ADVANCED SMALL LAUNCH VEHICLE STUDY

Prepared under Contract No. NAS1-10848

by

VOUGHT MISSILES AND SPACE COMPANY
LTV AEROSPACE CORPORATION
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for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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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.
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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 consistent 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

<table>
<thead>
<tr>
<th>DATA SOURCE</th>
<th>MISSION INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1968 NASA Lewis Unmanned Launch Vehicle Program for the 1970 Decade (Ref. 2)</td>
<td>Launch Vehicle Requirements and Launch Schedules</td>
</tr>
<tr>
<td>0 Current Space Experiments Support Program (SESP) (Ref. 3)</td>
<td>Experiment Type &amp; Characteristics, Spacecraft Requirements, Mission Data</td>
</tr>
<tr>
<td>0 1970 Space Science &amp; Applications (OSSA) (Ref. 4)</td>
<td>Approved Unmanned Launches, Expt. Type, Launch Vehicles, Mission Data</td>
</tr>
<tr>
<td>0 SATS Program &amp; Spacecraft Study Report (Ref. 5)</td>
<td>Experimental Orbits for SATS Applications</td>
</tr>
<tr>
<td>0 Role of Small Satellites in Space Application Missions (Ref. 6)</td>
<td>Orbit Data for Space Applications Missions</td>
</tr>
<tr>
<td>0 Modular Spacecraft Vehicle Study (Ref. 7)</td>
<td>Mission List for MSV Study</td>
</tr>
<tr>
<td>0 Selected Space Goals &amp; Objectives &amp; Their Relation to National Goals (Ref. 8)</td>
<td>Spacecraft &amp; Mission Data for Various Space Experiments</td>
</tr>
<tr>
<td>0 Estimates of Future Automated Space Mission Models for Use in NASA Launch Vehicle Planning (Ref. 9)</td>
<td>Comprehensive Mission Models, Launch Vehicle Requirements</td>
</tr>
<tr>
<td>0 Low Cost Launch Vehicle Families for Automated Missions (Ref. 10)</td>
<td>Preliminary Mission Model for Low Cost Launch Vehicle Study</td>
</tr>
<tr>
<td>0 Small Launch Vehicle Mission Models for 1971-1990 (Ref. 11)</td>
<td>Projected Thor Delta and Scout Missions for the next 20 years; Assessment of Space Shuttle on Mission Schedules.</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>SOURCE/MODEL</th>
<th>YEAR</th>
<th>Total</th>
<th>Avg. No. Launches Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battelle Models</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal</td>
<td>23</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Low</td>
<td>21</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>High</td>
<td>24</td>
<td>23</td>
<td>34</td>
</tr>
<tr>
<td>1968 NASA Lewis Unmanned</td>
<td>13</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Launch Vehicle Program</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Cost Launch Vehicle Family</td>
<td>10</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>Families for Automated Missions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YEAR</td>
<td>Total</td>
<td>Nominal</td>
<td>Low</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>1970</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>1971</td>
<td>7</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>1972</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>1973</td>
<td>10</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>1974</td>
<td>11</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>1975</td>
<td>11</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>1976</td>
<td>9</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>1977</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>1978</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>1979</td>
<td>7</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>1980</td>
<td>10</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>1981</td>
<td>11</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

**Note:** The table includes estimates of scout launch vehicle requirements for various years and models. The columns represent different data sources and models, with a total average number of launches per year. The data is presented in a tabular format with years from 1970 to 1981.
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**

<table>
<thead>
<tr>
<th>MISSION</th>
<th>Distribution of Missions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1968 Lewis Model</td>
</tr>
<tr>
<td><strong>Earth Orbits</strong></td>
<td></td>
</tr>
<tr>
<td>Circular (Alt &lt; 556 km)</td>
<td>8.8</td>
</tr>
<tr>
<td>(Alt &gt; 556 km)</td>
<td>17.7</td>
</tr>
<tr>
<td>Elliptic (Perigee 278-556 km)</td>
<td>5.5</td>
</tr>
<tr>
<td>(Perigee &gt; 556 km)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Special Orbits</strong></td>
<td></td>
</tr>
<tr>
<td>Elliptic Orbits</td>
<td></td>
</tr>
<tr>
<td>(Perigee &lt; 278 km)</td>
<td>6.1</td>
</tr>
<tr>
<td>Specified Orbit Precession</td>
<td></td>
</tr>
<tr>
<td>(Alt &gt; 556 km)</td>
<td>26.0</td>
</tr>
<tr>
<td>Specified Argument of Perigee</td>
<td>0.6</td>
</tr>
<tr>
<td>Injection into Synch Transfer</td>
<td>13.2</td>
</tr>
<tr>
<td>Synchronous Orbit</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Earth Ballistic</strong></td>
<td></td>
</tr>
<tr>
<td>Probes</td>
<td>1.1</td>
</tr>
<tr>
<td>Reentry</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>Earth Escape</strong></td>
<td>16.0</td>
</tr>
</tbody>
</table>

(1) Planned Scout Missions Included
<table>
<thead>
<tr>
<th>ORBIT</th>
<th>APPLICATIONS</th>
<th>LAUNCH VEHICLE REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elliptic Orbit/Perigee &lt; 278 km</td>
<td>Atmosphere Explorers, IMP type Experiments</td>
<td>Improved Accuracy</td>
</tr>
<tr>
<td>Specified Orbit Precession/Altitude &gt; 556 km</td>
<td>Sun-Synchronous, Geodetic, Transit, Mapping, Survey, SATS, Meteorology</td>
<td>Improved Accuracy; Restart Desirable</td>
</tr>
<tr>
<td>Elliptic Orbit/Specified Argument of Perigee</td>
<td>12 Hour Communication, Injun VI</td>
<td>Improved Accuracy, Parking Orbit Capability; High Velocity Upper Stages, Restart Desirable</td>
</tr>
<tr>
<td>Injection into Synchronous Transfer Orbit</td>
<td>Concept Test and Checkout for Communication, Meteorology, Navigation Satellite Equipment.</td>
<td>Improved Accuracy; Parking Orbit Capability; High Velocity Upper Stages, Restart Desirable</td>
</tr>
</tbody>
</table>
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 shortcomings 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 spacecraft 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>
<thead>
<tr>
<th>MISSION</th>
<th>PERCENT* MISSIONS</th>
<th>IMPROVED ACCURACY</th>
<th>PARKING ORBIT</th>
<th>RESTART CAPABILITY</th>
<th>HIGH VELOCITY UPPER STAGE</th>
<th>PREDICTED NUMBER MISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EARTH ORBITS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIRCULAR (ALTITUDE ≤ 556 km)</td>
<td>8.1</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>5</td>
</tr>
<tr>
<td>(ALTITUDE &gt; 555 km)</td>
<td>14.2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>DESIRABLE</td>
<td>7</td>
</tr>
<tr>
<td>ELLIPTIC (PERIGEE 278-556)</td>
<td>5.2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>5</td>
</tr>
<tr>
<td>(PERIGEE &gt; 556 km)</td>
<td>0.5</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>DESIRABLE</td>
<td>0</td>
</tr>
<tr>
<td>SPECIAL ORBITS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ELLIPTIC ORBITS (PERIGEE &lt; 278 km)</td>
<td>6.6</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>3</td>
</tr>
<tr>
<td>SPECIFIED ORBIT PRE-CESSION (≥ 555 km)</td>
<td>24.2</td>
<td>YES</td>
<td>NO</td>
<td>DESIRABLE</td>
<td>NO</td>
<td>12</td>
</tr>
<tr>
<td>SPECIFIED ARGUMENT OF PERIGEE</td>
<td>0.3</td>
<td>YES</td>
<td>YES</td>
<td>DESIRABLE</td>
<td>YES</td>
<td>4</td>
</tr>
<tr>
<td>INJECTION INTO SYNCH TRANSFER</td>
<td>21.6</td>
<td>YES</td>
<td>YES</td>
<td>DESIRABLE</td>
<td>YES</td>
<td>5</td>
</tr>
<tr>
<td>EARTH BALLISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROBES</td>
<td>0.6</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>SOME MISSIONS</td>
<td>2</td>
</tr>
<tr>
<td>REENTRY</td>
<td>1.0</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>SOME SOME SOME MISSIONS</td>
<td>3</td>
</tr>
<tr>
<td>EARTH ESCAPE</td>
<td>13.8</td>
<td>DESIRABLE</td>
<td>DESIRABLE</td>
<td>DESIRABLE</td>
<td>YES</td>
<td>4</td>
</tr>
</tbody>
</table>

*AVGVERAGE OF LEWIS, BATTELLE, AND LOW COST MODELS

50 TOTAL
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**

<table>
<thead>
<tr>
<th>REQUIREMENT</th>
<th>PERCENT OF MISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved Accuracy</td>
<td>66</td>
</tr>
<tr>
<td>Parking Orbit Capability</td>
<td>26</td>
</tr>
<tr>
<td>Restart Capability</td>
<td>0*</td>
</tr>
<tr>
<td>High Velocity Upper Stage</td>
<td>30</td>
</tr>
</tbody>
</table>

*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 \( \pm 1850 \text{ km} \) 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

<table>
<thead>
<tr>
<th>Mission</th>
<th>Projected No. of ASLV Missions</th>
<th>$\Delta H$ (%)</th>
<th>$\Delta H_A$ (%)</th>
<th>$\Delta H_p$ (%)</th>
<th>$\Delta i$ (deg)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIRCULAR ORBIT: $H \leq 740$ km</td>
<td>5</td>
<td>33.0</td>
<td>25.0</td>
<td>-</td>
<td>0.30 0.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIRCULAR ORBIT: $H \geq 740$ km</td>
<td>7</td>
<td>13.0</td>
<td>7.0</td>
<td>-</td>
<td>5.00 1.00</td>
<td></td>
</tr>
<tr>
<td>ELLIPTIC ORBIT: $H_p \leq 278$ km</td>
<td>3</td>
<td>-</td>
<td>20.0</td>
<td>3.3</td>
<td>5.00 1.00</td>
<td>$H_p$ based on 1 year lifetime</td>
</tr>
<tr>
<td>ELLIPTIC ORBIT: $H_p &gt; 278$ km</td>
<td>5</td>
<td>-</td>
<td>5.0</td>
<td>3.2</td>
<td>0.50 0.20</td>
<td></td>
</tr>
<tr>
<td>SPECIFIED ORBIT PRECESSION</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Sun-synch &amp; transit missions</td>
</tr>
<tr>
<td>SPECIFIED ARG. OF PERIGEE</td>
<td>2</td>
<td>-</td>
<td>1.0</td>
<td>0.7</td>
<td>1.00 0.50</td>
<td>12 hr orbit establ. min. tolerances</td>
</tr>
<tr>
<td>SYNCHRONOUS TRANSFER &amp; QUASI-SYNCHRONOUS</td>
<td>7</td>
<td>-</td>
<td>7.5</td>
<td>2.6</td>
<td>5.0 5.00</td>
<td></td>
</tr>
<tr>
<td>EARTH ESCAPE</td>
<td>4</td>
<td>-</td>
<td>10.0</td>
<td>10.0</td>
<td>15.0 13.0</td>
<td></td>
</tr>
</tbody>
</table>

#### Part II: Sub-Orbital Missions

<table>
<thead>
<tr>
<th>Mission</th>
<th>No. of ASLV Missions</th>
<th>$\Delta H_E$ (%)</th>
<th>$\Delta \gamma$ (deg)</th>
<th>$\Delta \alpha$ (deg)</th>
<th>$\Delta \psi$ (deg)</th>
<th>$\Delta \phi$ (deg)</th>
<th>$\Delta \lambda$ (deg)</th>
<th>$\Delta \omega$ (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>REENTRY</td>
<td>3</td>
<td>2.0 0.4</td>
<td>3.00 0.70</td>
<td>0.34 0.25</td>
<td>0.37 0.25</td>
<td>0.17 0.05</td>
<td>0.17 0.05</td>
<td>0.17 0.05</td>
</tr>
<tr>
<td>EARTH PROBE</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

$\Delta H$ - Error in circular orbit altitude, percent  
$\Delta H_A$ - Error in apogee altitude, percent  
$\Delta H_p$ - Error in perigee altitude, percent  
$\Delta H_E$ - Error in reentry altitude, percent  
$\Delta \alpha$ - 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.
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.
MEAN DENSITY 208 kgs/m$^3$ (13 lb/ft$^3$)
MEDIAN DENSITY 176 kgs/m$^3$ (11 lb/ft$^3$)
SELECTED AVERAGE 192 kgs/m$^3$ (12 lb/ft$^3$)

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>
<thead>
<tr>
<th>TABLE 9</th>
<th>FIXED WEIGHT SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight</td>
</tr>
<tr>
<td></td>
<td>(kg)</td>
</tr>
<tr>
<td>Intermediate Stage (Payload Shroud)</td>
<td>249-408</td>
</tr>
<tr>
<td>Injection Stage</td>
<td></td>
</tr>
<tr>
<td>o Without upper stage</td>
<td>55</td>
</tr>
<tr>
<td>o With upper stage (incl. spin table)</td>
<td>80</td>
</tr>
<tr>
<td>High Energy Upper Stage</td>
<td>11</td>
</tr>
</tbody>
</table>
FIGURE 4 PAYLOAD COMPARISON FOR FIFTH STAGE SIZING POINTS
<table>
<thead>
<tr>
<th>Fixed Subsystems</th>
<th>Subsystems Included In Stage Structural Factors*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intermediate Stage</strong></td>
<td>Each Stage (Except High Velocity Upper Stage)</td>
</tr>
<tr>
<td>° Payload Shroud</td>
<td>° Motor</td>
</tr>
<tr>
<td><strong>Injection Stage</strong></td>
<td>° Ignition System</td>
</tr>
<tr>
<td>° Guidance (incl. computer)</td>
<td>° Stage Structure &amp; Interstage</td>
</tr>
<tr>
<td>° Telemetry</td>
<td>° Separation System</td>
</tr>
<tr>
<td>° Spin Table (when applicable)</td>
<td>° Destruct System</td>
</tr>
<tr>
<td>° Batteries</td>
<td>° Control System</td>
</tr>
<tr>
<td>° Mounting Structure</td>
<td>° Electrical System</td>
</tr>
<tr>
<td><strong>High Velocity Upper Stage</strong></td>
<td>° Thrust Termination/Velocity Control</td>
</tr>
<tr>
<td>° Stage Structure and Interstage</td>
<td>(when applicable)</td>
</tr>
<tr>
<td>° Ignition</td>
<td></td>
</tr>
<tr>
<td>° Despin</td>
<td></td>
</tr>
</tbody>
</table>

* 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 II. 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>
<thead>
<tr>
<th>TABLE II SUMMARY OF STAGE STRUCTURE FACTORS AND SPECIFIC IMPULSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROPELLANT</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>SOLID</td>
</tr>
<tr>
<td>1ST STAGE</td>
</tr>
<tr>
<td>2ND STAGE</td>
</tr>
<tr>
<td>3RD STAGE</td>
</tr>
<tr>
<td>4TH STAGE</td>
</tr>
<tr>
<td>LIQUID-STORABLE</td>
</tr>
<tr>
<td>1ST STAGE</td>
</tr>
<tr>
<td>2ND STAGE</td>
</tr>
<tr>
<td>3RD STAGE</td>
</tr>
<tr>
<td>LIQUID - LOX/RP</td>
</tr>
<tr>
<td>1ST STAGE</td>
</tr>
<tr>
<td>2ND STAGE</td>
</tr>
<tr>
<td>LIQUID - LOX/LH₂</td>
</tr>
<tr>
<td>1ST STAGE</td>
</tr>
<tr>
<td>2ND STAGE</td>
</tr>
</tbody>
</table>
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, N₂O₄, or H₂O₂, 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>
<thead>
<tr>
<th>IMPROVED Scout Concepts</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPT. SOLID 1ST STAGE/COMBINATIONS OF SCOUT UPPER STAGES</td>
<td>SOLID</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>OPT. LIQUID 1ST STAGE/COMBINATIONS OF SCOUT UPPER STAGES</td>
<td>SOLID</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III</td>
<td>SHORT ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III OR STRETCHED ALGOL III</td>
<td>ALGOL III</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>ALGOL III + (2) CASTOR STRAP-ONS</td>
<td>SHORT ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III + (2) CASTOR STRAP-ONS</td>
<td>ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III + (2) CASTOR STRAP-ONS</td>
<td>ALGOL III</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>ALGOL III + (2) CASTOR STRAP-ONS</td>
<td>CASTOR IV (IIA PROP)</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III + (2) CASTOR STRAP-ONS</td>
<td>MM III 2ND STAGE</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III + (2) CASTOR STRAP-ONS</td>
<td>MM III 2ND STAGE</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>ALGOL III + (2) CASTOR STRAP-ONS</td>
<td>SOLID</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III + (3) CASTOR STRAP-ONS</td>
<td>SOLID</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>ALGOL III + (3) CASTOR STRAP-ONS</td>
<td>ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III + (4) CASTOR STRAP-ONS</td>
<td>ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>ALGOL III + (4) CASTOR STRAP-ONS</td>
<td>SOLID</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>ALGOL III + (2) STRETCHED CASTOR STRAP-ONS</td>
<td>SHORT ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NEW LAUNCH VEHICLE CONCEPTS</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIMIZED THREE STAGE SOLID</td>
<td>OPT. SOLID</td>
<td>OPT. SOLID</td>
<td>-</td>
</tr>
<tr>
<td>OPTIMIZED FOURTH STAGE SOLID</td>
<td>OPT. SOLID</td>
<td>OPT. SOLID</td>
<td>OPT. SOLID</td>
</tr>
<tr>
<td>OPTIMIZED TWO STAGE LIQUIDS (STORABLE &amp; CRYOGENIC)</td>
<td>OPT. LIQ. (STOR. &amp; CRYOG.)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OPTIMIZED THREE STAGE LIQUID (STORABLE)</td>
<td>OPT. LIQ. (STOR.)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MM III 1ST STAGE</td>
<td>MM III 2ND STAGE</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>MM III 1ST STAGE</td>
<td>MM III 2ND STAGE</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>MM III 1ST STAGE</td>
<td>ALGOL III</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>MM III 1ST STAGE</td>
<td>CASTOR IV (IIA PROP)</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>POSEIDON 1ST STAGE</td>
<td>POSEIDON 2ND STAGE</td>
<td>SOLID</td>
<td>SOLID</td>
</tr>
<tr>
<td>POSEIDON 1ST STAGE</td>
<td>POSEIDON 2ND STAGE</td>
<td>LIQUID</td>
<td>-</td>
</tr>
<tr>
<td>OFF-LOADED &quot;STRAIGHT 8&quot; THOR</td>
<td>TE 364-2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&quot;STRAIGHT 8&quot; THOR + (3) CASTOR STRAP-ONS</td>
<td>TE 364-2</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
for a total impulse of $2.4 \times 10^6$ 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**

<table>
<thead>
<tr>
<th></th>
<th>DEVELOPMENT COST</th>
<th>RECURRING COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Motor</td>
<td>$4.0$ M</td>
<td>$50K$</td>
</tr>
<tr>
<td>Cryogenic Hybrid</td>
<td>12.0</td>
<td>75</td>
</tr>
</tbody>
</table>

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/m² (4180 and higher, lb/ft²) 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 N2O4/Aerozine, LOX/RP, and LOX/LH2 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 fa...
### TABLE 14  IMPROVED SCOUT CONFIGURATIONS
CONFIGURATIONS WITH NEW AND ALGOL III FIRST STAGES

<table>
<thead>
<tr>
<th>NO.</th>
<th>1ST STAGE</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
<th>SHROUD WT.</th>
<th>PAYLOAD INTO 556 km (300 n. mi.) ORBIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(kg) 100 200 300 400 600 800 (lb) 200 400 600 800</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>OPT 71 SOLID</td>
<td>MOD CAST II A</td>
<td>HP X259</td>
<td>FW-4</td>
<td>249 (550)</td>
<td>83560 37902</td>
</tr>
<tr>
<td>11</td>
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<td>MOD CAST II A</td>
<td>HP X259</td>
<td></td>
<td>249 (550)</td>
<td>87800 39825</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>OPT SOLID</td>
<td>OPT SOLID</td>
<td>249 (550)</td>
<td>(lb) 73090 33153</td>
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<tr>
<td>10</td>
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<td>OPT LIQUID</td>
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<td></td>
<td>249 (550)</td>
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</tr>
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<td>OPT 71 SOLID</td>
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<td>7S2</td>
<td>OPT 75 SOLID</td>
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<td>FW-4</td>
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<tr>
<td>7S1</td>
<td>OPT 75 SOLID</td>
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<td>TE 364:3</td>
<td></td>
<td>318 (700)</td>
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</tr>
<tr>
<td>7T1</td>
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<td>OPT 75 SOLID</td>
<td></td>
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<td>LESS THAN 750 lbs</td>
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<tr>
<td>23A</td>
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<td>OPT 71 SOLID</td>
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<tr>
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<td>OPT 75 SOLID</td>
<td></td>
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<tr>
<td>23</td>
<td>STRETCHED ALGOL III</td>
<td>SHORT ALG III</td>
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<td>TE 364:3</td>
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<td>1ST STAGE</td>
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<td>3RD STAGE</td>
<td>4TH STAGE</td>
<td>SHROUD WT.</td>
<td>PAYLOAD INTO 556 km (300 n.mi.) ORBIT</td>
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<tr>
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<td>OPT SOLID</td>
<td>OPT SOLID</td>
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<td>LAUNCH WEIGHT (lb)</td>
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</tr>
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<td>DESIGN PAYLOAD</td>
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<td></td>
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<tr>
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<td>MM III 2ND</td>
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<td>OPT SOLID</td>
<td>249 (550)</td>
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<td></td>
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</tr>
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<td>CASTOR IV</td>
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<td>OPT SOLID</td>
<td>249 (550)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASTOR IV</td>
<td>HP X259</td>
<td>FW-4</td>
<td>408 (900)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CASTOR IV</td>
<td>HP X259</td>
<td>TE 364-3</td>
<td>408 (900)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASTOR IV</td>
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<td>FW-4</td>
<td>318 (700)</td>
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<td></td>
</tr>
<tr>
<td>CASTOR IV</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td>318 (700)</td>
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<tr>
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<td>1ST STAGE</td>
<td>2ND STAGE</td>
<td>3RD STAGE</td>
<td>4TH STAGE</td>
<td>SHROUD WT. kg</td>
<td>PAYLOAD INTO 556 km (300 n. mi.) ORBIT (lb)</td>
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<td>-----</td>
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<td>-----------------------</td>
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<tr>
<td>7E</td>
<td>ALGOL III + (2) CASTORS</td>
<td>ALGOL III</td>
<td>OPT SOLID</td>
<td>OPT SOLID</td>
<td>249 (550)</td>
<td>(91011) - 41282</td>
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<td>2F</td>
<td>ALGOL III</td>
<td>ALGOL III</td>
<td>MOD CAST IIA</td>
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<td>ALGOL III</td>
<td>HP X-259</td>
<td>FW-4</td>
<td>408 (900)</td>
<td>(89219) - 40469</td>
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<tr>
<td>7K</td>
<td>ALGOL III</td>
<td>ALGOL III</td>
<td>HP X-259</td>
<td>TE 364-3</td>
<td>408 (900)</td>
<td>(91128) - 41335</td>
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<td>ALGOL III</td>
<td>ALGOL III</td>
<td>TE 364-4</td>
<td>FW-4</td>
<td>318 (700)</td>
<td>(88845) - 40299</td>
</tr>
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<td>7J</td>
<td>ALGOL III</td>
<td>ALGOL III</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
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<td>SHORT ALG III</td>
<td>SHORT ALG III</td>
<td>HP X-259</td>
<td>FW-4</td>
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<td>(78994) - 35831</td>
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<tr>
<td>7U2</td>
<td>SHORT ALG III</td>
<td>SHORT ALG III</td>
<td>HP X-259</td>
<td>TE 364-3</td>
<td>408 (900)</td>
<td>(79748) - 36103</td>
</tr>
<tr>
<td>7U3</td>
<td>SHORT ALG III</td>
<td>SHORT ALG III</td>
<td>HP X-259</td>
<td>SHORT X-259</td>
<td>408 (900)</td>
<td>(80276) - 36594</td>
</tr>
<tr>
<td>7U</td>
<td>SHORT ALG III</td>
<td>SHORT ALG III</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td>318 (700)</td>
<td>(79203) - 35926</td>
</tr>
<tr>
<td>7U1</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td>318 (700)</td>
<td>(68787) - 31201</td>
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<tr>
<td>7U4</td>
<td>ALG III + (2) STRETCHED CASTORS</td>
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<td>HP X-259</td>
<td>FW-4</td>
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<td>(85389) - 38732</td>
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<td>7U5</td>
<td>SHORT ALG III</td>
<td>SHORT ALG III</td>
<td>HP X-259</td>
<td>TE 364-3</td>
<td>408 (900)</td>
<td>(86341) - 39163</td>
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### TABLE 15  IMPROVED SCOUT CONFIGURATIONS (CONT'D.)

**STRAP-ON CONFIGURATIONS**

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

**Note:**
- LAUNCH WEIGHT (lb) and LAUNCH WEIGHT (kg) are provided for each configuration.
- The design payload is indicated at the bottom of the table.
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 II was used throughout. Further, all liquid stages in Improved Scout configurations assume storable N_2O_4/Aeroxine 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 II 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, 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.

**Stretched Castor Strap-Ons**

Stretched 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, 70, 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/m² (5020 lb/ft²) 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 N₂O₄/Aerozine, LOX/RP, and LOX/LH₂.

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

<table>
<thead>
<tr>
<th>NO.</th>
<th>1ST STAGE</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
<th>SHROUD WT.</th>
<th>PAYLOAD INTO 556 km (300 n.mi.) ORBIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(lb)</td>
<td>100  200  300  400</td>
</tr>
<tr>
<td>13</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td></td>
<td>249</td>
<td>(52781) 23941</td>
</tr>
<tr>
<td>14</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>249</td>
<td>(44652) 20254</td>
</tr>
</tbody>
</table>

**SOLID PROPELLANT LAUNCH VEHICLES**

**LIQUID PROPELLANT LAUNCH VEHICLES**

|     |                |               |               |               | 249        | (44856) 20346                        |
|     | OPT N₂O₄/AEROZINE | OPT N₂O₄/AER |               |               | 249        | (48533) 22014                        |
| 20  | OPT N₂O₄/AEROZINE | OPT N₂O₄/AER | OPT N₂O₄/AER |               | 249        | (51681) 23442                        |
| 19  | OPT LOX/RP      | OPT LOX/RP    |               |               | 249        | (23281) 10560                        |
| 19A | OPT LOX/LH₂     | OPT LOX/LH₂   |               |               | 249        | (23281) 10560                        |

**LAUNCH WEIGHT**

**LAUNCH WEIGHT**

**DESIGN PAYLOAD**
TABLE 17  BOOSTER/LAUNCH VEHICLE DERIVATIVES

CONFIGURATIONS WITH MINUTEMAN, POSEIDON AND THOR FIRST STAGES

<table>
<thead>
<tr>
<th>NO.</th>
<th>1ST STAGE</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
<th>SHROUD WT.</th>
<th>PAYLOAD INTO 556 km (300 n.mi.) ORBIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>kg (lb)</td>
<td>LAUNCH WEIGHT (lb) LAUNCH WEIGHT kg</td>
</tr>
<tr>
<td>5C</td>
<td>MM III 1ST</td>
<td>MOD CAST IIA</td>
<td>HP X-259</td>
<td>OPT SOLID</td>
<td>249 (550)</td>
<td>(66767) 30285</td>
</tr>
<tr>
<td>5</td>
<td>MM III 2ND</td>
<td>HP X-259</td>
<td>FW-4</td>
<td></td>
<td>249 (550)</td>
<td>(66214) 30034</td>
</tr>
<tr>
<td>22</td>
<td>MM III 2ND</td>
<td>OPT SOLID</td>
<td></td>
<td></td>
<td>249 (550)</td>
<td>(71057) 32231</td>
</tr>
<tr>
<td>22A</td>
<td>MM III 2ND</td>
<td>OPT SOLID</td>
<td>OPT SOLID</td>
<td></td>
<td>249 (550)</td>
<td>(72276) 32784</td>
</tr>
<tr>
<td>22C</td>
<td>MM III 2ND</td>
<td>HP X-259</td>
<td>FW-4</td>
<td></td>
<td>408 (900)</td>
<td>(73264) 33323</td>
</tr>
<tr>
<td>22D</td>
<td>MM III 2ND</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td></td>
<td>318 (700)</td>
<td>(73874) 33509</td>
</tr>
<tr>
<td>22H</td>
<td></td>
<td>CASTOR IV</td>
<td>CASTOR IIA</td>
<td>HP X-259</td>
<td>295 (650)</td>
<td>(91722) 41604 1082 lbs</td>
</tr>
<tr>
<td>22M</td>
<td></td>
<td>CASTOR IV</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td>318 (700)</td>
<td>(82929) 37616</td>
</tr>
<tr>
<td>22E</td>
<td></td>
<td>ALGOL III</td>
<td>CASTOR IIA</td>
<td>HP X-259</td>
<td>295 (650)</td>
<td>(98061) 44479</td>
</tr>
<tr>
<td>5E</td>
<td>ALGOL III</td>
<td>MOD CAST IIA</td>
<td>FW-4</td>
<td></td>
<td>249 (550)</td>
<td>(95463) 43301</td>
</tr>
<tr>
<td>22G</td>
<td>ALGOL III</td>
<td>TE 364-4</td>
<td>FW-4</td>
<td></td>
<td>318 (700)</td>
<td>(88259) 40033</td>
</tr>
<tr>
<td>22F</td>
<td>ALGOL III</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td></td>
<td>318 (700)</td>
<td>(89322) 40516</td>
</tr>
<tr>
<td>NO.</td>
<td>1ST STAGE</td>
<td>2ND STAGE</td>
<td>3RD STAGE</td>
<td>4TH STAGE</td>
<td>SHROUD WT.</td>
<td>PAYLOAD INTO 556 km (300 n.mi.) ORBIT</td>
</tr>
<tr>
<td>-----</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(kg)</td>
<td>(lb)</td>
</tr>
<tr>
<td>22I</td>
<td>POSEIDON 1ST</td>
<td>POSEIDON 2ND</td>
<td>TE 364-4</td>
<td>-</td>
<td>318 (700)</td>
<td>(63915) (28991)</td>
</tr>
<tr>
<td>22B</td>
<td>OPT SOLID</td>
<td>OPT SOLID</td>
<td></td>
<td></td>
<td>249 (550)</td>
<td>(65001) (29484)</td>
</tr>
<tr>
<td>22K</td>
<td>HP X-259</td>
<td>FW-4</td>
<td></td>
<td></td>
<td>408 (900)</td>
<td>(65595) (29753)</td>
</tr>
<tr>
<td>22L</td>
<td>TE 364-4</td>
<td>FW-4</td>
<td></td>
<td></td>
<td>318 (700)</td>
<td>(65099) (29528)</td>
</tr>
<tr>
<td>22J</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td></td>
<td></td>
<td>318 (700)</td>
<td>(66085) (29975)</td>
</tr>
</tbody>
</table>

**THOR DELTA DERIVATIVES**

|     |           |           |           |           | LAUNCH WEIGHT (lb) |
|     |           |           |           |           | LAUNCH WEIGHT (kg) |
| 24A | OFF-LOADED "STRAIGHT 8" THOR | TE 364-2 | -         | -         | 318 (700)  |
|     | "STRAIGHT 8" THOR + 3 CASTORS | TE 364-2 | -         | -         | 318 (700)  |

DESIGN PAYLOAD
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.
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/m². 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

1ST LEVEL
- PAYLOAD
- DESIGN PROBLEMS
- PROPULSION COST

2ND LEVEL
- OFF-DESIGN PERFORMANCE
- STEP-DOWN MISSIONS
- GSE IMPACT
- RISK
- MILITARY PROCUREMENT
- PRELIMINARY COST

3RD LEVEL
- OFF-DESIGN PERFORMANCE
- RISK
- STEP-DOWN PAYLOAD MISSIONS
- PAYLOAD SHROUD SIZE
- COST

FINAL SELECTION
- PERFORMANCE
- COST

“THE WINNER”
TABLE 19
FIRST LEVEL SCREENING CRITERIA

- DESIGN MISSION - 340 kg/556 km ORBIT

- DESIGN PROBLEMS
  - DYNAMIC PRESSURE 167 500 N/m² (3 500 lb/ft²)
  - STAGE DIAMETER INCOMPATIBILITY
    1st Stage Dia = 1.14 - 1.88 m (45-74 in)
    Shroud Diameter = 1.52 m (60 in)

- PROPULSION STAGE COSTS

- 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/LH₂ 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.

<table>
<thead>
<tr>
<th>Total Development Cost ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Four Stage Solid</td>
</tr>
<tr>
<td>- 71 SOA Motors</td>
</tr>
<tr>
<td>- 75 SOA Motors</td>
</tr>
<tr>
<td>o Two Stage Liquid</td>
</tr>
<tr>
<td>- Propulsion System Only</td>
</tr>
<tr>
<td>- Engine plus Propulsion System</td>
</tr>
</tbody>
</table>

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
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$_2$O$_2$ 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$_2$O$_2$ 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.

Average Unit Stage Costs

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

<table>
<thead>
<tr>
<th>Stage Type</th>
<th>Development Cost</th>
<th>Recurring Cost</th>
<th>Ave. Unit Stage Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized 4 Stage Solid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 71 SOA</td>
<td>$22.9M</td>
<td>$1.325M</td>
<td>$1.783M</td>
</tr>
<tr>
<td>- 75 SOA</td>
<td>26.8</td>
<td>1.325</td>
<td>1.861</td>
</tr>
<tr>
<td>Optimized 2 Stage Liquid (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Propulsion Sys. and Engine Development</td>
<td>60.5</td>
<td>2.650</td>
<td>3.860</td>
</tr>
<tr>
<td>Existing Booster/Launch Vehicle Derivatives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- OPT 71 SOA/CASTOR IIA/HP X259/FW4</td>
<td>11.5</td>
<td>1.119</td>
<td>1.349</td>
</tr>
<tr>
<td>- ALGOL III/OPT 71SOA/OPT 71SOA/OPT 71SOA</td>
<td>11.9</td>
<td>1.088</td>
<td>1.326</td>
</tr>
<tr>
<td>- ALGOL III + 2 CASTORS/SHORT ALG. III/OPT 71SOA/OPT 71SOA</td>
<td>7.4</td>
<td>1.187</td>
<td>1.335</td>
</tr>
<tr>
<td>- ALGOL III + 2 CASTORS/CASTOR IV/OPT 71 SOA/OPT 71 SOA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- MM III 1st/MM III 2nd/OPT 71SOA/OPT 71 SOA</td>
<td>5.1</td>
<td>1.566</td>
<td>1.668</td>
</tr>
<tr>
<td>- POSEIDON 1st/POSEIDON 2nd/OPT 71 SOA/OPT 71 SOA</td>
<td>5.1</td>
<td>1.399</td>
<td>1.501</td>
</tr>
<tr>
<td>- STRAIGHT &quot;8&quot; THOR + 3 CASTORS/TE 364-2</td>
<td>0.2 (2)</td>
<td>1.894</td>
<td>1.897</td>
</tr>
</tbody>
</table>

(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:

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

Surviving configurations are highlighted in Table 21 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

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# TABLE 21  FIRST LEVEL SCREENING (CONT'D.)

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<th>EXCESSIVE DYN.</th>
<th>EXCESSIVE STAGE DIAM.</th>
<th>INCOMPAT.</th>
<th>EXCESSIVE COST</th>
<th>BACK-UP CONFIGURATION</th>
<th>CONFIGURATION ELIMINATED</th>
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TABLE 22
SECOND LEVEL SCREENING CRITERIA

- Off-Design Performance
  - Circular Orbit - 1111 km (600 n.mi.)
  - Synchronous Transfer
  - Earth Escape
- Phased Growth to 340 kg (750 lbs)
- Step-Down Complexity
- GSE and Launcher Impact
  - Vehicle Length/Diameter
  - Liquid Stages
  - Step-Down Payload
- Technical Risk
- Military Procurement
- Preliminary Launch Vehicle Cost - Recurring Plus Hardware Development
# Table 23: Off-Design Performance Summary – Second Level Screening

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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 Technical Risk - 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 down-rated in the category of technical risk.

4.2.2.6 Military Procurement - 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 Configuration Costs - 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

<table>
<thead>
<tr>
<th>CONFIGURATION NO.</th>
<th>1ST STAGE CONFIGURATION</th>
<th>2ND STAGE CONFIGURATION</th>
<th>3RD STAGE CONFIGURATION</th>
<th>4TH STAGE CONFIGURATION</th>
<th>AVERAGE UNIT LAUNCH COST – $M</th>
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<td>CASTOR II</td>
<td>X259</td>
<td>FW4</td>
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<tr>
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<td>OPT 71 SOLID</td>
<td>FW4</td>
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<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>TE 364-3</td>
<td>FW4</td>
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</tr>
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<td>7S2</td>
<td>OPT 75 SOLID</td>
<td>OPT 75 SOLID</td>
<td>TE 364-3</td>
<td>FW4</td>
<td></td>
</tr>
<tr>
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<td>TE 364-3</td>
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<td>OPT 71 SOLID</td>
<td>FW4</td>
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<td>HP X259</td>
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<tr>
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<td></td>
</tr>
<tr>
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<td>ALGOL III</td>
<td>HP X259</td>
<td>TE 364-3</td>
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</tr>
<tr>
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<td></td>
</tr>
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<td>TE 364-4</td>
<td>FW4</td>
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<td>22J</td>
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<td>STRAIGHT 8 + (3) CASTORS</td>
<td>TE 364-2</td>
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</tbody>
</table>

**Legend:**
- MM: Modified Module
- X259: X-259 Engine
- TE: Thor Engine
- FW: Firing System
### TABLE 25  SECOND LEVEL SCREENING

<table>
<thead>
<tr>
<th>NO.</th>
<th>TYPE</th>
<th>1ST STAGE</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
<th>POOR OFF. DESIGN</th>
<th>PERFORMANCE SUITABLE FOR PHASED GROWTH</th>
<th>STEP DOWN COMPLEXITY</th>
<th>HIGH TECH. ON GSE</th>
<th>RISK</th>
<th>RELIANCE ON MILITARY PROCUREMENT</th>
<th>HIGH COST</th>
<th>CONFIGURATION ELIMINATED</th>
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<td>22F</td>
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<tr>
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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>
<thead>
<tr>
<th>TABLE 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>THIRD LEVEL SCREENING CRITERIA</td>
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</tbody>
</table>

- OFF-DESIGN PERFORMANCE
- TECHNICAL RISK
- STEP-DOWN COMPLEXITY
- PAYLOAD SHROUD LENGTH
- COST - RECURRING PLUS HARDWARE DEVELOPMENT
<table>
<thead>
<tr>
<th>NO.</th>
<th>1ST STAGE</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
<th>PAYLOAD WEIGHT – kg</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1111 Km ORBIT</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(100 200 300)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SYNCHRONOUS TRANSFER</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(100 150 200)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ESCAPE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(50 100 150)</td>
</tr>
<tr>
<td>× 23A</td>
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<td>SHORT ALG III</td>
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<td>OPT 71 SOLID</td>
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<td></td>
</tr>
<tr>
<td>× 7U1</td>
<td>OPT 71 SOLID</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td></td>
<td></td>
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<tr>
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<tr>
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<td>SHORT ALG III</td>
<td>HP X259</td>
<td>FW4</td>
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</tbody>
</table>
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 II, 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 7UI 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>
<thead>
<tr>
<th>NO.</th>
<th>1ST STAGE</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
<th>AVERAGE UNIT LAUNCH COST – $M</th>
</tr>
</thead>
<tbody>
<tr>
<td>23A</td>
<td>ALGOL III</td>
<td>SHORT ALG III</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>2.0</td>
</tr>
<tr>
<td>7U</td>
<td>ALG III + (2) CASTORS</td>
<td>SHORT ALG III</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td>2.5</td>
</tr>
<tr>
<td>7U1</td>
<td>OPT 71 SOLID</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>7U2</td>
<td>SHORT ALG III</td>
<td>HP X259</td>
<td>TE 364-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7U3</td>
<td>SHORT ALG III</td>
<td>HP X259</td>
<td>SHORT X259</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7U4</td>
<td>ALG III + (2) STR. CASTORS</td>
<td>SHORT ALG III</td>
<td>HP X259</td>
<td>FW4</td>
<td></td>
</tr>
</tbody>
</table>
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 7UL 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

<table>
<thead>
<tr>
<th>NO.</th>
<th>1ST STAGE</th>
<th>2ND STAGE</th>
<th>3RD STAGE</th>
<th>4TH STAGE</th>
<th>MARGINAL DESIGN</th>
<th>TECHNICAL RISK</th>
<th>STEP DOWN COMPLEXITY</th>
<th>PAYLOAD SHROUD LENGTH</th>
<th>COST</th>
<th>ELIMINATED CONFIGURATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>23A</td>
<td>ALGOL III</td>
<td>SHORT ALG III</td>
<td>OPT 71 SOLID</td>
<td>OPT 71 SOLID</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>23A</td>
</tr>
<tr>
<td>7U</td>
<td>ALG III +</td>
<td>SHORT ALG III</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>7U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) CASTORS</td>
<td>OPT 71 SOLID</td>
<td>TE 364-4</td>
<td>TE 364-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7U1</td>
</tr>
<tr>
<td>7U1</td>
<td>SHORT ALG III</td>
<td>HP X259</td>
<td>TE 364-3</td>
<td>TE 364-3</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td>7U2</td>
<td>SHORT ALG III</td>
<td>HP X259</td>
<td>SHORT X259</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NONE</td>
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<tr>
<td>7U3</td>
<td>SHORT ALG III</td>
<td>HP X259</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7U4</td>
<td>ALG III +</td>
<td>SHORT ALG III</td>
<td>FW4</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>7U4</td>
</tr>
<tr>
<td></td>
<td>(2) STR. CASTORS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>
TABLE 30  FINAL EVALUATION

<table>
<thead>
<tr>
<th>PAYLOAD</th>
<th>AVERAGE UNIT LAUNCH COST ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>556 km (300 n.mi.) ORBIT</td>
<td>ALG III + (2) CASTORS/SHORT ALG III/HP X259/TE 364-3 7U2</td>
</tr>
<tr>
<td>1111 km (600 n.mi.) ORBIT</td>
<td>ALG III + (2) CASTORS/SHORT ALG III/HP X259/SHORT X259 7U3</td>
</tr>
<tr>
<td>SYNCHRONOUS TRANSFER</td>
<td></td>
</tr>
<tr>
<td>EARTH ESCAPE</td>
<td></td>
</tr>
</tbody>
</table>

MARGIN
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
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 $295 \text{ m/s}^2$ (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

<table>
<thead>
<tr>
<th>System Characteristic</th>
<th>Kearfott KT-70</th>
<th>Litton LN-30</th>
<th>GE SIR</th>
<th>Honeywell H-487</th>
<th>Teledyne TDS-2</th>
<th>Hamilton Standard DIGS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type IMU</strong></td>
<td>Gimballed (4)</td>
<td>Gimballed (4)</td>
<td>Gimballed (3)</td>
<td>Strapdown</td>
<td>Strapdown</td>
<td>Strapdown</td>
</tr>
<tr>
<td><strong>Computer</strong></td>
<td>SKC-2000</td>
<td>LC-4516</td>
<td>CP-24A</td>
<td>Modified HDC-250</td>
<td>Modified TDY-300</td>
<td>TDY-300 (Alternate Ham. Std. Comp.)</td>
</tr>
<tr>
<td><strong>IMU Status</strong></td>
<td>Production</td>
<td>Initial Production</td>
<td>Produced</td>
<td>Development</td>
<td>Development</td>
<td>Production</td>
</tr>
<tr>
<td><strong>Computer Status</strong></td>
<td>Initial Production</td>
<td>Production</td>
<td>Development</td>
<td>Development</td>
<td>Development</td>
<td>Production-Alternate Development</td>
</tr>
<tr>
<td><strong>Gyro</strong></td>
<td>Gyroflex</td>
<td>G-1200</td>
<td>Kearfott 2401</td>
<td>GG1009</td>
<td>SDG-2</td>
<td>RI-1139</td>
</tr>
<tr>
<td><strong>Accelerometer</strong></td>
<td>Kearfott 2414 &amp; 2401</td>
<td>A-1000</td>
<td>Kearfott 2564</td>
<td>GG326, GG177</td>
<td>FP-1</td>
<td>Kearfott 2401</td>
</tr>
<tr>
<td><strong>Weight:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMU, Computer &amp; Electronics*</td>
<td>22.6 kg 49.9 lb</td>
<td>18.1 kg 40 lb</td>
<td>23.3 kg 57.4 lb</td>
<td>15.4 kg 34 lb</td>
<td>13.6 kg 30 lb</td>
<td>37.8 kg 70 lb</td>
</tr>
<tr>
<td>Additional Control Electronics*</td>
<td>2.3 kg 5 lb</td>
<td>3.6 kg 8 lb</td>
<td>3.6 kg 8 lb</td>
<td>3.6 kg 8 lb</td>
<td>3.6 kg 8 lb</td>
<td>3.6 kg 8 lb</td>
</tr>
<tr>
<td>Power Cond. &amp; Interface</td>
<td>1.8 kg 4 lb</td>
<td>1.8 kg 4 lb</td>
<td>1.8 kg 4 lb</td>
<td>1.8 kg 4 lb</td>
<td>1.8 kg 4 lb</td>
<td>1.8 kg 4 lb</td>
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<tr>
<td>Rate Gyros</td>
<td>.9 kg 2 lb</td>
<td>.9 kg 2 lb</td>
<td>.9 kg 2 lb</td>
<td>.9 kg 2 lb</td>
<td>.9 kg 2 lb</td>
<td>.9 kg 2 lb</td>
</tr>
<tr>
<td>TOTAL SYSTEM WEIGHT</td>
<td>27.6 kg 60.9 lb</td>
<td>24.5 kg 54 lb</td>
<td>29.7 kg 65.4 lb</td>
<td>21.8 kg 48 lb</td>
<td>20.0 kg 44 lb</td>
<td>38.1 kg 84 lb</td>
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<tr>
<td>Power - Watts</td>
<td>355 W</td>
<td>254 W</td>
<td>195 W</td>
<td>180 W</td>
<td>90 W</td>
<td>215 W</td>
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<tr>
<td>Linear Acceleration Tests</td>
<td>m/s²</td>
<td>m/s²</td>
<td>m/s²</td>
<td>m/s²</td>
<td>m/s²</td>
<td>m/s²</td>
</tr>
<tr>
<td></td>
<td>245.4 25 g/s</td>
<td>166.9 17 g/s</td>
<td>157 16 g/s</td>
<td>- - g/s</td>
<td>- - g/s</td>
<td>147.2 15 g/s</td>
</tr>
<tr>
<td>Design Acceleration</td>
<td>&gt;196.3 20 g/s</td>
<td>&gt;196.3 20 g/s</td>
<td>&gt;392.6 40 g/s</td>
<td>&gt;490.8 50 g/s</td>
<td>&gt;245.4 25 g/s</td>
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</tr>
</tbody>
</table>

* 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>
<thead>
<tr>
<th>Error Source</th>
<th>Units</th>
<th>Kearfott KT-70</th>
<th>Litton LN-30</th>
<th>GE SIR</th>
<th>Honeywell H-487</th>
<th>Teledyne TDS-2</th>
<th>Hamilton Standard DIDS</th>
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<tr>
<td>Platform:</td>
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</tr>
<tr>
<td>Vertical Alignment</td>
<td>arc sec</td>
<td>20 (22)</td>
<td>20 (20)</td>
<td>15</td>
<td>30 (30)</td>
<td>30 (45)</td>
<td>11 (11)</td>
</tr>
<tr>
<td>Azimuth Alignment</td>
<td>arc sec</td>
<td>60 (47)</td>
<td>60 (60)</td>
<td>60</td>
<td>40 (40)</td>
<td>30 (60)</td>
<td>20 (20)</td>
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<td>Gyros:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non g-Sensitive Drift (Level)</td>
<td>deg/hr</td>
<td>.2 (.2)</td>
<td>.03 (.003)</td>
<td>.1</td>
<td>.33 (.1)</td>
<td>.007 (.01)</td>
<td>.033 (.033)</td>
</tr>
<tr>
<td>Non g-Sensitive Drift (Vertical)</td>
<td>deg/hr</td>
<td>.2 (.2)</td>
<td>.03 (.003)</td>
<td>.1</td>
<td>.33 (.25)</td>
<td>.007 (.01)</td>
<td>.033 (.033)</td>
</tr>
<tr>
<td>Mass Unbalance (Input Axis)</td>
<td>deg/hr/g</td>
<td>.05 (.05)</td>
<td>.05 (.01)</td>
<td>.15</td>
<td>.434 (.4)</td>
<td>.003 (.02)</td>
<td>.133 (.133)</td>
</tr>
<tr>
<td>Mass Unbalance (Output Axis)</td>
<td>deg/hr/g</td>
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<td>.05 (.03)</td>
<td>.15</td>
<td>.434 (.5)</td>
<td>.003 (.003)</td>
<td>.133 (.133)</td>
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<td>Compliance</td>
<td>deg/hr/g²</td>
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<td>.02 (.01)</td>
<td>.02</td>
<td>.02 (.3)</td>
<td>.02 (.02)</td>
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<td>Torquing Scale Factor Error</td>
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<td>NA</td>
<td>NA</td>
<td>.0033 (.05)</td>
<td>.0003 (.0003)</td>
<td>.005 (.005)</td>
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<tr>
<td>Input Axis Align.-SA Plane</td>
<td>arc sec</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>25 (40)</td>
<td>20 (30)</td>
<td>10 (10)</td>
</tr>
<tr>
<td>Input Axis Align.-OA Plane</td>
<td>arc sec</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>20 (40)</td>
<td>20 (20)</td>
<td>10 (10)</td>
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<td>Accelerometers:</td>
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<tr>
<td>Bias (Level)</td>
<td>µg</td>
<td>70 (70)</td>
<td>100 (10)</td>
<td>70</td>
<td>500 (500)</td>
<td>20 (20)</td>
<td>41.8 (41.8)</td>
</tr>
<tr>
<td>Bias (Vertical)</td>
<td>µg</td>
<td>70 (50)</td>
<td>100 (10)</td>
<td>70</td>
<td>50 (50)</td>
<td>20 (20)</td>
<td>41.3 (41.8)</td>
</tr>
<tr>
<td>Scale Factor Stability (Level)</td>
<td>µg/g</td>
<td>167 (100)</td>
<td>100 (250)</td>
<td>200</td>
<td>200 (620)</td>
<td>150 (150)</td>
<td>66 (66)</td>
</tr>
<tr>
<td>Scale Factor Stability (Vertical)</td>
<td>µg/g</td>
<td>200 (100)</td>
<td>100 (250)</td>
<td>200</td>
<td>167 (200)</td>
<td>150 (150)</td>
<td>66 (66)</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>µg/g²</td>
<td>7.5 (10)</td>
<td>40 (35)</td>
<td>10</td>
<td>0.0 0.0</td>
<td>20 (20)</td>
<td>1.67 (1.67)</td>
</tr>
<tr>
<td>Alignment</td>
<td>arc sec</td>
<td>20 (20)</td>
<td>20 (20)</td>
<td>20</td>
<td>10 (20)</td>
<td>15 (20)</td>
<td>10 (10)</td>
</tr>
</tbody>
</table>

( ) 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>
<thead>
<tr>
<th>Guidance System</th>
<th>$\sigma_x$</th>
<th>$\sigma_y$</th>
<th>$\sigma_z$</th>
<th>$\sigma_{vel}$</th>
<th>$\sigma_{\Delta v}$</th>
<th>$\sigma_{\Delta x}$</th>
<th>$\sigma_{\Delta y}$</th>
<th>$\sigma_{\Delta z}$</th>
<th>$\sigma_{\Delta v_{x}}$</th>
<th>$\sigma_{\Delta v_{y}}$</th>
<th>$\sigma_{\Delta v_{z}}$</th>
<th>$\sigma_{\Delta v_{x},\Delta v_{y}}$</th>
<th>$\sigma_{\Delta v_{y},\Delta v_{z}}$</th>
<th>$\sigma_{\Delta v_{x},\Delta v_{z}}$</th>
<th>$\sigma_{\Delta v_{x},\Delta v_{y},\Delta v_{z}}$</th>
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</thead>
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<tr>
<td>Kearfott KT-70</td>
<td>1.36</td>
<td>4.11</td>
<td>12.85</td>
<td>3.12</td>
<td>10.24</td>
<td>5.34</td>
<td>17.53</td>
<td>826</td>
<td>2711</td>
<td>1230</td>
<td>4037</td>
<td>789</td>
<td>2588</td>
<td>1542</td>
<td>5059</td>
</tr>
<tr>
<td>KT-70, Ref B-1 Error Budget</td>
<td>1.35</td>
<td>4.43</td>
<td>3.64</td>
<td>11.95</td>
<td>3.12</td>
<td>10.22</td>
<td>4.98</td>
<td>16.34</td>
<td>637</td>
<td>2096</td>
<td>1096</td>
<td>3595</td>
<td>691</td>
<td>2856</td>
<td>1447</td>
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<tr>
<td>Litton LM-30</td>
<td>3.29</td>
<td>10.73</td>
<td>2.57</td>
<td>8.42</td>
<td>1.79</td>
<td>5.87</td>
<td>4.36</td>
<td>14.88</td>
<td>883</td>
<td>2897</td>
<td>726</td>
<td>2391</td>
<td>728</td>
<td>2398</td>
<td>1357</td>
</tr>
<tr>
<td>LM-30, Ref B-1 Error Budget</td>
<td>3.29</td>
<td>11.12</td>
<td>2.45</td>
<td>8.04</td>
<td>1.63</td>
<td>5.34</td>
<td>4.49</td>
<td>14.72</td>
<td>1068</td>
<td>3505</td>
<td>1043</td>
<td>3401</td>
<td>956</td>
<td>3135</td>
<td>1772</td>
</tr>
<tr>
<td>GE-SIR</td>
<td>1.87</td>
<td>6.15</td>
<td>3.38</td>
<td>11.09</td>
<td>2.92</td>
<td>9.57</td>
<td>4.84</td>
<td>15.89</td>
<td>860</td>
<td>2822</td>
<td>1281</td>
<td>4203</td>
<td>928</td>
<td>3043</td>
<td>1799</td>
</tr>
<tr>
<td>Honeywell H-487</td>
<td>4.21</td>
<td>11.81</td>
<td>6.62</td>
<td>21.71</td>
<td>4.79</td>
<td>15.73</td>
<td>9.19</td>
<td>30.16</td>
<td>2471</td>
<td>8107</td>
<td>1807</td>
<td>5909</td>
<td>2065</td>
<td>6774</td>
<td>3701</td>
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<tr>
<td>H-487, Ref B-1 Error Budget</td>
<td>4.21</td>
<td>13.80</td>
<td>6.26</td>
<td>20.49</td>
<td>6.30</td>
<td>20.66</td>
<td>9.81</td>
<td>32.20</td>
<td>2609</td>
<td>9560</td>
<td>1951</td>
<td>6401</td>
<td>2339</td>
<td>7673</td>
<td>4011</td>
</tr>
<tr>
<td>Teledyne TDS-2</td>
<td>2.21</td>
<td>7.24</td>
<td>2.14</td>
<td>7.02</td>
<td>1.37</td>
<td>4.50</td>
<td>3.36</td>
<td>11.04</td>
<td>809</td>
<td>2654</td>
<td>865</td>
<td>2849</td>
<td>766</td>
<td>2513</td>
<td>1412</td>
</tr>
<tr>
<td>TDS-2, Ref B-1 Error Budget</td>
<td>2.27</td>
<td>7.46</td>
<td>2.97</td>
<td>9.75</td>
<td>1.93</td>
<td>6.34</td>
<td>4.21</td>
<td>13.61</td>
<td>963</td>
<td>3158</td>
<td>1225</td>
<td>4019</td>
<td>937</td>
<td>3075</td>
<td>1218</td>
</tr>
<tr>
<td>Hamilton Standard DIGS</td>
<td>.70</td>
<td>2.31</td>
<td>1.41</td>
<td>4.64</td>
<td>.96</td>
<td>3.21</td>
<td>1.86</td>
<td>6.10</td>
<td>656</td>
<td>2153</td>
<td>555</td>
<td>1822</td>
<td>661</td>
<td>2170</td>
<td>1085</td>
</tr>
</tbody>
</table>

( ) * TMAF routine results from Reference B-16

XYZ - Launch point vertical coordinate system
## TABLE 34  INERTIAL GUIDANCE INJECTION DEVIATIONS

185 km (100 n. mi.) ORBIT

<table>
<thead>
<tr>
<th>Guidance System</th>
<th>$\sigma_x$</th>
<th>$\sigma_y$</th>
<th>$\sigma_z$</th>
<th>$\sigma_{vel}$</th>
<th>$\sigma_x$</th>
<th>$\sigma_y$</th>
<th>$\sigma_z$</th>
<th>$\tau_{pos}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m/s</td>
<td>ft/s</td>
<td>m/s</td>
<td>ft/s</td>
<td>m/s</td>
<td>ft/s</td>
<td>m</td>
<td>ft</td>
</tr>
<tr>
<td>Keafott KT-70</td>
<td>1.60</td>
<td>5.26</td>
<td>2.88</td>
<td>9.46</td>
<td>2.01</td>
<td>6.60</td>
<td>3.86</td>
<td>12.68</td>
</tr>
<tr>
<td>KT-70, Ref B-1 Error Budget</td>
<td>3.96</td>
<td>12.48</td>
<td>2.53</td>
<td>8.11</td>
<td>2.03</td>
<td>6.69</td>
<td>3.38</td>
<td>11.10</td>
</tr>
<tr>
<td>Litton LN-30</td>
<td>2.16</td>
<td>6.68</td>
<td>2.40</td>
<td>7.89</td>
<td>1.37</td>
<td>4.50</td>
<td>3.51</td>
<td>11.52</td>
</tr>
<tr>
<td>LN-30, Ref B-1 Error Budget</td>
<td>2.57</td>
<td>8.42</td>
<td>2.32</td>
<td>7.60</td>
<td>1.16</td>
<td>3.80</td>
<td>3.66</td>
<td>12.01</td>
</tr>
<tr>
<td>GE SIR</td>
<td>1.63</td>
<td>5.26</td>
<td>2.68</td>
<td>8.60</td>
<td>2.47</td>
<td>8.12</td>
<td>4.00</td>
<td>13.11</td>
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<td>Honeywell H-457</td>
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<td>3.94</td>
<td>12.99</td>
<td>2.84</td>
<td>9.32</td>
<td>5.50</td>
<td>18.03</td>
</tr>
<tr>
<td>H-457, Ref B-1 Error Budget</td>
<td>2.63</td>
<td>8.44</td>
<td>4.35</td>
<td>14.28</td>
<td>5.81</td>
<td>19.05</td>
<td>7.72</td>
<td>25.33</td>
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<tr>
<td>Teledyne TDS-2</td>
<td>1.56</td>
<td>4.96</td>
<td>2.02</td>
<td>6.62</td>
<td>1.27</td>
<td>4.16</td>
<td>2.85</td>
<td>9.35</td>
</tr>
<tr>
<td>TDS-2, Ref B-1 Error Budget</td>
<td>1.59</td>
<td>5.22</td>
<td>2.76</td>
<td>9.06</td>
<td>1.83</td>
<td>6.01</td>
<td>3.68</td>
<td>12.06</td>
</tr>
<tr>
<td>Hamilton Standard DIGS</td>
<td>1.55</td>
<td>4.96</td>
<td>1.01</td>
<td>3.30</td>
<td>0.83</td>
<td>2.72</td>
<td>1.42</td>
<td>4.65</td>
</tr>
</tbody>
</table>

$\tau_{pos}$ - 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.m.i.) 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
CIRCULAR ORBIT
WALLOPS ISLAND LAUNCH

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
CIRCULAR ORBIT
WALLOPS ISLAND LAUNCH
NOMINAL INCLINATION = 37.68 DEGREES

INCLINATION DEVIATION, $\Delta_i$

DEGREES

0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99

PROBABILITY THAT $0 \leq |\text{DEVIATION}| \leq \Delta_i$ %

FIGURE 19 INERTIAL GUIDANCE INCLINATION DEVIATIONS,
185 km (100 n. mi.) ORBIT
<table>
<thead>
<tr>
<th>Error Source</th>
<th>Standard Deviations (1σ)</th>
<th>Velocity</th>
<th>Flight Path Angle</th>
<th>Azimuth Angle</th>
<th>Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>m/s</td>
<td>deg</td>
<td>deg</td>
<td>m</td>
</tr>
<tr>
<td>Algol IIB Performance</td>
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<td>21.1</td>
<td>0.081</td>
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<td>4.4</td>
<td>0.051</td>
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<td>X-259 Performance</td>
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<td>11.2</td>
<td>0.068</td>
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<td>FW-4S Performance</td>
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<td>11.7</td>
<td>38.4</td>
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<td>0.001</td>
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<tr>
<td>Guidance System (Pitch)</td>
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<td>6.9</td>
<td>22.8</td>
<td>0.100</td>
<td>0.001</td>
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<tr>
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<td>0.6</td>
<td>1.9</td>
<td>0.004</td>
<td>0.065</td>
</tr>
<tr>
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<td>27.8</td>
<td>0.006</td>
<td>0.002</td>
</tr>
<tr>
<td>Thrust Misalignment (Yaw)</td>
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<td>4.6</td>
<td>0.008</td>
<td>0.190</td>
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<td>Aerodynamic Drag</td>
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<td>Atmosphere</td>
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<td>0.001</td>
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<td>Tailwind</td>
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<td>6.6</td>
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<td>10.3</td>
<td>33.8</td>
<td>0.043</td>
<td>0.001</td>
</tr>
<tr>
<td>Stage 2 Boost Deadband (Roll)</td>
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<td>1.5</td>
<td>0.003</td>
<td>0.058</td>
</tr>
<tr>
<td>Stage 2 Boost Deadband (Yaw)</td>
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<td>0.5</td>
<td>1.6</td>
<td>0.004</td>
<td>0.035</td>
</tr>
<tr>
<td>Stage 2 Coast Deadband (Pitch)</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Stage 2 Coast Deadband (Roll)</td>
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<td>0.1</td>
<td>0.2</td>
<td>0.000</td>
<td>0.005</td>
</tr>
<tr>
<td>Stage 3 Boost Deadband (Pitch)</td>
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<td>32.9</td>
<td>0.060</td>
<td>0.001</td>
</tr>
<tr>
<td>Stage 3 Boost Deadband (Roll)</td>
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<td>0.2</td>
<td>0.8</td>
<td>0.001</td>
<td>0.017</td>
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<tr>
<td>Stage 3 Boost Deadband (Yaw)</td>
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<td>2.2</td>
<td>0.004</td>
<td>0.055</td>
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<td>Stage 4 Tipoff (Pitch)</td>
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<td>6.0</td>
<td>19.8</td>
<td>0.442</td>
<td>0.010</td>
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<td>Stage 4 Tipoff (Yaw)</td>
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<td>5.9</td>
<td>19.5</td>
<td>0.014</td>
<td>0.404</td>
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<tr>
<td>RSS TOTAL</td>
<td></td>
<td>25.1</td>
<td>82.5</td>
<td>0.480</td>
<td>0.466</td>
</tr>
</tbody>
</table>
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
5.2.2 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

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Standard Deviations (1σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td>m/s</td>
</tr>
<tr>
<td>Fourth Stage Tipoff</td>
<td>10.2</td>
</tr>
<tr>
<td>Second and Third Stage Boost Deadbands</td>
<td>15.4</td>
</tr>
<tr>
<td>Motor Performance (4 motors)</td>
<td>16.9</td>
</tr>
<tr>
<td>Drag Winds, Atmosphere</td>
<td>4.4</td>
</tr>
<tr>
<td>Guidance</td>
<td>7.5</td>
</tr>
<tr>
<td>First Stage Thrust Misalignment</td>
<td>9.1</td>
</tr>
<tr>
<td>RSS TOTAL</td>
<td>28.0</td>
</tr>
</tbody>
</table>
TABLE 37 - INJECTION DEVIATIONS - CURRENT SCOUT, 185 km (100 n.mi.) ORBIT

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Standard Deviations (1σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td>m/s</td>
</tr>
<tr>
<td>Fourth Stage Tipoff</td>
<td>8.2</td>
</tr>
<tr>
<td>Second and Third Stage Boost Deadbands</td>
<td>13.9</td>
</tr>
<tr>
<td>Motor Performance (4 motors)</td>
<td>13.4</td>
</tr>
<tr>
<td>Drag Winds, Atmosphere</td>
<td>5.8</td>
</tr>
<tr>
<td>Guidance</td>
<td>6.7</td>
</tr>
<tr>
<td>First Stage Thrust Misalignment</td>
<td>8.3</td>
</tr>
<tr>
<td>RSS TOTAL</td>
<td>24.3</td>
</tr>
</tbody>
</table>

118
<table>
<thead>
<tr>
<th>Modular Improvement</th>
<th>Standard Deviations (1σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td>m/s</td>
</tr>
<tr>
<td>Current Scout System</td>
<td>28.0</td>
</tr>
<tr>
<td>+ Fourth Stage Attitude Reference &amp; Control Sys.</td>
<td>26.5</td>
</tr>
<tr>
<td>+ Reduced Second &amp; Third Stage Boost Deadbands</td>
<td>21.9</td>
</tr>
<tr>
<td>+ Fourth Stage Velocity Control System</td>
<td>13.7</td>
</tr>
<tr>
<td>+ Third Stage Computer to Adjust Pitch Program and Fourth Stage Velocity Cutoff</td>
<td></td>
</tr>
<tr>
<td>• Compensate roll gyro g-sensitive drift, fin misalignment and pitch program</td>
<td>12.3</td>
</tr>
<tr>
<td>uncertainties</td>
<td></td>
</tr>
<tr>
<td>+</td>
<td></td>
</tr>
<tr>
<td>• Lateral accelerometers to correct first stage thrust misalignment</td>
<td>8.7</td>
</tr>
<tr>
<td>+</td>
<td></td>
</tr>
<tr>
<td>• Compensate (adjust pitch program) for flight path angle and attitude errors</td>
<td>8.7</td>
</tr>
<tr>
<td>during first three stages</td>
<td></td>
</tr>
<tr>
<td>Modular Improvement</td>
<td>Standard Deviations (1σ)</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td>m/s</td>
</tr>
<tr>
<td>Current Scout System</td>
<td>24.3</td>
</tr>
<tr>
<td>+ Fourth Stage Attitude Reference &amp; Control Sys.</td>
<td>23.1</td>
</tr>
<tr>
<td>+ Reduced Second &amp; Third Stage Boost Deadbands</td>
<td>18.9</td>
</tr>
<tr>
<td>+ Fourth Stage Velocity Control System</td>
<td>12.4</td>
</tr>
<tr>
<td>+ Third Stage Computer to Adjust Pitch Program and Fourth Stage Velocity Cutoff</td>
<td></td>
</tr>
<tr>
<td>• Compensate roll gyro g-sensitive drift, fin misalignment and pitch program uncertainties +</td>
<td>11.2</td>
</tr>
<tr>
<td>• Lateral accelerometers to correct first stage thrust misalignment +</td>
<td>7.8</td>
</tr>
<tr>
<td>• Compensate (adjust pitch program) for path angle and attitude errors during first three stages</td>
<td>7.8</td>
</tr>
</tbody>
</table>
CIRCULAR ORBIT
WALLOPS ISLAND LAUNCH

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 corres-
ponding 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>
<thead>
<tr>
<th>Error Source</th>
<th>Standard Deviations (1σ)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity</td>
<td>Flight Path Angle</td>
<td>Azimuth Angle</td>
<td>Altitude</td>
<td></td>
</tr>
<tr>
<td></td>
<td>m/s</td>
<td>ft/s</td>
<td>deg</td>
<td>deg</td>
<td>m</td>
</tr>
<tr>
<td>Fourth Stage Tipoff</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>
</tr>
<tr>
<td>Motor Performance (4 motors)</td>
<td>3.3</td>
<td>10.8</td>
<td>.174</td>
<td>.018</td>
<td>10128</td>
</tr>
<tr>
<td>Drag Winds, Atmosphere</td>
<td>8.1</td>
<td>26.5</td>
<td>.140</td>
<td>.076</td>
<td>3812</td>
</tr>
<tr>
<td>Guidance</td>
<td>9.1</td>
<td>29.8</td>
<td>.045</td>
<td>.146</td>
<td>1525</td>
</tr>
<tr>
<td>First Stage Thrust Misalignment</td>
<td>0.2</td>
<td>0.5</td>
<td>.074</td>
<td>.074</td>
<td>79</td>
</tr>
<tr>
<td>Fourth Stage Deadbands</td>
<td>19.9</td>
<td>65.3</td>
<td>.267</td>
<td>.206</td>
<td>13448</td>
</tr>
</tbody>
</table>

- 1111 km Circular Orbit
### TABLE 41 - INJECTION ERRORS - OPEN LOOP FOURTH STAGE GUIDANCE WITH VELOCITY CONTROL SYSTEM AND REDUCED DEADBANDS

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Standard Deviations (1σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td>m/s</td>
</tr>
<tr>
<td>Fourth Stage Tipoff</td>
<td>0</td>
</tr>
<tr>
<td>Second and Third Stage Boost Deadbands</td>
<td>4.4</td>
</tr>
<tr>
<td>Motor Performance (4 motors)</td>
<td>3.3</td>
</tr>
<tr>
<td>Drag Winds, Atmosphere</td>
<td>8.1</td>
</tr>
<tr>
<td>Guidance</td>
<td>9.1</td>
</tr>
<tr>
<td>First Stage Thrust Misalignment</td>
<td>0.2</td>
</tr>
<tr>
<td>Fourth Stage Deadbands</td>
<td>13.4</td>
</tr>
</tbody>
</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
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
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 approaches. 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:

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

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

<table>
<thead>
<tr>
<th>Development:</th>
<th>Guidance Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inertial Guidance</td>
</tr>
<tr>
<td>Hardware</td>
<td>$2.1M</td>
</tr>
<tr>
<td>Hardware</td>
<td>1.25M</td>
</tr>
<tr>
<td>Software</td>
<td>$67K</td>
</tr>
<tr>
<td>Amortized Development (50 Systems)</td>
<td>$210K</td>
</tr>
<tr>
<td>Unit Recurring</td>
<td>$277K</td>
</tr>
<tr>
<td>Total (Recurring Plus Amortized Development)</td>
<td></td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Weight:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg</td>
</tr>
<tr>
<td>IMU (Platform)</td>
<td>7.2</td>
</tr>
<tr>
<td>Computer</td>
<td>10.0</td>
</tr>
<tr>
<td>Power Conditioner</td>
<td>2.5</td>
</tr>
<tr>
<td>Electronics (Platform + Partial Control)</td>
<td>2.9</td>
</tr>
<tr>
<td>Rate Gyros</td>
<td>.9</td>
</tr>
<tr>
<td>Additional Control Electronics (Including Filters and Power Switching)</td>
<td>2.3</td>
</tr>
<tr>
<td>Additional Power Conditioning and Expanded Interface</td>
<td>1.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>27.6</td>
</tr>
</tbody>
</table>
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

- ALL MOTORS ARE MODIFICATIONS OF EXISTING FLIGHT HARDWARE
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 arrange-
ment 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 detonat-
ing 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 connec-
tions 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.
DETONATING CORD

PLASTIC MATRIX

FRANGIBLE DOUBLER

STEEL JACKET

BEFORE FUNCTION

SKIN

AFTER FUNCTION

FIGURE 28 LOCKHEED SUPER ZIP LINEAR SEPARATION SYSTEM
6.1.10 **Reaction Control Systems** - The control systems evaluated were current Scout hydrogen peroxide ($\text{H}_2\text{O}_2$), Solid Gas Generator (GG), Liquid Injection Thrust Vector Control (LITVC), and Hydrazine ($\text{N}_2\text{H}_4$). The current Scout $\text{H}_2\text{O}_2$ systems were selected for the ASLV for the following reasons:

1. The Scout hardware (thrusters, tanks, pressure regulators, and $\text{N}_2$ 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 $\text{N}_2\text{H}_4$ system would require development. Because of the high cost of the catalyst bed, the recurring cost of $\text{N}_2\text{H}_2$ thrusters is five times that of the Scout $\text{H}_2\text{O}_2$ thrusters. The density of $\text{N}_2\text{H}_4$ is about two-thirds that of $\text{H}_2\text{O}_2$. 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 $\text{M}$ 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 $\text{H}_2\text{O}_2$ or some other system would be required for the cost phase. The weight trade offs showed no payload improvement over the $\text{H}_2\text{O}_2$ system. In addition, a 3/4 $\text{M}$ 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 inertial 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

<table>
<thead>
<tr>
<th>Event</th>
<th>Weight</th>
<th>Center of Gravity</th>
<th>Moment of Inertia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb</td>
<td>kg</td>
<td>X (in)</td>
</tr>
<tr>
<td>STAGE 0 &amp; 1 IGNITION</td>
<td>80,194</td>
<td>36,368</td>
<td>542.04</td>
</tr>
<tr>
<td>STAGE 0 BURNOUT</td>
<td>47,454</td>
<td>21,520</td>
<td>443.14</td>
</tr>
<tr>
<td>STAGE 1 INTERIM</td>
<td>44,074</td>
<td>19,863</td>
<td>420.68</td>
</tr>
<tr>
<td>STAGE 1 BURNOUT</td>
<td>32,060</td>
<td>14,535</td>
<td>336.42</td>
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<tr>
<td>STAGE 2 IGNITION</td>
<td>27,571</td>
<td>12,503</td>
<td>278.11</td>
</tr>
<tr>
<td>STAGE 2 BURNOUT</td>
<td>9,571</td>
<td>4,340</td>
<td>178.66</td>
</tr>
<tr>
<td>STAGE 3 IGNITION</td>
<td>5,938</td>
<td>2,693</td>
<td>91.21</td>
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<tr>
<td>STAGE 3 BURNOUT</td>
<td>3,335</td>
<td>1,512</td>
<td>48.92</td>
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<tr>
<td>STAGE 4 IGNITION</td>
<td>2,857</td>
<td>1,296</td>
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<tr>
<td>STAGE 4 BURNOUT</td>
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<td>529</td>
<td>2.23</td>
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### TABLE 44
ASLV WEIGHT BREAKDOWN

<table>
<thead>
<tr>
<th>COMPONENT/EVENT</th>
<th>STAGE WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbs</td>
</tr>
<tr>
<td>PAYLOAD</td>
<td></td>
</tr>
<tr>
<td>STEP 4</td>
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<tr>
<td>E-Section</td>
<td>750</td>
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<tr>
<td>Systems</td>
<td></td>
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<tr>
<td>Structure</td>
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</tr>
<tr>
<td>Systems</td>
<td></td>
</tr>
<tr>
<td>Motor - Short 259</td>
<td>155</td>
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<tr>
<td>Burnout</td>
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</tr>
<tr>
<td>Motor Section</td>
<td>20</td>
</tr>
<tr>
<td>Ignition &amp; Guidance Harness, Misc.</td>
<td></td>
</tr>
<tr>
<td>Upper D</td>
<td>114</td>
</tr>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Systems</td>
<td></td>
</tr>
<tr>
<td>STAGE 4 BURNOUT</td>
<td>1167</td>
</tr>
<tr>
<td>Weight Consumed, Short 259 Motor</td>
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<tr>
<td>STAGE 4 IGNITION</td>
<td>2857</td>
</tr>
<tr>
<td>STEP 3</td>
<td></td>
</tr>
<tr>
<td>Lower D</td>
<td>25</td>
</tr>
<tr>
<td>Systems</td>
<td></td>
</tr>
<tr>
<td>Motor - HP-259</td>
<td></td>
</tr>
<tr>
<td>Burnout</td>
<td>213</td>
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<td>Motor Section</td>
<td>41</td>
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<tr>
<td>T/M &amp; Guid. Tunnels &amp; Harness</td>
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<tr>
<td>Destruct; Noz. Shroud; Misc.</td>
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<tr>
<td>Upper C</td>
<td>199</td>
</tr>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Systems</td>
<td></td>
</tr>
<tr>
<td>STAGE 3 BURNOUT</td>
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</tr>
<tr>
<td>Weight Consumed, HP-259 Motor</td>
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<tr>
<td>STAGE 3 IGNITION</td>
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<tr>
<td>P/L SHROUD</td>
<td>912</td>
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<td>COMPONENT/EVENT</td>
<td>STAGE WEIGHT</td>
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<tr>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td>lbs</td>
</tr>
<tr>
<td><strong>STEP 2</strong></td>
<td></td>
</tr>
<tr>
<td>Lower C</td>
<td>90</td>
</tr>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Systems</td>
<td></td>
</tr>
<tr>
<td>Motor - Short Algol III</td>
<td></td>
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<td>Burnout</td>
<td>2273</td>
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<tr>
<td>Motor Section</td>
<td>61</td>
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<tr>
<td>T/M &amp; Guidance Tunnels &amp; Harness</td>
<td></td>
</tr>
<tr>
<td>Destruct</td>
<td></td>
</tr>
<tr>
<td>Upper B</td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>drops with Stage 1</td>
<td></td>
</tr>
<tr>
<td>flies with Stage 2</td>
<td>87</td>
</tr>
<tr>
<td>Systems</td>
<td>210</td>
</tr>
<tr>
<td><strong>STAGE 2 BURNOUT</strong></td>
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</tr>
<tr>
<td>Weight Consumed, Short Algol III</td>
<td>9571</td>
</tr>
<tr>
<td><strong>STAGE 2 IGNITION</strong></td>
<td></td>
</tr>
<tr>
<td>Upper B - drop structure</td>
<td>27571</td>
</tr>
<tr>
<td><strong>STEP 1</strong></td>
<td></td>
</tr>
<tr>
<td>Lower B</td>
<td>223</td>
</tr>
<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Systems</td>
<td></td>
</tr>
<tr>
<td>Motor - Algol III</td>
<td></td>
</tr>
<tr>
<td>Burnout</td>
<td>3586</td>
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<tr>
<td>Motor Section</td>
<td>90</td>
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<tr>
<td>T/M &amp; Guidance Tunnels &amp; Harness</td>
<td></td>
</tr>
<tr>
<td>Destruct</td>
<td></td>
</tr>
<tr>
<td>Base A</td>
<td>533</td>
</tr>
<tr>
<td>Structure</td>
<td></td>
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<td>Systems</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Weight Consumed, Algol III</td>
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</table>


TABLE 44 (Concluded)

<table>
<thead>
<tr>
<th>COMPONENT/EVENT</th>
<th>STAGE WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1bs</td>
</tr>
<tr>
<td>STAGE 1 INTERIM BURNING (CASTORS OFF)</td>
<td>44074</td>
</tr>
<tr>
<td>STEP 0</td>
<td></td>
</tr>
<tr>
<td>Motor - Castor 5 (2)</td>
<td></td>
</tr>
<tr>
<td>Burnout</td>
<td>3042</td>
</tr>
<tr>
<td>Motor Section - Nose Fairing &amp; RCS (2)</td>
<td>338</td>
</tr>
<tr>
<td>STAGE 0 BURNOUT</td>
<td>47454</td>
</tr>
<tr>
<td>Weight Consumed, Castors (2)</td>
<td>16560</td>
</tr>
<tr>
<td>Weight Consumed, Algol III</td>
<td>16180</td>
</tr>
<tr>
<td>STAGE 0 IGNITION with 340 kg (750 lb) P/L</td>
<td>80194</td>
</tr>
</tbody>
</table>
**Figure 29: Payload Volume**

- **5 Stage**
  - 300 lb Payload, 25 ft³
  - Fifth Stage Motor FW-5

- **4 Stage**
  - Additional Payload Volume Available
  - Fourth Stage Motor (Short X-259)
  - Third Stage Motor HP X-259

- **3 Stage**
  - 760 lb Payload, 62.5 ft³
### Table 45 Summary of Characteristics of Selected Motors

<table>
<thead>
<tr>
<th>MOTOR</th>
<th>DIAMETER</th>
<th>LENGTH</th>
<th>WEIGHT</th>
<th>VACUUM DELIVERED SPECIFIC IMPULSE</th>
<th>VACUUM TOTAL IMPULSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm</td>
<td>inches</td>
<td>cm</td>
<td>inches</td>
<td>N-s/kg</td>
</tr>
<tr>
<td>TX 354-5 Strap-Ons</td>
<td>86.675</td>
<td>34.124</td>
<td>603.86</td>
<td>237.74</td>
<td>4423.1</td>
</tr>
<tr>
<td>Algol III First Stage</td>
<td>114.38</td>
<td>45.03</td>
<td>937.4</td>
<td>373</td>
<td>14442.6</td>
</tr>
<tr>
<td>Short Algol III Second Stage</td>
<td>114.38</td>
<td>45.03</td>
<td>660.4</td>
<td>260</td>
<td>9383.6</td>
</tr>
<tr>
<td>High Pressure X-259 Third Stage</td>
<td>74.4</td>
<td>29.3</td>
<td>389.1</td>
<td>113.8</td>
<td>1279</td>
</tr>
<tr>
<td>Short X-259 Fourth Stage</td>
<td>76.5</td>
<td>30.1</td>
<td>229</td>
<td>90</td>
<td>841.9</td>
</tr>
</tbody>
</table>
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 capability, 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
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.)
WALLOPS ISLAND LAUNCH
LAUNCH AZIMUTH = 90°
ASLV WITH FIFTH STAGE

SUPERIOR ORBITS

INFERIOR ORBITS

FIGURE 37  SOLAR PROBE PERFORMANCE — BURNOUT ALTITUDE 370 km (200 n. mi.)
WALLOPS ISLAND LAUNCH
LAUNCH AZIMUTH = 90°
ORBIT INCLINATION = 37.7°

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

<table>
<thead>
<tr>
<th>Systems</th>
<th>Dallas Sets</th>
<th>Wallops Island Sets</th>
<th>Vandenberg Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Guidance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Modify power switching and</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>gyro monitor circuits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Two axis torque table to</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>calibrate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Guidance system c/o</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(4) Miscellaneous system</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>components, switches, meters,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Cables to pad</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(6) Alignment of guidance</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>system to desired launch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>azimuth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) Resurvey of Bench marks</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Radar Beacon and C/D Receiver</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Modify GSE antenna to</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>properly match vehicle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>antenna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Modify console wiring,</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>switches, meters, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Cables to pad</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Ignition Destruct</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(1) Modify switching capacity</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>for additional pyrotechnic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>functions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Cable to pad</td>
<td>-</td>
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<td>1</td>
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TABLE 46 (Continued)

<table>
<thead>
<tr>
<th>Systems</th>
<th>Dallas Sets</th>
<th>Wallops Island Sets</th>
<th>Vandenberg Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reaction Control System</strong></td>
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<td></td>
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</tr>
<tr>
<td>(1) Modify existing consoles,</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>design and fabricate new</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>consoles and associated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cables, and switching for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>additional monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>capacity for the additional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCS installation for S3T only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Cable to pad</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(3) New RCS test panel in SLC</td>
<td>-</td>
<td>1</td>
<td>1</td>
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<tr>
<td>blockhouse to accommodate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>additional RCS system</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(4) Additional auxiliary</td>
<td>-</td>
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<tr>
<td>equipment, N2 carts,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>portable leak test set,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motor nozzle plugs and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flex hose</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Double size of remote</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>fueling unit</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Telemetry</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) New ground station decoding</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>and recording equipment,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minor mods to existing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>antenna, receiver and power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>switching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hydraulic System</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Modify hydraulic cart by</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>adding compatible wiring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and cabling mods to an</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3T equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Algol nozzle deflection</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>monitoring during servo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>system testing</td>
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<td></td>
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</table>
**TABLE 46 (Continued)**

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

169
TABLE 46 (Concluded)

<table>
<thead>
<tr>
<th>Systems</th>
<th>Dallas Sets</th>
<th>Wallops Island Sets</th>
<th>Vandenberg Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other GSE - Mechanical (Continued)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Optical alignment tools and equipment required to align the thrust vectors of the castors</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other GSE - Electrical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Modify flight readiness consoles and monitor consoles</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(2) Modify power supplies</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Provide new procedures for guidance system and Castor strap-ons</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
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 S³T 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 N₂ 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 N₂ and H₂O₂ 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 second 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:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>ASLV</td>
<td></td>
<td></td>
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<tr>
<td>Goal</td>
<td>.95</td>
<td></td>
</tr>
<tr>
<td>Estimate</td>
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<tr>
<td>Scout</td>
<td></td>
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<tr>
<td>Goal</td>
<td>.95</td>
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</tr>
<tr>
<td>Observed</td>
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TABLE 47
ASLV RELIABILITY GOAL ALLOCATION

<table>
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<tr>
<th>Subsystem</th>
<th>Goal</th>
</tr>
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<tbody>
<tr>
<td>Vehicle</td>
<td>0.9500</td>
</tr>
<tr>
<td>Propulsion</td>
<td>0.9792</td>
</tr>
<tr>
<td>Stage 1 (Algol III + 2 Castor Strap-Ons)</td>
<td>0.9910</td>
</tr>
<tr>
<td>Stage 2 (Short Algol III)</td>
<td>0.9960</td>
</tr>
<tr>
<td>Stage 3 (Hi-Pressure X259)</td>
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</tr>
<tr>
<td>Stage 4 (Short X259)</td>
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</tr>
<tr>
<td>Other Subsystems</td>
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</tr>
<tr>
<td>Structure</td>
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<tr>
<td>Ignition</td>
<td>0.9987</td>
</tr>
<tr>
<td>Payload Shroud</td>
<td>0.9980</td>
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<tr>
<td>RCS</td>
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<tr>
<td>Destruct</td>
<td>0.9967</td>
</tr>
<tr>
<td>Separation</td>
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<tr>
<td>Guidance</td>
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<tr>
<td>T/M</td>
<td>0.9947</td>
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<tr>
<td>Radar</td>
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### TABLE 48 - COMPARISON OF ASLV AND SCOUT RELIABILITY ESTIMATES

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<thead>
<tr>
<th>Configuration</th>
<th>Guidance</th>
<th>Propulsion</th>
<th>Ignition/Electrical</th>
<th>Destruct</th>
<th>Telemetry</th>
</tr>
</thead>
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<tr>
<td><strong>ASLV</strong></td>
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<td>.9987</td>
<td>.9967</td>
<td>.9947</td>
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<td>.9988</td>
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<td><strong>SCOUT</strong></td>
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<td>.9993</td>
<td>.9976</td>
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<table>
<thead>
<tr>
<th>Configuration</th>
<th>Separation</th>
<th>Attitude Control</th>
<th>Radar Beacon</th>
<th>Payload Shroud</th>
<th>Structure</th>
</tr>
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<tbody>
<tr>
<td><strong>ASLV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goals</td>
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<td>.9974</td>
<td>.9940</td>
<td>.9980</td>
<td>.9993</td>
</tr>
<tr>
<td>Estimates</td>
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<td>.9871</td>
<td>.9990</td>
<td>.9979</td>
<td>.9999</td>
</tr>
<tr>
<td><strong>SCOUT</strong></td>
<td>.9976</td>
<td>.9859</td>
<td>.9990</td>
<td>.9979</td>
<td>.9999</td>
</tr>
</tbody>
</table>

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 greater 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
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>
<thead>
<tr>
<th>TASK 1.0</th>
<th>TASK 2.0</th>
<th>TASK 3.0</th>
<th>TASK 4.0</th>
<th>TASK 5.0</th>
<th>TASK 6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTEM INTEGRATION</td>
<td>DESIGN AND ANALYSIS</td>
<td>ROCKET MOTORS</td>
<td>GUIDANCE</td>
<td>CONTROLS</td>
<td>ELECT, INTER-STAGES, ETC.</td>
</tr>
<tr>
<td>oProgram Coordination</td>
<td>oInterface Control Documents</td>
<td>oProcurement Specs</td>
<td>oProcurement Specs</td>
<td>oProcurement Specs</td>
<td>oProcurement Specs</td>
</tr>
<tr>
<td>oSystem Specification</td>
<td>oDesign Data Books</td>
<td>oDesign</td>
<td>oDesign</td>
<td>oDesign</td>
<td>oDesign</td>
</tr>
<tr>
<td>oDesign Control Plan</td>
<td>oReliability Plan</td>
<td>oVendor Selection Requirements</td>
<td>oVendor Selection Requirements</td>
<td>oVendor Selection Requirements</td>
<td>oVendor Selection Requirements</td>
</tr>
<tr>
<td>oGround Test Plan</td>
<td>oEMI Control Plan</td>
<td>oEngineering Changes</td>
<td>oEngineering Changes</td>
<td>oEngineering Changes</td>
<td>oEngineering Changes</td>
</tr>
<tr>
<td>oProgram Targeting Software</td>
<td>oElectrical Power</td>
<td>oMovable Nozzle Development</td>
<td>oTesting</td>
<td>oTesting</td>
<td>oTesting</td>
</tr>
<tr>
<td>oRange Safety</td>
<td>oSchematics</td>
<td>oGround Testing Delivery</td>
<td>oHardware Delivery</td>
<td>oHardware Delivery</td>
<td>oHardware Delivery</td>
</tr>
<tr>
<td>oDesign Reviews</td>
<td>oSeparation</td>
<td>oHardware</td>
<td>oReliability</td>
<td>oQuality</td>
<td>oQuality</td>
</tr>
<tr>
<td>oHardware Delivery</td>
<td>oInstrumentation</td>
<td>oReliability</td>
<td>oReliability</td>
<td>oReliability</td>
<td>oReliability</td>
</tr>
<tr>
<td>oConfiguration Management</td>
<td>oTelemetry</td>
<td>oDocumentation</td>
<td>oDesign Reviews</td>
<td>oDesign Reviews</td>
<td>oDesign Reviews</td>
</tr>
<tr>
<td>oDrawing &amp; Specification Tree</td>
<td>oDesign &amp; Test Reports</td>
<td>oPerformance</td>
<td>oDesign Reviews</td>
<td>oDesign Reviews</td>
<td>oDesign Reviews</td>
</tr>
<tr>
<td>Statement of Work</td>
<td>oConfiguration Studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural Loads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality Plan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance Requirements, Vehicle &amp; GSE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 49  SCOUT GROWTH PROGRAM TASK SUMMARY
<table>
<thead>
<tr>
<th>TASK 7.0</th>
<th>TASK 8.0</th>
<th>TASK 9.0</th>
<th>TASK 10.0</th>
<th>TASK 11.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESTING</td>
<td>ASSEMBLY &amp; CHECKOUT</td>
<td>GSE, PROCEDURES &amp; FACILITIES DESIGN &amp; FABRICATION</td>
<td>FIELD &amp; FLIGHT OPERATIONS</td>
<td>PROGRAM DOCUMENTATION</td>
</tr>
<tr>
<td>oTest</td>
<td>oAcceptance</td>
<td>oDesign Requirements</td>
<td>oSite Planning &amp; Activation</td>
<td>oStatus Reports</td>
</tr>
<tr>
<td>oProcedures</td>
<td>oTest Components &amp; Subsystems</td>
<td>oDesign Changes</td>
<td>oDesign Analysis</td>
<td>oDesign Analysis</td>
</tr>
<tr>
<td>oReports</td>
<td>oVehicle Assembly</td>
<td>oFabrication</td>
<td>oFlight Test Reports</td>
<td>oRange Reports</td>
</tr>
<tr>
<td></td>
<td>oVehicle Checkout</td>
<td>oInstallation</td>
<td>oDrawings</td>
<td>oData on Components</td>
</tr>
<tr>
<td></td>
<td>oAssembly</td>
<td>oCheckout</td>
<td>oHardware Pre-flight Checkout</td>
<td>and Subsystems</td>
</tr>
<tr>
<td></td>
<td>Procedures</td>
<td>oBuy Off</td>
<td>oLaunch 50 Vehicles</td>
<td>oData Analysis</td>
</tr>
<tr>
<td></td>
<td>oAcceptance and Checkout Procedures</td>
<td>oOperating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**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 consistent 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 consistent 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

**THRUĆST LEVEL & AXES**

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TYPE</th>
<th>Pitch</th>
<th>Yaw</th>
<th>Roll</th>
<th>Hardware Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRST</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oWith Strap-Ons</td>
<td>Movable</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Design Verified by test</td>
</tr>
<tr>
<td></td>
<td>Nozzle +6°</td>
<td></td>
<td></td>
<td></td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>RCS H₂O₂</td>
<td>2224</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Each Strap-On</td>
<td>(500)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Motors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Lower Base &quot;A&quot;</td>
<td>2224</td>
<td></td>
<td></td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>RCS H₂O₂</td>
<td>(500)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oWithout Strap-Ons</td>
<td>-Lower Base &quot;A&quot;</td>
<td>2224</td>
<td></td>
<td></td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>RCS H₂O₂</td>
<td>(500)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Motors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SECOND</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oBoost</td>
<td>Movable</td>
<td></td>
<td></td>
<td></td>
<td>Design verified by test</td>
</tr>
<tr>
<td></td>
<td>Nozzle +3°</td>
<td></td>
<td></td>
<td></td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>RCS H₂O₂</td>
<td>195.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 Motors</td>
<td>(44)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oCoast</td>
<td>RCS H₂O₂</td>
<td>195.7</td>
<td>195.7</td>
<td>195.7</td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>8 Motors</td>
<td>(44)</td>
<td>(44)</td>
<td>(44)</td>
<td></td>
</tr>
<tr>
<td><strong>THIRD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oBoost</td>
<td>RCS H₂O₂</td>
<td>213.5</td>
<td>213.5</td>
<td></td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>-4 Motors</td>
<td>(48)</td>
<td>(48)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-4 Motors</td>
<td></td>
<td></td>
<td>62.2</td>
<td>(14)</td>
</tr>
<tr>
<td>oCoast</td>
<td>RCS H₂O₂</td>
<td>62.2</td>
<td>62.2</td>
<td></td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>-4 Motors</td>
<td>(14)</td>
<td>(14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-2 Motors</td>
<td>8.9</td>
<td></td>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td><strong>FOURTH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oBoost</td>
<td>RCS H₂O₂</td>
<td>213.5</td>
<td>213.5</td>
<td></td>
<td>Scout</td>
</tr>
<tr>
<td></td>
<td>4 Motors</td>
<td>(48)</td>
<td>(48)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Includes Vernier)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Nitrogen</td>
<td></td>
<td></td>
<td></td>
<td>4.45 Burner II</td>
</tr>
<tr>
<td></td>
<td>8 Motors</td>
<td></td>
<td></td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>oCoast</td>
<td>-Nitrogen</td>
<td>4.45</td>
<td>4.45</td>
<td>4.45</td>
<td>Burner II</td>
</tr>
<tr>
<td></td>
<td>8 Motors</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** All Thrust values are vacuum.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>OBJECTIVE</th>
<th>TEST ENVIRONMENT</th>
<th>N. TEST LOCATION</th>
<th>HARDWARE REQUIRED</th>
</tr>
</thead>
</table>
| 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 Hydrostatic 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>
<thead>
<tr>
<th>ITEM</th>
<th>OBJECTIVE</th>
<th>TEST ENVIRONMENT</th>
<th>NO. TEST/LOCATION</th>
<th>HARDWARE REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Movable Nozzle and Actuation Test</td>
<td>○Obtain Design Data&lt;br&gt;○Certify Subsystem for Motor Firing</td>
<td>○Test Stand</td>
<td>Test Series&lt;br&gt;Vendor Facility</td>
<td>1 - Short Algol III Movable Nozzle&lt;br&gt;1 - Algol III Movable Nozzle&lt;br&gt;1 - Actuation Subsystem</td>
</tr>
<tr>
<td>5. X259 (H.P.) (Planned under current Scout Prgm.)</td>
<td>○Establish Motor Performance&lt;br&gt;○Obtain Data for Simulation Routines Development&lt;br&gt;oFlight Certify Design and Fabrication Procedures</td>
<td>○Altitude Test Stand</td>
<td>2 Tests&lt;br&gt;AEDC</td>
<td>2 - X259 (H.P.)</td>
</tr>
<tr>
<td>6. X259 (H.P.) Hydrostatic Test</td>
<td>○Confirm Structural Design&lt;br&gt;○Confirm Manufacturing Procedures</td>
<td>○Ambient Test Stand&lt;br&gt;oSimulated Flight Loads and case pressures</td>
<td>1 Test Vendor Facility</td>
<td>1 - X259 (H.P.) Case</td>
</tr>
<tr>
<td>7. Short X259 (H.P.)</td>
<td>○Establish Motor Performance&lt;br&gt;○Obtain Data for Simulation Routine Development&lt;br&gt;oFlight Certify Design and Fabrication Procedures</td>
<td>○Ambient Test Stand</td>
<td>2 Tests Vendor Facility</td>
<td>2 - Short X259 (H.P.)</td>
</tr>
<tr>
<td>8. Short X259 (H.P.) Hydrostatic Test</td>
<td>○Confirm Structural Design&lt;br&gt;○Confirm Manufacturing Procedures</td>
<td>○Ambient Test Stand&lt;br&gt;oSimulated Flight Loads and case pressures</td>
<td>1 Test Vendor Facility</td>
<td>1 - Short X259 (H.P.) Case</td>
</tr>
<tr>
<td>ITEM</td>
<td>OBJECTIVE</td>
<td>TEST ENVIRONMENT</td>
<td>NO. TEST LOCATION</td>
<td>HARDWARE REQUIRED</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
<td>------------------</td>
<td>----------------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>9. Inertial Guidance and Integration</td>
<td>oDevelopment</td>
<td>oAmbient Test Stand with Some Component</td>
<td>Test Series 1 - Development Model Vendor Facility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.Design Verification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.Environmental Investigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>oFlight Verification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.Establish Performance for Simulation Routine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.Environment Testing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>oEvaluation of Interfaces</td>
<td>oLaboratory</td>
<td>Test Series The Guidance Units from VMSC Item 8 will be used Other vehicle hardware will be used as necessary No special flight hardware will be procured for these tests</td>
<td></td>
</tr>
<tr>
<td></td>
<td>oSoftware Verification</td>
<td>oManufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>oSoftware Integration</td>
<td>oLaunch Vehicle Check-out</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>oVerify Procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>oSimulation Routine Data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Payload Shroud</td>
<td>oVerify Separation</td>
<td>oAmbient Test Stand</td>
<td>Test Series 1 - Payload Shroud VMSC 3 - Separation</td>
<td>Pyrotechnic Subsystems</td>
</tr>
<tr>
<td></td>
<td>oVerify Structural Design</td>
<td>oSimulated Structural Loads</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>oFlight Certify Design and Fabrication Procedures</td>
<td>oSimulated Separation &quot;G&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 51 GROUND TESTING REQUIREMENTS (Completed)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>OBJECTIVE</th>
<th>TEST ENVIRONMENT</th>
<th>NO. TEST LOCATION</th>
<th>HARDWARE REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Interstages</td>
<td>Verify Structural Design</td>
<td>Ambient Test Stand</td>
<td>Test Series</td>
<td>Each Interstage</td>
</tr>
<tr>
<td>oBase &quot;A&quot;</td>
<td>Subsystem Performance</td>
<td>Simulated Structural Loads</td>
<td>VMSC</td>
<td>Each Subsystem</td>
</tr>
<tr>
<td>oUpper &amp; Lower &quot;B&quot;</td>
<td>Obtain Data for Simulation Routine Development</td>
<td>Propulsion Test Stand</td>
<td>Installed in Each Interstage</td>
<td>3 - Each Separation Subsystem</td>
</tr>
<tr>
<td>oUpper &amp; Lower &quot;C&quot;</td>
<td>Flight Certify Design and Fabrication Procedures</td>
<td>i.e. after VMSC test hardware may be used in motor firings at Vendor facility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>oPayload Adapter</td>
<td>Verify Separation Subsystem</td>
<td></td>
<td></td>
<td>1 - Set of Cabling</td>
</tr>
<tr>
<td>12. Destruct and Separation</td>
<td>Verify Design</td>
<td>Ambient Test Stand</td>
<td>3 Test Elements</td>
<td>Element test Samples for Each Propulsion Stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>for each Motor Case Except Strap-Ons/VMSC</td>
<td></td>
</tr>
<tr>
<td>13. Wind Tunnel</td>
<td>Provide Design Aero Dynamics and Loads Data</td>
<td>Wind Tunnel</td>
<td>Test Series</td>
<td>Complete Scout Gov't Growth Model</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Facility Extrapayload Shroud</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 - Extra Base &quot;A&quot;</td>
</tr>
<tr>
<td>14. Strap-on Separation</td>
<td>Verify Design</td>
<td>Ambient Test Stand</td>
<td>Test Series</td>
<td>Sets of Pyrotechnics Motor Cases from ground test firings - mass balanced</td>
</tr>
</tbody>
</table>
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
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.
FIGURE 40  FUNDING REQUIREMENT AND ASLV LAUNCH DATES

(FIRST LAUNCH FULL 340 kg (750 lb) CAPABILITY)
(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<sub>sp</sub>, 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:
   - Fiscal funding peak is $2.392 million
   - 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<sub>sp</sub>, 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
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
ASLV GO-AHEAD

2ND STAGE

GUIDANCE

4TH STAGE GUIDANCE AND CONTROL, INTEGRATION (FW-4)

1ST STAGE

PAYLOAD SHROUD

3RD STAGE

4TH STAGE GUIDANCE AND CONTROL, INTEGRATION AND SHORT X-259


FIRST FLIGHT STEP 1

FIRST FLIGHT STEP 2

FIRST FLIGHT STEP 3

FIRST FLIGHT STEP 4

125 625 1,225 1,265 1,274 1,280 1,296 1,274 1,265 1,260 1,253 1,240 1,149 TOTAL = $14,531

FISCAL YEAR FUNDING REQUIREMENTS ($K)

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 third 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 cost of the ASLV based upon a 50 vehicle procurement of 10 step 1 vehicles, 10 step 2 vehicles, and step 3 in 200
<table>
<thead>
<tr>
<th>YEAR</th>
<th>ITEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>1. 4TH STAGE GUIDANCE AND CONTROL</td>
</tr>
<tr>
<td></td>
<td>AND INTEGRATION (FW-4)</td>
</tr>
<tr>
<td>1973</td>
<td>2. 2ND STAGE WITH MOVABLE</td>
</tr>
<tr>
<td></td>
<td>NOZZLE SHORT ALGOL III</td>
</tr>
<tr>
<td>1974</td>
<td>3. 1ST STAGE WITH MOVABLE</td>
</tr>
<tr>
<td></td>
<td>NOZZLE AND STRAP-ONS</td>
</tr>
<tr>
<td></td>
<td>(ALGOL III AND CASTOR III)</td>
</tr>
<tr>
<td>1975</td>
<td>4. PAYLOAD SPROUD</td>
</tr>
<tr>
<td>1976</td>
<td>5. 3RD STAGE (HP X-259)</td>
</tr>
<tr>
<td>1977</td>
<td>6. 4TH STAGE GUIDANCE</td>
</tr>
<tr>
<td></td>
<td>AND CONTROL, INTEGRATION AND</td>
</tr>
<tr>
<td></td>
<td>SHORT X-259</td>
</tr>
<tr>
<td>1978</td>
<td>FIRST LAUNCH</td>
</tr>
<tr>
<td>1979</td>
<td>FIRST LAUNCH WITH 750 LB</td>
</tr>
</tbody>
</table>

**FIGURE 46** ASLV – MAJOR MILESTONE PHASING SCHEDULE
units of 15 vehicles each is shown below:

<table>
<thead>
<tr>
<th>Description</th>
<th>$M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion, Interstages and Payload Shroud</td>
<td>1.221</td>
</tr>
<tr>
<td>Inertial Guidance and Control</td>
<td>0.350</td>
</tr>
<tr>
<td>Production Checkout</td>
<td>0.148</td>
</tr>
<tr>
<td><strong>Total Hardware Cost</strong></td>
<td>1.719</td>
</tr>
<tr>
<td>Launch Support Cost</td>
<td><strong>1.000</strong></td>
</tr>
<tr>
<td><strong>Total Hardware and Launch Cost</strong></td>
<td>2.719</td>
</tr>
<tr>
<td>Amortized Development Cost over 50 Vehicles</td>
<td>0.253</td>
</tr>
<tr>
<td><strong>Average Unit Launch Cost</strong></td>
<td>2.972</td>
</tr>
</tbody>
</table>

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

*Required only if an inertial guidance system is used.
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>RADAR BEACON &amp; C/D RECEIVER</td>
<td></td>
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<tr>
<td>IGNITION DESTRUCT</td>
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<td></td>
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<tr>
<td>REACTION CONTROL SYSTEM</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>TELEMETRY</td>
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<td></td>
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<tr>
<td>HYDRAULICS SYSTEM</td>
<td></td>
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<td></td>
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<tr>
<td>TRANSPORTER</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>LAUNCHER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTHER GSE – MECHANICAL</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>OTHER GSE – ELECTRICAL</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>PROCEDURES</td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

| 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

9.0 REFERENCES (Continued)

dated 1 July 1965.

1971.

Martin Marietta Corporation dated December 1971.

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.