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GENERAL DYNAMICS
ASTRONAUTICS
NOW COMBINED WITH CONVAIR
ATLAS/CENTAUR
LAUNCH-ON-TIME STUDY
FINAL REPORT (SURVEYOR MISSION)

Report Number GD/C-ACY65-001-4
7 July 1965

Contract Number NAS3-3228

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Manager
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GENERAL DYNAMICS
CONVAIR DIVISION
San Diego, California
Additional copies of this document may be obtained by contacting Centaur Resources Control and Technical Reports Department 954-4, Building 26, Kearny Mesa Plant, San Diego, California.
INTRODUCTION

Three specific launch-on-time areas are considered in this document.

a. A probability model has been developed which gives the probability of meeting a monthly launch opportunity. The results of this analysis are applied to the currently defined Centaur program.

b. An analysis of the GSE and facility systems of 36A and 36B was performed to determine contingency hold requirements and capabilities. This study updates similar studies previously reported.

c. An analysis of CSTS operations with the T-21 spacecraft and the AC-7 launch vehicle is performed.

This document is published under Contract NAS3-3228 to satisfy the requirements of NASA/Lewis Research Center Launch-On-Time Study, Sales Order 332-1-18. This report will be the last under present fiscal 1966 authorization.
Throughout the launch-on-time study, numerous program improvement changes were recommended and adopted by the Centaur Project Management. Other changes were recommended or disapproved for further study.

The following table presents the recommended program changes and their current disposition.

**RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Recommendation</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch day wind data reduction</td>
<td>Procedure change for time savings in data handling (LOT Bimonthly Report, 1 July 1964).</td>
<td>Adopted</td>
</tr>
</tbody>
</table>
**RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE (CONTINUED)**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Recommendation</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Performance Reserve (LPR)</td>
<td>Preplanned holds in terminal countdown of 60 minutes at T-90, and 40 minutes at T-5 for AC-5 and AC-6.</td>
<td>Adopted in AC-5 and AC-6 flight test plans. Open for AC-7 and on pending AC-6 countdown results.</td>
</tr>
</tbody>
</table>
### RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE (CONTINUED)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Recommendation</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Terminal Countdown</strong></td>
<td>Additional audio communication channels to be recorded to include the guidance and propellant loading systems (LOT Bimonthly Report, 7 May 1965).</td>
<td>Adopted for AC-6 and on.</td>
</tr>
<tr>
<td><strong>Length Reduction</strong></td>
<td>Use of voice tape recorder to replace manual recording by the data evaluator (LOT Bimonthly Report, 7 May 1965).</td>
<td>Not adopted.</td>
</tr>
<tr>
<td></td>
<td>Perform the Centaur LO₂ tanking and H₂ tank prechill operations simultaneously (LOT Bimonthly Report, 7 May 1965).</td>
<td>Not adopted.</td>
</tr>
<tr>
<td><strong>Launch Predictor Program</strong></td>
<td>Azimuthal constraints on the direct ascent mission (Reference GD/C-BTD65-069, 7 May 1965).</td>
<td>Study conducted under LOT funding. Not adopted.</td>
</tr>
<tr>
<td></td>
<td>Launch window versus maneuver.</td>
<td>Study under LOT funding. Study funding not approved.</td>
</tr>
<tr>
<td></td>
<td>Two-burn versus one-burn mission.</td>
<td>Study funding not approved.</td>
</tr>
<tr>
<td>Subject</td>
<td>Recommendation</td>
<td>Disposition</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pratt and Whitney Pump Inlet Valves</td>
<td>Delete requirement for vacuum-drying which constrains a one-day ARL (LOT Bimonthly Report, 10 November 1964).</td>
<td>This is a P&amp;WA requirement. Not adopted.</td>
</tr>
<tr>
<td>Liquid Helium Usage</td>
<td>Reduce LHe flow rate during ground chilldown to extend countdown hold capability (LOT Bimonthly Report, 10 November 1964).</td>
<td>Adopted for AC-5 and on.</td>
</tr>
<tr>
<td></td>
<td>Have two Cryenco dewars available for each launch operation (LOT Bimonthly Report, 12 March 1965).</td>
<td>Adopted for AC-5 and on.</td>
</tr>
<tr>
<td></td>
<td>Store two Cryenco dewars at supplier facility and ship to ETR just prior to need (LOT Bimonthly Report, 12 March 1965).</td>
<td>Not adopted.</td>
</tr>
<tr>
<td></td>
<td>Use GHe alone for purge of the Centaur LH₂ tank in place of GN₂ and GHe to eliminate a time constraint to a one-day ARL (LOT Bimonthly Report, 10 November 1964).</td>
<td>Adopted, effective AC-5 and on.</td>
</tr>
<tr>
<td></td>
<td>Use a continuous gas analysis sampling system to reduce the Centaur LH₂ purge constraint to a one-day ARL (LOT Bimonthly Report, 10 November 1964).</td>
<td>Not adopted. Must be considered if one-day ARL is required.</td>
</tr>
</tbody>
</table>
## RECOMMENDED CHANGES AND CURRENT DISPOSITION TABLE (CONTINUED)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Recommendation</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range Safety</td>
<td>Remove 6-hour limitation for RSC checkout which constrains countdown hold capability. (LOT Bimonthly Report, 10 November 1964).</td>
<td>Adopted. Limitation is 10.5 Hours for R&amp;D flights.</td>
</tr>
<tr>
<td>36B LO₂/LN₂ Subcooler</td>
<td>Provide remote level sensing and refill capability to increase system hold capability. Existing design can only support a maximum hold of 74 minutes, which is unacceptable.</td>
<td>Not adopted.</td>
</tr>
</tbody>
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SECTION I

PROBABILITY OF LAUNCH DURING A MONTHLY LAUNCH OPPORTUNITY, 1965 - 1968

1.1 INTRODUCTION

1.1.1 SCOPE. A probability model has been developed which gives the probability of the Atlas/Centaur meeting a monthly launch opportunity. The model includes surface winds, winds aloft, number of days in the launch opportunity, lunar lighting restraints, and turnaround time in the event of an abort. The model is based on past performance of Atlas vehicles at the Eastern Test Range (ETR).

Preliminary results of the analysis using this model are given in Table 1-1 for the currently defined Centaur program.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Month</th>
<th>Probability of Launch During Monthly Launch Opportunity, ( P_L )</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-6</td>
<td>July '65</td>
<td>0.92</td>
</tr>
<tr>
<td>AC-7</td>
<td>October '65</td>
<td>0.55</td>
</tr>
<tr>
<td>AC-8</td>
<td>January '66</td>
<td>0.64</td>
</tr>
<tr>
<td>AC-9</td>
<td>April '66</td>
<td>0.56</td>
</tr>
<tr>
<td>AC-10</td>
<td>May '66</td>
<td>0.78</td>
</tr>
<tr>
<td>AC-11</td>
<td>July '66</td>
<td>0.81</td>
</tr>
<tr>
<td>AC-12</td>
<td>October '66</td>
<td>0.70</td>
</tr>
<tr>
<td>AC-13</td>
<td>January '67</td>
<td>0.23</td>
</tr>
<tr>
<td>AC-14</td>
<td>April '67</td>
<td>0.56</td>
</tr>
<tr>
<td>AC-15</td>
<td>July '67</td>
<td>0.93</td>
</tr>
</tbody>
</table>
1.2 HISTORICAL DATA

1.2.1 ATLAS D-SERIES PROFILE. The launch history of Atlas D-Series vehicles at ETR was analyzed for statistical data. These vehicles consisted of R&D, Project Mercury, Atlas/Able, Midas, Atlas/Centaur, Ranger, Atlas/Agena, OGO, Project Fire and Mariner. As shown in Table 1-2, there were 124 launch attempts for 66 successful launches, giving a 0.53 factor of success.

<table>
<thead>
<tr>
<th>Month</th>
<th>No. Launch Attempts</th>
<th>No. Successful Launches</th>
<th>No. of Weather Aborts</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>11</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>February</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>March</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>April</td>
<td>12</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>May</td>
<td>10</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>June</td>
<td>11</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>13</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>8</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>September</td>
<td>12</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>October</td>
<td>17</td>
<td>8</td>
<td>1</td>
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<tr>
<td>November</td>
<td>11</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>December</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>TOTALS</td>
<td>124</td>
<td>66</td>
<td>14</td>
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</table>

A launch attempt is defined as a launch operation that begins with an official range countdown and terminates with either a successful launch or an abort.
1.3 PROBABILITY MODEL

1.3.1 MODEL APPLICATION. The probability of a successful launch attempt, \( P_L \), during a given monthly launch opportunity is equal to the conditional probability of a successful launch of the \( n \)th attempt, i.e.,

\[
P_L = p_1 + qp_2 + q^2p_3 + \cdots + q^{n-1}p_n,
\]

Where:
- \( P_L \) = probability of launch during a monthly opportunity,
- \( p_n \) = probability of success of an individual launch attempt,
- \( n \) = number of individual launch attempts,
- \( q = (1-p) \) = probability of failure of an individual launch attempt,
- \( p_1 = p_2 = \cdots = p_n \), and
- \( q_1 = q_2 = \cdots = q_n = q \).

The probability model works in the following manner; assuming a probability of individual launch success of \( p_n = 0.5 \), there is a cumulative probability with each succeeding launch attempt as shown in Figure 1-1.

![Cumulative PL vs Launch Attempts](cumulative_pl.png)

Figure 1-1. Probability of Launch \( P_L \) versus Number of Launch Attempts

1.3.2 MODEL IMPOSED CONDITIONS. The probability of an individual launch success for a given launch window (as opposed to the monthly launch opportunity) has been treated in Reference 9. This probability is directly dependent on the hold capability of the system and preplanned holds in the terminal countdown and is, therefore,
not considered a factor in the present monthly opportunity probability model. Application of this model will, however, include conditions imposed by ground winds, winds aloft, number of days in the launch opportunity imposed by lunar lighting restraints, and turnaround time in the event of an abort.

1.4 LAUNCH OPPORTUNITIES

1.4.1 DEFINITION. A launch opportunity is defined as a period of time, containing one or more days, during which performance of the Surveyor spacecraft mission is feasible. These days are generally successive. Unless otherwise stated, the launch opportunities considered are based on those opportunities presented in Reference 3, Direct Ascent Case A and Parking Orbit Ascent, Tables 1 and 4 respectively.

1.4.2 REQUIREMENTS. Each launch opportunity was examined, and only those windows in the opportunities which met or exceeded the minimum hours of sunlight remaining at the lunar landing site were used. The minimum hours of sunlight include those gained by shifting the landing site as much as 26 degrees longitude, east or west, on the lunar equator. As an example, during the March 1966 launch opportunity, an additional launch window is gained by shifting the landing site 26 degrees west longitude for the launch window giving on arrival date of 17 March. This window meets the lunar lighting requirements.

1.5 WEATHER EFFECTS ON PROBABILITY OF LAUNCH

1.5.1 ABORT DATA DUE TO WEATHER. Launch wind availability data was gathered from Reference 1,2,4, and 6. Actual launch aborts because of weather are given in Table 1-2.

In the 124 launch attempts of Atlas D-Vehicles at ETR (Table 1-2), 14 aborts were due to weather. Removing these aborts results in a probability of launch, \( p_n \), for any single launch attempt (minus weather) of 0.6000 \[ \frac{66}{124-14} \text{ or } \frac{66}{110} \]. Combining this launch probability with the wind "launch availability" for a given month, a probability of success \( p_w \) for any single launch attempt for that particular month is obtained as shown in Table 1-3.
The results of applying the probabilities of launch of Table 1-3 to the currently defined Centaur program are given in Table 1-1.

The history of weather aborted launch attempts is shown in Table 1-4. The $p_W$ for each month having weather aborts is included for comparison with percentage of total aborts here to weather.

### TABLE 1-3. PROBABILITY OF SUCCESS FOR A SINGLE LAUNCH ATTEMPT ($p_W$) BY MONTH BASED ON WIND LAUNCH AVAILABILITY

<table>
<thead>
<tr>
<th>Month</th>
<th>Wind Launch Availability</th>
<th>Probability of Launch ($p_W$ = $p_a \cdot p_g \cdot p_n$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aloft ($p_a$) (AC-7 thru AC-15)</td>
<td>Ground ($p_g$) (AC-6)</td>
</tr>
<tr>
<td>January</td>
<td>0.50</td>
<td>0.76</td>
</tr>
<tr>
<td>February</td>
<td>0.33</td>
<td>0.76</td>
</tr>
<tr>
<td>March</td>
<td>0.33</td>
<td>0.74</td>
</tr>
<tr>
<td>April</td>
<td>0.50</td>
<td>0.79</td>
</tr>
<tr>
<td>May</td>
<td>0.80</td>
<td>0.82</td>
</tr>
<tr>
<td>June</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td>July</td>
<td>1.00</td>
<td>0.97</td>
</tr>
<tr>
<td>August</td>
<td>1.00</td>
<td>0.93</td>
</tr>
<tr>
<td>September</td>
<td>0.90</td>
<td>0.79</td>
</tr>
<tr>
<td>October</td>
<td>0.80</td>
<td>0.69</td>
</tr>
<tr>
<td>November</td>
<td>0.50</td>
<td>0.74</td>
</tr>
<tr>
<td>December</td>
<td>0.34</td>
<td>0.78</td>
</tr>
</tbody>
</table>

### TABLE 1-4. ABORTS DUE TO WEATHER

<table>
<thead>
<tr>
<th>Month</th>
<th>Launch Attempts</th>
<th>Total Aborts</th>
<th>Weather Aborts</th>
<th>$p_W$ from Table 1-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>67</td>
</tr>
<tr>
<td>February</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>April</td>
<td>12</td>
<td>7</td>
<td>3</td>
<td>43</td>
</tr>
<tr>
<td>October</td>
<td>17</td>
<td>9</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>December</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>
Note that all weather aborts occurred during months having low probability of launch, \( p_W \) in Table 1-3. No weather aborts were recorded for the months having a high \( p_W \) from May through September.

1.6 TURNAROUND TIME VERSUS PROBABILITY OF LAUNCH

1.6.1 TURNAROUND CRITERIA. The space vehicle and launch site turnaround capability have a direct effect upon the probability of launch. The number of launch opportunity days (n'th term in probability model) is governed by the total number of days within a launch opportunity, and the number of days required for a turnaround operation in the event of an aborted launch attempt. A matrix for "n values" is presented in Table 1-5.

<table>
<thead>
<tr>
<th>Turnaround Time (Days)</th>
<th>Number of Days Available in Launch Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15</td>
</tr>
<tr>
<td>1</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15</td>
</tr>
<tr>
<td>2</td>
<td>1 1 2 2 3 3 4 4 5 5 6 6 7 7 8</td>
</tr>
<tr>
<td>3</td>
<td>1 1 1 2 2 2 3 3 4 4 4 5 5 5 5</td>
</tr>
</tbody>
</table>

1.6.2 EFFECTS OF TURNAROUND TIME ON LAUNCH PROBABILITY. Table 1-3, gives a probability of success for an individual launch attempt \( p_W \), of 0.52. This \( p_W \) is used in paragraphs 1.5 through 1.8 to show the effects on \( P_L \) the probability of launch during a monthly opportunity, of turnaround time, number and length of launch windows, and types of ascent. The monthly launch wind effects, given in Table 1-3, were not used in these sections because of the confounding effect on the variances caused by monthly wind probabilities.

Figure 1-2 graphically illustrates the effects that turnaround time has upon \( P_L \). Observe that after seven days of launch opportunity, the rate of increase in \( P_L \) diminishes rapidly with added days in the launch opportunity.

1.7 MINIMUM LAUNCH WINDOW VERSUS PROBABILITY OF LAUNCH

1.7.1 LUNAR LIGHTING REQUIREMENTS. The launch opportunities presented in Reference 3, Direct Ascent Case A, were compared using minimum launch windows of 20 minutes versus 10 minute minimum windows. Only those launch windows meeting the lunar lighting requirements indicated in Paragraph 1.4 were considered.
Figure 1-2. $P_L$ versus Days in Launch Opportunity Showing Effects of Turnaround Time
The results are shown in Table 1-6 for the average $P_L$ for the monthly launch opportunities from mid-1965 through 1968. Considering the case of a 2-day turnaround capability, there is a gain in the average $P_L$ from 0.7893 to 0.8070 by reducing the minimum launch window length to 10 minutes. Potential payload gains, in reducing the minimum launch window, are discussed in detail in Reference 8.

1.8 DIRECT ASCENT VERSUS PARKING ORBIT LAUNCH

1.8.1 MISSION CONDITIONS. All actual launch opportunities for direct and parking orbit ascent missions were examined under conditions previously stated in paragraph 1.5, and with a minimum launch window length of 20 minutes.

A comparison of the average $P_L$ for the direct ascent with that of the parking orbit is shown in Table 1-7. Considering the case of a 2-day turnaround capability, there is a gain in the average $P_L$ from 0.7893 for the direct ascent to 0.8958 for the parking orbit ascent. A gain of 183 acceptable launch windows for the parking orbit over the direct orbit ascent is also indicated.

It is important to note, from Table 1-6, the gain in $P_L$ associated with a decrease in turnaround time. For example, a direct ascent launch with a turnaround time of one day has an average $P_L$ equal to 0.8976 while the parking orbit ascent average $P_L$ for a two day turnaround, involving twice as many launch opportunities and nearly twice as many launch windows, is 0.8958. As shown previously in paragraph 1-5, decreasing the turnaround time in the event of an abort has a stronger effect on the $P_L$ than increasing the number of launch days in a launch opportunity.

1.9 CONCLUSIONS

1.9.1 FACTORS NEEDED FOR A SUCCESSFUL LAUNCH. The probability of a successful launch during any Surveyor launch opportunity is primarily dependent on the turnaround time in the event of an abort. However, with opportunities greater than seven days, there is little gain in decreased turnaround time. See Figure 1-2.

Turnaround time can offset the currently defined advantages of the parking orbit ascent, such as larger launch windows and more launch opportunities. For example, a turnaround time of one day gives the same probability of launch for the average monthly launch opportunity for the single burn mission, as the two day turnaround capability gives to the parking orbit ascent mode.

Weather has been responsible for 24 percent of launch aborts (not including launch rescheduling because of weather). It is more than fortuitous that all weather aborts have occurred during months having a low probability of launch, or, stated otherwise, there have been no recorded weather aborts from May through September at ETR. If at all possible, launches should not be scheduled with monthly launch probabilities of less than 0.5. See Table 1-1.
TABLE 1-6. COMPARISON OF $P_L$ FOR DIRECT ASCENT LAUNCH WITH MINIMUM LAUNCH WINDOW LENGTH OF 20 AND 10 MINUTES

<table>
<thead>
<tr>
<th>Turnaround Time Days</th>
<th>Launch Window 20 Min.</th>
<th>Launch Window 10 Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Launch Opportunities</td>
<td>Number of Launch Windows</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
<td>161</td>
</tr>
<tr>
<td>2</td>
<td>36</td>
<td>89</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>69</td>
</tr>
</tbody>
</table>

TABLE 1-7. COMPARISON OF $P_L$ FOR DIRECT ASCENT VERSUS PARKING ORBIT ASCENT LAUNCH, LAUNCH WINDOW $\geq$ 20 MINUTES

<table>
<thead>
<tr>
<th>Turnaround Time Days</th>
<th>Direct Ascent</th>
<th>Parking Orbit Ascent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Launch Opportunities</td>
<td>Number of Launch Windows</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
<td>161</td>
</tr>
<tr>
<td>2</td>
<td>36</td>
<td>89</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>69</td>
</tr>
</tbody>
</table>
2.1 INTRODUCTION

2.1.1 SCOPE. An analysis of the GSE and Facility Systems on Complex 36A and 36B was performed to determine the capability of each of the systems to meet the contingency hold requirements for a $3\sigma$ (.998) probability of launch for the Surveyor direct ascent and parking orbit missions. The hold requirement for individual launch attempts are given in Reference 9.

2.1.2 COMPLEX 36A. The GSE and Facility Systems on Complex 36A provide a total complex/vehicle $3\sigma$ probability of launch for the monthly launch opportunity at the opening of the launch window and, utilizing the primary systems for launch, the complex will support a launch window of approximately 93 minutes with a $3\sigma$ probability of launch. Using the secondary or backup systems, the complex will support a launch window of 10 minutes with a $3\sigma$ probability of launch. The limitations of the complex capability are as follows:

a. All GSE and Facility Systems meet the requirement for a $3\sigma$ probability of launch at the opening of the launch window; 126 minutes of reserve time required for range countdown period T-90 to T-0.

b. All GSE and Facility Systems, except the facility GN2 system (without recharge) and the backup air conditioning supply, meet the requirement for a $3\sigma$ probability of launch for the average single-burn launch window; 126 minutes of reserve time required for range countdown plus a 50 minute launch window. The backup air conditioning supply is not considered a major constraint.

c. The facility GN2 supply system (routine use) is the only major constraint to a $3\sigma$ probability of launch for the maximum single-burn window; 126 minutes of reserve time required for range countdown plus an 80 minute launch window.

d. The facility GN2 supply system is the only major constraint to a $3\sigma$ probability of launch for the average two-burn launch window; 126 minutes of reserve time required for range countdown plus a 150 minute launch window.

e. The LH2, LN2 air conditioning supply, primary helium supply and facility GN2 supply systems represent the primary constraints to a $3\sigma$ probability of launch for the maximum two-burn launch window; 126 minutes of reserve time required for range countdown plus a 270 minute launch window.
2.1.3 COMPLEX 36B. The GSE and Facility Systems on Complex 36B provide a total complex/vehicle probability of launch of .91 for the monthly launch opportunity. The limitations of the complex capability are as follows:

a. All GSE and Facility Systems, except the LO₂/LN₂ subcooler unit, meet the requirement for a 3σ probability of launch at the opening of the launch window; 126 minutes of reserve time required for range countdown period T-90 to T-0. The LO₂/LN₂ subcooler unit has only a 74 minute hold capability, which is unsatisfactory.

b. The LO₂ system, in addition to the LO₂/LN₂ subcooler, does not support the average single-burn launch window; 126 minutes of reserve time required for the range countdown plus a 50 minute launch window. The usable storage capacity of the LO₂ system would have to be increased to approximately 39,000 gallons to provide this hold capability.

c. The air conditioning GN₂ supply system, in addition to those previously mentioned, does not meet the requirements for the maximum single-burn launch window (206 minutes reserve time) and the average two-burn launch window (276 minutes reserve time). The system usable capacity would have to increased to approximately 155,000 pounds to have this hold capability; existing usable capacity is 146,500 pounds.

d. The LH₂ system, in addition to the LO₂, air conditioning GN₂ and LO₂/LN₂ subcooler systems, does not support the requirements for a 3σ probability of launch for the maximum two-burn launch window; 126 minutes reserve time required for the range countdown plus a 270 minute launch window. The LH₂ system usable capacity would have to be increased to approximately 32,000 gallons to provide this hold capability.

2.2 LAUNCH SUCCESS CRITERIA

2.2.1 GSE AND FACILITY SYSTEMS REQUIREMENTS. To achieve a high probability of launch success of the Atlas/Centaur vehicle during the monthly launch opportunity for the Surveyor Mission, the GSE and Facility Systems require a contingency hold and recycle capability commensurate with predictable countdown delays for each day of launch. The purpose of this analysis is to update the systems capability data for ETR Complex 36A, (Reference 10), and to determine the probability of launch for each of the GSE and Facility Systems on ETR Complex 36B. The launch probability of a system is determined from the available system reserve time (hold capability) and the historical Atlas D-Series flight data from ETR. The probability of launch during the monthly launch opportunity is then established from the number of available launch windows in the monthly opportunity and the complex/vehicle "turn-around" capability (paragraph 1.5).
2.3 DISCUSSION:

2.3.1 SYSTEM LAUNCH PERFORMANCE RESERVE. The Launch Performance Reserve (LPR) of a system (Reference 9), is a function of the usable storage capacity, the flow demands on the system during the normal performance of the range countdown, and the flow demands on the system in the event of a launch abort. The usable capacity of a system is established by subtracting the required residual (minimum level allowed) in the storage vessel from the maximum level permitted. A fill tolerance factor is also used to allow for level measurement inaccuracies and to permit loading the cryogenic storage vessels prior to launch day. The flow demands on a system were established by a detailed analysis of the range countdown and abort procedures, a review of the systems parameters document, (Reference 7), and by measured or estimated system flow rates. The system usage figures shown in paragraphs 2.4 and 2.5 of this report are subject to change because of procedural or system design modifications and by a comparison of actual consumption figures during a launch countdown with the estimated values.

2.3.2 SYSTEM PROBABILITY OF LAUNCH (P_L). The probability of launch of a system was established from the calculated available reserve time and the historical data of the Atlas D-Series launches from ETR, Reference 9. The data shows the probability of launch versus reserve time for the range countdown periods T-280 to T-0, T-90 to T-0, and T-10 to T-0 for the following six categories of vehicle launches:

a. All Atlas D-Series launches.

b. All Atlas D-Series launches excluding range and weather holds.


e. Atlas D-Series Space Vehicle launches excluding range and weather holds.


Table 2-1 shows the reserve time required for the range countdown period T-90 to T-0 for the six launch vehicle categories with a 3σ probability of launch during the monthly launch opportunity. The range countdown period T-90 to T-0 is used for this analysis because this period includes the more critical operations and time-sequenced events. The existing hold at T-90 minutes is treated as a portion of the range countdown in the calculation of system reserve time and is used to absorb countdown delays prior to T-90 minutes. Table 2-1 shows also the probabilities of single and multiple launch opportunities. For example, if three launch opportunity days are available, a single launch probability of .89 would be required for a 3σ probability of launching during the monthly opportunity. For the Atlas D-Series space launch vehicle category.
excluding range and weather holds, the reserve time required is 126 minutes, assum-
ing three launch opportunity days. For two launch opportunity days, 151 minutes of re-
serve time would be required. The actual system probability of launch is determined
from the appropriate table, (Reference 9), after the reserve time has been calculated.

TABLE 2-1. LPR REQUIRED FOR 3o LAUNCH PROBABILITY FOR
MONTHLY LAUNCH OPPORTUNITY

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.998(3o)</td>
<td>304</td>
<td>268</td>
<td>367</td>
<td>208</td>
<td>210</td>
<td>206</td>
</tr>
<tr>
<td>2</td>
<td>.96</td>
<td>209</td>
<td>184</td>
<td>248</td>
<td>151</td>
<td>151</td>
<td>148</td>
</tr>
<tr>
<td>3</td>
<td>.89</td>
<td>169</td>
<td>148</td>
<td>198</td>
<td>126</td>
<td>126</td>
<td>123</td>
</tr>
<tr>
<td>4</td>
<td>.79</td>
<td>137</td>
<td>121</td>
<td>159</td>
<td>107</td>
<td>106</td>
<td>103</td>
</tr>
</tbody>
</table>

The launch vehicle category used to determine the system probability of launch for
this analysis was the Atlas D-Series space launches excluding range and weather
holds. This category was selected for the following reasons:

a. There have been too few Atlas/Centaur launches to establish, with reasonable
   confidence, the reserve time required for a high probability of launch.

b. The Atlas D-Series space launch data includes the Atlas/Centaur, Atlas/
   Agena, and the Atlas/Mercury vehicles. These vehicles represent the opera-
   tional Atlas/Centaur complexity with regard to vehicle and GSE systems as
   well as the range requirements for launch success.

c. The Atlas D-Series space vehicle launch data reflects improved launch capa-
   bility because of the experience and learning gained during the R&D phase of
   flights.

d. The range and weather hold data was omitted to establish the system probabi-
   lity of launch at the opening of the launch window. For this analysis, the launch
   window will be used to absorb the range and weather holds.
2.3.3 SYSTEM PARAMETERS AND STUDY GROUND RULES. The analysis of the GSE and Facility Systems was performed to establish the following system parameters for ETR Complex 36B and to update the data for ETR Complex 36A, Reference 10:

a. The minimum reserve time available using existing procedure and operating requirements.

b. The probability of launch for the system at the opening of the launch window for a single launch opportunity day.

c. The probability of launch of the system during the monthly launch opportunity.

d. The reserve time available in excess of that required for a probability of launch of 3σ. The excess reserve time represents the portion of the launch window that can be used and maintain a probability of launch at 3σ.

A review of these system parameters will identify the systems constraining the total complex/vehicle probability of launch and will define the procedural or design modifications required to achieve a probability of launch of 3σ.

The ground rules used in the development of this analysis are as follows:

a. A monthly launch opportunity is assumed to consist of a minimum of five launch windows and three launch opportunities, i.e., a turnaround capability in the event of an abort of two days.

b. A probability of launch of 3σ for the monthly launch opportunity is required at the opening of the launch window.

c. The average and maximum single-burn launch windows are 50 and 80 minutes, respectively.

d. The average and maximum two-burn launch windows are 150 and 270 minutes, respectively.

2.4 COMPLEX 36A GSE AND FACILITY SYSTEMS

2.4.1 SYSTEMS RESERVE ANALYSIS. The Complex 36A GSE and Facility Systems data previously presented, (Reference 1), have been updated with current system operating requirements and system modifications. The data is summarized in Table 2-2. The detailed data calculations and general system schematics are shown in Appendix A. The schematics are presented only for basic orientation of the differences between Complex 36A and 36B and to show system capacities, usages and flow demands. Table 2-2 provides the following pertinent information for each system:
a. Column A identifies the system investigated and, where applicable, its prime function.

b. Column B denotes the system schematic number, Appendix A, from which the system usages can be identified.

c. Column C lists the usable capacity of the system. The usable capacity assumes maximum level at the start of the range countdown.

d. Column D shows the total demand on the system during the range countdown. For this analysis, the existing 60-minute scheduled hold at T-90 minutes is included as part of the range countdown.

e. Column E indicates the required demand on the system in the event of an aborted launch. The value shown represents the maximum requirement for an abort occurring after T-3 seconds.

f. Column F reports the maximum usage rate of the system.

g. Column G denotes the minimum reserve time available for the system. This figure is derived by dividing the system capacity available for holding by the maximum usage rate of the system. For example, the LH2 Systems' capacity available for holding is 11,200 gallons and the maximum usage rate is 45 gpm. Therefore, the minimum reserve time available is:

\[
\text{Reserve Time} = \frac{11,200 \text{ gallons}}{45 \text{ gpm}} = 249 \text{ minutes}
\]

h. Column H shows the single launch day probability of launch, based on the reserve time required for the time period T-90 minutes to T-0, at the opening of the launch window.

i. Column I shows the system probability of launch for the monthly launch opportunity.

j. Column J reports the reserve time available in excess of that required for a 3σ probability of launch for the monthly launch opportunity. The excess reserve time represents the launch window that can be met by each system with a 3σ probability of launch.

Only one of the GSE and Facility Systems at Complex 36A does not have the usable capacity required for a 3σ probability of launch at the opening of the launch window, the Atlas thrust section air conditioning system. This system is activated at T-5 minutes for the purpose of providing an inert atmosphere in the engine compartment prior to engine ignition. The system can be secured any time after activation in the event of a countdown delay and, with the 14 minute reserve time available, can support a minimum of three recycles. This capability is adequate to support the vehicle launch with a high probability of success.
TABLE 2-2. ETR COMPLEX 36A GSE & FACILITY

<table>
<thead>
<tr>
<th>System</th>
<th>Figure No.</th>
<th>Usable Capacity</th>
<th>Range Count-Down Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO₂ Transfer System</td>
<td>A-1</td>
<td>51,200 gallons</td>
<td>28,945 gallons</td>
</tr>
<tr>
<td>LO₂ Storage Tank Helium Pressurization Supply</td>
<td>A-1</td>
<td>1,392 lb</td>
<td>1,089 lb</td>
</tr>
<tr>
<td>LH₂ Transfer System</td>
<td>A-2</td>
<td>25,000 gallons</td>
<td>13,800 gallons</td>
</tr>
<tr>
<td>LHe System</td>
<td>A-3</td>
<td>900 gallons</td>
<td>160 gallons</td>
</tr>
<tr>
<td>LN₂ System, Facility</td>
<td>A-4</td>
<td>19,000 gallons</td>
<td>3,621 gallons</td>
</tr>
<tr>
<td>LN₂ System, Air Conditioning</td>
<td>A-5</td>
<td>177,000 lb</td>
<td>35,370 lb</td>
</tr>
<tr>
<td>Helium System, 3000 psig Primary Supply</td>
<td>A-6</td>
<td>42,800 scf</td>
<td>12,030 scf</td>
</tr>
<tr>
<td>Helium System, 6000 psig Emergency Supply</td>
<td>A-6</td>
<td>38,400 scf</td>
<td>22,220 scf</td>
</tr>
<tr>
<td>Helium System, 6000 psig Insulation Panel Purges</td>
<td>A-7</td>
<td>6,000 lb</td>
<td>1,625 lb</td>
</tr>
<tr>
<td>GN₂ System, 2400 psig Routine Use Using Facility Recharger</td>
<td>A-8</td>
<td>6,710 lb</td>
<td>5,700 lb</td>
</tr>
<tr>
<td>GN₂ System, 2400 psig Routine Use Without Facility Recharger</td>
<td>A-8</td>
<td>6,710 lb</td>
<td>3,150 lb</td>
</tr>
<tr>
<td>GN₂ System, 2400 psig Backup Air Conditioning Supply</td>
<td>A-5</td>
<td>146,500 lb</td>
<td>35,370 lb</td>
</tr>
<tr>
<td>GN₂ System, 8000 psig Hold-down &amp; Release</td>
<td>A-8</td>
<td>280 lb</td>
<td>55 lb</td>
</tr>
<tr>
<td>GN₂ System, Atlas Thrust Section</td>
<td>A-5</td>
<td>1,530 lb</td>
<td>400 lb</td>
</tr>
</tbody>
</table>

1. The excess reserve time is that portion of the launch window that can be met with a 3 second delay.
2. The excess reserve time is that portion of the launch window that can be met with a 3 second delay.
3. For 2 burn missions the range countdown usage is approximately 19,450 scf.
4. Usable capacity figure indicates static storage only. Use of the facility recharger with which includes 570 minutes reserve time of the facility LN₂ system.
5. In the event the facility recharger is inoperable for the range countdown, the air conditioned shown reflect routine GN₂ usage excluding the LN₂ flow demands.
6. The Atlas Thrust Section air conditioner is activated at T - 5 minutes. The time indicated is for routine GN₂ usage.
### SYSTEMS SUMMARY LAUNCH PERFORMANCE RESERVE ANALYSIS

<table>
<thead>
<tr>
<th>Abort Usage</th>
<th>Maximum Usage Rate</th>
<th>Minimum Reserve Time Available, Minutes</th>
<th>Probability of Launch</th>
<th>Excess Reserve Time, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>R&lt;sub&gt;L&lt;/sub&gt; Single Launch</td>
<td>P&lt;sub&gt;L&lt;/sub&gt; MLO</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>0</td>
<td>53 gpm</td>
<td>420</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>∞</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>0</td>
<td>45 gpm</td>
<td>249</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>0</td>
<td>5 gpm</td>
<td>148</td>
<td>0.954</td>
<td>0.999</td>
</tr>
<tr>
<td>200 gallons</td>
<td>26.7 gpm</td>
<td>570</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>60,870 lb</td>
<td>368.5 lb/min</td>
<td>219</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>12,000 scf</td>
<td>50 scfm</td>
<td>375</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>8,400 scf</td>
<td></td>
<td>∞</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>640 lb</td>
<td>280 lb/hour</td>
<td>800</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>4,075 lb</td>
<td>21.7 lb/min</td>
<td>879</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>2,250 lb</td>
<td>7.8 lb/min</td>
<td>161</td>
<td>0.984</td>
<td>0.999</td>
</tr>
<tr>
<td>60,870 lb</td>
<td>368.5 lb/min</td>
<td>136</td>
<td>0.923</td>
<td>0.999</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>∞</td>
<td>0.999</td>
<td>0.999</td>
</tr>
<tr>
<td>0</td>
<td>80 lb/min</td>
<td>14(6)</td>
<td>&lt;0.50</td>
<td>&lt;0.50</td>
</tr>
</tbody>
</table>

Probability of launch.

If a recharge capacity of 80 lb/min exceeds the demand flow and provides a reserve of 879 minutes, the recharge backup system will be utilized in lieu of the LN<sub>2</sub> air conditioning system. The figures noted allows a minimum of 3 recycle operations.
2.4.2 SYSTEMS CAPABILITY TO SUPPORT SINGLE AND TWO-BURN LAUNCH WINDOWS. Figure 2-1 summarizes the data of Column G of Table 2-2. The available reserve time of each of the GSE and Facility Systems at Complex 36A is shown in relation to the reserve time required to support and utilize the single and two-burn mission launch windows with a $3\sigma$ probability of launch. Lines B and C represent the reserve time required for the average and maximum single-burn launch windows. Lines D and E represent the reserve time required for the average and maximum two-burn launch windows, respectively. Line A is the reserve time required for a $3\sigma$ probability of launch at the opening of the launch window.

Four systems will not support the average single-burn launch window. They are the Atlas thrust section air conditioning system, the GN$_2$ system (routine use), the air conditioning backup GN$_2$ system, and the LHe system. As previously discussed, the Atlas thrust section air conditioning system can be secured at any time after activation and has the capability of a minimum of three recycles. This capability is considered adequate, and does not constrain the complex/vehicle probability of success. The 148 minute reserve time shown for the LHe system assumes continuous flow. This system, like the Atlas thrust section air conditioning system, can be secured in the event of a delay after activation, and can be reactivated at any time as long as temperature and time restrictions are met. This operating capability will extend the available reserve time to the maximum required. Therefore, this system does not appear to constrain the complex/vehicle probability of success.

The facility GN$_2$ (without recharger) and the air conditioning backup GN$_2$ supply systems are a backup mode of operation and are used only in the event that the facility recharger malfunctions. The system constraints, therefore, do not appear to be critical. If it becomes likely, however, that the situation would arise, and the maximum reserve time is essential, then the requirement to maintain GN$_2$ flow to the interstage adapter until the engine standby purges are reinstalled should be investigated. Securing the GN$_2$ flow at T +60 minutes instead of T +240 minutes will increase the air conditioning system reserve time to approximately 241 minutes, which exceeds the maximum single-burn launch window requirements. Consideration could then be given to transferring one of the 700 ft$^3$ GN$_2$ bottles in the backup air conditioning supply, (Figure A-8), to the facility GN$_2$ storage. This transfer would increase the facility GN$_2$ system reserve time to approximately 710 minutes and would reduce the air conditioning supply reserve time to approximately 225 minutes. The available reserve time for both systems will then exceed the requirements for the maximum single-burn launch window.

All GSE and Facility Systems, except those previously discussed, support the maximum single-burn launch window requirements.
Figure 2-1. Summary Available Reserve Time, GSE & Facility Systems, for Vehicles AC-6 & on, Complex 36A
For the two-burn mission, two systems in addition to those previously mentioned do not have the reserve time available to support the average and maximum two-burn launch windows, the LH₂ and the LN₂ air conditioning systems. By topping the LH₂ storage tank to maximum capacity on the day of launch, i.e., deleting the fill tolerance allowance, the LH₂ system will have adequate capacity to support the average two-burn launch window. Deleting the requirement to supply GN₂ to interstage adapter until the engine standby purges are reinstalled will increase the LN₂ air conditioning system reserve time to approximately 324 minutes. This reserve time is more than adequate to support the average two-burn launch window. Without major system modifications, however, neither the LH₂ nor LN₂ air conditioning systems will support the maximum two-burn launch window. The LHe and Atlas thrust section air conditioning systems are considered adequate because of the capability to secure their operation in the event of an extended delay. The facility GN₂ supply (without facility recharger) and air conditioning backup GN₂ system constraints are not considered critical because these systems would only be used in an emergency; i.e., a malfunction of the facility recharger unit.

2.4.3 SYSTEM CAPACITY VERSUS HOLD CAPABILITY. Figures 2-2 through 2-9 show usable capacity versus reserve time of the primary systems which affect complex/vehicle hold capability. The relationship of usable capacity to the average and maximum single and two-burn launch windows is also shown, points B, C, D and E. Point A is indicative of the existing system reserve time. For example, to obtain a 3σ probability of launch for the average two-burn launch window, the LH₂ usable capacity would have to be increased to approximately 26,500 gallons, point D, Figure 2-3. Conversely, the figures show the available reserve time for storage capacities other than maximum. For example, if the LO₂ storage capacity is 40,000 gallons instead of the maximum 51,000 gallons, the available reserve time is approximately 210 minutes, Figure 2-2. This capacity would be adequate to support the maximum single-burn launch window, point C, Figure 2-2.

2.5 COMPLEX 36B GSE AND FACILITY SYSTEMS

2.5.1 SYSTEMS RESERVE ANALYSIS. Complex 36B GSE and Facility Systems data which define the launch support capability are summarized in Table 2-3. The data shown reflects current system operating requirements and design. The detailed system data calculations and general system schematics are given in Appendix B. The schematics are presented for basic orientation of the differences between Complex 36A and 36B, and to show system capacities, usages and flow demands.
Figure 2-2. Complex 36A LO₂ System Capacity versus Hold Capability
Figure 2-3. Complex 36A LH2 System Capacity versus Hold Capability
Figure 2-4. Complex 36A, Facility LN₂ System Capacity versus Hold Capability

- A: Existing system reserve time
- B: Usable capacity, required for 30-ft. pl. for MLO, average one-burn launch window
- C: Usable capacity, required for 30-ft. pl. for MLO, average two-burn launch window
- D: Usable capacity, required for 30-ft. pl. for MLO, maximum two-burn launch window

Gallons x 10³

Facility LN₂ system usable capacity

Reserved time required for MLO or pl. launch

Reserved time for MLO or pl. window opening
Figure 2-5. Complex 36A, Air Conditioning LN2 System Capacity versus Hold Capability
Figure 2-7. Complex 36A, Routine Use GN₂ System Capacity versus Hold Capability without Recharger
Figure 2-8. Complex 36A, 6000 PSIG Helium System, Insulation Panel Purges
<table>
<thead>
<tr>
<th>System</th>
<th>Schematic Figure No.</th>
<th>Usable Capacity</th>
<th>Range Count-Down Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO₂ System</td>
<td>B-1</td>
<td>36,500 gallons</td>
<td>29,475 gallons</td>
</tr>
<tr>
<td>LH₂ System</td>
<td>B-2</td>
<td>25,000 gallons</td>
<td>13,800 gallons</td>
</tr>
<tr>
<td>LHe System</td>
<td>B-3</td>
<td>900 gallons</td>
<td>160 gallons</td>
</tr>
<tr>
<td>LN₂ System</td>
<td>B-4</td>
<td>25,000 gallons</td>
<td>2,875 gallons</td>
</tr>
<tr>
<td>LO₂/LN₂ Subcooler</td>
<td>B-4</td>
<td>1,204 gallons</td>
<td>228 gallons</td>
</tr>
<tr>
<td>LN₂ Storage Tank GN₂ Supply</td>
<td>B-4</td>
<td>5,110 lb</td>
<td>3,540 lb</td>
</tr>
<tr>
<td>Helium System, 6000 psig</td>
<td>B-5</td>
<td>92,800 scf</td>
<td>35,110 scf</td>
</tr>
<tr>
<td>Vehicle Pressurization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helium System, 6000 psig Insulation Panel Purges</td>
<td>B-6</td>
<td>6,000 lb</td>
<td>1,625 lb</td>
</tr>
<tr>
<td>GN₂ System, 6000 psig (Routine Use)</td>
<td>B-7</td>
<td>9,600 lb</td>
<td>3,234 lb</td>
</tr>
<tr>
<td>GN₂ System, 2400 psig Air Conditioning Supply</td>
<td>B-8</td>
<td>146,500 lb</td>
<td>34,040 lb</td>
</tr>
<tr>
<td>GN₂ System, 8000 psig Hold-Down &amp; Release</td>
<td>B-7</td>
<td>150 lb</td>
<td>12 lb</td>
</tr>
</tbody>
</table>

1. The excess reserve time is that portion of the launch window that can be met with a
2. For 2 burn missions, the range countdown usage is approximately 35,190 scf and th
3. The available reserve time is referenced to a 4 hour purge of the interstage adapter
The LO₂/LN₂ subcooler is the only GSE or Facility System that does not have the usable capacity required for a 3σ probability of launch at the opening of the launch window. This unit subcools the LO₂ during Atlas and Centaur LO₂ topping and has a usable capacity of 1204 gallons of LN₂. With a usage rate of approximately 13 gpm, the available reserve time is 74 minutes. This reserve time represents an unsatisfactory system probability of launch of approximately .55. A design modification similar to that provided on Complex 36A is required, i.e., the capability for remote level sensing and fill. This modification would increase the unit hold capability to the required maximum, and would decrease the hold capability of the LN₂ storage system to approximately 950 minutes. This capacity is more than adequate to support the Atlas/Centaur Vehicle single and two-burn launch missions.

2.5.2 SYSTEM CAPABILITY TO SUPPORT SINGLE AND TWO-BURN LAUNCH WINDOWS. Figure 2-10 summarizes the data of Column G of Table 2-3. The available reserve time of each of the GSE and Facility System at Complex 36B is shown in relation to the reserve time required to support the single and two-burn launch windows. Lines B and C represent the reserve time required for the average and maximum single-burn launch windows, respectively. Lines D and E represent the reserve time required for the average and maximum two-burn launch windows, respectively. Line A is the reserve time required for a 3σ probability of launch at the opening of the launch window.

Four systems do not support the average and maximum single-burn launch windows, the LO₂ system, the LHe system, the air conditioning GN₂ system and the LO₂/LN₂ subcooler. The LO₂/LN₂ subcooler hold capability is unsatisfactory and will require a design modification. The LHe system has the capability to be secured and reactivated in the event of a countdown delay, therefore, the system capacity is considered adequate to support the Surveyor Mission launches.

The LO₂ system will require an increase in usable storage capacity of approximately 4,000 gallons (total of 40,500 gallons) to provide the required hold capability for the average and maximum single-burn launch windows. The air conditioning GN₂ supply has adequate capacity for the average single-burn launch window. However, for the maximum window, the capacity would have to be increased to approximately 155,000 pounds to provide the required hold capability, existing usable capacity is 146,500 pounds. Deleting the requirement to maintain GN₂ flow to the interstage adapter until engine standby purges are reinstalled, in the event of an abort after T-3 seconds, will increase the system hold capability by approximately 82 minutes. This added capability would be adequate to support the single-burn mission requirements.

The LH₂ system, in addition to the systems previously discussed, does not support the average and maximum two-burn launch windows. Topping the LH₂ storage to maximum capacity on the day of launch will provide adequate capacity to support the average two-burn window. However, to support the maximum window, the LH₂ storage usable capacity would have to be increased to approximately 32,000 gallons.
<table>
<thead>
<tr>
<th>Component</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO₂ SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH₂ SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LHe SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LN₂ SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LO₂/LN₂ SUBCOOLER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LN₂ STORAGE TANK START</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LN₂ SUPPLY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HELIUM 6000 PSIG VEHICLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRESSURIZATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HELIUM 6000 PSIG INSULATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANEL PURGES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GN₂ 6000 PSIG CONTROLS &amp; PURGES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GN₂ 2400 PSIG AIR CONDITIONING</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GN₂ 8000 PSIG HOLD DOWN &amp; RELEASE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RESERVE TIME:

- 60
- 120
- 180
- 240
- 300
Figure 2-10. Summary of available Reserve Time, GSE & Facility System for Vehicles AC-6 & on, Complex 36B
2.5.3 SYSTEM CAPACITY VERSUS HOLD CAPABILITY. Figures 2-11 through 2-18 show the usable capacity versus reserve time for the primary systems affecting complex/vehicle hold capability. The relationship of the usable capacity to the average and maximum single and two-burn launch windows is also shown, points B, C, D and E. Point A is indicative of the existing system reserve time. For example, to obtain a \(3\sigma\) probability of launch for the average two-burn launch window, the \(\text{LH}_2\) storage usable capacity would have to be increased to approximately 26,500 gallons, point D, Figure 2-12. Conversely, the figures show the available reserve time for storage capacities other than maximum. For example, if the helium pressurization system capacity is 70,000 scf instead of 92,800 scf, the reserve time available would be 290 minutes, Figure 2-15. This capacity would be adequate to support the average two-burn launch window, point D, Figure 2-15.

2.6 CONCLUSIONS

2.6.1 CONSTRAINTS ON LAUNCH CAPABILITY. Table 2-4 summarizes the conclusions of the analysis. The systems that constrain the complex/vehicle launch capability are shown in relation to the launch requirements for a \(3\sigma\) probability of success. As the table shows, the primary constraint is the \(\text{LO}_2/\text{LN}_2\) subcooler unit on Complex 36B. This deficiency should be resolved. The remaining system constraints should be resolved as soon as firm program requirements are defined.

<table>
<thead>
<tr>
<th>System</th>
<th>Launch Window Opening</th>
<th>Launch Capability Constraints</th>
<th>Single-Burn</th>
<th>Two-Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex 36A:</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Facility GN(_2) (W/O Recharger)</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>LH(_2) System</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>LN(_2) Air Conditioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex 36B:</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>(\text{LO}_2/\text{LN}_2) Subcooler</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>(\text{LO}_2) System</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Air Conditioning GN(_2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH(_2) System</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 2-11. Complex 36B, LO₂ System Capacity versus Hold Capability
Figure 2-13. Complex 36B, LN₂ System Capacity versus Hold Capability
Figure 2-15. Complex 36B, 6000 PSIG Helium Pressurization System Capacity versus Hold Capability
Figure 2-16. Complex 36B, 6000 PSIG Helium Purge System, Capacity versus Hold Capability
Figure 2-17. Complex 36B, 6000 PSIG GN₂, Routine Use, System Capacity versus Hold Capability
Figure 2-18. Complex 36B, Air Conditioning GN2 System Capacity versus Hold Capability
SECTION III
COMBINED SYSTEMS TEST STAND

3.1 INTRODUCTION

3.1.1 PURPOSE. The main purpose of the Combined Systems Test (CST) Stand Pre-Operational Verification Test Program was to demonstrate the capability of the facility to perform integrated systems checkout. The T-21 Spacecraft and the AC-7 Launch Vehicle were used to demonstrate this capability. The checkout verified the hardware and procedures of CST as well as the electrical and mechanical interface of the spacecraft and launch vehicle.

3.1.2 CST TEST PROGRAM OBJECTIVES. Most of the basic objectives of the CST Test Program were met. These included the following:

- Demonstrated the mechanical compatibility of the Centaur and spacecraft, interstage adapter, and Centaur interfaces
- Verified the adequacy of the space vehicle launch preparations, handling and countdown procedures
- Verified the compatibility of the CST facility with the Surveyor spacecraft.

The following basic objectives were not met fully due to test equipment wiring problems and component out-of-tolerance malfunctions:

- Demonstrated the compatibility of the space vehicle electrical systems and GSE during the simulated second stage retromaneuver, including spacecraft operation
- Demonstrated the RF and electrical compatibility of the space vehicle inflight configuration.

It is anticipated that prior to the retest of the Atlas/Centaur vehicle for the CST site selloff demonstration, the GSE wiring problems and component out-of-tolerance malfunctions will be corrected.

3.2 CST WORK PLAN T-21/AC-7

The CST Model Work Plan is based upon a 40 M-day period, with 20 days allotted for GSE modification and 20 days for system test and evaluation, in accordance with the May LOT Report (Reference 11). The actual time span for the T-21/AC-7 CST work plan was 55 days. Engineering design changes and part shortages increased the GSE modification and checkout time beyond the model work plan 20 day period.
Most of the GSE installations encountered problems which resulted in the model work plan differing from the actual work schedule. The anticipated GSE modification time was to start on work day 42 and end on day 20. However, the GSE systems were undergoing modification and checkout starting at work day 55 and ending on work day 16, just prior to the planned arrival of the T-21 Spacecraft. It is anticipated that since the GSE is now in "operational configuration" the 40 day modification period from day 55 to day 16 would not be repeated and the more realistic period of 20 working days would be followed. The spacecraft arrival date slipped two days from day 15 to day 13. This caused minor changes in the model work plan schedule. In general the actual work plan followed the model work plan quite closely during the last 15 days. The spacecraft was shipped to ETR on schedule at the end of day 1.

3.2.1 CST WORK PLAN CHANGES. During the modification and test sequence several changes were made to the CST work plan. The need for rescheduled and deleted tasks was anticipated since this was the first time the spacecraft and the Atlas/Centaur launch vehicle were checked out in the CST facility. The changes to the CST work plan are described below.

a. Rescheduled tasks:

(1) Landline Installation Checkout - Procedure Number AY65-0531-001-13. Section C of this procedure was rescheduled to ensure proper landline cable operation just prior to the start of combined acceptance testing.

(2) Telemetry System Checkout - AY65-0531-002-13. Sections C and D of this procedure were rescheduled to ensure proper operation of the GD/C telemetry system just prior just prior to the start of combined acceptance testing.

(3) Remove Insulation Panels - AY65-0539-004-13. In the model work plan, the insulation panels were to be removed from the Centaur vehicle prior to the erection of the T-21 Spacecraft. However, it was decided that the insulation panels should remain on during the combined acceptance test to ensure system compatibility and more closely simulate inflight conditions. The insulation panel removal task was rescheduled to be performed after the T-21 Spacecraft had been demated from Centaur.

b. Deleted tasks:

(1) Electrical Power Checkout, AY65-0535-050-13. This procedure checks out the 400 cycle power control and distribution system. Included as part of this system is the 7 volt DC and 28 volt DC power supply system. This procedure was deleted since these systems were already in operational configuration as a result of the CST facility activation.
(2) Propulsion System Checkout, AY65-0535-056-13. This procedure checks out the ground side of the first and second stage engine control system. It was not run during the CST testing since the propulsion system was in operational configuration as a result of the CST facility activation.

(3) Launcher Simulator Checkout, AY65-0535-064-13. This procedure verifies that all of the ground handling equipment used for Atlas and Centaur are on site and in good condition ready for use. The procedure was incorporated into the Test Conductors Monitor System checkout, AY65-0535-067-13.

(4) Inertial Guidance System GSE Checkout, AY65-0535-061-13. This procedure was cancelled and never written. However, the current planning is that it will be written prior to the arrival of the next spacecraft. The factory checkout procedure was utilized to check out the GSE prior to the start of formal CST operations.

(5) Vehicle Power Checkout, AY65-0535-053-13. This procedure validates the first and second stage vehicle power ground control system and was accomplished when the vehicle power GSE was validated.

(6) T-21 Interaction Test, Hughes Aircraft Company Procedure. This test was deleted due to a schedule problem. The verification of the electrical and mechanical performance of the omnidirectional antennas, spacecraft landing legs, solar panel and planar array positioner, Surveyor/Centaur separation switches and the T.V. survey cameras were checked during the combined acceptance test.

3.3 CST SELLOFF

The CST selloff demonstration using the AC-7 launch vehicle started on June 28. The tests will be limited to the Atlas/Centaur vehicle and its GSE since the T-21 Spacecraft will not be available. The demonstration will follow the same sequence and procedures used during the T-21/AC-7 integrated systems checkout. The planned completion date is July 27 when the Centaur stage is shipped to ETR.

3.4 CST SCHEDULE

3.4.1 PLANNED OPERATIONS. The present planned operations for CST is to cycle all of the remaining launch vehicles, AC-8 through AC-15, through the facility for test and evaluation. These include all of the basic Atlas/Centaur/Surveyor vehicles of the following configurations:

a. 1-Burn R&D
b. 2-Burn R&D
c. 1-Burn Operational

d. 2-Burn Operational

e. Dual Capability - Operational.

The sequence of launch vehicles through CST is such that the flight mission changes with each successive vehicle, from a 1-burn mission to a 2-burn mission. This results in the necessity to perform a mission peculiar modification task for each vehicle and supporting CST GSE. Prior to the delivery of the AC-8 vehicle to CST, the GSE will have been modified to handle the basic 1- and 2-burn missions, but will not include mission peculiar instrumentation and landline changes. The model work plan allocates 40 working-days to accomplish the GSE modification, and Atlas/Centaur/Spacecraft testing. A schedule time period of greater than 40 working-days will allow slack time for unexpected contingencies. A schedule of less than 40 working-days can cause a constraint in the test program.

The master schedule for the AC-8, 2-burn mission, allocates 25 working-days for CST modification and test. While this period is not adequate for the CST operation, a schedule slack time of 41 working-days is available for GSE modification prior to the start of testing.

For the AC-10, 1-burn mission, 30 working-days are available for GSE modification and system testing. Due to schedule slack time an additional 10 working-days are available, making a total of 40 working-days.

AC-9 is a 2-burn mission vehicle. The time allocated for CST testing is 21 working-days. The available slack time is only 3 working-days. Based upon the 40 working-day model work plan, 24 working-days are not adequate to perform GSE modification and systems testing. This will require rescheduling the AC-9 test program.

AC-11, 1-burn mission, has allocated 35 working-days for CST operations with an additional 36 working-day slack period available, if required.

Launch Vehicles AC-12 through AC-15 are allocated the full 40 working-day period for CST operations. Adequate slack time is available, if required.

3.5 CST - MODIFICATION CENTER

Increasing effort is being applied to minimize or even eliminate the necessity for launch vehicle modification at ETR. The ideal situation would have a "clean" vehicle, one with all CIC changes incorporated, provided by the factory to CST and then delivered to ETR (Task 1, T.D. 12, LOT). This ideal situation is not likely to be attained because of the continuing stream of component changes and late parts which must be incorporated into the vehicles before launch.
3.5.1 LIMITATIONS. At present some modification to the Atlas and Centaur vehicles and CST GSE are being performed at the CST facility. These are post factory Form DD-250 changes to the flight hardware which must be incorporated prior to CST testing. Most of these changes involve flight component replacement or modification, wiring changes and instrumentation changes. Some of these changes require GSE revisions to insure proper checkout and test evaluation. These changes can be easily performed in the CST facility, however, any changes to the major systems, structure, pressurization system, engine system, etc., is now performed in the factory because of the specialized tools and test stands. Further modifications at CST is, at present, limited by the following items:

a. Physical limitation of CST to perform certain modifications
b. Accessibility of the launch vehicles for modification purposes
c. Time availability to perform modifications.

The accessibility of the Atlas and Centaur for modification is increased in the CST facility compared to the factory. The interstage adapter and Centaur vehicle can be erected in the vertical position in the CST test tower. Access platforms that fit around the vehicle are located at many levels making the task of modification quite easy. Access to the Atlas is improved over that in the factory.

The availability of time to incorporate modifications into the launch vehicle at CST is dependent upon the slack time built into the Master Schedule. Vehicles AC-8 through AC-10 have a minimum of slack time available for modification for changes other than those which must be incorporated for test purposes. Vehicles AC-11 through AC-15 have a sufficiently large amount of slack time which can be used to incorporate all of the post factory Form DD-250 changes.

In summary, it is possible and advantageous to use the CST facility as a modification center for small component changes, wiring revisions, instrumentation and landline changes and other revisions which do not require the use of large specialized tools or large complex systems to validate the change.
SECTION IV

REFERENCES


7. Centaur Unified Test Plan, Hydraulic, Pneumatic, Air Conditioning and Heating (Ground) Test Parameters, Section 9.3.2B, AY62-0047, 10 May 1965.


APPENDIX A

COMPLEX 36A GSE AND FACILITY SYSTEMS

RESERVE DATA CALCULATIONS AND GENERAL SYSTEM SCHEMATICS
ETR COMPLEX 36A

LAUNCH PERFORMANCE RESERVE ANALYSIS

**LO₂ TRANSFER SYSTEM**

- **Storage capacity**: 54,400 gal
- **Fill tolerance**: 3,200 gal
- **Usable capacity**: 51,200 gal

**Range Countdown Requirements**

**Atlas Tanking:**
- **Vehicle volume**: 18,960 gal
- **Boiloff**: 60 minutes @ 40 gpm = 2,400 gal
- **Engine bleeds**: 60 minutes @ 10 gpm = 600 gal

**Total Atlas LO₂**: 21,960 gal

**Centaur Tanking:**
- **Vehicle volume**: 2,775 gal
- **Boiloff**: 70 minutes @ 3 gpm = 210 gal

**Total Centaur LO₂**: 2,985 gal

**GSE Chilldown losses (estimated)**: 4,000 gal

**Total Range Countdown LO₂**: 28,945 gal

**Abort Requirement**

None

**Usage Rate**

- 53 gpm (Atlas & Centaur Boiloff)

**Reserve Time Available**

**LO₂ available for holding**: 51,200 - 28,945 = 22,255 gal

**Reserve time** = \( \frac{22,255}{53} \approx 420 \text{ minutes} \)
**LO₂ STORAGE TANK HELIUM SUPPLY**

Storage capacity (water volume), 4 trailers, 1392 ft³

Maximum pressure 2150 psig, \( p = 1.4 \text{ lb/ft}^3 \)

Minimum pressure 600 psig, \( p = 0.4 \text{ lb/ft}^3 \)

(assume temperature 70°F, 530°F)

Usable capacity = \((1.4 - 0.4) \times (1392) = 1392 \text{ lb}\)

**Range Countdown Requirements**

Helium required to transfer all LO₂ in storage tanks

**Tank No. 1**

Volume 4,120 ft³

Initial Pressure 15 psia, \( p = 0.029 \text{ lb/ft}^3 \)

Final pressure 65 psia, \( p = 0.121 \text{ lb/ft}^3 \)

(assume temperature -260°F, 200°F)

Helium required \((0.121 - 0.029) \times (4120) = 379 \text{ lb}\)

**Tank No. 2**

Volume 3,820 ft³

Initial pressure 15 psia, \( p = 0.029 \text{ lb/ft}^3 \)

Final pressure 115 psia, \( p = 0.215 \text{ lb/ft}^3 \)

(assume temperature -260°F, 200°F)

Helium required \((0.215 - 0.029) \times (3820) = 710 \text{ lb}\)

**Total Helium required for LO₂ transfer** 1089 lb

**Abort Requirement**

None

**Usage Rate**

0

**Reserve Time Available**

∞
LH₂ TRANSFER SYSTEM

Storage capacity 28,000 gal
Fill tolerance 3,000
Usable capacity 25,000 gal

Range Countdown Requirements

Vehicle tank volume 9,400 gal
Boiloff: 40 minutes @ 45 gpm 1,800
GSE Chilldown losses (estimated) 1,500
GSE Pressurization losses* 1,100

Total range countdown LH₂ 13,800 gal

Abort Requirement

None

Usage Rate

45 gpm (maximum boiloff rate)

Reserve Time Available

LH₂ available for holding, 25,000 - 13,800 = 11,200 gal

Reserve time = \frac{11,200}{45} = 249 \text{ minutes}

* GSE Pressurization losses:

Total storage volume 4120 ft³
Transfer pressure 52 psia, p = 0.216 lb/ft³
Initial pressure 15 psia, p = 0.056 lb/ft³

(assume ullage temperature 52° R)

LH₂ required = \frac{0.160 \times (4120)}{0.602 \text{ lb/gal}} = 1,100 \text{ gal}
LHe SYSTEM

Storage capacity 1,000 gal

Fill tolerance 100

Usable capacity 900 gal

Range Countdown Requirements

Storage tank pressurization losses ① 35 gal
GSE chilldown losses ② 40
LHe flow to vehicle: 17 minutes @ 5 gpm 85
Total range countdown LHe 160 gal

Abort Requirement
None

Usage Rate
3 - 5 gpm

Reserve Time Available
LHe available for holding, 900 - 160 = 740 gal
Reserve time = \( \frac{740}{5} = 148 \) minutes

① Storage tank pressurization:
Total storage volume
Transfer pressure 52 psia, \( p = 0.365 \text{ lb/ft}^3 \)
Initial pressure 15 psia, \( p = 0.11 \text{ lb/ft}^3 \)
(assume ullage temperature = 53° R)
LHe required = \( \frac{0.255 \times 147}{1.07 \text{ lb/gal}} = 35 \) gal

② Includes time from flow control valve open to P & W engine turbopump temperature of -310°F
**LN₂ SYSTEM, FACILITY**

<table>
<thead>
<tr>
<th>Description</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage capacity</td>
<td>20,000 gal</td>
</tr>
<tr>
<td>Fill tolerance</td>
<td>1,000</td>
</tr>
<tr>
<td>Usable capacity</td>
<td>19,000 gal</td>
</tr>
</tbody>
</table>

**Range Countdown Requirements**

**Atlas Helium bottle shrouds:**

- **Rapid fill:** 7 minutes @ 75 gpm
  - 525 gal
- **Topping:** 83 minutes @ 10 gpm
  - 830

**LO₂ Subcooler:**

- **Fill**
  - 822
- **Chilldown**
  - 80
- **Topping:** 34 minutes @ 6 gpm
  - 204

**Facility Recharger:**

- 340 minutes @ 3.4 gpm (~22 lb/minute) \(^1\)
  - 1,160

**Total Range Countdown LN₂**

- 3,621 gal

**Abort Requirement**

**Facility recharger:**

- 60 minutes @ 3.4 gpm
  - 200 gal

**Total Abort LN₂**

- 200 gal

**Usage Rate**

Approximately 26.7 gpm

**Reserve Time Available**

- LN₂ available for holding, 19,000 - 3,821 = 15,179 gal

- Reserve time \(\frac{15,179}{26.7} = 570\) minutes

\(^1\) Facility recharger has a recharge capability of approximately 60 lb/minute. The rate used in these calculations is the demand rate to maintain the routine GN₂ system at an acceptable pressure level.
**LN2 SYSTEM, AIR CONDITIONING**

- **Storage capacity**: 28,000 gal
- **Fill tolerance**: 2,000
- **Usable capacity**: 26,000 gal (177,000 lb)

### Range Countdown Requirements

- **Surveyor air conditioning**: 96 minutes @ 78.5 lb/minute = 7,530 lb
- **Forward compartment cooling**: 96 minutes @ 75 lb/minute = 7,200 lb
- **Interstage adapter heating**: 96 minutes @ 160 lb/minute = 15,360 lb
- **Atlas pod cooling**: 96 minutes @ 37 lb/minute = 3,550 lb
- **Leakage allowance**: 96 minutes @ 18 lb/minute = 1,730 lb

**Total range countdown LN2**: 35,370 lb

### Abort Requirements

- **Surveyor air conditioning**: 60 minutes @ 78.5 lb/minute = 4,710 lb
- **Forward compartment cooling**: 120 minutes @ 75 lb/minute = 9,000 lb
- **Interstage adapter heating**: 240 minutes @ 160 lb/minute = 38,400 lb
- **Atlas pod cooling**: 120 minutes @ 37 lb/minute = 4,440 lb
- **Leakage allowance**: 240 minutes @ 18 lb/minute = 4,320 lb

**Total abort GN2**: 60,870 lb
LN$_2$ SYSTEM, AIR CONDITIONING (Continued)

Usage Rate

368.5 lb/minute

Reserve Time Available

LN$_2$ available for holding, 177,000 - 96,240 = 80,760 lb

Reserve time $= \frac{80,760}{368.5} \approx 219$ minutes

1. Time assumes manual securing at T+120 minutes.

2. Figures assume abort after T-3 seconds.
HELUM SYSTEM, PRESSURIZATION SUPPLY

Primary Supply, 3,000 psig

Storage capacity (water volume) 403.1 ft³

Maximum pressure 3,000 psig, p = 1.91 lb/ft³

Minimum pressure 1,200 psig, p = 0.81 lb/ft³

(Assume temperature 70°F, 530°F)

Usable capacity (1.91 - 0.81) 403.1 = 443 lb = 42,800 scf

Range Countdown Requirements

Atlas Propellant tank pressurization 1,800 scf
LHe transfer line/P & W engine purge 5,650
Error contingencies (10% x gross) 4,580

Total range countdown helium 12,030 scf

Abort Requirements

LHe transfer line/P & W engine purge 12,000 scf

Total abort helium 12,000 scf

Usage Rate

50 scfm (LHe transfer line/P & W engine purge)

Reserve Time Available

Helium available for holding, 42,800 - 24,030 = 18,770 scf

Reserve time = \( \frac{18,770}{50} = 375 \text{ minutes} \)

Estimated flow rate
HELUM SYSTEM, PRESSURIZATION SUPPLY (Continued)

Emergency Supply, 6,000 psig
Storage capacity (water volume) 331.1 ft³
Maximum pressure 6,000 psig, p = 3.4 lb/ft³
Minimum pressure 3,550 psig, p = 2.2 lb/ft³
(assume temperature 70°F, 530°F)
Usable capacity = (3.4 - 2.2) 331.1 = 397 lb = 38,400 scf

Range Countdown Requirements
- Atlas airborne helium bottle charge 16,740 scf
- Centaur propellant tank pressurization 350
- Centaur airborne helium bottle charge 470
- Centaur inflight purge bottle charge 470
- P & W engine blowdowns 350
- Error contingencies (10% gross) 3,840
  Total range countdown helium 22,220 scf

Abort Requirements
- LH₂ tank purge 8,400 scf
  Total abort helium 8,400 scf

Usage Rate
0

Reserve Time Available
∞

1 For 2-burn missions, the helium required for bottle pressurization is 830 scf which increases the helium required for range countdown to approximately 22,780 scf.
HELIUM SYSTEM, INSULATION PANEL PURGE SUPPLY

Storage capacity (water volume) \( 2,205 \text{ ft}^3 \)

Maximum pressure \( 6,000 \text{ psig, } p = 3.4 \text{ lb/ft}^3 \)

Minimum pressure \( 1,000 \text{ psig, } p = 0.68 \text{ lb/ft}^3 \)

(assume temperature \( 70^\circ \text{ F, } 530^\circ \text{ R} \))

Usable capacity = \((3.4 - 0.68) \times 2,205 = 6,000 \text{ lb} \)

Range Countdown Requirements

Centaur Vehicle purges:
- Insulation panel purge
- P & W engine injector purge
- Hydraulic pump coupling purge
- \( \text{LH}_2 \) low pressure duct purge
- P & W seal cavity purge
- \( \text{LO}_2 \& \text{LH}_2 \) boost pump seal purge

Total purges - high flow rate \( 280 \text{ lb/hour} \)
- Helium required, 130 minutes @ \( 280 \text{ lb/hour} \) \( 605 \text{ lb} \)

Total purges - low flow rate \( 120 \text{ lb/hour} \)
- Helium required, 210 minutes @ \( 120 \text{ lb/hour} \) \( 420 \text{ lb} \)
- Error contingencies (10% x gross) \( 600 \text{ lb} \)

Total range countdown helium \( 1,625 \text{ lb} \)

Abort Requirements

Total purges - high flow rate
- Helium required, 60 minutes @ \( 280 \text{ lb/hour} \) \( 280 \text{ lb} \)

Total purges - low flow rate
- Helium required, 210 minutes @ \( 120 \text{ lb/hour} \) \( 360 \text{ lb} \)

Total abort helium \( 640 \text{ lb} \)

Usage Rate

\( 280 \text{ lb/hour} \) (high flow rate)

Reserve Time Available

Helium available for holding, \( 6,000 - 2,265 = 3,735 \text{ lb} \)

Reserve time = \( \frac{3,735}{280} \) (60) = \( 800 \text{ minutes} \)
GN\textsubscript{2} SYSTEM, ROUTINE USE

Storage capacity (water volume) \( 1,100 \text{ ft}^3 \)

Maximum pressure \( 2,400 \text{ psig, } p = 11.5 \text{ lb/ft}^3 \)

Minimum pressure \( 1,100 \text{ psig, } p = 5.4 \text{ lb/ft}^3 \)

(assume temperature 70°F, 530°F)

Usable capacity = \( (11.5 - 5.4) \times 1,100 = 6,710 \text{ lb} \)

Range Countdown Requirements

\textbf{LH}_2 \text{ vent stack purge (vehicle):}
6 minutes @ 10 lb/minute \( 60 \text{ lb} \)

\textbf{LH}_2 \text{ vent stack purge (storage tank):}
60 minutes @ 10 scfm \( 45 \text{ lb} \)

\textbf{Atlas gas generator purges:}
10 minutes @ 130 scfm \( 90 \text{ lb} \)

\textbf{Atlas }\text{LO}_2 \text{ dome purges:}
10 minutes @ 730 scfm \( 520 \text{ lb} \)

\textbf{Atlas hypergol purge:}
10 minutes @ 50 scfm \( 35 \text{ lb} \)

\textbf{Terminal box purges, controls & system bleeds:}
340 minutes @ 100 scfm (estimated) \( 2,400 \text{ lb} \)

\textbf{LN}_2 \text{ storage tank pressurization (air conditioning):}

\textit{Initial pressurization} \( 1,300 \text{ lb} \)

\textit{LN}_2 \text{ flow support 90 minutes @ 13.9 lb/min} \( 1,250 \text{ lb} \)

\textit{Umbilical boom hydraulic system charge} \( 55 \text{ lb} \)

Total range countdown GN\textsubscript{2} \( 5,755 \text{ lb} \)

Abort Requirements

\textbf{LH}_2 \text{ vent stack purge (vehicle):}
3 minutes @ 10 lb/minute \( 30 \text{ lb} \)

\textbf{Atlas }\text{LO}_2 \text{ dome purge:}
10 minutes @ 730 scfm \( 520 \text{ lb} \)

\textbf{Terminal box purges, controls & system bleeds:}
240 minutes @ 100 scfm (estimated) \( 1,700 \text{ lb} \)
GN₂ SYSTEM, ROUTINE USE (Continued)

Abort Requirements (Continued)

LN₂ storage tank pressurization (air conditioning):  
60 minutes @ 13.9 lb/minute = 835 lb  
180 minutes @ 5.5 lb/minute = 990 lb  
Total abort GN₂ = 4,075 lb

Usage Rate

Case A - 21.7 lb/minute  
Case B - 7.8 lb/minute

Reserve Time Available

The estimated GN₂ usage for routine use in addition to the required GN₂ to pressurize the air conditioning system LN₂ storage tank exceeds the system capacity by 3,120 pounds making it essential to utilize the facility recharger. In the event the facility recharger is inoperable, the air conditioning backup system will be utilized, relieving the demand on the routine GN₂ storage supply.

A. Reserve Time for Routine GN₂ System with Facility Recharger

The facility recharger has a maximum capacity of 60 pounds per minute which far exceeds the demand flow of routine GN₂ system including the air conditioning LN₂ storage tank demand flow. Therefore:

\[
\text{Reserve Time} = \text{facility LN₂ system reserve time} + \frac{\text{GN₂ usable capacity}}{\text{GN₂ usage rate}} \\
= 570 + \frac{6,710}{21.7} = 570 + 309 = 879 \text{ minutes}
\]

B. Reserve Time for Routine GN₂ System without Facility Recharger

In this case, the LN₂ air conditioning demand flow is deleted providing the following:

Range countdown usage - 3,205 lb  
Abort usage - 2,250 lb  
Usage rate - 7.8 lb/minute

\[
\text{Reserve time} = \frac{6710 - 5455}{7.8} = 161 \text{ minutes}
\]

(1) Exclude for case B reserve time calculations.
GN₂ SYSTEM, AIR CONDITIONING SUPPLY BACKUP

Storage capacity (water volume) 17,040 ft³
Maximum pressure 2,400 psig, \( p = 11.5 \text{ lb/ft}^3 \)
Minimum pressure 600 psig, \( p = 2.9 \text{ lb/ft}^3 \)
(assume temperature 70°F, 530°F)
Usable capacity = (11.5 - 2.9) 17,040 = 146,500 lb

Range Countdown Requirements

Surveyor air conditioning:
96 minutes @ 78.5 lb/minute 7,530 lb
Forward compartment cooling:
96 minutes @ 75 lb/minute 7,200 lb
Interstage adapter heating:
96 minutes @ 160 lb/minute 15,360 lb
Atlas pod cooling:
96 minutes @ 37 lb/minute 3,550 lb
Leakage allowance:
96 minutes @ 18 lb/minute 1,730 lb
Total range countdown GN₂ 35,370 lb

Abort Requirements

Surveyor air conditioning:
60 minutes @ 78.5 lb/minute 4,710 lb
Forward compartment cooling ¹:
120 minutes @ 75 lb/minute 9,000 lb
Interstage adapter heating ²:
240 minutes @ 160 lb/minute 38,400 lb
Atlas pod cooling ¹:
120 minutes @ 37 lb/minute 4,440 lb
Leakage allowance:
240 minutes @ 18 lb/minute 4,320 lb
Total abort GN₂ 60,870 lb

Usage Rate

368.5 lb/minute

Reserve Time Available

GN₂ available for holding, 146,500 - 96,240 = 50,260 lb
Reserve time = \( \frac{50,260}{368.5} = 136 \text{ minutes} \)

¹ Time shown assumes manual securing of GN₂ flow at T+120 minutes.
² Figure assumes abort after T-3 seconds.
GN₂ SYSTEM, HOLD-DOWN & RELEASE

Storage capacity (water volume) = 80 ft³

Maximum pressure = 8,000 psig, \( p = 27 \text{ lb/ft}^3 \)

Minimum pressure = 6,000 psig, \( p = 23.5 \text{ lb/ft}^3 \)

(assume temperature 70°F, 530°F)

Usable capacity = \((27 - 23.5) \times 80 = 280 \text{ lb}\)

Range Countdown Requirements

Pressurize launcher hold-down and release
Cylinders to 5,750 psig = 12 lb
Nose fairing jettison bottle
1,740 in.³ @ 2,535 psig = 15 lb
Launcher stabilization system = 14 lb
Error contingencies (10% x gross) = 28 lb

Total range countdown GN₂ = 69 lb

Abort Requirements
None

Usage Rate
0

Reserve Time Available
∞
GN\textsubscript{2} \textbf{SYSTEM, ATLAS THRUST SECTION HEATING}

Storage capacity (water volume) 1 trailer \hspace{1cm} 274 ft\textsuperscript{3}

Maximum pressure \hspace{1cm} 2,250 psig, \( p = 11 \text{ lb/ft}^3 \)

Minimum pressure \hspace{1cm} 1,100 psig, \( p = 5.4 \text{ lb/ft}^3 \)

(assume temperature 70°F, 530°F)

Usable capacity = \((11 - 5.4) \times 274 = 1,530 \text{ lb}\)

\textbf{Range Countdown Requirements}

Atlas thrust section heating

5 minutes @ 80 lb/minute \hspace{1cm} 400 lb

Total range countdown GN\textsubscript{2} \hspace{1cm} 400 lb

\textbf{Abort Requirements}

None

\textbf{Usage Rate}

80 lb/minute

\textbf{Reserve Time Available}

GN\textsubscript{2} available for holding, \( 1,530 - 400 = 1,130 \text{ lb} \)

Reserve time = \( \frac{1,130}{400} = 14 \text{ minutes} \)

\textbf{NOTE:} During the range countdown this system is used to provide an inert atmosphere in the Atlas thrust section prior to engine start. This system can be secured and flow restarted in the event of a hold after T-5 minutes. The 14-minute reserve time provides a minimum of three additional flows due to countdown delays.
Figure A-1. Complex 36A - LO₂ Transfer System (Simplified Schematic)
Figure A-4. Complex 36A - Facility LN₂ System (Simplified Schematic)
Figure A-5. Complex 36A - Vehicle Air Conditioning GN2 System
Figure A-7. Complex 36A - Insulation Panel Purge Helium System (Simplified Schematic)
Figure A-8. Complex 36A - Routine Use GN₂ System (Simplified Schematic)
Figure A-9. Complex 36A - Atlas Fuel Transfer System (Simplified Schematic)
APPENDIX B

COMPLEX 36B GSE AND FACILITY SYSTEMS

RESERVE DATA CALCULATIONS AND GENERAL

SYSTEM SCHEMATICS
ETR COMPLEX 36B

LAUNCH PERFORMANCE RESERVE ANALYSIS

**LO\textsubscript{2} TRANSFER SYSTEM**

| Storage capacity | 38,000 gal |
| Fill tolerance   | 1,500     |
| Usable capacity  | 36,500 gal |

Range Countdown Requirements

**Atlas tanking:**

- Vehicle volume: 18,960 gal
- Boiloff 60 minutes @ 40 gpm: 2,400
- Engine bleeds 60 minutes @ 10 gpm: 600

Total Atlas LO\textsubscript{2}: 21,960 gal

**Centaur tanking:**

- Vehicle volume: 2,775 gal
- Boiloff 70 minutes @ 3 gpm: 210

Total Centaur LO\textsubscript{2}: 2,985 gal

**GSE Pressurization losses**

- Total storage volume: 5,653 ft\textsuperscript{3}
- Maximum pressure: 165 psia, \( p = 2.8 \) lb/ft\textsuperscript{3}
- Initial pressure: 15 psia, \( p = 0.29 \) lb/ft\textsuperscript{3}

(assume ullage temperature 216° R)

\[
\text{LO}_2 \text{ required} = (2.8 - 0.29) \left( 5,653 \times \frac{7.48}{69.3} \right) = 1,530 \text{ gal}
\]

**GSE chilldown losses (estimated)**

- Total range countdown LO\textsubscript{2}: 3,000 gal

**Abort Requirement**

- None
LO$_2$ TRANSFER SYSTEM (Continued)

Usage Rate
53 gpm (Atlas & Centaur boiloff)

Reserve Time Available
LO$_2$ available for holding, $36,500 - 29,475 = 7,025$ gal
Reserve time $= \frac{7,025}{53} \approx 133$ minutes
LH₂ TRANSFER SYSTEM

Storage capacity 28,000 gal
Fill tolerance 3,000

Usable capacity 25,000 gal

Range Countdown Requirements

Vehicle tank volume 9,400 gal
Boiloff 40 minutes @ 45 gpm 1,800
GSE chilldown losses (estimated) 1,500
GSE pressurization losses* 1,100

Total range countdown LH₂ 13,800 gal

Abort Requirement

None

Usage Rate

45 gpm (maximum boiloff rate)

Reserve Time Available

LH₂ available for holding, 25,000 - 13,000 = 11,200 gal
Reserve time = \frac{11,200}{45} = 249 \text{ minutes}

*GSE pressurization losses

Total storage volume 4,120 ft³
Transfer pressure 52 psia, \( p = 0.216 \text{ lb/ft}^3 \)
Initial pressure 15 psia, \( p = 0.056 \text{ lb/ft}^3 \)
(assume ullage temperature 52° R)

\[
\text{LH}_2 \text{ required} = \frac{0.160 \times 4,120}{0.602 \text{ lb/gal}} = 1,100 \text{ gal}
\]
LHe SYSTEM

Storage capacity 1,000 gal
Fill tolerance 100

Usable capacity 900 gal

Range Countdown Requirements

- Storage tank pressurization 35 gal
- GSE chilldown losses 40 gal
- LHe flow to vehicle 17 minutes @ 5 gpm 85 gal

Total range countdown LHe 160 gal

Abort Requirement

None

Usage Rate

3 - 5 gpm

Reserve Time Available

LHe available for holding, 900 - 160 = 740 gal
Reserve time = \( \frac{740}{5} = 148 \text{ minutes} \)

Storage tank pressurization:
- Total storage volume 147 ft\(^3\)
- Transfer pressure 52 psia, \( p = 0.365 \text{ lb/ft}^3 \)
- Initial pressure 15 psia, \( p = 0.11 \text{ lb/ft}^3 \)
  (assume ullage temperature = 53° R)

LHe required = \( \frac{0.255 (147)}{1.07 \text{ lb/gal}} = 35 \text{ gallons} \)

Includes time from flow control valve open to P & W engine turbopump temperature of -310° F.
GD/C-ACY65-001-4
7 July 1965

LH₂ SYSTEM

Storage capacity 28,000 gal
Fill tolerance 3,000
Usable capacity 25,000 gal

Range Countdown Requirements

Atlas helium bottle shrouds:
Rapid fill 7 minutes @ 35 gpm = 245 gal
Topping 83 minutes @ 10 gpm = 830
LO₂ transfer system subcooler = 1,800
Total range countdown LN₂ 2,875 gal

Abort Requirement

None

Usage Rate

10 gpm (Atlas helium bottle shroud boiloff)

Reserve Time Available

LN₂ available for holding, 25,000 - 2,875 = 22,125 gal
Reserve time = \(\frac{22,125}{10} = 2,212\) minutes
**LO$_2$/LN$_2$ SUBCOOLER**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tr>
<td>Total capacity, LN$_2$</td>
<td>1,775 gal</td>
</tr>
<tr>
<td>Minimum level</td>
<td>571</td>
</tr>
<tr>
<td>Usable LN$_2$</td>
<td>1,204 gal</td>
</tr>
</tbody>
</table>

**Range Countdown Requirements**

- LN$_2$ boiloff rate $1/4$ gal/gal LO$_2$*
  - Centaur topping 38 gal
  - Atlas topping 190 gal

Total range countdown LN$_2$ 228 gal

**Abort Requirement**

None

**Usage Rate**

$1/4$ gal LN$_2$/gal LO$_2$, = 13.3 gpm*

**Reserve Time Available**

- LN$_2$ available for holding, $1,204 - 228 = 976$ gal

Reserve time $= \frac{976}{1/4 \text{ (total LO}_2\text{ topping rate)}}$

$= \frac{976}{53} = 73.6$ minutes

*Estimated value
LN₂ STORAGE TANK PRESSURIZING SYSTEM, GN₂

Storage capacity (water volume) 700 ft³
Maximum pressure 1500 psig, p = 7.8 lb/ft³
Minimum pressure 100 psig, p = 0.5 lb/ft³
(assume temperature 70° F, 530° R)
Usable capacity = (7.8 - 0.5) 700 = 5,110 lb

Range Countdown Requirement

GN₂ required to transfer all LN₂ from storage tank:

Total volume (storage tank) 4,120 ft³
Initial pressure, 15 psia, p = 0.24 lb/ft³
Transfer pressure, 65 psia, p = 1.1 lb/ft³
(assume ullage gas at saturation temp = 160° R)

GN₂ required = (1.1 - 0.24) (4,120 ft³) = 3,540 lb
Excess GN₂ available 1,570 lb

Abort Requirement

None

Usage Rate

0

Reserve Time Available

∞

The calculation assumes that all of the gas used for pressurizing the storage tank will remain as a gas and can be used for liquid transfer. Because of the storage tank configuration and operating pressures, this assumption may not be valid. As soon as the consumption rate can be measured, the results of this analysis will be updated.
HELIUM SYSTEM, PRESSURIZATION SUPPLY

Storage capacity (water volume) 800 ft³
Maximum pressure 6,000 psig, \( p = 3.4 \text{ lb/ft}^3 \)
Minimum pressure 3,550 psig, \( p = 2.2 \text{ lb/ft}^3 \)
(assume temperature 70°F, 530°F R)
Usable capacity = \((3.4 - 2.2) \times 800 = 960 \text{ lb} = 92,800 \text{ scf}\)

Range Countdown Requirements

- Atlas propellant tank pressurization 1,800 scf
- Atlas airborne helium bottle charge 16,740
- Centaur propellant tank pressurization 350
- Centaur airborne helium bottle charge 470
- Centaur inflight purge bottle charge 470
- LHe transfer line/P & W engine purges 5,650
- P & W engine blowdowns 350
- Error contingencies (10% gross) 9,280

Total range countdown helium 35,110 scf

Abort Requirements

- LH₂ tank purge 8,400 scf
- LHe transfer line/P & W engine purge 12,000 scf

Total abort helium 20,400 scf

Usage Rate

50 scfm (LHe transfer line/P & W engine purge)

Reserve Time Available

Helium available for holding, 92,800 - 55,510 = 37,290 scf
Reserve Time \( \frac{37,290}{50} \approx 746 \text{ minutes} \)

For 2-burn missions, the helium required for bottle charge is 830 scf which reduces the helium available for holding to 36,930 scf and the reserve time to approximately 739 minutes.
HELIUM SYSTEM, INSULATION PANEL PURGE SUPPLY

Storage capacity (water volume) 2,205 ft³
Maximum pressure 6,000 psig, \( p = 3.4 \text{ lb/ft}^3 \)
Minimum pressure 1,000 psig, \( p = 0.68 \text{ lb/ft}^3 \)
(assume temperature 70° F, 530° R)
Usage capacity = \((3.4 - 0.68) \times 2,205 = 6,000 \text{ lb}\)

Range Countdown Requirements

Centaur Vehicle purges:
- Insulation panel purge
- P & W engine injector purge
- Hydraulic pump coupling purge
- LH₂ low pressure duct purge
- P & W seal cavity purge
- LO₂ & LH₂ boost pump seal purge

Total purges - high flow rate 280 lb/hour
Helium required 130 minutes @ 280 lb/hour 605 lb
Total purges - low flow rate 120 lb/hour
Helium required 210 minutes @ 120 lb/hour 420 lb
Error contingencies (10% \times \text{ gross)} 600 lb
Total range countdown helium 1,625 lb

Abort Requirements

Total purges - high flow rate
Helium required 60 minutes @ 280 lb/hour 280 lb
Total purges - low flow rate
Helium required 180 minutes @ 120 lb/hour 360 lb
Total Abort helium 640 lb

Usage Rate

280 lb/hour (high flow rate)

Reserve Time Available

Helium available for holding \((6,000 - 2,265) = 3,735 \text{ lb}\)
Reserve Time = \(\frac{3,735}{280} \times (60) = 800 \text{ minutes}\)
GN₂ SYSTEM, ROUTINE USE

Storage capacity (water volume) 800 ft³
Maximum pressure 6,000 psig, p = 23.5 lb/ft³
Minimum pressure 2,300 psig, p = 11.5 lb/ft³
(assume temperature 70° F, 530° R)
Usable capacity = (23.5 - 11.5) 800 = 9,600 lb

Range Countdown Requirements

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH₂ vent stack purge (vehicle)</td>
<td>60 lb</td>
</tr>
<tr>
<td>6 minutes @ 10 lb/min</td>
<td></td>
</tr>
<tr>
<td>LH₂ vent stack purge (storage tank)</td>
<td>45 lb</td>
</tr>
<tr>
<td>60 minutes @ 10 scfm</td>
<td></td>
</tr>
<tr>
<td>Atlas gas generator purges</td>
<td>90 lb</td>
</tr>
<tr>
<td>10 minutes @ 130 scfm</td>
<td></td>
</tr>
<tr>
<td>Atlas LO₂ dome purges</td>
<td>520 lb</td>
</tr>
<tr>
<td>10 minutes @ 730 scfm</td>
<td></td>
</tr>
<tr>
<td>Atlas hypergol purge</td>
<td>35 lb</td>
</tr>
<tr>
<td>10 minutes @ 50 scfm</td>
<td></td>
</tr>
<tr>
<td>Terminal box purges, controls &amp; system bleeds</td>
<td>2,400 lb</td>
</tr>
<tr>
<td>340 minutes @ 100 scfm (estimated)</td>
<td></td>
</tr>
<tr>
<td>Nose fairing jettison bottle</td>
<td>15 lb</td>
</tr>
<tr>
<td>1,740 in³ @ 2,535 psig</td>
<td></td>
</tr>
<tr>
<td>Umbilical boom hydraulic system charge</td>
<td>55 lb</td>
</tr>
<tr>
<td>Launcher stabilization system</td>
<td>14 lb</td>
</tr>
<tr>
<td>Total range countdown GN₂</td>
<td>3,234 lb</td>
</tr>
</tbody>
</table>

Abort Requirements

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH₂ vent stack purge (vehicle)</td>
<td>30 lb</td>
</tr>
<tr>
<td>3 minutes @ 10 lb/min</td>
<td></td>
</tr>
<tr>
<td>Atlas LO₂ dome purge</td>
<td>520 lb</td>
</tr>
<tr>
<td>10 minutes @ 730 scfm</td>
<td></td>
</tr>
<tr>
<td>Terminal box purges, controls &amp; system bleeds</td>
<td>1,700 lb</td>
</tr>
<tr>
<td>240 minutes @ 100 scfm</td>
<td></td>
</tr>
<tr>
<td>Total abort GN₂</td>
<td>2,250 lb</td>
</tr>
</tbody>
</table>
GN\(_2\) SYSTEM, ROUTINE USE (Continued)

Usage Rate

Approximately 110 scfm (7.8 lb/minute)

Reserve Time Available

GN\(_2\) available for holding, 9,600 - 5,484 = 4,116 lb
Reserve time = \(\frac{4,116}{7.8} \approx 530\) minutes
GN₂ SYSTEM, AIR CONDITIONING SUPPLY

Storage capacity (water volume) 17,040 ft³
Maximum pressure 2,400 psig, \( p = 11.5 \text{ lb/ft}^3 \)
Minimum pressure 600 psig, \( p = 2.9 \text{ lb/ft}^3 \)
(assume temperature 70°F, 530°F R)
Usable capacity = \((11.5 - 2.9) 17,040\) = 146,500 lb

Range Countdown Requirements

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveyor air conditioning</td>
<td>7,530 lb</td>
</tr>
<tr>
<td>96 minutes @ 78.5 lb/min</td>
<td></td>
</tr>
<tr>
<td>Forward compartment cooling</td>
<td>7,200 lb</td>
</tr>
<tr>
<td>96 minutes @ 75 lb/min</td>
<td></td>
</tr>
<tr>
<td>Interstage adapter heating</td>
<td>15,360 lb</td>
</tr>
<tr>
<td>96 minutes @ 160 lb/min</td>
<td></td>
</tr>
<tr>
<td>Atlas thrust section heating</td>
<td>400 lb</td>
</tr>
<tr>
<td>5 minutes @ 80 lb/min</td>
<td></td>
</tr>
<tr>
<td>Atlas pod cooling</td>
<td>3,550 lb</td>
</tr>
<tr>
<td>96 minutes @ 37 lb/min</td>
<td></td>
</tr>
<tr>
<td><strong>Total range countdown GN₂</strong></td>
<td><strong>34,040 lb</strong></td>
</tr>
</tbody>
</table>

Abort Requirements

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveyor air conditioning</td>
<td>4,710 lb</td>
</tr>
<tr>
<td>60 minutes @ 78.5 lb/min</td>
<td></td>
</tr>
<tr>
<td>Forward compartment cooling</td>
<td>4,500 lb</td>
</tr>
<tr>
<td>60 minutes @ 75 lb/min</td>
<td></td>
</tr>
<tr>
<td>Interstage adapter heating</td>
<td>38,400 lb</td>
</tr>
<tr>
<td>240 minutes @ 160 lb/min</td>
<td></td>
</tr>
<tr>
<td>Atlas pod cooling</td>
<td>2,220 lb</td>
</tr>
<tr>
<td>60 minutes @ 37 lb/min</td>
<td></td>
</tr>
<tr>
<td><strong>Total abort GN₂</strong></td>
<td><strong>49,830 lb</strong></td>
</tr>
</tbody>
</table>

Usage Rate

350.5 lb/minute (2)

(1) Figure assumes abort after T-3 seconds.

(2) The flow rate shown does not include the Atlas thrust section air conditioning.
    This flow will be secured in the event of a countdown delay.
GN\(_2\) SYSTEM, AIR CONDITION SUPPLY (Continued)

**Reserve Time Available**

GN\(_2\) Available for holding, \(146,500 - 83,870 = 62,630\) lb

Reserve time \(= \frac{62,630}{350.5} \approx 179\) minutes
GN₂ SYSTEM, HOLD-DOWN & RELEASE

Storage capacity (water volume)  50 ft³
Maximum pressure  8,000 psig, p = 27 lb/ft³
Minimum pressure  6,500 psig, p = 24.5 lb/ft³
(assume temperature 70° F, 530° R)
Usable capacity = (27 - 24.5) 50 = 150 lb

Range Countdown Requirement

Pressurize launcher hold-down & release cylinders to 6,250 psig  12 lb

Abort Requirement

None

Usage Rate

0

Reserve Time Available

∞
Figure B-1. Complex 36B - LO₂ Transfer System (Simplified Schematic)
Figure B-2. Complex 36B - LH2 Transfer Systems (Simplified Schematic)
Figure B-5. Complex 36B - Helium Pressurization Supply System (Simplified Schematic)
Figure B-6. Complex 36B - Insulation Panel Purge Helium System (Simplified Schematic)
Figure B-7. Complex 36B - Routing Use GN2 System (Simplified Schematic)
Figure B-9. Complex 36B – Atlas Fuel Transfer System (Simplified Schematic)