Cycle $\phi$(CY1991)
NLS Trade Studies and Analyses Report

Book I - Structures & Core Vehicle


N93-16682
Unclas
G3/31 0127422
FOREWORD

This document is Book 1 of the Cycle Ø Study Report and documents the activities performed by MMC in support of the MSFC NLS Structures Team. The work was performed under NASA Contract NAS8-37143 between May 1991 and January 1992. This study report was prepared by Manned Space Systems, Martin Marietta Corporation, New Orleans, Louisiana for the NASA/Mississippi Space Flight Center.
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INTRODUCTION

This Report SR-1 (Book 1): Structures Trades and Analyses, documents the Core Tankage Trades and analyses performed in support of the NLS Cycle Ø preliminary design activities. The report covers trades that were conducted on the Vehicle Assembly, Fwd Skirt, LO2 Tank, Intertank, LH2 Tank and Aft Skirt of the NLS Core Tankage. For each trade study a two page executive summary and the detail trade study are provided. The trade studies contain study results, recommended changes to the Cycle Ø Baseline and suggested follow on tasks to be performed during Cycle 1.
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<td>5.2.7.4.1</td>
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3-S-001A
(CV-STR-18A)
Forward Skirt Alternate
Panel Construction

Prepared By: G.M. Roule
(504) 257-0020
Rev: Initial
Date: January 8, 1992

Approved By: M.R. Simms

MARTIN MARIETTA
MANAGED SPACE SYSTEMS

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Objective/Approach

Objective:
- Develop and Evaluate Forward Skirt Alternative
- Panel Construction To Determine Preferred Skin
- Concept Relative To Weight, Costs, & Manufacturing/Producibility Impacts.

Approach:
- Define Point Of Departure (P.O.D.) Forward Skirt
- Reference Geometry
- Identify Concept Options For Panels Using Various Structural Configurations.
- Estimate Weight Differences.
- Perform Cost Analysis.
- Evaluate Options With Respect To Evaluation Criteria.
- Select Preferred Option.
Groundrules & Assumptions

- Use NLS Baseline Forward Skirt As Point Of Departure (P.O.D.). Material = Al-2219. Configuration As Defined by MFSC Reference Layout:

Forward Skirt, NLS-0008 (Dated 10/9/91)

Reference Trade Studies:
CV-STR-14A "Forward Skirt Structural Design Configuration Enhancements".

- External Tank Tooling Will Be Used Wherever Possible Per NLS Program Requirements.
# Key Issues/Evaluation Criteria

- Manufacturing/Producibility.
- Weight Impacts.
- Costs.

<table>
<thead>
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<th>Evaluation Criteria</th>
<th>Rationale</th>
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<tr>
<td>Manufacturing/Producibility</td>
<td>Use Of ET Tooling Is An NLS Program Requirement. Selected Option Should Utilize Current Manufacturing Build Approach &amp; Assembly</td>
</tr>
<tr>
<td>Weight Impact</td>
<td>Any Additional Weight Must Be Traded Against Loss Of Payload Lift Capability.</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
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<tr>
<td>Non-Recurring</td>
<td>Minimal DDT&amp;E Desired.</td>
</tr>
<tr>
<td>Recurring</td>
<td>Low Cost Per Flight Desired For Expendable HLLV</td>
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</tbody>
</table>
Option 1 - Forward Skirt Baseline Panel (P.O.D.)

- Formed Metal Hat-Sections With Sheet Stock Membrane.
- Similar To ET Intertank Design.
- Utilizes Existing ET Processes And Tooling.
Option 2 - Blade-Stiffened Panel

- Integrally Machined Panel With Longitudinal Blade-Stiffening.
- Does Not Utilize Some Existing ET Processes And Tooling.
- Design Consistant With Maximum Axial Load.
# Manufacturing/Producibility Summary

<table>
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<tr>
<th>Option 1 (Baseline)</th>
<th>Barrel Assembly</th>
<th>Mechanical Assembly &amp; Installation To Tank</th>
<th>Intermediate Frame Attachment</th>
<th>TPS Application</th>
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<tr>
<td></td>
<td>• Baseline</td>
<td>• Baseline</td>
<td>Similar To Intertank</td>
<td>Slightly Difficult But Process Now Developed On ET</td>
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<td>• Can Use Intertank Tooling Etc.</td>
<td>• Similar To Intertank</td>
<td></td>
<td></td>
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<tr>
<td>Option 2 Machined Blade Stiffened Panel</td>
<td>• Less Fabrication</td>
<td>• Similar Mechanical Assembly</td>
<td>Same As Baseline</td>
<td>Easier (Smooth O.S.L.)</td>
</tr>
<tr>
<td></td>
<td>• Some Existing Tooling Available</td>
<td>• I/F At Tank Attach Is More Complex</td>
<td></td>
<td></td>
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<tr>
<td>Weight Impact Summary</td>
<td></td>
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<tr>
<td><strong>Total Weight Of Skin/Stringer Panels</strong></td>
<td><strong>P.O.D.</strong></td>
<td><strong>Option 1 (Baseline)</strong></td>
<td><strong>Option 2 Machined Blade Stiffened Panel</strong></td>
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<td><strong>P.O.D.</strong></td>
<td>1521.0</td>
<td>1596.5</td>
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<td><strong>Δ Weight From P.O.D. (lbs.)</strong></td>
<td><strong>0.0</strong></td>
<td><strong>4.3% Increase</strong></td>
<td><strong>+65.5</strong></td>
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**Evaluation Summary**

<table>
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<th>Weight Impacts</th>
<th>Manufacturing/Producibility Impacts</th>
<th>Other Impacts</th>
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<td><strong>Option 1</strong></td>
<td>Baseline</td>
<td>Baseline</td>
<td>Good Synergism With E.T.</td>
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<tr>
<td><em>(Baseline)</em></td>
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<tr>
<td><strong>Option 2</strong></td>
<td>65.5 lbs.</td>
<td>Less Fabrication Simple Welding W/Some Existing Tooling. TPS Appl. Easier</td>
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<td>Machined Blade Stiffened Panel</td>
<td>Increase</td>
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Conclusions

• Option 1 - Currently NLS Baseline, Is Synergistic With External Tank, And Requires The Least Development.

• Option 2 - Has Slight Weight Increase, May Be Easier To Apply TPS, Assembly Less Complex Than Baseline.
Recommendations

- Consider Alternate Fabrication Approaches If Alternate Proposed Forward Skirt Configuration (Ref. Trade # 3-S-001C) Is Adopted.
5.2.3.4.2 Alternate Panel Construction (#CV-STR-018-A)

Objective

This trade study developed and evaluated alternative construction methods for the forward skirt skin panels.

Approach

(a) Define a point of departure forward skirt panel.
(b) Identify concept option for skin panels using an alternate structural configuration.
(c) Estimate weight differences.
(d) Assess producibility impacts.
(e) Evaluate options with respect to evaluation criteria.
(f) Select preferred option.

Options Studied

Option 1 - Fabricated mech. attached to hat sections with sheet stock skin (Cycle Ø Baseline).
Option 2 - Integrally machined panel with internal longitudinal blade-stiffeners.

Key Study Results

Option 1 - (Baseline) is synergistic with External Tank due to its Intertank-like design.

Option 2 - has a 4.3 per cent increase in weight, but local sizing requirements due to internal stiffening would probably increase weight even further. Internal stiffening was chosen to minimize TPS application impacts. However this option can save fabrication efforts. Panels could be either mechanically attached or welded similar to LO2/LH2 barrels.

Conclusions

The fabricated hat section and sheet construction is the preferred approach due to it's lower weight, ease of TPS application, and potential for assembly using ET tooling. However, since the Intertank is a labor-intensive construction, and the forward skirt is similar in construction to the Intertank, the forward skirt should be considered as a good candidate for producibility enhancements.

Study Recommendations

Maintain Option 1 as Baseline for Cycle Ø. Consider alternative fabrication approaches if alternate proposed forward skirt configuration per Section 5.2.3.4.4 is adopted.
6.2.3.4.2 Alternate Panel Construction (#CV-STR-018-A)

Objective

This trade study developed and evaluated alternative construction methods for the forward skirt skin panels.

Approach

(a) Define a point of departure forward skirt panel.
(b) Identify concept option for skin panels using an alternate structural configuration.
(c) Estimate weight differences.
(d) Assess producibility impacts.
(e) Evaluate options with respect to evaluation criteria.
(f) Select preferred option.

Options Studied

Option 1 - Fabricated mech. attached to hat sections with sheet stock skin (Cycle 0 Baseline).
Option 2 - Integrally machined panel with internal longitudinal blade-stiffeners.

Key Study Results

Option 1 - (Baseline) is synergistic with External Tank due to its Intertank-like design.

Option 2 - has a 4.3 per cent increase in weight, but local sizing requirements due to internal stiffening would probably increase weight even further. Internal stiffening was chosen to minimize TPS application impacts. However this option can save fabrication efforts. Panels could be either mechanically attached or welded similar to LO2/LH2 barrels.

Conclusions

The fabricated hat section and sheet construction is the preferred approach due to it's lower weight, ease of TPS application, and potential for assembly using ET tooling. However, since the Intertank is a labor-intensive construction, and the forward skirt is similar in construction to the Intertank, the forward skirt should be considered as a good candidate for producibility enhancements.

Study Recommendations

Maintain Option 1 as Baseline for Cycle 0. Consider alternative fabrication approaches if alternate proposed forward skirt configuration per Section 6.2.3.4.4 is adopted.
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Stiffener Pitch Sensitivity Study

3-S-001B (CV-STR-18B) - Fwd Skirt
3-S-010B (CV-STR-15B) - LO2 Tank
3-S-009B (CV-STR-19B) - Intertank
3-S-008C (CV-STR-20C) - LH2 Tank

Prepared By: Dillip Dudaonkar
(504)257-0076

Rev: Initial
Date: January 8, 1992

Approved By: M.R. Simms

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Objective and Approach

Objective

- Evaluate the configuration if Revising the Stiffener Pitch will produce a lower weight design

Approach

- Use PANDA II Optimisation software
- Demonstrate PANDA II validity by correlating STAGS Program Results used for ET panels
- Evaluate Stiffener Pitch Sensitivity on:
  - Forward Skirt Skin Panels
  - LO2 Barrel Panels
  - Intertank Skin Panels
  - LH2 Barrel Panels
- Prepare Conclusions and Recommendations
## STAGS-C Vs. PANDA II Study

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<th>Knock down Factor</th>
<th>Nx/allow lb/in</th>
<th>Stresses in stringer</th>
<th>PANDA II NX lb/in</th>
<th>FSGEN</th>
<th>M. S General Instability</th>
<th>MS GEN Stresses in stringer</th>
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<td>514</td>
<td>2.0</td>
<td>0.52</td>
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</tr>
</tbody>
</table>
Panda II Optimisation Study

Factors of Safety used in Panda Optimization

- For General Instability (FS GEN) = 2.0
- For Panel Instability (FSPAN) = 2.0
- Minimum load factor of local buckling (FSLOC) = 0.72
  (allowing the skin to buckle after the limit load)
- Factor of safety for Stress (FSSTR) = 1.0
Panda II Optimization Study - Forward Skirt

Forward Skirt

Tbar vs Stringer Spacing

N_x lb/in

1500
2000
2500

0.18 0.16 0.14 0.12 0.1 0.08 0.06 0.04 0.02

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

(Bar (in))

6.0 7.0 8.0 9.0 10.0

Stringer Spacing (in)
Panda II Optimization Study - Forward skirt

<table>
<thead>
<tr>
<th>Current Design</th>
<th>Panda II Optimized Design (Nx = 2000 lb/in ult)</th>
<th>Optimized Design with Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringer Spacing = 7.33&quot;</td>
<td>Stringer Spacing = 5.0&quot;</td>
<td>Stringer Spacing = 5.0&quot;</td>
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<tr>
<td>Frame Spacing = 48.0&quot;</td>
<td>Frame Spacing = 48.0&quot;</td>
<td>Frame Spacing = 48.0&quot;</td>
</tr>
<tr>
<td>Tbar=0.151&quot;</td>
<td>Tbar=0.139&quot;</td>
<td>Tbar=0.149&quot;</td>
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</tbody>
</table>
Panda II Optimization Study - LO2 Tank

LO2 Tank
Tbar Vs Stringer Spacing

Stringer Spacing (in)

Nx lb/in

- 965
- 1345
- 1600

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MANNED SPACE SYSTEMS
# Stiffener Size and Pitch Sensitivity Trades - LO2 Tank

![Diagram of LO2 Tank with dimensions](image)

<table>
<thead>
<tr>
<th>Current Design</th>
<th>Optimized Design ( N_x = 960 \text{ lb/in} )</th>
<th>Optimized Design ( N_x = 1345 \text{ lb/in} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringer Spacing=10.832&quot;</td>
<td>Stringer Spacing=4.0&quot;</td>
<td>Stringer Spacing=4.0&quot;</td>
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<td>Frame Spacing=34.9&quot;</td>
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<tr>
<td>Tskin=0.170</td>
<td>Tskin=0.067</td>
<td>Tskin=0.075</td>
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<tr>
<td>Tbar=0.193</td>
<td>Tbar=0.0963</td>
<td>Tbar=0.104</td>
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</tbody>
</table>
Panda II Optimization Study - Intertank

Intertank
Tbar Vs Stringer Spacing

```
<table>
<thead>
<tr>
<th>Stringer Spacing (in)</th>
<th>tbar (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>0.29</td>
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<tr>
<td>5.0</td>
<td>0.28</td>
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<tr>
<td>6.0</td>
<td>0.27</td>
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<tr>
<td>7.0</td>
<td>0.26</td>
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<tr>
<td>8.0</td>
<td>0.25</td>
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<tr>
<td>9.0</td>
<td>0.24</td>
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<tr>
<td>10.0</td>
<td>0.23</td>
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<tr>
<td>11.0</td>
<td>0.22</td>
</tr>
<tr>
<td>12.0</td>
<td>0.21</td>
</tr>
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</table>
```

Nx lb/in
- 4400
- 5200
- 5600
## Panda II Optimization Study - Intertank

<table>
<thead>
<tr>
<th>Current Design</th>
<th>Panda II Optimized Design (Nx = 4400 lb/in ult)</th>
<th>Panda II Optimized Design (Nx = 5200 lb/in ult)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringer Spacing = 7.33&quot;</td>
<td>Stringer Spacing = 7.33&quot;</td>
<td>Stringer Spacing = 10.0&quot;</td>
</tr>
<tr>
<td>Frame Spacing = 45.0&quot;</td>
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<tr>
<td>Tbar=0.238&quot;</td>
<td>Tbar=0.21&quot;</td>
<td>Tbar=0.241</td>
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</table>

![Diagram](image.png)
Panda II Optimization Study - LH2 Tank

LH2 TANK
Tbar Vs Stringer Spacing

Graph showing the relationship between tbar (in) and stringer spacing (in) for LH2 Tank. The graph includes plots for different values of N (lb/in) with legend showing lines for 1700, 2600, and 3250.
## Stiffener Size and Pitch Sensitivity Trades - LH2 Tank

<table>
<thead>
<tr>
<th>Current Design</th>
<th>Optimized Design N_x=2600 lb/in</th>
<th>Optimized Design N_x=3250 lb/in</th>
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<tr>
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<td>Frame Spacing=26.7&quot;</td>
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<tr>
<td>Tskin=0.170</td>
<td>Tskin=0.061</td>
<td>Tskin=0.067</td>
</tr>
<tr>
<td>Tbar=0.193</td>
<td>Tbar=0.108</td>
<td>Tbar=0.123</td>
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</tbody>
</table>
Conclusions

Forward Skirt and Intertank
Weight sensitivity data was generated for varying stringer pitch for the reference configuration skin/hat fabricated construction approach.

Forward Skirt
When modified to produce practical designs the PANDA II minimum weight configuration did not offer significant weight savings to the baseline.

Intertank
The modified PANDA II minimum weight configuration was slightly lighter when compared to the baseline configuration. However, the sizing is close to the minimum weight for a common I/T driven by HLLV loads.

LO2 Tank and LH2 Tank
Weight sensitivity data was generated for varying stringer pitch for the reference configuration machined longitudinal Tee stiffened panel.

LO2 Tank
The PANDA II minimum weight configuration offers significant weight savings to the baseline configuration. However, it requires a thicker billet with closer stiffener pitch.

LH2 Tank
The PANDA II minimum weight configuration offers significant weight savings to the baseline configuration. However, it requires a thicker billet with stiffener pitch too close to be practical. A slightly greater pitch must be chosen resulting in slightly higher panel weight.
Recommendations

Forward Skirt
Maintain the reference configuration pitch and stringer size. During cycle 1, study other types of stringer sections such as blade, tee and Z section to see if they offer weight and producibility advantages.

Intertank
Maintain the reference configuration pitch and stringer size. During cycle 1, study other types of stringer sections when defining the 'stand alone' 1.5 stage intertank defined in section Trade Study # 3-S-009A

LO2 Tank
Maintain the reference configuration pitch and stringer size. During cycle 1, study alternate barrel panel with reduced stringer spacing and varying frame spacing

LH2 Tank
Maintain the reference configuration pitch and stringer size. During cycle 1, study alternate barrel panel with reduced stringer spacing. Also study varying frame spacing to define a barrel configuration with the minimum total frame plus barrel weight
5.2.3.4.3 Stiffener Pitch Sensitivity (# 3-S-001B)

Objective

To develop the weight sensitivities of the forward skirt if pitch and stringer size are varied.

Approach

(a) Use current configurations as baseline
(b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)
(c) Document assumptions made and factors of safety used.
(d) Produce t bar vs pitch sensitivities
(e) Prepare conclusions and recommendations

Key Study Results

The current hat section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. One intermediate ring frame is used to provide stability. The weight (t bar) trend shows that an optimum occurs at a stringer pitch of 5.0 inches for an axial compression load of 2000 lb/inch. However the optimum stringer section indicated by Panda needs an increase in the attachment flange width to provide room and edge distance for the skin/stringer attachments. Once this modification is incorporated the current reference becomes close to optimum.

Conclusions

Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. When modified to produce a practical design, the Panda II optimized configuration does not offer any significant weight savings compared to the baseline configuration.

Study Recommendations

Maintain the reference configuration Fwd skirt pitch and stringer size. During cycle 1, study other types of stringer sections such as I section and Z sections to see if they offer weight and producibility advantages.
### Stringer Spacing vs Tbar

![Graph showing stringer spacing vs Tbar](image)

#### Current Design
- Stringer Spacing = 7.33"
- Frame Spacing = 48.0"
- Tbar = 0.151"

#### Panda II Optimized Design (Nx = 2000 lb/in ult)
- Stringer Spacing = 5.0"
- Frame Spacing = 48.0"
- Tbar = 0.139"

#### Optimized Design with Modifications
- Stringer Spacing = 5.0"
- Frame Spacing = 48.0"
- Tbar = 0.149"

### Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.3.4.3 Stiffener Pitch Sensitivity (# 3-S-001B)

Objective
To develop the weight sensitivities of the forward skirt if pitch and stringer size are varied.

Approach
(a) Use current configurations as baseline
(b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)
(c) Document assumptions made and factors of safety used.
(d) Produce t bar vs pitch sensitivities
(e) Prepare conclusions and recommendations

Key Study Results
The current hat section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. One intermediate ring frame is used to provide stability. The weight (t bar) trend shows that an optimum occurs at a stringer pitch of 5.0 inches for an axial compression load of 2000 lb/inch. However the optimum stringer section indicated by Panda needs an increase in the attachment flange width to provide room and edge distance for the skin/stringer attachments. Once this modification is incorporated the current reference becomes close to optimum.

Conclusions
Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. When modified to produce a practical design, the Panda II optimized configuration does not offer any significant weight savings compared to the baseline configuration.

Study Recommendations
Maintain the reference configuration Fwd skirt pitch and stringer size. During cycle 1, study other types of stringer sections such as I section and Z sections to see if they offer weight and producibility advantages.
Stringer Spacing vs Tbar

Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results
3-S-001C
(CV-DI-02)
Alternate Fwd Skirt
Configuration Definition

Prepared By: Wayne Waguespack
(504)257-0032
Rev: Initial
Date: January 8, 1992

Approved By: R. Simms

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MANNED SPACE SYSTEMS
Issues And Objective

Issue

- Core Stage Cannot Be Fully Checked Out At Build Site Because Some Avionics And Propulsion Components Are Located In The Interstage Of The Encapsulated Payload.

Objective

- Determine If An Alternate Concept For The Fwd Skirt / Interstage Would Permit Full Core Stage IACO.
Approach

- Obtain Definition Of The Reference Configuration.
- Develop Concept For Packaging Launch Vehicle Avionics And RCS In An Expanded Fwd Skirt.
- Evaluate Against Reference Configuration.
- Prepare Conclusions And Recommendations.
### Ref Configuration Avionics

<table>
<thead>
<tr>
<th>Box Description</th>
<th>*Size</th>
<th>Weight</th>
<th>Aft</th>
<th>**Central</th>
<th>CTV</th>
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<tr>
<td>Batteries (Avionics)</td>
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<td>2</td>
<td>4</td>
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<td>Batteries (EMA)</td>
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<td>***16 OR ***24</td>
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<td>Power Distribution</td>
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<td>2</td>
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<td>Load Distribution</td>
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<td>3</td>
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<tr>
<td>Antenna Gimbal Drive</td>
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<td>50</td>
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<tr>
<td>Proximity Operations Sensor</td>
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<td>110</td>
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<tr>
<td>Earth Sensor</td>
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<td>2</td>
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<tr>
<td>GPS And Pre Amp</td>
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<td>Remote Voter Unit</td>
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<td>4</td>
<td>10</td>
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<td>MDU / RDU</td>
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<td>4</td>
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<td>Engine I/F Unit</td>
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<td>Pan / Tilt / Zoom Mech</td>
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<td>90</td>
<td>6</td>
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<td>Navigation Lights</td>
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<td>Navigation Light Converter</td>
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<td>S Band Transponder</td>
<td>9 X 16 X 4</td>
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<td>Ku Band Transponder</td>
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<td>Signal Processor</td>
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<tr>
<td>RF Combiner (Central)</td>
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<td>12</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF Combiner (Proximity Operations)</td>
<td>8 X 6 X 2</td>
<td>9</td>
<td>2</td>
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<tr>
<td>Power Amplifier</td>
<td>12 X 14 X 2</td>
<td>16</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

* First 2 Numbers Indicate The Mounting Surface Area.
** Central Avionics Are Located On The CTV For The HLLV And The Interstage For The Stage 1.5.
*** HLLV.
**** Stage 1.5.
Alternate Fwd Skirt Configuration

Proposed Fwd Skirt Configuration
Alternate Fwd Skirt Configuration

Avionics and RCS Contained in Proposed Fwd Skirt, Allowing Complete Check Out of Core Stage
Options Comparison

Reference Configuration

- Encapsulated Payload
- Fwd Skirt 96.00
- Core Stage
- RCS And Core Stage Avionics Packaged in Fwd Skirt
- STA 2473.80

Alternate Configuration

- Encapsulated Payload
- STA 2284.80
- Bolted Interface Between Skirt And Interstage

Avionics And RCS Packaged In Interstage

Core Stage

Fwd Skirt 189.70

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Conclusions And Recommendations

Conclusions
- Full IACO Of Core Stage
- Packaging Of Avionics Feasible.
- Requires Relocation Of Interface Joint.
- CTV Arrangement And Installation Scenario Unaffected.

Recommendations
- Study The Proposed Alternate Configuration In Cycle 1.
5.2.3.4.4 Alternate Fwd Skirt Configuration (#3-C-001C)

Objective

Determine if an alternate concept for the forward skirt and intertank would permit full core stage IACO at build site.

Issue

Core stage cannot be fully checked out at build site because some avionics and propulsion components are located in the interstage which is not part of the core stage. The interstage is required as part of the encapsulated payload concept and would be mated to the launch vehicle at KSC.

Approach

(a) Obtain definition of cycle Ø reference configuration.
(b) Develop concept for packaging launch vehicle avionics and RCS in an expanded fwd skirt.
(c) Evaluate against ref configuration.
(d) Prepare conclusions and recommendations.

Options Studied

Option 1 - Cycle Ø baseline
Option 2 - Alternate concept - interface joint relocated to sta 2379.70, avionics and RCS packaged in new extended fwd skirt.

Key Study Results

The RCS tankage size and location requires the skirt to be extended approx 8 feet to provide the required packaging volume. This extended skirt then has sufficient space to package the launch vehicle avionics. The new configuration still provides adequate clearance to allow the CTV engines to occupy the inner volume. Moving the field joint to its new location reduces the interface diameter which should result in a reduced weight.

Conclusions

The alternate concept will permit full IACO of Core Stage. The concept provides adequate space for packaging of avionics and propulsion components. It does however require the relocation of the interface joint and reduces the length of the interstage.

Study Recommendations

Study the alternate configuration further in cycle 1.
Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
6.2.3.4.4 Alternate Fwd Skirt Configuration (#3-C-001C)

Objective

Determine if an alternate concept for the forward skirt and intertank would permit full core stage IACO at build site.

Issue

Core stage cannot be fully checked out at build site because some avionics and propulsion components are located in the interstage which is not part of the core stage. The interstage is required as part of the encapsulated payload concept and would be mated to the launch vehicle at KSC.

Approach

(a) Obtain definition of cycle 0 reference configuration.
(b) Develop concept for packaging launch vehicle avionics and RCS in an expanded fwd skirt.
(c) Evaluate against ref configuration.
(d) Prepare conclusions and recommendations.

Options Studied

Option 1 - Cycle 0 baseline
Option 2 - Alternate concept - interface joint relocated to sta 2379.70, avionics and RCS packaged in new extended fwd skirt.

Key Study Results

The RCS tankage size and location requires the skirt to be extended approx 8 feet to provide the required packaging volume. This extended skirt then has sufficient space to package the launch vehicle avionics. The new configuration still provides adequate clearance to allow the CTV engines to occupy the inner volume. Moving the field joint to its new location reduces the interface diameter which should result in a reduced weight.

Conclusions

The alternate concept will permit full IACO of Core Stage. The concept provides adequate space for packaging of avionics and propulsion components. It does however require the relocation of the interface joint and reduces the length of the interstage.

Study Recommendations

Study the alternate configuration further in cycle 1.
Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
3-S-007
(CV-STR-21)
Alternate 1.5 Stage Support Trade

Prepared By: Ed Phillips
(504) 257-5540
Tom Severs
(504) 257-5226

Approved By: M. R. Simms

Rev: Initial
Date: January 8, 1992
Objective

- Develop impacts to the 1.5 stage when supported on the launch pad at the forward SRB thrust fittings instead of at the base of the vehicle.

Approach

- Review requirements, set ground rules.
- Determine critical load conditions and support loads.
- Review reference vehicle (common core) structure for critical conditions and loads.
- Identify impacts to reference vehicle.
- Evaluate weight impacts/savings for common core vehicle.
- Perform a dynamic assessment of the concepts
- Document results.
Ground Rules

- Reference Configuration definition & weight per MSFC baseline dated 9/20/91
- Tank ullage pressure profile similar to ET (i.e., 17.3 psig min at liftoff)
- Use 18° cone angle off centerline for clearance
- Hold down for 100% engine thrust on all engines
- Duplicate SRB stiffness for support structure
- Lateral loads reacted at ASRB fwd thrust fittings and vertical shear pins in base of engine module
- Rotation of supports delayed until thrust ball fittings have cleared thrust fittings on 1.5 stage
- Ground Winds as per NASA Cycle 0 loads issued 5-91, B. Graham to P. Thompson
1.5 Stage Fwd Support Loads

Case 1:
1.5 Stage - On Pad, Fully Loaded, No Wind

Case 2:
Pre-launch, 1-1.0 sec, 100% Power on 6 Engines w/1.1 Dynamic Factor, No Wind

All loads shown are Limit

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1.5 Stage Fwd Support Loads

Case 3:
1.5 Stage - On Pad, Fully Loaded, 60 Kt. Wind

Case 4:
Prelaunch, t= -1.0 sec, 100% Power on 6 Engines w/1.1 dynamic factor, 30 Kt. Wind

All loads shown are Limit
Alternate 1.5 Stage Support Trade

Impacts to 1.5 Stage Vehicle

- Crossbeam put back into Intertank with full thrust fittings

- Due to the hold down load on the Intertank:
  - Increase diameter of Fwd SRB Bolt by 1.0 in for the hold down load
  - Increase Thrust Fittings and inserts to accommodate the larger bolt
  - Add thickness to Outboard Lower Cap on Crossbeam
  - Add thickness to Crossbeam caps at center half of span
  - Add longerons inside Intertank fore and aft of the Crossbeam
  - Strengthen Intertank frames aft of the SRB fitting
  - Revise LH2 tank Barrel Panels and delete intermediate frames
  - May require stiffening to maintain the LOX aft dome/SRB beam clearance

- Redesign the propulsion module since the hold down loads are at Station 2985
  - Remove hold down structure
  - Add 4 lateral support shear pin receptacles to the engine module for Prelaunch support
Alternate 1.5 Stage Support Trade

LH2 Tank Weight Comparison with Alternate Support

- Unpressurized Tanks @ Prelaunch
- Min. Ullage Pressure = 17.3 psig at Launch

Diagram showing weight comparison between reference and alternate support configurations with different intermediate frames and Tbar values.
Alternate 1.5 Stage Support Trade

Common Core Weight Comparisons (17.3 psig at LO)

**Alternate Configuration A**
- Unpressurized Tanks at Prelaunch
- Min. Ullage Pressure = 17.3 psig at Launch

![Diagram of rocket configurations]

**Common Core Vehicle Mass Properties (Wt. LBS)**

<table>
<thead>
<tr>
<th>Components</th>
<th>Reference</th>
<th>Alternate</th>
<th>Δ (Deltas)</th>
</tr>
</thead>
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<tr>
<td>Intertank</td>
<td>12683</td>
<td>14683</td>
<td>+2000</td>
</tr>
<tr>
<td>LH2 Tank</td>
<td>39221</td>
<td>34421</td>
<td>-4800</td>
</tr>
<tr>
<td>Thrust Structure</td>
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<td>106325</td>
<td>-1800</td>
</tr>
<tr>
<td>Contingency (Included)</td>
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<td></td>
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<tr>
<td>Total Dry Wt.</td>
<td>204290</td>
<td>199250</td>
<td>-5040</td>
</tr>
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</table>
Alternate 1.5 Stage Support Trade

Common Core Weight Comparison (25 pig at LO)

Alternate Configuration B
- Unpressurized Tanks at Prelaunch
- Min. Pressure = 25 psig at Launch

Alternate Configuration B
Supported at Launch by the SRB Crossbeam

Current Configuration
Supported at Launch by the Aft Tie-down Longerons

<table>
<thead>
<tr>
<th>Components</th>
<th>Reference</th>
<th>Alternate</th>
<th>Δ (Deltas)</th>
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</thead>
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<tr>
<td>Intertank</td>
<td>12683</td>
<td>14683</td>
<td>+2000</td>
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<tr>
<td>LH2 Tank</td>
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<td>32921</td>
<td>-6300</td>
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<tr>
<td>Thrust Structure</td>
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<td>106325</td>
<td>-1800</td>
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<tr>
<td>Contingency</td>
<td>(Included)</td>
<td>(Included)</td>
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<tr>
<td>Total Dry Wt.</td>
<td>204290</td>
<td>197950</td>
<td>-6340</td>
</tr>
</tbody>
</table>

MARTIN MARIETTA
Alternate 1.5 Stage Support Trade

Launch Off Forward Support - Dynamic Assessment

• **Background**
  
  - Vehicles have been held down at aft end until thrust builds up and then released, e.g., Saturn V
  - Vehicles have been flown off supports, e.g. Shuttle
  - In each case stored strain energy has led to problems
  - The loads problems were worked with fixes
  - Extrusion pins slowed down energy release on Saturn
  - SRB ignition delay reduced strain energy on Shuttle

• New approach to hold down leads to new conditions
  
  - Larger strain energy in vehicle at Lift Off
  - Larger strain energy in hold down structure, more powerful liquid engines, smaller total vehicle weight

• New point/type of release
  
  - Blowing bolts at front end would release strain energy very rapidly
  - This "step change" in load in FWD Intertank would be more dramatic than the present shuttle.
Alternate 1.5 Stage Support Trade
Launch Off Forward Support - Dynamic Assessment

• **Assessment**
  
  - This system could be made to work but it would be difficult
  - The implications are that the launch transient would be more severe and the Lift Off loads would be higher

• **Primary Concerns**
  
  - The way to lower loads is to lower the strain energy at liftoff, Shuttle approach, or slow down the launch (Saturn approach).
  - The strain energy in the vehicle can only be reduced by making it stiffer, and therefore, heavier, which is undesirable.
  - Slowing the transient is possible, but it involves maintaining the vehicle in close proximity to the tower for a longer period of time, and this is certainly not desirable.
Conclusions

- Up to 5000 Lbs. can be saved by supporting the 1.5 Stage vehicle at the forward SRB fittings.

- Dramatic increase in design and launch complexity, particularly in the area of lift off dynamics and pin retraction.

Recommendations

- Consider redesigning the Intertank as a more practical weight savings option.

- Maintain the baseline approach for holding down the 1.5 Stage (i.e. Aft hold down on the Propulsion Module).
6.2.1.4.8 Alternate Hold Down for 1.5 Stage (3-S-007)

Objective

Evaluate the benefits and impacts to the 1.5 Stage vehicle when it is supported on the launch pad at the forward SRB fittings instead of being cantilevered from the base of the propulsion module.

Approach

(a) Review requirements, establish ground rules
(b) Determine critical load conditions and support loads
(c) Review reference vehicle (Common Core) for critical conditions and loads
(d) Identify impacts to the reference vehicle
(e) Evaluate weight impacts/savings for the common core vehicle
(f) Perform dynamic assessment of concepts
(g) Document results

Options Studied

GSE structure simulating the SRB stiffness would attach to the forward SRB fittings (Station 2985) and aft SRB fittings (Station 4058). The GSE structure would deploy at lift off to provide clearance for the vehicle.

Key Study Results

A crossbeam would have to be added to the Intertank and the shell stiffened locally to carry the increased (over the ET values) loads. Approximately 30 intermediate rings could be removed from the LH2 tank and the barrel membrane thickness reduced substantially. The propulsion module could be resized to remove the hold down structure.

Lift off is significantly more complex. Strain energy is stored in the structure when the engines are running, but before separation from the MLP. This energy can be released differently depending on the release method chosen, none of which are simple. Severe transient loads are induced from the sudden release of the strain energy. The more slowly the strain energy is released, the longer the vehicle will be in close proximity to the tower, which is not desirable.

Conclusions

Up to 5000 lbs. can be saved by supporting the 1.5 Stage vehicle at the forward SRB fittings. However, the concept is considered to be a high risk item, particularly in the area of lift off dynamics and hold down pin retraction.

Study Recommendations

Maintain the baseline approach for holding down the 1.5 Stage vehicle.
Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
3-S-008A
(CV-STR-20A)
Tank Length vs Facility Impacts

Prepared By: Robert Houston
(504) 257 - 1510
Rev: Initial
Date: January 8, 1992

Approved By: Don Lumley
Bob Simms
Tank Length vs Facility Impacts

Objective
Assess External Tank Manufacturing Tooling and Facilities
To Determine The Impact of Increased Tank Length

Approach
Analyze Major Tooling Positions & Processing Facilities To
Determine:

1) Maximum Length Capability of Tools and Processing
Cells

2) Define Impact of Length Growth
• Initial Investigation Performed Under TD 1.6.2.1-216 Stretched External Tank (1982/83) Contract No.NAS8-30300

• Further Study Under IR&D 1990
Tank Length vs Facility Impact

Tank Processing Cells

Cells B/C LH2 SOFI
Cell D LH2 Aft Dome SOFI
Cell E LH2 Int Clean
Cell F LO2 Hydro Test
Cell P Ext Clean & Prime
Cell A Veh. Stack

Cells N (Alternative) LH2 SOFI
Cells M LO2 SOFI

- Achievable with Minor Tooling and Facility Mods
- Major Facility Mods - (ET Downtime Greater Than 9 Mo.)
- Modify Alternative Facility
- New Facility Required
Tank Length vs Facility Impact

Assembly Impacts

- LH2 Major Weld Assy
- Final Assy (Bldg 103)
- LH2 Proof Test (Bldg 451)
- Test & Checkout (Bldg 420)

Growth (ft) 4 8 12 16 18

- Achievable with Minor Tooling and Facility Mods
- Facility Mods
- Relocate Fwd Dome Attach Tooling
- Extend Existing Bldg
- LH2 Tank Proof Test (Pressure Only) up to 11 ft (Applied Loads May Require New Facility)
• Cell E - Internal LH2 Clean and Iridite
  - Stretch 5 ft - Minor Tool & Facility Modification
  - Stretch 5 ft to 11 ft - Raise Roof & Lengthen Door
  - Stretch 11 ft to 17 ft - Raise Roof, Lengthen Door and Lower Sill
  - Stretch Over 17 ft - NEW CELL

• Cell A - Core Tankage Stack
  - 8 ft 6 in LH2 Stretch Without Major Facility Modification
  - Over 8 ft 6 in to 12 ft - Modify TPS Closeout Room
  - Over 12 ft. - NEW CELL
Summary

1. Reference Configuration LH2 Tank Stretch Feasibility Re-Confirmed
   - 5 ft Stretch Requires Minor or No Modifications

2. Tank Stretch up to 11 ft is Possible with Facility Modifications:
   - Cell E ~ Internal LH2 Clean & Iridite
   - Cell A ~ Core Tankage Vertical Stack
   - Cell P ~ External Clean & Prime
   - LH2 Major Weld Assy
   - LH2 Proof Test (Bldg 451)

3. New Facilities/Major Mods are Required above 11 ft
   - New Proof Test Facility @ 11 ft
   - New VAB Cell A @ 12 ft
   - New VAB Cell E @ 17 ft
5.2.6.4.3 Tank Length vs Facility Impacts (#3-S-008A)

Objective

Assessed the external tank manufacturing tooling and facilities to determine the impact of increased tank length.

Approach

Each major tooling position and processing facility was analyzed to determine:

1. current maximum length capability of tools and cells
2. modifications required for each step of incremental growth up to building or other limitation.

Key Study Results

Cell E - Internal LH2 Clean and Iridite:

- Minor Tool & Facility Modification  
  - Stretch up to 5 ft  
  - Stretch 5 to 11 ft  
  - Stretch 11 to 17 ft  
  - Stretch Over 17 ft

- Raise Roof & Lengthen Door  
  - Raise Roof, Lengthen Door & Lower Sill  
  - New cell

Cell A - Core Tankage Stack:

- No major facility mod.  
  - Stretch LH2 Tank 8 ft 6 in to 12 ft  
  - Stretch Over 12 ft

- Modify TPS Closeout Room  
  - New cell

Reactivate existing Cells M & N for LO2 & LH2 Tank SOFI

Existing Proof Test facility can accommodate up to 11 ft stretch (Pressure Only). Applied loads may require new facility

Conclusions

Reference configuration 5 ft LH2 Tank stretch confirmed  
Tank Stretch up to 11 ft is possible with modifications  
New Facilities/Major Mods are Required above 11 ft but can be accommodated

Recommendations

Use study results as an input to Propulsion Tank Stretch Study P-001
Tank Processing Cells

Cells B/C LH2 SOFI
Cell D LH2 Aft Dome SOFI
Cell E LH2 Int Clean
Cell F LO2 Hydro Test
Cell P Ext Clean & Prime
Cell A Veh. Stack

Cells N (Alternative) LH2 SOFI
Cells M LO2 SOFI

---

Achievable with Minor Tooling and Facility Mods
Major Facility Mods - (ET Downtime Greater Than 9 Mo.)
Modify Alternative Facility
New Facility Required

Length vs Facility impacts for Tank processing cells

LH2 Major Weld Assy
Final Assy (Bldg 103)
LH2 Proof Test (Bldg 451)
Test & Checkout (Bldg 420)

Achievable with Minor Tooling and Facility Mods
Facility Mods
Relocate Fwd Dome Attach Tooling
Extend Existing Bldg
LH2 Tank Proof Test (Pressure Only) up to 11 ft (Applied Loads May Require New Facility)

Length vs Facility impacts for Assembly Facilities

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results

75
6.2.6.4.3 Tank Length vs Facility Impacts (#3-S-008A)

Objective

Assessed the external tank manufacturing tooling and facilities to determine the impact of increased tank length.

Approach

Each major tooling position and processing facility was analyzed to determine:

1. Current maximum length capability of tools and cells
2. Modifications required for each step of incremental growth up to building or other limitation.

Key Study Results

Cell E - Internal LH2 Clean and Iridite:
- Stretch up to 5 ft: Minor Tool & Facility Modification
- Stretch 5 to 11 ft: Raise Roof & Lengthen Door
- Stretch 11 to 17 ft: Raise Roof, Lengthen Door & Lower Sill
- Stretch Over 17 ft: New cell

Cell A - Core Tankage Stack:
- Stretch LH2 Tank 8 ft 6 in: No major facility mod.
- Stretch 8 ft 6 in to 12 ft: Modify TPS Closeout Room
- Stretch Over 12 ft: New cell

Reactivate existing Cells M & N for LO2 & LH2 Tank SOFI

Existing Proof Test facility can accommodate up to 11 ft stretch (Pressure Only). Applied loads may require new facility

Conclusions

Reference configuration 5 ft LH2 Tank stretch confirmed. Tank stretch up to 11 ft is possible with modifications. New Facilities/Major Mods are Required above 11 ft but can be accommodated

Recommendations

Use study results as an input to Propulsion Tank Stretch Study P-001
Tank Processing Cells

Cells B/C LH2 SOFI
Cell D LH2 Aft Dome SOFI
Cell E LH2 Int Clean
Cell F LO2 Hydro Test
Cell P Ext Clean & Prime
Cell A Veh. Stack

Cells N (Alternative) LH2 SOFI
Cells M LO2 SOFI

Achievable with Minor Tooling and Facility Mods
Major Facility Mods - (ET Downtime Greater Than 9 Mo.)
Modify Alternative Facility
New Facility Required

Length vs Facility impacts for Tank processing cells

LH2 Major Weld Assy
Final Assy (Bldg 103)
LH2 Proof Test (Bldg 451)
Test & Checkout (Bldg 420)

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results
3-S-008B
(CV-STR-20B)
LH2 Tank Impact vs. Ullage
Pressure Trade Study

Prepared By: Tom Severs
(504) 257-5226

Rev: Initial
Date: January 8, 1992

Approved By: R. Simms

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Objective and Approach

Objective

• This trade develops the impacts to the LH2 tank pressure shell for ullage pressures of 34 psig (the baseline) to 80 psig.

Approach

• Determine pressure capability of the reference configuration.

• Establish critical loading conditions.

• Perform analysis to determine membrane and weld land thickness requirements for pressures above the capability of the Reference Configuration.
Approach (Continued)

- Develop weight impacts compared to the Reference Configuration.

- Evaluate the weight savings if the biaxial yield theory is used in the proof test analysis.

- Evaluate impact to manufacturing for increased thicknesses. Document results of the study and prepare conclusions.
Ground Rules & Assumptions 3-S-008-B

- Nominal tank configuration as per MSFC Cycle 0 definition as per 10/9/91. (34 psi maximum ullage pressure)
- The study addresses tank membrane and weld land requirements only, stiffener size and pitch, and frame size and pitch is from the reference configuration.
- Thicknesses are taken to a zero margin before additional material is added.
- SF = 1.40 on ultimate, 1.10 on yield. Room Temp. Proof Factor = 1.05
- Pneumatic proof test. (Similar to the ET.)
Ullage Pressure Req't vs. Capability  3-S-008-B

34 psi Ullage

Insufficient Capability

Flight Pressure

Flight Capability

Proof Pressure

Proof Capability

Pressure [psi]

Pressure [psi]
Ullage Pressure Req't vs. Capability

40 psi Ullage

Insufficient Capability
Flight Pressure, 40 psi Ullage
Flight Capability

Ref. Ullage (34 psi)

Proof Pressure
Flight Pressure
Proof Capability
Insufficient Capability

TJS-B1-117

MARTIN MARIETTA
MANNED SPACE SYSTEMS
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Fwd Dome</td>
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<td>Bbls 3 &amp; 4</td>
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<td>Bbls 1 &amp; 2</td>
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<tr>
<td>Barrel 1a</td>
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<td>40.2, 44.3, 50.0, 54.3, 60.0, 64.3</td>
</tr>
<tr>
<td>Aft Dome</td>
<td>40.0</td>
<td>46.5</td>
<td>40.2, 44.3, 50.0, 54.3, 60.0, 64.3</td>
</tr>
</tbody>
</table>

- **Flight**: Pressure for normal operation.
- **Proof**: Pressure for proof testing.
# Delta Membrane Thicknesses

**Thicknesses in Inches**

<table>
<thead>
<tr>
<th>Location</th>
<th>Ref. Config. Thickness</th>
<th>Max. Ullage Pressure [psig]</th>
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<tr>
<td></td>
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<td>34 psi</td>
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<tr>
<td>Fwd Dome</td>
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<td>.007</td>
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<tr>
<td>Bbils 3 &amp; 4</td>
<td>.170</td>
<td>.000</td>
</tr>
<tr>
<td>Bbils 1 &amp; 2</td>
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<td>.000</td>
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<tr>
<td>Barrel 1a</td>
<td>.190</td>
<td>.000</td>
</tr>
<tr>
<td>Aft Dome</td>
<td>.160 to .087</td>
<td>.000</td>
</tr>
</tbody>
</table>
# Weld Land Thicknesses

**Thicknesses in Inches**

<table>
<thead>
<tr>
<th>Location</th>
<th>Ref. Config. Thickness</th>
<th>Max. Ullage Pressure [psig]</th>
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<tr>
<td></td>
<td></td>
<td>34 psi</td>
</tr>
<tr>
<td>Fwd Dome</td>
<td>.066 to .084</td>
<td>.204</td>
</tr>
<tr>
<td>Bbls 3 &amp; 4</td>
<td>.170</td>
<td>.204</td>
</tr>
<tr>
<td>Bbls 1 &amp; 2</td>
<td>.180</td>
<td>.229</td>
</tr>
<tr>
<td>Barrel 1a</td>
<td>.190</td>
<td>.229</td>
</tr>
<tr>
<td>Aft Dome</td>
<td>.160 to .087</td>
<td>.236</td>
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</table>
# Membrane Delta Weight [Lbs.]

<table>
<thead>
<tr>
<th>Location</th>
<th>Delta Wt. 34 psi</th>
<th>Delta Wt. 40 psi</th>
<th>Delta Wt. 50 psi</th>
<th>Delta Wt. 60 psi</th>
<th>Delta Wt. 70 psi</th>
<th>Delta Wt. 80 psi</th>
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<tr>
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<td>380</td>
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<td>2273</td>
<td>6783</td>
<td>11523</td>
<td>16247</td>
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</table>

| Wt. Factor 1 | 1.00 | 1.01 | 1.06 | 1.17 | 1.29 | 1.41 |

**NOTE:** 1) Wt. factor is based on weight increase to total LH2 tank. Ref. Wt = 39,220 Lbs.
Manufacturing Impacts

- Effect of Increased Tank Weld Land Thickness

Stretch Form of Gore Panels
- Current vendor: American Hydro-Forming CA
- Plate Thickness Capability Up To 0.5 Inches
- Requires Incremental Development Program to Determine Max Thickness Capability
- New Grippers & Hydraulic System Mod
- No Commitment without Test Panel

Option: Perform Industry Survey to Locate Potential Suppliers
  - Larger Machine Tools Do Exist
    Manufactured by L&F Industries CA
Manufacturing Impacts

- Dome Assembly:

Weld Land Thickness Tooling Capacity

Up To 0.400" - Minor Mods Only

0.400" to 0.425" - Extensive Mod to Clamping System on 1/2 Dome & Full Dome Weld Fixtures

0.425" to 0.500" - Extensive Mod to Clamping System on 1/4 Dome Weld Fixtures

0.500" to 0.627" - Major Rework on all Dome Tool for New Clamps and Clamping Loads
Summary

• LH2 tank weight impacts:
  - 694 Lbs. impact at 40 psig
  - 16,319 Lbs. impact at 80 psig

• Weld thickness manufacturing impact:
  - Extensive modifications necessary for ullage pressures above 60 psi.

• Stretch Forming Impact:
  - Uncertain capability for thicknesses beyond .5 inches.
Biaxial Yield Theory Savings

<table>
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<tr>
<th>Pressure [psig]</th>
<th>ΔWt. [Lbs.]</th>
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</tr>
<tr>
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<td>0</td>
</tr>
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<td>0</td>
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<td>900</td>
</tr>
<tr>
<td>70</td>
<td>1100</td>
</tr>
<tr>
<td>80</td>
<td>1200</td>
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</table>

Weight Impact for Ullage Pressure Increase

Weight Impact for Ullage Pressure Increase if Biaxial Yield Criterion is used
Issues Identified During Study

Issue: The number and spacing of frames can change as the skin is increased for a more fully optimized configuration.

Resolution: The stringer size and pitch sensitivity study underway will help identify the magnitude of the potential weight savings.

Issue: The study was based on ET type pressure time history data. The STME requires a different pressure profile which is currently being defined by the propulsion team.

Resolution: Update this trade once the new pressure data is obtained from the propulsion group.
5.2.6.4.4 LH2 Tank Sizing vs. Pressure (3-S-008B)

Objective

This trade study develops the impacts to the LH2 tank pressure shell for increasing ullage pressures up to 80 psig. (The baseline pressure is 34 psig).

Approach

(a) Determine pressure capability of the Reference Configuration
(b) Establish critical load conditions
(c) Perform analysis to determine membrane and weld land thickness requirements for pressures above the capability of the Reference Configuration
(d) Develop weight impacts to the Reference Configuration
(e) Evaluate impact to manufacturing for increased thickness
(f) Evaluate whether impacts can be reduced by the use of the biaxial yield theory and frame size reduction.
(g) Document results of the study and prepare conclusions

Options Studied

Ullage pressures from 34 psig to 80 psig.

Key Results

The weight impact is roughly 450 Lbs. per psi. No tooling impacts are identified until ullage pressures reach 50 psig. Major tooling impacts occur once ullage pressures exceed 70 psig. There is no weight savings for ullage pressure below the baseline pressure because the skin is sized for compression, not pressure induced tension. There is no weight savings for frame redesign since the frames are required for an unpressurized condition. The weight penalty may be mitigated by 500 to 1200 lbs., depending on the maximum ullage pressure, if the biaxial yield theory is adopted.

Conclusions

This study identified the weight impacts for ullage pressures between 20 and 80 psig. The weight increase is fairly linear and unbounded for increasing ullage pressures.

Recommendation

Use the results of this trade as an input to the propulsion studies of engine performance vs. ullage pressure.
Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results
6.2.6.4.4 LH2 Tank Sizing vs. Pressure (3-S-008B)

Objective

This trade study develops the impacts to the LH2 tank pressure shell for increasing ullage pressures up to 80 psig. (The baseline pressure is 34 psig).

Approach

(a) Determine pressure capability of the Reference Configuration
(b) Establish critical load conditions
(c) Perform analysis to determine membrane and weld land thickness requirements for pressures above the capability of the Reference Configuration
(d) Develop weight impacts to the Reference Configuration
(e) Evaluate impact to manufacturing for increased thickness
(f) Evaluate whether impacts can be reduced by the use of the biaxial yield theory and frame size reduction.
(g) Document results of the study and prepare conclusions

Options Studied

Ullage pressures from 34 psig to 80 psig.

Key Results

The weight impact is roughly 450 Lbs. per psi. No tooling impacts are identified until ullage pressures reach 50 psig. Major tooling impacts occur once ullage pressures exceed 70 psig. There is no weight savings for ullage pressure below the baseline pressure because the skin is sized for compression, not pressure induced tension. There is no weight savings for frame redesign since the frames are required for an unpressurized condition. The weight penalty may be mitigated by 500 to 1200 lbs., depending on the maximum ullage pressure, if the biaxial yield theory is adopted.

Conclusions

This study identified the weight impacts for ullage pressures between 20 and 80 psig. The weight increase is fairly linear and unbounded for increasing ullage pressures.

Recommendation

Use the results of this trade as an input to the propulsion studies of engine performance vs. ullage pressure.
Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results
Stiffener Pitch Sensitivity Study

3-S-001B (CV-STR-18B) - Fwd Skirt
3-S-010B (CV-STR-15B) - LO2 Tank
3-S-009B (CV-STR-19B) - Intertank
3-S-008C (CV-STR-20C) - LH2 Tank

Prepared By: Dilip Dudgaonkar
(504)257-0076

Rev: Initial
Date: January 8, 1992

Approved By: M.R.Simms
5.2.6.4.5 Stiffener Pitch Sensitivity Study (# 3-S-008C)

Objective

To develop weight sensitivities of the LH2 tank by varying pitch and stiffener size.

Approach

a) Use current configurations as baseline
b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)
c) Document assumptions made and factors of safety used.
d) Produce t bar vs pitch sensitivities
e) Prepare conclusions and recommendations

Key Study Results

The current internal T section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight (tbar) trend shows that an optimum occurs at a stringer pitch of 2.0 inches for an axial compression load of 2600 lb/inch. However, 2.0 inch spacing may not be practical. It appears that stringer spacings of 4 to 5 inches may offer sizable benefits.

Conclusions

Weight sensitivity data was generated by varying the stringer pitch while maintaining the the reference configurations integrally machined longitudinal tee stiffened panel approach. The Panda II optimized configuration developed offers weight savings compared to the baseline configuration but is not considered producable.

Study Recommendations

Maintain the reference configuration LH2 tank barrel configuration. During cycle 1, study an alternate barrel panel with stringer spacing and/or varying frame spacing increased over the optimized configuration but less than the reference. In addition study the impact of varying frame spacing on the stiffener pitch.
LH2 TANK
Stringer Spacing Vs Tbar

![Graph showing stringer spacing vs Tbar with Tbar values: 0.05, 0.1, 0.15, 0.2, 0.25 on the y-axis and stringer spacing values: 2.0, 4.0, 5.0, 7.33, 10.0 on the x-axis.]

- **Current Design**
  - Stringer Spacing = 10.832"
  - Frame Spacing = 26.7"
  - $T_{skin} = 0.170$
  - $T_{bar} = 0.193$

- **Optimized Design with $N_x = 2600$ lb/in**
  - Stringer Spacing = 2.0"
  - Frame Spacing = 26.7"
  - $T_{skin} = 0.061$
  - $T_{bar} = 0.108$

- **Optimized Design with $N_x = 3250$ lb/in**
  - Stringer Spacing = 2.0"
  - Frame Spacing = 26.7"
  - $T_{skin} = 0.067$
  - $T_{bar} = 0.123$

**Additional Information**

Details of this study are contained in Doc #MMC.NLS.SR.001.BOOK 1
6.2.6.4.5 Stiffener Pitch Sensitivity Study (# 3-S-008C)

Objective

To develop weight sensitivities of the LH2 tank by varying pitch and stiffener size.

Approach

a) Use current configurations as baseline
b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)
c) Document assumptions made and factors of safety used.
d) Produce t bar vs pitch sensitivities
e) Prepare conclusions and recommendations

Key Study Results

The current internal T section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight (tbar) trend shows that an optimum occurs at a stringer pitch of 2.0 inches for an axial compression load of 2600 lb/inch. However 2.0 inch spacing may not be practical. It appears that stringer spacings of 4 to 5 inches may offer sizable benefits.

Conclusions

Weight sensitivity data was generated by varying the stringer pitch while maintaining the the reference configurations integrally machined longitudinal tee stiffened panel approach. The Panda II optimized configuration developed offers weight savings compared to the baseline configuration but is not considered producable.

Study Recommendations

Maintain the reference configuration LH2 tank barrel configuration. During cycle 1, study an alternate barrel panel with stringer spacing and/or varying frame spacing increased over the optimized configuration but less than the reference, in addition study the impact of varying frame spacing on the stiffener pitch.
LH2 TANK
Stringer Spacing Vs Tbar

<table>
<thead>
<tr>
<th>Current Design</th>
<th>Optimized Design N=2600 lb/in</th>
<th>Optimized Design N=3250 lb/in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringer Spacing=10.832&quot;</td>
<td>Stringer Spacing=2.0&quot;</td>
<td>Stringer Spacing=2.0&quot;</td>
</tr>
<tr>
<td>Frame Spacing=26.7&quot;</td>
<td>Frame Spacing=26.7&quot;</td>
<td>Frame Spacing=26.7&quot;</td>
</tr>
<tr>
<td>Ts=0.170</td>
<td>Ts=0.061</td>
<td>Ts=0.067</td>
</tr>
<tr>
<td>Tbar=0.193</td>
<td>Tbar=0.108</td>
<td>Tbar=0.123</td>
</tr>
</tbody>
</table>

Additional Information

Details of this study are contained in Doc #MMC.NLS.SR.001.BOOK 1
Objective/Approach

Objective
• Develop And Evaluate Alternative Construction Methods For The LO2 & LH2 Tank Barrel Panels To Determine Preferred Design Concepts Relative To Weight, Costs, & Manufacturing/Producibility.

Approach
• Define Point Of Departure (P.O.D.) LO2 & LH2 Tank Panel Construction Reference Method.
• Identify Concept Options For Various Structural Configurations.
• Estimate Weight Differences.
• Perform Cost Analysis.
• Assess Producibility Impacts.
• Evaluate Options With Respect To Evaluation Criteria.
• Select Preferred Option.
Groundrules & Assumptions

- Use NLS Baseline LO2 & LH2 Tank Panels As Point Of Departure (P.O.D.). Material = Al-2219. Configurations As Defined by MFSC Reference Layouts:
  LH2 Tank, NLS-0005 (Dated 10/9/91)
  LO2 Tank, NLS-0006 (Dated 10/9/91)

Reference Trade Studies:
CV-STR-14B "LO2 Tank Structure Design Definition".
CV-STR-14D "LH2 Tank Structure Design Definition".

- External Tank Tooling Will Be Used Wherever Possible Per NLS Program Requirements.

- Material Considered For All Options = Al-2219. Assume 1.5 Inch Maximum Stock Plate Thickness (Readily Available).

(Cont.)
Groundrules & Assumptions (Cont.)

- Weldalite Not Considered.

- Dimensions Based On ROM Sizing.
### Key Issues/Evaluation Criteria

- Manufacturing/Producibility.
- Weight Impacts.
- Costs.

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing/Producibility</td>
<td>Produdibility is a major factor in concept selection. Selected option should not impact NLS manufacture on ET tooling.</td>
</tr>
<tr>
<td>Weight Impact</td>
<td>Any additional weight must be traded against loss of payload lift capability.</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
</tr>
<tr>
<td>Non-Recurring</td>
<td>Minimal DDT&amp;E desired.</td>
</tr>
<tr>
<td>Recurring</td>
<td>Low cost per flight desired for expendable HLLV</td>
</tr>
</tbody>
</table>
Option 1 - LO2 & LH2 Baseline Panel (P.O.D.)

- Integrally Machined Panel With Longitudinal Tee-Stiffening.
- Synergistic With ET Tank Pressure Vessel Designs.
- Utilizes Existing ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.
Option 2 - Machined Blade-Stiffened Panel (LO2 & LH2)

- Integrally Machined Panel With Longitudinal Blade-Stiffening.
- Derived From NLS LO2 Tank Pressure Vessel Design (POD).
- May Not Utilize Some Existing ET Processes And Tooling.
- Design Consistant With Maximum Axial Load Distribution.
Option 3 - Machined Waffle Panel (LO2 & LH2)

- Integally Machined Waffle Panel with Longitudinal & Transverse Stiffening.
- New Processes and Tooling Required.
- Designed for Maximum Axial & Bending Loading Conditions.
Option 4 - Machined Isogrid Panel (LO2 & LH2)

- Integrally Machined Iso-Grid Panel With Multi-Directional Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Bending Conditions & Bi-Directional Loading.
Option 5 - Welded Panel (LO2 & LH2)

- Machined Panel With Welded Extruded Longitudinal Tee-Stiffening.
- Similar To ET Tank Pressure Vessel Designs.
- New Processes And Tooling Required.
- Design Consistant With Maximum Axial Load Distribution.
Option 6 - Mechanically Fastened Panel (LO2 & LH2)

Mach. Skin Panel

10.832

.125

OSL

.125

Extrusion (Typ)

1.50

1.25

.10

- Stock Plate Skin With Machined Slots To Accept Extrusions.
- Extruded Tee Stiffeners.
- Mechanically Assembled (Tack Weld Or Fasten Ends To Prevent Slipage.
- New Processes And Tooling Required.

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MARTIN MARIETTA
MANNED SPACE SYSTEMS
Option 7 - Extruded Panel (LO2 & LH2)

ALS Derived Technology Status:
- Required Tooling On Order.
- AL 2219 Material Peirced & Forged.
- Scheduled Extrusion Of 2219 In Early Jan.'92.
- Weldalite-049 Material Has Been Cast.
- Weldalite Panels Planned For Mid-Jan.'92.

* This Option Considered To Be The Same Design As Option 1 (P.O.D.).

- Panels Extruded Through Circular Die (Stringers Extruded On Outside Of Circle).

- After Extrusion Panels Are Brought To Die Heater Contractor Where They Are Heated And Rolled Out Into Flat Panels And Allowed To Cool.

- Requires 35,000 Ton Press.

- New Processes And Tooling Required.
## Manufacturing/Producibility Summary

<table>
<thead>
<tr>
<th></th>
<th>Barrel Weld Assembly</th>
<th>Mechanical Assembly &amp; Installation To Tank</th>
<th>Intermediate Frame Attachment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1 (Baseline)</strong></td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td><strong>Option 2 Machined Blade Stiffened Panel</strong></td>
<td>Same As Baseline</td>
<td>(-) Requires Separate Frame Attach. Brkts.</td>
<td>(-) Complex Bracket Arrgt. Required.</td>
</tr>
<tr>
<td><strong>Option 5 Welded Panel</strong></td>
<td>Same As Baseline</td>
<td>(-) Some High Development WorkTo Adapt ET Tooling. Higher Weld Costs.</td>
<td>Same As Baseline</td>
</tr>
<tr>
<td><strong>Option 6 Mechanically Fastened Panel</strong></td>
<td>Same As Baseline</td>
<td>(-) Some High Development WorkTo Adapt ET Tooling.</td>
<td>Same As Baseline</td>
</tr>
<tr>
<td><strong>Option 7 Extruded Panel</strong></td>
<td>Same As Baseline</td>
<td>Same As Baseline</td>
<td>Same As Baseline</td>
</tr>
</tbody>
</table>

---

GMR.91352

MARTIN MARIETTA
MANNED SPACE SYSTEMS
# Weight Impact Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Total Wt. Of LO2 Barrels</th>
<th>Total Wt. Of LH2 Barrels</th>
<th>Total Wt. Of Panels</th>
<th>Δ Weight From P.O.D. (lbs.)</th>
<th>% Weight Increase/Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1 (Baseline)</td>
<td>5,998</td>
<td>20,458</td>
<td>26,456</td>
<td>P.O.D.</td>
<td>0 %</td>
</tr>
<tr>
<td>Option 2 Machined Blade Stiffened Panel</td>
<td>5,195</td>
<td>19,205</td>
<td>24,401</td>
<td>-2,055</td>
<td>-8 %</td>
</tr>
<tr>
<td>Option 3 Machined Waffle Panel</td>
<td>5,348</td>
<td>19,742</td>
<td>25,091</td>
<td>-1,365</td>
<td>-5 %</td>
</tr>
<tr>
<td>Option 4 Machined Iso-Grid Panel</td>
<td>4,925</td>
<td>18,471</td>
<td>23,394</td>
<td>-3,060</td>
<td>-12%</td>
</tr>
<tr>
<td>Option 5 Welded Panel</td>
<td>5,998</td>
<td>20,458</td>
<td>26,456</td>
<td>0</td>
<td>0 %</td>
</tr>
<tr>
<td>Option 6 Mechanically Fastened Panel</td>
<td>6,064</td>
<td>20,699</td>
<td>26,763</td>
<td>+307</td>
<td>+1 %</td>
</tr>
<tr>
<td>Option 7 Extruded Panel</td>
<td>5,998</td>
<td>20,458</td>
<td>26,456</td>
<td>0</td>
<td>0 %</td>
</tr>
</tbody>
</table>
## Costs Impact Summary

<table>
<thead>
<tr>
<th>Cost Factor</th>
<th>Non-Recurring</th>
<th>Recurring</th>
<th>Adjusted For Assy Impacts</th>
<th>Cost Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1 (Baseline)</td>
<td>13.0</td>
<td>Baseline 1.0</td>
<td>13.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Option 2 Machined Blade Stiffened Panel</td>
<td>17.0</td>
<td>0.9</td>
<td>19.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Option 3 Machined Waffle Panel</td>
<td>24.0</td>
<td>1.1</td>
<td>42.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Option 4 Machined Iso-Grid Panel</td>
<td>26.0</td>
<td>1.1</td>
<td>28.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Option 5 Welded Panel</td>
<td>40.0</td>
<td>1.1</td>
<td>43.0</td>
<td>1.1</td>
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<tr>
<td>Option 6 Mechanically Fastened Panel</td>
<td>33.0</td>
<td>0.8</td>
<td>35.0</td>
<td>0.8</td>
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<tr>
<td>*Option 7 Extruded Panel</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

* Insufficient Data Exists To Effectively Assess This Option.
# Evaluation Summary

<table>
<thead>
<tr>
<th></th>
<th>Weight Impacts</th>
<th>Cost Ranking</th>
<th>Manufacturing/Producibility Impacts</th>
<th>Other Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1 (Baseline)</td>
<td>P.O.D.</td>
<td>1</td>
<td>None</td>
<td>Good Synergism With E.T.</td>
</tr>
<tr>
<td>Option 2</td>
<td>8% Decrease</td>
<td>2</td>
<td>Sim. To Baseline, But Req.</td>
<td></td>
</tr>
<tr>
<td>Stiffened Panel</td>
<td></td>
<td></td>
<td>Some High Development</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Work To Adapt ET Tooling.</td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>5% Increase</td>
<td>5</td>
<td>Some High Dev. Work To</td>
<td>Fewer Intermediate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 4</td>
<td>12% Decrease</td>
<td>3</td>
<td>Some High Dev. Work To</td>
<td>Fewer Intermediate</td>
</tr>
<tr>
<td>Panel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 5</td>
<td>Same As</td>
<td>6</td>
<td>Some High Development</td>
<td>Good Synergism With E.T.</td>
</tr>
<tr>
<td>Welded Panel</td>
<td>Baseline</td>
<td></td>
<td>Work To Adapt ET Tooling.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Higher Weld Costs.</td>
<td></td>
</tr>
<tr>
<td>Option 6</td>
<td>1% Increase</td>
<td>4</td>
<td>Some High Development</td>
<td>Good Synergism With E.T.</td>
</tr>
<tr>
<td>Mechanically Fastened</td>
<td></td>
<td></td>
<td>Work To Adapt ET Tooling.</td>
<td></td>
</tr>
<tr>
<td>Panel</td>
<td>Same As</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>* TBD</td>
<td>New Processes And Tooling Required.</td>
<td>Good Synergism With E.T.</td>
</tr>
<tr>
<td>Option 7</td>
<td>Same As</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extruded Panel</td>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Insufficient Data Exists To Effectively Assess This Option.
Conclusions

• Option 1 - Is Currently NLS Baseline, Is The Most Synergistic With External Tank And Requires The Least Development.

• Option 2 - Will Reduce Weight Over Baseline At Small Additional Costs, However Weight Reduction May Be Offset By Additional Weight For Frame Attachment. Requires Additional DDT&E.

• Option 3 - Has Highest Weight, Potential To Eliminate Some Intermediate Frames, And Reduced Panel Weight At Extensive Additional DDT&E Costs.

• Option 4 - Has The Least Weight And The Potential To Eliminate Some Intermediate Frames. May Be Able To Reduce Panel Weight At Additional DDT&E Costs.

• Option 5 - No Weight Increase, But Requires Some New Technology And Extensive Additional DDT&E Costs.

• Option 6 - Slight Weight Increase, But Requires Some New Technology And Additional DDT&E Costs.

• Option 7 - Most Promising Concept If Proven To Be Feasible.
Recommendations

- Maintain Baseline (Option 1) For Cycle Ø & Cycle 1.

- Continue To Study The Following Viable LO2 & LH2 Tank Alternative Skin Panel Designs During Cycle 1:

  Option 1 - Baseline Panel.

  Option 4 - Machined Isogrid Panel.

- Follow Progress & Development Of Option 7 (Extruded Panel). This Option Has The Potential To Generate Substantial Cost Savings Over The Course Of Sustained Program.
5.2.6.4.6 Alternate Panel Construction (#CV-STR-015-C)

Objective

This trade study developed and evaluated alternative panel construction methods for the LH2 tank barrel panels.

Approach

(a) Define a point of departure LO2 tank panel.
(b) Identify concept options for skin panels.
(c) Estimate weight deltas, producibility, and cost.
(d) Evaluate options.
(e) Select preferred option.

Options Studied - LH2 Tank

Option 1 - Machine Panel With Tee Stiffeners (Baseline)
Option 2 - Machined Blade-Stiffened Panel
Option 3 - Machined Waffle Panel
Option 4 - Machined Isogrid Panel
Option 5 - Welded Panel
Option 6 - Mechanically Fastened Stiffened Panel
Option 7 - Extruded Panel

Key Study Results

All options were compared to the Option 1 Reference Configuration. Option 2 had an 8% decrease in weight and ranked 2nd lowest cost. Option 3 had a 5% increase in weight and was the 5th lowest cost. Option 4 had a 12% decrease in weight and was 3rd lowest cost. Option 5 had the same weight as baseline and had the highest costs. Option 6 had an increase weight of 1% and was 4th lowest cost. Option 7 had no weight increase. Cost estimates could not be performed on this option due to insufficient data.

Conclusions

Seven alternative construction methods were studied. The longitudinal tee-stiffened panels offered excellent synergism with ET and related tooling, and were lower in costs. Option 2 was eliminated due to poor External Tank synergism and complicated intermediate frame attachment. Option 3 was eliminated due to excessive DDT&E costs. Option 4, although requiring additional development work, may be an attractive method of construction due to the possibility of eliminating intermediate frames and weight. Option 5's ET synergism was excellent but was eliminated due to excessive DDT&E costs. Option 6 also had excellent ET synergism, but was also eliminated due to excessive DDT&E costs. Option 7 could be the most promising of all the if the technology proves to be feasible.

Study Recommendations

Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:

- Option 1 - M/C Panel With Tee Stiffeners (Baseline)
- Option 4 - Machined isogrid panel
- Follow the progress and development of Option 7
Option 1 - Baseline Panel (F.O.D.)
- Machined Panel W/ Tee-Stiffening.
- Synergistic W/ External Tank.
- Utilizes Existing ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 2 - Mach.Blade-Stiff. Panel
- Machined Panel W/ Blade-Stiffening.
- May Not Utilize ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 3 - Machined Waffle Panel
- Machined Waffle Panel W/ Long. & Transv. Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Axial & Bending Loading Conditions.

Option 4 - Machined Isogrid Panel
- Machined Iso-Grid Panel With Multi-Directional Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Bending Conditions & Bi-Directional Loading.

Option 5 - Welded Panel
- Skin With Machined Slots To Accept Extrusions.
- Extruded Tee Stiffeners.
- Mechanically Assembled.
- New Processes And Tooling Required.

Option 6 - Mechanically Fastened Panel Required
- Panels Extruded Through Circular Die (Stringers Extruded On Outside Of Circles).
- After Panels Are Extruded They Are Heated And Rolled Out Into Flat Panels And Allowed To Cool.
- Requires 35,000 Ton Press.
- New Processes And Tooling Required.

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
6.2.6.4.6 Alternate Panel Construction (#CV-STR-015-C)

Objective

This trade study developed and evaluated alternative panel construction methods for the LH2 tank barrel panels.

Approach

(a) Define a point of departure LO2 tank panel.
(b) Identify concept options for skin panels.
(c) Estimate weight deltas, producibility, and cost.
(d) Evaluate options.
(e) Select preferred option.

Options Studied - LH2 Tank

Option 1 - Machine Panel With Tee Stiffeners (Baseline)
Option 2 - Machined Blade-Stiffened Panel
Option 3 - Machined Waffle Panel
Option 4 - Machined Isogrid Panel
Option 5 - Welded Panel
Option 6 - Mechanically Fastened Stiffened Panel
Option 7 - Extruded Panel

Key Study Results

All options were compared to the Option 1 Reference Configuration. Option 2 had an 8% decrease in weight and ranked 2nd lowest cost. Option 3 had a 5% increase in weight and was the 5th lowest cost. Option 4 had a 12% decrease in weight and was 3rd lowest cost. Option 5 had the same weight as baseline and had the highest costs. Option 6 had an increase weight of 1% and was 4th lowest cost. Option 7 had no weight increase. Cost estimates could not be performed on this option due to insufficient data.

Conclusions

Seven alternative construction methods were studied. The longitudinal tee-stiffened panels offered excellent synergism with ET and related tooling, and were lower in costs. Option 2 was eliminated due to poor External Tank synergism and complicated intermediate frame attachment. Option 3 was eliminated due to excessive DDT&E costs. Option 4, although requiring additional development work, may be an attractive method of construction due to the possibility of eliminating intermediate frames and weight. Option 5's ET synergism was excellent but was eliminated due to excessive DDT&E costs. Option 6 also had excellent ET synergism, but was also eliminated due to excessive DDT&E costs. Option 7 could be the most promising of all if the technology proves to be feasible.

Study Recommendations

Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:
- Option 1 - M/C Panel With Tee Stiffeners (Baseline)
- Option 4 - Machined isogrid panel.
- Follow the progress and development of Option 7
Option 1 - Baseline Panel (P.O.D.)

- Machined Panel W/Tee-Stiffening.
- Synergistic W/ External Tank.
- Utilizes Existing ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 2 - Mach. Blade-Stiff. Panel

- Machined Panel W/ Blade-Stiffening.
- May Not Utilize ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 3 - Machined Waffle Panel

- Machined Waffle Panel W/ Long. & Transv. Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Axial & Bending Loading Conditions.

Option 4 - Machined Iso-Grid Panel

- Machined Iso-Grid Panel With Multi-Directional Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Bending Conditions & Bi-Directional Loading.

Option 5 - Welded Panel

- Skin With Machined Slots To Accept Extrusions.
- Extruded Tee Stiffeners.
- Mechanically Assembled.
- New Processes And Tooling Required.

Option 6 - Mechanically Fastened Panel

- Panels Extruded Through Circular Die (Stringers Extruded On Outside Of Circle).
- After Panels Are Extruded They Are Heated And Rolled Out Into Flat Panels And Allowed To Cool.
- Requires 35,000 Ton Press.
- New Processes And Tooling Required.

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
Objective

- Identify the Commonality Between HLLV, 1.5 Stage, & STS Intertanks

Approach

- Develop a "Standalone" 1.5 Stage Intertank Configuration
- Develop a "Standalone" HLLV Intertank Configuration
- Compare "Standalone" Configs with Ref Config & ET I/T's
- Identify Part Commonality
  (A) Identical to ET Part
  (B) Similar to ET Part
  (C) Unique Part for NLS
- Develop Weight Estimates for "Standalone" Configurations & Compare to Reference Configuration
Groundrules

- Intertank Structure Definition Per MSFC Reference Layout NLS-0001 Dated 10/9/91
- NLS Ref Intertank Used As The HLLV Intertank For This Study
1.5 Stage Intertank Groundrules CV-STR-19A

- Intertank Length & Dia As ET
- Basic Panel Construction Similar To ET
- Omit All Scars For SRB Attach/Loads
- Ground/Subsystem I/F's & Penetrations As Ref (HLLV)
- Frame Locations As Ref., Frames May Be Omitted
- Frame Depths May Vary
Design Loads Comparison

Shell Axial Design Loads – Limit

Loads – lb/in

- 0 – 250
- 251 – 1000
- 1001 – 1500
- 1501 – 4000
- 4001+

Standard ET

ET-Derived Core Tankage

HLLV 1.5 Stage Common Core
• ET Intertank Definition
ET Intertank Arrangement

- Ring Frame (4)
  - Fabricated I-Beam

- SRB Beam
  - Fabricated I-Beam

- Main Ring Frame (1)
  - Fabricated I-Beam

- SRB I/F Ftg
  - Machined Forging

- Skin/Stringer Panels (6)
  - Mechanically Fastened
  - Stringer-Stiffened Panel

- Thrust Panels (2)
  - Machined, Blade Stiffened
Standalone HLLV Intertank*  CV-STR-19A

- ET Ring Frame (4)
  - Fabricated I-Beam
- ET Main Ring Frame (1)
  - Fabricated I-Beam
- ET SRB Beam
  - Fabricated I-Beam
- ET SRB I/F Ftg
  - Machined Forging
- NLS Skin/Stringer Panels (6)
  - Mechanically Fastened Stringer-Stiffened Panel
- ET Thrust Panels (2)
  - Machined, Blade Stiffened

* Same As NLS Common Core Intertank

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MANNED SPACE SYSTEMS
Standalone 1.5 Stage I/T

ET Ring Frame (5)
- Fabricated I-Beam

NLS Skin/Stringer Panels (8)
- Mechanically Fastened Stringer-Stiffened Panel
Standalone 1.5 Stage Intertank  CV-STR-19A

- Skin/Stringer Panel XSection

<table>
<thead>
<tr>
<th>Frame</th>
<th>XSect Area</th>
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<tbody>
<tr>
<td>Xn 2897.1</td>
<td>2.14 in sq</td>
</tr>
<tr>
<td>Xn 2941.4</td>
<td>2.14 in sq</td>
</tr>
<tr>
<td>Xn 2985.675</td>
<td>2.14 in sq</td>
</tr>
<tr>
<td>Xn 3034.2</td>
<td>2.14 in sq</td>
</tr>
<tr>
<td>Xn 3082.0</td>
<td>2.14 in sq</td>
</tr>
</tbody>
</table>

Nominal Stiffener Detail

Lo2 Tank I/F
Xn 2852.80
Xn 2941.4
Xn 2985.675
Xn 3034.2
Xn 3082.0
Xn 3123.15
LH2 Tank I/F

12.00 Typ
4 Frs

165.00 R
ISL (Ref)

20.00

2.50

15°

.92

1.38

.066

MARTIN MARIETTA
MANNED SPACE SYSTEMS
# Weight Estimates

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<thead>
<tr>
<th>Hardware</th>
<th>ET 120</th>
<th>HLLV Ref</th>
<th>1.5 Stage Ref</th>
<th>1.5 Stage</th>
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<td>Panel # 1</td>
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<td>920.97</td>
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<td>900.03</td>
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<tr>
<td>SRB Ring Frame (2985)</td>
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<td>1532.70</td>
<td>1532.70</td>
<td>1058.20</td>
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<td>625.80</td>
<td>625.80</td>
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<td>203.20</td>
<td>203.20</td>
<td>211.64</td>
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<td>Ring Frame (3034)</td>
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<td>220.20</td>
<td>220.20</td>
<td>211.64</td>
</tr>
<tr>
<td>Ring Frame (3082)</td>
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<td>259.70</td>
<td>259.70</td>
<td>211.64</td>
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<tr>
<td>SRB Beam &amp; Fittings</td>
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<td>Total Dry Wt</td>
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<td>13818.15</td>
<td>12065.55</td>
<td>7246.40</td>
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<td>Contingency (5%)</td>
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<td>690.91</td>
<td>603.28</td>
<td>362.32</td>
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<tr>
<td>Total Dry Wt</td>
<td>12732.20</td>
<td>14509.06</td>
<td>12668.30</td>
<td>7608.72</td>
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</table>
1.5 Stage Tooling Impacts CV-STR-19A

- Adaptors Required To Locate Frames With A Decreased Depth In The Half Section Tack Tool (T06A7395) & The Half Section Finish & Inspect Tool (T06A7399)
  - Further Impacts If The Frame Depth Should Increase
- Intertank Assembly Tool (T06A7391) Will Not Be Impacted
- Thrust Panel Handling Fixture Must Be Modified To Interface With New ±Y Fabricated Panels
- Systems Installation Tool (T06A7424) Would Require Modification Only If Frame Depths Increased
• Intertank Commonality Assessment
<table>
<thead>
<tr>
<th>Part</th>
<th>Title</th>
<th>Part Status</th>
<th>1.5 Stage Modification</th>
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</thead>
<tbody>
<tr>
<td>P3</td>
<td>Panel # 3</td>
<td>E N U</td>
<td>Resized For 1.5 Stage Loads</td>
</tr>
<tr>
<td>P4</td>
<td>Panel # 4 (-Y)</td>
<td>E E U</td>
<td>Thurst Panels Replaced By Skin/Stringer Panels</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>On 1.5 Stage. Common Panels ±Y</td>
</tr>
<tr>
<td>P5</td>
<td>Panel # 5 (+Y)</td>
<td>E E U</td>
<td>Resized For 1.5 Stage Loads</td>
</tr>
<tr>
<td>P6</td>
<td>Panel # 6</td>
<td>E N U</td>
<td>Resized For 1.5 Stage Loads</td>
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<tr>
<td>P7</td>
<td>Panel # 7</td>
<td>E N U</td>
<td>Identical To Panel # 2</td>
</tr>
<tr>
<td>P8</td>
<td>Panel # 8 (-Z)</td>
<td>E N U</td>
<td>Resized For 1.5 Stage Loads</td>
</tr>
<tr>
<td>B1</td>
<td>SRB Beam</td>
<td>E E U</td>
<td>SRB Beam Omitted</td>
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</table>

**Legend:**
- E = As External Tank
- N = NLS Unique (HLLV)
- U = 1.5 Stage Unique
Intertank Commonality
# Intertank Commonality

<table>
<thead>
<tr>
<th>Part</th>
<th>Title</th>
<th>Part Status</th>
<th>1.5 Stage Modification</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ET  HLLV</td>
<td>1.5 Stg</td>
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<tr>
<td>F1</td>
<td>Frame 2897.1</td>
<td>E  E  U</td>
<td>Common 12.0 Frames On 1.5 Stage, Resized For 1.5 Stage Loads</td>
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<tr>
<td>F2</td>
<td>Frame 2941.4</td>
<td>E  E  U</td>
<td></td>
</tr>
<tr>
<td>F3</td>
<td>Frame 2985.675</td>
<td>E  E  U</td>
<td></td>
</tr>
<tr>
<td>F4</td>
<td>Frame 3034.2</td>
<td>E  E  U</td>
<td>Resized For 1.5 Stage Loads</td>
</tr>
<tr>
<td>F5</td>
<td>Frame 3082.0</td>
<td>E  E  U</td>
<td>Resized For 1.5 Stage Loads</td>
</tr>
<tr>
<td>P1</td>
<td>Panel #1 (+Z)</td>
<td>E  N  U</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>Panel #2</td>
<td>E  N  U</td>
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</table>

E = As External Tank  
N = NLS Unique (HLLV)  
U = 1.5 Stage Unique
## Evaluation Summary

<table>
<thead>
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<th>Criteria</th>
<th>Common Core</th>
<th>Unique</th>
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<tr>
<td></td>
<td>HLLV</td>
<td>* 1.5 Stage</td>
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<tr>
<td>Weight</td>
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<td>12668</td>
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<tr>
<td># Of New Major Assys</td>
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<td># Of New Instls</td>
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<td>1</td>
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<td>Tooling Assy Impacts</td>
<td>NLS Ref</td>
<td>As Ref</td>
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<td>Test</td>
<td>STA Reqd</td>
<td>Verified By Analysis</td>
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</table>

* Unique For 1.5 Stage Only, On NLS Common Core
Conclusions

• Significant Weight Savings (approx. 5 Klbs) Can Be Realized By Designing A Standalone/Unique 1.5 Stage Intertank
• Unique Design Can Still Be Produced On Existing ET Tooling With Minimum Modifications To Locators Etc.
• Very Little Commonality Exists Between HLLV & 1.5 Stage When Designed As "Standalone" Configurations
• Unique Designs Requires 2 STA's

Recommendation
• Perform A More In Depth Analysis During Cycle 1 To Confirm Weight Savings
5.2.5.4.2 Intertank Commonality Assessment(#3-S-009A)

Objective

Study the commonality between HLLV, 1.5 Stage, and STS Intertanks and recommend degree of commonality.

Approach

(a) Develop a "Standalone" HLLV intertank config.
(b) Develop a "Standalone" 1.5 Stage intertank config.
(c) Compare "Standalone" configs. with the reference.
(d) Identify the level of part commonality between HLLV, 1.5 Stage, and STS intertanks.
(e) Develop weight estimates and compare to reference.

Groundrules

Intertank length and diameter as ET.
Basic panel construction similar to ET.
Omit all requirements for SRB attachment on 1.5 Stage.
Interfaces and penetrations as the reference.
Frame locations as reference, frames may be omitted or reduced in size.
Frame depths may vary.

Key Study Results

The standard HLLV intertank was identified as almost identical to the common core NLS intertank, indicating that ASRB loads are the prime driver. A significant weight saving of over 5 Klbs can be achieved by designing a standalone 1.5 Stage intertank. This requires an additional STA which adds DDT&E cost. The standalone intertank can be produced on existing ET tooling with minimal modifications.

Conclusions

A standalone intertank for the 1.5 Stage is very attractive due to the significant weight savings (40%). Very little part commonality exists between STS, HLLV and 1.5 Stage intertanks when designed as unique standalone configurations. Commonality does exist in panel construction methods, tooling, and build approach.

Study Recommendations

During Cycle 1 a more in depth study should be performed to confirm 1.5 Stage intertank weight savings. This study should also incorporate results from trade study on stiffener pitch sensitivity (see 5.2.5.4.3).
Common Ring Frame (5)  
- Fabricated I-Beam

NLS Skin/Stringer Panels (8)  
- Mechanically Fastened  
Stringer-Stiffened Panel  
(Thrust Panels Omitted)

<table>
<thead>
<tr>
<th>Intertank</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSTS</td>
<td>12152</td>
</tr>
<tr>
<td>HLLV</td>
<td>14509</td>
</tr>
<tr>
<td>1.5 Stage</td>
<td>7608</td>
</tr>
</tbody>
</table>

Nominal Stiffener Detail  
1.5 Stage Standalone Intertank

Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.5.4.2 Intertank Commonality Assessment(#3-S-009A)

Objective

Study the commonality between HLLV, 1.5 Stage, and STS Intertanks and recommend degree of commonality.

Approach

(a) Develop a "Standalone" HLLV intertank config.
(b) Develop a "Standalone" 1.5 Stage intertank config.
(c) Compare "Standalone" configs. with the reference.
(d) Identify the level of part commonality between HLLV, 1.5 Stage, and STS intertanks.
(e) Develop weight estimates and compare to reference.

Groundrules

Intertank length and diameter as ET.
Basic panel construction similar to ET.
Omit all requirements for SRB attachment on 1.5 Stage.
Interfaces and penetrations as the reference.
Frame locations as reference, frames may be omitted or reduced in size.
Frame depths may vary.

Key Study Results

The standard HLLV intertank was identified as almost identical to the common core NLS intertank, indicating that ASRB loads are the prime driver. A significant weight saving of over 5 Klbs can be achieved by designing a standalone 1.5 Stage intertank. This requires an additional STA which adds DDT&E cost. The standalone intertank can be produced on existing ET tooling with minimal modifications.

Conclusions

A standalone intertank for the 1.5 Stage is very attractive due to the significant weight savings (40%). Very little part commonality exists between STS, HLLV and 1.5 Stage intertanks when designed as unique standalone configurations. Commonality does exist in panel construction methods, tooling, and build approach.

Study Recommendations

During Cycle 1 a more in depth study should be performed to confirm 1.5 Stage intertank weight savings. This study should also incorporate results from trade study on stiffener pitch sensitivity (see 6.2.5.4.3).
Common Ring Frame (5)
- Fabricated I-Beam

NLS Skin/Stringer Panels (8)
- Mechanically Fastened
Stringer-Stiffened Panel
(Thrust Panels Omitted)

<table>
<thead>
<tr>
<th>Intertank</th>
<th>Weight</th>
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<tbody>
<tr>
<td>NSTS</td>
<td>12152</td>
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<tr>
<td>HLLV</td>
<td>14509</td>
</tr>
<tr>
<td>1.5 Stage</td>
<td>7608</td>
</tr>
</tbody>
</table>

Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
Stiffener Pitch Sensitivity Study

3-S-001B (CV-STR-18B) - Fwd Skirt
3-S-010B (CV-STR-15B) - LO2 Tank
3-S-009B (CV-STR-19B) - Intertank
3-S-008C (CV-STR-20C) - LH2 Tank

Prepared By: Dilip Dudgaonkar
(504)257-0076

Rev: Initial
Date: January 8, 1992

Approved By: M.R. Simms
5.2.5.4.3 Stiffener Pitch Sensitivity Study (# 3-S-009B)

Objective

Develop the intertank weight sensitivities of varying pitch and stiffener size.

Approach

a) Use current configurations as baseline
b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)
c) Document assumptions made and factors of safety used.
d) Produce t bar vs pitch sensitivities
e) Prepare conclusions and recommendations

Key Study Results

The current hat section stringers were used as the baseline configuration and Panda II was used to optimize stiffener size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight(tbar) trend results shows that an optimum occurs at a stringer pitch of 7.33 inches for an axial compression load of 4400lb/in. However the optimum stringer section indicated by Panda needs an increase in the attachment flange width to provide room and edge distance for the skin/stringer attachments. Once this modification is incorporated the current reference becomes close to optimum.

Conclusions

Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. The modified Panda II optimized configuration is lighter compared to the baseline configuration. However modifications to produce a practical design may not provide significant weight savings on a common I/T driven by HLLV loads.

Recommendations

Maintain the reference configuration I/T stringer pitch and size. During cycle 1, study different stringer configurations when defining the 'stand alone' 1.5 stage intertank identified in section 5.2.5.4.2
Intertank
\(Nx \text{ Vs } t\text{bar}\)

\begin{itemize}
  \item Stringer Spacing = 4.0"
  \item Stringer Spacing = 5.0"
  \item Stringer Spacing = 7.33"
  \item Stringer Spacing = 10.0"
  \item Stringer Spacing = 12.0"
\end{itemize}

<table>
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<tr>
<th>Current Design</th>
<th>Panda II Optimized Design ((Nx = 4400 \text{ lb/in ult}))</th>
<th>Panda II Optimized Design ((Nx = 5200 \text{ lb/in ult}))</th>
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</thead>
<tbody>
<tr>
<td>Stringer Spacing = 7.33&quot;</td>
<td>Stringer Spacing = 7.33&quot;</td>
<td>Stringer Spacing = 10.0&quot;</td>
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Additional Information
Details of this study are contained in Doc #MMC.NLS.SR.001.Book 1
6.2.5.4.3 Stiffener Pitch Sensitivity Study (# 3-S-009B)

Objective

Develop the intertank weight sensitivities of varying pitch and stiffener size.

Approach

a) Use current configurations as baseline

b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)

c) Document assumptions made and factors of safety used.

d) Produce t bar vs pitch sensitivities

e) Prepare conclusions and recommendations

Key Study Results

The current hat section stringers were used as the baseline configuration and Panda II was used to optimize stiffener size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight (t bar) trend results show that an optimum occurs at a stringer pitch of 7.33 inches for an axial compression load of 4400 lb/in. However, the optimum stringer section indicated by Panda needs an increase in the attachment flange width to provide room and edge distance for the skin/stringer attachments. Once this modification is incorporated, the current reference becomes close to optimum.

Conclusions

Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. The modified Panda II optimized configuration is lighter compared to the baseline configuration. However, modifications to produce a practical design may not provide significant weight savings on a common I/T driven by HLLV loads.

Recommendations

Maintain the reference configuration I/T stringer pitch and size. During cycle 1, study different stringer configurations when defining the 'stand alone' 1.5 stage intertank identified in section 6.2.5.4.2
Intertank
 Nx Vs tbar

Current Design | Panda II Optimized Design (Nx = 4400 lb/in ult) | Panda II Optimized Design (Nx = 5200 lb/in ult)

<table>
<thead>
<tr>
<th>Stringer Spacing = 7.33&quot;</th>
<th>Stringer Spacing = 7.33&quot;</th>
<th>Stringer Spacing = 10.0&quot;</th>
</tr>
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<tbody>
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<td>Tbar=0.238&quot;</td>
<td>Tbar=0.21&quot;</td>
<td>Tbar=0.241&quot;</td>
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</table>

Additional Information
Details of this study are contained in Doc #MMC.NLS.SR.001.Book 1
3-S-010A
(CV-STR-15A)
LO2 Tank Impact vs. Ullage Pressure Trade Study

Prepared By: Tom Severs
(504) 257-5226

Approved By: R. Simms

Rev: Initial
Date: January 8, 1992

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Objective

- This trade develops the impacts to the LO2 tank pressure shell for ullage pressures ranging from 10 psig to 80 psig.

Approach

- Determine pressure capability of the reference configuration.
- Establish critical conditions assuming uniformly distributed loads.
- Determine the minimum ullage allowable ullage pressure below which no further weight savings is realized.
- Perform analysis to determine membrane and weld land thickness requirements of the Reference Configuration for various pressures.
• Develop weight impacts compared to the Reference Configuration.
• Evaluate impact to manufacturing for increased thicknesses.
• Evaluate the weight savings if the biaxial yield theory is used in the proof test analysis.
• Document results of the study and prepare conclusions.
Ground Rules & Assumptions

- Nominal tank configuration as per MSFC Cycle 0 definition as of 9/13/91. (30 psi maximum ullage pressure)
- The study addresses tank membrane and weld land requirements only, stiffener sizing and pitch, and frame configuration and pitch is as the reference configuration.
- Thicknesses are taken to a zero margin before additional material is added.
- SF = 1.40 on ultimate, 1.10 on yield. Room Temperature Proof Factor = 1.05
- Room temperature material properties. Al 2219-T87, Ftu = 63 ksi (Parent), Ftu= 31 ksi (Weld)
- Constant tank internal volume assumed.
- Hydrostatic proof test. (Similar to the ET.)
Ullage Pressure Req't vs. Capability  3-S-010-A

![Diagram showing flight pressure and capability with pressures listed in a table]

<table>
<thead>
<tr>
<th>Location</th>
<th>Ref. Config. Capability</th>
<th>Proof Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd Dome</td>
<td>40.0</td>
<td>41.3</td>
</tr>
<tr>
<td>Fwd Barrel</td>
<td>46.2</td>
<td>45.8</td>
</tr>
<tr>
<td>Aft Barrel</td>
<td>58.5</td>
<td>50.3</td>
</tr>
<tr>
<td>Aft Dome</td>
<td>70.6</td>
<td>67.4</td>
</tr>
</tbody>
</table>
Proof Test Requirements

- Max. Design Pressures Based on Proof Test

<table>
<thead>
<tr>
<th>Location</th>
<th>Ref. Config. Capability</th>
<th>30 psi</th>
<th>40 psi</th>
<th>50 psi</th>
<th>60 psi</th>
<th>70 psi</th>
<th>80 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd Dome</td>
<td>40.0</td>
<td>41.3</td>
<td>51.3</td>
<td>61.3</td>
<td>71.3</td>
<td>81.3</td>
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<tr>
<td>Fwd Barrel</td>
<td>46.2</td>
<td>45.8</td>
<td>55.8</td>
<td>65.8</td>
<td>75.8</td>
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<tr>
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<td>58.5</td>
<td>50.3</td>
<td>60.3</td>
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<td>80.3</td>
<td>90.3</td>
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<tr>
<td>Aft Dome</td>
<td>70.6</td>
<td>67.4</td>
<td>77.4</td>
<td>87.4</td>
<td>97.4</td>
<td>107.4</td>
<td>117.4</td>
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</table>
# Delta Membrane Thicknesses

**Thicknesses in Inches**

<table>
<thead>
<tr>
<th>Location</th>
<th>Ref. Config. Thickness</th>
<th>30 psi</th>
<th>40 psi</th>
<th>50 psi</th>
<th>60 psi</th>
<th>70 psi</th>
<th>80 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd Dome</td>
<td>.066 to .084</td>
<td>.005</td>
<td>.042</td>
<td>.078</td>
<td>.115</td>
<td>.152</td>
<td>.189</td>
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<tr>
<td>Fwd Barrel</td>
<td>.170</td>
<td>.000</td>
<td>.035</td>
<td>.072</td>
<td>.109</td>
<td>.146</td>
<td>.183</td>
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<tr>
<td>Aft Barrel</td>
<td>.215</td>
<td>.000</td>
<td>.007</td>
<td>.043</td>
<td>.080</td>
<td>.117</td>
<td>.154</td>
</tr>
<tr>
<td>Aft Dome</td>
<td>.122 to .136</td>
<td>.000</td>
<td>.025</td>
<td>.062</td>
<td>.099</td>
<td>.135</td>
<td>.172</td>
</tr>
</tbody>
</table>

**Max. Ullage Pressure [psig]**
## Weld Land Thicknesses [Inches]

<table>
<thead>
<tr>
<th>Location</th>
<th>Ref. Config. Thickness</th>
<th>30 psi</th>
<th>40 psi</th>
<th>50 psi</th>
<th>60 psi</th>
<th>70 psi</th>
<th>80 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd Dome</td>
<td>.200</td>
<td>.200</td>
<td>.274</td>
<td>.327</td>
<td>.381</td>
<td>.434</td>
<td>.487</td>
</tr>
<tr>
<td>Fwd Barrel</td>
<td>.320</td>
<td>.320</td>
<td>.320</td>
<td>.351</td>
<td>.405</td>
<td>.458</td>
<td>.511</td>
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<tr>
<td>Aft Barrel</td>
<td>.360 to .387</td>
<td>.320</td>
<td>.322</td>
<td>.375</td>
<td>.429</td>
<td>.482</td>
<td>.535</td>
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<tr>
<td>Aft Dome</td>
<td>.320</td>
<td>.320</td>
<td>.413</td>
<td>.467</td>
<td>.520</td>
<td>.573</td>
<td>.627</td>
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<td></td>
<td>Reference Wt.</td>
<td>Delta Wt. 30 psi</td>
<td>Delta Wt. 40 psi</td>
<td>Delta Wt. 50 psi</td>
<td>Delta Wt. 60 psi</td>
<td>Delta Wt. 70 psi</td>
<td>Delta Wt. 80 psi</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------</td>
<td>------------------</td>
<td>------------------</td>
<td>------------------</td>
<td>------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>FWD DOME</td>
<td>1,225.90</td>
<td>65.60</td>
<td>551.05</td>
<td>1,023.37</td>
<td>1,508.82</td>
<td>1,994.27</td>
<td>2,479.71</td>
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<tr>
<td>FWD BARREL</td>
<td>2,473.16</td>
<td>0.00</td>
<td>475.91</td>
<td>979.01</td>
<td>1,482.11</td>
<td>1,985.21</td>
<td>2,488.31</td>
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<tr>
<td>AFT BARREL</td>
<td>3,205.16</td>
<td>0.00</td>
<td>95.18</td>
<td>584.69</td>
<td>1,087.79</td>
<td>1,590.89</td>
<td>2,093.99</td>
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<tr>
<td>AFT DOME</td>
<td>2,226.50</td>
<td>0.00</td>
<td>328.00</td>
<td>813.45</td>
<td>1,298.90</td>
<td>1,771.22</td>
<td>2,256.67</td>
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<tr>
<td>SUB-TOTAL</td>
<td>9,130.72</td>
<td>65.60</td>
<td>1,450.14</td>
<td>3,400.52</td>
<td>5,377.61</td>
<td>7,341.59</td>
<td>9,318.68</td>
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<tr>
<td>CONTINGENCY (8%)</td>
<td>730.46</td>
<td>5.25</td>
<td>116.01</td>
<td>272.04</td>
<td>430.21</td>
<td>587.33</td>
<td>745.49</td>
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<tr>
<td>TOTAL</td>
<td>9,861.18</td>
<td>70.85</td>
<td>1,566.15</td>
<td>3,672.56</td>
<td>5,807.82</td>
<td>7,928.91</td>
<td>10,064.18</td>
</tr>
<tr>
<td>Wt. Factor^3</td>
<td>1.00</td>
<td>1.11</td>
<td>1.25</td>
<td>1.40</td>
<td>1.54</td>
<td>1.69</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: 1) Barrel section weight does not include stringers.
2) Barrel weight, MSFC database 9/30/91.
3) Wt. factor is based on weight increase to total LOX tank.
Additional Results

- The minimum ullage pressure for the LOX tank barrel sized for the proof test is approximately 10 psig. This allows compression in the shell. To preclude compression in the LOX barrel in flight the pressure can not go below 25 psig.
Manufacturing Impact Assessment 3-S-010-A

- Manufacturing Impacts of Increased Thicknesses

1.) Stretch Form of Gore Panels
   - Current vendor: American Hydro-Forming CA
   - Plate Thickness Up To 0.5"
   - Requires Incremental Development Program to Determine Max Thickness Capability
   - New Grippers & Hydraulic System Mod
   - No Commitment without Test Panel

Option: Perform Industry Survey to Locate Potential Suppliers
   - Larger Machine Tools Do Exist Manufactured By L&F Industries CA
Manufacturing Impact Assessment  3-S-010-A

- Dome Assembly:

2.) Weld Tooling Land Thickness Capacity

Up To 0.400"  - Minor Mods Only

0.400" to 0.425"  - Extensive Mod to Clamping System on
1/2 Dome & Full Dome Weld Fixtures

0.425" to 0.500"  - Extensive Mod to Clamping System on
1/4 Dome Weld Fixtures

0.500" to 0.627"  - Major Rework on all Dome Tool for New
Clamps and Clamping Loads
Summary

- Significant weight impacts identified for increasing ullage pressure.
  - 3673 Lbs. at 50 psi
  - 10064 Lbs at 80 psi

- Thicker membrane will allow for some weight savings.
  - 50 Lbs at 50 psi
  - 600 Lbs at 80 psi

- Application of the biaxial yield theory will reduce the weight impacts by 200 Lbs. to 400 Lbs.

- Impacts for dome tooling identified once ullage pressure exceeds 40 psi.

- Impacts to gore stretch form tooling for ullage pressures in excess of 50 psi.
Issues Identified During the Study

**Issue:** LOX density decreases as the pressure increases. This may result in a larger LOX tank volume requirement.

**Resolution:** LOX volume is not significantly affected by the increased ullage pressure if the tank is vented to LOX saturation shortly before launch. (This is the current procedure.)

**Issue:** Thicker membrane will reduce the stiffener requirement.

**Resolution:** Optimization of the LOX tank wall construction (frames and stringers) is estimated to save up to 600 Lbs. (Small compared to the overall impact.)
Issues Identified During the Study  3-S-010-A

**Issue:** The study was based on ET type pressure time history data. The STME requires a different pressure profile which is currently being defined by the propulsion team.

**Resolution:** Update this trade once the new pressure data is obtained from the propulsion group.
5.2.4.4.3 LO2 Tank Sizing vs. Pressure (3-S-010A)

Objective

This trade study develops the impacts to the LO2 tank pressure shell for ullage pressures of 10 psig to 80 psig. (The baseline ullage pressure is 30 psig).

Approach

(a) Determine pressure capability of the Reference Configuration
(b) Assume uniform load distribution and establish critical load conditions
(c) Perform analysis to determine membrane and weld land thickness requirements for pressures above the capability of the Reference Configuration
(d) Develop weight impacts to the Reference Configuration
(e) Evaluate impact to manufacturing for increased thickness
(f) Evaluate whether impacts can be reduced by the use of the biaxial yield theory and frame size reduction.
(g) Document results of the study and prepare conclusions

Options Studied

Ullage pressures in 10 psig increments from 10 psig to 80 psig

Key Results

The weight impacts for a specific pressure is approximately 200 Lbs per psi. Minor tooling modifications are necessary for any increase in ullage pressure. Major tooling impacts occur once ullage pressures exceed 40 psig. There is a weight reduction to the LOX tank for ullage pressures below 30 psig. Ullage pressure may be as low as 10 psig before the weight reduction trend ends. Since the shell is sized for the proof test, a 300 Lbs. to 400 Lbs. reduction to the weight penalty may be realized by using the biaxial yield theory. This weight reduction is limited by the flight membrane thickness requirement.

Conclusions

This study identified the weight impacts for ullage pressures between 10 and 80 psig. The weight increase is fairly linear and unbounded for increasing ullage pressures. The weight reduction is linear and bounded for decreasing ullage pressures.

Recommendations

Use the results of this trade as an input to the propulsion studies of engine performance vs. ullage pressure.
Additional Information

See Doc #MMC.NLS.SR.001.Book 1 for more detailed results
Objective

This trade study develops the impacts to the LO2 tank pressure shell for ullage pressures of 10 psig to 80 psig. (The baseline ullage pressure is 30 psig).

Approach

(a) Determine pressure capability of the Reference Configuration
(b) Assume uniform load distribution and establish critical load conditions
(c) Perform analysis to determine membrane and weld land thickness requirements for pressures above the capability of the Reference Configuration
(d) Develop weight impacts to the Reference Configuration
(e) Evaluate impact to manufacturing for increased thickness
(f) Evaluate whether impacts can be reduced by the use of the biaxial yield theory and frame size reduction.
(g) Document results of the study and prepare conclusions

Options Studied

Ullage pressures in 10 psig increments from 10 psig to 80 psig

Key Results

The weight impacts for a specific pressure is approximately 200 Lbs per psi. Minor tooling modifications are necessary for any increase in ullage pressure. Major tooling impacts occur once ullage pressures exceed 40 psig. There is a weight reduction to the LOX tank for ullage pressures below 30 psig. Ullage pressure may be as low as 10 psig before the weight reduction trend ends. Since the shell is sized for the proof test, a 300 Lbs. to 400 Lbs. reduction to the weight penalty may be realized by using the biaxial yield theory. This weight reduction is limited by the flight membrane thickness requirement.

Conclusions

This study identified the weight impacts for ullage pressures between 10 and 80 psig. The weight increase is fairly linear and unbounded for increasing ullage pressures. The weight reduction is linear and bounded for decreasing ullage pressures.

Recommendations

Use the results of this trade as an input to the propulsion studies of engine performance vs. ullage pressure.
Additional Information

See Doc #MMC.NLS.SR.001.Book 1 for more detailed results
Stiffener Pitch Sensitivity Study

3-S-001B (CV-STR-18B) - Fwd Skirt
3-S-010B (CV-STR-15B) - LO2 Tank
3-S-009B (CV-STR-19B) - Intertank
3-S-008C (CV-STR-20C) - LH2 Tank

Prepared By: Dilip Dudgaonkar
(504)257-0076
Rev: Initial
Date: January 8, 1992

Approved By: M.R.Simms
5.2.4.4.4 Stiffener Pitch Sensitivity Study (# 3-S-010B)

Objective

Develop the LO2 Tank weight sensitivities of varying pitch and stiffener size.

Approach

a) Use current configurations as baseline
b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)
c) Document assumptions made and factors of safety used.
d) Produce t bar vs pitch sensitivities
e) Prepare conclusions and recommendations

Key Study Results

The current internal T section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight (tbar) trend shows that an optimum occurs at a stringer pitch of 4.0 inches for an axial compression load of 960 lb/inch.

Conclusions

Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configurations integrally machined longitudinal tee stiffened panel approach. The Panda II optimized configuration developed offers weight savings compared to the baseline configuration. It does however require a thicker billet and closer stiffener pitch.

Study Recommendations

Maintain the reference configuration LO2 tank barrel configuration. During cycle 1, study an alternate barrel panel with reduced stringer spacing and/or varying frame spacing.
Lox Tank
Nx Vs Tbar

![Graph showing Nx vs Tbar with data points and labels.]

Current Design
- Nx=960 lb/in
- Stringer Spacing=10.832"
- Frame Spacing=34.9"
- Takln=0.170
- Tbar=0.193

Optimized Design
- Nx=1345 lb/in
- Stringer Spacing=4.0"
- Frame Spacing=34.9"
- Takln=0.067
- Tbar=0.0963

Optimized Design
- Nx=1600 lb/in
- Stringer Spacing=5.0"
- Frame Spacing=34.9"
- Takln=0.075
- Tbar=0.1043

Additional Information
Details of this study are contained in Doc #MMC.NLS.SR.001.Book 1
6.2.4.4.4 Stiffener Pitch Sensitivity Study (# 3-S-010B)

Objective

Develop the LO2 Tank weight sensitivities of varying pitch and stiffener size.

Approach

a) Use current configurations as baseline
b) Use the Panda II program to produce panel weight data with varying stringer pitch and axial loading (lb per circumferential inch)
c) Document assumptions made and factors of safety used.
d) Produce t bar vs pitch sensitivities
e) Prepare conclusions and recommendations

Key Study Results

The current internal T section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight (tbar) trend shows that an optimum occurs at a stringer pitch of 4.0 inches for an axial compression load of 960 lb/inch.

Conclusions

Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configurations integrally machined longitudinal tee stiffened panel approach. The Panda II optimized configuration developed offers weight savings compared to the baseline configuration. It does however require a thicker billet and closer stiffener pitch.

Study Recommendations

Maintain the reference configuration LO2 tank barrel configuration. During cycle 1, study an alternate barrel panel with reduced stringer spacing and/or varying frame spacing.
Lox Tank

Nx Vs Tbar

<table>
<thead>
<tr>
<th>Stringer Spacing</th>
<th>Nx</th>
<th>Stringer Spacing</th>
<th>Nx</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>965</td>
<td>5.0</td>
<td>1345</td>
</tr>
<tr>
<td>7.33</td>
<td>1600</td>
<td>10.0</td>
<td></td>
</tr>
</tbody>
</table>

Current Design

| Stringer Spacing=10.832" | Frame Spacing=34.9" | Tskin=0.170 | Tbar=0.193 |

Optimized Design

| Stringer Spacing=4.0" | Frame Spacing=34.9" | Tskin=0.067 | Tbar=0.0963 |

Optimized Design

| Stringer Spacing=4.0" | Frame Spacing=34.9" | Tskin=0.075 | Tbar=0.1043 |

Additional Information

Details of this study are contained in Doc #MMC.NLS.SR.001.Book 1
3-S-010C
(CV-STR-15C)
LO2 Tank Alternate Panel
&
3-S-008D
(CV-STR-20D)
LH2 Tank Alternate Panel
Construction

Prepared By: G.M.Roule
(504) 257-0020

Rev: Initial
Date: January 8, 1992

Approved By: M.R.Simms
5.2.4.4.5 Alternate Panel Construction (#CV-STR-015-C)

Objective

Develop and evaluate alternative panel construction methods for the LO2 tank barrel panels.

Approach

(a) Define a point of departure & Identify concept options for skin panels.
(b) Estimate weight deltas, producibility, and cost.
(c) Evaluate options.
(d) Select preferred option.

Options Studied - LO2 Tank

Option 1 - Machine Panel With Tee Stiffeners (Baseline)
Option 2 - Machined Blade-Stiffened Panel
Option 3 - Machined Waffle Panel
Option 4 - Machined Isogrid Panel
Option 5 - Welded Panel
Option 6 - Mechanically Fastened Stiffened Panel
Option 7 - Extruded Panel

Key Study Results

All options were compared to the Option 1 Reference Configuration. Option 2 had an 8% decrease in weight and ranked 2nd lowest cost. Option 3 had a 5% increase in weight and was the 5th lowest cost. Option 4 had a 12% decrease in weight and was 3rd lowest cost. Option 5 had the same weight as baseline and had the highest costs. Option 6 had an increase weight of 1% and was 4th lowest cost. Option 7 had no weight increase. Cost estimates could not be performed on this option due to insufficient data.

Conclusions

Seven alternative construction methods were studied. The longitudinal tee-stiffened panels offered excellent synergism with ET and related tooling, and were lower in costs. Option 2 was eliminated due to poor External Tank synergism and complicated intermediate frame attachment. Option 3 was eliminated due to excessive DDT&E costs. Option 4, although requiring additional development work, may be an attractive method of construction due to the possibility of eliminating intermediate frames and weight. Option 5's ET synergism was excellent but was eliminated due to excessive DDT&E costs. Option 6 also had excellent ET synergism, but was also eliminated due to excessive DDT&E costs. Option 7 could be the most promising of all if the technology proves to be feasible.

Study Recommendations

Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:

- Option 1 - M/C panel with tee stiffeners (Baseline)
- Option 4 - Machined isogrid panel.
- Follow the progress and development of Option 7
Option 1 - Baseline Panel (P.O.D.)
- Machined Panel W/Tee-Stiffening.
- Synergistic W/ External Tank.
- Utilizes Existing ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 2 - Mach. Blade-Stiff. Panel
- Machined Panel W/ Blade-Stiffening.
- May Not Utilize ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 3 - Machined Waffle Panel
- Machined Waffle Panel W/ Long. & Transv. Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Axial & Bending Loading Conditions.

Option 4 - Machined Isogrid Panel
- Machined Iso-Grid Panel With Multi-Directional Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Bending Conditions & Bi-Directional Loading.

Option 5 - Welded Panel
- Welded Panel With Welded Extruded Tee-Stiffening.
- Similar To External Tank.
- New Processes And Tooling Required.
- Design Consistent With Maximum Axial Load Distribution.

Option 6 - Mechanically Fastened Panel
- Skin With Machined Slots To Accept Extrusions.
- Extruded Tee Stiffeners.
- Mechanically Assembled.
- New Processes And Tooling Required.

Option 7 - Extruded Panel
- Panels Extruded Through Circular Die (Stringers Extruded On Outside Of Circle).
- After Panels Are Extruded They Are Heated And Rolled Out Into Flat Panels And Allowed To Cool.
- Requires 35,000 Ton Press.
- New Processes And Tooling Required.

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
6.2.4.4.5 Alternate Panel Construction (#CV-STR-015-C)

Objective

Develop and evaluate alternative panel construction methods for the LO2 tank barrel panels.

Approach

(a) Define a point of departure & Identify concept options for skin panels.
(b) Estimate weight deltas, producibility, and cost.
(c) Evaluate options.
(d) Select preferred option.

Options Studied - LO2 Tank

Option 1 - Machine Panel With Tee Stiffeners (Baseline)
Option 2 - Machined Blade-Stiffened Panel
Option 3 - Machined Waffle Panel
Option 4 - Machined Isogrid Panel
Option 5 - Welded Panel
Option 6 - Mechanically Fastened Stiffened Panel
Option 7 - Extruded Panel

Key Study Results

All options were compared to the Option 1 Reference Configuration. Option 2 had an 8% decrease in weight and ranked 2nd lowest cost. Option 3 had a 5% increase in weight and was the 5th lowest cost. Option 4 had 12% decrease in weight and was 3rd lowest cost. Option 5 had the same weight as baseline and had the highest costs. Option 6 had an increase weight of 1% and was 4th lowest cost. Option 7 had no weight increase. Cost estimates could not be performed on this option due to insufficient data.

Conclusions

Seven alternative construction methods were studied. The longitudinal tee-stiffened panels offered excellent synergism with ET and related tooling, and were lower in costs. Option 2 was eliminated due to poor External Tank synergism and complicated intermediate frame attachment. Option 3 was eliminated due to excessive DDT&E costs. Option 4, although requiring additional development work, may be an attractive method of construction due to the possibility of eliminating intermediate frames and weight. Option 5's ET synergism was excellent but was eliminated due to excessive DDT&E costs. Option 6 also had excellent ET synergism, but was also eliminated due to excessive DDT&E costs. Option 7 could be the most promising of all the if the technology proves to be feasible.

Study Recommendations

Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:

- Option 1 - M/C panel with tee stiffeners (Baseline)
- Option 4 - Machined isogrid panel.
- Follow the progress and development of Option 7
Option 1 - Baseline Panel (P.O.D.)
- Machined Panel W/ Tee-Stiffening.
- Synergistic W/ External Tank.
- Utilizes Existing ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 2 - Mach.Blade-Stiff. Panel
- Machined Panel W/ Blade-Stiffening.
- May Not Utilize ET Processes And Tooling.
- Design Consistent With Maximum Axial Load.

Option 3 - Machined Waffle Panel
- Machined Waffle Panel W/ Long. & Transv. Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Axial & Bending Loading Conditions.

Option 4 - Machined Isogrid Panel
- Machined Iso-Grid Panel With Multi-Directional Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Bending Conditions & Bi-Directional Loading.

Option 5 - Welded Panel
- Skin With Machined Slots To Accept Extrusions.
- Extruded Tee Stiffeners.
- Mechanically Assembled.
- New Processes And Tooling Required.

Option 6 - Mechanically Fastened Panel
- Panels Extruded Through Circular Die (Stringers Extruded On Outside Of Circle).
- After Panels Are Extruded They Are Heated And Rolled Out Into Flat Panels And Allowed To Cool.
- Requires 35,000 Ton Press.
- New Processes And Tooling Required.

Option 7 - Extruded Panel
- Panels Extruded Through Circular Die (Stringers Extruded On Outside Of Circle).
- After Panels Are Extruded They Are Heated And Rolled Out Into Flat Panels And Allowed To Cool.
- Requires 35,000 Ton Press.
- New Processes And Tooling Required.

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
3-S-011
(CV-STR-22)
Slosh Baffle Requirements &
Design Definition

Prepared By: Derek A. Townsend
(504)257-0021

Approved By: M. R. Simms

Rev: Initial
Date: January 8, 1991

MARTIN MARIETTA
MANNED SPACE SYSTEMS

DAT.91336
NLS LO2 Tank Slosh Baffle

3-S-011

Objective
- Perform Studies On The LO2 Tank Slosh Baffle To Assess Potential Changes To The Reference Configuration.

Approach
- Task 1 - Evaluate Sensitivity Of The Slosh Damping Requirement
- Task 2 - Assess A Common Baffle Design With Unique Applications
  - 1.5 Stage (Full Length Baffle)
  - HLLV (Partial Length Baffle)
- Task 3 - Assess The Feasibility Of Integral Baffles Using LO2 Tank Frames
- Prepare Conclusions & Recommendations
- Identify Potential Cycle 1 Tasks
3-S-011
(CV-STR-22)
Appendix 1

• Sensitivity To Slosh Damping Reqmt
Slosh Damping Sensitivity

Background

- Reference Configuration Slosh Baffle Design Is Based On 1% Minimum Slosh Damping Requirement
- Controls Analysis & Previous Launch Vehicle Reqmts. Indicate That Requirement May Be As High As 4%
- Damping Requirement
  - Slosh Damping To Be Provided In The Critical Region When Slosh Mass To Vehicle Mass Ratio Is > 10%
  - In The Region Where Slosh Mass Is Critical To Control Stability, Up To 4% Of Critical Damping Or Less Is Reqd.
- Early ET Requirement For 4% Was Reduced To 1% Due To Greater Than Anticipated Guidance Control System Stability. The Applicability Of The 4% Slosh Criteria Will Also Be Determined By Control System Stability.
Slosh Baffle Comparisons

Intermediate Frame

Xn 2571.60

32.00

Xn 2851.00

8.5 Nominal

Localized Clipping To Main Frame

1.0 Min. Clearance

Aft Dome Baffles

314.0 Across Flats

FWD

25.88

Anti-Vortex Baffle

4% Reqmt

Baffle Weight 2880 lbs*

1% Reqmt

Baffle Weight 2345 lbs*

* Ref ET Baffle Weight = 1500 lbs

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Conclusions

- 1% Requirement Requires 5 x 25.88 Deep Baffles
- 4% Requirement Requires 9 x 32.00 Deep Baffles
- In Order To Meet The 4% Criteria, Slosh Baffles Will Have To Be Placed In The LO2 Aft Dome
- Common Core Baffles Are Designed By 1.5 Stage Requirements
- Additional Weight Impact Of 535 lbs For A 4% Damping Baffle Configuration (Over Reference 1% Design)
Recommendation

• Work With Controls Panel To Finalize Damping Requirement For Cycle 1
• Update Cycle 1 Baseline Configuration To Reflect Selected Damping Requirement
3-S011
(CV-STR-22)
Appendix 2

- 1.5 Stage/HLLV Unique Baffle Configurations
Unique Baffle Configurations

Background

- The Reference Common Core LO2 Baffle Configuration Is Designed By 1.5 Stage Vehicle Requirements.

Objective

- Assess If The Common Core Baffle Design Can Be Adapted For Unique Vehicle Applications

Approach

- Using The Reference Configuration As The 1.5 Stage Assess The LO2 Baffle HLLV Vehicle Requirements For Both 1% & 4% Slosh Damping
- Define The Potential Omissions/Modifications To The Reference When Installing HLLV Baffle Configuration
1% 1.5 Stage Slosh Baffle Conf. 3-S-011

- Reference Common Core Configuration

8.5 Nominal

Xn 2571.60  Xn 2711.30  Xn 2851.00

Intermediate Frame

314.0 Across Flats

1.0 Min. Clearance

Xn 2643.95  Xn 2778.65

Localized Clipping To Main Frame

Anti-Vortex Baffle

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1% HLLV Stage Slosh Baffle

- Weight Impact -492 lbs From Reference
4% 1.5 Stage Slosh Baffle Conf.  3-S-011

- Recommended Reference Common Core Configuration

8.5 Nominal

Xn 2571.60

Xn 2851.00

36.00

1.0 Min. Clearance

Intermediate Frame

314.0 Across Flats

FWD

32.00

Anti-Vortex Baffle

Aft Dome Baffles
4% HLLV Tank Slosh Baffle

- Unique HLLV Configuration

Xn 2571.60 8.5 Nominal Xn 2851.00

Fwd Attach At Main Frame Xn 2711.30
Instl LH2 Fwd Dome Frame

1.0 Min. Clearance

Anti-Vortex Baffle

29.50

Aft Dome Baffles

44.00

314.0 Across Flats

- Weight Impact -526 lbs From Reference 4% Configuration

DAT.S1336

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4% HLLV Tank Slosh Baffle

- HLLV Configuration Derived From Common Core

- Weight Impact -417 lbs From Reference 4% Configuration
Recommendation

Conclusions

- 400 - 500 lbs Of Weight Can Be Saved On The HLLV Vehicle If A Non-common Baffle Is Used
- Unique Designs Save Very Little Weight
- HLLV Baffle Is Best Configured By Deleting Frames Rather Than Developing A Unique Design

Recommendation

- Maintain Common Baffle Design On Reference Configuration Unless HLLV Becomes Weight Critical
3-S-011
(CV-STR-22)
Appendix 3

- Integral Baffle Feasibility Study
Integral Baffle Sensitivities  3-S-011

Issue

• The Change Of LO2 Tank Skin Design From Smooth To A Machined 'T' Stiffened Panel Allows For An Integral Intermediate Frame/Baffle Design To Be Considered

Objective

• Evaluate The Feasibility & Potential Advantages/Disadvantages To An Integral Baffle Design
Integral 4% Slosh Baffle Conf.  3-S-011

- Common Core Configuration

Xn 2571.60  Xn 2851.00

Intermediate Frame  Main Frame

36.00

FWD

40.00

Aft Dome Baffles

Anti-Vortex Baffle

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Evaluation

+ More Efficient Design Could Have Potential Weight Savings
+ Reduced Number Of Parts
+ Eliminates External Baffle Assembly Tooling Position & Baffle Insertion Operation
+ Inherent Increase In Baffle Stiffness
+ Better Adapts To Unique HLLV & 1.5 Stage Configurations
- Limited Access For Frame Assembly & Inspection
- Additional Manufacturing Flow Time (Increase In Number Of Turnovers From Welding Tool To Mechanical Assy)
- Reduced Commonality With ET
Recommendation

Conclusions
- Integral Baffles Appear To Be An Attractive Proposition For An Alternative Design
- No Major Manufacturing Impacts With Integral Baffles
- Integral Baffles Are More Attractive With A One Piece Barrel

Recommendations
- Define & Evaluate An Integral Baffle Design During Cycle 1
Items For Cycle 1 Study

- Finalize Damping Requirement For Cycle 1 & Update Reference Configuration
- Define & Evaluate An Integral Baffle Design
5.2.4.4.6 Alternate Slosh Baffles(#3-S-011)

Objective

Perform studies on the LO2 tank slosh baffle to assess potential changes to the reference configuration.

Approach

(a) Evaluate sensitivity of the slosh damping requirement.
(b) Assess a common baffle with unique applications.
(c) Assess the feasibility of integral baffles using LO2 tank frames.

Options Studied

(a) 1% vs 4% Slosh damping requirement.
(b) HLLV vs 1.5 Stage configurations.
(c) Integral baffle concept.

Key Study Results

The reference was designed to meet a 1% damping requirement. Recent controls analysis indicates that 4% may be required. A 4% damping capability requires an increase in baffle depth plus an additional 4 baffles. A 4% baffle configuration will add baffles to the aft dome for an overall weight impact of 535 lbs. The full baffle configuration is required for 1.5 Stage, a 400-500 lbs of weight saving can be achieved on the less critical HLLV slosh baffle by omiting the two forward baffles. By integrating the baffles with the intermediate frames a more efficient design could be achieved with potential weight savings. In addition an integral baffle design would reduce the number of parts and eliminate the external baffle assembly tooling position and the baffle insertion operation.

Conclusions

Baffle damping requirements significantly impact the configuration and must therefore be established prior to further design work. The baffle configuration is driven by 1.5 Stage slosh requirements. An integral baffle and frame design appears to be an attractive proposition for an alternative design.

Study Recommendations

During Cycle 1 finalize the damping requirement and update the baseline configuration. The reference configuration is designed for 1.5 Stage and should remain common unless HLLV weight savings are required. A study should be performed during Cycle 1 to define the weight savings and manufacturing impacts for an integral baffle and frame design.
1% - 4% Slosh Baffle Comparison

4% 1.5 Stage - HLLV Configuration Comparison

Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.4.4.6 Alternate Slosh Baffles(#3-S-011)

Objective

Perform studies on the LO2 tank slosh baffle to assess potential changes to the reference configuration.

Approach

(a) Evaluate sensitivity of the slosh damping requirement.
(b) Assess a common baffle with unique applications.
(c) Assess the feasibility of integral baffles using LO2 tank frames.

Options Studied

(a) 1% vs 4% Slosh damping requirement.
(b) HLLV vs 1.5 Stage configurations.
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The reference was designed to meet a 1% damping requirement. Recent controls analysis indicates that 4% may be required. A 4% damping capability requires an increase in baffle depth plus an additional 4 baffles. A 4% baffle configuration will add baffles to the aft dome for an overall weight impact of 535 lbs. The full baffle configuration is required for 1.5 Stage, a 400-500 lbs of weight saving can be achieved on the less critical HLLV slosh baffle by omiting the two forward baffles. By integrating the baffles with the intermediate frames a more efficient design could be achieved with potential weight savings. In addition an integral baffle design would reduce the number of parts and eliminate the external baffle assembly tooling position and the baffle insertion operation.

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During Cycle 1 finalize the damping requirement and update the baseline configuration. The reference configuration is designed for 1.5 Stage and should remain common unless HLLV weight savings are required. A study should be performed during Cycle 1 to define the weight savings and manufacturing impacts for an integral baffle and frame design.
Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
CV-DI-O1A
LO2/LH2 Tank Access Trade Study

Prepared By: Wayne Waguespack
(504)257-0032

Approved By: R. Simms

Rev: Initial
Date: January 8, 1992

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MANNED SPACE SYSTEMS
Objective

- Determine Internal Access Requirements For The NLS Core Tankage And Assess Potential Access Solutions.

Approach

- Investigate STS External Tank Access Capability.
- Research Actual Tank Access History During Processing At KSC.
- Evaluate Need For Access During Build At MAF.
- Develop NLS Tank Access Requirements.
- Develop Options For Providing Access.
- Evaluate Options Against Requirements.
- Document Study And Prepare Conclusions.
Ground Rules And Assumptions

- Utilize MSFC Cycle 0 Reference Configuration As Defined On 9/27/91
  - Core Tankage
  - Propulsion Module
  - Interstage Design And CTV Location.
- CPR 488 Type SOFI Required On LO2 And LH2 External Surfaces.
- Utilize Existing Access Equipment If Possible.
ET Access Capability LH2

LH2 Siphon Ftg

36" Manhole

LH2 Fwd Dome

LH2 Aft Dome
External Tank Access Tooling

LH2 Aft Dome Access Kit (Manhole Protector)

LO2 Aft Dome Access Kit
External Tank Access Tooling

LH2 Internal Access Platform Set
External Tank Access Tooling

LH2 Tank Internal Access Equipment (1 Man)
### External Tank Access History At KSC

<table>
<thead>
<tr>
<th>ET Number</th>
<th>No. Of Entries</th>
<th>Reason For Entry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LH2</td>
<td>LO2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>23,27,29,</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>32-47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>2</td>
</tr>
</tbody>
</table>

**Note:** All Tank Entries Were Made Thru The Aft Domes Using The LO2/LH2 AFT Dome Access Kits. Vehicles Were Located In The VAB, No Tank Entries Were Made On The Pad.
## LO2 Access Capability On ET

**Horizontal Position After Major Weld And Prior To Cleaning And TPS Application**

<table>
<thead>
<tr>
<th>Access Location</th>
<th>Process</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO2 Fwd Cover Plate</td>
<td>Welding</td>
<td>• Remove Close-out Weld Mandrel.</td>
</tr>
<tr>
<td></td>
<td>Internal Cleaning</td>
<td>• Remove Debris</td>
</tr>
</tbody>
</table>
|                       | Mechanical Assy  | • Complete Instl Of Fwd Slosh Baffle  
|                       |                  | • Tie In Aft Baffle.                                                        |
|                       |                  | • Clean Up And X-Ray (After Proof Test).                                   |
| LO2 Aft Dome          |                  | None                                                                      |
## LO2 Access Capability On ET (Cont)

### During Cleaning, TPS Application And Final Assy

<table>
<thead>
<tr>
<th>Access Location</th>
<th>Cell E (Vertical)</th>
<th>Cleaning Probe Insl</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO2 Fwd Cover Plate</td>
<td>Cell G,H (Vertical)</td>
<td>Heat Duct Insl</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For TPS Curing</td>
</tr>
<tr>
<td></td>
<td>Final Assy (Horizontal)</td>
<td>Fwd Mast Installation</td>
</tr>
<tr>
<td>LO2 Aft Dome</td>
<td>Cell E (Vertical)</td>
<td>LO2 Aft Sensor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mast Insl.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Siphon Screen Insl</td>
</tr>
<tr>
<td></td>
<td>Cell G,H (Vertical)</td>
<td>Heat Duct Insl</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For TPS Curing</td>
</tr>
<tr>
<td></td>
<td>Final Assy (Horizontal)</td>
<td>Contingency Access Only</td>
</tr>
<tr>
<td>Access Location</td>
<td>LH2 Fwd Dome</td>
<td>LH2 Aft Dome</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Process</td>
<td>Welding</td>
<td>Mechanical Ass'y</td>
</tr>
<tr>
<td>Operation</td>
<td>Remove Close-out Weld</td>
<td>Install 1129 Frame Stabilizer Supports.</td>
</tr>
<tr>
<td></td>
<td>Mandrel. Clean Tank</td>
<td>Install Fwd Sensor Mast Clean Up And X-Ray (After Proof Test).</td>
</tr>
</tbody>
</table>
## LH2 Access Capability On ET (Cont)

### During Cleaning, TPS Application And Final Assy

<table>
<thead>
<tr>
<th>Access Location</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH2 Fwd Dome</td>
<td>Cell E (Vertical)</td>
<td>Cleaning Probe Instl</td>
</tr>
<tr>
<td></td>
<td>Cell B,C,D (Vertical)</td>
<td>Heat Duct Instl For TPS Curing</td>
</tr>
<tr>
<td></td>
<td>Final Assy (Horizontal)</td>
<td>Contingency Access Only</td>
</tr>
<tr>
<td>LH2 Aft Dome</td>
<td>Cell A (Vertical)</td>
<td>Inspect For Condensation</td>
</tr>
<tr>
<td></td>
<td>Cell E (Vertical)</td>
<td>LH2 Aft Sensor Mast Instl, Siphon Screen Instl</td>
</tr>
<tr>
<td></td>
<td>Cell D (Vertical)</td>
<td>Heat Duct Instl For TPS Curing</td>
</tr>
<tr>
<td></td>
<td>Final Assy (Horizontal)</td>
<td>Fwd Sensor Mast Instl</td>
</tr>
</tbody>
</table>
NLS Manhole Size

OSHA Requirements
- OSHA Chapter XVII, Section 1910.106, Para Vb Specifies That Pressure Vessel Be Built In Accordance With The ASME Code For Boiler And Pressure Vessels. Section VIII, Division 2, Para AD-1020-1 Of The ASME Code Specifies A Minimum Dia Of 15" For Access.

MIL-STD-1472 Requirements (Human Factors)
- Para 5.7.8.3 of MIL-STD-1472 Specifies That Min Dia Of Circular Hatches Shall Be 30.0".

ET Tooling Installation Requirements
- Max Size Of Tooling That Must Be Passed Thru The Manhole Is 22.0" x 26.0".
- This Results In A Min Requirement Of 36.0" In Dia.

Close Out Weld Mandrel Removal Tool, Installed In Tank At 20 Degree Angle
NLS Core Tank Access Reqmts Summary

Build At MAF

- Same As ET:
  - Access Manhole In Fwd Dome Of LO2 Tank
  - Access Manhole In Aft Dome Of LO2 Tank
  - Access Manhole In Fwd Dome Of LH2 Tank
  - Access Manhole In Aft Dome Of LH2 Tank

KSC Processing

- No Planned Requirement
- Potential For Contingency Access Only
  - VAB
  - PAD
### NLS Core Tank Access Reqmts Sum (Cont)

**During Build At MAF - Based On ET Capability**

<table>
<thead>
<tr>
<th>Build Location</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Welding</td>
<td>Remove Close-out Weld Mandrel</td>
</tr>
<tr>
<td>Mechanical Assy</td>
<td>Tie In Slosh Baffles, Install Fwd Sensor Mast Supports, Clean up And X-Ray</td>
</tr>
<tr>
<td>Internal Cleaning</td>
<td>Cleaning Probe Installation</td>
</tr>
<tr>
<td>TPS Application</td>
<td>Heat Duct Attachment For TPS Curing, Both Domes</td>
</tr>
<tr>
<td>Vertical Position</td>
<td>Aft L02/LH2 Sensor Mast And Siphon Screen Installation</td>
</tr>
<tr>
<td>Horizontal Position (After Tank Stacking)</td>
<td>Fwd L02/LH2 Sensor Mast Installation</td>
</tr>
</tbody>
</table>
# NLS L02 Tank Access Requirements

**Horizontal Position After Major Weld And Prior To Cleaning And TPS Application**

<table>
<thead>
<tr>
<th>Access Location</th>
<th>Process</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO2 Fwd Dome</td>
<td>Welding</td>
<td>• Remove Close-out Weld Mandrel.</td>
</tr>
<tr>
<td></td>
<td>Internal Cleaning</td>
<td>• Remove Debris</td>
</tr>
<tr>
<td></td>
<td>Mechanical Assy</td>
<td>• Complete Instl Of Fwd Slosh Baffle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tie In Aft Baffle.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clean Up And X-Ray (After Proof Test).</td>
</tr>
<tr>
<td>LO2 Aft Dome</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Access Location</td>
<td>LO2 Fwd Dome</td>
<td>LO2 Aft Dome</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td></td>
<td>Cell E (Vertical)</td>
<td>Cell E (Vertical)</td>
</tr>
<tr>
<td></td>
<td>Cleaning Probe Instl</td>
<td>LO2 Aft Sensor Mast Instl Siphon Screen Instl</td>
</tr>
<tr>
<td></td>
<td>Heat Duct Instl For TPS Curing</td>
<td>Heat Duct Instl For TPS Curing</td>
</tr>
<tr>
<td></td>
<td>Fwd Mast Installation</td>
<td>Contingency Access Only</td>
</tr>
</tbody>
</table>
# NLS LH2 Tank Access Requirements

## Horizontal Position After Major Weld And Prior To Cleaning And TPS Application

<table>
<thead>
<tr>
<th>Access Location</th>
<th>Process</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH2 Fwd Dome</td>
<td>Welding</td>
<td>• Remove Close-out Weld Mandrel.</td>
</tr>
<tr>
<td></td>
<td>Mechanical</td>
<td>• Clean Tank</td>
</tr>
<tr>
<td></td>
<td>Assy</td>
<td>• Install 1129 Frame Stabilizer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Install Fwd Sensor Mast Supports.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clean Up And X-Ray (After Proof Test).</td>
</tr>
<tr>
<td>LH2 Aft Dome</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
## NLS LH2 Tank Access Requirements (Cont) CV-DI-01-A

### During Cleaning, TPS Application And Final Assy

<table>
<thead>
<tr>
<th>Access Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LH2 Fwd Dome</strong></td>
<td></td>
</tr>
<tr>
<td>Cell E (Vertical)</td>
<td>Cleaning Probe Instl</td>
</tr>
<tr>
<td>Cell N (Vertical)</td>
<td>Heat Duct Instl For TPS Curing</td>
</tr>
<tr>
<td>Final Assy (Horizontal)</td>
<td>Contingency Access Only</td>
</tr>
<tr>
<td><strong>LH2 Aft Dome</strong></td>
<td></td>
</tr>
<tr>
<td>Cell A (Vertical)</td>
<td>Inspect For Condensation</td>
</tr>
<tr>
<td>Cell E (Vertical)</td>
<td>LH2 Aft Sensor Mast Instl Siphon Screen Instl</td>
</tr>
<tr>
<td>Cell N (Horizontal)</td>
<td>Heat Duct Instl For TPS Curing</td>
</tr>
<tr>
<td>Final Assy (Horizontal)</td>
<td>Fwd Sensor Mast Instl</td>
</tr>
</tbody>
</table>
Options (NLS L02 Tank)

• Option 1- Baseline (MSFC Ref Cycle 0 Design).

• Option 2- Relocate Aft Dome Feedline Penetrations To Allow For The Addition Of A 30" Dia Manhole In Bottom Of Tank. Relocate Fwd Dome Manhole To Match ET.

• Option 3- Design Aft Dome Feedline Penetration To Be Bolted On Which Would Allow Removal For Access. Relocate Fwd Dome To Match ET.

• Option 4- Provide Smaller Manhole In Aft Dome Without Relocating Feedlines. Relocate Fwd Dome Manhole To Match ET.
LO2 Option 1 (MSFC Cycle 0)

Aft Dome
No Tank Access Available

+Z
SRB Cross Beam (HLLV Only)

Fwd Dome

+Z
36" Dia Manhole
LO2 Option 4

36" Dia Manhole, Located
Same As ET LH2 Fwd Dome

+Z

Fwd Dome

Add 20" Dia Manhole

SRB Cross Beam
(HLLV Only)

+Z

Aft Dome

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MANNED SPACE SYSTEMS
<table>
<thead>
<tr>
<th>Activity</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal Of Close-Out Weld Mandrel Thru Fwd Manhole (Welding)</td>
<td>Location Of Manhole Requires Mods To Tank Access Tools</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Complete Instl Of Fwd Slosh Baffle. Access Thru Fwd Manhole (Mech Assy)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Tie In Aft Baffle. Access Thru Fwd Manhole. (Mech Assy)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Clean Up And X-ray. Access Thru Fwd Manhole. (Mech Assy)</td>
<td>Location Of Manhole Requires Mods To Tank Access Tools</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Install Internal Cleaning Probe Thru Fwd Manhole (Cell -E, Vertical)</td>
<td>Location Of Manhole Requires Mods To Cleaning Probe</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Install Heat Ducts For TPS Curing Thru Both Domes (Cell - M, Vertical)</td>
<td>No Aft Manhole Available</td>
<td>Yes</td>
<td>Requires Removal Of Feedline Fitting And Mods To Aft Heat Duct</td>
<td>Aft Manhole Size Requires Mods To Heat Duct</td>
</tr>
</tbody>
</table>
### NLS LO2 Access Option Summary (Cont)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install Aft Level Sensor Mast. Access Thru Aft Manhole. (Cell - E, Vertical)</td>
<td>No Aft Manhole Available</td>
<td>Yes</td>
<td>Requires Removal Of Feedline Fitting</td>
<td>Aft Manhole Size Requires Mods To Tooling</td>
</tr>
<tr>
<td>Install Siphon Screen. Access Thru Aft Manhole. (Cell - E, Vertical)</td>
<td>No Aft Manhole Available</td>
<td>No Aft Manhole Available</td>
<td>No Aft Manhole Available</td>
<td>Aft Manhole Size Req's Redesign Of Siphon Screen</td>
</tr>
<tr>
<td>Install Fwd Level Sensor Mast. Access Thru Fwd Manhole. (Final Assy - Horizontal)</td>
<td>Location Of Manhole Requires Mods To Tank Access Tools</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Install Tank Entry Tooling Thru Aft Manhole</td>
<td>No Aft Manhole Available</td>
<td>Yes</td>
<td>Requires Removal Of Feedline Fitting</td>
<td>Aft Manhole Size Requires Mods To Tooling</td>
</tr>
<tr>
<td>Contingency Access Thru Fwd Dome</td>
<td></td>
<td></td>
<td>Unstack Payload And CTV</td>
<td></td>
</tr>
<tr>
<td>Criteria</td>
<td>Option 1</td>
<td>Option 2</td>
<td>Option 3</td>
<td>Option 4</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Can A Common Cleaning Probe Location Be Achieved Between ET &amp; NLS</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Is There Provisions For Connection Of TPS Cure Heat Ducts</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Can Existing Tank Access Platforms Be Utilized Without Modifications</td>
<td>NO (Use LH2 Tooling)</td>
<td>YES (Use LH2 Tooling)</td>
<td>YES (Use LH2 Tooling)</td>
<td>YES (Use LH2 Tooling)</td>
</tr>
<tr>
<td>Can Weld Close Out Mandrel Be Removed Thru Fwd Manhole</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>What Is The Extent Of The Tooling And Facility Mods</td>
<td>MAJOR</td>
<td>MINOR</td>
<td>MINOR</td>
<td>MINOR</td>
</tr>
<tr>
<td>Redesign Access Tooling, Relocate Cleaning Probe And TPS Heat Duct</td>
<td>Reference</td>
<td>NONE</td>
<td>NONE</td>
<td>NONE</td>
</tr>
<tr>
<td>What Is The Estimated Weight Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is Internal Access Feasible After Tank Stacking At MAF</td>
<td>NO *</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Is Contingency Access At KSC Feasible</td>
<td>NO *</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

* Requires Aft Dome Manhole To Install Access Tooling.
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is There Provisions For Connection Of TPS Cure Heat Ducts</td>
<td><strong>NO</strong></td>
<td><strong>YES</strong></td>
<td><strong>YES</strong> Requires Removal Of Siphon Fitting</td>
<td><strong>YES</strong></td>
</tr>
<tr>
<td>Can Existing Tank Acces Platforms Be Utilized Without Modifications</td>
<td><strong>NO</strong></td>
<td><strong>NO</strong></td>
<td><strong>NO</strong></td>
<td><strong>NO</strong></td>
</tr>
<tr>
<td>Can Tank Be Manufactured Using Existing ET Tooling And Processes</td>
<td><strong>NO</strong></td>
<td><strong>YES</strong></td>
<td><strong>NO</strong></td>
<td><strong>NO</strong></td>
</tr>
<tr>
<td>What Is The Extent Of The Tooling And Facility Mods</td>
<td>MAJOR NO Tank Opening For TPS Heat Duct, Unable To Access Tank For Final Assy</td>
<td>MINOR Provide Adapter For TPS Heat Duct</td>
<td>Significant Relocate TPS Heat Duct And Provide Adapter</td>
<td>Significant Relocate TPS Heat Duct And Provide Adapter</td>
</tr>
<tr>
<td>What Is The Estimated Weight Impact</td>
<td>Reference</td>
<td>+90 lbs</td>
<td>+20 lbs</td>
<td>+60 lbs</td>
</tr>
<tr>
<td>Is Internal Access Feasible After Tank Stacking At MAF</td>
<td><strong>NO</strong></td>
<td><strong>YES</strong></td>
<td><strong>NO</strong> *</td>
<td><strong>YES</strong></td>
</tr>
<tr>
<td>Is Contingency Access At KSC Feasible</td>
<td><strong>NO</strong></td>
<td><strong>YES</strong></td>
<td><strong>NO</strong> *</td>
<td><strong>YES</strong></td>
</tr>
</tbody>
</table>

* Requires Removal Of Siphon Ftg And Feedline Assy
Conclusions - NLS L02 Tank Access

- Option 2 is preferred:
  - Allows tank to be manufactured using existing ET tooling and processes.
  - Provides internal access to tank at MAF.
  - Provides contingency access to tank at KSC prior to payload mating.
Options (NLS LH2 Tank)

• Option 1- Baseline (MSFC Ref Cycle 0 Design).

• Option 2- Design Aft Dome Sump As "Bolt On" To Allow Access. Relocate Fwd Dome Manhole To Match ET.

• Option 3- Adopt MSFC Alternate Prop Arrangement An Add 30" Dia Manhole To Aft Dome Cap. Relocate Fwd Dome Manhole To Match ET.
LH2 Option 1 (MSFC Cycle 0)

Fwd Dome

36" Dia Manhole

Aft Dome

48" Dia Sump

No Tank Access Available
LH2 Option 2

36" Dia Manhole located same as ET

Design 48" Dia Sump to be bolted on to allow tank access

Aft Dome

Fwd Dome

+Z
# NLS LH2 Access Option Summary

<table>
<thead>
<tr>
<th>BUILD AT MAF</th>
<th>Activity</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Removal Of Close-Out Weld Mandrel Thru Fwd Manhole (Welding)</td>
<td>Location Of Manhole Requires Mods To Tank Access Tools</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Install 1129 Frame Stabilizer. Access Thru Fwd Manhole. (Mech Assy)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Install Fwd Level Sensor Mast Supports. Access Thru Fwd Manhole. (Mech Assy)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clean Up And X-ray. Access Thru Fwd Manhole. (Mech Assy)</td>
<td>Location Of Manhole Requires Mods To Tank Access Tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Install Internal Cleaning Probe Thru Fwd Manhole (Cell -E, Vertical)</td>
<td>Location Of Manhole Requires Mods To Cleaning Probe</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Install Heat Ducts For TPS Curing Thru Both Domes (Cell - N, Horizontal)</td>
<td>No Aft Manhole Available</td>
<td>No Aft Manhole Available</td>
<td>Yes</td>
</tr>
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</table>
## NLS LH2 Access Option Summary (Cont)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install Aft Level Sensor Mast. Access Thru Aft Manhole. (Cell - E, Vertical)</td>
<td>No Aft Manhole Available</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Install Siphon Screen. Access Thru Aft Manhole. (Cell - E, Vertical)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check For Condensation After Proof Test. Access Thru Aft Manhole. (Cell - A, Vertical)</td>
<td>No Aft Manhole Available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Install Fwd Level Sensor Mast. Access Thru Aft Manhole. (Final Assy - Horizontal)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KSC Processing</td>
<td>Install Tank Entry Tooling Thru Aft Manhole</td>
<td>No Aft Manhole Available</td>
<td>No Aft Manhole Available</td>
</tr>
<tr>
<td>Contingency Access Thru Fwd Dome</td>
<td></td>
<td>Unstack Payload And CTV</td>
<td>Yes</td>
</tr>
<tr>
<td>Criteria</td>
<td>Option 1</td>
<td>Option 2</td>
<td>Option 3</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Can A Common Cleaning Probe Location Be Achieved Between ET &amp; NLS</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Is There Provisions For Connection Of TPS Cure Heat Ducts</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Can Existing Tank Access Platforms Be Utilized Without Modifications</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Can Weld Close Out Mandrel Be Removed Thru Fwd Manhole</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>What Is The Extent Of The Tooling And Facility Mods</td>
<td>MAJOR</td>
<td>NONE</td>
<td>NONE</td>
</tr>
<tr>
<td>Rdesign Access Tooling, Relocate Cleaning Probe And TPS Heat Duct</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What Is The Estimated Weight Impact</td>
<td>Reference</td>
<td>NONE</td>
<td>NONE</td>
</tr>
<tr>
<td>Is Internal Access Feasible After Tank Stacking At MAF</td>
<td>NO *</td>
<td>NO *</td>
<td>YES</td>
</tr>
<tr>
<td>Is Contingency Access At KSC Feasible</td>
<td>NO *</td>
<td>NO *</td>
<td>YES</td>
</tr>
</tbody>
</table>

* Requires Aft Dome Manhole To Install Access Tooling.
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is There Provisions For Connection Of TPS Cure Heat Ducts</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Can Existing Tank Access Platforms Be Utilized Without Modifications</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Can Tank Be Manufactured Using Existing ET Tooling And Processes</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>What Is TheExtent Of The Tooling And Facility Mods</td>
<td>MAJOR</td>
<td>MINOR</td>
<td>MINOR</td>
</tr>
<tr>
<td></td>
<td>NO: Tank Opening For TPS Heat Duct, Unable To Access Tank For Final Assy</td>
<td>MINOR: Provide Adapter For TPS Heat Duct</td>
<td>MINOR: Provide Adapter For TPS Heat Duct</td>
</tr>
<tr>
<td>What Is The Estimated Weight Impact</td>
<td>Reference</td>
<td>+20 lbs</td>
<td>-114 lbs</td>
</tr>
<tr>
<td>Is Internal Access Feasible After Tank Stacking At MAF</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Is Contingency Access At KSC Feasible</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>
Conclusions - (NLS LH2 Tank Access)

- Option 3 is preferred:
  - Allows Tank to be manufactured using existing ET tooling and processes.
  - Provides internal access to tank at MAF.
  - Provides contingency access to tank at KSC.
Conclusions

- Commonality With ET Tooling And Facilities Can Be Improved By Incorporating The Preferred Options Identified By This Study.

- Incorporation Of The Recommended Options Also Provides A Contingency Access Capability.

Recommendations

- Incorporate Results Of This Study Into Cycle 1 Reference Configuration Definition.

- Evaluate Impact Of Single LO2 Feedline Currently Under Consideration By MSFC Propulsion.

- Initiate A Study To Evaluate If A Level Sensor Mast Can Be Designed That Can Be Installed Without The Need For Internal Access.
5.2.4.4.2 Tank Access Trade Study(#CV-DI-01-A)

Objective

This trade study evaluated if additional tank access should be provided in the reference configuration Core Tankage. The Cycle Ø baseline contains a 36in diameter manhole in the forward domes of both LO2 and LH2 Tanks. No manholes are provided in the aft domes.

Approach

(a) Investigate STS ET access capability
(b) Research actual tank access history at KSC
(c) Evaluate need for access during build at MAF
(d) Develop NLS Tank access requirements
(e) Develop and evaluate options for providing access

Options Studied - LO2 Tank

Option 1 - Cycle Ø Baseline
Option 2 - Relocate Fwd Manhole to ET loctn.; relocate F/L's; Add 30in Ø M/hole in Aft Cap
Option 3 - Relocate Fwd Manhole to ET loctn.; revise LO2 F/L Outlets as removable
Option 4 - Relocate Fwd Manhole to ET location; retain F/L loc'n; Add small Manhole in Aft Cap

Options Studied - LH2 Tank (Reference only)

Option 1 - Cycle Ø Baseline
Option 2 - Relocate Fwd Manhole to ET location; make Aft LH2 tank sump removable
Option 3 - Relocate Fwd Manhole to ET loctn.; delete Sump, Add 30in Dia Manhole in Dome Cap

Key Study Results
24 tank entries were made on ET at KSC(all on first 30 tanks). MIL-STD-1472 specifies that minimum manhole size is 30 inches. Existing Weld mandrel is 22in x 26in and is removed thru fwd dome. This requires a 36 in dia hole. For build at MAF similar access requirements to ET are required. This requires a manhole in each dome. Fwd manhole needs to be in same location on ET & NLS as tanks are processed thru the same facilities. Location is primarily driven by cleaning probe insertion in Cell E. KSC access is contingency only.

Conclusions
Option 2 is preferred for the LO2 tank this option allows the NLS to be manufactured using ET tooling and facilities. It also provides for internal access at MAF and contingency access at KSC.

Study Recommendations
Revise cycle Ø baseline to incorporate Option 2(LO2 Tank). Perform a feasibility study to evaluate if the level sensors can be designed for removal and installation from the outside. (see 5.2.6.4.1)
36 in dia manhole at this location on both L02 & LH2 tanks (No manhole in either aft dome)

NLS Cycle Ø Baseline

Relocated 36in dia manhole

Relocated F/L Outlets

30 in dia manhole

Relocated 36in dia manhole

Sump Deleted

30 in dia manhole

Additional Information
See Doc# MMC.NLS.SR.001.Book 1 for more detailed results
5.2.6.4.2 Tank Access Trade Study(#CV-DI-01-A)

Objective

This trade study evaluated if additional tank access should be provided in the reference configuration Core Tankage. The Cycle Ø baseline contains a 36in diameter manhole in the forward domes of both LO2 and LH2 Tanks. No manholes are provided in the aft domes.

Approach

(a) Investigate STS ET access capability
(b) Research actual tank access history at KSC
(c) Evaluate need for access during build at MAF
(d) Develop NLS Tank access requirements
(e) Develop and evaluate options for providing access

Options Studied - LH2 Tank

Option 1 - Cycle Ø Baseline
Option 2 - Relocate Fwd Manhole to ET location & make Aft LH2 tank sump removable
Option 3 - Relocate Fwd Manhole to ET locm; delete Sump & Add 30in Dia Manhole in Dome Cap

Options Studied - L02 Tank (Reference only)

Option 1 - Cycle Ø Baseline
Option 2 - Relocate Fwd Manhole to ET loctn.; relocate F/L’s; add 30in Ø M/hole in Aft Cap
Option 3 - Relocate Fwd Manhole to ET loctn.; revise L02 F/L Outlets as removable
Option 4 - Relocate Fwd Manhole to ET location; retain F/L loc’n; add small Manhole in Aft Cap

Key Study Results

24 tank entries were made on ET at KSC(all on first 30 tanks). MIL-STD-1472 specifies that minimum manhole size is 30 inches. Existing Weld mandrel is 22in x 26in and is removed thru fwd dome. This requires a 36 in dia hole. For build at MAF similar access requirements to ET are required. This requires a manhole in each dome. Fwd manhole needs to be in same location on ET & NLS as tanks are processed thru the same facilities. Location is primarily driven by cleaning probe insertion in Cell E. KSC access is contingency only.

Conclusions

Option 3 is preferred for the LH2 tank. This option allows the NLS to be manufactured using ET tooling and facilities. It also provides for internal access at MAF and contingency access at KSC.

Study Recommendations

Revise cycle Ø baseline to incorporate Option 3(LH2 Tank). Perform a feasibility study to evaluate if the level sensors can be designed for removal and installation from the outside. (see 5.2.6.4.1)
36 in dia manhole at this location on both L02 & LH2 tanks (No manhole in either aft dome)

NLS Cycle Ø Baseline

<table>
<thead>
<tr>
<th>L02 Fwd Dome</th>
<th>L02 Aft Dome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relocated 36in dia manhole</td>
<td>30 in dia manhole</td>
</tr>
<tr>
<td>Relocated F/L Outlets</td>
<td>Sump Deleted</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LH2 Fwd Dome</th>
<th>LH2 Aft Dome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relocated 36in dia manhole</td>
<td>30 in dia manhole</td>
</tr>
</tbody>
</table>

Proposed Update to NLS Cycle Ø Baseline

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
6.2.4.4.2 Tank Access Trade Study(#CV-DI-01-A)

Objective

This trade study evaluated if additional tank access should be provided in the reference configuration Core Tankage. The Cycle Ø baseline contains a 36in diameter manhole in the forward domes of both LO2 and LH2 Tanks. No manholes are provided in the aft domes.

Approach

(a) Investigate STS ET access capability  
(b) Research actual tank access history at KSC  
(c) Evaluate need for access during build at MAF  
(d) Develop NLS Tank access requirements  
(e) Develop and evaluate options for providing access

Options Studied - LO2 Tank

Option 1 - Cycle Ø Baseline  
Option 2 - Relocate Fwd Manhole to ET locn.; relocate F/L's; Add 30in Ø M/hole in Aft Cap  
Option 3 - Relocate Fwd Manhole to ET locn.; revise L02 F/L Outlets as removable  
Option 4 - Relocate Fwd Manhole to ET location; retain F/L loc'n; Add small Manhole in Aft Cap

Options Studied - LH2 Tank (Reference only)

Option 1 - Cycle Ø Baseline  
Option 2 - Relocate Fwd Manhole to ET location; make Aft LH2 tank sump removable  
Option 3 - Relocate Fwd Manhole to ET locm.; delete Sump, Add 30in Dia Manhole in Dome Cap

Key Study Results

24 tank entries were made on ET at KSC(all on first 30 tanks). MIL-STD-1472 specifies that minimum manhole size is 30 inches. Existing Weld mandrel is 22in x 26in and is removed thru fwd dome. This requires a 36 in dia hole. For build at MAF similar access requirements to ET are required. This requires a manhole in each dome. Fwd manhole needs to be in same location on ET & NLS as tanks are processed thru the same facilities. Location is primarily driven by cleaning probe insertion in Cell E. KSC access is contingency only.

Conclusions

Option 2 is preferred for the LO2 tank this option allows the NLS to be manufactured using ET tooling and facilities. It also provides for internal access at MAF and contingency access at KSC.

Study Recommendations

Revise cycle Ø baseline to incorporate Option 2(L02 Tank). Perform a feasibility study to evaluate if the level sensors can be designed for removal and installation from the outside. (see 6.2.6.4.1)
36 in dia manhole at this location on both L02 & LH2 tanks (No manhole in either aft dome)

NLS Cycle Ø Baseline

- Relocated 36in dia manhole
- Relocated F/L Outlets
- 30 in dia manhole

L02 Fwd Dome
L02 Aft Dome

- Relocated 36in dia manhole

LH2 Fwd Dome
LH2 Aft Dome

Proposed Update to NLS Cycle Ø Baseline

Additional Information
See Doc# MMC.NLS.SR.001.Book 1 for more detailed results
6.2.6.4.2 Tank Access Trade Study(#CV-DI-01-A)

Objective

This trade study evaluated if additional tank access should be provided in the reference configuration Core Tankage. The Cycle Ø baseline contains a 36in diameter manhole in the forward domes of both LO2 and LH2 Tanks. No manholes are provided in the aft domes.

Approach

(a) Investigate STS ET access capability
(b) Research actual tank access history at KSC
(c) Evaluate need for access during build at MAF
(d) Develop NLS Tank access requirements
(e) Develop and evaluate options for providing access

Options Studied - LH2 Tank

Option 1 - Cycle Ø Baseline
Option 2 - Relocate Fwd Manhole to ET location & make Aft LH2 tank sump removable
Option 3 - Relocate Fwd Manhole to ET locm; delete Sump & Add 30in Dia Manhole in Dome Cap

Options Studied - LO2 Tank (Reference only)

Option 1 - Cycle Ø Baseline
Option 2 - Relocate Fwd Manhole to ET locm.; relocate F/L's; add 30in Ø M/hole in Aft Cap
Option 3 - Relocate Fwd Manhole to ET locm.; revise LO2 F/L Outlets as removable
Option 4 - Relocate Fwd Manhole to ET location; retain F/L loc'n; add small Manhole in Aft Cap

Key Study Results

24 tank entries were made on ET at KSC(all on first 30 tanks). MIL-STD-1472 specifies that minimum manhole size is 30 inches. Existing Weld mandrel is 22in x 26in and is removed thru fwd dome. This requires a 36 in dia hole. For build at MAF similar access requirements to ET are required. This requires a manhole in each dome. Fwd manhole needs to be in same location on ET & NLS as tanks are processed thru the same facilities. Location is primarily driven by cleaning probe insertion in Cell E. KSC access is contingency only.

Conclusions

Option 3 is preferred for the LH2 tank. This option allows the NLS to be manufactured using ET tooling and facilities. It also provides for internal access at MAF and contingency access at KSC.

Study Recommendations

Revise cycle Ø baseline to incorporate Option 3(LH2 Tank). Perform a feasibility study to evaluate if the level sensors can be designed for removal and installation from the outside. (see 6.2.6.4.1).
36 in dia manhole at this location on both L02 & LH2 tanks (No manhole in either aft dome)

NLS Cycle Ø Baseline

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
CV-DI-01B
Alternate Transportation Attachment Points Evaluation

Approved by: R. Simms

Prepared by: R. B. Newton
(504) 257 0389
Rev: Initial
Date January 8, 1992
Objective

- Evaluate if the core stage can be handled and transported when supported using an alternate transportation approach

Approach

- Determine manufacturing preference for core tankage and core stage handling and transportation
- Assess impact to core tankage design
- Prepare conclusions and recommendations
Handling Loads - Hoisting at MAF VAB

Hoisting load factors
MMMC Tool design manual

Vertical ± 2.0
Include 15 deg cone angle

Remove from Stack

74008 X 2 X 1.4 = 207222 lb

41814 X 2 X 1.4 = 117080 lb

35564 X 2 X 1.4 = 99600 lb

38444 X 2 X 1.4 = 107643 lb

Hoist and rotate

Horizontal hoist

32192 X 2 X 1.4 = 90138 lb

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Handling Loads - Final assembly

Assemble PM

35564 \times 1 \times 1.4 = 49790 \text{ lb ult (without PM)}

38444 \times 1 \times 1.4 = 53821 \text{ lb (Without PM)}

thrust structure and propulsion equip etc 30,000 \text{ lb approx}

Install engines

25822 \times 1 \times 1.4 = 36150 \text{ lb ult}

137827 \times 1.0 \times 1.4 = 192957 \text{ lb ult}

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Handling - Complete Vehicle on Barge

Support ring

STN 2473.8

96

283

270.2

1138.4

1720.85

STN 2852.8

STN 4122

STN 4194.65

Roll ring

114554 lb Ult

137827X 2.5 X 1.4 = 482394lb ult

Compression load 780 lb/in ult (compares with 2800lb in Standing 47 kt loaded case)

STN 2473.8

Support ring

25822 X 2.5 X 1.4 = 90377 lb ult

Transport load factors (Water transport):

Ref SP 8077

Longitudinal ± .5

Lateral ± 2.5

Vertical ± 2.5
Handling Loads - Hoist at KSC VAB

Hoisting load factors
MMMC Tool design manual

Vertical \[ \pm 2.0 \]

Include 15 deg cone angle

25822 X 2 X 1.4 = 72301 lb ult

137827 x 2.0 x 1.4 = 385920 lb ult

458217 lb ult

STN 2473.8

STN 4194.65

Martin Marietta
Manned Space Systems
Support At Fwd Skirt

EXISTING TOOLING BOLT LOCATIONS PER ET
Bolt circle radius = 166.21

ET bolt dia 9/16
Hole dia .61 dia

Holist and transport Frame

Flight conical adapter(ref)

3/8 dia bolt 125 ksl for hoisting

Stn 2473.8

.38

.58

2.5

.16

Section AA
Conclusions and Recommendations

Conclusions

- Alternate transportation approach has no impact on ref. configuration core tankage sizing
- Fwd ring can be attached using Fwd skirt/interstage attachment hardware holes

Recommendations

- Adopt alternate transportation approach
  - eliminates need for additional hardware on 1.5 stage I/T
  - permits core tankage and core Stage T and H
- Define with the aft structure panel the preferred location of the aft transportation ring
5.2.1.4.7 Alt. Trans Attach Points (#CV-DI-01B)

Objective

Evaluate whether the Core Stage can be handled and transported when supported using an alternate transportation approach.

Approach

(a) Determine manufacturing preference for core tankage and core stage handling and transportation.
(b) Define the handling loads for each step of assembly, hoisting and transportation.
(c) Assess impact on core tankage design.
(d) Prepare conclusions and recommendations.

Options Studied

Option 1 - Support as on ET - at SRB beam and aft LH2 tank frame.
Option 2 - Support at Fwd frame of Fwd skirt and major frame in propulsion module.

Key Study Results

The ET transporter was designed for the 75,000 lb max standard weight ET. It was concluded that new transporters will be needed for the 163,000 lb Core stage. Therefore this task concentrated on the option (2) alternate support.

The loads at support points for each assembly, position, hoist and transport event, including barge shipment to KSC were determined and found to have no impact to the reference configuration.

Conclusions

(a) Alternate transportation approach has no impact on ref. configuration core tankage sizing.
(b) Fwd ring can be attached using Fwd skirt/interstage attachment hardware holes.

Study Recommendations

(a) Adopt alternate transportation approach:
   - Eliminates need for additional hardware on 1.5 stage I/T
   - Permits Core Tankage and Core Stage transportation and handling.

(b) Define with the aft structure panel the preferred location of the aft transportation ring.
Option 1) ET support system  ET weight 66000 lb

New transporter needed:
- Heavier vehicle
- Longer vehicle
- Lower vehicle clearance for roll rings. (Roll rings are needed to provide access to pod engines)

42865 lb  23123 lb

Option 2) Alternate support system  NLV weight 163646 lb

25822 lb  137827 lb

*1.5 stage does not need heavy frame at stn 4058
*Both Hlv and 1.5 stage have a massive frame at stn 4194
*1.5 stage does not need a heavy frame at stn 2985

Design loads at support points

Hoisting load factors
- Vertical ± 2.0
- Cone angle 15 deg
- Sea transport load factors
- Vertical +2.5
- Lateral ± 2.5

Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results
6.2.1.4.7 Alt. Trans Attach Points (#CV-DI-01B)

Objective

Evaluate whether the Core Stage can be handled and transported when supported using an alternate transportation approach.

Approach

(a) Determine manufacturing preference for core tankage and core stage handling and transportation.
(b) Define the handling loads for each step of assembly, hoisting and transportation.
(c) Assess impact on core tankage design.
(d) Prepare conclusions and recommendations.

Options Studied

Option 1 - Support as on ET - at SRB beam and aft LH2 tank frame.
Option 2 - Support at Fwd frame of Fwd skirt and major frame in propulsion module.

Key Study Results

The ET transporter was designed for the 75,000 lb max standard weight ET. It was concluded that new transporters will be needed for the 163,000 lb Core stage. Therefore this task concentrated on the option (2) alternate support.

The loads at support points for each assembly, position, hoist and transport event, including barge shipment to KSC where determined and found to have no impact to the reference configuration.

Conclusions

(a) Alternate transportation approach has no impact on ref. configuration core tankage sizing.
(b) Fwd ring can be attached using Fwd skirt/interstage attachment hardware holes.

Study Recommendations

(a) Adopt alternate transportation approach:
   - Eliminates need for additional hardware on 1.5 stage I/T
   - Permits Core Tankage and Core Stage transportation and handling.
(b) Define with the aft structure panel the preferred location of the aft transportation ring.
Option 1) ET support system  ET weight 66000 lb

42865 lb  23123 lb

New transporter needed:
- Heavier vehicle
- Longer vehicle
- Lower vehicle clearance for roll rings (roll rings are needed to provide access to pod engines)

Option 2) Alternate support system  NLV weight 163646 lb

25822 lb  137827 lb

- 1.5 stage does not need heavy frame at stn 4058
- Both Hlv and 1.5 stage have a massive frame at stn 4194
- 1.5 stage does not need a heavy frame at stn 2985

Design loads at support points

Hoisting load factors
Vertical ± 2.0
Cone angle 15 deg
Sea transport load factors
Vertical ± 2.5
Lateral ± 2.5

Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
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CV-STR-14A
Forward Skirt Structural Reference
Configuration Enhancements

Prepared By: Anthony C Grotefeld
(504)257-5284

Approved By: M.R. Simms

Rev: - Initial
Date: January 8, 1992
**Objective**
- Study And Evaluate Enhancements To The Cycle Ø Reference Forward Skirt Structure And Recommend Potential Modifications

**Approach**
- Obtain Detail Definition From MSFC
- Identify Potential Study Items
- Define, Evaluate And Analyze Selected Study Items
- Identify Recommended Changes To Ref. Configuration
- Produce Forward Skirt Part Definition
  - Usage And/Or Similarity Of ET Parts
  - NLS Part Commonality
- Identify Candidates For Further Study
Groundrules & Assumptions

Ground Rules

- Forward Skirt Structure Definition Per MSFC Reference Layout NLS-0008 Dated 8/27/91
- Mass Properties As Defined On 10/7/91
- Loads & Factors From Memo To P. Thomson From Bart Graham, Dated 5/10/91

Assumptions

- Access Doors And Vent Are In The Interstage
- Encapsulated Payload I/F Between Interstage And Forward Skirt
- Loads Evenly Distributed (From Interstage To Forward Skirt)
- Common Skirt For 1.5 Stage And HLLV
Potential Study Items

- Alternate Fwd Skirt To Interstage Interface Concept
- Shell Penetration Definition
- Potential Use Of ET Tooling To Build Forward Skirt
- Stringer Pitch Revision
- Sizing Changes

Related Tasks (Results Not Incorporated In This Study)
- CV-STR - 14G  External Hardware Definition
- CV-STR - 16H  TPS Reference Definition
- CV-STR - 16D  Transportation And Handling
- CV-D1-01-B  Alternate Transportation Attach Points
- 3-S-001-B  Skin Stiffener Pitch Sensivity
## Recommended Changes

<table>
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<th>Study Item</th>
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<th>Back Up Data</th>
<th>Wt(Lb) Impact</th>
<th>Status</th>
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<td>• Alternate I/F Concept</td>
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<td>• Shell Penetration Defn</td>
<td>Add Penetrations</td>
<td>Append 2</td>
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<td>• Stringer Pitch Dimension</td>
<td>Revise Method Of Dimensioning</td>
<td>Append 3</td>
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<td>Append 5</td>
<td>+ 213 - 157</td>
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Incorp - Now Incorporated In MSFC Baseline Layouts  
Accepted - Agreed But Not Yet Incorporated  
Pending - Being Evaluated By MSFC
CV-STR-14A
Appendix 1

• Alternate Interface Concept
Alternate Interface Concepts

**Issue**
- Current Reference For Forward Skirt/Conical Adapter Interface Requires Internal Access For Installation Of Attach Hardware

**Objective**
- Define And Evaluate Alternate Forward Skirt/Conical Adapter Interfaces
Options Studied

Reference

Option #1

Option #2

Option #3

Option #4

Option #5

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Option 1 - External I/F

Conic Adapter

Externally Installed Fastener

Chord Similar To ET I/T Fwd Chord

Fwd Skirt
Option 3 - Internal I/F

Conic Adapter
Roll Ring Forging
Insert

Internally Installed Fastener

Extruded Fwd Chord
Fwd Skirt
Option 4 - Conical External I/F

- Conic Adapter
- Nutplate
- Externally Installed Fastener
- Fwd Skirt
- Extruded Fwd Chord
Option 5 - Cylindrical Ext I/F

Conic Adapter

Extruded Fwd Chord

Nutplate

Externally Installed Fastener

Fwd Skirt
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<th>Option 3</th>
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<td>Roll Ring Forging</td>
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<td>Simple Extrusion</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<td>No - Local C/O Req'd</td>
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<td>No</td>
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<td>Pot'l Use of ET Tool'g</td>
<td>New I/F Tool Req'd</td>
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<td>- 443</td>
<td>-133</td>
<td>-133</td>
<td>-144</td>
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* To Accommodate Bolt Offset
Conclusions

- Reference Configuration
  - Joint Not Susceptible To Aeroheating
  - Requires Internal Access
  - Requires Additional Backup Fittings
  - Heaviest Option
- Option 1
  - External Access And Good Joint Integrity
  - Potential Use Of ET Tooling
  - Aeroheating Impact
- Option 2
  - External Access And Good Joint Integrity
  - Complex Parts/Machining
- Option 3
  - Simple Interface With Good Joint Integrity
  - Internal Access
  - Complex Parts
- Option 4
  - External Access And Excellent Joint Integrity
  - Lightweight
  - Conical Interface Drives Complex Tooling
- Option 5
  - External Access And Excellent Joint Integrity
  - Lightweight
  - Cylindrical Interface Drives Complex Tooling
Conclusions & Recommendations

Conclusion

- Option 1 is preferred
  - Simple External Interface
  - Potential use of ET tooling
  - Good load paths, no need for backup fittings

Recommendations

Determine if an external flange is acceptable for aeroheating. If so, incorporate Option 1 during Cycle 1.
CV-STR-14A
Appendix 2

• Shell Penetration Definition
CV-STR-14A

Shell Penetration Definition

GO2 P/L Aperture

GO2 Vent Aperture

CT Aperture

-30 Deg

Xn 2473.8

Xn 2521.8

Xn 2569.8

130.0 Typ

Fwd

+Z

-Y

-Z

+Y

-7

0

1

2

3

4

5

6

8

96.00

ACG92014

300

c-4
GO2 P/L Penetration

Panel #3 - NLS Ref Configuration

- GO2 Pressline Aperture *
- 2.0 Ref
- LH2 C/T Aperture *

- Frame at Xn 2521.8 Interferes With GO2 P/L & LH2 C/T Cutouts

* Cutouts Positioned Relative to Panel as ET Intertank

Xn 2473.80
Xn 2514.64
Xn 2521.8
Xn 2522.65
Xn 2569.80

ACG92014
GO2 P/L Penetration

Conclusion
• Cutouts Positioned Relative to ET Intertank Interfere with Frame

Recommendation
• Relocate Cutouts 1.00 Forward of Frame and Revise Shell Accordingly
• Add Penetrations For Cabletray, GO2 Pressline And GO2 Vent During Cycle 1
Stringer Pitch

Conclusion

- 7.33 Pitch Quoted on Ref Configuration and Layouts is Correct if Measured at Top of Stiffeners
- ET Drawings/Tooling Utilize 7.20 Measured at ISL (2.5° Pitch)

Recommendation

- Revise Method of Dimensioning to Quote Pitch at ISL
Ref Stringer Geometry

Reference: 144 Stringers @ 7.33 Pitch (Measured at Top of Hat)
Proposed: 144 Stringers @ 7.20 Pitch (2.5° Pitch Measured at ISL - Same as ET)
CV-STR-14A
Appendix 4

- Use Of ET Tooling
Study Results

- The Following Tools Can Be Used To Fabricate The Forward Skirt
  - 'C' Frame Riviter
  - 90 degree Frame Segment To 180 degree ET Frame Splice Tool
  - ET Master Drill Jigs (On Major Assembly Tool)
  - Small Tools ie Drill Motors, Slings And Handling Equipment

- 3 New Tools Are Required
  - Fwd Skirt I/F Tool
  - Combined Tack And Final Assembly Tool
  - Systems Installation Tool

- New I/F Tool Can Be Eliminated If Results Of Appendix 1 Are Incorporated
- See Mfg, Tooling And Facilities Trade CV-STR-16 For Further Details
Use Of ET Tooling In F/S Build

Conclusions

- ET Tooling Can Be Used For Some Aspects Of The Fwd Skirt Build
- Depending On Selected Configuration, 2 To 3 New Tools Are Required To Supplement The ET Tooling

Recommendations

- Use ET Tooling As Appropriate To Fabricate Forward Skirt
CV-STR-14A
Appendix 5

Sizing Changes

- Impact Of No TPS
- Stress Analysis
No TPS Impacts

Issue

- Reference Fwd Skirt Does Not Have TPS But Current Fwd Skirt Was Not Designed For Heating Rates Produced During Launch Without TPS.

Impacts

<table>
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<tr>
<th>TPS Thk</th>
<th>Stringer Thk</th>
<th>Skin Thk</th>
<th>Weight Impact</th>
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<tr>
<td></td>
<td>Ref.</td>
<td>Reqd.*</td>
<td>Ref.</td>
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<tr>
<td>.00</td>
<td>.071</td>
<td>.090</td>
<td>.063</td>
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- Total Weight Impact +765lbs

* Based On Remtec Heating Data
No TPS Impacts

Conclusion

- Total Weight Impact Of 765 lbs Required To Withstand Aeroheating Environment Without The Addition Of TPS

See Study CV-STR-14H For Further Details

Recommendation

- Incorporate 1" Of TPS On Fwd Skirt
F/S Alternate Chord Sect'n

Issue

- ET Chord Used On Reference Aft Skirt I/F Is Larger And Heavier Than NLS Structural Requirements Indicated

Objective

- Determine If An Alternate Aft Chord Be Substituted That It Would Result In A Lower Weight
Alternate Chord Section

CV-STR-14A

.380 Dia Hole

1.69

1.11(ET)

.25

.58

.50R

.38

.08

.630 REF

2.50 REF

1.930 (ET)

1.12 (ET)

.460 .440 (ET)

.563 Dia

1.00 R

4.800 (ET)

5.00 REF

NLS Reference F/S I/F Aft Chord
(Similar To ET I/T To LO2 I/F Chord-ET Extrusion 2L1002)

Alternate NLS F/S I/F Aft Chord (New Extrusion)

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Conclusions

- 157 lbs Weight Savings For Alternate Chord
- Alternate Chord Is Feasible And Meets Load Requirements

Recommendation

- Incorporate Alternate Chord In Cycle 1 Baseline
CV-STR-14A
Appendix 6
• Fwd Skirt Part Definition
Fwd Skirt Structural Definition  CV-STR-14A

Shell Definition
- Part Configuration - Recommended Configuration
- Aft Chords
- Panels 1 Thru 8

GO2 P/L Aperture

Frame 1  Xn 2473.8
Frame 2  Xn 2521.8
Chord  Xn 2569.8

130.0 Typ

GO2 Vent Aperture

C/T Aperture

Fwd

ACG92014

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# Fwd Skirt Panel Definition

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<tr>
<th>Part</th>
<th>Title</th>
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<tr>
<td>P1</td>
<td>Panel 1</td>
<td>✔</td>
<td></td>
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<tr>
<td>P1</td>
<td>Panel 2</td>
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<td>Panels 1,2,4,5,7 &amp; 8 Are Identical.</td>
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<td>P1</td>
<td>Panel 4</td>
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<td>P1</td>
<td>Panel 5</td>
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<tr>
<td>P1</td>
<td>Panel 7</td>
<td>✔</td>
<td></td>
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<tr>
<td>P1</td>
<td>Panel 8</td>
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<td></td>
</tr>
<tr>
<td>P-2</td>
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<td>Panel 3 Is Unique. Cutouts For C/T, GO2 Press Line Penetrations Are Located In This Panel.</td>
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<td>The GO2 Ventline Penetration Is Located In Panel 6</td>
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<tr>
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<td>Frame 2473.8</td>
<td>√</td>
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<td>F2</td>
<td>Frame 2521.8</td>
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Candidates For Further Study

- Determine If An External I/F Between Fwd Skirt And Interstage Is Acceptable For Aeroheating
- Redefine Forward Skirt Configuration Based On Results Of This Trade And The Following Related Trades:
  
  CV-STR-14G  External Hardware Definition  
  CV-STR-14H  TPS Reference Definition  
  CV- D1-01B  Alt Trans Attach Points  
  3- S-001A  Alt Panel Construction  
  3- S-001B  Stiffener Pitch Sensitivity  
  3- S-001C  Alt Fwd Skirt Configuration  

- Obtain Better Definition Of P/L Loads And Incorporate Any Load Eccentricities
5.2.3.4.1 Forward Skirt Trade Study (#CV-STR-14A)

Objective

The study evaluated enhancements to the Cycle Ø Reference Forward Skirt structure and recommended potential modifications.

Approach

(a) Obtain Forward Skirt detail definition from MSFC.
(b) Define, evaluate and analyze selected study items.
(c) Identify recommended changes to Ref.configuration.
(d) Produce Forward Skirt part definition.
(e) Identify candidates for further study.

Items Studied

Item 1 - Alternate Fwd Skirt to Interstage I/F concept.
Item 2 - Shell penetration definition.
Item 3 - Potential use of ET tooling to build Fwd. Skirt.
Item 4 - Stringer pitch dimensioning approach.
Item 5 - Sizing changes and impact of no TPS.
Item 6 - Fwd Skirt part definition.

Key Study Results

Five I/F's were developed and compared with the Reference configuration. Option 1 with its external fastener installation and good joint integrity is preferred. It is the lightest option and reduces weight by 443 lbs.
Shell penetrations for GO2 Pressline, cabletray and GO2 vent were investigated. Cabletray and GO2 Pressline penetrations interfere with the intermediate frame and require relocating 1.0 inch forward.
The Fwd Skirt structure can be manufactured on ET intertank tooling with the addition of one new tool for tacking and final assembly (ref 5.2.1.4.3).
Part sizing analysis showed a weight saving of 157 lbs by substituting an alternate aft I/F chord: analysis indicated a weight impact of 764 lbs if the structure is sized as a heatsink to withstand aeroheating without use of TPS (ref 5.2.1.4.2).

Conclusions

Several enhancements to the Cycle Ø Fwd Skirt structure definition were studied. Incorporation of these enhancements will reduce weight by 600 lbs and improve producibility. In addition, the potential use of ET Intertank tooling for Fwd Skirt fabrication was confirmed.

Study Recommendations

The Reference definition should be revised to reflect the enhancements proposed in this study.
- Determine if an external I/F flange is acceptable from a aeroheating aspect.
- Incorporate external I/F between Fwd Skirt and Interstage (Cycle 1 Task).
- Incorporate relocated C/T and GO2 Pressline penetrations.
- Substitute alternate aft chord.
- Incorporate 1” of TPS on Fwd Skirt acreage.
ALTERNATE INTERFACE
Option # 1

Option # 3

Option # 4

Option # 5

ALTERNATE CHORD

\[ \text{.380 DIA HOLE} \]
\[ \text{1.69} \]
\[ \text{1.11 (ET)} \]
\[ \text{.25} \]
\[ \text{.58} \]
\[ \text{.50R} \]
\[ \text{4.25} \]

\[ \text{.630 REF} \]
\[ \text{2.50 REF} \]
\[ \text{1.930 (ET)} \]
\[ \text{1.12 (ET)} \]
\[ \text{.460 Dia} \]
\[ \text{.440 (ET)} \]
\[ \text{.563} \]
\[ \text{1.00 R} \]
\[ \text{5.00 REF} \]
\[ \text{4.800 (ET)} \]

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
6.2.3.4.1 Forward Skirt Trade Study (#CV-STR-14A)

Objective

The study evaluated enhancements to the Cycle Ø Reference Forward Skirt structure and recommended potential modifications.

Approach

(a) Obtain Forward Skirt detail definition from MSFC.
(b) Define, evaluate and analyze selected study items.
(c) Identify recommended changes to Ref.configuration.
(d) Produce Forward Skirt part definition.
(e) Identify candidates for further study.

Items Studied

Item 1 - Alternate Fwd Skirt to Interstage I/F concept.
Item 2 - Shell penetration definition.
Item 3 - Potential use of ET tooling to build Fwd. Skirt.
Item 4 - Stringer pitch dimensioning approach.
Item 5 - Sizing changes and impact of no TPS.
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Five I/F's were developed and compared with the Reference configuration. Option 1 with its external fastener installation and good joint integrity is preferred. It is the lightest option and reduces weight by 443 lbs.

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The Reference definition should be revised to reflect the enhancements proposed in this study.

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- Incorporate relocated C/T and GO2 Pressline penetrations.
- Substitute alternate aft chord.
- Incorporate 1" of TPS on Fwd Skirt acreage.
ALTERNATE INTERFACE

Option # 1

Option # 2

Option # 3

Option # 4

Option # 5

ALTERNATE CHORD

.380 DIA

HOLE

1.69

1.11 (ET)

.25

.38

.58

.50R

.460

.563

Dia

1.00 R

4.25

5.00

(ET)

(ET)

.440

1.12

2.50

1.930

(ET)

(ET)

.630

.125

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
CV-STR-14B
LO2 Tank Structural Reference
Configuration Enhancements

Prepared By: Derek A. Townsend
(504)257-0021

Revision Initial
Date: January 8, 1991

Approved By: M. R. Simms
Objective

- Study & Evaluate Enhancements To The Cycle Ø
Reference LO2 Tank Structure And Recommend Potential Modifications

Approach

- Obtain Detail Definition From MSFC
- Identify Potential Study Items
- Define, Evaluate And Analyze Selected Study Items
- Identify Recommended Changes To Ref. Configuration
- Produce LO2 Tank Part Definition
  - Usage And/Or Similarity Of ET Parts
  - NLS Part Commonality
- Identify Candidates For Study During Cycle 1
Groundrules & Approach  CV-STR-14B

Groundrules

- Tank Structure Definition Per MSFC Reference Layout NLS-0006 Dated 10/9/91
- Mass Properties As Defined On 10/7/91
- Loads & Factors From Memo To P. Thompson From Bart Graham, Dated 5/10/91
Potential Study Items

- Clarification Of Barrel/Frame Geometry Definition
- Substitution Of Alternate Forward Dome Chord
- Definition Of Reference Slosh Baffle
- Definition Of Anti-Vortex Baffle
- Definition Of External Hardware Mtg Provisions
- Evaluation Of Dome Chord/Barrel Weld Land Mismatch
- Level Sensor Mtg Provisions & Installation Approach
- Stress Analysis To Finalize Size & Qty Of Intermediate Frames

Related Tasks (Results Not Incorporated In This Task)

- CV-STR-14G External Hardware Definition
- CV-STR-14H TPS Reference Definition
- CV-STR-16D Transportation & Handling
- CV-DI-01A Tank Access
- 3-S-011 Slosh Baffle Reqmts & Definition
## Recommended Changes

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<th>Study Item</th>
<th>Recommendation</th>
<th>Back Up Data</th>
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Incorp - Now Incorporated In MSFC Baseline Layouts
Accepted - Agreed But Not Yet Incorporated

* Weight Impacts Include 8% Contingency
CV-STR-14B
Appendix 1

• Barrel/Frame Geometry Definition
Proposed Geometry Definition  CV-STR-14B

Note: See Appendix 2 For Further Update To This Proposed Geometry
CV-STR-14B
Appendix 2

• Substitution Of Alternate Fwd Dome Chord & Frame (Including Geometry Update)
Alt. Fwd Dome Chord & Frame  CV-STR-14B

Reference Fwd Dome Chord

Xn 2569.80

10.75

Xn 2576.55

Varies 10.00 To 21.75

- ET LH2 Tank Fwd Dome Chord
- ET LH2 Tank Frame 1129.9
- Fr Installed On Aft Face

Alternate Fwd Dome Chord

Xn 2569.80

9.8

Xn 2571.30

Fr Moved To Fwd Face

10.00 Constant

- ET LO2 Tank Aft Dome Chord With Reduced Weld Lands
- New Frame Based On ET Fr 1129.9 Lwr Segments For Both Upr & Lwr Segments
- Fr Instl On Fwd Face (Mfg Preference)

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Alt. Fwd Dome Chord & Frame  CV-STR-14B

Modified Geometry*

Xn 2569.80

-----------
  9.8
-----------

128.70

-----------
  6.00
-----------

Xn 2852.80

-----------
  9.8
-----------

Xn 2571.30

335

Xn 2643.95

Xn 2711.30

Xn 2778.65

Xn 2851.00

165.50 R OSL (Ref)

* Update Geometry Recommended In Appendix 1 As Illustrated

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DAT.91315
Alt. Fwd Dome Chord & Frame    CV-STR-14B

Results

- Standardizes LO2/LH2 Tank Dome Chords & Frames
- Improves Method Of Frame Assembly
- Potential Weight Savings 50 lbs
- No Major Manufacturing Impacts
- Requires Modified Frame Locations & Barrel Lengths

Recommendation

- Change Fwd Dome Chord & Frame Segments
- Revise Tank Geometry To Accommodated New Chord
CV-STR-14B
Appendix 3

• Definition Of Reference Slosh Baffle Design
Definition

Definition is ET LO2 Tank Baffles "As Is" Configuration & ET Slosh Baffle Usage

Authority Requirements For Slosh considered To Date

Baffle Design
Configurations

Ice "As Is" ET Configuration
- Baffle - Aft Barrel Only
- Baffle - Both Barrel Length

Slosh Baffle Definition For Reference

Slosh Baffle Approach Using Ring Frames
Is Being Studied Under 3-S-011
Damping Criteria

- For This Study Current ET Damping Requirements Were Assumed
  - Slosh Damping Be Provided In The Critical Region When Slosh Mass To Vehicle Mass Ratio Is Greater Than 10%
  - In The Region Where Slosh Mass Is Critical To Control Stability, 1% Of Critical Damping Or Less Is Required
Damping Criteria Explanation

- Simple Single Degree Of Freedom Equation of Motion
  \[ M \ddot{x} + c \dot{x} + kx = F \]
  \[ \text{Natural Frequency} = \omega = \sqrt{\frac{k}{M}} \]
  \[ \text{Critical Damping} = Cr = \frac{2k}{\omega} \]

- Critical Damping physically occurs when there is no resultant oscillation due to an external disturbance

1% damping is actually 1% of critical damping i.e.: \( c = 0.01Cr \)
ET Baffle Definition

Xt 744.85

4.0 Nominal

ET LO2 Tank

Xt 745.10
Xt 780.39
Xt 815.68
Xt 851.00

25.88

322.24 Across Flats

- Designed For 1% Slosh Damping
Opt 1, ET Baffles

Barrel Intermediate Frame Repositioned
4.0 Nominal

Redesigned Intermediate Frames
1.00 Clearance
1.25 Stiffener Height
1.75 Maximum Int. Frs

25.88

322.24 Across Flats

Xn 2745.10
(Was Xn 2746.475)

Xn 2780.39

Xn 2815.68

Xn 2851.00

- Inadequate Damping For Control Authority
- Insufficient Depth Available For Intermediate Frames
- Requires Repositioning Intermediate Frames

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Opt 2 - Extended ET Type Baffles CV-STR-14B

- Extended Length And Reduced Across Flats
- Inadequate Damping For 1.5 Stage
- Provides 1% Damping On HLLV
- Provides For Reference Intermediate Frames
- Across Flats Reduced From 322.24
Opt 3 - Extended ET Type Baffles  CV-STR-14B

- Adequate Damping For 1.5 Stage
- Provides 1% Damping On HLLV
- Provides For Reference Intermediate Frames
- Across Flats Reduced From 322.24
### Option Evaluation

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<th>Opt.</th>
<th>Remarks</th>
<th>Weight Impact</th>
<th>Meets Baffle Reqmts 1.5 Stage</th>
<th>Meets Baffle Reqmts HLLV</th>
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</table>
| 1    | + Uses ET Baffle Assy  
- Minimal Framing Height Available  
- Requires Repositioning Of Int Frames | Ref | No | No |
| 2    | + Can Be Installed Similar To ET  
+ Permits Req'd Intermediate Fr Height  
- Minimal Similarity To ET | 134 | No | Yes |
| 3    | + Permits Req'd Intermediate Fr Height  
- Minimal Similarity To ET  
- Mid Barrel Clipping Required | 774 | Yes | Yes |

- Increased Weights Incl 8% Contingency
- Baffle Requirements Based On NSTS Requirements
Recommendation

Recommendation
- Select Option 3 For Reference Configuration
- Work With Flight Mechanics Team To Finalize Damping Requirements

Study Items Under 3-S-011
- Optimize ET Type Baffle For NLS (Opt 3)
- Common Baffle Design With Unique Applications
  - 1.5 Stage (Full Length Baffle)
  - HLLV (Partial Length Baffle)
- Integral Baffles (Use Of Ring Frames As Baffles)
- Sensitivity Of Baffle Design To Damping Requirements From 1% To 4%
CV-STR-14B
Appendix 4

Definition Of Reference Anti-Vortex Baffle
External H/W Mtg Provisions

**Objective**
- Define Locations For External Hardware Mounting Provisions On The LO2 Tank

**Groundrules (Pending Completion Of CV-STR-14G)**
- Cable Tray/Pressure Line Ftg Interface Locations Are Based On Ref. Geometry
- NLS Cable Tray Size Assumed Double In Volume & Weight To ET Cable Tray
- Cable Tray & Press Line Centerlines In Same Radial Location As ET
External H/W Mtg Provisions  CV-STR-14B

- Cable Tray & Pressure Line Interfaces

External Ftg Attachment
Similer To ET LH2 Tank
Barrel 80914200998-001
(See Drg Sht 5 View C)

2576.55  2851.00

31° 31'

Cable Tray
Size TBD

3.42 Ref

Press Line

1.75 Ref

Barrel ISL

Section A-A

ÇL External Ftg (31°31')

DAT.91315

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MANNED SPACE SYSTEMS
External H/W Mtg Provisions  CV-STR-14B

Recommendation

- Add External Hardware Mtg Provisions To Reference LO2 Tank Definition
CV-STR-14B
Appendix 6

- Chord/Barrel Weld Land Mismatch Evaluation
Aft Chord/Barrel Mismatch

CV-STR-14B

Issue

- Weld Land Mismatch Occurs Between Aft Dome Chord
- Chord Barrel Weld Land = 0.397; Barrel Weld Land = 0.32

Recommendation

- Modify Aft LO2 Tank Barrel Weld Land To 0.387
CV-STR-14B
Appendix 7

• LO2 Tank Part Definition
<table>
<thead>
<tr>
<th>Part</th>
<th>Title</th>
<th>Part Status</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>FD</td>
<td>Fwd Dome Cap</td>
<td>-</td>
<td>Common To NLS LH2 Tank Fwd Dome</td>
</tr>
<tr>
<td>FG1</td>
<td>Dome Gore Plain</td>
<td>-</td>
<td>Similar To ET &amp; NLS Fwd LH2 Dome Gores, With</td>
</tr>
<tr>
<td>FG2</td>
<td>Dome Gore SRB*</td>
<td>-</td>
<td>Membrane Thickness</td>
</tr>
<tr>
<td>FG3</td>
<td>Dome Gore Press</td>
<td>-</td>
<td>Modified For Proof Test Requirements</td>
</tr>
<tr>
<td>FG4</td>
<td>Dome Gore Sensor</td>
<td>-</td>
<td>Requires 2 Feedline Outlets</td>
</tr>
<tr>
<td>FG5</td>
<td>Dome Gore Vent</td>
<td>-</td>
<td>ET LO2 Aft Dome Chord</td>
</tr>
<tr>
<td>AD</td>
<td>Aft Dome Cap</td>
<td>-</td>
<td>Fr Depth Increased To Meet Baffle Definition</td>
</tr>
<tr>
<td>AG1</td>
<td>Dome Gore Frame 2851.0</td>
<td>√</td>
<td>Use LH2 Tank Fr 1377.35</td>
</tr>
<tr>
<td>F1</td>
<td>- Outer Chord</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Frame</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>Frame 2711.775</td>
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* Selected For Commonality With LH2 Fwd Dome
<table>
<thead>
<tr>
<th>Part</th>
<th>Title</th>
<th>Part Status</th>
<th>Remarks</th>
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</table>
| F3   | Frame 2576.55*  
- Outer Chord | - √ - | Use ET Fr 1129.9 |
|      | - Frame Segments | - √ - | Use Frame Opposite To Aft LO2 Fr 2851 For Baffle Support |
| AB1  | Aft Barrel Panel | - - √ | Unique Length Barrel Panel, But Based On ET Type LH2 Machined Barrel Panel |
| AB2  | Aft Barrel Panel | - - √ | Similar To AB1 With C/T & Press Line I/F’s |
| FB1  | Fwd Barrel Panel | - - √ | Similar To AB1 With Unique Membrane Thickness |
| FB2  | Fwd Barrel Panel | - - √ | Similar To AB2 With C/T & Press Line I/F’s |

* Selected For Commonality With LH2 Fwd Dome
<table>
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<th>Part</th>
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<th>Remarks</th>
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<tr>
<td>IF1</td>
<td>Intermediate Fr (Typical 6 Places)</td>
<td>-</td>
<td>Unique Size Intermediate Frame, Similar Construction To ET LH2 Tank Intermediate Frames</td>
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</table>
Candidate Items For Cycle 1

- Resize The LO2 Tank Based On:
  - Cycle 1 Loads
  - Local Impacts On Barrel Of SRB Punch Loads
  - Cycle 1 Ullage Pressure & Associated Proof Test Requirements
  - Cycle 1 Payload I/F Loads (Assumed Equally Distributed For Cycle Ø)
- Optimization Of Intermediate Frame Sizes
- Update Design Definition To Incorporate Results From:
  - CV-STR-14G      External Hardware Definition
  - CV-STR-14H      TPS Reference Definition
  - CV-DI-01A       Tank Access
  - 3-S-010B        Stiffener Pitch Sensitivity
  - 3-S-011         Slosh Baffle Reqmts & Definition
  - A/R             Other Panel Trades (eg. Single LO2 Feedline)
Candidate Items For Cycle 1

- Investigate Barrel Length Requirement & Maximum
  Manufacturing Capability To Permit One Section (Eliminates
  2 Circumferential Welds)
- Impact Assessment Of Using Common Domes In Both
  Tanks
- Consider Use Of ET Aft LH2 Dome Cap Geometry For
  LO2 Aft Dome
5.2.4.4.1 Reference LO2 Tank Enhancements(#CV-STR-14B)

Objective

This study evaluated enhancements to the Cycle Ø Reference LO2 Tank structure and recommended potential modifications.

Approach

(a) Identify potential Study Items.
(b) Define, evaluate and analyze selected Study Items.
(c) Identify recommended changes to the ref.Configuration.
(d) Produce LO2 Tank Part Definition.
(e) Identify candidates for study during Cycle 1.

Items Studied

Item 1 - Revised barrel and frame geometry.
Item 2 - Alternate forward dome chord and frame.
Item 3 - Reference Slosh Baffle definition.
Item 4 - Anti-Vortex Baffle definition.
Item 5 - Definition of external hardware mounting provisions.
Item 6 - Chord to barrel weld land mismatch.
Item 7 - Reference part definition.

Key Study Results

The forward dome chord and frame were designed for Orbiter bi-pod loads and are inefficient for this application. The existing ET slosh baffle assembly will not provide the 1% damping required on NLS and must be extended to a full length baffle, with a subsequent weight impact of 774 lbs. Reference ET anti-vortex baffle must be modified for dual outlets. The aft barrel weld lands must be increased at the aft dome weld joint in order to accommodate the LO2 aft dome chord thickness.

Conclusions

The Cycle Ø definition made use of existing ET assemblies with some modified components, plus common parts from the NLS LH2 tank. LO2 tank weight and manufacturing complexity can be further improved by revising some of these components to better match NLS and LO2 tank sizing requirements. These modified components can still be produced on ET tooling with the minor modifications already identified.

Study Recommendations

The reference Cycle Ø definition should be revised to reflect the enhancements proposed in this study:

- Revise reference definition to use aft chord & frame in forward location.
- Revise reference slosh baffle to proposed full length configuration.
- Include proposed Anti-Vortex Baffle definition.
- Incorporate the proposed definition of external hardware mtg. provisions.
- Increase barrel weld land at dome chord welds to .387.
Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.4.4.1 Reference LO2 Tank Enhancements(#CV-STR-14B)

Objective

This study evaluated enhancements to the Cycle Ø Reference LO2 Tank structure and recommended potential modifications.

Approach

(a) Identify potential Study Items.
(b) Define, evaluate and analyze selected Study Items.
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Item 1 - Revised barrel and frame geometry.
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- Revise reference slosh baffle to proposed full length configuration.
- Include proposed Anti-Vortex Baffle definition.
- Incorporate the proposed definition of external hardware mtg. provisions.
- Increase barrel weld land at dome chord welds to .387.
Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
CV-STR-14C
Intertank Structural Reference Configuration Enhancements

Prepared By: Derek A. Townsend
   (504)257-0021
Carl W Hedden
   (504)257-5507

Rev: Initial
Date: January 8, 1991

Approved By: M. R. Simms

MARTIN MARIETTA
MANNED SPACE SYSTEMS
NLS Intertank Definition  

Objective
- Study & Evaluate Enhancements To The Cycle Ø
- Reference Intertank Structure And Recommend Potential Modifications

Approach
- Obtain Detail Definition From MSFC
- Identify Potential Study Items
- Define, Evaluate And Analyze Selected Study Items
- Identify Recommended Changes To Ref. Configuration
- Produce LO2 Tank Part Definition
  - Usage And/Or Similarity Of ET Parts
  - NLS Part Commonality
- Identify Candidates For Further Study
Groundrules

- For Intertank Structure Definition Use MSFC Reference Layout NLS-0010 Dated 10/22/91
- Mass Properties As Defined On 10/7/91
- Loads & Factors From Memo To P. Thompson From Bart Graham, Dated 5/10/91
Intertank Geometry

CV-STR-14C

- From NLS Reference System Definition, May 91
  - Length 270.35 (LO2 Tank I/F to LH2 Tank I/F)

SRB I/F Ftg
CV-STR-14C

Intertank Geometry

- From Intertank Panel Lead, 10/9/91

Xn 3123.15
LH2 Tank I/F

Xn 3034.2
Xn 3082.0

Xn 2985.675

Xn 2897.1
Xn 2941.4

Xn 2852.80
LO2 Tank I/F

12.00 Typ
4 Frs

165.00 R
ISL (Ref)

20.00

DAT.91...
Potential Study Items

- Frame Mods Due To SRB Beam Omittance For 1.5 Stage
- Shell Penetrations Definition
- Impacts To Ref Of No TPS
- Purge & Vent
- Sizing Changes

Related Tasks (Results Not Incorporated In This Task)

- CV-STR-14G External Hardware Definition
- CV-STR-14H TPS Reference Definition
- 3-S-009 Intertank Configuration & Construction Trade
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</table>

Incorp - Now Incorporated In MSFC Baseline Layouts
Accepted - Agreed But Not Yet Incorporated
CV-STR-14C
Appendix 1

• Fr Xn 2985.675 Mods For 1.5 Stage
Frame Mods For 1.5 Stage CV-STR-14C

Issue
• SRB Beam, Frame Xn 2985.675, And Thrust Panel Have An Integral ± Y Interface. When The SRB Beam Is Omitted For 1.5 Stage These Interfaces Require Mods To The Frame.

The Reference 1.5 Stage Has A 200 lb Weight Impact For Plug Plate & Associated Doublers, But No Allowance Or Details Of The Frame Joint.

Objective
• Define & Evaluate Options To Complete Fr Xn 2985.675 To Thrust Panel Joint
Groundrules & Options

Groundrules
- Intertank/Core Handling Will Not Be At SRB Ftg Interface As ET
- The Reference 1.5 Stage Weight For The GSE Ftgs And Associated Plates & Doubler Is 200 lbs

Options
- Option 1 - Install SRB Ftg Without XBeam
- Option 2 - Install Modified SRB Ftg Removing Beam & SRB I/F's
- Option 3 - New Fabricated Fr/Thrust Panel Joint
- Option 4 - Fabricated Joint With Modified Thrust Panel
Option 1, Omit XBeam

Xn 2985.675/SRB Ftg I/F

New Packing Plate
Gusset
SRB Thrust Fitting
Porkchop Fitting (4)
Thrust Panel
Gusset

Fwd

New Packing Plate

C

D

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Option 1, Omit XBeam

New Packing Plate

Gusset

SRB Thrust Fitting

Porkchop Fitting (4)

Fr 2985.675

Fwd

New Packing Plate

View C-C

Thruster Panel

Gusset
Option 1, Omit XBeam

CV-STR-14C

SRB Thrust Fitting

Thrust Panel

Porkchop Fitting (4)

View D-D Looking Aft

Fr 2985.675
Opt 2, Modified SRB Ftg.  

Xn 2985.675/SRB Ftg I/F

- New Packing Plate
- Modified SRB Thrust Fitting
- Porkchop Fitting (4)
- New Packing Plate
- Thrust Panel
- Gusset

- Machine To Match Thrust Panel Curvature

• Machine Off SRB/SRB Beam Interfaces Not Required
Opt 2, Modified SRB Fig.  

Machine To Match Thrust Panel Curvature  
Modified SRB Thrust Fitting  
Thrust Panel  
Porkchop Fitting (4)  
View F-F Looking Aft  
Fr 2985.675  

MARTIN MARIETTA  
MANNED SPACE SYSTEMS
Opt 3, New Fabricated Joint
CV-STR-14C
Xn 2985.675/SRB Ftg I/F

Plug Machined To Match Thrust Panel Curvature

Pick-Up Existing Hole Patterns

Thrust Panel

Existing Porkchop Fitting Top Only (2)

New Web Splice Plate

Modified Porkchop Fitting

Fwd
Opt 3, New Fabricated JointCV-STR-14C

New Web Splice Plate

New Plug Plate

Existing Upr Porkchop Fitting (2)

Machine To Match Thrust Panel Curvature

New Angle Clip

View H-H Looking Aft

Sect J-J

Fr 2985.675
Opt 4, Modified Thrust Panel  CV-STR-14C

- New Filler Plate
- Existing Upr Porkchop Fitting (2)
- New Web Splice Plate
- Modified Lwr Porkchop Fitting
- Thrust Panel
- SRB Ftg Bearing Hole Omitted From Thrust Panel
- Omit Hole Patterns For SRB Ftg & Gusset Ftgs

Xn 2985.675  Fwd

K  L

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Opt 4, Modified Thrust Panel  CV-STR-14C

Machine To Match Thrust Panel Curvature

New Web Splice Plate

New Filler Plate

Thrust Panel

Existing Upr Porkchop Fitting (2)

Fr 2985.675

Sect M-M

New Angle Clip

View L-L Looking Aft

MARTIN MARIETTA
MANNED SPACE SYSTEMS
<table>
<thead>
<tr>
<th>Opt.</th>
<th>Remarks</th>
<th>Weight Impact*</th>
</tr>
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<tr>
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<td>- Complex Assy</td>
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* 200 lbs Allocated in Ref Config Weights
* Increased Weights Incl 8% Contingency
Recommendation

Recommendation

- Incorporate Option 3 Into Reference Definition Of 1.5 Stage Intertank

Items For Further Study

- More Producible SRB Beam to Panel/Frame Attachment for HLLV I/T
- Unique Thrust Panel Design for 1.5 Stage I/T
CV-STR-14C
Appendix 2

- Intertank Shell Penetrations
LO2 Feedline Penetration  

Objective

- Assess LO2 Feedline Intertank Penetration Clearances, and Define Any Structural Impacts

Groundrules

- NLS Feedline Geometry Definition Via Telephone And Per Fax Dated November 15, 91 From Dick Cloyd To Carl Hedden

Assumptions

- Feedline Material As ET
- Feedline Wall Thickness
  - Elbow .058 - .080
  - Downcomer .050 Stock
  - Internal Duct .062
- Elbow TPS Thickness .62 ±.25
LO2 Feedline Penetration  

Issues

- Feedline Clearances With Frames & Skin Cutout
- Static (Ambient Manufacturing Tolerances)
- Thermal (LO2 Fill 1st; LH2 Fill 1st; Cryo Filled)
- Loads
- Dynamic (In Flight)
Feedline Loads & Dynamics  CV-STR-14C

Displacements At Intertank Penetration

Forward Displacements
- Manufacturing & Installation
- Thermal
  - LH2 Fill First
- Static Loads
  - LO2 Fill
- Aero Loads
- Dynamic Loads
  - Lift Off
  - Max g
- LO2 Aft Dome Displacement

Aft Displacements
- Manufacturing & Installation
- Thermal
  - LO2 Fill First
- Dynamic Loads
- LH2 Dome Displacement

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ET L02 F/L Geometry

CV-STR-14C

Max Fwd Loc
Max Aft Loc

Nominal Feedline Clearance

* Derived from L02 F/L Motion Study 1-27-86
† Worst Case Thermal Displacement During Fill

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NLS LO2 Feedline Geom.  CV-STR-14C

Nominal Penetration/Feedline Clearance

MSFC Supplied

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MANNED SPACE SYSTEMS
NLS LO2 F/L Penetration

Thermal Displacements

LH2 Fill 1st = 3.982 Fwd*

Xn 2985.675

14.910

10.928 (Min)

Xn 3034.2

CL

4.66

3.114 Nominal Clearance

.322 Interference

L02 Fill 1st = 3.436 Aft*

MSFC Supplied

* = Thermal Displacement at Fill

Interference Exist With Only Thermal Displacement Applied

DAT.91345

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NLS LO2 F/L Penetration

Feedline Centralized For Max Clearances

Xn 3009.3
(was 3016.9)

Xn 3034.2

Xn 2985.675

CL

7.3 Nominal Clearance

Reduced from X° to Y°

7.3 Nominal Clearance

• This Option Shows Approximate Feedline Location To Give Maximum Fwd & Aft Clearance
Conclusions

- The Reference Configuration LO2 Feedline Will Interfere With The Cutout Aft Intertank Structure With Only Thermal Displacements Applied
- To Avoid Major Mods To Fr 3034.2 The Feedline Geometry Must Be Modified To Better Center The Feedline Between The Two Adjacent Frames
- ET Studies Conclude That The Maximum Thermal Displacements Can Be Up To 5.0 Aft/4.0 Fwd & Occur During Tanking Only. NLS Displacements Will Be Larger Due To Increased Length Of Feedline & 1.5 Stage Loading Conditions.
- ET Worst Case Manufacturing Tolerances Can Further Reduce Clearances By 3.0 Aft & 2.0 Fwd

CV-STR-14C
LO2 Feedline Penetration

Items For Further Study

- Reassess Situation Based On Selected Cycle 1 Feedline Configuration
- Detailed Feedline Motion Study
CV-STR-14C
Appendix 3

• Intertank Impacts Of No TPS
No TPS Impacts

Issue
- Reference Intertank Does Not Have TPS But Current Intertank Was Not Designed For Heating Rates Produced During Launch Without TPS.

Impacts

<table>
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<th>Skin Thk</th>
<th>Weight Impact</th>
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<tr>
<td>.00</td>
<td>.071</td>
<td>.090</td>
<td>.150</td>
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- Total Weight Impact -172 lbs

* Based On Remtec Heating Data (Fwd Skirt Body Point Used Due To No Suitable Intertank Body Point)

§ Minimum Required For Heat Sink Design Based On Assuming .100 Skin Thickness Required For Loads. Revised Weight Impact Would Include An Additional 413 lbs (.100 To .120)
Intertank Purge & Vent

Issue

• The Intertank Venting is Passive and Controlled by 2 Forward Aerovents and the Orifices around the Subsysyem Penetrations. The Reference Intertank has 2 Feedline Fairings for 20" LO2 Feedlines compared to the Single 17" LO2 Feedline on ET

Requirements

• No Air Intrusion During Ascent
• LH2 Dome Limit .21 psid
• Maintain O2 Level Below 4%
• Nitrogen Mass Flow Rate from Launch Complex GSE is Limited to 110-134 Lbs/Min

MARTIN MARIETTA
MANNED SPACE SYSTEMS
## Intertank Purge & Vent

**CV-STR-14C**

- **Total ET Intertank Vent Area**

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**60 Sq In Mean Total Vent Area**
Intertank Purge & Vent

Fairing/Feedline Clearances

- After the Seal instl the actual gap is measured in 30 places as above. The gap must meet the following requirements:
  - Average of the 30 gap measurements must be within range .616 to .677 inches
  - Any gap measurement may be less than basic dimension by .10 inches max.
  - Any gap may exceed the basic dim as long as the vent area req is met.

F/L with TPS

LO2 F/L Fairing

Clearance Maintained & Measured at 30 Locs Shown Varing from .200 To 1.170.

Seal

TFE Plastic Sheet

.200 Ref

1.170 Ref

MARTIN MARIETTA
MANNED SPACE SYSTEMS
## Intertank Purge & Vent

- Approx. NLS Reference Intertank Vent Area

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<tr>
<td><strong>Total</strong></td>
<td><strong>94.68</strong></td>
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</table>
Intertank Purge & Vent

Conclusions

- Current ET Vent Arrangement Requires Improvement
  - Labor Intensive Operation
  - High MRB Action
- To Maintain Vent Area To ET Values Will Reduce Gap Between Feedline And Seal
- To Maintain ET Dimensions Between Feedline And Seal May Impact Launch Complex GSE
- NLS Cp Profile Will Differ From ET - Will Result In Different Flight $\Delta p$'s
Intertank Purge & Vent

CV-STR-14C

Recommendation

- Evaluate Alternate Methods Of Providing Appropriate Vent Area (e.g. Flex Seal Between Feedline And I/T With Fixed Aerovents)
- Perform A Venting Analysis To Determine Purge Requirements
CV-STR-14C
Appendix 5

• Intertank Sizing Modifications
Intertank Sizing Mods

CV-STR-14C

- Panel Skin Thickness Can Be Significantly Reduced To Approximately .10 With TPS or .12 Bare
  - Weight Impact To Skin; 618 lbs Bare or 1031 lbs + TPS
- Stiffener Thickness Of .071 Must Be Increased To .090 If Intertank Has No TPS

Item For Further Study

- Evaluate Panel Fore & Aft Attach Flanges For Potential Loads Greater Than ET
CV-STR-14C
Appendix 6

- Intertank Part Definition
Intertank Part Definition

CV-STR-14C

B1

Fwd

P1b P5 P4 P2 P1 P3 P4

Y+ Y- Z+

F1 F2 F3 F4 F5

DAT.91345

417
# Intertank Part Definition

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<td>F3</td>
<td>Frame 2985.675</td>
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<td>F4</td>
<td>Frame 3034.2</td>
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<td>Resized For NLS Loads</td>
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<td>Panel</td>
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<td>P3</td>
<td>Panel</td>
<td>-</td>
<td></td>
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<tr>
<td>P4</td>
<td>Thrust Panel (±Y)</td>
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<td>1.5 Stage Modified To Omit SRB Ftg Hole</td>
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<tr>
<td>P5</td>
<td>Panel</td>
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<tr>
<td>B1</td>
<td>SRB Beam</td>
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<td>HLLV Only</td>
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* 1.5 Stage Only
Candidate Items For Cycle 1  CV-STR-14C

- Resize The Intertank Based On Cycle 1 Loads
- Perform A Frame/SRB Interface Beam Producability Study
- Evaluate Alternate Methods Of Controlling LO2 Feedline Vent Area
- Re-evaluate Feedline Penetration Study Based On Selected Cycle 1 Feedline Configuration
- Perform A Detailed Feedline Motion Study Once Configuration Is Finalized
- Evaluate Alternate Thrust Panels For 1.5 Stage Intertank
- Update Design To Incorporate Results From:
  - CV-STR-14G  External Hardware Definition
  - CV-STR-14H  TPS Reference Definition
  - 3-S-009A  Intertank Commonality Assessment
  - A/R  Other Panel Trades (e.g. Single LO2 Feedline)
5.2.5.4.1 Reference Intertank Enhancements(#CV-STR-14C)

Objective

This study evaluated enhancements to the Cycle 0 Reference Intertank structure and recommended potential modifications.

Approach

(a) Identify potential Study Items.
(b) Define, evaluate and analyze selected Study Items.
(c) Identify recommended changes to the ref.Configuration.
(d) Produce Intertank Part Definition.
(e) Identify candidates for study during Cycle 1.

Items Studied

Item 1 - 1.5 Stage frame 2985 modifications.
Item 2 - Shell penetrations definition.
Item 3 - Impacts to reference for no TPS.
Item 4 - Purge and vent.
Item 5 - Sizing changes.
Item 6 - Reference part definition.

Key Study Results

The main frame, thrust panel, & ASRB Beam have an integral I/F. When the SRB Beam is omitted (1.5 Stage vehicle) the simplest option is to complete the I/F with a new fabricated joint. The LO2 feedline penetration was found to interfere with the panel cutout when thermal displacements were applied; clearance could be achieved by relocating the feedline to center it in the cutout. The reference skin/stringer panels were resized for a net impact of -172 lbs. The feedline fairing is used on ET intertanks as the primary vent area. On NLS the two larger LO2 feedline fairing outlets will double the venting area if ET type clearances are maintained. This requires a modified design to reduce the venting area or a modification to the launch facility to increase the purge gas capacity.

Conclusions

Several enhancements to the Cycle 0 intertank definition were studied. The proposed modifications do not impact use of ET tooling. In addition, further potential enhancements were identified for study during Cycle 1.

Study Recommendations

The reference definition should be revised to reflect that proposed in this study.

- Revised the 1/f/ASRB Beam I/F to the new fabricated joint.
- Center the LO2 feedline within the cutout and study the feedline motion (Cycle 1 task).
- Redefine the skin/stringer sizing (Cycle 1 task).
- Study alternate methods of sealing the LO2 feedline penetrations and potential for a fixed vent area (Cycle 1 task).
New Fabricated Frame/Thrust Panel Joint (1.5 Stage Only)

**Existing Hole Pattern**

**New Lower Fitting**

- New Web Joint Plate
- Existing Hole Pattern
- Thrust Panel
- New Plug Plate

**New Fabricated Frame/Thrust Panel Joint (1.5 Stage Only)**

Xn 3034.2

LH2 Fill 1st =
3.982 Fwd*
Xn 2985.675

10.928 (Min)

.322 Interference

**L02 Fill 1st =
3.436 Aft***

*Thermal displacement

Reference L02 Feedline Penetration

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<th>Maintain ET Vent Area</th>
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<td>LH2 Tank Elect. Conduit Opening</td>
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<td><strong>Total</strong></td>
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**NLS Intertank Vent Area**

**Additional Information**
See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.5.4.1 Reference Intertank Enhancements(#CV-STR-14C)

Objective

This study evaluated enhancements to the Cycle Ø Reference Intertank structure and recommended potential modifications.

Approach

(a) Identify potential Study Items.
(b) Define, evaluate and analyze selected Study Items.
(c) Identify recommended changes to the ref.Configuration.
(d) Produce Intertank Part Definition.
(e) Identify candidates for study during Cycle 1.

Items Studied

Item 1 - 1.5 Stage frame 2985 modifications.
Item 2 - Shell penetrations definition.
Item 3 - Impacts to reference for no TPS.
Item 4 - Purge and vent.
Item 5 - Sizing changes.
Item 6 - Reference part definition.

Key Study Results

The main frame, thrust panel, & ASRB Beam have an integral I/F. When the SRB Beam is omitted (1.5 Stage vehicle) the simplest option is to complete the I/F with a new fabricated joint. The LO2 feedline penetration was found to interfere with the panel cutout when thermal displacements were applied; clearance could be achieved by relocating the feedline to center it in the cutout. The reference skin/stringer panels were resized for a net impact of -172 lbs. The feedline fairing is used on ET intertanks as the primary vent area. On NLS the two larger LO2 feedline fairing outlets will double the venting area if ET type clearances are maintained. This requires a modified design to reduce the venting area or a modification to the launch facility to increase the purge gas capacity.

Conclusions

Several enhancements to the Cycle Ø intertank definition were studied. The proposed modifications do not impact use of ET tooling. In addition, further potential enhancements were identified for study during Cycle 1.

Study Recommendations

The reference definition should be revised to reflect that proposed in this study.
- Revised the fr./ASRB Beam I/F to the new fabricated joint.
- Center the LO2 feedline within the cutout and study the feedline motion (Cycle 1 task).
- Redefine the skin/stringer sizing (Cycle 1 task).
- Study alternate methods of sealing the LO2 feedline penetrations and potential for a fixed vent area (Cycle 1 task).
New Fabricated Frame/Thrust Panel Joint (1.5 Stage Only)

LH2 Fill 1st =
3.982 Fwd*
Xn 2985.675

L02 Fill 1st =
3.436 Aft*

* Thermal displacement
Reference LO2 Feedline Penetration

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<td><strong>Total</strong></td>
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NLS Intertank Vent Area

Additional Information
See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
CV-STR-14D
LH2 Tank Structural Reference Configuration Enhancements

Prepared By: Derek A. Townsend
(504)257-0021
Carl Hedden
(504)257-5507

Rev: Initial
Date: January 8, 1991

Approved By: M.R. Simms
NLS LH2 Tank Definition  CV-STR-14D

Objective
- Study & Evaluate Enhancements To The Cycle Ø
Reference LH2 Tank Structure And Recommend Potential Modifications

Approach
- Obtain Detail Definition From MSFC
- Identify Potential Study Items
- Define, Evaluate, And Analyze Selected Study Items
- Identify Recommended Changes To Ref. Configuration
- Produce LH2 Tank Part Definition
  - Usage And/Or Similarity Of ET Parts
  - NLS Part Commonality
- Identify Candidates For Study During Cycle 1
Approach & Groundrules

Groundrules
- Tank Structure Definition Per MSFC Reference
- Layout NLS-0005 Dated 10/9/91
- Mass Properties As Defined On 10/7/91
- Loads & Factors From Memo To P. Thompson From Bart Graham, Dated 5/10/91
Potential Study Items

- Barrel/Frame Geometry Definition
- Alternate Forward Dome Chord & Frame
- External Hardware Interfaces
- Dome Chord/Barrel Weld Land Mismatch
- Handling Points Required By CV-STR-16D
- Alt Aft Dome Gore Configuration
- SRB Interfaces
- RSS Interfaces & Intallation
- Level Sensor Interfaces & Installation
- Frame Stablizer Configuration
- Size & Qty Of Intermediate Frames
- Barrel 1A Impacts From PM Assessment
- Vortex Baffle Definition
Related Tasks

- CV-STR-14G
- CV-STR-14H
- CV-STR-16D
- CV-DI-01A

External Hardware Definition
TPS Reference Definition
Transportation & Handling
Tank Access
## Recommended Changes

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Incorp - Now Incorporated In MSFC Baseline Layouts  
Accepted - Agreed But Not Yet Incorporated

* Weight Impacts Include 8% Contingency

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MANNED SPACE SYSTEMS
CV-STR-14D
Appendix 1

- Barrel/Frame Geometry Definition
Alternate Geometry Definition CV-STR-14D

Potential Enhancements

- Standardize Barrels And Frames
- Resolve Barrel 1A Geometry Mismatch
- Make 4058 Outer Chord Cross Section Symmetrical

Approach

- Modify Frame 3871 To Be Similar To Frs 3377.35 & 3623.8
  - ET Deep Fr Not Required
- Change Barrel 2 Length To 240.45" As Barrels 3 & 4
  - Common Barrel Panels
- Change Frame 3871 To 6.0" Wide As Frs 3377.35 & 3623.8
  - Common Frames
- Modify Barrel 1 Length To 179.25"
  - Unique Barrel From ET Could Modify Easily
- Select Width For Fr 4058 And Adjust Barrel 1A Length
Ref Geometry Definition

Unique Panel Length

Xn 3123.15
240.45
10.75
6.00
Xn 3129.9
Xn 3377.35

240.45
6.00
Xn 3623.8

240.2
8.00
177.500
11.394
5.50
Xn 3871

Unique Frame Width

Xn 4122.65
48.950
9.8

165.50 R OSL (Ref)
623.15 By Datum
63.144 By Dimn

Xn 4058

Geometry Will Not Add Up In This Area

2 Standard Barrels & Frames

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DAT.91269
Alternate Geometry Definition  CV-STR-14D

Modified

3 Standard Barrels & Frames

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Recommendation

Potential Enhancements

- Barrel Commonality Can Be Improved By Revising Geometry (Barrel 2 Can Be Common To Barrel 3 & 4)
- Frame 3377.35 Can Be Identical To Frames 3623.8 & 3871
- Frame 4058 Can Be Symmetrical (11.0 Wide)

Recommendation

- Use New Geometry, Frames & Barrels
CV-STR-14D
Appendix 2

- Substitution Of Alternate Fwd Dome Chord & Frame (Including Geometry Update)
**Alt. Fwd Dome Chord & Frame**  
**Reference Fwd Dome Chord**

- ET LH2 Tank Fwd Dome Chord
- ET LH2 Tank Frame 1129.9
- Fr Installed On Aft Face

- Xn 3123.15
- 10.75
- Xn 3129.9
- Varies 10.00 To 21.75

**Alternate Fwd Dome Chord**

- ET LO2 Tank Aft Dome Chord With Reduced Weld Lands
- New Frame Based On ET Fr 1129.9 Lwr Segments For Both Upr & Lwr Segments
- Fr Instl On Fwd Face (Mfg Preference)

- Xn 3123.15
- 9.8
- Xn 3124.65

**Fr Moved To Fwd Face**

- 10.00 Constant
Alt. Fwd Dome Chord & Frame  CV-STR-14D

Modified Geometry

Modified Geometry Will Still Permit Increased Barrel Commonality Recommended By Appendix 1
Alt. Fwd Dome Chord & Frame  CV-STR-14D

Results

- Standardizes LO2/LH2 Tank Dome Chords & Frames
- Improves Method Of Frame Assembly
- Potential Weight Savings 50 lbs
- No Major Manufacturing Impacts
- Requires Modified Frame Locations & Barrel 1 Length

Recommendation

- Change Fwd Dome Chord & Frame Segments
- Revise Tank Geometry To Accommodated New Chord
CV-STR-14D
Appendix 3

• External Hardware Interface Definition
External H/W Mtg Provisions  CV-STR-14D

Objective
- Define Locations For External Hardware Mounting Provisions On The LH2 Tank

Groundrules (Pending Completion Of CV-STR-14G)
- Cable Tray/Pressure Line Ftg Interface Locations Are Based On Ref. Geometry
- NLS Cable Tray Size Assumed Double In Volume & Weight
- Cable Tray & Press Line Centerlines In Same Radial Location As ET
- LO2 Feedlines Assumed On ± Z Axis
External H/W Mtg Provisions

Cable Tray/Pressure Line Interfaces

External Ftg Attachment
Similar To ET LH2 Tank Barrel 80914200998-001
(See Drg Sht 5 View C)

Ext Ftg Locations:
Barrel 1a = Xn 4092.6
Barrel 1 = Xn 4028, Xn 3960.8, Xn 3916.2
Barrel 2 = Xn 3851.6, Xn 3787, Xn 3722.4, Xn 3657.8
Barrel 3 = Xn 3593.2, Xn 3528.6, Xn 3464, Xn 3399.4
Barrel 4 = Xn 3334.8, Xn 3270.2, Xn 3205.6, Xn 3151.84

Fwd

+Z

Section A-A
(Typ)

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External H/W Mtg Provisions  CV-STR-14D

- Locations On ±Z, Based On Reference Geometry

LO2 Feedline ± Z Axis

LO2 Feedline Support

Xn3129.9  Xn3377.35  Xn3623.8  Xn3871.0  Xn4121.15

Dome Chord Feedline

Frame Feedline Support Interface Similar To
Support Interface Similar To
80914500961 Sh 4 View R Fr Xn3377.35
8091450097 Sh 15 View V
80914500961 Sh 13 View BL Frs Xn3623.8 & Xn3871

331.0 O/D

DAT.91269

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External H/W Mtg Provisions  CV-STR-14D

Modify The Dome Gores To Provide Mtg Provisions (Similar To ET)

LO2 Cable Tray
GO2 Press Line 2.0 ID
GO2 Vent/Relief Valve
GO2 Vent/Relief Line
LH2 Fwd Dome Looking Aft

GO2 Press Line Support, For Mtg Provisions See Drg 80914160981

GO2 Vent/Relief Line Support, For Mtg Provisions See Drg 80914160984

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External H/W Mtg Provisions CV-STR-14D

Recommendation

- Add External Hardware Mtg Provisions To Reference LH2 Tank Definition
CV-STR-14D
Appendix 4

- Chord/Barrel Weld Land Mismatch Evaluation
LH2 Tank Structural Definition  CV-STR-14D

Issue

- LH2 Aft Dome Utilizes A LO2 Aft Dome Chord
- Weld Land Mismatch Occurs Between Chord And LH2 Barrel 1A & Dome Gores
  - Chord Gore Weld Land = .330; Gore Weld Land = .200
  - Chord Barrel Weld Land = .397; Barrel Weld Land = .320

Recommendation

- Modify ET Aft LO2 Tank Chord 80912640001-001 By Machining Gore Weld Land To. 210 And Barrel Weld Land To .330
CV-STR-14D
Appendix 5

- Transportation & Handling Point Interfaces
LH2 Tank Handling Point I/F's  CV-STR-14D

Objective
- Define LH2 Tank Transportation & Handling Interfaces

Approach
- Obtain Transportation & Handling Locations Defined By Trade Study CV-STR-16D
- Define, Evaluate & Analyze Handling Interfaces
- Identify Tank Part Impacts
- Recommend Selected Interface Configuration
LH2 Tank Handling Points I/F's CV-STR-14D

- Transportation & Handling Point Locations Defined By CV-STR-16D

Fwd Loc'ns Used For Core Tankage Handling, Aft Loc'ns Used For LH2 Tank Handling Only

* Approx. Stringer Locations
+Z Handling Point I/F's

Xn 4018 Approx CL Interm. Fr

5.416 Ref

CL Stringer

Xn 4058

Xn 4098 Approx CL Interm. Fr

Weld

Additional I/F Locn's

See Detail B

Fwd

I/F Locn's Pattern Per ET Drg 80914961960 Sh 4 View C

View 1 (Shown)

View 2 (Opposite)

(Handling Tools Not Shown For Clarity)
Fwd Handling Point I/F's

Handling Tool/Barrel I/F Locn's (4)

Handling Tool I/F Locn's

See Detail C 2 PL

CL Stringer

Tapped Holes for 34L2-5

Xn 4018 Aprox

2.50

Section A-A Rotated

CL Stringer

CL Stringer

Detail C

(Handling Tool Not Shown For Clarity)

MANNED SPACE SYSTEMS
Aft Handling Point I/F's

Tool I/F Hole Pattern To Match Fr 4058

Handling I/F Adapter Tool (Ref)

CL Stringer

CL Stringer

Section D-D

Shear Hole .75 Dia

Sloted Hole .75 Radius

Tapped Holes for 34L2-5 (4 PL)

Detail B Rotated (Handling Tool Not Shown For Clarity)

CV-STR-14D
-Z Aft Handling Point I/F

Tool I/F Hole Pattern To Match Fr 4058

Shear Hole .75 Dia

Sloted Hole .75 Radius

Fwd

Xn 4098 Approx

Tapped Holes for 34L2-5 (4 PL)

Detail E

Hole Pattern Drilled After Assy Weld
(Handling Tool Not Shown For Clarity)

Section F-F

Handling I/F
Adapter Tool (Ref)

- Z

CL Stringer

CL Stringer

1.0 Ref

F

2.75

DAT.91269

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LH2 Tank Handling Points

Barrel Panel Commonality Impacts

Modified Panels

CV-STR-14D
LH2 Tank Handling Points

**Recommendation**

- Incorporate The Transportation & Handling Points As Configured By This Study
CV-STR-14D
Appendix 6

- Alternate Aft Dome Configuration
Alternate Aft Dome Config.  

+Z  Gores Designed By Orbiter Loads (3 Types)  +Z  Common To -Z

NLS Ref  
- ET Aft Dome Except Substitution Of Feedline Outlet Gore  
- Contains 5 Unique Gores  
- 3 Gores Designed By Orbiter Loads

Alt. Configuration  
- 1/4 Panel Assy Common With ET -Z  
- 1/4 Panels  
- Contains 2 Unique Gores

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MANNED SPACE SYSTEMS

DAT.91269
Recommendation

Recommendation
- Use -Z Quarter Panels In Place Of +Z

Item For Further Study
- Analyze ± Y Gores For SRB Load Impacts To Determine
  If All Gores Can Be Common
- 5 ft Stretch Isolates Dome From SRB Loads
CV-STR-14D
Appendix 7

• Fwd Sensor Installation
Fwd Sensor Installation

Issue

- Limited Access To LH2 Tank Fwd Dome After Core Stacking And Installation Of Feedlines Will Make LH2 Tank Entry To Install Or Rework LH2 Fwd Dome Level Sensors Difficult.

Objective

- To Develop A Concept To Install/Rework LH2 Level Sensors Not Requiring Tank Access
Fwd Sensor Instn Options

Reference - ET Mast

Option 1 - Single Dome Cap Stinger
Option 2 - Dual Stingers, Additional Radial Stinger In Gore
Option 3 - Dual Stingers, Gore Stinger With Vertical Instln
Option 4 - Dual Stingers, With Additional Access
Option 5 - Triple Stingers, With Additional Access
Option 6 - Dual Stingers, Additional Angled Stinger In Gore
Ref. Config. Fwd Sensor Mtg.  CV-STR-14D

Liquid Level Sensors  (7)
Sta 3033.4  Overfill
  3040.6  100% +
  3044.6  100%  (2)
  3048.6  100% -
  3102.1  98%  (2)

Ullage Temp Sensor
Sta 3035.0

Requires Internal Access for Installation & maintenance

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Opt 1 Fwd Sensor Config.

- Single Stinger
- Location Based On Utilizing Existing Feedthru Plate Location

CV-STR-14D

Sta 3033.4
3035.0
3040.6
3044.6
3048.6

LO2 Aft Dome
LH2 Fwd Dome

Withdrawn Position

Sta 3102.1

87.0

Stinger

Feed-through Plate

Liquid Level Sensors (7)
Sta 3033.4 Overfill
3040.6 100% +
3044.6 100% (2)
3048.6 100% -
3102.1 98% (2)

Ullage Temp Sensor
Sta 3035.0

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Opt 2 Fwd Sensor Config.

- Dual Stinger
- 100% Sensor Utilizes Existing Feedthru Plate Location
- 98% Sensor Located On Unique Stinger
Opt 3 Fwd Sensor Config.

- Dual Stinger
- 100% Sensor Utilizes Existing Feedthru Plate Location
- 98% Sensor Located On Unique Stinger
Opt 4 Fwd Sensor Config.

- Dual Stinger
- 100% Sensor Utilizes Existing Feedthru Plate Location
- 98% Sensor Located On Unique Stinger
Opt 5 Fwd Sensor Config.

- Triple Stinger
- Overfill Sensor Utilizes Existing Feedthru Plate Location
- 100% & 98% Sensor Located On Unique Stingers

Liquid Level Sensors

- Sta 3033.4 Overfill
  - 3040.6 100% +
  - 3044.6 100% (2)
  - 3048.6 100% -
- Sta 3102.1 98% (2)

CV-STR-14D

MARTIN MARIETTA
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Opt 6 Fwd Sensor Config.  

- Dual Stinger  
- 100% Sensor Utilizes Existing Feedthru Plate Location  
- 98% Sensor Located On Unique Stinger  

CV-STR-14D  

Liquid Level Sensors (7)  
- Sta 3033.4 Overfill  
  3040.6 100% +  
  3044.6 100% (2)  
  3048.6 100% -  
  3102.1 98% (2)  

Ullage Temp Sensor  
- Sta 3035.0

Stinger

Feed-through Plate

Sta 3033.4
3035.0
3040.6
3044.6
3048.6

LO2 Aft Dome

Withdrawn Position

I/T

24.0

LH2 Fwd Dome

Sta 3102.1

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Fwd Sensor Mounting

- Optional Tripod Support

LH2 Fwd Dome

Sensors

Stinger

Support Bearing

Tripod Support Installed Prior To Tank/Intertank Mate

Attach Brackets Welded To Fwd Dome Cap

Tripod Attached to Inside of Dome Cap
# Fwd Sensor Instn Evaluation

## CV-STR-14D

<table>
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<th>Options</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Ref</td>
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</table>
| Instl & Service       | - Tank Access Reqd.  
- Difficult After Stacking  |
| Penetrations          | - Existing Feed Thru                                                    |
|                       | **1**                                                                 |
|                       | - No Tank Access Reqd.  
- Can Not Instl/Service After Stacking  |
|                       | **2**                                                                 |
|                       | - No Tank Access Reqd.  
- 2nd Instl Thru I/T Acess Door  |
|                       | **1 In Dome Cap**  
- Additional 1 In Gore  |
|                       | **1 In Dome Cap**  
- Additional 1 In Gore  |
|                       | **1 In Dome Cap**  
- Additional 1 In Gore  |
| Tank Impacts          | **Reference**                                                          |
|                       | **Modified Dome Cap & Gore**                                           |
| Design Integrity      | **Uses ET Mast Assy**                                                  |
|                       | **87" Stinger Difficult To Design With Adequate Stiffness**            |
|                       | **65" Stinger Difficult To Design With Adequate Stiffness**            |
| Weight Impact         | **Reference**                                                          |
|                       | 6 lbs                                                                 |
|                       | 15 lbs                                                                 |

### Major Impacts

- Increased Weights Incl 8% Contingency
## Fwd Sensor Instn Evaluation

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<td>Instl &amp; Service</td>
<td>+ No Tank Access Req'd.</td>
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<td></td>
<td>• Additional Access Thru A 2nd I/T Door</td>
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<td>Penetrations</td>
<td>• 1 In Dome Cap</td>
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<td>• Additional 1 In Gore</td>
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<td>Tank Impacts</td>
<td>• Modified Dome Cap &amp; Gore</td>
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<td></td>
<td>• Additional I/T Access Door Req'd</td>
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<tr>
<td>Design Integrity</td>
<td>• 34&quot; Stinger May Require Stabilizer Suppt</td>
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<td>• Complex Gore Ftg Reqd</td>
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<tr>
<td>Weight Impact</td>
<td>19 lbs</td>
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**Major Impacts**
- Increased Weights Incl 8% Contingency
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<th>Options</th>
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<td>Instl &amp; Service</td>
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<tr>
<td>+ No Tank Access Req'd</td>
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<tr>
<td>- Difficult To Gain Access For Instl</td>
<td></td>
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<tr>
<td>Penetrations</td>
<td></td>
</tr>
<tr>
<td>- 1 In Dome Cap</td>
<td></td>
</tr>
<tr>
<td>- Additional 1 In Gore</td>
<td></td>
</tr>
<tr>
<td>Tank Impacts</td>
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</tr>
<tr>
<td>- Modified Dome Cap &amp; Gore</td>
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<tr>
<td>Design Integrity</td>
<td></td>
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<tr>
<td>- 34&quot; Stinger May Require Stabilizer Suppt</td>
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</tr>
<tr>
<td>Weight Impact</td>
<td>6 lbs</td>
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Major Impacts
Conclusions

- Option 1 Stinger Interferes With LO2 Aft Dome In The Withdrawn Position
- Option 2 Gives The Best Access During Installation & Removal
- Option 3 Has A Very Complicated Gore Fitting For Vertical Installation
- Options 4 & 5 Require An Additional Intertank Access Door In Close Proximity To The Intertank/LH2 Tank Bolted Interface
- Option 6 Gives The Least Design Impacts But Is Difficult To Install
Recommendation

- Incorporate Option 2 As Reference

Items For Study In Cycle 1

- Establish Sensor Requirements & Locations
  - Can 98% Fill Be Changed To 99%
  - 100% Fill Level For NLS To Be Defined
- Re-evaluate Options Based On Cycle 1 Sensor Locations
CV-STR-14D
Appendix 8

- LH2 Tank Part Definition
LH2 Tank Dome Configurations CV-STR-14D

- Part Definition

![Diagram of LH2 Tank Dome Configurations]

- Fwd Dome
  - +Z: FG3, FG1, FG1
  - -Z: FG1, FG2, FG1
  - +Y: FG4, FG1
  - -Y: FG1

- Aft Dome
  - +Z: AG1, AG1, AG2, AG3, AG4, AG4
  - -Z: AG5, AG1, AG2, AG3, AG4, AG4
  - +Y: AG5, AG3, AG3
  - -Y: AG3
# LH2 Tank Dome Part Definition CV-STR-14D

<table>
<thead>
<tr>
<th>Part</th>
<th>Title</th>
<th>Part Status</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>FD</td>
<td>Fwd Dome Cap</td>
<td>-</td>
<td>Common To NLS LO2 Tank Fwd Dome</td>
</tr>
<tr>
<td>FG1</td>
<td>Dome Gore Plain</td>
<td>-</td>
<td>Similar To ET Fwd LH2 Dome &amp; NLS Fwd LO2 Dome Gores, With Membrane Thickness Mod For Proof Test Reqmts</td>
</tr>
<tr>
<td>FG2</td>
<td>Dome Gore SRB</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>FG3</td>
<td>Dome Gore Press</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>FG4</td>
<td>Dome Gore Sensor</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>FG5</td>
<td>Dome Gore Vent</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>AD</td>
<td>Aft Dome Cap</td>
<td>-</td>
<td>Contains Sump</td>
</tr>
<tr>
<td>AG1</td>
<td>Dome Gore</td>
<td>√</td>
<td>Configuration Could Be Modified As Orbiter Loads Are Eliminated (See Appendix 6)</td>
</tr>
<tr>
<td>AG2</td>
<td>Dome Gore</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>AG3</td>
<td>Dome Gore</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>AG4</td>
<td>Dome Gore</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>AG5</td>
<td>Dome Gore</td>
<td>√</td>
<td></td>
</tr>
</tbody>
</table>
LH2 Tank Shell Definition

- Part Configuration

Barrel Panels

\[ \text{Xn 3129.9} \quad \text{Xn 3377.35} \quad \text{Xn 3623.8} \quad \text{Xn 3871} \quad \text{Xn 4058} \quad \text{Xn 4120.85} \]

Main Frames

- F1
  - B3P1
  - B4P2
  - B3P1
  - B3P1
  - B3P1
  - B3P1
  - B3P1

- F2
  - B3P1
  - B3P2
  - B3P1
  - B3P1
  - B3P1
  - B3P1

- F3
  - B2P1
  - B2P2
  - B2P1
  - B2P1
  - B2P1
  - B2P1

- F4
  - B1P3
  - B1P2
  - B1P1
  - B1P4
  - B1P1
  - B1P1

- F5
  - B1aP3
  - B1aP2
  - B1aP1
  - B1aP4
  - B1aP1
  - B1aP1

- F6
  - B1aP2
  - B1aP1
  - B1aP1
  - B1aP5
  - B1aP1
  - B1aP1

CL of Press Lines & C/T

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# LH2 Tank Main Frames

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<td>F1</td>
<td>Frame 3129.9</td>
<td>-</td>
<td>+ Z Quadrant Modified To</td>
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<tr>
<td></td>
<td>- Outer Chord</td>
<td>√</td>
<td>Delete Bi-Pod Attach, LO2</td>
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<td></td>
<td>- Frame Segments</td>
<td>-</td>
<td>Feedline Changed To ± Z Locn</td>
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<td></td>
<td></td>
<td></td>
<td>Constant 10.0 Deep Frame</td>
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<tr>
<td>F2</td>
<td>Frame 4058</td>
<td>-</td>
<td>New With ET Fr 2058 SRB</td>
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<td></td>
<td>- Outer Chord</td>
<td>√</td>
<td>I/F’s, Orbiter I/F’s Omitted</td>
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<tr>
<td></td>
<td>- Frame Segments</td>
<td>-</td>
<td>Use ET Fr 2058 Segments*</td>
</tr>
<tr>
<td>F3</td>
<td>Frame 3871</td>
<td>-</td>
<td>Use ET Fr 1623.8 Modified For</td>
</tr>
<tr>
<td></td>
<td></td>
<td>√</td>
<td>± Z LO2 Feedlines</td>
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* Segments Could Be Modified Because Of Absense Of Orbiter Loads
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<td>F4</td>
<td>Frame 3623.8</td>
<td>-</td>
<td>Use ET Fr 1623.8 Modified For ± Z LO2 Feedlines</td>
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<tr>
<td>F5</td>
<td>Frame 3377.35</td>
<td>-</td>
<td>Use ET Fr 1377.35 Modified For ± Z LO2 Feedlines</td>
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<td>F6</td>
<td>Frame 3129.9</td>
<td>-</td>
<td>Use ET Fr TBD Modified For ± Z LO2 Feedlines</td>
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<tr>
<td></td>
<td>- Outer Chord</td>
<td>-</td>
<td>Use ET Fr 1129.9 Lower Segment Assys, In Place Of</td>
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<td>- Frame Segments</td>
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<td>Upper &amp; Lower Segments</td>
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# LH2 Tank Barrel Panels

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<tr>
<td>B1aP1</td>
<td>Barrel Panel</td>
<td>-</td>
<td>Unique Length Barrel Panel, Based On ET Type LH2 Machined Barrel Panel</td>
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<tr>
<td>B1aP2</td>
<td>Barrel Panel</td>
<td>-</td>
<td>Similar To B1aP1 With C/T &amp; Press Line I/F's</td>
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<tr>
<td>B1aP3</td>
<td>Barrel Panel</td>
<td>-</td>
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<tr>
<td>B1aP4</td>
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<td>B1aP5</td>
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<td>B1aP6</td>
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<tr>
<td>B1P1</td>
<td>Barrel Panel</td>
<td>-</td>
<td>Unique Barrel Panel, Based On ET Barrel 1Type LH2 Machined Barrel Panel</td>
</tr>
<tr>
<td>B1P2</td>
<td>Barrel Panel</td>
<td>-</td>
<td>Similar To B1P1 With C/T &amp; Press Line I/F's</td>
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</tbody>
</table>

MARTIN MARIETTA
MANNED SPACE SYSTEMS
<table>
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<th>Remarks</th>
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<td>B1P4</td>
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<tr>
<td>B2P1</td>
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<tr>
<td>B2P2</td>
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<td>Similar To B2P1 With C/T &amp; Press Line I/F's</td>
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<td>B3P2</td>
<td>Barrel Panel</td>
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<td>Similar To B3P1 With C/T &amp; Press Line I/F's</td>
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</table>
LH2 Tank Intermediate Frs CV-STR-14D

[Diagram of tank with labeled dimensions and spacing]

\[ n = \text{Number Of Equal Spaces} \]
<table>
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<tr>
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<th>Title</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF1A</td>
<td>Intermediate Fr</td>
<td>Unique Size Intermediate Frame, Similar Construction To ET LH2 Tank</td>
</tr>
<tr>
<td>IF2</td>
<td>Intermediate Fr</td>
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</tr>
<tr>
<td>IF3</td>
<td>Intermediate Fr</td>
<td></td>
</tr>
</tbody>
</table>

**LH2 Tank Intermediate Frs**

**CV-STR-14D**
Candidate Items For Cycle 1 CV-STR-14D

- Resize The LH2 Tank Based On:
  - Cycle 1 Loads
  - Cycle 1 Ullage Pressure & Associated Proof Test Requirements
  - Impacts From Aft Skirt Interface Loads
  - Optimization Of Intermediate Frame Sizes
  - Revise Frame 4058 (No Orbiter Loads)
  - Revise Aft Dome Gores (Reduced SRB Loads)
- Update Design Definition To Incorporate Results From:
  - CV-STR-14G External Hardware Definition
  - CV-STR-14H TPS Reference Definition
  - CV-DI-01A Tank Access
  - 3-S-008C Stiffener Pitch Sensitivity
  - A/R Other Panel Trades (eg. Single LO2 Feedline)
Items For Cycle 1 Study

• Further Define Sensor Mast Concept
• Re-evaluate Intermediate Frame Sizing
• Study Weight Savings Benefit Of A Unique LH2 Tank Design For 1.5 Stage
• Impact Of Aft Structure Loads On Barrel #1
• Impact Assessment Of Using Common Domes In Both Tanks
• Define The Aft Dome Vortex Baffle Concept
5.2.6.4.1 Reference LH2 Tank Enhancements(#CV-STR-14D)

Objective

This study evaluated enhancements to the Cycle φ Reference LH2 Tank structure and recommended potential modifications.

Approach

(a) Identify, define, evaluate and analyze selected Study Items.
(b) Identify recommended changes to the ref. Configuration.
(c) Produce LH2 Tank Part Definition.
(d) Identify candidates for study during Cycle 1.

Items Studied

Item 1 - Revised barrel and frame geometry.
Item 2 - Alternate forward dome chord and frame.
Item 3 - Def. of external hardware mounting provisions.
Item 4 - Chord to barrel weld land mismatch.
Item 5 - Definition of handling points
Item 6 - Alternate aft dome configuration
Item 7 - Level sensor installation
Item 8 - Reference part definition.

Key Study Results

The fwd dome chord and frame were designed for Orbiter bi-pod loads and are inefficient for this application. The ref. used a LO2 tank aft dome chord in the LH2 tank aft dome, this creates a weld land mismatch requiring the chord weld lands to be reduced. ET level sensor installation requires internal assembly. In order to reduce the requirement for access a series of options were produced to show a method of installing level sensors on a mast that's installed externally thru the fwd dome.

Conclusions

The Cycle φ definition made use of ET assemblies with some modified components. Weight and manufacturing complexity can be further improved by revising more of these components to better match NLS sizing requirements. These modified components can still be produced on ET tooling with the minor modifications already identified. Installation of level sensors without internal access was determined to be feasible.

Study Recommendations

The reference Cycle φ definition should be revised to reflect the enhancements proposed in this study:
- Revise reference definition to use LO2 aft chord and revised LH2 fwd frame in forward location.
- Incorporate the proposed definition of external hardware mtg. provisions.
- Increase barrel weld land at dome chord welds to .387.

During Cycle 1 further define the level sensor installation and re-evaluate intermediate frame sizing.
Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.6.4.1 Reference LH2 Tank Enhancements(#CV-STR-14D)

Objective

This study evaluated enhancements to the Cycle Ø Reference LH2 Tank structure and recommended potential modifications.

Approach

(a) Identify, define, evaluate and analyze selected Study Items.
(b) Identify recommended changes to the ref.Configuration.
(c) Produce LH2 Tank Part Definition.
(d) Identify candidates for study during Cycle 1.

Items Studied

Item 1 - Revised barrel and frame geometry.
Item 2 - Alternate forward dome chord and frame.
Item 3 - Def. of external hardware mounting provisions.
Item 4 - Chord to barrel weld land mismatch.
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- Revise reference definition to use LO2 aft chord and revised LH2 fwd frame in forward location.
- Incorporate the proposed definition of external hardware mtg. provisions.
- Increase barrel weld land at dome chord welds to .387.

During Cycle 1 further define the level sensor installation and re-evaluate intermediate frame sizing.
Additional Information

See Doc # MMC.NLS.SR.001 Book 1 for more detailed results.
CV-STR-14G
NLS Core Tankage
External Hardware Definition

Prepared By: Wayne Waguespack
(504)257-0032

Approved By: R. Simms

Rev: Initial
Date: January 8, 1992
Objectives And Approach

Objective
- Study And Evaluate HLLV And 1.5 Stage External Cable Tray Requirements And Recommend A Configuration To Meet These Requirements.

Approach
- Investigate STS External Tank Cable Tray And Press Line Design.
- Define Potential NLS Configuration.
- Document Study And Prepare Conclusions.
- Identify Items For Study During Cycle 1.
Ground Rules And Assumptions

• Utilize MSFC Cycle 0 Reference Configuration As Defined On 9/27/91
  - Core Tankage
  - Propulsion Module
  - Interstage Design And CTV Location.
• Increase Size Of Cable Tray To 7 X 11 Inches.
Typical LO2 Cable Tray Support Fitting
( View Looking Aft )

Typical LH2 Cable Tray Support Fitting
Options Comparison

Typical L02 Support Fitting (View Looking Aft)

Typical LH2 Support Fitting
Ref Configuration

Typical L02 Support Fitting (View Looking Aft)

Typical LH2 Support Fitting
Alt Configuration
Swap GH2 / GO2 Press Line Locations
To Simplify Support Fitting Design
Conclusions

- For HLLV Add SRB Cable Tray Extension To LH2 Cable Tray.
- For HLLV Add SRB Cross-over Cable Tray To Aft Skirt Def.

Recommendations

- Incorporate Results Of This Study Into Cycle 1 Baseline.
- Study The Following In Cycle 1
  - System Tunnel Approach.
  - Angular Location Of Cable Trays And Press Lines.
  - Refine Cable Tray Size.
5.2.1.4.1 External Hardware Design Definition (#CV-STR-14G)

Objective

Study and evaluate HLLV external cable tray and press line requirements and recommend a configuration to meet these requirements.

Approach

(a) Investigate STS ET cable tray and press line design.
(b) Study potential NLS configurations.
(c) Document study results and prepare conclusions.
(d) Identify items for study in cycle 1.

Items Studied

Item 1 - Size and location of cable tray.
Item 2 - Core Stage to SRB cable tray concept.
Item 3 - Location of press lines relative to cable tray.

Key Study Results

ET cable tray arrangement has separate cable trays on the L02 and LH2 tanks. These are located at different angular locations. The cable trays do not run along the intertank as their purpose is to feed cables into and out of the intertank. On NLS a different situation exists; primary cable routing is between the interstage and the propulsion module with only a few cables going into the intertank. Therefore the NLS cable tray should be continuous. A simplified attach structure can be devised if the location of the GO2 and GH2 press lines is Reversed. Initial estimates indicate that the cable tray cross section needs to be about 3 times greater on NLS due to increased quantity of cables. Additional cable trays will be needed to provide for cable routing to the aft SRB attach as well as a cross over cable tray between port and stbd SRBs.

Conclusions

The proposed concept provides a continuous longitudinal cable tray and provides a means for routing cables to the solid rocket boosters.

Study Recommendations

Revise cycle 0 baseline to incorporate the proposed configuration. In cycle 1, study a system tunnel approach and angular location of cable tray/press lines and cable tray size.
Proposed External Hardware Definition

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
6.2.1.4.1 External Hardware Design Definition (#CV-STR-14G)

Objective

Study and evaluate 1.5 Stage external cable tray and press line requirements and recommend a configuration to meet these requirements.

Approach

(a) Investigate STS ET cable tray and press line design.
(b) Study potential NLS configurations.
(c) Document study results and prepare conclusions.
(d) Identify items for study in cycle 1.

Items Studied

Item 1 - Size and location of cable tray.
Item 2 - Location of press lines relative to cable tray.

Key Study Results

ET cable tray arrangement has separate cable trays on the LO2 and LH2 tanks. These are located at different angular locations. The cable trays do not run along the intertank as their purpose is to feed cables into and out of the intertank. On NLS a different situation exist; primary cable routing is between the interstage and the propulsion module with only a few cables going into the intertank. Therefore the NLS cable tray should be continuous. A simplified attach structure can be devised if the location of the GO2 and GH2 press lines is Reversed. Initial estimates indicate that the cable tray cross section needs to be about 3 times greater on NLS due to increased quantity of cables.

Conclusions

The proposed concept provides a continuous longitudinal cable tray and provides a means for routing cables to the solid rocket boosters.

Study Recommendations

Revise cycle Ø baseline to incorporate the proposed configuration. In cycle 1, study a system tunnel approach and angular location of cable tray/press lines and cable tray size.
Typical L02 Support Fitting
(View Looking Aft)

Typical LH2 Support Fitting

Single Cable Tray
(Extended Thru Intertank Area)

Additional Information
See Doc # MMC.NLS.SR.001.Book 1 for more detailed results.
CV-STR-14H
TPS Reference Definition

Prepared By: Neil A Duncan
(504)257-0161

Approved By: M.R. Simms

Rev: Initial
Date: January 8, 1992

NAD.0072
NLS TPS Ref Definition  CV-STR-14H

Objective

- Prepare Recommended TPS Definition for the Reference NLS Core Vehicle

Related Tasks

- CV-STR-14-B  LO2 Tank Design Definition
- CV-STR-14-C  Intertank Design Definition
- CV-STR-14-D  LH2 Tank Design Definition
- CV-STR-14-F  Interface Hardware Definition
- CV-STR-14-G  External Hardware Definition
- CV-STR-16-B  Facility Impacts
Approach

Part 1
Evaluate Thermal Protection options for each individual element of the Core Vehicle

Part 2
Define & evaluate several Thermal Protection options for the entire Core Vehicle

Identify Recommended changes to the Reference Configuration
Study Items

Aeroheating & ASRM shock impingement heating

Propellant Conditioning - Ground & Flight

Ice & Liquid Air Formation

Influence of Vehicle Aeroheating & Propellant Temperature on Structure material properties

Application of ET TPS Process / Manufacturing requirements to NLS configuration

Sensitivity analyses - Variation in propellant conditioning assumptions
- Freon 11 replacement at MAF
Groundrules

• For Vehicle Definition Use MSFC Reference Definition Dated 8/28/91
• Tank Length May Not Be Changed
• Use Remtech Prelim Aeroheating data
• No Deorbit Requirements Included
• Impacts Associated With Localized TPS Closeouts Are Not Included in this Study. This Work was Deferred till Cycle 1
• Core Vehicle Defined as: Forward Skirt, LO2 Tank Intertank & LH2 Tank
Assumptions

• Use ET Criteria where the Reference Vehicle data is incomplete

• ET type GN2 Purge in Fwd Skirt, Intertank & Propulsion Module

• BX-250 SOFI Assumed For Barrel Acreage. CPR-488 (SOFI used on ET Barrels) Withstands Higher Heating Rates Than BX-250, But also Requires Substrate Heating During Application. Lower NLS Heating Rates Allow Use of BX-250 Which Reduces Manufacturing Cost (no Substrate Heating)
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Rationale</th>
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<tbody>
<tr>
<td>Core Vehicle Design</td>
<td>Identify any major vehicle design concerns associated with TPS options</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Assess impact to manufacturing based on structure &amp; TPS design</td>
</tr>
<tr>
<td>Operability</td>
<td>Identify operability impacts due to propellant conditioning requirements and ice or liquid air formation</td>
</tr>
<tr>
<td>Performance / Weight</td>
<td>Identify relative performance of each option</td>
</tr>
<tr>
<td>Cost</td>
<td>Identify any major cost differentials between options</td>
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Study Outline

Objective, Approach, Groundrules & Assumptions

Part 1 - Core Element Thermal Evaluation

Part 2 - Core Vehicle Thermal Evaluation

Conclusions & Recommendations

Appendix 1 - Thermal Analysis

  Parametric Skin Temp vs Thickness vs TPS Thickness

Appendix 2 - Fluid Conditioning Data

  Parametric Ground & Flight Conditioning Data

Appendix 3 - Sensitivity Study

  Propellant Conditioning Variables

Appendix 4 - TPS Data

  Spray Process on I/T type Structures, Closeouts, Weights

Appendix 5 - Freon Replacement

  Status of Freon replacement at MAF

Appendix 6 - Ice & Liquid Air Formation

  Requirements, TPS, Ice/Frost Data, Saturn Data
Part 1
Core Element Thermal Evaluation
  • Aeroheating
  • Propellant Conditioning
  • Structural Design & Material Properties
  • TPS Manufacturing Issues
  • Operational & Safety Issues
  • Weight / Performance
  • Cost
<table>
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<tr>
<th>Options - Forward Skirt</th>
<th>CV-STR-14H</th>
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<tbody>
<tr>
<td>Option 1</td>
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<tr>
<td>Ref Configuration</td>
<td>Rationale</td>
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<tr>
<td>Option 1</td>
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</tr>
<tr>
<td>Heat Sink Design</td>
<td>Point Of Departure</td>
</tr>
<tr>
<td>Option 2</td>
<td></td>
</tr>
<tr>
<td>Nominal TPS thickness=</td>
<td>1.0&quot;</td>
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<tr>
<td>Option 3</td>
<td>Partial Heat Sink / TPS Design</td>
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<tr>
<td>Nominal TPS thickness=</td>
<td>1.0&quot;</td>
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<tr>
<td>Option 4</td>
<td>Reference Structure + TPS to protect from Aeroheating affects</td>
</tr>
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</table>
Fwd Skirt - Configuration CV-STR-14H

- Skin & Stringer Construction
- ET type design
- TPS Options assume sprayed TPS per ET processes

Fabricated Panel Typ 8 Pi

Fwd 331" DIA

96"
# Fwd Skirt - Results

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<thead>
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<th>Structure t (in)</th>
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<th>TPS Wt Δ (lbs)</th>
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## Evaluation - Forward Skirt  CV-STR-14H

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<th>Ref Config Bare</th>
<th>Option 1 Heatsink</th>
<th>Option 2 Nom TPS=.75</th>
<th>Option 3 Nom TPS=1.0</th>
<th>Option 4 Nom TPS=1.5</th>
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<tr>
<td>Aeroheating causes Structural failure</td>
<td>Ref</td>
<td>Additional TPS &amp; Thermal Design Required - Minimal Effort</td>
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<thead>
<tr>
<th>Manufacturing</th>
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<th>Ref</th>
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<tr>
<td>ET Spray &amp; Closeout Processes No facility/tooling impacts</td>
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</table>

<table>
<thead>
<tr>
<th>Operability</th>
<th>Significant Ice Formation @ LO2 I/F</th>
<th>Significant Ice Formation @ LO2 I/F</th>
<th>Ice worse than ET @ LO2 I/F</th>
<th>Ice same as ET @ LO2 I/F</th>
<th>Less Ice than ET @ LO2 I/F</th>
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<td>Weight Delta (lbs)</td>
<td>Metal</td>
<td>Ref</td>
<td>+765</td>
<td>+227</td>
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<tr>
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<td>TPS</td>
<td>—</td>
<td>—</td>
<td>+159</td>
<td>+213</td>
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<tr>
<td></td>
<td>$\Sigma$</td>
<td>Ref *</td>
<td>+765 *</td>
<td>+386 *</td>
<td>+358</td>
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<th>Cost</th>
<th>Non-rec</th>
<th>Ref</th>
<th>Recurring</th>
<th>Ref</th>
<th>TPS / Thermal Design = $120k</th>
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<tbody>
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<td>Material Cost = $60k</td>
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<td></td>
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</tr>
</tbody>
</table>

- Least desirable impacts

* Ice Wt Impact Unknown

---

**Martin Marietta**

Manned Space Systems
Fwd Skirt Conclusions

• Reference option cannot withstand Aeroheating environment

• Lack of any TPS will cause significant Ice formation on the Reference option & Option 1 at the LO2 Interface flange. Options 3 will perform in a manner similar to ET I/T flange areas with respect to ice formation, while Options 2 & 4 will produce more & less Ice respectively than ET.

  Note that adding a two feet long 1.0" thick TPS closeout (approx wt = 53 lbs) to the Reference & Option 1 is possible to prevent local ice formation but was not considered here - See Appendix 4

• Adding 1.0" TPS saves approx 400lbs at very little additional cost compared to the Heatsink approach (Option 1) and eliminates Ice problem

Option 3 Recommended
<table>
<thead>
<tr>
<th>Option</th>
<th>Rationale</th>
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<tbody>
<tr>
<td>Ref Configuration</td>
<td>Point Of Departure</td>
</tr>
<tr>
<td><strong>Option 1</strong></td>
<td>Defines Minimum Structure to Survive Heating Without TPS</td>
</tr>
<tr>
<td>Heat Sink Design</td>
<td></td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td>Partial Heat Sink / TPS Design</td>
</tr>
<tr>
<td>Nominal TPS thickness= .75&quot;</td>
<td></td>
</tr>
<tr>
<td><strong>Option 3</strong></td>
<td>Partial Heat Sink / TPS Design</td>
</tr>
<tr>
<td>Nominal TPS thickness= 1.0&quot;</td>
<td></td>
</tr>
<tr>
<td><strong>Option 4</strong></td>
<td>Minimum Structure + TPS to protect from Aeroheating affects</td>
</tr>
<tr>
<td>Nominal TPS thickness= 1.5&quot;</td>
<td></td>
</tr>
</tbody>
</table>
CV-STR-14H

- ET I/T type design
- All Panels similar to ET
- TPS Options, assume sprayed TPS per ET processes

Intertank - Config

Fabricated Panel
Typ 6 Pl

330.0 l/d

270.35

526
## Intertank - Results

<table>
<thead>
<tr>
<th>Option</th>
<th>TPS (Nom)</th>
<th>Structure ( t ) (In)</th>
<th>Structure Wt ( \Delta ) (lbs)</th>
<th>TPS Wt ( \Delta ) (lbs)</th>
<th>Total Wt ( \Delta ) (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref Config</td>
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<td>0</td>
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<td>-173</td>
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<tr>
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<td>+348</td>
<td>-434</td>
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<tr>
<td>Option 3</td>
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<td>+464</td>
<td>-451</td>
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<tr>
<td>Option 4</td>
<td>1.5''</td>
<td>.181</td>
<td>-1009</td>
<td>+696</td>
<td>-313</td>
</tr>
</tbody>
</table>

- .071" stringer gage on Reference is inadequate, should be .090" min. but reference also has excess skin thickness. Reference assumed good based on some redistribution of mass from skins to stringers.
- Results also indicate that the thrust panels do not require TPS for Aeroheating or ASRM shock impingement.
- Above results assume thrust panels are masked during TPS spray operations.
# Evaluation - Intertank

### CV-STR-14H

<table>
<thead>
<tr>
<th>Core Vehicle Design</th>
<th>Ref Config Bare</th>
<th>Option 1 Heatsink</th>
<th>Option 2 Nom TPS=.75&quot;</th>
<th>Option 3 Nom TPS=1.0&quot;</th>
<th>Option 4 Nom TPS=1.5&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ref</td>
<td>Ref</td>
<td>Additional TPS &amp; Thermal Design Required - Minimal Effort</td>
<td>ET Spray &amp; Closeout Processes No facility/tooling impacts</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufacturing</th>
<th>Ref</th>
<th>Ref</th>
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<tbody>
<tr>
<td></td>
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</table>

## Operability

<table>
<thead>
<tr>
<th>Weight Delta (lbs)</th>
<th>Metal TPS</th>
<th>Operability</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>Significant Ice Formation @ LH2 &amp; LO2 I/F's &amp; Liquid Air formation on LH2 Tank</td>
<td>Ice worse than ET @ LO2 &amp; LH2 I/F's</td>
<td>Ice same as ET @ LO2 &amp; LH2 I/F's</td>
<td>Less Ice than ET @ LO2 &amp; LH2 I/F's</td>
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<tr>
<td></td>
<td></td>
<td>Potential TPS damage / repair req'd @ KSC</td>
<td>-782</td>
<td>-915</td>
<td>-1009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+348</td>
<td>+464</td>
<td>+696</td>
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<tr>
<td></td>
<td>0 *</td>
<td></td>
<td>-434</td>
<td>-451</td>
<td>-313</td>
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</table>

<table>
<thead>
<tr>
<th>Cost</th>
<th>Non-rec</th>
<th>Recurring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Ice Wt Impact Unknown

☐ Least desireable impacts

---

**NAD.007**

---

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**MANNED SPACE SYSTEMS**
I/T Conclusions

- All options survive Aeroheating environment

- Lack of any TPS will cause significant Ice formation on the Reference & Option 1 at the LO2 & LH2 Interface flanges. Option 3 will perform in a manner similar to ET I/T flange areas with respect to ice formation, while Options 2 & 4 will produce more and less ice respectively than ET.

  Note that adding two 2 feet long X 1.0" thick TPS closeouts (approx wt = 53lbs each) to the Reference & Option 1 is possible to prevent ice formation but was not considered here - See Appendix 4

- Option 3 saves approx 451 lbs at some additional cost compared to the Reference configuration with no ice problem.

Option 3 Recommended
<table>
<thead>
<tr>
<th>Options - LO2 Tank</th>
<th>CV-STR-14H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option</strong></td>
<td><strong>Rationale</strong></td>
</tr>
<tr>
<td><strong>Ref Configuration</strong></td>
<td>Point Of Departure</td>
</tr>
<tr>
<td>.5&quot; TPS on Domes</td>
<td></td>
</tr>
<tr>
<td><strong>Option 1</strong></td>
<td>Adding TPS to Barrel</td>
</tr>
<tr>
<td>Add .5&quot; TPS to Barrel</td>
<td>Section Reduces Ice &amp; May Improve Payload</td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td>Adding 1.0&quot; TPS to Barrel</td>
</tr>
<tr>
<td>Add 1.0&quot; TPS to Barrel</td>
<td>Barrel Section Reduces Ice Even More &amp; May Improve Payload</td>
</tr>
</tbody>
</table>

Note - Acreage TPS only, no flange or bracket ice / frost closeouts
LO2 Tank - Configuration CV-STR-14H

Reference Configuration
- .5" TPS on Domes
- Bare Barrel
- 5000 Gallons/Minute (GPM)
- Helium Inject
- 5 Hour Loading
- 1 ET Vent Valve (Without Stroke Limiter)

Options 1 & 2 add TPS to the Barrel
Results - Stress Analysis

- Membrane is Sized by Proof Load for Weld Lands & Exceeds Heat Sink Design Requirements

<table>
<thead>
<tr>
<th>Lox Barrel</th>
<th>Skin Gauge Ref Config</th>
<th>Skin Gauge for Heat Sink Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd</td>
<td>.170</td>
<td>.115</td>
</tr>
<tr>
<td>Aft</td>
<td>.215</td>
<td>.111</td>
</tr>
</tbody>
</table>

Conclusion - LO2 TPS Configuration is Independent of Membrane Aeroheating effects
LO2 Results

Payload penalty derivation

Payload penalty derived by combining the following effects:

- Payload reduction due to decreased LOX density, calculated as lost LOX density (lbs) \( \times 0.075 \). The 0.075 factor is based on performance analysis experience, and a sensitivity analysis was performed against study results for this factor.

- Window penalty, due to launching off-optimum during hold

- Additional TPS mass

- Additional Vent Valve & Ducting mass
LO2 Payload vs TPS

NLS Baseline Propellant Conditioning Parameters
5000 Gpm, GHe Inject, 5 Hr. Min. Load to Launch

Option 2  Option 1  Ref Config

Worst Payload Reduction

1 Vent Valve - NLS Baseline

0 = ET density at end of replenish
LO2 Ice / Frost Weight  CV-STR-14H

- Even thin Ice/Frost build-up generates significant weight
- Actual build-up will depend on weather conditions and variations in TPS thickness

Assumes Ice/Frost 57 lb/ft³ for shallow build-up
(See Appendix 6)
LO2 Flight Results  

- Wall temperature & ullage pressure calculated for various TPS & skin gauges

- TPS thickness & wall thickness do affect ullage pressure

- Results meet NPSP requirements, but should be re-evaluated if autogenous flow rates are reduced in the future

Conclusion - no impact on study results
## Evaluation - LO2 Tank

### CV-STR-14H

<table>
<thead>
<tr>
<th></th>
<th>Ref Config Bare</th>
<th>Option 1 .5&quot; TPS</th>
<th>Option 2 1.0&quot; TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Core Vehicle Design</strong></td>
<td>Ref</td>
<td>Additional TPS Design Required</td>
<td>Minimal Effort</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ET Spray Processes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mods to Cell M required for LO2 barrel spray</td>
<td></td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td>Ref</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operability</strong></td>
<td>Large Ice</td>
<td>Much higher probability than ET of Ice formation on</td>
<td>Ice Formation same as ET</td>
</tr>
<tr>
<td></td>
<td>Formation</td>
<td>any given day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Performance (lbs)</strong></td>
<td>0 Ice Wt Impact Unknown</td>
<td>+324 Ice Wt Impact Unknown</td>
<td>+195 Ice Wt Impact Unknown</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Non-rec Ref</td>
<td>TPS Design $50K</td>
<td>= $550k</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cell M Spray Fixture $500K</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recurring Ref</td>
<td>Production Ops $29K</td>
<td>= $89k</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Material $60K</td>
<td></td>
</tr>
</tbody>
</table>

☐ Least desireable impacts
LO2 TPS Conclusions

• All options satisfy known ground & flight requirements

• Major uncertainties do exist regarding ice formation and possible retention during flight for configurations with less than the ET configuration of 1.0" nominal TPS (Ref & Option 1)

• Reference option shows lowest cost approach, but does not address additional operational costs associated with ice formation

• Option 2 provides the lowest risk approach with what was judged to be:
  - Relatively insignificant performance loss compared with Option 1 (-129 lbs)
  - Low cost increase

Option 2 Recommended
LH2 Tank Results
### Options - LH2 Tank

<table>
<thead>
<tr>
<th>Option</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref Configuration</td>
<td>Point Of Departure - .5&quot; TPS on Domes &amp; Barrels</td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td></td>
</tr>
<tr>
<td>1.0&quot; TPS on Bbls</td>
<td>1.0&quot; TPS on Barrel Section</td>
</tr>
<tr>
<td></td>
<td>Reduces Ice &amp; May Improve Payload</td>
</tr>
</tbody>
</table>

**Note** - Acreage TPS only, no flange or bracket ice / frost closeouts
LH2 - Ref Vehicle Config
CV-STR-14H

Reference Configuration has
.5" TPS on Domes & Barrels
& 1 ET Vent Valve
(without stroke limiter)

Option 1 has 1.0 TPS on the Barrels

1263.00"
331" Dia
999.50"
LH2 Payload vs TPS

CV-STR-14H

5 Hour Min Load to Launch

1" BX - Option 1

.5" BX

1 Vent Valve

NLS Baseline

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LH2 Ice / Frost Weight  CV-STR-14H

- Even thin Ice/Frost build-up generates significant weight
- Only .023" of Ice required to negate 761 lbs of .5" TPS performance gain relative to Option 1 assuming TPS remains after launch (see previous TPS / Payload chart)
- Actual build-up will depend on weather conditions and variations in TPS thickness
LH2 Flight Results

- Same as LO2 flight results
- Wall temperature & ullage pressure calculated for various TPS & skin gauges
- TPS thickness & wall thickness do affect ullage pressure
- Results meet NPSP requirements, but should be re-evaluated if autogenous flow rates are reduced in the future

Conclusion - no impact on study results
<table>
<thead>
<tr>
<th></th>
<th>Ref Config .5&quot; TPS</th>
<th>Option 1 1.0&quot; TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Vehicle Design</td>
<td>Ref</td>
<td>No Impact</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Ref</td>
<td>No Impact</td>
</tr>
<tr>
<td>Operability</td>
<td>Much higher probability than ET of ice formation on any given day</td>
<td>Ice Formation same as ET</td>
</tr>
<tr>
<td>Performance (lbs)</td>
<td>0</td>
<td>-761 lbs</td>
</tr>
<tr>
<td></td>
<td>Ice Wt Impact Unknown</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Non-rec Ref $0k</td>
<td>Recurring Material = $60k</td>
</tr>
</tbody>
</table>

☐ Least desirable impacts
LH2 Conclusions

CV-STR-14H

- Both options satisfy known ground & flight requirements

- No significant cost difference between options, but the Reference option does not address additional operational costs associated with ice formation

- Major uncertainties do exist regarding ice formation and possible retention during flight for configurations with less than the ET configuration of 1.0" nominal TPS.

- Option 1 shows a significant performance loss compared with the Reference. However, an ice build up of only .023" would negate the Reference advantage should the ice remain after launch.

Option 1 Recommended
Part 2

Core Vehicle Thermal Protection
Core Vehicle Options  CV-STR-14H

Reference
- BARE
- .5 TPS LH2 TANK AND ALL DOMES

"Heatsink" Option
- LO2 BARE
- Heatsink Design
- .5 TPS LH2 TANK AND ALL DOMES

Full TPS Option
- 1.0" TPS ALL CYLINDRICAL SURFACES & .5" TPS ALL DOMES
Ref Configuration

- Forward Skirt fails due to Aeroheating
- Ice/Frost formation within 2ft of LO2 I/F

CV-STR-14H

- Ice/Frost & Liquid Air formation within 2ft of LH2 I/F
- Ice/Frost & Liquid Air formation possible over entire LH2 barrel. Will occur with much greater frequency than on ET (ET has 1.0" TPS)

- Significant Potential for Excessive Ice/Frost formation over entire LO2 Barrel

- Lowest Weight & Cost Core Option but:
  - Fails due to Aeroheating
  - No Estimate of Increased Weight & Cost for Ice & Liquid Air Formation

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"Heatsink" Vehicle

CV-STR-14H

- Ice/Frost formation within 2ft of LO2 I/F
  - 765 lbs
- Ice/Frost & Liquid Air formation within 2ft of LH2 I/F
  - 173 lbs
- Ice/Frost & Liquid Air formation possible over entire LH2 barrel. Will occur with much greater frequency than on ET (ET has 1.0" TPS)

5 TPS LH2 TANK AND ALL DOMES

Heatsink Design

- Significant Potential for Excessive Ice/Frost formation over entire LO2 Barrel

- Low Cost Core Option (Same as Reference)
- 592 lbs weight penalty to adjust for true Heatsink design
- No Estimate of Increased Weight & Cost for Ice & Liquid Air Formation

Compared with Ref Config
Wt + 592 lbs
Cost - No Change

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Full TPS Vehicle

- Probability of Ice/Frost & Liquid Air formation on Core is the same as ET today
- No Performance, Operations or Safety uncertainty

+358 lbs -195 lbs -451 lbs +761 lbs

1.0" TPS ALL CYLINDRICAL SURFACES & .5" TPS ALL DOMES

- Extra 121 lbs vs "Heatsink" option removes uncertainties due to Ice & Liquid Air
- Cost Increase relatively low

Compared with Ref Config
+ 713 lbs
+ $.72M Non-Rec
+ $1.1M Recurring

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## Evaluation - Core Vehicle

**CV-STR-14H**

<table>
<thead>
<tr>
<th>Category</th>
<th>Reference</th>
<th>Heatsink</th>
<th>Full TPS (Nominal 1.0&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Vehicle Design</td>
<td><strong>Fwd Skirt Falls due to Aeroheating</strong></td>
<td>Ref</td>
<td>Additional TPS Design required</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Ref</td>
<td>Ref</td>
<td>ET TPS Processes Mods to Cell M required for LO2 barrel spray</td>
</tr>
<tr>
<td>Operability</td>
<td><strong>Significant potential for excessive Ice / Frost &amp; Liquid Air Formation</strong></td>
<td></td>
<td>No Ice Problem (same as ET)</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>0</td>
<td>+592</td>
<td>+713</td>
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<tr>
<td></td>
<td><strong>Ice Wt Impact unknown</strong></td>
<td>Ice Wt Impact unknown</td>
<td>No Ice Problem</td>
</tr>
<tr>
<td>Cost</td>
<td>Non-rec Ref</td>
<td>Ref</td>
<td>= $0.72M</td>
</tr>
<tr>
<td></td>
<td>Recurring Ref</td>
<td>Ref</td>
<td>= $1.1M</td>
</tr>
</tbody>
</table>

Least desirable impacts

---

NAD.0072
Core Conclusions

• Reference Forward Skirt requires additional protection from Aeroheating.

• Heatsink option solves Forward Skirt Aeroheating problem but not Ice / Frost & Liquid Air concerns. Core Tankage Weight increase 592 lbs. This option also is harder to re-design in response to increased heating rates than a TPS design (it is easier to spray more TPS than add more metal).

• Neither of the above options includes increased Weight or Operations costs due to Ice formation.

• 1.0" Nominal TPS + Flange closeouts adds an additional 121 lbs compared with the Heatsink option, but deletes the Ice / Frost & Liquid Air problems. Cost Delta's are +$0.72M Non-rec & +$1.1M Recurring
Core Recommendations

CV-STR-14H

- Recommend the Full TPS option (1.0" nominal TPS) as lowest risk approach
  - Improves Launch Operations Significantly
  - Minimal Performance Penalty
  - Acreage Spraying of TPS is Relatively Inexpensive
  - Provides Margin for Changes in Environments

- Most TPS cost is in multiple ice frost / aeroheating closeouts of cable tray & propellant line supports. Future efforts should be concentrated on tailoring requirements to avoid the need for TPS closeouts on these items.

- Assess potential impact of De-orbit requirements on NLS TPS design.
Appendices

Appendix 1 - Thermal Analysis
  Parametric Skin Temp vs Thickness vs TPS Thickness

Appendix 2 - Fluid Conditioning Data
  Parametric Ground & Flight Conditioning Data

Appendix 3 - Sensitivity Study
  Propellant Conditioning Variables

Appendix 4 - TPS Data
  Spray Process on I/T type Structures, Closeouts, Weights

Appendix 5 - Freon Replacement
  Status of Freon replacement at MAF

Appendix 6 - Ice & Liquid Air Formation
  Requirements, TPS, Ice/Frost Data, Saturn Data
Appendix 1
Thermal Analysis Results
Assumptions

- Nominal Remtech Prelim data modified to represent dispersed rates (3 sigma)
- Thermal analyses of Fwd Skirt & Intertank assume an ET based factor to include stringer effects
- Based upon heating rates, BX-250 can be used for domes & barrels (instead of CPR-488 on barrels & BX-250 on domes)
Heating Rates

CV-STR-14H

- Rockwell data was received after work had begun using the Remtech data
- The data were so similar that it was decided to continue using the Remtech data
- Data shown are nominal rates

<table>
<thead>
<tr>
<th>Location</th>
<th>NLS Config</th>
<th>Remtech</th>
<th></th>
<th>Rockwell</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Body Point</td>
<td>Heating Rate (Btu/ft² - sec)</td>
<td>Heat Load (Btu/ft²)</td>
<td>Body Point</td>
</tr>
<tr>
<td>Fwd Skirt &amp; LO2 Tank</td>
<td>1.5 HLLV</td>
<td>BP7</td>
<td>.7852</td>
<td>74.51</td>
<td>A7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BP17</td>
<td>1.122</td>
<td>136.1</td>
<td>B7</td>
</tr>
<tr>
<td>Intertank</td>
<td>1.5 HLLV</td>
<td>BP8</td>
<td>.7569</td>
<td>71.61</td>
<td>A8</td>
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<td></td>
<td></td>
<td>BP17</td>
<td>1.122</td>
<td>136.1</td>
<td>B8</td>
</tr>
<tr>
<td></td>
<td>1.5 HLLV</td>
<td>BP18</td>
<td>11.1</td>
<td>667.2</td>
<td>B12</td>
</tr>
<tr>
<td>LH2 Tank</td>
<td>1.5 HLLV</td>
<td>BP9</td>
<td>.7298</td>
<td>68.83</td>
<td>A9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BP19</td>
<td>2.218</td>
<td>205.3</td>
<td>B9</td>
</tr>
</tbody>
</table>

- Note that only the HLLV heating data were used in the subsequent evaluation section (HLLV rates > 1.5 Rates) to define the reference vehicle
1.5 Stage Bodypoints  CV-STR-14H

- Body Point #7 used for both Fwd Skirt & LO2 Tank
HLLV Bodypoints

CV-STR-14H

Core Tankage

Fwd Skirt  LO2 Tank  Intertank  LH2 Tank

- Body Point #17 used for Fwd Skirt, LO2 Tank and Intertank
- Body Point #18 represents local heating on I/T due to ASRM shock impingement
## Thermal Analysis Runs

<table>
<thead>
<tr>
<th>Location</th>
<th>Metal Thickness (In)</th>
<th>TPS Thickness (In)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd Skirt - Stringer</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>- Skin</td>
<td>0.053</td>
<td>0.071</td>
</tr>
<tr>
<td>- Insulated</td>
<td>0.053</td>
<td>0.063</td>
</tr>
<tr>
<td>LO2 - Bare</td>
<td>.1,.13,.16,.23,.3</td>
<td>0.1,.156,.16,.23,.3</td>
</tr>
<tr>
<td>- Insulated</td>
<td>0.1 &amp; .3</td>
<td>0.1 &amp; .3</td>
</tr>
<tr>
<td>Intertank - Stringer</td>
<td>.071</td>
<td>.071</td>
</tr>
<tr>
<td>- Skin</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>- Thrust Panels *</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LH2 - Bare **</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>- Insulated</td>
<td>0.1 &amp; .3</td>
<td>0.1 &amp; .3</td>
</tr>
<tr>
<td>Element Joints ***</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Analysis results (curves) not available electronically

* Massive enough not to require bulk TPS for Aeroheating

** Bare LH2 was not considered to be a viable option (excessive boil off)

*** No closeout of bolted I/F's required due to aeroheating alone
Appendix 2

Fluid Conditioning Data
LO2 Loading Assumptions CV-STR-14H

- **LO2 Tank Volume**
  - Overall Length = 504.26"
  - Dome Height = 124.375

  - Total Mold Line Volume = 20,982 ft³
  - Plus Feedline Volume = 535
  - Less Panel/Internals Volume = 65
  - Less Ullage Volume (3.3%) = 743

  - Total Liquid Volume = 20,709 ft³

- **Barrel Area = 1870 ft²**
- **Bubble Volume = 40 ft³**
- **Ambient Pressure = 14.65 @ Vent Exit**
- **Nominal ET End of Replenish Density = 71.13 lb/ft³**
- **Icing Rate Follows 75% of Liquid Level in Fastfill**
- **Dome Heat Gains Per Current Thermal Data Book Nominal Cases**

- **Timeline = 5 hr. Min. Load and Replenish Plus 3 hr. Max. Hold**
- and = 2 hr. Min. Load and Replenish Plus 6 hr. Max. Hold

- **GHe Inject = ET Nominal Rate**
- **One ET Vent Valve CdA = 15 in² (Fully Open)**
- **GHe Effects Assume Bubble Volume Not Refilled at End of Replenish Unless Stated on Plot**
- **All Ice on Bare or Insulated Surfaces Falls Off at Launch**

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LH2 Loading Assumptions  CV-STR-14H

- LH2 Liquid Volume 55,426 ft$^3$
  - Based on ET Cryo Vented
  - Additional 5 ft Barrel Volume

- Ambient Pressure = 14.65 @ Vent Exit

- Nominal ET End of Replenish Density = 4.41 lb/ft$^3$

- Dome Heat Gains Per Current Thermal Data Book Nominal Cases

- Timeline = 5 hr. Min. Load and Replenish Plus
  3 hr. Max. Hold
  and = 2 hr. Min. Load and Replenish Plus
  6 hr. Max. Hold

- One ET Vent Valve CdA = 15 in$^2$ (Fully Open)

- All Ice on Bare or Insulated Surfaces Falls Off at Launch
LH2 Propellant Conditioning CV-STR-14H

- Effects Examined
  - Barrel TPS Thickness (.5" BX, 1.0" BX)
  - Vent Valve Quantity (1, 2 or 3 ET Vent Valves)
  - Loading Timeline (5 hrs. Min. and 2 hrs. Min.)

- Criteria for Recommendation
  - Payload Increase or Decrease (Delta Payload)
  - Currently Independent of LO2 Interaction

- Payload Effects Based Conclusion
  - Reduced Fastfill Should Be Eliminated
    - 2 hr. Minimum Not Possible With Current ET Loading Procedure
Flight CV-STR-14H

Establish Expected Wall Temperature Ullage Pressure and NPSP Variations Due to Tank Skin and Insulation Thickness Changes

- Baseline

  - NLS 1.5 Stage Trajectory

  - Pressurant Supply (Nominal - Steady State)

    | LO2         | LH2         |
    |-------------|-------------|
    | 3.0 lbm/sec/engine | 1.4 lbm/sec/engine |
    | 700 Deg R       | 400 Deg R       |

- SSME Start and Throttle Transients Modeled

- Temperature Transients Due to Pressline Also Included

- Tank Sizes (Ambient)

  - 20631 ft LO2
  - 55946 ft LH2

- Analysis Does Not Consider Liquid Convection Currents

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Flight Results

- TPS Thickness and Wall Thickness Affects Ullage Pressure
  - Should Be Accounted for When Ullage Pressure Requirements Are Defined

- TPS Thickness and Wall Thickness Affect NPSP
  - LO2
    - 0 - 1" TPS Thickness Range is 1.5 °F (1.28 psi Vapor Pressure)
    - .1" - .3" Wall Thickness Range is Negligible
    - Liquid Head Gives More Than Adequate Margin
  - LH2
    - .25" = 1" TPS Thickness Range is .3 °F (.67 psi Vapor Pressure)
    - .1" - .3" Wall Thickness Range is Negligible
    - Ullage Pressure Gives More Than Adequate Margin
    - Caveat: Reduction of Autogenous Flow is Under Consideration - May Affect Results

Note: Analysis results (curves) not available electronically
TPS Impact on Propulsion  CV-STR-14H

- Propellant Conditioning
  - Propellant Density
  - Vent Valve Size
  - Replenish Time

- Flight
  - Ullage Pressure
  - NPSP
  - Engine Start Requirements

- Anti-geyser
Appendix 3
Sensitivity Analysis for Propellant Conditioning Variables
LO2 Sensitivity Analysis

Propellant Conditioning Variables

- Several Variables were considered in addition to TPS Config
  - Fill Rate 1400 gpm (ET @ KSC) & 5000 gpm (NLS Spec)
  - GHe Inject (ET Rate) & no GHe Inject (NLS Baseline Uncertain)
    10% increase in GHe inject decreases payload 4.9 lbs
  - 1, 2 or 3 ET Vent Valves (Bare LO2 Barrel Increases Boil Off)
  - 5 Hour (ET) or 2 Hour Loading (Possible Air Force Requirement)

- Results are shown as Payload vs TPS & No of Vent Valves

for variable Fill Rate, Loading Time & GHe Inject

Note: Analysis results (curves) not available electronically
Sensitivity Analysis

Payload Factor Sensitivity

- Nominal Factor is .064 lb Payload/lb Propellant With 6:1 Mixture Ratio

- LO2 Densification Effects
  - Density at Optimum Hold Relatively Insensitive to Payload Factor Change
  - Delta Payload at Optimum Density Time Decreases 0.55 lb for 10% Increase in Payload Factor (for 5000 GPM, .5" BX, 1 Vent Valve, GHe Inject, 5 Hour Minimum)

- LH2 Densification Effects
  - Density at Optimum Hold Relatively Insensitive to Payload Factor Change
  - Delta Payload at Optimum Density Time Decreases 2.8 lb for 10% Increase in Payload Factor (.5" BX, 1 Vent Valve, 2 Hour Minimum)
LO2 Payload vs TPS

NLS Baseline Propellant Conditioning Parameters
5000 Gpm, GHe Inject, 5 Hr. Min. Load to Launch

Option 2  Option 1  Ref Config

Worst Payload Reduction

1 Vent Valve - NLS Baseline

0 = ET density at end of replenish

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MANNED SPACE SYSTEMS
LO2 Sensitivity Analysis

No GHe Inject
5000 Gpm, No GHe Inject, 5 Hr. Min. Load to Launch

Diagram showing total delta payload in Lbs for different conditions:
- 1" TPS
- .5" TPS
- Iced Bare
- 1 Vent Valve
- 2 Vent Valves
- 3 Vent Valves

Values shown:
- -455
- -401
- -280
- -276
- -151
- -148
- -501
LO2 Sensitivity Analysis  CV-STR-14H
No GHe & Reduced Loading Time
5000 Gpm, No GHe Inject, 2 Hr. Min. Load to Launch

![3D Bar Graph]

Total Delta Payload - Lbs

-1600 -1400 -1200 -1000 -800 -600 -400 -200 0

1" TPS
.5" TPS
Iced Bare
1 Vent Valve
2 Vent Valves
3 Vent Valves

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MANNED SPACE SYSTEMS
LO2 Sensitivity Analysis

Reduced Loading Time
5000 Gpm, GHe Inject, 2 Hr. Min. Load to Launch

Total Delta Payload - Lbs

-1600
-1400
-1200
-1000
-800
-600
-400
-200
0
1" TPS
.5" TPS
Iced Bare
1 Vent Valve
2 Vent Valves
3 Vent Valves
LO2 Sensitivity Analysis  CV-STR-14H

ET Fill Rate & Short Fill Time

1400 Gpm, No GHe Inject, 2 Hr. Min. Load to Launch

---

Diagram showing total delta payload in lbs for different configurations:
- 1 Vent Valve
- 2 Vent Valves
- 3 Vent Valves
- Iced Bare
- 1" TPS
- .5" TPS

Values at each configuration:
- 1 Vent Valve:
  - Iced Bare: -722 lbs
  - 1" TPS: -520 lbs
  - .5" TPS: -472 lbs
- 2 Vent Valves:
  - Iced Bare: -382 lbs
  - 1" TPS: -328 lbs
  - .5" TPS: -321 lbs
- 3 Vent Valves:
  - Iced Bare: -329 lbs
  - 1" TPS: -325 lbs
  - .5" TPS: -329 lbs

NAD.0072
LO2 Sensitivity Analysis

ET Fill Rate
1400 Gpm, No GHe Inject, 5 Hr. Min. Load to Launch

[3D bar chart showing the effects of different vent valve configurations and TPS conditions on total delta payload in Lbs.]
LH2 Payload vs TPS

2 Hour Min Load to Launch

Total Delta Payload - Lbs

1" BX - Option 1

5" BX

1 Vent Valve

3 Vent Valves

2 Vent Valves

-1307

-1220

-1272

-646

-599

-636

NLS Baseline

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MANNED SPACE SYSTEMS
Appendix 4
TPS Manufacturing
Spray Process

- TPS Thickness on tank barrels is readily controlled with a tolerance of + .38", - .00"

- TPS spray thickness on skin / stringer type structures varies due to expanding foam masking some areas on the sides of stringers during successive spray gun passes

- The following pages show four possible spray patterns which were considered for this study
Stringer TPS Profile

CV-STR-14H

Option 1

.18 + .25
- .00

.5 + .38
- .00

.5" min on skins gives .18 min on stringers

.75" nominal TPS thickness used for mass properties
Stringer TPS Profile

Option 2

.75 + .38
- .00

.25 + .25
- .00

.75" min on skins gives .27 min on stringers

1.0" nominal TPS thickness used for mass properties
Stringer TPS Profile

Option 3

1.4 + .38
- .00

1.4" min on skins required to give
.5 min on stringers

.5 Min + .25
- .00

1.5" nominal TPS thickness used for mass properties
Stringer TPS Profile

Option 4

1.7" min on skins required to give .75 min on stringers

+ .38
-.00

1.7

+.25
-.00

.75

+- .00

1.7

+- .38
-.00

MARTIN MARIETTA
MANNED SPACE SYSTEMS
<table>
<thead>
<tr>
<th>Conclusions</th>
<th>CV-STR-14H</th>
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<td>Option 1</td>
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<td>Option 3</td>
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<td>Option 4</td>
<td>Excessive TPS thickness</td>
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TPS Closeouts
Ice / Liquid Air Suppression  CV-STR-14H

Assumes bare Fwd Skirt & I/T

Detail A

Theoretical TPS Profile

Manufacturing TPS Profile
80 lbs per detail shown

Detail A
Closeouts

Flange Closeouts
- Bolted joints between components
- No TPS required for NLS heating rates
- TPS is required for ice/frost & liquid air prevention
- No flange closeouts used in Reference configuration
- Three flange closeouts added to Full TPS option @ 80 lbs per closeout

Fwd Skirt & Intertank Closeouts
- Definition of openings in the Reference incomplete
- Closeouts may be required for aeroheating
- Design goal should be to minimize closeouts by designing heatsink enclosures at each penetration
- These closeouts not included in current study

Cable Tray & Propellant Line supports
- Definition of supports in the Reference incomplete
- Design goal should be to minimize TPS closeouts for aeroheating
- Supports on cryo-tankage will cause ice/frost formation.
- Requirements should try to accept ice/frost formation to avoid costly TPS closeouts
# TPS Weights

## CV-STR-14H

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<th>Reference TPS Weights (LBS)</th>
<th>MMMSS Config</th>
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<td>Nom TPS</td>
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<td>Fwd Skirt</td>
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<td>LO2 Tank</td>
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</table>

* From MSFC Baseline Mass Properties 3/25/91
** No contingency included

# Flange or bolted joint closeouts

Note that LO2 & LH2 results in CV-STR-14H contain performance related delta's in addition to TPS weight deltas.
Appendix 5
Freon Replacement
Freon Replacement

CV-STR-14H

- Montreal Protocol set worldwide Chlorofluorocarbon (CFC) reduction goals in 1987
- ET currently uses Freon 11 (a CFC) as a TPS blowing agent
- EPA regulations (1988) set CFC production phase out schedule
- Clean Air Act Amendments of 1990 accelerated CFC phase out & established a Hydrochlorofluorocarbon (HCFC) phase out schedule
  - CFC production finishes 2000AD
  - HCFC production finishes 2015AD
HCFC's also affect ozone layer but to a lesser degree than CFC's
Freon Replacement - Contd  CV-STR-14H

- ET (as an interim solution) will replace Freon 11 with Freon 141b (an HCFC) by 1998. Qualified foams using Freon 141b should be available by 1995. (An ALS developed foam SS-1228 from IPI is expected to replace BX-250 with a material cost reduction of approx 75%)

- ET will pay all non-recurring costs

- Requirements to minimise air emissions / maximise reuse of HCFC's will cause an increase in recurring costs compared with current ET foam processing

- Freon 141b replacement is TBD
Appendix 6

Ice & Liquid Air Formation
Ice & Liquid Air Req'mts  CV-STR-14H

Level III SRD states that ice & liquid air formation is acceptable if not detrimental to vehicle systems / operation

**Ice Formation**

1.0 " TPS - ET Nominal - Ice does form & can scrub launch.

.5" TPS - Ice will form for more launches & will be thicker, ice formation still calculatable.

Iced Bare - Much more difficult to predict ice formation, and thicker ice will form than for above cases. Very large uncertainties in ice density, conductivity, quantity & adhesion after launch.

Is ASRM designed for ice debris?

**Safety / liquid air**

SOFI in contact with liquid air is a fire hazard. SOFI is self extinguishing in air. It is not self extinguishing if oxygen is above 25% which happens if liquid air is present
Ice Sensitivity

• Saturn IB Experience Indicated Total of 6150 lbs. Adhered to Vehicle at Launch in One Case

• Ice/Frost Density Varies from 6 thru 57 lb/ft\(^3\). Initial ice density is approx 57 lb/ft\(^3\), decreasing as thickness increases

• Ice/Frost Thermal Conductivity Varies About 50:1

• Minimum Ice/Frost Accumulation Could Cause a Payload Penalty Greater Than Gain from Decreasing Barrel Insulation

• Large Uncertainty Here Would Increase Required Flight Reserve
- Even thin Ice/Frost build-up generates significant weight
- Actual build-up will depend on weather conditions and variations in TPS thickness
Ice Sensitivity

CV-STR-14H

References

- "Ice/Frost Formation on Cryogenic Propellant Tanks", TD-S&E-ASTN-XSG-10, January 1972, Chrysler Huntsville

- Multiple Inter Company Correspondence, Chrysler Space Division, MAF, 10 October 1972 thru 7 February 1973, Saturn IB Ice/Frost Accumulation in Rain

- "Saturn IB Performance Effects of Ice/Frost Accumulation Prior to Launch", Chrysler Space Division, TB-AP-73-204, January 26, 1973
5.2.1.4.2 TPS Reference Definition (#CV-STR-14-H)

Objective

Develop the recommended TPS definition for the Reference NLS Core Vehicle (acreage only) which will maintain propellant quality and protect vehicle structure/subsystems during pre-launch and ascent phases.

Approach

Part 1 - Evaluate thermal protection options individually for each major structural element of the core vehicle.

Part 2 - Evaluate thermal protection options for the entire Core Vehicle based on data generated in Part 1. Identify recommended changes to the Reference NLS Core Vehicle TPS.

Part 2 Options Studied

Reference Configuration; Heatsink Configuration; 1.0" TPS Configuration.

Key Study Results

Propellant conditioning during pre-launch and ascent is acceptable (with variations in performance) for all options. The Reference structure survives Aeroheating with the exception of the Forward Skirt. Modifying the Reference to provide a true Heatsink design adds mass to the Fwd Skirt & removes some from the Intertank. The LO2 tank is adequate for heatsink as designed, while the LH2 tank must have some TPS to prevent excessive boil-off.

The 1.0" TPS option was designed to avoid the ice & liquid air problem. Less than 1.0" of TPS on each component gives rise to a significant increase in the probability of ice & liquid air formation compared with ET. Ice & liquid air formation is hard to predict quantitatively. Ice may adhere after launch with subsequent performance(payload)impacts. There is a significant potential for launch delays due to ice. Ice debris & liquid air/flammability are safety issues.

Conclusions

The Heatsink option solves the problems with the Reference configuration. It shows that 592 lbs must be added to the Reference to develop a true Heatsink design, and this option still has additional unknown weight, cost, operability & safety impacts due to ice & liquid air formation. It is also harder to re-design for increased heating rates than an equivalent TPS design (easier to spray more TPS than add more metal). No cost increase is anticipated over the Reference option.

There is an additional performance loss of 121 lbs (vs the Heatsink) assuming 1.0" of TPS on the entire Core. This avoids all the problems associated with ice & liquid air formation. The cost of applying acreage TPS is not felt to be prohibitive to avoid the above system level uncertainties / problems. Cost delta's are +$.72M Non-rec & +$1.1M Recurring.

Study Recommendations

Revise Cycle Ø baseline to incorporate 1.0" of TPS.
REFERENCE CONFIGURATION
- Forward Skirt fails due to Aerohating
- Ice/Frost formation within 2ft of LO2 I/F
- Ice/Frost & Liquid Air formation within 2ft of LH2 I/F
- Ice/Frost & Liquid Air formation possible over entire LH2 barrel. Will occur with much greater frequency than on ET (ET has 1.0” TPS)

HEATSINK CONFIGURATION
- Ice/Frost formation within 2ft of LO2 I/F
- Ice/Frost & Liquid Air formation within 2ft of LH2 I/F
- Ice/Frost & Liquid Air formation possible over entire LH2 barrel. Will occur with much greater frequency than on ET (ET has 1.0” TPS)

1.0” TPS VEHICLE
- Probability of Ice/Frost & Liquid Air formation on Core is the same as ET to-day
- No Performance, Operations or Safety uncertainty

Lowest Weight & Cost Core Option but:
- Fwd Skirt fails due to Aerohating
- No Estimate of Increased Weight & Cost due to Ice & Liquid Air

Low Cost Core Option (Same as Reference)
- 592lbs weight added for true Heatsink design
- No Estimate of increased Weight & Cost for Ice & Liquid Air Formation

Extra 121 lbs (vs Heatsink option) removes any uncertainties due to Ice & Liquid Air
- Cost increase relatively low

Additional Information
See Doc # MMC.NLS.SR.001.Book 1 for more detailed results
6.2.1.4.2 TPS Reference Definition (#CV-STR-14-H)

Objective

Develop the recommended TPS definition for the Reference NLS Core Vehicle (acreage only) which will maintain propellant quality and protect vehicle structure/subsystems during pre-launch and ascent phases.

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Part 2 - Evaluate thermal protection options for the entire Core Vehicle based on data generated in Part 1. Identify recommended changes to the Reference NLS Core Vehicle TPS.

Part 2 Options Studied

Reference Configuration; Heatsink Configuration; 1.0" TPS Configuration.

Key Study Results

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There is an additional performance loss of 121 lbs (vs the Heatsink) assuming 1.0" of TPS on the entire Core. This avoids all the problems associated with ice & liquid air formation. The cost of applying acreage TPS is not felt to be prohibitive to avoid the above system level uncertainties / problems. Cost delta's are +$.72M Non-rec & +$1.1M Recurring.

Study Recommendations

Revise Cycle Ø baseline to incorporate 1.0" of TPS.
REFERENCE CONFIGURATION
- Forward Skirt fails due to Aeroheating
- Ice/Frost formation within 2ft of LO2 I/F
- Ice/Frost & Liquid Air formation within 2ft of LH2 I/F
- Ice/Frost & Liquid Air formation possible over entire LH2 barrel. Will occur with much greater frequency than on ET (ET has 1.0" TPS)

Lowest Weight & Cost Core Option but:
- Fwd Skirt fails due to Aeroheating
- No Estimate of Increased Weight & Cost due to Ice & Liquid Air

HEATSINK CONFIGURATION
- Ice/Frost formation within 2ft of LO2 I/F
- Ice/Frost & Liquid Air formation possible over entire LH2 barrel. Will occur with much greater frequency than on ET (ET has 1.0" TPS)

Low Cost Core Option (Same as Reference)
- 592lbs weight added for true Heatsink design
- No Estimate of increased Weight & Cost for Ice & Liquid Air Formation

1.0" TPS VEHICLE
- Probability of Ice/Frost & Liquid Air formation on Core is the same as ET to-day
- No Performance, Operations or Safety uncertainty

Extra 121 lbs (vs Heatsink option) removes any uncertainties due to Ice & Liquid Air
- Cost increase relatively low

Additional Information
See Doc # MMC.NLS.SR.001.Book 1 for more detailed results
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Coretank - Manufacturing Plan

Objective

To Develop a Core Tankage Manufacturing, Tooling and Facilities Plan that Utilizes ET Tooling, Facilities and Infrastructure

Groundrules

- Build at Michoud Using ET Tooling & Facilities
- NLS Production Requirement up to 13/yr
- ET Production Requirement 8/yr
Coretank Manufacturing Flow - Forward Skirt

T06AXXXX
SKIRT TACK & ASSEMBLY

T06A7398
RIVET

T06AXXXX
SYSTEMS INSTALL BRACKETS

T25L7272
SOFI APPLY & TRIM

TO CELL L LO2/INTERTANK MATE
Coretank Manufacturing Flow - Domes

T01A5001 GORE/GORE TRIM/WELD
T01A6191 CHORD/QUARTER PANEL TRIM
T01A5132 CHORD/QUARTER PANEL WELD
T01A5087 HALF DOME TRIM & WELD

TO
T01A5103 DOME BODY TRIM & WELD
T01A5005 DOME BODY TO CAP TRIM & WELD

TO
T02A5003 / T02A5083 X-RAY

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Coretank Manufacturing Flow - Rings

STA 3377, 3624 AND 3871 RING ASSEMBLIES

T04A5017 WELD → T08A7362 ASSEMBLY → T08A6005 MACHINE → TO T05A5019 LH2 TANK WELD

STA 2711.3, and 4058 RING ASSEMBLIES

T04A5017 WELD → T08A6005 MACHINE → TO LO2 TANK WELD

LH2 TANK SHORT BARREL / AFT DOME SUB ASSY WELD IN LO2 TANK WELD TOOL
Coretank Manufacturing Flow - LO2 Barrel

1. (2) 10 ft + BARRELS
2. T04A5015 TRIM & WELD
3. T04A5102 X-RAY
4. T40S9343 ROLL RING INSTALL
5. T03A6165 TRIM
6. TO LO2 TANK WELD
Coretank Manufacturing Flow - LO2 Major Weld

TO

CELL P

T05AXXX POST PROOF X-RAY

CELL F PROOF TEST

T05AXXX MECHANICAL

T05AXXX LO2 TANK ASSY & WELD

BARRELS RING SLOSH BAFFLES DOMES
Coretank Manufacturing Flow - LH2 Barrels

AFT BARREL
T04A5015 TRIM, WELD & X-RAY

5 FOOT BARREL
T04A5015 TRIM, WELD & X-RAY

FORWARD BARREL
T04A5016 TRIM & WELD

T40S0343 ROLL RING INSTALL
T04A7086 FRAME INSTALL

T03A6165 TRIM
TO T05A5019 LH2 TANK WELD

TO LH2 TANK SHORT BARREL / AFT DOME SUB ASSY WELD

T04A7003 FRAME INSTALL
T03A6165 TRIM

TO T05A5019 LH2 TANK WELD
Coretank Manufacturing Flow - Clean, TPS & Stack

LO2 TANK

LH2 TANK

CELL P
EXTERNAL CLEAN AND PRIME

CELL M
APPLY TPS

CELL L
FWD SKIRT/LO2 TANK/INTERTANK SPlice

CELL E
INTERNAL CLEAN

TO
CORE STAGE ASSEMBLY

CELL N
APPLY TPS

CELL E
INTERNAL CLEAN
5.2.1.4.3  Manufacturing Plan (CV-STR-16A)

Objective

Develop a manufacturing plan for production of three core tanks for the Heavy Lift Launch Vehicle (HLLV) and ten Stage-and-a-Half Vehicles per year concurrent with an NSTS External Tank production rate of eight per year.

Approach

(1) Develop manufacturing sequence flow for core tankage design.
(2) Review ET major tooling capacities to determine new tooling requirements
(3) Define Tool and Facilities requirements (5.2.1.4.4 & 5.2.1.4.5)

Groundrules and Assumptions

Since the combined production rate for the NLS and ET assemblies (21) will not exceed the twenty four per year production rate capability of the tooling and facilities at MAF, it is assumed there will be no overall schedule impact.

Assume manufacture of the launch vehicle will utilize current ET manufacturing technologies and established processes.

All construction will be at MAF using detail parts and sub-assemblies sub-contracted to outside suppliers.

Key Study Results

Manufacturing processes for the Core Tankage from receipt of the detail parts and assemblies through to the vertical assembly of the Liquid Hydrogen (LH2) Tank, Intertank (IT), Liquid Oxygen (LO2) Tank and the Forward Skirt, in the MAF Vertical Assembly Building (VAB) have been assessed. Subsequent assembly and test and checkout operations are addressed in a separate study. Manufacturing flow diagrams have been prepared to identify the core tankage major production activities through vertical stacking in the VAB.

All mechanically fastened subassembly operations maximize use of ET fixturing, and the existing large 'C'- frame riveter for automatic rivet installation.

The LH2 and LO2 tank barrel sequence flows are similar to ET and use ET fixtures, tooling, NDE facilities etc. The procured barrel skin panels, will be cleaned in the existing MAF facility prior to welding. Weld assembly, trim, and frame installation is to be accomplished on ET tooling and will utilize ET roll rings and roll ring installation tooling.

H & J Rings will be procured, machined, stretched formed, aged and trimmed in 90° sections. These sections will be welded together to form the 360° rings, machined and drilled, etc. in the ET ring tools.
Dome fabrication will use the ET dome weld tooling; new adaptive tools will be required for the new design dome caps and fittings. A new tool is required for LH2 Tank Aft Dome mechanical installations.

New tooling will be required for the assembly of the Anti vortex and Slosh Baffle assemblies and will be located in the MAF Bldg 103. Elements of these assemblies will be procured from outside suppliers as preassembled subassemblies.

LH2 and LO2 tank assembly sequence will be similar to the ET process using existing tooling and facilities. The flow differs from ET only in that a new tool is required for LO2 tank major weld operations. Internal and external clean and prime operations will use the ET LH2 tank processing cells, except that the LO2 tank will be processed through the ET LH2 tank processing Cell P for external clean and prime; TPS operations will be performed in re-activated Cells M & N.

Intertank assembly will use ET Intertank tooling.

Forward Skirt major assembly will use a dedicated assembly fixture; subassembly activities will use ET Intertank tooling. The Skirt/LO2 tank interface bolt hole pattern will be identical to ET LO2/IT/LH2 Tank interface pattern and will use drill plates mastered from existing ET tooling.

Core Tankage assembly is similar to the ET except Forward Skirt/LO2 Tank/Intertank stack will be in Cell L. The assembly will be transferred to Cell A for stacking to the LH2 Tank and TPS closeout of the Intertank/LH2 tank interface. The completed stack will be lowered to the horizontal position, and processed according to plans specified in IACO studies.

Conclusions

The NLS Core Tankage Manufacturing Plan has been developed for total assembly at the NASA-Michoud Assembly Facility (MAF). The plan makes effective use of manufacturing areas, existing tooling and facility capacities, and infrastructure on a non-interference basis with the on-going External Tank (ET) project.

Study Recommendations

Existing NLS program groundrule for building NLS Core Tankage using ET tooling and MAF facilities should be maintained.

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results
6.2.1.4.3 Manufacturing Plan (CV-STR-16A)

Objective

Develop a manufacturing plan for production of three core tanks for the Heavy Lift Launch Vehicle (HLLV) and ten Stage-and-a-Half Vehicles per year concurrent with an NSTS External Tank production rate of eight per year.

Approach

(1) Develop manufacturing sequence flow for core tankage design.
(2) Review ET major tooling capacities to determine new tooling requirements
(3) Define Tool and Facilities requirements (6.2.1.4.4 & 6.2.1.4.5)

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All mechanically fastened subassembly operations maximize use of ET fixturing, and the existing large 'C'- frame riveter for automatic rivet installation.

The LH2 and LO2 tank barrel sequence flows are similar to ET and use ET fixtures, tooling, NDE facilities etc. The procured barrel skin panels, will be cleaned in the existing MAF facility prior to welding. Weld assembly, trim, and frame installation is to be accomplished on ET tooling and will utilize ET roll rings and roll ring installation tooling.

H & J Rings will be procured, machined, stretched formed, aged and trimmed in 90° sections. These sections will be welded together to form the 360° rings, machined and drilled, etc. in the ET ring tools.
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Intertank assembly will use ET Intertank tooling.

Forward Skirt major assembly will use a dedicated assembly fixture; subassembly activities will use ET Intertank tooling. The Skirt/LO2 tank interface bolt hole pattern will be identical to ET LO2/IT/LH2 Tank interface pattern and will use drill plates mastered from existing ET tooling.

Core Tankage assembly is similar to the ET except Forward Skirt/LO2 Tank/Intertank stack will be in Cell L. The assembly will be transferred to Cell A for stacking to the LH2 Tank and TPS closeout of the Intertank/LH2 tank interface. The completed stack will be lowered to the horizontal position, and processed according to plans specified in IACO studies.

Conclusions

The NLS Core Tankage Manufacturing Plan has been developed for total assembly at the NASA - Michoud Assembly Facility (MAF). The plan makes effective use of manufacturing areas, existing tooling and facility capacities, and infrastructure on a non-interference basis with the on-going External Tank (ET) project.

Study Recommendations

Existing NLS program groundrule for building NLS Core Tankage using ET tooling and MAF facilities should be maintained.

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results
CV-STR-16B
Core Tankage
Facilities Plan

Prepared By: Robert J. Houston
(504) 257-1510
George R. Charron
(504) 257-2917

Approved By: Donald F. Lumley

Rev: Initial
Date: January 8, 1992
Core Tankage - Facilities Plan

Objective

To Identify the Facilities Locations and Modifications Necessary to Meet the Requirements Specified in the Tooling Plan CV-STR-16C and the Flows shown in the Manufacturing Plan CV-STR-16A Maximizing Utilization of the Existing External Tank Facilities and Infrastructure

Groundrules

- Build at Michoud Using ET Tooling & Facilities
- NLS Production Requirement up to 13/yr
- ET Production Requirement 8/yr
Core Tankage Modifications (103 & 420)

- LH2 Tank Mechanical
  - Foundation Mods
  - Floor Mods
  - Utilities

- LO2/LH2 Post-Proof Inspection
  - Foundations
  - Utilities

- Slosh & Anti-Vortex Baffle Assembly
  - Relocate Al-Li Crib
  - Floor Mods & Utilities

- Final Assembly
  - Crane Coverage
  - Floor Mods
  - Foundation Mods

- Fwd Skirt TPS & Systems
  - Foundation Mods
  - Utilities
  - Enclosure
  - HVAC

- New LO2 Major Weld
  - Floor Mods
  - Utilities

- Test & Checkout Cells 1 & 2
  - Crane Coverage
  - Floor Mods
  - Extend Cells 10 ft
  - Apron Mods

- LH2 Aft Barrel Mechanical
  - Foundation
  - Utilities

- LH2 Aft Dome Mechanical
  - Foundation Mods
  - Utility Mods

- Forward Skirts & Frames
  - Crane Coverage
  - Foundations
  - Utilities
  - Relocate Tool Fabrication (103)

- ASRM

Building 103

Building 420
Core Tankage Modifications (110/114/131)

- **LO2/IT to LH2 Stack**
  - Cell A
  - Access Platforms
  - Closeout Room Mods
  - HVAC

- **LH2/LO2 Internal Clean**
  - Cell E
  - Cell Extension
  - New LO2 Probe
  - Platforms

- **LO2 Proof Test**
  - Cell F
  - Platforms
  - Tank Fill Lines

- **Prime & SOFI LO2 Domes**
  - Cell M
  - Rotation Foundation
  - Utilities
  - HVAC Mods
  - Proportioner Room
  - Control Room

- **SOFI LH2 Tanks**
  - Cell N
  - Utilities
  - HVAC Mods
  - Proportioner Room
  - Control Room

- **LO2 External Clean**
  - Cell P
  - Rotation Foundation
  - Utilities
  - Mod Spray Boom

- **Fwd Skirt, LO2 Tank & Intertank Stack**
  - Cell L
  - Platforms
  - Utilities
Core Tankage Modifications - 103

Requirement
- Rivet LO2 & LH2 frames
- Rivet forward skirt frames
- Assemble forward skirts

Tooling Effort
- New frame tables
- New skirt assembly fixture
- New sustainer assembly fixture

Work Scope
- Frame table utilities
- Assembly fixtures foundations & utilities

Note:
- The following work scope has been identified to the Core Tankage mod cost
  - 5 ton crane & crossover
    - Relocate tooling raw material, master model, tool inspection & tool fabrication
  - Reconfigure bulk commodities & prod. control
  - Reconfigure miscellaneous cribs
Core Tankage Modifications - 103

Requirement
- LO2/LH2 major weld
- LO2/LH2 mechanical installations
- LO2/LH2 post-proof inspection

Tooling Effort
- Relocate LH2 mechanical installation T05A5069
- New LO2 major weld fixture T05AXXXX
- Remove/surplus LO2 rotation fixture T05A7419
- Relocate two post-proof T05A7077's

Work Scope
- Floor & utility modifications for T05AXXX
- Floor/foundation & utility mods for T05A5069
- Foundation & utility mods for T05A7077's
Core Tankage Modifications - 103

Requirement
- Aft skirt bracket installation
- Aft skirt SOFI
- Aft skirt SOFI trim
- Aft skirt systems installation

Tooling Effort
- Modify T06A7272
  - Bracket installation
  - SOFI spray
- New trim & systems installation fixture

Work Scope
- T06A7272 enclosure
  - Partial walls & door
  - HVAC & utilities
- Trim & systems installation fixture
  - Floor modifications
  - Platform HVAC & utilities
Core Tankage Modifications - 103

Requirement
- LH2 aft dome mechanical

Tooling Effort
- Remove existing T02A7018
- New LH2 aft dome mechanical tool

Work Scope
- Modify tool foundation/floor
- Modify utilities

Dome Mechanical Area

New LH2 aft dome mechanical tool T02A7019

Thru-Aisle

ASRM Area
Core Tankage Modifications - 103

**Requirement**
- LO2 slosh baffle
- LO2/LH2 anti-vortex baffles

**Tooling Effort**
- New LO2 slosh baffle fixture
- New LO2 slosh baffle offload
- New LO2/LH2 anti-vortex baffles fixture

**Work Scope**
- Relocate Al-Li crib
- Provide utilities
Core Tankage Modifications - Cell F

Requirement
- Hydrostatic proof test LO2 tanks

Tooling Effort
- Weld access platforms/ladders
- Drying duct extensions
- Drain line modification

Work Scope
- Tilt-up dome access platforms
- Remove/modify 86 ft EL platform
- Tilt-up crane access platforms
- Standpipe modifications.

VAB (110) Cell F

Elevations
- 75 ton Colby
- 75 ton Ederer

ET access platforms in up position

New LO2 dome access platforms in down position @ EL 81'/83'

New tilt-up crane hook access platforms @ EL 65'/67'
(Two @ 180°)

Ground level 26

MARTIN MARIETTA
MANNAED SPACE SYSTEMS
Core Tankage Modifications - Cell E

**Requirement**
- Internal clean LH2 & LO2 tanks

**Tooling Effort**
- Drying duct extensions
- Bottom washer modifications

**Work Scope**
- 5 ft stretch No Sump
  - Tilt-up LO2 dome & crane access platforms
  - New LO2 probe
- 5 ft stretch with Sump
  - Lengthen cell & drop door
  - Lower drop door sill
  - Tilt-up LH2 crane access platforms
  - New LH2 probe

---

1. **Elevations**
2. **VAB (110) Cell E**
3. **Raised cell roof & lid**
4. **New LH2 crane access platforms in down position @ EL 108'**
   (Two @ 180°)
5. **ET access platforms in up position**
6. **New LO2 dome access platforms in down position @ EL 59/61'**
   (Two @ 180°)
7. **New LO2 crane access platforms in down position @ EL 42/44'**
   (Two @ 180°)
8. **Ground level 26**
Core Tankage Modifications - Cell P

Requirement
- External clean & prime LH2 tanks
- External clean LO2 tanks

Tooling Effort
- New forward LO2 dome spray platform
- New forward LO2 rotation fixture
- Modify aft LH2 dome spray platform

Work Scope
- Forward LO2 rotation fixture foundation
- Forward LO2 platform utilities
- Modify sidewasher

Building 131
Core Tankage Modifications - Cell N

**Requirement**
- SOFI LH2 tanks

**Tooling Effort**
- New forward dome spray platform
- Relocate aft dome spray platform & carriage

**Work Scope**
- Platform & spray carriage utilities
- Extend spray carriage floor plates
- Modify for spray control room
- SOFI pot/proportioner room
- SOFI supply lines

**Building 131**
Core Tankage Modifications - Cell M

**Requirement**
- Prime LO2 tanks
- SOFI LO2 domes

**Tooling Effort**
- New roll fixtures
- New dome spray platforms
- New barrel spray carriage & platform

**Work Scope**
- Aft rotation fixture foundation
- Spray carriage floor plates
- Platform & spray carriage utilities
- SOFI spray control room
- SOFI pot/proportioner room
- SOFI supply lines

Building 131
Core Tankage Modifications - Cell L

**Requirement**
- Stack LO2 tank on intertank
- Stack forward skirt on LO2 tank

**Tooling Effort**
- Intertank stands
- Intertank interior platforms

**Work Scope**
- Tilt-up intertank/LO2 flange access platforms
- Tilt-up LO2/skirt flange access platforms
- Tilt-up forward skirt crane access platforms

High Bay (114) Cell L

- 20 ton crane with 113' hook EL
- New tilt-up forward skirt crane access platforms in down position @ EL 74'/76'
  (Two @ 180°)
- New LO2 tank/forward skirt flange access platform in down position @ EL 69'/71'
  (360° Access)
- New intertank/LO2 tank flange access platform in down position @ EL 49'
  (360° Access)

Ground level
Core Tankage Modifications - Cell A

**Requirement**
- Stack intertank/LO2/forward skirt combination on LH2 tank
- Closeout SOFI LH2/intertank flange

**Tooling Effort**
- None

**Work Scope**
- No stretch
  - Tilt-up forward skirt crane access platforms
- 5 ft stretch delta
  - SOFI closeout enclosure
    - Raise tilt-up roof
    - New sliding doors
    - Flange access platforms
    - HVAC modifications

---

VAB (110) Cell A

Existing mobile crane hook access gantry for ET ogive

New tilt-up crane hook access platforms @ EL 164'/171'
(Two @ 180°)

Relocated closeout room roof & new doors @ EL 132'

Ground level
5.2.1.4.4 Facilities Plan (CV-STR-16B)

Objective

Prepare a facilities plan for manufacture of the NLS reference configuration HLLV and 1.5 Stage vehicles at the NASA Michoud Assembly Facility, integrated with the existing External Tank production.

Approach

(a) Analyze manufacturing plan
(b) Determine requirements for foundations
(c) Determine requirements for new and/or modified structures, craneage, support equipment and services
(d) Prepare preliminary design layouts

Key Study Results

Structural assembly areas within the MAF Bldg 103 will be required for the new fixtures for LO2 Tank Major Weld, Forward Skirt Assembly, Slosh Baffle Assembly and Frame Assembly. These positions will be located under existing crane coverage, except for the forward skirt assembly tools which will be covered by an extension to the crane system, and will be supplied with all necessary utilities.

An additional position with a reinforced foundation, located in the North East corner of building 103, will be required for the new Aft Dome Mechanical Installation Fixture.

Cells A, E, F and L will require modifications to add access platforms and stairs for installation and removal of handling equipment. Cell E may also require modification to raise the cell roof and lift door, to accommodate an aft dome sump, and a new probe and cover plate for the LO2 Tank internal cleaning.

Final Assembly and Test and Checkout operations are not included in this study but have been addressed in IACO studies.

Conclusions

Manufacture of the cycle 0 reference configuration vehicles can be accommodated within the existing ET manufacturing facilities with relatively minor impact.

Study Recommendations

Existing NLS program groundrule for building NLS Core Tankage at the MAF has been confirmed and should be maintained.

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.1.4.4 Facilities Plan (CV-STR-16B)

Objective

Prepare a facilities plan for manufacture of the NLS reference configuration HLLV and 1.5 Stage vehicles at the NASA Michoud Assembly Facility, integrated with the existing External Tank production.

Approach

(a) Analyze manufacturing plan
(b) Determine requirements for foundations
(c) Determine requirements for new and/or modified structures, cranage, support equipment and services
(d) Prepare preliminary design layouts

Key Study Results

Structural assembly areas within the MAF Bldg 103 will be required for the new fixtures for LO2 Tank Major Weld, Forward Skirt Assembly, Slosh Baffle Assembly and Frame Assembly. These positions will be located under existing crane coverage, except for the forward skirt assembly tools which will be covered by an extension to the crane system, and will be supplied with all necessary utilities.

An additional position with a reinforced foundation, located in the North East corner of building 103, will be required for the new Aft Dome Mechanical Installation Fixture.

Cells A, E, F and L will require modifications to add access platforms and stairs for installation and removal of handling equipment. Cell E may also require modification to raise the cell roof and lift door, to accommodate an aft dome sump, and a new probe and cover plate for the LO2 Tank internal cleaning.

Final Assembly and Test and Checkout operations are not included in this study but have been addressed in IACO studies

Conclusions

Manufacture of the cycle Ø reference configuration vehicles can be accommodated within the existing ET manufacturing facilities with relatively minor impact.

Study Recommendations

Existing NLS program groundrule for building NLS Core Tankage at the MAF has been confirmed and should be maintained.

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results.
CV-STR-16C
Core Tankage Tooling Plan

Prepared By: Robert J. Houston
(504) 257-1510
George R. Charron
(504) 257-2917

Approved By: Donald F. Lumley

Rev: Initial
Date: January 8, 1992
Coretank - Tooling Plan

Objective

To Define the Tooling Requirements of the Manufacturing Flow shown in the Manufacturing Plan CV-STR-16A Maximizing Utilization of the ET Tooling, Facilities and Infrastructure

Groundrules

- Build at Michoud Using ET Tooling & Facilities
- NLS Production Requirement up to 13/yr
- ET Production Requirement 8/yr
# Core Tankage - Tooling

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Core Tankage - Tooling

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# Core Tankage - Tooling

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<td>Access Platform Forward</td>
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</table>
5.2.1.4.5 Tooling Impacts (CV-STR-16C)

Objective

Determine tooling impacts resulting from the integration of NLS vehicle production into the NASA External Tank manufacturing environment.

Approach

Analyze existing ET tooling to determine the maximum capacity of each tool and/or facility in terms of its major function, and to evaluate the capability to produce ET, HLLV and 1.5 Stage Vehicle core tankage.

Key Study Results

Modify existing Dome weld tooling to accommodate feedline fittings and outlet locations.

New LH2 Aft Dome Mechanical Installation Tool required.

Use existing ET tools for LH2 Tank assembly.

New LO2 Tank major weld assembly tool required due to capacity limitation. This tool will also weld the LH2 5 ft barrel to the STA 4058 "Tee" ring, and the aft dome assembly.

Internal and external cleaning and LH2 Tank external finishing operations will be performed in the existing ET processing cells. TPS operations for both the LO2 and LH2 tanks will be performed in reactivated Cells M & N respectively. New adaptor tooling will be provided in those tools and cells which use the Orbiter or SRB interfaces during ET processing. In addition, new support tooling will be required in Cell L for the Forward Skirt/LO2 Tank/Intertank stack operation.

A new dedicated fixture will be required for the Forward Skirt Assembly and for any non-ET compatible Frame Assemblies.

Conclusions

The cycle Ø reference configuration NLS vehicles can be fabricated on the ET tooling with minor impact.

Study Recommendations

Maintain NLS program groundrule to utilize ET tooling.

Review tooling requirements for vehicle structural assembly and systems installations as design matures and make appropriate changes to ensure production capability and improved manufacturing efficiency.

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.1.4.5 Tooling Impacts (CV-STR-16C)

Objective

Determine tooling impacts resulting from the integration of NLS vehicle production into the NASA External Tank manufacturing environment.

Approach

Analyze existing ET tooling to determine the maximum capacity of each tool and/or facility in terms of its major function, and to evaluate the capability to produce ET, HLLV and 1.5 Stage Vehicle core tankage.

Key Study Results

Modify existing Dome weld tooling to accommodate feedline fittings and outlet locations.

New LH2 Aft Dome Mechanical Installation Tool required.

Use existing ET tools for LH2 Tank assembly.

New LO2 Tank major weld assembly tool required due to capacity limitation. This tool will also weld the LH2 5 ft barrel to the STA 4058 "Tee" ring, and the aft dome assembly.

Internal and external cleaning and LH2 Tank external finishing operations will be performed in the existing ET processing cells. TPS operations for both the LO2 and LH2 tanks will be performed in reactivated Cells M & N respectively. New adaptor tooling will be provided in those tools and cells which use the Orbiter or SRB interfaces during ET processing. In addition, new support tooling will be required in Cell L for the Forward Skirt/LO2 Tank/Intertank stack operation.

A new dedicated fixture will be required for the Forward Skirt Assembly and for any non-ET compatible Frame Assemblies

Conclusions

The cycle Ø reference configuration NLS vehicles can be fabricated on the ET tooling with minor impact.

Study Recommendations

Maintain NLS program groundrule to utilize ET tooling.

Review tooling requirements for vehicle structural assembly and systems installations as design matures and make appropriate changes to ensure production capability and improved manufacturing efficiency.

Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results.
CV-STR-16D
Transportation and Handling Requirements

Prepared By: Robert L. Gallagher
(504) 257-2861
Robert J. Houston
(504) 257-1510

Approved By: Donald F. Lumley

Rev: Initial
Date: January 8, 1992
Groundrules And Assumptions

- Core Tankage Manufactured at Michoud Assembly Facility

- Vertical Cells Used for Internal Clean, and TPS Application

- Use Existing Handling & Locating Hardware Where Possible

- Rotate During Core Stage Integration, Assy & Checkout

- Propulsion Module Handling Not Included In Study

- Forward Skirt Assembled With LO2/Intertank Assembly
Objective

Determine Handling and Transportation Points Required on Core Tankage Subassemblies for Manufacturing of the Core Tankage and IACO/Transportation of the Core Stage.
## Study Results – LO2 Tank

<table>
<thead>
<tr>
<th>Operation / Lift Position</th>
<th>Lift Point Location (Sta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straddle Carrier</td>
<td>Belly Band at 2852.8 &amp; Flg. at 2569.8</td>
</tr>
<tr>
<td>Mech. Assy./Horiz., Cells/Vert. Horiz. to Vert.</td>
<td>Flgs. at 2569.8 and 2852.8</td>
</tr>
</tbody>
</table>
Study Results – LH2 Tank

3 - Attach Points per Station
Locate 120° Apart, From -Y Axis

<table>
<thead>
<tr>
<th>Operation / Lift Position</th>
<th>Lift Point Location (Sta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell E / Vert.</td>
<td>3 - Fittings Located at 4098 and 4058</td>
</tr>
<tr>
<td>Cell A / Vert</td>
<td>3 - Fittings Located at 4018 and 4058</td>
</tr>
<tr>
<td>Straddle Carrier</td>
<td>Belly Band Located at 3123.15 and 3665.15 Lateral Support at Figs.</td>
</tr>
<tr>
<td>Cell P / Horiz.</td>
<td>Roll Rings at 3123 and 4122</td>
</tr>
<tr>
<td>Horiz. to Vert. &amp; Tank Inversion</td>
<td>Fig. at 3123 and Fittings at 4058 and 4018</td>
</tr>
</tbody>
</table>
Study Results – Fwd. Skirt / LO2 / Intertank

<table>
<thead>
<tr>
<th>Operation / Lift Position</th>
<th>Lift Point Location (Sta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Stack in Cell A</td>
<td>Fig. at 2284.8</td>
</tr>
</tbody>
</table>
Transportation and Handling

Study Results – Core Tankage Stack

Roll Ring / Lift Adapter Installed in Cell A

<table>
<thead>
<tr>
<th>Operation / Lift Position</th>
<th>Lift Point Location (Sta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack In Cell A, Vert. Support</td>
<td>3 - Places at 4058 and 4018</td>
</tr>
<tr>
<td>Lift Fr. Stack and Vert. To Horiz.</td>
<td>Fitting at 2284.8 and 2 Fittings at 4058 and 4018</td>
</tr>
</tbody>
</table>
Transportation and Handling

Study Results – Core Stage IACO & Ship

Rotate

Roll Ring

Intermediate Support During PM Mate. Fitting at Sta 4058 and 4018

Sta. 2473.8

Sta. 4261.4

<table>
<thead>
<tr>
<th>Operation / Lift Position</th>
<th>Lift Point Location (Sta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IACO / Rotate Stage</td>
<td>Support at 2473.8, Support and Drive at 4261.4</td>
</tr>
<tr>
<td>Transportation of Core Stage</td>
<td>Vert., Support on Roll Ring at 2473.8 Fixed Support on Roll Ring at 4261.4. Sea State Loads Apply</td>
</tr>
</tbody>
</table>
Transportation and Handling

Study Results – LH2 Tank Loads

Core Tankage Stack

<table>
<thead>
<tr>
<th>Load Case</th>
<th>a</th>
<th>b</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26780</td>
<td></td>
<td>Cell A, 3 - Plc</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>19166</td>
<td>Horiz. to Vert., 2 - Plcs</td>
</tr>
</tbody>
</table>
Summary – T & H Impacts to Core Tankage

- Frames Required at Sta 4018 and 4098

- Bolt Attach Points Required at (3) Equally Spaced Positions around circumference at Stations 4018, 4098 and 4058 (Mid Point at the "Z")

- Use Flanges on LO2, LH2 Tanks and Fwd. Skirt for Vert. and Horiz. Lifts and Stabilization Locations

- Frames at Sta. 2852.8 and Flange at Sta. 2569.8 on LO2 Tank and Sta. 3123 on the LH2 Tank to Support Tankage During Straddle Carrier Transportation

- Fwd. Skirt Flange to Support Core Tankage Static Weight in Vert. and Horiz. Attitudes

- Roll Ring Attach Points on Fwd. Skirt Flange Sta. 2473.8 & Propulsion Module Sta. 4261.4

- Roll Ring Positioned at Sta. 2473.8 and Locating Tooling at Sta. 4058 Support Core Tankage During P.M. Integration.

- Sea State Shipping Loads Taken at Propulsion Module Roll Ring Position
5.2.1.4.6 Transportation & Handling Requirements (CV-STR-16D)

Objective

Determine handling and transportation points required on Core Tankage subassemblies for manufacturing of the core tankage and IACO/Transportation of the Core Stage.

Approach

Analyze the core tankage subassemblies, assembly and IACO activities to determine the tooling and transportation interface point requirements for handling and processing operations enabling maximization of the existing ET tools, equipment and facilities.

Key Study Results

(1) Frames required at Sta 4018 and 4098.

(2) Bolt attach points required at (3) equally spaced positions around Sta 4018, 4098 and 4058 (Mid Point at the "-Z").

(3) Use flanges on LO2, LH2 Tanks and Fwd. Skirt for vertical and horizontal lifts and stabilization locations.

(4) Frames at Sta. 2852.8 and flange at Sta. 2569.8 on LO2 Tank and Sta. 3123.15 on the LH2 Tank to support tankage during straddle carrier transportation.

(5) Fwd. Skirt flange to support Core Tankage static weight in vertical and horizontal attitudes.

(6) Roll Ring attach points on Fwd. Skirt flange Sta. 2473.8 & Propulsion Module Sta. 4261.4.

(7) Roll Ring at Sta. 2473.8 and locating tooling at Sta. 4058 support Core Tankage during P.M. integration.

(8) Sea state shipping loads taken at Fwd skirt & propulsion module roll ring positions.

Conclusions

The defined lifting point locations and methods of lifting, roll ring locations, and positions for processing cells and transportation adaptor tooling can be accommodated in the core tankage design without impact. A new transporter is required to accommodate the Core Stage which is considerably heavier than ET.

Study Recommendations

Revise cycle Ø baseline to incorporate the proposed configuration and new transporter requirement. In cycle 1, determine frame and flange sizes, and incorporate attachment holes for tooling adaptors.
Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results.
6.2.1.4.6 Transportation & Handling Requirements (CV-STR-16D)

Objective

Determine handling and transportation points required on Core Tankage subassemblies for manufacturing of the core tankage and IACO/Transportation of the Core Stage.

Approach

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(7) Roll Ring at Sta. 2473.8 and locating tooling at Sta. 4058 support Core Tankage during P.M. integration.

(8) Sea state shipping loads taken at Fwd skirt & propulsion module roll ring positions.

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Revise cycle Ø baseline to incorporate the proposed configuration and new transporter requirement. In cycle 1, determine frame and flange sizes, and incorporate attachment holes for tooling adaptors.
Additional Information

See Doc# MMC.NLS.SR.001 Book 1 for more detailed results.
CV-STR-17A
Alternate Aft Skirt Configuration

Prepared By: Nell A Duncan
(504)257-0161
Rev: Initial
Date: January 8, 1992

Approved By: M. R. Simms
Alternate Aft Skirt Definition  CV-STR-17A

Objective

- Determine if an alternate Aft Skirt configuration is required or is beneficial for the core tankage

Related Tasks

- CV-STR-14-D  LH2 Tank Design Definition
- CV-STR-14-G  External Hardware Definition
Approach

• Identify Ref Aft Skirt Design

• Define Alternate Aft Skirt Configurations

• Identify Design & Manufacturing Impacts for each option

• Identify Recommended changes to the Reference Configuration
Groundrules & Assumptions CV-STR-17A

Groundrules

• For Vehicle Definition Use MSFC Reference Definition Dated 8/28/91, Supplemented by October 9-10th Structure Layouts (Config Freeze)
• Maintain MSFC Aft Structure Frame Stations

Assumptions

• Alternate Aft Skirt fabrication techniques similar to the Reference Configuration
Ref Config Aft Skirt

CV-STR-17A

Aft structure is a closed compartment consisting of a cylindrical structure, internal thrust cone & rear heat shield.

Bolted Joint I/F with LH2 Tank
External Stiffeners
"Super Zip" Stage Separation

Thrust Cone

Aft Skirt is Integral Part of Aft Structure
Reference Configuration  
CV-STR-17A

- Aft Skirt Part of Aft Structure
- 87.67" Long Skirt
- Sustainer Penetration within Aft Structure
Ref Config - Design & Manuf. CV-STR-17A

- Fabricated structure with rivetted "I" section stiffeners - section properties constant around circumference

- Additional stiffening & increased skin gauges are expected at holddown locations. Addition of larger integral or bolt-on stiffeners should not impact interface with the Core Vehicle.

- Core / Aft Structure radial positioning critical during mating operations
Problems
- LN2 build up inside Aft Structure
- Nitrogen ice debris
- Impact on component design & qual
- Possible venting impact
Ref - LN2 Options

Annular TPS drip step
- LN2 & ice form on dome & Aft Struct
- LN2 drips / runs down to intermediate frame
- Ice debris may be retained by frame

Drain holes

#1 Catch & Drain LN2

#3 Switch to Helium purge does not liquify at LH2 temp (Helium is 5 X cost of N2)

CV-STR-17A

STA XN 4122.65

Aft Structure

BX 250 Foam
Remove foam from this area to allow for contraction / expansion

No Access

Frames prevent access after mate for TPS application, machining & inspection

#2 Foam Crotch Area After Core / Aft Structure Mate

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Option 1

Aft Skirt Welded to Core Vehicle

New Aft Skirt Weld

Bolted Joint Relocated From XN 4122.65

XN 4122.65 XN 4134.65

12.00 Aft Skirt

XN 4210.32

Separation Plane

Sustainer Line

- Aft Skirt Welded to LH2 Frame
- Part of Core Vehicle
- 12" Long Skirt

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Option 1 - Weld Requirements CV-STR-17A

- Maintain ET Mismatch Requirements
  (Max Mismatch 10% of land)
- 6.0" Min Depth Required for Clamps & Supporting Tooling

Weld skirt from outside

36.0 Chord

Weld from inside dome

6.0 Min

Chord / Gore Weld

Clamps & Supports

Skirt / LH2 weld

- Chord Must Be Extended By Almost 2 Ft
- Gore/Dome Weld Must Be Repositioned (Major Tooling Impact)

Welded Skirt Not Feasible
Option 2

Short Bolt-on Skirt

New Bolted Joint

XN 4122.65  XN 4134.65

12.00 Minimum Length Separate Aft Skirt

- Separate Aft Skirt
- Part of Core Vehicle
- 12" Long

XN 4210.32

Separation Plane

Sustainer Line

CV-STR-17A
Option 2 - Design & Manuf

XN 4122.65  XN 4134.65

- Load path is less efficient than the reference but it is adequate. Tension loads carried in bending through two bolted joints instead of one.

- Additional bolted joint adds weight, complexity & cost to the design

- Core / Aft Structure radial positioning less critical during mating operations - more radial clearance

- Fabrication method assumed similar to reference
**Option 2 - LN2 Options**

- **Annular TPS drip step**
  - LN2 & ice form on dome & Aft Struct
  - LN2 drips / runs down to intermediate frame
  - Ice debris may be retained by frame

- **Drain holes**

---

**#1 Catch & Drain LN2**

**#2 Foam Crotch Area After Core / Aft Structure Mate**

**#3 Switch to Helium purge does not liquify at LH2 temp (Helium is 5 X cost of N2)**

---

**STA XN 4122.65**

**Aft Structure**

**BX 250 Foam**

Remove foam from this area to allow for contraction / expansion

**Access**

Excellent access for TPS operations prior to Aft Structure mate
Option 3

Long Bolt-on Skirt

New Bolted Joint

XN 4122.65
XN 4170.65
XN 4210.32

Separation Plane

48.00 Aft Skirt

Sustainer Line

- Separate Aft Skirt
- Part of Core Vehicle
- 48" Long
- Frame at XN 4170.65 is not part of skirt

NAD.0082

MARTIN MARIETTA
MANNED SPACE SYSTEMS
Option 3 - Design & Manuf  CV-STR-17A

- Longer version of Option 2
- Adequate load paths
- Additional bolted joint adds weight, complexity & cost to the design
- Core / Aft Structure radial positioning not critical during mating operations - large radial clearance
- Crotch access harder but possible (Core Vehicle only)
Option 3 - LN2 Options

- LN2 & ice form on dome & Aft Struct
- LN2 drips / runs down to intermediate frame
- Ice debris may be retained by frame

#1 Catch & Drain LN2

#3 Switch to Helium purge does not liquify at LH2 temp
(Helium is 5 X cost of N2)

CV-STR-17A

STA
XN 4122.65

Aft Structure

12.0

BX 250 Foam
Remove foam from this area to allow for contraction / expansion

48.00"

4 ft reach required for access

Acceptable access for TPS operations prior to mate

#2 Foam Crotch Area After Core / Aft Structure Mate

NAD.0082
<table>
<thead>
<tr>
<th></th>
<th>Ref Config</th>
<th>Option 2 12&quot; Skirt</th>
<th>Option 3 48&quot; Skirt</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM Installation to Core</td>
<td>Adequate</td>
<td>Improved</td>
<td>Improved</td>
</tr>
<tr>
<td>No. of Bolted Joints</td>
<td>Good</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Load Path Assessment</td>
<td>Yes- He Purge only Alternate Solution</td>
<td>Less Efficient than Ref</td>
<td>Less Efficient than Ref</td>
</tr>
<tr>
<td>LN2 &amp; Ice Formation</td>
<td>Not Possible</td>
<td>Foam or He Purge Solutions</td>
<td>Foam or He Purge Solutions</td>
</tr>
<tr>
<td>Ease of TPS Crotch Application</td>
<td>After PM Inst'1</td>
<td>Good</td>
<td>Adequate</td>
</tr>
<tr>
<td>Installation of Cross over Cable Tray</td>
<td>Ref</td>
<td>After PM Inst'1</td>
<td>Prior to PM Inst'1</td>
</tr>
<tr>
<td>Weight Impact</td>
<td></td>
<td>+ 600 lbs</td>
<td>+ 600 lbs</td>
</tr>
</tbody>
</table>

Preferred
Conclusions & Recommendations

Conclusions
- All Options except Welded Skirt (Option 1) are Feasible
- Reference Configuration has best Load Path
- Weight Impact & Cost is Least on Reference
- LN2 & Ice will form in Crotch on Reference

Recommendations
- Maintain Reference Configuration
- Study LN2 & Nitrogen Ice Formation During Cycle 1
- Consider Local Helium purge in Crotch Area only as another possible Solution
5.2.7.4.1 Alternate Aft Skirt Configuration (#CV-STR-17-A)

Objective
To determine if an alternate Aft Skirt configuration is required or is beneficial for the Core Vehicle.

Approach
Define alternate Aft Skirt configurations. Identify design & manufacturing impacts for each option, and any recommended changes to the Reference Aft Skirt configuration.

Options Studied
Reference configuration Aft Skirt (part of Aft Structure)
Option 1 - Aft Skirt welded to Core Vehicle
Option 2 - Short (12") Bolt-On Skirt (part of Core Vehicle)
Option 3 - Long (48") Bolt-On Skirt (part of Core Vehicle)

Key Study Results
Chord & weld geometry / tooling requirements were found to make Option 1 impractical.

Options 2 & 3 add a new bolted joint which adds 600 lbs of weight & additional cost, but they also reduce the risk associated with Core / Aft Structure mate.

Formation of LN2 & Nitrogen ice in the crotch area was identified as a potential problem. Nitrogen ice may break free causing ice debris during flight. LN2 accumulation would impact component design & qualification, and LN2 boil-off would also impact Aft Compartment venting. Use of a drip tray within the Aft Structure to catch LN2 and drain it overboard is possible, but does not fully address the ice debris concern. A Helium purge in all or part of the Aft Structure is the only known alternate means of addressing this problem on the Reference configuration, as the crotch area cannot be foamed after core to Aft Structure mate due to lack of access (Helium is currently approximately 5 times the cost of Nitrogen gas). Options 2 & 3 offer increased design flexibility as they do allow foaming of the crotch prior to Core / Aft Structure mate thus eliminating the ice & liquid air problem.

Conclusions
With the exception of Option 1 all Options studied are feasible. Options 2 & 3 offer some increased design flexibility but have associated weight and cost impacts.

Additional analysis is required to make a quantitative assessment of LN2 & Nitrogen ice formation.

Study Recommendations
Maintain the Reference Aft Skirt configuration. Study the LN2 & ice debris problem further during Cycle 1.
REFERENCE CONFIGURATION
XN 4122.65

Bolted Joint

87.67 Aft Skirt

LN2 & Ice Formation

No Access to Foam Crotch Area After Mate

Sustainer Line

OPTION 1 - AFT SKIRT WELDED TO CORE VEHICLE
XN 4122.65 XN 4134.65
New Aft Skirt Weld
Bolted Joint Relocated From XN 4122.65

Weld Geometry Impractical

12.00 Aft Skirt

OPTION 2 - SHORT BOLT-ON SKIRT
XN 4122.65 XN 4134.65
New Bolted Joint

Crotch Foaming Possible Prior to Mate

12" Aft Skirt

OPTION 3 - LONG BOLT-ON SKIRT
XN 4122.65 XN 4170.65
New Bolted Joint
Crotch Foaming Possible Prior to Mate

48" Aft Skirt

Sustainer Line

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results

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6.2.7.4.1 Alternate Aft Skirt Configuration (#CV-STR-17-A)

Objective

To determine if an alternate Aft Skirt configuration is required or is beneficial for the Core Vehicle.

Approach

Define alternate Aft Skirt configurations. Identify design & manufacturing impacts for each option, and any recommended changes to the Reference Aft Skirt configuration.

Options Studied

Reference configuration Aft Skirt (part of Aft Structure)
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Study Recommendations

Maintain the Reference Aft Skirt configuration. Study the LN2 & ice debris problem further during Cycle 1.
REFERENCE CONFIGURATION

XN 4122.65

Bolted Joint

87.67 Aft Skirt

XN 4210.32

Fabricated Joint Integral to Aft Structure

Sustainer Line

No Access to Foam Crotch Area After Mate

LN2 & Ice Formation

OPTION 1 - AFT SKIRT WELDED TO CORE VEHICLE

XN 4122.65 XN 4134.65

Weld Geometry Impractical

XN 4210.32

New Aft Skirt Weld

Bolted Joint Relocated From XN 4122.65

12.00 Aft Skirt

OPTION 2 - SHORT BOLT-ON SKIRT

XN 4122.65 XN 4134.65

New Bolted Joint

Crotch Foaming Possible Prior to Mate

12" Aft Skirt

Sustainer Line

OPTION 3 - LONG BOLT-ON SKIRT

XN 4122.65 XN 4170.65 XN 4210.32

New Bolted Joint

Crotch Foaming Possible Prior to Mate

48" Aft Skirt

Sustainer Line

Additional Information

See Doc # MMC.NLS.SR.001.Book 1 for more detailed results