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CONCEPTUAL DESIGN OF A HIGH ENERGY ASTRONOM OBSERVATORY - VOLUME 1- PRELIMINARY ANALYSIS VOLUME 11 - APPENDICES

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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VOLUME II — APPENDICES

By Program Development

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. ABSTRACT

In response to a request from the Office of Space Science and Applications, a Phase A — Preminary Analysis of a High Energy Astronomy Observatory was undertaken by the George C. arshall Space Flight Center. Results of this study are reported in two volumes, Volume I coning the preliminary analysis and conceptual design of a baseline spacecraft and Volume II ontaining supporting technical data and discussion of mission and spacecraft alternatives..

The High Energy Astronomy Observatory treated in this work is the first of four planned acecraft in the High Energy Astronomy Observatory program, designated in this report as EAO-A. The primary mission objective of the HEAO-A spacecraft is to completely survey the lestial sphere for high energy X-rays, gamma-rays, and cosmic-rays, with primary emphasis the galactic belt region; the secondary mission objective is selective pointing at specific lestial targets.

To ensure a comprehensive system analysis for feasibility assessment, a baseline mission d spacecraft was defined with a realistic, but hypothetical, experiment package. Total weight the baseline spacecraft is approximately 19 000 pounds and launch is assumed from ETR on the itan IIID launch vehicle in March 1974. The satellite is placed into a 200-n. mi. circular orbit ith a 28.5-degree inclination; during the first month in orbit the slowly rotating satellite scans region measuring ±8.5 degrees from the galactic plane; during the next 6 months the entire lestial sphere is scanned; and during the last 5 months of the first mission year the satellite nploys a pointing mode for selected source investigations. Satellite design lifetime is 1-year inimum, with 2 years desired.

. KEY WORDS
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1. Observatories -- Design

I. T

II. T: High ... observatory

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ACKNOWLEDGMENTS

In response to a request from the Office of Space Science and Applications, the George C. Marshall Space Flight Center undertook a preliminary analysis of the initial satellite in the planned High Energy Astronomy Observatory program. Phase A program management was assigned to the Space Physics Group in the Mission and Payload Planning Office of MSFC's Program Development Organization.

Program Development's Preliminary Design Office was assigned to support the Space Physics Group with a 10-week technical effort to conclude the Phase A — Preliminary Analysis study effort and to compile the final Phase A study document.

Program Development's Advanced Systems Analysis Office was responsible for much of the material concerned with the launch vehicle selection and analysis, and the Advanced Program Support Office investigated facilities and manufacturing requirements.

Program Managements' Mission Operations Office contributed Section XII — Mission Operations.

Science and Engineering's Astrionics Laboratory accomplished the design of the fold-out solar panels presented in Appendix H of Volume II, and the Space Sciences Laboratory gave valued consultation in Space Physics, particularly in the analysis of the natural radiation background problem.

Grateful acknowledgment is made of the excellent efforts of MSFC's support contractor team. The Brown Engineering Company, Inc., under Contract NAS8-20166, made substantial contributions throughout the Phase A study and much of their design and analysis effort is incorporated in this final report. Lockheed Missiles and Space Corporation, under Contract NAS8-20082, assisted with the mission analysis and operations.

The Launch Vehicle Programs Office of OSSA, the Centaur Office of LeRC, the Titan Programs Offices of SAMSO and Aerospace Corporation, and the Unmanned Launch Operations Office at KSC contributed to the launch vehicle selection and anlaysis. Special acknowledgment is made to the Martin-Marietta Corporation/Denver for providing Titan vehicle data.

SECTION III. LAUNCH VEHICLE

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In keeping with the overall philosophy of the HEAO project, the selection of the Titan IIID launch vehicle was based on the use of the lowest cost existing system with sufficient payload capability. Other considerations in the launch vehicle selection were the use of systems which will be used by other automated space projects during the operational time frame of the HEAO missions, and the availability of facilities and equipment on a schedule which involves no interference with other high-priority projects.

This philosophy eliminated all but existing launch vehicle systems, and the requirements of the HEAO project quickly polarized the selection to the Titan family of launch vehicles. While the Titan IIIC can accomplish the HEAO launches without modifications to the primary vehicle system, the Titan IIID with modifications to adapt to Eastern Test Range (ETR) may be more cost effective if the same modifications required by the Viking program can be utilized. The Titan IIID, as shown in Figure III-1 (without transtage upper stage and therefore less expensive than Titan IIIC), is capable of meeting the requirements of the HEAO launches, but some modification to the Titan IIID guidance system (either on the ground or on board) is required to use this system at ETR. The cost of the Titan IIID, including modifications, is expected to be lower than the cost of Titan IIIC. The Titan IIID is therefore the selected baseline launch vehicle for the HEAO launches. Since the Titan III with Centaur upper stage is being developed and will be launched from ETR in 1972 and 1973, the alternative of using the Centaur guidance system in the Titan IIID for the HEAO launches becomes attractive and was selected as the baseline system for the Phase A study effort.

The final selection of the astrionics system and other modifications to the Titan IIID launch vehicle for the HEAO missions must be made during Phase B launch vehicle studies in concert with the overall HEAO mission requirements.

Use of the Titan IIID at ETR involves two primary launch vehicle hardware configuration decisions: (1) guidance system and (2) payload fairing selection.

The following sections describe the basic Titan IIID launch vehicle and the modifications required to adapt it as the launch vehicle for the HEAO missions to be launched from the ETR. The launch vehicle capabilities and the environments which the payload will experience are presented and a section is devoted to the discussion of the payload shroud and its interface with the launch vehicle and the payload.

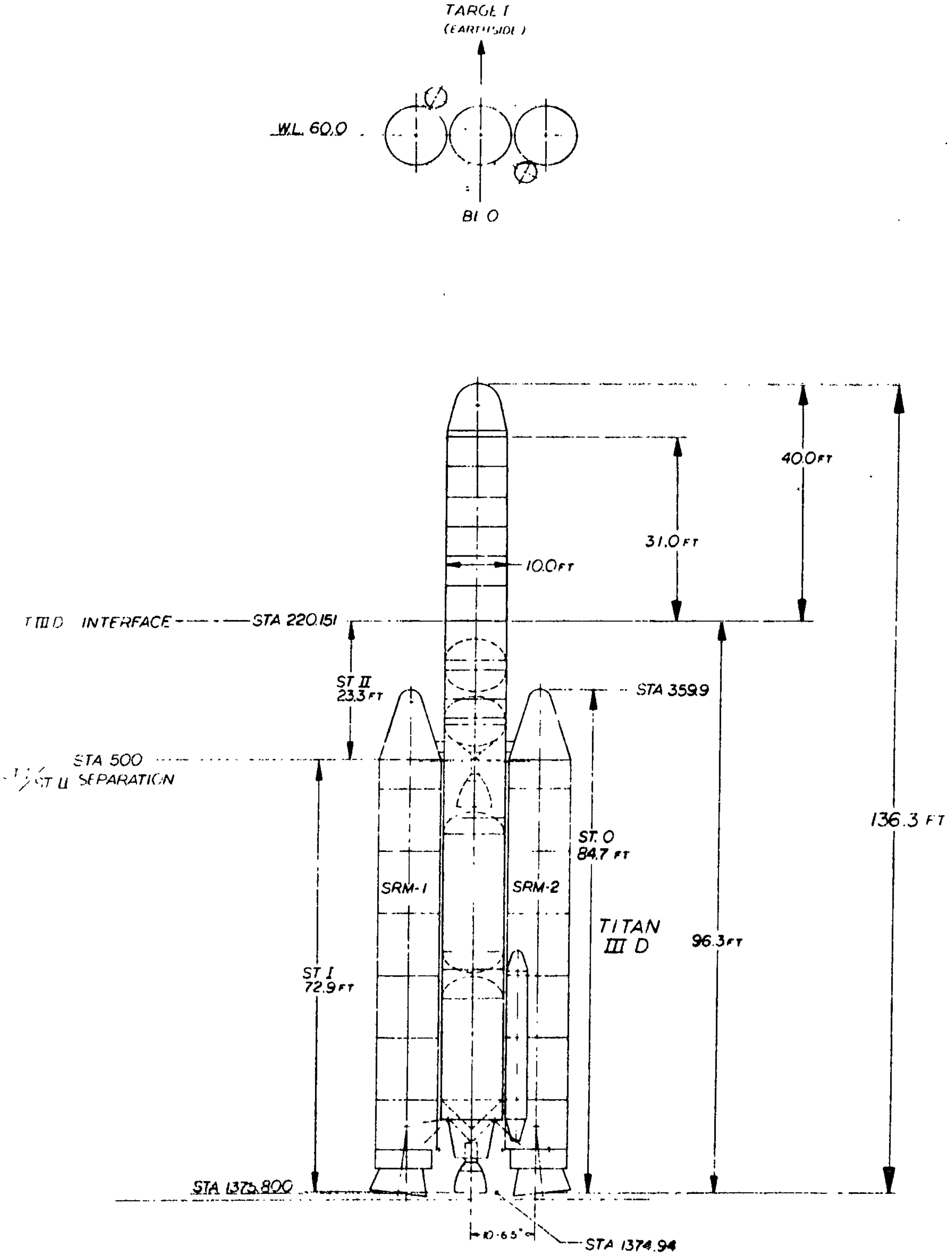


Figure III-1. Titan IIID launch vehicle (HEAO-A Mission).

A. Titan IIID Baseline Vehicle

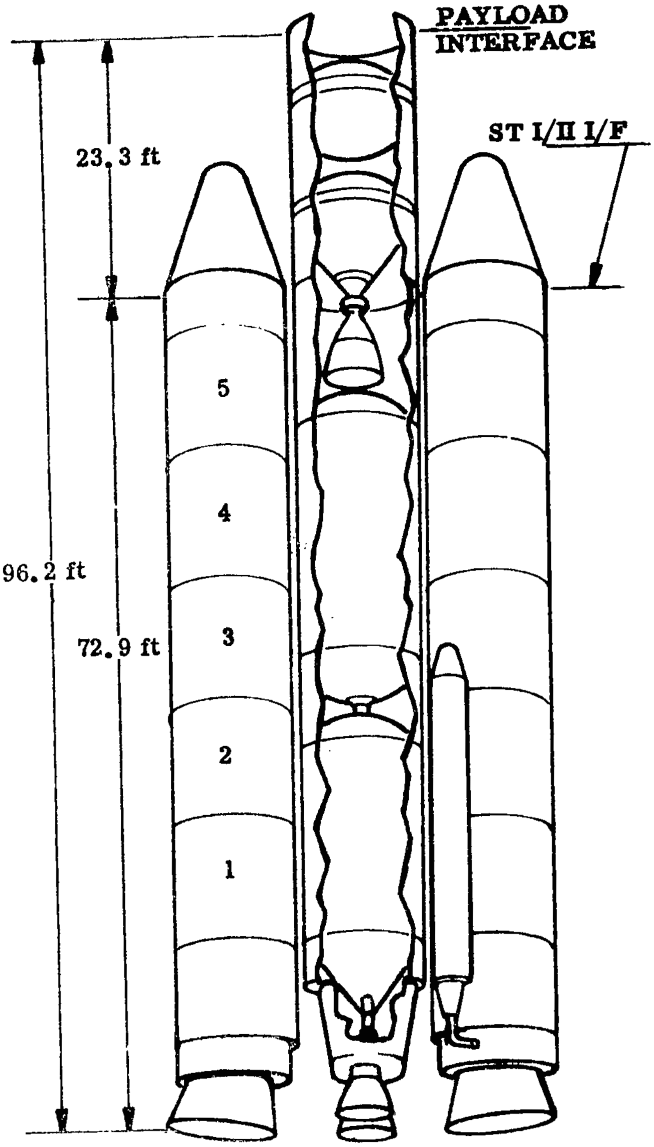
This section presents a general description of the Titan IIID launch vehicle as it is now configured for launch from Western Test Range (WTR).

1. Configuration. The Titan IIID vehicle is a three-stage/solid and liquid propellant vehicle as shown in Figure III-2. It was developed from, and is nearly identical to, the Titan IIIC space launch vehicle and is described more fully in Reference 1, except that the Titan IIIC Transtage is deleted. The Titan IIID uses the solid rocket motors that were developed on the Titan IIIC program. Stage 0 consists of two solid rocket motors, each consisting of five solid segments, two closures, an ignition system, a nozzle assembly, and an ullage blowdown type thrust vector control system. The approximate burn duration of the solid rocket motors is 120 seconds.

The Titan IIID Stage I and Stage II is the "common core" used on other Titan III family vehicles, with Titan IIID-peculiar requirements added. These stages use earth-storable liquid propellants.

2. Guidance System. The Titan IIID guidance system consists of a BTL/WECO Series 600 Radio Guidance System which operates in conjunction with a ground guidance station located approximately 13 miles north of the launch pad at WTR. The system is capable of performing the guidance function during all of Stage I operation and during the first 70 percent of Stage II operation. It is limited by SRM plume attenuation during Stage 0 operation and by radar antenna look-angle constraint during the latter portion of Stage II flight.

3. Flight Control System. The Titan IIID flight control system consists of an analog computer, a programmer, a velocity meter, a staging timer, a three-axis reference (gyro) system, a rate gyro, and on each stage a thrust vector control system. The flight control system performs open-loop guidance (programmed trajectory) during Stage 0 operation and during the latter portion of Stage II flight. During Stage I and early Stage II operation, the flight control system reacts to a steering command issued by the radio guidance system. The velocity meter is initiated late in Stage II flight by radio guidance, and upon achieving the preset velocity-to-be-gained, issues the shutdown command and initiates payload staging. Except for initiation of the velocity meter, the flight control system is the primary source for discrete signals, and also performs open-loop guidance throughout flight in the event of guidance failure.



HARDPOINTS - 36
EQUALLY SPACED
GUIDANCE - RADIO INERTIAL

STAGE II
PROPELLANTS LOADED 67,338 lb
I_{sp} NOM 316.9(vac) sec
THRUST 101,890 (vac) lb
LOADED WEIGHT 73,254 lb

STAGE I
PROPELLANTS LOADED 258,860 lb
I_{sp} NOM 299 (vac) sec
THRUST 523,000 (vac) lb
LOADED WEIGHT 274,452 lb

STAGE 0
PROPELLANT WEIGHT 848,494 lb
TVC (N_2O_4) LOADED 16,848 lb
I_{sp} NOM 231.8 (S.L.) sec
THRUST 2,340,000 (S.L.) lb
LOADED WEIGHT 1,016,050 lb

LIFT OFF
- THREE STAGES WITHOUT PAYLOAD OR PAYLOAD FAIRING

WEIGHT 1,362,976 lb
THRUST 2,327,430 lb

Figure III-2. Standard Titan IIID launch vehicle.

4. Other Systems. The Titan IIID vehicle also includes an airborne electrical system, flight safety system, instrumentation system, and propulsion system.

B. Launch Vehicle Modifications

The launch vehicle hardware modifications result primarily from the guidance and payload fairing systems. The modifications required include the guidance system support truss, packaging of added guidance components, and installing a pull-away umbilical. Installation of the Titan IIIC payload fairing requires increasing the forward ring frame size on Stage II. The above items are discussed in more detail in the following paragraphs.

1. Guidance System. The guidance system requiring minimum changes for use in the Titan IIID vehicle at ETR is the currently used radio guidance system. However, according to current planning, the BTL ground station at ETR will not be used by NASA after late 1971. Unless other programs require its usage — and none are foreseen at this time — the total costs of operation, update, and maintenance would be imposed on the HEAO program. Since yearly operation is currently estimated to be about 2 million dollars, its cost has been judged to be prohibitive. Therefore, an inertial guidance system for the Titan IIID appears necessary; however, should other programs use the radio guidance system, it would become very cost effective. For these reasons, other systems have been considered.

Five optional guidance systems which are either developed or being developed for use in the 1973 period are as follows:

- BTL/WECO radio guidance/analog flight control (Fig. III-3) Titan IIID.

- ACED inertial guidance/digital flight control system (Fig. III-4) (Titan IIIC).

- Thor Delta strapdown inertial guidance/digital flight control with specially developed input/output electronics (Fig. III-5).

- The same as Thor Delta system above but with Ascent Agena strapdown inertial guidance hardware (Fig. III-5).

- Improved Centaur inertial guidance/analog flight controls (Fig. III-6).

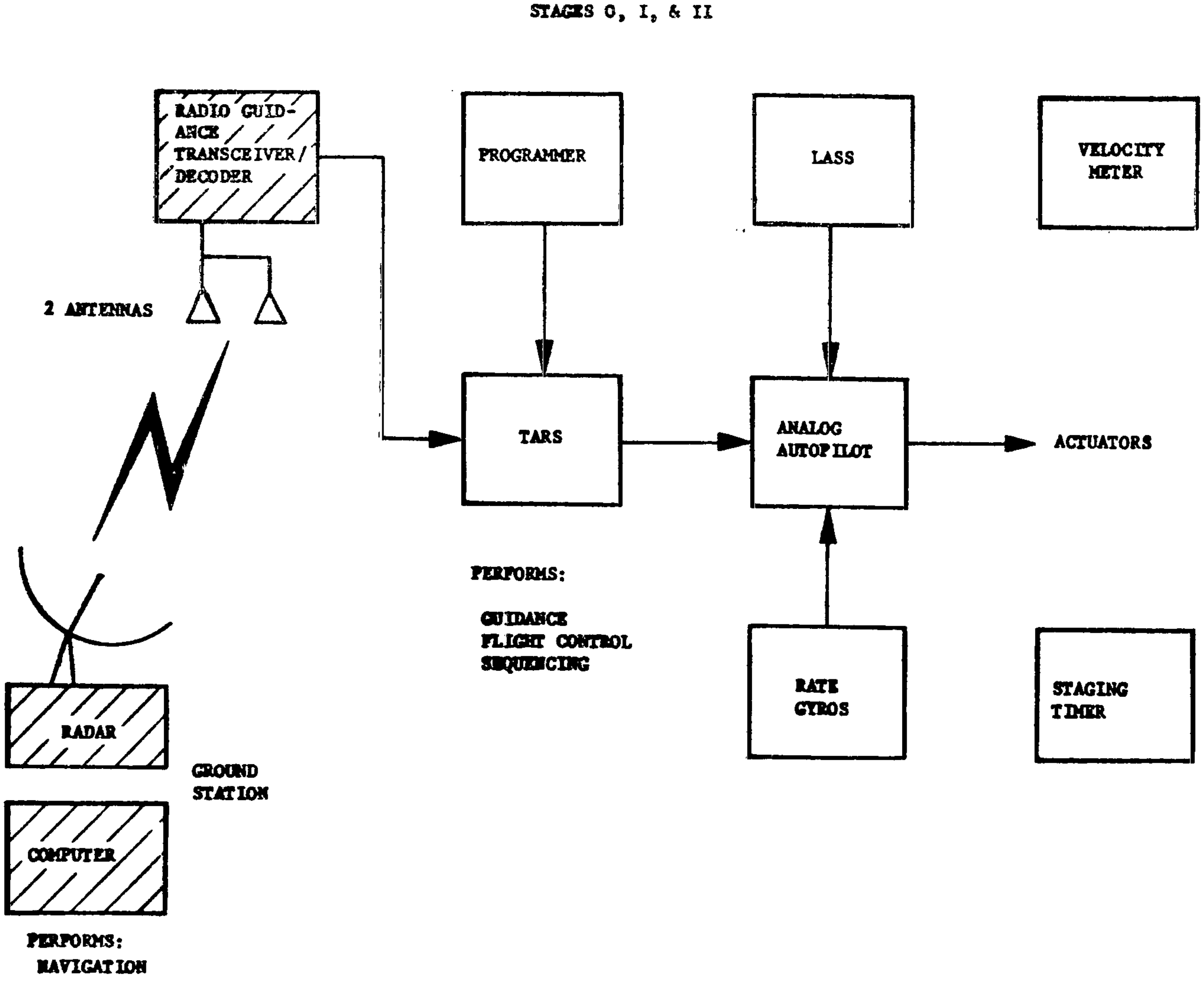


Figure III-3. BTL/WECO radio guidance/analog flight control — Titan IIID.

STAGES 0, I, & II

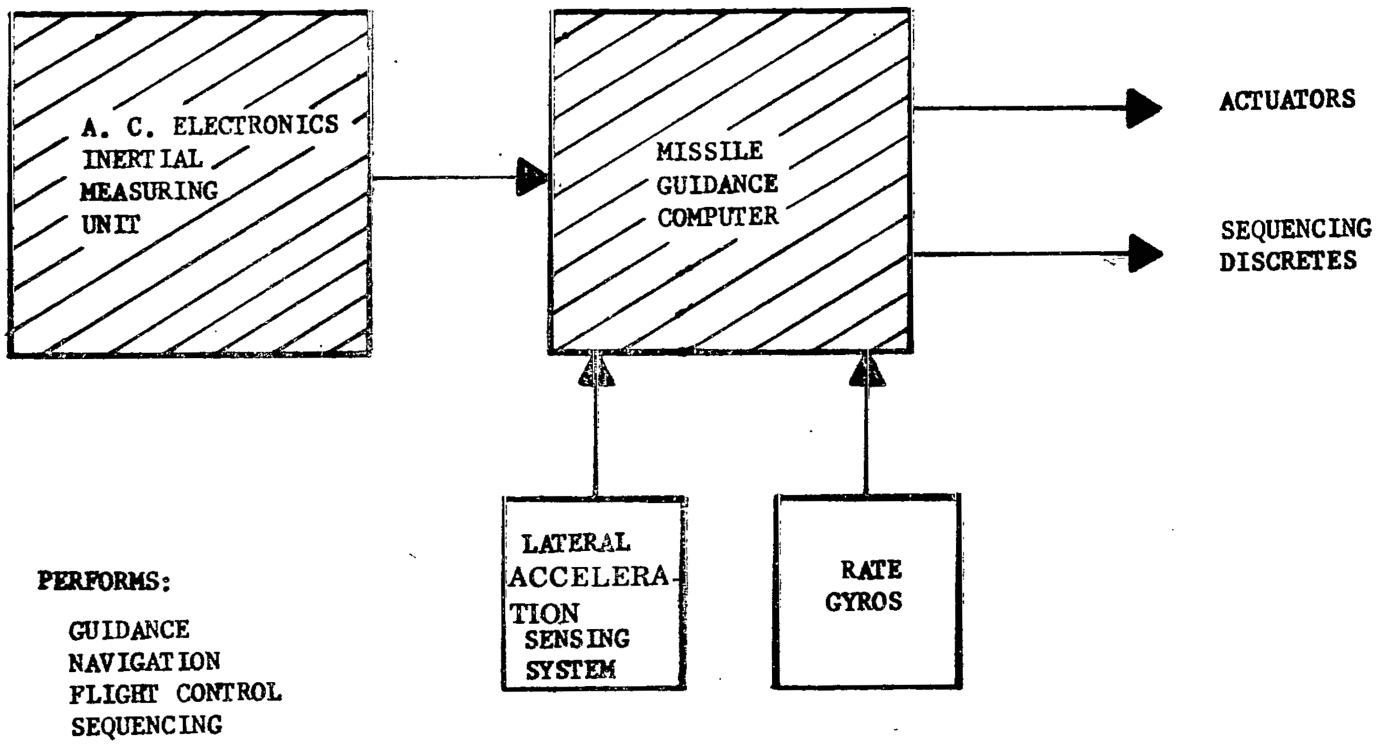
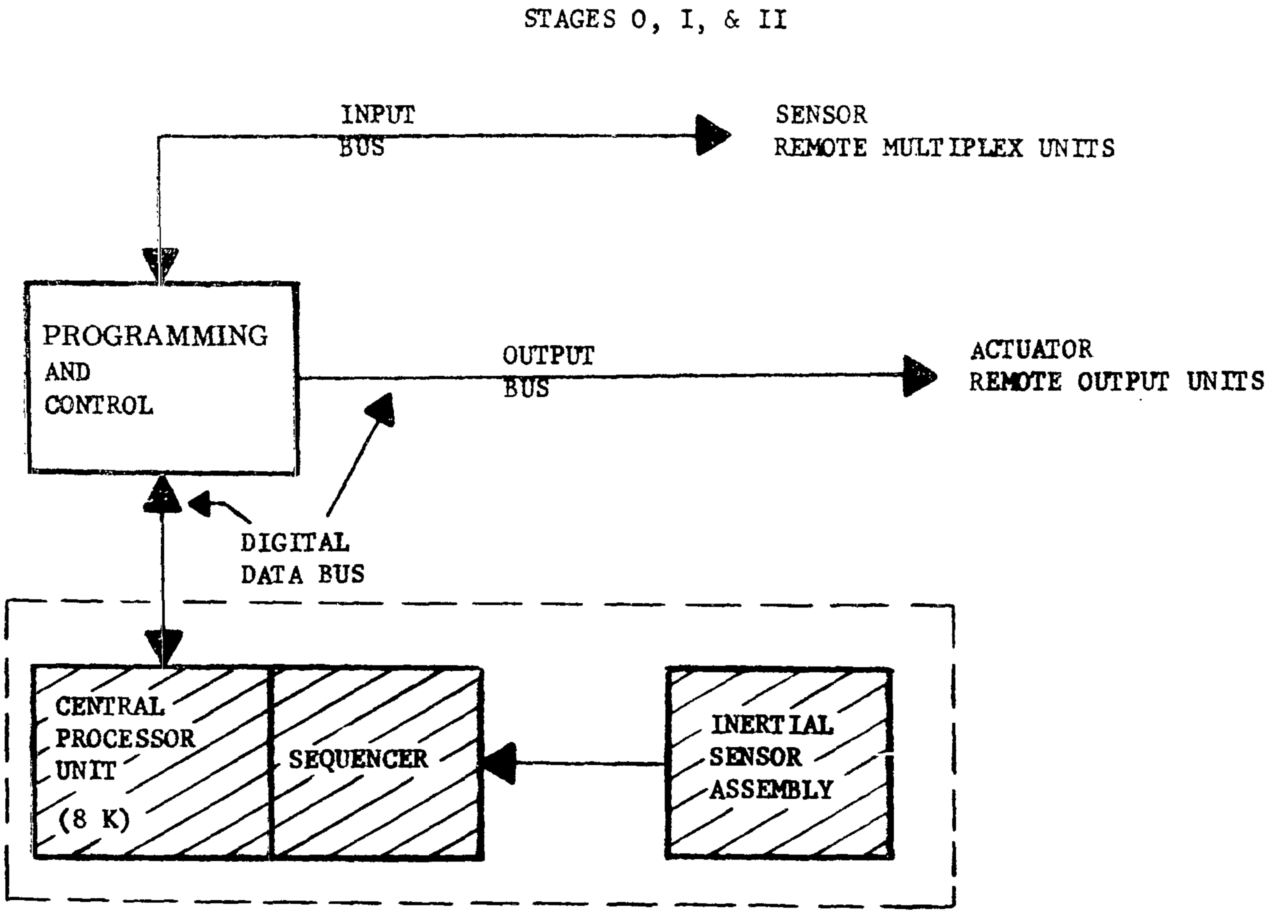


Figure III-4. Titan IIIC ACED inertial guidance/digital flight control.



PERFORMS:

GUIDANCE
NAVIGATION
FLIGHT CONTROL
SEQUENCING

Figure III-5. Ascent Agena or Thor-Delta inertial guidance/digital flight control.

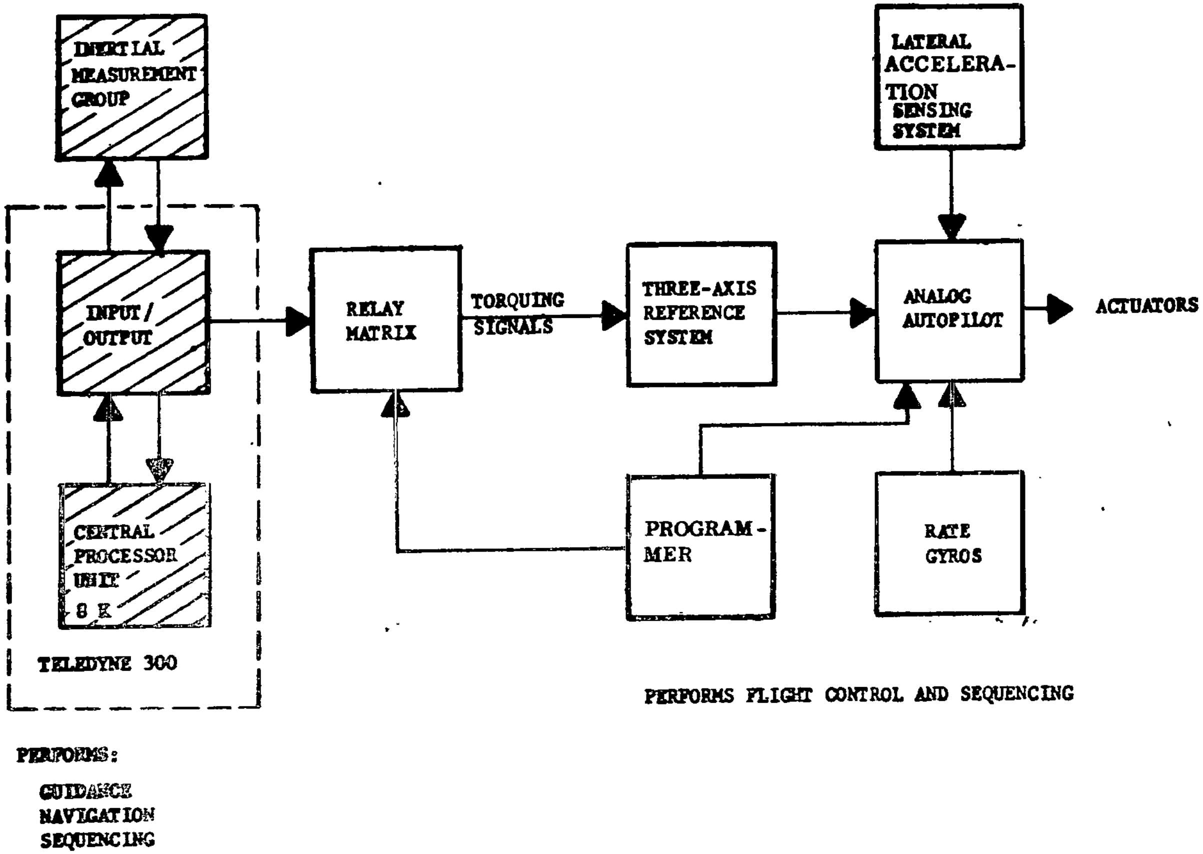


Figure III-6. Centaur inertial guidance/analog flight control.

These systems are more fully described in the following paragraphs.

a. BTL/WECO radio guidance system. The changes required to the existing Titan IIID radio guidance and flight controls are as follows:

(1) Use Titan IIID/Centaur autopilot.

(2) Relocate radio guidance dorsal and ventral antennas.

(3) Install repeater antennas.

(4) Update WECO/Univac ground guidance computer.

(5) Relocate RIME to AGE van.

These changes are depicted in Figure III-7 and described below.

The Titan IIID/Centaur flight controls computer includes a modification to change the direction of the pitch program. Because of on-pad alignment differences, the pitch down open-loop trajectory program at WTR becomes pitch up at ETR. This is accomplished by internally reversing pitch program polarity within the Titan IIID/Centaur flight controls autopilot. This same autopilot will be available for this mission.

A second required change is to relocate the dorsal and ventral radio guidance antennas. This will require analysis to evaluate the look angles, followed by antenna relocation and waveguide modification.

Repeater and pickup antennas must be installed on the mobile service tower, vertical integration building, and BTL ground station to permit prelaunch test and checkout.

The major area of change is updating the BTL/WECO radio guidance ground station with an improved Univac computer. The existing 8000-word Athena drum machine will be replaced by a much faster general-purpose Univac 1230 with a random access core. This improvement will provide increased computation capability and improved reliability.

The remaining change is installation of an existing RIME set into an existing AGE trailer to permit radio guidance subsystem checkout.

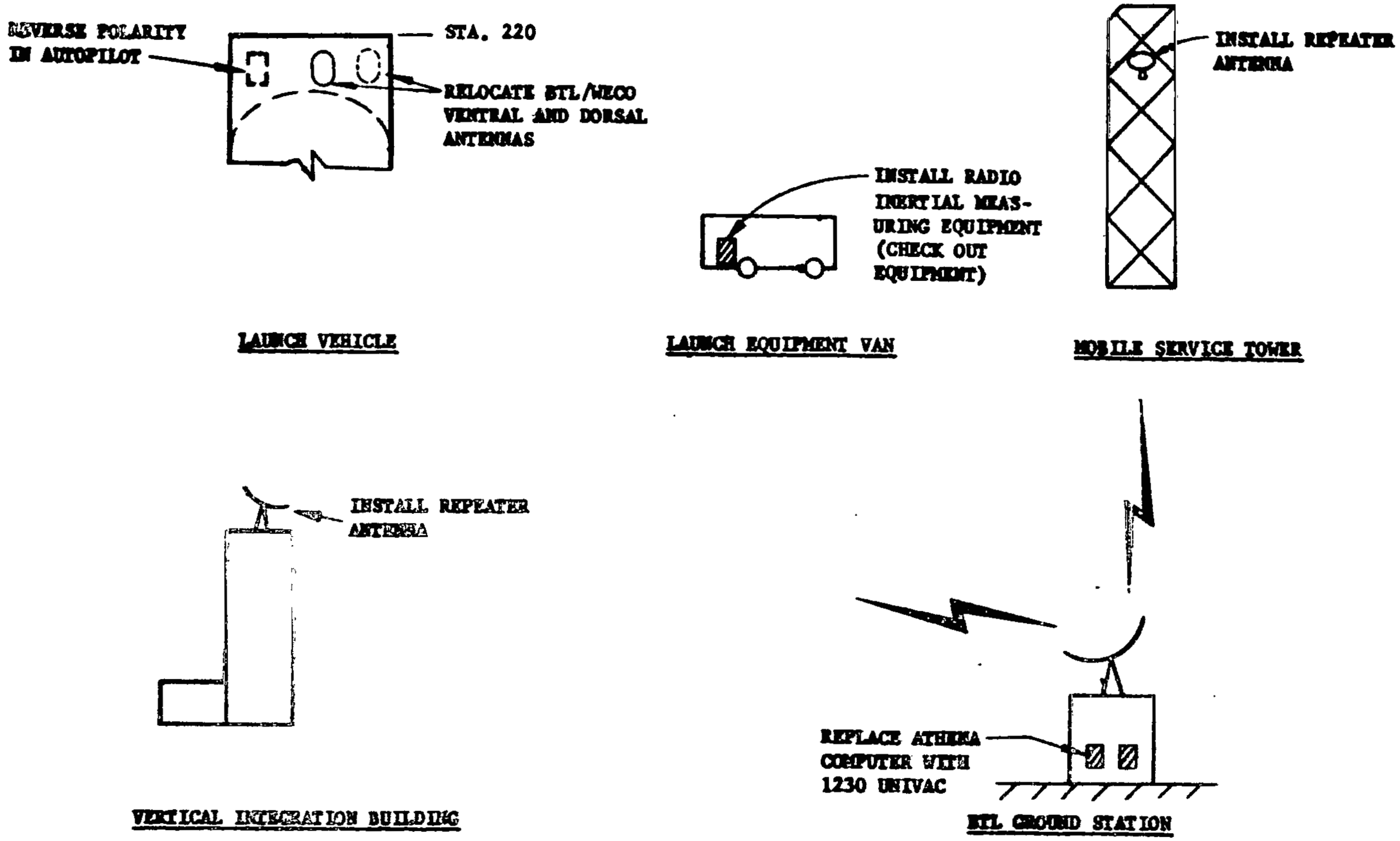


Figure III-7. BTL/WECO system modifications for usage at ETR.

b. ACED inertial guidance system. The ACED system in its present configuration with the Titan IIIC IMU and MGC is not as cost competitive as the other systems. However, the MGC will be replaced with a new low-cost computer by 1972. This Titan IIIC configuration with the low-cost computer has been included in the cost comparison based on projected computer costs. The new computer that will be developed for Titan IIIC will include all of the I/O electronics to properly interface with the Titan IIID flight control sensors and actuation devices, as well as the electrical sequencing system so no new black box development is required for this system. The ACED configuration utilizing the new computer has the largest weight and power penalty of any of the inertial systems.

c. Strapdown inertial guidance system. The Thor-Delta or Ascent Agena configurations would use the inertial sensor assembly as presently configured, but the central processor unit (airborne computer) would require a memory expansion from 4000 to 8000 words (expansion capability provided in the Ascent Agena configuration). Special I/O electronics would be required to interface the Thor-Delta or Ascent Agena CPU's to the Titan IIID vehicle. Martin Marietta has a developed I/O electronics concept that can effectively provide this interface by using a PAC, two RMU's, and three ROU's. The CPU communicates with the vehicle sensors, actuation devices, and sequencing system through the PAC with addressed digital signals on one input and one output data bus. The RMU's convert analog sensor data at the rate gyros and lateral accelerometers (load relief sensors) to digital data for the data bus and the ROU's convert digital data to analog commands for the actuation devices. The inertial guidance/digital flight control configurations using Thor-Delta or Ascent Agena hardware present the lowest weight and power utilization of any of the inertial systems.

d. Centaur inertial guidance system. The Improved Centaur configuration would use the same guidance and flight control components presently designed for the Titan IIID/Centaur vehicle that is scheduled to launch the Viking payload in 1973. The Honeywell IMG and Teledyne computer would be moved into Stage II of the Titan IIID which results in a weight and power penalty, although not as severe as the ACED inertial system.

e. Weight and cost comparison. Table III-1 presents a preliminary weight and cost comparison of the various guidance and control systems examined. (These data must be reverified during the Phase B effort.) Delta costs compared to a baseline of Titan IIID at WTR using radio guidance with the present multiprogram utilization of the ground station are shown. The recurring costs per launch include selected airborne hardware costs and

TABLE III-1. TITAN IIID AT ETR

GUIDANCE AND CONTROL WEIGHT COST COMPARISON
ROM ($M)

	Δ Weight (lb)	Nonrecurring Cost ($)	Recurring Cost/Launch ($)	Delta Cost Per Launch ($)	4 Vehicles/1/yr Total Delta Cost ($)
BTL Radio @ WTR (baseline)	0	0	0.28	0	NA (Baseline)
BTL Radio @ ETR (Titan IIID launches only)	0	1.2	2.2	1.9	8.8
ACED Inertial	+385	2.9	0.72	0.44	4.7
Thor-Delta or Ascent Agena Inertial	0	3.5	0.40	0.12	4.0
Improved Centaur	+175	1.5	0.75	0.47	3.4

the proper portion of the radio guidance ground station maintenance costs. Common guidance and control airborne hardware such as rate gyros, actuators, and hydraulic power supplies were excluded because they did not impact the estimate of delta costs.

f. Conclusions. Based on this preliminary study, the following conclusions have been reached:

(1) If one or more other programs use radio guidance and have a combined launch rate of two or more vehicles per year, then radio guidance should be used on Titan IIID at ETR.

(2) All of the inertial systems can meet the anticipated accuracy requirements of Titan IIID at ETR although the ACED system is significantly more accurate than the other inertial concepts.

(3) The Improved Centaur inertial system has the lowest schedule and cost risk based on the advanced state of development of the components involved.

(4) The costs of the inertial systems examined are approximately equal. Since weight is not a dominant factor, the inertial systems should be examined in more depth in the near future because of the near equivalent cost comparison.

(5) For the purpose of a baseline, for use in performance determination, the Improved Centaur system was selected.

2. <u>Titan IIID Modifications To Adapt Payload Fairing</u>. The Titan IIID Stage II forward skirt requires an increase in the Titan Station 220 ring frame size. This modification is shown in Figure III-8 and is judged to be a minor modification.

C. Performance Capability

The performance capability of the Titan IIID launch vehicle to the proposed orbit of 200-n.mi. altitude and 28.5-degree inclination is 20 920 pounds. The assumptions made for the performance calculations are given in Appendix B. This payload was injected by direct ascent to a 200-n. mi. altitude. The Titan IIID vehicle was designed for placing payload in low earth orbit (altitude < 150 n. mi.).

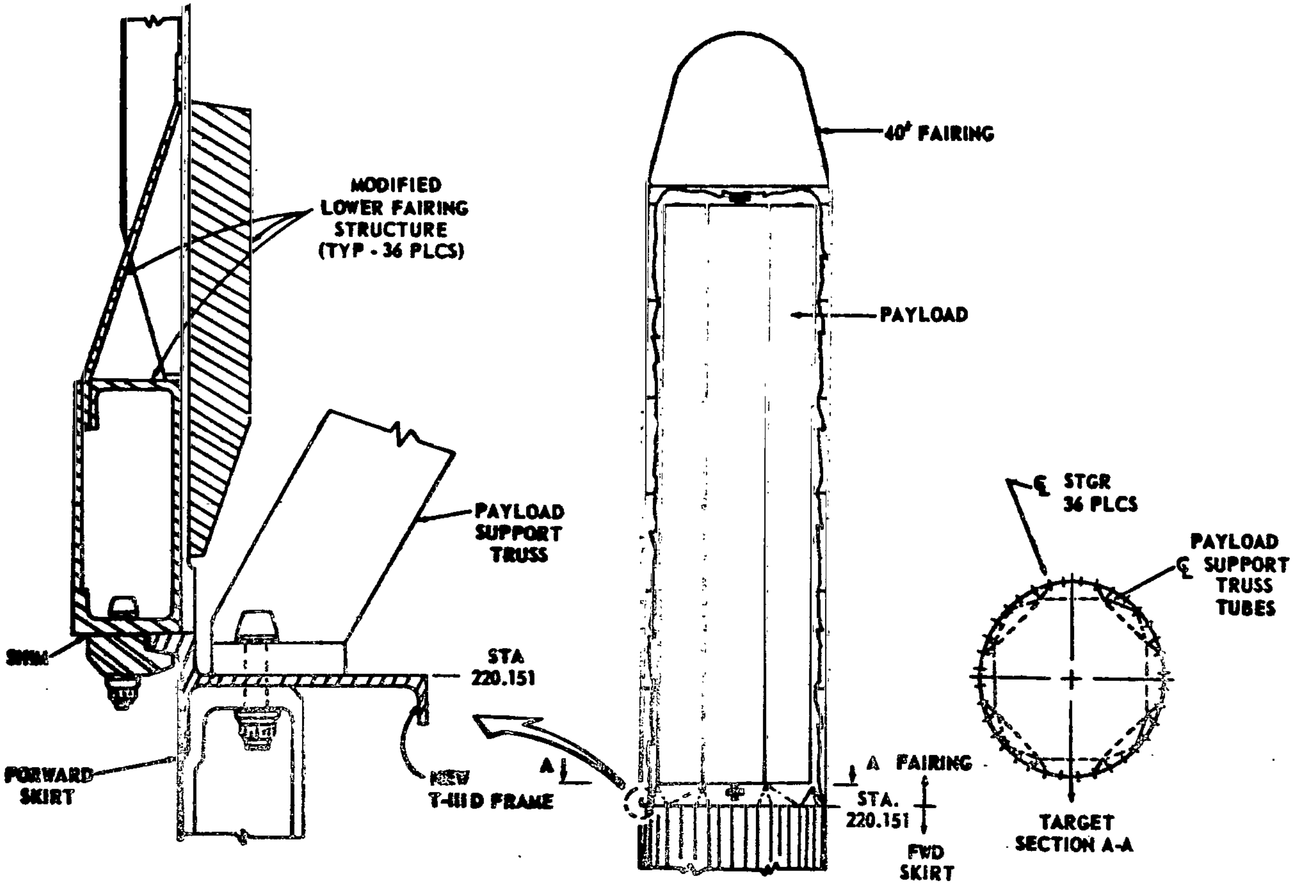


Figure III-8. Titan IIIC PLF adaption to Titan IIID forward skirt.

Improvement in performance capability of the Titan IIID can be attained by either (1) modifying the HEAO orbit to an elliptical orbit which would have a perigee and apogee sufficient to guarantee a minimum lifetime of 1 year for the $+2\sigma$ solar activity or (2) modifying the Titan IIID by adding a kick stage to the vehicle so that a trajectory could be achieved whereby the main stage would inject kick stage and payload into a 90- by 200-n. mi. elliptical orbit and the kick stage would inject the payload from the 90- by 200- to 200- by 200-n. mi. circular orbit. Adding the kick stage, a payload increase of up to 6000 pounds could be realized. Choosing an elliptical orbit of 1-year lifetime, a payload increase of up to 4800 pounds could be achieved.

Table III-2 contains the Titan IIID performance weight summary and trajectory data for direct injection into a 200-n. mi. circular orbit.

Recent performance data from Lewis Research Center on the Titan IIID vehicle indicated a payload of 20 641 pounds and is presented in Appendix B for comparison. This variation in payload is probably caused by the heavier payload shroud and the time that it was jettisoned; however, differences of this nature will become items for closer scrutiny during Phase B.

D. Payload Fairing

A payload fairing is required to enclose the payload. The payload fairing will interface with the Stage II forward skirt (Titan Sta. 220), and inflight separation of the fairing will occur at this interface. Two payload fairing configurations meeting the basic requirements are available for use in this program. They are as follows:

1. Titan IIIC universal operational fairing used at ETR.

2. Titan IIID fairing used at WTR.

The Titan IIIC fairing was selected for this application because the fairing has been used in previous missions launched from ETR. All major facility and launch pad (Pad 41) modifications required to accommodate the Titan IIIC fairing will have been made and the necessary GSE will be available. No GSE for the Titan IIID fairing will be available at ETR. Therefore, use of the Titan IIIC fairing will induce minimum program costs. Trisection separation of the Titan IIIC fairing also provides better payload/fairing clearance during separation than the two-section separation of the Titan IIID fairing.

TABLE III-2. TITAN IIID PERFORMANCE AND TRAJECTORY DATA FOR A 200-n. mi. 28.5-DEGREE-INCLINATION CIRCULAR ORBIT

Stage	Parameters[a]	Engine Characteristics	Weight (lb)
0	Effective sea level thrust (lb)	2 340 000	
	Sea level specific impulse (sec)	232	
	Lift-off weight		1 387 272
	SRM Propellant consumed		842 960
	SRM TVC Injectant		14 561
	Service items expended		9 089
	Heat shield jettisoned		513
	Core stage propellant consumed		19 440
	Vehicle weight at SRM cutoff (lb)	500 709	500 709
	SRM weight at separation		153 953
	Thrust-to-weight ratio at lift-off	1.687	
I	Vacuum thrust (lb)	532 000	
	Vacuum specific impulse (sec)	299	
	Weight at SRM separation		346 756
	Core stage propellant capacity		251 523
	Propellant consumed (after SRM cutoff)		232 082
	Vehicle weight at stage cutoff		114 674
	Stage weight at separation		17 197

[a] 90-degree azimuth angle lift-off.

TABLE III-2. (Continued)

Stage	Parameters[a]	Engine Characteristic	Weight (lb)
II	Vacuum thrust (lb)	100 893	
	Vacuum specific impulse (sec)	310	
	Weight at ignition		97 477
	Standard payload fairing		2 310
	Propellant consumed		64 967
	Vehicle weight at stage cutoff		30 200
	Stage weight at separation		6 978
	Gross Payload		23 222
	Weight to be subtracted		
	Flight performance reserves		1 500
	Astrionic equipment		800
	Total weight to be subtracted		2 300
	Net payload		20 922

a. 90-degree azimuth angle lift-off.

1. Titan IIIC Payload Fairing.

a. Basic configuration. The Titan IIIC UPLF is 10 feet in diameter. The building block concept for this fairing is illustrated in Figure III-9. A 9-foot-long nose module and a 6-foot-long base are assembled to build a 15-foot UPLF. Longer lengths, up to 50 feet, may be assembled by utilizing the nose, base, and one or more 5-foot-long cylindrical, or intermediate, modules. A 40-foot-long baseline configuration for this mission is shown in Figure III-9. The UPLF is divided longitudinally into three sections as shown in Figure III-10. Each longitudinal joint contains a contamination-free separation system. The major characteristics of the fairing are described in the following paragraphs:

(1) Nose section. The nose section has a 45-inch-radius hemispherical nose, a cone with a 15-degree slope, and a cylindrical section 1 foot long. This section is of monocoque construction, with aluminum skin and ring frame stiffening.

(2) Midbody modules. The 5-foot cylindrical modules consist of aluminum skin, ring frames, and external hat-shaped stringers. They are configured in three basic type modules: a forward unit containing the air-conditioning inlet, a standard lightweight module, and a version of increased structural load capability. The increased strength is provided by thicker gage stringers and closer rivet spacings. The lighter modules are used in the upper portion of the midbody and the stronger modules are used in the lower region.

(3) Base section. The 6-foot base, like the 5-foot cylindrical module, is made of aluminum skin, ring frames, and external hat-shaped stringers. In addition, there are eight machined longerons and tension hooks to provide tension and compression load capability. An access door, 2 feet by 2 feet, is provided in each section of the base to allow access to the PLF systems and the payload compartment. The fairing air-conditioning inlet is also installed in a 2-foot by 2-foot door. There is also a large standard access door in the nose of Trisection III to provide payload access. All doors are structural doors to provide continuity to the structural shell.

(4) UPLF separation subsystems. The UPLF separation subsystems include the base separation shear pin system and the longitudinal thrusting joint that stages the PLF trisections. The longitudinal thrusting joint is activated by an electroexplosive detonator which initiates a linear explosive contained in a flexible bellows. The thrusting joints run the length of the fairing from the base to the nose. Initiation causes the gas to inflate

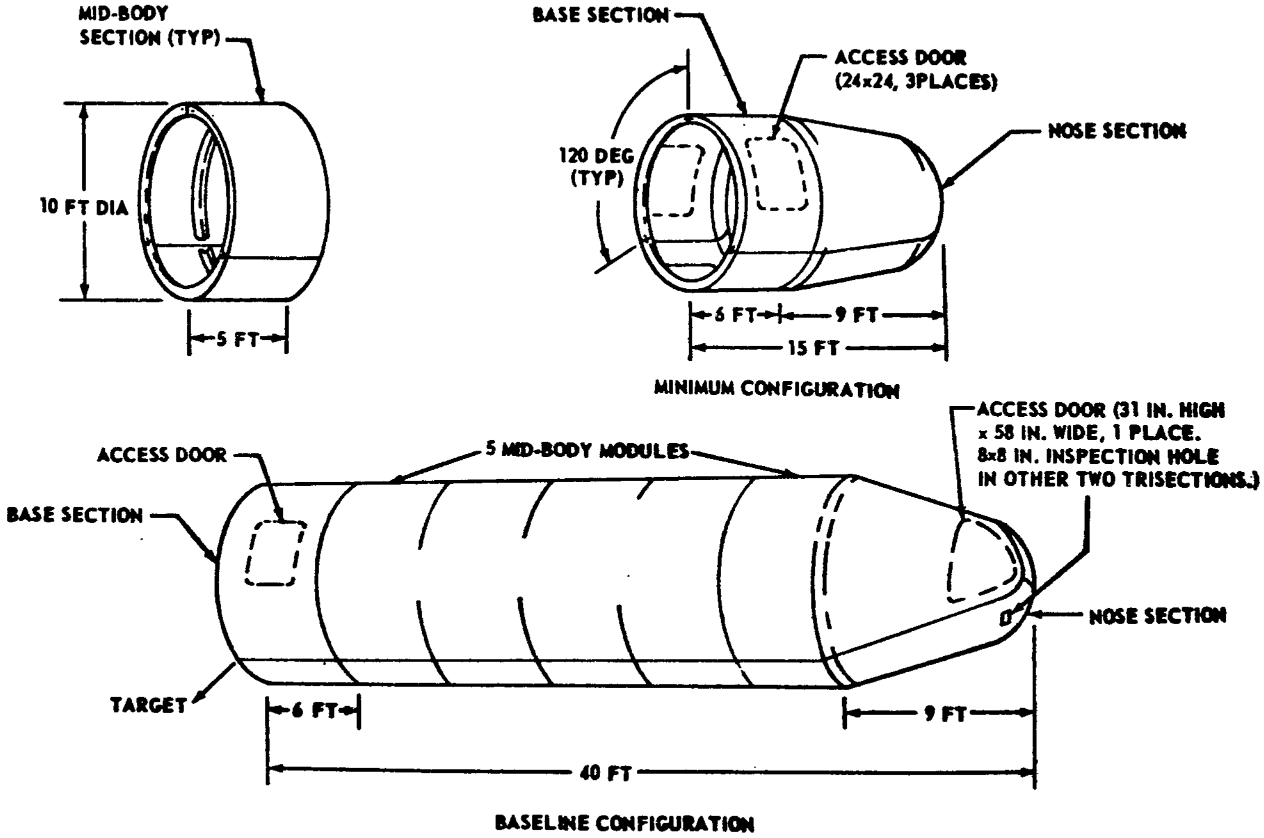
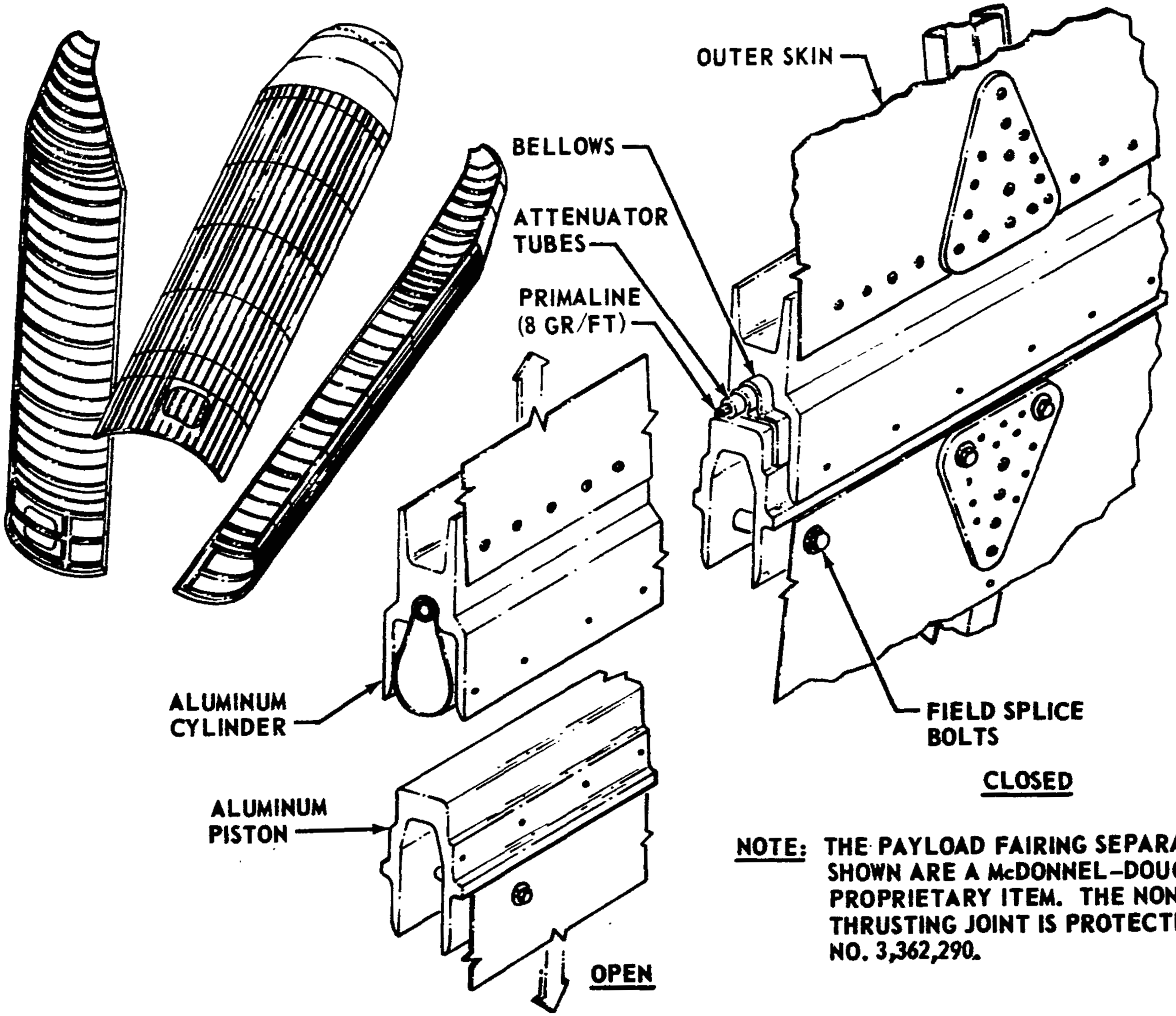


Figure III-9. PLF building block concept (HEAO-A PLF configuration).



NOTE: THE PAYLOAD FAIRING SEPARATION DETAILS SHOWN ARE A McDONNEL-DOUGLAS CORP. PROPRIETARY ITEM. THE NONCONTAMINATING THRUSTING JOINT IS PROTECTED BY US PATENT NO. 3,362,290.

Figure III-10. PLF separation.

the bellows which, upon expanding, shears the structural rivets and parts the trisections.

(5) Thermal characteristics. The PLF is designed such that no point on its internal wall exceeds 300° F. Internal surfaces of the PLF have an emissivity less than 0. 30 to minimize aerodynamic heating heat flux to the payload. Thermal protection is provided by external insulation.

(6) UPLF/launch vehicle assembly. The UPLF is assembled to the launch vehicle in three longitudinal sections as shown in Figure III-10. The assembly is accomplished at the launch pad after the payload has been assembled on the launch vehicle.

b. Modifications for Titan IIID. The basic fairing will be modified at the 6-foot base section to provide a load introduction at 36 points to match the 36 stringers of the Titan IIID forward skirt at Station 220. Also, the Stage II forward skirt would require an increase in frame size. One concept for these modifications is illustrated in Figure III-8. The structural load capability of this combination is shown in Figure III-11. It is probable that the fairing strength will exceed that shown after the 36-stringer modification. Further analysis and definition of both the structural modification concept and the structural load capability of the final design selected must be accomplished in a Phase B definition effort.

c. Payload dynamic envelope. The basic payload dynamic envelope is shown in Figure III-12. Based on a conservative estimate of the structural and dynamic characteristics of the modified Titan IIIC UPLF, a maximum payload dynamic envelope of 107.27 inches was selected (Ref. 1).

E. Payload Environment

1. Flight Loads. On the recommendation of the Martin-Marietta Corporation, Denver Division, the conceptual designs developed in this study were based on maximum load conditions of 6. 0 g's longitudinally at burnout of Stage I and 1. 5 g's laterally at lift-off. Additional iterative loads analysis will be required during follow-on study phases when the payload is more clearly defined. Individual components, e. g. , antennas, will experience substantially higher acceleration loads.

2. Interior Acoustics. The predicted maximum interior acoustic levels for the payload are shown in Figure III-13. The acoustical environments

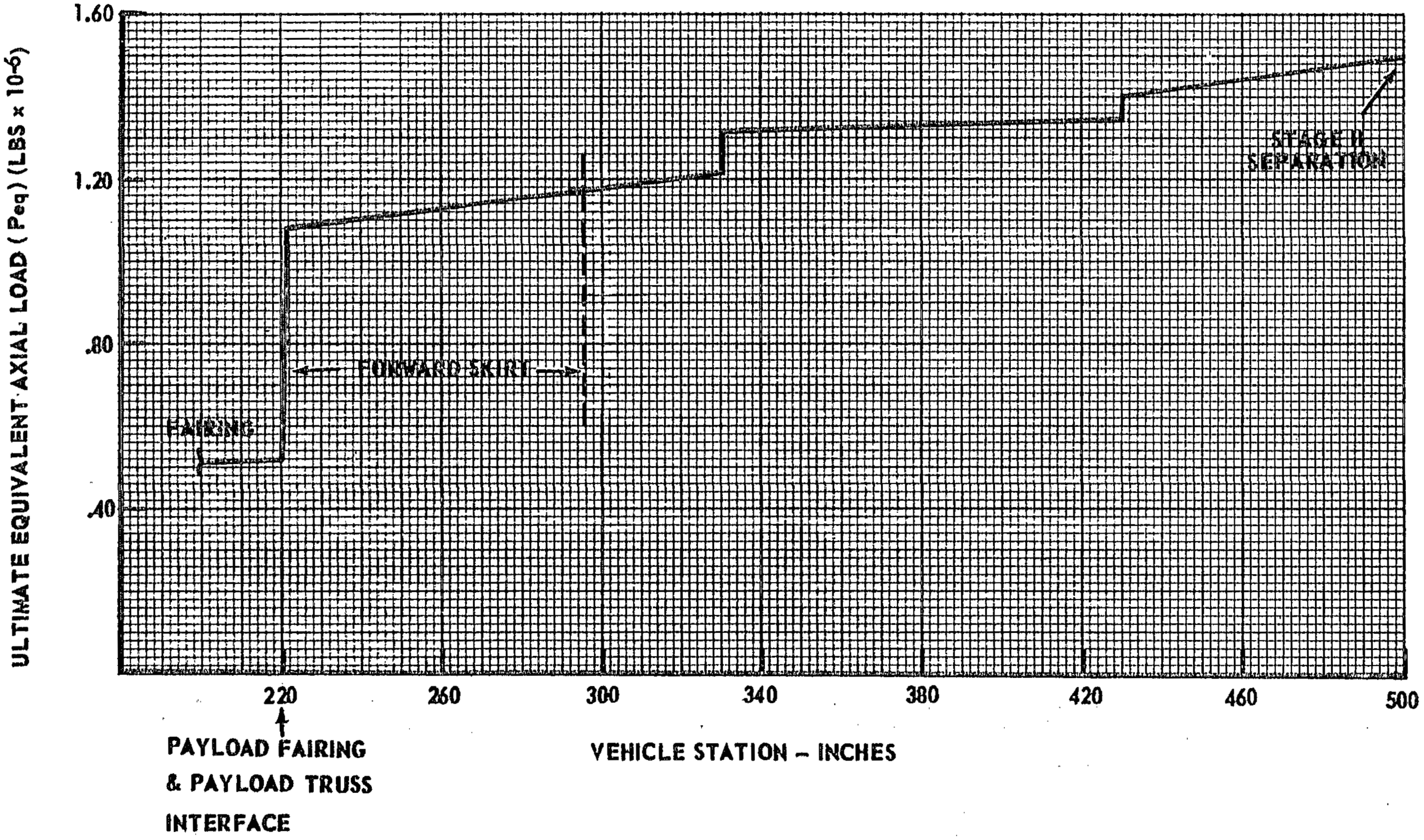


Figure III-11. Titan IIID forward skirt and Titan IIIC PLF ultimate design equivalent axial load.

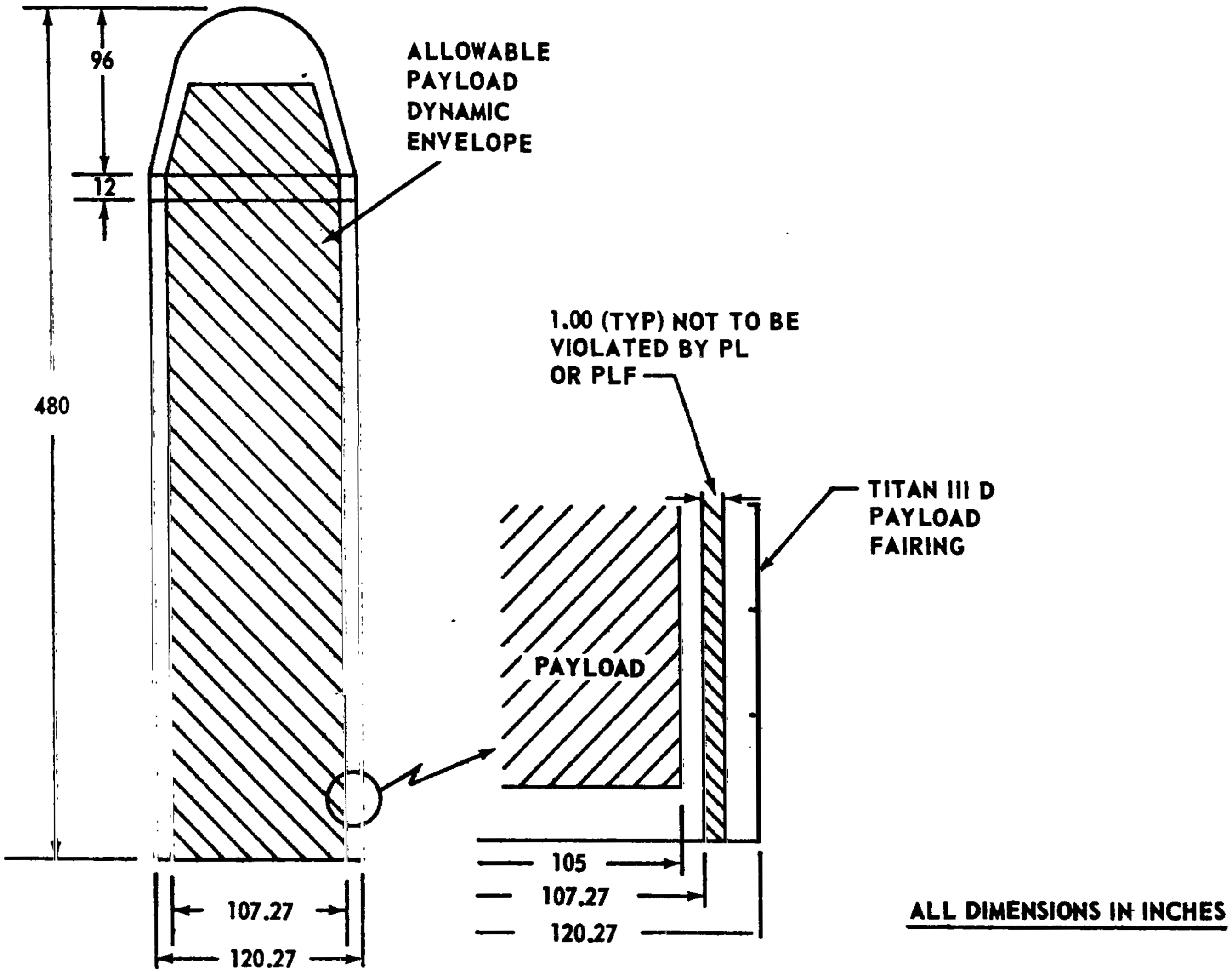


Figure III-12. Payload dynamic envelope.

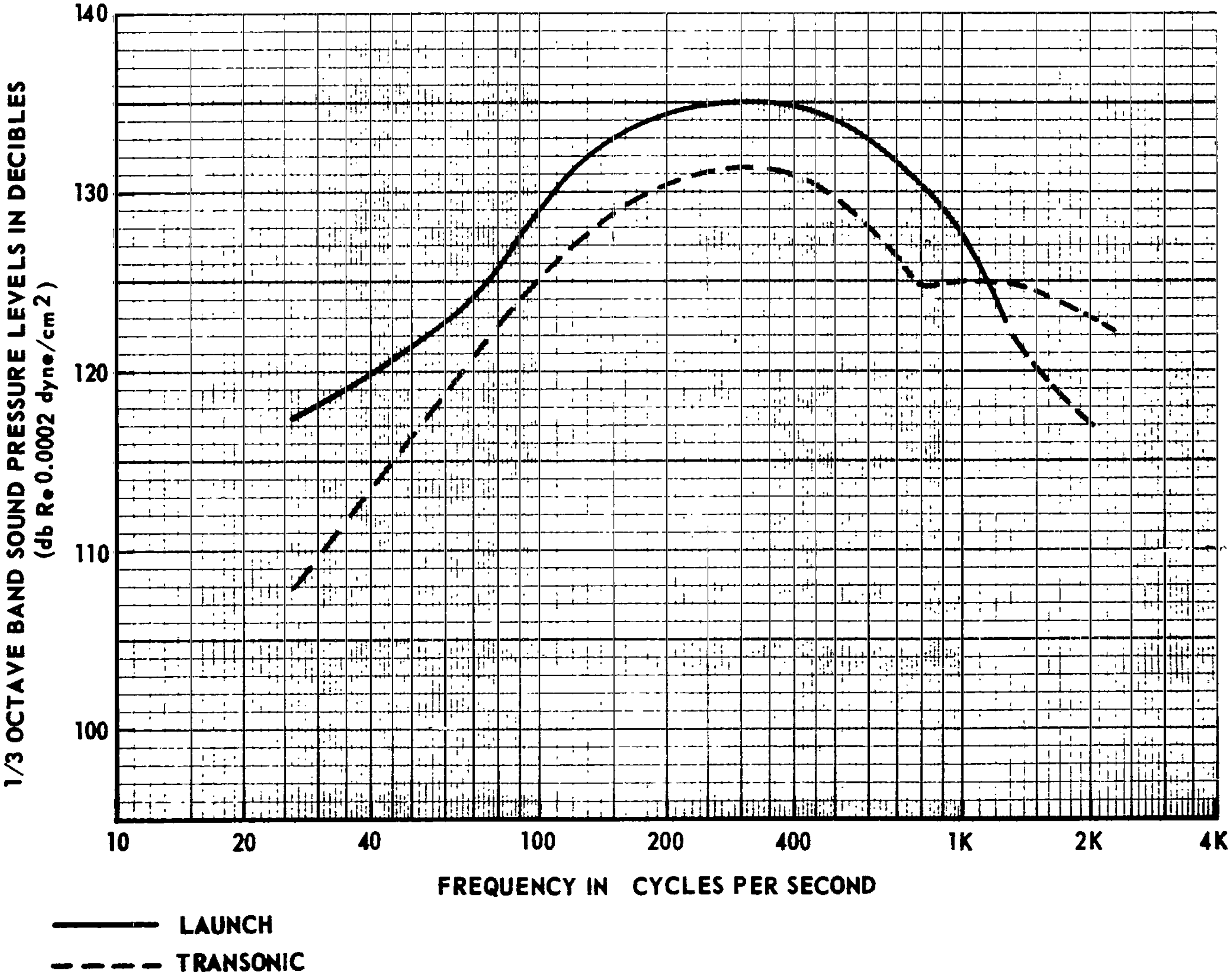


Figure III-13. Predicted maximum interior acoustic levels.

shown are based on extrapolation of measured data obtained from flights of the Titan IIIC vehicle and wind tunnel test programs. The data presented are based on the following assumptions:

a. The payload fairing does not include thermal and/or acoustic insulation.

b. The maximum dynamic pressure (q max) will not exceed 900 pounds per square foot.

Extrapolation from measured internal acoustic data together with external measurements on Titan IIIC flights have permitted the establishment of external/internal noise reduction levels for both launch and transonic periods of flight. These noise reduction values were applied to the predicted external levels to obtain the predicted internal acoustic levels shown in Figure III-13. These levels are considered to be conservative since they are based on the maximum external levels measured during Titan IIIC flights.

3. Vibration. The vibration environments are based on data measured during flight tests of Titan IIIC. Figure III-14 presents predicted vibration levels transmitted to the payload from the Titan IIID.

4. Shock. The shock environments specified are from pyrotechnic devices used to separate the payload fairing and the payload. Data on which these shock environments are based were taken during various ground tests conducted by the Martin-Marietta Corporation and associates. The shock environment due to payload fairing separation is based on data from the Titan IIIC fairing, and is given in Figure III-15. The payload separation is assumed to consist of eight explosive nuts at the payload/payload truss interface, generating levels as specified in Figure III-16. Due to the high levels near the explosive nut and their location at the interface, a curve showing shock attenuation with distance is given in Figure III-17.

Additional analysis and reevaluation of data shown in this paragraph will be necessary when the payload is more clearly defined and more details of the payload support truss structure design are available.

5. Temperature. There are three primary temperature conditions that may impose design constraints on the payload under consideration. These conditions are as follows:

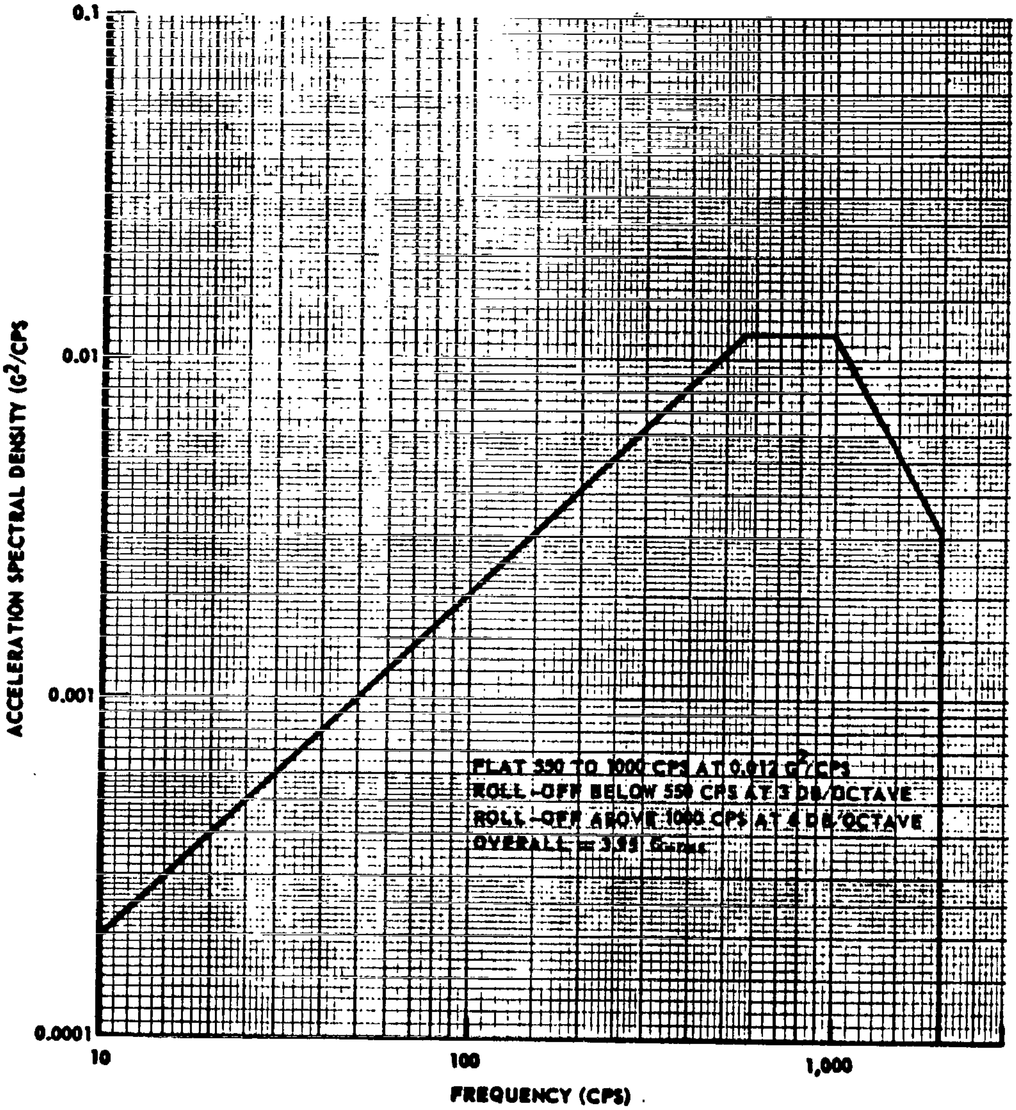


Figure III-14. Random vibration specification at payload interface, launch and flight environment.

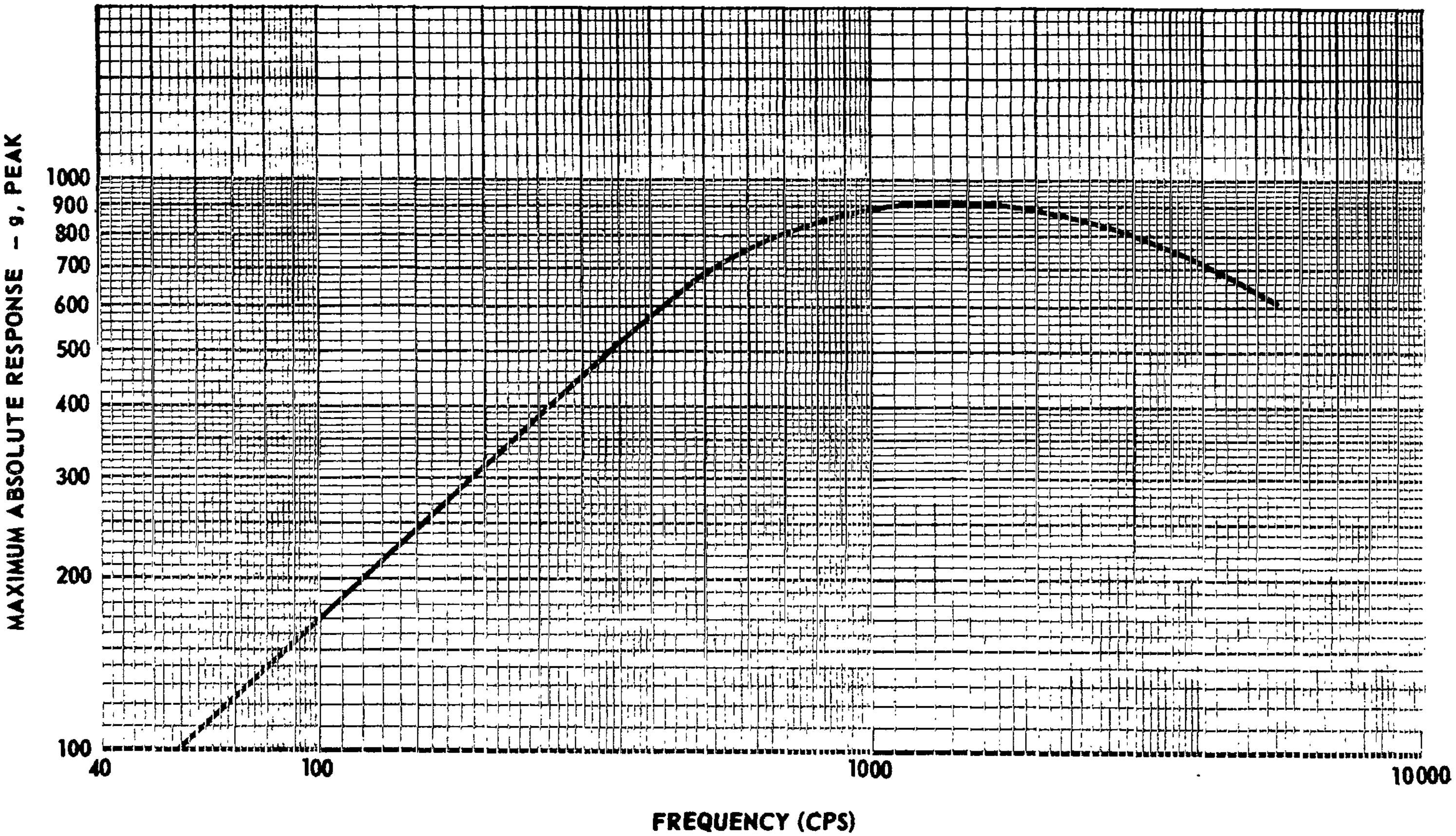


Figure III-15. PLF separation shock level at PLF to PLF adapter interface.

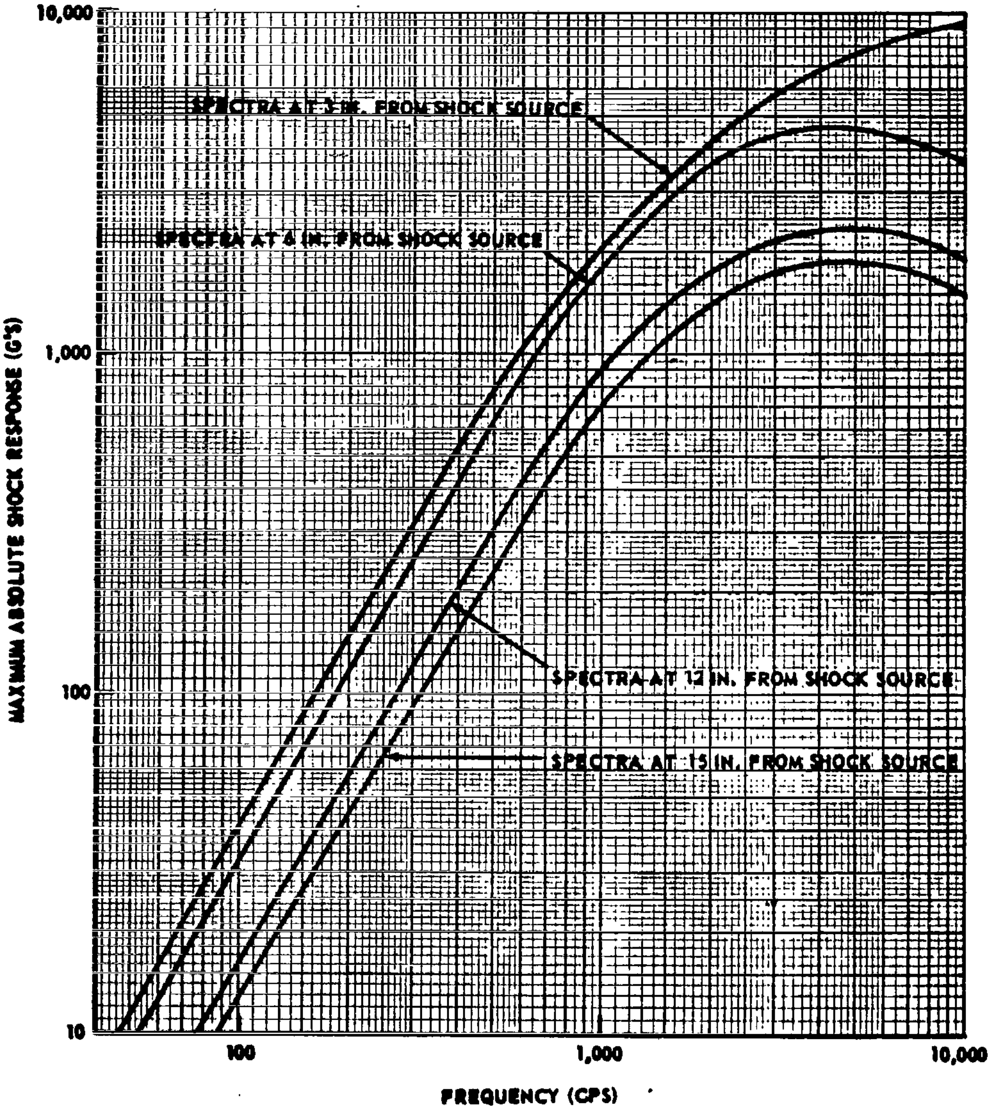


Figure III-16. Shock response spectra explosive nut shock (with 5-percent damping).

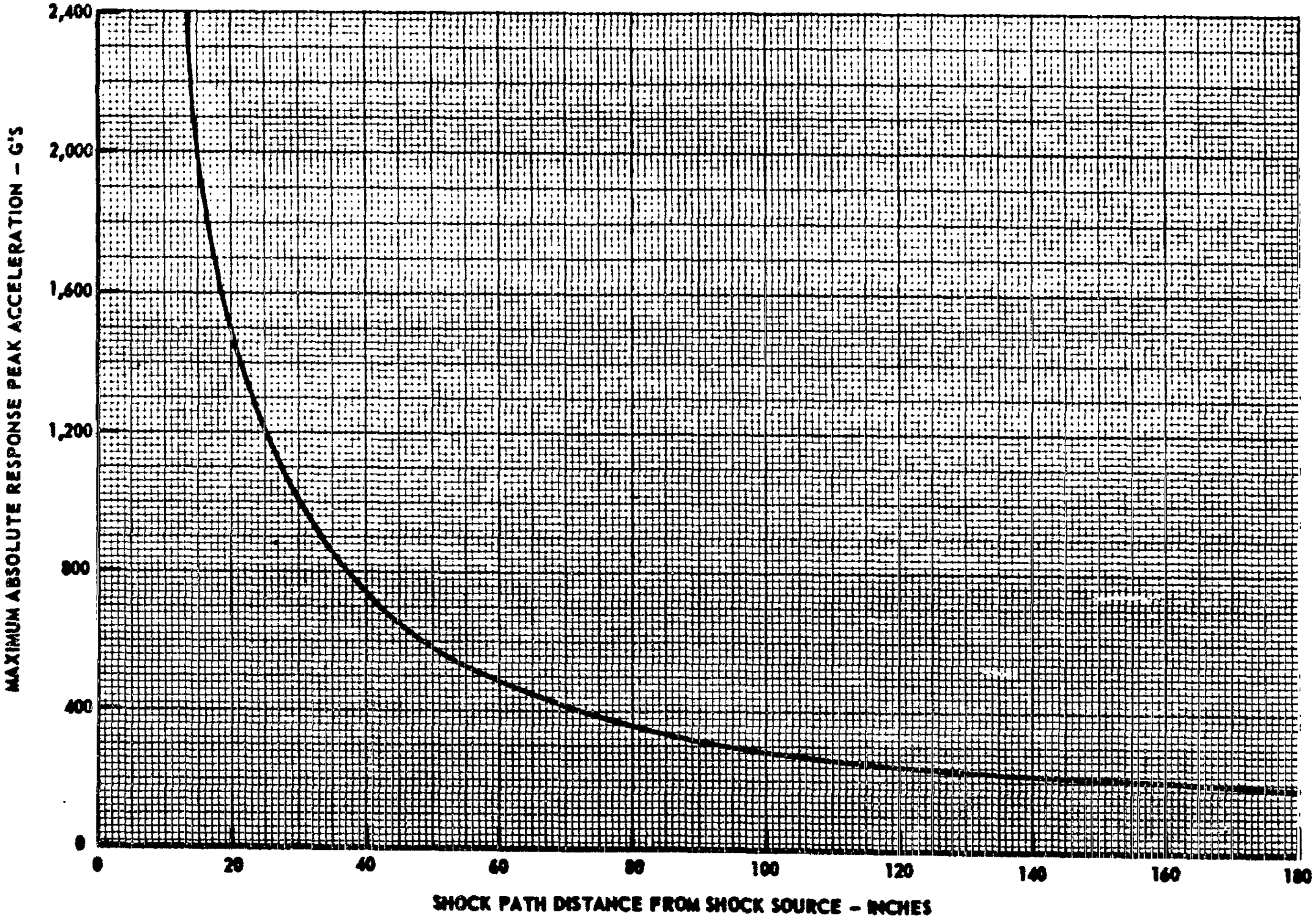


Figure III-17. Ordnance shock response decay curve.

a. Prelaunch. After the payload is erected, the environmental enclosure at the launch facility provides the following environment:

Temperature:	72° F ± 5° F
Relative Humidity:	50-percent maximum
Positive Pressure:	0.25 inch of H_2O minimum
Filtration:	35-percent efficiency when tested with atmospheric dust per National Bureau of Standards test

After MST removal, the payload fairing with the payload inside would be exposed to ambient conditions for 2 to 3 hours prior to launch. Solar heating is a major temperature variable which is partly compensated for by an air-conditioning umbilical.

b. Ascent phase (with payload fairing). The fairing is designed to protect the payload from aerodynamic heating during ascent with an internal surface temperature $< 300°$ F. Figure III-18 shows a typical payload fairing temperatures versus flight time curves.

F. Launch Operations

1. ETR Existing Facilities. The Titan facilities at the ETR are shown and described in Reference 2. In addition to the SRM segment receiving and processing facilities, ITL consists of the Vertical Integration Building where the core (Stage I and Stage II) is placed on the transporter and checked out; the SMAB, where solids are added to the core on transporter; and the two launch pads. This mobile mode of operation can provide quick turnaround capability. On-pad assembly of the launch vehicle can also be accomplished.

2. Titan IIID/Centaur. A NASA application of the Titan IIID vehicle with Centaur is now underway for the Pioneer-G and Viking missions. The Titan IIID/Centaur vehicle is derived by mating Centaur to Stage II of the Titan IIID vehicle. Launch Pad 41 will be modified to meet a launch date of the first Titan IIID/Centaur in the last quarter of 1972. Use of this pad for the HEAO mission would avoid mixing the Titan IIID mission with the Titan IIIC launches from Launch Pad 40, and would benefit from previous modifications at Pad 41 for the Titan IIID/Centaur.

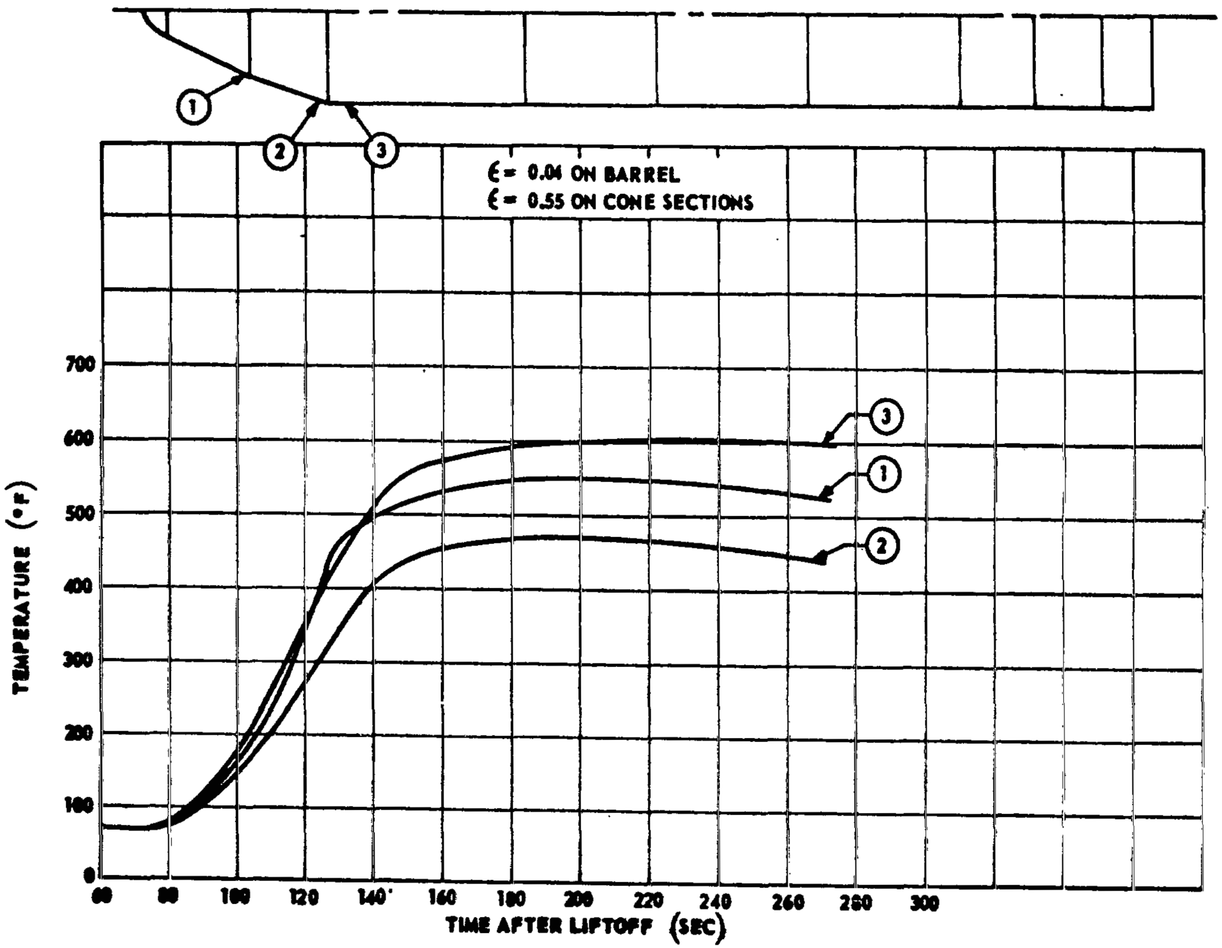


Figure III-18. Typical PLF temperature versus flight time.

3. Launch Complex Modifications. The launch complex requires minimum modifications resulting from astrionics changes and implementing of Titan IIID because the facility will have previously been adapted to the Titan IIIC and the Titan IIID/Centaur vehicles. Minor changes to the launch tower may be required for umbilicals. Additional studies are required to define these modifications, but no major impact is anticipated.

4. Space Vehicle Assembly. The Titan IIID launch vehicle will be checked out on Launch Pad 41 prior to the integration of the spacecraft and payload adapter on top of Stage II. The payload fairing is then added to the space vehicle and necessary checkout functions performed by the spacecraft integration contractor under the direction of KSC. Additional studies are required to define the on-pad assembly processes required for the HEAO missions.

REFERENCES

1. T-IIID Launch Vehicle at ETR for High Energy Astronomical Observatory, Revision 1, Martin/Denver, September 19, 1969.

2. MCR-68-62 Titan IIIC Payload Users' Guide. Revision 1, Martin Marietta Corporation, Denver Division, Systems Engineering, April 17, 1969.

APPENDIX B. LAUNCH VEHICLE ALTERNATIVES

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APPENDIX B. LAUNCH VEHICLE ALTERNATIVES

1. Introduction

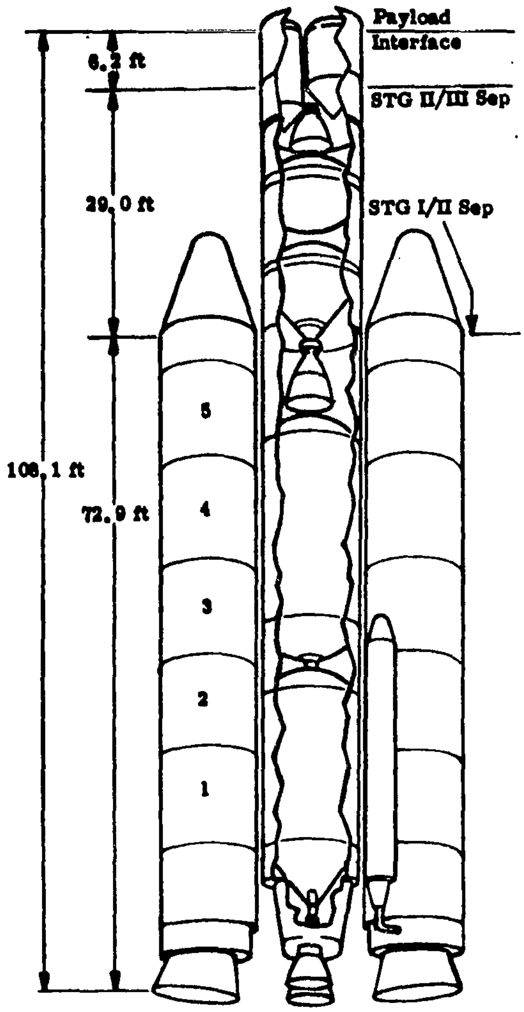
Although some consideration was given very early in the Phase A studies to the possible use of the Atlas Centaur (SLV3-C), the Titan IIIB, and the Saturn IB launch vehicles for the HEAO mission, all of these vehicles were very quickly eliminated from further consideration. The Atlas Centaur and Titan IIIB were eliminated because of lack of payload capability to deliver the entire HEAO payload on a single launch. It was found that these vehicles would not compete on a cost effectiveness comparison even if the single launch requirement were waived and the HEAO payload divided into multiple payload packages small enough to fit on these vehicles. The possible use of existing Saturn IB launch vehicles was eliminated from consideration early in the study since these vehicles are currently scheduled for manned launches in the Apollo Applications Program, and because other unmanned programs during the time frame of HEAO are currently planning to use Titan vehicles.

These considerations determined that the launch vehicle selection should be between the Titan IIID and Titan IIIC. Although modifications to the Titan IIID guidance system are required to adapt the Titan IIID to ETR, it was selected as the baseline launch vehicle from an overall cost effectiveness standpoint. The Titan IIIC, therefore, becomes the primary alternate to the Titan IIID launch vehicle for the HEAO missions. Either of two possible situations could develop which would make the Titan IIIC launch vehicle more attractive, but neither of these situations is anticipated at the time: (1) problems arise in adapting Titan IIID to ETR which cause its cost to exceed Titan IIIC cost; and (2) growth of the HEAO payload which would preclude the use of Titan IIID.

A brief description of the Titan IIIC and comparative launch vehicle performance capability data for the Titan IIID and Titan IIIC are presented in this appendix.

2. Titan IIIC Launch Vehicle

The Titan IIIC consists of a three-stage liquid propellant core vehicle supplemented by two SRM strap-ons, as shown in Figure B-1. The complete



HARDPOINTS - 8
UNEQUALLY SPACED
GUIDANCE - ALL INERTIAL

STAGE III (TRANSTAGE)
PROPELLANTS LOADED 23,470 lb
I_{sp} NOM 302 (vac) sec
THRUST 16,000 (vac) lb
LOADED WEIGHT 27,477 lb

STAGE II
PROPELLANTS LOADED 67,299 lb
I_{sp} NOM 316.9(vac) sec
THRUST 101,890 (vac) lb
LOADED WEIGHT 73,171 lb

STAGE I
PROPELLANTS LOADED 258,996 lb
I_{sp} NOM 299 (vac) sec
THRUST 523,000 (vac) lb
LOADED WEIGHT 274,398 lb

STAGE 0
PROPELLANT WEIGHT 848,494 lb
TVC (N_2O_4) LOADED 16,848 lb
I_{sp} NOM 231.8 sec
THRUST 2,340,000 lb
LOADED WEIGHT 1,016,050 lb

LIFTOFF
FOUR STAGES WITHOUT PAYLOAD OR PAYLOAD FAIRING
WEIGHT 1,390,340 lb
THRUST 2,327,430 lb

Figure B-1. Titan IIIC launch vehicle.

four-stage launch vehicle (less payload and fairing) has an overall length of approximately 110 feet and a lift-off weight of approximately 1.4 million pounds.

The Titan IIIC space launch vehicle uses the ITL complex at the ETR.

a. Airframe. Stage 0 consists of two identical SRM's mounted 180 degrees apart on the core vehicle. Each is approximately 10 feet in diameter and 85 feet long, weighs about 0.5 million pounds, and produces an initial thrust of 1.2 million pounds. The TVC is provided by liquid injection of pressurized liquid N_2O_4.

Stage I is 10 feet in diameter and approximately 71.5 feet long, is of aluminum skin-stringer construction, and consists of two liquid propellant tanks with the necessary skirts and two gimbaled engine assemblies.

Stage II is 10 feet in diameter and approximately 31 feet long, is of the same type of construction as Stage I, and consists of two liquid propellant tandem tanks with skirts, between-tank truss, and one gimbaled engine assembly.

The Transtage (Stage III) is 10 feet in diameter and approximately 14.5 feet long, is of aluminum skin-stringer construction, and consists of two liquid propellant titanium tandum tanks, two equipment trusses, and two gimbaled engine assemblies. Payload and fairing interfaces are provided at the forward end of the Transtage.

b. Core Propulsion. The Stage I propulsion system uses an Aerojet YLR87-AJ-11 engine assembly comprising two gimbaled engines and related equipment. The engines are pump fed and combined regenerative and ablative cooled. The normal vacuum thrust is approximately 520 000 pounds. Propellants are aerozine-50 and N_2O_4.

The Stage II propulsion system uses an Aerojet YLR91-AJ-9 engine assembly consisting of a single-gimbaled engine and related equipment and a gimbaled gas generator exhaust nozzle for roll control. It is pump fed and ablative cooled. Normal vacuum thrust is approximately 100 000 pounds. Propellants are identical to those of Stage I.

The Transtage main propulsion system uses an Aerojet AJ10-138 engine assembly consisting of two 8000-pound nominal vacuum thrust engines. These engines are ablative cooled and pressure fed, using helium as pressurant. Propellants are identical to those used for Stages I and II. Multiple start capability is provided.

The Transtage multipurpose ACS uses a monopropellant blowdown hydrazine system and fixed thruster assemblies to provide attitude control; propellant settling; orbit adjust, maneuvering, and vernier control; and multipayload deployment and controlled dispersion.

c. Electrical. All electrical power required for the Transtage payload fairing and payload is derived from Transtage-mounted silver-zinc storage batteries. Power is a nominal 28 vdc on five different buses and is available from lift-off until approximately 6.75 hours.

d. Tracking and Flight Safety. Engine shutdown and destruct commands are supplied by two redundant independent UHF systems. Tracking is provided by C-band pulse transponder and related equipment.

e. Hydraulics. The hydraulics system is used in each of the three liquid propellant stages to gimbal the thrust chambers of the respective stage. In Stage II, the gas generator exhaust nozzle is also gimbaled for roll control. Electric valves are included in Stage 0 for TVC injectant and require no hydraulics.

f. Guidance. The Titan IIIC inertial guidance system (IGS) consists of an IMU that is a gimbaled platform with three pendulous integrating gyro accelerometers; an MGC, which is a random access, thin film core memory, parallel, binary, digital computer; a TCU that provides liquid coolant circulated in the IMU and MGC; and an SC.

g. Flight Controls. The flight control system stabilizes the attitude of the vehicle in all phases of flight from launch through payload separation. This system establishes the flight path of the vehicle by implementing all steering commands issued by the IGS. It consists of software in the MGC, Stage I and II attitude rate sensors, LASS, TVC for the SRM's, and hydraulic actuators in the three core stages.

h. Instrumentation. The instrumentation system, a PCM/FM system, operates in the S-band frequency. Data signals are sampled and encoded by two RMIS's, each of which includes a group of RMU's, and a single central converter. The RMU samples, amplifies, and holds the signals to provide a serial PAM output train to the central converter.

3. Launch Vehicle Capabilities

Performance data on the Titan IIID and the Titan IIIC launch vehicles required for HEAO-A mission planning are presented in this section. These data are presented in a general fashion and are therefore applicable to missions other than HEAO-A. Trajectory and performance assumptions, vehicle characteristics, payload capabilities, trajectory profiles, time histories for the inertial velocity, flight path angle, longitudinal acceleration, Mach number, dynamic pressure, and altitude are presented for the Titan IIID and/or the Titan IIIC launch vehicles.

While these data are sufficient for planning purposes and preliminary studies, additional performance studies will be required when more definitive weights data and mission parameters are available. It should be noted that slightly different weights assumptions were used in developing the performance charts in this paragraph from those used and documented in Paragraph 4 and which are based on recent data from the Lewis Research Center. In addition, the payload fairing is assumed to be dropped at 283 seconds, which is approximately 100 seconds later than shown in Paragraph 4. However, these discrepancies in assumptions should not impair the comparative quality of the data presented since the magnitude of the performance numbers differ only slightly.

a. Assumptions and Data Sources. Assumptions and data sources used in the Titan IIID and Titan IIIC trajectory calculations are as follow:

- Vehicle weight and propulsion data from SMSD-PVEL-191, "Titan III Vehicle Description," Brown Engineering Company, August 1968, Unclassified.

- Payload shroud and payload adapter weights from BMI-NLVP-ICM-69-92, "Titan IIIC, Titan IIID, and Titan IIID/Centaur Performance (to 200 n.mi. orbits)," July 17, 1969, Unclassified.

- Aerodynamic data from SSD-CR-66-103, "Titan III Data Book for Performance Calculations (V), AF04 (695) - 997," August 1967, Confidential.

- Launch from KSC on an azimuth of 90 degrees measured from north to south over east.

- The two 5-segment 120-inch SRM's ignited on the pad.

- Vertical ascent for 10 seconds, initiation and execution of a constant pitch rate program until 30 seconds' flight, after which a zero angle-of-attack was flown until SRM burnout. At that point atmospheric effects were neglected since the dynamic pressure was less than 13 lb/ft^2. The altitude achieved was 188 370 feet (Titan IIID to a 200-n. mi. orbit).

- The 271-pound heat shield and the 242-pound starter propellant jettisoned 107 seconds after lift-off.

- The main stage engines (Core Stages I and II ignited at 110 and 253.682 seconds after lift-off. The transtage, Titan IIIC only, was ignited at 457.906 seconds after lift-off.

- The SRM cases, the Core Stage I, and the Core Stage II for Titan IIID were jettisoned at 121, 253.682, and 453.297 seconds after lift-off (stage cutoff). Titan IIIC was the same as Titan IIID, except Core Stage II and the transtage were jettisoned at 457.906 and 859.850 seconds, respectively, after lift-off.

- Vacuum flight thrust angles optimized via steepest ascent method.

- The 2310-pound payload shroud jettisoned at 283.682 seconds after lift-off.

- Payload is defined for Titan IIID as weight above the Core Stage II at stage injection. The Titan IIIC payload is defined as weight above the transtage at stage injection.

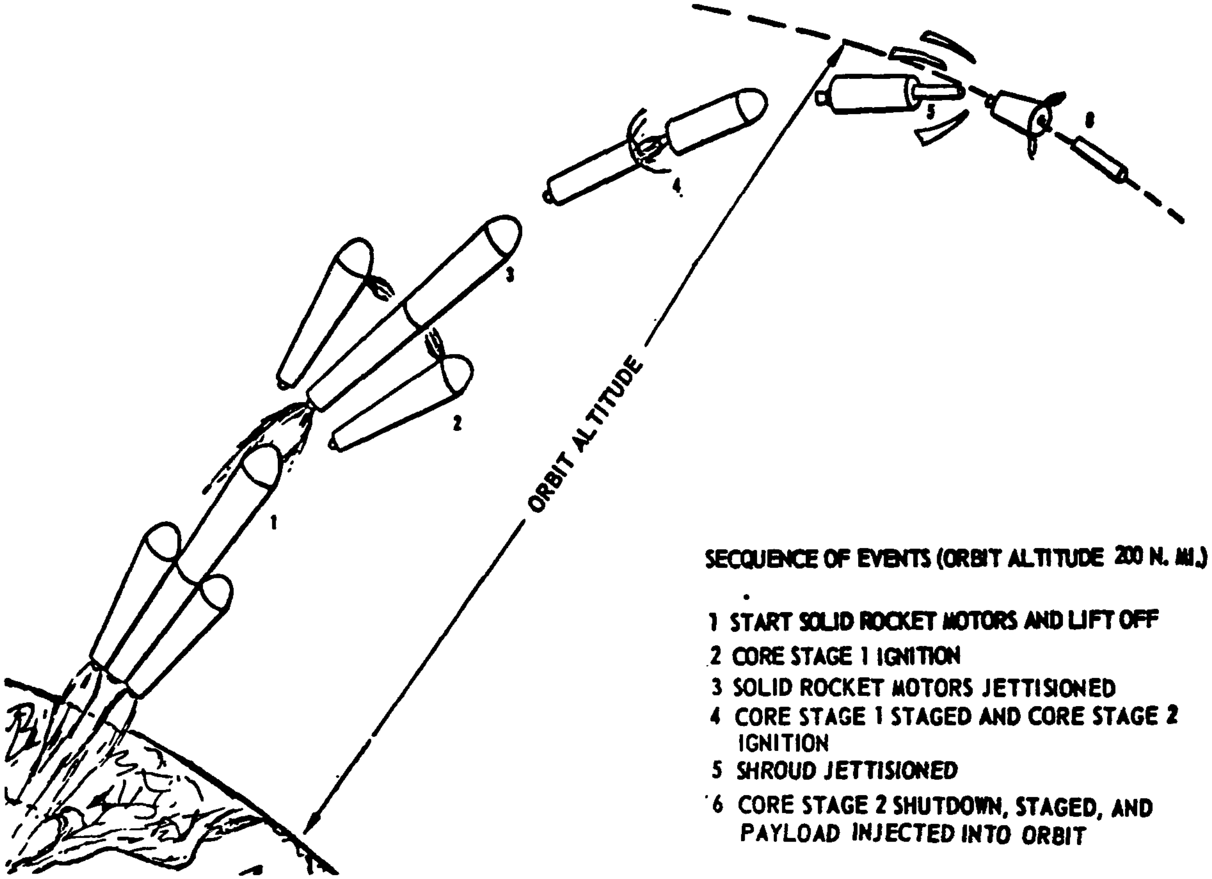
b. Trajectory Profile. The Titan IIID trajectory profile is three stages (0, Core I, and Core II) direct-ascent to orbit. The Titan IIIC trajectory profile is four stages (0, Core I, Core II, and transtage) direct-ascent to orbit. The following typical Titan IIID launch-to-orbit profile is illustrated in Figure B-2.

- Start SRM's and lift-off at 0.0 second.

- Core Stage I ignition at 110 seconds.

- Solid rocket motors jettisoned at 121 seconds.

- Core Stage I staged and Core Stage II ignited at 253.682 seconds.



SECQUENCE OF EVENTS (ORBIT ALTITUDE 200 N. MI.)

1 START SOLID ROCKET MOTORS AND LIFT OFF
2 CORE STAGE 1 IGNITION
3 SOLID ROCKET MOTORS JETTISIONED
4 CORE STAGE 1 STAGED AND CORE STAGE 2 IGNITION
5 SHROUD JETTISIONED
6 CORE STAGE 2 SHUTDOWN, STAGED, AND PAYLOAD INJECTED INTO ORBIT

Figure B-2. Typical Titan IIID launch-to-orbit profile.

- The 2310-pound shroud jettisoned at 283.682 seconds.

- For Titan IIID, Core Stage II cutoff, staged, and payload injected into orbit at 453.297 seconds.

- For Titan IIIC, Core Stage II staged and the transtage ignited at 457.906 seconds.

- For Titan IIIC, transtage cutoff, staged, and payload injected into orbit at 859.85 seconds.

c. Payloads and Trajectory Data. Graphs and tables of payloads and trajectory data for the Titan IIID and Titan IIIC launch vehicles are presented and explained as follows:

- Figure B-3 is a graph showing net payload as a function of orbital altitude for the Titan IIIC and Titan IIID launch vehicles. For these missions the trajectories were direct ascent to circular orbit with an orbital inclination of 28.5 degrees.

- Figure B-4 is a graph of net payload versus apogee altitude for the Titan IIIC and Titan IIID launch vehicles. For these missions the trajectories were direct ascent to an elliptical orbit with an orbital inclination of 28.5 degrees and a perigee injection at 90 n.mi.

- Figure B-5 is a graph of net payload versus perigee altitude for the Titan IIID launch vehicle. For these missions the trajectories were direct ascent to an elliptical orbit with an orbital inclination of 28.5 degrees, with a 1-year orbital lifetime, associated with a plus two-sigma solar activity.

- Figure B-6 is a graph of apogee altitude versus perigee altitude for the HEAO having a 1-year orbital lifetime associated with a plus two-sigma solar activity. This graph is to be used in conjunction with data presented in Figure B-5 in determining payload, apogee, or perigee when two of of the three parameters are specified.

- Figure B-7 is a graph of inertial velocity, inertial flight path angle, and longitudinal acceleration versus flight time for the Titan IIID launch vehicle. For this mission, the trajectory was a direct ascent to a 200-n.mi. circular orbit with an orbital inclination of 28.5 degrees.

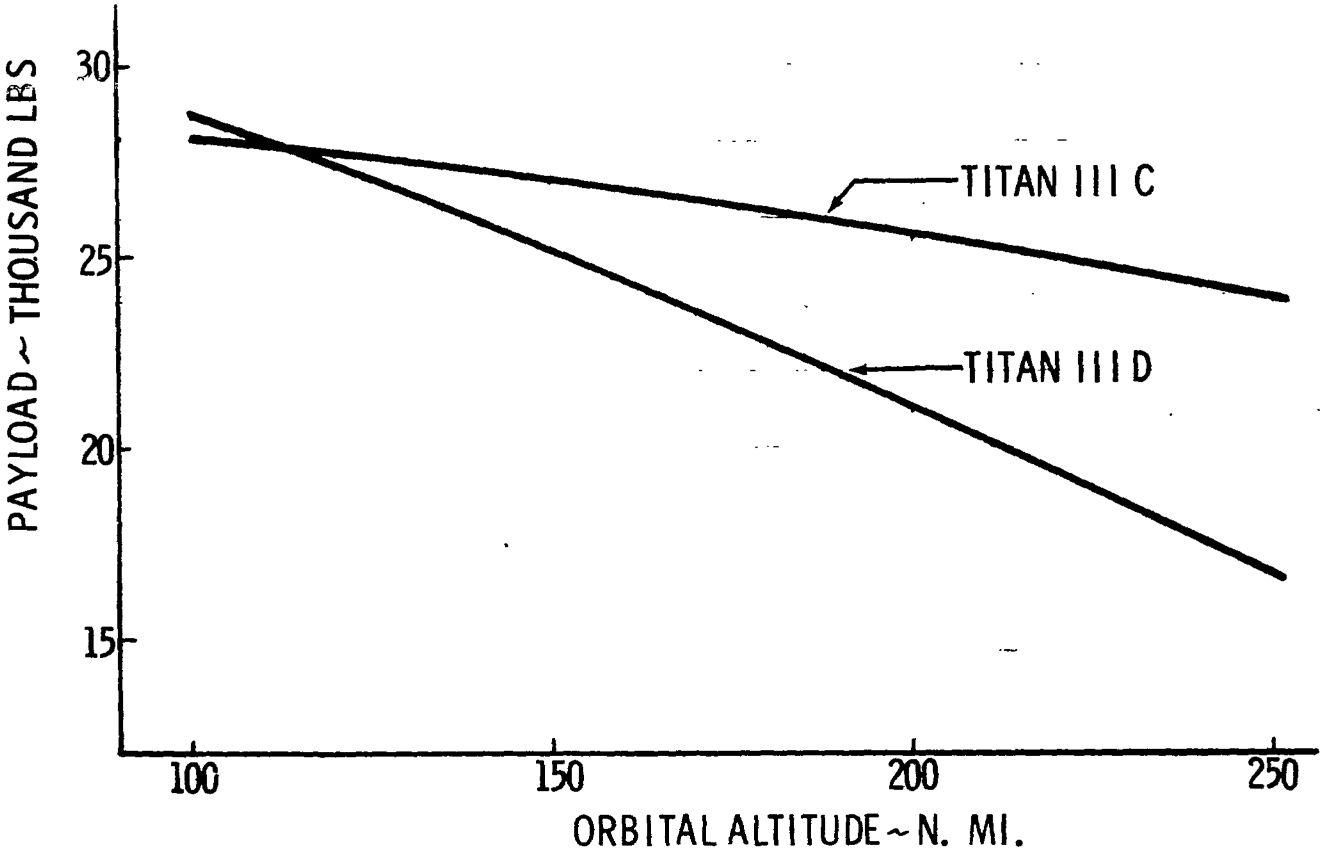


Figure B-3. Titan IIID and IIIC performance to circular orbit inclination 28.5 degrees.

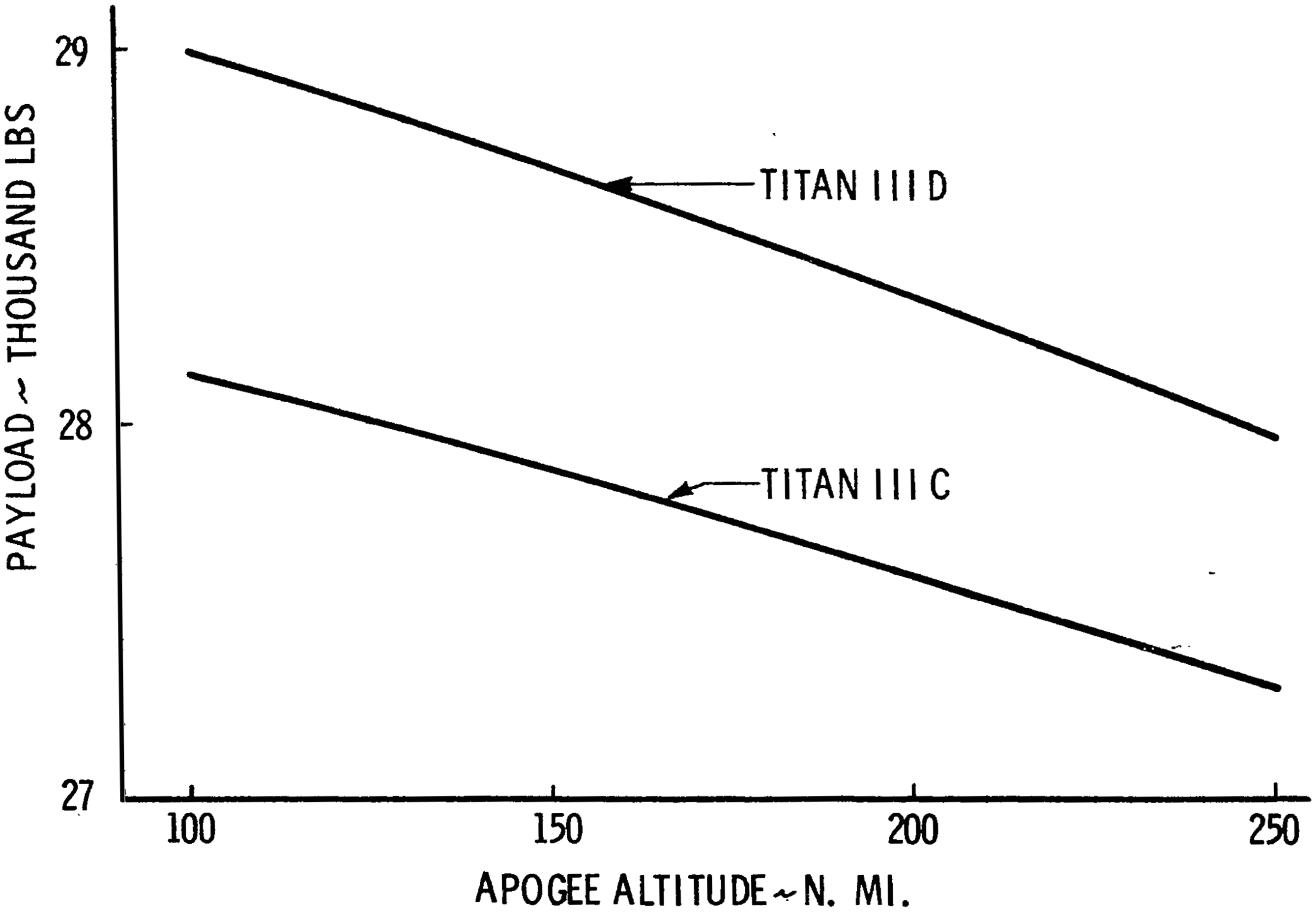


Figure B-4. Titan IIID and IIIC performance-to-perigee injection at 90 n. mi. versus apogee altitude.

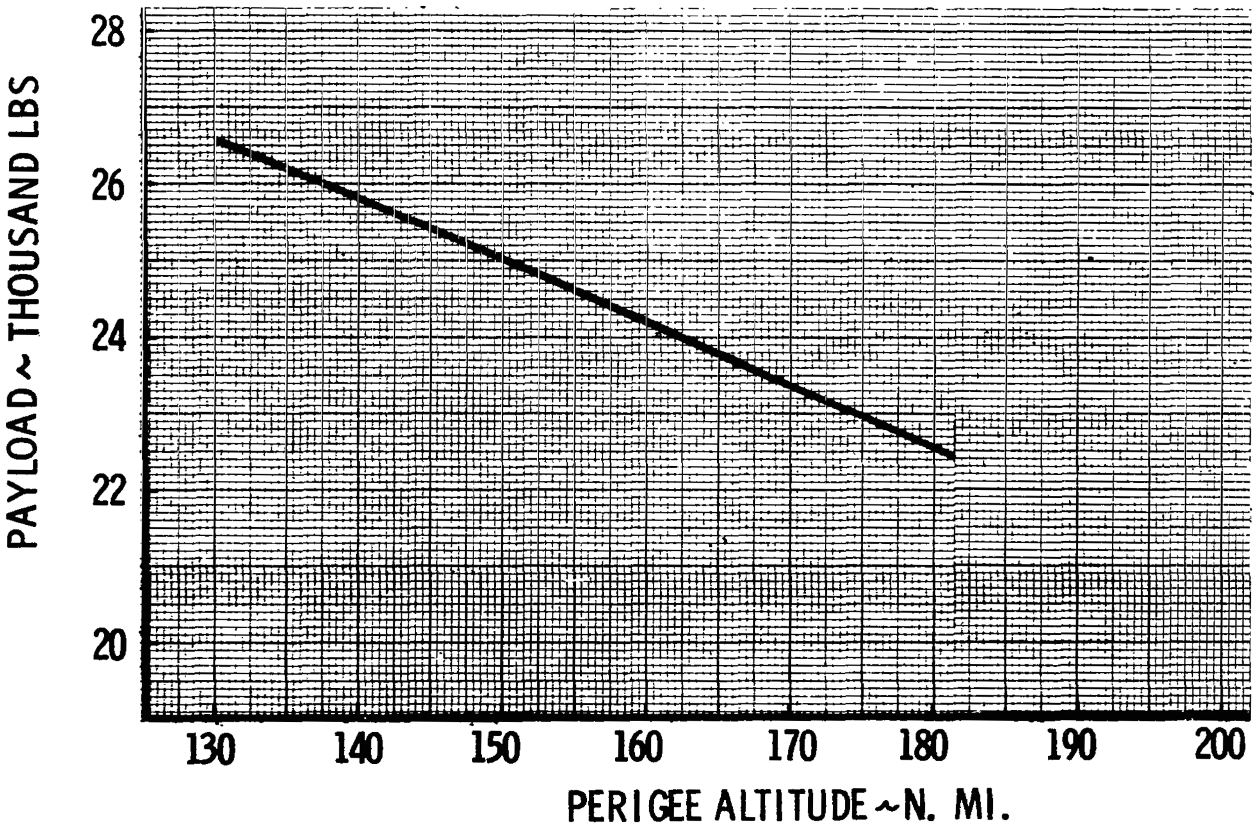


Figure B-5. Titan IIID payload capability for elliptical orbit injection with 1 year minimum orbital lifetime for +2σ solar activity.

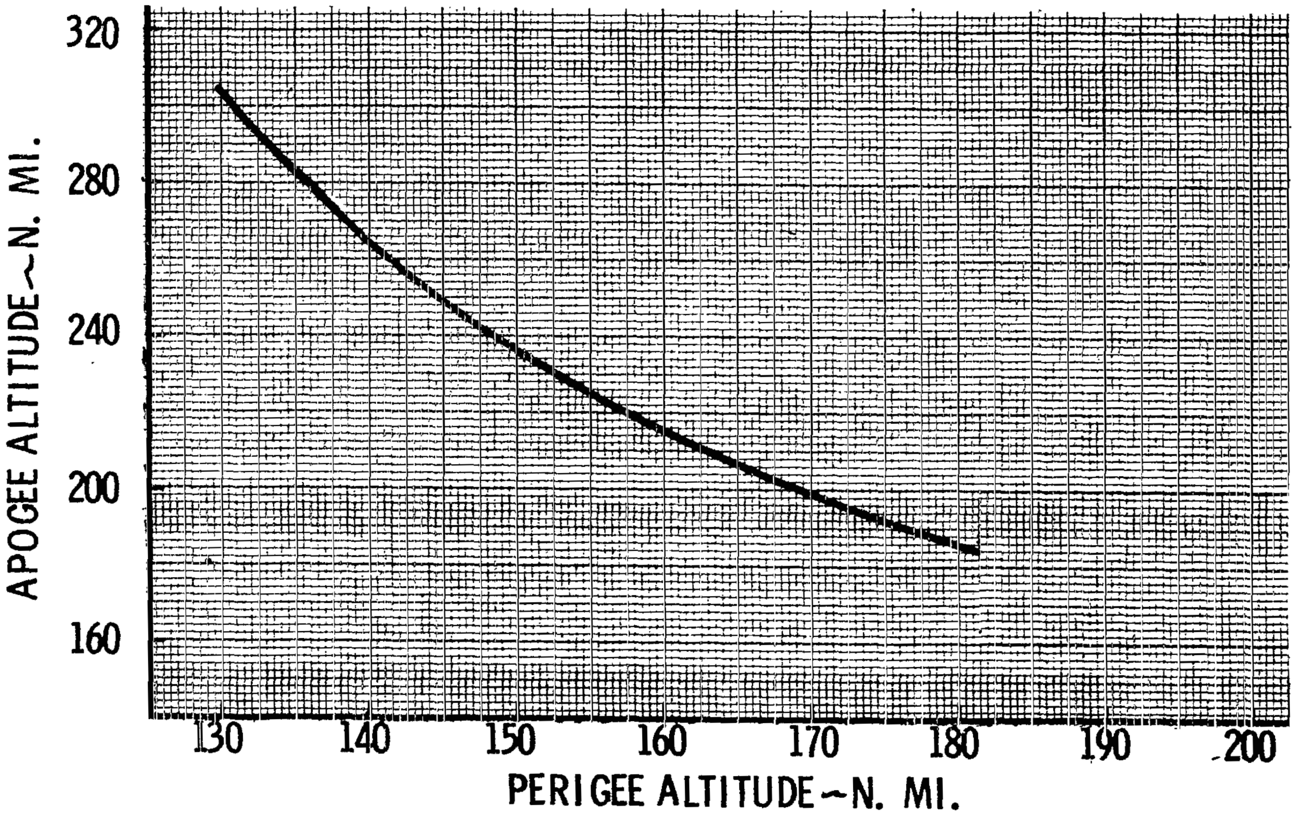


Figure B-6. Apogee versus perigee altitude of HEAO spacecraft with 1 year orbital lifetime and +2σ solar activity.

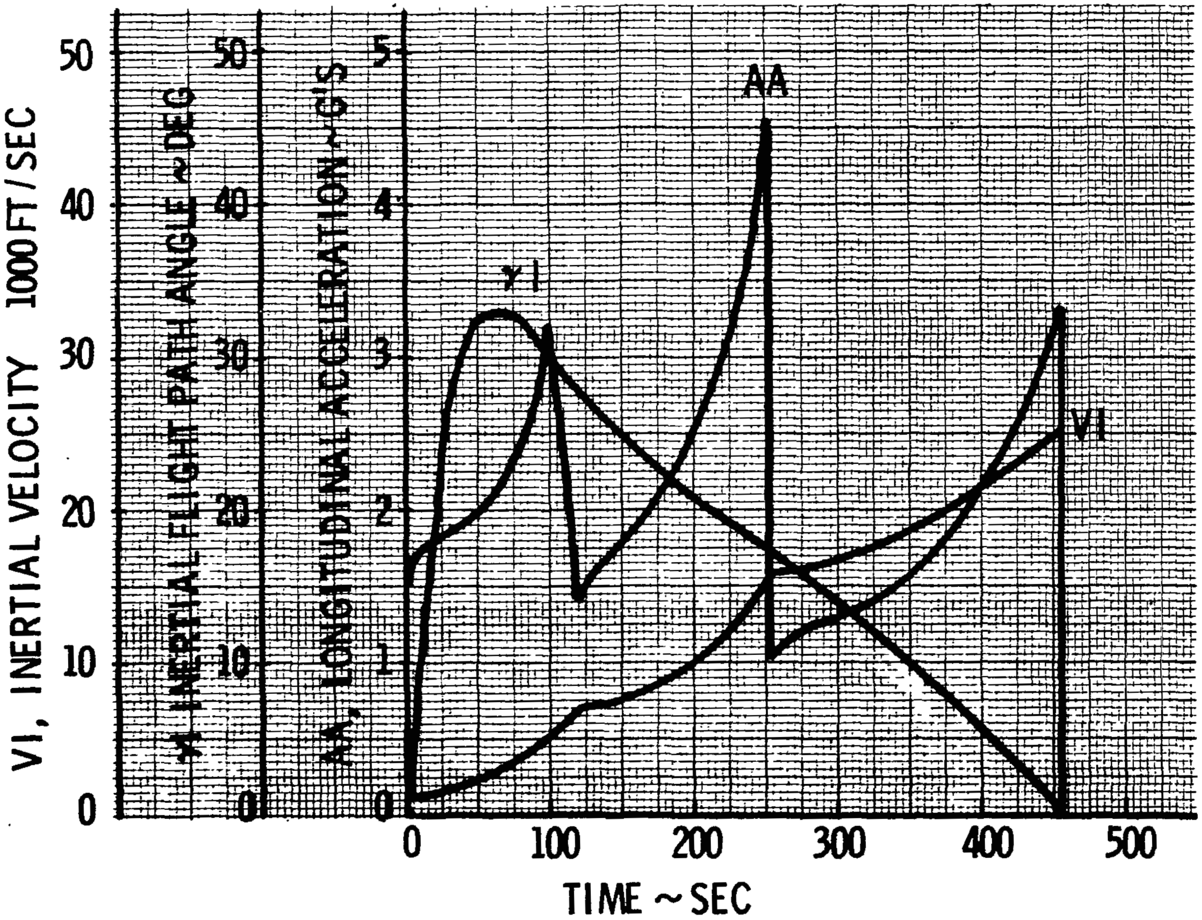


Figure B-7. Titan IIID trajectory parameters direct injection into a 200-n.mi. circular orbit, 28.5-degree inclination.

- Figure B-8 is a graph of Mach numbers and dynamic pressure versus flight time for the Titan IIID launch vehicle. For this mission the trajectory was a direct ascent to a 200-n. mi. circular orbit and an orbital inclination of 28. 5 degrees.

- Figure B-9 is a graph of altitude versus flight time for the Titan IIID launch vehicle. For this mission the trajectory was a direct ascent to a 200-n. mi. circular orbit with an orbital inclination of 28. 5 degrees.

- Figure B-10 is a graph of net payload versus orbital inclination for the Titan IIID launch vehicle. For these missions the trajectories were direct ascent to 100-, 200-, and 300-n. mi. circular orbits with and without yaw steering. For the northerly launch, the vehicle was launched with a 45-degree launch azimuth, and yaw steering was initiated at 90 seconds after lift-off.

- Table B-1 contains payload capabilities for the Titan IIIC and Titan IIID launch vehicles to a 200-n. mi. circular orbit with an orbital inclination of 28. 5 degrees. This table gives the payload capabilities to a 200-n. mi. circular orbit by direct ascent and by Hohmann transfer. To achieve a 200-n. mi. circular orbit by Hohmann transfer, the vehicle was assumed to go direct-ascent to a 90- by 200-n. mi. elliptical parking orbit, inject at perigee and circularize at apogee.

  The Titan IIIC transtage is restarted to circularize at apogee. To circularize at apogee, 695 pounds of transtage propellant was required.

  The Titan IIID Core Stage II has no restart capabilities. To do a Hohmann transfer, a kick stage was added to the payload. This stage was composed of four SRM's. To circularize at apogee, 620 pounds of solid rocket propellant was required (see Appendix G).

- Table B-2 contains Titan IIIC and Titan IIID performance data to a 200-n. mi. circular orbit with orbital inclinations of 28. 5 degrees, 20 degrees, 15 degrees, and 10 degrees. Titan IIID performance below 28. 5 degrees inclination is not shown. The Core Stage II on the Titan IIIC or IIID is not restartable. This fact causes a yaw maneuver to be performed at off optimum position in the trajectory to effect lower inclination orbit; the lowest inclination which can be achieved by the Titan IIID is 23 degrees with a payload of zero. The payload drops off linearly from 20 920 pounds at 28. 5 degrees to zero at 23 degrees. The performance was calculated assuming the following mission profile:

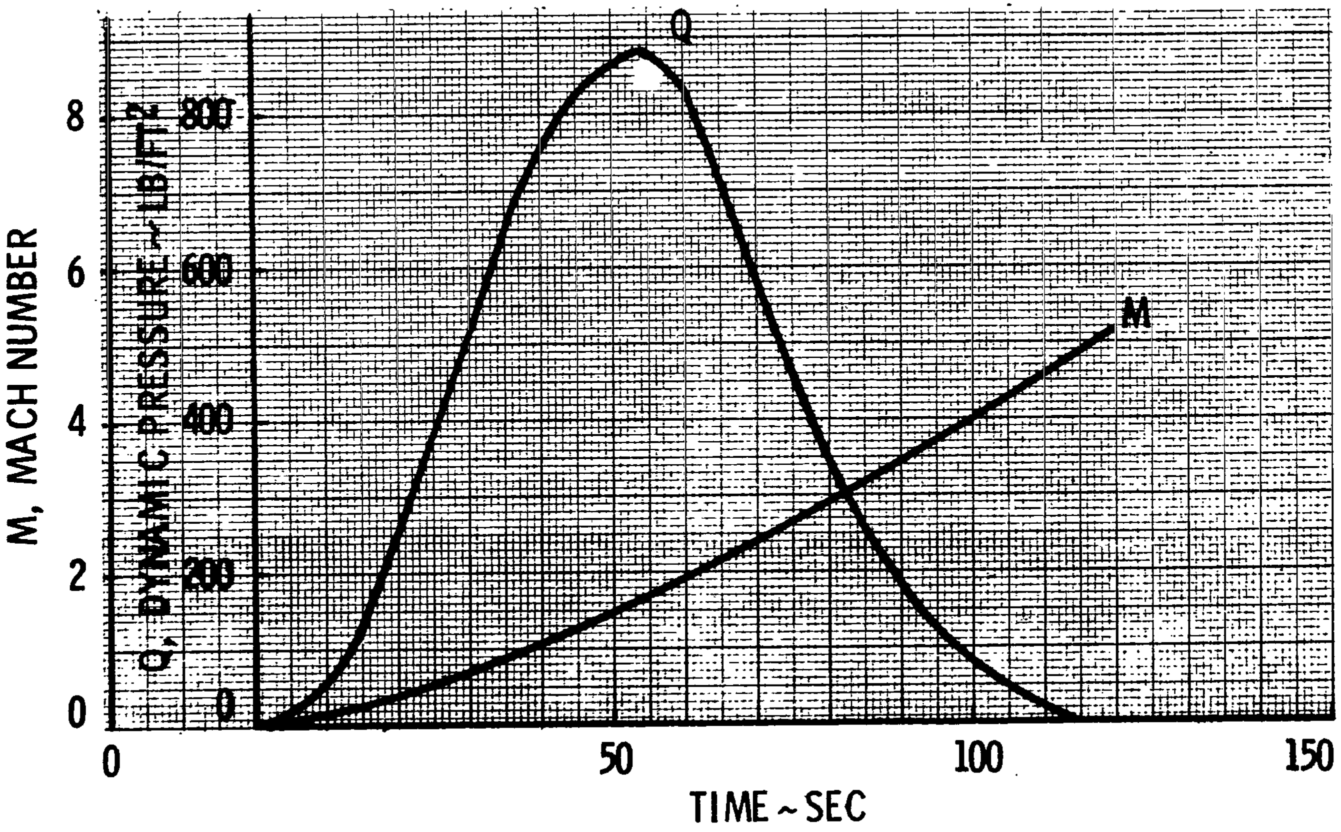


Figure B-8. Titan IIID trajectory parameter direct injection into a 200-n. mi. circular orbit, 28.5-degree inclination.

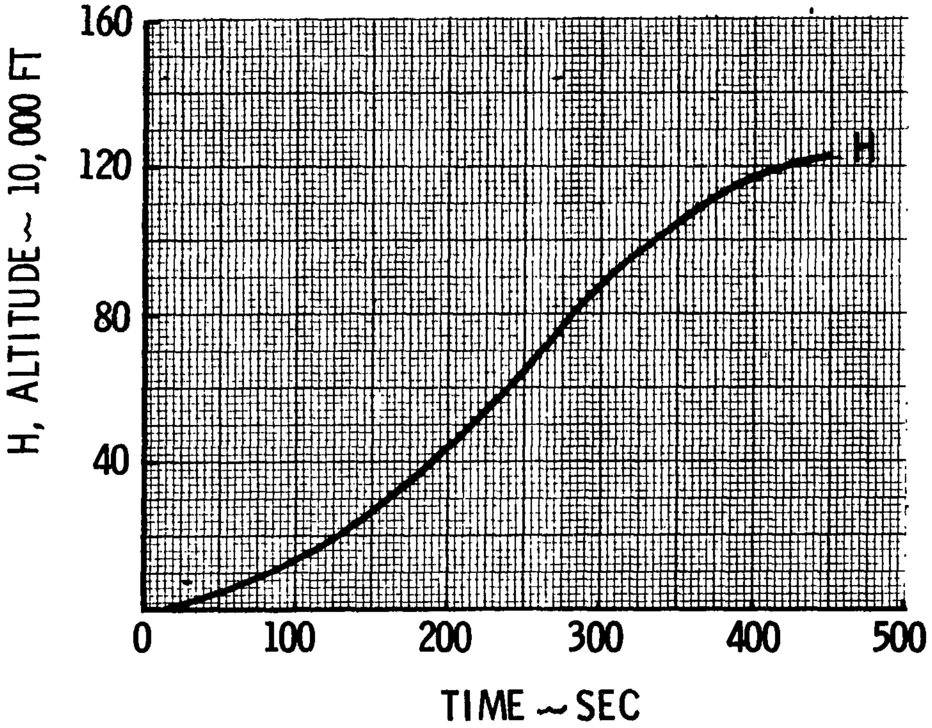


Figure B-9. Titan IIID direct ascent, 200-n.mi. orbit, 28.5-degree inclination.

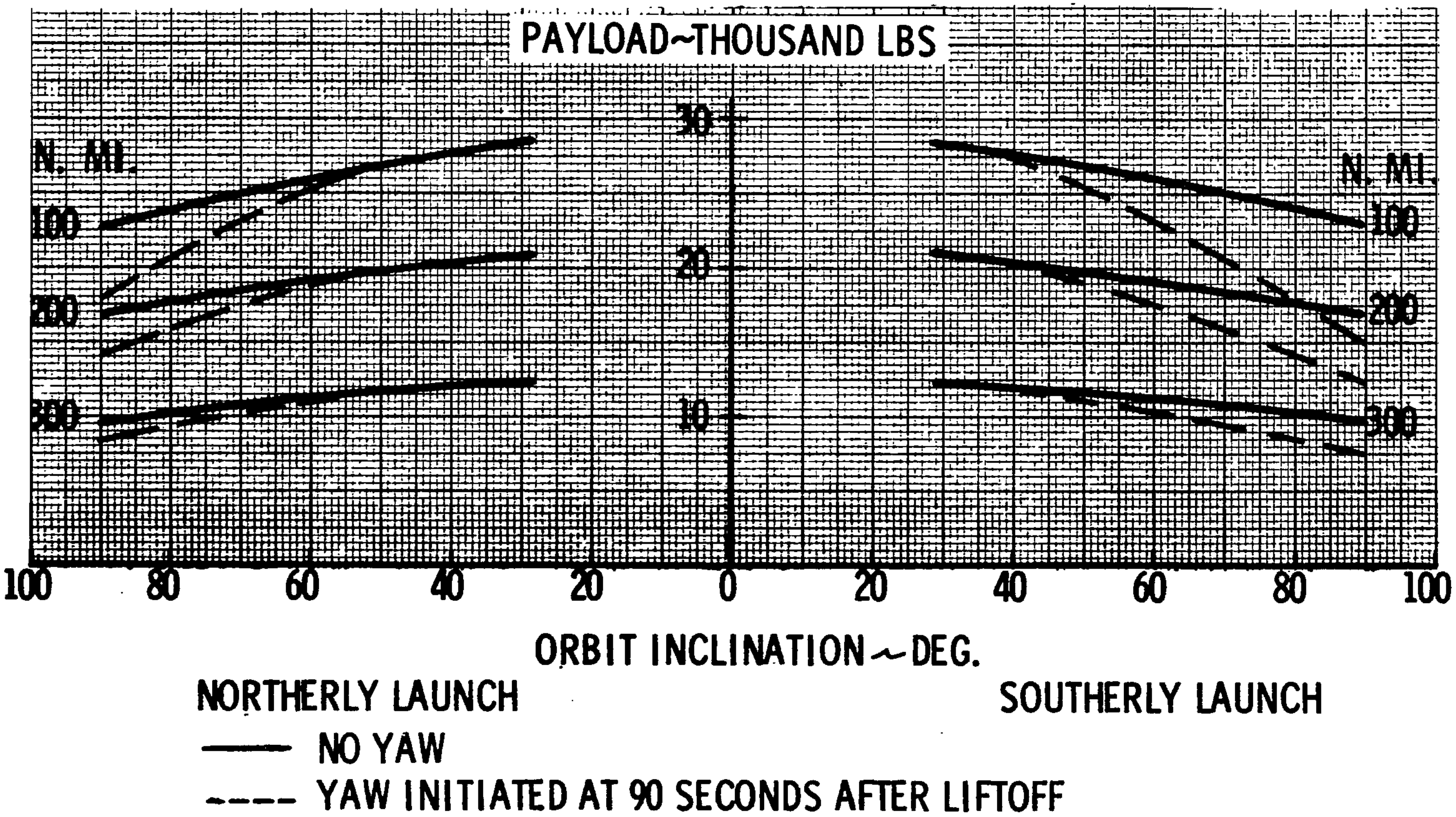


Figure B-10. Titan IIID payload capability to circular orbit.

TABLE B-1. TITAN IIIC AND TITAN IIID PAYLOAD CAPABILITY TO 200-N. MI. CIRCULAR ORBIT WITH 28.5-DEGREE INCLINATION

Direct Ascent

Vehicle	Payload (lb)
Titan IIIC	25 424
Titan IIID	20 922

Hohmann Transfer[a]

Vehicle	Payload (lb)
Titan IIIC	26 898
Titan IIID[b]	27 582

a. The vehicle was assumed to go direct-ascent to a 90-n. mi. perigee and circularize at a 200-n. mi. apogee.

b. Hohmann transfer was accomplished by adding a kick stage to the payload.

TABLE B-2. TITAN IIIC AND TITAN IIID PAYLOAD CAPABILITIES TO A 200-N. MI. CIRCULAR ORBIT WITH 28.5-, 20-, 15-, AND 10-DEGREE INCLINATIONS

Direct Ascent

Vehicle	28.5 deg. incl.
Titan IIIC	25 424 lb
Titan IIID	20 922 lb

Hohmann Transfer[a]

Vehicle	28.5 deg. incl.	20 deg. incl.	15 deg. incl.	10 deg. incl.
Titan IIIC	26 304 lb	16 148 lb	11 069 lb	6816 lb
Titan IIID[b]	20 922 lb	-	-	-

a. The vehicle was assumed to go direct-ascent to a 100-n. mi. circular parking orbit with a 28.5-degree inclination and then a two-burn Hohmann transfer with necessary plane changes to a 200-n. mi. circular orbit.

b. Direct ascent (Core Stage II not restartable).

(1) The vehicle achieved a 100-n.mi. parking orbit.

(2) The 100-n.mi. parking orbit had a 28.5-degree orbital inclination.

(3) Hohmann transfer to a 200-n.mi. circular orbit.

(4) Necessary plane changes are made during Hohmann transfer to achieve desired orbital inclination.

4. Titan IIID Performance Capability

Based on recent data from Lewis Research Center, the preliminary estimate of Titan IIID spacecraft system weight (separated spacecraft, adapter, etc.) capability for the HEAO Mission is 20 641 pounds. A tabulation of vehicle weights and event times for selected flight events is given in Table B-3.

The ground rules for this performance analysis were as follows:

1. Launch azimuth — 93 degrees.
2. Direct injection into a 200-n.mi. circular orbit.
3. Orbital inclination — 28.5 degrees.
4. Shroud weight (40 feet long, 10 feet in diameter) — 2877 pounds.
5. Shroud jettison — T + 182 seconds (360 000 feet).
6. No spacecraft adapter nor any special spacecraft support equipment.
7. Titan Stage II modifications — 76 pounds.
8. Titan Stage II specific impulse — 313 seconds (vac).
9. Improved Centaur Guidance System substituted for BTL Radio Guidance System.
10. Flight performance reserves — 1800 pounds.
11. No launch vehicle contingency.

TABLE B-3. FLIGHT EVENTS AND WEIGHTS (HEAO-A MISSION)

Event	Time (sec)	Vehicle Weight (lb)
Lift-off	0.0	1 381 382
Solid motor burnout Stage I ignition	110.45	527 779
Solid motor jettison	121.45	346 375
Shroud jettison	182.00	237 338
Stage I burnout	253.92	111 238
Stage II ignition	254.92	93 998
Stage II burnout	458.63	29 261
Stage II jetison weight		8 620
Basic Stage II jettison weight	6444	
Stage II modifications	76	
Centaur guidance system	300	
FPR	1800	
Spacecraft system weight capability		20 641

It should be recognized that this performance analysis includes several uncertainties. Among these are the identification of the hardware penalties for modifications to the Titan IIID vehicle to accommodate the HEAO Mission and the determination of the trajectory simulation and the flight performance reserves. In addition to these performance aspects, it should also be recognized that a detailed evaluation of the interface of the Centaur Guidance System with the Titan IIID, including environmental considerations associated with guidance equipment relocation, will be required.

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