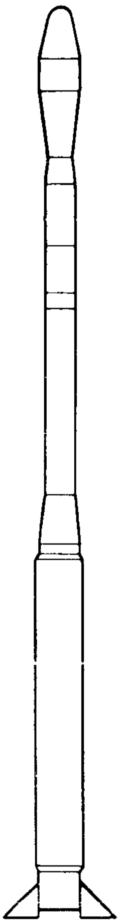
N72-24917

NASA CR – 112054

FINAL REPORT

ADVANCED SMALL LAUNCH VEHICLE (ASLV) STUDY



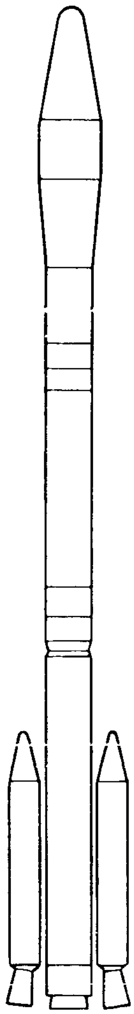
REPORT NO. T 186-1
8 MARCH 1972

SPONSORED BY

NATIONAL AERONAUTICS
AND
SPACE ADMINISTRATION

LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23365

CONTRACT NAS1-10848



VOUGHT MISSILES AND SPACE COMPANY

FINAL REPORT

ADVANCED SMALL LAUNCH VEHICLE STUDY

REPORT NO. T186-1

8 MARCH 1972

CONTRACT NAS1-10848

SPONSORED BY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23365

Prepared by:

G. E. Reins
J. F. Alvis

Reviewed by:

A. I. Sibila

Approved by:

M. Green

VOUGHT MISSILES AND SPACE COMPANY
LTV AEROSPACE CORPORATION
DALLAS, TEXAS 75222

NASA CR-112054

FINAL REPORT

ADVANCED SMALL LAUNCH VEHICLE STUDY

Prepared under Contract No. NAS1-10848

by

VOUGHT MISSILES AND SPACE COMPANY
LTV AEROSPACE CORPORATION
DALLAS, TEXAS 75222

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23365

FOREWORD

This final report presents the results of a nine-month conceptual design study performed by the Vought Missiles and Space Company (VMSC), LTV Aerospace Corporation, to determine the most economical approach for an Advanced Small Launch Vehicle (ASLV) for use over the next decade. The design study was conducted under NASA Contract NAS1-10848 during the period from May 1971 to February 1972 and monitored by the Scout Project Office at the NASA Langley Research Center. The Technical Representative was W. C. Hoggard, with T. L. Owens assisting. Other key Scout Project Office contacts were R. D. English, S. J. Ailor, A. Leiss, J. L. Allen, Jr., and V. D. Crowder. VMSC also wishes to express its appreciation to the following companies for their contributions to this study: Hercules, Incorporated, Bacchus Works; Thiokol Chemical Corporation; Aerojet General Corporation; United Technology Center, Division United Aircraft Corporation; Kearfott Division, Singer-General Precision, Inc.; Hamilton Standard Division, United Aircraft Corporation; Teledyne Systems Company; Litton Industries; General Electric Company; Honeywell; and TRW Systems.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

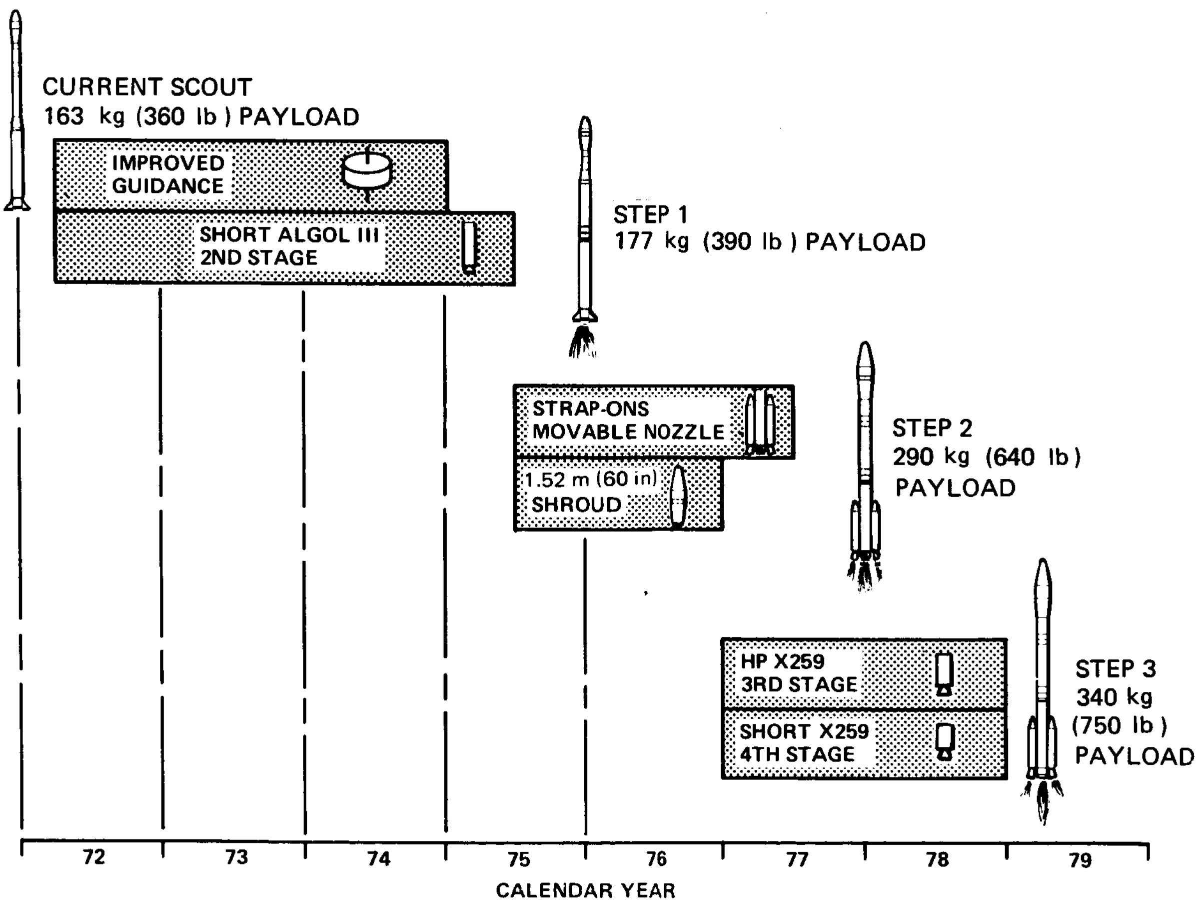
LIST OF TABLES

LIST OF TABLES (Continued)

1.0 SUMMARY

A conceptual design study was conducted to determine the most economical (lowest cost/launch) approach for the development of an Advanced Small Launch Vehicle (ASLV) for use over the next decade. The ASLV design objective was to place a 340 kg (750 lb) payload into a 556 km (300 n.mi.) circular orbit when launched due east from Wallops Island, Virginia. The investigation encompassed improvements to the current Scout launch vehicle; use of existing military and NASA launch vehicle stages; and new, optionally staged vehicles. Staging analyses included use of liquid, solid, and hybrid propellants. Improvements in guidance, controls, interstages, telemetry, and payload shroud were also considered.

It was concluded that the most economical approach is to progressively improve the Scout launch vehicle in three phased steps, as shown below.



This approach was selected because it:

(1) Provides improved orbit injection accuracy at an early date and preserves Scout payload capability,

(2) Exhibits a suitable, economic means for performing payload missions in the current Scout range (deletion of Strap-on),

(3) Incorporation of third and fourth stage motors as the final steps permits consideration of any improvements in propulsion stage-of-the-art during the first five years (I_{SP}, Mass Fraction and Stop/Start),

(4) Requires commitment for only one step at a time and permits periodic redirection of launch vehicle objectives, if desired or required,

(5) Keeps peak fiscal year funding under $2.5 million, and

(6) Yields the design payload and improved orbital accuracy at an average unit launch cost of $2.97 million. (Includes $0.25 million of amortized development cost.)

The end product is a four stage ASLV with an optional fifth stage for high velocity missions. The first stage consists of the Scout Algol III, augmented with two Castor II strap-ons. The second stage is a shortened Algol III. Both first and second stage Algol III motors have movable nozzles. The third stage uses the Scout HP X259 motor with a modified nozzle to increase chamber pressure and the fourth stage consists of a shortened X259 with a contoured nozzle. When a fifth stage is required, the FW5 motor provides near maximum performance. For missions in the current Scout payload range, the two Castor II strap-ons are deleted.

Vehicle improvements include replacement of the Scout third stage open loop guidance by an improved fourth stage guidance system; fourth stage attitude stabilization and vernier velocity control capability. To accommodate the larger payloads, the shroud diameter was increased from 107 cm (42 in) to 152 cm (60 in). Total ASLV lift-off weight is approximately 36400 kg (80200 lb) compared to 21500 kg (47400 lb) for the current Scout.

Required changes to ground support equipment (GSE) and facilities included guidance system checkout equipment and modifications to the launcher and transporter because of the increase weight and configuration profile. The impact on the remaining GSE was minor. Required GSE modifications can be accomplished without impairing the ability to assemble, checkout and launch the present Scout with the modified GSE.

2.0 INTRODUCTION

Since its first operational flight in 1960, the NASA/DOD Scout has launched a wide variety of small scientific and applications satellites on orbital, reentry, and probe missions. During this period of operation, planned improvements have increased both the payload carrying capacity and flight reliability. For example, payload into a 556 km circular orbit has been stepped-up three-fold to the current 163 kg. This performance improvement has been carefully programmed to preserve the high demonstrated flight reliability of 52 successes in 55 flights, with 23 consecutive successes presently. At the same time, the average unit launch cost of Scout has risen only moderately during this period.

Looking ahead toward the next decade, however, the role of the small launch vehicle must be re-examined in anticipation of more diverse and increasingly stringent mission requirements. The relationship between Scout and the other launch vehicles within the NASA inventory, including the space shuttle, also plays an integral part in establishing the requirements for a Scout-class launch vehicle for use during the next decade.

2.1 OBJECTIVE AND SCOPE

The objective of this study was to define the most economical approach of meeting Scout-class launch vehicle requirements - launch requirements which cannot be economically met by other space booster systems. In ascertaining the most economical approach, the whole spectrum of configurations was considered - ranging from an updated Scout which capitalizes on existing hardware, facilities and GSE, to development of a completely new launch vehicle designed specifically to fulfill the mission requirements defined herein.

2.2 STUDY GUIDELINES

This study was performed under the following technical guidelines:

(1) Payload capability up to 340 kg for an easterly launch from Wallops Island, Virginia, into a 556 km circular orbit.

(2) Provision for elliptical orbit, planetary probe, reentry, and transfer missions.

(3) Payload step-down capability to the current Scout performance range.

(4) No single configuration is required to satisfy all vehicle missions.

(5) Use of solid, liquid, and hybrid propellants was to be considered. Motor cut-off and shut-down capabilities and their effect on mission performance were also to be investigated.

(6) Emphasis was to be placed on inherent reliability in the development of the conceptual design.

(7) In consideration of upgrading the present Scout launch vehicle, cost comparisons were to consider modifications of vehicle subsystems in addition to motors.

(8) Expected launch rate of five launches per year over a ten-year period.

(9) Vehicle costs were to be amortized over the anticipated launch rate. Costs of currently planned Scout subsystem improvements were to be noted but kept separate and not amortized.

(10) Consideration was to be given only to launch vehicle subsystems within the state-of-the-art. SOA is defined as subsystems which will require no new development for availability consistant with launch date requirement. Modifications or changes to existing flight hardware are not considered development improvement in the SOA.

(11) Launch complex and ground support equipment requirements were to be determined, but associated costs were to be listed separately and not amortized.

(12) Reliability and launch accuracy as well as improvement of payload capability were to be considered.

2.3 STUDY APPROACH

VMSC's approach to determine the most economical launch vehicle for Scout-class mission requirements was to (1) establish additional launch vehicle requirements, (2) synthesize and analyze candidate launch vehicles,

(3) screen the various configurations on the basis of performance, design and cost, (4) select the most promising and economical launch vehicle concept, (5) lay out a conceptual design and appraise its detailed performance, reliability, and cost, and (6) prepare a development plan for the ASLV.

To insure an objective study, two approaches, each with a similar baseline performance, were developed and evaluated. The first approach emphasized a logical growth pattern for Scout through a series of incremental improvements. Various combinations of stage improvements, strap-ons, and new stages, coupled with other subsystem improvements, were investigated. The second approach emphasized new vehicles based on optimized arrangements of motors, including consideration of those available in the national inventory, together with state-of-the-art subsystems.

The decade, or 10 year program, as discussed above is interpreted to be the time period 1975 to 1985.

3.0 LAUNCH VEHICLE REQUIREMENTS

Looking back at the first fourteen years of space flight, certain trends have been observed in regard to payloads and missions. As larger payload capability becomes available, spacecraft designers soon seize the opportunity to take advantage of these gains, either through inclusion of more scientific equipment or by relaxing weight and volume restrictions. As a result, the trend has been toward larger and heavier payloads and this trend is expected to continue into the next decade. At the same time, the trend has shifted towards more diverse and sophisticated missions, placing ever-expanding requirements on launch vehicle versatility and accuracy.

In establishing requirements for the ASLV, it was imperative. therefore, to (1) obtain the best possible mission model for the intended operational period, (2) establish accuracy goals to aid in the definition of guidance hardware, and (3) examine past and planned spacecraft dimensions to determine payload volume requirements and shape parameters for the ASLV payload shroud design.

A list of data sources, which provided the bulk of the information on projected missions and launch vehicle requirements, is given in Table 1.

3.1 MISSION ANALYSIS

A comprehensive review of total projected NASA unmanned launch vehicle requirements was undertaken to determine launch schedules, frequencies, and mission distributions, including the occurrence of missions with special orbits - orbits that demand unique launch vehicle features. Scout missions, both past and planned, were also analyzed. A mission model was then constructed for the ASLV to assist in definition of vehicle subsystem requirements. A quantitative assessment of the impact of the shuttle, as it becomes operational, has also been made.

3.1.1 Launch Schedules and Frequencies.

Estimates of unmanned launch vehicle requirements represent, to a large extent, a compromise between overall NASA planning activities and budget projections. It is not uncommon, therefore, to see a spectrum of mission models which reflect variations in emphasis on the space topics

TABLE 1 - DATA SOURCES FOR DEFINITION OF MISSION REQUIREMENTS

DATA SOURCE	MISSION INFORMATION
o 1961 NASA Space Task Group Report (Ref. 1)	Projected Launch Schedules for 3 Mission Plans.
o 1968 NASA Lewis Unmanned Launch Vehicle Program for the 1970 Decade (Ref. 2)	Launch Vehicle Requirements and Launch Schedules
o Current Space Experiments Support Program (SESP) (Ref. 3)	Experiment Type & Characteristics, Spacecraft Requirements, Mission Data
o 1970 Space Science & Applications (OSSA)(Ref. 4)	Approved Unmanned Launches, Expt. Type, Launch Vehicles, Mission Data
o SATS Program & Spacecraft Study Report (Ref. 5)	Experimental Orbits for SATS Applications
o Role of Small Satellites in Space Application Missions (Ref. 6)	Orbit Data for Space Applications Missions
o Modular Spacecraft Vehicle Study (Ref. 7)	Mission List for MSV Study
o Selected Space Goals & Objectives & Their Relation to National Goals (Ref. 8)	Spacecraft & Mission Data for Various Space Experiments
o Estimates of Future Automated Space Mission Models for Use in NASA Launch Vehicle Planning (Ref. 9)	Comprehensive Mission Models, Launch Vehicle Requirements
o Low Cost Launch Vehicle Families for Automated Missions (Ref. 10)	Preliminary Mission Model for Low Cost Launch Vehicle Study
o Small Launch Vehicle Mission Models for 1971-1990 (Ref. 11)	Projected Thor Delta and Scout Missions for the next 20 years; Assessment of Space Shuttle on Mission Schedules.

(e.g., physics, astronomy, planetary, applications, etc.) as well as forecasted funding levels. A representative cross-section of total OSSA launch vehicle requirements is presented in Table 2. The first three models were derived from Reference 9, the NASA Lewis model was obtained from Reference 2, and the mission model for the Low Cost Launch Vehicle Family was excerpted from Reference 10. The latter model does not include Scout-class launches. The Battelle Memorial Institute report (Reference 9), recommended the first three mission models for future planning purposes. These models reflect nominal, low, and high flight activity, respectively, for the next eleven years. Since these models correspond to fluctuations in funding levels, it should be expected that, as funding varies, emphasis will shift between space projects and, hence, requirements for the types of launch vehicles will also vary. This aspect is illustrated in Table 3, which identifies Scout launch vehicle requirements for various mission models.

The Battelle Mission model for the nominal funding level calls for a larger number of Scout launches than the one for the high funding level, where emphasis shifts towards the larger, more costly launch vehicles. With low funding levels, Scout launches are reduced along with launches of all other NASA launch vehicles. Nonetheless, the lowest projected Scout launch rate is still 6.7 per year. The 1968 NASA Lewis model shows an average launch rate of 4.9 per year. Review of Scout launch schedules, including future planning for the 1970-75 time frame, indicates an average launch frequency of 8.8 per year. Thus, it appears that a launch rate of 5 per year established in the guidelines is a conservative number for the ASLV mission model, particularly in view of the planned payload increase that was not apparent when these models were drafted.

The effect of the Space Shuttle on the ASLV mission model was assessed from the information of reference 11. This study shows that the number of Scout missions in the 1971-1990 time period is reduced only slightly by introduction of the Shuttle in 1979 from a total of 146 (7.3/yr) launches without the Shuttle to 135 (6.8/yr) with the Shuttle. This small reduction is not unanticipated since current indications that the space transportation system of the 1980's will consist primarily of the Shuttle

TABLE 2 - ESTIMATES OF TOTAL OSSA LAUNCH VEHICLE REQUIREMENTS

SOURCE/MODEL	YEAR												Total	Avg. No. Launches Per Year
	70	71	72	73	74	75	76	77	78	79	80	81		
Battelle Models														
Nominal		23	23	27	34	31	27	30	33	32	29	28	317	28.8
Low		21	19	27	30	27	22	28	26	33	28	24	285	25.9
High		24	23	34	36	35	33	34	34	41	31	30	355	32.3
1968 NASA Lewis Unmanned Launch Vehicle Program	13	12	14	21	19	18	24	23	16	17			177	17.7
Low Cost Launch Vehicle Families for Automated Missions		10	15	19	19	25	24	29	27	32	22	22	244	22.2

TABLE 3 ESTIMATES OF SCOUT LAUNCH VEHICLE REQUIREMENTS

SOURCE/MODEL	YEAR												Total	AVG. NO. LAUNCHES PER YEAR
	70	71	72	73	74	75	76	77	78	79	80	81		
Battelle Models														
Nominal		9	7	10	10	10	10	11	9	11	8	8	103	9.4
Low		8	5	7	8	9	5	8	5	8	5	6	74	6.7
High		8	6	8	11	8	9	9	7	10	7	7	90	8.2
1968 NASA LEWIS UNMANNED LAUNCH VEHICLE PROGRAM/MISSION MODEL	5	4	5	5	5	5	5	5	5	5			49	4.9
SCOUT LAUNCH SCHEDULE, INCLUDING FUTURE PLANNING (1970-1975)(May 70)	4	12	6	8	13	10							53	8.8

and the Scout would portend a high Scout utilization. While the forecast of reference 11 did not specifically consider the effect of increased Scout capability such as being considered for the ASLV, the same reasoning would apply. Consequently, it is felt that the introduction of the Shuttle will have little impact on the number of ASLV launches.

3.1.2 Mission Classification and Distributions

Those mission models - the nominal funding level Battelle Model, the 1968 NASA Lewis model, and the Low Cost Launch Vehicle model were analyzed in further detail with the objective of categorizing the missions into general and special earth orbits, probe and reentry launches, and earth escape trajectories. Past and presently planned Scout launches were also categorized in the same manner. The resulting distributions of missions in the various orbit categories are given in Table 4.

Missions were categorized and subdivided as shown, because each of the entries places varying requirements on a launch vehicle and these requirements, in conjunction with the distribution of missions, are useful in establishing ASLV requirements. Special earth orbits, which constitute a large percentage of the missions, were categorized separately because they impose more demanding requirements on the launch vehicle than the remainder of the missions. These special orbits, their applications, and related special requirements are outlined in Table 5.

All special orbits require accurate orbit insertion. For example, Atmospheric Explorer-type missions generally require tolerances of about 10 km on perigee altitude (Reference 3). Similarly, sun-synchronous missions dictate tolerances of 35 to 55 km on altitude and 0.3 degrees on inclination (Reference 12) in order to achieve desired operational lifetime. Accuracy requirements are discussed in greater detail in Section 3.2.

Restart on the injection stage is desirable, though not essential for all but the first special orbit category in Table 5 because it improves payload capability. Elliptic orbits with specified arguments of perigee and injection into synchronous transfer orbits require use of a high velocity upper stage for injection into these orbits. A parking orbit capability is also necessary for the latter two missions in order to

TABLE 4

COMPARISON OF MISSION MODELS

MISSION	Distribution of Missions (%)				
	1968 Lewis Model	Battelle Model Nominal	Low Cost Model (1)	Past Scout	Planned Scout
Earth Orbits					
Circular (Alt < 556 km)	8.8	11.1	4.4	3.0	9.4
(Alt > 556 km)	17.7	15.9	9.1	7.5	24.6
Elliptic (Perigee 278-556 km)	5.5	6.6	3.4	22.4	18.9
(Perigee > 556 km)	0	1.1	0.3	13.4	0
Special Orbits					
Elliptic Orbits (Perigee < 278 km)	6.1	4.4	9.4	0	0
Specified Orbit Precession (Alt > 556 km)	26.0	23.6	22.6	0	37.8
Specified Argument of Perigee	0.6	0	0.3	31.3	1.9
Injection into Synch Transfer	13.2	21.9	29.9	0	0
Synchronous Orbit	3.3	4.0	4.4	0	0
Earth Ballistic					
Probes	1.1	0	0.7	7.5	3.7
Reentry	1.7	0.7	0.7	14.9	3.7
Earth Escape	16.0	10.7	14.8	0	0

(1) Planned Scout Missions Included

TABLE 5 - SPECIAL ORBIT APPLICATIONS

ORBIT	APPLICATIONS	LAUNCH VEHICLE REQUIREMENTS
Elliptic Orbit/Perigee $<$ 278 km	Atmosphere Explorers, IMP type Experiments	Improved Accuracy
Specified Orbit Precession/ Altitude $>$ 556 km	Sun-Synchronous, Geodetic, Transit, Mapping, Survey, SATS, Meteorology	Improved Accuracy; Restart Desirable
Elliptic Orbit/Specified Argument of Perigee	12 Hour Communication, Injun VI	Improved Accuracy, Parking Orbit Capability; High Velocity Upper Stages, Restart Desirable
Injection into Synchronous Transfer Orbit	Concept Test and Checkout for Communication, Meteorology, Navigation Satellite Equipment.	Improved Accuracy; Parking Orbit Capability; High Velocity Upper Stages, Restart Desirable.

orient the vehicle for injection into the desired orbit.

3.1.3 Selected ASLV Mission Model

Using the mission models of Table 4 as guides, the ASLV mission model presented in Table 6, was developed. In arriving at this model, consideration was given to the mission trends in Table 4, the projected improvement in payload capability, and the peculiar attributes and short-comings of a small launch vehicle of the Scout-class. For example, Scout has historically been a good candidate for reentry and probe missions and it is anticipated that Scout will continue to launch a small number of these types of payloads for both NASA and DOD. Thus, two and three missions have been assigned to probe and reentry, respectively, in the ASLV model.

Scout has never been used to place a payload into an earth escape trajectory, although capability exists to inject about 45 kg into a solar probe trajectory with the five stage Scout. The ASLV, with a projected escape capability in excess of 90 kg, is expected to launch a limited number of these missions and four launches have been allocated. This might include such potential spacecraft as advanced solar electric propulsion for out-of-the-ecliptic excursions.

The large number of launches assigned to the special orbits is in consonance with the projected trends of future missions and correlates directly with both the NASA and Scout models. The relatively large number of missions in the "specified orbit precession" category is attributed to the Navy's Transit navigation satellites and applications-type missions in sun-synchronous orbits. The ASLV, with a synchronous transfer payload capability between 135 and 160 kg is expected to launch a number of space-craft into this type of orbit.

3.1.4 Requirements for Special Launch Vehicle Features

Table 6 also outlines the areas where improvement or new features are required, or desired, over those of the current Scout. In view of the total number of missions that are flagged for additional accuracy, an improvement in this area is deemed necessary. Likewise, a parking orbit requirement with attendant attitude control and reorientation capability is indicated for a substantial number of launches. Restart capability will improve payload capability significantly for medium to high circular orbits

TABLE 6 SELECTED ASLV MISSION MODEL

MISSION	PERCENT* MISSIONS	IMPROVED ACCURACY	PARKING ORBIT	RESTART CAPABILITY	HIGH VELOCITY UPPER STAGE	PREDICTED NUMBER MISSIONS
EARTH ORBITS						
CIRCULAR (ALTITUDE < 556 km)	8.1	YES	NO	NO	NO	5
(ALTITUDE > 555 km)	14.2	NO	NO	DESIRABLE	NO	7
ELLIPTIC (PERIGEE 278-556)	5.2	NO	NO	NO	NO	5
(PERIGEE > 556 km)	0.5	NO	NO	DESIRABLE	NO	0
SPECIAL ORBITS						
ELLIPTIC ORBITS (PERIGEE < 278 km)	6.6	YES	NO	NO	NO	3
SPECIFIED ORBIT PRE- CESSION (> 555 km)	24.2	YES	NO	DESIRABLE	NO	12
SPECIFIED ARGUMENT OF PERIGEE	0.3	YES	YES	DESIRABLE	YES	4
INJECTION INTO SYNCH TRANSFER	21.6	YES	YES	DESIRABLE	YES	5
EARTH BALLISTICS						
PROBES	0.6	NO	NO	NO	SOME MISSIONS	2
REENTRY	1.0	NO	NO	NO	SOME MISSIONS	3
EARTH ESCAPE	13.8	DESIR- ABLE	DESIR- ABLE	DESIRABLE	YES	4
						50 TOTAL

*AVERAGE OF LEWIS, BATTELLE, AND LOW COST MODELS and will also provide payload gains for missions requiring a parking orbit. While restart presents no problem for liquids, this feature is considered borderline insofar as current state-of-the-art in solid propellant motor technology and is therefore treated as a growth item - one that should be available in the second-half of this decade. Requirements for a kick stage on high velocity missions are also noted in Table 6. A synopsis of launch vehicle requirements, discussed above, is given in Table 7.

3.2 ACCURACY REQUIREMENTS

3.2.1 Approach and Ground Rules - The mission model Section 3.1.3 disclosed a need for improved guidance accuracy on future missions. The approach taken in establishing accuracy requirements for the ASLV was to examine the experimentors' requirements and compare these with analysis where possible. Accuracy requests for both past and projected missions were collected from experimentors and reviewed. Care was exercised to insure that accuracy data thus obtained reflected initial user requirements and not the launch vehicle accuracy. When accuracy data were lacking for specific missions, requirements were estimated based on the knowledge of the mission objectives. The combined accuracy information was then analyzed, grouped, and correlated with the ASLV mission model.

Payload accuracy data were obtained from Scout records, SAMSO/SESP reports (Reference 3), and discussions with spacecraft designers and experimentors. In all, accuracy requirements for a total of 82 missions were compiled, including 47 Scout launches, 16 SAMSO/SESP payloads, 14 missions identified by spacecraft designers and 5 missions for which accuracies were estimated. The last five missions encompass gravity gradient, 12 hour communication satellite, sun-synchronous, synchronous transfer, and quasi-synchronous. Each of these types of missions have specific requirements, but accuracy data were not found in the list of spacecraft designer's requests, except for the sun-synchronous missions. Rationale for establishing accuracy requirements on these five missions is given below.

Gravity Gradient - To achieve adequate pointing accuracy with satellites that are stabilized via gravity gradient booms, orbit eccentricity must be minimized. Using an allowable pointing error of 3 degrees as

TABLE 7 - LAUNCH VEHICLE REQUIREMENTS

REQUIREMENT	PERCENT OF MISSIONS
Improved Accuracy	66
Parking Orbit Capability	26
Restart Capability	0*
High Velocity Upper Stage	30

*Not required, but desirable for 64% of missions.

an acceptable maximum deviation the maximum allowable orbit eccentricity becomes 0.0525.

12 Hr. Communication Orbit - Another mission of interest is a 12 hour highly elliptic communication satellite which, for example, could dwell over the U.S. for an extended period on every revolution to permit continuous communication between the east and west coast during this dwell period. Tight control on both period (and, hence, apogee/perigee altitudes) and inclination are required to control apsidal advance and orbit precession so that the orbit remains in a propitious orientation for communication. In establishing accuracy requirements for this mission, it was assumed that orbit parameters would be controlled to permit communication between the east and west coast of the U.S. on every revolution for a period of one month.

Sun-Synchronous Orbit - A mounting number of spacecraft, particularly in the applications area, are being placed into sun-synchronous orbits due to the inherent advantage of this type of orbit for geological, agricultural, and meteorological mapping. In view of this, an analytical investigation was conducted to complement, as well as verify, the accuracy data obtained from the payload agencies. The key to success of this mission lies in close control of the orbital precession rate, which is functionally dependent on orbital period (or altitude) and inclination.

A 15 degree deviation in the orbital precession over a period of a year was selected as an accuracy goal because an angular drift of this magnitude appears to be acceptable for the success of most missions.

Synchronous Transfer - Another prominent mission involves the placement of a spacecraft on a synchronous transfer trajectory. The ASLV with a projected payload weight between 135-160 kg for this mission, appears attractive for concept test and validation of new communication, meteorology, and navigation equipment. The approach would be to retain the spacecraft in the synchronous transfer orbit, rather than injecting it into the synchronous orbit, since this orbit partially simulates the environment of a true synchronous orbit. Accuracy requirements for this mission were thus formulated to permit the spacecraft to achieve near synchronous altitudes for approximately 2 hours each side of apogee.

Alternately, if injection into a true synchronous orbit is desired, an apogee kick motor, usually considered part of the spacecraft, is used to inject into the true synchronous orbit. Since orbit maneuvering and stationkeeping is generally considered necessary for this mission, it was assumed that the above accuracy requirements for the synchronous transfer orbit would be sufficient because onboard propulsion could be used to eliminate remaining injection errors.

Quasi-Synchronous Orbits -Closely related to the synchronous transfer mission, the quasi-synchronous orbit offers complementary advantages. While this orbit does not reach synchronous orbit altitude, it permits the spacecraft to dwell over a fixed location on the earth for extended periods with very little relative motion. Apogee altitude must be controlled to $\pm$1850 km or less to obtain success on missions of this type.

3.2.2 Accuracy Summary

Accuracy information on the 82 missions fell into various mission categories as outlined in Table 8. Allowable altitude deviations are presented in terms of percent. This method was found most advantageous in the correlation of the accuracy data from the many sources and individual missions. Both average and minimum accuracy requirements are indicated. The average value represents a weighted average of all data points within each category, while the minimum value corresponds to the most stringent requirement observed within each group. Prior to tabulation, requirements in each category were reviewed and those which were found to have either very loose or unrealistically tight requirements (due to special applications) were eliminated; hence, information in Table 8 represents weighted values.

To aid in the definition of orbital accuracy requirements, data from Table 8 were converted into dimensional units. Figure 1 depicts accuracy requirements for circular and near-circular orbits. The cross-hatched areas in this curve are bounded by mean and minimum accuracy requirements. The allocation of the number of missions in accordance with the ASLV mission model is also shown.

Low altitude, circular orbits are usually employed in exploratory-

TABLE 8 MISSION ACCURACY SUMMARY

Part I: Orbital and Escape Missions

MISSION	Projected No. of ASLV Missions	ΔH (%)		ΔH_A (%)		ΔH_P (%)		Δi (DEG)		COMMENTS
		AVG	MIN	AVG	MIN	AVG	MIN	AVG	MIN	
CIRCULAR ORBIT: $H < 740$ km	5	33.0	25.0	-	-	-	-	0.30	0.15	
$H \geq 740$ km	7	13.0	7.0	-	-	-	-	5.00	1.00	
ELLIPTIC ORBIT: $H_p \leq 278$ km	3	-	-	20.0	3.3	12.0	2.3	5.00	1.00	H_P BASED ON 1 YEAR LIFETIME
$H_P > 278$ km	5	-	-	5.0	3.2	7.0	3.0	0.50	0.20	
SPECIFIED ORBIT PRECESSION	12	-	-	5.0	3.1	6.0	3.1	0.45	0.13	SUN-SYNCH & TRANSIT MISSIONS
SPECIFIED ARG. OF PERIGEE	2	-	-	1.0	0.7	10.0	7.5	1.00	0.50	12 HR ORBIT ESTABL. MIN. TOLERANCES
SYNCHRONOUS TRANSFER & QUASI-SYNCHRONOUS	7	-	-	7.5	2.6	39.0	33.0	5.0	5.00	
EARTH ESCAPE	4	-	-	10.0	10.0	15.0	13.0	-	-	

Part II: Sub-Orbital Missions

MISSION	No. of ASLV MISSIONS	ΔH_E (%)		$\Delta \gamma$ (DEG)		$\Delta \alpha$ (DEG)		$\Delta \psi$ (DEG)		$\Delta \phi$ (DEG)		$\Delta \lambda$ (DEG)	
		AVG	MIN	AVG	MIN	AVG	MIN	AVG	MIN	AVG	MIN	AVG	MIN
REENTRY	3	2.0	0.4	3.00	0.70	0.34	9.05	0.37	0.25	0.17	0.05	0.17	0.05
EARTH PROBE	2	-	-	-	-	0.25	0.25	0.25	0.25	0.10	0.10	0.10	0.10

ΔH - ERROR IN CIRCULAR ORBIT ALTITUDE, PERCENT
ΔH_A - ERROR IN APOGEE ALTITUDE, PERCENT
ΔH_P - ERROR IN PERIGEE ALTITUDE, PERCENT
ΔH_E - ERROR IN REENTRY ALTITUDE, PERCENT

Δi - ERROR IN INCLINATION, DEG.
$\Delta \alpha$ - ERROR IN ANGLE-OF-ATTACK, DEG.
$\Delta \gamma$ - ERROR IN FLIGHT PATH ANGLE, DEG.
$\Delta \psi$ - ERROR IN VELOCITY HEADING, DEG.
$\Delta \phi$ - ERROR IN LATITUDE, DEG
$\Delta \lambda$ - ERROR IN LONGITUDE, DEG

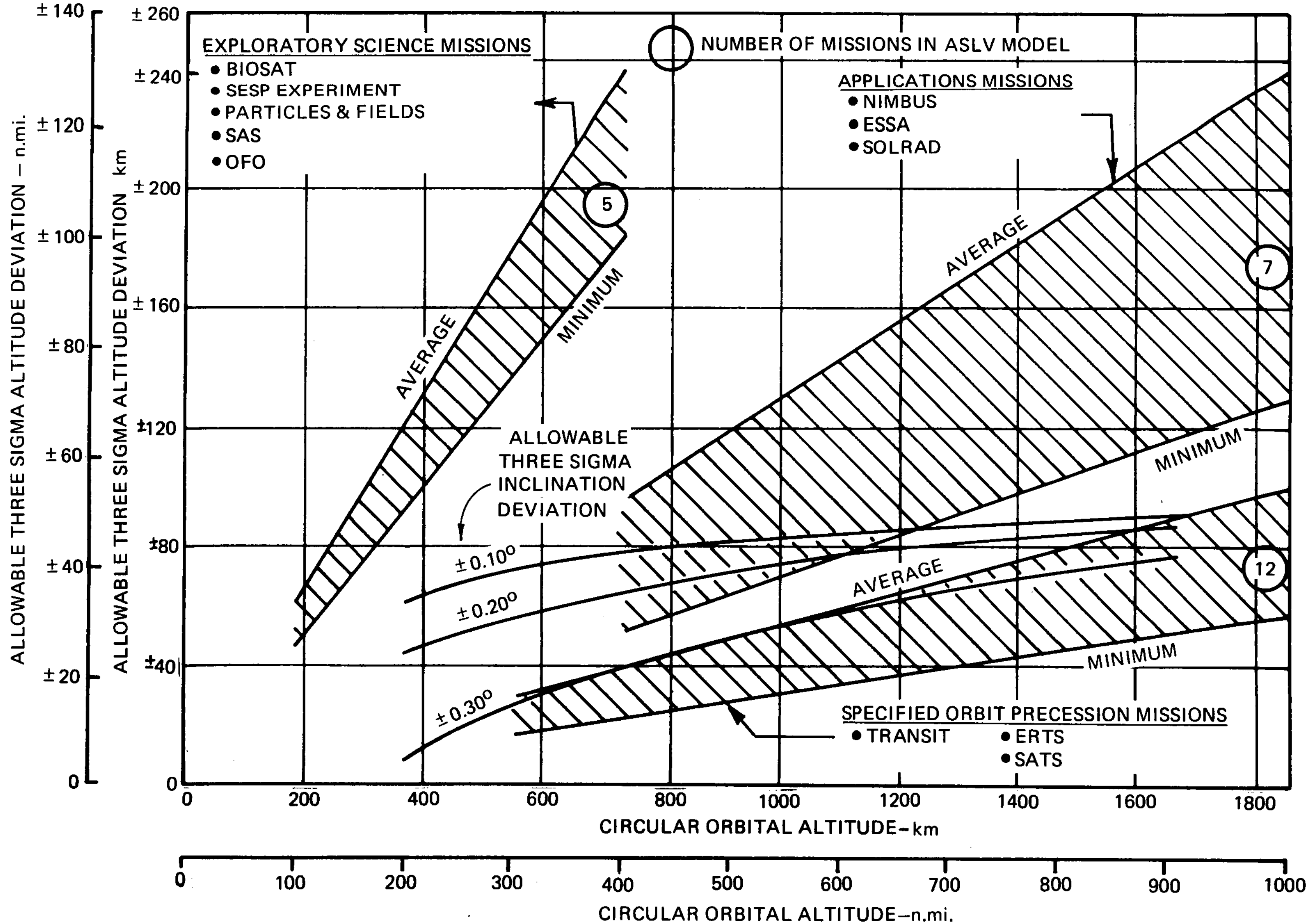


FIGURE 1 ORBIT ACCURACY REQUIREMENTS

type missions where accuracy is not critical, provided the desired life time is achievable. This is substantiated in Figure 1. Applications satellites, however, favor higher altitudes and require closer tolerance in percent of orbital altitude to fulfill mission objectives. The tightest tolerances are demanded by spacecraft that rely on a specified orbital precession rate for accomplishment of their mission objectives.

Information on orbits with specified orbit precession, shown in the related cross-hatched area, is based only on the accuracy data received from payload agencies. For comparison, three curves for the same mission, but representing various inclination accuracies, have been superimposed on Figure 1. These curves were calculated analytically and are based on a three sigma deviation of 15 degrees in the precession of the orbital plane over a period of a year.

The current Scout three-sigma deviations in altitude and inclination are about ±340 km and ±1.2 degrees, respectively, for a 1111 km circular orbit. Improvements in both parameters are necessary to meet the indicated requirements. If full inertial guidance is incorporated in the ASLV design, an inclination accuracy on the order of 0.1 degrees can be expected. With this accuracy, altitude errors up to about ±90 km can be tolerated on sun-synchronous mission. If augmented open-loop guidance, with a forecasted inclination accuracy of about 0.3 degrees, is implemented, orbit altitude errors must be limited to about ±50 km for this mission.

Analysis of accuracy requirements for the sun-synchronous mission and those for the remainder of the missions in Table 8 showed that the sun-synchronous mission placed the most stringent accuracy requirements on the launch vehicle. This mission, therefore, defined the accuracy requirements for the ASLV. This mission was therefore chosen to define the accuracy goals for the ASLV. However, it should be kept in mind that the degree to which such requirements are met needs to be tempered with trade-offs in guidance subsystem cost, weight, and technical risks, as well as with judgement based on past experience in meeting user requirements. Guidance subsystem trade-offs as related to accuracy requirements are reviewed in greater detail in Section 5.0.

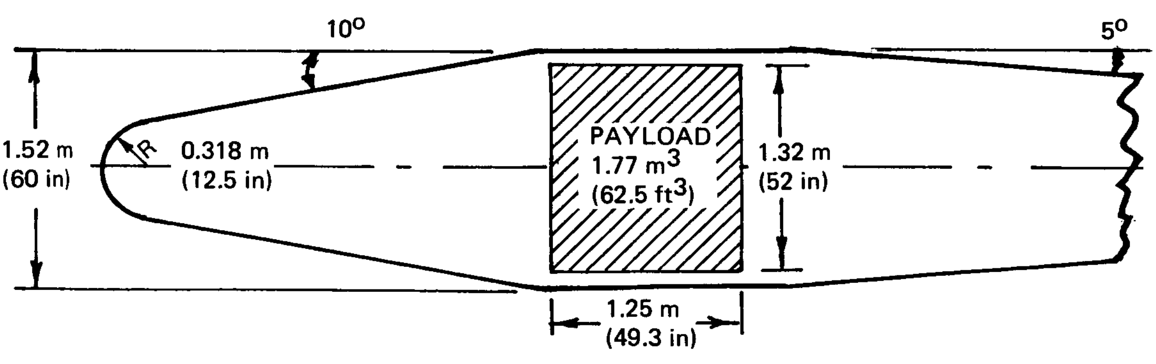
3.3 PAYLOAD SHROUD REQUIREMENTS

A survey of spacecraft densities and dimensions was made to establish envelope requirements for the design payload of 340 kg. Information was compiled on a total of 40 spacecraft within the weight region of interest.

Spacecraft densities resulting from this survey are illustrated in Figure 2. A selected average density of 192 kg/m^3 was used as a reasonable design number for payload shroud design purposes. For the 340 kg payload weight, the required payload volume with this density is 1.77 m^3. Payload dimensional data are presented in Figure 3 in terms of length-to-diameter ratio (L/D). A selected average value of 0.94 for L/D was used as a guide for payload shroud design purposes.

It was considered desirable, as a design goal, to define the payload shape as cylindrical. With the selected volume and L/D values derived above, the corresponding payload cylinder diameter is approximately 1.32 m and the associated length is 1.25 m. An allowance of 20.3 cm was added to the basic payload diameter for shroud structure and payload clearance giving a shroud outside diameter of 1.52 m.

Additional detail shroud design requirements for nose radius, nose cone angle, and boattail angle were defined as shown in the sketch below.



These factors were based primarily on aerodynamic drag and buffet considerations stemming from experience with the design of the Scout 1.066 m diameter payload shroud.

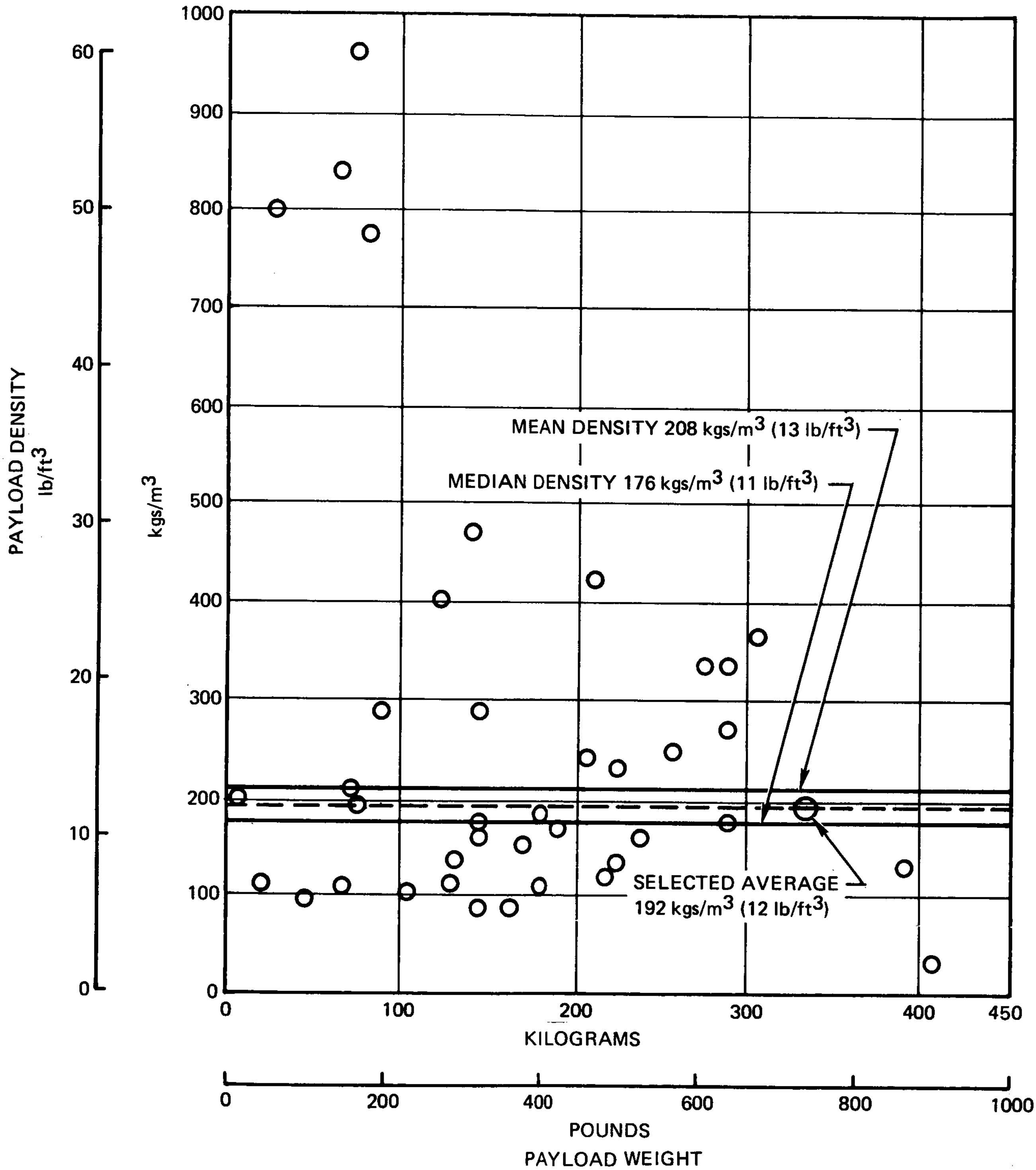


FIGURE 2 SMALL SPACECRAFT DENSITY MODEL

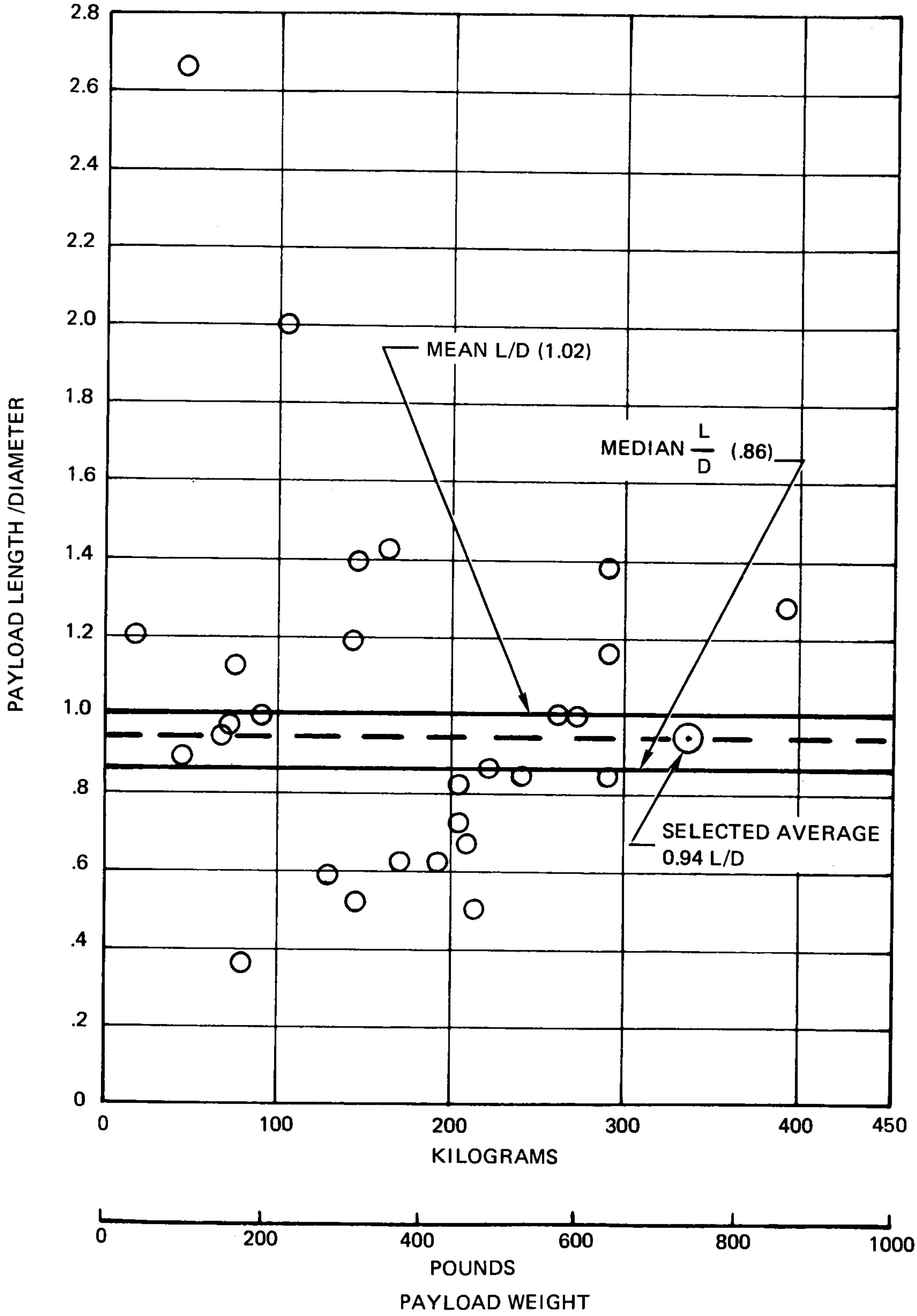


FIGURE 3 SMALL SPACECRAFT DIMENSIONAL CHARACTERISTICS

4.0 LAUNCH VEHICLE SYNTHESIS AND ANALYSIS

Definition of the most economical approach for satisfying the design payload launch requirements dictated careful consideration of a broad range of launch vehicle configurations - from upgrading the current Scout vehicle to development of a completely new vehicle tailored specifically to the guidelines and requirements delineated in Sections 2.0 and 3.0. Accordingly, an orderly, systematic approach was taken to (1) identify potential staging arrangements, (2) synthesize conceptual configurations, and (3) select and evaluate the most practical and economical launch vehicle.

Staging arrangements were grouped into two categories: Improved Scout configurations and New Launch Vehicles. In the Improved Scout category, stage improvements, replacement of current motors with new motors, and use of strap-ons were considered individually and collectively. Two avenues were pursued in the definition of New Launch Vehicles. The first was directed towards definition of new, optimally staged vehicles to satisfy mission requirements. Both liquid and solid propellant configurations were considered. The second focused on adaptation of existing booster and launch vehicle hardware; specifically, Minuteman, Polaris/Poseidon, and Thor Delta stages.

Synthesis of individual configurations was accomplished by sizing selected stages so as to allow the launch vehicle to place a 340 kg payload into a 556 km circular orbit. For new, optimally staged vehicles, all stages were sized to satisfy this mission requirement at minimum launch weight; for configurations characterized by a mix of existing and new stages, the new stages were sized to complement the existing stages in satisfying the design mission. Characteristics of the new stages, thus defined, aided in locating other existing motors, or engines, in the desired size range. When available, these newly located motors and engines were substituted for the new stages and performance was reappraised in terms of the design mission.

In support of the configuration synthesis, trade studies and analyses in the propulsion, control, guidance, structural design, cost and other disciplines were carried out to (1) review applicable state-of-the-art design and hardware developments, (2) identify characteristics of candidate propulsion and guidance systems, (3) generate parametric subsystem size data and sensitivities, and (4) provide subsystem performance, weight, dimensional, GSE, operational, reliability, and cost data.

Configurations were subjected to three sequential levels of screening to narrow the list of candidates to two configurations. Screening criteria included such factors as performance, cost, impact on GSE, design aspects, technical risk, and complexity associated with step-down payload missions. A winning configuration was then selected after a final evaluation.

4.1 STAGING ANALYSIS

4.1.1 Staging Ground Rules and Assumptions - Prior to configuration synthesis a number of ground rules were established and appropriate assumptions were made to facilitate the sizing effort and, at the same time, provide a common basis for configuration comparison. These are summarized below.

Design Mission

All launch vehicles are sized to place a 340 kg payload into a 556 km orbit when launched due east from Wallops Island, Virginia.

Injection Stage

The injection stage is attitude stabilized about all three axes and contains a guidance and control system. Velocity control is provided by thrust termination or vernier correction with the reaction control system. Candidate vehicles with liquid injection stages will use the inherent and proven capability for engine restart by injecting into a Hohmann transfer orbit from an initial altitude of 185 km. Restart on solids, on the other hand, has not been space qualified at this point and vehicles with a solid propellant injection stage assume a direct ascent to the desired altitude.

High Velocity Upper Stage

A high energy solid propellant upper stage is employed on high characteristic velocity missions, such as earth escape, synchronous transfer and reentry flights. This stage, mounted above the normal injection stage, is spin stabilized and sized to maximize payload into the synchronous transfer orbit. A number of considerations led to selection of the synchronous transfer mission for upper stage sizing. First, a number of synchronous transfer missions are forecasted in the ASLV mission model. Next, selection of this sizing point eliminates the requirement for restart on the injection stage for this mission, because the fifth stage can be sized to provide the discrete velocity increment needed to inject into the transfer orbit. Finally, an upper stage sized for synchronous transfer injection exhibits reasonable escape performance, as revealed in Figure 4. This figure shows fifth stage payload curves based on two upper stage sizing points - synchronous transfer and earth escape - for a typical four-stage launch vehicle that is optimally staged for the 340 kg payload/556 km orbit design mission.

Vehicle Sizing

To assist in the general launch vehicle sizing, subsystem weights were divided into fixed and variable weights. Subsystem weights that remain essentially fixed regardless of stage size were handled as discrete weights. In contrast, subsystem weights which vary with stage size were included in the stage structure factor, defined as the ratio of stage burnout weight to total stage weight (excluding fixed weights). Distribution of subsystems in these two categories is denoted in Table 10.

The fixed weights used throughout the staging analysis, except in the final refinement of the conceptual design, are given in Table 9.

TABLE 9
FIXED WEIGHT SUMMARY

	Weight (kg)	Weight (lbs)
Intermediate Stage (Payload Shroud)	249-408	550-900
Injection Stage		
o Without upper stage	55	121
o With upper stage (incl. spin table)	80	154
High Energy Upper Stage	11	24

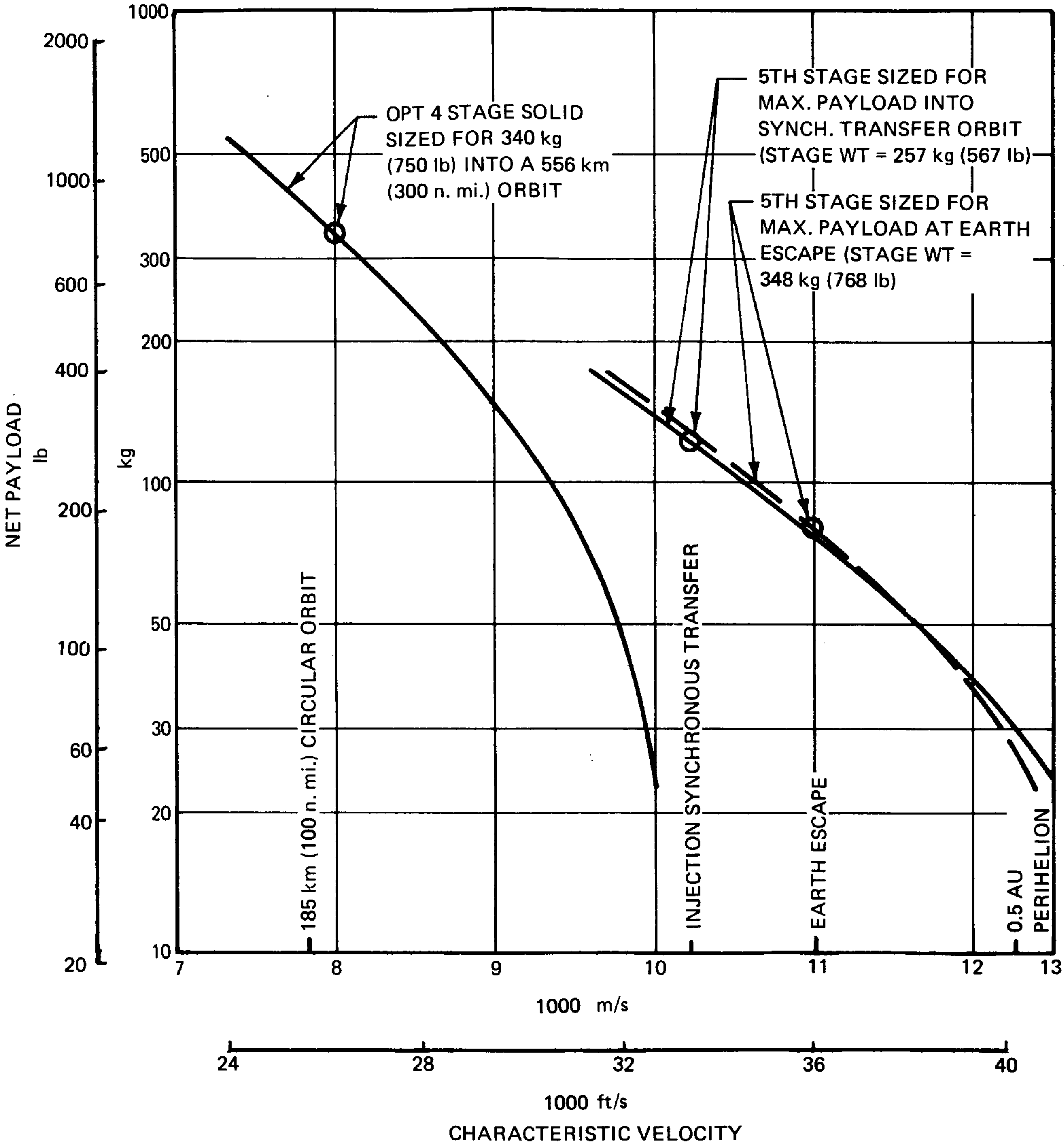


FIGURE 4 PAYLOAD COMPARISON FOR FIFTH STAGE SIZING POINTS

TABLE 10

SUBSYSTEM WEIGHT DISTRIBUTION FOR STAGING ANALYSES

Fixed Subsystems	Subsystems Included In Stage Structural Factors*
Intermediate Stage ° Payload Shroud Injection Stage ° Guidance (incl. computer) ° Telemetry ° Spin Table (when applicable) ° Batteries ° Mounting Structure High Velocity Upper Stage ° Stage Structure and Interstage ° Ignition ° Despin	Each Stage (Except High Velocity Upper Stage) ° Motor ° Ignition System ° Stage Structure & Interstage ° Separation System ° Destruct System ° Control System ° Electrical System ° Thrust Termination/Velocity Control (when applicable)

* Depend on stage size and weight.

The shroud is allocated to the last stage which accelerates it prior to ejection. While discrete weights were used, shroud weight varies from configuration to configuration due to the peculiar characteristics of each vehicle.

Variable weights, expressed in terms of stage structure factor, were obtained from correlation of existing stage data, projected characteristics of current state-of-the-art motors and engines, and specific requirements imposed on individual stages. A synopsis of the stage structure factors used in sizing launch vehicles stages is provided in Table 11. Corresponding values of vacuum delivered specific impulse are also denoted. In sizing individual stages, these parameters were, of course, varied due to the effects of stage size, operating regime, and stage equipment and iteration on structure factor and specific impulse was generally required.

TABLE 11 SUMMARY OF STAGE STRUCTURE FACTORS AND SPECIFIC IMPULSES

PROPELLANT	STAGE STRUCTURE FACTOR	VACUUM DELIVERED SPECIFIC IMPULSE	
		N-sec/kg	lbf-sec/lbm
SOLID			
1ST STAGE	0.100	2565	262
2ND STAGE	0.140	2771	283
3RD STAGE	0.150	2814	287
4TH STAGE	0.185	2821	288
LIQUID-STORABLE			
1ST STAGE	0.049	2814	287
2ND STAGE	0.093	3020	308
3RD STAGE	0.114	2971	303
LIQUID - LOX/RP			
1ST STAGE	0.059	2834	289
2ND STAGE	0.124	3069	313
LIQUID - LOX/LH_2			
1ST STAGE	0.134	3755	383
2ND STAGE	0.145	4353	444

When existing stages were integrated into a launch vehicle configuration, actual stage weights and propulsion performance were used. Equipment, such as control, destruct, etc., was added when required. Likewise, weight variations were estimated for stage modifications (e.g., attachments for strap-ons) and adapter size.

In integrating existing motors, rather than stages, stage subsystem weights were based on Scout components, updated to current state-of-the-art, and scaled on the basis of weight above the stage and stage diameter. In the design of the configuration finally selected, weights were based on engineering analyses and vehicle layouts rather than component scaling or stage structure factors.

Payload Weight Definition

Launch vehicle performance is customarily presented in terms of weight in orbit, or useful load, instead of net payload weight. In this study, however, the ASLV was sized for a net payload, or spacecraft weight, of 340 kg. In differentiating between weight in orbit and net payload, weight in orbit is the sum of net payload weight and injection stage fixed weight, i.e., net payload plus 55 kg. When a high energy upper stage is required, weight in orbit corresponds to net payload plus 11 kg. This distinction becomes valuable during the evaluation cycle because injection stage or upper stage fixed weights trade one to one with payload and thus allow immediate evaluation of the impact on top stage fixed weight on payload. At the same time, this definition avoids fictitiously high payload weight indications. Current Scout net payload weight corresponding to this definition is 163 kg (360 lb) in the 556 km (300 n.mi.) orbit with the 107 cm (42 in) diameter shroud.

4.1.2 Candidate Staging Concepts - The initial step in the configuration synthesis was directed toward definition of candidate staging concepts. A staging concept is identified by the number of stages, the type of propellant in each stage, and, in some instances, specific motors or engines. Unidentified stages may be either new or existing motors/engines and their sizes are not specified. In relation to a staging concept, all stages of a launch vehicle configuration are identified by motor designation or stage characteristics such as size, propellant performance, etc., of a new motor.

The aggregate of staging concepts considered in this study is presented in Table 12. Each of the concepts is explored in the following sections. Concepts with stages denoted by "solid" or "liquid" were first evaluated by optimizing stages so noted, in conjunction with the designated stages, for a 340 kg payload in the 556 km orbit. Characteristics of the optimized stages were then applied in surveying existing motors/engines for applicable propulsion systems. If existing motors close to required size were available, they were integrated into the staging stack, and payload performance was reassessed. Use of existing motors was, of course, stressed throughout the configuration synthesis to minimize technical risk and development cost.

Hybrid Propulsion

Hybrid stages do not appear in Table 12 because they were withdrawn from consideration early in the study. A review of hybrid propulsion systems, based primarily on information in Reference 13, indicated (1) conventional propellant hybrids are non-competitive in performance to solids, (2) development of cryogenic oxidizer hybrids is not far enough along to merit consideration for ASLV application, and (3) both development and recurring costs are higher than those of solids.

Hybrids using conventional oxidizers such as RFNA, N_2O_4, or H_2O_2, deliver a propellant specific impulse in the same range as current solids, i.e., between 2750 and 2940 n-sec/kg. However, motor structure factors (motor inert wt./loaded wt.) of hybrids (.13) are poorer than those of solids (.08) and hybrids thus achieve less performance for a motor of the same weight.

Hybrids with cryogenic oxidizers provide comparable, and in some cases, better performance than solids. For example, a FLOX/LITHIUM hybrid will deliver up to 3730 N-sec/kg of specific impulse and, even with its poor motor structure factor (.15), will provide better performance than solids. However, cryogenic hybrids are still in the technology demonstration phase and are not considered within the state-of-the-art guidelines for the ASLV.

Development and recurring costs of solid motors and cryogenic hybrid systems, ascertained from Reference 13, are compared in Table 13

TABLE 12 CANDIDATE STAGING CONCEPTS

1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE
IMPROVED SCOUT CONCEPTS			
OPT. SOLID 1ST STAGE/COMBINATIONS OF SCOUT UPPER STAGES			
OPT. LIQUID 1ST STAGE/COMBINATIONS OF SCOUT UPPER STAGES			
ALGOL III	SOLID	SOLID	SOLID
ALGOL III	SOLID	LIQUID	–
ALGOL III OR STRETCHED ALGOL III	SHORT ALGOL III	SOLID	SOLID
ALGOL III + (2) CASTOR STRAP-ONS	SOLID	SOLID	SOLID
ALGOL III + (2) CASTOR STRAP-ONS	SOLID	LIQUID	–
ALGOL III + (2) CASTOR STRAP-ONS	SHORT ALGOL III	SOLID	SOLID
ALGOL III + (2) CASTOR STRAP-ONS	ALGOL III	SOLID	SOLID
ALGOL III + (2) CASTOR STRAP-ONS	ALGOL III	LIQUID	–
ALGOL III + (2) CASTOR STRAP-ONS	CASTOR IV (IIA PROP)	SOLID	SOLID
ALGOL III + (2) CASTOR STRAP-ONS	CASTOR IV (IIA PROP)	LIQUID	–
ALGOL III + (2) CASTOR STRAP-ONS	MM III 2ND STAGE	SOLID	SOLID
ALGOL III + (2) CASTOR STRAP-ONS	MM III 2ND STAGE	LIQUID	–
ALGOL III + (3) CASTOR STRAP-ONS	SOLID	SOLID	SOLID
ALGOL III + (3) CASTOR STRAP-ONS	SOLID	LIQUID	–
ALGOL III + (3) CASTOR STRAP-ONS	ALGOL III	SOLID	SOLID
ALGOL III + (4) CASTOR STRAP-ONS	SOLID	SOLID	SOLID
ALGOL III + (4) CASTOR STRAP-ONS	SOLID	LIQUID	–
ALGOL III + (2) STRETCHED CASTOR STRAP-ONS	SHORT ALGOL III	SOLID	SOLID
NEW LAUNCH VEHICLE CONCEPTS			
OPTIMIZED THREE STAGE SOLID	OPT. SOLID	OPT. SOLID	–
OPTIMIZED FOURT STAGE SOLID	OPT. SOLID	OPT. SOLID	OPT. SOLID
OPTIMIZED TWO STAGE LIQUIDS (STORABLE & CRYOGENIC)	OPT. LIQ. (STOR. & CRYOG.)	–	–
OPTIMIZED THREE STAGE LIQUID (STORABLE)	OPT. LIQ. (STOR.)	–	–
MM III 1ST STAGE	MM III 2ND STAGE	SOLID	SOLID
MM III 1ST STAGE	MM III 2ND STAGE	LIQUID	–
MM III 1ST STAGE	ALGOL III	SOLID	SOLID
MM III 1ST STAGE	CASTOR IV (IIA PROP)	SOLID	SOLID
POSEIDON 1ST STAGE	POSEIDON 2ND STAGE	SOLID	SOLID
POSEIDON 1ST STAGE	POSEIDON 2ND STAGE	LIQUID	–
OFF-LOADED "STRAIGHT 8" THOR	TE 364-2	–	–
"STRAIGHT 8" THOR + (3) CASTOR STRAP-ONS	TE 364-2	–	–

for a total impulse of 2.4 x 10^6 N-sec, corresponding to a typical fourth stage motor. Development costs include the number of test firings required to achieve a reliability of about 98-99%.

TABLE 13 COST COMPARISON OF SOLID AND HYBRID PROPELLANT MOTORS

	DEVELOPMENT COST	RECURRING COST
Solid Motor	\$4.0 M	\$50K
Cryogenic Hybrid System	12.0	75

Based on the above data, hybrids were not included as candidate propulsion configurations.

4.1.2.1 Improved Scout Concepts - In deriving staging concepts for the Improved Scout, the objective was to retain as much Scout hardware as possible and minimize motor development. Accordingly, concepts in this category feature, as a minimum, either the Algol III or Scout upper stages, or both.

Strap-ons appear attractive for the Improved Scout because they provide an effective means of increasing the payload capability to the required 340 kg and may be deleted for step-down missions in the current Scout payload range. Castor II strap-ons of the type used by Thor/Delta are readily adaptable to the Scout Algol III and are prime candidates. Stretched Castor II-A strap-ons are currently being considered as a growth step for Thor/Delta, if a requirement for further performance capability arises. Should this motor go into development and production, it might also be very attractive for the ASLV and is therefore included in the Improved Scout concepts.

Other strap-on motors such as Algol IIB, Castor IV, and Algol III, as well as two Algol III stages side-by-side, were excluded from consideration for numerous reasons. First, configurations using these motor combinations became rather heavy. Second, first stage thrust-to-weight will result in dynamic pressures of about 200 000 N/m^2 (4180 and higher, lb/ft^2) depending on the specific configurations, and significant structural modifications and weight increases would be required for the resulting loads.

Another detracting factor for configurations with either two or three Algol III motors in the first stage is that one motor may burn out before the other, making vehicle control difficult.

Choice of existing motors for the second stage is constrained by total impulse and stage diameter. The current Castor IIA second stage on Scout was considered too small in diameter and, in most cases, total impulse; however, it was included in some configurations as a matter of interest.

Diameter becomes an important parameter on the second stage because payload diameters established in Section 3.3 dictate a payload shroud diameter of around 1.52m and a second stage with small diameter may have difficulty in sustaining the resulting bending moments. If the third stage has a large diameter, the second/third stage adapter must be relatively long to minimize the flow expansion angle to avoid buffeting. On the other hand, if the third stage has a small diameter, it must be encased by the payload shroud to sustain the loads and avoid buffeting. In this case, the shroud boattail must taper from 1.52m into a second stage with small diameter, or a cylindrical section with second stage diameter that surrounds the third stage. In either case, the length of the boattail, governed by the maximum allowable flow expansion angle and second stage diameter, results in a relatively large and heavy shroud.

A minimum second stage diameter of about 1.0 m was selected because it represents a compromise in that adapters or payload shrouds for second stage diameters less than this value are considered too long and heavy, but choice of this diameter does allow inclusion of existing motors such as the Algol IIB and Castor IV.

The Algol IIB and Castor IV motors have the same dimensions and approximately the same total impulse; hence, only the Castor IV was considered for second stage application. Further, the Castor IV manufacturer has stated that, with some engineering modifications, the higher performance Castor IIA propellant could be used in the Castor IV. Thus, this high performance version of the Castor IV (with altitude nozzle) was used in the performance analyses.

Other candidate second stage motors are the Minuteman III second stage with an outside diameter of 1.32m, the Algol III, modified with an altitude nozzle, and a shortened version of the Algol III with an altitude nozzle. These last two versions, when used in combination with an Algol III first stage, offer the same diameter as the first stage and thus simplify the interstage design.

In considering third and fourth stage motors, either existing or new ones, the number of stages in the configurations was limited to no more than three when a liquid stage was used as an upper stage and to no more than four when only solid motors were addressed. This limitation was made because stage structure factors for liquids deteriorate rapidly as stages become small, while stage structure factors of solids remain favorable, even for relatively small stages.

4.1.2.2 New Launch Vehicle Concepts - Staging concepts for new launch vehicles were divided into (1) new, optimized vehicles and (2) existing booster/launch vehicle derivatives. For new, optimized solid propellant vehicles, three and four stage configurations were considered. Past experience shows that due to the relatively poor specific impulse and stage structure factors of lower stage solids, solid propellant launch vehicles require at least three stages to preclude excessive lift-off weight and to achieve adequate mission flexibility. Liquid stage structure factors and specific impulse, on the other hand, are considerably better than those of solids as stages get large and liquids therefore require fewer stages than solids. In this study, two stage liquids using N_2O_4/Aerozine, LOX/RP, and LOX/LH_2 were considered. A three stage storable liquid was also sized as a matter of interest.

In adapting existing boosters for use on ASLV, only production Minuteman III and Poseidon stages appear attractive because earlier versions of these boosters are reaching the end of their projected shelf life and would also require refurbishment. Redirection of the Minuteman I and II or Polaris A2 and A3 boosters to a launch vehicle program with launch schedules into the mid-1980's would entail an extensive program, including test firings, to ascertain the potential shelf life extensions of these motors and was, therefore, considered undesirable.

Second stage candidates for the Minuteman III first stage consist of the Castor IV with Castor IIA propellants and altitude nozzle, the Algol

III and of course, the Minuteman III second stage.

Concepts based on the Poseidon booster utilize both existing first and second stages, in conjunction with new upper stages, because the 1.88m first stage diameter, in combination with the first/second stage adapter design on this vehicle, precluded use of other existing second stages.

Two derivatives of the Thor/Delta launch vehicle were also included in the category of launch vehicle derivatives. These are an off-loaded "Straight 8" Thor first stage and a fully loaded "Straight 8" first stage with three Castor strap-ons. A TE364-2 motor was added as a second stage and serves as the injection motor.

4.1.3 Improved Scout Configurations - The Improved Scout staging concepts indicated in Table 12 have been expanded into specific configurations comprised of new and/or existing stages. These configurations are listed in Tables 14 and 15, which serve to identify the staging stack, shroud weight, total vehicle launch weight, and the payload that can be placed into a 556 km circular orbit.

New motors, as indicated previously, were optimized to permit the configuration to place a 340 kg payload into a 556 km orbit at the minimum launch weight. If a 340 kg capability could not be achieved with a particular configuration thus optimized, the new motor was sized to maximize payload for that configuration.

New solid propellant motors are denoted by one of three abbreviations - Optimum Solid, Optimum 71 Solid, and Optimum 75 Solid. "Optimum Solids" typify structure factors and propellant performance levels of existing motors as given in Table 11. As such, configurations containing "Optimum Solids" provide a guide for exploring the use of existing motors that can replace the "Optimum Solids" in those configurations, but do not define characteristics of motors that could be built with 1971 state-of-the-art propulsion technology. If new motors were required or desired for a configuration, new stages were optimized for 1971 state-of-the-art motor characteristics in order to take advantage of recent performance and design improvements. Stages thus optimized are symbolized by "Optimum 71 Solid." If the resulting design was marginal and the integration of a motor was far

TABLE 14 IMPROVED SCOUT CONFIGURATIONS
CONFIGURATIONS WITH NEW AND ALGOL III FIRST STAGES

NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	SHROUD WT. kg. (lb)	PAYLOAD INTO 556 km (300 n. mi.) ORBIT — LAUNCH WEIGHT (lb)	LAUNCH WEIGHT kg
NEW FIRST STAGE/COMBINATIONS OF SCOUT UPPER STAGES							
8	OPT 71 SOLID	MOD CAST IIA	HP X259	FW-4	249 (550)	(83560)	37902
11	OPT LIQUID	MOD CAST IIA	HP X259	–	249 (550)	(87800)	39825
ALGOL III FIRST STAGE/COMBINATIONS OF NEW/EXISTING STAGES							
7	ALGOL III	OPT SOLID	OPT SOLID	OPT SOLID	249 (550)	(73090)	33153
10	↓	OPT 71 SOLID	OPT LIQUID	–	249 (550)	(73996)	33564
7R1	↓	OPT 71 SOLID	OPT 71 SOLID	FW-4	249 (550)	(55676)	25254
7R2	↓	OPT 71 SOLID	OPT 71 SOLID	TE 364-3	249 (550)	(54851)	24880
7S2	↓	OPT 75 SOLID	TE 364-4	FW-4	318 (700)	(56285)	25530
7S1	↓	OPT 75 SOLID	TE 364-4	TE 364-3	318 (700)	(54896)	24900
7T1	↓	MOD CAST IIA	OPT 75 SOLID	OPT 75 SOLID	249 (550)	LESS THAN 750 lbs	
7A	↓	ALGOL III	CASTOR IIA	OPT SOLID	249 (550)	(77900)	35335
23A	↓	SHORT ALG III	OPT 71 SOLID	OPT 71 SOLID	249 (550)	(62882)	28523
23B	↓	SHORT ALG III	OPT 75 SOLID	OPT 75 SOLID	249 (550)	(58977)	26751
23	STRETCHED ALGOL III	SHORT ALG III	TE 364-4	TE 364-3	249 (550)	DELETED	

Payload scale: kg. → 100, 200, 300, 400; (lb) → 200, 400, 600, 800. DESIGN PAYLOAD

TABLE 15 IMPROVED SCOUT CONFIGURATIONS STRAP-ON CONFIGURATIONS

NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	SHROUD WT. kg (lb)	PAYLOAD INTO 556 km (300 n.mi.) ORBIT — LAUNCH WEIGHT (lb)	LAUNCH WEIGHT kg
2K	ALGOL III + (2) CASTORS	OPT SOLID	OPT SOLID	OPT SOLID	249 (550)	(85658)	38854
2D		CASTOR IIA	X259	OPT SOLID	249 (550)	(67817)	30761
2E		CASTOR IIA	X259	OPT LIQUID	249 (550)	(68117)	30897
2B		CASTOR IIA	X259	FW-4	249 (550)	(67809)	30757
2		MOD CAST IIA	HP X259	FW-4	249 (550)	(67539)	30635
7G		MM III 2ND	OPT SOLID	OPT SOLID	249 (550)	(76051)	34496
7F		CASTOR IV	OPT SOLID	OPT SOLID	249 (550)	(83722)	37975
7M		CASTOR IV	HP X259	FW-4	408 (900)	(85590)	37916
7O		CASTOR IV	HP X259	TE 364-3	408 (900)	(84008)	38105
7L		CASTOR IV	TE 364-4	FW-4	318 (700)	(82973)	37636
7N		CASTOR IV	TE 364-4	TE 364-3	318 (700)	(83991)	38097

Payload scale: kg 100, 200, 300, 400; (lb) 200, 400, 600, 800. DESIGN PAYLOAD →

TABLE 15 IMPROVED SCOUT CONFIGURATIONS (CONT'D.)
STRAP-ON CONFIGURATIONS

NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	SHROUD WT. kg (lb)	PAYLOAD INTO 556 km (300 n. mi.) ORBIT — LAUNCH WEIGHT (lb)	LAUNCH WEIGHT kg
7E	ALGOL III + (2) CASTORS	ALGOL III	OPT SOLID	OPT SOLID	249 (550)	(91011)	41282
2F		ALGOL III	MOD CAST IIA	OPT SOLID	249 (550)	(97716)	44323
7H		ALGOL III	HP X-259	FW-4	408 (900)	(89219)	40469
7K		ALGOL III	HP X-259	TE 364-3	408 (900)	(91128)	41335
7I		ALGOL III	TE 364-4	FW-4	318 (700)	(88845)	40299
7J		ALGOL III	TE 364-4	TE 364-3	318 (700)	(90569)	41081
7U6		SHORT ALG III	HP X-259	FW-4	408 (900)	(78994)	35831
7U2		SHORT ALG III	HP X-259	TE 364-3	408 (900)	(79748)	36103
7U3		SHORT ALG III	HP X-259	SHORT X-259	408 (900)	(80276)	36594
7U		SHORT ALG III	TE 364-4	TE 364-3	318 (700)	(79203)	35926
7U1		OPT 71 SOLID	TE 364-4	TE 364-3	318 (700)	(68787)	31201
7U4	ALG III + (2) STRETCHED CASTORS	SHORT ALG III	HP X-259	FW-4	408 (900)	(85389)	38732
7U5		SHORT ALG III	HP X-259	TE 364-3	408 (900)	(86341)	39163

Payload scale: kg 100, 200, 300, 400; (lb) 200, 400, 600, 800. DESIGN PAYLOAD →

TABLE 15 IMPROVED SCOUT CONFIGURATIONS (CONT'D.) STRAP-ON CONFIGURATIONS

NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	SHROUD WT. kg (lb)	PAYLOAD INTO 556 km (300 n.mi.) ORBIT: LAUNCH WEIGHT (lb)	LAUNCH WEIGHT kg
3	ALGOL III + (3) CASTORS	CASTOR IIA	X-259	FW-4	249 (550)	(77521)	35163
3B	↓	ALGOL III	HP X-259	FW-4	408 (900)	(100035)	45375
3D	↓	ALGOL III	TE 364-4	FW-4	318 (700)	(99484)	45125
3C	↓	ALGOL III	TE 364-4	TE 364-3	318 (700)	(100518)	45594
4A	ALGOL III + (4) CASTORS	CASTOR IIA	X-259	FW-4	249 (550)	(87491)	39685
4B	↓	MOD CAST IIA	HP X-259	OPT SOLID	249 (550)	(88374)	40086
4	↓	MOD CAST IIA	HP X-259	FW-4	249 (550)	(87201)	39554

Payload scale: kg → 100, 200, 300, 400; (lb) → 200, 400, 600, 800

DESIGN PAYLOAD →

enough downstream in time, advantage could be taken of projected improvements in the next few years, i.e., "Optimum 75 Solids." When existing stages or motors are used, the motor designation is used to describe the stage.

In sizing liquid stages, no distinction was drawn between current propellant performance and liquid engine/stage design status and that projected in the immediate future; rather, information given in Table 11 was used throughout. Further, all liquid stages in Improved Scout configurations assume storable N_2O_4/Aerozine propellants.

For uniformity, all configurations contain an improved guidance system on the injection stage. The Hohmann transfer was assumed for configurations with liquid injection stages while the direct ascent route was used for configurations with solid upper stages, as discussed previously. Variations in payload shroud weights shown in these tables are attributed to the relationships between upper stage diameter and shroud diameter as well as the structural load carrying capabilities of the various stages.

4.1.3.1 Configurations with New and Algol III First Stages

New First Stages

Improved Scout configurations characterized by new first stages and selected Scout upper stages are depicted in the upper portion of Table 14. Configuration 8, a four stage vehicle, features a new solid propellant first stage in conjunction with a Castor IIA, modified with a light weight nozzle, a high pressure X259, and the standard FW4. Later considerations indicated that the 249 kg shroud weight initially estimated for this stack would have to be increased to approximately 408 kg because both the HP X259 and FW4 will have to be encased due to (1) structural load problems with the HP X259 and (2) the long boattail necessary to taper from a 1.52m shroud to the 0.788 m diameter Castor IIA. Hence, the first stage would have to be enlarged to compensate for this increase in shroud weight.

Configuration 11 of Table 14, a three stage vehicle, achieves the design payload at a comparable launch weight to that of Configuration 8 through use of a new liquid first stage in conjunction with Scout upper stages. As in Configuration 8, the 249 kg shroud appears inadequate and will have to be increased by approximately 45 kg which will, in turn, require a somewhat larger first stage. Also, the small diameter of the Castor IIA may induce bending load problems for this motor.

Algol III First Stage

Configurations distinguished by the Algol III as a first stage motor and various combinations of new and existing upper stages are listed in the lower portion of Table 14. The "Optimum 71 Solids" in this table were sized for specific impulse values of 2810, 2930, and 2900 N-sec/kg and motor structure factors (empty motor weight/loaded motor weight) of 0.122, 0.084, and 0.088 in the second, third, and fourth stages, respectively. Similarly, "Optimum 75 Solids" are based on specific impulses of 2950, 3070, and 3060 N-sec/kg for corresponding stages. No improvement in motor structure factors over those for the "Optimum 71 Solids" is forecasted for 1975. Since launch vehicle weight will grow quite rapidly if this motor performance cannot be met, configurations with "Optimum 71 Solids", and certainly configurations with "Optimum 75 Solids", exhibit an element of risk.

Aside from the optimized second stages, a modified Castor IIA, an Algol III, and a shortened version of the Algol III were also considered as second stage candidates. Problems with the small diameter of the Castor IIA were discussed previously; further Configuration 7T1, which utilizes this motor, does not meet the required payload capability. A full size Algol III (Configuration 7A) weighs down the first stage and results in an inefficient vehicle. However, a shortened Algol III (Configurations 23, 23A, 23B) is attractive because it has the same diameter as the first stage and alleviates the problem of weighing down the first stage. Discussions with the motor manufacturer disclosed that reduction in length does not present a major problem and can be accomplished economically.

Use of a stretched Algol III in the first stage was also considered initially, but subsequent vendor information revealed that propellant erosion would be a major problem. Thus, Configuration 23, was dropped from further consideration.

4.1.3.2 Strap-On Configurations - Configurations comprised of the Algol III first stage, augmented by various numbers of Castor strap-ons, exhibit a practical approach toward definition of an economical, cost-effective launch vehicle. First, these protean configurations satisfy the step-down payload requirement with least impact on the launcher and ground support equipment by simple deletion of the strap-on motors on the less demanding missions. Second, strap-ons avoid development of a new first stage which is considerably more costly than upper stage motor development. Improved Scout configurations featuring two, three, and four Castor strap-ons are listed in Table 15.

Candidate Second Stage Motors

Second stage candidates for these configurations include the Castor IIA, the Castor IV with the Castor IIA propellant, the Minuteman III second stage, the Algol III, short Algol III, and an Optimum 71 Solid.

Review of Configuration 2K disclosed the requirement for a second stage motor with around 8160 kg propellant for configurations with two strap-ons. Two applicable existing motors which approach this propellant weight are the Minuteman III second stage with a 1.32m diameter and the Castor IV with a 1.02m diameter, but both deviate from this weight by several thousand kilograms.

The Castor IIA with approximately 3760 kg propellant is thus inadequate for meeting the required payload as verified by Configurations 2D, 2E, 2B, and 2. The propellant weight of the Minuteman III second stage falls several thousand kilograms short of 8160 kg and this configuration does not meet the design payload.

Configurations with Castor IV (7F, 7M, 7O, 7L, 7N), Algol III (7E, 2F, 7H, 7K, 7I, 7J), and a shortened version of the Algol III with 8160 kg propellant (7U6, 7U2, 7U3, 7U) yield payloads near 340 kg. The full-sized Algol III is the least desirable of these motors because the configuration could not be flown without the two strap-ons for the step-down payload missions. Since some development is involved for both the Castor IV and the short Algol III, advantages in diameter and shorter length, performance, and cost (discussed in Section 4.2.1) favor the short Algol III.

Streteched Castor Strap-Ons

Streteched Castor IIA strap-ons with approximately 4980 kg propellant show an increase of nearly 45 kg payload over comparable configurations with two regular Castor (TX354-5) strap-ons and raise the payload weight to, or slightly above, the required level on some configurations. When used with the short Algol III second stage (7U4, 7U5), excess payload capability exists. With an estimated development cost on the order of $1M, this motor also becomes an attractive candidate.

Three and Four Castor Strap-Ons.

Payload capability of configurations with three and four regular Castor Strap-ons is indicated on the last page of Table 15. Scout D, appropriately modified for improved guidance on the 4th stage and larger payload shroud, is unable to achieve the design payload with either three or four regular Castor Strap-ons, as shown by Configurations 3 and 4A.

In the case of three Castor strap-ons, use of an Algol III as a second stage, concomitant with various upper stages, does advance the payload above 340 kg as indicated by Configurations 3B, 3D, and 3C. The design payload can also be obtained via a Castor IV or short Algol III second stage, as may be inferred from the payload trends in Table 15 by comparing configurations 7M, 7O, 7L, 7N with 7H, 7K, 7I, 7J, respectively. However, since the design payload can be achieved with only two Castor strap-ons and proper combinations of existing and modified upper stages, implementation of three strap-ons is considered a back-up option and/or a growth item. Furthermore, configurations with three strap-ons that satisfy the design payload tend to be heavy and complicate the ground support equipment.

In synthesizing configurations with four strap-ons, maximum utilization of existing Scout hardware is stressed because recurring costs will be relatively high due to the four added strap-on motors. If additional motor development and integration are required, these costs must be amortized, thereby further increasing the average unit launch cost.

Only one of the three configurations with four strap-ons shown in Table 15 delivers a 340 kg or larger payload. But, this configuration is not considered a viable launch vehicle because it encounters maximum dynamic pressures of around 240 000 N/m^2 (5020 lb/ft^2) which, in combination with the small second stage diameter and 1.52m heat shield, would produce unacceptable loads.

Liquid Upper Stages

Use of liquids was also investigated for Improved Scout configurations to reduce the number of stages. The payload goal could not be achieved, however, with existing lower stage motors and a liquid third stage. Since at least one new solid lower stage motor and a liquid upper stage engine would have to be developed, liquid third stages were withdrawn from the list of candidate upper stages. This conclusion is further supported by the fact that two new solid upper stages can be developed at a lower cost than a lower stage solid motor and an upper stage liquid engine, as shown later in Section 4.2.1.3.

4.1.4 New Launch Vehicles - The category of New Launch vehicles covers two disparate groups of configurations - new, optimally staged launch vehicles and booster/launch vehicle derivatives. In the first of these two groups, both solid and liquid propellant launch vehicles were sized to deliver the design payload into a 556 km circular orbit at minimum launch weight. In the second group, Minuteman III and Poseidon booster stages and the "Straight 8" Thor first stage provide lower stage propulsion units which are supplemented with other new and/or existing motors to define candidate configurations.

New Optimally Staged Launch Vehicles

The assortment of optimally staged launch vehicles evaluated in this study is depicted in Table 16. In the area of solid propulsion, both three and four stage vehicles were synthesized. Liquid propellant configurations utilized the common propellants - storable N_2O_4/Aerozine, LOX/RP, and LOX/LH_2.

Analysis of stage characteristics of Configuration 18 disclosed that the Titan first and second core stage engines provide approximately the desired thrust level and could possibly be adapted for use in the respective stages of this configuration, thereby reducing engine development cost. Applicable existing engines do not exist, though, for the remainder of the liquid configurations.

Booster/Launch Vehicle Derivatives

Configurations derived from existing booster and launch vehicles are denoted in Table 17. In converting the Minuteman and Poseidon stages

TABLE 16 NEW OPTIMALLY STAGED LAUNCH VEHICLES

NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	SHROUD WT. kg (lb)	PAYLOAD INTO 556 km (300 n.mi.) ORBIT — LAUNCH WEIGHT (lb)	LAUNCH WEIGHT kg
SOLID PROPELLANT LAUNCH VEHICLES							
13	OPT 71 SOLID	OPT 71 SOLID	OPT 71 SOLID	–	249 (550)	(52781)	23941
14	OPT 71 SOLID	OPT 71 SOLID	OPT 71 SOLID	OPT 71 SOLID	249 (550)	(44652)	20254
LIQUID PROPELLANT LAUNCH VEHICLES							
18	OPT N_2O_4/AEROZINE	OPT N_2O_4/AER	–	–	249 (550)	(44856)	20346
20	OPT N_2O_4/AEROZINE	OPT N_2O_4/AER	OPT N_2O_4/AER	–	249 (550)	(48533)	22014
19	OPT LOX/RP	OPT LOX/RP	–	–	249 (550)	(51681)	23442
19A	OPT LOX/LH_2	OPT LOX/LH_2	–	–	249 (550)	(23281)	10560

Payload scale: kg 100, 200, 300, 400; (lb) 200, 400, 600, 800. Bars extend to DESIGN PAYLOAD.

TABLE 17 BOOSTER/LAUNCH VEHICLE DERIVATIVES

CONFIGURATIONS WITH MINUTEMAN, POSEIDON AND THOR FIRST STAGES

NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	SHROUD WT. kg (lb)	PAYLOAD INTO 556 km (300 n.mi.) ORBIT: LAUNCH WEIGHT (lb)	LAUNCH WEIGHT kg
5C	MM III 1ST	MOD CAST IIA	HP X-259	OPT SOLID	249 (550)	(66767)	30285
5	↓	MOD CAST IIA	HP X-259	FW-4	249 (550)	(66214)	30034
22	↓	MM III 2ND	OPT SOLID	–	249 (550)	(71057)	32231
22A	↓	MM III 2ND	OPT SOLID	OPT SOLID	249 (550)	(72276)	32784
22C	↓	MM III 2ND	HP X-259	FW-4	408 (900)	(73264)	33323
22D	↓	MM III 2ND	TE 364-4	TE 364-3	318 (700)	(73874)	33509
22H	↓	CASTOR IV	CASTOR IIA	HP X-259	295 (650)	(91722)	41604 (1082 lbs)
22M	↓	CASTOR IV	TE 364-4	TE 364-3	318 (700)	(82929)	37616
22E	↓	ALGOL III	CASTOR IIA	HP X-259	295 (650)	(98061)	44479
5E	↓	ALGOL III	MOD CAST IIA	FW-4	249 (550)	(95463)	43301
22G	↓	ALGOL III	TE 364-4	FW-4	318 (700)	(88259)	40033
22F	↓	ALGOL III	TE 364-4	TE 364-3	318 (700)	(89322)	40516

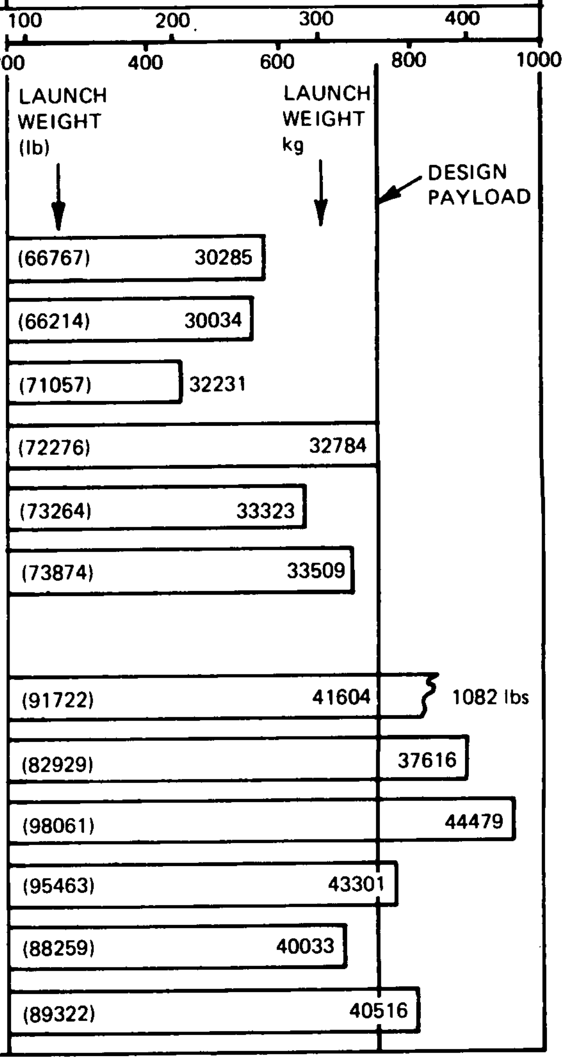


TABLE 17 BOOSTER/LAUNCH VEHICLE DERIVATIVES (CONT'D.)
CONFIGURATIONS WITH MINUTEMAN, POSEIDON AND THOR FIRST STAGES

NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	SHROUD WT. kg (lb)	PAYLOAD INTO 556 km (300 n.mi.) ORBIT — LAUNCH WEIGHT (lb) / LAUNCH WEIGHT kg
POSEIDON FIRST STAGE/COMBINATIONS OF NEW AND EXISTING UPPER STAGES						
22I	POSEIDON 1ST	POSEIDON 2ND	TE 364-4	–	318 (700)	(63915) 28991
22B	↓		OPT SOLID	OPT SOLID	249 (550)	(65001) 29484
22K	↓		HP X-259	FW-4	408 (900)	(65595) 29753
22L	↓		TE 364-4	FW-4	318 (700)	(65099) 29528
22J	↓		TE 364-4	TE 364-3	318 (700)	(66085) 29975
THOR DELTA DERIVATIVES						
24A	OFF-LOADED "STRAIGHT 8" THOR	TE 364-2	–	–	318 (700)	(159740) 72456
24	"STRAIGHT 8" THOR + 3 CASTORS	TE 364-2	–	–	318 (700)	(218955) 99316

Payload scale: kg → 100, 200, 300, 400; (lb) → 200, 400, 600, 800. DESIGN PAYLOAD line indicated.

into lower stages of launch vehicles, two modifications were made. First, destruct systems were added to all stages, and, second, a coast control system was added to the second stage for payload shroud separation and also mission flexibility (e.g., reentry missions which require extensive coast periods between second and third stage burn phases). Further, a new payload shroud was required and a new, common guidance system was assumed for uniformity.

Launch vehicle configurations with the Minuteman III first stage are presented on the first page of Table 17. Second stage candidates include the Castor IIA, the Minuteman III second stage, Castor IV, and Algol III. Staging stacks with the Castor IIA do not satisfy payload requirements. Similarly, the Minuteman III second stage is too small, in terms of propellant weight, to achieve the design goal with existing upper stages.

Vehicles with Minuteman III first stages and Castor IV or Algol III second stages satisfy the payload objective with certain combinations of existing upper stage motors. The Castor IV second stage motor is preferred, from a performance standpoint, over the Algol III, because it provides a larger payload, as verified by comparing configurations 22M with 22F; however, the Algol III appears more attractive because of its 1.14 m diameter which must be adapted to the 1.66m first stage diameter. A short Algol III, not shown in Table 17, offers the most favorable compromise between payload and diameter, and is preferred for integration with the Minuteman III first stage. Launch weight would be slightly less than with the Castor IV.

A three stage vehicle comprised of the Minuteman III first and second stages and a liquid third stage was also sized, but did not achieve the 340 kg design payload.

Launch vehicles consisting of the Poseidon first and second stages and combinations of new and existing upper stages, shown on the second page of Table 17, offer the design mission capability at lowest launch weight, except for the new, optimally staged configurations discussed previously. The second stage in these configurations was modified by deletion of thrust termination and related hardware and addition of a coast control system.

Three stage vehicles using the Poseidon first and second stages and either a solid or liquid third stage (not shown) did not produce a 340 kg payload capability; however, several four stage configuration matched or exceeded the payload design goal.

Two Thor Delta derivatives were also considered for the small launch vehicle role. The new "Straight 8" first stage and a modified, attitude stabilized, Burner II second stage provide the baseline for these configurations. In the first case, Castor II strap-ons are deleted and the first stage propellants was off-loaded to increase the initial thrust-to-weight ratio to approximately 1.3. In the second version, a fully loaded first stage, augmented by three Castor strap-ons, was used. The Burner II stage, comprised of the TE 364-2 motor, structure, and control system, but with a new guidance system, serves as the second stage in both cases. The first configuration fell short in payload performance, but the latter, fully loaded version with strap-ons provided more than adequate payload capability.

(This Page Intentionally Left Blank)

4.2 CONFIGURATION SCREENING AND SELECTION

The Improved Scout configurations and New Launch Vehicles were subjected to three sequential levels of screening to narrow the list of candidates and a final selection was made as outlined in Table 18. In each successive screening level,configuration data were penetrated in greater depth.

The screening criteria, rationale, and supporting data are denoted in the following sections and screening results for each level are summarized at the end of each section.

4.2.1 First Level Screening - The objective of the first level screening was to filter out configurations with inadequate payload performance, obvious design problems, and substantial cost impacts. As such, the screening thresholds on design aspects and costs are set relatively high so as not to arrogate the elimination of marginal configurations. Criteria for first level screening are depicted in Table 19.

4.2.1.1 Payload - The 340 kg payload requirement into a 556 km circular orbit, established in the initial ground rules, was used for the initial screening.

4.2.1.2 Design Items - Two screening criteria were introduced as part of the preliminary vehicle design evaluation. These are dynamic pressure and the relationship between stage diameters. Maximum dynamic pressure was limited to 167 500 N/m^2. This value strikes a balance between control requirements, bending loads and payload shroud design considerations on one hand, and maximum utilization of existing motors in the synthesis of candidate configurations on the other.

The relationships between successive stage diameters, or payload shroud diameter and adjoining stage diameter, become important from the standpoints of bending loads and aerodynamic buffeting, as discussed in Section 4.1.2. Since first stages of all candidate configurations have diameters of at least 1.14 m and the payload shroud diameter was established at 1.52 m, intermediate stage diameters less than around 1.02 m present difficulties. First, bending loads on smaller diameter motors, such as the 0.76 m diameter Castor IIA, become critical. Second, abrupt diameter changes from the 1.52 m payload shroud to an adjoining motor of small diameter portend potential buffeting problems.

TABLE 18 CONFIGURATION SCREENING LEVELS

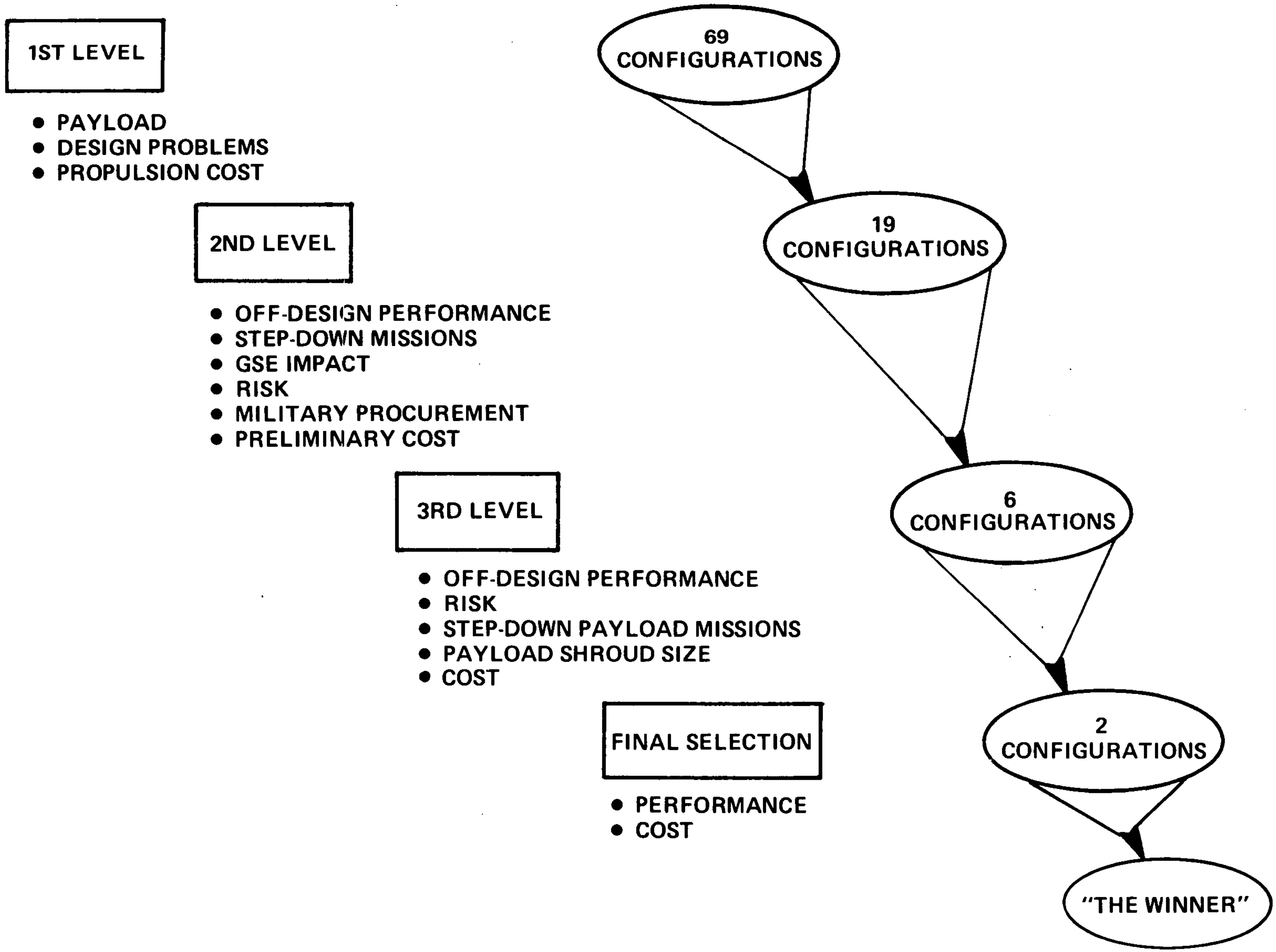


TABLE 19

FIRST LEVEL SCREENING CRITERIA

- o DESIGN MISSION - 340 kg/556 km ORBIT

- o DESIGN PROBLEMS
  - DYNAMIC PRESSURE 167 500 N/m^2 (3 500 lb/ft^2)
  - STAGE DIAMETER INCOMPATIBILITY
    - 1st Stage Dia = 1.14 - 1.88 m (45-74 in)
    - Shroud Diameter = 1.52 m (60 in)

- o PROPULSION STAGE COSTS

- o BACK-UP CONFIGURATION

Choice of a minimum stage diameter of 1.02 m represents a reasonable compromise because it allows retention of such motors as the Castor IV and Algol II for second stage candidates, but, at the same time, forestalls the need for excessively long interstage sections in order to achieve satisfactory boattail angles. On four-stage configurations where the third stage motor diameter is less than 1.02 m, the payload shroud was designed to house the payload, the fourth stage, and the third stage, but was jettisoned from the second stage before third-stage ignition.

4.2.1.3 Costs - In the first level screening, parametric cost data were applied to eliminate configurations that do not measure up to an economical approach for satisfying ASLV missions. This first level cost screening was based only on propulsion stage costs (motor/engine, attitude control and interstage). Payload shroud, guidance system, vehicle integration, and launch support costs were assumed invariant from vehicle to vehicle. Propulsion stage costs were deemed valid for first level cost screening because (1) they provide a uniform basis for comparing solid stages with liquid stages, and (2) they constitute by far the largest hardware investment for the remaining part of a launch vehicle, both in terms of development and recurring costs.

Stage Development Costs - Liquid engine and propulsion stage development costs are presented in Figure 5. This information was extracted from the USAF Space Planner's Guide (Reference 14) and denotes cost to the government. (Liquid cost information in Figure 5 was found to compare favorably with similar parametric cost data in Reference 13). Engine development costs are broken out separately from the remainder of the propulsion system development costs. If neither engine nor propulsion system (which includes airframe, interstage, pressurization and feed systems, and controls), were available among existing already developed hardware, these costs must be added to obtain stage development costs. As indicated, engine development costs for LOX/LH_2 propellants are between one and two orders of magnitude higher than those for LOX/RP and storable propellants and are obviously not economically justifiable development costs for an ASLV.

Development cost information on solid propellant stages is

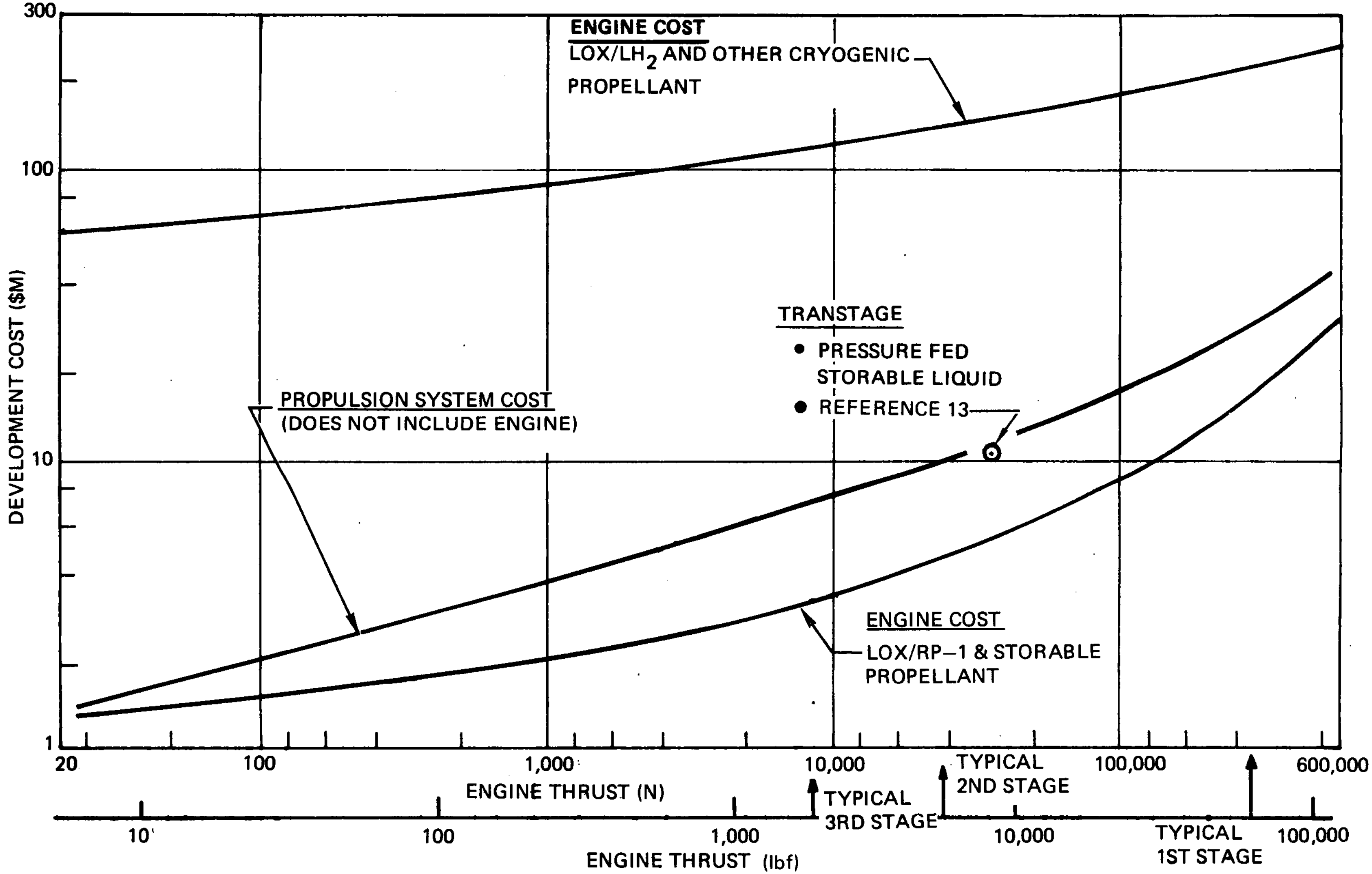


FIGURE 5 LIQUID PROPULSION SYSTEM AND ENGINE DEVELOPMENT COSTS

graphically illustrated in the upper portion of Figure 6 for the thrust and total impulse ranges of a typical four stage solid propellant ASLV. Costs are indicated for propulsion development status in 1971 and projected status in 1975 and reflect costs to the government. First and second stage development costs include movable nozzle, roll control, and interstage. Upper stage costs cover H_2O_2 reaction control systems in lieu of movable nozzles and separate roll control systems. The length of each cost bar encompasses variations in estimated development costs by different propulsion vendors.

Development costs for 75 state-of-the-art stages are significantly higher than those for equivalent size 71 state-of-the-art motors; however, this cost increase is largely offset by smaller stage sizes afforded through improvements in 75 state-of-the-art stages.

For comparison, development costs of storable and LOX/RP propulsion stages are depicted in the lower portion of Figure 6. These costs are based on the data in Figure 5 and are broken out for complete stage development as well as for development of the propulsion system around existing engines.

Taking the midpoint of each cost bar, development costs were totaled, as shown below, for four stage 71 and 75 state-of-the-art solids and two stage liquids, both with and without engine development.

	Total Development Cost ($M)
o Four Stage Solid	
- 71 SOA Motors	22.9
- 75 SOA Motors	26.8
o Two Stage Liquid	
- Propulsion System Only	39.3
- Engine plus Propulsion System	60.5

These costs clearly favor development of an all new four-stage solid over a two stage liquid, even if engines in the required thrust ranges exist and liquid stage development is reduced to propulsion system development only.

Data in Figure 6 also show that combined development of 71 state-of-the-art solid propellant third and fourth stages ($4.6M) is less than

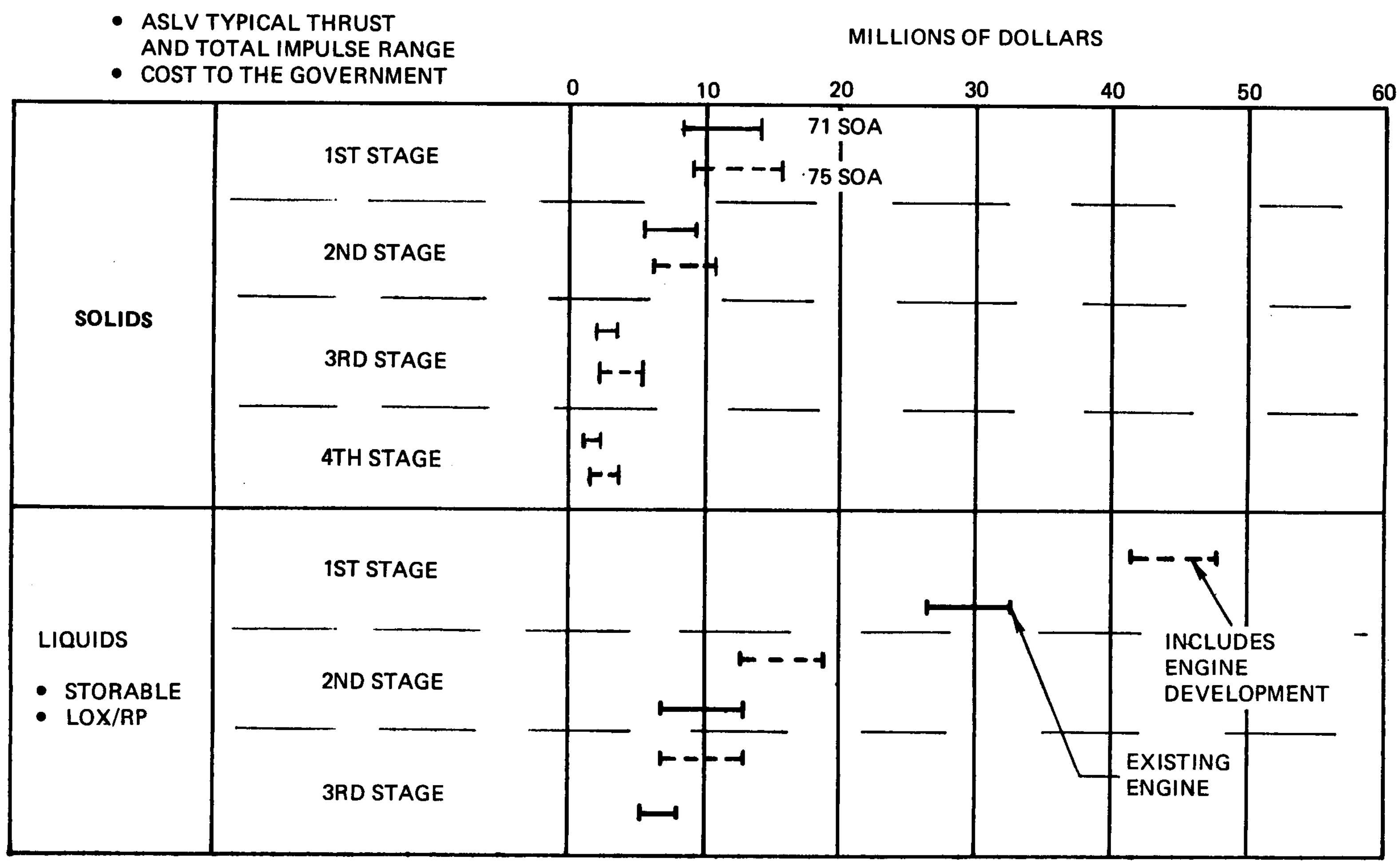


FIGURE 6 PROPULSION STAGE DEVELOPMENT COSTS

development of the propulsion system of a liquid third stage ($6.3M). Further, development of 75 state-of-the-art solid propellant third and fourth stages ($6.3M) can be achieved at a lower cost than complete development of a liquid third stage ($9.8M).

Stage Recurring Costs - Liquid stage recurring costs are presented in Figure 7. These costs are all inclusive, i.e., they contain both engine and propulsion system costs, and denote cost to the government. Recurring costs of LOX/LH_2 systems, typified by the Centaur stage, are about two times higher than those of other conventional liquid stages. In view of the considerably higher development and recurring costs, LOX/LH_2 stages are obviously not consistent with the most economical approach for development of an ASLV and were deleted from further consideration.

Recurring cost ranges of new and modified existing solid propellant stages are identified in the upper portion of Figure 8. Stage recurring costs include motor, attitude control and interstage. On new stages, movable nozzles and roll control systems were included in the first and second stages. All Poseidon and Minuteman stages, as well as Algol III stages with strap-ons and the short Algol III, were also costed with movable nozzle and roll control. The Algol III first stage, however, when used without strap-ons, is priced with jet vanes and fins for control. Two second stage candidates, the Scout Castor II and the Castor IV, were costed with H_2O_2 reaction control systems because configurations using these stages did not require movable nozzles. Third and fourth stage recurring costs for both new and modified existing stages include H_2O_2 reaction control systems.

Review of vendor cost information revealed that there is no appreciable difference in the recurring costs of 71 and 75 state-of-the-art motors; hence, only one range is given for each stage. For existing NASA motors, recurring costs were taken from Reference 15 and updated, as required, for modifications. Military stage recurring costs were estimated by VMSC on the basis of vendor information on applicable motors and cost information from previous programs involving Minuteman and Poseidon

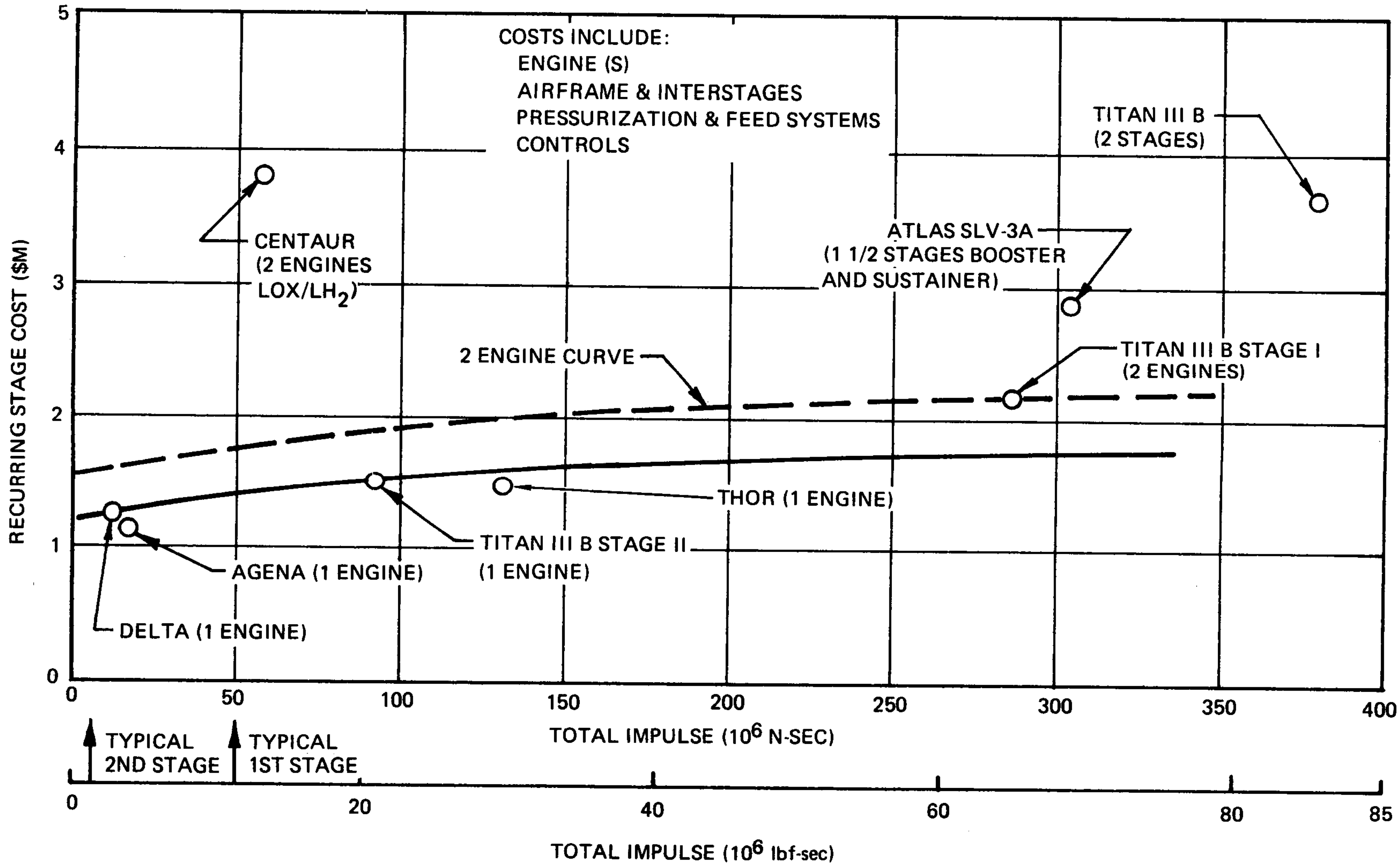


FIGURE 7 LIQUID PROPULSION STAGE RECURRING COST

- NUMBERS IN () -RECURRING COST $K
- ASLV TYPICAL THRUST AND IMPULSE RANGE
- COST TO THE GOVERNMENT

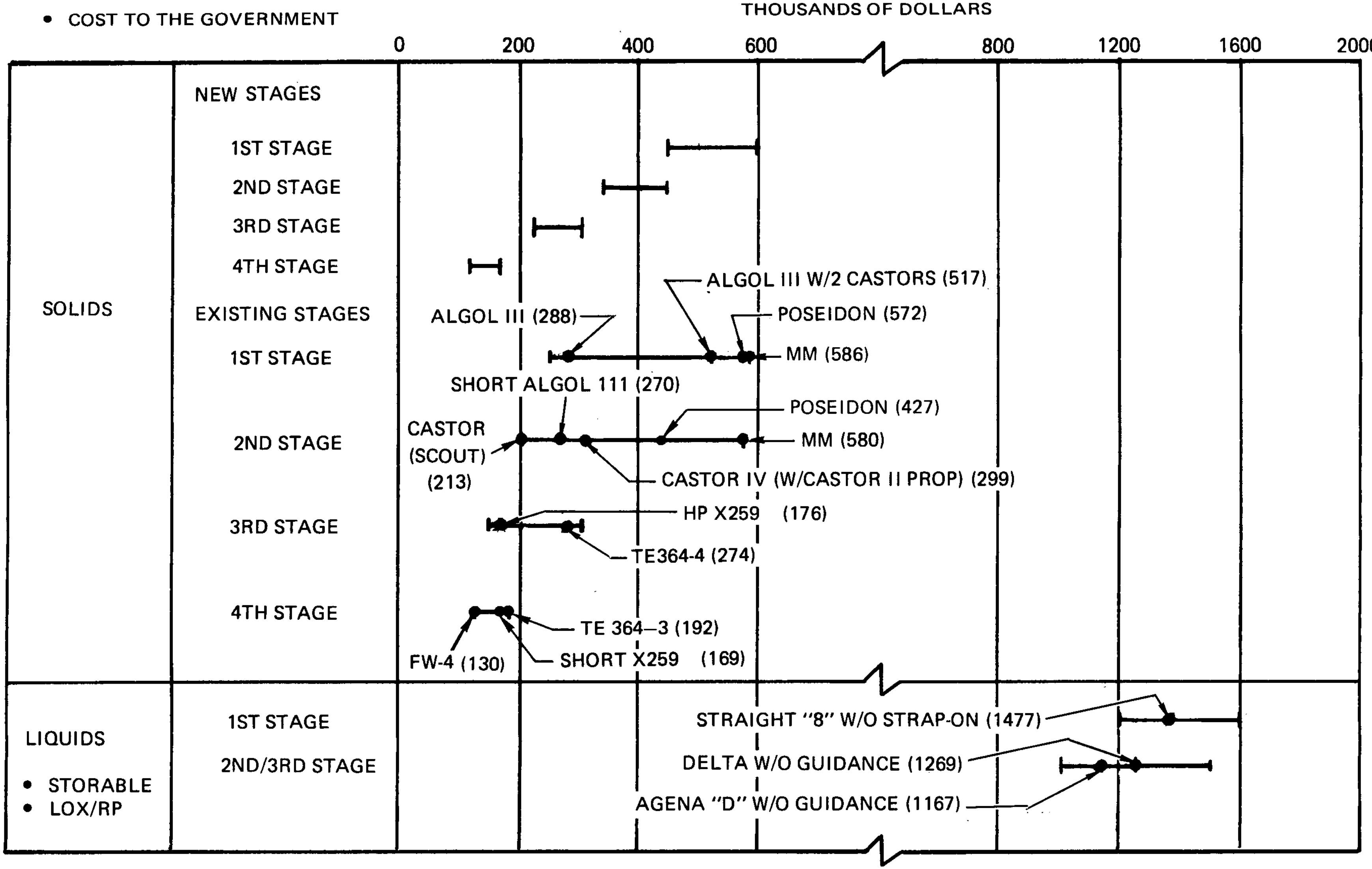


FIGURE 8 PROPULSION STAGE RECURRING COSTS

boosters. Movable nozzle, reaction control system, and interstage costs were developed from vendor information as well as cost data on similar systems on the Scout launch vehicle.

The Poseidon and Minuteman stage costs shown are based on current, relatively high, production runs and will undoubtedly rise significantly when purchased in small quantities after completion of military production. Section 4.2.2.6, Military Procurement, discusses this aspect in greater detail.

Liquid stage recurring costs, inclusive of engine and propulsion system, are shown in the lower portion of Figure 8 for comparison. These recurring costs are representative of typical ASLV liquid stage sizes indicated in Figure 7. Costs of existing liquid stages, exclusive of guidance and mission peculiar items, are superimposed for reference. Due to the small differences in recurring costs of typical liquid second and third stages, both are represented by a common cost bar.

Examination of Figure 8 discloses that stage recurring costs of a two stage liquid, even using the low end of the cost ranges, exceed recurring costs of any four stage solid by at least \$0.5M.

<u>Average Unit Stage Costs</u>

In comparing candidate launch vehicle stage costs, development costs were amortized over 50 launches in conformance with the guidelines in Section 2.2 and added to the stage recurring costs. The sum of recurring plus amortized development costs, referred to as average unit stage costs, are illustrated in Table 20 for new launch vehicles, both solid and liquid, and representative launch vehicles developed around existing stages.

For new stages, development costs are based on the information in Figure 6; development costs associated with modifications of existing stages were derived from vendor data and VMSC cost analyses. Recurring costs were taken from Figure 8.

The following conclusions were drawn from the foregoing cost discussions and comparative data in Table 20, and applied in screening configurations on the basis of cost:

(1) Development of new, optimally staged liquid or solid propellant launch vehicles is unjustifiable in view of the large number of configurations with existing

TABLE 20

AVERAGE UNIT STAGE COSTS

	DEVELOPMENT COST	RECURRING COST	AVE. UNIT STAGE COST
o OPTIMIZED 4 STAGE SOLID			
-71 SOA	$22.9M	$1.325M	$1.783M
-75 SOA	26.8	1.325	1.861
o OPTIMIZED 2 STAGE LIQUID (1)			
-Propulsion Sys. Development/Exist. Engines	39.3	2.650	3.436
-Propulsion Sys. and Engine Development	60.5	2.650	3.860
o EXISTING BOOSTER/LAUNCH VEHICLE DERIVATIVES			
-OPT 71 SOA/CASTOR IIA/HP X259/FW4	11.5	1.119	1.349
-ALGOL III/OPT 71SOA/OPT 71SOA/OPT 71SOA	11.9	1.088	1.326
-ALGOL III + 2 CASTORS/SHORT ALG. III/OPT 71SOA/ OPT 71 SOA	7.4	1.187	1.335
-ALGOL III + 2 CASTORS/CASTOR IV/OPT 71 SOA/ OPT 71 SOA	8.0	1.216	1.376
-MM III 1st/MM III 2nd/OPT 71SOA/OPT 71 SOA	5.1	1.566	1.668
- POSEIDON 1st/POSEIDON 2nd/OPT 71 SOA/OPT 71 SOA	5.1	1.399	1.501
-STRAIGHT "8" THOR + 3 CASTORS/TE 364-2	0.2 (2)	1.894	1.897

(1) Storable Propellants

(2) Allowance for Interstage Development

stages that satisfy design mission requirements at considerably lower average unit stage costs;

(2) Development of a new first stage, either solid or liquid propellant, is not justifiable because of existing candidates like the Minuteman, Poseidon, Algol III (with and without strap-ons), and the Straight "8" Thor first stages;

(3) Only existing upperstage motors are considered economically competitive for configurations comprised of Minuteman III or Poseidon first and second stages due to the relatively high recurring costs of these stages;

(4) Both development and recurring costs of a liquid upper stage are higher than the combined development and recurring costs of solid propellant third and fourth stages. Liquid propellant upper stages were therefore eliminated from further considerations.

Configurations utilizing the Straight "8" Thor first stage were not eliminated on the basis of cost in the first level screening, even though they exhibit rather high average unit stage costs. This exception was made because the total launched costs, including integration and launch support - not evaluated in this screening, should consider these factors as affected by an on-going Thor Delta program.

4.2.1.4 Back-Up Configurations - There are a number of configurations that are categorized as back-up configurations. The term back-up implies that a particular configuration either includes new upper stages whereas a similar configuration in the same family achieves the design payload with one or two existing motors, or a similar configuration provides the design payload at less risk, e.g., with optimum 71 rather than optimum 75 state-of-the-art motors. For example, Configuration 2K which consists of an Algol III first stage with two Castor strap-ons and optimum 71 state-of-the-art upper stages is rated as a back-up configuration to Configurations 70 and 7N which have the same first stage but satisfy the design missions with existing upper stages. A back-up configuration thus involves development of more motors, more advanced performance upper stages, or a more costly stage than a similar configuration at less development, risk, and cost.

4.2.1.5 Configuration Rating - Rating of the candidate configurations is accomplished in Table 21 where an "X" denotes a deficiency in a particular category. A single "X" in any of the rating categories eliminates a configuration from further consideration.

As a result of the first level screening, the initial list of 69 candidate configurations in Tables 14, 15, 16 and 17 was narrowed to 19 configurations which were subjected to more thorough evaluation in the second level of screening. This first level screening eliminated configurations with:

- o All new solid stages
- o All new liquid stages
- o New liquid/solid first stages
- o Liquid upper stages

Surviving configurations are highlighted in Table by a dashed line box.

4.2.2 Second Level Screening - Configurations that survived the first level screening were analyzed in greater depth for the second level screening and rated on the criteria in Table 22.

4.2.2.1 Off-Design Performance - While configurations must satisfy the design mission, performance on other missions, i.e., off-design performance, is equally important in the design of an ASLV. This factor was accentuated by the trends in projected missions, outlined earlier in Table 4, and the subsequently derived ASLV mission model in Table 6. These trends indicate proportionately large percentages of missions in the high altitude circular orbit (including orbits with specified orbit precession), synchronous transfer and earth escape categories. Accordingly, configuration performance was evaluated for these missions.

Off-design performance of the surviving configurations from the first level screening is illustrated in Table 23. A 1111 km (600 n.mi.) altitude was chosen for payload performance evaluation on the high altitude circular orbit mission because this altitude typifies application satellite orbit altitudes, including sun-synchronous missions. Payload capability on the synchronous transfer and earth escape missions was based on a high energy upper stage sized for the synchronous transfer injection velocity increment of approximately 2470 m/s.

TABLE 21 FIRST LEVEL SCREENING – IMPROVED SCOUT

NO.	CONFIGURATION: 1ST STAGE	CONFIGURATION: 2ND STAGE	CONFIGURATION: 3RD STAGE	CONFIGURATION: 4TH STAGE	INSUFFICIENT PAYLOAD	EXCESSIVE DYN. PRESSURE	STAGE DIA. INCOMPAT.	EXCESSIVE COST	BACK-UP CONFIGURATION	CONFIGURATION ELIMINATED
8	OPT SOLID	COMBINATION OF SCOUT UPPER STAGES					X	X		8
11	OPT LIQUID	COMBINATION OF SCOUT UPPER STAGES					X	X		11
7, 10	ALGOL III	OPT SOLID OR LIQUID UPPER STAGES						X	X	7, 10
7R1, 7R2		OPT 71	OPT 71	EXISTING 4TH STAGE						NONE
7S1, 7S2		OPT 75	EXISTING UPPER STAGES							NONE
7T1		MOD CAST II	OPT 75 UPPER STAGES		X		X			7T1
7A		ALGOL III	CAST II	OPT SOLID	X		X			7A
23A		SHORT ALGOL III	OPT 71 UPPER STAGES							NONE
23B		SHORT ALGOL III	OPT 75 UPPER STAGES						X	23B
2K	ALGOL III + (2) CASTORS	OPT UPPER STAGES						X	X	2K
2D, 2E, 2B, 2		CAST II	X259	NEW OR EXIST 4TH	X	X	X			2D, 2E, 2B, 2
7G		MM III 2ND	OPT UPPER STAGES		X			X		7G
7F		CAST IV	OPT UPPER STAGES						X	7F
7M, 7L		CAST IV	HP X259 OR TE 364-4	FW4	X					7M, 7L
7O, 7N		CAST IV	HP X259 OR TE 364-4	TE 364-3						NONE
7E		ALG III	OPT UPPER STAGES						X	7E
2F		ALG III	CAST II	OPT SOLID			X			2F
7H, 7I		ALG III	HP X259 OR TE 364-4	FW4	X					7H, 7I
7K, 7J		ALG III	HP X259 OR TE 364-4	TE 364-3						NONE
7U6		SHORT ALG III	HP X259	FW4	X					7U6
7U2		SHORT ALG III	HP X259	TE 364-3						NONE
7U3		SHORT ALG III	HP X259	SHORT X259						NONE
7U, 7U1		OPT 71 SOLID OR SHORT ALG III	TE 364-4	TE 364-3						NONE
7U4	ALGOL III + (2) STRETCHED CAST	SHORT ALG III	HP X259	FW4						NONE
7U5		SHORT ALG III	HP X259	TE 364-3					X	7U5
3	ALG III + (3) CASTORS	CASTOR II	X259	FW4	X	X	X			3
3B, 3D, 3C		ALG III	EXISTING UPPER STAGES						X	3B, 3D, 3C
4A, 4	ALG III + (4) CASTORS	CAST II	X259	FW4	X	X	X			4A, 4
4B		MOD CAST II	HP X259	OPT SOLID		X	X			4B

TABLE 21 FIRST LEVEL SCREENING (CONT'D.)
NEW LAUNCH VEHICLES

NO.	CONFIGURATION: 1ST STAGE	CONFIGURATION: 2ND STAGE	CONFIGURATION: 3RD STAGE	CONFIGURATION: 4TH STAGE	INSUFFICIENT PAYLOAD	EXCESSIVE DYN. PRESSURE	STAGE DIA. INCOMPAT.	EXCESSIVE COST	BACK-UP CONFIGURATION	CONFIGURATION ELIMINATED
	NEW, OPTIMALLY STAGED LAUNCHED VEHICLES									
13, 14, 18, 20, 19, 19A	MM III 1ST	MOD CAST II	NEW OR EXISTING UPPER STAGES		X	X	X	X		13, 14, 18, 20, 19, 19A
5C, 5										5C, 5
22		MM III 2ND	OPT SOLID		X					22
22A		MM III 2ND	OPT SOLID	OPT SOLID				X		22A
22C, 22D		MM III 2ND	EXISTING UPPER STAGES		X					22C, 22D
22H		CASTOR IV	CAST II	HP X259			X			22H
22M		CASTOR IV	TE 364-4	TE 364-3						NONE
22E		ALGOL III	CASTOR II	HP X259			X			22E
5E		ALGOL III	CASTOR II	FW4			X			5E
22G		ALGOL III	TE 364-4	FW4	X					22G
22F		ALGOL III	TE 364-4	TE 364-3						NONE
22I	POSEIDON 1ST	POSEIDON 2ND	TE 364-4		X					22I
22B		POSEIDON 2ND	OPT SOLID	OPT SOLID				X	X	22B
22K		POSEIDON 2ND	HP X259	FW4	X					22K
22J		POSEIDON 2ND	TE 364-4	TE 364-3						NONE
22L		POSEIDON 2ND	TE 364-4	FW4						NONE
24A	OFF-LOADED "STRAIGHT 8" 1ST STAGE	TE 364-3			X					24A
24	"STRAIGHT 8" 1ST STAGE + (3) CASTORS	TE 364-2								NONE

TABLE 22

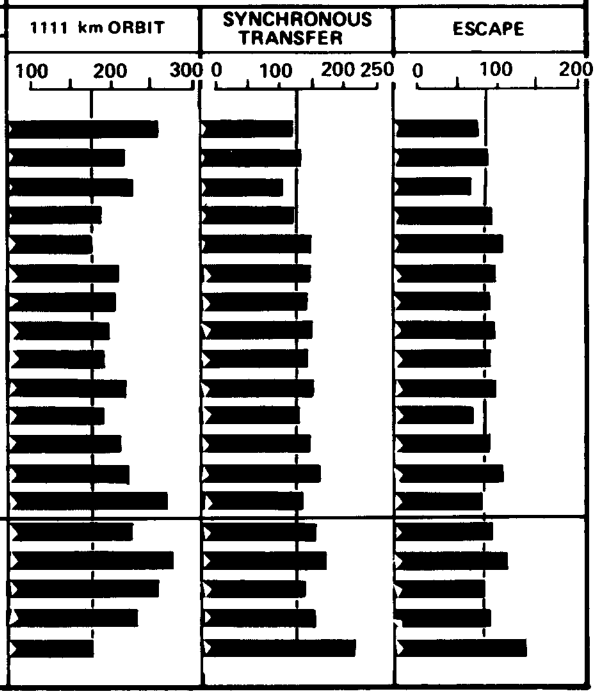
SECOND LEVEL SCREENING CRITERIA

- o Off-Design Performance
    - Circular Orbit - 1111 km (600 n.mi.)
    - Synchronous Transfer
    - Earth Escape
- o Phased Growth to 340 kg (750 lbs)
- o Step-Down Complexity
- o GSE and Launcher Impact
    - Vehicle Length/Diameter
    - Liquid Stages
    - Step-Down Payload
- o Technical Risk
- o Military Procurement
- o Preliminary Launch Vehicle Cost - Recurring Plus Hardware Development

TABLE 23 OFF-DESIGN PERFORMANCE SUMMARY – SECOND LEVEL SCREENING

NO.	CONFIGURATION	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE
X 7R1	IMPROVED SCOUT	ALGOL III	OPT 71 SOLID	OPT 71 SOLID	FW4
X 7R2		↓	OPT 71 SOLID	OPT 71 SOLID	TE 364-3
X 7S2		↓	OPT 75 SOLID	TE 364-4	FW4
X 7S1		↓	OPT 75 SOLID	TE 364-4	TE 364-3
23A		↓	SHORT ALG III	OPT 71 SOLID	OPT 71 SOLID
7Q		ALG III + (2) CASTORS	CASTOR IV	HP X259	TE 364-3
7N		↓	CASTOR IV	TE 364-4	TE 364-3
7K		↓	ALGOL III	HP X259	TE 364-3
7J		↓	ALGOL III	TE 364-4	TE 364-3
7U		↓	SHORT ALG III	TE 364-4	TE 364-3
X 7U1		↓	OPT 71 SOLID	TE 364-4	TE 364-3
7U2		↓	SHORT ALG III	HP X259	TE 364-3
7U3		↓	SHORT ALG III	HP X259	SHORT X259
X 7U4		ALG III + (2) STR. CAST.	SHORT ALG III	HP X259	FW4
22K	NEW LAUNCH VEHICLE	MM III 1ST	CASTOR IV	TE 364-4	TE 364-3
22F			ALGOL III	TE 364-4	TE 364-3
22L		POSEIDON 1ST	POS 2ND	TE 364-4	FW4
22J			POS 2ND	TE 364-4	TE 364-3
24		STRAIGHT 8 + (3) CASTORS	TE 364-2	–	–

PAYLOAD WEIGHT (kg)



Examination of Table 23 shows that configurations which demonstrate superior payload capability on the high altitude mission generally yield relatively low payload performance on the synchronous transfer and earth escape missions, and vice versa. This behavior is attributable to the relative sizes of the stages in each configuration. Since ASLV launches are projected for all three of these missions, it is desirable to strike a balance between payload performance on the three indicated missions. Therefore, in rating configurations on off-design performance, minimum desired payload weights of 182 kg (400 lbs) for the high altitude mission, 136 kg (300 lbs) on the synchronous transfer and 91 kg (200 lbs) on escape trajectories were selected as payload screening criteria. These magnitudes were chosen because payload weights much less than these are not considered attractive, nor practical, for future space launches on these types of missions.

Configurations downgraded on off-design performance are denoted by an "X" before the configuration number in Table 23.

4.2.2.2 Phased Growth - A phased-growth approach represents a practical avenue for gradual step improvement in payload capability and vehicle accuracy from the present Scout to the ASLV. This is important in evaluating configurations because it (1) permits time-phased integration and evaluation of individual hardware items and thus eliminates the need for development flights, (2) provides flexibility for redirection of growth objectives, if deemed necessary, (3) allows for timely incorporation of new advances in technology, e.g., new high performance propellants, and (4) avoids large spikes in fiscal funding for vehicle development. For these reasons, a configuration amenable to the phased growth approach was preferred over one that replaces the current Scout at a certain point in time in one step.

In judging configurations suitable or unsuitable to this approach, the rationale was based on the number of stages, or motors, that are replaced at one time. If a single stage could be replaced at a time, the configuration was considered adaptable to a phased growth; if more than one stage had to be integrated at one time, it was downrated in the phased growth category.

Approximately one half of the configurations in Table 23 required integration of more than one stage or motor at a time. Configurations 70, 7N, 7K, and 7J, for example, required addition of Castor strap-ons at the same time that the new second stage was integrated, otherwise the initial thrust-to-weight became marginal for Configurations 70 and 7N, and unacceptable for Configurations 7K and 7J. Strap-ons cannot be added prior to integration of the second stage because the dynamic pressure rises to unacceptably high values. The 22-series configurations, likewise, required simultaneous incorporation of the first and second stages to constrain dynamic pressure.

4.2.2.3 Step-Down Complexity - The requirement for handling current Scout-class missions in the 136-181 kg payload range ostensibly favored configurations with strap-ons due to the simplicity of deleting these performance augmentors for the lower payload missions. However, those strap-on configurations that were thrust-to-weight limited without strap-ons, as well as the non-strap-on configurations, must rely on stage deletion (usually the third stage) for step-down performance. Launch vehicle electrical and mechanical interface problems, as well as operating procedure changes associated with stage deletion detract from the advantage of the step-down capability. Thus, configurations that required stage deletion for the step-down payloads are downgraded in the category of step-down complexity.

4.2.2.4 GSE and Launcher Impact - A qualitative assessment of the impact of each configuration on the current Scout ground support equipment and overall launch complex was also used in the comparative evaluation of the candidate launch vehicles. Configurations using the Algol III, with or without strap-ons, as first stage motors have much less of an impact on the launcher, transporter, and related handling equipment than configurations with Minuteman and Poseidon stages which require major modifications to all of the ground support equipment. An assessment of launcher modifications can be obtained from the size relationships between several of the candidate launch vehicles and the current Scout launcher, graphically illustrated in Figure 9. In addition to new ground support equipment, the "Straight 8" Thor configuration would also require new propellant and fueling facilities, if deployed at Wallops Island, since this launch site is not equipped for handling LOX/RP.

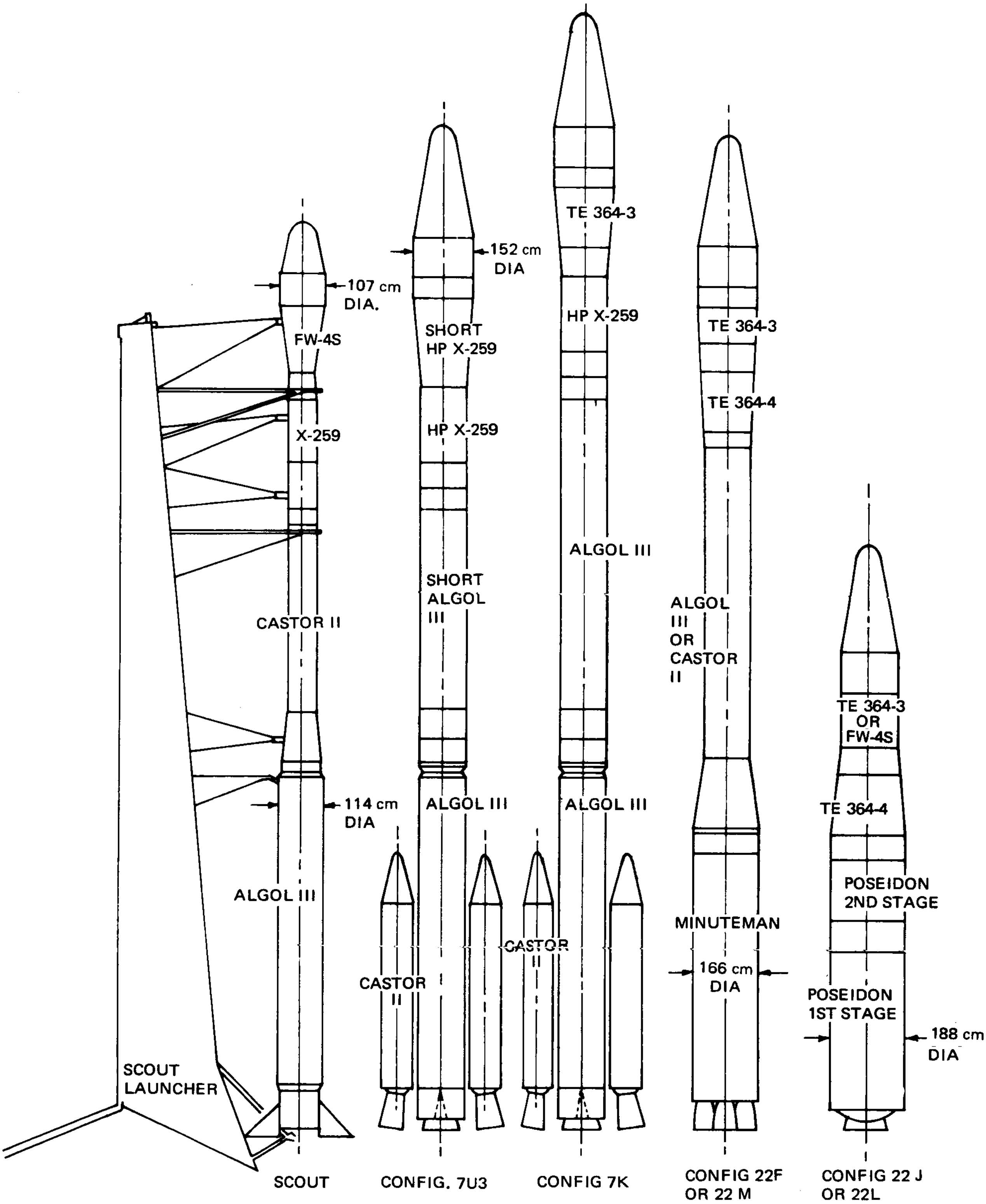


FIGURE 9 ASLV/SCOUT LAUNCHER COMPARISON

Configurations that achieve the step-down capability via stage deletion also pose a larger problem in terms of the launcher because retaining clamp and umbilical locations will differ between full-size and step-down configurations. Similarly, the transporter will require adapters to handle the different configurations.

4.2.2.5 <u>Technical Risk</u> - Vehicles that employ "Optimum 75 Solid" stages to satisfy the design mission demonstrate a higher element of risk in that some advances in solid propulsion technology are necessary to achieve the quoted motor performance and design. Even though programs currently under development are expected to provide these advances, configurations that require these improvements nevertheless exhibit some risk and are thus downrated in the category of technical risk.

4.2.2.6 <u>Military Procurement</u> - Reliance on military motors or stages (Minuteman III and Poseidon) results in some problems, when used in a non-military launch vehicle that, in many cases, is used for international and cooperative-venture spacecraft.

First, many details of the motors, including performance, are generally classified for security reasons. This would result in problems in flight planning with the payload agencies, especially foreign users. Next, military production schedules will probably not be compatible with ASLV procurement requirements. Cost shown for military boosters are based on best information available reflecting current relatively high production runs. It is unlikely that these boosters will be in production over the time span of ASLV procurement. Best estimates for small quantity buys of Minuteman III after production runs are completed show an increase of 20 to 30% over the costs in Figure 8. Algol III costs, on the other hand, are based on small quantity buys typical of Scout and ASLV procurement.

For the reasons cited above, configurations that rely on Minuteman III and Poseidon stages are downgraded.

4.2.2.7 <u>Configuration Costs</u> - Total vehicle costs were determined for use in the second level screening. The build-up of vehicle costs was based on the following considerations.

(1) Propulsion stage costs were based on data in Figures 6 and 8 which account for motor (or engine and propulsion system for liquids), control system, and interstage.

(2) A common improved guidance system with a $1.0M development and $213K recurring cost was used on all configurations.

(3) Payload shroud costs were determined for the various shroud sizes.

(4) A uniform launch support cost of $1.0M was included in the recurring cost of each vehicle, except for the Straight "8" Thor/TE 364-2 (Configuration 24). Launch support cost for this latter configuration was estimated at $900K.

(5) Engineering and tool design, fabrication and vehicle integration were not costed for each configuration; however, a cost of $6.0M was assessed for these items, and this number was used on all configurations for uniformity. The lone exception was Configuration 24 which had no cost assessed to it for these functions. While some costs would no doubt be incurred for these functions, the total cost would be considerably less on Configuration 24 than for the remaining configurations since the upper stage motor is already in the Thor/Delta launch vehicle motor inventory.

Costs for each of the configurations remaining from the first level screening are summarized in Table 24. The average unit launch costs shown in this table represent recurring costs plus development amortized over 50 launches. Launch support costs are included in the recurring costs. Average unit launch costs for Scout are provided for reference.

Average unit launch costs of the surviving configurations in Table 24 fall in a relatively narrow range, except for Configuration 24.

4.2.2.8 Configuration Rating

The second level screening is accomplished in Table 25, which displays the rating of the remaining configurations for each of the seven criteria discussed above. Since more detailed analysis of screening factors was utilized in the second level screening, only those configurations that are downgraded in two or more categories were eliminated from further

TABLE 24 PRELIMINARY CONFIGURATION COSTS – SECOND LEVEL SCREENING

CONFIG-URATION NO.		1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE
	SCOUT	ALGOL III	CASTOR II	X259	FW4
7R1	IMPROVED SCOUT	ALGOL III	OPT 71 SOLID	OPT 71 SOLID	FW4
7R2		↓	OPT 71 SOLID	OPT 71 SOLID	TE 364-3
7S2		↓	OPT 75 SOLID	TE 364-4	FW4
7S1		↓	OPT 75 SOLID	TE 364-4	TE 364-3
23A		↓	SHORT ALG III	OPT 71 SOLID	OPT 71 SOLID
70		ALG III + (2) CASTORS	CASTOR IV	HP X259	TE 364-3
7N		↓	CASTOR IV	TE 364-4	TE 364-3
7K		↓	ALGOL III	HP X259	TE 364-3
7J		↓	ALGOL III	TE 364-4	TE 364-3
7U		↓	SHORT ALG III	TE 364-4	TE 364-3
7U1		↓	OPT 71 SOLID	TE 364-4	TE 364-3
7U2		↓	SHORT ALG III	HP X259	TE 364-3
7U3		↓	SHORT ALG III	HP X259	SHORT X259
7U4		ALG III + (2) STR. CAST.	SHORT ALG III	HP X259	FW4
22M	NEW LAUNCH VEHICLE	MM III 1ST	CASTOR IV	TE 364-4	TE 364-3
22F		↓	ALGOL III	TE 364-4	TE 364-3
22L		POSEIDON 1ST	POS 2ND	TE 364-4	FW4
22J		↓	POS 2nd	TE 364-4	TE 364-3
24		STRAIGHT 8 + (3) CASTORS	TE 364-2	–	–

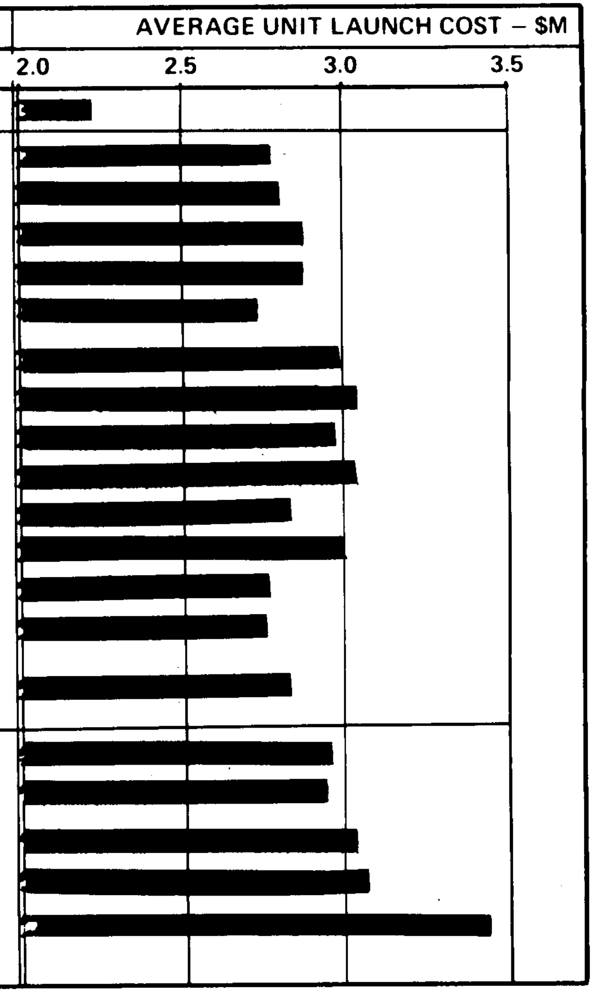


TABLE 25 SECOND LEVEL SCREENING

NO.	TYPE	CONFIGURATION: 1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	POOR OFF-DESIGN PERFORMANCE	UNSUITABLE FOR PHASED GROWTH	STEP-DOWN COMPLEXITY	HEAVY IMPACT ON GSE	HIGH TECH. RISK	RELIANCE ON MILITARY PROCUREMENT	HIGH COST	CONFIGURATION ELIMINATED
7R1		ALGOL III	OPT 71 SOLID	OPT 71 SOLID	FW4	X		X					7R1
7R2			OPT 71 SOLID	OPT 71 SOLID	TE 364-3	X		X					7R2
7S2			OPT 75 SOLID	TE 364-4	FW4	X		X		X			7S2
7S1			OPT 75 SOLID	TE 364-4	TE 364-3	X		X		X			7S1
23A			SHORT ALG III	OPT 71 SOLID	OPT 71 SOLID			X					NONE
7O	IMPROVED SCOUT	ALG III + (2) CASTORS	CASTOR IV	HP X259	TE 364-3		X	X	X				7O
7N			CASTOR IV	TE 364-4	TE 364-3		X	X	X				7N
7K			ALGOL III	HP X259	TE 364-3		X	X	X				7K
7J			ALGOL III	TE 364-4	TE 364-3		X	X	X				7J
7U			SHORT ALG III	TE 364-4	TE 364-3								NONE
7U1			OPT 71 SOLID	TE 364-4	TE 364-3	X							NONE
7U2			SHORT ALG III	HP X259	TE 364-3								NONE
7U3			SHORT ALG III	HP X259	SHORT X259								NONE
7U4		ALG III + (2) STR. CASTOR	SHORT ALG III	HP X259	FW4	X							NONE
22M	NEW LAUNCH VEHICLE	MM III 1ST	CASTOR IV	TE 364-4	TE 364-3		X	X	X		X		22M
22F			ALGOL III	TE 364-4	TE 364-3		X	X	X		X		22F
22L		POSEIDON 1ST	POS 2ND	TE 364-4	FW4		X	X	X		X		22J
22J			POS 2ND	TE 364-4	TE 364-3		X	X	X		X		22J
24		STRAIGHT 8 + (3) CASTORS	TE 364-3	–	–				X			X	24

consideration.

The second level screening reduced the number of candidates from 19 to 6. This screening eliminated all configurations utilizing Minuteman III and Poseidon stages and the Straight "8" Thor configuration. Configurations comprised of military stages were each downgraded in four categories and the Straight "8" Thor configuration was eliminated primarily on cost which was significantly higher than those of the remaining configurations. If deployed at Wallops Island, as stipulated in the guidelines (Section 2.2) the impact on GSE would also be rather extensive and Configuration 24 was therefore also downgraded in this category.

4.2.3 Third Level Screening - Selection of the most promising configuration from the remaining candidates entails determination of the best overall compromise between performance, design considerations, and cost. The six remaining candidates, representing the 7U and 23A configuration families, were thus further refined and rated on the criteria on Table 26.

4.2.3.1 Off-Design Performance - The off-design performance of the six remaining configurations is shown in Table 27. In assessing relative worths in the area of performance, attention is directed to the ASLV mission model in Table 7 which purports the dominance of high altitude circular orbit missions (19 out of 50 missions or 38%). A minimum payload capability of about 182 kg was previously designated in Section 4.2.2 for missions in this category. All of the five 7U configurations deliver payloads in excess of 182 kg into a 1111 km orbit, as shown in Table 27; however, the 179 kg payload of Configuration 23A falls slightly short of this value.

Configuration 23A and three of the 7U configurations (7U, 7U2, 7U3) satisfy the synchronous transfer and earth escape payload requirements of 136 and 91 kg, respectively, that were specified in the second level screening. Those configurations down-rated on off design performance are denoted by "X" in front of the Configuration number in Table 27.

4.2.3.2 Technical Risk - Configuration 23A is sensitive to weight since this configuration relies only on the Algol III for first stage thrust. The configuration contains two new 1971 state-of-the-art motors. If the projected propellant performance and stage weights assumed in sizing this

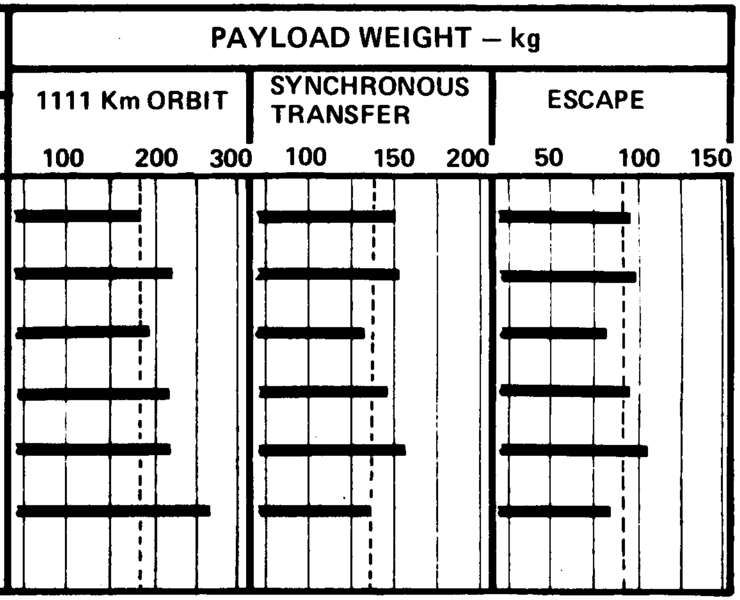
TABLE 26

THIRD LEVEL SCREENING CRITERIA

- OFF-DESIGN PERFORMANCE
- TECHNICAL RISK
- STEP-DOWN COMPLEXITY
- PAYLOAD SHROUD LENGTH
- COST - RECURRING PLUS HARDWARE DEVELOPMENT

TABLE 27 OFF-DESIGN PERFORMANCE – THIRD LEVEL SCREENING

CONFIGURATION				
NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE
x 23A	ALGOL III	SHORT ALG III	OPT 71 SOLID	OPT 71 SOLID
7U	ALG III + (2) CASTORS	SHORT ALG III	TE 364-4	TE 364-3
x 7U1		OPT 71 SOLID	TE 364-4	TE 364-3
7U2		SHORT ALG III	HP X259	TE 364-3
7U3		SHORT ALG III	HP X259	SHORT X259
x 7U4	ALG III + (2) STR. CASTOR	SHORT ALG III	HP X259	FW4



configuration cannot be achieved, stage sizes will have to be increased to meet the design payload objective and launch weight will increase proportionately. The initial thrust/weight of Configuration 23A is already marginal, however, and any increases in weight would decrease the initial thrust/weight to the point where gravity losses would off-set any gains derived from increased stage sizes. Thus, Configuration 23A exhibits an element of risk.

Configurations in the 7U family, on the other hand, either have an adequate performance margin to cover design contingencies or, if not, provide the latitude to compensate for contingencies through slight increases in the size of the Short Algol III, Optimum 71 solid, or short X259 motors since these configurations have more than adequate thrust at vehicle lift-off.

4.2.3.3 Step-Down Complexity - The simplicity, in terms of vehicle interfaces, ground support equipment, and launcher, afforded by strap-on configurations in conversion to the step-down payload configurations was previously covered in Section 4.2.2 and clearly favors configurations in the 7U family.

4.2.3.4 Payload Shroud - Due to the small diameters and limited load carrying nature of the third stage motors in the 7U configuration family, the payload shroud was designed to house both third and fourth stage motors. This results in somewhat longer and heavier payload shrouds than that for Configuration 23A because the third stage motor of this latter configuration can be designed to the same diameter as the second stage (1.14m) and its payload shroud can be mounted to the top of the third stage motor.

Payload shrouds for four of the five configurations in the 7U family are illustrated in Figure 10. The TE364-4 and -3 combination shown on the right side of the figure results in the shortest overall payload shroud length because both motors are packaged in a compact manner, i.e., they both feature submerged nozzles and larger diameters than the HP X259 motor versions. Total shroud length of the HP X259/TE364-3 combination increases nearly 1.22 m (4 ft) over the TE364-4/TE-364-3 shroud due to the length of the HP X259 motor, and another 0.76 m (2.5 ft) when the short HP X259 is used as the fourth stage motor. Total shroud length for Configuration 7U4 which uses the FW4 as the fourth stage motor is

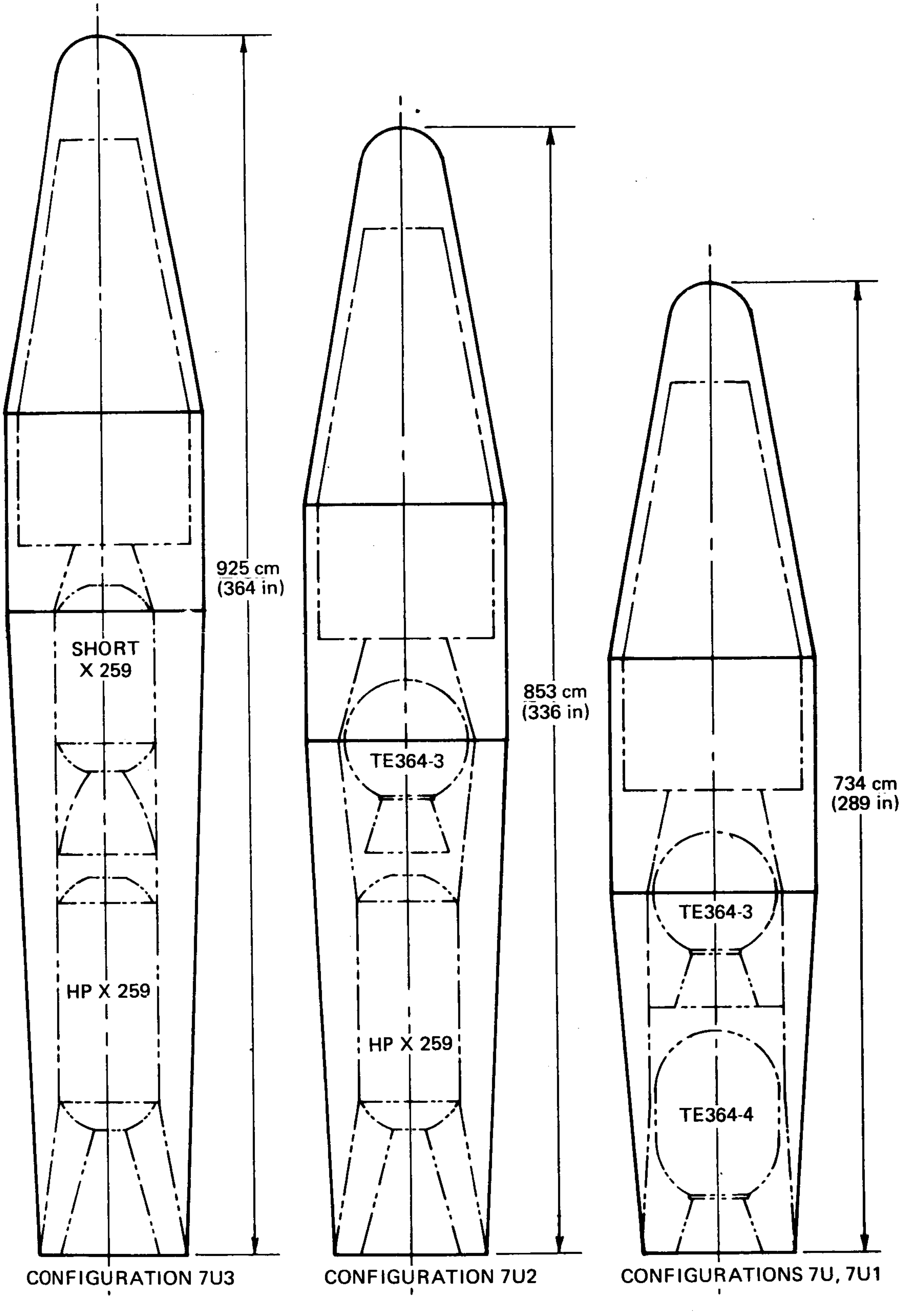


FIGURE 10 COMPARISON OF PAYLOAD SHROUD CONFIGURATIONS

essentially the same as that for Configuration 7U2, shown in the center of Figure 10, since the FW4 is approximately of the same length as the TE364-3. In contrast, the payload shroud of Configuration 23A is approximately 2.54 m (100 in) shorter than those for Configuration 7U and 7U1 due to the 1.14 m diameter, load carrying third stage motor of Configuration 23A.

While long shrouds lead to a moderate reduction in interstage structure between the third and fourth stages, additional weight and complexity in shroud design more than off-set this reduction in interstage weight. (It may be possible to beef up the third stage motors to the point where they can carry the required flight bending loads; however, analyses in this conceptual study did not penetrate to sufficient depth to determine the required motor modifications). Configurations in the 7U family were thus downgraded relative to Configuration 23A.

4.2.3.5 Cost - Cost data for the six remaining configurations were updated from the second level for the third level screening to reflect refinements in the configurations and final cost inputs from guidance and propulsion vendors. These costs are summarized in Table 28.

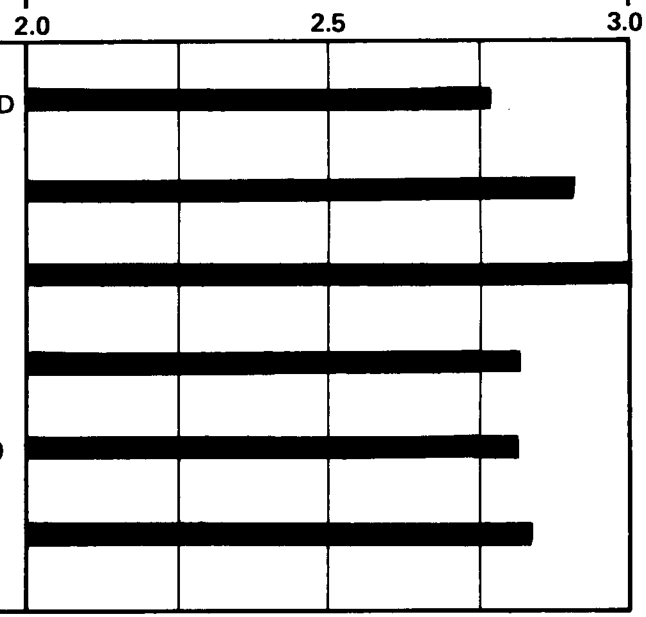
Comparison of configuration costs in Table 28 indicates that (1) Configuration 23A is the lowest cost launch vehicle, (2) average unit costs of Configurations 7U2, 7U3, and 7U4 are only about 2.5% higher than those of the lowest cost configuration, and (3) the highest cost configurations, 7U and 7U1, differ less than 10% from the lowest cost configuration. Even though development costs of two new motors and those associated with the short Algol III were amortized, Configuration 23A resulted in the lowest average unit launch cost because this configuration is not burdened by the recurring costs of the two Castor strap-ons.

In view of the limited depth of configuration analysis and the preliminary nature of the costing information in this conceptual design phase, cost differences on the order of 2.5% are considered inadequate for a clear cut selection of one configuration over another on the basis of cost; however the cost differences exhibited by Configurations 7U and 7U1 are considered indicative of a trend towards a less economical configuration and these configurations were downgraded on cost in the third level screening.

4.2.3.6 Configuration Rating - The comparative rating of the six remaining

TABLE 28 REFINED CONFIGURATION COSTS – THIRD LEVEL SCREENING

CONFIGURATION					AVERAGE UNIT LAUNCH COST – $M
NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	
23A	ALGOL III	SHORT ALG III	OPT 71 SOLID	OPT 71 SOLID	
7U	ALG III + (2) CASTORS	SHORT ALG III	TE 364-4	TE 364-3	
7U1		OPT 71 SOLID	TE 364-4	TE 364-3	
7U2		SHORT ALG III	HP X259	TE 364-3	
7U3		SHORT ALG III	HP X259	SHORT X259	
7U4	ALG III + (2) STR. CASTOR	SHORT ALG III	HP X259	FW4	



configurations is summarized in Table 29. Configurations with two or more "X" were eliminated, leaving Configurations 7U2 and 7U3 for final selection.

Configuration 23A, with a 2.5% lower average unit cost than the two remaining candidates, was withdrawn from further consideration primarily for reasons of technical risk associated with the two new motor developments discussed previously in this section, and the complexity of stage deletion for step-down payload missions.

Elimination of Configuration 7U and 7U1 stemmed from cost considerations, and, in the case of the latter configuration, from cost-related risk associated with new motor development. Recurring costs of the TE364-4 and -3 motors are both higher than those of the HPX259 and short X259 third stage motors, resulting in higher average unit costs for these configurations.

In the case of Configuration 7U4, development and somewhat higher recurring costs of the stretched Castor strap-ons, in conjunction with below-par off-design performance, were the factors that eliminated this configuration.

4.2.4 Final Selection - The final evaluation and selection of the winning configurations was based on overall mission performance and costs of the final contenders - Configurations 7U2 and 7U3.

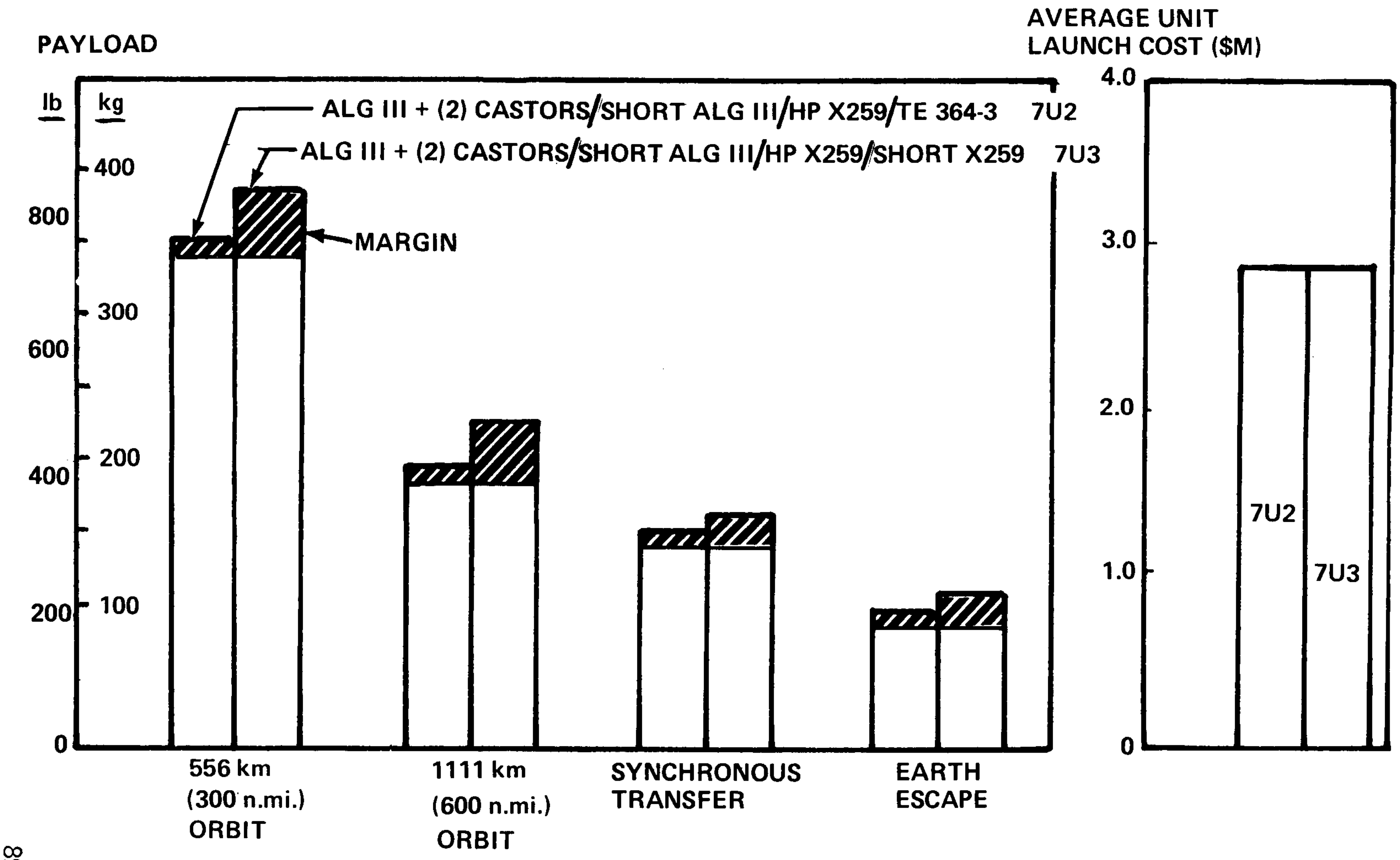
Review of design mission and off-design performance, as denoted in Table 30, clearly shows that configurations 7U3 yields higher payloads on all missions. It also has approximately an 11% payload margin for the design mission to allow for contingencies in the detailed design, whereas the corresponding design margin of Configuration 7U2 is less than 2%. Average unit launch costs, shown on the right hand side of Table 31, differ by only about $1.0K, with Configuration 7U3 being the lower cost vehicle.

Configurations 7U2 and 7U3 were penalized only for their lengthy shroud in the third level screening. While the shroud of Configuration 7U3 is about 0.76 m longer than that of Configuration 7U2, neither shroud presents a serious design problem and the difference is shroud length does not become a deciding factor.

TABLE 29 THIRD LEVEL SCREENING

	CONFIGURATION									
NO.	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE	MARGINAL OFF-DESIGN PERFORMANCE	TECHNICAL RISK	STEP-DOWN COMPLEXITY	PAYLOAD SHROUD LENGTH	COST	ELIMINATED CONFIGURATIONS
23A	ALGOL III	SHORT ALG III	OPT 71 SOLID	OPT 71 SOLID	X	X	X			23A
7U	ALG III + (2) CASTORS	SHORT ALG III	TE 364-4	TE 364-3				X	X	7U
7U1		OPT 71 SOLID	TE 364-4	TE 364-3	X			X	X	7U1
7U2	↓	SHORT ALG III	HP X259	TE 364-3				X		NONE
7U3	↓	SHORT ALG III	HP X259	SHORT X259				X		NONE
7U4	ALG III + (2) STR. CASTORS	SHORT ALG III	HP X259	FW4	X			X		7U4

TABLE 30 FINAL EVALUATION



Configuration 7U3 was therefore selected as the winning configuration. This configuration consists of:

1st Stage: Scout Algol III with Movable Nozzle and 2 Castor Strap-Ons.

2nd Stage: Short Algol III with 8160 kg (18000 lb) Propellant and Movable Nozzle

3rd Stage: Scout X259, Modified with Smaller Throat Diameter Nozzle

4th Stage: Short X259 with 770 kg (1690 lb) Propellant and Contoured Nozzle

Payload Shroud: 1.52 m (60 in) diameter; 9.3 m (30.3 ft) length.

The fourth stage of the ASLV is attitude stabilized about all three axes and contains the guidance and reaction control systems. It was found that the FW5 motor is an excellent candidate for the spin-stabilized fifth stage on synchronous transfer and earth escape missions. It can also be used on highly elliptic orbit and reentry missions.

4.2.5 Growth Plan - With the ASLV configuration selected, determination of logical growth plan that permits buildup of the ASLV from the current Scout through time-phased integration of individual stages was undertaken. The obvious advantages of such an approach are (1) control of peak fiscal year funding, (2) elimination of flight test vehicle(s) since individual improvements are sequentially flight proven, and (3) commitment of only one growth step at a time which permits redirection of ASLV objectives, if required, and/or incorporation of new improvements in propulsion, as they become available.

Emphasis on guidance accuracy was stressed in the ASLV Program Plan and verified by the accuracy requirements analysis in Section 3.2. Early improvement in guidance, concurrent with increased payload capability, therefore represents a desirable approach toward a phased growth program. Accordingly, improved guidance was introduced in the first growth step. Three options are available for motor integration in the initial growth step - addition of strap-on motors, incorporation of the short Algol III, or parallel integration of the HP X259 and short X259 upper stage motors.

Addition of strap-ons does not present a viable first step improvement because dynamic pressures become excessive and extensive modifications are required to the Scout upper stages to sustain the resulting loads and provide adequate control.

Time-phased ASLV Growth Plans for the remaining two options are presented in Figure 11, which shows sequential payload performance in terms of calendar years for a 556 km (300 n.mi.) circular orbit mission. The cross-hatched areas represent the contingency margin, Table 31. The upper bound corresponds to currently predicted payload performance, while the lower bound denotes the lowest estimate of the ASLV payload capability.

The approach on the left of this table concentrates on early implementation of improved fourth stage guidance in conjunction with the HP X259 third stage and short X259 fourth stage motors, and delays integration of the short Algol III and Castor strap-ons until the latter half of the decade. While early improvement in guidance accuracy is obtained with this option, payload drops during the first phase and shows only a modest gain when the new second stage is added at the end of 1977.

The growth option depicted on the right hand side of Figure 11 also provides early inclusion of improved fourth stage guidance, but accompanied by the Short Algol III as the first step. Castor strap-ons are integrated in the second growth step and incorporation of the HP X259 and short X259 represents the last step.

The growth option on the right hand side exhibits an early improvement in guidance accuracy as well as steady improvements in payload performance. Delay in integrating the short X259 until mid 1979 also improves the opportunity for incorporation of state-of-the-art improvements such as higher specific impulse, restart system, etc., on this stage, should the development status warrant incorporation at that time. A disadvantage of this option is that the guidance system will have to be integrated initially with the current FW4 and then later on with the short X259. However, in view of the favorable payload performance, this approach has been selected for the ASLV Program. Figure 11 presents a pictorial view of the selected growth approach. Shaded areas in this figure indicate the sequential hardware improvements. Payload performance presented is

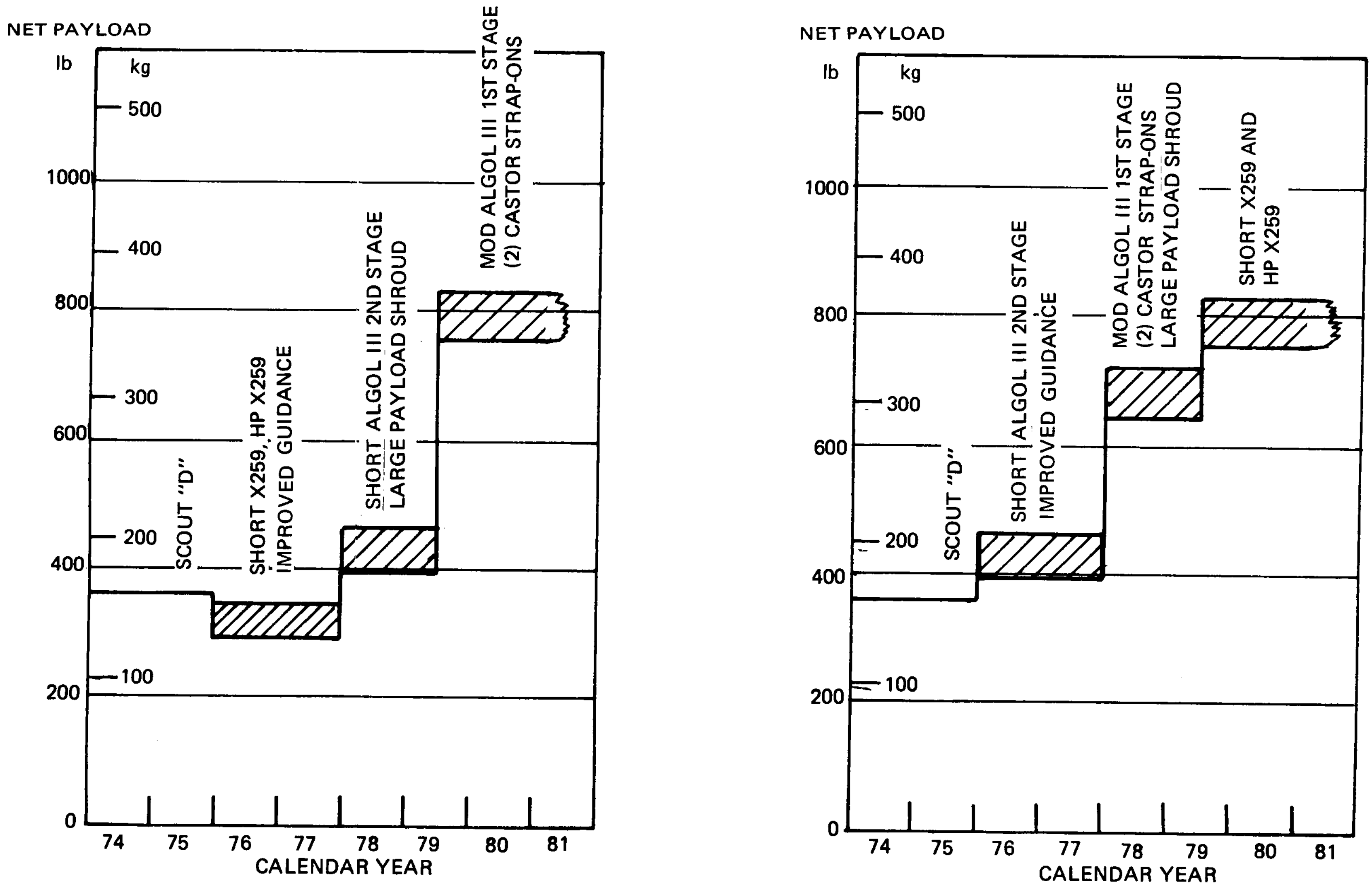
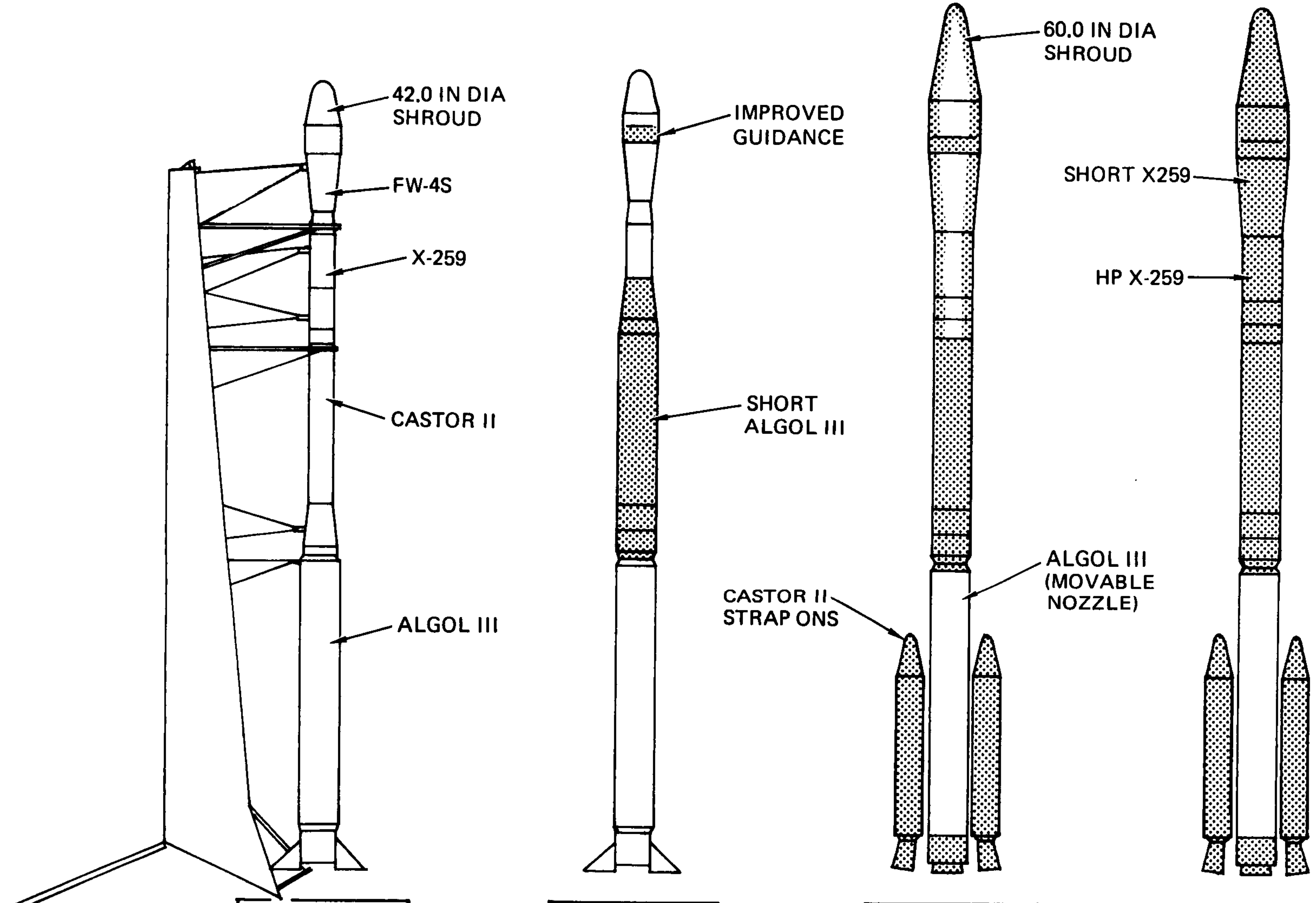


FIGURE 11 PHASED GROWTH APPROACHES



	SCOUT D	STEP 1	STEP 2	FINAL CONF.
LIFT OFF WT.– kg	21 500	26 200	35 800	36 400
* PAYLOAD WT.– kg (lb)	163 (360)	177 (390)	290 (640)	340 (750)
* STEP-DOWN WT. –kg (lb)			147 (324)	190 (420)

FIGURE 12 SELECTED GROWTH APPROACH

* 556 km (300 n.mi.) CIRCULAR ORBIT

conservative in that it reflects the lowest estimate, i.e., it assumes that the total contingency margin has been lost during design.

The performance curves in Figure 13 indicate circular orbit capability for the growth steps of the option selected above. As a matter of interest, the predicted gains for a Hohmann transfer that would be possible with a restartable short X259 are also shown. All curves show both predictions and the lowest estimate of payload performance based on no contingency margin. Scout D orbital performance is also presented for reference.

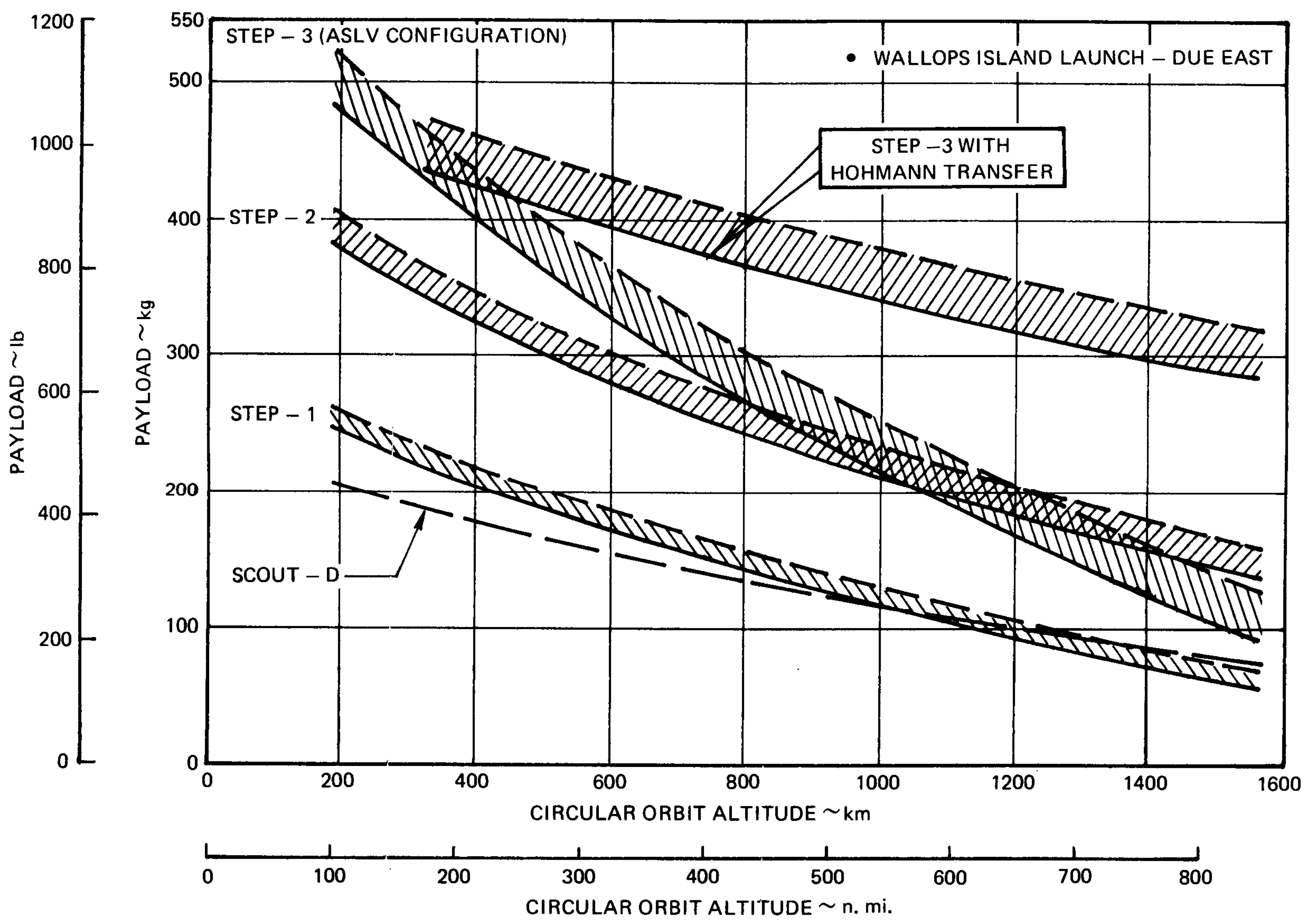


FIGURE 13 SEQUENTIAL IMPROVEMENT IN ORBIT PERFORMANCE

5.0 GUIDANCE

A need for improvement over the current Scout guidance accuracy was identified previously in Section 3.2. This section discusses the analysis and comparative evaluation of various guidance approaches for the ASLV.

Three basic guidance approaches were considered:

(1) Complete inertial system in an attitude stabilized, non-spinning fourth stage;

(2) Modular additions, or sequential improvements, to the existing Scout third stage, open-loop, preprogrammed system in conjunction with a spin-stabilized fourth stage; and

(3) Open-loop inertial reference package located in an attitude stabilized fourth stage.

Equipment utilization, performance, weight, and cost data are discussed in the following sections for the candidate systems considered in each guidance approach. Projected orbital accuracies achievable with the various implementations/systems are also provided for two representative circular orbits that cover the spectrum of anticipated altitudes. Finally, the three approaches are compared on the bases of predicted orbital accuracy, weight, and cost.

5.1 INERTIAL GUIDANCE

The first approach investigated the use of an inertial guidance system (composed of an inertial measurement unit, computer and associated electronics) to control the launch vehicle throughout the boost and final injection phases.

5.1.1 Equipment and Utilization - Inertial guidance hardware data were requested from six vendors to ascertain the physical, cost and equipment performance data for the most promising candidates. The ground rules and guidelines outlined to govern the guidance system operation and performance were:

(1) Existing state-of-the-art to be used.

(2) Guidance to be located in the injection stage of the launch vehicle

(3) Injection stage will be attitude stabilized.

(4) Environmental and qualification requirements for fourth stage equipment will parallel those of existing Scout.

(5) Maximum axial acceleration will be 295 m/s^2 (30 g's).

(6) Production or near-production status preferred.

(7) No gyro or accelerometer development to be considered.

(8) Minimum platform and computer development or modification.

(9) Sensor calibration cycle: 30 days minimum, 60 to 90 days preferred.

(10) Maximum guidance operating time: 900 second boost (to fourth stage burnout), followed by a maximum coast time of one hour. Only attitude and timing functions needed during the one-hour coast.

(11) Near-vertical vehicle orientation at launch.

(12) System weight goal: 23 to 27 kg (50 to 60 pounds)

The summary characteristics of the candidate guidance systems are shown in Table 31. The vendor information requests indicated no preference for gimballed or strapdown inertial measurement units (IMU) and, as noted in the table, three gimballed and three strapdown systems were proposed. The system production status, platform sensors, system linear acceleration design values and test levels are shown in Table 31. Each production IMU and computer has completed or is currently involved in a qualification test program, but none completely satisfies the anticipated ASLV operating environment. The indicated guidance system weights include additional weight increments to account for increases in control electronics, power conditioning and switching relays that will be needed in an ASLV application. Since the vehicle design is at the conceptual level, the detailed interface requirements of the control electronics which show signal characteristics for discretes, proportional attitude error signals and control motor commands have not been defined. Some of the guidance system configurations as provided by the vendors include partial control electronics and others include none. The added increments were adjusted to account for these variations. Any filtering that is not mission dependent would be accomplished by analog means in the control electronics. Also, some weight

TABLE 31 SUMMARY OF CANDIDATE INERTIAL GUIDANCE SYSTEMS

System Characteristic	Candidate Guidance System											
	Kearfott KT-70		Litton LN-30		GE SIR		Honeywell H-487		Teledyne TDS-2		Hamilton Standard DIGS	
Type IMU	Gimballed (4)		Gimballed (4)		Gimballed (3)		Strapdown		Strapdown		Strapdown	
Computer	SKC-2000 (or GPK-20)		LC-4516		CP-24A		Modified HDC-250		Modified TDY-300		TDY-300 (Alternate Ham. Std. Comp.)	
IMU Status	Production		Initial Production		Produced		Development		Early Development		Production	
Computer Status	Initial Production		Production		Development		Development		Production		Production-Alternate Development	
Gyro	Gyroflex		G-1200		Kearfott 2401		GG1009		SDG-2		RI-1139	
Accelerometer	Kearfott 2414 & 2401		A-1000		Kearfott 2564		GG326, GG177		FP-1		Kearfott 2401	
Weight:												
IMU, Computer & Electronics*	kg 22.6	lb 49.9 ▽	kg 18.1	lb 40	kg 23.3	lb 51.4	kg 15.4	lb 34	kg 13.6	lb 30	kg 31.8	lb 70
Additional Control Electronics◊	2.3	5	3.6	8	3.6	8	3.6	8	3.6	8	3.6	8
Power Cond. & Interface◊	1.8	4	1.8	4	1.8	4	1.8	4	1.8	4	1.8	4
Rate Gyros	.9	2	.9	2	.9	2	.9	2	.9	2	.9	2
TOTAL SYSTEM WEIGHT	27.6	60.9	24.5	54	29.7	65.4	21.8	48	20.0	44	38.1	84
Power - Watts	355		254		195		180		90		215	
Linear Acceleration Tests	m/s^2 245.4	g's 25	m/s^2 166.9	g's 17	m/s^2 157	g's 16	m/s^2 -	g's -	m/s^2 -	g's -	m/s^2 147.2	g's 15
Design Acceleration	245.4-294.5	25-30	>196.3	>20	>196.3	>20	>392.6	>40	>490.8	>50	>245.4	>25

* Vendor Weight Estimates

◊ Conservative estimate of additional equipment needed

▽ Includes partial control electronics

margin is included to account for possible computer weight increases when the final required capacity is established and the input/output capabilities are defined. The total guidance system weights are considered conservative and can be achieved in production systems.

Equipment error budgets for each of the candidate inertial systems were established following several discussions with each of the vendors. The sensor error sources are defined in terms of expected (standard deviation) values. Definition of the expected values required a number of iterations because many vendors use the maximum error magnitude, especially in procurement specifications, since significant number of test measurements are needed to establish the characteristics and properties of the individual error distributions. The error budgets assigned to each of the inertial guidance systems are shown in Table 32.

Table 32 lists separate values of non-g sensitive gyro drift, accelerometer bias, and accelerometer scale factor for the level and vertical sensors. The terms "level" and "vertical" refer to the launch site orientation, with "vertical" being along the local gravity vector and "level" in the earth's tangent plane. The reason the error budgets are expressed in this manner is that some systems employ different sensors within the same cluster or block and this must be reflected in the simulations. Also, a few vendors quoted gyro drift as a function of the orientation of the gyro spin axis relative to the gravity vector.

The analyses and equipment data from Reference 16 were used for supplementary and comparative purposes in establishing guidance system characteristics. Error budget values from this source are shown in parentheses in Table 32.

5.1.2 Accuracy Analysis - The objective of the accuracy analysis was to obtain a statistical description of orbital accuracies achievable with the various candidate guidance implementations. Orbital accuracy was evaluated for 185 km (100 n.mi.) and 1111 km (600n.mi.) circular orbit missions, launched due east from Wallops Island, and is displayed in series of joint apogee/perigee distributions and cumulative distributions of inclination deviation. The 185 km altitude is typical of parking orbits, while the

TABLE 32 INERTIAL GUIDANCE ERROR BUDGETS

Error Source	Units	Candidate Guidance System					
		Kearfott KT-70	Litton LN-30	GE SIR	Honeywell H-487	Teledyne TDS-2	Hamilton Standard DIGS
Platform:							
Vertical Alignment	arc sec	20 (22)	20 (20)	15 -	30 (30)	30 (45)	11 (11)
Azimuth Alignment	arc sec	60 (47)	60 (60)	60 -	40 (40)	30 (60)	20 (20)
Gyros:							
Non g-Sensitive Drift (Level)	deg/hr	.2 (.2)	.03 (.003)	.1 -	.33 (.1)	.007 (.01)	.033 (.033)
Non g-Sensitive Drift (Vertical)	deg/hr	.2 (.2)	.03 (.003)	.1 -	.33 (.25)	.007 (.01)	.033 (.033)
Mass Unbalance (Input Axis)	deg/hr/g	.05 (.05)	.05 (.01)	.15 -	.434 (.4)	.003 (.02)	.133 (.133)
Mass Unbalance (Output Axis)	deg/hr/g	.1 (.1)	.05 (.03)	.15 -	.434 (.5)	.003 (.003)	.133 (.133)
Compliance	deg/hr/g^2	.03 (.03)	.02 (.01)	.02 -	.02 (.3)	.02 (.02)	.02 (.02)
Torquer Scale Factor Error	%	NA	NA	NA	.0033 (.05)	.0003 (.0003)	.005 (.005)
Input Axis Align.-SA Plane	arc sec	NA	NA	NA	25 (40)	20 (30)	10 (10)
Input Axis Align.-OA Plane	arc sec	NA	NA	NA	20 (40)	20 (20)	10 (10)
Accelerometers:							
Bias (Level)	μg	70 (70)	100 (10)	70 -	500 (500)	20 (20)	41.8 (41.8)
Bias (Vertical)	μg	70 (50)	100 (10)	70 -	50 (50)	20 (20)	41.3 (41.8)
Scale Factor Stability (Level)	μg/g	167 (100)	100 (250)	200 -	200 (620)	150 (150)	66 (66)
Scale Factor Stability (Vertical)	μg/g	200 (100)	100 (250)	200 -	167 (200)	150 (150)	66 (66)
Nonlinearity	μg/g^2	7.5 (10)	40 (35)	10 -	0.0 0.0	20 (20)	1.67 (1.67)
Alignment	arc sec	20 (20)	20 (20)	20 -	10 (20)	15 (20)	10 (10)

( ) Indicates the error budget values used in Reference B-1

1111 km orbit is representative of high altitude applications missions, including sun-synchronous missions.

First, standard deviations in position and velocity vectors were determined at orbit injection using VMSC's Guidance Accuracy Analysis Routine (GAAR). This program considers all equipment uncertainties listed in Table 32 and uses preprogrammed attitude and acceleration time histories to compute position and velocity deviations throughout the boost and coast phases of the trajectory. These deviations are a function of time and the applied, non-gravitational forces and are assumed to be statistically independent and normally distributed.

Preprogrammed attitude and acceleration time histories for the two circular orbits were based on two Scout pre-flight trajectories for similar orbits. These time histories, which are required input to GAAR, served as a reference in the evaluation of the inertial guidance system error sources. Pertinent orbital characteristics resulting from these trajectories are denoted below:

1. Scout 173C
   - Perigee = 213.5 km (115.5 n.mi.)
   - Apogee = 800.1 km (432.0 n.mi.)
   - Inclination = 2.9 deg
2. Scout 176C
   - Perigee = 1089.5 km (588.3 n.mi.)
   - Apogee = 1175.8 km (634.9 n.mi.)
   - Inclination = 90.0 deg

While Scout 173C was targeted for an elliptic orbit, the launch-to-injection phase of this mission is quite similar to that for an 185 km circular orbit and the resulting attitude and acceleration time histories of this mission are therefore considered valid for evaluation of guidance system accuracy on the low altitude circular orbit mission. The Scout 176C pre-flight orbit is very close to the desired high altitude circular orbit and associated time histories of attitude and acceleration would be practically identical to those of a 1111 km circular orbit.

Injection deviations (at the end of fourth stage boost) for the six guidance systems defined in Tables 31 and 32 are shown in Tables 33 and 34

TABLE 33 INERTIAL GUIDANCE INJECTION DEVIATIONS 1111 km (600 n. mi.) ORBIT

Guidance System	$\sigma_{\dot{X}}$		$\sigma_{\dot{Y}}$		$\sigma_{\dot{Z}}$		σ_{Vel}		σ_X		σ_Y		σ_Z		σ_{pos}	
	m/s	ft/s	m/s	ft/s	m/s	ft/s	m/s	ft/s	m	ft	m	ft	m	ft	m	ft
Kearfott KT-70	1.86	6.11	3.92	12.85	3.12	10.24	5.34	17.53	826	2711	1230	4037	789	2588	1542	5059
KT-70, Ref B-1 Error Budget	1.35	4.43	3.64	11.95	3.12	10.22	4.98	16.34	637	2098	1096	3595	691	2268	1447	4749
							(5.0)*	(16.40)*							(1375)*	(4511)*
Litton LN-30	3.29	10.78	2.57	8.42	1.79	5.87	4.36	14.88	883	2897	726	2391	728	2389	1357	4451
LN-30, Ref B-1 Error Budget	3.39	11.12	2.45	8.04	1.63	5.34	4.49	14.72	1068	3505	1043	3421	956	3135	1772	5815
							(4.39)*	(14.40)*							(1770)*	(5806)*
GE-SIR	1.87	6.15	3.38	11.09	2.92	9.57	4.84	15.89	860	2822	1281	4203	928	3043	1799	5902
Honeywell H-487	4.21	13.81	6.62	21.71	4.79	15.73	9.19	30.16	2471	8107	1807	5929	2065	6774	3701	12144
H-487, Ref B-1 Error Budget	4.21	13.80	6.26	20.49	6.30	20.66	9.81	32.20	2609	8560	1951	6401	2339	7673	4011	13158
							(10.12)*	(33.20)*							(3121)*	(10240)*
Teledyne TDS-2	2.21	7.24	2.14	7.02	1.37	4.50	3.36	11.04	809	2654	868	2849	766	2513	1412	4634
TDS-2, Ref B-1 Error Budget	2.27	7.46	2.97	9.75	1.93	6.34	4.21	13.81	963	3158	1225	4019	937	3075	1818	5965
							(4.11)*	(13.50)*							(1834)*	(6017)*
Hamilton Standard DIGS	.70	2.31	1.41	4.64	.98	3.21	1.86	6.10	656	2153	555	1822	661	2170	1085	3559
							(2.21)*	(7.26)*							(688)*	(2258)*

( )* TEAP routine results from Reference B-16

XYZ - Launch point vertical coordinate system

TABLE 34 INERTIAL GUIDANCE INJECTION DEVIATIONS
185 km (100 n. mi.) ORBIT

Guidance System	$\sigma \dot{X}$		$\sigma \dot{Y}$		$\sigma \dot{Z}$		σ Vel		σ X		σ Y		σ Z		σ Pos	
	m/s	ft/s	m/s	ft/s	m/s	ft/s	m/s	ft/s	m	ft	m	ft	m	ft	m	ft
Kearfott KT-70	1.60	5.26	2.88	9.46	2.01	6.60	3.86	12.68	359	1179	568	1865	344	1129	755	2478
KT-70, Ref B-1 Error Budget	.96	3.15	2.53	8.31	2.03	6.65	3.38	11.10	232	760	486	1596	335	1098	634	2081
Litton LN-30	2.16	7.08	2.40	7.89	1.37	4.50	3.51	11.52	436	1432	523	1715	282	924	737	2418
LN-30, Ref B-1 Error Budget	2.57	8.42	2.32	7.60	1.16	3.80	3.66	12.01	536	1757	511	1678	308	1010	802	2631
GE SIR	1.63	5.35	2.68	8.80	2.47	8.12	4.00	13.11	363	1192	563	1847	411	1348	786	2579
Honeywell H-487	2.58	8.45	3.94	12.92	2.84	9.32	5.50	18.03	628	2062	703	2308	527	1729	1081	3545
H-487, Ref B-1 Error Budget	2.63	8.64	4.35	14.28	5.81	19.05	7.72	25.33	703	2305	831	2727	1088	3570	1539	5049
Teledyne TDS-2	1.56	5.12	2.02	6.62	1.27	4.16	2.85	9.35	343	1126	426	1399	299	981	624	2046
TDS-2, Ref B-1 Error Budget	1.59	5.22	2.76	9.06	1.83	6.01	3.68	12.06	371	1218	591	1939	412	1351	810	2659
Hamilton Standard DIGS	.55	1.82	1.01	3.30	.83	2.72	1.42	4.65	158	518	206	675	189	620	321	1053

XYZ - Launch point vertical coordinate system for Scout trajectories 176C and 173C respectively. The deviations are expressed in a launch point vertical coordinate system with X being downrange in the earth's tangent plane at the launch point, Z contained in the trajectory plane and parallel to the launch gravity vector, and Y completing a right-handed system. The columns titled "σ Vel" and "σ Pos" depict the magnitudes of the standard deviations in total velocity and position. Table 33 includes, for comparison, the values of "σ Vel" and "σ Pos" from Reference 16 for the same trajectory.

A comparison of the error budgets plus the injection position and velocity deviations shows that the Kearfott KT-70, Litton LN-30, GE SIR and Teledyne TDS-2 are all very closely grouped in terms of system errors at injection. The Hamilton Standard DIGS is the most accurate system of all. The least accurate is the Honeywell H-487 which utilizes lower precision instruments, or sensors, but it has an attendant advantage of lower hardware cost. The comparison also reveals that significant variations can occur in the individual equipment error terms and yet achieve almost equivalent injection accuracies. The constrained, or non-acceleration sensitive, gyro drift rates of the GE SIR, KT-70 and H-487 are essentially an order of magnitude higher than any of the other systems. Significant differences also occur in the acceleration dependent gyro drift rates resulting from mass unbalance. The accelerometer terms are more comparable (differences not exceeding a factor of about three) except for the bias error of the H-487 level accelerometers.

The final step in evaluating the performance of the inertial guidance systems was to determine the orbital deviations resulting from the injection deviations. The KT-70 and H-487 systems were used in the computation of the orbital deviations because they represent systems with medium and maximum sensor error budgets. The intent was to bracket the performance achievable with this range of inertial systems. Obviously, the DIGS would result in smaller orbital deviations because of the more accurate injection conditions. The injection deviations, as shown in Tables 33 and 34, are due to equipment measurement uncertainties only; an additional contribution of 15% of the total measurement errors was included to account for guidance logic, computational, corrective delta velocity, and similar type errors. It was assumed that this error contribution was independent of the velocity control technique - either thrust termination or velocity correction with the attitude control system.

Combined injection deviations in position and velocity were translated into bivariate apogee/perigee altitude distributions and cumulative inclination distributions using VMSC's Statistical Orbit Analysis Routine (SOAR). Injection conditions are sampled some 10000 times to provide an adequate statistical description of the population density. Isoprobability contours of apogee/perigee deviations were then generated which define the percent of the population within the area bounded by each contour. These contours thus indicate the probability that a random bivariate apogee/perigee deviation will be equal to or less than that defined by the contour.

Apogee/perigee deviations for the 1111 and 185 km circular orbits are given in Figures 14 through 17 for probability levels of 0.997, 0.95, and 0.75. Related inclination deviations for corresponding orbits are illustrated in Figures 18 and 19. These data provide excellent visibility of the deviations in the orbital parameters. The 0.997 apogee (or perigee) deviations for the 1111 km orbit are 31.5 km (17 n.mi.) with the KT-70 system and 63 km (34 n.mi.) with the H-487. The corresponding inclination deviations are 0.05 deg and 0.08 deg, respectively.

5.2 AUGMENTED SCOUT

The second guidance option considered modular or sequential improvements (augmentations) to the existing Scout third stage open-loop system. In addressing this option, the major open-loop contributors to the Scout injection errors were examined and an attempt was made to reduce or provide compensation for each major contributor. Since the ASLV design is conceptual at this point, magnitudes and characteristics of the uncertainties in predicting nominal performance data, which define the magnitude of the error contributions, have not been established. The basic Scout data were therefore used as a reference to evaluate this concept and establish orbital accuracies. The major Scout error sources and resulting standard deviations in injection parameters are listed in Table 35. These values have been adjusted to provide agreement with Scout flight results as obtained from a sample of 24 flights. The basis for the adjustments is the variation in velocity, flight path angle,

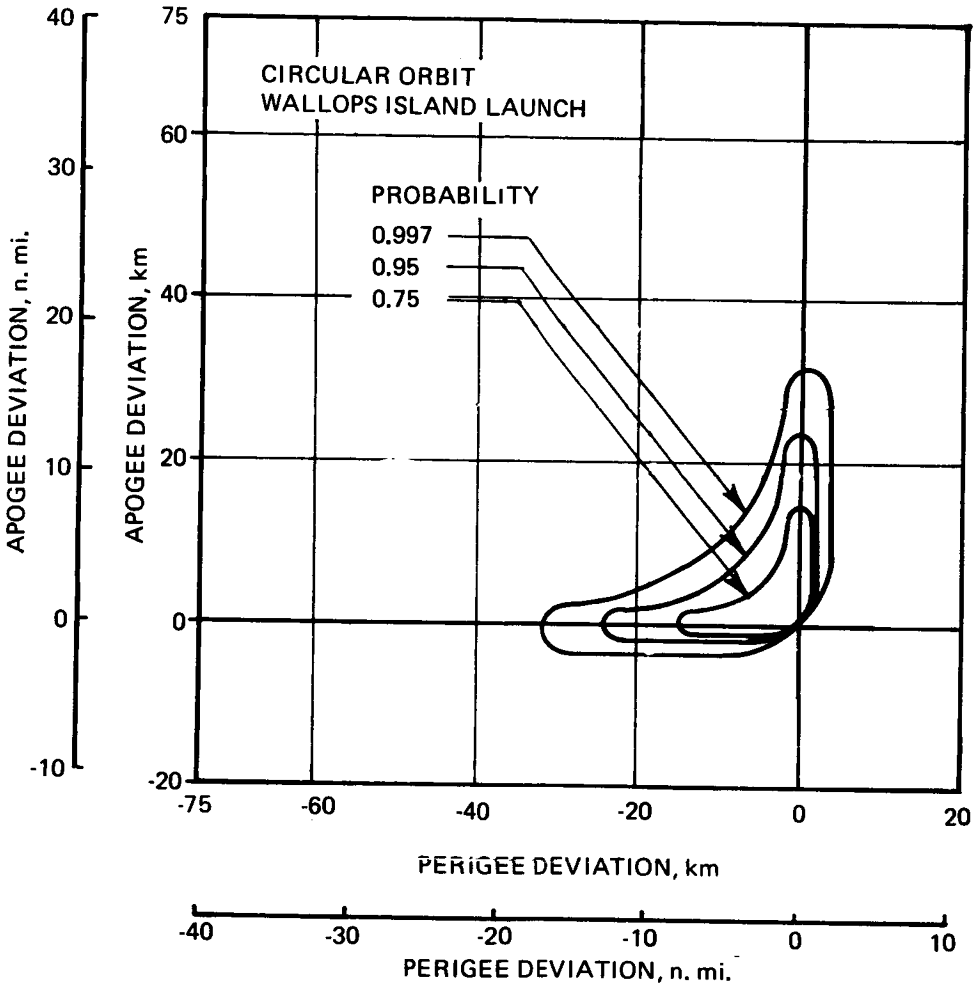


FIGURE 14 ORBITAL ACCURACY – KT-70 INERTIAL SYSTEM, 1111 km (600 n.mi.) ORBIT

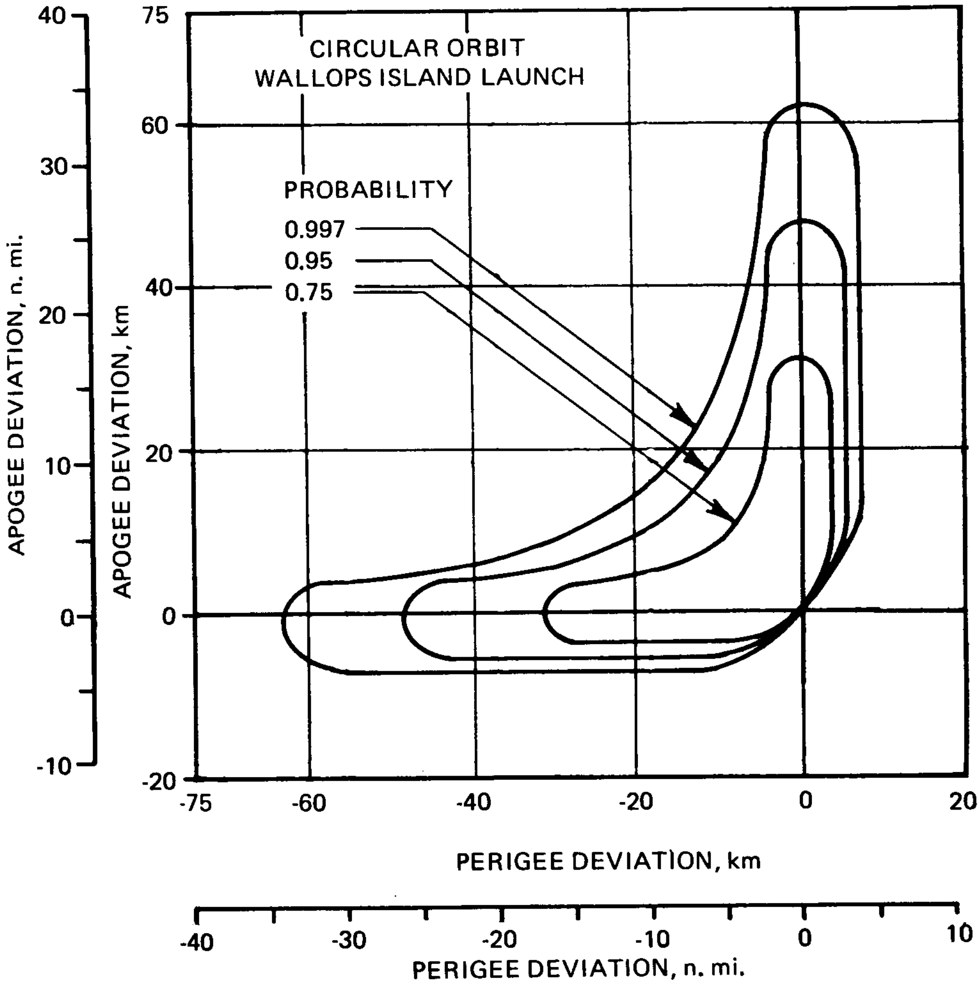


FIGURE 15 ORBITAL ACCURACY – H-487 INERTIAL SYSTEM, 1111 km (600 n.mi.) ORBIT

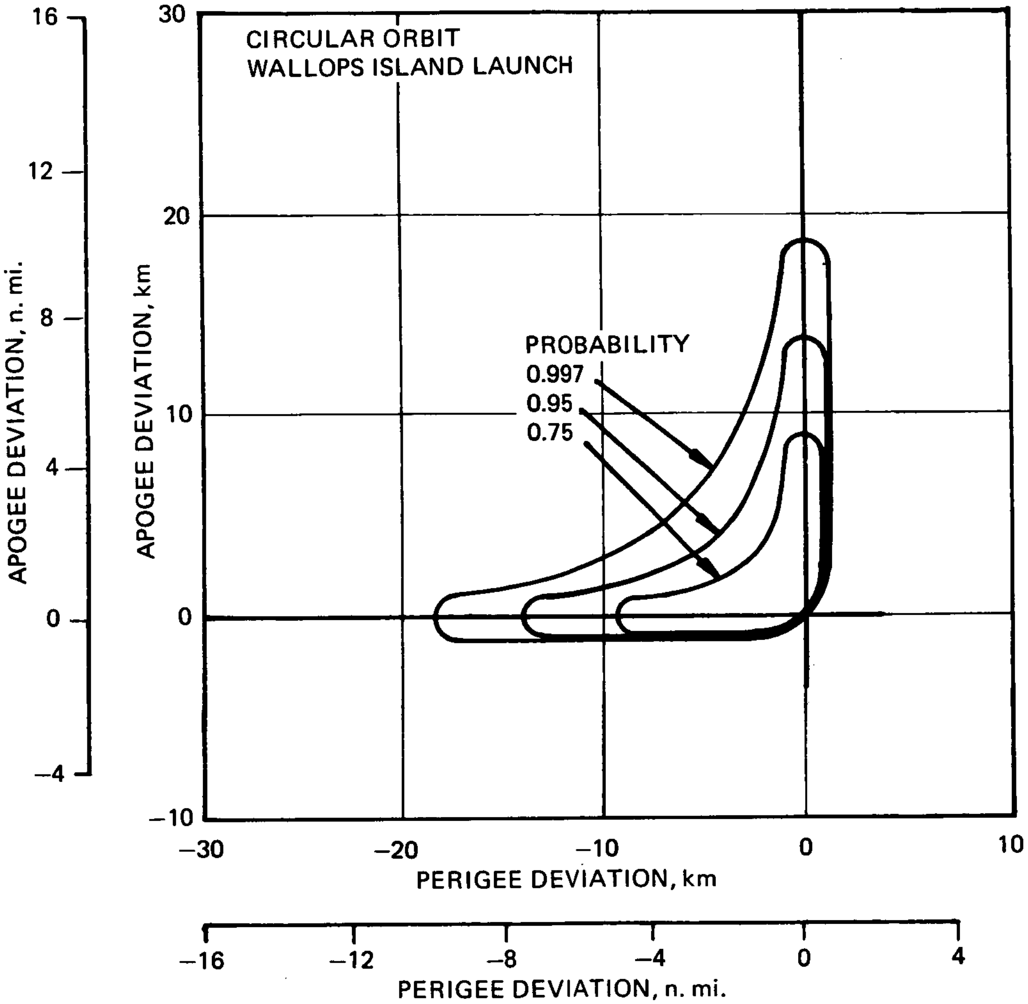


FIGURE 16 ORBITAL ACCURACY – KT-70 INERTIAL SYSTEM, 185 km (100 n.mi.) ORBIT

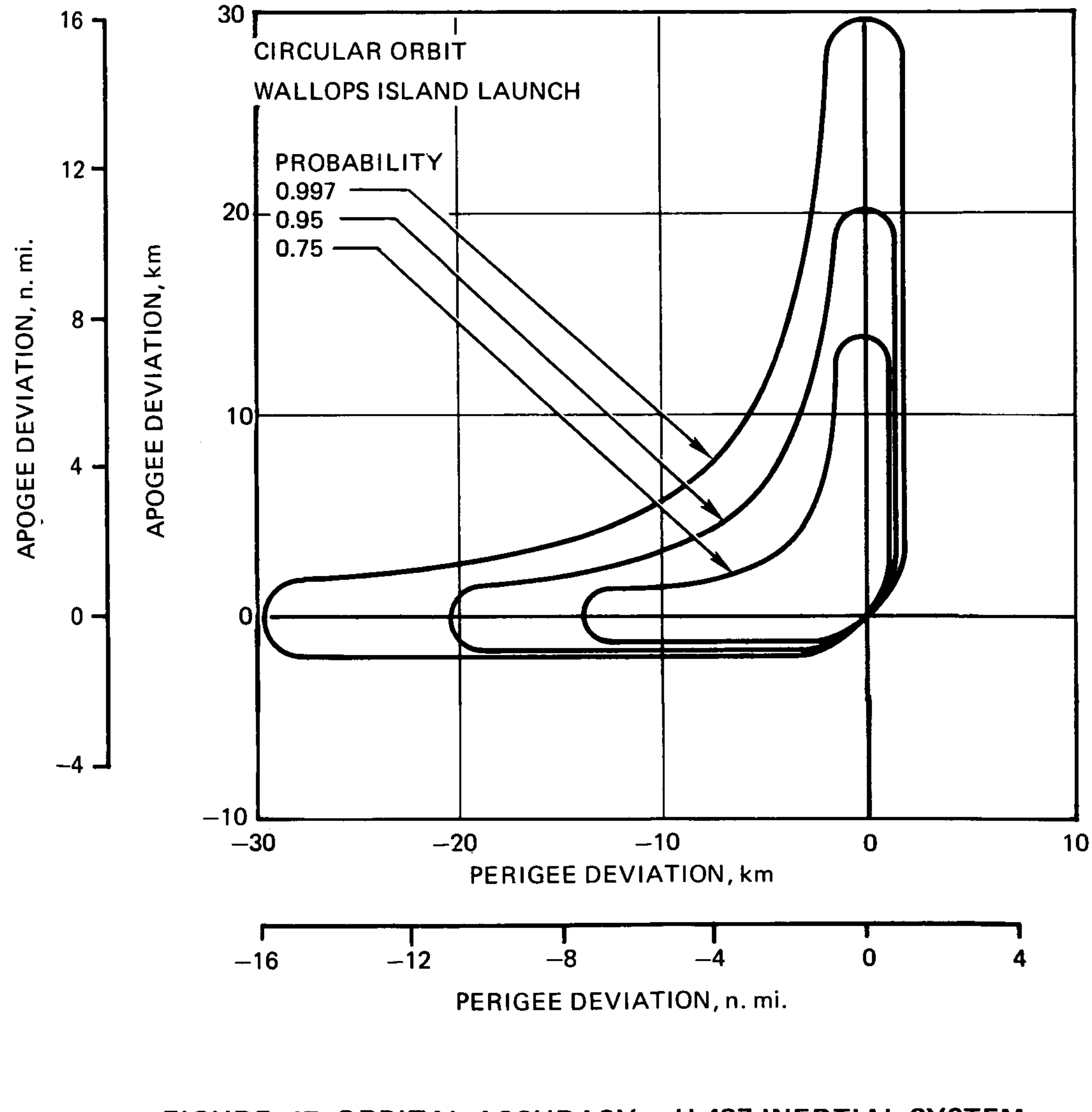


FIGURE 17 ORBITAL ACCURACY – H-487 INERTIAL SYSTEM, 185 km (100 n. mi.) ORBIT

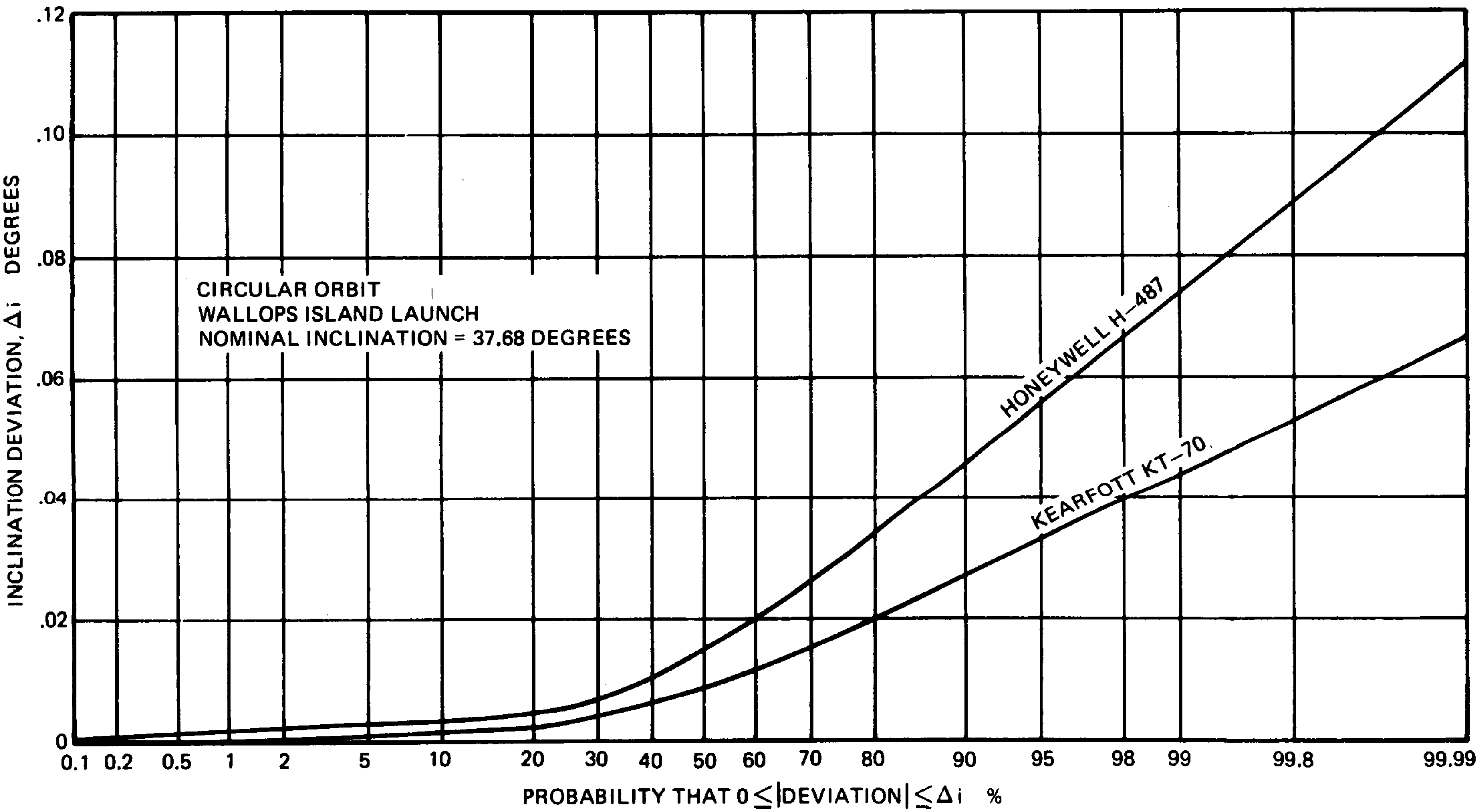


FIGURE 18 INERTIAL GUIDANCE INCLINATION DEVIATIONS, 1111 km (600 n. mi.) ORBIT

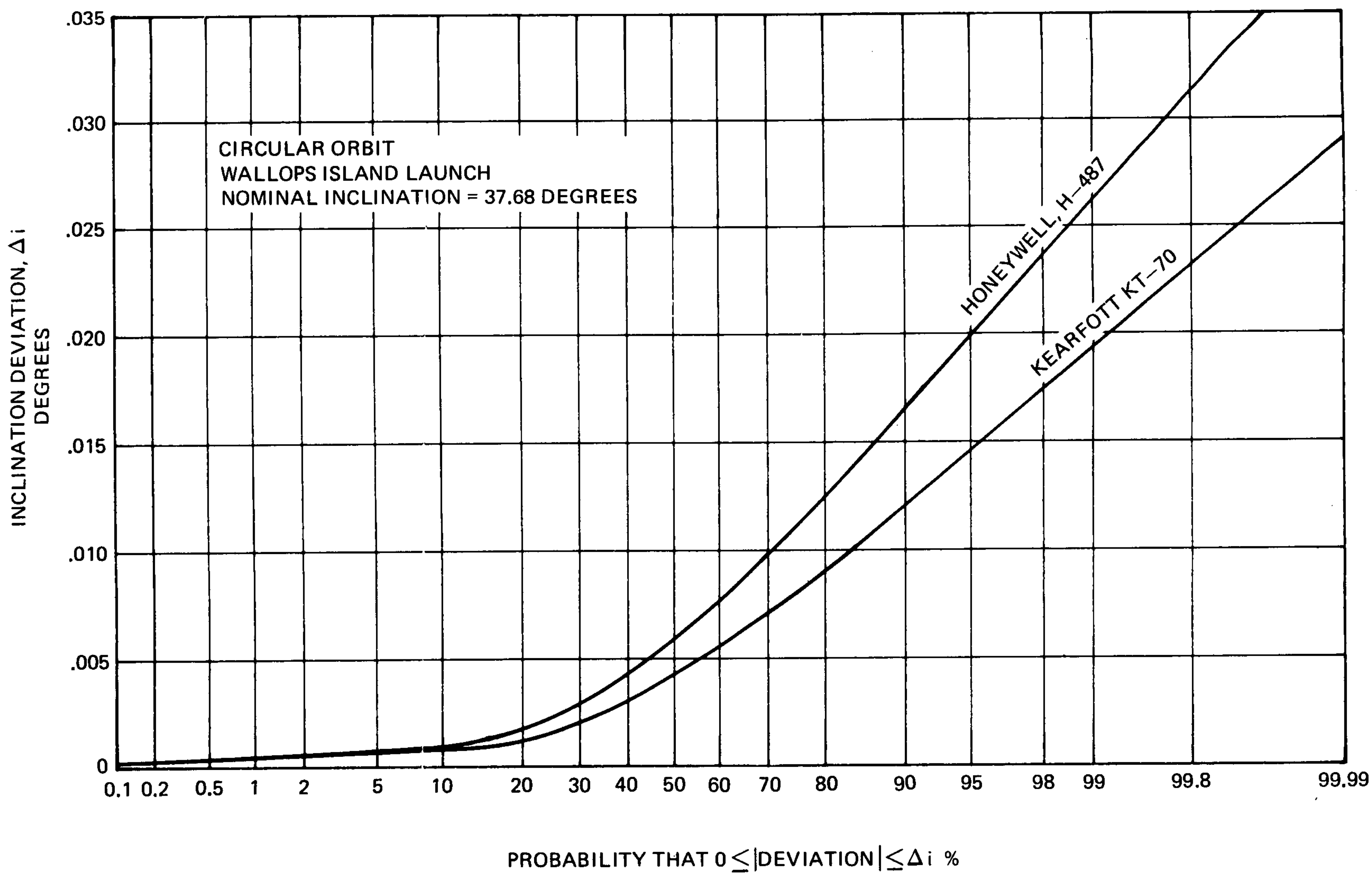


FIGURE 19 INERTIAL GUIDANCE INCLINATION DEVIATIONS, 185 km (100 n. mi.) ORBIT

TABLE 35 - INJECTION DEVIATIONS - CURRENT SCOUT, 556 km (300 n.mi.) ORBIT

Error Source	Standard Deviations (1σ)					
	Velocity		Flight Path Angle	Azimuth Angle	Altitude	
	m/s	ft/s	deg	deg	m	ft
Algol IIB Performance	6.4	21.1	.081	.002	4465	14650
Castor II Performance	1.3	4.4	.051	.001	1981	6500
X-259 Performance	3.4	11.2	.068	.002	2195	7200
FW-4S Performance	11.7	38.4	.008	.001	26	85
Guidance System (Pitch)	6.9	22.8	.100	.001	1682	5520
Guidance System (Yaw)	.6	1.9	.004	.065	51	166
Thrust Misalignment (Pitch)	8.5	27.8	.006	.002	701	2300
Thrust Misalignment (Yaw)	1.4	4.6	.008	.190	53	174
Aerodynamic Drag	2.1	6.8	.047	.001	1667	5470
Atmosphere	2.0	6.5	.047	.001	1707	5600
Tailwind	5.3	17.4	.017	.002	180	590
Crosswind	2.0	6.6	.030	.067	509	1670
Stage 2 Boost Deadband (Pitch)	10.3	33.8	.043	.001	2393	7850
Stage 2 Boost Deadband (Roll)	.5	1.5	.003	.058	65	212
Stage 2 Boost Deadband (Yaw)	.5	1.6	.004	.035	99	324
Stage 2 Coast Deadband (Pitch)	0.0	0.0	.000	.000	1	3
Stage 2 Coast Deadband (Roll)	.1	0.2	.000	.005	6	20
Stage 3 Boost Deadband (Pitch)	10.0	32.9	.060	.001	2630	8710
Stage 3 Boost Deadband (Roll)	.2	0.8	.001	.017	10	32
Stage 3 Boost Deadband (Yaw)	.7	2.2	.004	.055	102	334
Stage 4 Tipoff (Pitch)	6.0	19.8	.442	.010	722	2370
Stage 4 Tipoff (Yaw)	5.9	19.5	.014	.404	22	72
RSS TOTAL	25.1	82.5	.480	.466	7163	23500

azimuth angle and altitude between analytical and observed flight data. Accordingly, the individual error sources, as defined by analytical simulations, were changed (ratioed) to correspond to the flight results. The individual error sources were then grouped in a manner compatible with possible improvements.

5.2.1 Equipment and Utilization - The basic assumption in establishing the modular improvements was that the current Scout inertial reference package (IRP) and its associated equipment would be retained in the third stage and that the fourth stage would remain spin-stabilized. The following improvement approaches, or augmentations, were considered:

(1) Addition of a separate attitude reference and control system in the spinning fourth stage - This system would provide a means of correcting the attitude disturbances resulting from the fourth stage separation and motor ignition (tip-off). The fourth stage system would obtain its initial reference from the third stage IRP. It would be aligned mechanically to the IRP prior to launch and use the predicted fourth stage separation attitude as its initial condition. Equipment measurement uncertainties and spinning body control errors associated with this system were used to replace the current Scout fourth stage tip-off values.

(2) Reduction of boost deadbands - Second and third stage boost deadbands cause injection errors that can be decreased in direct proportion to the reduction in the magnitude of the deadbands. No additional equipment is needed to accomplish this improvement.

(3) Addition of a fourth stage velocity control system - A velocity meter with an attendant fourth stage thrust termination or velocity correction system would provide a means of reducing the error in the magnitude of the injection velocity vector which results from variations in motor performance, drag, winds and atmosphere. The approach considered in utilizing a velocity meter was

to operate the unit from launch. The delta velocity (or axial velocity which is the measured parameter) of each stage would be measured and compared with a nominal or reference value. The difference, together with a predetermined sensitivity factor, which accounts for the propagation of the axial velocity deviation of that stage into injection velocity, would provide an adjustment, or corrective velocity magnitude, at fourth stage burnout. The adjustment values for each stage would be added to the stored velocity cutoff to define the thrust termination point or vernier magnitude. A technique of this type would account for the differences in sensitivity of injection velocity error to variations in each stage. Using only the magnitude of the axial velocity to determine the correction could be detrimental rather than helpful. For example, a second stage velocity variation may result primarily in flight path and azimuth deviations at injection, thus a change in the magnitude of the velocity vector would not reduce the total system error.

(4) Addition of a third stage digital computer - The addition of a small third stage computer would permit compensation of the IRP roll gyro g-sensitive and elastic restraint drift terms plus fin misalignment and pitch program uncertainties. These compensations would require acceleration inputs from the fourth stage velocity meter and attitude errors from the IRP.

(5) Addition of lateral accelerometers to the velocity meter - A measure of cross-axis accelerations would be needed to compute corrections for first stage thrust misalignment plus flight path and azimuth angle errors caused by deviations in motor performance, drag, winds and atmosphere.

5.2.2 Accuracy Analysis - Injection and orbital deviations were computed for 1111 km and 185 km circular orbits. The analyses considered the reduction achievable in injection deviations by implementing the individual augmentations. However, the system, or approach, identified as "Augmented Scout" incorporates all five improvements outlined.

Injection deviations were first determined for the existing Scout by using previous Scout accuracy analyses and the flight adjusted error contributions depicted in Table 35. Using flight experience values as a reference, the Scout injection deviations for the two orbits are given in Tables 36 and 37. The error sources are grouped according to areas of potential improvement rather than the individual contributors. The reductions in injection deviation expected from the implementation of the modular improvements are given in Tables 38 and 39. No detail logic was developed for each augmentation; instead, the affected error sources were reduced to the expected uncertainties in the measurement and processing equipment.

The isoprobability contours of apogee-perigee deviations corresponding to the final injection deviations, as given in Tables 38 and 39, are shown in Figures 20 and 21. The 0.997 deviations of 148 km (80 n.mi.) for the 1111 km orbit are considerably larger than those obtained with inertial guidance. The inclination deviations for the Augmented Scout approach are shown in Figure 22.

5.3 OPEN-LOOP FOURTH STAGE

The final guidance option examined was an open-loop approach equivalent to the current system except the inertial reference would be located in an attitude-stabilized fourth stage. The primary reason for considering this method was to eliminate some of the hardware duplication inherent in the Augment Scout approach. The addition of a velocity control system and reduction of second and third stage boost deadbands was also included in the open-loop fourth stage approach.

5.3.1 Equipment and Utilization - The operation of the fourth stage open-loop system would be exactly the same as that for current Scout except the inertial reference would operate through the entire boost trajectory and the fourth stage would be stabilized at the desired thrusting attitude. The tip-off errors would then be completely eliminated but additional errors would result from the fourth stage attitude control system deadbands. Errors associated with the guidance system would increase because it would

TABLE 36 - INJECTION DEVIATIONS - CURRENT SCOUT, 1111 km (600 n.mi.) ORBIT

Error Source	Standard Deviations (1σ)					
	Velocity		Flight Path Angle	Azimuth Angle	Altitude	
	m/s	ft/s	deg	deg	m	ft
Fourth Stage Tipoff	10.2	33.5	.568	.514	847	2778
Second and Third Stage Boost Deadbands	15.4	50.6	.089	.072	5680	18634
Motor Performance (4 motors)	16.9	55.3	.174	.018	10128	33227
Drag Winds, Atmosphere	4.4	14.5	.078	.067	5400	17715
Guidance	7.5	24.5	.120	.065	3812	12506
First Stage Thrust Misalignment	9.1	29.8	.045	.146	1525	5002
RSS TOTAL	28.0	91.9	.619	.547	13474	44206

TABLE 37 - INJECTION DEVIATIONS - CURRENT SCOUT, 185 km (100 n.mi.) ORBIT

Error Source	Standard Deviations (1σ)					
	Velocity		Flight Path Angle	Azimuth Angle	Altitude	
	m/s	ft/s	deg	deg	m	ft
Fourth Stage Tipoff	8.2	26.9	.403	.404	570	1871
Second and Third Stage Boost Deadbands	13.9	45.7	.067	.089	2808	9213
Motor Performance (4 motors)	13.4	43.9	.107	.011	4225	13863
Drag Winds, Atmosphere	5.8	19.1	.063	.067	1888	6194
Guidance	6.7	22.1	.091	.067	1328	4357
First Stage Thrust Misalignment	8.3	27.3	.017	.190	555	1820
RSS TOTAL	24.3	79.7	.436	.465	5630	18472

TABLE 38 - SCOUT IMPROVEMENTS SUMMARY - 1111 km (600 n.mi.) ORBIT

Modular Improvement	Standard Deviations (1σ)					
	Velocity		Flight Path Angle	Azimuth Angle	Altitude	
	m/s	ft/s	deg	deg	m	ft
Current Scout System +	28.0	91.9	.619	.547	13474	44206
Fourth Stage Attitude Reference & Control Sys. +	26.5	86.8	.347	.282	13446	44114
Reduced Second & Third Stage Boost Deadbands +	21.9	72.0	.336	.273	12293	40332
Fourth Stage Velocity Control System +	13.7	45.0	.336	.273	12246	40177
Third Stage Computer to Adjust Pitch Program and Fourth Stage Velocity Cutoff						
• Compensate roll gyro g-sensitive drift, fin misalignment and pitch program uncertainties +	12.3	40.5	.322	.268	11860	38911
• Lateral accelerometers to correct first stage thrust misalignment +	8.7	28.6	.319	.227	11768	38611
• Compensate (adjust pitch program) for flight path angle and attitude errors during first three stages	8.7	28.6	.289	.227	8480	27823

TABLE 39 - SCOUT IMPROVEMENTS SUMMARY - 185 km (100 n.mi.) ORBIT

Modular Improvement	Standard Deviations (1σ)					
	Velocity		Flight Path Angle	Azimuth Angle	Altitude	
	m/s	ft/s	deg	deg	m	ft
Current Scout System	24.3	79.7	.436	.465	5630	18472
+ Fourth Stage Attitude Reference & Control Sys.	23.1	75.9	.240	.288	5607	18395
+ Reduced Second & Third Stage Boost Deadbands	18.9	62.0	.231	.275	4919	16140
+ Fourth Stage Velocity Control System	12.4	40.7	.231	.275	4918	16137
+ Third Stage Computer to Adjust Pitch Program and Fourth Stage Velocity Cutoff						
• Compensate roll gyro g-sensitive drift, fin misalignment and pitch program uncertainties	11.2	36.7	.219	.270	4854	15924
+ • Lateral accelerometers to correct first stage thrust misalignment	7.8	25.7	.219	.194	4824	15828
+ • Compensate (adjust pitch program) for path angle and attitude errors during first three stages	7.8	25.7	.200	.194	3515	11532

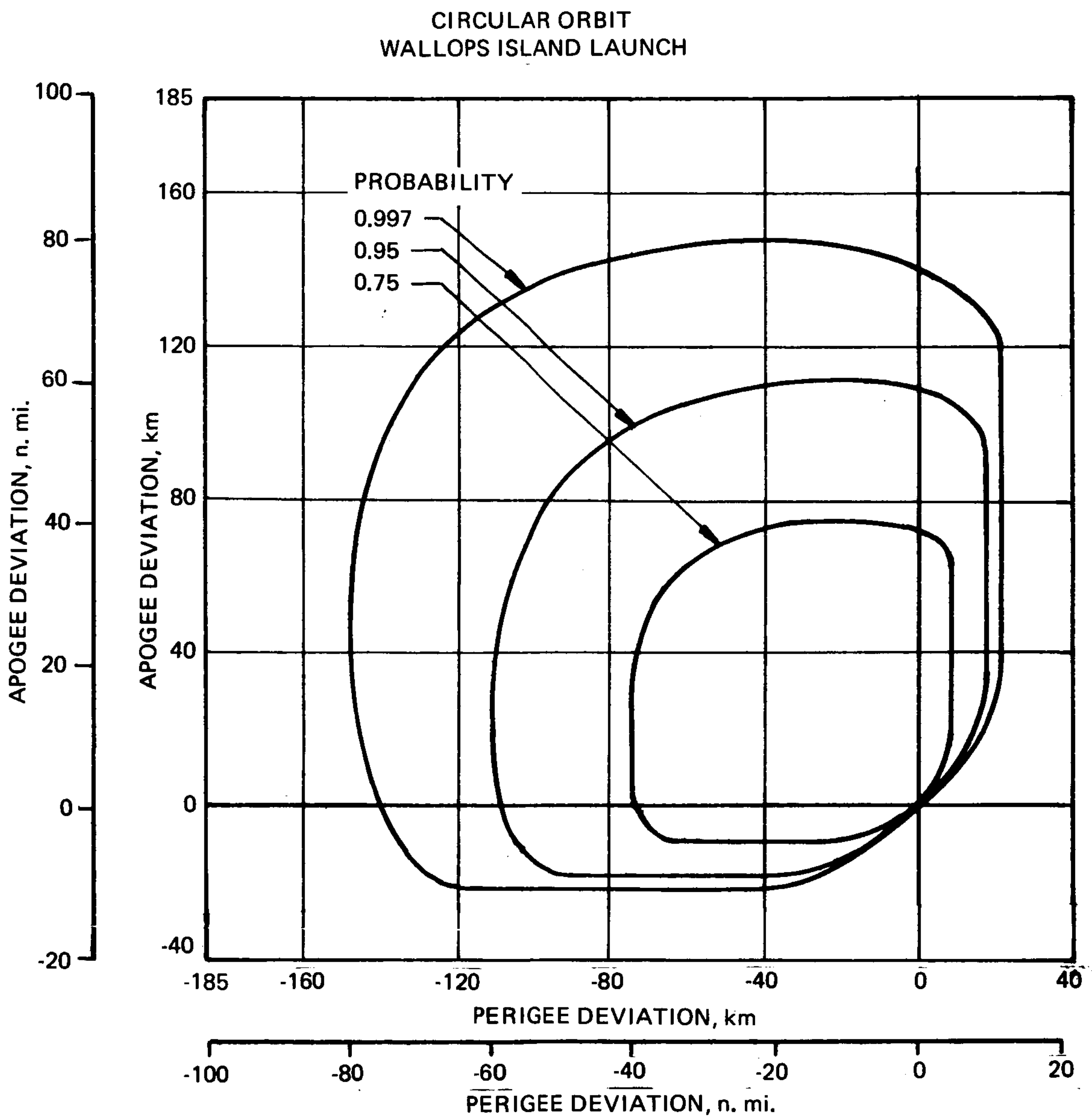


FIGURE 20 ORBITAL ACCURACY - AUGMENTED SCOUT, 1111 km (600 n.mi.) ORBIT

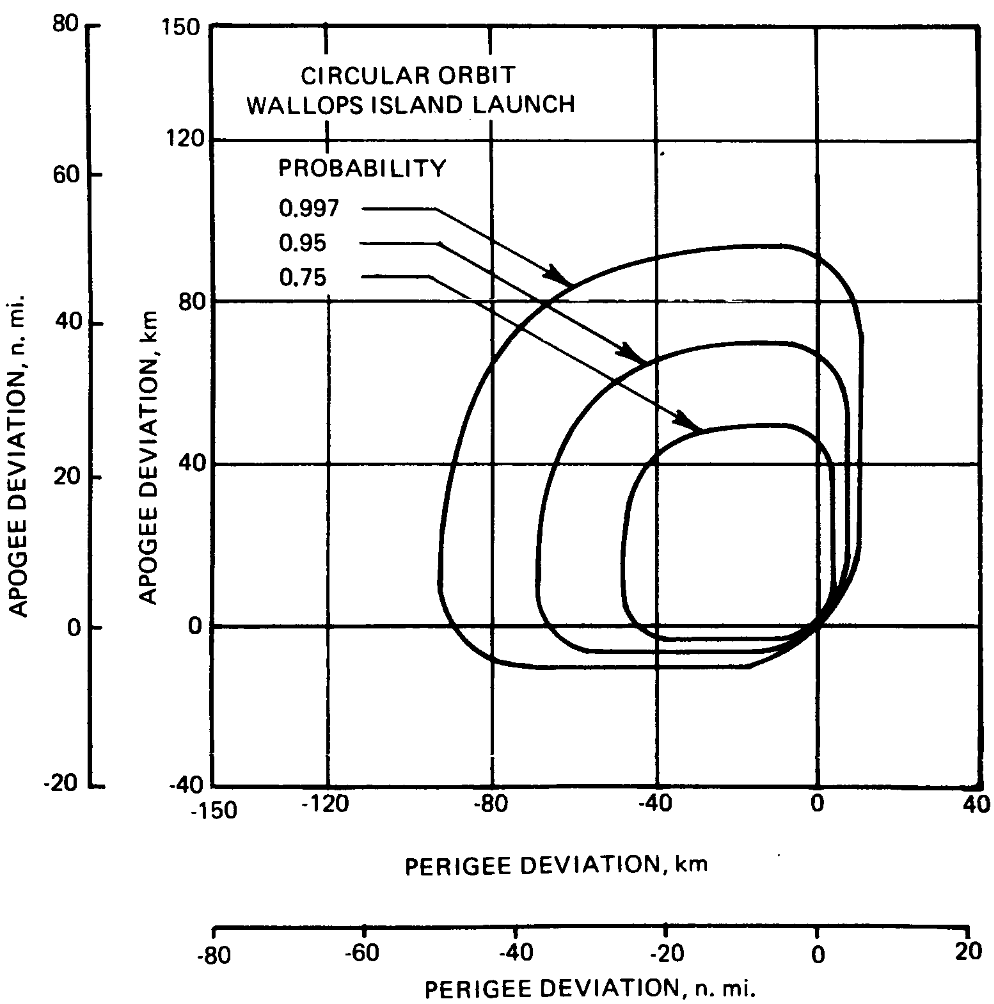


FIGURE 21 ORBITAL ACCURACY – AUGMENTED SCOUT, 185 km (100 n. mi.) ORBIT

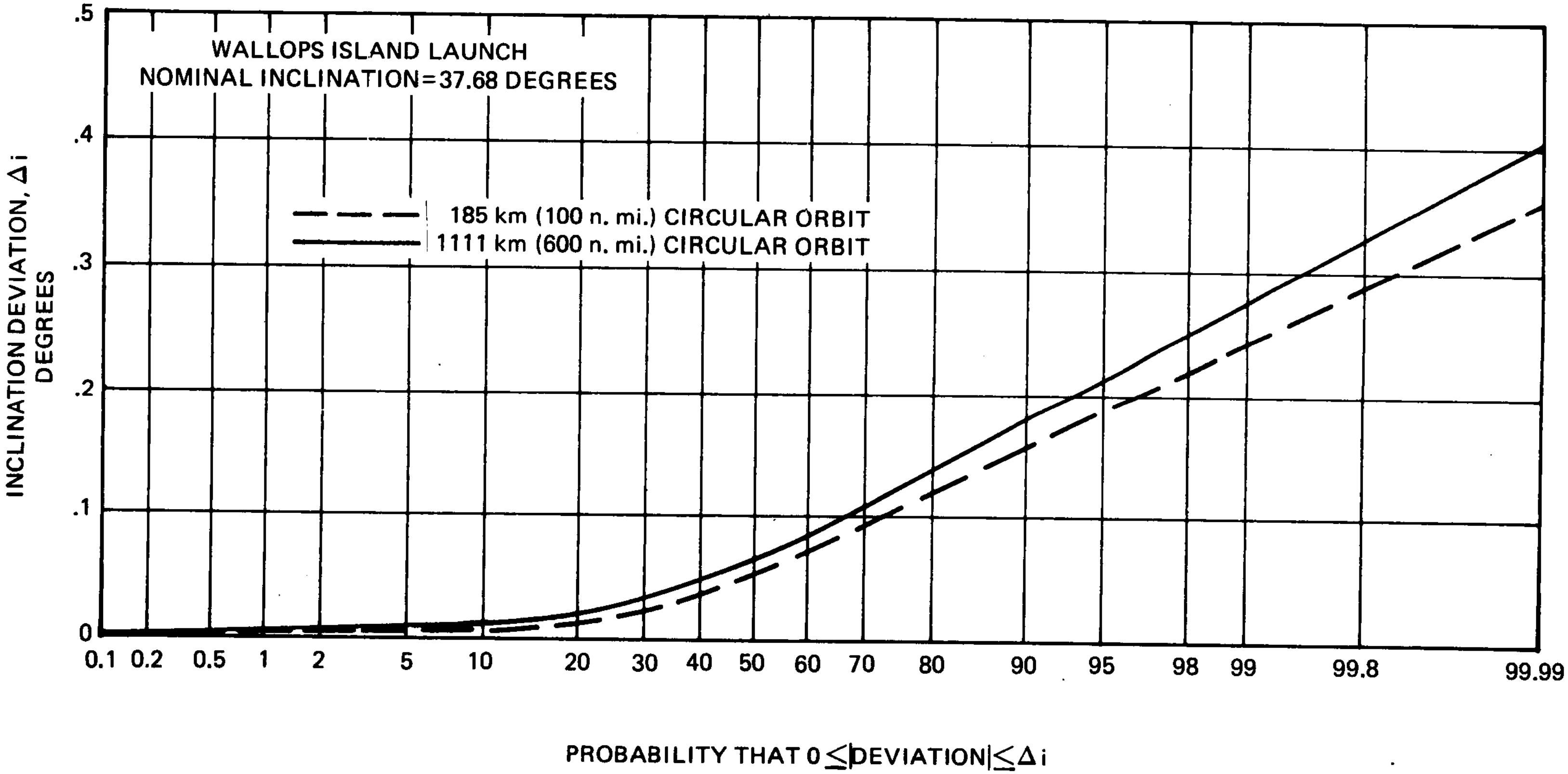


FIGURE 22 AUGMENTED SCOUT GUIDANCE INCLINATION DEVIATIONS

be subjected to the fourth stage acceleration environment and the operating time would increase. The areas of improvement included in this approach were:

(1) Addition of a fourth stage velocity control system - The equipment and its usage would be the same as that for the Augmented Scout approach. The velocity meter and the velocity correction system would be subjected to the same operating environment and the corrections would be accomplished in a similar fashion.

(2) Reduction of boost deadbands - Second and third stage boost deadband reductions would be implemented with no equipment modifications.

5.3.2 Accuracy Analysis - Assessment of the accuracies achievable with the open-loop fourth stage options followed the same procedure as that for the Augmented Scout approach. One assumption made in moving the IRP to the fourth stage was that there would be no change in the guidance components. It is recognized that some improvement could be realized from the use of more accurate gyros; however, this would not be significant when compared to the other error sources. The injection deviations corresponding to incorporation of a velocity control system in the open-loop fourth stage guidance and subsequent reduction in deadbands are listed in Tables 40 and 41. The grouping of the error contributors is identical to the Augment Scout analysis.

The apogee-perigee deviations resulting from these two guidance techniques are shown in Figures 23 and 24. The 0.997 deviations are about 262 km (142 n.mi.) when the velocity control system is included and 194 km (105 n.mi.) with the additional deadband reductions. The inclination deviations are given in Figure 25.

No further additions to the open-loop fourth stage guidance were considered. The next logical step would be the addition of cross-axis accelerometers and a computational capability to correct for first stage thrust misalignment and reduce the flight path and azimuth angle errors. However, these additions would result in basic elements equivalent to those of a full inertial system and all components would be located in the fourth

TABLE 40 - INJECTION ERRORS - OPEN LOOP FOURTH STAGE GUIDANCE WITH VELOCITY CONTROL SYSTEM

<table>
<tr><th rowspan="3">Error Source</th><th colspan="6">Standard Deviations (1σ)</th></tr>
<tr><th colspan="2">Velocity</th><th>Flight Path Angle</th><th>Azimuth Angle</th><th colspan="2">Altitude</th></tr>
<tr><th>m/s</th><th>ft/s</th><th>deg</th><th>deg</th><th>m</th><th>ft</th></tr>
<tr><td>Fourth Stage Tipoff</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Second and Third Stage Boost Deadbands</td><td>15.4</td><td>50.6</td><td>.089</td><td>.072</td><td>5680</td><td>18634</td></tr>
<tr><td>Motor Performance (4 motors)</td><td rowspan="2">3.3</td><td rowspan="2">10.8</td><td>.174</td><td>.018</td><td>10128</td><td>33227</td></tr>
<tr><td>Drag Winds, Atmosphere</td><td>.078</td><td>.067</td><td>5400</td><td>17715</td></tr>
<tr><td>Guidance</td><td>8.1</td><td>26.5</td><td>.140</td><td>.076</td><td>3812</td><td>12506</td></tr>
<tr><td>First Stage Thrust Misalignment</td><td>9.1</td><td>29.8</td><td>.045</td><td>.146</td><td>1525</td><td>5002</td></tr>
<tr><td>Fourth Stage Deadbands</td><td>0.2</td><td>0.5</td><td>.074</td><td>.074</td><td>79</td><td>260</td></tr>
<tr><td>RSS TOTAL</td><td>19.9</td><td>65.3</td><td>.267</td><td>.206</td><td>13448</td><td>44120</td></tr>
</table>

• 1111 km Circular Orbit

TABLE 41 - INJECTION ERRORS - OPEN LOOP FOURTH STAGE GUIDANCE WITH VELOCITY CONTROL SYSTEM AND REDUCED DEADBANDS

<table>
<tr><th rowspan="3">Error Source</th><th colspan="6">Standard Deviations (1σ)</th></tr>
<tr><th colspan="2">Velocity</th><th>Flight Path Angle</th><th>Azimuth Angle</th><th colspan="2">Altitude</th></tr>
<tr><th>m/s</th><th>ft/s</th><th>deg</th><th>deg</th><th>m</th><th>ft</th></tr>
<tr><td>Fourth Stage Tipoff</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Second and Third Stage Boost Deadbands</td><td>4.4</td><td>14.6</td><td>.025</td><td>.021</td><td>1609</td><td>5280</td></tr>
<tr><td>Motor Performance (4 motors)</td><td rowspan="2">3.3</td><td rowspan="2">10.8</td><td>.174</td><td>.018</td><td>10128</td><td>33227</td></tr>
<tr><td>Drag Winds, Atmosphere</td><td>.078</td><td>.067</td><td>5400</td><td>17715</td></tr>
<tr><td>Guidance</td><td>8.1</td><td>26.5</td><td>.140</td><td>.076</td><td>3812</td><td>12506</td></tr>
<tr><td>First Stage Thrust Misalignment</td><td>9.1</td><td>29.8</td><td>.045</td><td>.146</td><td>1525</td><td>5002</td></tr>
<tr><td>Fourth Stage Deadbands</td><td>0.2</td><td>0.5</td><td>.074</td><td>.074</td><td>79</td><td>260</td></tr>
<tr><td>RSS TOTAL</td><td>13.4</td><td>43.8</td><td>.253</td><td>.183</td><td>12295</td><td>40338</td></tr>
</table>

- 1111 km Circular Orbit

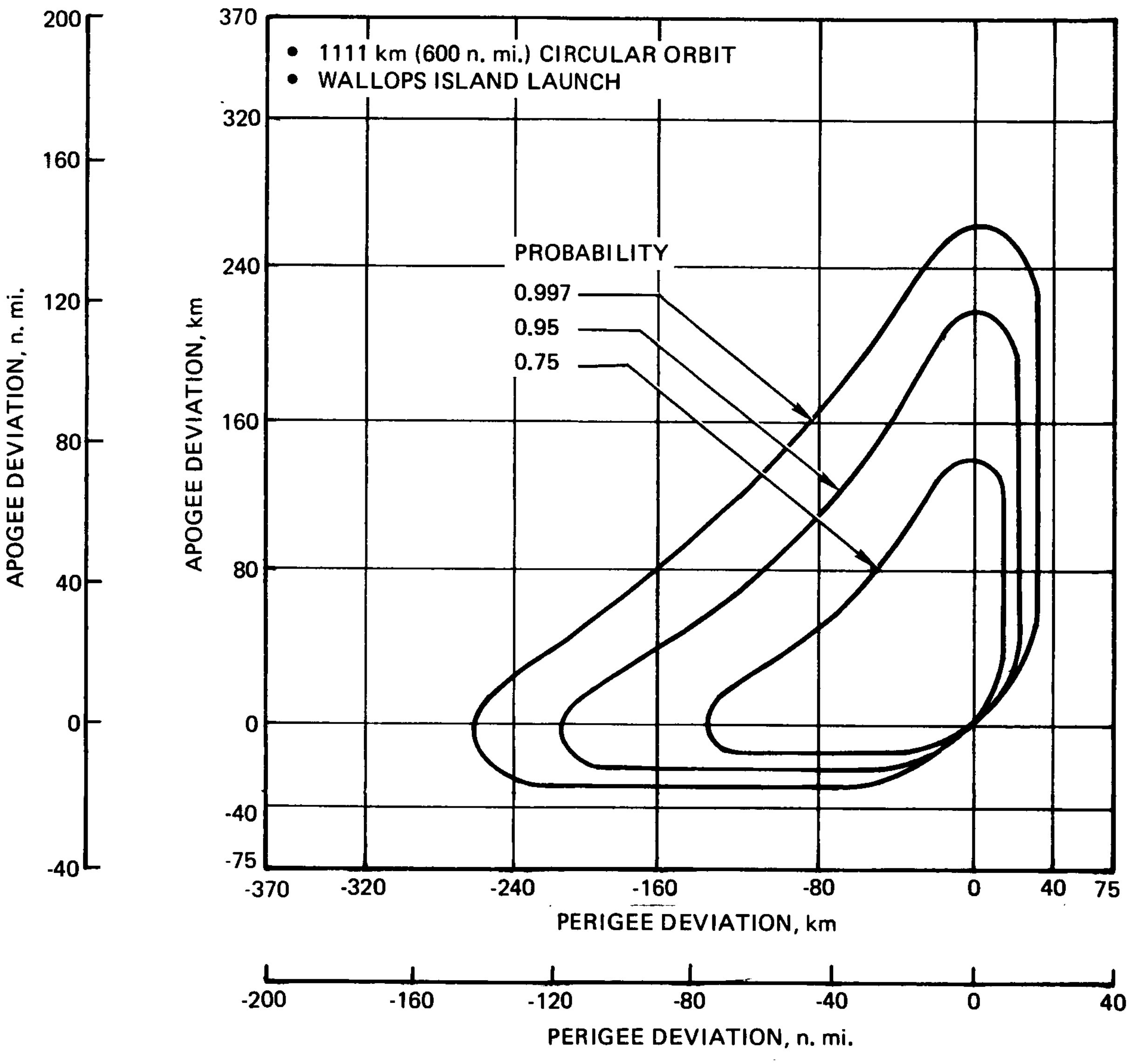


FIGURE 23 ORBITAL ACCURACY – OPEN LOOP FOURTH-STAGE GUIDANCE WITH VELOCITY CONTROL SYSTEM

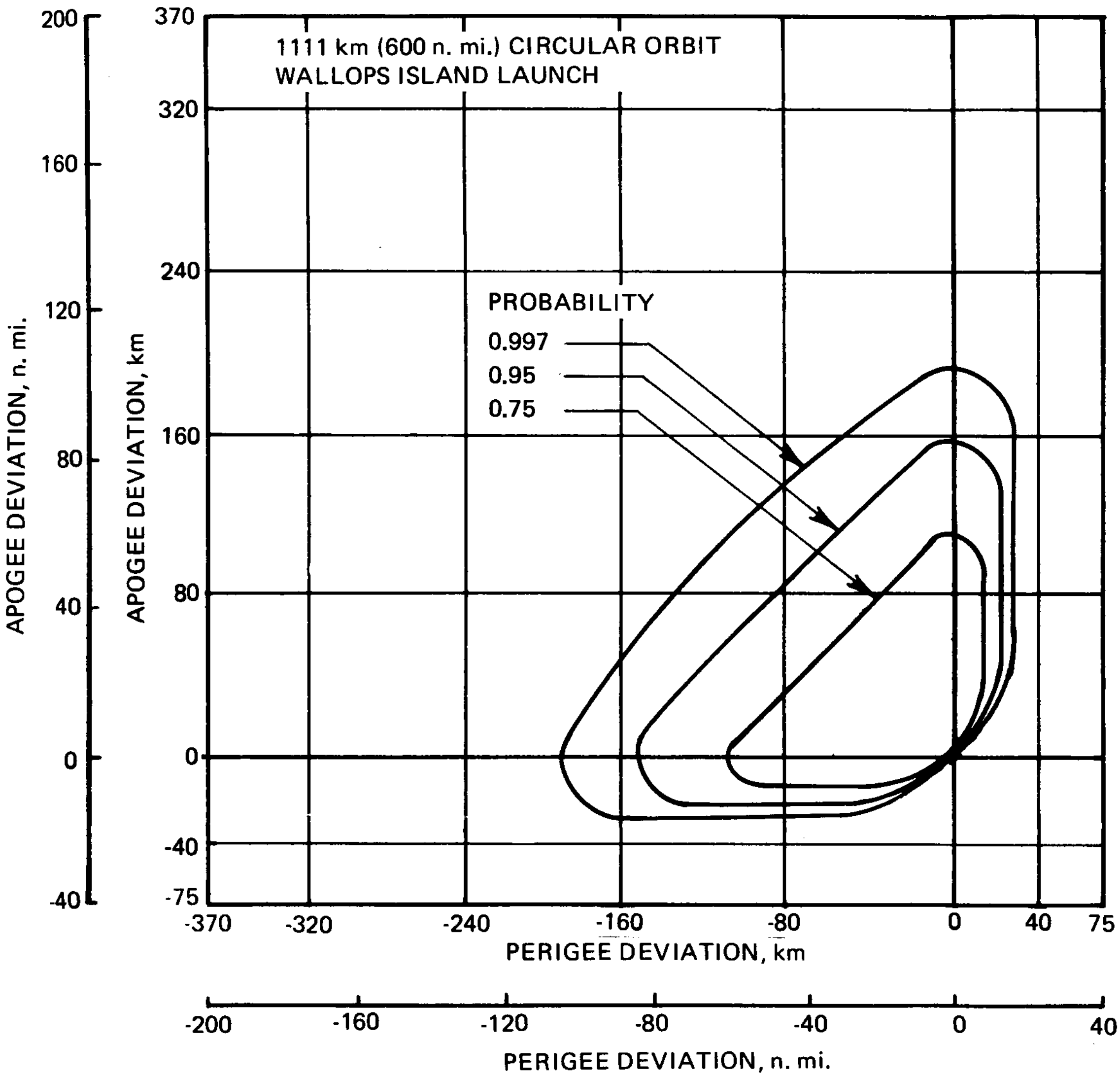


FIGURE 24 ORBITAL ACCURACY – OPEN LOOP FOURTH-STAGE GUIDANCE WITH VELOCITY CONTROL AND REDUCED DEADBANDS

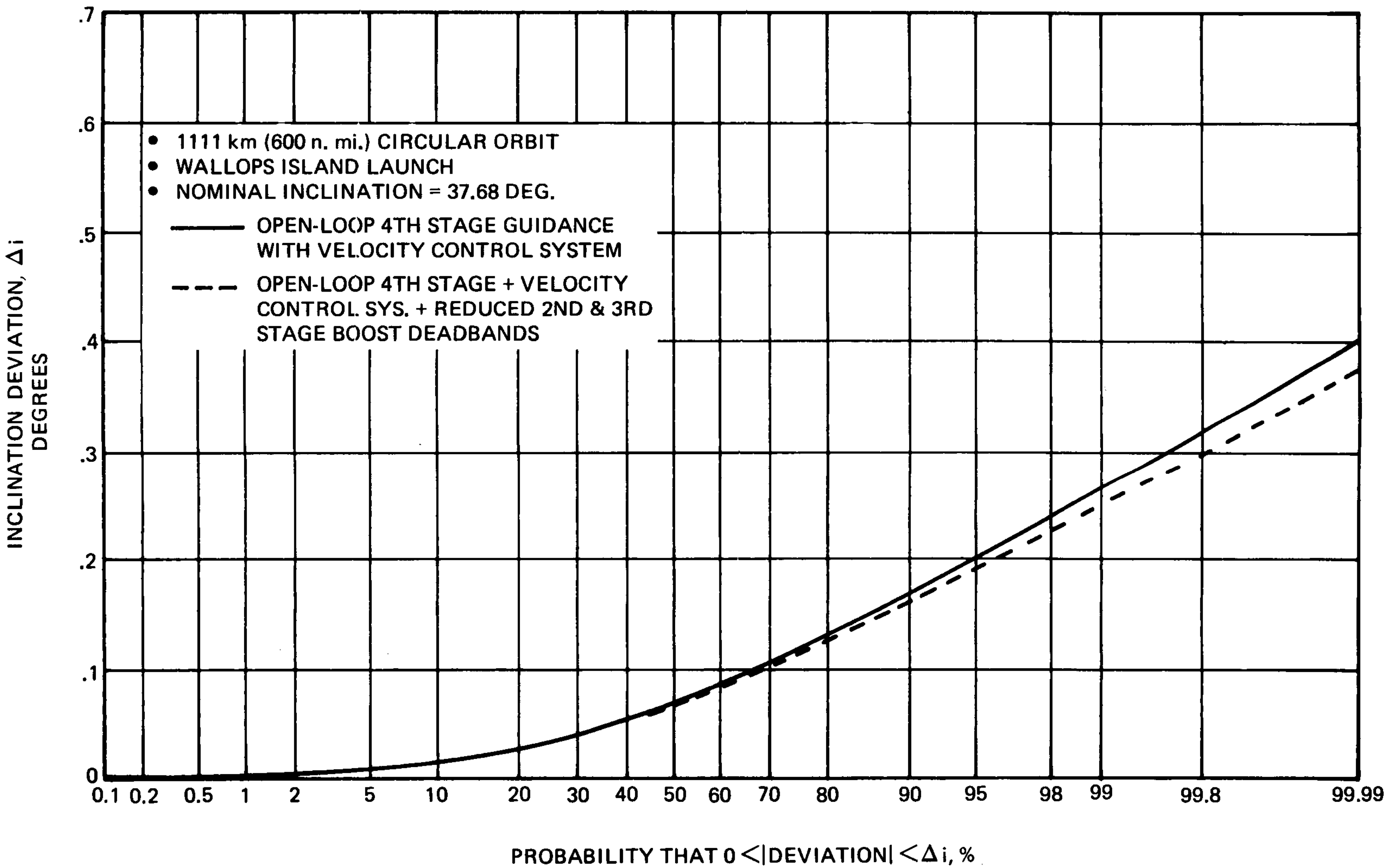


FIGURE 25 INCLINATION DEVIATIONS – OPEN LOOP 4TH STAGE GUIDANCE APPROACHES

stage. In this case, the most advantageous usage of the equipment would be the implementation of the inertial guidance approach with appropriate guidance and control logic.

In subsequent discussions, the system identification "Open-Loop Fourth Stage" will be used to refer to the most accurate approach within this option. This includes both the velocity control system and the reduced second and third stage boost deadbands.

5.4 GUIDANCE COMPARISONS

5.4.1 Accuracy - The 0.997 isoprobability contours of apogee-perigee deviations and three sigma inclination deviations for the current Scout and the three basic guidance approaches are shown in Figure 26. Orbital accuracy requirements from Section 3.2 have also been superimposed on Figure 26 and are indicated by the cross-hatched area. The outer bound of this area indicates permissible apogee-perigee deviations with a three-sigma inclination deviation of 0.1 degrees; whereas the inner bound defines permissible apogee-perigee deviations with a three-sigma inclination deviation of 0.3 degrees.

The accuracies achieved with inertial systems fall well inside the requirements area. Obtainable accuracies with the Augmented Scout and Open-Loop Fourth Stage approaches fall outside the indicated requirements and also exceed required accuracies for the high altitude application missions indicated in Figure 1. Both Augmented Scout and Open-Loop Fourth Stage approaches, however, offer significant improvements over the current Scout system.

5.4.2 Weight - Comparison of guidance systems on the basis of weight is an important factor since every pound of guidance system weight trades one-for-one with payload weight. A comparison of representative fourth stage weights for each of the three guidance approaches is shown in the following tabulation. For the Augmented Scout approach, all guidance system related weight in the third stage was translated into equivalent fourth stage weight to allow a comparison on a common basis. Attitude and orbital correction system weights are also included because the weight for this system differs between approaches since the fourth stage in the Augmented Scout approach is spin-stabilized.

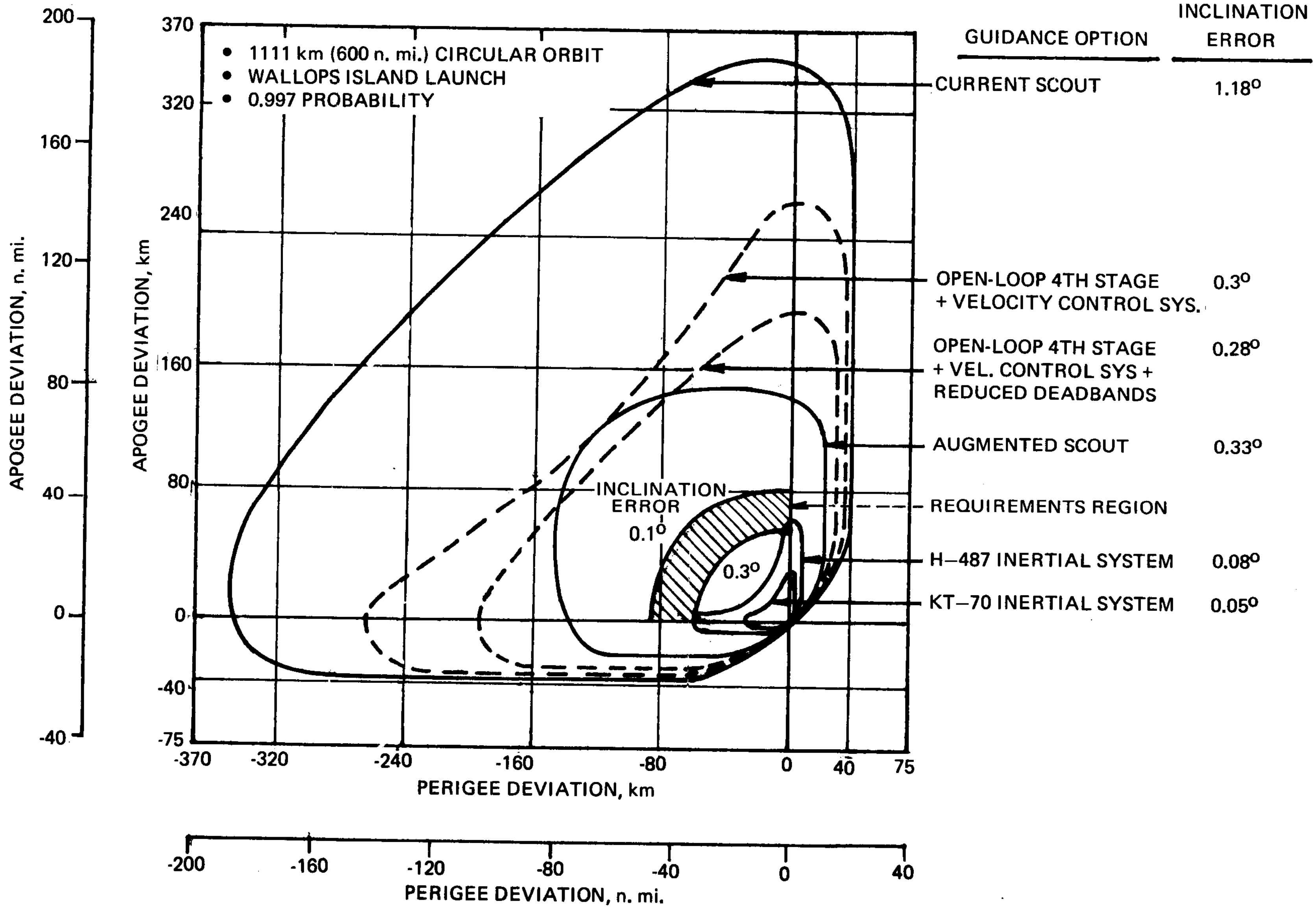


FIGURE 26 ORBITAL ACCURACIES – BASIC GUIDANCE APPROACHES

	GUIDANCE OPTION					
	Inertial Guidance		Augmented Scout		Open-Loop Fourth Stage	
	kg	lb	kg	lb	kg	lb
Guidance Equipment	33.1	73	18.1	40	30.4	67
Attitude & Orbital Correction System	29.5	65	18.1	40	29.5	65
3rd Stage Guidance Equipment (Equivalent 4th Stage Weight)	--	0	17.2	38	--	0
TOTAL	62.6	138	53.5	118	59.9	132

In arriving at representative guidance system weights, weight estimates of inertial guidance systems were based on an intermediate weight of 27.7 kg (61 lb) plus 5.4 kg (12 lb) for a battery. This intermediate guidance system weight was determined from Table 31 which indicates a weight range from 20 to 38 kg (44 to 84 lb) for inertial guidance systems, excluding batteries.

The weight of the current Scout open-loop system was used for the Augmented Scout and Open-Loop Fourth Stage appraoches. Weight estimates for additional equipments were obtained from vendor data. The 18.1 kg guidance equipment weight in the Augmented Scout system includes the attitude reference and correction subsystem for the spinning fourth stage plus the velocity meter. Estimated weight of the orbital correction system for this option is an additional 18.1 kg. The total weights in the above table indicate no significant advantage of one approach over another on the basis of weight.

5.4.3 Costs - An assessment of total guidance system costs including hardware and software development costs plus recurring unit costs was made for each of the three approaches. Costs for inertial guidance systems were based on vendor estimates. Costs of the basic open-loop equipment used in the other two approaches were assumed to be the same as those of the current Scout system; however, vendor cost estimates were obtained for each of the improvements.

Variations in estimated equipment costs are summarized below:

	Inertial Guidance	Augmented Scout	Open-Loop Fourth Stage
Non-Recurring Hardware Development (Vendor Design, Integration and Tests)	$1.3M to $2.59M	$560K to $840K	$280K to $420K
Unit Recurring Cost (50 Systems)	$112K to $266K	$232K to $269K	$150K to $164K

This cost comparison considers only the guidance equipment and control electronics. No increments are included for the actuators and electronics associated with first stage, gimbal nozzle control, rate gyro units, or attitude control hardware. Costs of these equipments would be essentially equivalent for all options and the intent is to provide a relative guidance comparison.

An overall cost comparison is provided in Table 42. The software development costs include associated analyses; development of all guidance and control logic and equations; plus the generation, verification, and validation of all flight computer programs. The equipment cost for the Augmented Scout includes an integral nitrogen attitude correction system to correct fourth stage separation and motor ignition disturbances, but does not include the velocity correction capability.

Since the Augmented Scout and Open-Loop Fourth Stage systems both utilize the existing Scout IRP, the lower cost bounds were used for comparison. No full inertial system has been used in a Scout-type environment, thus the costs for this approach were assumed to be near the maximum values.

Table 42 shows a total cost savings of slightly over $100K per system for the Open-Loop Fourth Stage system relative to inertial guidance. The cost of the Augmented Scout, however, is almost equivalent to that of inertial guidance.

TABLE 42 - GUIDANCE COST SUMMARY

	Guidance Option		
	Inertial Guidance	Augmented Scout	Open-Loop Fourth Stage
Development:			
Hardware	$2.1M	$560K	$280K
Software	1.25M	800K	280K
Amortized Development (50 Systems)	$67K	$27.2K	$11.2K
Unit Recurring	$210K	$232K*	$150K
Total (Recurring Plus Amortized Development)	$277K	$259.2K	$161.2K

* Includes Nitrogen Attitude Correction System for Spinning Fourth Stage.

5.5 GUIDANCE CONCLUSIONS

Results of the accuracy evaluation of the guidance options (Figure 26) show that an inertial guidance system with an attitude stabilized fourth stage can satisfy all accuracy requirements. Both the Augmented Scout and Open-Loop Fourth Stage options offer significant improvements in apogee-perigee deviations and inclination accuracy. The cost comparison shows no major difference between the Augmented Scout and inertial guidance. The cost penalty for the inertial system relative to the Open-Loop Fourth Stage system is approximately $100K per system.

The following conclusions were drawn from the guidance comparisons:

(1) The Augmented Scout is the least desirable approach. It suffers from equipment duplications and increased costs, and yet does not meet all the accuracy requirements.

(2) If the accuracy requirements established in Section 3.2 are to be met, the choice is full inertial guidance.

(3) The Open-Loop Fourth Stage will reduce the current Scout deviations by a factor of two and inclination error by a factor of four at a lower cost than the full inertial approach.

The weight and cost of the inertial guidance system were used in the ASLV Development Plan in order to be conservative in the planning phase. All six inertial guidance systems proposed will satisfy the orbital accuracy requirements. A representative inertial guidance system is shown in the general arrangement drawing at the back of this report. The objective was to show a realistic system installation and provide sufficient space for any of the candidate systems. The system shown in the drawing includes the KT-70 platform, associated power conditioner, electronics package, and the Kearfott SKC-2000 computer. A detailed weight statement for this guidance system is shown below.

	Subsystem:	Weight: kg	Weight: lbs
o	IMU (Platform	7.2	16.0
o	Computer	10.0	22.0
o	Power Conditioner	2.5	5.5
o	Electronics (Platform + Partial Control)	2.9	6.5
o	Rate Gyros	.9	2.0
o	Additional Control Electronics (Including Filters and Power Switching)	2.3	5.0
o	Additional Power Conditioning and Expanded Interface	1.8	4.0
	TOTAL	27.6	61.0

(This Page Intentionally Left Blank)

6.0 CONCEPTUAL DESIGN

6.1 CONFIGURATION DESCRIPTION

This section contains a summary description and mass properties of the major components of the ASLV selected conceptual design. This design is shown on the general arrangement drawing which is included as the last page of this volume. This drawing is a fold out and the description herein starts at the first stage and flows up to the payload, stage by stage. It should be noted that the conceptual design derived in this section is intended to provide a guide for the detail design of an ASLV at a later date. The choice of subsystems in no way indicates a final selection. During the conceptual design, engineering judgement was used to select subsystems that would satisfy the intended usage and be representative of the weight, volume, performance, and cost characteristics of the design phase. During the detail design phase final subsystem selections will be made based upon more detailed design investigations.

The launch vehicle configuration resulting from the conceptual design study is a solid propellant rocket motor four stage vehicle with first stage thrust augmentation provided by strap-on motors. These motors are current Scout motors or modification thereof as shown in Figure 27. Vehicle total length is 25.3 meters (82.9 feet). The maximum diameter of the vehicle is 152 centimeters (60 inches). First stage motors are the current Scout Algol III with two strap-on TX 354-5 Castor motors. The second stage motor is a short Algol III. Third and fourth stage motors are the High Pressure (HP) X-259 and short X-259. The short X-259 is a modification of the HP X-259. These motors are connected by the conventional interstage structure which also provides volume for stage subsystem installations.

A jettisonable payload shroud covers the payload and the third and fourth stages of the vehicle. External tunnels along the first and second stages cover the instrumentation and guidance electrical wiring and destruct systems over this portion of the vehicle. Electrical wiring and destruct systems for the third and fourth stages are located under the payload shroud.

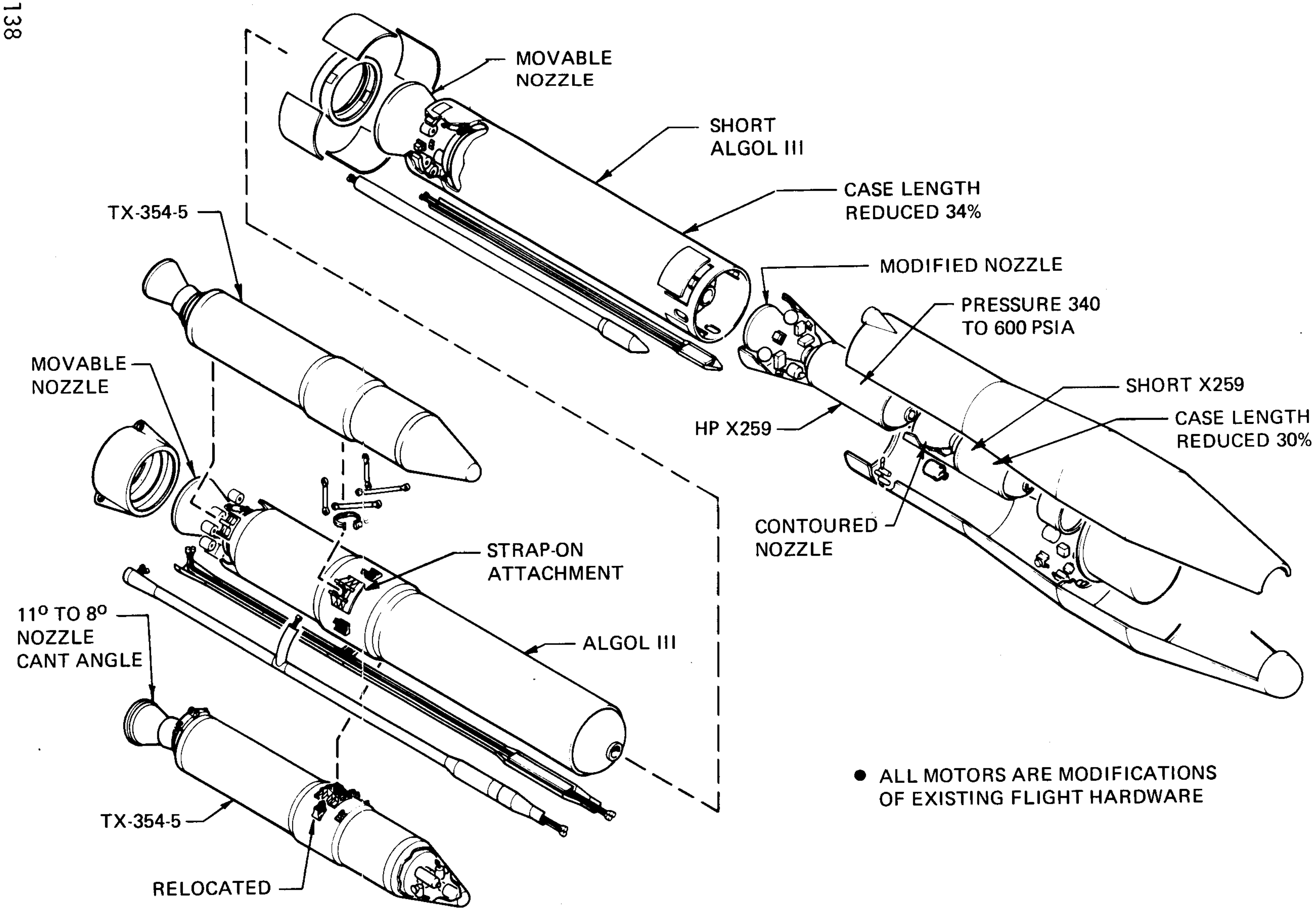


FIGURE 27 ASLV MOTOR MODIFICATIONS

The nozzles of the first and second stage Algol III motors are movable and provide pitch and yaw control during firing of these motors. Vehicle roll control during first stage boost is obtained by reaction control systems mounted in the nose cone of each strap-on motor and in the base section of the first stage. The roll control system in the base section of the first stage is used when the strap-on motors are dropped. A reaction control system on the second stage provides roll control during second stage motor firing and vehicle complete control during second stage coast. Pitch, yaw, and roll control of the third and fourth stages is accomplished by reaction control systems mounted on the transition sections between second and third, and third and fourth stage motors. The fourth stage reaction control system also provides vernier velocity correction after stage burnout.

6.1.1 Strap-On Castor Motors - Two TX 354-5 strap-on Castor motors are attached to the first stage Algol III motor. These motors are located 180 degrees apart and are positioned such that the aft end of the Castor motor case skirt is aligned with the aft end of the Algol III motor case skirt. Loads from the strap-on motors are transmitted to the Algol III motor case by means of a thrust ball and sway brace fittings located in the forward region of the strap-on motor case and rollers with a track arrangement at the aft end of the Castor motor case.

A conical shape aerodynamic fairing is attached to the forward end of the Castor motor case. Housed within this fairing is a reaction control system and auto destruct. The RCS provides roll control for the vehicle during the time of Castor Strap-on motor firing.

6.1.2 First Stage - The first stage base section is a cylindrical section consisting of metal skins, longitudinal members and circular frames with access doors as required. The diameter of the section is 114.3 centimeters (45 in). The section houses the movable nozzle of the first stage Algol III motor, the hydraulic supply and actuation system for the nozzle, and a RCS for roll control. The RCS provides roll control for the vehicle during first stage boost after ejection of the TX 354-5 Castor motors. Also contained within the base section are two hoist and launch fittings. The vehicle to launcher interface points are located the same as on Scout.

However, the base section pin interface points are forward of the Scout location because of the need for a shorter base section to provide clearance for the movable nozzle actuation. Thus, the ASLV launch pins must be longer than the current Scout pins.

The construction, manufacture and processing of the first stage will be very similar to the current Scout. The first stage motor, Algol III, is the same as Scout except for the movable nozzle and strap-on fittings.

6.1.3 Second Stage - The transition section between the first and second stage motors provides the primary structure for this portion of the vehicle. This section is configured to interface with the current Scout first stage Algol III because step 1 of the phased growth approach uses the Scout first stage. The forward portion of the section is a cylinder of 114.3 centimeters (45 in) diameter which tapers to a diameter of 101.6 centimeters (40 in) at the aft end to interface with the current Scout Algol III motor flange. The transition section consists of metal skins, longitudinal members and circular frames with access doors as required. The section houses the movable nozzle of the second stage short Algol III motor, the hydraulic supply and actuation system for the nozzle and a reaction control system. The RCS provides vehicle roll control during second stage motor firing and pitch, yaw and roll control during second stage coast between second stage burnout and third stage ignition.

A hoist ring and lug, for erecting the vehicle on the launcher, are an integral part of this section. The hoist ring is at the aft end of the tapered portion of the section at the interface of the transition section and the first stage Algol III motor case.

The construction, manufacture and processing of this stage will be similar to current Scout because the short Algol III motor is similar to the Scout first stage except for the movable nozzle.

6.1.4 Third Stage - The second and third stage motors are joined by a transition section that provides the vehicle primary structure between these motors. The section is conical with a diameter of 114.3 centimeters at the interface with the second stage and tapers to a diameter of 75.2 centimeters (30 in) at the interface with the HP X259 third stage motor. The transition section consists of metal skins, longitudinal members, circular frames, and access doors as required.

This section houses the nozzle of the third stage, HP X259 motor, reaction control system for pitch, yaw, and roll control, telemetry relay box, ignition and destruct batteries, destruct antennae and receiver.

The construction, manufacture and processing of this stage will be the same as the current Scout.

6.1.5 Fourth Stage - A cylindrical transition section connects the third and fourth stage motors. It is 76.2 centimeters (30 in) in diameter and provides the vehicle primary structure between these two motors. The section consists of metal skins, access doors, longitudinal members and circular frames.

A reaction control system for vehicle fourth stage pitch, yaw and roll control is mounted on this transition section. This RCS provides the orbital correction for vernier velocity control after fourth stage burnout.

The construction, manufacture and processing of this stage will be similar to current Scout but more complex because of the addition of reaction control and destruct systems.

6.1.6 Payload Adapter - A cylindrical adapter section 76.2 centimeters (30 in) in diameter joins the payload to the fourth stage motor case. This section consists of metal skins, longitudinal members, circular frames, and access doors as required. Included in the items mounted on this section are the guidance system, telemetry transmitter and associated equipment, radar transponder, batteries, and the payload separation system.

6.1.7 Payload Shroud - The payload shroud covers the payload and the third and fourth stage motors. This shroud provides protection for the payload and third and fourth stage motors from aerodynamic heating and serves as the major aerodynamic load carrying structure during first and second stage boost. This shroud is jettisoned as one piece.

The forward 433.45 centimeters (170.65 inches) of the shroud covers the payload and payload adapter. This part has a conical nose section 281.05 centimeters (110.65 inches) long with a half cone angle of 10 degrees and a nose radius of 31.75 centimeters (12.5 inches). The aft portion is a cylinder 152.4 centimeters long and 152.4 centimeters in diameter. The shell of the conical and cylindrical sections is a solid laminate phenolic reinforced fiberglass with a metal nose cap. The shell is reinforced with circular frames and contains venting, umbilical, and access doors as required.

The shroud continues aft covering the third and fourth stages and interfaces with the transition section between second and third stage motors at a point located 52.07 centimeters (20.5 inches) forward of the forward face of the second stage short Algol III motor case. The forward portion of this third and fourth stage part is shaped as a frustum of a cone 223.8 centimeters (88.1 inches) long. It tapers from a diameter of 152.4 centimeters at the payload to fourth stage interface plane to a diameter of 114.3 centimeters at the interface with the second stage. The shell of the forward portion of this part is solid laminate phenolic reinforced fiberglass and is reinforced with circular frames. The aft portion is a metal shell cylinder 256.24 centimeters (100.88 inches) long with a diameter of 114.3 centimeters and it is reinforced with circular frames.

6.1.8 Structure - The structural arrangement resulting from the conceptual design study provides good structural continuity with direct structural load paths throughout the vehicle. Also, this arrangement will result in use of commonly used methods of analysis and fabrication which have been used on the current Scout vehicle. The design ultimate load used to determine structure size was 1.25 x limit load.

Cork insulation will be applied to the external surfaces of the vehicle as required to protect the structure, equipment, and instrumentation from aerodynamic heating.

6.1.9 Separation - Separation of the vehicle components and stages occur in the following sequence: Strap-on Castor motors, first stage, payload shroud (after second stage burnout), second stage, third stage, fourth stage, and payload.

Separation of the two strap-on Castor motors is initiated by the release of a Marman type clamp at the thrust ball joint and separation occurs simultaneously. Release of the clamp is accomplished by the discharge of an explosive nut attaching the clamp. As these motors start to fall away, two jettison bars located forward on the Castor motor case force the forward end of the motors to rotate out and away from the first stage Algol III motor. Rollers on the aft end of the motor cases mate to a track arrangement which is mounted on the first stage base section. This arrangement assures rotation of the strap-on Castor motor and also guides them away from the first stage base section and the Algol III motor nozzle. This attachment and separation arrangement of the strap-on motor is the same as that used on the thrust augmented Thor vehicle.

All other structural joint separations on the vehicle as shown on the drawing, except payload separation, are accomplished by the use of the Super Zip Linear Separation System which is manufactured by Lockheed. This linear separation system, Figure 28, is an integrated, structural, frangible joint containing a dual length of detonating cord. The detonating cord is confined in a plastic and is surrounded by a metal jacket. Upon detonation of the cord, the plastic and metal jacket expands without rupturing and fractures the separation joint. All products of combustion are retained. The linear charge separation provides a system with no contamination and fragments. The system has been flight tested and is used on the Titan III and Atlas Agena launch vehicles. The length of the payload separation on the Titan IIID is 18.2 m (59.5 feet) compared to 9.1 m (29.9 feet) for the ASLV.

After separation of the first stage, a part (33.5 cm) of the second stage interstage structure is separated to provide clearance for the movable nozzle actuation. This same function is accomplished on other rocket stages having movable nozzles, e.g., Minuteman.

The payload is attached to the fourth stage adapter by means of a vee-band clamp and separation is initiated by discharge of explosive nuts attaching the clamp. As the clamp is released, compressed springs housed within the fourth stage adapter section assure separation by pushing the payload away from the adapter and the expended fourth stage.

Separation of electrical wiring across the stage separation joints is accomplished by disconnect plugs and lanyard pulls. Electrical connections between the payload and the fourth stage are disconnected by plugs across the Vee band clamp joint. This type of payload separation has been used very successfully on Scout.

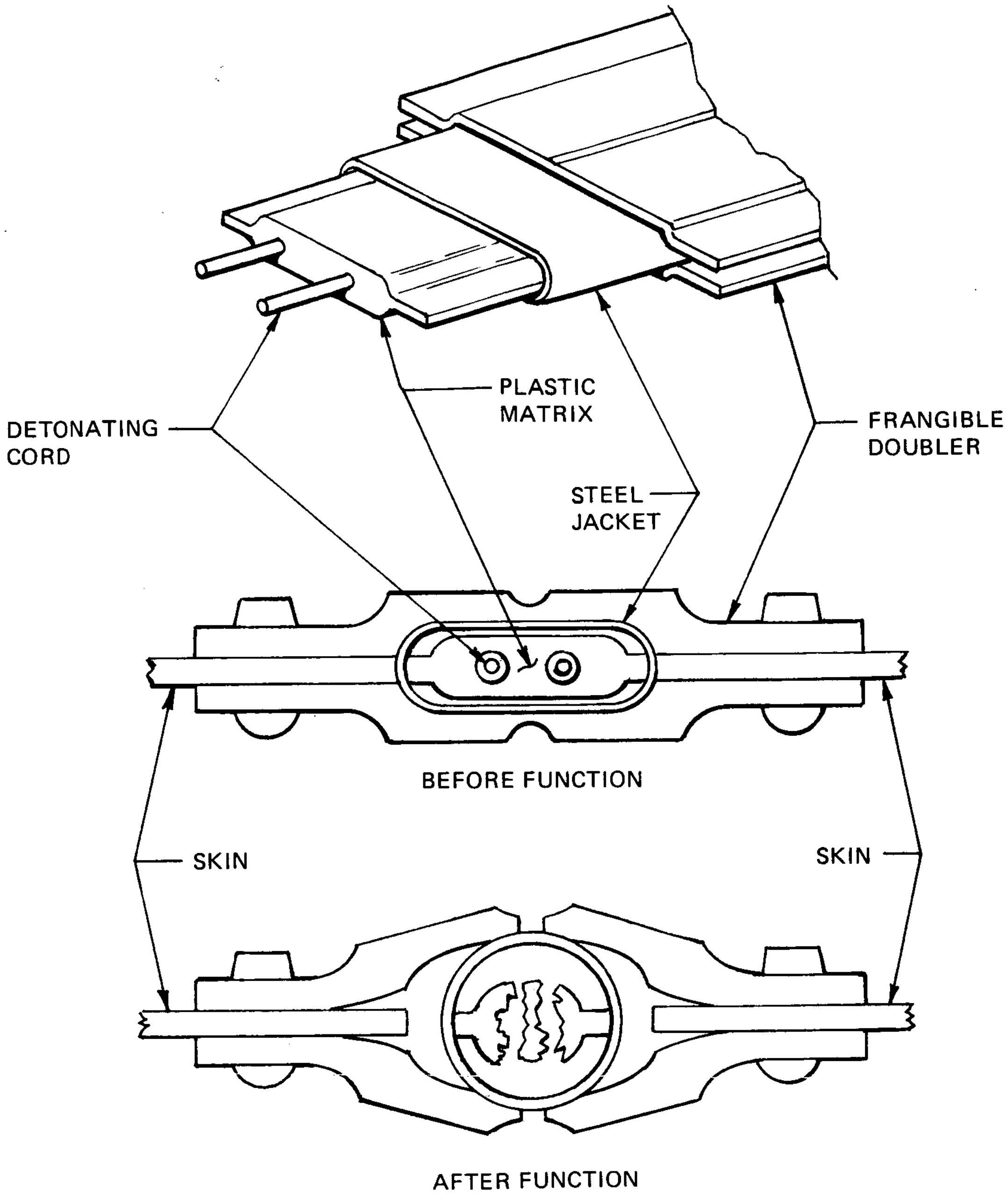


FIGURE 28 LOCKHEED SUPER ZIP LINEAR SEPARATION SYSTEM

6.1.10 Reaction Control Systems - The control systems evaluated were current Scout hydrogen peroxide (H_2O_2), Solid Gas Generator (GG), Liquid Injection Thrust Vector Control (LITVC), and Hydrazine (N_2H_4). The current Scout H_2O_2 systems were selected for the ASLV for the following reasons:

(1) The Scout hardware (thrusters, tanks, pressure regulators, and N_2 supply) without modification could be used for all requirements, e.g., first stage roll control with and without strap-on motors; second stage roll control during boost phase and pitch, yaw and roll during the coast phase; third stage pitch, yaw and roll for boost and coast phase; and fourth stage pitch, yaw and roll for boost and coast phase and vernier velocity control after fourth stage motor burnout.

(2) The Scout hardware is flight proven and no development phase with its associated cost is necessary.

(3) The N_2H_4 system would require development. Because of the high cost of the catalyst bed, the recurring cost of N_2H_2 thrusters is five times that of the Scout H_2O_2 thrusters. The density of N_2H_4 is about two-thirds that of H_2O_2. Thus, for a given total impulse, the volume will be the same. Hence, no weight reduction in the tankage and associated hardware weight.

(4) Because the Solid GG must burn throughout the total time a stage must be controlled (no start-stop operation possible), this approach exhibited no payload weight improvement when used on the first and second stages and a payload loss when used on the third and fourth stage. Also, a 2-1/2 $M development cost would be necessary to develop a system for the ASLV requirements. The LITVC systems are only effective during the boost phase since the reaction is obtained by injecting a fluid into the boost motor nozzle exhaust gases. Thus, an H_2O_2 or some other system would be required for the cost phase. The weight trade offs showed no payload improvement over the H_2O_2 system. In addition, a 3/4 $M development phase would be necessary to developed ASLV hardware.

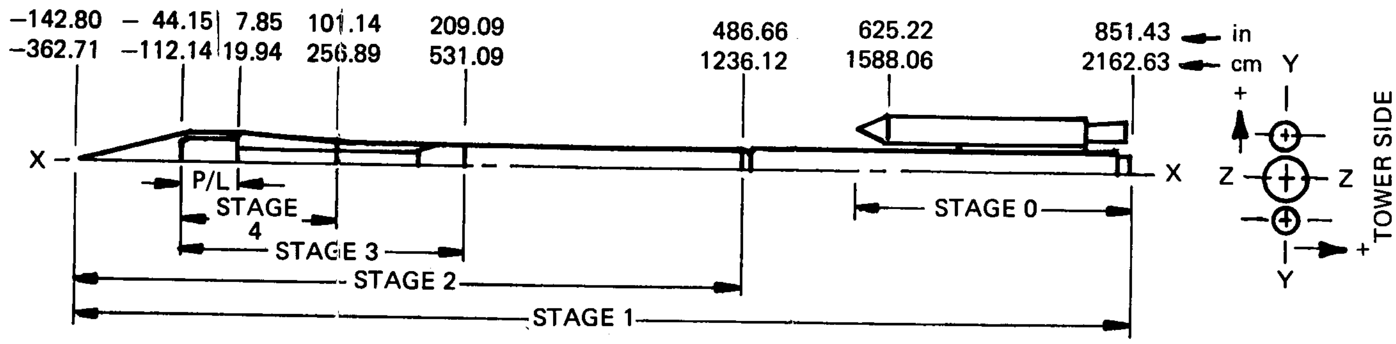
6.1.11 Telemetry - The selection of a PCM telemetry system over the present Scout PAM system was made because of the use of the interial guidance system. It was considered that more accurate telemetry data would be required for monitoring the inertial guidance.

6.1.12 Mass Properties - The current mass properties data for the selected conceptual design with a 340 kg payload weight is shown in Tables 43 and 44. The Scout vehicle S-178, with actual weights of transition sections, was used as the basis for scaling data for the ASLV. Where the structural or subsystem requirements differ from Scout, appropriate analyses were made to produce nominal weight data. Motor mass properties are considered nominal since they are either vendor inputs or estimates based on existing motors.

6.1.13 Payload Volume - A schematic arrangement of the four and five stage vehicles is shown in Figure 29. The conversion to a five stage vehicle requires the addition of a fifth stage motor, spin table, payload separation, adapter, spin rockets, electrical and other equipment as required. The combined weight of this fifth stage installation including the payload must not exceed the design payload capability of the basic four stage vehicle.

6.1.14 Motor Performance - The performance and physical characteristics of the selected solid rocket motors are shown in Table 45.

TABLE 43 ASLV MASS PROPERTIES DATA SUMMARY WITH 340 kg (750 lb) PAYLOAD



EVENT	WEIGHT		CENTER OF GRAVITY						MOMENT OF INERTIA					
			X		Y		Z		I_{XX}		I_{YY}		I_{ZZ}	
	lb	kg	in	cm	in	cm	in	cm	SLUG·ft^2	kg-cm^2 X 10^{-6}	SLUG·ft^2	kg-cm^2 X 10^{-6}	SLUG·ft^2	kg-cm^2 X 10^{-6}
STAGE 0 & 1 IGNITION	80,194	36,368	542.04	1,376.78	100.00	254.00	100.03	254.08	12,178	165.2	827,790	11,226.5	835,750	11,334.4
STAGE 0 BURNOUT	47,454	21,520	443.14	1,125.57	100.00	254.00	100.05	254.13	4,499	58.5	536,495	7,275.9	537,847	7,294.3
STAGE 1 INTERIM	44,074	19,983	420.68	1,068.53	100.00	254.00	100.05	254.13	3,022	41.0	463,913	6,291.6	463,915	6,291.6
STAGE 1 BURNOUT	32,050	14,535	336.42	854.51	100.00	254.00	100.07	254.18	2,122	28.8	262,787	3,563.9	262,790	3,563.9
STAGE 2 IGNITION	27,571	12,503	278.11	706.40	100.00	254.00	100.03	254.08	1,631	22.1	105,168	1,426.3	105,170	1,426.3
STAGE 2 BURNOUT	9,571	4,340	178.66	453.80	100.00	254.00	100.09	254.23	631	8.6	61,956	840.2	61,958	840.3
STAGE 3 IGNITION	5,938	2,693	91.21	231.67	100.00	254.00	100.00	254.00	194	2.6	6,043	819.6	6,045	819.8
STAGE 3 BURNOUT	3,335	1,512	48.92	124.26	100.00	254.00	100.00	254.00	129	1.7	2,852	386.8	2,854	387.0
STAGE 4 IGNITION	2,857	1,296	28.40	72.14	100.00	254.00	100.00	254.00	110	1.5	918	124.5	919	124.6
STAGE 4 BURNOUT	1,167	529	2.23	5.66	100.00	254.00	100.00	254.00	68	0.9	533	75.0	554	75.1

TABLE 44

ASLV WEIGHT BREAKDOWN

COMPONENT/EVENT	STAGE WEIGHT	
	lbs	kgs
PAYLOAD	750	340.1
STEP 4		
E-Section	128	58
Structure Systems		
Motor - Short 259		
Burnout	155	70.3
Motor Section	20	9.1
Ignition & Guidance Harness, Misc.		
Upper D	114	51.7
Structure Systems		
STAGE 4 BURNOUT	1167	529.3
Weight Consumed, Short 259 Motor	1690	766.4
STAGE 4 IGNITION	2857	1295.7
STEP 3		
Lower D	25	11.3
Structure Systems		
Motor - HP-259		
Burnout	213	96.6
Motor Section	41	18.6
T/M & Guid. Tunnels & Harness Destruct; Noz. Shroud; Misc.		
Upper C	199	90.2
Structure Systems		
STAGE 3 BURNOUT	3335	1512.4
Weight Consumed, HP-259 Motor	2603	1180.5
STAGE 3 IGNITION	5938	2692.9
P/L SHROUD	912	413.6

TABLE 44 (Continued)

COMPONENT/EVENT	STAGE WEIGHT lbs	STAGE WEIGHT kgs
STEP 2		
Lower C	90	40.8
Structure		
Systems		
Motor - Short Algol III		
Burnout	2273	1030.8
Motor Section	61	27.7
T/M & Guidance Tunnels & Harness		
Destruct		
Upper B		
Structure		
drops with Stage 1		
flies with Stage 2	87	39.4
Systems	210	95.2
STAGE 2 BURNOUT	9571	4340.4
Weight Consumed, Short Algol III	18000	8163.0
STAGE 2 IGNITION	27571	12503.4
Upper B - drop structure	47	21.3
STEP 1		
Lower B	223	101.1
Structure		
Systems		
Motor - Algol III		
Burnout	3586	1626.3
Motor Section	90	40.8
T/M & Guidance Tunnels & Harness		
Destruct		
Base A	533	241.7
Structure		
Systems		
STAGE 1 BURNOUT	32050	14534.7
Weight Consumed, Algol III	12024	5452.9

TABLE 44 (Concluded)

COMPONENT/EVENT	STAGE WEIGHT	
	lbs	kgs
STAGE 1 INTERIM BURNING (CASTORS OFF)	44074	19987.5
STEP 0		
Motor - Castor 5 (2)		
Burnout	3042	1379.5
Motor Section - Nose Fairing & RCS (2)	338	153.3
STAGE 0 BURNOUT	47454	21520.4
Weight Consumed, Castors (2)	16560	7510.0
Weight Consumed, Algol III	16180	7337.6
STAGE 0 IGNITION with 340 kg (750 lb) P/L	80194	36368.0

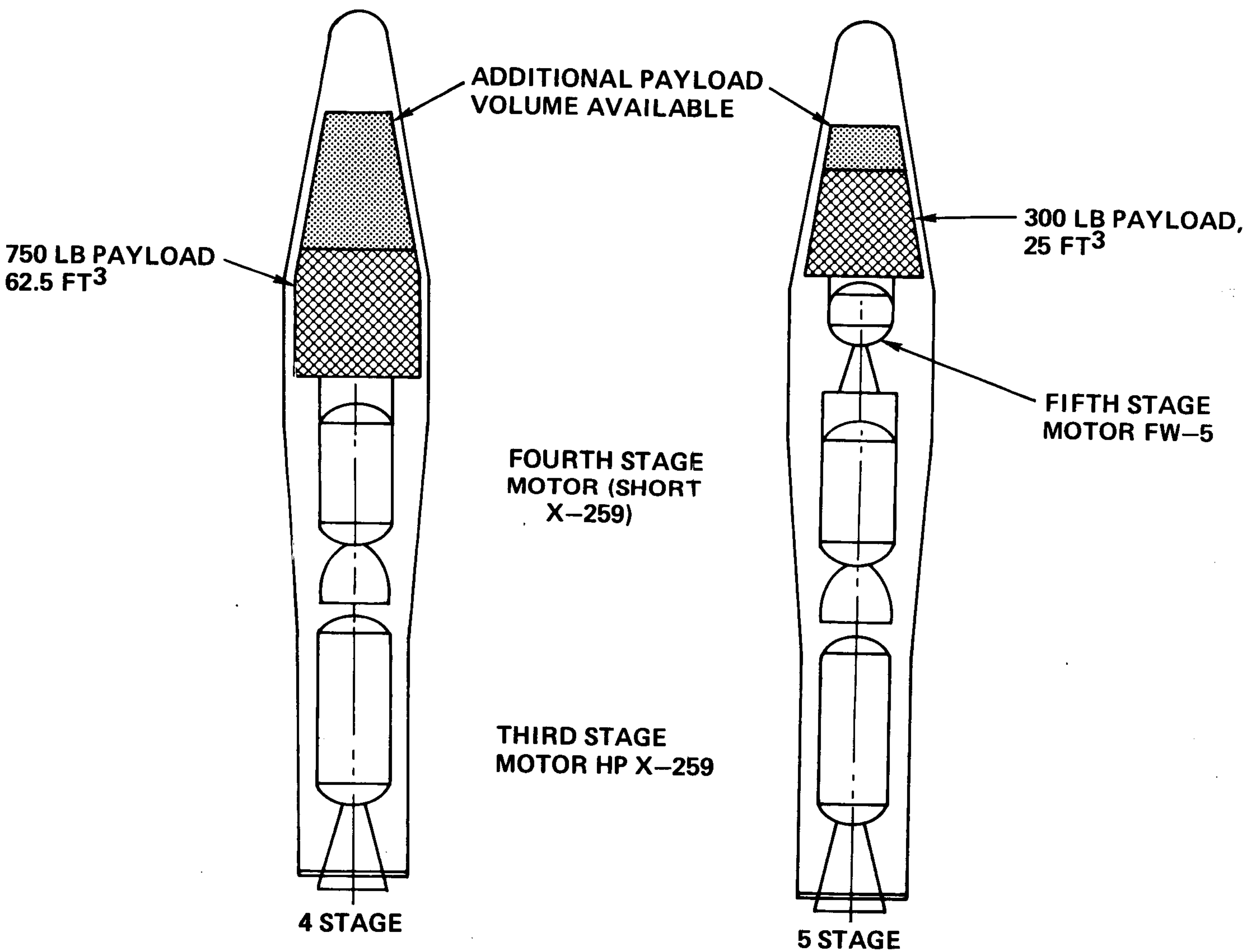


FIGURE 29 PAYLOAD VOLUME

TABLE 45 SUMMARY OF CHARACTERISTICS OF SELECTED MOTORS

MOTOR	DIAMETER		LENGTH		WEIGHT		VACUUM DELIVERED SPECIFIC IMPULSE		VACUUM TOTAL IMPULSE	
	cm	inches	cm	inches	kg	lbm	N-s/kg	lbf-sec/lbm	N-s	lbf-sec
TX 354-5 Strap-Ons	86.675	34.124	603.86	237.74	4423.1	9751.0	2609	266.1	9727776	2187000
Algol III First Stage	114.38	45.03	937.4	373	14442.6	31840.0	2600	265.0	33004160	7420000
Short Algol III Second Stage	114.38	45.03	660.4	260	9383.6	20687.0	2772	282.7	2257360	5075000
High Pressure X-259 Third Stage	74.4	29.3	389.1	113.8	1279	2820	2801	285.6	3269280	735000
Short X-259 Fourth Stage	76.5	30.1	229	90	841.9	1856	2915	297.3	2213770	497700

6.2 VEHICLE PERFORMANCE

The ASLV performance capabilities are presented in this section for orbit, reentry, earth and solar probe missions. The rocket motor performance, physical characteristics, and vehicle weights important to ASLV performance calculations are described in Tables 43, 44, and 45. These values have been used for the generation of the ASLV performance. The selected ASLV configuration includes approximately a 10 percent margin above the required payload capability of 340 kg into a 556 km circular orbit. The payload margin has been introduced to account for possible component weight growth and changes in motor performance. The orbital, reentry, and earth probe performance data is presented for the selected four stage ASLV with thrust augmentation. To define the synchronous transfer and solar probe cabability, a typical fifth stage (FW-4 or FW-5) was incorporated into the vehicle.

6.2.1 Trajectory - All trajectories utilized in developing the performance data in this section were computed using the six-degree-of-freedom, digital computer routine described in Reference (17). These trajectories were based on nominal information and did not include any deviations in vehicle systems operation or external disturbances.

6.2.2 Performance Data - The ASLV performance data presented in the following sections reflects the use of a Wallops Island launch site and a launch azimuth of 90 degrees (due east). The orbit altitudes are based on a mean earth radius of 6370.076 km (3439.566 n.mi.).

The characteristic velocity which can be achieved with the four stage ASLV is presented in Figure 30. Also, presented in Figure 30 is the characteristic velocity which can be obtained with the addition of a fifth stage sized for maximum payload into a synchronous transfer orbit. The fifth stage motor size required to inject maximum payload into a synchronous transfer orbit was 287.5 kg (634 lbs) with a propellant weight of 262.6 kg (579 lbs). With the five stage ASLV configuration, approximately 157 kg (347 lbs) of payload can be injected into a synchronous transfer orbit and approximately 105 kg (231 lbs) into an earth escape trajectory.

Also presented is the characteristic velocity which can be achieved with a FW-4 or FW-5 type fifth stage.

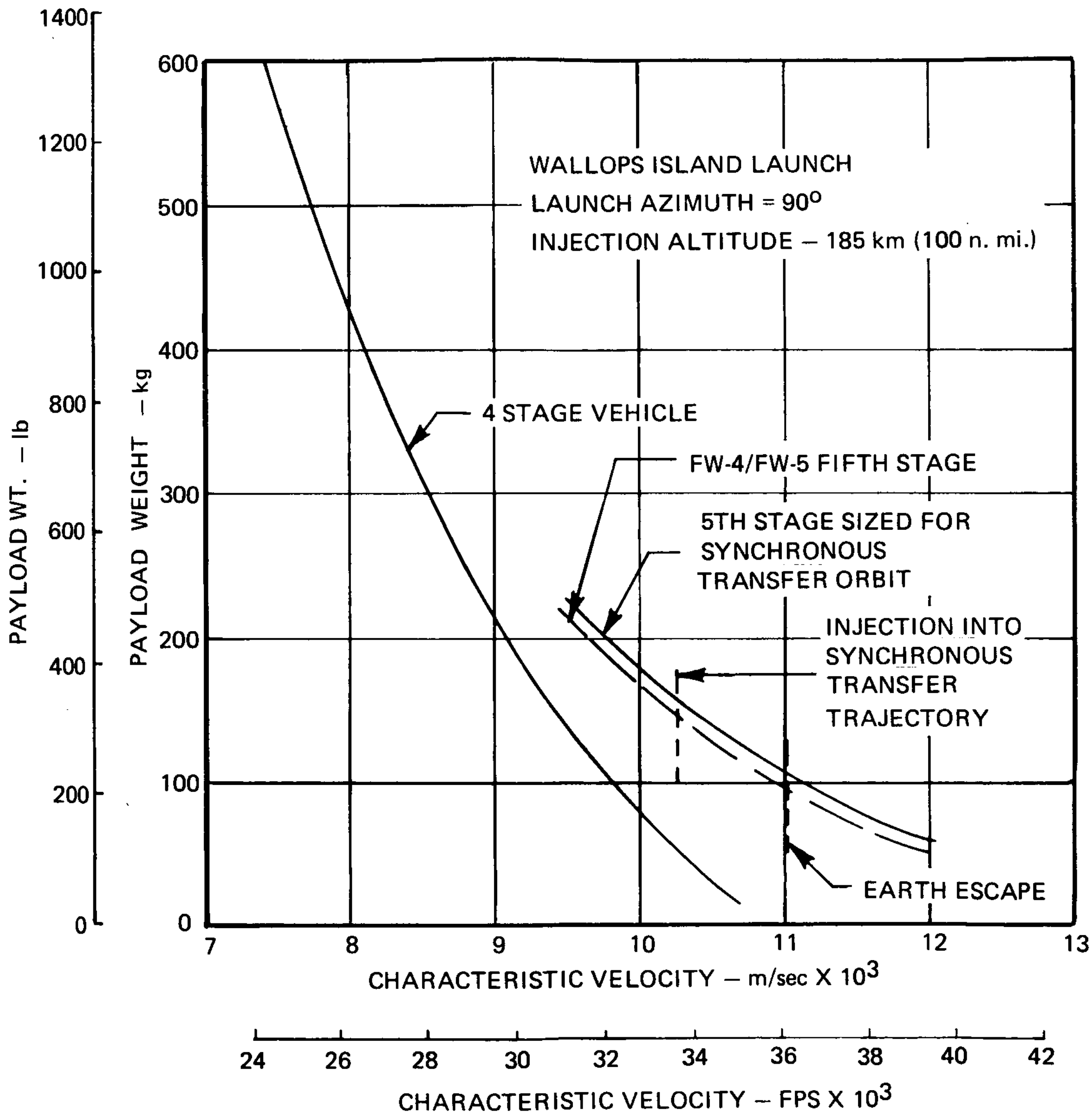


FIGURE 30 PERFORMANCE COMPARISON – EFFECT OF FIFTH STAGE

Orbit Missions

For orbit missions the ASLV utilizes the first three stages to boost the fourth stage and payload to the desired injection altitude. The fourth stage then accelerates the payload to the desired injection velocity.

The circular and elliptical orbital capability of the ASLV is presented in Figure 31. The ASLV trajectories are designed so that injection occurs at zero flight path angle and thus injection altitude is perigee altitude. The due east launch from Wallops Island results in an orbit inclination of about 37.7 degrees. The ASLV circular orbit payload capability varies from 476 kg (1050 lbs) into a 200 km (108 n.mi.) orbit to approximately 23 kg (50 lbs) into a 1925 km (1040 n.mi.) orbit.

The ASLV's maximum elliptical apogee altitude of 73154 km (39500 n.mi.) occurs with a perigee altitude of 200 km (108 n.mi.) and a payload weight of 23 kg (50 lbs).

Reentry Mission

Reentry trajectories represent a radical departure from orbit trajectories after stage two burnout. The third and fourth stages are generally used to drive the payload back into the atmosphere. The exact ignition time and position of the third stage are determined by the reentry test conditions. For convenience, reentry conditions are quoted at the time of final stage burnout.

The reentry performance presented in Figures 32 and 33 were obtained by simulating gravity turn trajectories. There are many factors and special limitations (i.e., altitude-range profile, shaped trajectories, reentry range, etc.) which are normally specified for a reentry mission. These factors and special limitations are usually unique for each reentry mission. However, to present the ASLV overall reentry performance capabilities, data are shown for gravity turn trajectories only. The data are calculated for a launch azimuth of 90 degrees from Wallops Island.

Because of the reentry range considerations needed to reenter in the general area of the Bermuda tracking stations, the reentry performance is presented for trajectories which incorporate two stages to boost and two stages to drive the reentry vehicle through the specified reentry altitude.

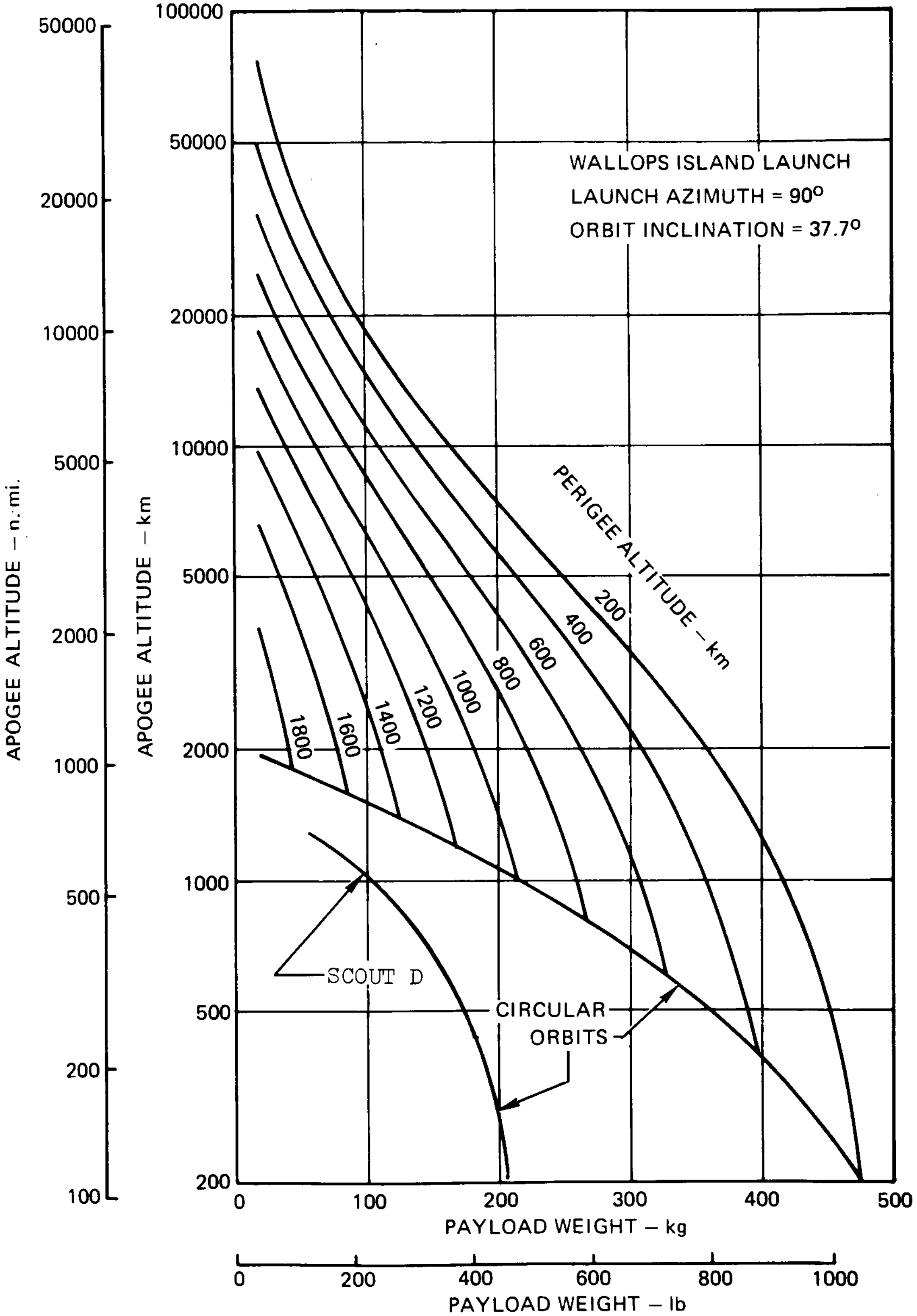


FIGURE 31 CIRCULAR AND ELLIPTICAL ORBIT PERFORMANCE

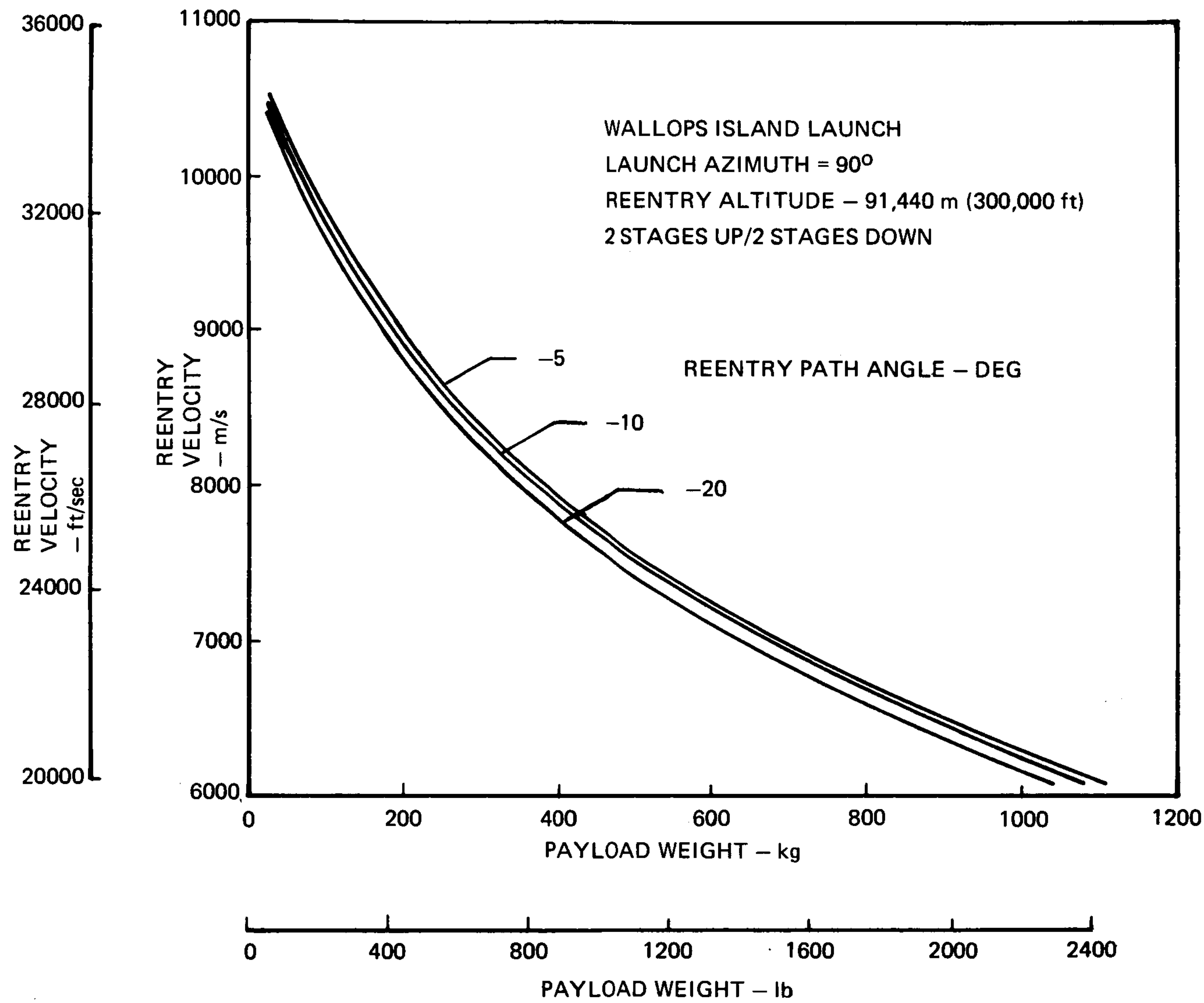


FIGURE 32 REENTRY PERFORMANCE – 91 440 m ALTITUDE

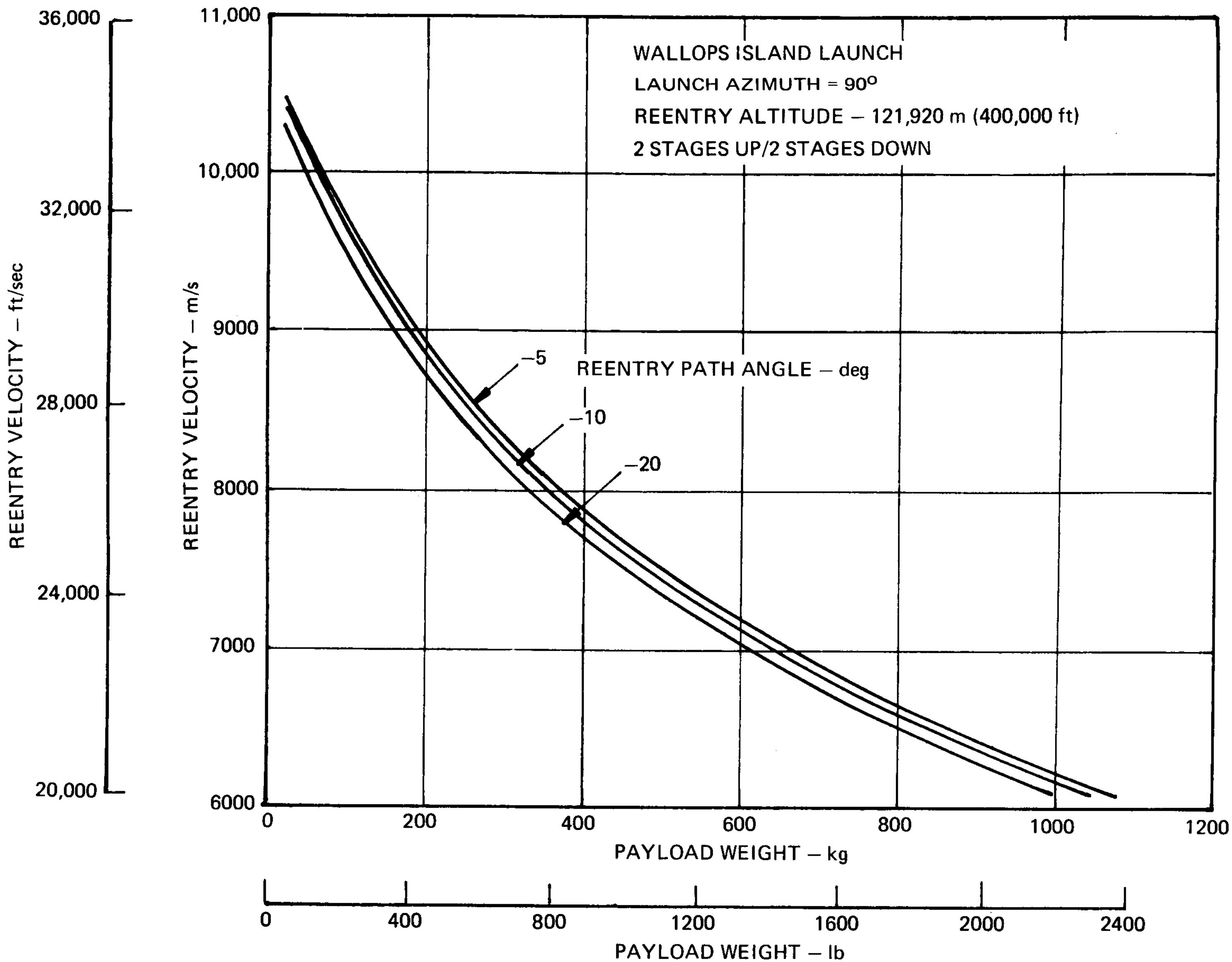


FIGURE 33 REENTRY PERFORMANCE – 121 920 m ALTITUDE

Figures 32 and 33 present the ASLV reentry capability for reentry altitudes of 91440 meters (300000 ft) and 121920 meters (400000 ft), respectively. These data are presented as a function of three different reentry angles.

Probe Missions

Usually, the objective for a probe mission is to impart the maximum energy of the booster system to the payload, allowing the payload to ascend to the highest altitude possible. Maximum performance results from minimum coast times between stages during the boost phase of the trajectory.

(1) Earth Probe

Figure 34 presents the ASLV apogee altitude capability as a function of payload weight and launch angle. Note that below a payload weight of approximately 225 kg (496 lbs), the trend in the curve reverses, with shallow trajectories achieving higher apogee altitudes than those launched in a "steep" trajectory. The higher velocities reached with light weight payload, combined with the effects of the smaller burnout flight path angles of the shallow trajectories produces this result. Smaller burnout flight path angles tend to reduce gravity losses and earth's rotational velocity losses.

Figure 35 presents "zero g time", the time of flight during which the payload is in a weightless environment. This time is measured from fourth stage burnout until the payload reenters the earth's atmosphere on the descent leg of the trajectory. Atmospheric reentry is assumed at 91440 kg (300000 ft).

(2) Solar Probe Mission

The boost trajectory for an ASLV solar probe mission requires a five stage configuration to achieve excess velocity over the escape velocity of the earth. Generally, a solar probe is designed to inject the maximum payload weight into a specified solar orbit (perihelion, aphelion, and inclination to the ecliptic). Therefore,

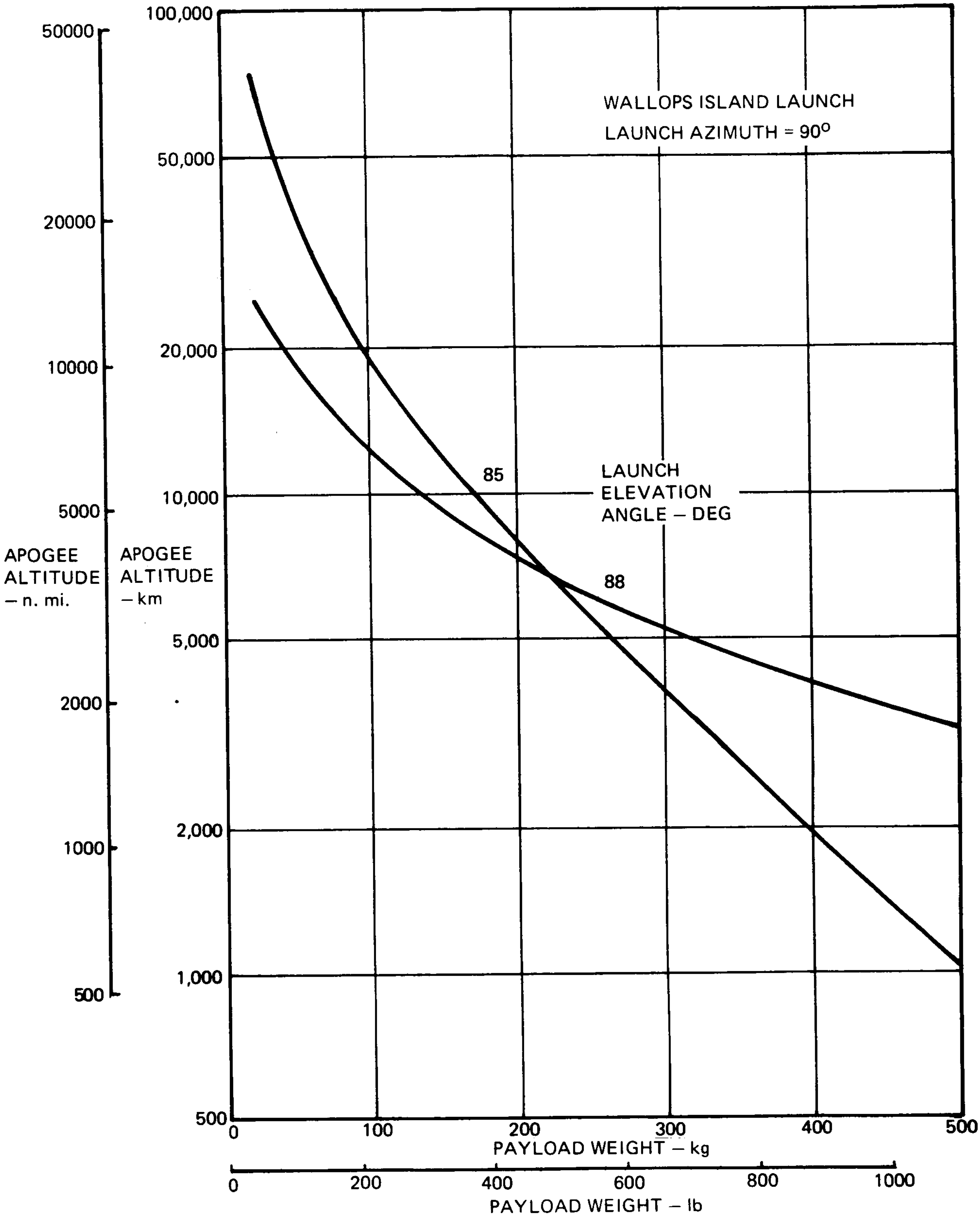


FIGURE 34 EARTH PROBE MISSION APOGEE ALTITUDE

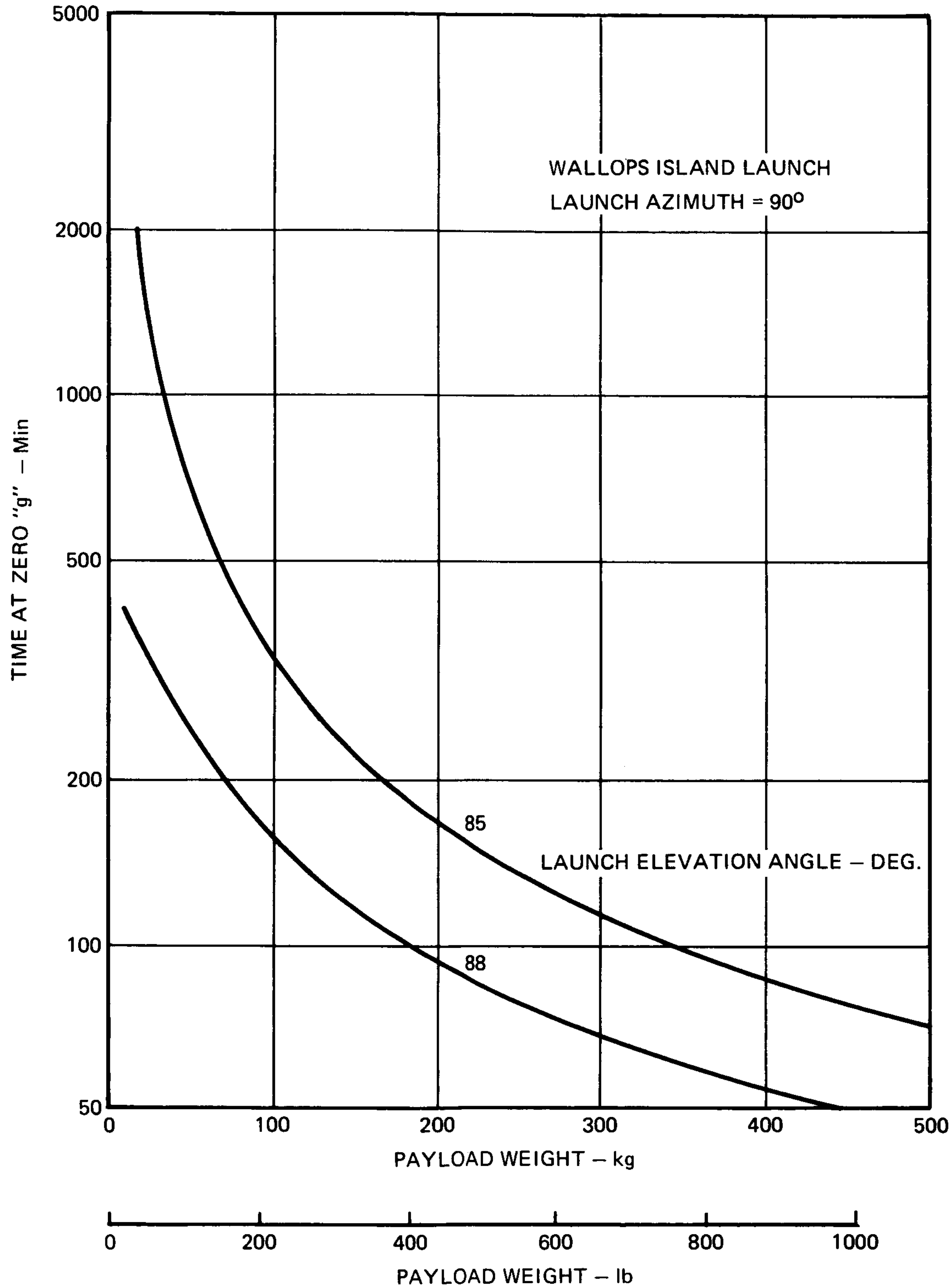


FIGURE 35 EARTH PROBE MISSION TIME AT ZERO "g"

the ASLV payload capability shown in the following figures represents the use of minimum energy trajectories.

Figures 36 and 37 present the solar probe capabilities for the five stage ASLV for burnout altitudes of 185 km (100 n.mi.) and 370 km (200 n.mi.), respectively. It is shown in Figure 36 that the maximum payload weight capability into a solar orbit is approximately 98 kg (215 lbs). Figure 37 illustrates that for a burnout altitude of 370 km (200 n.mi.), the maximum ASLV solar probe capability is approximately 86 kg (189 lbs).

6.2.3 ASLV Step-Down Performance - One of the stipulated performance requirements of the ASLV is the requirement to place current Scout type payload weight of the order of 136-181 kg (300-400 lbs) into orbit. To accomplish this requirement, the ASLV can be flown without the two Castor strap-on motors. With this configuration, the ASLV has the payload capability to place approximately 181 kg (400 lbs) into a 556 km circular orbit. The present Scout payload capability for the same circular orbit altitude is about 163 kg (360 lbs). The overall range of payload capability for the ASLV step-down configuration is within the payload range of the present Scout vehicle as shown in Figure 38.

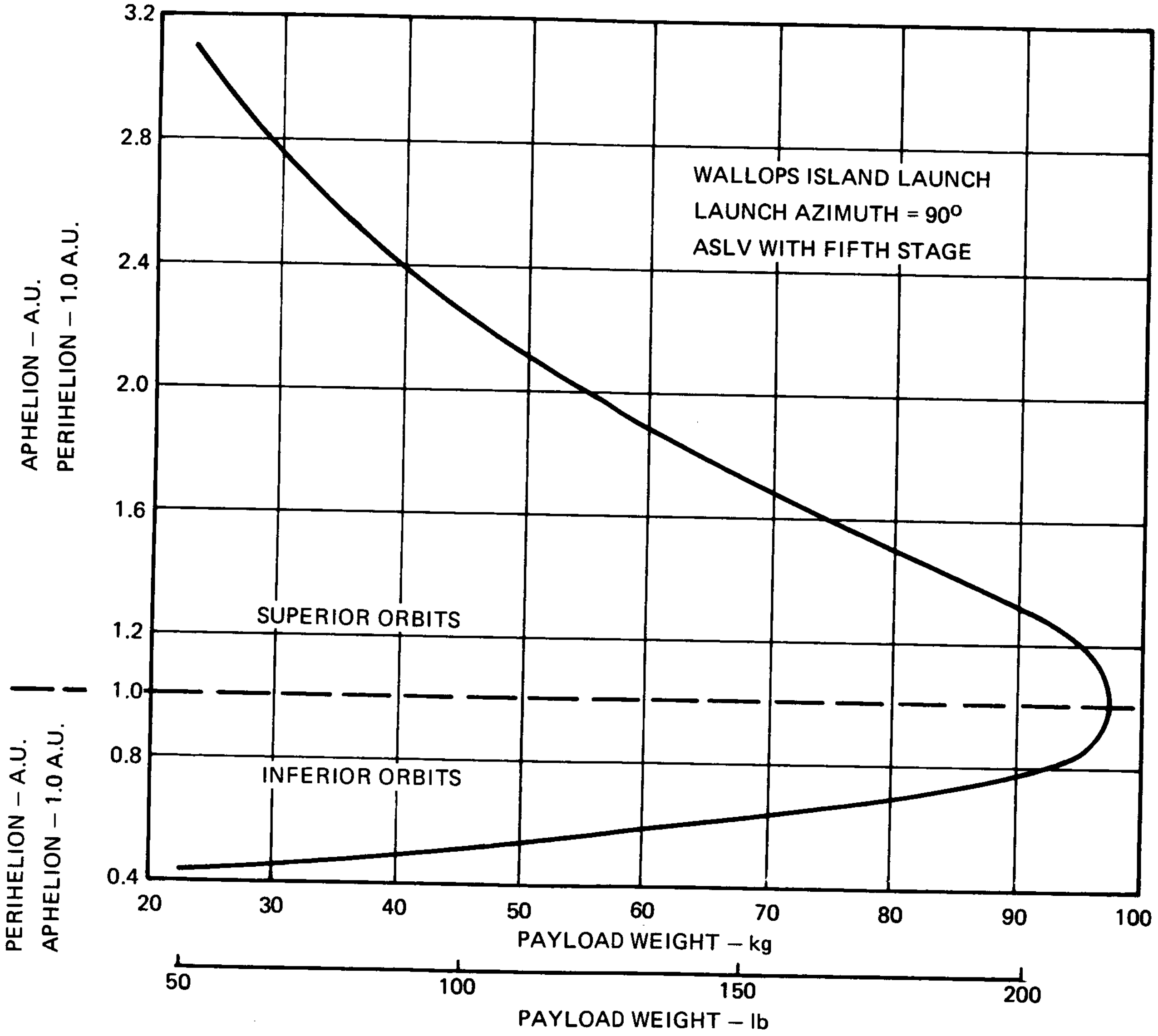


FIGURE 36 SOLAR PROBE PERFORMANCE – BURNOUT ALTITUDE 185 km (100 n. mi.)

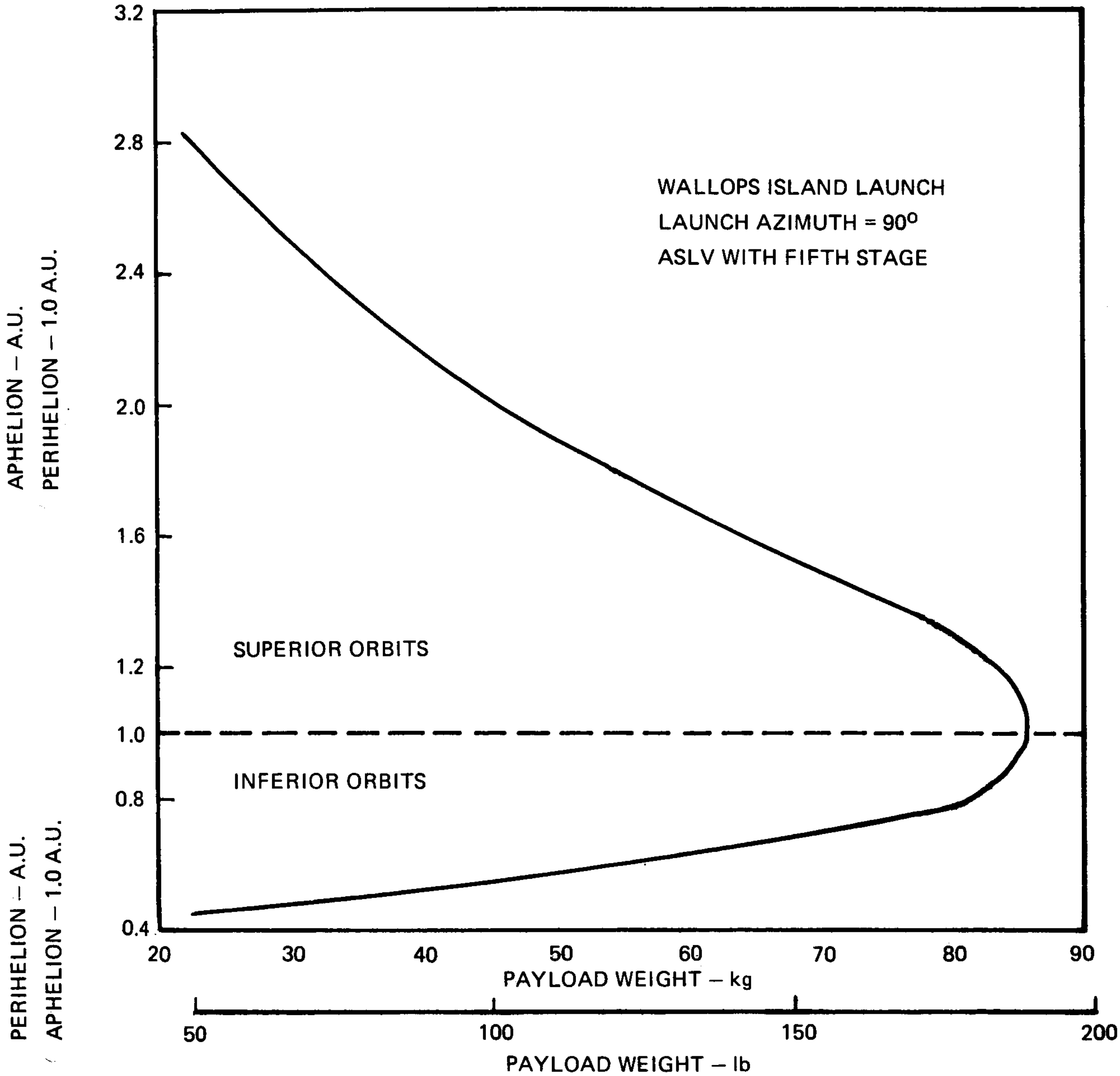


FIGURE 37 SOLAR PROBE PERFORMANCE – BURNOUT ALTITUDE 370 km (200 n. mi.)

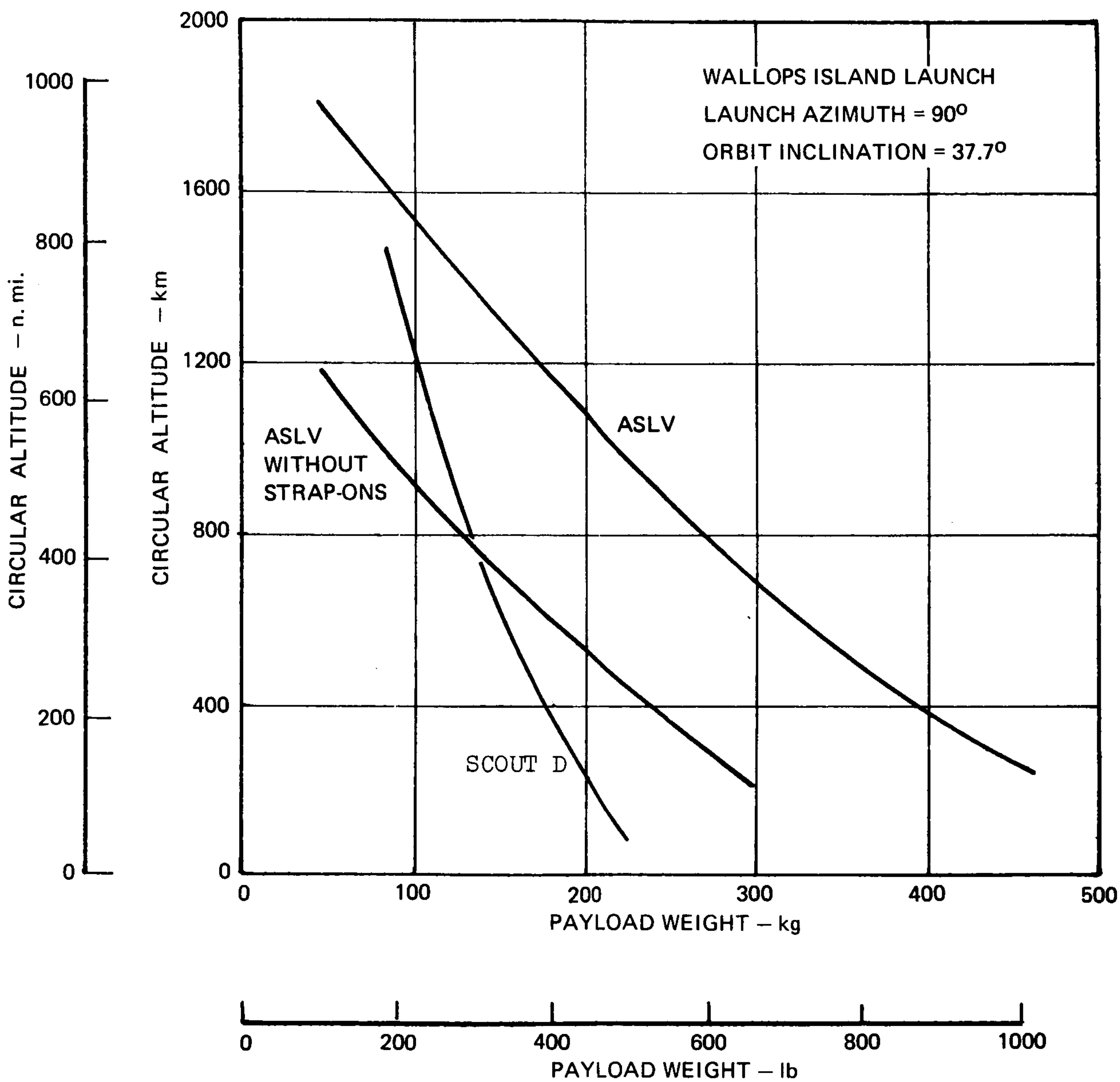


FIGURE 38 ASLV STEPDOWN PERFORMANCE

6.3 GSE AND LAUNCH COMPLEX IMPACT

The ASLV configuration selected will make use of existing Scout GSE and facilities with modification as necessary at each assembly, checkout and launch facility (Dallas, Wallops Island, and Vandenberg Air Force Base). The greatest changes anticipated are in the area of guidance system checkout equipment and in the launcher and transporter systems. Only minor modification will be required on the remaining equipment, with some new or additional equipment being required to facilitate checkout. These modifications to the current Scout equipment and facilities, both in-plant and at the field sites to support the selected conceptual design, are technically and economically feasible.

They can be accomplished without impairing the ability to prepare and checkout the vehicles for launch and launch of either the current Scout vehicle or the ASLV. To accomplish the capability to launch either vehicle will require design criteria such as (1) current launcher "C" and "D" support arms and umbilical modifications must be made reversible to fit either launch vehicle, (2) vehicle to launcher support point for the launch fittings must remain at the same reference point circumferentially and from the vehicle centerline, and (3) transporter changes must permit the use of either the Scout or ASLV motor cradles or payload shrouds.

A summary listing of changes and location are shown in Table 46. A brief summary of the modifications required are discussed below.

6.3.1 Guidance and Control System - The vehicle inertial guidance system will use three displacement gyros and three accelerometers on the stabilized cluster. An integral part of the system is a programmable digital computer. Additional rate gyros, similar to the current Scout units, will be required.

A two-axis servo table is required to calibrate the gyros and accelerometers. The power switching and gyro monitor circuits now in use can be adapted to the new gyros with minor modifications.

Vehicle computer checkout will require new equipment. A computer equivalent to the one in the vehicle will be required for monitoring. Also, an input-output device will be required to allow GSE operators to command the airborne computer.

TABLE 46 GSE AND PROCEDURE EQUIPMENT REQUIREMENTS

Systems	Dallas Sets	Wallops Island Sets	Vandenberg Sets
Guidance			
(1) Modify power switching and gyro monitor circuits	1	2	2
(2) Two axis torque table to calibrate	1	1	1
(3) Guidance system c/o	1	2	2
(4) Miscellaneous system components, switches, meters, etc.	1	2	2
(5) Cables to pad	-	1	1
(6) Alignment of guidance system to desired launch azimuth	-	1	1
(7) Resurvey of Bench marks	-	1	1
Radar Beacon and C/D Receiver			
(1) Modify GSE antenna to properly match vehicle antenna	-	1	1
(2) Modify console wiring, switches, meters, etc.	1	2	2
(3) Cables to pad	-	1	1
Ignition Destruct			
(1) Modify switching capacity for additional pyrotechnic functions	1	2	2
(2) Cable to pad	-	1	1

TABLE 46 (Continued)

Systems	Dallas Sets	Wallops Island Sets	Vandenberg Sets
Reaction Control System			
(1) Modify existing consoles, design and fabricate new consoles and associated cables, and switching for additional monitoring capacity for the additional RCS installation for S^3T only	1	1	1
(2) Cable to pad	-	1	1
(3) New RCS test panel in SLC blockhouse to accommodate additional RCS system	-	1	1
(4) Additional auxiliary equipment, N_2 carts, portable leak test set, motor nozzle plugs and flex hose	-	1	1
(5) Double size of remote fueling unit	-	1	1
Telemetry			
(1) New ground station decoding and recording equipment, minor mods to existing antenna, receiver and power switching	1	2	2
Hydraulic System			
(1) Modify hydraulic cart by adding compatible wiring and cabling mods to an S^3T equipment	1	1	1
(2) Algol nozzle deflection monitoring during servo system testing	1	1	1

TABLE 46 (Continued)

Systems	Dallas Sets	Wallops Island Sets	Vandenberg Sets
Hydraulic System (Continued)			
(3) Modify SLC blockhouse consoles to double capacity plus cable increase to serve two hydraulic systems	-	1	1
Transporter			
(1) General overall "beef-up" to support increased weight	-	1	1
(2) Extensive mods for second and fourth stage motor cradles	-	1	1
(3) Outrigger cradles to support Castor strap-ons	-	1	1
(4) Major mod to forward end to accommodate 60" shroud	-	1	1
(5) Existing rails moved to provide proper clearance	-	1	1
Launcher			
(1) Overall beef-up for new support arms and Castor strap-ons	-	1	1
(2) Relocation of C/D support arms and umbilical supports	-	1	1
(3) Additional screw jacks launch beam pivot points, azimuth bearing and outer race attachment	-	1	1
Other GSE - Mechanical			
(1) Minor mods to motor handling dollies, hoist sling adapters, new work stands and fixtures for interstage	1	1	1

TABLE 46 (Concluded)

Systems	Dallas Sets	Wallops Island Sets	Vandenberg Sets
Other GSE - Mechanical (Continued)			
(2) Optical alignment tools and equipment required to align the thrust vectors of the castors	1	1	1
Other GSE - Electrical			
(1) Modify flight readiness consoles and monitor consoles	-	1	1
(2) Modify power supplies	1	1	1
Procedures			
(1) Provide new procedures for guidance system and Castor strap-ons	1	-	-

The remaining guidance system components, such as RCS control electronics, power distribution, switching and monitor circuits will be similar enough to current Scout systems so that existing equipment can be used with only minor wiring and cabling modifications. Some additional instrumentation readout and switches will be required to accomplish the checkout.

Alignment of the guidance system to the desired launch azimuth will be critical. It has been assumed that an auto-collimating type device will be used for this purpose.

6.3.2 Radar Beacon and Command/Destruct Receivers - These systems will be nearly identical to current Scout systems and only minor wiring and cabling changes will be required. The GSE Antennae may require design changes to properly match vehicle antennae.

6.3.3 Ignition-Destruct Systems - Electrically, these systems will be similar to current Scout systems. The new configuration will have more pyrotechnic functions because of the strap-on Castors and stage separation functions. Therefore, greater switching capacity will be required. This can be accomplished by modifications to existing equipment. The Scout Standard System Test S^3T equipment will require minor wiring and cabling changes for new components associated with the additional fourth stage and strap-on motors destruct systems.

6.3.4 Reaction Control System - With the 6 RCS installations in the vehicle, more switching and monitoring capacity will be required. SLC blockhouse equipment must be expanded to accommodate the four additional systems. Additional cabling between the blockhouse and the launcher and a new RCS test panel, or a major redesign of the existing panel, will be required.

Existing auxiliary support equipment, such as N_2 carts, portable leak test sets, motor nozzle plugs, and flex-hoses can be used, but some additional units will be required to provide for efficient checkout operations.

A major change will be required to the Remote Fueling Unit (RFU). The N_2 and H_2O_2 capacity of the current unit must be at least doubled with corresponding increase in monitoring, switching and plumbing functions, or a second similar unit must be added.

6.3.5 Telemetry System - New ground station decoding and recording equipment will be required to handle PCM/FM signals. Existing antenna, receiver and power switching equipment will require only minor modifications. Other commercial equipment such as counters, oscilloscopes, panoramic displays can be used as is.

6.3.6 Hydraulic System - Existing equipment can be used with minor modifications for hydraulic system and servicing, including frequency response and gains checks on the servo systems. The current Scout hydraulic carts have adequate pressure and flow capacity and existing power switching and monitoring circuits can be made compatible with minor wiring and cabling modifications.

Instrumentation will be required to allow monitoring of nozzle deflection angles during servo-system testing.

The SLC blockhouse console contains switching and monitoring circuitry for the one hydraulic system now used in Scout. This capacity must be doubled, with corresponding cabling increase, to serve the first and seocnd stage hydraulic systems.

6.3.7 Transporter - The transporters will require modifications to provide adequate structural capability because of the increase in launch weight from 21500 kg (47404 lb) to 36400 kg (80200 lb) and the major change in physical shape, Figure 12. Cradles for the first and third-stage motors will not require any changes since the same motors are used on current Scout. The second and fourth-stage motor cradles will require extensive modification, or perhaps new cradles because of the use of the short Algol III and the short X-259 motors. Additional "outrigger" cradles will be required to support the Castor strap-on motors. This extra weight over the rear wheels may necessitate the addition of a third wheel set.

The transporter forward end will require major modification to accommodate the increase in diameter from Scout at 1.07 m to ASLV with a 1.52 m shroud. The existing rails must be moved outboard and some structure reworked to provide the necessary clearance.

6.3.8 Launcher - Additional wiring and plumbing will be required on existing launchers to serve the additional requirements of the ASLV guidance, RCS, and hydraulic systems primarily.

Major structure modification will be required to support the weights noted above and the addition of new support arms for the Castor strap-ons support until the vehicle is elevated to the vertical position.

Relocation of the "C" and "D" support arms and the vehicle umbilical support arms will be required. These modifications must be reversible so that current Scout launch capability will not be lost.

Because of the increase in vehicle weight noted above, major modification will be required in four critical areas: (1) screw jacks, larger jacks may be required; (2) screw jack and launch beam pivot points; (3) azimuth bearing; and (4) azimuth bearing outer race attachments.

6.3.9 Other GSE - Mechanical - Motor handling dollies, hoist slings and adapters will require minor modifications to handle the short Algol III and short X-259 motors.

New handling fixtures and work stands will be required for the interstage sections.

Optical alignment tools and equipment will be required to accomplish alignment of the thrust vectors (nozzle centerline) of the Castors with the centerline of the main rocket will be critical, particularly with regard to induced roll moments. This equipment exists for attachment of and the alignment of the Castor motors when installed on the thrust-augmented Thor. With some minor modification, this equipment can be used for the ASLV.

6.3.10 Other GSE - Electrical - Most commercial equipment now used on current Scout can be used on the ASLV.

6.3.11 Procedures - Processing for the ASLV will be the same as for current Scout vehicles; therefore, similar operational procedures will be used.

Most ASLV procedures will evolve from existing Scout Standard Operating Procedures (SOP's). However, new procedures will be required for guidance system and strap-on motors installation, checkout, and alignment.

6.3.12 General - Since the selected ASLV conceptual design is an improvement growth which will occur in three different steps over a 7 1/2 year period, no problem with storage of the current Scout and the ASLV hardware is anticipated. Therefore, no cost impact has been included.

The length of the selected conceptual design is 25.3 meters (82.8 feet) which is approximately 3 meters (10 feet) longer than current Scout "D". This length increase or the diameter increase due to the first stage Castor strap-on does not require any changes to the shelter.

6.4 RELIABILITY

Reliability evaluations of vehicle elements and the total vehicle consisted of both quantitative and qualitative analyses.

6.4.1 Quantitative Analyses - For the quantitative reliability estimates, the sources of generic failure rates used in the analyses were MIL-HDBK-217A and the RADC Reliability Notebook. Failure rate estimates were derived for each ASLV system candidate assuming the exponential case of chance failure distribution, i.e., equipment failures are assumed to occur by chance at random intervals in time. The product law of reliability was then applied to subsystem estimated reliability values to yield the estimated reliability for the ASLV.

6.4.2 Reliability Goal - To provide a reference point for comparative purposes with the reliability estimates, reliability goals were established for the vehicle and the systems. A reliability goal of 0.95 was established for the ASLV. This value is considered to be representative of current technology state-of-the-art and is identical to an informal goal used for the Scout launch vehicle.

The ASLV reliability goal was apportioned to the system level by use of weighting factors. The weighting factors were obtained by ranking the systems in terms of their relative reliability. The results of the reliability goal allocation to the system level are shown in Table 47.

6.4.3 System Reliability Estimates - Failure rate estimates for each system were made based upon consideration of generic failure data, historical data, the qualitative ranking, and Scout experience. A summary of the results of the ASLV system reliability estimates compared with the goals and with Scout are shown in Table 48. A comparison of the reliability at the vehicle level is as follows:

ASLV	
Goal	.95
Estimate	.9516
Scout	
Goal	.95
Observed	.9454

TABLE 47

ASLV RELIABILITY GOAL ALLOCATION

Vehicle			0.9500
Propulsion		0.9792	
Stage 1 (Algol III + 2 Castor Strap-Ons)	0.9910		
Stage 2 (Short Algol III)	0.9960		
Stage 3 (Hi-Pressure X259)	0.9960		
Stage 4 (Short X259)	0.9960		
Other Subsystems		0.9702	
Structure	0.9993		
Ignition	0.9987		
Payload Shroud	0.9980		
RCS	0.9974		
Destruct	0.9967		
Separation	0.9960		
Guidance	0.9954		
T/M	0.9947		
Radar	0.9940		

TABLE 48 - COMPARISON OF ASLV AND SCOUT RELIABILITY ESTIMATES

Configuration		Guidance	Propulsion	Ignition/ Electrical	Destruct	Telemetry
ASLV	Goals	.9954	.9792	.9987	.9967	.9947
	Esti-mates	.9992	.9725	.9993	.9976	.9988
SCOUT		.9977	.9816	.9993	.9976	.9975

Configuration		Separation	Attitude Control	Radar Beacon	Payload Shroud	Structure
ASLV	Goals	.9960	.9974	.9940	.9980	.9993
	Esti-mates	.9996	.9871	.9990	.9979	.9999
SCOUT		.9976	.9859	.9990	.9979	.9999

Some specific points of interest in this comparison are:

(1) The ASLV system reliability estimates exceeded the goals except in the area of propulsion and attitude control.

(2) The ASLV propulsion reliability estimate is less than that for the Scout. Since the rocket motors used are the same or modifications of the Scout motors, this is not caused by the use of less reliability motors. The difference results from the number of motors used, six for the ASLV and four for Scout.

(3) Some ASLV systems which include more equipment than the corresponding Scout system, exhibit reliability estimates equal to or getter than Scout, e.g., Guidance, Destruct, Telemetry, Attitude control and Ignition/Electrical.

This results from the fact that for the ASLV operating time period, the design state-of-the-art will result in the availability of components having a higher inherent reliability.

6.4.5 Vehicle Reliability - The Scout vehicle observed reliability growth based upon the current 55 launch history and the ASLV projected reliability growth are shown in Figure 39.

The data points for the projected ASLV reliability growth were derived from analyses of Scout observed and generic reliability data. Experience and state-of-the-art improvement factors were computed and applied to the ASLV reliability estimate at accumulative launch intervals to yield the ASLV growth curve. As noted, the projected ASLV reliability growth closely approximates the observed reliability of the Scout vehicle, but exceeds the established reliability goal of .95, at approximately the 45th vehicle.

The initial Scout observed reliability level of Figure 39 is a demonstrated value. The initial, projected ASLV reliability level was derived in the same manner as other points on the growth curve except that it received less weighting based on the Scout experience.

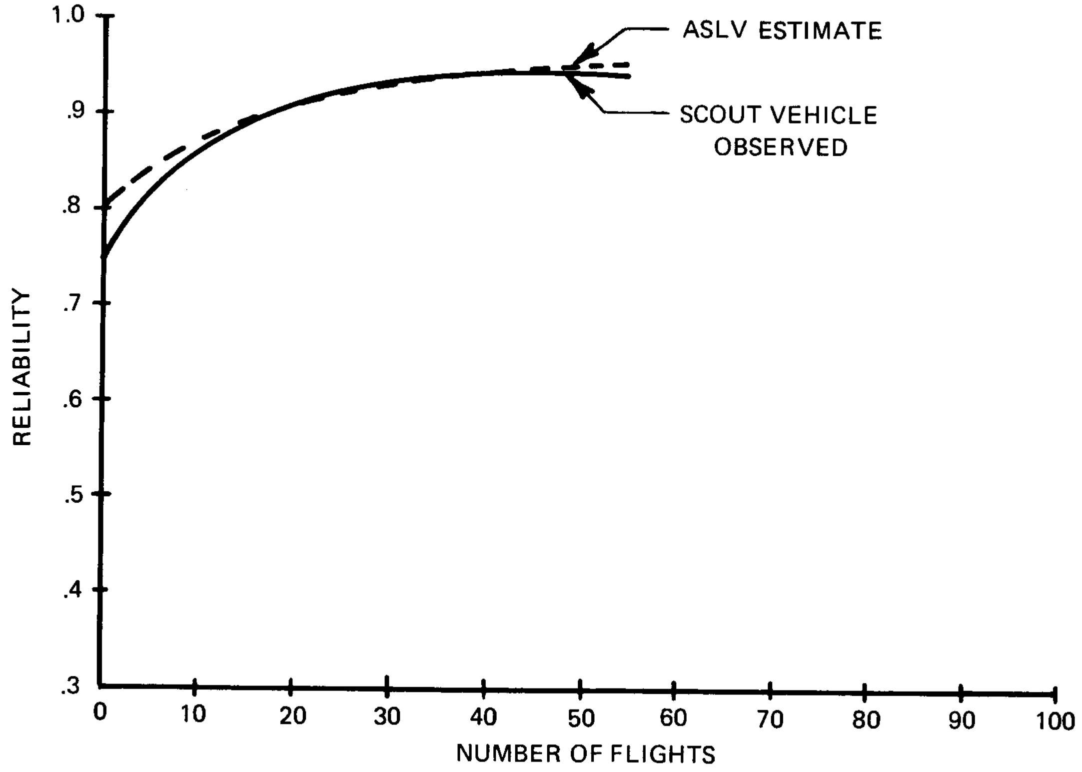


FIGURE 39 SCOUT VEHICLE AND ASLV RELIABILITY GROWTH

(THIS PAGE INTENTIONALLY LEFT BLANK)

7.0 DEVELOPMENT PLAN

The ASLV development plan for the selected conceptual design is presented in this section. The plan is based upon a phased growth improvement approach (Section 4.2.5) and consists of a Preliminary Program Plan, Development Funding and a Major Milestone Phasing Schedule.

7.1 PRELIMINARY PROGRAM PLAN

The program plan provides a summary task description of the major program elements.

7.1.1 Management

The management of the Phased Growth Improvement Program will be accomplished by the current Scout Program Management organization. This is the most cost effective approach, because many of the functions, key management personnel and procedures exist. The cost presented herein are based on this management approach for the ASLV design and development phase.

7.1.2 Program Task Summary

The ASLV will be organized into eleven major tasks as shown on Table 49.

Task 1.0 System Integration

This task covers the establishment of organization responsibility coordination of the effort of all participants, the preparation and maintenance of all control documents, development and checkout of all software, and development of an integrated ground test plan to achieve compatibility between all subsystems and GSE.

Task 2.0 Analysis and Design

This task will consist of the engineering required for the drawings, specifications, test programs, procedures and software for the fabrication, procurement, assembly, test, checkout and launch of the launch vehicle.

Task 3.0 Rocket Motor Task

This task involves the analysis, design studies, procurement, ground testing required to provide the propulsion motors for the ASLV. This task includes the efforts of the Sub-Contractors. The ASLV motors are all Scout motors or modifications thereof.

TABLE 49 SCOUT GROWTH PROGRAM TASK SUMMARY

TASK 1.0 SYSTEM INTEGRATION	TASK 2.0 DESIGN AND ANALYSIS	TASK 3.0 ROCKET MOTORS	TASK 4.0 GUIDANCE	TASK 5.0 CONTROLS	TASK 6.0 TELEMETRY ELECT, INTER-STAGES, ETC.
oProgram Coordination	oInterstages	oProcurement Specs	oProcurement Specs.	oProcurement Specs.	oProcurement Specs.
oSystem Specification	oPayload Shroud	oDesign Requirements	oDesign Requirements	oDesign Requirements	oDesign Requirements
oInterface Control Documents	oFlight Environment	oVendor Selection	oVendor Selection	oVendor Selec-tion	oVendor Selection
oDesign Data Books	oTest Environments	oEngineering Changes	oEngineering Changes	oEngineering Changes	oEngineering Changes
oReliability Plan	oDrawings	oMovable Nozzle Development	oTesting	oTesting	oTesting
oEMI Control Plan	oStructural	oGround Testing	oHardware Delivery	oHardware Delivery	oHardware Delivery
oGround Test Plan	oStability & Control	oHardware Delivery	oQuality	oQuality	oQuality
oProgram Targeting Software	oElectrical Power	oQuality	oReliability	oReliability	oReliability
oRange Safety	oSchematics	oReliability	oDocumentation	oDocumentation	oDocumentation
oDesign Reviews	oSeparation	oDocumentation	oDesign Reviews	oDesign Reviews	oDesign Reviews
oHardware Delivery	oInstrumentation	oDesign Reviews	oAccuracy Analysis		
oConfiguration Management	oTelemetry				
oDrawing & Specifi-cation Tree	oDesign & Test Reports				
Statement of Work	oConfiguration Studies				
Structural Loads	oPerformance				
Quality Plan					
Maintenance Require-ments, Vehicle & GSE					

TABLE 49 SCOUT GROWTH PROGRAM TASK SUMMARY (CONTINUED)

TASK 7.0 TESTING	TASK 8.0 ASSEMBLY & CHECKOUT	TASK 9.0 GSE, PROCEDURES & FACILITIES DESIGN & FABRICATION	TASK 10.0 FIELD & FLIGHT OPERATIONS	TASK 11.0 PROGRAM DOCUMENTATION
oTest oProcedures oReports	oAcceptance oTest Components & Subsystems oVehicle Assembly oVehicle Checkout oAssembly Procedures oAcceptance and Checkout Procedures oTooling oQuality/Reliability	oDesign Requirements oDesign Changes oFabrication oInstallation oCheckout oBuy Off oOperating Procedures oQuality/Reliability oMaintenance	oSite Planning & Activation oOperations Plan oHardware Preparation oHardware Pre-flight Checkout oLaunch 50 Vehicles oData Analysis	oStatus Reports oDesign Analysis oFlight Test Reports oRange Reports oDrawings oData on Components and Subsystems

First Stage Motors

This stage consists of the present Scout Algol III with modifications to accommodate the addition of a movable nozzle and attachments for the Castor II thrust augmentation. The movable nozzle development will be accomplished in conjunction with the short Algol III which will be used as the second stage motor. The strap-on attachment requires local increase in case thickness in the area of the ball joint. This is an engineering modification type change which will require only a hydrostatic pressure test for flight clearance. However, in conjunction with the movable nozzle, one motor firing will be accomplished.

Second Stage Motor

This stage consists of the present Scout Algol III motor shortened by removing a cylindrical section of the case and the addition of a movable altitude nozzle. The shortening of the motor is considered an engineering change because the nozzle throat will be reduced in diameter to retain a chamber pressure consistant with the Algol III grain and case design. The movable nozzle design has completed some development testing. The motor change will be evaluated during the test firings planned for the movable nozzle development. This motor will be procured first and the same movable nozzle design will be used for the first stage except it will have a sea level nozzle and the nozzle throat diameter will be larger. This approach will reduce the movable nozzle and Algol III development cost.

Third Stage Motor

This will be the high pressure X-259 which is a Scout "D" X-259 motor planned growth development. There will be no changes required for incorporation of this motor into the vehicle.

Fourth Stage Motor

This stage consists of the third stage motor High Pressure X259 shortened by removing a cylindrical section of the case and the addition of a contour nozzle. The present X-259 propellant will be used but a nozzle and a grain change are necessary to retain the chamber pressure consistant with the X-259 grain and case design. The grain change also provides a lower thrust level near motor burn out to reduce the peak "g" level to within the selected guidance system current design requirements.

Task 4.0 Guidance Subsystem

This task involves the procurement, analysis, design studies, and testing required to provide the improved guidance subsystem for the fourth stage. The basic components are existing designs which will require test and re-packaging to fit within the ASLV installation requirements. Typical components and installation are shown on the general arrangement drawing which is the last page of this volume.

Task 5.0 Controls

This task involves the effort associated with the attitude control subsystems required for each stage, and the vernier velocity control system for the fourth stages. The Scout hydrogen peroxide components will be used for all stages. The characteristics of the subsystem for each stage is shown in Table 50. The requirements for the control subsystems will be defined under this task. However, the movable nozzles will be procured under Task 3.0 Rocket Motors. The movable nozzle actuation subsystem will be procured under this task.

Task 6.0 Other Subsystems

All the effort associated with the electrical, separation, range safety, antennas, telemetry, beacon, instrumentation, payload shroud, interstages, cabling, and adapter subsystems will be performed under this task.

Task 7.0 Testing

All ground testing accomplished by the Contractor will be done under this task. A listing of these tests, objective and hardware requirements are shown on Table 51. No separate flight test launches will be used because the ASLV program will be accomplished by only incorporating one or two of the improvement items before a vehicle flight occurs. Therefore flight test data will be acquired during a payload launch. The number of engineering changes to be incorporated on a given launch will be controlled so that reliability confidence can be based upon ground test results. The current Scout program changes have been accomplished in this manner with good success.

Task 8.0 Assembly and Checkout

The ground test and flight hardware will be fabricated, assembled,

TABLE 50 REACTION CONTROL HARDWARE

STAGE	TYPE	THRUST LEVEL & AXES N/lb Pitch	Yaw	Roll	Hardware Origin
FIRST					
oWith Strap-Ons	-Movable Nozzle ±6°	X	X		Design Verified by test
	-RCS H_2O_2 Each Strap-On 2 Motors			2224 (500)	Scout
	-Lower Base "A" RCS H_2O_2			2224 (500)	Scout
oWithout Strap-Ons	-Lower Base "A" RCS H_2O_2 2 Motors			2224 (500)	Scout
SECOND					
oBoost	-Movable Nozzle ±3°				Design verified by test
	-RCS H_2O_2 8 Motors			195.7 (44)	Scout
oCoast	-RCS H_2O_2 8 Motors	195.7 (44)	195.7 (44)	195.7 (44)	Scout
THIRD					
oBoost	-RCS H_2O_2 -4 Motors	213.5 (48)	213.5 (48)		Scout
	-4 Motors			62.2 (14)	
oCoast	RCS H_2O_2 -4 Motors		62.2 (14)	62.2 (14)	Scout
	-2 Motors	8.9 (2)			
FOURTH					
oBoost	-RCS H_2O_2 4 Motors (Includes Vernier)	213.5 (48)	213.5 (48)		Scout
	-Nitrogen 8 Motors			4.45 (1)	Burner II
oCoast	-Nitrogen 8 Motors	4.45 (1)	4.45 (1)	4.45 ( )	Burner II

NOTE: All Thrust values are vacuum.

TABLE 51 GROUND TESTING REQUIREMENTS

ITEM	OBJECTIVE	TEST ENVIRONMENT	N. TEST LOCATION	HARDWARE REQUIRED
1. Short Algol III	oEstablish Motor Performance oEvaluate Movable Nozzle and Actuation Subsystem oObtain Data for Simulation Routines oFlight Certify the Design and Fabrication Procedures	oAmbient Test Stand oAltitude Test Stand (1 test)	3 Tests Vendor Facility and AEDC	3 - Short Algol III 3 - Movable Nozzles 3 - Actuation Subsystems
2. Algol III	oEstablish Motor Performance oEvaluate Movable Nozzle and Actuation Subsystem oObtain Data for Simulation Routines oFlight Certify Design and Fabrication Procedures	oAmbient Test Stand oSimulate Strap-On Motor Loads	1 Test Vendor Facility	1 - Algol III 1 - Movable Nozzle 1 - Actuation Subsystem
3. Algol III Case Hydro static Test	oConfirm Structural Design oConfirm Manufacturing Procedure	oAmbient Test Stand oSimulated Flight Loads and Case Pressures oSimulated Transient Flight Load and Pressures	1 Test Vendor Facility	1 - Algol III Motor Case

TABLE 51 GROUND TESTING REQUIREMENTS (Continued)

ITEM	OBJECTIVE	TEST ENVIRONMENT	NO. TEST/ LOCATION	HARDWARE REQUIRED
4. Movable Nozzle and Actuation Test	oObtain Design Data oCertify Subsystem for Motor Firing	oTest Stand	Test Series Vendor Facility	1 - Short Algol III Movable Nozzle 1 - Algol III Movable Nozzle 1 - Actuation Subsystem
5. X259 (H.P.) (Planned under current Scout Prgm.)	oEstablish Motor Performance oObtain Data for Simulation Routines Development oFlight Certify Design and Fabrication Procedures	oAltitude Test Stand	2 Tests AEDC	2 - X259 (H.P.)
6. X259 (H.P.) Hydrostatic Test	oConfirm Structural Design oConfirm Manufacturing Procedures	oAmbient Test Stand oSimulated Flight Loads and case pressures	1 Test Vendor Facility	1 - X259 (H.P.) Case
7. Short X259 (H.P.)	oEstablish Motor Performance oObtain Data for Simulation Routine Development	oAmbient Test Stand	2 Tests Vendor Facility	2 - Short X259 (H.P.)
	oFlight Certify Design and Fabrication Procedures	oAltitude Test Stand	2 Tests AEDC	2 - Short X259 (H.P.)
8. Short X259 (H.P.) Hydrostatic Test	oConfirm Structural Design oConfirm Manufacturing Procedures	oAmbient Test Stand oSimulated Flight Loads and case pressures	1 Test Vendor Facility	1 - Short X259 (H.P.) Case

TABLE 51 GROUND TESTING REQUIREMENTS (Continued)

ITEM	OBJECTIVE	TEST ENVIRONMENT	NO. TEST LOCATION	HARDWARE REQUIRED
9. Inertial Guidance and Integration	oDevelopment .Design Verification .Environmental Investigation	oAmbient Test Stand with Some Component Environmental Test Capability	Test Series Vendor Facility	1- Development Model
	oFlight Vertification .Establish Performance for Simulation Routine .Environment Testing	oAmbient Test Stand and Full System Environmental Capability	Test Series Vendor Facility	1 - Flight Unit
	oEvaluation of Interfaces oSoftware Verification oSoftware Integration oVerify Procedures oSimulation Routine Data	oLaboratory oManufacturing oLaunch Vehicle Check-out	Test Series VMSC	The Guidance Units from Item 8 will be used. Other vehicle hardware will be used as necessary. No special flight hardware will be procured for these tests.
10. Payload Shroud	oVerify Separation oVerify Structural Design oFlight Certify Design and Fabrication Procedures	oAmbient Test Stand oSimulated Structural Loads oSimulated Separation "G"	Test Series VMSC	1 - Payload Shroud 3 - Separation Pyrotechnic Subsystems

TABLE 51 GROUND TESTING REQUIREMENTS (Completed)

ITEM	OBJECTIVE	TEST ENVIRONMENT	NO. TEST LOCATION	HARDWARE REQUIRED
11. Interstages oBase "A" oUpper & Lower "B" oUpper & Lower "C" oUpper & Lower "D" oPayload Adapter	oVerify Structural Design oSubsystem Performance oObtain Data for Simulation Routine Development oFlight Certify Design and Fabrication Procedures oVerify Separation Subsystem	oAmbient Test Stand oSimulated Structural Loads oPropulsion Test Stand i.e. after VMSC test hardware may be used in motor firings at Vendor facility	Test Series VMSC	1-Each Interstage 1 - Each Subsystem Installed in Each Interstage 3 - Each Separation Subsystem 1 - Set of Cabling
12. Destruct and Separation	oVerify Design	oAmbient Test Stand	3 Test Elements for each Motor Case Except Strap-Ons/ VMSC	3 - Element test Samples for Each Propulsion Stage
13. Wind Tunnel	oProvide Design Aero Dynamics and Loads Data	oWind Tunnel	Test Series Gov't Facility	1 - Complete Scout Growth Model 1 - Extra Payload Shroud 2 - Extra Base "A"
14. Strap-on Separation	oVerify Design	oAmbient Test Stand	Test Series VMSC	3 - Sets of Pyrotechnics - Motor Cases from ground test firings - mass balanced

and delivered to the designated test or launch site. The components and subassemblies will be acceptance tested prior to assembly into a vehicle. Prior to delivery, a complete checkout will be accomplished using dummy rocket motors and pyrotechnic devices.

Task 9.0 GSE and Procedures Design and Fabrication

The GSE changes required to support the ASLV will be designed, fabricated, installed, and checked out under this task. These changes and modifications will be accomplished so that either the current Scout or ASLV may be handled or launched with the same equipment. The major items requiring changes or modifications are:

(1) Transporter - Strap-ons and Weight
(2) Launcher - Weight and Length
(3) Lifting Equipment - Weight and Length
(4) Guidance - Inertial Guidance Checkout and Alignment Equipment.
(5) Movable Nozzle Checkout Equipment
(6) Strap-on Alignment Equipment

Task 10.0 Field and Flight Operations

The facilities and services required at the range will be documented. Procedures for receiving, assembly, checkout and launch of the vehicle will be prepared. The launch support required will be provided for the launch of all 50 vehicles over the planned program life. The flight test data from all flights will be recorded, reduced and anomalies will be investigated and corrective action taken. These data will be correlated with ground test data and theoretical results to complete the development of simulation routines and data catalog.

Task 11.0 Program Documentation

The documentation required and distribution thereof will be in accordance with the current Scout program requirements.

7.2 DEVELOPMENT FUNDING

7.2.1 Guidelines

The following guidelines were used during the preparation of this development plan.

(1) The scheduled incorporation of improvements will be

phased to achieve a growth in payload capability for each improvement while not requiring the expenditure of a flight test vehicle for reliability verification.

(2) The phased growth steps will be accomplished in such a relationship that redesign of interstage structure for each step will not be necessary.

(3) For amortization purposes, the launch rate will be five (5) launches per year over a ten-year period.

(4) The growth steps will be phased such that the current Scout "D" payload capability will be preserved for the first step.

(5) The funding and schedules will be based on the assumption that an inertial guidance system will be installed on the fourth stage. Therefore, funding and scheduling requirement will be adequate regardless of the final guidance decision.

(6) The launch complex and ground support equipment cost shall be estimated but not amortized.

(7) The launch support costs will be estimated and included as a part of the recurring cost.

(8) All costs will be based on 1971 dollars and will be costs to the Government.

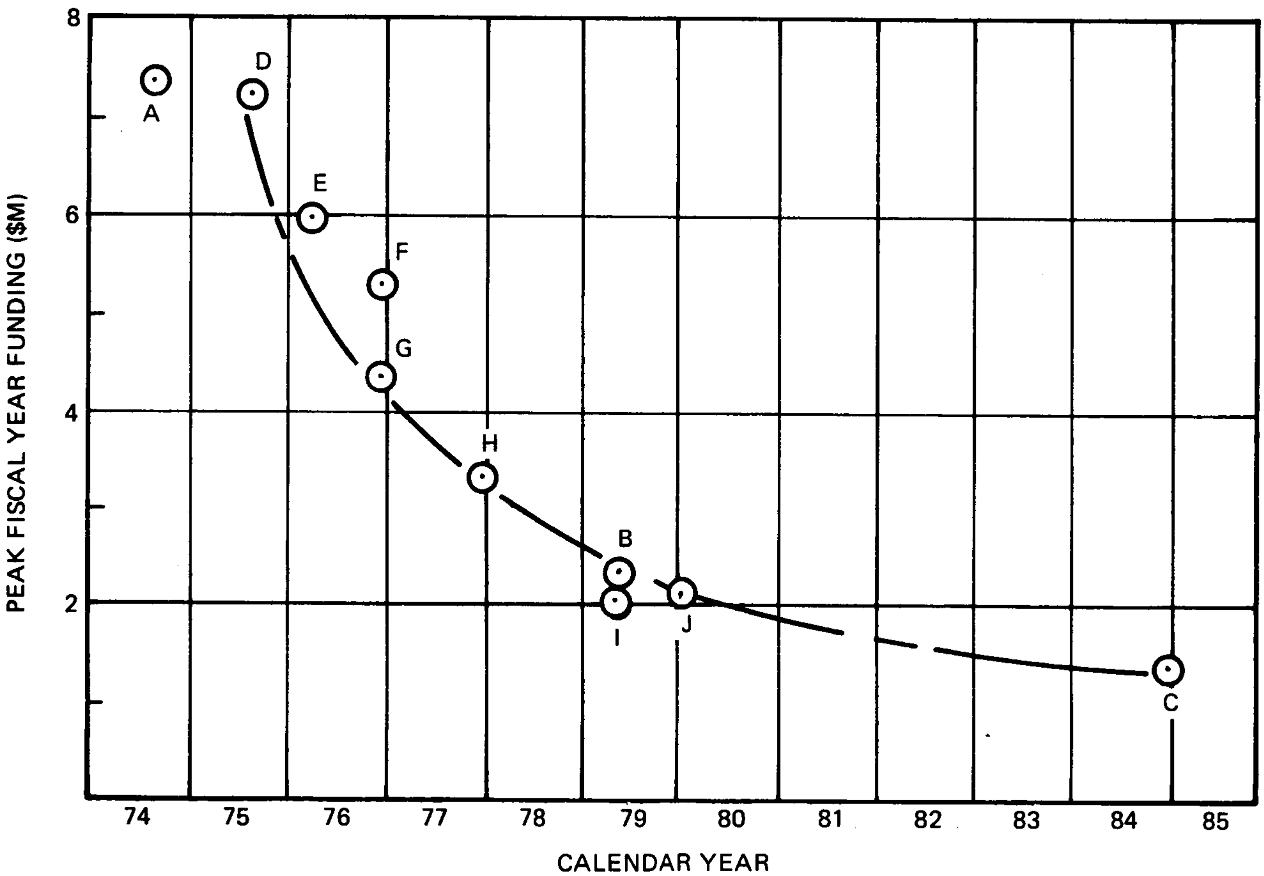
(9) The Launch Support Cost will be same as for Scout $1M.

7.2.2 Fiscal Year Funding

The phased growth approach presents a number of schedule options with a wide range of peak fiscal year funding. A total of ten schedules options having an ASLV launch date variation over a decade were investigated. These schedule variations are shown on Figure 40. Taking into consideration future NASA budgets, projected user demand schedule, total development cost the most attractive funding schedules are likely to fall to the right of schedule H. Discussion of these schedules follows:

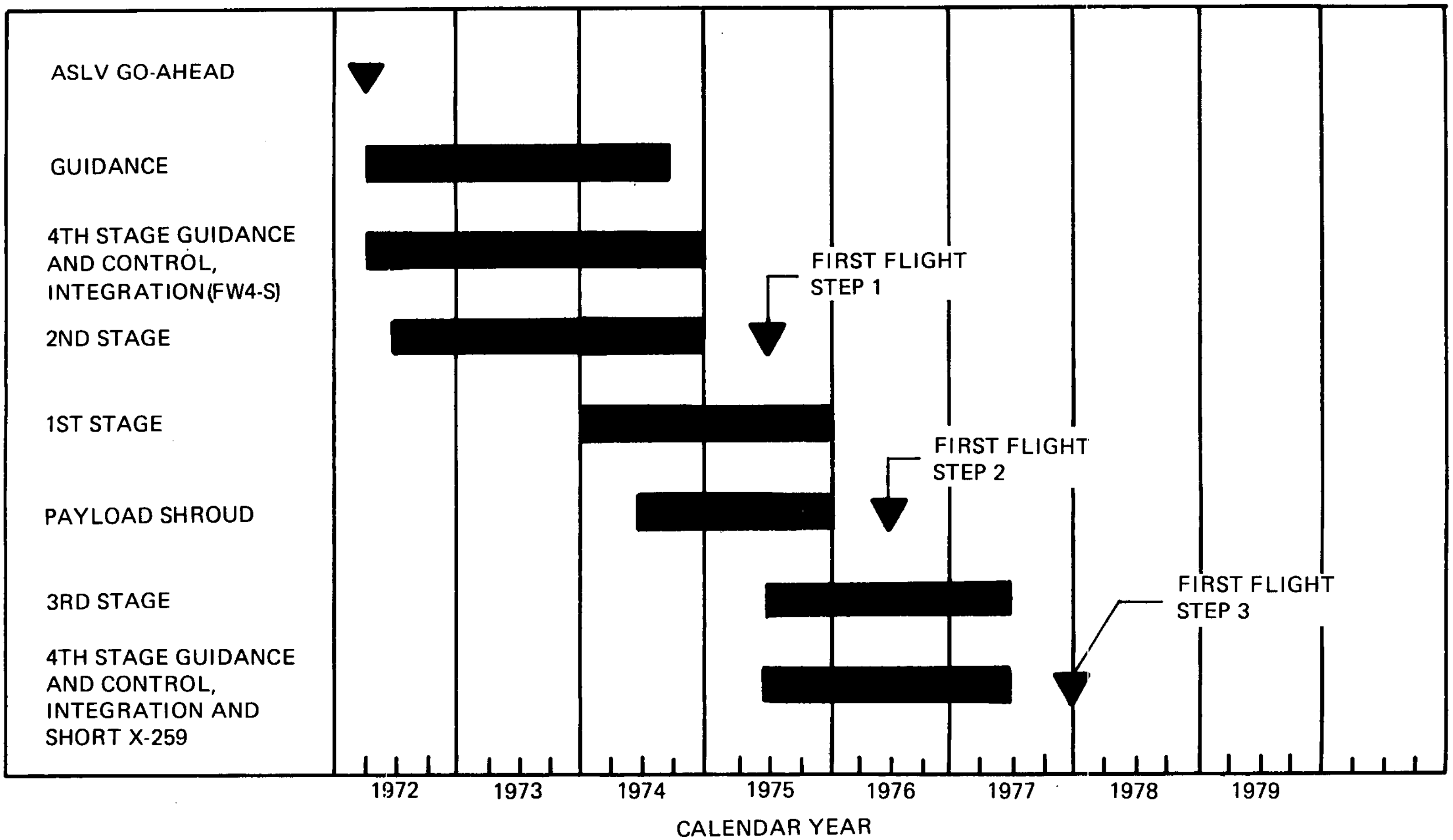
Schedule H - Figure 41

(1) Improved orbit injection accuracy is achieved at the earliest possible date.



(FIRST LAUNCH FULL 340 kg (750 lb) CAPABILITY)

FIGURE 40 FUNDING REQUIREMENT AND ASLV LAUNCH DATES



FISCAL YEAR FUNDING REQUIREMENTS ($K)	400	2 655	3 270	3 127	1 988	1 209	0	TOTAL = $12,649

FIGURE 41 SCHEDULE H-ASLV FISCAL FUNDING

(2) With Step 1, the Scout payload capability is preserved with improved accuracy.

(3) Upper stage (3rd and 4th) motors development delayed sufficiently to permit consideration of any propulsion improvement in State-of-the-Art (I_{SP}, Mass Fraction, and Stop/Restart).

(4) Minimum inflation impact because highest development items are incorporated early.

(5) Peak fiscal year funding is $3.27 million.

(6) Total development cost is $12.649 million

Schedule B - Figure 42

(1) The same points as schedule H except:

- o Fiscal funding peak is $2.392 million
- o Launch dates for each step occurs later. First 340 kg launch occurs two years later.

Schedule I - Figure 43

(1) Guidance incorporated as the last step. Only one integration of guidance with the fourth stage which reduces total development cost by 543 $K.

(2) Fourth stage motor development delayed sufficiently to permit consideration of propulsion improvement in State-of-the-art (I_{SP}, Mass Fraction, and Stop/Restart).

(3) Peak fiscal year funding is $2.172 million

(4) Total development cost is reduced 543 $K because the fourth stage/guidance integration occurs only once.

Schedule J - Figure 44

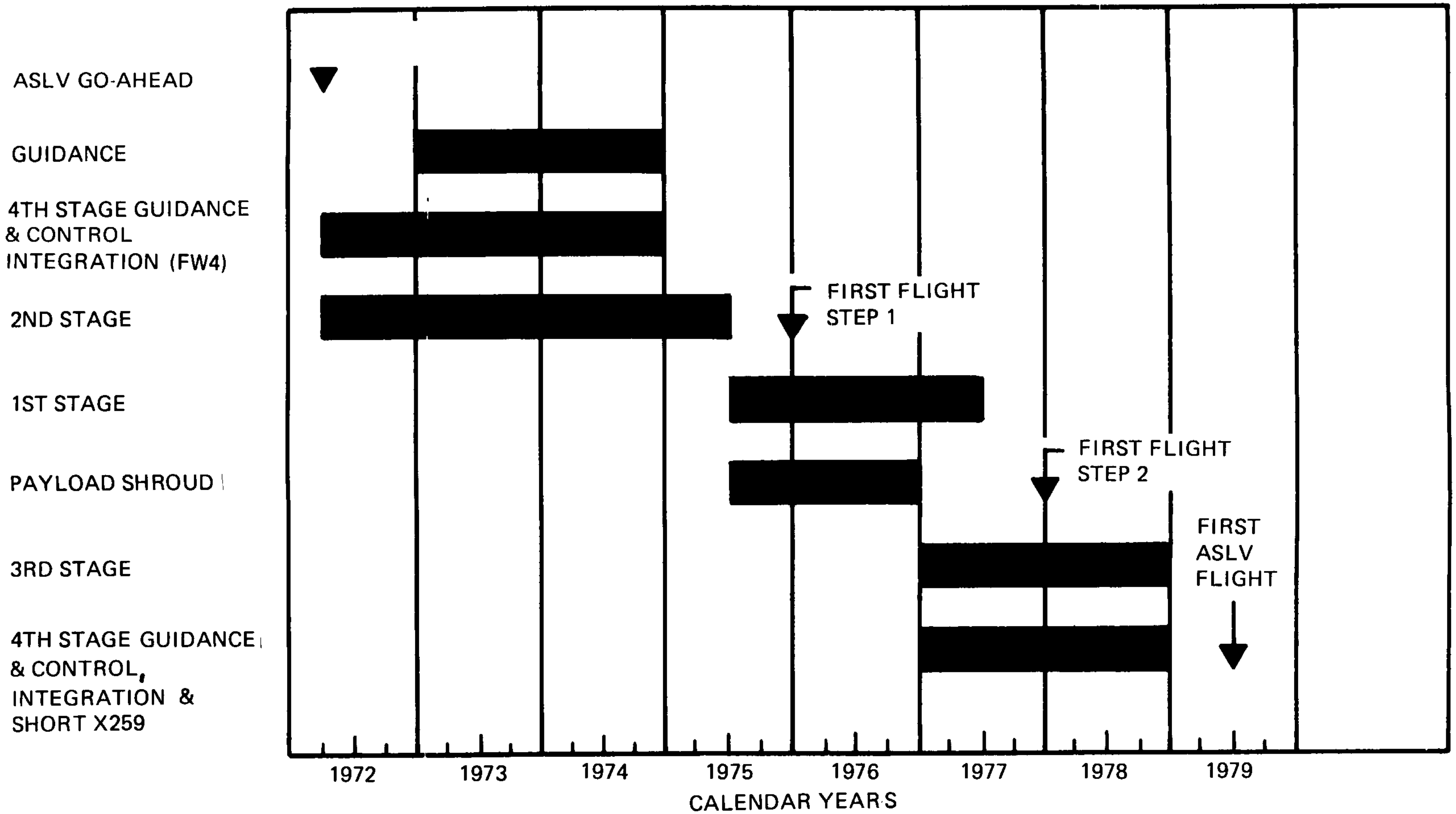
(1) Total development cost increased by 543 $K because the guidance is integrated with the fourth stage twice.

(2) Peak year fiscal funding of $2.032 million.

(3) The propulsion improvements (First, Second, and Third stages) are incorporated before guidance improvement is incorporated.

Schedule C - Figure 45

(1) Upper stage (3rd and 4th) motors development delayed



400	2 366	2 392	2 139	1 715	1 478	1 205	954	$12,649 K TOTAL

FISCAL YEAR FUNDING —REQUIREMENTS ($K)

FIGURE 42 SCHEDULE B — ASLV FISCAL FUNDING

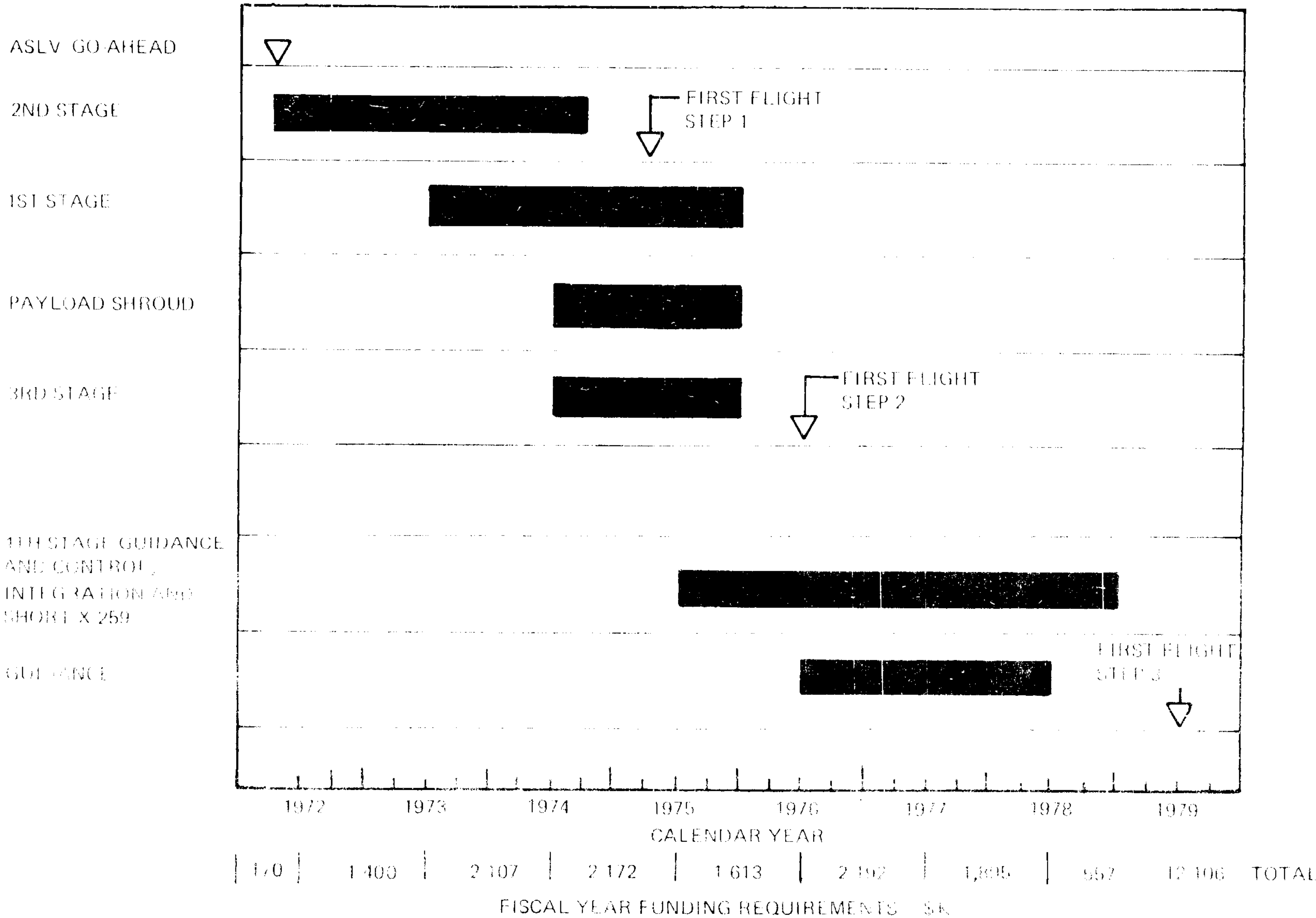


FIGURE 43 SCHEDULE I – ASLV FISCAL FUNDING

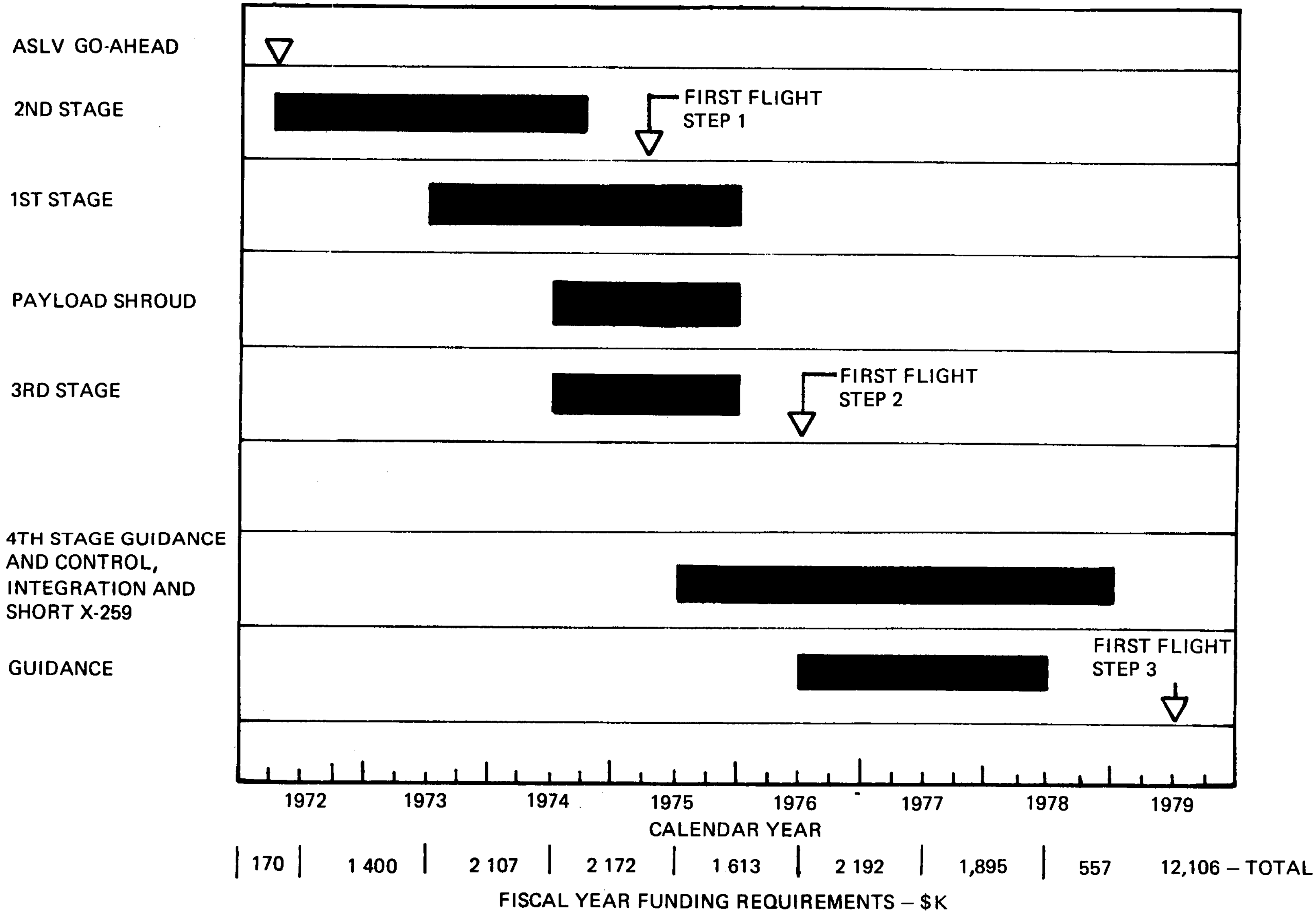


FIGURE 43 SCHEDULE I – ASLV FISCAL FUNDING

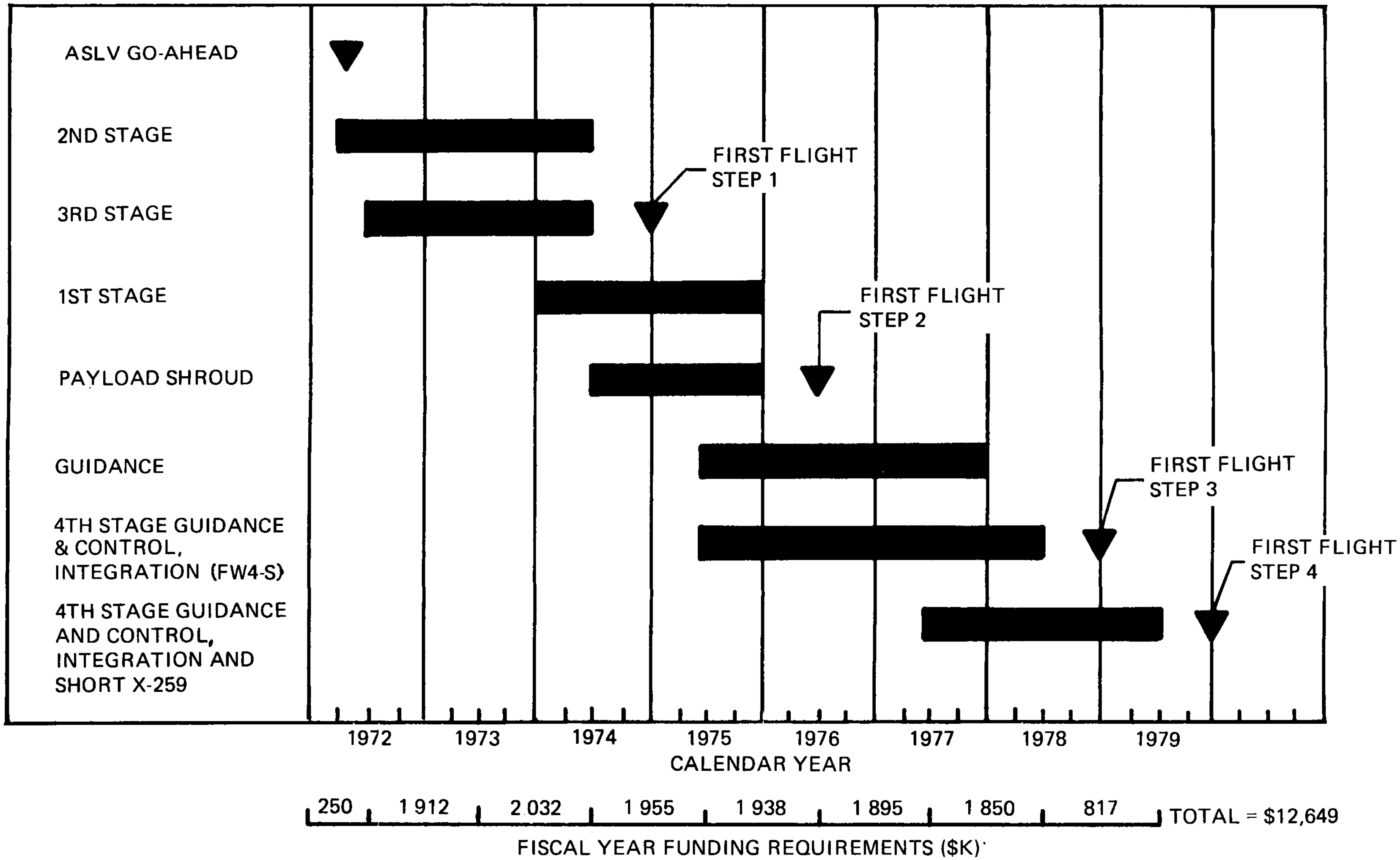


FIGURE 44 SCHEDULE J-ASLV FISCAL FUNDING

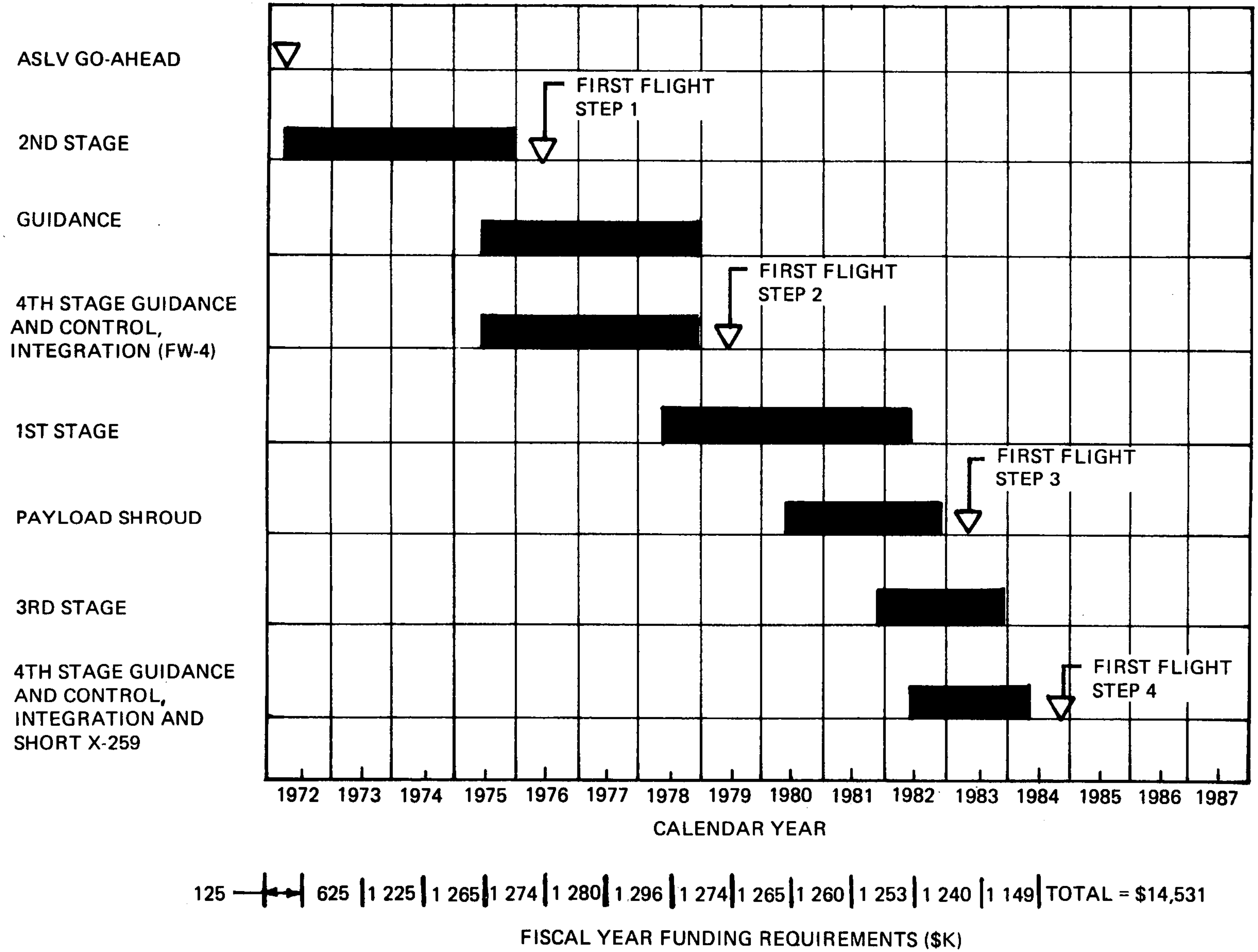


FIGURE 45 SCHEDULE C – ASLV FISCAL FUNDING

sufficiently to permit consideration of any propulsion improvement in State-of-the-art (I_{SP}, Mass Fraction, and Stop/Restart)

(2) Peak fiscal year funding of $1.296 million.

(3) Total development cost of $14.531 million because the Program is stretched out over a 10 year period.

7.2.2.1 Selected Schedule. - Schedule B, Figure 42, is selected for the ASLV development based on the following reasons:

(1) Provides a logical growth pattern as discussed in Schedule B, above,

(2) The peak fiscal year funding of $2.4 million considered to be reasonable for current budget trends.

7.3 MAJOR MILESTONE PHASING SCHEDULE

The ASLV program major milestone phasing schedule for the selected schedule B above is shown in Figure 46. The first phase is 45 months in duration and assuming a 1 April 1972 go-ahead the first launch of step 1 occurs 1 December 1975. This configuration incorporates the inertial guidance and attitude and vernier velocity control systems on the Scout 4th stage as well as the short Algol III with movable nozzle for the second stage. This vehicle can place a 170 kg (390 lb) payload into a 556 km circular orbit when launched due east from Wallops Island, Va. Step 2 incorporating the modified first stage (Algol III with movable nozzle and Castor II strap-ons) and the large payload shroud has a first launch of December 1977. This configuration can place a 260 kg (580 lb) payload into the same orbit. The third phase, which incorporates the high pressure X-259 for the thrid stage and short X-259 for the fourth stage, achieves the design goal of 340 kg (750 lbs) payload capability into the same circular orbit. The first launch with this full capability occurs in July 1979.

7.4 ASLV AVERAGE UNIT LAUNCH COST

The average unit launch sost of the ASLV based upon a 50 vehicle procurement of 10 step 1 vehicles, 10 step 2 vehicles, and step 3 in 2

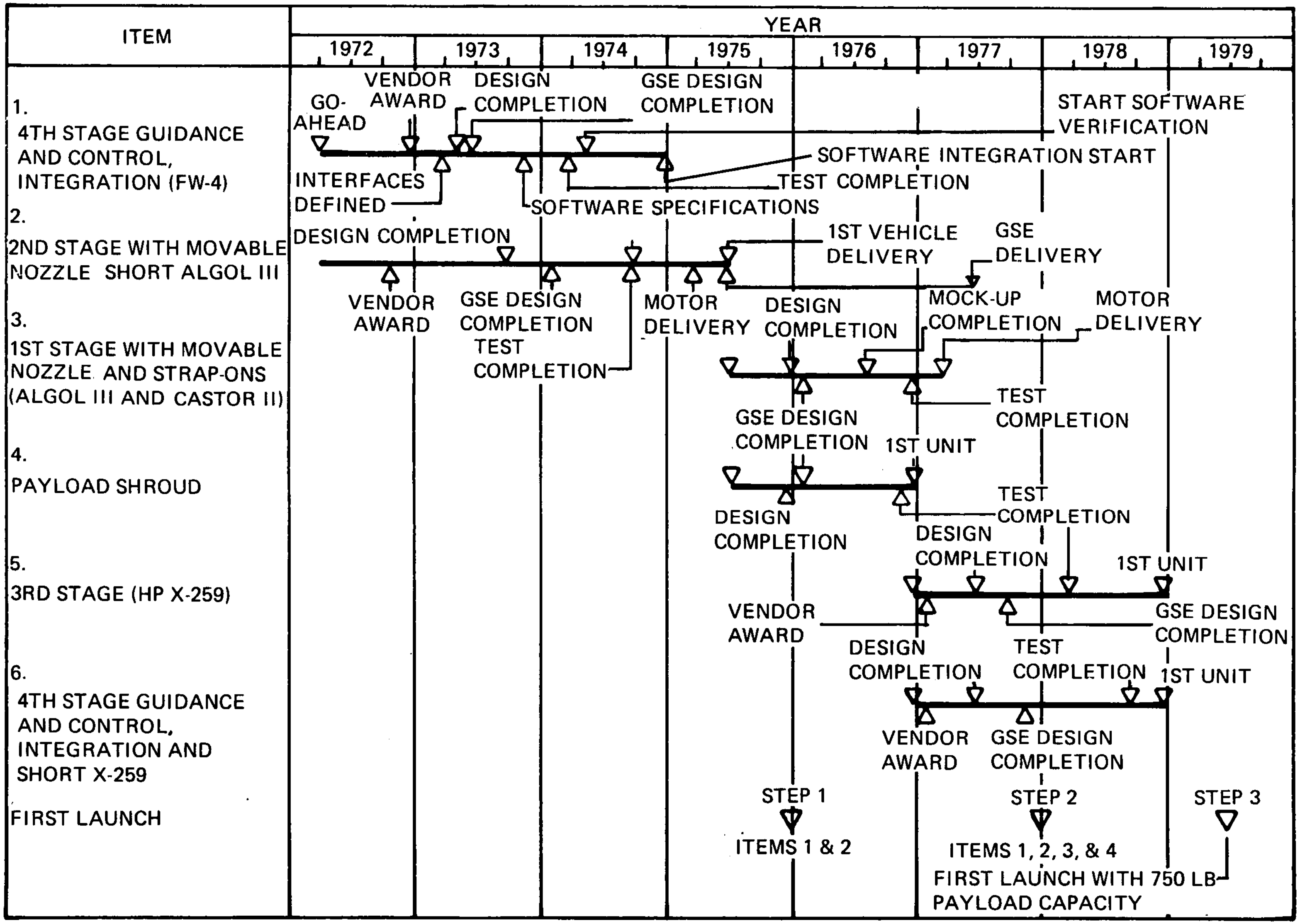


FIGURE 46 ASLV – MAJOR MILESTONE PHASING SCHEDULE

units of 15 vehicles each is shown below:

	$M
Propulsion, Interstages and Payload Shroud	1.221
Inertial Guidance and Control	0.350
Production Checkout	0.148
Total Hardware Cost	1.719
Launch Support Cost	1.000
Total Hardware and Launch Cost	2.719
Amortized Development Cost over 50 Vehicles	0.253
Average Unit Launch Cost	2.972

7.5 GSE AND PROCEDURES COST

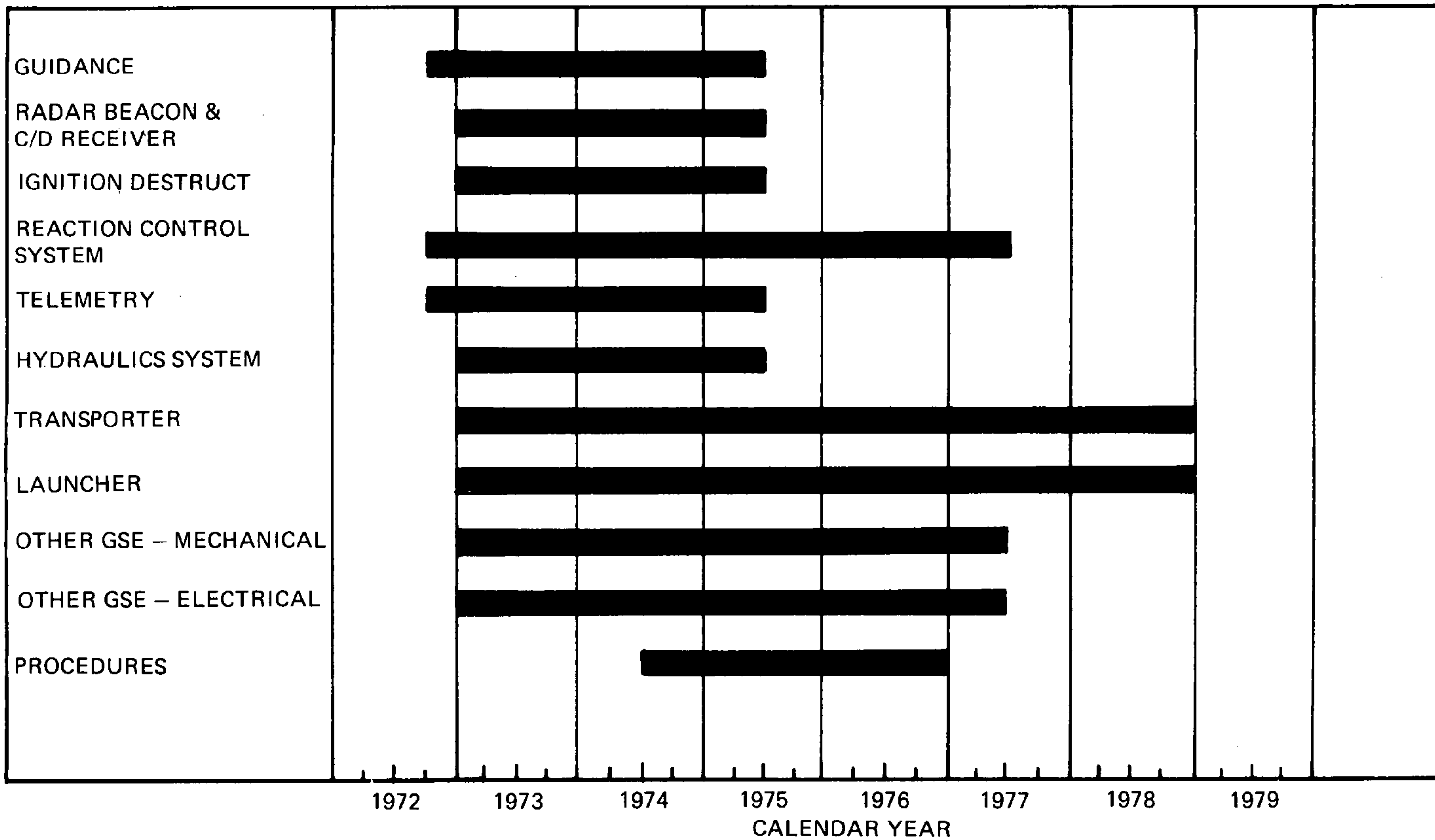
The cost of the GSE and procedures for the ASLV are shown on Table 52 for Dallas, Wallops Island and Vandenberg. The number of sets of equipment and modification are listed in Table 46, Section 6.3. The procedures cost is based upon the preparation and release of new procedures for the guidance and the strap-on motors only. All other procedure changes are assumed to be accomplished as addendum to current Scout procedures prepared by the launch support personnel. Thus, these costs are a part of the 1 $M launch support cost.

The fiscal year funding for the GSE and procedure cost is shown in Figure 47 for Dallas and Wallops Island.

TABLE 52 GSE AND PROCEDURES COST

SYSTEMS	DALLAS	WALLOPS ISLAND	SUBTOTAL	VANDENBERG	TOTAL
Guidance	325.1K	523.0K	848.1K	523.0K	1371.1K
Radar Beacon and C/D Receivers	13.3K	13.5K	26.8K	13.5K	40.3K
Ignition-Destruct System	17.6K	9.7K	27.3K	9.7K	37.0K
Reaction Control System	62.8K	68.8K	131.6K	68.8K	200.4K
*Telemetry	130.6K	225.3K	355.9K	225.3K	581.2K
Hydraulic	30.5K	20.9K	51.4K	20.9K	72.3K
Transporter*	34.3K	23.3K	57.6K	23.3K	80.9K
Launcher	50.5K	68.4K	118.9K	68.4K	187.3K
Other GSE-Mechanical	157.7K	130.6K	288.3K	130.6K	418.9K
Other GSE-Electrical	9.8K	5.6K	15.4K	5.6K	21.0K
Total GSE	832.2K	1089.1K	1921.3K	1089.1K	3010.4K
Procedures	146.7K	-	146.7K	-	146.7K
Total GSE Procedures and Facilities.	978.9K	1089.1K	2068.0K	1089.1K	3157.1K

*Required only if an inertial guidance system is used.



FISCAL YEAR FUNDING $K		236.4	869.0	589.6	205.1	160.0	5.0	2.9	TOTAL = 2068.0

FIGURE 47 ASLV GSE AND PROCEDURE FISCAL FUNDING (DALLAS AND WALLOPS ISLAND)

8.0 CONCLUSIONS

Based on the results of the study reported herein, the following conclusions are presented:

(1) The most economical approach to provide the specified payload design objectives is to continue the current Scout launch vehicle product improvement program. This capability growth can be accomplished by modifications to the current Scout hardware except for the inertial guidance and telemetry systems.

(2) All hardware involved in the product improvement program is current design state-of-the-art.

(3) The manufacturing, checkout, and processing of the launch vehicle will be similar to current Scout.

(4) A requirement exists for an improved Scout guidance capability.

(5) No new ground support equipment or facility procurements are necessary to support the launch vehicle except for the improved guidance, strap-on motor alignment, and telemetry systems. They can be accomplished economically without impairing the ability to assemble, checkout and launch the current Scout vehicle.

(6) All rocket motors are solid propellant and are existing or modification of existing flight hardware.

9.0 REFERENCES

1. "America's Next Decades in Space," A Report for the Space Task Group, National Aeronautics and Space Administration, September 1969.
2. "Report to the Launch Vehicle Working Group on LeRC Studies," NASA Lewis Research Center, 15 July 1968.
3. "Current SESP Payloads," Space Experiments Support Program, Department of Defense, 1 March 1970, REV., 1 December 1970.
4. "Space Science and Applications," NASA, October 1970
5. "Small Applications Technology Satellite: - Program and Spacecraft Study Report" NASA Goddard Spaceflight Center, Report No. X-730-70-350, September 1970.
6. "The Role of Small Satellites in Space Applications Missions," A. I. Sibila, Vought Missiles and Space Company, April 1971.
7. "Engineering Study for Modular Spacecraft Vehicles," Vought Missiles and Space Company, Report No. T136-001, 10 August 1970.
8. "Selected Space Goals and Objectives and Their Relationship to National Goals" NASA Contractor Report by Battelle Memorial Institute, NASA CR-105304, November 1969.
9. "Estimates of Future Automated Space Mission Models for Use in NASA Launch Vehicle Planning," Battelle Memorial Institute, Columbus, Ohio Laboratories, Rept. No. BMI-NLVP-TR-70-1, 15 May 1970.
10. Statement of Work for "Low Cost Launch Vehicle Families for Automated Missions," NASA Lewis Research Center, RFP C-476673, 1971
11. "Small Launch Vehicle Mission Models for 1971-1990," Battelle Memorial Institute, Columbus Lab oratories, Letter No. BMI-NLVP-IL-71-129, dated 2 July 1971.
12. The Second Decade of the Global Operational Weather Satellite System and its Data Utilization, AIAA Paper 71-836, july 1971.
13. NASA CR 94002 (SGC Report 1069-FR-1 October, 1967). Design Criteria for Spacecraft Propulsion Systems, Space General Corporation, NAS 7-519, Volumes II, IIb, and V.

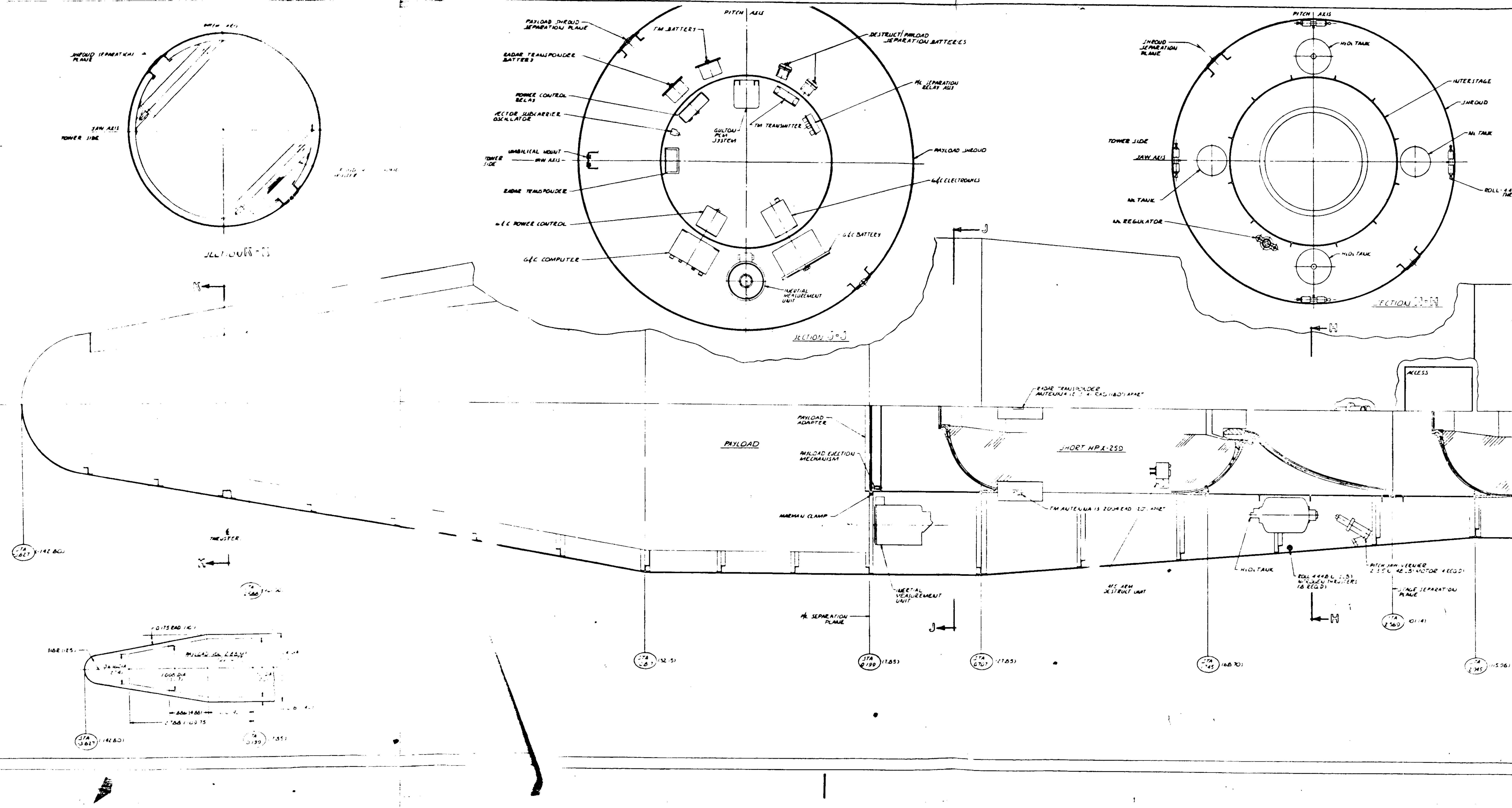
9.0 REFERENCES (Continued)

14. United States Air Force Systems Command "Space Planners Guide," dated 1 July 1965.

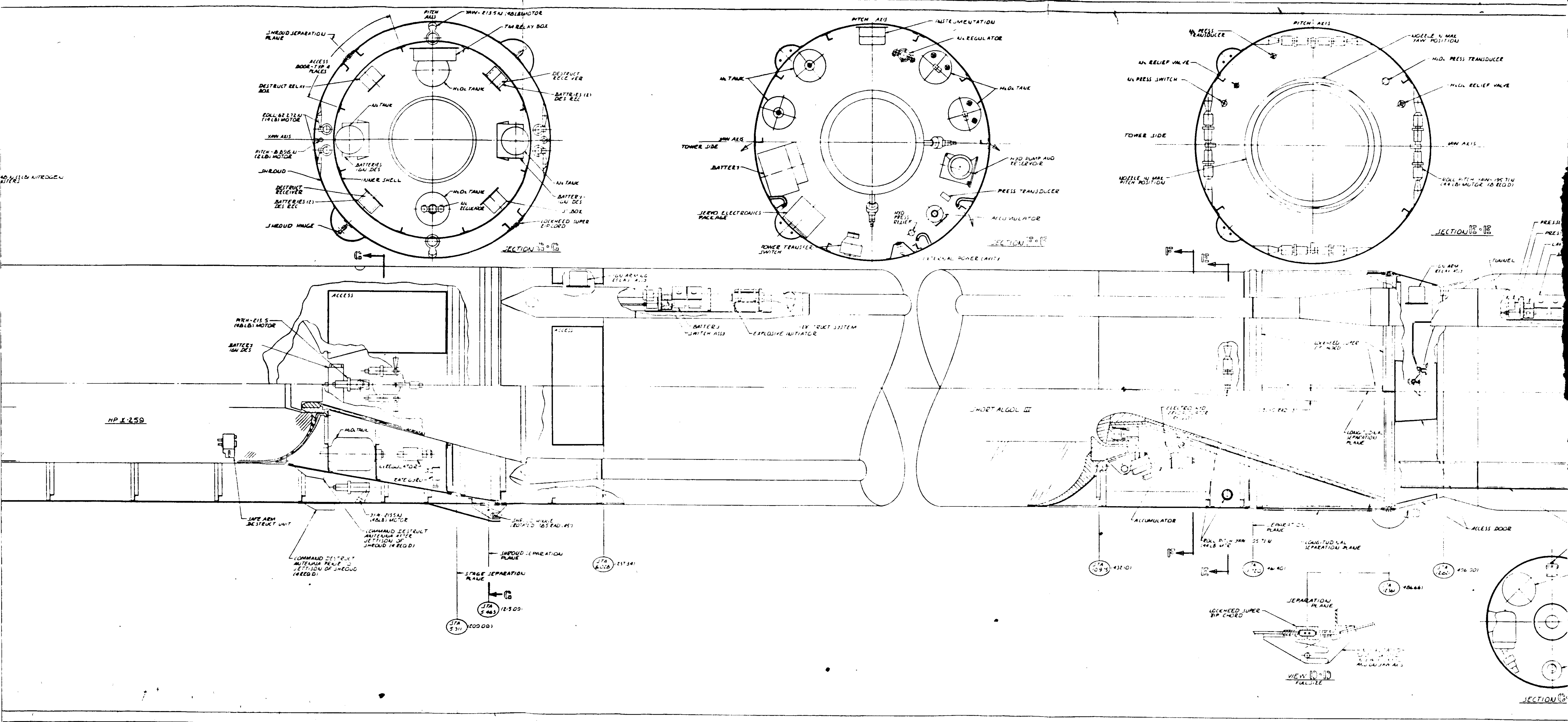
15. Excerpts from NASA's "Economic Data Document," No. BMI-NLVP-DO-3-(71), 1971.

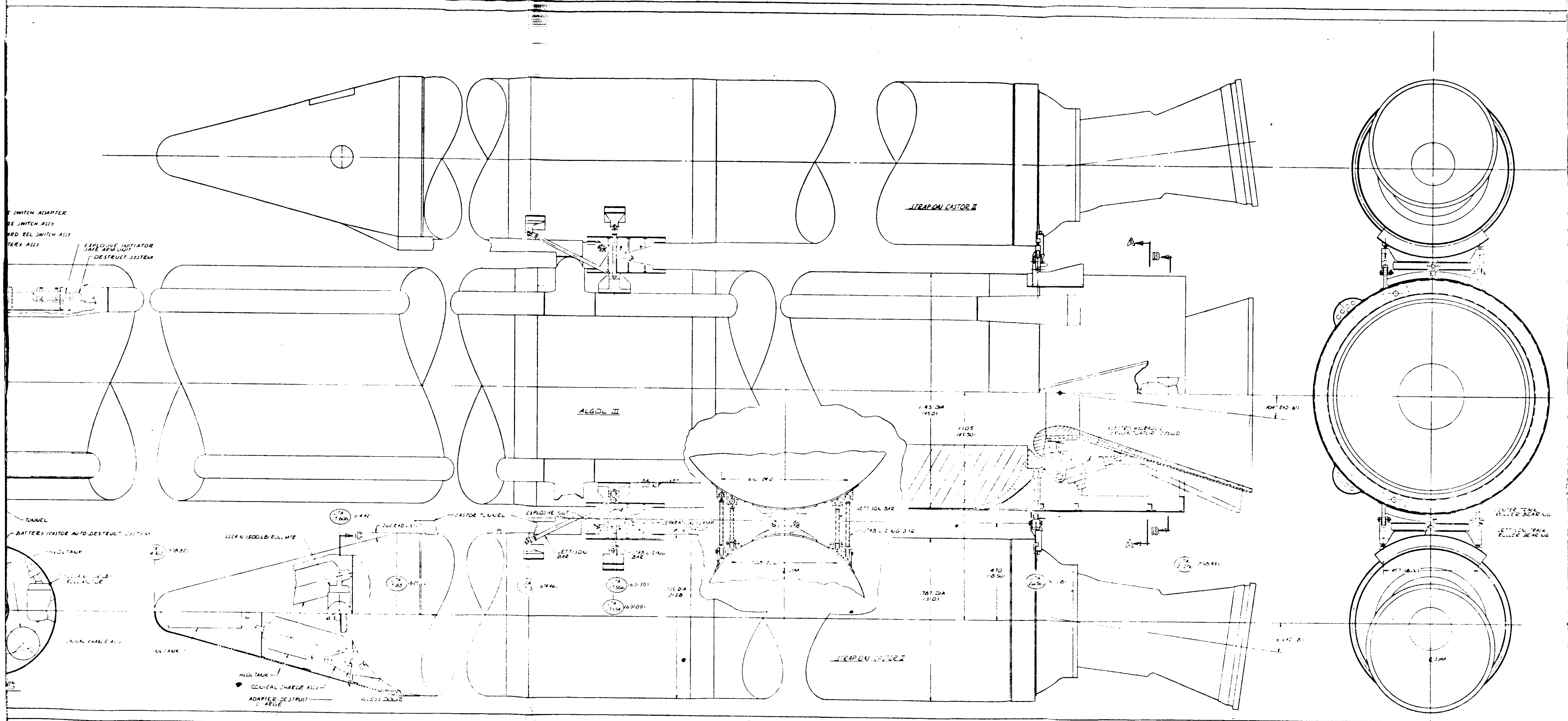
16. "Improved Guidance Hardware Study for the Scout Launch Vehicle," Martin Marietta Corporation dated December 1971.

17. "The Near-Earth Mission Analysis Routine, LA0076," Report No. 00.1371, dated 1 March 1971.

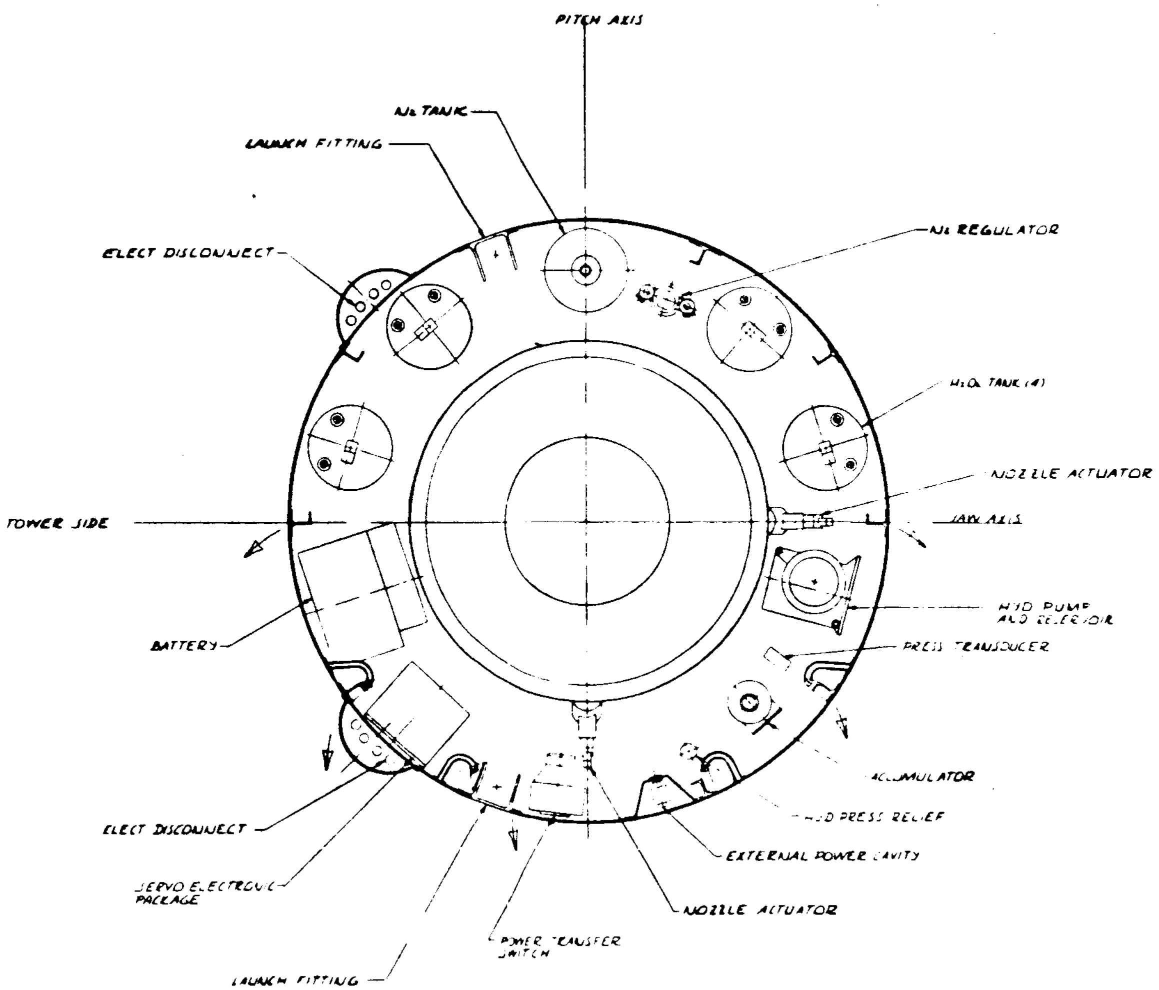


PITCH AXIS
PAYLOAD SHROUD SEPARATION PLANE
TM BATTERY
DESTRUCT/PAYLOAD SEPARATION BATTERIES
RADAR TRANSPONDER BATTERY
P/L SEPARATION RELAY ASSY
POWER CONTROL RELAY
SECTOR SUBCARRIER OSCILLATOR
GULTON PCM SYSTEM
TM TRANSMITTER
UMBILICAL MOUNT
TOWER SIDE
YAW AXIS
PAYLOAD SHROUD
RADAR TRANSPONDER
G/C ELECTRONICS
G/C POWER CONTROL
G/C BATTERY
G/C COMPUTER
INERTIAL MEASUREMENT UNIT
SECTION J-J
SHROUD SEPARATION PLANE
INTERSTAGE
SHROUD
N_2 TANK
H_2O_2 TANK
N_2 REGULATOR
SECTION H-H
ACCESS
RADAR TRANSPONDER ANTENNA
PAYLOAD ADAPTER
PAYLOAD
PAYLOAD EJECTION MECHANISM
SHORT HPX-250
MARMAN CLAMP
TM ANTENNA
INERTIAL MEASUREMENT UNIT
P/L SEPARATION PLANE
P/L ARM DESTRUCT UNIT
ROLL NITROGEN THRUSTERS (8 REQ'D)
PITCH-YAW VERNIER MOTOR (4 REQ'D)
STAGE SEPARATION PLANE
THRUSTER

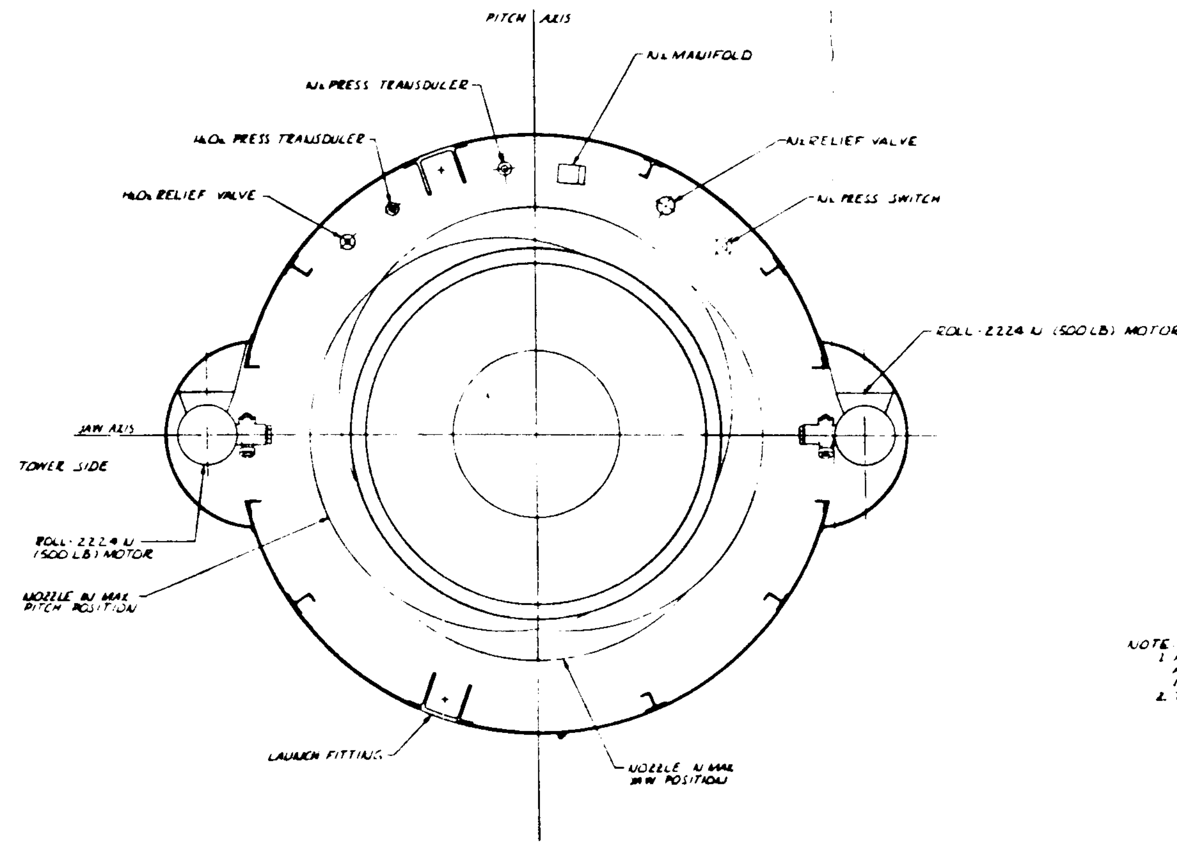

SHROUD SEPARATION PLANE
ACCESS DOOR - TYP 4 PLACES
DESTRUCT RELAY BOX
YAW AXIS
SHROUD
INNER SHELL
DESTRUCT RECEIVER
SHROUD HINGE
PITCH AXIS
TM RELAY BOX
DESTRUCT RECEIVER
LOCKHEED SUPER ZIP CORD
SECTION
INSTRUMENTATION
TOWER SIDE
BATTERY
SERVO ELECTRONICS PACKAGE
POWER TRANSFER SWITCH
PRESS TRANSDUCER
ACCUMULATOR
SECTION
TOWER SIDE
YAW AXIS
SECTION
ACCESS
HP X-259
SAFE ARM DESTRUCT UNIT
EXPLOSIVE INITIATOR
SHORT ALGOL III
ACCUMULATOR
ACCESS DOOR
SHROUD SEPARATION PLANE
STAGE SEPARATION PLANE
LONGITUDINAL SEPARATION PLANE
SEPARATION PLANE
LOCKHEED SUPER ZIP CHORD
VIEW
FULL SIZE
SECTION



SWITCH ADAPTER
RE SWITCH ASSY
ARD REL SWITCH ASSY
TERY ASSY
EXPLOSIVE INITIATOR
SAFE ARM UNIT
DESTRUCT SYSTEM
STRAP ON CASTOR II
ALGOL III
TUNNEL
CASTOR TUNNEL
EXPLOSIVE NUT
JETTISON BAR
CONICAL CHARGE ASSY
ADAPTER DESTRUCT CHARGE
ACCESS DOOR
STRAP ON CASTOR II
CENTER TRACK ROLLER BEAR UG
JETTISON TRACK ROLLER BEAR UG



SECTION A-A



SECTION B-B

NOTE
1. ALL UNITS ARE GIVEN IN THE INTERNATIONAL SYSTEM OF UNITS (SI UNITS) AND ARE FOLLOWED BY THE CORRESPONDING ENGLISH UNITS NOTED IN PARANTHESIS
2. THE SI UNITS OF MEASURE ARE FOLLOWS

LENGTH	METER
ANGLE	RADIAN
POUND FORCE	NEWTON

VOUGHT MISSILES AND SPACE COMPANY

SLV
GENERAL ARRANGEMENT

11813 T174A000001

LIBRARY CARD ABSTRACT

NASA CR-xxxxx
National Aeronautics and Space Administration
Advanced Small Launch Vehicle (ASLV) Study

G. E. Reins, J. F. Alvis,
8 March 1972
(NASA Contractor Report T186-1)
Contract No. NAS1-10848

A conceptual design study was conducted to define the most economical approach for an Advanced Small Launch Vehicle (ASLV) for use over the next decade. Payload design objective was 340 kg (750 lb) into a 556 km (300 n.mi.) circular orbit when launched due east from Wallops Island, Virginia. Investigation included liquid, solid and hybrid rocket propellants using existing, modified, or new propulsion stages. Based on the conceptual design study results, it was concluded that the most economical approach is to progressively improve the current Scout launch vehicle in three phased steps. Step 1 incorporates a modified Algol III in the second stage, and improved guidance, and attitude and vernier velocity control in the fourth stage. Step 2 consists of adding two strap-on Castor motors to the first stage Algol III and 1.52 m diameter payload shroud. A high pressure X-259 third stage and a modified X-259 fourth stage are added in Step 3.

Time phased growth plans and fiscal year funding options are presented.