic means, doing tasks often distasteful and which sometimes seemed purposeless, because they knew that unless they gained the confidence of a group that had notably little faith in the ability of the Air Force to manage development, no approval would be forthcoming for Titan III.

Virtually all key decisions on Titan III were made at the level of assistant secretary of defense. Data, and basic recommendations, were generally drawn directly from the program office. The Joint Chiefs of Staff played no role, the Air Secretariat was chiefly an intermediary, the Air Staff had no real authority in program matters, and the influence of Air Force Systems Command headquarters was limited. These were circumstances strange and unpalatable to a service which thought of its authorities and responsibilities in terms of the 1947 defense reorganization act. By 1962, the fact that the level of decision for research and development had shifted well upward could not be denied. Explanations and proposed remedies were abundant, but of no concern to Titan III. In a very real sense, Titan III was the first major system to survive such handling and to emerge sound and vigorous. That circumstance, rather than any subsequent excellence in guiding the course of technology, was certainly the best testimonial to the effectiveness of program management in its first three years.

R. L. P.

June 1964

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* That generalization is also faulty, folklore again being wrong, in that the Atlas program was rigidly limited in the amount of money it had. But in a broad sense such money as was available had to be used to buy time by funding parallel efforts, the most promising of which were later chosen for incorporation in the basic weapon development.

TITAN III

CHRONOLOGY

1961	Jan	3	A preliminary report was released on the Phoenix Study, a definitive analysis of an economical standardized high performance space vehicle system, prepared by AFBMD and Aerospace Corporation.
		9	The Air Force Deputy Chief of Staff, Development, urged continuation of the Phoenix study. He also recommended that the Air Force study the need for a space capability which would cover the payload gap between Atlas-Centaur (9,000 pounds) and the early Saturn (19,000 pounds).
	Feb	23	NASA and DOD agreed to exchange information on space launch vehicle programs under consideration by both agencies.
	Apr	7	Air Force Undersecretary J. V. Charyk informed Secretary E. M. Zuckert the Air Force was studying a proposal to develop a new Titan II upper stage with a 35,000 pound thrust fluorine-hydrazine engine capable of injecting six to seven tons in a 300 mile orbit.
	Apr-May		A special ad hoc panel on large boosters, established by Presidential science advisor J. B. Wiesner, reviewed available vehicles and those proposed for development.
	May	1	The Air Force submitted a proposal for a National Space Program to the Secretary of Defense.
		18	J. H. Rubel, Deputy DDR&E, proposed to the Advanced Research Projects Agency that the Institute for Defense Analyses define standard spacecraft and launch vehicles.
		25	President Kennedy announced that manned exploration of the moon was a national space goal and that NASA would conduct the program.
	Jun		AFSC submitted the Phoenix study to the Air Staff setting forth the concept of parallel stages and building blocks to create modular rockets adaptable to varying performance requirements.

[redacted]

1961	Jul	7	J. E. Webb, NASA Administrator, informed Secretary of Defense R. S. McNamara of his plan to establish a "Large Launch Vehicle Planning Group" (LLVPG), to review the requirements of all agencies involved in space activities.
	Aug	1	The DOD created an ad hoc committee for Standardized Workhorse Launch Vehicle Selection to review the merits of a Titan II with Centaur upper stages, Titan II with a fluorine-hydrazine upper stage, and a Phoenix A launch vehicle system.
		18	The Standardized Workhorse Launch Vehicle Committee recommended that Atlas-Centaur be used through 1965, that Titan II with strap-on solid rockets and a high-energy upper stage be used after 1965 and that Saturn C-1 be used for early Dyna Soar flights.
	Sep	15	J. H. Rubel requested that AFSC prepare a special study of the Titan II strap-on solid booster concept.
	Oct	5	SSD forwarded to command headquarters a study report of the Titan II with strap-on solid boosters--named the Titan III.
		11	J. H. Rubel was impressed with the Air Force plan to develop Titan III and agreed to recommend that the plan be approved by the DOD and NASA.
		13	The DOD authorized the Air Force to take initial steps leading to accelerated development of Titan III.
		17-18	Air Force headquarters forwarded to the DOD fund requirements for development of Titan III. It was estimated $12.58 million would support Phase I definition studies to be completed by February 1962.
		20	Air Force headquarters instructed AFSC to undertake "expedited" actions to begin Phase I of the Titan III program.
	Nov		Golovin Committee (LLVPG) recommended immediate development of Titan III based on its prospects as the most satisfactory vehicle yet proposed to meet the nation's post 1963 requirements.

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1961	Nov	1	SSD appointed its first Titan III source selection board for procurement of solid propellant motors.
		3	Assistant SAF (R&D) B. McMillan advised Secretary E. M. Zuckert that Titan III development would also serve as a project for demonstrating cost reduction, organizational and management innovations.
		17	Secretariat and administrator level representatives from the DOD, NASA and Air Force agreed to reconvene the Golovin Committee (LLVPG) to consider the implications of Titan III development.
		18	DDR&E approved the start of Phase I of the Titan III program "subject to the availability of funds."
	Dec	5	Among other recommendations the reconvened Golovin Committee advised use of Titan II for Mercury Mark II (later Gemini) rendezvous missions and reliance on Titan III after 1965.
		11	SSD received $2 million of the $12.58 million necessary to support Titan III through Phase I.
		23	DDR&E released an additional $6.5 million to the Titan III program--received at SSD on 15 January 1962.
1962	Jan	17	Assistant SAF (Mat) J. S. Imirie advised DDR&E that continued Titan III funding difficulties had caused delay in completion of Phase I until 30 April 1962.
Feb-Mar			SSD awarded Phase I study contracts to Martin Marietta, Aerojet-General and Aerospace Corporations.
	Mar	19	Undersecretary J. V. Charyk and J. H. Rubel, deputy DDR&E, approved preliminary Titan III design, elimination of Agena "D" upper stage and development of a new transtage, and further study of Centaur as the Titan III upper stage. They also requested Air Force preparation of a "white paper" which would report the philosophy and technical approach applied in the Titan III program.
	Apr	3	DDR&E established a technical group under the Institute for Defense Analyses to furnish an independent appraisal of Titan III's Phase I accomplishments.

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1962 Apr 7 A Titan III source selection board recommended United Technology Corporation as developer of solid fuel boosters.

May 3 Formal completion of Phase I and presentation of the Titan III Proposed System Package Plan to the Systems Review Board. The plan called for Titan II core, two strap-on solid motors, 17 test flights, "ITL" facilities at both the Atlantic and Pacific Missile Ranges and "Blue Suit" capability at both ranges for a total development cost of $1.113 billion.

4 The Institute for Defense Analyses (Brady Committee) forwarded a generally favorable Titan III review report to DDR&E.

7 Titan III Proposed System Package Plan forwarded to DDR&E.

16 J. H. Rubel directed the Air Force to supplement the Titan III proposed plan by additional technical information and reasons supporting the requirement for "ITL" launch complexes at both the Atlantic and Pacific missile ranges.

Jun 14 Date of an Air Force - DDR&E meeting which marked the introduction of several significant changes in the proposed Titan III system.

28 DDR&E directed the Air Force to include five specific items in the Titan III program change proposal.

Jul 13 The Air Force and DDR&E agreed on the scope and details of Titan III program changes.

19 The Secretary of the Air Force signed the formal Titan III Program Change Proposal.

Aug 16 As recommended by DDR&E the Secretary of Defense approved full scale development of the Titan III standardized launch vehicle system with certain innovations: limit on engineering changes, use of incentive contracts and improved management techniques.

20 The DOD announced selection of Martin Marietta Corporation as systems integration contractor for Titan III and that development-production contract negotiations were underway with United Technology Corporation and Aerojet-General Corporation. It was also announced that approval had been given to use of a modified Titan II AC Spark Plug guidance system in the Titan III booster.

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1962	Sep	4	An additional $15 million, allocated to the Titan III program, was received by SSD. In accordance with plan, it was anticipated the money would be used to support limited preliminary Phase II actions.
		11	DDR&E denied an Air Force request for an additional $17.9 million to carry Titan III into Phase II activity prior to final approval of definitized contracts.
		15	SSD was granted authority to award a contract to AC Spark Plug Division of General Motors for Titan III Phase I guidance study.
		27	SSD proposed a plan which would permit termination of Phase I contracts on 31 October and an orderly transition to Phase II development by 1 December 1962.
	Oct	15	Air Force headquarters issued a System Program Directive for the Titan III Space Booster.
		15	SSD published the <u>Titan III System Package Program.</u>
		19	Air Force headquarters issued Specific Operational Requirement 201, for the Titan III Space Launching System.
	Nov	27	DDR&E released $100 million to partially fund Titan III development through fiscal 1963.
	Dec	1	Beginning of Titan III, Phase II, system hardware development.
		3	Secretary of Defense R. S. McNamara directed the Air Force to submit a comprehensive reply to eight questions concerning the Titan III program. The report was to be submitted by 1 April 1963.
1963	Jan	19	R. S. McNamara announced his intention of reviewing the Titan III program in "considerable detail both in Washington and at the contractor's plants."
		23	Division scientific Advisory Groups on Titan III stated their confidence in its "basic feasibility" and in its "operational simplicity and readiness."

[redacted]

1963	Feb	23	First firing of a Titan III solid motor at United Technology Center. A single center segment successfully met its test objectives.
	Mar	27	AFSC published three significant reports for Air Force submission to the Secretary of Defense. These were, Response to Questions Posed by the Secretary of Defense Pertaining to the Titan III Program, Titan III Project Review and Data Book, and Relation of Titan III to the National Launch Vehicle Program and Alternate Courses of Action.
	Apr	1	Effective date of reorganization of Corps of Engineers Cape Canaveral District to assure efficient direction of the vast space launching facilities construction program underway by both NASA and the Air Force.
	Jun	13	The Corps of Engineers awarded a contract for construction of Titan III "ITL" launch installations at the Atlantic Missile Range to C. H. Leavell and Peter Kiewit and Sons, joint venture contractors, at a bid cost of $12,678,873.
		20	NASA members of the Launch Vehicle Panel of the Aeronautics and Astronautics Coordinating Board indicated their lack of complete agreement with Air Force replies to three of McNamara's "eight questions."
	Jul	15	Secretary of Defense McNamara stated that "the development of the Titan III launch vehicle should be continued in accordance with approved plans."
		20	The first full scale five segment firing of a 120-inch solid propellant motor. All test objectives were met: the motor exerted a thrust of 940,000 pounds, operated for 110.8 seconds, and thrust vector control operated satisfactorily.
		23	Aerojet-General successfully tested a transtage engine for a long duration firing including two shut down and restart actions.
	Aug	6	Contract for construction of Atlantic Missile Range Titan III launch facilities--other than pad construction--was awarded to Morrison, Knudson, and Paul Hardeman at a bid cost of $22,480,000.

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1963	Aug	20	The Titan III program office forwarded to system command headquarters a "Titan III Follow-on Production Plan."
		25	Preparation of the Titan III "ITL" site at the Atlantic Missile Range was completed.
	Sep	17	Completion of modifications of Complex 20 at the Atlantic Missile Range to accommodate launch of Titan III in an "A" configuration.
		17	Construction of Edwards AFB Titan III Solid Motor Test Complex was completed.
	Dec	10	Dyna Soar, long planned as a manned space glider and slated to be the first payload for the Titan III launch system, was cancelled and plans for a Manned Orbiting Laboratory (MOL) were announced.

CHAPTER I

BACKGROUND OF SPACE BOOSTER DEVELOPMENT

During October and November 1957 the United States came to the dismal realization that the Soviet Union, through a series of dramatic space achievements, had not only demonstrated an astonishing superiority in at least one area of technology but had, in that process, employed rocket boosters more powerful than anything the Americans could hope to produce for several years.* Efforts to depreciate the Soviet triumph, or to offset its effect by citing evidences of United States achievement in other fields, solaced the public ego but did little to even the technological imbalance. Explanations, even perfectly valid explanations, tended to pale before the continued evidences of Soviet proficiency in the space arts. It was quite true that American rockets were less powerful than their Soviet counterparts because the United States had developed less weighty nuclear warheads and needed less thrust to propel its intercontinental ballistic missiles. But it was also true, though the facts were generally obscured, that for the preceding 10 years it had been national policy to depreciate space science, that for five years the Department of Defense had deliberately forbidden the diversion of "military hardware" to space programs, and that in the immediate past the use of the term "space" had been forbidden. There lay the real explanation.

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* Sputnik I, launched 4 October 1957, was the smallest of Russian satellites, a sphere measuring 22.8 inches in diameter and weighing 184 pounds. Sputnik II, launched on 3 November 1957, weighed approximately 1,120 pounds but its dimensions were undisclosed. In contrast, the first United States spacecraft, about the size of a large grapefruit and designed for launch by the star-crossed Vanguard rocket, was a sphere six inches in diameter and weighing 3.25 pounds. The first United States spacecraft to enter orbit, Explorer I, launched by a four-stage Army Jupiter booster on 31 January 1958, was an 80-inch cylinder, six inches in diameter and weighing 30.8 pounds.

The bitterness that marked the resulting discourse carried over into the election campaigns of 1958 and 1960, with the predictable consequence that political partisanship and technical requirements became entangled. Certain facts stood clear, nonetheless. As a people, Americans had refused to acknowledge that a supposedly backward nation like the Soviet Union, handicapped by an archaic and awkward system of government and economics and recuperating from dreadful wounds acquired in four years of savage war, could hope to compete in science and technology with the United States. Fume as they would, supporters of an expanded missile and space effort had to concede that until October 1957 the attitude of the nation's political leadership toward space proposals had reflected the mood and desires of the population at large. Anti-intellectualism was an attribute of the early 1950's, and it was an intellectual elite which argued most fiercely for a large scale rocket development program. In that enviornment, the bitterly won right to develop an intercontinental ballistic missile and to keep alive a single meaningful satellite program--WS 117L-- represented a very substantial achievement. Attempts to expand that program, or even to make its financial foundations sturdier, were decidedly unpopular with administrators who had been told their mission in life was to keep the national budget in balance and the tax bill low.

Intercontinental missiles of themselves were so embarrassingly expensive that it was difficult to secure adequate resources for their development even though their importance to the structure of national defense was generally--if not universally--conceded. Space boosters, particularly any which might require greater thrust than a ballistic missile and which in those terms had no "economical" military application, stood little chance of acceptance. The very concept of a space program was so completely unacceptable to the Department of Defense that the Air Force in early 1957 had to expend a great deal of time and considerable ingenuity to disguise space-oriented projects in order to prevent their capricious cancellation. One of the chief clerical occupations of the immediate post-Sputnik weeks was retyping mid-1957 proposals for "upper atmosphere research" and "instrumentation developments" in their original format.

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In the Atlas missile the United States Air Force had the nation's only high-thrust rocket. It was slated to boost the only approved satellite--WS 117L--which had the capacity for meaningful payloads. From mid-1954 onward, the goal of missile supporters had been the development of an intercontinental ballistic weapon--an objective that project personnel pursued with single minded determination, even though support from above often seemed apathetic.

The ultimate necessity for booster programs separate from missile development was recognized early, but there was no great sense of urgency. Realistically, the ballistic missile people acknowledged that other matters had precedence. From 1956 on, weapons planners occasionally urged development of very-high-thrust propulsion systems for future space programs, but to a singularly apathetic audience. In November 1956, a special panel of the Scientific Advisory Board told the Air Force chief of staff that "The possibility of very large thrust requirements (we have heard mention of 5,000,000 pounds) for satellite or more ambitious missions in the rather near future appears. . . to pose rocket sizing problems. These problems should be studied to provide guidance in planning rocket development and rocket testing facilities."[1] Less than a year later, in August 1957, the Bacher Panel, made up of some of the nation's leading scientists, reported that "The growth potential of the liquid propellant missile appears to be such that an appropriately directed research program on it will provide booster components for advanced satellite and space travel vehicles."[2] That observation, made three months in advance of Sputnik I, did not prompt consideration of any specific programs, but it clearly revealed that at least one segment of the scientific community had more than a casual interest in preparing for a certain future in space activity.

It was apparent to the discerning and to those aware of the accelerated Soviet space program that Russia already possessed a ". . . comprehensive space-flight effort, coordinated and supported at the highest level in their very important Academy of Sciences; and this effort is being directed by men of the highest stature, both scientifically and politically." It took a long time

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to grasp that the nation was "up against a first-class opponent who will move forward in space flight with all possible vigor. No more comfort can be derived from an assessment of his intentions than from estimates of his capabilities."[3]

After the first Sputnik, the Air Force, possessing to a high degree both space hardware and technical competence, prepared for a tardy but now inevitable increase in space activity. Through November and December 1957 the Air Force Ballistic Missile Division constructed plans for accelerating its astronautics programs. On 3 January 1958 the division forwarded a series of interesting space proposals: use a Thor intermediate range missile plus a Vanguard second stage as a basic space vehicle (the Thor would be available as a space booster about a year ahead of the Atlas) to orbit recoverable capsule satellites by September 1958; land an object on the moon by the last quarter of 1958; recover an animal satellite and circle the moon by January 1959. Other programs were also suggested. There was no shortage of proposals for space projects. Apparently the nation was increasingly willing to support a vastly augmented effort. Yet in the general ferment of the time, other questions relating to national space programs and policies began pressing for attention. Within the Department of Defense ultimate assignment of space roles and missions was far from clear, as was the somewhat artificial question of whether military or civilian orientation should control the nation's total space effort. These and related problems were some of the central issues which demanded resolution before any final commitment to a national space policy and objective.[4]

Even though the preparation of plans and proposals--or the fact that they now were seriously entertained in Washington--represented substantial progress, something more had to be done. Specific proposals had to be approved and funded. Specific agencies had to be strengthened, or created. No national goal had been stated, no national objective defined, but in the nine months following Sputnik I there was enough general activity to create an impressive stir in the field of space enterprise. Before anything meaningful in the long term could be undertaken, however, the responsibilities of the several agencies now clambering into the space project business had to be sorted out. After the appointment of individual "czars" failed to quiet public and congressional clamor, the Department of Defense on 7 February 1958 established the Advanced Research Projects Agency to direct and conduct space research leading toward operational systems and, presumably, to prevent duplication of activity within the military services.[5] The new agency promptly set about consolidating its position, in the process absorbing some of the decision-making authority of the Air Force.

ARPA, as it was inevitably called, had scarcely completed this process before enactment of the National Aeronautics and Space Act of 1958 (29 July) created a new, separate, civilian-managed agency which by law had custody of all space programs except those clearly oriented toward military objectives. Since it was administration policy to work toward the "peaceful uses of space"--a slogan which must have thoroughly baffled Soviet analysts who certainly knew that the United States had not the least vestige of a non-military space vehicle program at the time--the new civilian agency acquired custody over the infant man-in-space program which had for some months been ARPA's chief interest.

Inevitably, several Air Force projects which had been conducted under ARPA's general management were included in the prize awarded the civilian agency; man-in-space, lunar probes, million-pound-thrust engine, and space exploration programs were adjudged to be peaceful in intent and were transferred, together with the $58.8 million allocated to them. On 1 October 1958 an executive order from the President made the switch formal. By 21 October, prospective contractors had been invited to Washington to hear a briefing on a 1.5 million-pound engine. In December, the Department of Defense and the National Aeronautics and Space Administration agreed on the essentials of a national booster program, and later that month the chief Army missile agency, at Redstone Arsenal, was made "responsive" to the civilian agency's development requirements.[6]

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Standing alone, such events might have meant little. But the military establishment had since 1953 been obliged to operate in accordance with the doctrine that all development must support defined objectives identifiable with an approved weapon system. In the early months of 1958, when the Air Force Ballistic Missile Division had prepared six successive development plans for Man-In-Space, it had become clear that the major technical obstacle to manned space flight was the lack of a high performance booster, one capable of lifting substantial payloads into orbit.[7] With the transfer of program authority to the civilian space agency, the obvious justification for developing high thrust rocket engines had also vanished. Payloads still assigned to the Air Force had been tailored to the available boosters, mostly Thor and Atlas. Unless the Air Force could identify a requirement for a heavy, bulky space system with unmistakable military value, there would be no service-developed big booster.[8]

Through the last of 1958 and into 1959, an intense but unrewarding endeavor to define a military space role other than reconnaissance, preoccupation of higher authorities with matters of seemingly greater moment, and rapid expansion of the civilian space agency presaged a diminished military role in the nation's total space program.[9]

In addition, there were significant changes and adjustments in Department of Defense management concepts, particularly for increasingly expensive research and development programs. During the years immediately preceding early 1959, the individual services had a constantly diminishing influence in the selection of weapon systems for ultimate acquisition. In part, that trend stemmed from ferocious inter- and intra-service rivalries and a consistent inability of the military services to agree on a mutually acceptable space program. Repeatedly, the defense department had to force or impose decisions. The enormous cost of the military budget and the vastly more complex technology it now embodied also induced escalation of the decision level. It was in this intellectual and managerial climate that the Department of Defense, on 10 February 1959, abolished the position of the Assistant Secretary of Defense for Research and Engineering, transferred

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all relevant functions to the Office of the Director of Defense Research and Engineering, and significantly enlarged the duties and responsibilities of that office. Such duties included not only review of military department research and development projects and development of systems and standards for the management of approved plans and programs, but also direction and control, including assignment and reassignment, of "research and engineering activities that the Secretary of Defense deems to require centralized management." Moreover, the director was empowered to "approve, modify or disapprove programs and projects of the military departments and other Department of Defense agencies in his assigned fields to eliminate unpromising or unnecessarily duplicative programs, and initiate or support promising ones for research and development."[10]

A sequel to this action occurred several months later. Since administration of space programs and satellite projects presented special problems, the Secretary of Defense, on 18 September 1959, asked the Joint Chiefs of Staff and the Director of Defense Research and Engineering for suggestions on the best way of handling these matters. They subsequently agreed that, for the time being, the Advanced Research Projects Agency would continue to direct research and development leading to the demonstration of operational feasibility. None contended that this was a good management arrangement. They also agreed, therefore, "to begin the development of a plan for the orderly transfer of space projects to the appropriate military departments." That transfer would normally be made "during the development phase at an appropriate time to be determined by the Secretary of Defense."* Although satellite and space vehicle operations would be assigned to the appropriate military department, the Air Force would henceforth be responsible for the

* On 17 November 1959, full development responsibility for Discoverer, Midas and Samos programs was returned to the Air Research and Development Command and thence to the Air Force Ballistic Missile Division.

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development, production and launching of space boosters and the "systems integration incident thereto." This was an important step in removing, at least in part, some of the uncertainty which heretofore had prevailed in the development and operation of space programs.[11]

The Air Force hopefully anticipated relief from the repetitious and detailed technical reviews favored by the Advanced Research Projects Agency. Many in the services felt that the agency's review process was an exasperating and time consuming interference with single-service management responsibilities. But any hope for real change--beyond a temporary stay--was disposed of by Secretary of Defense Neil McElroy's ruling that "the Director of Defense Research and Engineering will review and approve the detailed research and development programs in the space and satellite field. . . . . ."[12]

Shrinking the role of the Advanced Research Projects Agency and enlarging the authority of the Director of Defense Research and Engineering, accompanied by transfer of key people from the former agency to the latter, confirmed the view of those who held that, ". . . ARPA type project engineering and the ARPA-type concern over minute technical detail have not been reduced or eliminated." Particularly for space projects, experience had shown that the review of detailed research and development programs was a continuing activity, with the Air Force and Department of Defense going through "an interminable series of fiscal proposals and counter-proposals on each space system."[13]

The atmosphere of change, and particularly the probable interposition of new elements in Air Force weapon system acquisition policies and procedures, led the Air Force to realistic appraisals of forces affecting the future role and mission of the Air Force. The most penetrating of contemporary studies was that conducted in October 1959 by the Ballistic Missile

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and Space System Panel, usually called the Bleymaier Panel after its chairman, Colonel J. S. Bleymaier.* The panel's findings were widely influential in shaping later Air Force policies and actions. In addition to recommending reorientation of the Air Research and Development Command and the Air Materiel Command along lines which eventually marked the reorganization of 1 April 1961, the panel strongly urged adoption of package plan programming, assignment of responsibility for all military space functions to the Air Force, and clarification of the responsibilities of the Department of Defense and National Aeronautics and Space Administration. The panel also proposed specific changes in the kind of management which heretofore characterized space project development. The group observed that:

> The Director of Research and Engineering, Department of Defense, has specific delegated authority, which he is now exercising, to issue instructions to military departments; to approve, modify, or disapprove programs and projects of these departments and other Defense agencies in the interest of eliminating unpromising or unnecessarily duplicative programs; and to initiate or support promising programs and projects for research and development. In exercising his responsibilities, he is authorized to contract directly with private or government agencies or contract indirectly through the military departments. . . . It is the nucleus of an organization which will eventually exercise management control over all significant weapon system development and production activities in the Department of Defense.

As the panel saw it, the United States ". . . presently has no approved space policy or any specific program or experimental weapon system specifically implementing the policy." In the panel's opinion, the many aspects of space research in which the military services and the civilian space agency were involved were not integrated to achieve a common goal.[14]

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* Other members of the committee were Lieutenant Colonel C. Burch from the Air Force Ballistic Missile Division; Colonel R. R. Hogan from the Air Force Ballistic Missile Center; Colonel A. W. Koser, Colonel H. L. Wood, Colonel R. E. Zachman, Lieutenant Colonel J. G. Pallo, and Mr. T. V. Lucas, all of the Air Staff; Lieutenant Colonel D. G. LePart from the Air Training Command; and Colonel F. E. Wikstrom from the Strategic Air Command's 1st Missile Division.

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Paralleling the Bleymaier Panel report, the ballistic missile division continued to plan and study development programs leading to high performance boosters and launching systems. In pursuit of this objective the Air Force was also aided by the increasing maturity of space technology. No formal requirement existed for a military man in space, but the gamut of possible applications now included an observation station on the moon, an earth orbital experimental way station, and manned satellite defense systems. There was mounting interest in developing a comprehensive analysis of all the factors involved in creating a space launching system most suitable to meet future military requirements.

A significant step in this direction occurred on 6 November 1959 when the missile development division published a plan for a "Military Booster Development Program." The plan offered a projection of a theoretical launch vehicle system designated, for the sake of identification, as "Phoenix." This effort was followed, on 4 January 1960, by another internal planning study entitled, "Air Force Space Systems Program," which carried the Phoenix idea several steps forward by defining potential space systems of primary interest and projecting the precise techniques and performance capabilities needed to make these systems possible. The basic thesis of the Phoenix effort was to devise a space launching system of wide versatility and low cost--low enough to significantly reduce the enormous costs of space operations.[15]

Some of the highly promising elements in the proposed plan began to attract attention. On 12 February the missile division formally proposed the "Phoenix Launch Vehicle System" to Dr. J.V. Charyk, Air Force undersecretary. On 23 February, Air Force headquarters asked the Air Force Ballistic Missile Division for appropriate data to support a request for emergency funds to speed the Phoenix program. The division, on 11 March 1960, furnished the requested data and included a proposal to orient a large element of the rocket propulsion applied research program, conducted at Edwards Air Force Base, to supply engineering verification of propulsion judgments and interpolations included in the study. In any event, it was now recognized that here was a proposal moderate enough to have a

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chance of approval. Momentarily $8 million in emergency funds was assigned to get the program underway--an allocation which was finally withheld by the Bureau of the Budget.* Nevertheless, this indication of high level interest stimulated the Air Force to concentrate on further exploitation of the Phoenix concept.

On 4 April 1960 the Phoenix analysis was formally assigned as a contractual effort to the engineers and scientists at Space Technology Laboratories; actually, the space laboratories had been working on the study at a moderate level since the first of the year. It now became a priority effort. New work included a comparison of ballistic vehicle systems with and without recoverable stages in one size range only. The study was then extended to include an examination of all competitive launch systems over the complete range of interest and probable utility.[16]**

From this effort there developed one of the most thorough investigations of space vehicle systems thus far undertaken. Contractors familiar with space problems and propulsion systems were asked to contribute to the study and specialists from Rand Corporation assisted in the cost analysis portion of the work.*** Requirements were weighed against available

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* Allocation of this amount was approved, surprisingly, by Deputy Director J.H. Rubel, Defense Research and Engineering. In all probability, however, the Bureau of the Budget saved the Air Force some embarrassment. In the preliminary phase of the Phoenix study it would have been difficult to apply $8 million to direct support of the program although the money might have been expended with profit on applied research and analysis related to the Phoenix concept.

** Although available in briefing form much earlier, the Phoenix Space Launching System Study: Phase I Final Report DCAS-TDR-62-24, was not published until 28 January 1962 and Phase II Final Report, DCAS-TDR-62-25, did not appear until 31 March 1962.

*** In addition to Rand, United Technology Corporation proposed solid rocket system design; Aerojet-General furnished thrust vector control analysis; Rocketdyne submitted an engine recovery analysis; General Electric proposed an engine design and included an analysis of cost of development; and Pratt and Whitney furnished a design for a propellant feed system.

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alternatives--costs, availability of specific systems, performance, resources, and time. It became apparent for the first time that the Air Force, from its painfully accumulated fund of space data, possessed resources for planning the acquisition of a complete and adequate space system. As the study continued--it was transferred to the newly created Aerospace Corporation in August 1960 together with most of the people who were working on the project--detailed engineering specifications for a space vehicle system began to take shape. Several revolutionary ideas were introduced into system planning. Among these was a proposal for design of a new, economical and efficient launching system which promised to reduce the staggering costs of putting space systems into orbit.[17]

The first phase of the study was compressed to an effective briefing which, during January 1961, was presented at command and Air Force headquarters. Mounting interest in the Phoenix idea coincided with increasing concern in space affairs, whetted by the apparent ease with which the Soviets either anticipated or surpassed each American space feat. The proposed Phoenix program seemed an ideal space vehicle to many of those who possessed the strong conviction that an augmented military space capability was essential to the nation's survival.[18]

A significant factor in the momentum of the space booster proposals was the administrative overturn in the Department of Defense that occurred when the Kennedy administration assumed control in January 1961. Less thoroughly committed to a low cost space effort and more open minded on the matter of "peaceful uses of space," the new regime was intent on a rapid expansion of effective United States military strength. With some exceptions, policy officials in the Air and Defense secretariats changed at the same time. Perhaps most important in the long term was a gradual but appreciable relaxation of fiscal stringencies; in the next two years the defense budget grew to 125 percent of its 1960 total.

The Air Force plan for development of a high performance and relatively economical standardized space booster gained increasing favor in the Department of Defense and, to a lesser degree, in the National Aeronautics

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and Space Administration. During February 1961, under pressure from the White House, those agencies reached an understanding on a National Launch Vehicle Program. An Aeronautics and Astronautics Coordinating Board, made up of representatives of the two organizations, was assigned the responsibility for ". . . development and procurement of launch vehicles for space purposes, some of which are the responsibility of the DOD and some of the NASA and all of which taken together comprise an integrated space booster program consistent with national space objectives and requirements." This new entity in space affairs was to exercise primarily a coordinating role. A Launch Vehicle Panel was selected to do the paper work and keep abreast of current developments. But the crux of the agreement between the Department of Defense and the National Aeronautics and Space Administration, approved by the secretary of defense on 23 February 1961, was that ". . . neither the DOD nor the NASA will initiate the development of a launch vehicle or booster for space without the written acknowledgment of the other agency that such a new development would be deemed consistent with the proper objectives of the National Launch Vehicle Program." In effect this erected another administrative barrier to be surmounted prior to beginning any new booster development effort, even though it suggested that such a development might now be favorably considered. The agreement also prohibited duplication of costly space vehicle development programs and tended to stimulate consideration of a space launching system which would meet both military and civilian requirements. Conceivably, in the absence of complete understanding, the agreement might also permit one organization to veto a development effort considered vital by the other.[19]

On 6 March 1961, shortly after this arrangement was concluded, the Department of Defense issued a directive which clearly defined the role of the Air Force in military space programs. Each military department and defense agency was authorized to conduct preliminary research of small scope to develop new ways of using space technology. Any proposals for space programs beyond this level were to be submitted to the Director of Defense Research and Engineering. He, in turn, would make appropriate

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recommendations to the Secretary of Defense, who would have the power of approval or disapproval. In any case, the directive specified that "research, development, test, and engineering of Department of Defense space development programs or projects, which are approved hereafter, will be the responsibility of the Air Force."[20]

These various management arrangements, agreements, and the final clear cut space assignment to the Air Force reflected governmental preoccupation with the depressing state of our space race with Russia. Observing the pace of Soviet space accomplishments--and the mammoth weights of their spacecraft as compared with ours--the cynic might wonder if we were, in fact, still in the race.* Notwithstanding our apparent inability to surpass Soviet space achievements by ordinary measures, or more probably because of it, there was an increasing demand that the nation adopt a firm space goal and launch a determined all out effort to achieve it. To this end President Kennedy requested Vice President Johnson, as chairman of the National Space Council, to conduct ", . . an overall survey of where we stand in space." This request was reinforced by several specific questions which focused on the possibilities of beating the Soviets to the moon. What would such a program cost? What would be the best propulsion system for such a venture? Were we really making a maximum effort to achieve space supremacy?

To get his answers Vice President Johnson solicited several sources, among them Lieutenant General B.A. Schriever, commander of the new Air Force Systems Command. Schriever replied to the Vice President on 30 April 1961, his point by point answer to the several questions eloquently stating Air Force space policy and views regarding the nation's space program.

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* Obviously contributing to this uneasy state of mind was a series of Soviet space triumphs (Sputnik VII-launched 4 February 1961; Sputnik VIII-launched 12 February; Sputnik IX-launched 9 March: Sputnik X-launched 25 March; and Vostok I-launched 12 April 1961) during the first months of 1961 which projected into orbit payloads weighing from 10,330 to 14,292 pounds. A Venus probe satellite, weighing 1,419 pounds was launched from Sputnik VIII in a parking orbit and the first manned orbital space flight in Vostok I was successfully completed.

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In Schriever's opinion, given forthright decisions and support, the United States could begin to outperform the Soviets in space. If a program were started immediately he said, it should be possible to demonstrate a spacecraft rendezvous and return to earth by 1963, to orbit a useful communications satellite by 1963, to have nuclear propulsion for upper-stage rockets by 1965, and to complete a manned lunar landing and return by 1967. He emphasized the urgent requirement for large boosters, particularly for energetic development of segmented solid motors for first stage application as well as continued development of liquid engines for upper stages. (This was the crux of the Phoenix study.) Such a program, Schriever estimated, would cost about $4 to $5 billion a year.[22]

But General Schriever's most important response displayed concern about the intensity of the nation's space effort. He expressed his conviction that ". . . we have not been making a maximum effort. We have been operating our national space program under the artificial and dangerous constriction of 'space for peaceful purposes' and 'space for military uses.' " Schriever contended that our space programs were ". . . characterized by an attitude of defeatism and seeming resignation to second place for the United States in the space competition with the Soviets." To overtake the Soviets would require ". . . singleness of purpose, a sense of urgency, a full acceptance of the Soviet challenge, and a refusal to admit there is any place for the United States but first." Said Schriever, "It is my conviction that to get there first will require an approach similar to that taken in the accelerated development of the ICBM program in 1954."[23]

The Air Force, said Schriever, was ready to undertake a Manned Lunar Expedition as the national space goal* and was also prepared to develop

* In October 1960, General Schriever had appointed a group of the nation's ". . . most eminent scientists and executives, under the chairmanship of Mr. Trevor Gardner, to advise and assist the ARDC in carrying out its vital development responsibilities in the critical decade ahead." The group submitted its report to General Schriever on 20 March 1961, advising urgently needed decisions and actions essential to a strong space program.

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the space vehicle launching system necessary to start the program. In a briefing given to Secretary of the Air Force Zuckert on 28 April 1961, the Space Systems Division unequivocally stated that, "The most immediate problem area requiring attention is the large booster program. Our deficiencies in this area are the primary cause of our lagging the Soviets in space. Booster improvement is the keystone of any effort to equal or surpass them. It is essential for support of all recommended actions. . . ."[24]

These actions--essentially similar to those which General Schriever proposed in his 30 April 1961 letter to Vice President Johnson--included a recommendation to develop a Titan II - Chariot combination.*

Chariot--a proposed program which never attained development status--would have been a high energy upper stage using fluorine-hydrazine 35,000 pound thrust engines. In the opinion of the Air Force this vehicle, rather than the cryogenic-fuel Saturn vehicle under development by the National Aeronautics and Space Administration, would best do the job required. In addition to the prime goal of a manned lunar landing and safe return to earth, the Air Force proposed stepping-stone and parallel programs of specific military value: a communications satellite, manned maneuverable recoverable spacecraft, an orbital command post, and satellite defense systems.[25]

Other interests and agencies were, of course, deeply involved in defining a new national space effort. On 8 May 1961 the Secretary of Defense, Robert S. McNamara, and James E. Webb, Administrator, National Aeronautics and Space Administration, jointly recommended a national program leading to a manned lunar landing and return. They proposed parallel development, at equal priority, of liquid engines and solid propulsion motors for either the first or second stages of a new Nova launch vehicle to support the moon mission. Furthermore, because development of both systems was to be continued until the superiority of one approach over the other was demonstrated, it was agreed that the Air Force would be responsible for development of solid rocket motors. McNamara and Webb also strongly urged accelerated booster development as a military necessity although

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* An advanced Titan intercontinental range ballistic missile, designated Titan II, had been under development since May 1960. It differed from Titan I in that it utilized storable noncryogenic propellants, all inertial guidance, and somewhat higher thrust and payload performance.

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"military potential and implications are largely unknown." They agreed that "without the capacity to place large payloads reliably into orbit, our nation will not be able to exploit whatever military potential unfolds in space." Based on these various necessities it was mutually decided that $62 million would be allocated to the Department of Defense in fiscal 1962 to start the program.[26]

That a manned lunar expedition would become the first major goal in the conquest of outer space seemed assured. Although the plan to send a manned expedition to the moon in advance of the Soviets captured public imagination, the proposal for Air Force management of the enterprise did not fare so well. On 25 May 1961 the President assigned the program to the National Aeronautics and Space Administration, making it a national objective. The civilian space agency immediately embarked on preparations for the decade-long assignment. The Air Force promptly turned over to the National Aeronautics and Space Administration the detailed studies and plans on which it had based its own proposal for a manned lunar program.[27]

Despite this disappointment--which was less severe that it might have been since it had generally been anticipated--the Air Force continued to press for development of a high-thrust space vehicle capable of lofting a wide weight range of military payloads. Continuing study identified vehicles of alternative sizes, stages, and fuel combinations to meet the thrust requirements of multi-ton payloads. By May 1961 these ideas had begun to boil down to two essential choices: a new vehicle using solid motors for the first stage and a liquid powered second stage or, as recommended in a study of boosters for Dyna Soar, a Titan II with strap-on solid motors for the first stage.* This notion, proposed in the Phoenix study, was new for Titan but was not a new concept. A solid-rocket-booster Thor had been proposed in 1958, and ideas of using solid motors to hasten acquisition of a

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* After nearly a decade of preliminary conceptual studies, the Dyna Soar project was started in 1958 by Wright Air Development Center. The Boeing Airplane Company and the Martin Company were awarded study contracts to fully define their approaches to system development. (Cont'd)

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high thrust booster later came from many directions. Advances in the size, thrust, and reliability of solid propellant motors had inspired the conviction that they could be quickly and economically developed to create the super-vehicle needed to pull ahead of the Russians. The success of Minuteman and Polaris seemed to support that idea. Engineering specialists convincingly announced that recent advances in solid motor design and performance would, with a minimum development effort, provide the large boosters the nation urgently needed.[28]

A Need Is Recognized

As might reasonably have been expected, the Director of Defense Research and Engineering became increasingly involved in the effort to ". . . speed up the acquisition of basic capabilities in space for which we do not have a suitable planning or project mechanism." On 15 May 1961, the deputy director, J.H. Rubel, defined some ideas in development of space hardware which he called a "Unified Program Concept." The essence of the proposal, of particular interest to the Air Force, was that standardized launch vehicles and standardized spacecraft should be used with a variety of payloads. "The creation of standardized, 'work-horse' spacecraft and launch vehicles, suitable for many payload (project) applications but specifically optimized for few or none would be the goal." Rubel also suggested that it would be desirable to specify the design of the space vehicle and spacecraft in advance of system development--perhaps the skeleton of a "Phase I"

In November 1959 Boeing was selected as the glider and system integration prime contractor with Martin furnishing modified Titan missiles for boosters. Additional detailed study of the total program was completed in April 1960. On 9 May 1960 the Air Force received approval to move into "Step 1" phase of the program--development of a full scale, minimum sized manned glider boosted into hypersonic flight by a Titan missile. Step II involved use of a more powerful booster and a manned spacecraft capable of orbital velocities and a controlled safe landing within the United States. The program was finally cancelled, after months of vacillation, in December 1963, at which time the manned orbiting laboratory--MOL--program was given to the Air Force.

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concept about which more will be said later. In any event, he requested that " . . . the Air Force undertake a study and submit recommendations for a set of 'work-horse' launch vehicle and spacecraft developments." These were to meet the needs of the Air Force over the next two or three years, or even longer if the concepts proved useful. The large launch vehicle should have sufficient power to lift a 10,000 pound spacecraft into a 300 nautical mile earth orbit or a 1,500 pound spacecraft to escape velocity. Possibly, he suggested, a Titan II with a new upper stage might be the vehicle needed. The Air Force was to submit the report by 16 June 1961.[29]

On the next day Rubel--one can only speculate on the energy resources of the deputy director--requested the Air Force and the National Aeronautics and Space Administration to jointly prepare a series of "white papers" one of which was to " . . . outline the principal objectives toward which a large scale solid booster development program would be aimed." The whole management structure, technical supervision, testing, in fact all elements of the program were to be its province.[30]

As the Air Force bent to this task, on 23 May 1961 the undersecretary, Dr. J.V. Charyk, telephoned Major General O.J. Ritland, Commander, Space Systems Division, to request a condensed plan for development of large solid motors. The next day the division suggested that solid motor development should meet the requirements of the Phoenix launching system and noted that " . . . study of the launching needs of the Step Two Dyna Soar has led to consideration of a Titan II vehicle with a solid supplement to the first stage." The division urged development of "building blocks," a phrase that was now coming into more frequent use, and recommended thorough testing of solid propellant motors ranging in size from 100 to 140 inches in diameter and weighing from 50,000 to 100,000 pounds. A development program such as that proposed would take an estimated 30 months and, if started immediately, would require an expediture of $62 million in fiscal 1962. The division promised to submit a complete report by 9 June 1961.[31]

Thus the Air Force, and particularly the space division, became involved in two important directed studies at the same time. One represented

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an effort to design a high performance, reliable and economical space vehicle--a task undertaken by the Air Force on previous occasions--with the other directed toward solid rocket technology applicable to large space vehicles. Merger of these two closely related interests appeared increasingly imminent.

May 1961 marked the beginning of an intense planning activity that was to continue for several months. Of the two Department of Defense assignments, "USAF Studies Relative to Space Programs" was, because it presented a host of alternatives, the most demanding. Notwithstanding its technical complexities the report was completed and submitted to Washington authorities on 7 June as requested. The essence of the Space Systems Division's recommendation was that existing hardware be fully exploited to create a single basic launch vehicle combination. It was to be a vehicle selected from the "forefront of present technology" and possessing an ample margin of performance to permit significant improvements over the next five to ten years.[32]

The most pervasive consideration affecting the division's recommendation was to select a vehicle able to handle the only approved heavy-payload Air Force space vehicle: Dyna Soar. Evaluation of alternative combinations of stages, fuels, weights and configurations had cleared the field of all but two space vehicles capable of performing the task and possessing, as well, significant growth possibilities. The first choice, by a small margin, was a launch vehicle with a first stage assembled from segmented solid motors and a single oxygen-hydrogen engine for the second stage. This vehicle combination promised to be somewhat smaller and more reliable than a modified Titan II, although development costs would be on the order of $100 million more. It was clear, however, that despite the additional cost of developing the booster it would furnish an additional margin of versatility and long term growth in performance. These were ideal attributes for a launcher to be used by the Air Force and, if needed, by the civilian space agency as well.[33]

Another very attractive concept was Titan II with added solid motors. This would be a large and relatively heavy vehicle (weighing as much as

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856,000 pounds at launch, including the 508,000-pound solid motors and the 17,500-pound Dyna Soar glider) capable of placing a 20,000 pound payload into a 300 nautical mile earth orbit, with an increase in solid motor size making a payload increase relatively easy. Inasmuch as the vehicle would require no large scale research and development effort an immediate start could see it ready to operate from the Atlantic Missile Range by July 1964. Titan II development costs would be about $230 million, solid motor development would require another $200 million, and the Cape Canaveral launching installation would cost at least an additional $20 million. If a new concept of space launch operation was adopted, and there were compelling reasons for doing so, the launching system would cost $75 million. Preliminary analysis indicated that no new upper stage would be needed.[34]

Meanwhile the division was completing the "white paper" defining engineering objectives and a management structure for large solid rocket development. On 5 June 1961 Dr. Charyk cautioned--somewhat after the fact, for the study was already finished--that in " . . . developing the specifics of the program, defense requirements should be kept in mind even though the primary purpose of the program is satisfying the back-up requirements for NASA's lunar program."[35]

These instructions were probably not intended to guide the preparation of the solid propellant "white paper", since it was completed the next day, but rather to reflect undersecretary Charyk's views on deriving maximum technical benefit from the solid rocket development program. Two important applications of solid motors were contemplated: improvement in the performance of existing ballistic hardware, and creation of a second generation family of multi-purpose launching vehicles " . . . which will yield attractive cost effectiveness in terms of dollars per pound in orbit." It was becoming more apparent that solid motor development might be the key to the space launch vehicle the Air Force so urgently needed.[36]

But during May and June 1961 no booster decisions were forthcoming while studies, proposals, projections of future needs, and plans to meet the stated national space goals continued to descend into a scientific labyrinth

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of reviews and evaluations. Between 29 June and 12 July, the division made a series of presentations covering the gamut of Air Force proposals for various aspects of its development programs. Audiences included the Undersecretary of the Air Force, the Deputy Director of Defense Research and Engineering, members of the Air Staff, and General Schriever and his staff at command headquarters. By mid-July 1961 the need for a decision had inspired the appointment of a joint planning group that included representatives from the National Aeronautics and Space Administration, the Department of Defense, and Air Force headquarters. This became the Large Launch Vehicle Planning Group, headed by Dr. N.E. Golovin of the civilian space agency, seconded by Dr. L.L. Kavanau, Special Assistant for Space in the Department of Defense. The group was assigned the responsibility for developing a detailed projection of the total national space program.[37]

During the summer of 1961 this group generated ideas supporting a new launch system development program. In addition, the Institute for Defense Analyses independently endorsed space vehicle standardization and thus added weight to arguments for development of a new booster.

One of the most popular approaches to emerge from the plethora of of reviews and scientific discussions was that "building blocks" might be used in suitable combinations to perform a wide variety of missions. (The idea was scarcely new, of course.) Applying this concept to the Titan II resulted in definition of a basic "core" to which component building blocks could be added to create a high performance vehicle of potentially great promise. As this idea gained ascendency, the Department of Defense created another Ad Hoc Group, under the chairmanship of Dr. O. F. Schuette (on the staff of the defense engineering office), to refine the work already completed on the optimum design of a "workhorse" booster--a word now so frequently used it was no longer hyphenated. The separate paths of space vehicle development planning, large solid propellant motors on one hand

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and a standardized all-purpose second generation launch vehicle on the other, were finally merging as one development program.[38*]

The spate of committee reviews continued into mid-summer with another Ad Hoc Group, established by Rubel and the Air Force Assistant Secretary for Research and Development, Brockway McMillan. This group followed a well-plowed scientific furrow by considering eleven possible vehicle combinations ranging from Atlas-Centaur, Titan II with strap-on solid motors and various upper stages, through Phoenix, Saturn C-1 and, finally, a completely new all solid booster. Performance "flight rules" were nearly as before; the vehicle should be capable of orbiting a 10,000 pound payload 300 nautical miles from earth and also be able to inject a 1,500 pound payload into a 24-hour orbit or a 25,000 pound manned payload into a 100-nautical mile orbit. After carefully weighing the familiar host of complex factors the group in a review report (completed by mid-August 1961) recommended reliance on Atlas-Centaur for the period through 1965--although there was no discernable evidence that the anticipated operational date was attainable. Fortunately, other recommendations of the group were more realistic. Prominent among these was development of the Titan II with strap-on solids and a high energy upper stage to meet booster needs beyond 1965. Finally, the Air Force accepted the suggestion with some reservations, since as the National Aeronautics and Space Administration Saturn C-1 vehicle would presumably be available sooner than the Titan II booster the Rubel-McMillan group suggested that Saturn be used for early Dyna Soar launches.[39]

The recommendations of the Rubel-McMillan group were of paramount interest to the Air Force even though application of the suggestions would

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* On 5 July 1961, Lieutenant General H.M. Estes, Deputy Commander for Aerospace Systems, advised the Space Systems Division that the ". . . nucleus of a system program office [for large solids] be established at the earliest possible date. . ." Estes further commented that the ". . . overall program to be conducted by the USAF may be enlarged over that previously contemplated."

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require rather delicate gauging of the not-necessarily-compatible interests of the Air Force and the civilian space agency. At the same time the Air Force took the realistic view that endorsement of a solid boosted Titan II by the Rubel-McMillan group would significantly improve Air Force chances for securing a new booster as a back-up for the Dyna Soar and Apollo programs in the event Saturn development should falter. In any case, McMillan was convinced that in these recommendations there lay a " . . . sensible approach for the Air Force to take," and energetic development of the Titan II with first stage solid boosters seemed an avenue to realization of the Phoenix concept. He urged the Air Force secretary to immediately request release of funds from the Department of Defense and to begin work on solid boosters as the first step in the development undertaking.[40]

While the Air Force was preparing to act on the assistant secretary's recommendations, other related events were taking place in Washington which markedly affected Air Force space vehicle development. During late August and early September, actions involving space matters were primarily directed to advancing the nation's lunar program.* But quietly pursuing their own ways, scientific groups, busy in Washington during the summer of 1961, finally tipped the scales toward a new launch vehicle program.[41]

The fate of most studies was quiet oblivion in an obscure file; not so for three study reports which were subjected to the intensive review of the Director of Defense Research and Engineering and his staff during the summer of 1961.** These studies stimulated a thorough review of the

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* An event somewhat outside the main stream of Titan III development yet to affect later disposition of ground elements of the system occured on 24 August 1961. The vastness of the lunar undertaking and mammoth size of the launching area and installations which would be required at the Atlantic Missile Range required new Air Force and National Aeronautics and Space Administration support arrangements. To insure efficient handling of these and related matters, General B.A. Schriever established a special steering group to prepare preliminary drafts of proposed agreements between the two organizations.

** These were the Institute for Defense Analyses Report, "Study of Standardized Spacecraft and Launch Vehicles," dated June 1961; (Cont'd)

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nation's military space requirements and presented, more than anything else, ". . . the attractive potential of a standardized workhorse launch vehicle based upon the Titan II vehicle."

The concept appeared to be so well thought out and so operationally attractive that Rubel, on 15 September 1961, instructed the Air Force to furnish ". . . further detailed studies of this standardized launch vehicle which we should now call Titan III."[42*]

Air Force Report, "Standardized Launch Vehicles for Space Applications," undated but submitted 6 June 1961; and a report of the Ad Hoc Committee for Standardized Workhorse Launch Vehicles, dated 18 August 1961.

* By no means an original designation. It had been used before, as early as mid-1959, to indicate a vehicle conceived as a successor to Titan II "with a capability of fulfilling the Saturn space mission." Space Technology Laboratories, as engineering contractor to the ballistic missile development division, then projected a Titan III vehicle as a "two stage 160-inch diameter non-cryogenic missile, and the Centaur as the third stage."

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13. Study, "Impact of the OSD 'Space Operations' Memorandum on the AFBMD Space Program," 27 Oct 1959, in Hist Div files.

14. Rpt, Ballistic Missile and Space System Panel, A Management Report, Oct 1959, prep by AFBMD, in Hist Div files. This was one of several panel studies prepared for the "Anderson Committee" which was studying weapons acquisition management throughout the Air Force.

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17. Chronology of the Phoenix Program, circa Feb 1961; Phoenix - Military Space Launching System Study, Dec 1960, prep by Aerospace Corp, in Hist Div files.

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35. Memo, J. V. Charyk, SAFUS, to Gen C. LeMay, VCofS, 5 Jun 1961, subj: Air Force Program for Development of Large Solid Propellant Motor, in Doc Vol.

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CHAPTER 2

TITAN III: VEHICLE FOR CHANGE

By September 1961 the Department of Defense had accepted the concept of creating a new launch vehicle by combining the Titan II--suitably modified--with strap-on solid rocket motors. Although the Air Force had reduced the concept to specifics of thrust and weight in orbit, and apparently believed that such specifics had also been accepted (with appropriate allowances for adjusting the system parameters as circumstances might later require), there was a considerable gap between the Air Force appreciation of the situation and the defense department viewpoint. Common ground included the notion of a building block approach, the use of the two-stage Titan II, adoption of an additional (final) stage, and provision of strap-on solid fuel rockets for first stage thrust augmentation. But whereas the Air Force had generally considered the objective of system development to be placement of 10,000 to 15,000 pounds in a 300-mile orbit, J. H. Rubel in his 15 September letter to Air Force Assistant Secretary McMillan had identified a 25,000-pound payload for low orbits and a 3,500-pound payload for a 24-hour orbit. The differences were significant. Equally important differences were later to become apparent, but for the moment the fact of greatest meaning was that there was agreement only on the most fundamental items. *

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* In his 15 September letter, Rubel suggested that Titan III could be assembled in four combinations, "A" through "D": a two-stage booster; a two-stage booster plus a final stage; solid-fuel rockets plus a two-stage booster; and solid-fuel rockets plus the two stage vehicle plus the upper stage. In these various combinations the launch vehicle would have maximum flexibility for missions extending through the 25,000 pound payload in low orbit and the 3,500 pound payload in 24-hour orbit.

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The favorable analysis which led to the 15 September decision also made inevitable a next step--exhaustive examination of every aspect of the Titan III proposal.[1]

Rubel instructed the Air Force to undertake ". . . a comprehensive study of important aspects of this proposed Titan III vehicle system program to provide essential technical and program information required for guiding any future implementing decisions or actions." Specifically, he wanted answers to questions in four areas; what tasks would the Titan III perform; what details of its design would have an important bearing on its performance, reliability and cost; what structural modifications would the Titan II have to undergo; and what would be the specifications for the solid propellant motors? Finally, he urged ". . . a comprehensive development plan for the standardized vehicle system should be set forth, together with a master development schedule." Development plans and schedules for each major building block and testing program were to be included in the overall plan. All of these development factors were to be run through a ". . . PERT[2] type analysis to insure that time-phased compatibility exists with all major program elements." Estimated development costs for each of the building blocks, in combination, and for the total program, were also included in the study. Finally the Air Force was advised that "The possibility of developing the Titan III system or portions thereof on the basis of a fixed price contract should be explored."[3]

The completed study, even more detailed than a conventional system development plan, was to be on Rubel's desk on or before 6 October 1961. It was already beyond mid-September. Assistant Secretary McMillan, in something of a prize understatement, said on 18 September that meeting the 6 October target date ". . . will require an expedited effort on the part of AFSC and the contractors involved." In his forwarding letter to the systems command, McMillan stressed the extreme importance of preparing ". . . the most comprehensive report possible in the time available, even though certain detailed analyses may have to continue beyond this date." He also instructed the space division, which would be doing most of the work, to emphasize that development of large size solid motors for the

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Titan III program would contribute significantly to solution of engineering problems associated with the development of ". . . larger solid motors ultimately required for the NASA lunar launch vehicles." Furthermore, the division was to emphasize that Titan II ground test and launch facilities could be economically adapted to the Titan III program. Notwithstanding these additional suggestions, it was McMillan's final advice to treat the Titan III studies as a "matter of extreme urgency" and to base the resulting data on "the utmost objectivity."[4]

On 5 October, bound copies of the report, entitled "Titan III, Standardized Space Launch Vehicle," were on their way to Washington. Despite the haste with which the work was completed, it was an excellent preliminary plan for the large scale effort which Titan III development would require.* The projected development schedule was extremely compressed. Assuming prompt approval, it called for the first flights of the standard core Titan III in the summer of 1963 and a full scale flight with solid motors in January 1964. Although Titan III development did not require giant technical leaps forward, one of the reasons for its selection being its status as a largely developed system, an immense volume of applied engineering would be necessary.[5]

Cost estimates contained in the study were prepared hastily but complete development, production and launch, military construction, and modification of the Agena B upper stage was estimated to total $551.729 million. Development alone, it was judged, would cost $359.307 million. Military construction at the east and west coast missile ranges and test facilities

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* The study, referred to locally as the "Blue Book," contained an analysis of the system's capabilities, descriptions of vehicle combinations using solid motors and an Agena B upper stage, and a development and test plan. Major General O. J. Ritland, Space Systems Division Commander, writing of the study, said that it was ". . . prepared in eleven days including two week ends. Maximum use was made of our previous study data on standard launching systems, our Dyna Soar Studies, and contractor data. It is a very comprehensive report, and apprears to me to be well done. However, extensive rechecking has not been accomplished."

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at Edwards Air Force Base were estimated at $56.102 million. The balance of the total was made up of production and launch costs.[6]

But what of the capacity of the Air Force to conduct the development program on schedule? Said Major General O. J. Ritland, space division commander: "I believe that we should undertake the program on this schedule only if we are given almost immediate approval (1 November is stated in the report), sweeping obligation authority, and management freedom equal to or greater than now available under the 375 series regulations." Meanwhile, the division was preparing a plan for managing the proposed development program, "within the SSD organization."[7]

Early planning and managerial actions were conducted on a high plane of enthusiasm. On 9 and 10 October the division presented the proposed program at Air Force headquarters staff and secretarial level and to the office of the deputy director of defense engineering. At the same time members of the division staff were preparing detailed listings of actions to be taken between mid-October and 1 February 1962 if the proposed development schedule was approved. In general, the listed actions centered on organizing a contractual program. The task of contractor selection--a highly sensitive and involved procedure--was simplified in this instance by selection of Titan II as the basic core of the new launch system. Thus within the procedures controlling such arrangements, Martin Marietta Company, Denver, Colorado, contractor for the Titan II airframe, would produce the Titan III core and Aerojet-General Corporation, Sacramento, California, Titan II engine contractor, would develop and produce liquid propulsion units for the Titan III system. In addition, equally important procurement actions involving system integration, ground equipment, guidance and control, solid motors, design and installation of ground facilities, and materiel supply were listed and scheduled. As pointed out in the summary of actions to be taken, the first necessary move was to obtain program approval and enough money to get the program started; $12.580 million was needed by 1 November 1961 to make initial contractual actions possible.[8]

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The systems command and the space division were, of course, basing their plans on the assumption that program decision and funding actions would be given the high priority handling demanded by the compressed development schedule and the apparent significance of the program in the nation's overall launch vehicle effort. It was also assumed that the Air Force Systems Command and the Space Systems Division would conduct and manage the development program with the concomitant responsibility and authority such programs customarily entailed.

At the time the division was hopefully briefing committees on the proposed Titan III program, during the second week in October, Rubel completed an analysis which markedly affected the course of Titan III development. The paper, actually a memorandum to the assistant secretaries for research and development in the three military departments, set forth the objectives of good management and, by contrast, critically reviewed the methods and results of contemporary military research and development programs.

Rubel began with the important issue of shortening lead time. Lead time was affected by contractor performance, he remarked, and by ". . . administrative red tape and delays, by requirements for unnecessary but repetitive review in series with the chain of action, by unrealistic funding, by promising too much at the start, by permitting the constant introduction of unnecessary changes, by failing to provide an adequate supply of advance technologies . . . and by numerous other factors as well." Moreover, he added, defense contracting procedures often resulted in increased costs and wasted money, while enormous overruns often made it impossible to plan with confidence for the future allocation of research and development resources. These tendencies and trends established the necessity for strong control and more accurate prediction of costs.[9]

As a complication to the total problem of effective management, Rubel observed, many large programs were started with totally inadequate preliminary planning. The military service might accept a contractor's unrealistic cost, schedule and performance figures as the service "position."

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Although inadequate, these figures were often the only ones available on which to formulate decisions, resulting in a serious erosion of confidence in the planning process. "This process, and the abdication of responsibility that often abets it, needs to be changed," Rubel said. And this was not, in Rubel's view, the only practice that needed changing. Contractor selection was awkard and unrealistic. New companies were given contracts just a few months before experienced companies ran out of work. "An enormous amount of unnecessary time and effort is utterly wasted in the bidding process, which has grown to involve, routinely, the invitation of large groups to bidders briefings and the invitation and acceptance of formal bids in ridiculous numbers." Furthermore, it was clear that the criteria for selection stimulated "brochuremanship" since defense contracting practices seemed to prove that" . . . radical promises have usually seemed to pay off better than solid performance on current work. Thus is much of our finest talent needlessly and harmfully diverted from sharp focus on tasks at hand."

There was also evidence of a great deal of incompetence throughout the entire management process. Said Rubel: "We have not created a situation which discourages unwanted changes and encourages people at all levels to keep their eye on the ball." Our designs are ". . . characteristically over-embellished, over-complicated, over-refined, and correspondingly less useful and more costly largely, if not always exclusively, through the aggregation of 'improvements.' "

The direction of Rubel's criticism demanded reforms. There was a need to ". . . define more accurately the nature of our undertakings, and to match our management policies and procedures to the job we are trying to do." Much more efficient contracting practices, more fixed price contracting, and improved use of cost accounting methods were essential. Finally, it was of vital importance to ". . . establish more carefully the phases that make up a major development effort, to describe how the decision points are defined, who has the authority to make major decisions at these points and to match the definitions with the appropriate corresponding management measurement and control mechanisms." [10]

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In such a management climate the Air Force was attempting to secure approval for starting the largest and most important rocket development program undertaken within the defense department since the beginning of the accelerated ballistic missile effort, seven years earlier. Not that the shortcomings of the past had gone unrecognized within the Air Force. For nearly two years, starting in the spring of 1959, the Anderson Committee, a special group of Air Force general officers concerned with research, development, procurement and production had wrestled with the problem of how best to organize to cope with the intracicies of space age technology. Prompted in part by the assignment of near-total military space program responsibility to the Air Force and in part by pressure from impatient Kennedy Administration defense appointees, a select group in the Pentagon had carried through a massive functional realignment of Air Force materiel responsibilities in April 1961. Its chief product was the Air Force Systems Command, created by a combination of the original Air Research and Development Command of 1951 with procurement and production functions earlier assigned to the Air Material Command--which had now become the Air Force Logistic Command. In the view of General Schriever, who headed the new systems command, the organization had to be oriented to take advantage of all measures which would enhance management of the systems acquisition process, being particularly concerned with improvement of planning, research, development, test, and engineering responsibilities.[11]

In the case of Titan III, the first hint that radically new procedures might be instituted came with a request to "define" the program.* (To some extent, innovations had been anticipated but there was no sure knowledge of their scope.) The concept which later came to be called "program definition" had first been defined on 4 October 1961, when the office of

* Standing alone, program definition was by no means a revolutionary approach. The Air Force had practiced variations on the theme for some years. Such major programs as Dyna Soar, the B-70, and even Minuteman had been preceded by months (even years) of study and preliminary planning. The Skybolt program, which began its development phase in May 1959, was the first in which certain practices were used which the defense engineering office later adopted as (Cont'd)

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defense engineering approved development of a standardized Agena upper stage. This was also the first time that a "Phase I" effort was made a formal requirement of a development program. This first phase effort--Rubel a few days later cited this definition as applicable to Titan III---was to be aimed at ". . . establishing, with considerably greater confidence, the feasibility of accomplishing what is claimed, and establishing organizational and procedural mechanisms for better insuring that we achieve the desired results in accordance with plan." This meant, in effect, that the contractor had to produce a preliminary design of the standardized vehicle in sufficient detail to accurately forecast what the costs would be and assure that a multitude of late changes would not be necessary. Finally, the preliminary work should validate the specific requirement for the development program.[12]

The first official response to the detailed Titan III proposals presented in Washington on 9 and 10 October was surprisingly prompt. On 13 October 1961, Rubel instructed McMillan ". . . to set in motion on an expedited basis the actions necessary to move rapidly into a Phase I effort which may lead to the development of a family of launch vehicles based on the Titan III." Rubel felt that the Air Force had done an excellent job. Although additional action would have to precede authorization for system development, Rubel said the Air Force could expect its proposal ". . . will be approved by this office when. . . received." Rubel also explained what was really wanted in the Titan III Phase I effort (citing the definition of Phase I in his 4 October 1961 memorandum on a Standardized Agena).[13]

> During the Phase I period, the principal preliminary design efforts needed to solidify understanding and to define the scope of the undertaking with much greater accuracy will be required. At the end of the Phase I period the principal areas of technical risk should be identifiable and the undertakings necessary to give a high confidence of success should be laid out. It should be possible to specify

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essentials of a new development approach. These included use of the period between source selection and contractual commitment to study design, technical problems, future operations, cost effectiveness and development planning schedules. This period was also useful to prepare for negotiation of definitized fixed cost or incentive type contracts--an innovation that was not too clearly worked out until Titan III development permitted its application.

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> what is wanted with considerable precision. It should be possible to estimate the scope of the program with improved accuracy and confidence. It should be possible to define a set of development principles that will not change during the life of the program so that continuity and focused effort may be assured. If these and other conditions can be met, we may proceed with the development effort. If they cannot be, we will terminate our efforts at the end of the Phase I period.

Although it was anticipated that Phase I would end about 1 February 1962, the memorandum emphasized--for the second time--that early effort directed toward program definition and schedule protection would not commit funds and resources to the project unless all technical and managerial uncertainties were resolved satisfactorily. The Air Force was also enjoined to establish a strong Titan III project organization and to place every facet of the development undertaking--including solid motors, ground equipment, and launch facilities--under the authority of the program office.[14]

Rubel's office, already committed to deep involvement in every aspect of the program, anticipated formidable problems, particularly in "interface" areas of Titan II and the Titan III upper stage. He emphasized that it would also be necessary for the Air Force project office to insist that major contractors set up separate and strong centralized project-type organizations to work exclusively on Titan III development and production. He also pointed out that the Air Force program office should establish appropriate management mechanisms ". . . such as PERT, accounting centers, accounting and auditing practices. . . during this Phase I period," and warned that the adequacy of these management arrangements would be a ". . . major consideration in granting and withholding project approval following Phase I." It seemed fair to conclude from these statements that the ultimate fate of Titan III rested not on military necessity alone but rather on a favorable evaluation of the Phase I effort and the acceptability of the Titan III management structure to Rubel's group. The Air Force, undoubtedly sensitive to the degree of Department of Defense concern with minute aspects of the program, could sense that program management would not conform to convention. Nonetheless, Rubel was moved to tell McMillian, "The excellent work and cooperation of your staff and all Air Force elements that have been

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involved over a period of many months is very much appreciated."[15]

On 20 October 1961 General B. A. Schriever instructed Major General O. J. Ritland, space division commander, to establish a strong Titan III project organization. Schriever foresaw that the importance of the project and its compressed schedule would demand a management arrangement with ". . . positive authority over all elements of the vehicle development." During the interim period, as various organizational and administrative matters were resolved and manpower was sorted out, Titan III affairs were handled by people in the division's booster development directorate, the solid motor office established in early July, and the Dyna Soar directorate.[16]

But the temporary lack of a formal program office did not delay Titan III actions. The most urgent activity in late October was preparation of contractor work statements covering preliminary definition studies of the upcoming program. Use of a modified Martin Titan II ballistic missile as the core of the Titan III system meant that preparation of launch complex design criteria, preliminary airframe design and advanced planning studies would be the responsibility of the Martin Marietta Corporation at Denver. Aerojet-General, developer and producer of the Titan II propulsion system, was solicited to prepare propulsion system studies for the Titan III system. Final issue of formal work statements for Phase I solid motor and guidance studies was delayed pending assurance that the program would be approved for development. However, contractor selection was to move forward rapidly. The division set in motion procedures to select a solid motor development contractor--possibly the second most important element in the entire program. By 1 November requests for proposals were being prepared and Aerospace Corporation was ready to furnish formal system engineering and technical direction to the new development effort.[17]

But there was an obstacle. The $12.580 million needed by 1 November was not yet available. This was the total estimated on 11 October and still considered as the amount necessary to complete the first phase by 1 February 1962. The division, not anxious to start the program by missing its first milestone date, asked command headquarters to intervene to hasten

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allocation of Titan III funds. The division message was forwarded to Air Force headquarters on 3 November. As matters turned out, division anxiety lest it miss the approved program "kick-off" date proved to be premature.[18]

Higher issues involving Titan III, considered at the working level to be safely resolved, emerged again on the Washington scene for review and discussion. Since early July 1961, the Large Launch Vehicle Planning Group, under the leadership of Dr. N. E. Golovin, had been studying the relationship of launch vehicle system development requirements to long range space goals and programs. The Golovin Committee, early in November, recommended development of the Titan III as the vehicle most satisfactory for carrying out post-1963 booster assignments for the defense department and as a back-up for the space agency's moon program. However, this recommendation was overtaken either by events or by after-thoughts. At a luncheon meeting on 16 November 1961, attended by high level representatives of the Department of Defense and the civilian space agency,* those present agreed to recall the Golovin committee to again study the "Composition of the long term National Launch Vehicle program with particular emphasis upon the role of Titan III in that program, based upon thorough assessment of the performance potential and schedules of all vehicles actively considered."[19]

Seamans and Rubel were assigned mutual responsibility for the preparation of the study, which was to be analyzed and approved by the whole committee before its formal release. It would appear that at this point the Titan III program was actually suspended, a situation brought about by the absence of a "satisfactory resolution" of NASA and DOD viewpoints on whether there was indeed a valid requirement for Titan III. Thus the reason for passing the 1 November starting date and continued delays through

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* Present were R. S. McNamara, Secretary of Defense; R. L. Gilpatrick, Deputy Secretary of Defense; J. E. Webb, Administrator of the National Aeronautics and Space Administration; Dr. R. C. Seamans, Associate Administrator; Dr. H. Brown, Director of Defense Research and Engineering; J. H. Rubel, Deputy Director of Defense Research and Engineering; and Dr. J. V. Charyk, Undersecretary of the Air Force.

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November became clear. If matters proceeded to an agreement with the civilian space agency, the project would be funded to the extent necessary ". . . to allow the issuance of Requests for Proposals for essential parts of this procurement." Happily for the future of the Titan III program, the uncertainty was ended on 5 December when the Golovin committee agreed that Titan III was essential to post-1965 space vehicle requirements. In effect, the National Aeronautics and Space Administration conceded the necessity for going ahead with the development of a launch vehicle which would fill the performance gap between Atlas-Centaur and the space agency's Saturn IB booster.[20]

With affirmation of a national requirement for the Titan III launch vehicle, on 11 December 1961 the division received $1.150 million to fund the initial Titan III contractual effort plus $600,000 for solid motor studies and $250,000 to start architectural and engineering facilities design work.[21]

As these events were taking place, the space division was completing preparations to establish a strong (sometimes described as "autonomous") program management office. On 27 November 1961 General Ritland named Colonel Joseph S. Bleymaier, an officer with extensive experience in management of missile and space programs, to be the system program director. There followed selection of engineering and technical specialists from the booster development directorate, the solid motor office and the Dyna Soar directorate to man the 624A System Program Office, which began its official life on 15 December 1961.[22*]

Colonel Bleymaier and the program office staff immediately plunged into the work of budget planning, institutionalizing a management system, evaluating advance briefings, and taking care of a host of accessory details. The most immediate concern of the program office was to start the contractors on their preliminary studies.** This was accomplished without undue difficulty

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* Designated as the Space Booster Building Block Program 624A, on 31 November 1961.

** More detailed information on contracting is contained in Chapter 4.

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by issuing fixed fee study contracts covering Phase I objectives. Of more concern was the problem of contract definition, on which the start of actual hardware development and production hinged. In this connection, Air Force Assistant Secretary J. S. Imirie pointed out that the Titan III program was "... regarded by Messrs Rubel and Morris, with Secretary McNamara's concurrence, as an experiment to pave the way toward improved management of future DOD development-production projects of this nature."

The particular focus of this experiment was to be on contracting procedures, a procurement function normally hedged about with elaborate procedural safeguards. This painstaking process was the occasion for a Washington visit, on 30 November and 1 December 1961, of Colonel L. F. Ayres, Colonel Bleymaier's deputy for solid motor development. Colonel Ayers described the division's solid motor procurement plan to General Schriever, key members of the Air Staff, Dr. J. V. Charyk, Mr. Max Golden, Air Force Chief Counsel, and Imirie. They agreed that their best approach was to limit requests for proposals to firms recommended by the source selection board and to award a cost plus fixed fee contract. On 1 December the procurement plan was presented to Rubel and the resulting discussion centered on the purpose and substance of requests for proposals. It prompted a more detailed Rubel memorandum to the Air Force five days later and marked another major turning point in the evolution of the Titan III program.[23]

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NOTES - CHAPTER 2

1. Memo, Rubel to Asst SAF (R&D), 15 Sep 1961; memo, Brockway McMillian, Asst SAF (R&D), to C/S, 18 Sep 1961, subj: Request for Studies of Titan II as a Standardized Space Launch Vehicle, in Doc Vol.

2. This was the first reference to a technique of management which was to play an important role in Titan III development--PERT, for Program Evaluation Review Techniques. The idea started in early 1958 when the Navy asked Booz, Allen and Hamilton, management consultants, to devise procedures for planning and scheduling the 70,000 or more parts going into the Polaris missile system. The idea evolved to emerge as a basic management tool which would prepare realistic contract bids, schedule efficient use of manpower and other required resources, locate trouble areas, and suggest revised plans to meet project deadlines. Management had always performed these functions, but increasing complexity of contemporary development and other applicable tasks enlisted the aid of a computer to perform rapid planning and project accurate cost calculations. Generally, as the PERT system evolved into PERT/Cost, all the jobs that made up a project were identified, then charted and lines drawn between them to create a logical network; the estimated time each task would take was recorded; and the cost of each task was estimated. The mass of data was then fed into a computer which, hopefully, revealed the costs and target date of each step and totals for the complete program. The system could thus be used to find how long a project would take, how much money it would cost and in what order the steps should be taken. A good capacity computer--and programmer--could juggle time and cost factors around as desired or predict optimum tradeoffs. PERT could be tied with various accounting systems by giving each company involved in a program a code number compatible with its accounting system. Ideally, and eventually, if sufficient resources were applied to its use, a PERT system might be integrated on a nationwide scale. In that event, the Department of Defense or any other level of management would be able to know at a moment's notice the complete time and cost status of any or all development programs. As might be suspected, the system was in itself costly and perhaps, in many applications, more expensive than its use would seem to warrant. By 1962, such a system had become standard practice in major Department of Defense and National Aeronautics and Space Administration procurement actions.

3. Memo, Rubel, to SAF (R&D), 15 Sep 1961; Business Week, "Shortcut for Project Planners, PERT/Cost is Hottest New Tool in Space Age Research and Development," 7 Jul 1962; Aviation Week, Editorial, "A Lesson in Management," 29 Jan 1962, in SSD Library.

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4. Memo, McMillian, Asst SAF (R&D), to C/S, 18 Sep 1961.

5. Rpt, Titan III Standardized Space Launch Vehicle, 5 October 1961, prep by SSD and Aerospace Corp, in Hist Div files; ltr, MajGen O. J. Ritland, Cmdr, SSD, to Gen B. A. Schriever, Cmdr, AFSC, 4 Oct 1961, no subject, in Doc Vol.

6. Rpt, Titan III, Standardized Space Launch Vehicle, 5 Oct 1961.

7. Ltr, Ritland to Schriever, 4 Oct 1961.

8. MFR, Col R. M. Herrington, SSD 11 Oct 1961, subj: Action Required to Protect Titan III Schedule, in Doc Vol.

9. Memo, J. H. Rubel, DDR&E, to Asst Secs (R&D) of the Army, Navy and AF, 9 Oct 1961, subj: Management of Research and Engineering, in Doc Vol.

10. Ibid.

11. R. F. Piper, The Space Systems Division--Background (1957-1962), SSD Hist Ofc, Feb 63, pp 77-90; ltr, Gen B. A. Schriever, Cmdr AFSC, to Cmdrs AFSC Divs, 11 Oct 1961, subj: Policy on Management of Space Systems, in Doc Vol.

12. Memo, J. H. Rubel, DDR&E, to Asst SAF (R&D), 4 Oct 1961, subj: Standardized Agena, in Doc Vol; Reference to Skybolt based on a historical study of Skybolt by W. D. Putnam, SSD Historian.

13. Memo, J. H. Rubel, DDR&E, to Asst SAF (R&D), 13 Oct 1961, subj: Titan III Launch Vehicle Family, in Doc Vol.

14. Ibid.

15. Memo, J. H. Rubel, Dep DDR&E, to Asst SAF (R&D), 13 Oct 1961; TWX, AFSDC-S-8 71987, Hq USAF to Hq AFSC, 20 Oct 1961, in Doc Vol.

16. Ltr, Gen B. A. Schriever, Cmdr, AFSC, to MajGen O. J. Ritland, Cmdr, SSD, 20 Oct 1961, subj: Titan III Management, in Doc Vol; Hist Rpt, 624A Prog Ofc, Jan-Jun 1962, in Hist Div files.

17. TWX, AFSDC-S-8 71987, Hq USAF to AFSC, Info SSD, 20 Oct 1961; ltr, Col R. Nudenberg, Dir Space Programs, AFSC, to Gen B. A. Schriever, 13 Nov 1961, subj: Titan III, in Hq AFSC files.

18. TWX, SSVN-1-11-11, SSD to Hq AFSC, 1 Nov 1961; TWX, SKGN-2-11-5, Hq AFSC, to Hq USAF, 3 Nov 1961; ltr, MajGen R. E. Greer, V/Cmdr, SSD to Hq AFSC, 1 Nov 1961, subj: Titan III Solid Motor Development, in Doc Vol.

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19. Ltr, R. S. McNamara, SOD, to Admn NASA, 17 Nov 1961, no subj, in Doc Vol as atch to memo, R. L. Gilpatrick, Dep Sec of Def, to J. V. Charyk, Undersecretary of the AF, 21 Nov 1961, subj: DOD NASA.

20. Quotations from ltr, J. S. Imirie, Asst SAF (Materiel), to C/S, 4 Dec 1961, subj: Titan III; background from ltr, McNamara, to Admn NASA, 17 Nov 1961, in Doc Vol; memo, J. H. Rubel, Dep DDR&E, and R.C.Seamans, Asst Admn NASA, to SOD and Admn NASA, 5 Dec 1961, subj: Recommendations Relative to Titan III and Titan II½, in Hist Div files.

21. Memo, H. Brown, DDR&E, to SAF, 13 Dec 1961, subj: Approval of FY 62 RDT&E Program Related to Titan III, in Doc Vol; Hist Rpt, 624A Prog Ofc, Sep-Dec 1961, in Hist Div files. Chronology of funding actions, in Hq AFSC files.

22. AFSC SO M-21, 27 Nov 1961; Hist Rpt, 624A Prog Ofc, Jan-Jun 1962, in Hist Div files; ltr, Col F. H. Hickman, Dir of Prog, DCS/Compt, AFSC, to DCAS, 31 Oct 1961, subj: New Advanced Systems Programs, in Doc Vol.

23. Ltr, Col R. Nudenberg, Dir Space Programs, to Gen B. A. Schriever, 13 Nov 1961, in Hq AFSC files; memo, Imirie, to C/S, 4 Dec 1961, subj: Titan III; MFR, Col L. F. Ayers, Asst Dep, Solid Motor Dev, 12 Dec 1961, subj: Report on Briefings on RFP for Large Solid Motor for Titan III, in Doc Vol.

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CHAPTER 3

PHASE I: ISSUES AND PROBLEMS

The 1 December 1961 meeting of Air Force representatives with J.H. Rubel engendered ideas which, in their application, brought about far reaching changes in Department of Defense procurement policies. The primary concept with which all agreed was that the Air Force should make every effort to sign final contracts as soon as possible. It was at this point that departures from the "normal" research and development contracting procedures became apparent.

The Department of Defense, in the person of Rubel, decided that all the "ground rules and objectives" of the contractual development should be stated before requests for proposals were issued to contractors. The instrument of this new approach was to be the work statement. Research and development work statements dealt in large part with indefinite quantities, so they were to distinguish between "definable," "uncertain," and "unkown" tasks for which cost estimates were to be obtained. Other specific instructions on the preparation of requests for proposals made the new policy clear--they had to be written to assure early "definitization" and "to make sure that definitization of the bulk of the job is not held up because a relatively small part . . . cannot be fully specified at the start." Moreover, Rubel wished to insure that requests for proposals emphasized the need for adequacy of contractor management efforts. Proposals would have to include reporting and scheduling techniques, organizational arrangement, cost accounting systems, and a declaration that the contractor would modify his accounting system to comply with government requirements, making it easier to move from a cost plus fixed fee contract to an incentive or a fixed price agreement.[1]

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One important key in this new management approach was a requirement for positive assurances that the contractor would establish a "PERT" system. As then envisioned, the Department of Defense, aided by the designated "PERT" management firm, would establish three closely linked complimentary networks. At the topmost rung would be the network in the Office of the Secretary of Defense, to assist in " . . . decision making, monitoring and controlling the program . . . " A second connected network would perform similar functions at the level of the Air Force system program office and the third network would cover the internal operations of the Titan III contractors. Like other ideas introduced into the request for proposal work statements, this elaborate concept represented a marked deviation from conventional contracting procedures. Finally, Rubel emphasized that the 1 February 1962 deadline for completion of Phase I was not inviolable. "It is more important to do this job right than to do it in any one particular week," Rubel said. As a parting admonition he forbade the Air Force to issue requests for proposals until the modifications and actions " . . . which stem from the meeting and from this memorandum, have been accomplished. It is requested that these be reviewed with me before RFP's are sent out.[2]

The task of revising work statements became, in fact, a review of the entire contracting effort involved in the Titan III program. Through early December 1961 it absorbed the time and talents of many people including General B. A. Schriever, Major General J. R. Holzapple, Assistant Deputy Chief of Staff, Systems and Logistics, at Air Force headquarters, members of their respective staffs, Assistant Secretary of the Air Force for Materiel J. S. Imirie and Secretary of the Air Force E. M. Zuckert. As the Air Force approved various changes they were to be forwarded to Rubel and to the Assistant Secretary of Defense, Installation and Logistics, T. D. Morris, for their endorsement before being issued. It was anticipated that this involved process of coordination would take up most of the month of December.[3]

Despite the snail-like course of certain aspects of the program there were signs of encouraging progress during December. On the 13th Harold Brown, director of the defense engineering office, released his approval of fiscal 1962 research, development, test and evaluation funding

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for the Titan III program "subject to the availability of funds." A total of $7.8 million of $15 million requested for work on the Titan III core and $17.5 million for development of 120-inch diameter solid motors, against $50 million requested, was approved. A fund of $1.28 million was also set aside for design of ground facilities. As suggested in Brown's qualifying statement, however, approving these ceiling totals and actually finding and allocating the money were two distinct and widely separated actions.[4]

Brown advised the Air Force that in addition to the definitive studies currently underway--a study of compatibility of the Standardized Agena D with Titan III and a study of an integrated-transfer-launch facility for the Pacific Missile Range--the Phase I effort should be further expanded by studying a plan to insure compatibility of Titan III with the Centaur upper stage. Also the study of the launch complex concept should encompass a similar installation at the Atlantic Missile Range and include an " . . . analysis of the need for these facilities as well as the details of their construction. . . " Furthermore, Brown added, any changes in the Phase I study program or in its funding requirements or " . . . any other modification as may be necessary to assure a comprehensive Phase I effort," were to be submitted to Brown's office for approval by 28 December 1961.[5]

By the end of December the request for proposals covering solid propellants had satisfied all reviewers and, by 3 January 1962, following final consultation with top echelons of Air Force management, it was approved for release.* It set the pattern for all major Titan III contracting, including use of the cost-plus-incentive fee contracts. (In late 1961 the defense engineering office had suggested that the solid propellant contract might be the occasion for use of an incentive type contract.) It was now apparent that the 1 February 1962 date for completion of Phase I was unrealistic, and there were no seismic consequences when the Air Force suggested a 15 March 1962 completion date.

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* Thomas D. Morris, Assistant Secretary of Defense, Installations and Logistics, approved the solid propellant request for proposals from contractors on 24 January 1962, subject to approval by the Department of the Air Force--which, of course, had already been given.

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Assistant Secretary Imirie cited late release and general inadequacy of funding as the chief causes of program delay but beneath Imirie's surface analysis could be discerned more fundamental issues. Political considerations which affected the recommendations of the Golovin committee as well as the fervor of the defense engineering office for using Titan III as a vehicle for management reform were certainly causes of Phase I delay. Uncertainty concerning the relationship of Titan III to Mercury II (later Gemini), consideration of possible upper stages other than the Agena, and irresolution in the matter of Dyna Soar requirements also inhibited program progress. Futhermore, lack of funds seemed certain to delay the schedule by at least six to nine months. That circumstance had an effect less than two weeks after Imirie stated his views to the Department of Defense; he advised the defense engineering office that because of continued funding delays Phase I would not be completed until 30 April 1962.[6]

Nevertheless, certain essential procurement activities did move forward. The Aerospace Corporation Titan III team, established on 1 December 1961 under the direction of Dr. D. A. Dooley, accelerated its effort in system engineering and technical direction aspects and during January, Martin and Aerojet-General began work on architectural-engineering design studies. Preparation of the "PERT II" cost network proved to be more complex than originally surmised, but in mid-January Operations Research Incorporated produced a contractual exhibit describing the methodology of the system based upon cost estimating and contractor data gathering by activity (as opposed to task or project grouping). Through January and early February contractor cost projections were analyzed and compared, networks were reviewed, and contractor "PERT" capabilities assessed as a part of the source selection procedure. As this phase of the work continued into February it became apparent that establishing such an elaborate cost system as had been contemplated would cost more than any realistic appraisal of its potential value warranted.[7]

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Happily, more positive evidence of program advancement was demonstrated as contracts were let to Martin Marietta Corporation and Aerojet General Corporation as well as to architectural and engineering firms who would design a solid motor development test complex at Edwards Air Force Base and an integrate-transfer-launch complex at the Atlantic Missile Range. Certain technical problems demanded immediate attention. For one, it was apparent that the Agena space vehicle would require appreciable modification to qualify as a Titan III system component. Not only would its fuel capacity have to be enlarged, but there were enough additional problems of compatibility with the Titan III core to suggest that it would be more feasible and technically more sound to develop a new upper stage than to redesign the Agena. By mid-December a thorough review of the problem was underway. The upper-stage decision represented the first of several technical issues which were later to become the subjects of review and investigation, not to mention controversy, at all levels of management.[8]

Study of probable Titan III mission assignments highlighted the incompatibility of the Agena upper stage with booster performance requirements, to the extent that complete redesign seemed necessary. In the face of this difficulty, technical judgement tended to favor development of an integrated upper stage capable of both restart and precise navigation. On 19th March 1962, Dr. J. V. Charyk, for the Air Force, and J. H. Rubel, for the Department of Defense, accepted the program office recommendations to develop a new transtage and to eliminate further consideration of the Agena D as a Titan III component.[9]

An even more crucial technical decision involved selection of the Titan III guidance and control system. Basic Titan III development philosophy implied a conservative approach to system acquisition. Between October 1961 and February 1962 the Aerospace Corporation conducted a thorough study of Titan III guidance performance accuracy and reliability requirements. Guidance specialists concluded that no existing system was capable of satisfying the requirements. The issue immediately became a matter of major concern at all management levels.[10]

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In addition, in the early winter of 1961-1962, there were increasing demands on the Titan III program office to furnish reviews and briefings to the defense engineering office and its scientific advisors. Most were designed to hasten the decision making process, though that goal proved an illusion. General Schriever expressed concern over the unprecedented extent and detail of information required in these reviews and the nature of the decisions being withheld while the energies of those responsible for program management were being consumed in the generation of volumes of information for each succeeding managerial level. Despite the abundance of technical information, and contrary to reasonable expectations, decisions on matters that had never been previously reviewed were withheld "for inordinate lengths of time." Indeed, more people at the defense department staff level were "evaluating" Titan III program actions than monitored the program at system command level. General Schriever protested at one point that decisions were so often withheld that "while we are responsible for performance schedules and costs, we are gradually losing the authority that should accompany this responsibility.[11]

Despite--or perhaps because of--inhibiting constraints and attenuation of the command's authority, the program continued to progress. A new and of necessity flexible management philosophy evolved in the process. Technical decisions were largely based on second generation missile technology successfully demonstrated in the Titan II and Minuteman programs. The program office resisted the temptation to adopt "second-and-a half or third generation techniques." Hence the primary development emphasis was on reliability, system simplicity, and conservative design. In Colonel Bleymaier's judgement, that was how the program office had been instructed to proceed.[12]

Complicating the design development task were shifts in technical opinion and emphasis which were often communicated to the division through informal discussions and casual contacts with the defense engineering office. For example, during December 1961 and January 1962, the Titan III program office was led to believe that the most important requirement for Titan III was to achieve a core demonstration flight during 1963, but the idea was then apparently abandoned. During March and April the defense engineering office

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emphasized vehicle capacity to place a minimum of 3,000 pounds in a 24-hour equatorial orbit, a requirement that dictated major changes in the design of the system. Solid motors would have to be redesigned to five segments, although the division much preferred to start with a four segment development, and a transtage with a 22,000 pound propellant capacity became a program necessity. Such changes were introduced into the Proposed System Package Plan schedule for submission by 30 April 1962, a date marking the formal conclusion of the Phase I effort.[13]

To compound the difficulties attendant on supplying frequent and voluminous reports and briefings to Washington the defense engineering office announced, on 30 March 1962, a plan for an independent technical review and evaluation of the "Titan III Standardized Workhorse Launch Vehicle Program" by a technically qualified group under the chairmanship of G. W. Brady of the Institute for Defense Analyses.* This group was to conduct its review during April and to submit a report at approximately the time Phase I was completed and the Titan III development plan submitted. Panels were organized to analyze guidance and control, solid and liquid propulsion, and vehicle design and performance. The committee began its work on 4 April 1962, drawing the bulk of its information, naturally enough, from the space division, Aerospace Corporation, Martin Company and "such other organizations as appropriate." Requirements for presentations and data summaries, which had briefly subsided, again inundated the Space Systems Division.[14]

On 5 April 1962 Rubel proposed that, inasmuch as the Titan III vehicle was not designed to meet the requirements of a particular mission but rather to serve "the largest practical variety of such missions," the Air Force should prepare a standardized launch vehicle requirement document which would define and justify the various desired launch vehicle specifications based

* Instructions at Titan III briefings in Washington during March revealed that the Department of Defense and the Secretary of the Air Force planned additional detailed review of the 624A program. The division wearily contended that such a review was unwaranted, but promised "on or after 23 April 1962 to make material available to any committee appointed for this purpose."

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on mission payload needs and " . . . against which the Titan III development program can be evaluated." The report was to include a reasonably comprehensive survey of mission payloads for various projects, their orbital characteristics, reliability and cost considerations, special requirements of a military nature, and "man rating" needs. Rubel pointed up the requirements problem by citing missions which presented design contradictions. He noted, for example, that while Dyna Soar might be better served by four segment solid rocket motors, the additional thrust provided by five segments was essential for 24-hour synchronous orbit systems. Rubel was convinced that a five segment development would, in the long run, furnish the maximum degree of utility.[15] He was also voicing, though discreetly, a degree of pessimism concerning the future of Dyna Soar.

In some part, Rubel's desires for the configuration of Titan III were shaped by the convolutions of the Dyna Soar program. On 23 February 1962 Defense Secretary McNamara had formally terminated the suborbital aspects of that development and had made the attainment of orbital flight its major goal. More significantly, he insisted that Dyna Soar henceforth be treated as a research program rather than a weapon prototype. The orbiting glider thereupon became considerably less significant; indeed, its eventful demise (which was delayed for another 21 months) probably dated from the February 1962 decision--and if much of the Air Force refused to heed the portents, Rubel had no such compunctions.[16]

It proved quite impossible to meet a 16 April deadline for general launch vehicle specifications, particularly when the guidelines remained a bit vague. As for the five-segment motor, Assistant Secretary McMillian on 13 April pointed out to Rubel that the primary reason for emphasizing a four-segment unit was to avoid taking on a high risk program early in the development, even though all concerned conceded the ultimate desirability of the five-segment version.[17]

Immediately thereafter, a member of the Air Staff who had apparently caught the implications of recent Dyna Soar decisions introduced a new word of caution. In a note to General Schriever, General Holzapple suggested that the systems command evade commitment to a four-segment booster

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because a Titan III so designed would be too closely tied to Dyna Soar. Instead, Holzapple suggested, the command should abandon its conservative outlook and give greater consideration to endorsement of the five-segment alternative. He also cautioned against increasing the complexity of the transtage design--the final stage--without due regard for probable consequences.[18]

General Holzapple was essentially urging the systems command to examine and weigh the hard facts of life which were influencing the attitudes of the Directorate of Defense Research and Engineering. He saw, perhaps because he was closer to the scene, that a rigid bond between Titan III and Dyna Soar could cause the two programs to collapse together if one were sufficiently weakened. He also saw clearly that concessions to the directorate outlook were inevitable, even if not abstractly desirable.

Basic problems of dollars in hand helped delay the program. Money to fund Phase I studies was still allocated on a piecemeal basis. Sufficient money to support Phase I had been slated to be available 1 November 1961. Instead of the necessary $15 million, $1.150 million was released to the division on 8 December 1961 and $6.650 million on 15 January 1962. On 15 March 1962 the Systems Command stated a pressing requirement for an additional $2.9 million to support the program through 10 May 1962. Not until 9 April however, did the defense engineering office release an additional $1.9 million to bring the total amount of available Titan III funds to $9.7 million.[19]

Notwithstanding such technical and managerial decision delays, the Proposed System Package Plan was published on 30 April 1962. It represented six months of intensive analysis and program planning, bringing together vast quantities of data and cost projections. The objectives assigned the division--establishing a strong system program office, organizing and applying appropriate management techniques, establishing a sound contractor structure (by requesting proposals based on detailed work statements) and preparing a complete system package plan--had been completed. The program office was convinced that "Analysis has shown that the Titan III has wide mission applicability and is in fact fundamental to the present and future military space programs." General Schriever urged Air Force headquarters to take

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" vigorous action . . . to obtain the earliest approval from DOD in order that we may proceed with the development program." [20]

With the completion of Phase I the Air Force expected the Department of Defense either to reject the proposed program or approve it for development and production. Immediately following the 30 April 1962 submission date, details of the proposed development plan were presented at command and Air Force headquarters levels. On 3 May the Air Force Designated Systems Management Group heard details of the proposed Titan III system--and endorsed the program plan. On 7 May Dr. Brockway McMillan, Assistant Secretary of the Air Force for Research and Development, formally forwarded the proposed plan for a "Standardized Space Launch System (Titan III)" to the Director, Defense Research and Engineering. On 11 May 1962, allowing a few days for study of the plan, the program was briefed to the director of the defense engineering office, Dr. Harold Brown, his deputy, J. H. Rubel, and Dr. L. L. Kavanau, Special Assistant for Space. [21]

The plan as presented contained a description of the system, its projected development costs, and development and delivery schedules. It was described as the product of the ". . . most comprehensive advance development planning effort ever undertaken by the Air Force . . . " McMillian said the program was based on " . . . realistic cost estimates, reasonable schedules, and a firm fix on technical problems, a program which will provide not only proven, reliable hardware, but also the facilities, operational capability, and production capacity to put the system to work." Moreover, the assistant secretary reported that the Air Force had opened preliminary negotiations with all development and production contractors involved in the program except for the solid motor and transtage propulsion unit. He reiterated Air Force awareness that no contracts were to be awarded until the development program was approved. [22]

As then planned, the Titan III vehicle would have two four-segment solid propellant motors (each containing approximately 400,000 pounds of propellant and delivering over 900,000 pounds of thrust throughout a burning time of approximately 105 seconds) attached one on each side of a Titan II core. The core would consist of a 430,000 pound thrust first stage, a second stage generating 100,000 pounds of thrust, and a transtage equipped with two 8,000 pound

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thrust chambers. The plan proposed 17 test flights, construction of a three pad integrated-transfer-launch facility at the Atlantic Missile Range and a two pad integrated-transfer-launch complex at the Pacific Missile Range, development of a new guidance system rather than use of "off-the-shelf" components, 12 flight tests with solid motors in a four segment configuration, a "Blue Suit" capability at both east and west coast test ranges, a malfunction detection system to permit man-rating, and production for mission assignments. First launch of the Titan III core (designated Configuration A) was planned for 21 months after the development program started; the first complete unit with solid motors (designated Configuration C) was scheduled eight months later. Because the program included some changes and additions to the plan of October 1961, an increase of $99.6 million would be necessary over the amount specified in the President's budget for Titan III in fiscal 1963. Military construction funds would also have to be increased by $12.6 million over the President's budget. All told, the development would cost $931.1 million, plus $161.45 million to finance construction of facilities at the Atlantic and Pacific missile ranges and at Edwards Air Force Base (the rocket engine test site). The increase would be partially offset, however, by a reduction of $53 million in the anticipated cost of solid motor development and $16 million by elimination of Agena D procurement, test, and ground equipment.[23]

An important factor in understanding the Air Force recommendation was the Dyna Soar program. The long thwarted Air Force desire for a manned space system was currently focused on Dyna Soar--which had been in some stage of proposal or development for nearly a decade. In the minds of virtually all Air Force planners the two were linked, for better or for worse. Dyna Soar was designed around Titan III (or an improved Titan II, at least) and could only become a real manned space system if a proper booster were available. Such considerations almost certainly explained why the 3 May meeting of the systems management group heard a proposal for a four-segment motor and a relatively complex final stage rather than the five-segment simplified model Holzapple had urged and Rubel had virtually ordered.[24]

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If the final decision could not be predicted in all its details, it was certain at least that funding problems would be important. While endorsing system command recommendations with relative enthusiasm, the Systems Review Board had cautioned that if the Air Force had to fund the program within earlier ceilings, a major reappraisal of schedules and development consequences would be necessary.[25]

Meanwhile the division program office had slight opportunity to sit back and wait for the fateful program decision. On the contrary, absence of a Titan III verdict made it necessary to keep the Phase I effort alive until a decision was reached. Then, if the program were approved, it was apparent that the period of transition from Phase I study contracts to Phase II development and production contracts would be complicated and difficult. The contractors had to be kept in a ready-to-go status without any Air Force commitment to award a specific Phase II contract. Since the only solution was to extend Phase I contracts, the division requested, on 10 May 1962, release of sufficient funds to sustain the program ". . . on an interim level of effort basis using current expenditure rates." Applying this formula, beginning 15 May 1962 and every two weeks thereafter, Martin would need $750,000 and Aerojet would require $90,000. Aerospace Corporation would have to have $800,000 to keep staff paid and studies underway until 1 July, when another $250,000 would be required to tide the corporation over to 15 July.[26]

If there had been any hope that satisfactory completion of Phase I would alleviate the demand for technical information, these hopes were dashed by continued Washington requests for additional technical data and briefing reviews. Within a week after the program director had presented details of the proposed development plan to the director of defense engineering and his staff, additional information was requested on certain specific items in the development plan. In addition, the space division was continuing preparation of an analysis of Titan III mission requirements requested by Rubel on 5 April.[27]

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Rubel, the father of the Phase I concept, at least in this particular application, prefaced certain uncomplimentary comments on the proposed plan with the note that he was ". . . pleased with the amount of effort which went into Phase I and the extent of the technical analyses." In his initial evaluation of the Titan III plan, forwarded to the Assistant Secretary of the Air Force for Research and Development on 16 May, he criticized the system package plan as not containing adequate technical information "in the report form necessary to accomplish the DDR&E review." On the other hand, he said, " I feel quite confident this data is in existence and can be supplied on an expedited basis." The kind of additional information desired was an illuminating commentary on the management philosophy practiced by the defense engineering office. First, a complete description of Air Force relationships with industrial organizations involved in the Titan III program and the role and functions of each organization including ". . . at least the names of all senior supervisory personnel to about three levels below the organizational project manager" was desired. Second, more information on anticipated operations, mission analysis and long range plans for using Titan III was necessary. Third, additional civil engineering information covering "ITL's" at the two range locations was needed. Fourth, much more budget detail and financial information was requested. Finally, many more technical details of the entire system were required.[28]

The area in which the most marked difference of opinion continued to exist was the yet unresolved question of the number of segments to use in the solid motors. Since the Air Force had not yet accepted the five segment design thesis, Rubel asked for a list of the program changes necessary if five segment motors with a burning time of 120-seconds were selected. In addition, he requested a technical analysis to support the Air Force opinion that a five segment development would result in a ". . . significantly greater risk than the presently planned two-step four and five segment development." Analytical transtage data of a more penetrating quality was to be forwarded together with additional data on guidance system specifications. Data from past guidance experience to measure and compare "advertised versus measured results" was requested. The accuracy and reliability of those components

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constituting the proposed system--Space Technology Laboratories and Arma were tentatively slated to develop an inertial guidance system--and those already in use by the Titan II ballistic missile were to be included in the submitted data. Also, "a description of the growth potential and product improvement associated with the subsystem should be included for programming perspective." All of this additional information was to be made available by 23 May 1962, to " expedite the DDR&E review action.[29]

Although the defense engineering office had been closely associated with every step in Titan III development planning, certain features of the program, to the surprise of the Air Force, were being reexamined from their beginning. Interestingly enough, the gradually increasing costs projected for the total program were not the cause; nobody important had as yet expressed any particular concern about dollar totals. In the judgement of Assistant Secretary McMillian, the compelling issue was vehicle performance. Since virtually all aspects of vehicle performance had either been original with or specifically reviewed and approved by the defense engineering establishment, that development seemed a bit strange. And at that point in time (late May 1962) there was a sudden emphasis on speedy decisions--probably because the defense engineering staff was committed to complete its Titan III review, in progress throughout May, and present an assessment of the proposed program to Secretary McNamara by 11 June. With less than two weeks remaining before that deadline, there still were five principle areas of contention in which the Air Force had to be prepared to advise McNamara.[30]

Appalled program managers were discovering that at this late date there were still high level disagreements on what Titan III was supposed to do. Originally, in the glow of the universal "workhorse" concept, a Titan III vehicle was envisioned which would loft payloads from 5,000 to 15,000 pounds into low orbit and thrust lesser payloads into high orbits or on escape journeys. But in May 1962 the adoption of certain favored ideas--particularly the use of storable fuel in the transtage rather than advanced high energy propellants, a choice which would limit performance in the intermediate, high orbit, and escape payload range--would limit Titan IIIA to putting only 6,700 pounds into low orbit. Payload capacity would jump to 27,000 pounds in low orbit when

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solid motors were added to make up the Titan IIIC configuration. Even with performance augmented by solid motors, Titan IIIC would be able to place only 1,400 to 1,700 pounds of payload in a 24-hour synchronous orbit. Since there was a good probability that many space missions in the future would be in the 8,000 to 20,000 pound payload range, two basic issues were raised anew: how was this payload range to be accommodated, and did Titan III indeed satisfy the concept of a standardized "workhorse" vehicle with a ten year span of usefulness?[31]

Intertwined with the overall problem of vehicle performance was the continuing difficulty of choosing between the four and five segment solid motors. The Air Force was not opposed to an eventual five segment motor if permitted to retain the four-segment development. Considerations of standardization and future performance growth favored a five segment motor but technical design limitations of Dyna Soar--still the only specific mission then awaiting the Titan III--required four segment, slow burning solid motors unless costly changes were introduced into the glider. As a way out of this dilemma, McMillan requested that the Dyna Soar program office perform a detailed analysis of the consequences of using the five segment motor, while the possibility of designing a greater degree of Dyna Soar compatibility into a five segmented solid motor was also to be examined.[32]

Another troublesome question was the design of the transtage. Since transtage performance characteristics would directly affect payload weights in the intermediate range the reasons for concentrated attention on this design were understandable. Technical uncertainties involved such alternatives as pump-fed versus pressure fed propulsion system, size and capacity of the stage, and the design engineering required to accomodate advanced high energy propellants. Some key procurement questions also demanded attention: should already developed Agena or Ablestar components be used to build the system, and if development were started from "scratch" what contractor would be selected? To further cloud the problem, the scientific advisor to the Air Force Deputy Chief of Staff, Systems and Logistics, H. J. Weigand, entered the fray with a suggestion that the transtage idea probably would be criticised by the civilian space agency as not entirely

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satisfying the concept of a workhorse booster. He advised the Air Force to examine the effect on costs and schedules of eliminating the transtage module altogether. Despite these contradictory voices--and there were probably others--McMillan stated, hopefully, "We must objectively evaluate the alternative approaches to the transtage development and assure ourselves of the proper choice."[33]

An equally controversial and perhaps much more fundamental problem, considering the far reaching issues involved, centered on the choice of the Titan III guidance system. Although expert opinion supported the ultimate need for a new guidance system, the basic question arose on the need for starting its development at the inception of the program. There was general agreement that Titan III could get along for awhile--to exactly what extent or for how long was more debatable--on the Titan II guidance system already in production. Its selection would offer the advantage of economy in the short run and probably, with some modifications, it could guide payloads on less sophisticated missions with adequate precision. By the last of May there was evidence that these limited advantages were appealing to the defense engineering office.

At this point, budget pressures became increasingly important in Titan III planning. The Pacific Missile Range integrated-transfer-launch facility, while ultimately essential to future Air Force space operations, became financially attractive because it might be postponed to relieve the strain on fiscal 1963 funding requirements. Since policy controversies, imponderables, and uncertainties had become adjuncts of the program to a degree never before experienced, McMillian concluded that wisdom would be better served if such matters were referred to the serious personal attention of the senior members of the Air Staff.[34]

While the Air Staff was preparing to wrestle with these problems, program costs were becoming a larger problem than earlier judgment had predicted. To forestall premature budgetary entrenchment of the defense engineering office position before Titan III recommendations reached Secretary McNamara, Undersecretary of the Air Force J. V. Charyk on 31 May 1962 advised the

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defense engineering director that the Air Force was continuing to evaluate certain critical elements of the program. "In the area of over-all costs," he noted, "we are endeavoring to determine an effective phasing of the program elements that will accomplish our objectives and yet minimize the funding problems in FY 1963." Charyk added that the Air Force was also continuing to assess ". . . certain of the technical elements in the area of the solid motor development, the transtage, and general vehicle performance to assure that Titan III provides the most practical vehicle possible in meeting the future requirements of a standardized launch vehicle." He added that on 11 June the Air Force would like to discuss possible program alternatives with the director of defense engineering. This was about the time the Secretary of Defense was slated to complete his assessment of the Titan III program.[35]

The determined effort of the Air Force to get a hearing before Titan III positions had thoroughly congealed was not entirely successful, although the 11 June defense engineering office presentation to the Secretary of Defense was rescheduled for a later date.

Through the first two weeks of June there occured a series of Systems Review Board and Designated Systems Management Group meetings, culminating in a conference of Air Force and defense engineering representatives on 14 June. Discussions at that time went far to shape the final form and character of the Titan III. Rubel, spokesman for the office of defense engineering, again emphasized the overriding priority of heavy payload, high orbit performance. Even more positively than before, he maintained that there was no choice but to hold the design of the transtage to a configuration which would put 3,200 pounds in a 24-hour orbit. Again he reiterated the basic requirement for a five-segment motor.

It was clear from Rubel's stand that the compatibility of the Titan III configuration with the existing requirements of Dyna Soar held second place, at best, to the demand for a system capable of placing very heavy payloads in low orbit and substantial payloads in a 24-hour orbit--the "stationary" orbit required for a satellite that would appear to remain above one spot on the earth. That priority ranking might not be palatable to the Air Force, but there was no mistaking Rubel's fondness for it.

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Mr. Rubel was considerably less dogmatic in his opinion on the type of guidance system essential to Titan III. He observed that the choice was a technical matter properly within the decision responsibilities of the system program office, a viewpoint which came as something of a surprise to the program office and which proved, in any case, to be fleeting.

The spectre of money shortages haunted the 14 June meeting. Air Force representatives got the impression that an arbitrary funding ceiling might be imposed--at a level below that on which schedules and work statements had been predicted. If this occured it could leave the program office in the highly embarrassing position of appearing to have carried on prolonged negotiations with contractors in bad faith. So, although important decisions were made in the 14th June meeting, it did not resolve all Titan III problems and it offered a new area of concern to program management.[36]

It became obvious, following the 14 June meeting, that formal changes would have to be introduced into the program.* After two more weeks which were presumably applied to additional review and study, defense engineering unveiled several more decisions. Funding difficulties, rather than technical considerations, now seemed to condition the decisions and define the alternatives. There was at least a faint suggestion that delaying the start of the program was being considered as one means of reducing fiscal 1963 funding requirements.

Whatever the presuppositions, the Air Force was instructed to make several drastic program changes--which reoriented the entire program--as a prerequisite to development approval. The first of these changes would delay the start of "Blue Suit" training until after completion of the Phase II

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* There is some evidence that formal documentation of changes the defense engineering office wanted in the Titan III program were requested as early as 28 May. In a 28 June memorandum from Harold Brown to Brockway McMillan, reference was made to a letter dated 28 May, which requested formal changes to the Titan III program. The 28th of May was the same date on which the Air Force was mounting a strong effort to assure that its viewpoint was adequately represented in the program assessment slated to be presented to Secretary McNamara on 11 June. It seemed possible that the Air Force presented its case to people who had already made up their minds.

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development effort. Second, reversing Rubel's stand of 14 June, his chief, Harold Brown, ruled that Titan III was to use Titan II guidance with minimum modifications. The other changes had all been pronounced during the 14 June meeting: an upper stage optimized for 24-hour orbit capability, a control module (normally a part of the transtage but capable of separation) to be developed as a separate sub-system, and the five-segment solid motor. Finally, only a minimum two-pad integrated-transfer-launch complex would be constructed at the Atlantic Missile Range instead of the three-pad complex the Air Force proposed. Modifications to Pad 20--a Titan II test pad--were approved, however. The Air Force was instructed to prepare all the program documentation these changes entailed and to submit them to the defense engineering office as soon as possible.[37]

Two months of discussion, study, and program review had passed since 30 April 1962--the completion of Phase I. During those two months, the program office had been thoroughly absorbed in maintaining a viable effort poised at the "starting line" for a signal to begin actual development. Although the Air Force was advised frequently enough to hasten its work, Washington authorities sometimes seemed utterly indifferent to the consequences of their own prodigal use of time. For example, shortly after the Brady committee submitted its 4 May report and an accompanying series of "white papers" to the defense engineering office--papers which were not made available to the Air Force--the committee was reconvened for another review of the Titan III program, this time to report on major technical problems involved in the development of the system. But the final report of the Brady committee, submitted in early June, apparently was no more satisfactory than the initial report, for later during June the technical staff of the defense engineering office embarked on its own review of the Titan III program plan. The quantity of information prepared by the program office and brought to Washington had now reached a total of some 1,650 charts and graphs supported by some 400 pages of technical discussion. In addition, the program office had also prepared and submitted to the Washington engineering office a review report of Phase I, Management Philosophy and Technical Approach, dated 9 June 1962. At the same time two other important documents were in preparation for later

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publication: A Mission Analysis, forecasting potential requirements of the Titan III system, and a Preliminary Operation Concept.[38]

As program activity continued through May, June and into July, the division had to obtain week by week funding to keep the program alive while awaiting a Washington decision on Phase II. In early May the total Titan III plan for fiscal 1963 was visibly wrenched by deletion of $50 million--a funds deficit which would inevitably have to be balanced by compressing expenditures in later fiscal years. Submitted formally on 7 May, the change reduced fiscal 1963 funding requirements to $279 million. On 4 June the defense engineering office released $2.56 million to carry the Titan III contractors to 15 June and on 21 June another $2.74 million to keep Phase I work alive until 15 July. By then it was a near certainty that Phase II could not start by 1 July, which had the effect of lowering minimum requirements for fiscal 1963 to $254 million. If delays continued after 1 July, program funding requirements for fiscal 1963 would be reduced by roughly $20 million per month. They would, of course, be increased as much or more in later years, but this seemed to cause little concern in the Pentagon. If contractual inaction persisted into fiscal 1963, contract negotiations would encounter mounting difficulties since the complex program schedules would require extensive revision.[39]

The new fiscal year opened without the Department of Defense approval to move into the second phase of the program. On 7 July the Titan III program office began to act on the revised program--procurement of the five segment motor, elimination of four segment motor tests, and completion of design of a transtage with a 22,000-pound propellant capacity. In Washington, further details of the adjusted program were reviewed in a 13 July meeting between Rubel, McMillan, Hozapple, and Major General J. G. Merrell, Air Force Director of the Budget. The main subject of the meeting was money. Funds available for Titan III during fiscal 1963 had now dwindled to $225 million. And, apart from other involvements, Titan III changes had a serious impact on the Dyna Soar program. Studies had now confirmed the earlier Air Force contention that the change to a five segment solid motor would require either modification of the Dyna Soar orbital glider or re-activation of the four segment

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motor program. In view of the rigidity of the defense engineering office stand it was likely that Dyna Soar would be modified; either course would take money that was not readily available.[40]

On 19 July 1962 Secretary Zuckert signed the Titan III Program Change Proposal. Thus the months of intense study and technical discussion over the issues involved in Titan III program changes were ostensibly closed. But not entirely, for at this juncture in the program another technical-management crisis appeared. This centered on the final selection of a guidance system, a procedure that had already been underway for several months. Negotiations had been conducted with Space Technology Laboratories and Arma Corporation, a joint venture in this instance, to develop a highly reliable advanced guidance system. Discussions of contractual arrangements were then interrupted when the defense engineering office took the position that the Titan II all-inertial guidance system would probably perform well enough for the time, and at a great deal less cost, most assignments foreseen for the Titan III launch vehicle. Negotiations with the two guidance contractors had to be suspended and the Air Force was not able to proceed with any alternate procurement action until it had received further instructions.[41]

By mid-July, despite the remaining uncertainties in the Titan III program, Colonel Bleymaier's office was negotiating with contractors in a point by point effort to pioneer a relatively new medium of contractual understanding for research and development. The instruments were cost-plus-incentive-fee contracts to become effective if and when approval was received to proceed with the second phase of the program. By mid-July use of the "PERT" management system, introduced into the Titan III program with such high promise, was reduced to those functions which it could perform best--scheduling and cost estimating for contractor day to day performance, and furnishing data to the central program office for overall "PERT-Cost" management of the total program. At this level the program appeared to be most useful, even though it played something less than the monumental role originally envisioned.[42]

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Although it was becoming more probable that development of Titan III would ultimately be approved, the program was still marking time on a week to week basis. On 12 July the division appealed to command headquarters for more money to keep the program going. At the same time a warning was issued to contractors still on extended Phase I contracts that they were not to spend any money in expectation of receiving a development contract. A total of $2.168 million was requested to support the sustaining effort between 15 July and 15 August. When received, these funds were applied to special Phase I studies, small scale test work, preliminary transtage design, and guidance system research.[43]

On 16 July 1962 the defense engineering office told the systems command it would have to furnish additional justification for the Titan III system before further action on the program could be approved. This time estimates of Titan III production and operation costs, in configurations "A" and "C", were requested. The Titan III program office furnished the information with an understandable minimum of enthusiasm. Said Colonel Bleymaier, "We are reluctant to submit data according to the format [requested] inasmuch as that implies a degree of precision and accuracy which is not possible at this time."[44] The relevance of the desired information to pending decisions was somewhat obscure. Furnishing the information also posed the hazard ". . . that additional hasty cost quotations will be inappropriately interpreted by comparison both with actual experience on other systems and with the degree of completeness and accuracy characteristic of 624A development cost estimates."[45*]

Later the same week the Pentagon forwarded a request for additional information on the status of technical specifications, work statements, and contract negotiations. Part of the request concerned a comparison of the ". . . relative merits of the STL/Arma guidance system which had been selected for development and an AC Spark Plug guidance system." The latter system was becoming increasingly attractive to decision makers in the defense engineering office even though they had been exhaustively briefed on the

* One Air Force spokesman went even further: ". . . the improper use of such hastily prepared estimates, more than any other factor, is believed to account for the large program 'cost overruns' which are so deplored publicly by DDR&E."

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requirement for selection of the more advanced system. By the first part of August it was reasonably certain that the Titan II guidance system produced by AC Spark Plug would be selected for Titan III use.*

Significant as were the contractual innovations and engineering questions, they remained peripheral to the central issue which--although long since thought resolved--obstinately refused to stay resolved. In early August the director of the defense engineering office questioned Colonel Bleymair regarding the adequacy of the requirement for the Titan III standardized launch system. It was difficult to understand the rationale for such a question at that point in time--after some of the best scientific minds in the nation had recommended its development, after eight months of intensive effort, and following the expenditure of approximately $15 million on Phase I studies. The Air Force was also cautioned to avoid overruns and program slippages. Three months had then passed since the formal completion of Phase I, costs were running approximately $2 million a month, and everything awaited a Department of Defense decision to start Titan III hardware development.[46]

On 10 August 1962, after extended and exhausting appraisals and re-appraisals, the ultimate decision was faced. The deputy director of the research and engineering office, J. H. Rubel, recommended to the Secretary of Defense that full scale development of Titan III be approved. Rubel explored alternatives, weighed potential missions, described the Titan III system in some detail, projected overall costs, reported the results of the Phase I

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* The Titan III program office was sorely disappointed by the selection of the Titan II guidance system. The decision's implications were clear: elimination of a broad space mission spectrum, minimized flexibility and growth potential, and ultimately a major guidance system block change. It appeared that, to the defense engineering office, capability to oppose the Russian space threat was secondary to developing the Titan III as cheaply as possible: "The capability that the military is attempting to convince the DDR&E we should be able to accomplish some four years from now is about equivalent to the capability the Russians are demonstrating in actuality as this paper is being written." (13 August 1962)

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approach, and made some subjective judgements.* Specifically, he recommended a program to cost $817 million, $750 million of which would be for research, development, and test. These funds would purchase development of solid five-segment 120-inch motors, a liquid propelled center core consisting of three stages and a control module, test facilities at Edwards Air Force Base, and a two pad integrated-transfer-launch complex at Cape Canaveral. Pad 20 at the Cape would be modified and used for Configuration A (core) launches. In addition, he recommended use of Air Force funds originally slated for development of large solid propellant motors. (Fiscal 1963 Titan III funds included $32.85 million carried over from the fiscal 1962 solid motor development budget. Since it was necessary for the Air Force to reprogram an additional $18.15 million to obtain sufficient money for Titan III, he recommended that this amount be taken from fiscal 1963 large solid motor development funds.) Finally, selected milestones marking the development program were listed: a development engineering inspection, July 1963; first flight test launch, core only, May 1964; first launch of a core plus solid motors, January 1965; and the 17th and last flight test launch, March 1966.[47]

The Air Force was pleased with the recommendation for decision, but it was soon apparent that approval of the development program did not imply any easing of the defense engineering office's intense interest in every detail of the undertaking. To begin with, the Air Force was instructed to undertake no major program effort until ". . . contracts are definitized or a level of effort approval is obtained in writing from DDR&E." Major funds would not

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* Attested by this quotation: "If the Phase I effort had not been undertaken--if, on the contrary, Air Force proposals of last fall had been accepted and development begun on a large scale right away--it is certain that few or none of these management innovations would have been made and it is equally certain that design decisions that have been made during the past eight months would have come in as major program change proposals which would have cost many millions of dollars. If you approve the Titan III Program as presented here, I estimate that the Phase I effort will have saved at least $100 million simply by eliminating the need to repeat design efforts initially aimed at design concepts which would later have been changed."

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be released except for obligation against definitized contracts. These were unusual conditions since they required that all contracts, including their incentive plans, had to be completely negotiated and then reviewed by the Department of Defnese prior to fund authorization and final program "go ahead." These strictures were confirmed by Secretary of Defense McNamara in his 16 August authorization to the Air Force to proceed with Titan III. Furthermore, final program approval was made contingent on the defense engineering office's review and acceptance of a revised Technical Development Plan which was to include detailed cost figures and plans for fixed price procurement. This development plan was to be submitted to the defense engineering office by 15 October 1962.[48]

Thus, before development could begin, the Titan III system program office was confronted with two immediate demands: complete definitization of contracts already being negotiated; and discontinuing already well advanced contract negotiations with Space Technology Laboratories--Arma Corporation. AC Spark Plug, builder of the Titan II guidance system, was to supply modified inertial guidance units. Creating cost plus incentive fee definitized contracts that were meaningful, yet economically realistic, proved to be a task requiring weeks of research and protracted negotiations. Surprisingly, considering the complexity of the assignment, procurement specialists made relatively rapid progress in multi-million dollar negotiations with Martin, Aerojet-General, and United Technology Corporation.

By mid-August, despite the absence of sole source justification, the Space Systems Division was preparing contractual documents necessary for procurement of guidance equipment from AC Spark Plug. Detailed analysis of the procurement problem opened a veritable Pandora's box of technical questions: what performance specifications should be established for the system? what specific modifications should be required for particular components?* Decisions on these technically difficult questions

* Preliminary assessment of these problems indicated that changes would have to be made to the inertial measurement unit gimbal assembly to give increased gimbal freedom on the azimuth, roll, and pitch gimbals; adding slip rings on the inner and outer gimbal assemblies; changing gimbal angle (Cont'd)

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had to precede preparation of work statements and program definition. The incredible aspect of this activity was not that it continued, for it was normal to any complex vehicle development project, but that higher headquarters and the defense engineering office continued to be so deeply involved in direction of these minute engineering details.[49]

Notwithstanding the guidance system difficulties and the complex contract negotiations, by the last week in August the Titan III undertaking was apparently moving ahead at all levels. A Space Systems Division Program 624A Configuration Control Board was established and assigned the undramatic but crucial responsibility of approving or disapproving all requests for changes in the overall system.* Also program definition effort was far enough along to permit accurate scheduling of remaining tasks so that existing Phase I contracts would terminate on 31 October. As the tentative plan developed there appeared to be strong assurance that negotiation of definitive contracts for Phase II development would be completed by mid-November. At that time, all contracts--with the exception of that for the guidance system--would go forward for approval at command headquarters and final review by the Department of Defense.

To cover the transition from Phase I to Phase II--a problem which was of particular concern to the Air Force--the division proposed that all contractors attempt a phased build-up from 1 September through 15 November 1962, ordering long lead time items, taking care of critical program elements, and managing an orderly manpower expansion. When the contractors had signed their contracts, between 31 October and 15 November, full program "go-ahead" would be authorized. Anticipatory costs would be authorized until final approval of contracts was obtained. Admittedly, negotiating incentive contracts on a tight schedule while keeping the program viable without obligating the government before final approval by the Department of Defense was a difficult task that required intricate timing.[50]

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pick off assemblies to provide better gimbal angle quantization levels; and modification of the computer capacity to furnish more discretes and to solve explicit guidance equations.

* Colonel J. Pellegrini, head of the 624A Program Requirements and Standardization Office, was appointed chairman of the board.

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If the plan was to be followed, substantial amounts of money would be needed. There were sufficient funds to extend Phase I contracts from 1 September through 31 October but interim "go-ahead" actions between 31 October and 30 November would require approximately $17.6 million. In addition, an immediate release of $16.7 million in construction funds was necessary to meet scheduled advertising dates for award of Titan III facilities construction.* If these commitments could be honored by the close of November, the final Phase I objective--award of all major definitized contracts with the exception of guidance--would have been attained.[51]

Another ambiguity in the Titan III program remained. Department of Defense instructions released in July 1962 required a delay in the start of military operational training until completion of Phase II development. But if military training was to begin immediately after completion of Phase II it would be necessary for the Air Training Command to take certain preliminary actions early in the Phase II effort--actions whose costs so far had not been approved in the Titan III budget total. For example, almost with the start of Phase II, the quantity of manpower required to operate the system and their necessary level of training and skills would have to be determined. Trainers would have to be designed and their procurement started if they were to be available by 1966. Through 1966 this pre-training activity would cost a total of $15.22 million. Therefore the program office moved to include this fiscal 1963 and 1964 budgetary change among those actions which required approval prior to the start of Phase II.[52**]

* Advertising dates for award of construction contracts: 23 August advertisement of contract for the solid motor test complex facilities to be built at Edwards Air Force Base; 27 August advertising for award of a modification contract on Pad 20 at the Atlantic Missile Range; and 8 October advertisement for a contract to prepare the construction site for the two pad integrated-transfer-launch complex at the Atlantic Missile Range.

** Anticipated expenditures by fiscal years: $1.26 million in 1963, $1.5 million in 1964, $7.71 million in 1965, and $4.75 million in 1966.

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The major energies of the program office were expended, during the fall months of 1962, on myriad details and problems associated with "definitization" of all contracts. One of the first significant events marking advance in this phase of the program occured on 20 August 1962 when the Department of Defense announced that the Martin Marietta Corporation had been selected as systems integration contractor for Titan III.[53]

As a follow-up to this contract, which had been negotiated some weeks before, Colonel Bleymaier instructed Martin and other Titan III major contractors to prepare for formal cost negotiations, cautioning that ". . . expedient consummation is not only essential but mandatory." Furthermore, the contractors were told that only by hastening final proposal revisions and promptly forwarding their data for audit and cost analysis could the procurement cycle be shortened, Department of Defense review speeded, and a final "go-ahead" obtained for the program.[54]

So far the division plan for the orderly achievement of signed contracts by mid-November 1962 appeared to be doing well. On 22 August the defense engineering office informed the Air Force that $15 million had been allocated to the Titan III program. The Secretary of the Air Force promptly responded that the Air Force would need an additional $17.9 million to fund the program through November. In any event, the $15 million provided for initial procurement actions on long lead time items, response to any other critical need and ". . . an orderly manpower build up for all contractors." Specifically, the division considered it a matter of sound management to permit contractor purchase of raw materials to support tooling and fabrication of one set of liquid engines, an engine frame, two solid motor cases and one motor nozzle to get a head start on the program. The necessity of taking certain actions before granting final approval to start Phase II was recoginized by the defense engineering office and release of $15 million to the Air Force was accepted as sanction for these particular preliminary actions.[55]

Unfortunately, at the same time the division was assuming release of the $15 million implied tacit approval for preliminary Phase II actions, Harold Brown explained to the Secretary of the Air Force why he was denying any additional program funds until all contracts had been definitized and

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reviewed by his office. Said Brown, in a statement which both criticised and praised the Air Force: ". . . increased expenditure and further extension in contract definitization dates may represent a serious departure from the Titan III program that the Air Force has so effectively and carefully prepared during the past several months." Brown was particularly concerned about spending too much money before the contracts were approved and hence weakening ". . . the ability of the Air Force to negotiate definitized contracts on favorable terms." Moreover, the director felt that in the particular circumstances $17.9 million was too much for one month's work. He also felt there had been excessive delay in negotiating final contracts. In rebutting an Air Force position, Brown maintained that the execution of contracts was never contingent on the prior release of government funds but only on the existence of an authorized program. Furthermore, the prolonged Air Force contract definition effort, along with the large funding request, represented an inconsistency with the plans and approach so carefully followed during Phase I. Concluded Brown: "Certainly both of us want to be satisfied that the excellent achievements of the past nine months are not undermined and that no change in the policies and approach formerly agreed upon is contemplated."[56]

The pitfalls accompanying minute direction of a complex program from a distant pinnacle continued to be apparent. Two days after Brown protested Air Force plans for preliminary Phase II actions, Colonel Bleymaier met in Washington with secretary Zuckert, undersecretary Charyk, General Schriever and representatives of the Air Staff.* Zuckert immediately got to the point of the meeting, citing the memorandum from Dr. Brown in which the Air Force was charged with actions inconsistent with agreed Phase I plans and objectives. Colonel Bleymaier reviewed the background and reasoning which had guided

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* Others present at the meeting were Major General J. R. Hozapple, Assistant Deputy Chief of Staff, Systems and Logistics; Brigadier General R. D. Curtin, Director of Advanced Engineering; Colonel H. W. Gainer, Systems and Logistics; and Colonel H. Dorfman, Office of the Assistant Secretary of the Air Force for Research and Development.

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program office decisions and recommendations.* Sufficient funds were available to keep the Phase I effort going through 31 October. The additional $15 million released in early September could not be used until all Phase II contracts had been defined and subsequently approved by the Department of Defense. But there was an added complication. The program office strongly felt that using the new development money without additional approval and funds for the start of scheduled construction of test and launch facilities would be "highly undesirable and illogical." Furthermore, said Bleymaier, "If we are to spend money for instrumentation, engine cases, etc., without providing [an] engine test facility for the firing of this equipment, then the two efforts are not compatible, and consequently, program scheduling and milestones will be impossible to meet." Zuckert agreed, calling the entire briefing "logical and acceptable."[57]

The next day General Schriever, General Curtin, Colonel Gainer, and Colonel Bleymaier met with Mr. J. H. Rubel, Dr. O. F. Schuette and Dr. L. L. Kavanau from the defense engineering office to discuss the Air Force problem of contract definitization and disposition of funds. Colonel Bleymaier presented the Air Force position, declaring at the outset that since the Air Force was apparently not reflecting the intent of defense department guidance, ". . . it was necessary that certain clarifications be reached."[58]

The Air Force frankly stated that it felt enmeshed in ill considered strictures which had the effect of preventing an orderly start of the program. Secretary McNamara had instructed the Air Force to prepare and submit

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* Colonel Bleymaier recalled a January 1962 Washington meeting attended by J. H. Rubel, Deputy Director of Defense Research and Engineering, Mr. T. D. Morris, Assistant Secretary of Defense for Materiel, and J. S. Imirie, Assistant Secretary of the Air Force for Materiel, to review--for the third time--the request for proposals from contractors for development of large solid motors and consider the difficulties of transition from Phase I to Phase II. The transition problem had been discussed at length and ". . . an understanding of all concerned with regard to the exact and precise approach . . . " to be taken by the Air Force was defined. Bleymaier felt that his service had honored that understanding.

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a technical development plan, a revised system package plan, and "numerous other plans." In addition the Assistant Secretary of Defense (Comptroller) was to review the final contracts after they had been signed and prior to the release of any funds. Under these terms, the program was still in Phase I and could not proceed logically into Phase II. If the Air Force was not to proceed as it had planned, why had the defense engineering office released $15 million to the program? Rubel was assured that Phase I contracts then currently in effect with the Martin Company, Aerojet and United Technology Corporation could not be used to ". . . provide for the start or accomplishment of Phase II type tasks." Since the Air Force had the $15 million, Bleymaier wanted to apportion the funds to provide proper contractor manpower assignments and to begin procurement of long lead time items needed to begin Phase II when program go-ahead was given.

Rubel agreed that this was the proper course to follow. He agreed that as contracts were signed he would immediately authorize the Comptroller to release the needed funds for the balance of fiscal 1963. He disclaimed any interest in the business of program management at that point in time.

After Rubel left the meeting, discussion continued to range over the central issues--when could Phase II actually start? What did program "go-ahead" really mean? Colonel Bleymaier said he favored October as the starting month if the $15 million could be used and military construction money could be released to start the facilities program. Dr. L. L. Kavanau, in charge of space development for the defense engineering office, thought this was a satisfactory solution to the problem.[59]

But no action was forthcoming. By the last week in September it was apparent that a development directive was needed to get the program off "dead center." Permission to use the $15 million for an orderly transition into Phase II by 1 December was required, approval and authority to advertise for construction work by 1 October was necessary, as was relief from the requirement that Assistant Secretary Imirie review and approve all proposed incentive contracts. Imirie had already been briefed in detail on incentive plans to be used in all major elements of the program. The program office had concluded that Department of Defense review of all Titan III

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specifications would cause indefinite postponement of the start of Phase II. Finally, the program office wanted permission to allow anticipatory costs. This long series of conditions represented sharpening contentration on a problem not yet quite in focus.[60]

Dr. Lawrence Kavanau visited the space division on 27 September 1962 in an effort to clear up Titan III uncertainties. He eliminated a minor irritant by approving of limited purpose military training as proposed by the program office and then devoted his attention to contract problems and the complex of actions scheduled prior to the formal start of Phase II. It was understood that these included ". . . not only those stipulated by the Secretary of Defense, such as the revision of the program plan, approval of system specifications and submission of reliability and PERT plans, but also other events such as the release of facilities funds, the advertisement of construction work and the finalization of a master program schedule.[61]

While the list of essential preliminaries to Phase II appeared to be growing longer, the program office came up with a plan based on some practical provisions. While Phase I contracts would expire on 31 October, definitive incentive contracts would have been signed by the major contractors and would require only administrative review and approval by mid-November. Quite legally the contracting officer could date the contract back to the first of November and authorize anticipatory costs from that time forward. Thus if the negotiations were concluded on schedule, contractors would be fully covered during the transition from Phase I to Phase II. But any contractor who was unwilling to agree on reasonable terms ran the risk of not being reimbursed for costs incurred during the period of delay. In effect, this gave the program director a convenient and powerful lever for insuring that definitive contracts were negotiated on schedule, ". . . in full accordance with the philosophy which has been so carefully developed during Phase I." Anticipatory costs, of course, would be subjected to specific limitations and conditions.[62]

The plan called for start, during November, of a $14.5 million program which would allow individual contractors to establish a limited personnel structure and to order long lead time items. An additional half million dollars

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would start AC Spark Plug on a Phase I guidance study for 60 days at $400,000, and the Massachusetts Institute of Technology on a related study for $100,000. An interesting aspect of the plan was that November would not be considered the start of Phase II but as a transition period from Phase I to Phase II. Thus December would mark the first month of the program and milestone events would be dated from December. For example, the first configuration "A" test flight would take place in the 21st month after December 1962. Colonel Bleymaier found further encouragement in Kavanau's view that the defense engineering office would not attempt to review the multi-volume mass of technical specifications before granting program approval. In fact, Kavanau agreed to ". . . limit the DDR&E requirements to the top system specifications; the model specifications for the airframe components and the system control procedural documents."[63]

The division's plan for moving ahead was accepted by Air Force headquarters and the defense engineering office. Hence the way was clear for the Air Force to issue, on 15 October 1962, its most important Titan III document thus far, "System Program Directive for Titan III Space Booster," which confirmed the plan for development of a two configuration booster vehicle with a modified Titan II guidance system and launch facilities located at the Atlantic Missile Range. The directive confirmed the 1 December 1962 "go-ahead" date for Phase II and provided that schedules were to be coordinated with the Dyna Soar program--the first approved payload for the new launch vehicle.[64]

Thus, the first of December marked the formal beginning of Phase II of the Titan III program. All the major contracts, with the exception of that for the guidance system, were sufficiently well "definitized" to assure a properly felicitous beginning of the development effort. Major program issues had apparently been resolved and, hopefully, contentious questions or high level differences would not be permitted to vitiate management energies or further delay system development.

However, on 3 December 1962, Secretary of Defense R. S. McNamara informed the Secretary of the Air Force that, "A number of questions have been raised concerning the Titan III program."[65] Considering the history

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of the program thus far, that was a tame opening. The singular nature of the event lay in the content of the questions, which had come out of a discussion with members of the President's Scientific Advisory Committee.* The various queries had been sorted into eight primary questions chiefly concerned with the requirements for and tehcnical capabilities of the Titan III, "as it is presently conceived." In summary, the first three questions involved Titan III mission payloads, and the next three concerned performance variables affected by the presence or absence of solid motors and a comparison of these variables with the Saturn C-1 launch vehicle under development by the civilian space agency. The seventh question suggested an alternative configuration and the eighth question was concerned with development and operational costs as compared with similar costs projected for Saturn C-1.** The timing and substance of these questions, when compared to the vast quantity of study

* On 5 October 1962 the program office, experts from Aerospace Corporation, and major Titan III contractors presented a detailed technical briefing to the committee. In addition, J. H. Rubel briefed the committee on, "Why Titan III?" As a result certain questions were again asked about the program and comparative merits of various approaches--questions that had been throughly explored months before. It was these questions, answered then in part by Rubel and Kavanau, for which McNamara now wanted complete answers.

** Briefly summarized the questions were as follows: (1) Will it take as long or longer to develop Titan III payloads as to develop the Titan III itself? (2) If the answer is yes, what are payloads now and what will they be in the near future? (3) What fraction of future payloads need the instant launch of storable fuels as opposed to Saturn C-1 cryogenic fuel type of operation? Why? To what degree? (4) Compare reliability of Titan III and Saturn C-1. Compare the Titan III core alone; the Titan III with solid motors. (5) What percentage of Titan III launches will be the core only? Why would not a Titan II or a Gemini Titan II do the job just as well? (6) Why not have a larger core and eliminate the solid motors for most launches? (7) What percentage of Titan III payloads will be in the 15,000 to 25,000 pound low orbit? If the percentage is small why not optimize the solid motors to hoist 15,000 pounds rather than 25,000 pounds in low orbit? (8) Specify total development costs foreseen in the Titan III program. What are the cost differences between a Titan III and a Saturn C-1 launch? Will the Air Force and its contractors state that projected Titan III development costs will not be exceeded? If not, what are the maximums? If the costs rise over those projected are the Air Force and its contractors willing to agree ". . . the Titan III development program will be canceled?"

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previously directed to analyses of the need for and technical characteristics of the Titan III program, produced an air of unreality. It was obvious that considerations other than military requirements and identified national space objectives were once again influencing the course of the Titan III program.[66]

If the eight questions posed a new threat to the existence of the program it was potentially an expensive one, for the questions did not require reply until 1 April 1963, by which time the Titan III program would have become relatively costly to liquidate. In any case, of all the questions put to the Air Force, McNamara considered the response to question eight, on total program costs, the most crucial. Going one step further, he asked the Air Force to ". . . secure the written concurrence of all prime contractors to the USAF response to this question."[67]

The Air Force wasted no time in arming itself for another semantic skirmish. In early January 1963 arrangements were concluded with R. C. Seamans, Associate Administrator of the National Aeronautics and Space Administration, to obtain program and planning data from which "an identification can be made of missions wherein the performance capabilities of the Titan III might be applicable." The Air Force also asked for performance, cost, schedule and reliability data on the Saturn C-1 and C-1B which would permit valid comparisons of the C-1 and the Titan III. A Titan III Task Group was appointed by the secretary--headed by Major General R. J. Friedman, Director of Aerospace Programs, Deputy Chief of Staff Programs and Requirements, at Air Force headquarters. The group began work during December. Air Force headquarters was to define payloads, preparation of costing data was assigned to system command headquarters, and technical comparisons were made by the Titan III program office.[68]

Thus 1963 began with another review of the Titan III program. Concurrently, the defense department in mid-January began to examine Dyna Soar, the manned space glider project, and Gemini, the civilian space agency program to develop parking orbit rendezvous techniques, to determine if redundant military capabilities existed in the two programs. The same purpose might also be discerned in the "eight questions" and in a parallel review of the Titan III program which McNamara planned for both Washington

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and contractor installations at the earliest possible date. In particular, the defense secretary expressed interest in a comparison of Titan III with alternative launch vehicles and in a detailed analysis of the costs and operating advantages of each.[69]

By the end of January the task force was well on the way to completing the "eight questions" assignment. The civilian space agency had reviewed its probable mission requirements and had furnished the Air Force an analysis of using Titan III in its own programs.[70] The space agency held that the Gemini and Apollo low orbit missions would be completed before Titan III became operational. The ten flight Surveyor moon probe program, to begin in late 1965 and continue through 1967, was scheduled to use the Atlas-Centaur booster but might use a Titan III core with a high energy upper stage, ". . . provided this is attractive with respect to cost and reliability." Four Mariner payloads, 550 to 1,500 pounds, programmed for Mars and Venus during 1966 and 1967, might find Titan III a useful launch vehicle. Beyond 1967, additional payloads had not yet been defined with sufficient clarity to predict their booster requirements. Predictably, the civilian space agency anticipated no overwhelming need for the Titan III.[71]

In addition to the Titan III "eight question" assignment the command was preparing for the simultaneous Department of Defense reviews of the Titan III, Dyna Soar, and Gemini programs. It seemed probable that McNamara planned to decide "the goals, content, and scale of the DOD program to develop 'building blocks' for future manned military space systems" on the basis of current studies. Air Force concern was clearly warranted; a decision once taken would be difficult to alter; a negative finding would be impossible to reverse. Therefore within the systems command, Major General O. J. Ritland, Deputy Commander for Manned Space Flight, set about organizing a concerted effort by the space division, the aeronautical division and command headquarters, to prepare comprehensive, well knit responses at once. Regarding the assignment ". . . as one of the highest priority jobs facing the Command at this time," General Ritland directed the two development divisions to work together in preparing a valid comparison of Dyna Soar and Gemini. The work was to be divided appropriately between the divisions to present absolute and comparative

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capabilities in "factual and meaningful terms." For example, the role of a Gemini-Titan III combination in developing techniques essential to such follow-on systems as manned orbital space stations and satellite inspectors was to be emphasized, while the importance of Dyna Soar's exclusive characteristic--its capability of returning from orbit to a precise landing in the United States--was to be stressed. Other complex elements in the relationship of the three programs were to be weighed and evaluated to assure a positive statement of the nation's military interest and Air Force aims. The total study was to be completed and presented at command headquarters on 28 February 1963.[72]

While these activities were underway, preparations for Secretary Mcnamara's review of Titan III were nearing completion. A 30 January 1963 meeting of the Division Advisory Groups,* subsidiary panels of the Air Force Scientific Advisory Board, strongly endorsed development of the Titan III system on the grounds of operational simplicity and instant readiness. The group also cited Titan III's economic advantages--if more than 100 vehicles were launched during its operational life--as well as the realism of basing the development on known and demonstrated technologies.[73]

Meanwhile, the "eight questions" task group accepted the reports of the "NASA - DOD Large Launch Vehicle Planning Group, published 1 February 1962 and 24 September 1962. . . " as the doctrinal rationale for the Titan III system. The group also decided not to seek formal coordination of its report with the Launch Vehicle Panel of the Aeronautics and Astronautics Coordinating Board before the report was submitted to the Secretary of Defense. Rules and formats for comparing Titan III configurations, costs and reliability with Saturn C-1 were discussed and coordinated with the Secretary of the Air Force, the Department of Defense, and officials of the civilian space agency. Every effort was made to include technically accurate and impartial answers to the secretary's questions.[74]

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* The Division Advisory Groups--one each for the Space Systems and Ballistic Systems Division--included such well known scientific and industrial leaders as Dr. Clark B. Millikan, Dr. Homer J. Stewart, Dr. Ernst H. Plesset, Dr. Gerald M. McDonnel, and General Earle E. Partridge (Ret).

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By 8 February the "eight questions" report was ready in rough draft form for review by assistant secretary McMillan. This review, together with McNamara's 19 January 1963 request for a ". . . comparison of Titan III with alternative launch vehicles and a detailed analysis of the costs and operating advantages of each . . . " had led to a "white paper" on program alternatives and a project review and data book. These documents later appeared as volumes entitled "Relation of the Titan III to the National Launch Vehicle Program and Alternative Courses of Action," and the "Titan III Project Review and Data Book" which, like the "Response to Questions . . . " bore a publication date of 27 March 1963. Taken together, these documents constituted a technically detailed account of every major aspect of the Titan III program.[75]

Concurrently, some loose ends of the "eight questions" assignment were being taken care of. On 18 February 1963, General Schriever, as head of the systems command, asked each of the Titan III associate contractors for a commitment not to exceed their programmed expenditures. This somewhat odd procedure, asking for letters which would mean little or nothing contractually, produced prompt and carefully phrased replies which reached the desk of the Secretary of Defense by 15 March 1963.[76] Whatever the contractual implications, of course, McNamara had assurances that all contractors were aware of the possible consequences of an overrun.

The task group response to the "eight questions" and corollary reports furnished by the Titan III program office were intended, hopefully, to establish the position of the program firmly enough to discourage further attacks. Also there was now available, in three carefully prepared volumes, an encyclopedic source of Titan III information to answer questions still to come.[77]

Task group answers to the questions, giving due consideration to the risks of abbreviation, may be summarized as follows: (1) In all probability it would take as long to develop Titan III payloads as it would to develop Titan III. The Air Force termed this circumstance a benefit which contributed to full vehicle standardization and sound management of payload development programs. (2) In addition to Dyna Soar, the first planned payloads foreseen for Titan III

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were space reconnaissance, communications, military orbital development system, satellite inspection and interception, surveillance and early warning, and nuclear test detection. (3) All payloads would benefit from the "greater simplicity and higher reliability of the Titan III final countdown . . ." as opposed to use of the Saturn C-1. (4) Available data seemed to indicate that Titan IIIC would be a little more reliable than Saturn C-1 (.89 to .84). (5) Titan III third stage restart capability and a superior margin of performance--for example, its two-minute hold to launch for extended periods of time--excluded the choice of any other space vehicle for the vast majority of Titan III missions. (6) If the core were redesigned to a larger size it would require redesign of the whole system and eliminate economies associated with the use of Titan II components. Neither would any other system be compatible with Dyna Soar requirements. (7) An estimated 64 percent of all Titan III payloads would be in excess of 15,000 pounds. Redesign of solid motors to smaller size would require an additional year of development and reduce overall performance of the system which might be of utmost importance at a later time. (8) Total development costs of the Titan III were estimated to be $874.7 million. Including development costs and 50 launches per year over a five year period, costs per vehicle would average $11 million per launch. Saturn C-1 for the same period and number of vehicles would average $18.9 million per launch.[78]

It did not take long for the report to stir up more questions--and not surprisingly, strong dissent. Meanwhile, the three volumes including the Air Force official response to the eight questions were forwarded, on 8 April 1963, to the Secretary of Defense. The Secretary of the Air Force, in a letter accompanying the volumes, used the occasion once again to emphasize the need for sound financial support of the program. Said Zuckert, ". . . it is my strong conviction that program funding should now be increased, in realistic anticipation of unpredictable contingencies, from the presently approved $808.3 million to $874.7 million, as recommended in the attached volumes." The secretary then concluded, "I will, therefore, submit for your approval a PCP for the additional money to provide the recommended RDT&E contingency funding level."[79]

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Copies of the three-volume set were sent to the White House Executive Office for the use of the President's Scientific Advisory Committee. At least one member, Dr. N. E. Golovin, was confirmed in his conviction that inasmuch as Titan III development costs were essentially the same as those for a new booster, Titan III should then be either smaller or larger than the Saturn C-1. In any case, on 2 May, Golovin asked Dr. O. F. Schuette, defense engineering office, to furnish additional detailed cost comparisons between Titan III and Saturn C-1--to be completed by the next day or two but not later than "PM Monday, May 6."[80] Lest the urgency of the request be overlooked, Roswell Gilpatric, Deputy Secretary of Defense, instructed Dr. L. L. Kavanau, in charge of space matters for the defense engineering office, to prepare the information within the time requested. The systems command was little considered in this exchange although Kavanau coordinated the draft of his reply with Major General R. J. Friedman, who had headed the original "eight questions" task group. In addition, within the following week, the Air Staff and systems command headquarters assembled a more detailed cost data report in the unlikely event that General Friedman might be solicited for more information of the same sort. Hopefully, this would be the final event in the unusual "questions" episode. Lest, however, there be a relapse, the Air Staff systems booster office, directed by Colonel H. W. Gainer, produced during the last of 1963 two relevant studies, "Titan III, Its Objectives, Status and Merits as Compared With Saturn II (CIB)" and a draft paper for the Secretary of Defense, "Titan III, Its Objectives and Merits."[81*]

But if the defense establishment seemed content with the "eight questions" report, the civilian space agency members of the Launch Vehicle Panel of the Aeronautics and Astronautics Coordinating Board were not. They strongly objected to Air Firce answers to ". . . Questions Numbered 3, 4, and 8a."

* Curiously, although nearly every other Washington authority appeared at sometime to be involved in Titan III reviews, the Joint Chiefs of Staff never formally passed on the validity of the Titan III requirement. This unusual omission may have been due to the status of Titan III as a non-weapon system, or to the nature of the Joint Chiefs. In practice, the Joint Chiefs were kept advised of Titan III developments through informal channels.

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ANALYSIS OF PHASES I AND II TITAN III DEVELOPMENT PROGRAM

January 1963

	PCP	SPP	Present SPO Estimate	Analysis	Recommendations
Core and Integration	364.7	364.7	364.7	378.0	
Liquid Engines (Stages I and II)	46.4	46.4	46.4	57.0	
Upper Stage Engine	11.7	11.7	11.7	19.0	
Solid Motors	223.0	223.0	223.0	222.0	
Phase I Reimbursements*			15.0*		
Subtotal	645.8	645.8	660.8	676.0	660.8
Guidance, Including Integration	51.5	51.5**	86.0	82.5	86.0
TOTAL Major Contractors	697.3	697.3	746.8	758.5	746.8
Other R&D (SE/TD, Propellant, Transportation)	48.2	48.2	48.2	48.2	48.2
ECP's Increase				11.1	11.1
TOTAL R&D	745.5	745.5	795.0	817.8	806.1
MCP					
Adv. Planning	-0-	5.8	5.8	5.8	5.8
Mil. Construction	62.8	62.8	62.8	62.8	62.8
TOTAL MCP	62.8	68.6	68.6	68.6	68.6
TOTAL	808.3	814.1	863.6	886.4	874.7

* SPO's request for reimbursement (not included in SPP)

** Preliminary estimate

From: Report, Response to Questions Posed by the Secretary of Defense Pertaining to the Titan III Program, 27 March 1963, prepared by Titan III Task Group.

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Generally, the civilian group took exception to adverse comparison of the performance of Saturn C-1 with Titan III. The point which generated the strongest response was the Air Force assertion that Titan III was more reliable than Saturn C-1. Space agency spokesmen warmly contended that statistics were available which supported a contrary view. Moreover, in the opinion of space agency experts, cost comparisons of the two vehicles were biased; they proposed an alternative cost-per-pound standard by which Titan III would emerge distinctly second best.[82]

The Air Force moved to reconcile these differences in views as rapidly as possible. General Schriever directed the Air Force Task Group which had prepared the "Responses to Questions" to get together with the people in the civilian space agency, recognizing that there was room for adjustment. On the matter of reliability, an uncertain species of prognosis at best, Schriever said ". . . the DOD realizes and agrees with NASA that attention to detail in the design, fabrication and operational use of the launch vehicle is fundamental to reliability." In the matter of costs, Schriever noted, the Air Force had addressed itself to cost differentials in successful launches and saw no point to comparisons on a cost per pound basis.* In the viewpoint of the Space Systems Division, some of the counter arguments introduced irrelevancies which only further confused cost calculation comparisons.[83]

The matter was finally resolved by a relatively complex organizational expedient. Dr. A. H. Flax and Mr. M. W. Rosen, representing the Air Force and the civilian space agency respectively, and co-chairmen of the Launch Vehicle Panel, appointed Brigadier General J. S. Bleymaier, (newly promoted), Titan III program director, and Dr. H. Hall of the civilian space agency to resolve their differences of fact or opinion and prepare a report for the panel. Their meetings during the month of July produced a paper of understanding. The paper represented an adjustment of views which admitted that statistical projections of reliability were far from absolute, thus removing any basic differences in estimates of the reliability of the Saturn and Titan III vehicles, and incidentally denying validity to both projections, impartially. It also

* One Air Force observer of this phase remarked: "What the hell are we supposed to be buying, sliced liverwurst?"

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recognized that military requirements imposed performance specifications which could only be met by the Titan III space vehicle. The report was accepted by the Aeronautics and Astronautics Coordinating Board at a meeting held 17 September 1963, thus bringing the whole matter to a bloodless conclusion.[84]

Through all this furor, the beleaguered Titan III program office kept the program moving on schedule. With the official start of Phase II on 1 December 1962--although formalities involving several of the major contracts were not actually concluded until well into 1963--a degree of stability was introduced into the conduct of program affairs. Funding requirements could now be projected with reasonable accuracy. Financial planning called for a total expenditure of $814.1 million to develop Titan III including $5.8 million for advance planning of military construction. Research, development, test and evaluation would cost $745.5 million and military construction would total $62.8 million.[85]

The first Phase II budget allocation was ample enough to suggest the era of money "spoon feeding" was over. On 30 November 1962, $100 million--$22 million had earlier been approved--was made available from the approved fiscal 1963 development fund total of $220 million.[86] This was sufficient to keep the program operating through April 1963. On 1 April the Air Force requested the balance of the year's approved development funds be released--$98 million remained--to fund the program until fiscal 1964 budgetary allowances would be available, estimated to be 20 September 1963.[87]

Funding, which had been proceeding smoothly since the start of Phase II, now became a critical element in the program. The Air Force was confronted with the serious possibility that a lapse or restriction in processing fiscal 1964 funds would allow the "contractors an opportunity to void the tight controls under the incentive clauses of the contract."[88]

At the same time the defense engineering office was reluctant to release more funds until it had received the final Titan III Production Plan and a "PERT System Document" reporting the application of that device throughout the program. Nevertheless, on 24 April, another $30 million was assigned to

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Titan III development.[89] Then, during May, the systems command, confronted by a financial emergency in the Minuteman program, obtained approval from the Secretary of Defense to reduce fiscal 1963 Titan III development funds to $175 million in order to release some $45 million to the Minuteman effort. On 26 June the final increment of the $175 million--$23 million--was assigned to Titan III.[90] Despite the late release of the remaining money, it was possible to commit $173.6 million to the contractual effort. And, in terms of money obligated, $148.5 million was so assigned of the total $175 million budgeted to the fiscal 1963 development program.[91]

But of increasing concern to the Air Force was the mounting discrepancy between the approved program--now $745.5 million for research and development and the likely probability of an increased requirement. This discomfiting possibility was brought forward officially in the Air Force response to the "eight questions." The approved financial plan did not allow for the costs arising from an extended delay in starting Phase II. Moreover, although changes were few, those adopted entailed additional costs and there was no provision for funding additive expenses which were not immediately identifiable but must reasonably be expected.[92] Sound judgment indicated that an overall eight percent increase, an additional $60.6 million, would eventually be needed. During July 1963 the Air Force submitted a funding change proposal requesting an increase in total program expenditures by this amount.[93]

A financial analysis of the program in July 1963 revealed fiscal 1962 research and development expenditures of $18.5 million and a military facilities construction cost of $16.7 million, for a $35.2 million total. The fiscal 1963 budget for research and development was $175 million and military construction was allocated $41.1 million for a total of $216.1 million--far less, because of Phase II delay, than originally planned. Fiscal 1964 would see program activity and supporting costs mount to $324.6 million and construction costs decrease to a low of $5 million or a total planned expenditure of $329.6 million. Thereafter development costs would decline to program completion schedule in early fiscal 1966.[94]

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The money was beginning to produce visible evidence of development progress and management systems were beginning to function effectively. The Martin Company, which held the largest and most important Titan III contract, was first to fully exploit "PERT" management techniques as a tool for meeting its incentive performance obligations. The first three months of its "PERT" operation, concluded in July, indicated that the system could predict time and cost factors essential to remaining on schedule. Other major contractors were also beginning operation of "PERT" networks intended to enable the program office to determine the status of every contractor and element of the program. The program office created an adjunct of the "PERT" system with the rather ponderous designation of "Schedule Interface Log." Like "PERT," the system used electronic data processing equipment to list several thousand items and create a log which ". . . maintained and provided descriptive information of schedule interfaces; cites need, promise, and schedule dates, and relates the information to specific activities on PERT networks."[95]

Shortly after the beginning of Phase II the intricate tendrils of management had reached out to offices, laboratories, and shops. On 23 February 1963 the first 120-inch single segment solid motor was successfully tested. United Technology Corporation appeared to be rapidly advancing in its development effort. By the close of March solid motor test facilities were under construction at Edwards Air Force Base, California. Dredges and bulldozers at Cape Canaveral were preparing Titan III launching sites. The Martin Company's task of Titan III component engineering drawings was well underway and over a thousand hours of wind tunnel testing had already been completed. Aerojet-General, Sacramento and Azusa divisions, was embarked on a strong engine development program for the three core stages, starting with design work and preliminary testing. Design of the ground elements of the system, using as many Titan II components as possible, was moving forward on schedule. By mid-June the program office had completed a draft of the Titan III production plan. This plan, requested by Secretary of Defense McNamara, detailed the transition from research and development to production, outlined booster-user relationship procedures, the programming and funding concept to be applied, and the raw material resources essential to a production program.[96]

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Happily, the forward course of the program also included early test success. On 18 June 1963, at the United Technology Center near Palo Alto, California, the second single segment 120-inch motor was successfully fired. But the greatest engineering triumph in the early program occured on 20 July 1963 with the firing of the first five-segment, full size, 250-ton solid rocket motor to produce more than one million pounds of thrust. Three days later Aerojet-General, Azusa, successfully demonstrated a long duration firing of the transtage engine.* These were significant and encouraging milestones in Titan III development.[97]

But, inevitably, as the program gained momentum, some difficulties became apparent. Facilities construction fell behind schedule at Edwards Air Force Base. Although core design and fabrication and solid motor development were progressing on schedule, development of core first and second stage engines was a source of concern. A major engineering problem loomed in the continued extreme longitudinal oscillation difficulty first observed in static and flight test operation of the Titan II weapon system. A shortage of storable fuels became a potential threat to the program. And, apart from specific engineering, technical and procurement difficulties, the program office suffered from the chronic complaint of the Space Systems Division--a shortage of qualified personnel.[98]

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* The engine operated for four minutes and 44 seconds, during which it was stopped and started three times. A more crucial test of restart capability would be demonstrated later in a vacuum cell at Arnold Engineering Development Center, Tullahoma, Tennessee.

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CHAPTER 4

BUYING THE SYSTEM

From the beginning of the Titan III program it was apparent that certain innovations would be introduced in the attempt to solve the basic problem of every development effort--converting an advanced concept into the hardware and facilities of an operational system at a reasonable cost.

One of the first tasks undertaken by the newly organized program office was to conduct an intensive study regarding the type of contract that should be used in the Titan III undertaking: cost-plus-fixed-fee, fixed-price, fixed-price-incentive-fee or cost-plus-incentive-fee. The study indicated that cost-plus-incentive-fee contracts would best fulfill the program objectives, although their application to large scale development contracts was largely a step into the unknown. The Titan III program office, urged on by the Department of Defense, began an intensive study of all elements involved in incentive contracting. Although complicated and difficult to administer, contracts providing incentives for achievement of reasonable goals--without too high a risk for either party--had advantages. All features were not happy, however, since the difficult task of preparing incentive contracts required months of effort, a vast accumulation of cost data, and protracted negotiations.[1]

The first and most urgent contractual task confronting the program office was to prepare Phase I contracts covering the efforts to define the program, plan development, and project detailed costs. For the most part, fixed price contracts were awarded to those contractors who possessed the capability to undertake Phase II hardware development but there was no commitment beyond conclusion of the studies.

Martin Marietta Corporation

Since two of the basic elements in the Titan III system--the Titan II two-stage "core" produced by Martin Marietta Corporation, Denver, Colorado,

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and its liquid fueled engines produced by Aerojet-General Corporation, Sacramento, California--were already developed, no involved contractor selection procedures were necessary. The Air Force, on 25 October 1961, asked the Martin Company to submit a proposal for a Titan III Phase I study contract. The company responded on 2 January 1962 and was awarded a cost-plus-fixed-fee contract, valued at $8,563,250, on 19 February 1962. As Phase I was extended to the final cut-off date on 31 October 1962, the total cost of Martin's Phase I contract increased to $14,754,250.* Martin also had a fixed price contract covering test stand and ground equipment design, valued at $310,300 and awarded on 14 March 1962.[2]

On 10 March 1962, the Air Force invited Martin to propose Phase II work to include design, development, fabrication and delivery of Titan III standard cores, system integration, launch, and related services. Expectations that Phase II would begin shortly following the scheduled close of Phase I, 30 April 1962, left little time for contract preparation and negotiations although incentive fee contracts were of necessity complex legal instruments. Agreements over a wide area of potential controversy were called for but gradually certain provisions were worked out which became standard practice in the Titan III program. A target cost was selected as the overall cost of the contract on which incentives were calculated. If the contractor successfully met all requirements--which included cost reduction, establishment of a sound "PERT" system, meeting qualification test and delivery schedules, and completing flight tests and milestone actions on time--he could increase his fee to a maximum of seven to fifteen percent of the target cost. If he performed dismally, on the other hand, he could only earn a minimum one percent of the target costs.**

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* Contract AF 04(695)54.

** Generally, determination of incentive performance was left to an incentive review board. The parties to the contract maintained a detailed log of all events and data relevant to performance. Also both parties appointed representatives to the review board. With the detailed facts available, in most instances, it did not prove too difficult to arrive at a fair judgment of incentive performance.

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These arrangements and the development of certain incentive concepts, plus the addition and deletion of work requirements and other program variables, caused the program office to issue a new proposal request to Martin on 31 August 1962. After many conferences and reviews, final contract negotiations started in mid-September 1962. On 8 October Martin offered to develop the three stage core airframe and perform system integration, launch and related services for a target cost of $395,208,086 and a fee of $27,664,566, (equal to seven percent of the cost) a total of $422,872,652. Then began an exhaustive series of price evaluations by the Administrative Contracting Office, Air Force Auditor, the program office--including Aerospace Corporation engineering price specialists--and the Air Force Procurement officer. Final negotiations approached the scope of a major confrontation between the giants of capital and labor. Between 29 October and 4 December 1962 as many as 75 contractor and 35 Air Force people shared in the bargaining. The final result, for the Air Force, was worthwhile--a contract with a target cost of $285,042,298 and a target fee of $19,952,960.* The contract was signed by late December, although it was dated from 1 December, and forwarded to command headquarters in early January for final review and signature prior to its distribution on 1 March 1963. The contract, in addition to system integration, test and launching services, included production of 17 cores, assorted ground equipment and four instrumentation vans, all to be completed by September 1966.[3]

United Technology Corporation

The next largest contract, and the most significant in terms of new technology, was negotiated with the United Technology Corporation, a subsidiary created by United Aircraft Corporation to develop, test and produce large solid propellant rocket motors. New facilities, named United Technology Center, were located at Morgan Hill, near Palo Alto, California. Very early in the Titan III program the Air Force recognized the value of the new company in furthering large solid motor development.

* Contract AF 04(695)-150

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On 6 November 1961 a solid propellant source selection board was established at Space Systems Division to approve a work statement and select a contractor. Board meetings during November produced a qualified bidders list and a decision to award a cost-plus-fixed-fee contract to the successful bidder by 16 February 1962. In late 1961, however, the defense engineering office instructed the division to set up a more comprehensive contractor "PERT" system and suggested that this might be the occasion to introduce an incentive type of contract. Requests for contractor proposals were revised accordingly and issued on 22 January 1962. The source selection board convened during March to consider proposals from Lockheed Propulsion Company, Thiokol, Aerojet-General, United Technology Corporation, Atlantic Research Corporation, Hercules Powder Company, and Rocketdyne Division of North American Aviation. On 9 May 1962 the Air Force announced its intention of negotiating with United Technology Corporation for development of Titan III large solid motors. Because much of the preliminary Phase I planning work had already been completed by the Air Force and Aerospace Corporation, contract planning called for the start of solid propellant Phase II development by 1 July--if program approval was forthcoming in time. In mid-June instructions were issued to begin, instead, a Phase I study starting 1 July and extending to 15 August at a cost of $785,000. Subsequent delays in starting Phase II resulted in an extenstion of the Phase I effort, first to 15 September at an additional cost of $564,000, and then to 31 October at a further additional cost of $1,454,000. A total of $2,803,000 was thus expended on Phase I planning studies for solid fuel rockets.[4]

During the months following the start of Phase I studies, a series of contractual negotiations on price factors and incentive provisions resulted in a combination cost-plus-fixed-fee and cost-plus-incentive-fee contract totaling $172,642,000.* Of this amount $24,424,000 was a cost-plus-fixed-fee contract for ground installations at Edwards Air Force Base and the Atlantic Missile Range. The target cost of the development contract was $138,521,000 with a maximum incentive fee of $20,778,150 for top performance and only

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* Contract AF 04(695)-156

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$1,385,210 for the contractor in case he faltered seriously. The contract, for the production of 12 pairs of motors, became effective 1 November although the contractor's signature was not affixed until 19 November and subsequent command approval and final distribution did not take place until 21 December 1962.[5]

Aerojet-General Corporation

Propulsion development constituted the next highest dollar volume expenditure in the program although, with the exception of completely new engines on the third stage, the contractor only needed to improve the reliability and performance of existing Titan II first and second stage propulsion units. A request for proposal for a Phase I study was forwarded to Aerojet-General, Sacramento, on 6 November 1961. The contract was awarded on 7 February 1962 and by means of repeated extensions continued to 31 October 1962 at a total cost of $907,235 for planning every element of design, performance and production of first and second stage core engines. The engines were already designed to use storable fuels--nitrogen tetroxide (N_2O_4) and a 50-50 mixture (by weight) of hydrazine and unsymmetrical dimethylhydrazine (UDMH)--but certain changes were to be introduced to improve their performance and reliability. A request for proposal for Phase II development and production was issued to the company on 10 September 1962. After prolonged negotiations, the contractor signed the agreement on 23 January 1963. The contract required Aerojet-General to produce 19 first and second stage core engines at a target cost of $38,750,000 and a target fee of $2,712,500.* The contract--scheduled for completion by 31 August 1966--was finally distributed on 20 March 1963, although it became effective on 1 November 1962.[6]

Aerojet-General was also selected to develop and produce the propulsion system for the third stage--for a time called the transtage. This was to be a pressure fed engine, using the same fuels as the first two stages, with two

* Contract AF 04(695)-126

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gimballed thrust chambers producing 8,000 pounds of thrust each and capable of as many as three starts in a six hour period. A board for evaluation and selection of the Titan III third stage contractor was appointed 16 March 1962. Requests for proposals were issued to qualified contractors in early April and a bidders conference was convened on 16 April. Careful evaluation of all technical factors involved in the third stage engine development, consideration of experience with storable fuel engines, and weighing the effect of the interface with the existing program, led to the selection of Aerojet-General, Azusa, California, as developer of the propulsion system. A Phase I contract valued at $348,200 was awarded the company for work performed between 17 July and 31 October 1962. A request for proposal to undertake Phase II development and production of the engines was issued to the company 10 September 1962. The contract for the production of 38 engines, signed by the contractor on 14 January 1963, was valued at $11,675,800.* The target cost was $10,912,000 and the target fee was $763,800, seven percent of the target cost. The fee ceiling was established at $1,309,440 and the minimum fee at $272,800. The contract, effective 1 November 1962, was distributed on 1 March 1963, and was scheduled for completion by 31 August 1966.[7]

Architectural-Engineering and Management Contracts

At this point in the early months of the program several contracts were awarded which, if relatively small, were nevertheless vital to the progress of Titan III development. The most important of these were awards to architectural-engineering firms for design work on Titan III facilities. On 13 March 1962 a contract was awarded to Aetron Division of Aerojet-General to design test stands capable of checking out mammoth solid motors (up to 1,500,000 pounds of thrust), a control center, and associated facilities to be built at Edwards Air Force Base, California. This was a fixed price contract

* Contract AF 04(695)-197

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to cover work performed between 12 February and 10 October 1962 at a cost of $651,400.* The largest contract for architectural-engineering services was awarded to Ralph M. Parsons Company to furnish the necessary design and engineering for modification of Complex 20 and a two pad integrated transfer launch complex at the Atlantic Missile Range.** The fixed price contract, awarded on 28 March 1962, covered design work from 15 January 1962 through 23 February 1963 and it was then extended to August 1964 at a total cost of $3,497,986.[8]

Once architectural-engineering work was completed, major building projects were started as quickly as contractors could be selected and men and machines put to work. Construction of the $8.2 million Edwards Air Force Base Test Complex 1-36 was started on 1 December 1962 and scheduled for completion in December 1963. Complex 20 at the Atlantic Missile Range was modified between December 1962 and September 1963 at a cost of $1,800,000. The integrated transfer launch facility was an undertaking of such size that even the designs for the site were not completed until October 1962. The site was to be prepared by a combination of grading and dredging fill from the bottom of the Banana River. Site preparation--covered by a $6,700,000 item in the $16.7 million total facilities expenditure funded in fiscal 1962--started in December 1962, was completed in June of 1963. Design of the vastly complicated launch facilities was not completed until February 1963; construction, which was to last until August 1965, was started a little over a month later. Fiscal 1963 expenditures, presaging an all out assault on the Cape Canaveral construction program, would total an additional $41,100,000.

The final architectural-engineering fixed price contract during this phase of the program was awarded to Stearns-Roger Manufacturing Company for design of an integrated transfer launch complex to be located at the Pacific

* Contract AF 04(695)-109

** Contract AF 04(695)-177

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Missile Range. The contract,* dated 24 July 1962, covered work from 14 June 1962 through January 1963 at a cost of $146,421. The small size of this contract--compared with that awarded to Ralph M. Parsons Company, was due to the relative simplicity of the design work involving preliminary engineering planning and application of Atlantic Missile Range "ITL" designs to the environment and terrain of the Pacific Missile Range.[9]

In addition, a cost-plus-fixed-fee contract for $381,000 was awarded to Operations Research Incorporated on 30 April 1962 in compensation for its "PERT" work through fiscal 1963** and another to Automated Information Management Systems Incorporated, to cover work involved in reducing "PERT" data submitted by the contractors, processing the information through a computer, and producing meaningful data.*** The $100,750 contract was awarded in June 1962 to cover work performed through October 1963. Finally, a cost-plus-fixed-fee contract was negotiated with Aerospace Corporation, effective 1 December 1961, to furnish system engineering and technical engineering direction to the program through fiscal 1962 at a cost of $3,556,100.[10]

AC Spark Plug Guidance System Contract

Acquisition of the Titan III guidance system emerged as a major contractual difficulty involving wide ranging issues. The problem originated, innocently enough, in the intense effort of Space Systems Division to define all aspects of the program in time to meet the first Phase I deadline. Thus between October 1961 and February 1962 the Aerospace Corporation studied the Titan III guidance concept in light of the general performance requirement

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* Contract AF 04(695)-173

** Contract AF 04(695)-115

*** Contract AF 04(695)-154

[redacted]

postulated for the new space booster. The decision reached was that no ". . . existing guidance system was capable of satisfying the requirement (including the present Titan II ICBM guidance system) . . . " although the existing state of guidance technology furnished a basis for rapidly developing a system to do the precise and demanding guidance job.[11]

The program office then prepared the preliminary documents, keeping in constant contact with the defense engineering office to obtain approval of work statements, specifications, and the general approach to the problem. These documents were approved by a source selection board on 9 February and thereafter transmitted to qualified bidders.* After the proposals had been evaluated, the board's recommendation was forwarded through channels, culminating in a presentation to the Secretary and Undersecretary of the Air Force. The selection was reviewed by J. H. Rubel, deputy director of the defense engineering office, on 18 April 1962. In early May the space division was authorized to start preliminary contract negotiations with Space Technology Laboratories for procurement of their proposed system.[12]

At that point the guidance source selection board rather casually disclosed its finding that development of a guidance system would be a 24 to 27 month job--despite promises from all bidders to finish in 16 months. Confronted by a requirement for early flight before the guidance system would be available, the selection board recommended that Titan IIIA rely for the nonce on an unmodified Titan II guidance system. This concept was included in the proposed system package plan approved by the Air Force Designated Systems Management Group on 3 May 1962.[13]

The first intimation that the defense engineering office might favor continued use of the Titan II guidance system came in a 16 May 1962 Rubel request

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* The following firms were invited to submit bids: Autonetics Division of North American Aviation; AC Spark Plug Division of General Motors; General Precision, Incorporated; Hughes Aircraft Company; Litton Systems, Incorporated; Lockheed Aircraft Corporation; Minneapolis-Honeywell Regulator Company; Nortronics Division of Northrop Corporation; Radio Corporation of America; Defense Electronics Group; Norden Division of United Aircraft Company; International Business Machines; Space Technology Laboratories; and Sperry Rand Corporation.

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for additional data. The idea of sticking to the Titan II guidance system, admittedly less accurate, was again brought up by L. L. Kavanau of the defense engineering office in May 1962.[14]

In the next few weeks confusion became apparent. At the Washington level there was increasing interest in changing to the Titan II guidance system--yet there was no decision. On 28 June, Harold Brown, director of the defense engineering office, asked the Air Force to document certain changes in the Titan III program, mentioning "The Phase II development utilizing Titan II guidance system with minimum modifications . . . " without stating that such an arrangement would displace the Space Technology Laboratories' proposal.[15] On 29 June, Brockway McMillan told the Air Force Chief of Staff". . . it is desirable to defer development of a new guidance sub-system for the Titan III system." He added, "The program change proposal currently being prepared for 624A should, therefore, be revised to contain funds for procurement and modification of Titan II guidance systems as originally planned for interim use."[16] Although not clearly identifying which system was being considered for long term use, McMillan's statement indicated that the decision to use modified Titan II guidance might have had its origin in a misunderstanding of the original proposal of an interim measure. Curiously, through the month of June, when deliberations over the choice of a Titan III guidance system were most active, there was no evidence that the views of the development command or the program office were solicited.[17]

On 19 July the Air Force accepted a program change which directed use of Titan II guidance as an interim system but even yet the question was far from resolved. Between 26 July and 17 August there occurred a series of high level discussions and presentations on the subject. The major issue was how much the AC Spark Plug all-inertial system would have to be modified to perform "scaled down" Titan III mission assignments. At a 26 July meeting in Los Angeles--attended by McMillan, Bleymaier, Colonel F. M. Box (head of the program's guidance development), and several Aerospace Corporation guidance engineers--the assistant secretary agreed to support sole source procurement of the AC Spark Plug system if that became the approved option.

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At the 31 July meeting in Washington, the same key people discussed the Space Technology Laboratories and AC Spark Plug systems further, apparently agreeing that the AC Spark Plug system could, with minor modification, perform basic Titan III missions at a net savings of $50 million in research and development money. However, use of the AC system would require an eventual "block change" to an entirely new guidance system which in the long run would cost more than the original Space Technology Laboratories' proposal. Nevertheless, McMillan and Charyk agreed "that the Air Force should go to the AC Spark Plug route." McMillan also reiterated his promise to furnish sole source justification for AC Spark Plug procurement and provide a statement of precisely what modifications were to be introduced in the Titan II system.[18]

The final guidance decision came about two weeks later. On 14 August 1962, Colonel Bleymaier summarized for Assistant Secretaries McMillan and Imirie the implications inherent in the guidance block change proposal. At this time the program director learned that on the recommendation of Assistant Secretary McMillan the Secretary of the Air Force had, that morning, endorsed the decision of the Secretary of Defense to use Titan II guidance for the Titan III. The guidance issue was considered closed.

On 20 August 1962 a press release announced the Department of Defense decision to use a modified version of the Titan II AC Spark Plug guidance system in the Titan III space booster.[19] *

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* As might be expected, abandonment of the Space Technology Laboratories-ARMA guidance proposal created a minor political furor. The day after the Pentagon announcement the New York state congressional delegation called Air Force officials for an explanation. Congressman H. A. Shepard, representing a district in southern California, protested the action to Secretary Zuckert. Space Technology Laboratories formally protested to Rubel. The President requested an explanation. An embarrassment to McMillan--who appeared to bear the brunt of the outcry--was that AC Spark Plug was originally a losing bidder. He was forced to insist that, "The Air Force was not voiding an award and then giving the contract to another, neither the inertial platform nor the computer to be used in the interim guidance system is the same as was proposed by the AC Spark Plug-Rand team in the losing proposal."

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A somewhat different rationale for selecting the Titan II guidance system was offered by Assistant Secretary McMillan in a 24 August memorandum to the Air Force vice chief. He asserted that the original Air Force guidance proposal for the Titan III system had contained a basic contradiction. A guidance system was needed early in the program yet it had to be sufficiently flexible to meet the requirements of the most versatile space booster yet developed. Air Force experience suggested an early change in the guidance system might have to be made as soon as knowledge of more advanced space missions became better defined. And, said McMillan, "because of the comparative simplicity of the early missions and the limited performance diversification required, the Titan II guidance system, with clearly defined modifications, appeared to be fully adequate." Furthermore, McMillan continued, the near certainty that the first guidance system would require modifications, ". . . led to the obvious conclusion that our best course is to use the proved Titan II guidance system for the earliest Titan III missions."[20]

In any event, now that the decision was made it was necessary to determine schedule implications of AC Spark Plug selection, inaugurate essential program adjustments, and move as rapidly as possible into Phase I procurement. Hence, as program office effort continued through August, a major portion of the activity involved incorporating new inertial guidance factors into work statements, specifications, and the system package plan. By 24 August all work statements and specifications were "definitized" except those required for AC Spark Plug. The program office as yet had not received direction to proceed with this procurement although some unofficial "sounding out" contacts had been arranged with the contractor.[21]

In the absence of the promised instructions, the program office used ensuing weeks to develop an AC Spark Plug guidance plan. Mission characteristics which the system would have to support were defined as: direct orbital injection with gravity turn, single and multi-orbit Dyna Soar missions, low altitude orbit with plane change, and most demanding in terms of performance accuracy, 24-hour synchronous equatorial orbit. The second step was to

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establish, through close coordination with Dyna Soar program management, a clear definition and agreement of the trajectories planned for the space glider.* By mid-September, although instructions to begin guidance procurement actions were still withheld in Washington, preparation of the AC Spark Plug work statement was started. The plan was to begin with a Phase I contract which would run for 28 weeks--thus allowing time for preparation, negotiation and signing of a definitized incentive fee Phase II contract. During this period the now established Phase I formula--resolution of technical problems, definition of design criteria, analysis of mission requirements, preparation of a technical development plan with detailed costs, and review of exhibits and specification--would be completed. Moreover, to assure that in dealing with a system of such complexity nothing was overlooked, it was decided to award study contracts to the Massachusetts Institute of Technology and to Logicon, Incorporated. These studies were to precisely define component modifications essential to reliable performance of Titan III's anticipated mission.[22]

These ideas and the AC Spark Plug plan were reviewed with assistant secretary McMillan in Washington on 13 September 1962. On 15 September the secretary forwarded the much delayed--it had been promised by 3 August--authority to negotiate a Phase I contract with AC Spark Plug. The division sent a request for proposal to the company four days later.[23]

The guidance program rapidly advanced through Phase I contract negotiations during the first week of October. AC Spark Plug agreed to perform Phase I tasks from 3 October 1962 to 4 February 1963 for $915,000.** The contract

* As early as 24 August 1962, Colonel Bleymaier directed establishment of procedures for close interchange of relevant information between the X-20 (Dyna Soar) and 624A management offices by means of briefings, working groups, and provisions for X-20 liaison officers to work directly within the 624A program office.

** Contract AF 04(695)-219

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with Massachusetts Institute of Technology to determine the modifications necessary in the Titan II all inertial guidance platform became effective on 1 November 1962 and extended to 30 April 1963 at a fixed price of $270,800.* The contract with Logicon, Incorporated provided $50,000 for work extending from 18 October 1962 through 30 April 1963.[24**]

The answer to the question, ". . . whether developing a more elaborate guidance system is justified at this time," hinged on precise determination of the capabilities of the modified AC Spark Plug all inertial system, a task which required several months of analysis, simulation, and detailed programming of guidance equations through a computer. A complete answer also awaited a more precise analysis of future Titan III space missions. Yet by October 1962 it seemed certain that the weight of the inertial computer unit, its excessive power consumption, and the limited flexibility of the air-borne computer and inertial measurement unit would ultimately dictate substitution of a more advanced system. In any such planning it was essential to remember that 30 to 36 months of development time and a year or two of flight testing would be required to bring such a system to optimum reliability so that three to five years lead time would be required to obtain a new subsystem.[25]

Nevertheless, AC Spark Plug began Phase I work in October. By mid-December the sole source justification had been issued, authorizing AC Spark Plug to perform ". . . planning, design, modification, development, test, integration, coordination, fabrication and application of a modified Titan II inertial guidance system . . ." and a request for proposal was forwarded to the company on 17 December 1962. Completion of cost evaluations and technical reviews permitted the start of negotiations by 4 March 1963, their completion by 19 April, and contract signature on 25 April 1963. The AC Spark Plug subsystem, like other major Titan III components, would be acquired through a cost-plus-incentive-fee contract. For work performed from 1 January 1963 through 31 August 1966 the negotiated cost of $44,276,168 included a target fee of $2,900,000. The small but vital contract with Massachusetts Institute of Technology, which was scheduled to terminate on

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* Contract AF 04(695)-231

** Contract AF 04(695)-232 [redacted]

30 April 1963, was extended to 30 September 1963 without additional cost. The equally important contract with Logicon, Incorporated, was extended from 30 April 1963 to January 1964, at an additional cost of $181,036. Thus by the close of April 1963 all major Phase II contractual development efforts were underway and the Titan III program was on schedule.[26]

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2. Table, Contracts Awarded, Contractual Information, as of 30 Jun 1962, prep by 624A Prog Ofc; Chart, Contracts as of 31 Dec 1962, prep by 624A Proc Ofc, in Hist Div files.

3. Chart, Contracts, as of 31 Dec 1962; Hist Rpt, 624A Prog Ofc, Jul-Dec 1962, in Hist Div files; Contractual document, Exhibit "C" to Contract AF 04(695)-150, in SPO files.

4. Ltr, MajGen R. E. Greer, V/Cmdr, SSD, to Hq AFSC, 1 Nov 1961, subj: Titan III Solid Motor Development; Schedule of Verbal Presentations, 15 Mar 1962, in Doc Vol; Ltr, Col R. Nudenberg, Dir Space Prog, Hq AFSC, to Gen B. A. Schriever, Cmdr, AFSC, 22 Jan 1962, subj: Titan III Large Solid RFP's; TWX, SSBS 1-22-2, SSD to AFSC, 23 Jan 1962, in Hq AFSC files.

5. Ltr, Col J. S. Bleymaier, 624A SPD, to Hq AFSC, 2 Nov 1962, subj: Large Solid Motor Development for the 624A Program; Contractual Document, Exhibit "B" to AF 04(695)-156, "Incentive Plan," in SPO files.

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8. Hist Rpts, 624A Prog Ofc, Jul-Dec 1962; Jul-Dec 1963, in Hist Div files; SPP, 15 Oct 1962, prep by 624A Prog Ofc, in SPO files.

9. Chart as of 31 Dec 1962; rpt, Titan III Proj Review and Data Book, 27 Mar 1963; Hist Rpt, 624A Prog Ofc, Jul-Dec 1962; rpt, Relation of the Titan III to the National Launch Vehicle Prog, 27 Mar 1963, in Hist Div files.

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11. Rpt, Factors Relating to the Approval of Titan III Program, 11 Sep 1963, prep by 624A Prog Ofc, in Hist Div files.

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16. Memo, B. McMillan, Asst SAF (R&D), to the C/S Hq USAF, 29 Jun 1962, subj: 624A Program for FY 1963, in Doc Vol.

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CHAPTER 5

ENGINEERING AND CONSTRUCTION

Design of the Titan III space vehicle system was the result of a straightforward effort by military planners to increase low orbit payload weight to 25,000 pounds, establish a high degree of standardization, and provide significantly greater economies of operation. By mid-1961 the scientific and engineering consensus favored a space vehicle assembled from standard building blocks, thus possessing high reliability and mission flexibility.*

An obvious choice for the core was Titan II, most powerful of the intercontinental missiles already in development. After further study, the concept grew to include a new pressure fed third stage topped by a control module and a standard payload fairing. This basic "core," designated Titan IIIA, would be capable of lofting significant payload weights--5,800 pounds into a low (100 nautical mile) circular orbit or 3,600 pounds into a 1,000 nautical mile circular orbit. But the technically unique element of the system--as much in its application as in it its design--was the addition of solid propellant motors to vastly augment an otherwise nominal payload capacity. Two solid propellant segmented motors, fastened one on either side of the core in the same plane, would increase payload capacity to an awesome 25,100 pounds in low circular orbit, 2,140 pounds into a synchronous equatorial orbit, or 5,100 pounds to escape. The vehicle would measure over 125 feet in length--the height of an average 10 story building. The solid motors as well as the core would each be 10 feet in diameter and when vertical on the launch stand ready to launch,

* The Air Force Phoenix Study, the Department of Defense Schuette Committee, the National Aeronautics and Space Administration, and joint committees of these agencies were unanimous in their support of the general requirement for a space vehicle system which would meet these performance specifications.

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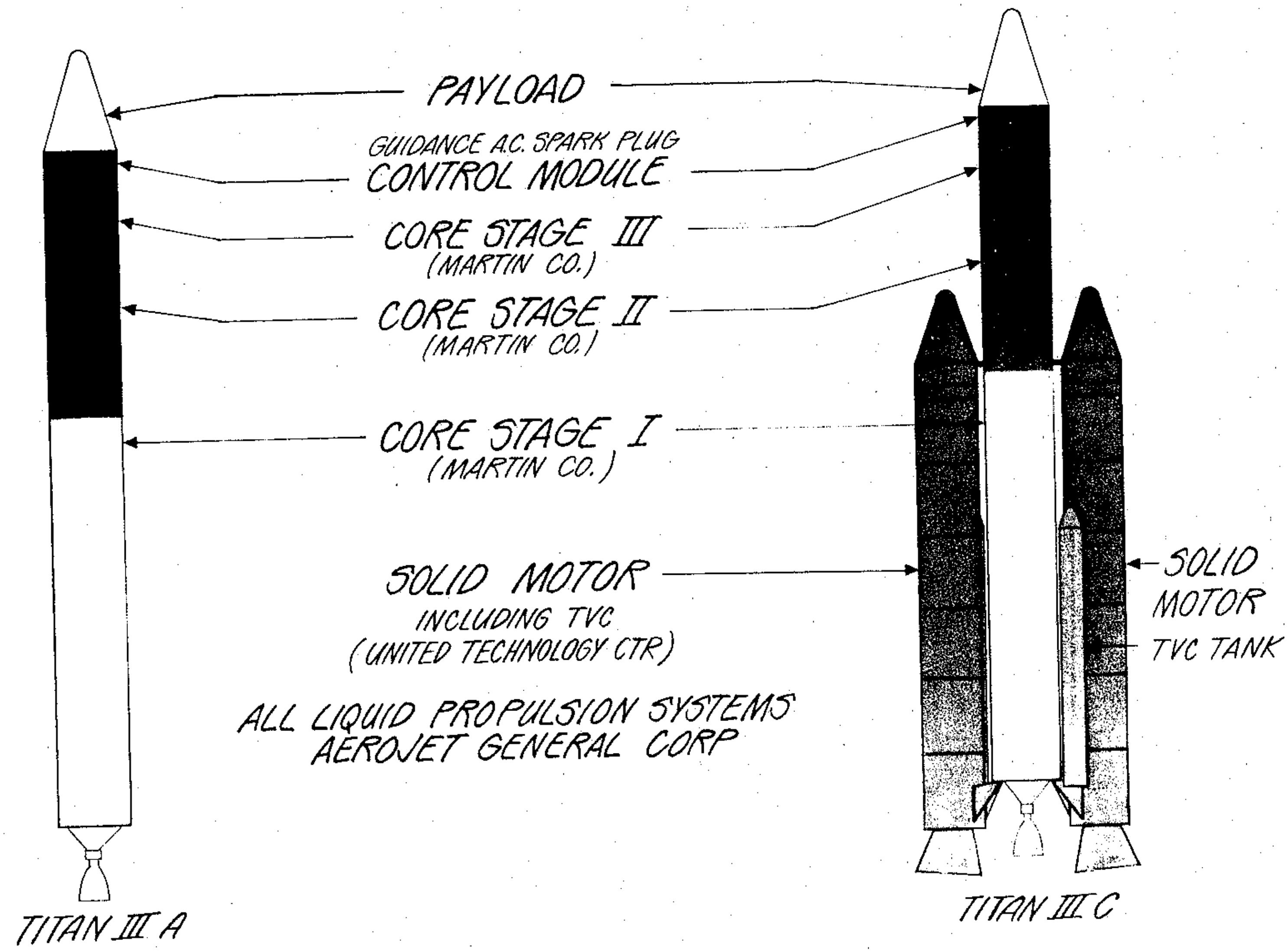

TITAN III CONFIGURATIONS

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but for the payload, its weight would total 1,361,680 pounds. To lift this mass of metal, fuel and additional payload off the pad and into space the solid motors would release 2,276,000 pounds of thrust. Throughout the 105 seconds of solid motor operation, thrust would average 1,970,000 pounds.[1]

Beyond its great size and advanced performance there was little in the total Titan III concept technically new or startling. Indeed Titan III selection was based in large part on a design concept which called for full exploitation of existing technology. Thus the first stage of the core was a modified Titan II stage possessing simplified propulsion and electrical systems. In addition to the liquid fuel engine and related equipment, the first stage would contain "black boxes" for telemetry, malfunction detection and flight safety. The airframe structure would be more rugged than that of the Titan II but otherwise its design and construction would be the same.

The Aerojet-General first stage engine--designated LR 87--would differ from the Titan II engine in having an altitude start capability and insulation around the engine compartment to protect against heat radiated by the solid motors. Using storable propellants,* the engine was rated at430,000 pounds of thrust (or 474,000 pounds vacuum thrust, a more useful measurement as the engine would operate in a rapidly thinning atmosphere). The engine included two gimballed thrust chamber assemblies, two turbopumps, and two gas generators. Two solid propellant cartridges would furnish the energy to start the turbines spinning during the engine start sequence. An ingenious autogenous system was designed to pressurize the propellant tanks. Batteries for operating electrical equipment were located in the engine compartment and between the propellant tanks. The completely assembled first stage, including the engine, would be approximately 70 feet long.[2]

The second stage, like the first stage, was essentially a variation on Titan II design. Its structure was reinforced and propulsion changes were

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* Nitrogen tetroxide (N_2O_4) and a 50-50 mixture by weight of hydrazine and unsymmetrical dimethylhydrazine (UDMH).

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made to assure utmost reliability and safety. In other respects the Titan III second stage instrumentation, power supply and their location were similar to the first stage. The LR91 storable propellant, turbopump fed engine was designed to produce 100,000 pounds of thrust at altitude, through a single gimballed rocket nozzle. The length of the second stage, including the engine, was slightly under 36 feet.[3]

The most striking feature of the Titan III core was the design of the third stage wherein rested much of the vehicle's potential for successful operation. The third stage, primarily a propulsion unit to perform trajectory changes and final orbital placement, was designed to have a "Siamese twin" relationship with the control module, which contained the intricate guidance and control apparatus. Both were designed as independent units and could be separated if the space mission so required. The length of the stage, measured by the width of the outer shell surrounding the engine like a belt, was only 18 inches. The engine itself extended below and above to require a total length of nearly 15 feet--the tankage extended into the control module above and reached down into the top of the second stage below, along with operating parts of the engine and the two ablation cooled thrust chambers. The engine was designed to extract 16,000 pounds of thrust from the same storable fuels as the first and second stage engines. The most important aspect of third stage performance would be its ability to stop and start three times during a six and one-half hour period.[4]

The control module, assembled around the third stage, contained all the electronic gear to guide and control the vehicle through its staging sequences, telemetry equipment for data transmission, communications equipment, and an electrical power supply. All guidance and control commands would originate in the module by means of equipment which could be programmed as each mission required. Tracking and communications would be performed by a beacon transponder and pulse-code-modulated (PCM) reciever encoder. In addition to this complex equipment the module would also contain the controls for malfunction detection and retrothrust operation, as well as the auxiliary propulsion system. The latter system would function like an extra stage to furnish attitude and propellant settling control during coast periods.

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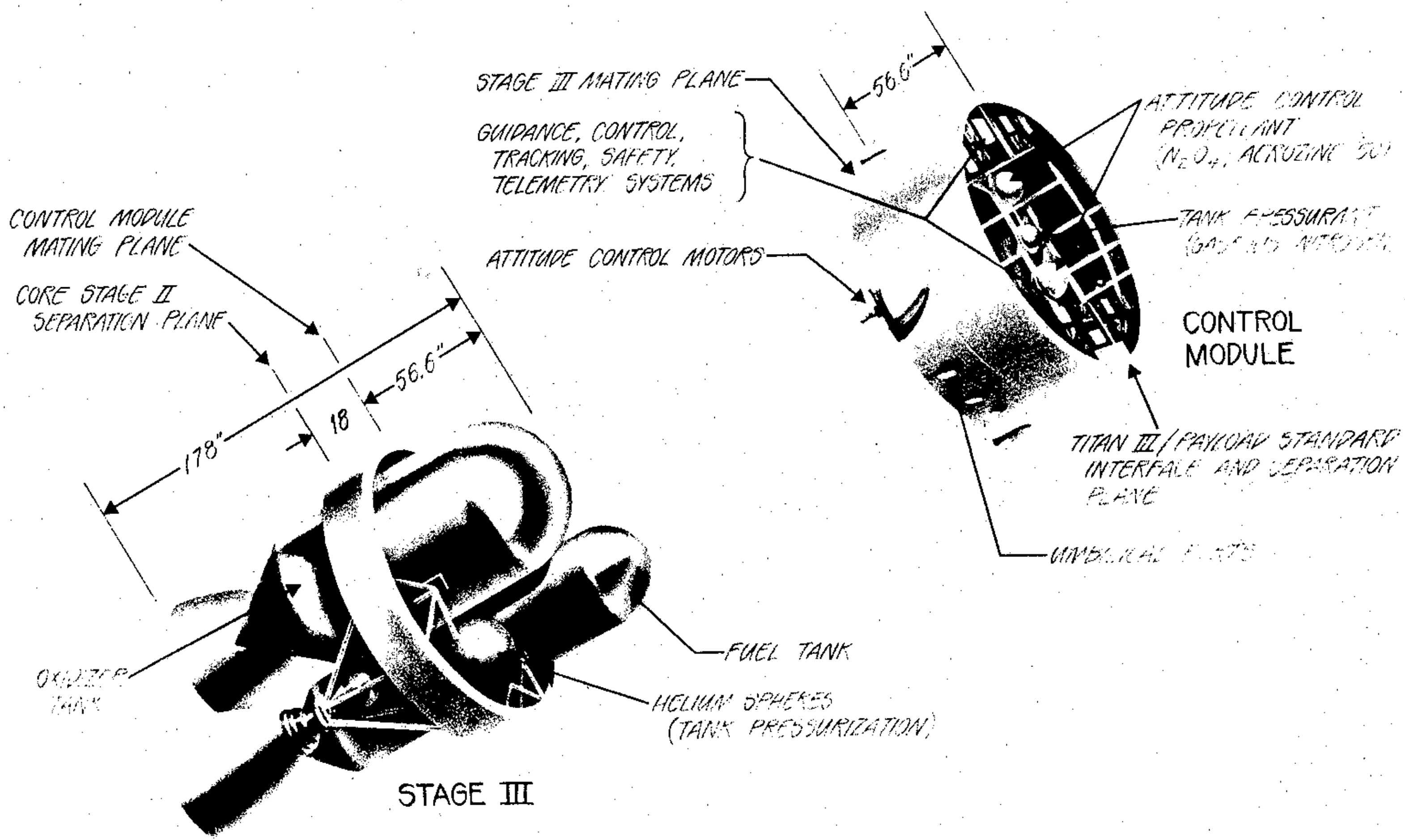

TITAN III TRANSTAGE AND CONTROL MODULE

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Thrust would be obtained by using a storable bipropellant fuel through eight nozzles arranged in pairs mounted at 90 degree intervals around the circumference of the control module to furnish propellant settling, pitch, yaw, and roll control. Propellant capacity of the auxillary propulsion system really determined the length of the restart period for the third stage. Engineers estimated it would hold sufficient fuel to maintain attitude control for a six and one-half hour period. The measurements for this collection of esoteric electronic-mechanical equipment were considerably larger than those of the third stage: the diameter was the same size but the control module would measure four and two-thirds feet in length.[5]

Standard Core and Engine Development

Starting with Phase II, Martin began the massive task of producing thousands of engineering drawings and tooling a plant for production. By July 1963, the major portion of the engineering work was completed (95 percent), fabrication of core airframe structures was underway, and over a thousand hours of wind tunnel testing with scale models had returned early and vital engineering data.* Nearly half of the large number of engineering drawings and plans for Titan III ground equipment were completed and by mid-July a full scale engineering mockup of the third stage and control module was on display. Martin also completed a vital but undramatic task dubbed "Project Avalanche" which required nearly six months of work updating and correcting vehicle model specifications.[6]

But as with any development program, the shadows of problems to come began to appear. Based on engineering data of July 1963, the burnout weights of all three stages would be 810 pounds above specifications and stringent weight control measures and improved design would be necessary to solve the problem. Another acute but hopefully temporary problem concerned

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* Scale model (5.5 percent) wind tunnel tests were performed at Arnold Engineering Development Center to define the first stage heating environment during a solid motor firing. Analytical wind tunnel tests were also conducted at Ames and Langley wind tunnels.

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adequate control of electromagnetic interference to assure clear channel communications and operation of the vehicle. An area of increasing concern, however, arose in the development of the LR 87 first stage and LR 91 second stage engines by Aerojet-General (Sacramento) where the slow rate of development progress caused increasing uneasiness over the adequacy of management.[7]

The problem of engine development was compounded by disappointed hopes. Designed to reap the advantages of using fully developed rocket engines, Titan III also inherited serious engineering problems which Titan II development had not fully solved by the early fall of 1963. Some of these involved engine gearbox breakdowns, pressure sequencing valve failures and starter cartridge difficulties. Aside from these strictly "local" complications, an even more pressing difficulty was the "Pogo" problem--severe longitudinal oscillation of the entire vehicle at low frequencies. Happily, this somewhat foreboding state of affairs rapidly improved. First stage engine "battleship" testing was completed in November and testing of the second stage ablative "skirt" permitted approach to a final acceptable design by the end of December. The first engines for use in a flight vehicle arrived at Martin on 29 November, just when need for them was becoming acute. By December 1963 development of more reliable first and second stage engine start cartridges was going well. In addition, Titan II engine development furnished its anticipated benefits: new thrust chamber valves and a new first stage gear box were adopted to improve Titan III engine reliability.[8]

Problems requiring long range solutions remained: second stage instability, which was under attack in the Gemini program, and the long range but serious problem of a rapidly developing scarcity of nitrogen tetroxide, the storable propellant. Only a fraction of the overall July 1963 demand (37 percent) could be met by current production. While posing no immediate threat--significant Titan III propellant consumption would not occur until flight tests, scheduled to begin August 1964--it did require long term planning to assure adequate supply. Finally, problems encountered by Arnold Engineering

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Development Center in maintaining the schedule of Titan III engine and wind tunnel testing threatened to significantly delay the program.* The latter two problems could only be alleviated by assigning top priority to Titan III development.[9]

The program office, in September 1963, established a special working group to wrestle with such problems as overweight, dangerous heating of the aft core area, solid motor thrust termination loads and general performance improvement. From this action stemmed a weight control program, addition of a protective shroud or "boat tail" covering the first stage engine compartment, and reduction in solid motor thrust termination ports from four to two. By the close of 1963 basic core engineering was completed and development emphasis was focused on hardware production.[10]

Third stage propulsion system development during the first months of Phase II encountered few difficulties as Aerojet-General, Azusa, established a strong management engineering organization which kept the development effort on schedule. By the close of June, firing tests on experimental engines were going well and over 100 minutes of sea level hot firing had been performed. On 23 July 1963 this progress was marked by a most encouraging long duration firing test--four minutes and 44 seconds. The engine, mounted in a "battleship" version of the transtage, was started twice and stopped three times in a first thorough checkout of the engine and integrated pressure fed fuel system. The test also revealed a disquieting incompatibility between the engine injector and thrust chamber. Tests at Arnold Engineering Center during August confirmed the suspicion that the ablative thrust chamber would burn through before completion of a full duration firing. Moreover, gimballing the engine in a cold environment disclosed a bi-propellant valve malfunction

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* Arnold Engineering Center problems were primarily limited facilities and too great a demand for their use. For example, Titan III and Apollo test schedules conflicted to the detriment of the former program. There was delay in the completion of a large environmental space laboratory in which the complete transtage would be subjected to rigorous tests including vacuum start, near absolute zero operation, and operation in an environment of intense solar radiation and heating. Some substitute for these tests had to be found to keep the program on schedule.

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and a nozzle extension weakness. Hence, by the close of 1963, an extensive redesign and testing program was underway to eliminate these difficulties so the contractor could make his first delivery of flight engine hardware--due in mid-December 1963.[11]

Solid Propellant Motors

At the end of World War II solid propellant rockets, while used in some minor weapons applications, were still in their development infancy. For several years thereafter solids remained out of the main stream of rocket development, although in the early 1950's the several services successfully produced a number of small solid propellant missiles and take-off-assist units. As the decade advanced there was rapidly accumulating evidence that if gains in such areas as metallurgy, chemistry and high temperature materials were fully exploited, solid propellant technology might well move rapidly forward.[12]

In April 1956, following about nine months of intensive study, the Western Development Division--later the Air Force Ballistic Missile Division--contracted with several major industrial firms to explore new and improved technology leading to a feasibility demonstration of solid propellant motors for use in ballistic missiles.* Because the ballistic missile organization was completely absorbed in liquid rocket weapon development, contract administration was transferred to Wright Air Development Center. Within a year, under this contract, large solid rocket motors containing as much as 25,000 pounds of propellant had been assembled and successfully fired. Motor cases up to 60 inches in diameter were successfully tested and multi-batch high performance propellants of uniform quality were manufactured. New methods of nozzle cooling were devised and preliminary experimentation strongly indicated that thrust vector control could be attained through use of gimballed nozzles.[13]

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* Contracts were awarded to Phillips Petroleum Company, Aerojet-General Corporation, Grand Central Rocket Company, and Standard Oil Company of Indiana.

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These advances in a hitherto moribund technology induced Air Force adoption of a new development program leading to an advanced "second generation" intercontinental ballistic missile. Thus the Minuteman was born. The Navy, at about the same time, was developing the Polaris solid propellant intermediate range missile. Validity of the concept was dramatically demonstrated on 1 September 1959 when the first large size solid propellant, flight weight motor, over 24 feet long and over five feet in diameter, weighing over 50,000 pounds, was successfully fired.[14]

Notwithstanding the engineering effort involved in the ultimate development of an operational Minuteman the horizons of solid propellant technology were still remote. Far sighted weapons planners and rocket visionaries were thinking in terms of millions of pounds of thrust and repeatedly pressed their recommendations for renewal of large scale solid propellant research. In 1957, Wright Air Development Center's Solid Rocket Branch (Power Plant Laboratory), which had taken over solid rocket development contracts from the ballistic missile division, urged a continued well planned research effort.* In March 1959, the laboratory invited industry to bid on demonstrating a solid motor producing 20 million pound-seconds of thrust. On 27 April 1959 an evaluation board recommended selection of Aerojet-General to conduct the defined development work. Then there followed months of reviews and evaluations at command, Air Force headquarters, and Department of Defense levels before the contract was finally awarded, on 5 August 1960. It was funded at a level of $2,937,131 for fiscal 1961. On this relatively thin budget Aerojet achieved startling success, becoming the first company to experiment successfully with the "breakthrough" idea of segmented motors. A segmented solid motor was made of huge single-castings (grains) stacked on top of each other--with the ends knocked out and in a single casing made by bolting together the several segment walls--to create motors of massive size

* In mid-1959, the liquid and solid rocket branches of the laboratory were transferred to Air Force Flight Test Center at Edwards Air Force Base, California, where eventually they became the Rocket Research Laboratory.

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and thrust. Aerojet demonstrated the first such rocket motor on 3 June 1961--a 100 inch diameter single center segment motor which delivered 450,000 pounds of thrust for 45 seconds. On 29 August a two segment motor delivered 460,000 pounds of thrust and operated for 67 seconds. These were the highest thrust performances so far recorded for any solid propellant motor.[15]

As contractors advanced their research programs, solid propellant technology continued to score significant gains. Grand Central Rocket Company, on a small Air Force contract--$318,000 in fiscal 1960 and $413,000 in fiscal 1961--performed studies, motor designs, and research on segmented motor joints. At the same time United Technology Corporation proceeded with its privately funded program to develop and test a giant, single-segment, 256,000 pound thrust motor and a two-segment, 482,000 pound thrust motor. The segmented solid motor concept, new high performance solid propellants, and lightweight materials promised wide vistas of bold new applications. Moreover, tests which demonstrated virtually unlimited thrust possibilities were particularly attractive to those searching for means of large gains in space vehicle performance. Thus, technical evolution merged with military necessity to create the combined solid-liquid propulsion techniques utilized in the Titan III launch vehicle.[16]

Titan III solid motors, while resting on a foundation of proven techniques, nevertheless required another long engineering stride forward to become operationally acceptable. Motors of Titan III size and thrust had never been manufactured and tested. Phase I studies had defined vehicle requirements and solid motor performance factors such as burning time, thrust, regressivity, and other specifications which were then carefully weighed to establish the exact dimensions of the solid motors. The design for each motor was fixed at five interchangeable 121 inch diameter segments plus forward and aft closures. The entire motor, including the forward shroud containing the two thrust termination ports and the streamlined cap, measured nearly 80 and

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one-half feet in length. A composite propellant,* relatively easy to manufacture, was selected to fuel the motors.[17]

United Technology Center, building on advances made in the Minuteman and Polaris programs, fabricated steel cases approximately one-third of an inch thick using roll and weld construction. As designed, the segments consisted of the outside steel shell, a lining of Buna-type rubber insulation about one and one-half inches thick at the ends of the segment and thinner at the center, and the solid propellant. Four segments would have a cylindrical opening about four feet in diameter in the center of the grain with the forward segment core in an eight-pointed star configuration. The segments were designed to be bolted together with a clevis-pin type of joint integral with the case. Burning would progress longitudinally and radially simultaneously by starting at the core; then all the grain surfaces would burn together for about 105 seconds. The aft segment was designed to be assembled with the nozzle throat assembly and exit cone.** The nozzle of each solid motor was designed with a six-degree outboard cant to furnish added flight stability. Finally, the closure of the forward segment would include two thrust termination ports which could be blown out on command. Thrust termination would be a vital adjunct of flight safety, abetted by a command destruct system which would be able to reduce solid motor thrust to zero within milliseconds.[18]

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* Polybutadiene acrylonitrite-acrylic acid.

** The throat assembly, to withstand the hurricane of hot gases during firing, was designed to include three carbon rings, about four inches wide and eight to ten inches thick and 38-inches in diameter on the inside--the size of the motor's carbon throat. The outside of the rings were designed to be wound with silica phenolic tape and bonded to a steel sleeve. This complete assembly would in turn be bonded to a steel shell and bolted to the aft motor closure. The exit cone, about 10 feet long and an ingenious combination of steel, silica phenolic and aluminum, would be fabricated in two sections and bolted together, then bolted to the segment's aft closure to create the motor's thrust chamber.

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United Technology Center, perhaps because of the basic simplicity of solid propellant motors, was the first Titan III contractor to launch hardware fabrication and motor testing. By early 1963 the company was assigning specialized development areas to subcontractors.* The early development effort was rapidly organized to start fabrication, cast propellants and activate a testing program. A "PERT/TIME/Cost" system network was completed on 15 February 1963 (an event favorably affecting the company's incentive fee). The first single segment 120-inch motor was successfully tested on 23 February and the second on 18 June.**

These tests were successful preliminaries to the first full scale five segment firing test on 20 July 1963 which was, quite properly, considered to be one of the most crucial tests in the development of the Titan III system. The 75-foot-high motor, probably the largest ever tested anywhere, was mounted on the Center's test stand near Coyote, California, and fired with outstanding success. The motor produced 1.2 million pounds of thrust--just one of the 273 test factors which were measured. Motor burning time was approximately 112 seconds, which included about 110 seconds of action time before thrust "tail off" began. This test once again proved the validity of the liquid injection thrust vector control system by demonstrating a vector deflection of

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* Among these were Curtiss-Wright and Westinghouse, fabrication of steel cases; H. I. Thompson Fiber Glass Company and Tapco Division of Thompson-Ramo-Wooldridge, manufacture of nozzles; Ling-Tempco-Vought, valves and electrical subsystem; Allison Division of General Motors, tank structures; Rohr Industries, hydraulic system; Lockheed, injectant manifold of the thrust vector control system; Tapco Division and Rohr Industries, motor insulation; and Sikorsky/Division of United Aircraft Corporation, motor skirts and fairings.

** The first motor segment produced 231,000 pounds of thrust, operated for 107.3 seconds and achieved a maximum thrust vector control angle of from five to six degrees. The second motor firing on 18 June produced a maximum thrust of 229,250 pounds, operated for 108.2 seconds and accomplished a thrust vector control angle over five degrees.

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five degrees. Subsequent test would advance to firings of operationally configured motors which would present a far more difficult--and crucial--test environment.[19]

But through the last month of 1963 the optimistic promise of the successful first full scale test was eroded by difficulties arising mainly from production problems and poor subcontractor quality control. These difficulties were not considered crucial but they were sufficient to postpone the second five segment motor test firing into 1964--two months late. It was anticipated that accumulating contractor experience and improved subcontractor quality and scheduling control would solve these problems without delaying the overall program.[20]

Guidance System

Future Titan III assignments would require accurate navigation and injection of the payload into circular orbits, synchronous positioning of satellites, and missions through escape into outer space. Electronics linked with delicate mechanical equipment would perform these extraordinary feats of guidance. The airborne computer would compare deviations in vehicle attitude signaled by the inertial guidance system and the rate gyro packages with the programmed attitude and flight path. Corrective signals would then be transmitted to the proper thrust vectoring element and, during the first phase of flight, fluid would be injected into the solid rocket motor nozzles to provide the thrust variants necessary to keep the vehicle steady on course. The system would respond rapidly to correct flight attitudes--accentuated by the large surface area of the Titan III vehicle--induced by winds, wind cross-currents and gusts. The same procedure would characterize operation of the core's three stages. Corrective signals obtained from the inertial guidance system and rate gyro packages would be transmitted into gimbal movements of the liquid engine nozzles. Guidance of the third stage-control module and its payload would be somewhat more complex. During the coast phase the guidance system would send corrective attitude control adjustments to the control module's auxiliary propulsion equipment. The auxiliary propulsion system would also perform a propellant settling function to provide

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three starts of the third stage engine during a possible maximum six and one-half hour period of intermittent coast and powered flight. Thus the mission would be accomplished by accurately following the programmed flight path selected for the spacecraft.[21]

The decision to adapt Titan II's all-inertial guidance system to the more demanding duties of guiding a high performance space vehicle required an intensive study of Titan III's future guidance needs. These technical expectations focused on requirements for Dyna Soar and the 24-hour synchronous satellite. If the system could perform these guidance tasks with precision it would also be sufficiently versatile to undertake other far ranging missions. It was determined that, with a substantial list of modifications, the Titan II AC Spark Plug system could be expected to meet flight tests and less sophisticated early operational assignments. Studies of necessary alterations to the system continued through the summer of 1963.[*] During the last months of 1963 components were produced in sufficient quantity to assemble the first Titan III guidance set--assigned to the prosaic but essential task of supporting vehicle acceptance tests at Martin's Denver plant. Other vital system components: inertial measurement units, guidance computers, video bandwidth reducer, and pulse code modulator and signal conditioner, were in production.[22]

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* The Titan II guidance system inertial measurement unit was changed to allow for increased gimbal freedom and its electrical circuits were modified to cope with the thermal and pressure conditions of space as well as to withstand an accentuated vibration environment. The capacity of the airborne computer was enlarged while its design was altered to resist severe vibration and operate effectively in the space environment. Other complex adjuncts of the system, the pulse code modulator and signal conditioner, were subjected to changes to make them suitable for Titan III operation. A video bandwidth reducer was added for high altitude communication while a pressure and thermal controller was added to the airborne system to assure adequate cooling and pressurization of the system during its lengthened operating time. Modifications were also planned in guidance alignment checkout instruments and other elements of ground guidance equipment.

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Vehicle--Payload

The philosophy of Titan III standardization precluded significant vehicle design change to accommodate a particular payload. Rather, the defense engineering office and the systems command were committed to the policy that payloads must be designed to match the booster. Yet, inasmuch as Dyna Soar was the only payload specifically committed to Titan III, the program office worked closely with the Aeronautical Systems Division to insure that vehicle and payload designs and hardware were mutually compatible.

Early in 1962 space and aeronautical division conferences and briefings were arranged and Titan III technical planning was significantly influenced by the booster performance requirements of the Dyna Soar system.[23] As Titan III planning matured, parallel plans were created for closer liaison between the 620A (Dyna Soar) and 624A system program offices. During May 1962 the space division offered a suggestion to the commander of the aeronautical division to ". . . designate one or two of your personnel to be assigned to the 624A Program Office in a liaison capacity." Major General R. E. Greer, then vice commander of the space division, proposed a data exchange meeting and the establishment of working groups in specific problem areas.[24]

The data exchange meeting was held at the space division during the week of 18 June 1962. Such matters as adoption of document exchange procedures, development of policies on meetings between associate contractors of each system, and establishment of working groups in problem areas were arranged. These measures, once set in motion, were considered adequate to solve any interface problem. Lieutenant General H. M. Estes, the Air Force Systems Command's Deputy Commander for Aerospace Systems, said it was his intention to call occasional "scheduled interprogram coordination meetings" which senior representatives of all participating agencies would attend. Thus, by the close of June, the means for rapid technical communications affecting the two programs were available.[25]

They had to be. One of the early technical issues in Titan III development--choosing between four and five segment solid motors--was of vital moment to

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the design of Dyna Soar. During June 1962 there was a move afoot to permit control of the boost trajectory by the Dyna Soar pilot. If adopted, this would require compatibility of the Dyna Soar guidance system with the Titan III flight control system.[26] As development of both programs continued, a number of intricate technical interface design interactions were uncovered. By 1 August it was decided to postpone a decision on pilot boost control until the question of Titan III guidance and flight control system had been resolved. Flight path and trajectory constraints imposed by structural and thermal environment limits of the glider remained uncertain. In addition, there were acoustical and vibration environment problems to investigate. Indeed, the gamut of related problems was of sufficient importance to suggest the need for study by the division's scientific advisory group, which was convened for this purpose during the week of 9 August 1962. The group recommended, along with specific technical provisions, establishment of "single point management" of certain program areas.[27]

As the program moved into September the space division was instructed to assist the Dyna Soar program office in a study to determine the specific requirement for a pilot-in-the-loop system and in the "determination as to whether or not this capability can be provided within the funds available and on an acceptable schedule." In passing, it was noted that the system would need a new airborne digital computer development, a requirement that would be costly in money and time. In any event, a joint technical meeting on 19-20 September 1962 was sufficiently important to merit the presence of General Estes and Major General R. G. Ruegg, Commander of Aeronautical Systems Division, as chairmen. The problem of pilot control of boost trajectory and improved technical relationships between the two programs was critically reviewed.[28]

This technical meeting produced the conclusion that a "pilot-in-the-loop" restraint imposed engineering changes which could not be incorporated in the Titan III guidance and flight control system in time for the 17 scheduled flight tests. However, relevant technical data was to be assembled and a study group established, after which, if the idea proved technically practical,

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recommendations could go to command and Air Force headquarters for approval. Furthermore, working groups covering technical development areas were organized of representatives from the 620A and 624A program offices and Aerospace Corporation* and actually set to work on assigned problems.[29]

At the close of 1962 the problem of Dyna Soar pilot-in-the-loop and back-up guidance continued to hang fire. The entire X-20 program and its relation to Titan III were reviewed by the systems command council on 5-6 December 1962. Proposals advanced by the aeronautical division, it was felt, imposed demands in excess of the capacity of the planned guidance system and it appeared that boosting Dyna Soar into a multi-orbit mission might well require development of a new third stage. Nevertheless, studies to confirm the feasibility and detailed requirements of the proposals were scheduled for review late in January. In addition, certain important "interface decision dates" were agreed upon. These dates covered major technical development areas and ranged from a decision on a definite design trajectory--to be determined by 31 January 1963--to the final agreement on "launch loads analysis, axial and transverse load factors"--to be reached by 1 August 1963.[30]

A joint aeronautical and space division meeting was held as scheduled on 31 January 1963 to review the pilot-in-the-loop and back-up guidance proposals. An ad hoc study group was then appointed to determine if flying a booster "by wire" with adequate reliability was within the engineering state of the art--a determination that, after several meetings of the group, was assigned as a five month study contract issued to Martin in mid-October 1963. Until cancellation of the Dyna Soar program on 10 December 1963, the two program offices continued to act jointly to resolve the major technical problems involved in mating the Dyna Soar glider payload to the Titan III launch vehicle.[31]

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* Technical areas covered by the groups included launch vehicle-spacecraft integration, performance, structural loads and dynamics, environmental criteria, abort systems and procedures, electronic and radio frequency interface, aerospace ground equipment, facilities, and test operations.

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Vehicle Operation

Solid motor operation would begin with electrical activation of the pyrogenic ignition system--basically a squib placed within the motor so as to insure instant, positive ignition. As the vehicle lifted off the pad, stability and guidance would be obtained by injection of nitrogen tetroxide into the thrust stream through nozzles located within the thrust chamber. (It had been discovered that Titan III's regular fuel worked just as well as more exotic fluids and had the added advantage of simplifying logistics.) Injection fluid would be contained in two tanks about three feet in diameter and 30 feet long attached to the outside of each motor.[32]

As Titan III gained altitude, axial accelerometers would sense thrust decay, announcing exhaustion of the solid motor's fuel supply, and signal the start of the core's first stage engine to maintain thrust and assure continued guidance control. A parallel signal would activate explosive separation devices holding the solid motors to the core and at the same time four sets of small rockets mounted at the forward and aft ends of the two solid motors would be ignited to push the spent motors quickly out of the way. After the first stage core engine took over the propulsion task, propellant sensors would again in time sense near exhaustion of the fuel supply and signal first stage engine shutdown, the start of second stage burn, and release of the explosive fasteners holding the two stages together. As the second stage engine accelerated to full operation, exhaust pressure would mount against the first stage and thrust it backward while accelerating the remaining stages and payload forward. Then, as the fuel supply of the second stage neared exhaustion, explosive fasteners holding the second and third stages together would be released, three retro-thrust rockets located in the aft second stage skirt would be ignited to retard its forward movement, and the third stage engine would ignite, accelerating the payload forward. Separation of the third stage from the payload would be accomplished by similar retrothrust methods. The entire staging sequence, including removal of the streamlined shroud protecting the payload by shattering its explosive fasteners, may be observed in the accompanying illustration.[33]

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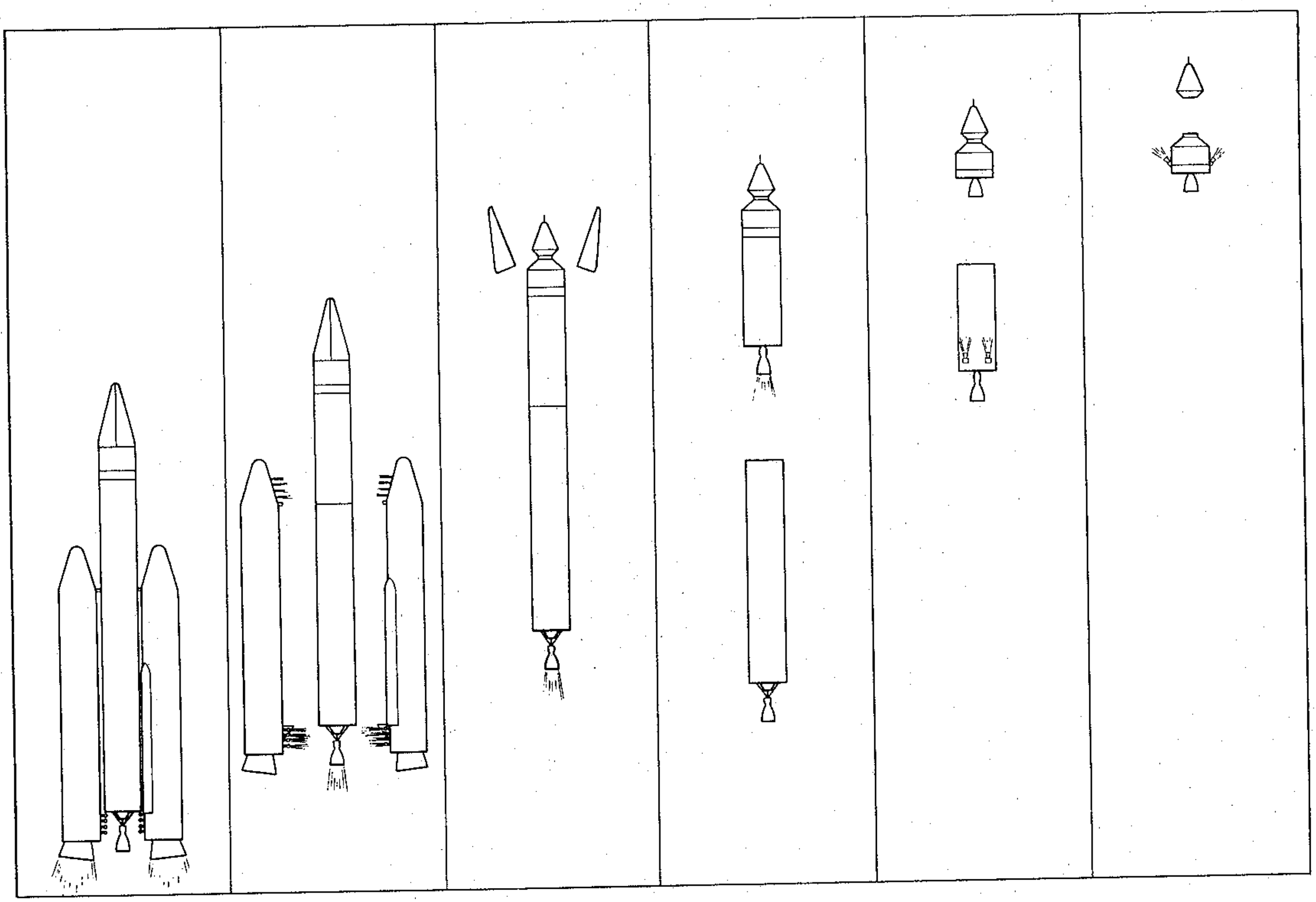
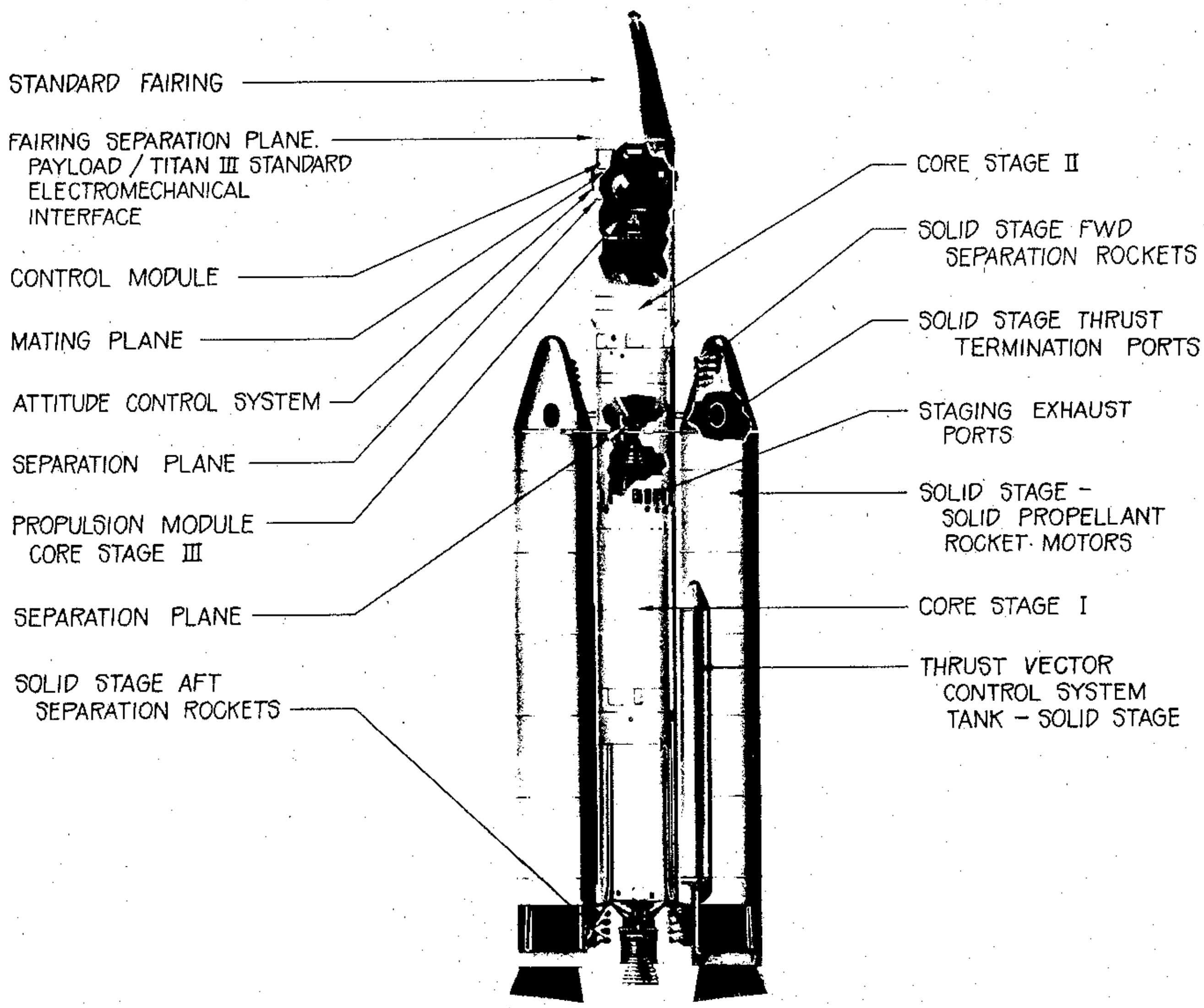


STAGE SEPARATION



TITAN III CONFIGURATION C

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Despite the complexity of certain Titan III subsystems, the vehicle design was adaptable to standardization, ease of adjustment, and service maintenance. This was particularly true in the design of the electrical system. Battery power sources located in each stage would supply current to the guidance and control system, instruments, and telemetry communications. There would be independent electrical power sources for command control receivers and destruct system devices. Instruments aboard the vehicle would translate physical data and performance information into signals for transmission to ground stations. To assure optimum safety for manned flight, Titan III would possess an automatic malfunction detection system which would be able to sense a potentially catastrophic malfunction in sufficient time for successful escape of any flight crew. Scattered throughout the vehicle, sensors would monitor sensitive elements of every vital operation. If something should go wrong there would be time for thrust termination-engine shutdown and spacecraft abort prior to destruction of the vehicle. In addition, a conventional range safety destruct system would be provided. As planned, the destruct command receiver could signal propulsion shutdown and destruct upon receiving an appropriate signal. Indeed, every conceivable scientific precaution was applied to both improving system reliability and furnishing a means of escape in the event of vehicle disaster.[34]

Edwards Air Force Base Test Facilities

The first test triumphs in development of the Minuteman solid propellant intercontinental ballistic missile occurred at Edwards Air Force Base. Thus the skills and resources already available there strongly suggested their usefulness in the large solid propellant testing program which Titan III development would require. One of the earliest decisions in Titan III planning was to augment the base's existing test capacity by new construction to accommodate static testing of 4,000,000 pound thrust motors and installation of complex test instrumentation and measuring devices.[35]

By mid-February 1962, Aetron Division of Aerojet-General had begun architectural-engineering planning of an $8.2 million solid motor test facility, designated Complex 1-36. United Technology Center, responsible for testing Titan III's solid motors, exercised a strong influence over design of the test

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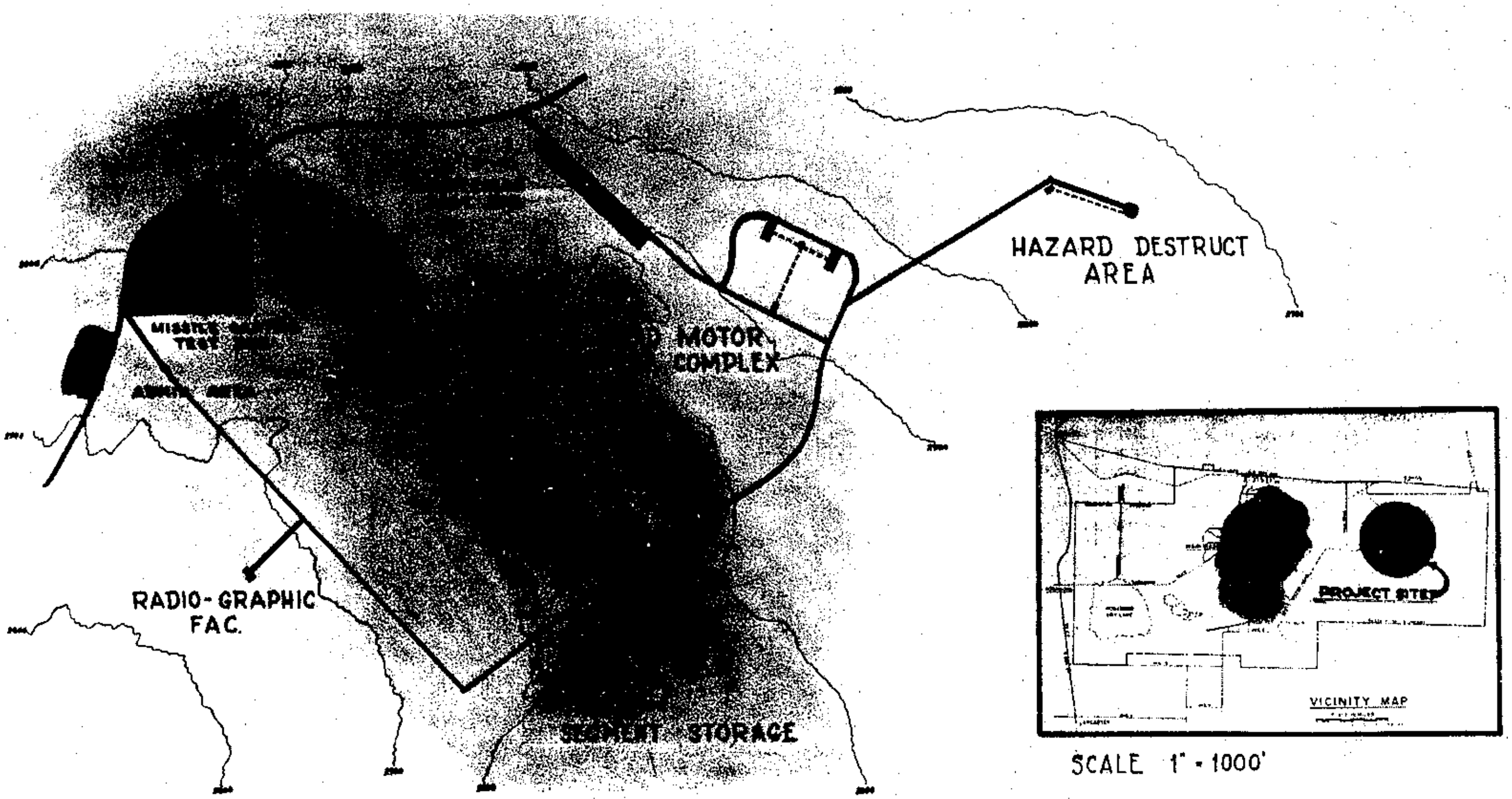

624A Program Military Construction Solid Motor Test Complex - Edwards AFB

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complex, a task that was completed on 10 October 1962. Because it cost relatively little more to increase test capacity to meet probable future needs, facilities were designed to accommodate solid motors up to 160-inches in diameter. Beyond this, a letter contract was issued to United Technology Center on 7 December, authorizing the contractor to furnish, install, checkout and operate the test complex instrumentation and control system.* This work, authorized in October, was to be completed by 10 December 1963. Meanwhile, construction bids were solicited and the Army Corps of Engineers, on 20 November, awarded a construction contract to Diverco Company. Within 10 days construction work was underway at the site.[36]

The new solid motor test facilities included construction of test stand 1-36A, designed as a single bay for horizontal tests of either one 120-inch motor or one 160-inch motor, and test stand 1-36B--located a safe distance away--a more elaborate facility for vertical testing of either one 120-inch or one 160-inch motor. The latter stand, primarily designed for testing the liquid-thrust vector control system, consisted of two enclosed 90-foot-high, 30-foot-square towers. In addition to the test stands, a hardened instrumentation and control building contained a complex maze of equipment for controlling test operations and recording test data. A shop building, administration and instrumentation building, solid motor storage buildings, an instrument relay building, several other minor support structures, and a heavy duty connecting roadway would complete the test installation.[37]

A field office of the space division's engineering directorate was established at Edwards Air Force Base to monitor construction progress and manage installation and checkout of instrumentation and control systems. As construction continued into the spring of 1963 it was apparent that the already tight work schedule was falling behind. Bad weather interfered with concrete placement and high winds delayed installation of metal siding. Then, on 20

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* The need for prompt action overrode the usual Titan III rule against use of letter contracts. During May 1963 the contract (AF 04(695)-244) was defined and priced at $4,830,000.

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May, a jurisdictional strike not directly involving work at the test complex but which prevented work there, delayed construction another 10 days. The contractor, Diverco, then declared bankruptcy, and while the bonding company installed a new prime contractor (Tidmarsh) there were several more weeks of reduced operations. In addition, mainly because the now compressed schedule offered no other course, installation and checkout of test instrumentation was undertaken before the completion of construction, always a harried and difficult task. In the face of all these difficulties, construction was completed by 17 September 1963. The pacing element was now installation and checkout of the test instrumentation. In this connection, performance of United Technology Center's instrumentation subcontractor, Fischback and Moore, was a source of Air Force worry--with adequate reason. Any significant delay beyond the 10 December 1963 contractual closing date endangered the entire Titan III development schedule. By the close of 1963 their work was continuing but progress appeared to favor a completion date of 10 February 1964--a delay which with some stress could be absorbed without altering the overall development timetable.[38]

Titan III Launching System

In the fall of 1961, when the space division was directed to begin specific Titan III planning, an immediate effort was made to apply some important concepts of the Phoenix study to produce tangible advances in space operations. Among the most important of these was a proposal to completely revamp conventional space launching methods by adopting a bold new concept for the entire launching process. Heretofore, space operations had been characterized by an expensive and lengthy sequence of assembly and checkout beginning, usually, in a shop some distance from the launch stand. When every component was operating properly the vehicle would be torn down, transferred to the launch stand, erected, and the booster and payload assembled once again. Then the exhaustive checkout procedure would be repeated. Inevitably there were repairs to be made and faulty components to be replaced. Finally, following days and sometimes weeks of checking--while monopolizing the launch stand--the vehicle would be ready for launch.[39]

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The answer to the problem was not the superficial expedient of building more launch stands, even if there were sufficient land in the right places and enough money, but rather one of assembling and checking out the complete launch vehicle relatively close to the launch pad and then transferring in on a mobile platform to the launching pad in a "ready to go" status. Thus was generated the concept of the "integrate-transfer-launch" sequence, usually abbreviated as the "ITL" system, one of the most important advances included in development of the Titan III space vehicle system.[40]

The first preliminary Titan III development plan, submitted to the defense engineering office on 5 October 1961, recommended construction of "ITL" launch facilities at both the Atlantic and Pacific Missile Ranges. It was estimated that the system would permit up to 75 launches a year from two launch pads. This launching rate, if conducted by means of conventional launch procedures, would cost at least $80 million a year more than those performed with the new system. These savings were possible, said one engineering authority, because the "ITL" concept was an ". . . application of industrial engineering principles and assembly-line procedures (insofar as they are practical) to the design of entire ground systems for launching space vehicles."[41] By 13 December 1961, plans for the new launching system had been informally approved by the defense engineering office. The space division's engineering directorate detached six of its people to work directly with the Titan III program office organization. Architectural-engineering work statements were prepared, estimating and budgeting of construction costs was completed, design criteria were developed, and vital reviews and conferences were held so construction could begin on schedule. Study of potential sites was begun, although the choice was sharply limited. The results indicated that various constraints--separation distances dictated by acoustic, safety, and toxic factors, and real estate availability--would make it necessary to create land fill and locate much of Titan III's "ITL" launching system out in the Banana River at a safe distance from the older launching areas.[42]

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By early January 1962, site selection surveys were underway at Cape Canaveral. It was apparent that selecting an exact site location would be difficult although the problem was alleviated somewhat by an early decision to convert the Titan II Complex 20 to a Titan IIIA capability. Titan III site location was also complicated by the interests of other cape users, particularly the civilian space agency, whose ambitions and launching requirements were rapidly expanding.* After weighing these various considerations, the space division proposed locating the pads north of the older sites and sufficiently distant (9,400 feet) to be safe.[43]

Engineering planning was directed accordingly. In February, Ralph M. Parsons Company was selected as the architect-engineer to design the new system. The contract was signed on 28 March. Kononoff and Smith were selected to assist the Parsons Company in engineering work at the site. The division also enlisted the Corps of Engineers District Engineering Office, Jacksonville, Florida, to perform site surveys and test borings of tentatively selected construction areas.[44]

On 2 March 1962 an informal site selection committee representing the Department of Defense, the command, the space division and the missile test center examined the proposed site and informally agreed to the siting plan.**

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* An 24 August 1961 agreement between the Department of Defense and the civilian space agency applied to all users of Cape Canaveral facilities. The Webb-Gilpatric Agreement designated the Air Force manager of all cape space functions in behalf of ". . . NASA, as well as other users. This management function includes the Master Planning, which involves the site selection of launch areas and support facilities to meet the long-term requirements of all users, both DOD and NASA."

** The group included J. H. Rubel and L. L. Kavanau, Department of Defense; Colonel F. Kane and Lieutenant Colonel D. L. Carter, Systems Command; Colonel J. S. Bleymaier, program director, Space Systems Division; and Major General L. I. Davis, Commander, and Lieutenant Colonel M. R. Carey, Air Force Missile Test Center.

[redacted]

The division was then instructed, on 19 March, to proceed with preparation of detailed designs of the "ITL" facilities to be located "... north of Launch Complex 37 in the area commonly known as the False Cape."[45]

This decision permitted an immediate start on preparation of detailed site engineering design work. It proved to be an involved and complicated task requiring complete integration of varied subsystems into an efficient functioning launching system. Close coordination between interested agencies--the program office, Aerospace Corporation, Martin, United Technology Center and the architect-engineer--was maintained by a nearly continuous series of meetings and engineering conferences and the practical expedient of assigning contractor representatives to work in each other's design offices. By mid-July 1962 design work for modification of Complex 20 was completed and the site engineering planning for the remainder of the mammoth installation was on schedule.[46]

As may be observed in the accompanying illustrations, a large part of the Titan III site area was created by dredging new land fill out of the Banana River for storage and assembly buildings and the roadway to the launching pads. Major system components would be received and processed at the southern end of the site located on a man-made island connected to the cape by a rail line causeway. (The first plan to ship in solid motors by barge was dropped in favor of all rail shipment.) In any case, here would occur the most important step in the launching sequence. A vertical integration building--a four bay 20-story structure (350 by 260 feet and 240 feet high)--was planned to furnish space for assembly of the booster and payload vertically mounted on the rail-mobile transporter platform. The booster and payload would be linked to associated ground equipment and checkout instrumentation by connecting cables. A launch control center within the building would contain the equipment to perform complete checkout of the booster and its payload and it would serve as the "nerve center" for final checkout, launch, and control of the flight vehicle. Cables would connect the launch control center with the ground equipment vans and the flight vehicle at the launching pad.[47]

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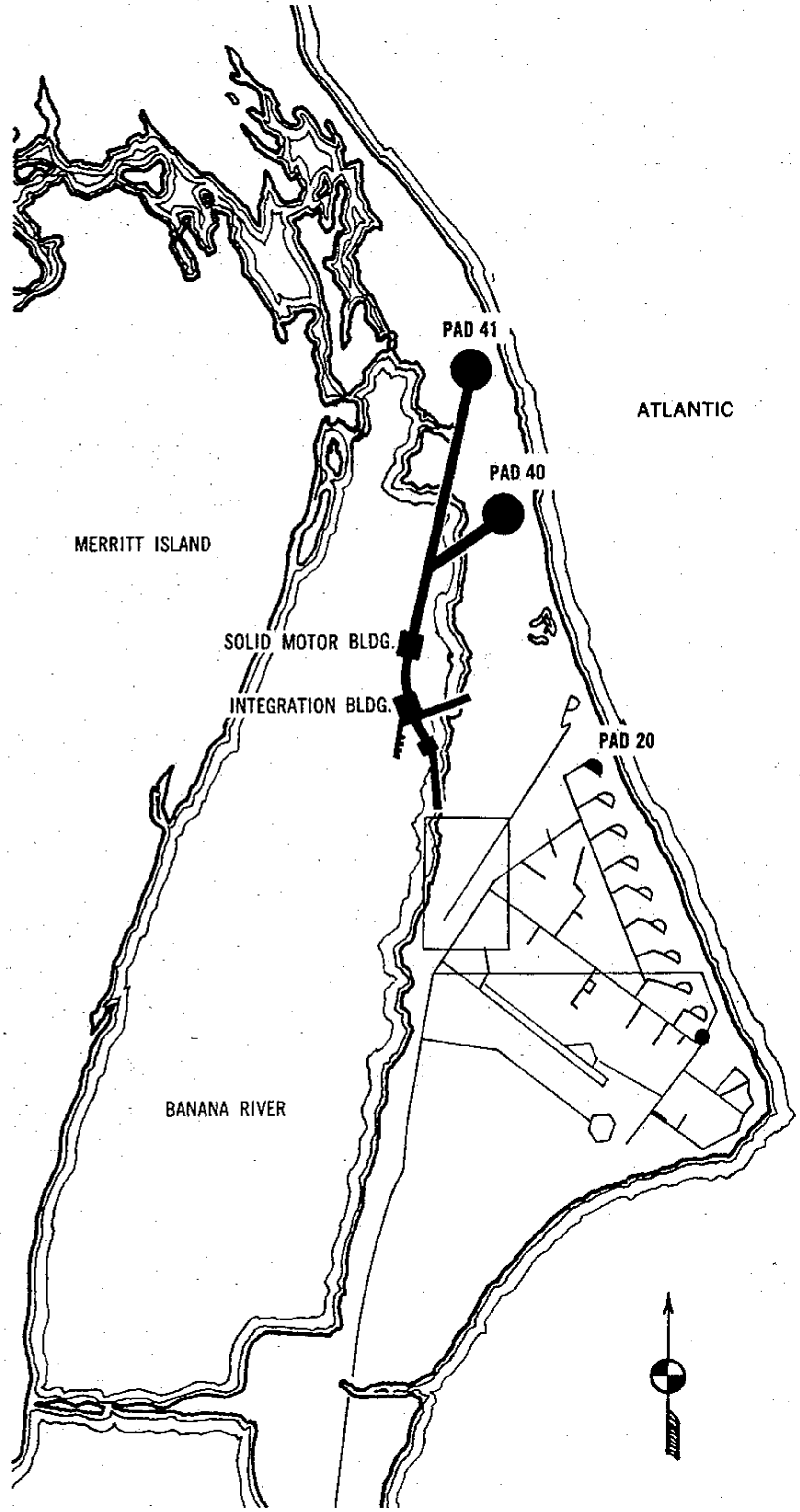

AMR ITL SYSTEM LOCATION

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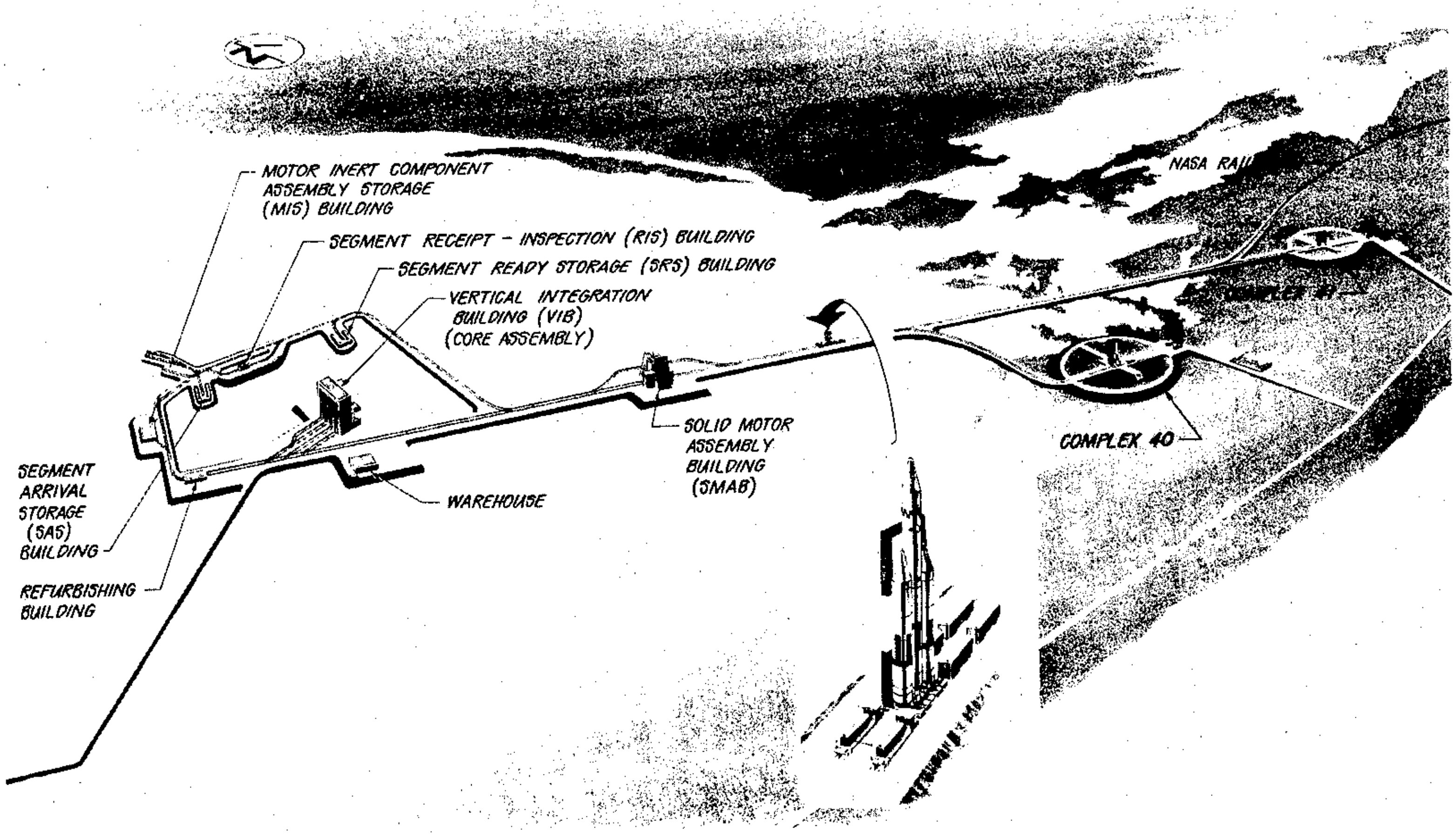

Titan III ITL Complex Site Plan

[redacted]

When the assembly and checkout work was completed, the mobile platform with the Titan IIIA and its two umbilical masts towering overhead would move along two sets of railroad tracks 27 feet apart, powered by two 1,000 horsepower diesel-electric locomotives. Four mobile vans of ground equipment would move along behind the platform, linked to the booster and payload by connecting cables through the umbilical masts. If it was a configuration IIIA launch, the complete assembly would move directly to the launch pad. If an additional 2,000,000 pounds of thrust was necessary for the space mission, the booster-payload would be moved through the solid motor assembly building for an 8-hour installation of the two solid motors. The entire assembly would then be moved to the launching pad for liquid fueling, final brief checkout and launch.[48]

The launch pads, except for being larger, would be similar to other installations at the cape. Each pad deck and foundation would contain approximately 10,000 cubic yards of concrete spread over a diameter of about 600 feet. The pad would contain a dry flame deflector and exhaust duct as well as support and service structures located about or under the launching pad. On arriving at the launch pad, Titan III would be lowered into launch position by hydraulic lifters, equipment vans would be moved to the protection of concrete buildings, and the umbilical masts would be removed. A mobile 240-foot high service tower would remain adjacent to the flight vehicle during checkout and servicing and then be rolled away before launch. Pad 40 would be completed first and then pad 41, farther north, would be finished to complete the entire "ITL" construction program. Pad 42, planned but not funded, would be added later if future operations so required.[49]

By the close of October 1962, site design effort for the "ITL" system was complete and, on 12 November, a contract for preparation of the site was awarded. The award of successive construction contracts now marked the progress of the program. On 5 December a contract to modify the Complex 20 engineering building was issued and on 10 December a contract to modify the launch stand and associated ground equipment to accept Titan IIIA. Meanwhile, designs of the steel and concrete "ITL" structures, started in July 1962 and underway through the balance of the year, were completed late in February 1963.[50]

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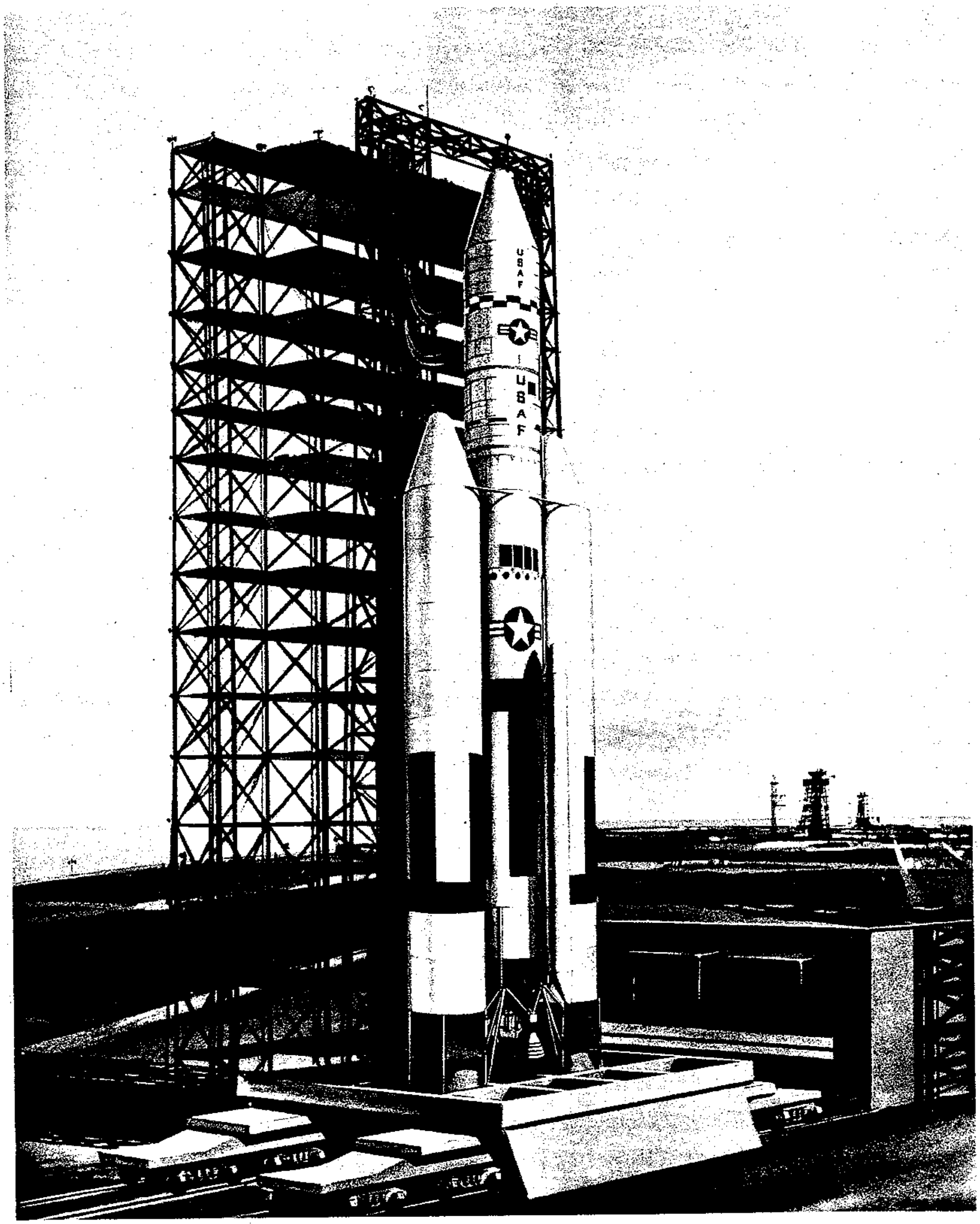

Titan IIIC on Transporter

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As the construction program prepared to move into full activity, the Air Force became increasingly concerned lest the construction effort, under the control of the Army Corps of Engineers, be enveloped by the enormous civilian space agency moon shot construction program already underway at the cape. On 26 March 1963 a meeting was arranged between General B. A. Schriever and Major General A. C. Welling, in charge of Army Corps of Engineers South Atlanta Division. General Welling indicated that he was prepared to enter into certain arrangements to assure "... proper Corps of Engineer's attention to the accomplishments of the Titan III work at the Cape." General Welling also announced organization of a new Corps of Engineers Canaveral District with two deputy district engineers, one for the civilian space agency and one for the Air Force. The Air Force, on its part, had certain Gordian knots to untangle. To shorten the administrative channel between the Titan III program office and the contracting officer supervising construction, an engineering - management office was created within the 6555th Aerospace Test Wing. The new office would be manned by both government engineers and contract architectual-engineering personnel and would have "the maximum of authority and responsibility... to manage and direct the construction effort." Furthermore, the Corps contracting officer would be "... responsive directly and immediately to the 6555th ATW without the intervention of the Division Engineer, the AFRCE-SAR or higher Air Force or Corps of Engineer's authority."[51]

The plan became effective 1 April 1963 and the new civil engineering organization of the 6555th Aerospace Test Wing rapidly assumed field construction surveillance of the work in progress. Lieutenant Colonel A. Wright was appointed Titan III Task Force Civil Engineer with Air Force and architectual-engineering personnel working under his direction. Colonel Wright held a "two hat" responsibility. As the Titan III chief field engineer he was responsible through the 6555th commander to the commander of the space division to assure that Titan III facilities were built properly and on time. He was also the Air Force Regional Civil Engineer, responsible for surveillance of the Titan III construction work, reporting directly to the Director, Civil Engineering, at Air Force headquarters.[52]

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To assure that steel and concrete would not form a monument to human error, design criteria and plans covering civil, electrical, mechanical, structural and architectural engineering were thoroughly reviewed and revised before construction began, a task not completed until 10 June 1963. To ease contractual administration of the mammoth task, the total "ITL" construction program was divided into four "packages,"* thus simplifying review of the drawings, allowing for design of the larger structures, and furnishing a means of breaking down the whole program into logical groupings for allocation to contractors.[53]

The first design package ready for contracting was forwarded to the Corps of Engineers on 5 April 1963. Size and complexity of construction eliminated all but those contractors possessing the greatest resources to perform the work. Bids were opened 6 June and a contract for package two--construction of Complex 40, 41, and related installations--was awarded to two joint venture contractors, C. H. Leavell and Peter Kiewit, on 13 June 1963 at a bid cost of $12,678,873.** Slightly less than two weeks later, on 26 June, trucks and men moved in to start construction of the Air Force's first "Integrate-Transfer-Launch" system.[54]

The Corps of Engineers combined the remaining three packages into one contract. This contract, like the first, was offered to a selected list of bidders on 26 June. The bids were opened on 30 July and the contract was awarded 6 August 1963 to joint contractors Morrison, Knudson and Paul

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* Package one included the warehouse, ready building, supply and issue buildings; package two, Complex 40, 41 and related facilities; package three, "ITL" rail system and utilities; package four, vertical integration building (VIB), solid motor assembly building (SMAB), segment-receipt-inspection building (RIS), motor inert component assembly-storage building (MIS), segment arrival storage building (SAS), and segment ready storage building (SRS)

** The contract included launch pad and mount, aerospace ground equipment building, umbilical tower, mobile service tower and support facilities. The Air Force estimated the contract would cost $5,743,020 for Pad 40 and $5,666,540 for Pad 41.

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Hardeman at a bid cost of $22,480,000. Building construction work started just three days later.[55]

Construction was off to a good start. Site preparation of the entire "ITL" installation was completed by 25 August and construction activity continued without delay. On 16 September modifications of Complex 20 to accomodate launch of Titan IIIA (core only) were completed. By the close of 1963, construction of the two pad installations was 25 percent complete--the entire job was to be finished by the close of February 1965. Construction of utilities and buildings was 12 percent complete and on schedule with the total construction job scheduled to be finished in October 1964.[56]

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SUMMARY

In retrospect, the early Titan III program not only demonstrated a capacity for survival amid difficulties but established, as well, a record of significant achievement. By 1961 the Air Force, the victim of a technological fate which threatened its traditional role and no longer in full control of its development programs, confronted a historical moment of change. Yet, by adjusting to the new situation, the Air Force obtained the assent and resources necessary to start development of an advanced high performance space launch vehicle it resolutely held essential to the nation's defense.

At mid-point, the success of the Titan III program was measured more in the managerial emanations from briefing rooms and council chambers of the Pentagon than from completed vehicles and flight tests. In the program's short life span the most dramatic triumphs had been those of persuasion. Indeed, the Air Force found it necessary several times over to assure and convince assorted audiences that Titan III was essential to the nation's security. Yet, as the program continued through 1963, there was increasing recognition of Titan III's basic utility. Secretary of Defense R. S. McNamara, at a 10 December 1963 Pentagon news briefing, said that although the potential requirements for manned military operations in space were not clear, the administration saw the need for "a carefully controlled and carefully scheduled program of developing the techniques which would be required were we to ever suddenly be confronted with a military mission in space . . . " He added: ". . . it is for that reason . . . we proposed and the Congress approved the Titan III program."

The lesson was clear.

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GLOSSARY OF ABBREVIATIONS

AACB	Aeronautics and Astronautics Coordinating Board
Admn	Administration
AEC	Atomic Energy Commission
AFBMD	Air Force Ballistic Missile Division
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
AJ	Aerojet General (Corporation)
AMD	Aerospace Medical Division
AMC	Air Materiel Command
AMR	Atlantic Missile Range
ARDC	Air Research and Development Command
ARPA	Advanced Research Projects Agency
ASAF	Assistant Secretary of the Air Force
ASC	Aerospace Corporation
Asst	Assistant
ATC	Air Training Command
Bd	Board
Br	Branch
BrigGen	Brigadier General
BSD	Ballistic Systems Division
Ch	Chief
Civ	Civil
Cmdr	Commander
Col	Colonel
Comm	Communications
Corp	Corporation
C/S	Chief of Staff
DAG	Division Advisory Group
DCAS	Deputy Commander, Air Force Systems Command, for Aerospace Systems
DCS	Deputy Chief of Staff
DCS/D	Deputy Chief of Staff, Development
DCS/Mat	Deputy Chief of Staff, Materiel
DCS/Plans	Deputy Chief of Staff, Plans
DCS/S&L	Deputy Chief of Staff, Systems and Logistics
DCS/R&E	Deputy Chief of Staff, Research and Engineering
DDR&E	Director of Defense Research and Engineering
Def	Defense
Dep	Deputy

Dev	Development
Dir	Director; Directive
Div	Division
Doc	Document
DOD	Department of Defense
DSMG	Designated Systems Management Group
Engr	Engineering
Eqp	Equipment
Flt	Flight
FY	Fiscal Year
Gen	General
GO	General Order
GOR	General Operational Requirement
Gp	Group
Hist	History/Historical
Hq	Headquarters
ICBM	Intercontinental Ballistic Missile
IDA	Institute for Defense Analyses
Ind	Indorsement
ITL	Integrate-Transfer-Launch
JCS	Joint Chiefs of Staff
LLVPG	Large Launch Vehicle Planning Group
Lt	Lieutenant
Ltr	Letter
Maint	Maintenance
Maj	Major
Mat	Materiel
Memo	Memorandum
MFR	Memorandum for the Record
Mtg	Meeting
Msg	Message
NASA	National Aeronautics and Space Administration
Nr	Number
NSC	National Security Council
Ofc	Office
Off	Officer
Opns	Operations
Ord	Order
OSD	Office of the Secretary of Defense

PCP	Program Change Proposal
Prep	Prepared
Presn	Presentation
Prog	Program
Proj	Project
PSAC	President's Scientific Advisory Committee
R and D	Research and Development
RDT&E	Research, Development, Test and Engineering
Rep	Representative
Res	Research
Rpt	Report
RTD	Research and Technology Division
SA	Secretary of the Army
SAB	Scientific Advisory Board
SAC	Strategic Air Command; Scientific Advisory Committee
SAF	Secretary of the Air Force
SAFUS	Undersecretary of the Air Force
Sat	Satellite
Sci	Science
Sec	Secretary
SLV	Standard Launch Vehicle
SN	Secretary of the Navy
SO	Special Order
SOD	Secretary of Defense
SPD	System Program Director
SPO	System Program Office
SPP	System Program Package
SR	System Requirement
SRB	Systems Review Board
SSD	Space Systems Division
STL	Space Technology Laboratories
Subj	Subject
Sys	System
TAM	Technical Area Manager
Tech	Technology
TRW	Thompson-Ramo-Wooldridge Corporation
Undtd	Undated
USAF	United States Air Force
UTC	United Technology Corporation
V/Cmdr	Vice Commander
V/CS	Vice Chief of Staff
Vol	Volume
V/Pres	Vice President

WADC	Wright Air Development Center
WDD	Western Development Division
Wkly	Weekly
WS	Weapon System
Yr	Year

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