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Marshall Space Flight Center
Michoud Assembly Facility

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Book I - Structures & Core Vehicle

Cycle Ø(CY1991) NLS Trade Studies and Analyses Report

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/Marshall 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.

Study Task Cross Reference Matrix (by Trade #)

TRADE STUDY #		T/S SUM PARA #		TRADE STUDY TITLE
MSFC	MMC	HLLV	1.5 ST	
3-S-001A	CV-STR-18A	5.2.3.4.2	6.2.3.4.2	Fwd Skirt Alt Panel Construction
3-S-001B	CV-STR-18B	5.2.3.4.3	6.2.3.4.3	Fwd Skirt Stiffener Pitch Sensitivity Study
3-S-001C	CV-DI-02	5.2.3.4.4	6.2.3.4.4	Alternate Fwd Skirt Configuration Definition
3-S-007	CV-STR-21	N/A	6.2.1.4.8	Alternate 1.5 Stage Support Trade
3-S-008A	CV-STR-20A	5.2.6.4.3	6.2.6.4.3	Tank Length vs Facility Impacts
3-S-008B	CV-STR-20B	5.2.6.4.4	6.2.6.4.4	LH2 Tank Impact vs Ullage Pressure T/S
3-S-008C	CV-STR-20C	5.2.6.4.5	6.2.6.4.5	LH2 Tank Stiffener Pitch Sensitivity Study
3-S-008D	CV-STR-20D	5.2.6.4.6	6.2.6.4.6	LH2 Tank Alt Panel Construction
3-S-009A	CV-STR-19A	5.2.5.4.2	6.2.5.4.2	Intertank Commonality Assessment
3-S-009B	CV-STR-19B	5.2.5.4.3	6.2.5.4.3	Intertank Stiffener Pitch Sensitivity Study
3-S-010A	CV-STR-15A	5.2.4.4.3	6.2.4.4.3	L02 Tank Impact vs Ullage Pressure T/S
3-S-010B	CV-STR-15B	5.2.4.4.4	6.2.4.4.4	L02 Tank Stiffener Pitch Sensitivity Study
3-S-010C	CV-STR-15C	5.2.4.4.5	6.2.4.4.5	L02 Tank Alt Panel
3-S-011	CV-STR-22	5.2.4.4.6	6.2.4.4.6	Slosh Baffle Requirements & Design Definition
—	CV-DI-01A	5.2.4.4.2	6.2.4.4.2	L02/LH2 Tank Access Trade Study
—	CV-DI-01B	5.2.1.4.7	6.2.1.4.7	Alt Transportation Attachment Points Evaluation
—	CV-STR-14A	5.2.3.4.1	6.2.3.4.1	Fwd Skirt Structural Ref Config Enhancements
—	CV-STR-14B	5.2.4.4.1	6.2.4.4.1	L02 Tank Structural Ref Config Enhancements
—	CV-STR-14C	5.2.5.4.1	6.2.5.4.1	Intertank Structural Ref Config Enhancements
—	CV-STR-14D	5.2.6.4.1	6.2.6.4.1	LH2 Tank Structural Ref Config Enhancements
—	CV-STR-14G	5.2.1.4.1	6.2.1.4.1	NLS Core Tankage External Hardware Definition
—	CV-STR-14H	5.2.1.4.2	6.2.1.4.2	TPS Reference Definition
—	CV-STR-16A	5.2.1.4.3	6.2.1.4.3	Core Tankage Manufacturing Plan
—	CV-STR-16B	5.2.1.4.4	6.2.1.4.4	Core Tankage Facilities Plan
—	CV-STR-16C	5.2.1.4.5	6.2.1.4.5	Core Tankage Tooling Plan
—	CV-STR-16D	5.2.1.4.6	6.2.1.4.6	Transportation & Handling Requirements
—	CV-STR-17A	5.2.7.4.1	6.2.7.4.1	Alternate Aft Skirt Configuration

Study Task Cross Reference Matrix (by Element)

Element	T/S #	T/S SUM PARA #		TRADE STUDY TITLE
		HLLV	1.5 ST	
Vehicle Assy Eng	CV-STR-14G	5.2.1.4.1	6.2.1.4.1	NLS Core Tankage External Hardware Definition
	CV-STR-14H	5.2.1.4.2	6.2.1.4.2	TPS Reference Definition
	CV-STR-16A	5.2.1.4.3	6.2.1.4.3	Core Tankage Manufacturing Plan
	CV-STR-16B	5.2.1.4.4	6.2.1.4.4	Core Tankage Facilities Plan
	CV-STR-16C	5.2.1.4.5	6.2.1.4.5	Core Tankage Tooling Plan
	CV-STR-16D	5.2.1.4.6	6.2.1.4.6	Transportation & Handling Requirements
	CV-DI-01B	5.2.1.4.7	6.2.1.4.7	Alt Transportation Attachment Points Evaluation
	3-S-007	N/A	6.2.1.4.8	Alternate 1.5 Stage Support Trade
Fwd Skirt	CV-STR-14A	5.2.3.4.1	6.2.3.4.1	Fwd Skirt Structural Ref Config Enhancements
	3-S-001A	5.2.3.4.2	6.2.3.4.2	Fwd Skirt Alt Panel Construction
	3-S-001B	5.2.3.4.3	6.2.3.4.3	Fwd Skirt Stiffener Pitch Sensitivity Study
	3-S-001C	5.2.3.4.4	6.2.3.4.4	Alternate Fwd Skirt Configuration Definition
L02 Tank	CV-STR-14B	5.2.4.4.1	6.2.4.4.1	L02 Tank Structural Ref Config Enhancements
	CV-DI-01A	5.2.4.4.2	6.2.4.4.2	L02 Tank Access Trade Study
	3-S-010A	5.2.4.4.3	6.2.4.4.3	L02 Tank Impact vs Ullage Pressure T/S
	3-S-010B	5.2.4.4.4	6.2.4.4.4	L02 Tank Stiffener Pitch Sensitivity Study
	3-S-010C	5.2.4.4.5	6.2.4.4.5	L02 Tank Alt Panel
	3-S-011	5.2.4.4.6	6.2.4.4.6	Slosh Baffle Requirements & Design Definition
Intertank	CV-STR-14C	5.2.5.4.1	6.2.5.4.1	Intertank Structural Ref Config Enhancements
	3-S-009A	5.2.5.4.2	6.2.5.4.2	Intertank Commonality Assessment
	3-S-009B	5.2.5.4.3	6.2.5.4.3	Intertank Stiffener Pitch Sensitivity Study
LH2 Tank	CV-STR-14D	5.2.6.4.1	6.2.6.4.1	LH2 Tank Structural Ref Config Enhancements
	CV-DI-01A	5.2.6.4.2	6.2.6.4.2	LH2 Tank Access Trade Study
	3-S-008A	5.2.6.4.3	6.2.6.4.3	Tank Length vs Facility Impacts
	3-S-008B	5.2.6.4.4	6.2.6.4.4	LH2 Tank Impact vs Ullage Pressure T/S
	3-S-008C	5.2.6.4.5	6.2.6.4.5	LH2 Tank Stiffener Pitch Sensitivity Study
	3-S-008D	5.2.6.4.6	6.2.6.4.6	LH2 Tank Alt Panel Construction
Aft Skirt	CV-STR-17A	5.2.7.4.1	6.2.7.4.1	Alternate Aft Skirt Configuration

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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

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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.

Evaluation Criteria		Rationale
Manufacturing/Producibility		Use Of ET Tooling Is An NLS Program Requirement.Selected Option Should Utilize Current Manufacturing Build Approach & Assembly
Weight Impact		Any Additional Weight Must Be Traded Against Loss Of Payload Lift Capability.
Costs	Non-Recurring	Minimal DDT&E Desired.
	Recurring	Low Cost Per Flight Desired For Expendable HLLV

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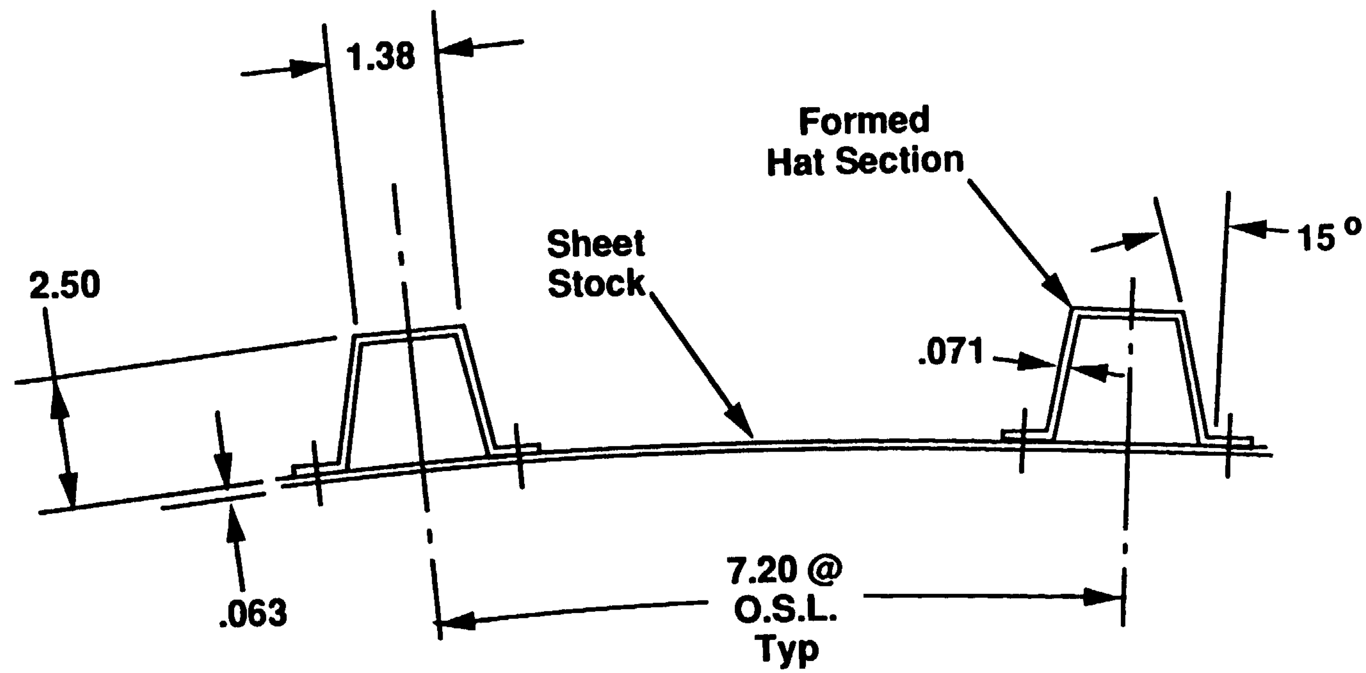
Option 1 - Forward Skirt Baseline Panel (P.O.D.)



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

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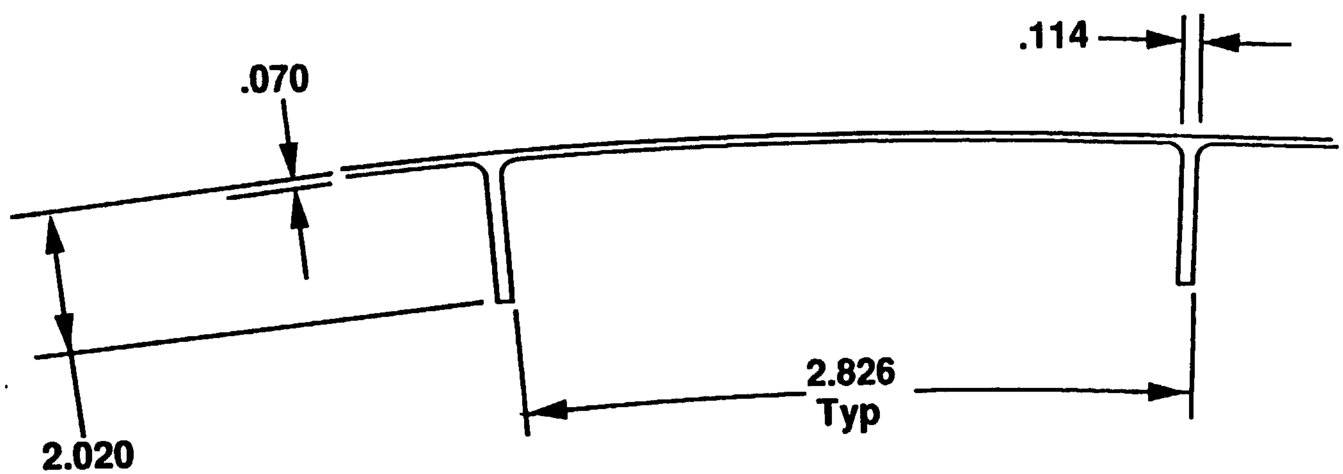
Option 2 - Blade-Stiffened Panel



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

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Manufacturing/Producibility Summary

	Barrel Assembly	Mechanical Assembly & Installation To Tank	Intermediate Frame Attachment	TPS Application
Option 1 (Baseline)	• Baseline • Can Use Intertank Tooling Etc.	• Baseline • Similar To Intertank	Similar To Intertank	Slightly Difficult But Process Now Developed On ET
Option 2 Machined Blade Stiffened Panel	• Less Fabrication • Some Existing Tooling Available	• Similar Mechical Assembly • I/F At Tank Attach Is More Complex	Same As Baseline	Easier (Smooth O.S.L.)

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Weight Impact Summary

	Total Weight Of Skin/Stringer Panels	Δ Weight From P.O.D. (lbs.)	% Weight Increase/ Decrease
Option 1 (Baseline)	1521.0	P.O.D.	0.0
Option 2 Machined Blade Stiffened Panel	1586.5	+65.5	4.3% Increase

Evaluation Summary

	Weight Impacts	Manufacturing/ Producibility Impacts	Other Impacts
Option 1 (Baseline)	Baseline	Baseline	Good Synergism With E.T.
Option 2 Machined Blade Stiffened Panel	65.5 lbs. Increase	Less Fabrication Simple Welding W/ Some Existing Tooling. TPS Appl. Easier	—

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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.

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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 appli-cation, 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 alternatative 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 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.

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The fabricated hat section and sheet construction is the preferred approach due to it's lower weight, ease of TPS appli-cation, 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 alternatative 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

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Rev: Initial
Date: January 8, 1992

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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

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STAGS-C Vs. PANDA II Study

ET LH2 Tank Thickness (nominal) in	STAGS Nx/crit lb/in	Knock down Factor	Nx/allow lb/in	Stresses in stringer	PANDA II NX lb/in	FSGEN	M. S General instability	MS GEN Stresses in stringer
0.149	1193	0.514	613	3533	1193 1193 613	2.0 1.0 2.0	-0.29 0.42 0.38	3492
0.141	1082	0.518	560	3382	1082 1082 560	2.0 1.0 2.0	-0.25 0.51 0.46	3342
0.132	983	0.523	514	3260	983 983 514	2.0 1.0 2.0	-0.21 0.59 0.52	3232

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Panda II Optimisation Study

Factors of Safey 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

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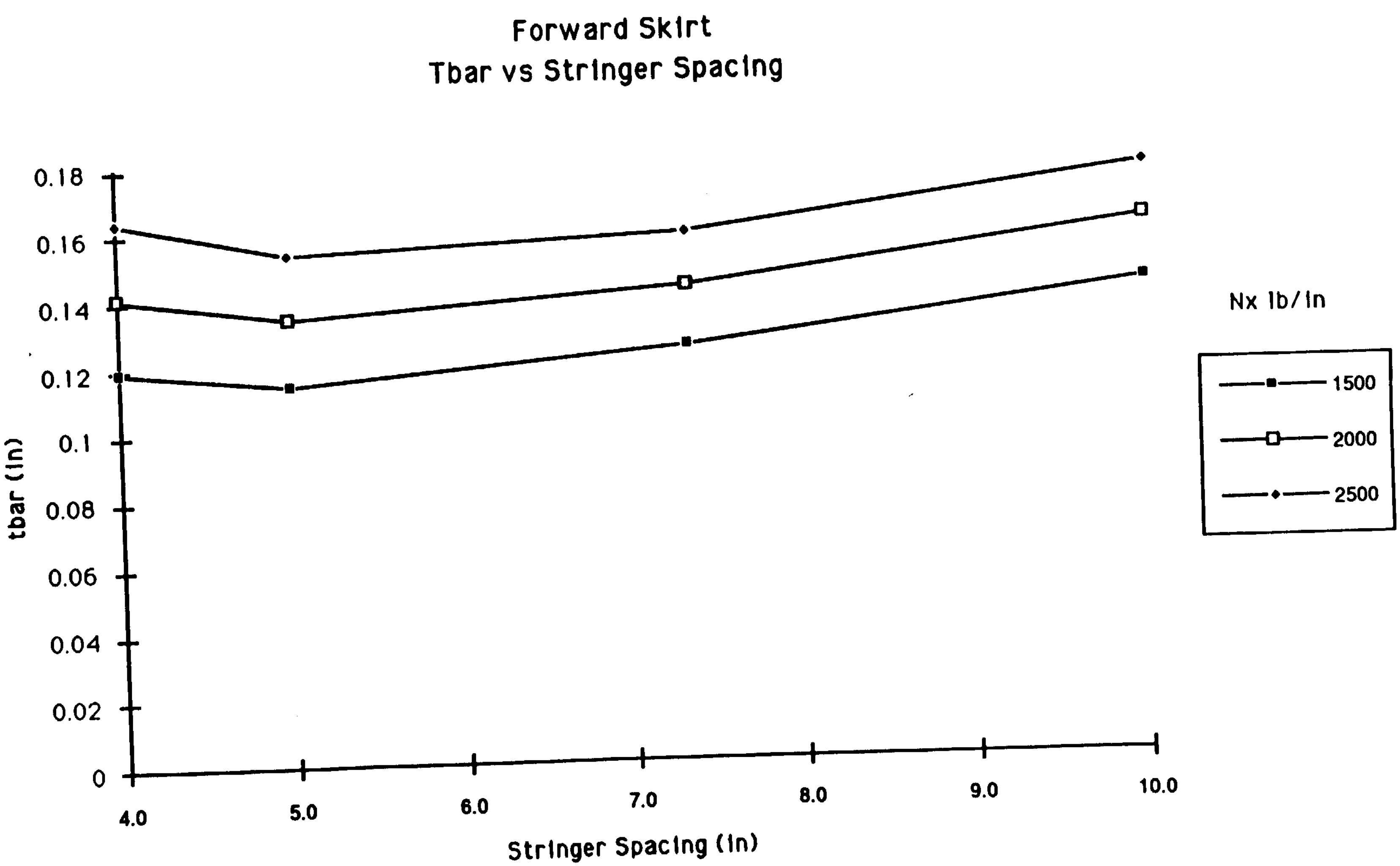
Panda II Optimization Study - Forward Skirt



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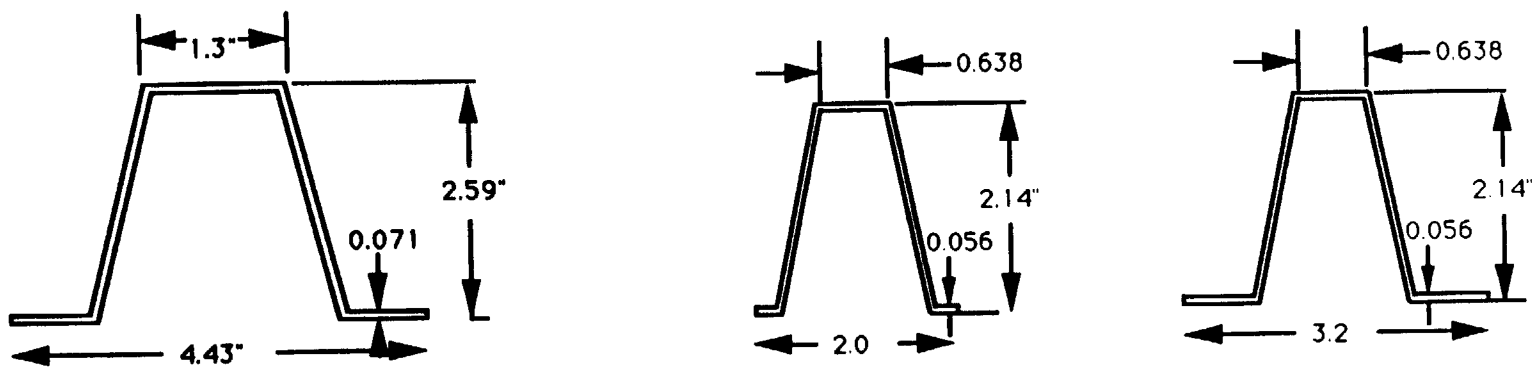
Panda II Optimization Study - Forward skirt



Current Design	Panda II Optimized Design (Nx = 2000 lb/in ult)	Optimized Design with Modifications
Stringer Spacing = 7.33"	Stringer Spacing = 5.0"	Stringer Spacing = 5.0"
Frame Spacing = 48.0"	Frame Spacing = 48.0"	Frame Spacing = 48.0"
Tbar=0.151"	Tbar=0.139"	Tbar=0.149"

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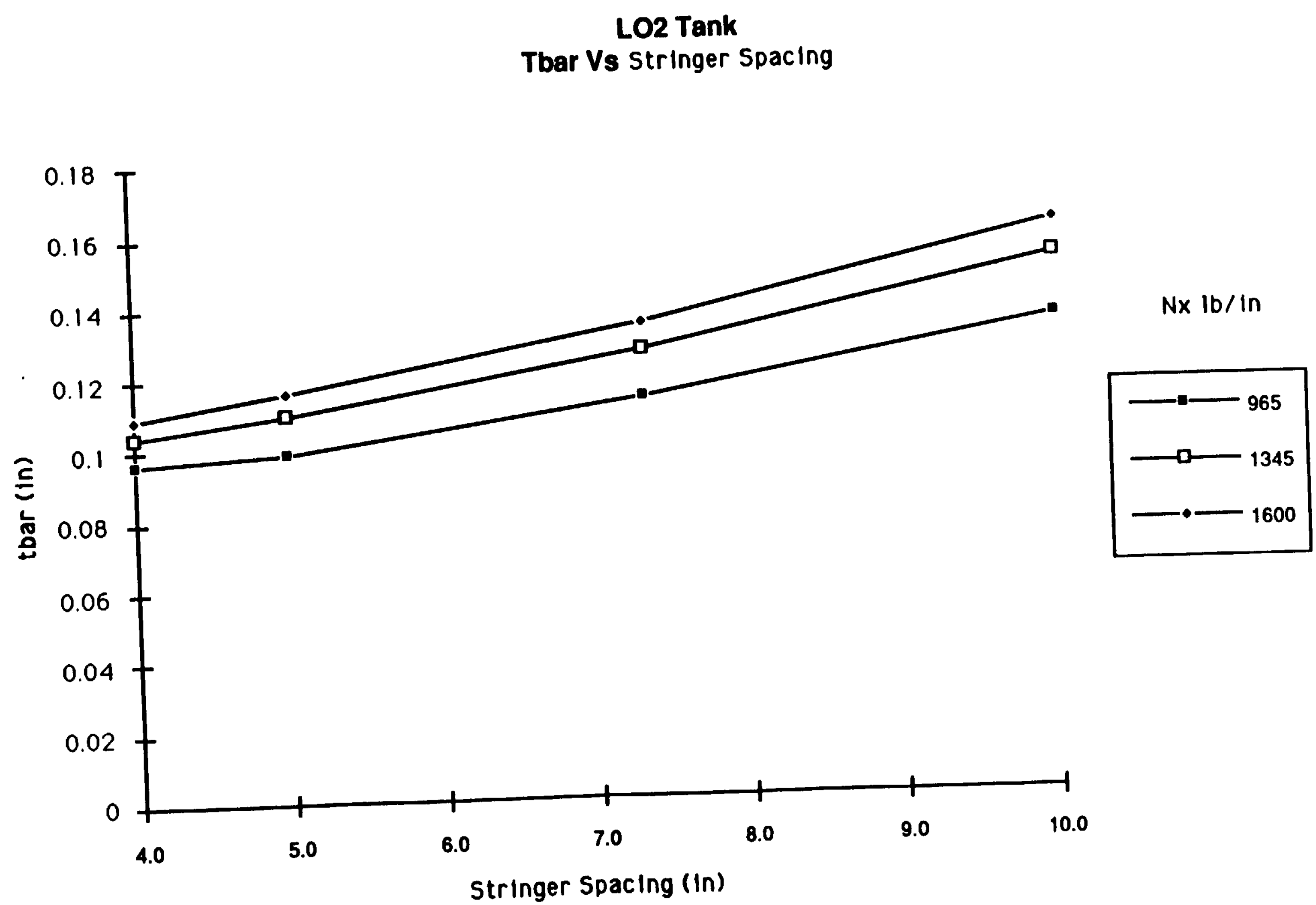
Panda II Optimization Study - LO2 Tank



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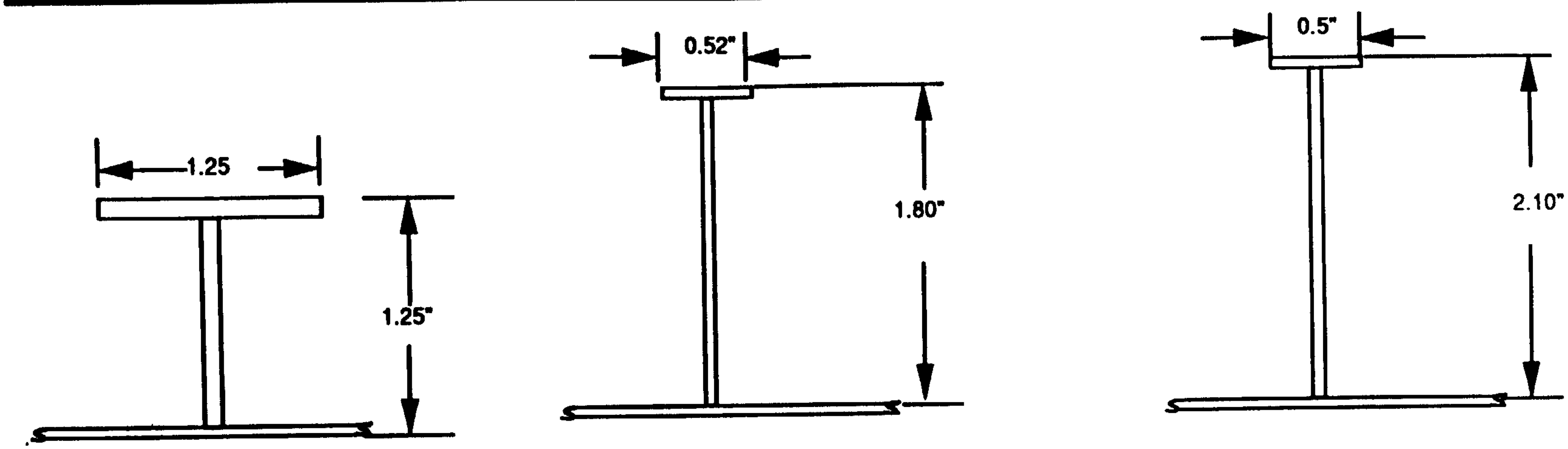
Stiffener Size and Pitch Sensitivity Trades - LO2 Tank



LO2 Tank

Current Design	Optimized Design Nx=960 lb/in	Optimized Design Nx=1345 lb/in
Stringer Spacing=10.832"	Stringer Spacing=4.0"	Stringer Spacing=4.0"
Frame Spacing=34.9"	Frame Spacing=34.9"	Frame Spacing=34.9"
Tskin=0.170	Tskin=0.067	Tskin=0.075
Tbar=0.193	Tbar=0.0963	Tbar=0.104

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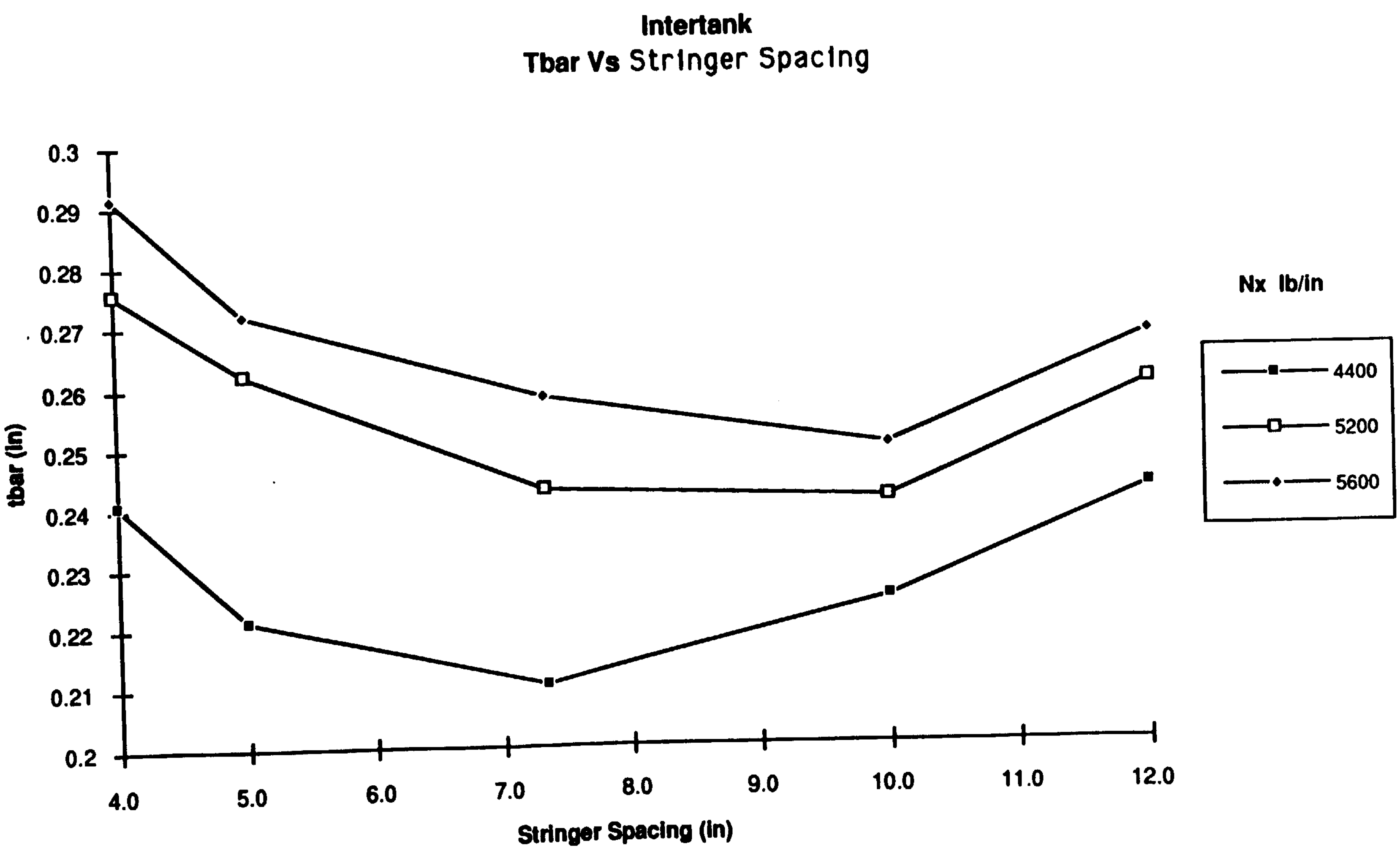
Panda II Optimization Study - Intertank



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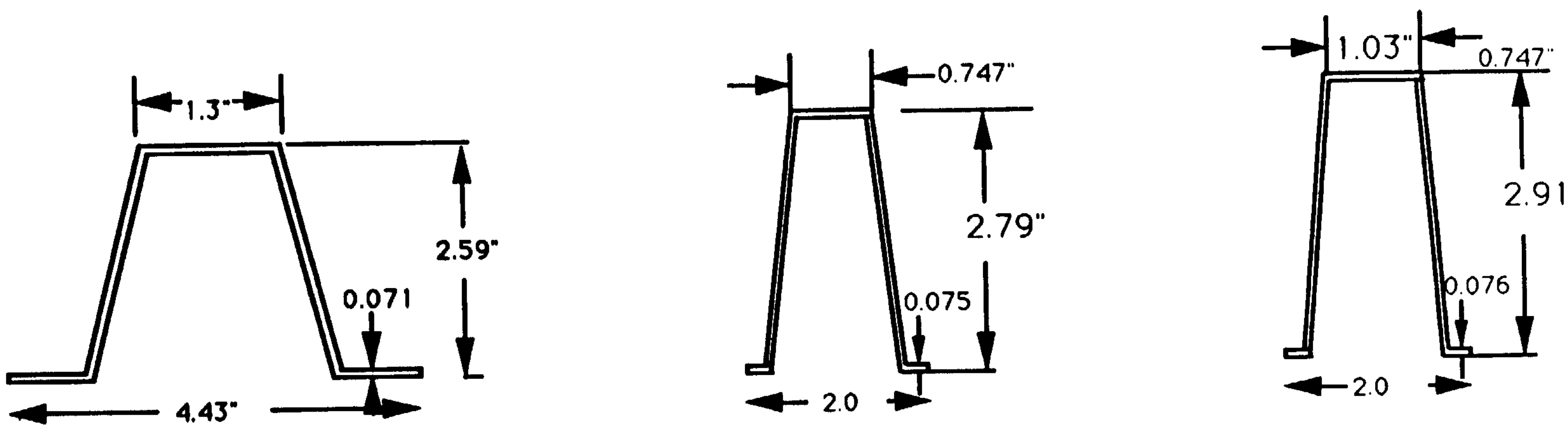
Panda II Optimization Study - Intertank



Current Design	Panda II Optimized Design (Nx = 4400 lb/in ult)	Panda II Optimized Design (Nx = 5200 lb/in ult)
Stringer Spacing = 7.33"	Stringer Spacing = 7.33"	Stringer Spacing = 10.0"
Frame Spacing = 45.0"	Frame Spacing = 45.0"	Frame Spacing = 45.0"
Tbar=0.238"	Tbar=0.21"	Tbar=0.241

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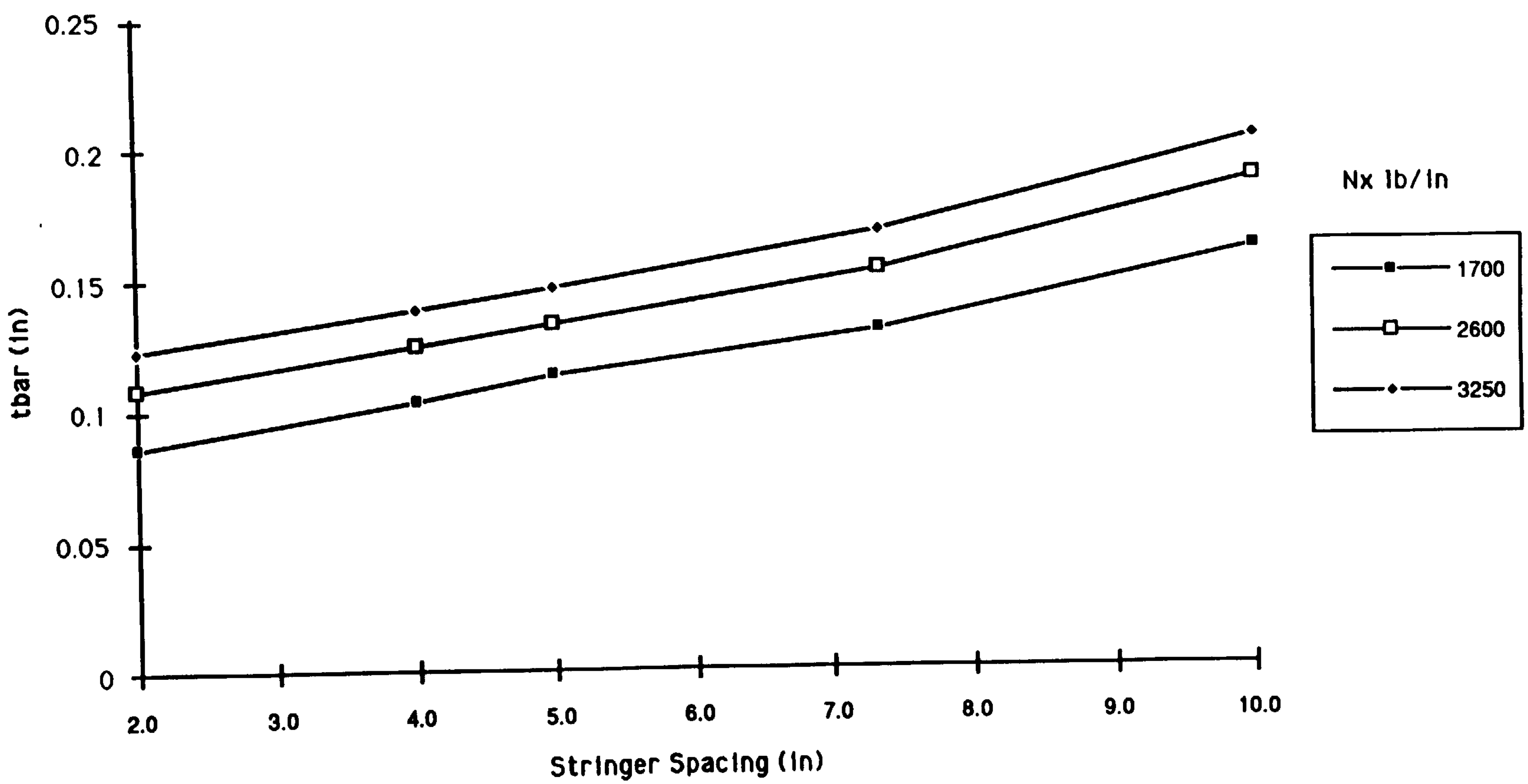
Panda II Optimization Study - LH2 Tank

LH2 TANK
Tbar Vs Stringer Spacing



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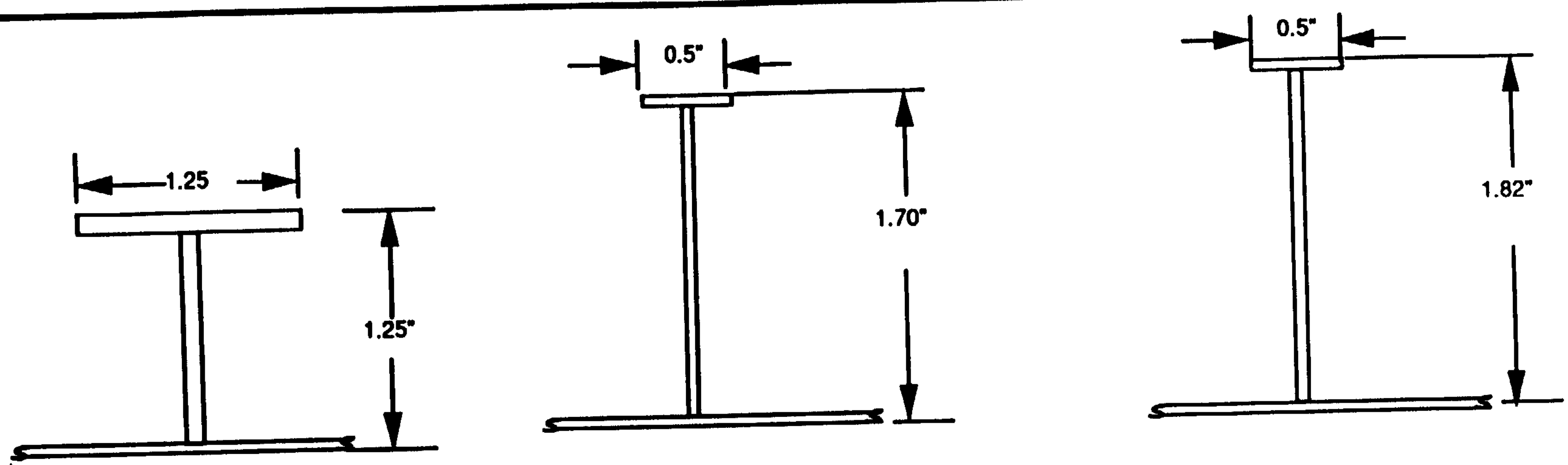
Stiffener Size and Pitch Sensitivity Trades - LH2 Tank



LH2 Tank

Current Design	Optimized Design Nx=2600 lb/in	Optimized Design Nx=3250 lb/in
Stringer Spacing=10.832"	Stringer Spacing=2.0"	Stringer Spacing=2.0"
Frame Spacing=26.7"	Frame Spacing=26.7"	Frame Spacing=26.7"
Tskin=0.170	Tskin=0.061	Tskin=0.067
Tbar=0.193	Tbar=0.108	Tbar=0.123

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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.

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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

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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 sensititivities
(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.

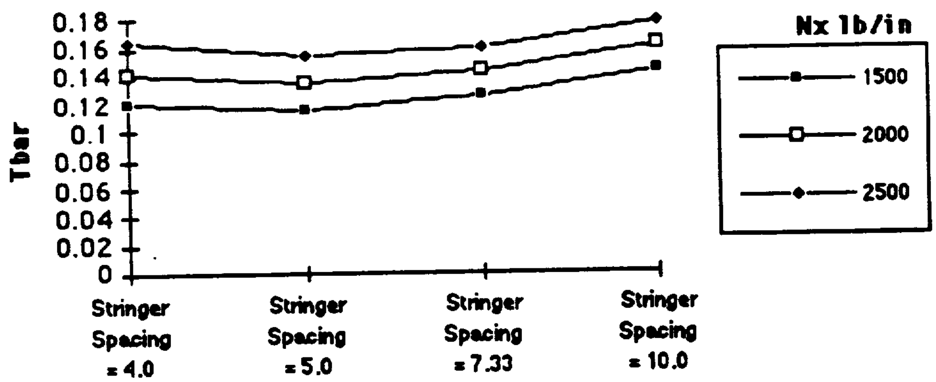
Conclusions

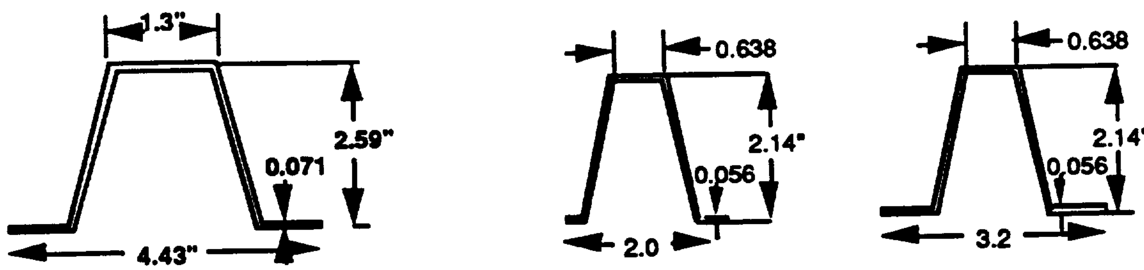
Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. When modified to produce a practical design,the Panda II optimized configuration does not offer any significant weight savings compared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

Stringer Spacing vs Tbar





Current Design	Panda II Optimized Design (Nx = 2000 lb/in ult)	Optimized Design with Modifications
Stringer Spacing = 7.33"	Stringer Spacing = 5.0"	Stringer Spacing = 5.0"
Frame Spacing = 48.0"	Frame Spacing = 48.0"	Frame Spacing = 48.0"
Tbar=0.151"	Tbar=0.139"	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 sensititivities
(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.

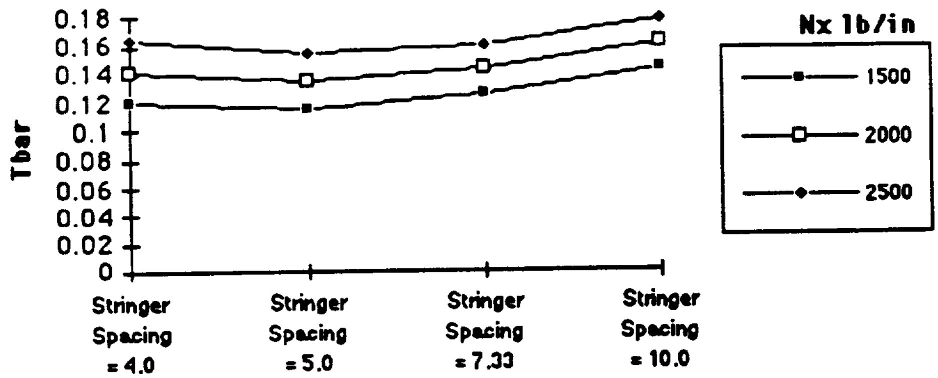
Conclusions

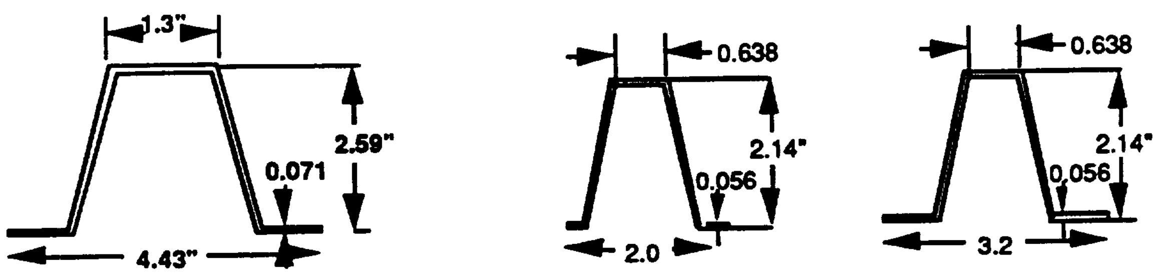
Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. When modified to produce a practical design,the Panda II optimized configuration does not offer any significant weight savings compared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

Stringer Spacing vs Tbar





Current Design	Panda II Optimized Design (Nx = 2000 lb/in ult)	Optimized Design with Modifications
Stringer Spacing = 7.33"	Stringer Spacing = 5.0"	Stringer Spacing = 5.0"
Frame Spacing = 48.0"	Frame Spacing = 48.0"	Frame Spacing = 48.0"
Tbar=0.151"	Tbar=0.139"	Tbar=0.149"

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

Approved By: R.Simms

Rev: Initial
Date: January 8, 1992

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WRW.NLS.91350

Issues And Objective

3-S-001-C

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.

WRW 91350

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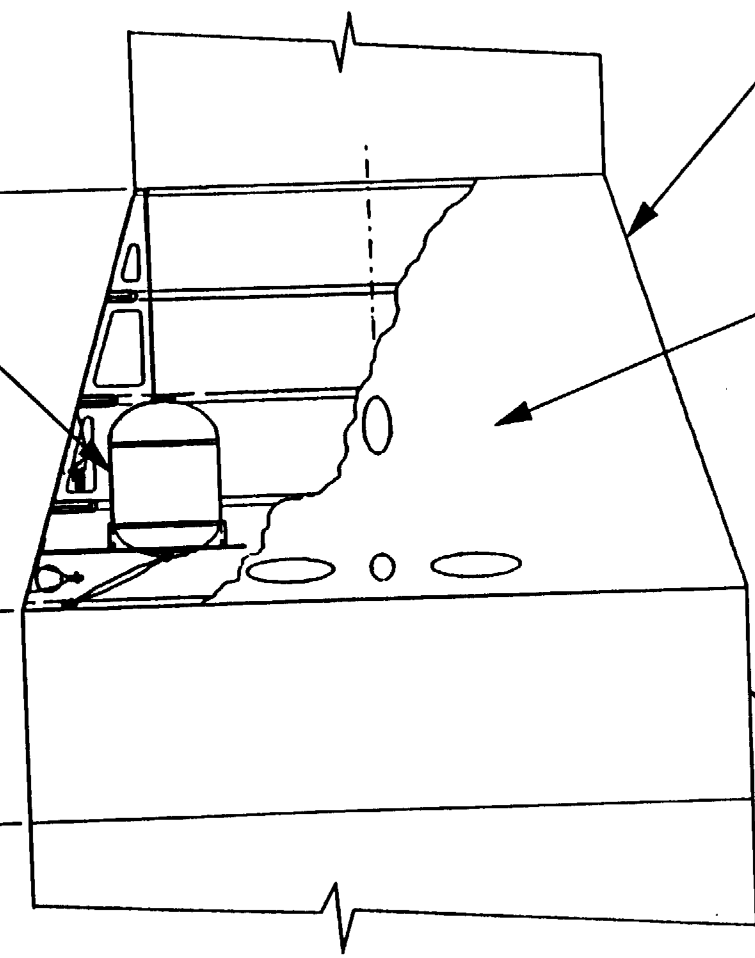
Approach

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

Reference Fwd Skirt Configuration

3-S-001-C



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WRW 91350

Ref Configuration Avionics

Box Description	*Size	Weight	Quantity And Location		
			Aft	**Central	CTV
Batteries (Avionics)	20 X 17 X 12	135	2	2	4
Batteries (EMA)	11 X 21X 8	125	***16 OR ****24		
Power Distribution	20 X 16 X 12	100	2	2	
Load Distribution	20 X 17 X 8	75			2
Inertial Navigation Unit / CPU	11 X 17.5 X 8	67		3	
Rate Gyro Unit	7.6 x 8.25 x 6.25	15	3		
Antenna Gimbal Drive	6 X 8 X 6	50			1
Proximity Operations Sensor	12 X 14 X 8	110			1
Earth Sensor	8 X 8 X 7	15			2
GPS And Pre Amp	7 X 11 X 7	15			2
Sun Sensor	4 X 4 X 4	2			2
CAM Hardware	8 X 10 X 8	30			2
Remote Voter Unit	6 X 10 X 6	35	6	4	3
MDU / RDU	8 X 12 X 8	12	2	4	10
Engine I/F Unit	8 X 10 X 6	20	4		
Mechanism Control Electronics	8 X 10 X 8	20			2
Video Camera	4 X 8 X 6	5			2
Lights	6 X 6 X 6	10			2
Pan / Tilt / Zoom Mech		90			1
Navigation Lights	3 X 3 X 3	1			6
Navigation Light Converter	4 X 4 X 2	2			2
S Band Transponder	9 X 16 X 4	15		2	
Ku Band Transponder	4 X 13 X 6	15			2
Signal Processor	15 X 8 X 8	15		2	
RF Combiner (Central)	8 X 6 X 2	12		1	
RF Combiner (Proximity Operations)	8 X 6 X 2	9			2
Power Amplifier	12 X 14 X 2	16		2	2

* 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.

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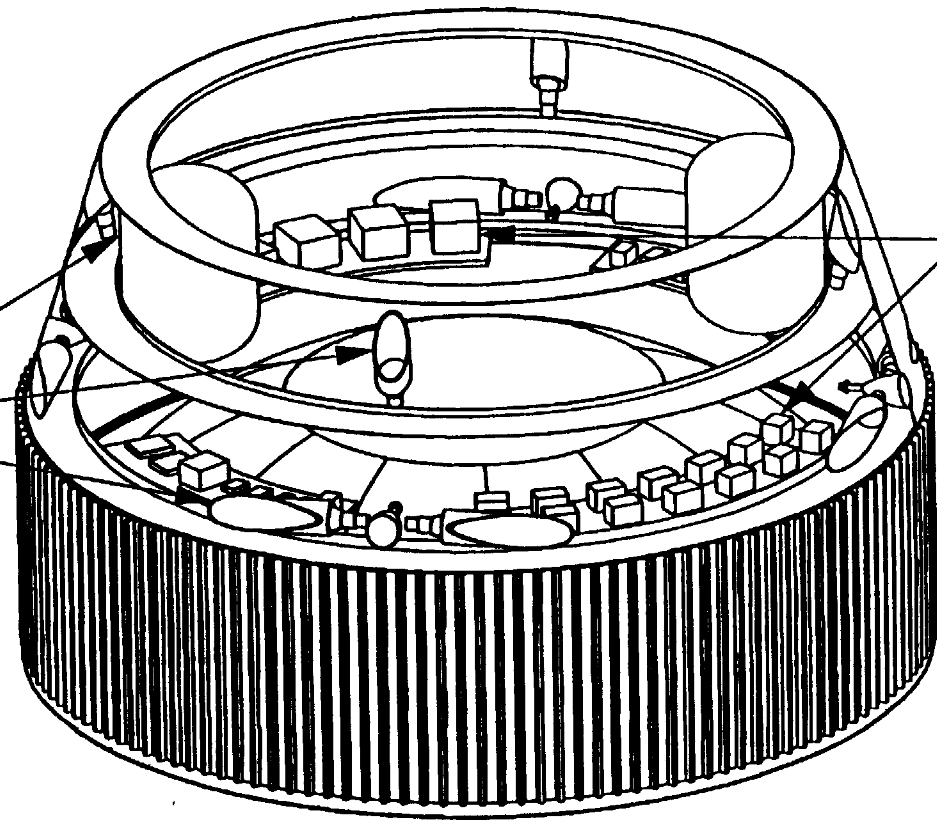
WRW.NLS.91350

Alternate Fwd Skirt Configuration

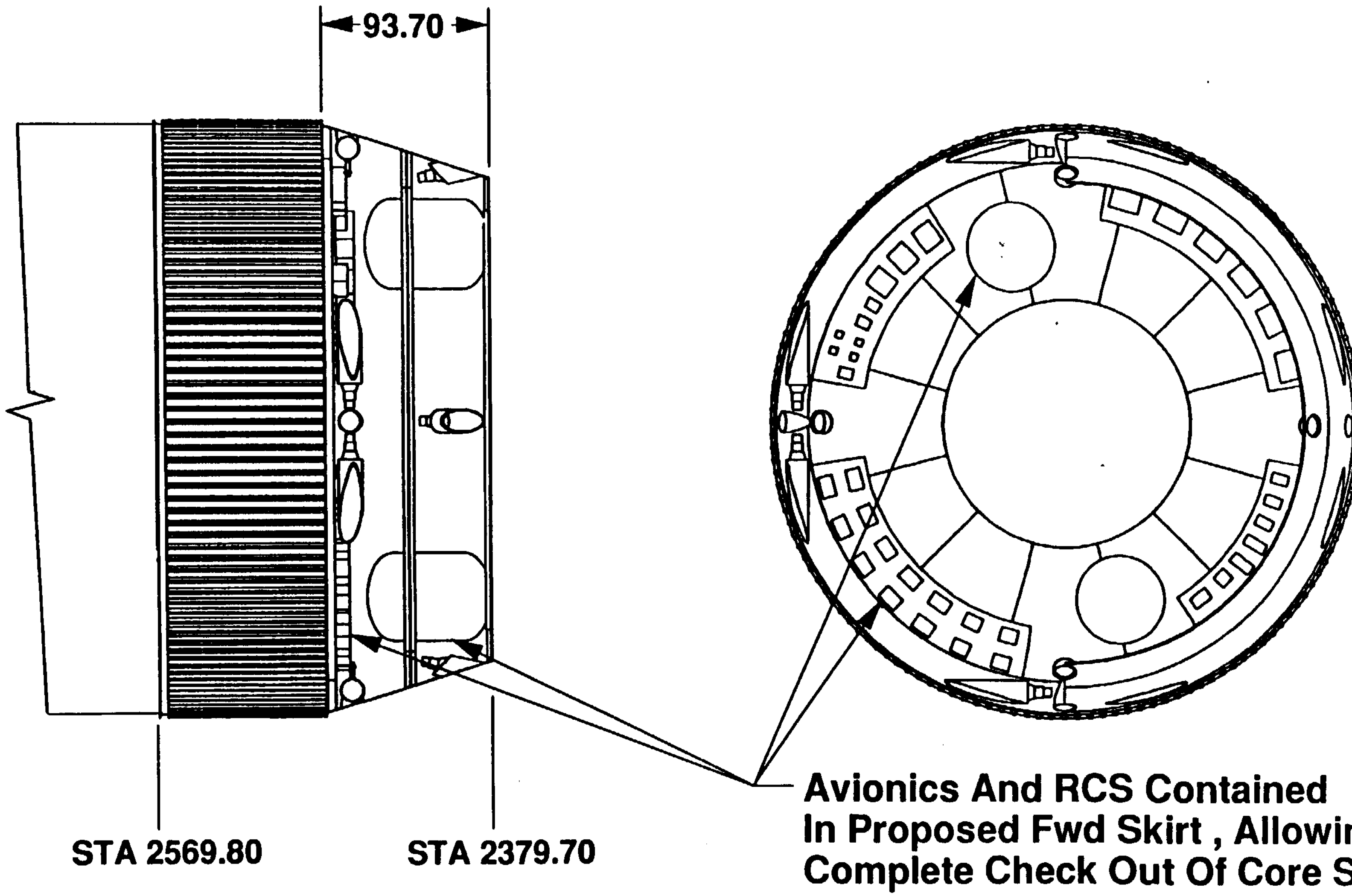
3-S-001-C



Proposed Fwd Skirt Configuration

Alternate Fwd Skirt Configuration

3-S-001-C



WRW.NLS.91350

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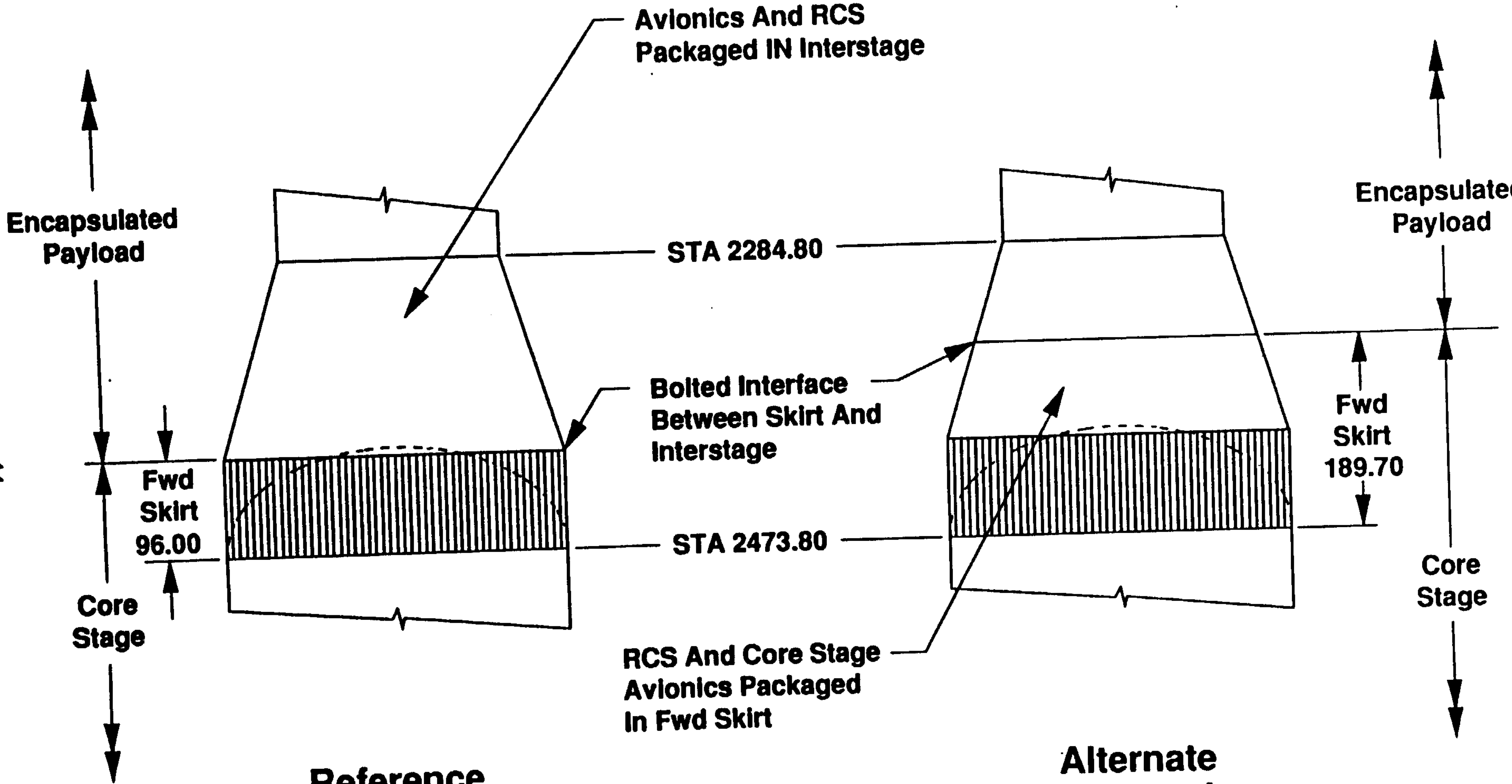
Options Comparision



Reference Configuration

Alternate Configuration

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WRW.N 91350

Conclusions And Recommendations

3-S-001-C

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.

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WRW.NLS.91350

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

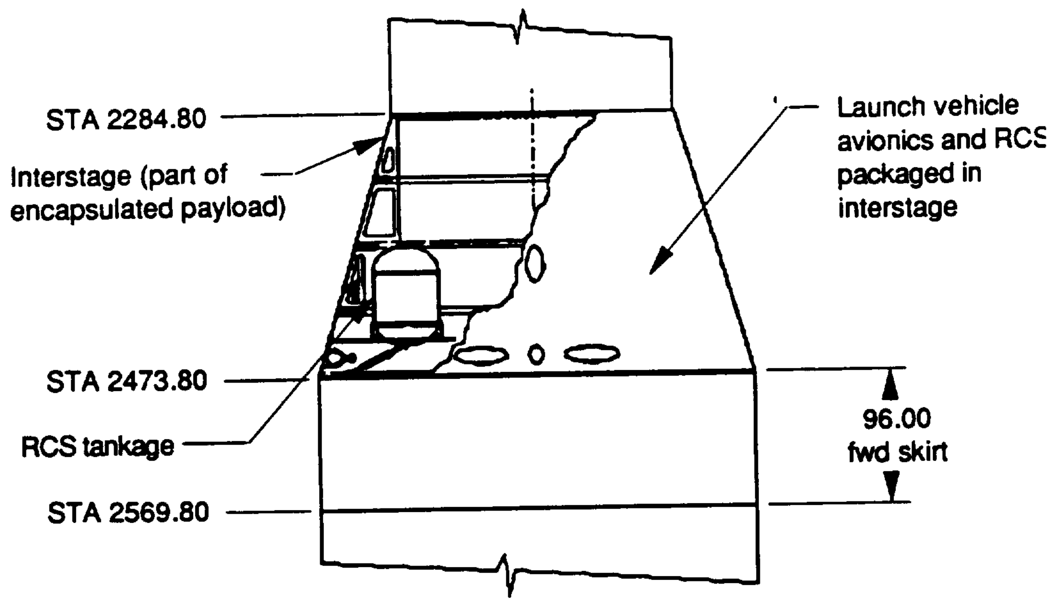
The RCS tankage size and location requires the skirt to be extended approx 8 feet to provide the required packaging volume. This extended skirt then has sufficient space to package the launch vehicle avionics. The new configuration still provides adequate clearance to allow the CTV engines to occupy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

Conclusions

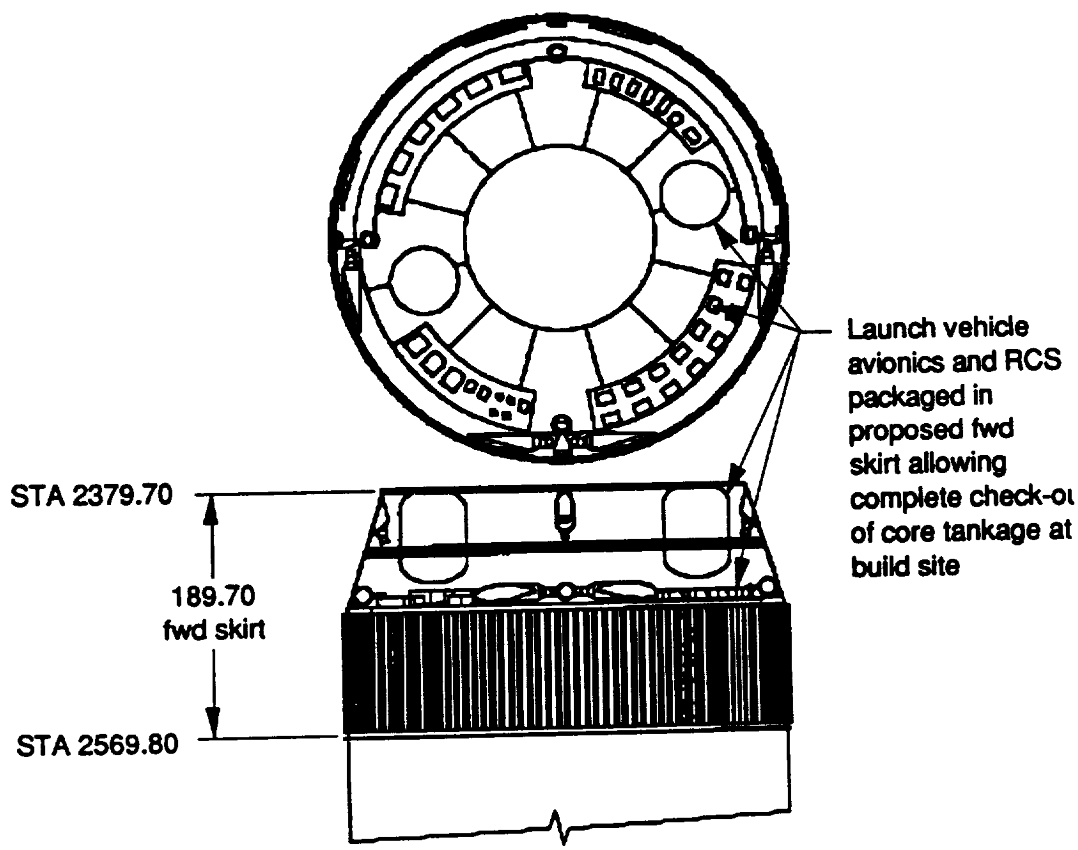
The alternate concept will permit full IACO of Core Stage. The concept provides adequate space for packaging of avionics and propulsion components. It does however require the relocation of the interface joint and reduces the length of the interstage.

Study Recommendations

Study the alternate configuration further in cycle 1.



Cycle Ø baseline



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 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

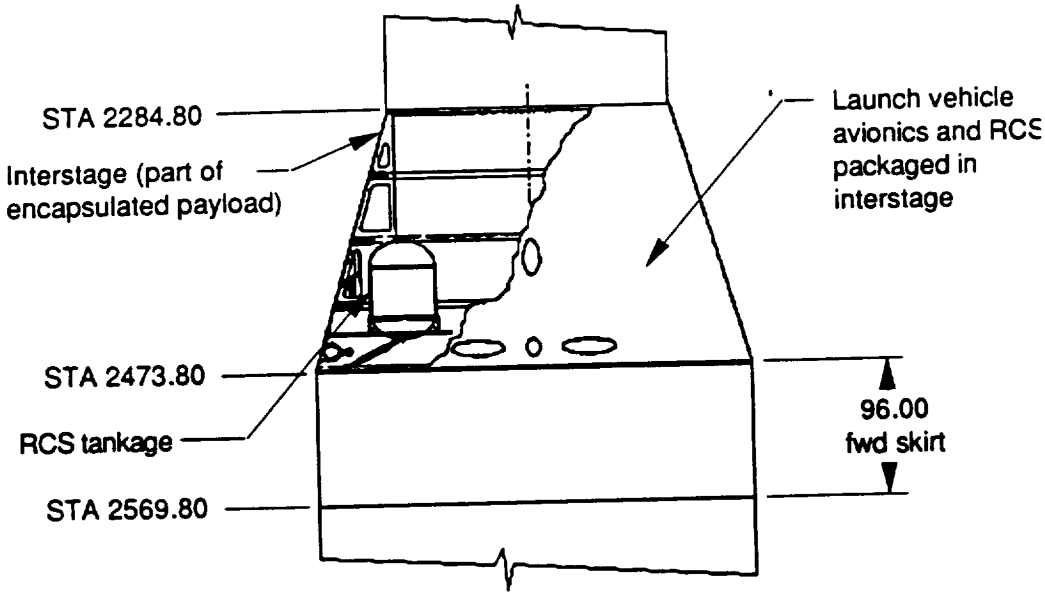
The RCS tankage size and location requires the skirt to be extended approx 8 feet to provide the required packaging volume. This extended skirt then has sufficient space to package the launch vehicle avionics. The new configuration still provides adequate clearance to allow the CTV engines to occupy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

Conclusions

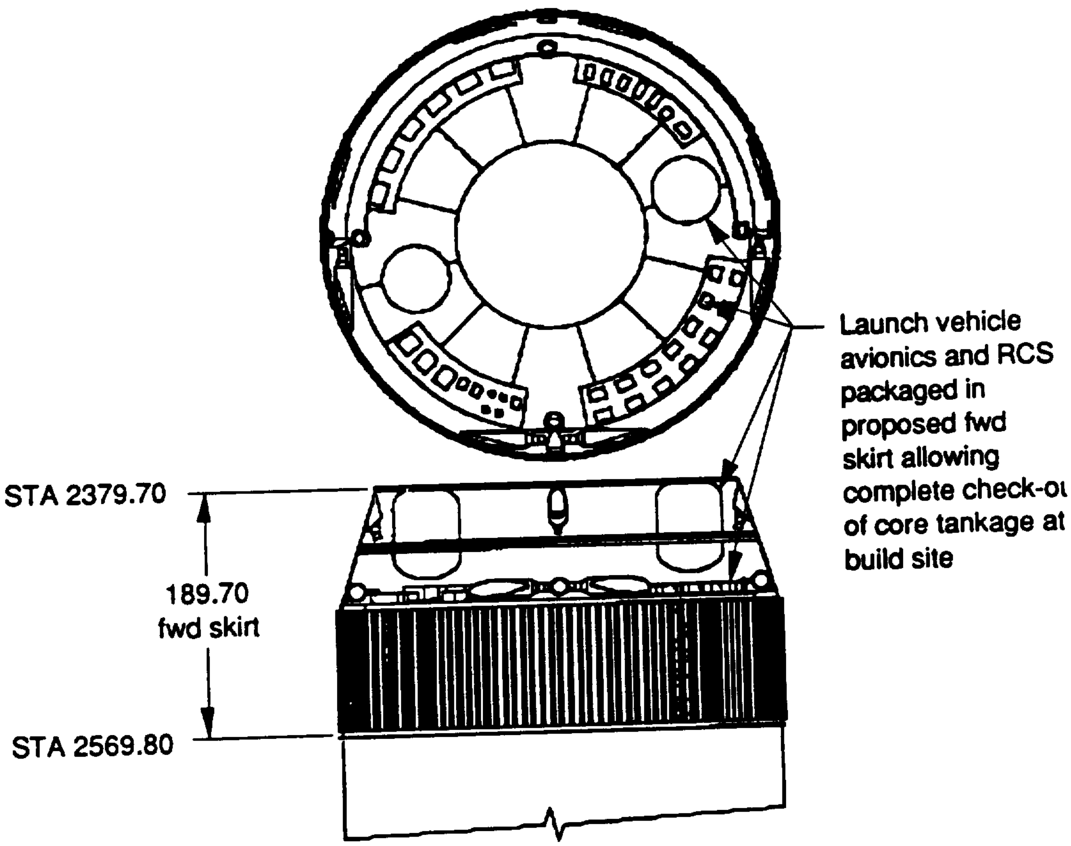
The alternate concept will permit full IACO of Core Stage. The concept provides adequate space for packaging of avionics and propulsion components. It does however require the relocation of the interface joint and reduces the length of the interstage.

Study Recommendations

Study the alternate configuration further in cycle 1.



Cycle Ø baseline



Additional Information

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

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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

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EP/TJS-B1-143

Alternate 1.5 Stage Support Trade 3-S-007

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.

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Ground Rules 3-S-007

- 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

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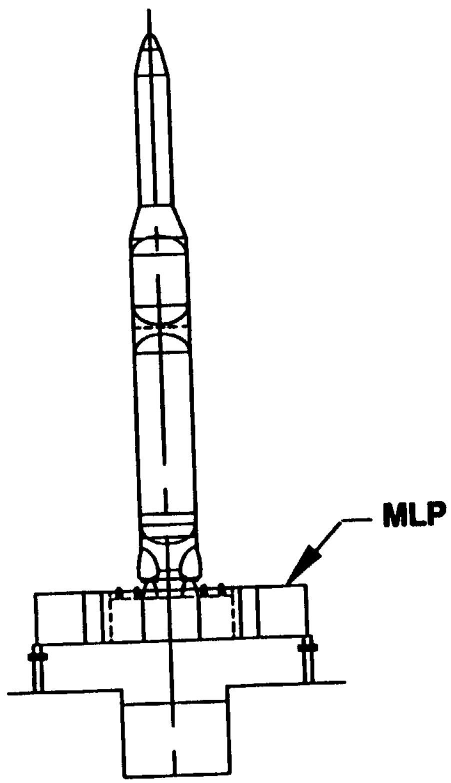
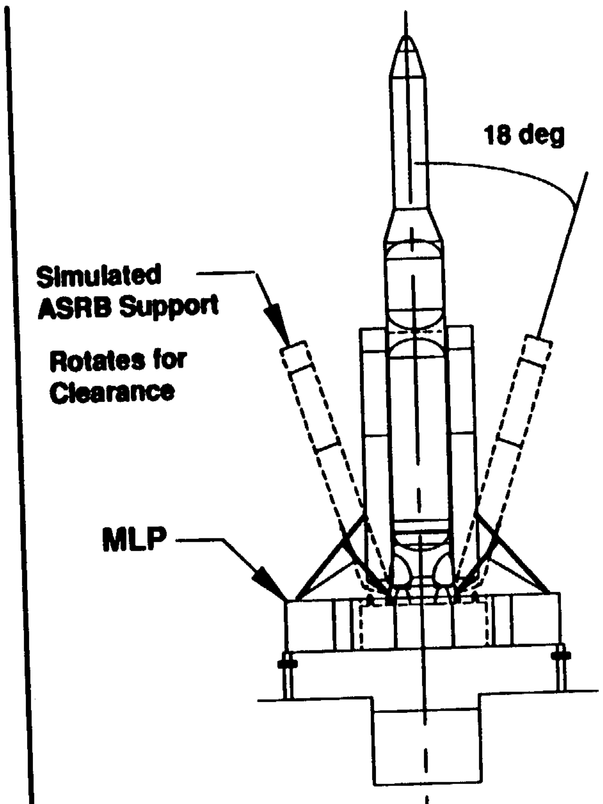
EP/TJS-B1-143

Alternate Hold Down Concept For 1.5 Stage 3-S-007

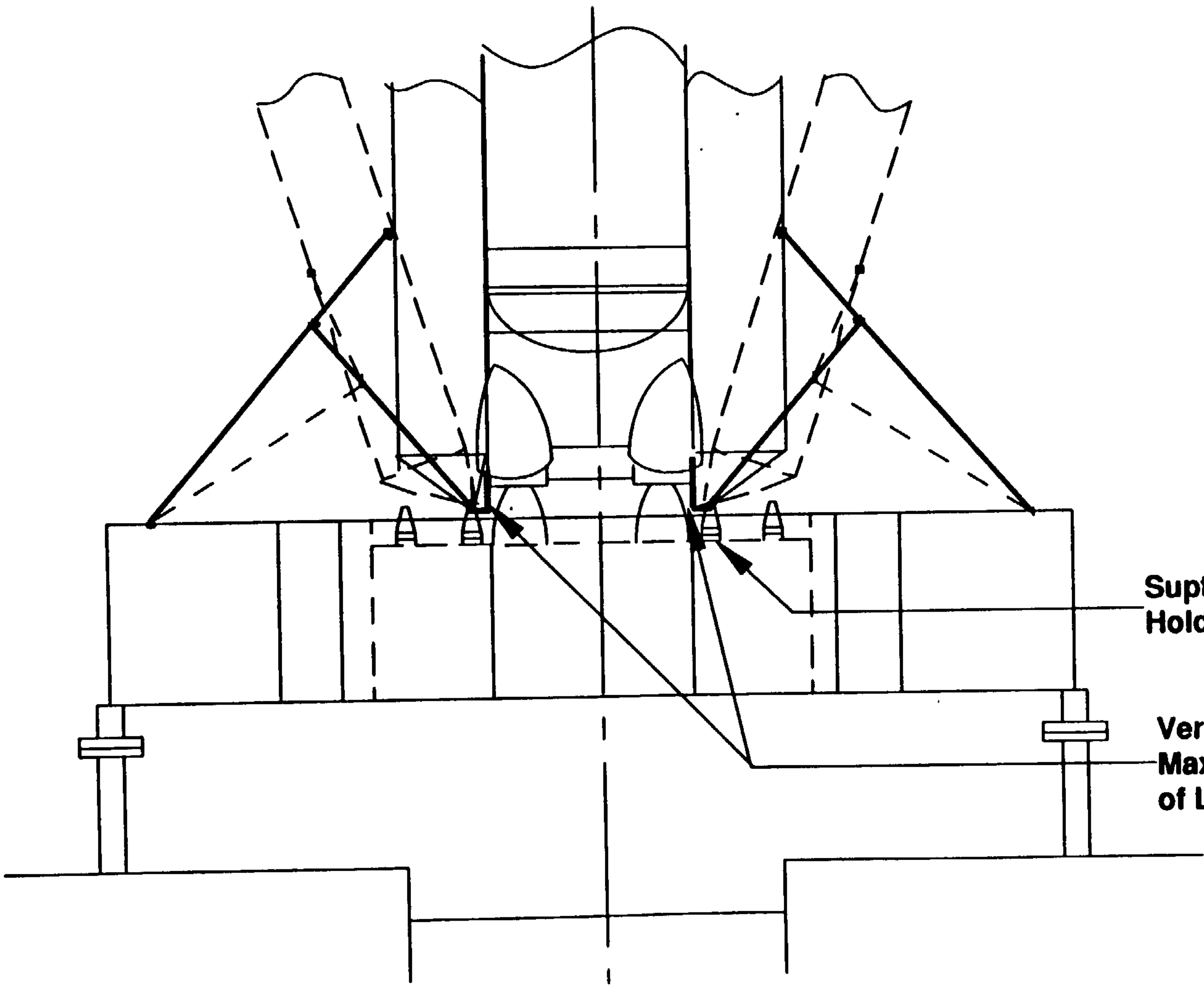
Reference



Alternate



Launch Pad Support Details



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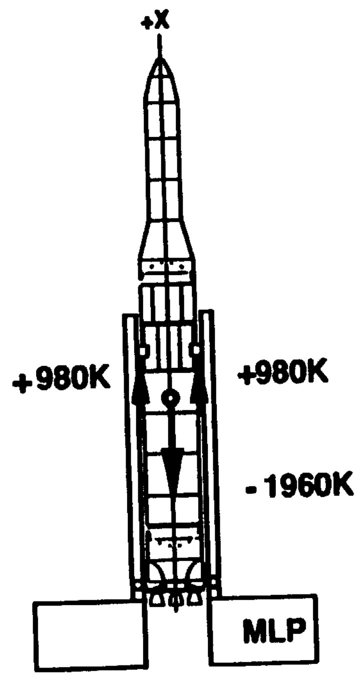
EP/TJS-B1-143

1.5 Stage Fwd Support Loads 3-S-007

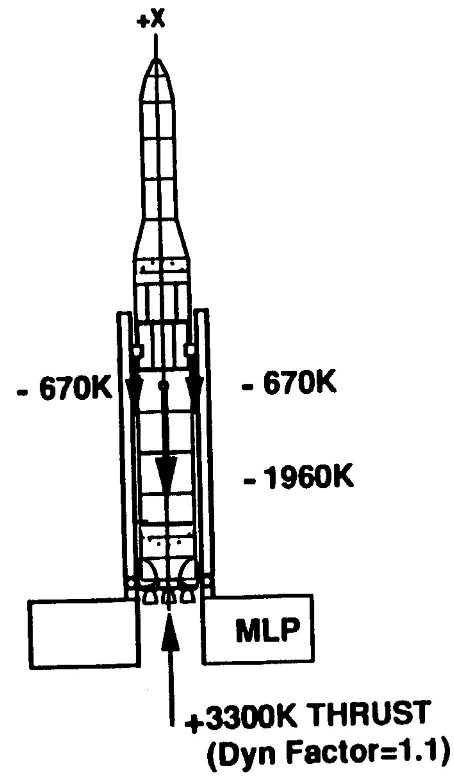
Case 1:

1.5 Stage - On Pad, Fully Loaded, No Wind



Case 2:

Prelaunch, t -1.0 sec, 100% Power on 6 Engines w/1.1 Dynamic Factor, No Wind



All loads shown are Limit

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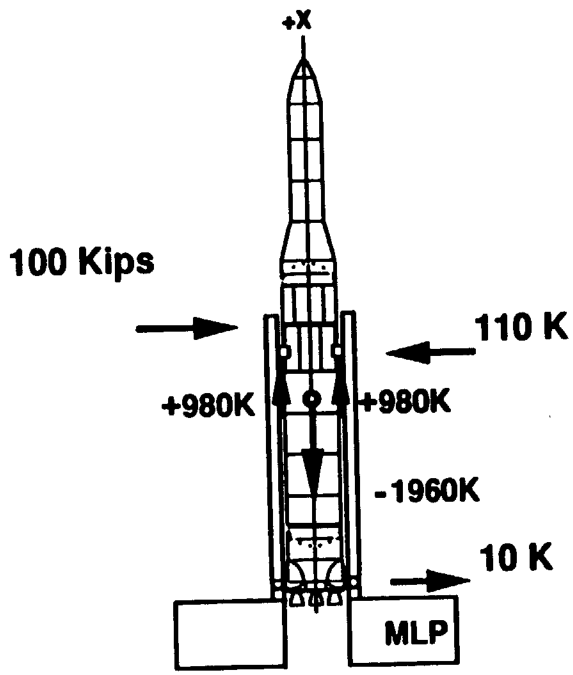
EP/TJ' '43

1.5 Stage Fwd Support Loads

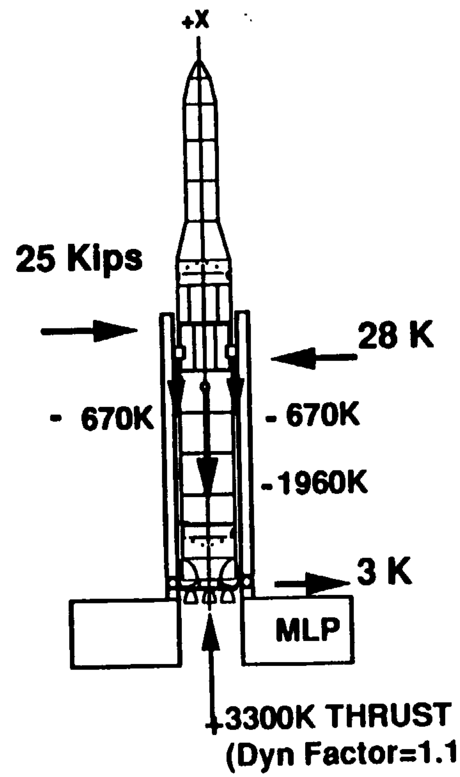
Case 3:

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

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EP/TJS-B1-143

Alternate 1.5 Stage Support Trade 3-S-007

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

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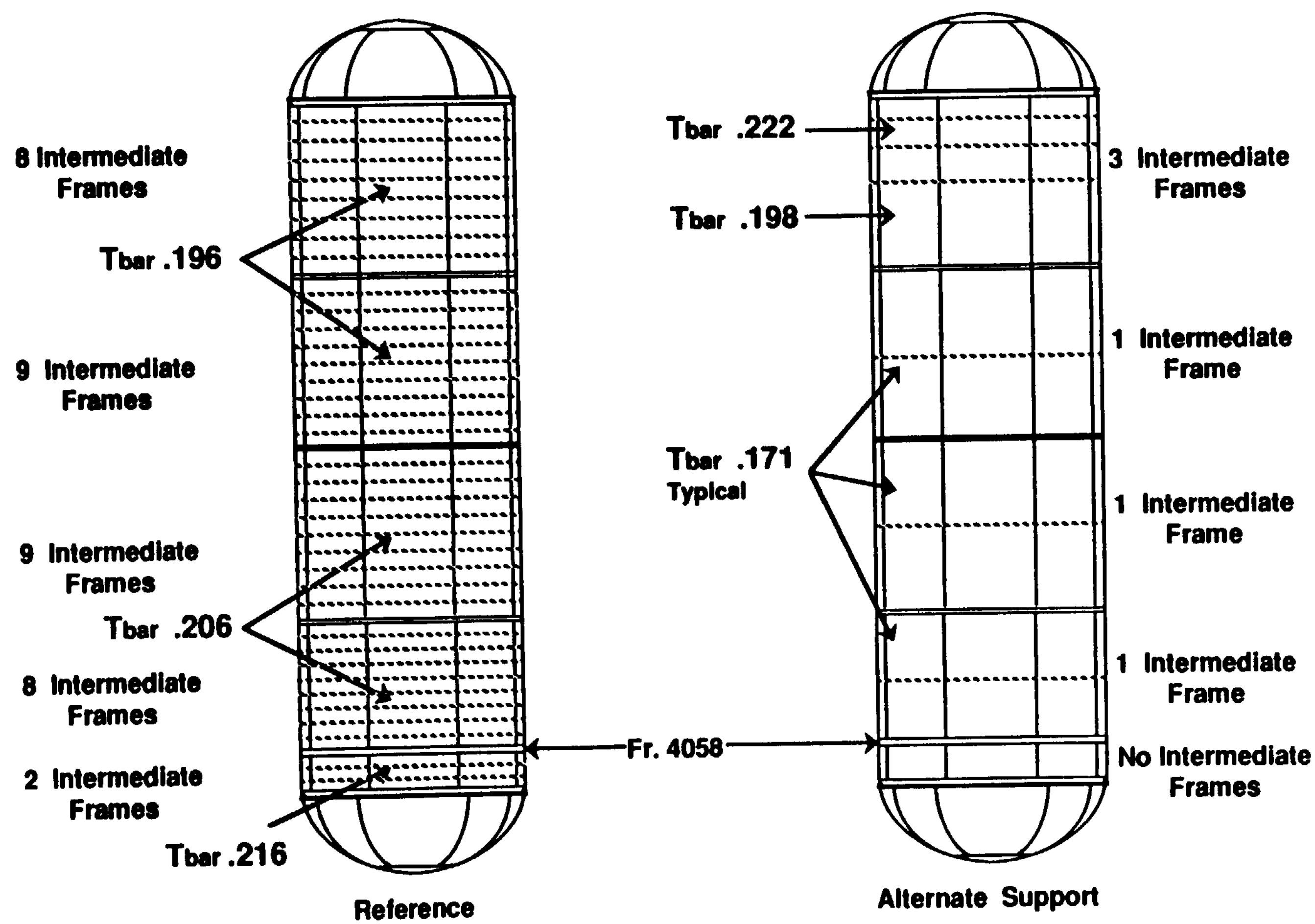
Alternate 1.5 Stage Support Trade 3-S-007

LH2 Tank Weight Comparison with Alternate Support

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



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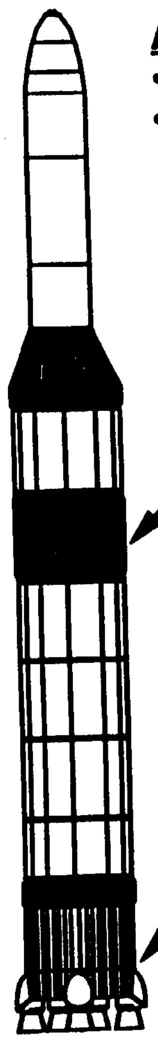
EP/TJS-B1-143

Alternate 1.5 Stage Support Trade 3-S-007

Common Core Weight Comparisons (17.3 pig at LO)



Alternate Configuration A

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

	Common Core Vehicle Mass Properties (Wt. LBS)		
Components	Reference	Alternate	Δ (Deltas)
Intertank	12683	14683	+2000
LH2 Tank	39221	34421	-4800
Thrust Structure	108125	106325	-1800
Contingency	(Included)	(Included)	-240
Total Dry Wt.	204290	199250	-5040

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Alternate 1.5 Stage Support Trade   3-S-007

Common Core Weight Comparison (25 pig at LO)

<u>Alternate Configuration B</u>
- Unpressurized Tanks at Prelaunch
- Min. Pressure = 25 psig at Launch

Components	Common Core Vehicle Mass Properties (Wt. LBS) Reference	Alternate	Δ (Deltas)
Intertank	12683	14683	+2000
LH2 Tank	39221	32921	-6300
Thrust Structure	108125	106325	-1800
Contingency	(Included)	(Included)	-240
Total Dry Wt.	204290	197950	-6340

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EP/TJS-B1-143

Alternate 1.5 Stage Support Trade — 3-S-007

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.

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EP/TJ? '43

Alternate 1.5 Stage Support Trade — 3-S-007

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.

Alternate 1.5 Stage Support Trade   3-S-007

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.

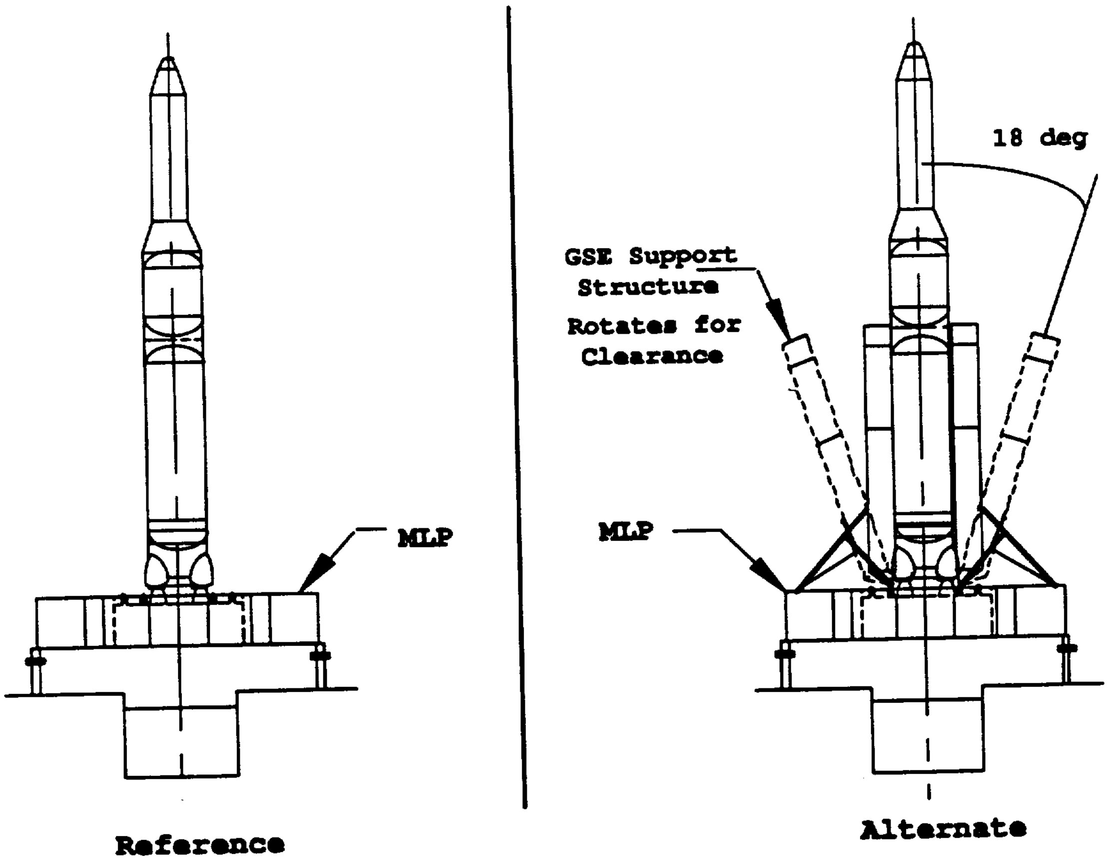
Lift off is significantly more complex. Strain energy is stored in the structure when the engines are running, but before separation from the MLP. This energy can be released differently depending on the release method chosen, none of which are simple. Severe transient loads are induced from the sudden 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.



	Common Core Vehicle Mass Properties (Wt. LBS)		
Components	Reference	Alternate	Δ (Deltas)
Intertank	12683	14683	+2000
LH2 Tank	39221	34421	-4800
Thrust Structure	108125	106325	-1800
Contingency	(Included)	(Included)	-240
Total Dry Wt.	204290	199250	-504

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

Approved By: Don Lumley
Bob Simms

Rev: Initial
Date: January 8, 1992

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Tank Length vs Facility Impacts 3-S-008A

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

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Background

3-S-008A

- 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

MARTIN MARIETTA
MANNED SPACE SYSTEMS

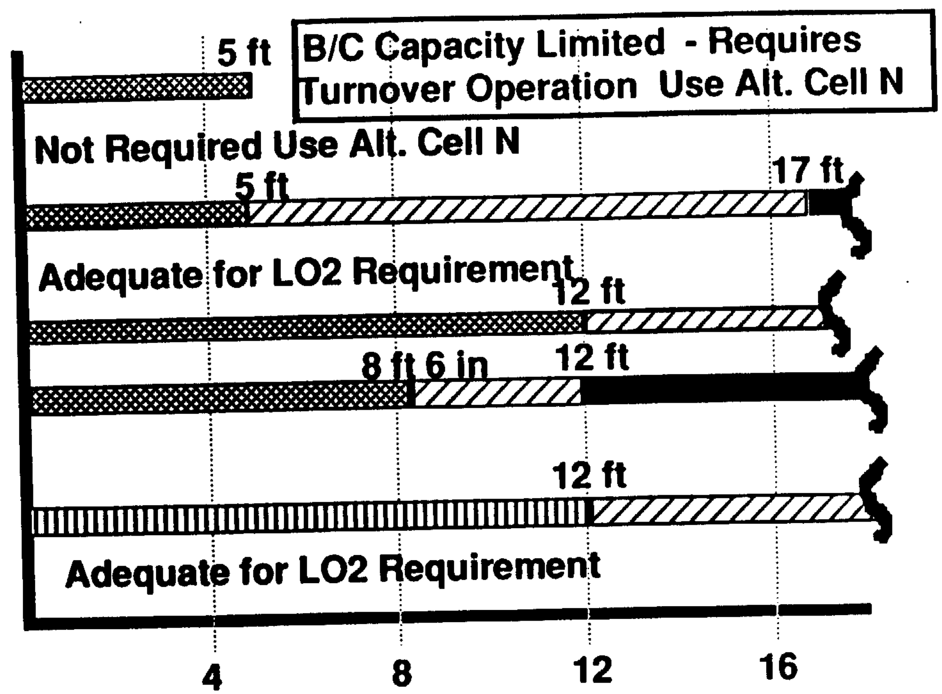
Tank Length vs Facility Impact

3-S-008A

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

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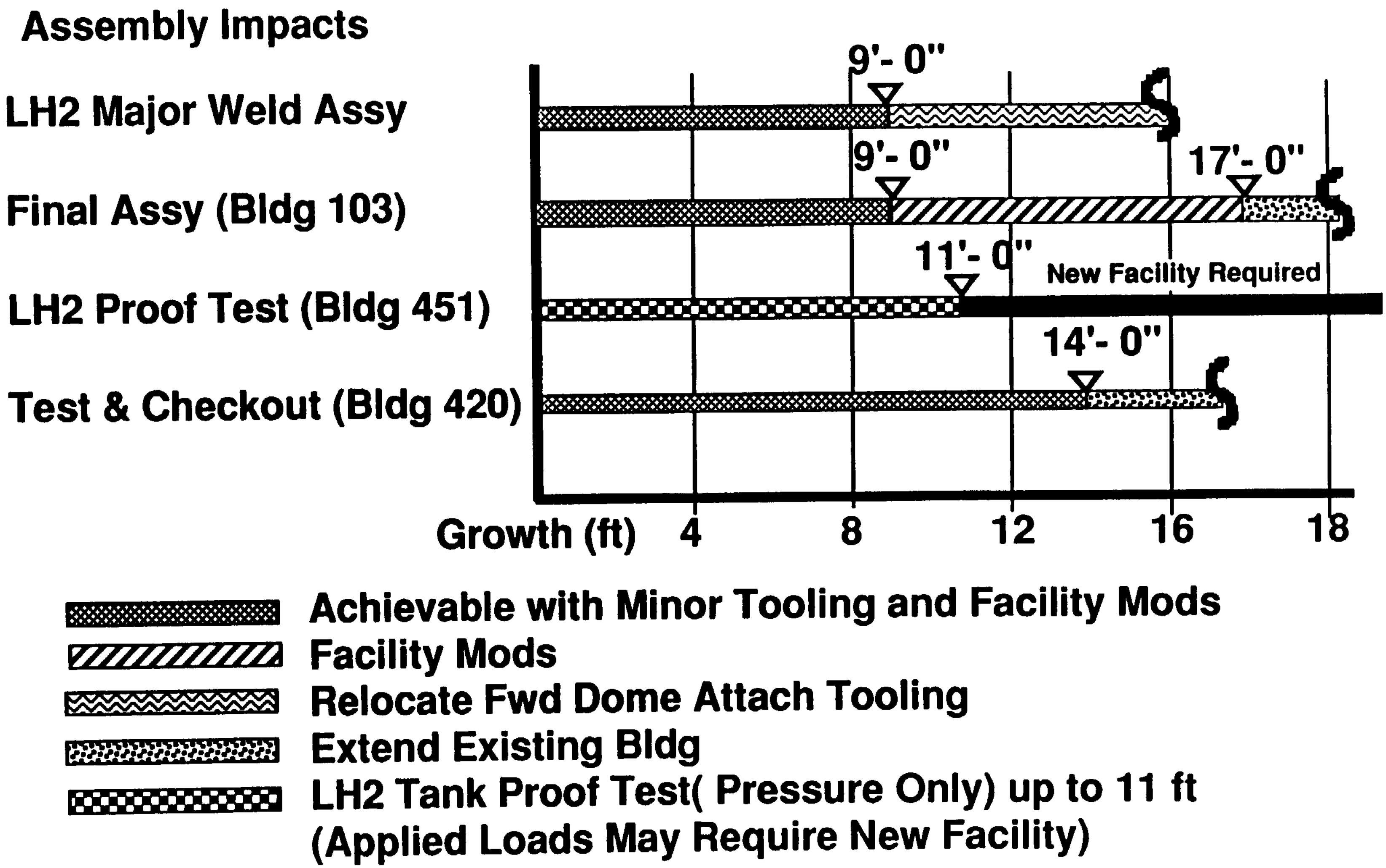
MANNED SPACE SYSTEMS

Tank Length vs Facility Impact

3-S-008A



MARTIN MARIETTA
MANNED SPACE SYSTEMS

Critical Facility Impacts - One-of-a-Kind Cells 3-S-008A

- Cell E - Internal LH_2 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 LH_2 Stretch Without Major Facility Modification
- Over 8 ft 6 in to 12 ft - Modify TPS Closeout Room
- Over 12 ft. - NEW CELL

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Summary

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

- 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)

- 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

MARTIN MARIETTA
MANNED SPACE SYSTEMS

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:

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

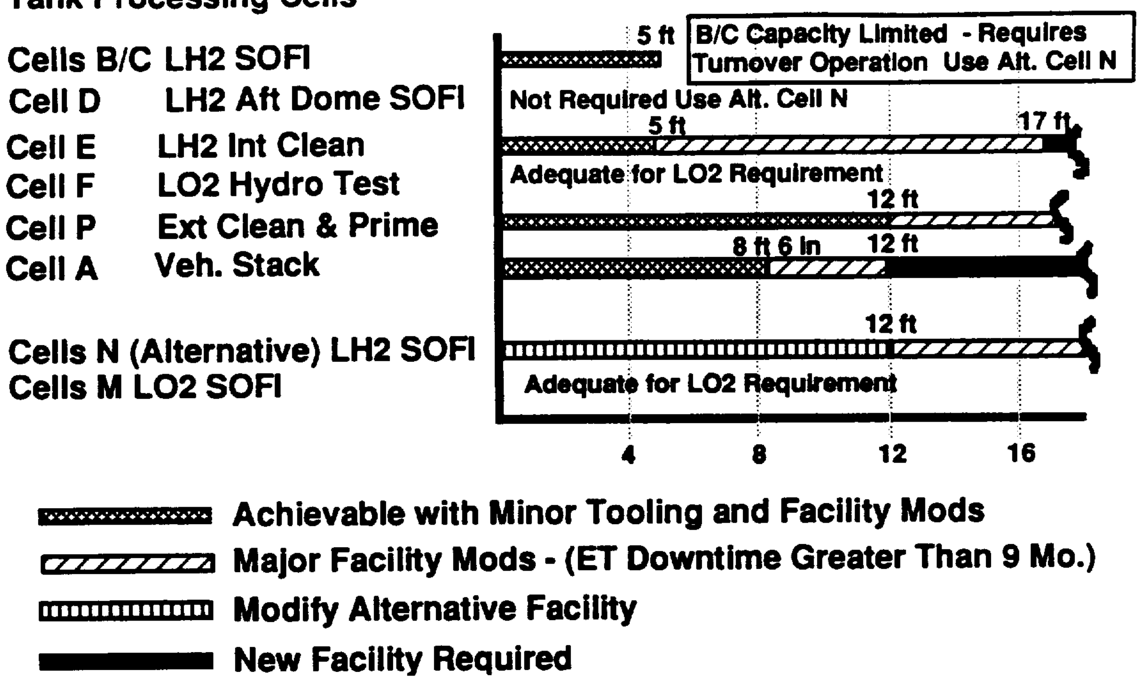
Conclusions

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

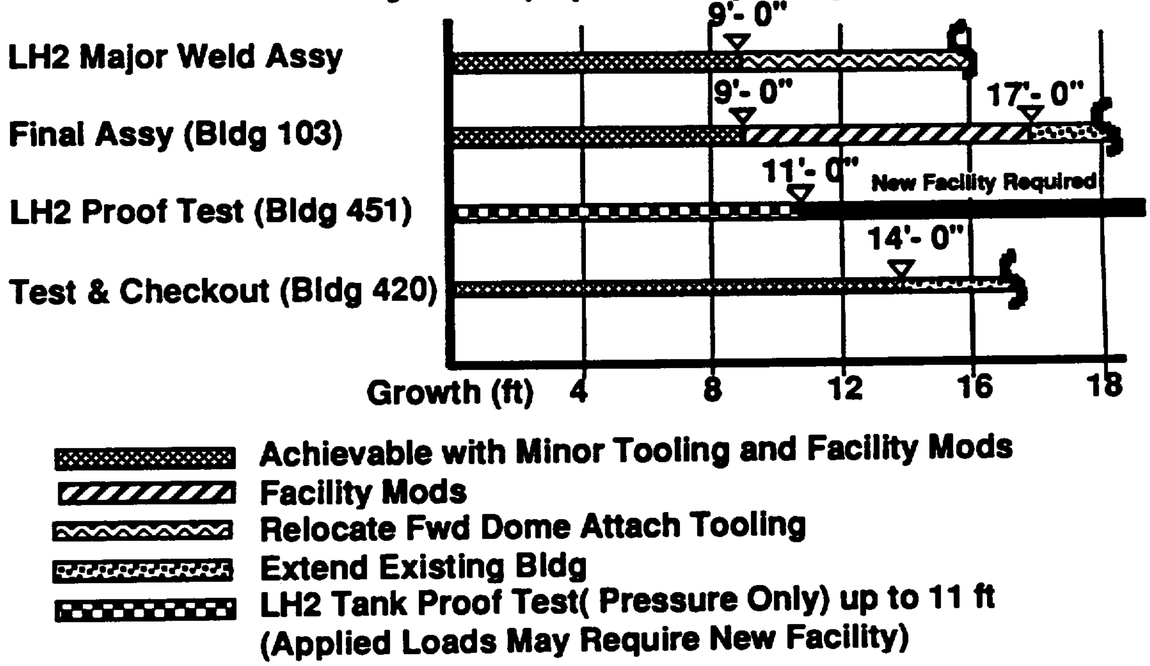
Recommendations

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

Tank Processing Cells



Length vs Facility impacts for Tank processing cells



Length vs Facility impacts for Assembly Facilities

Additional Information

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

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

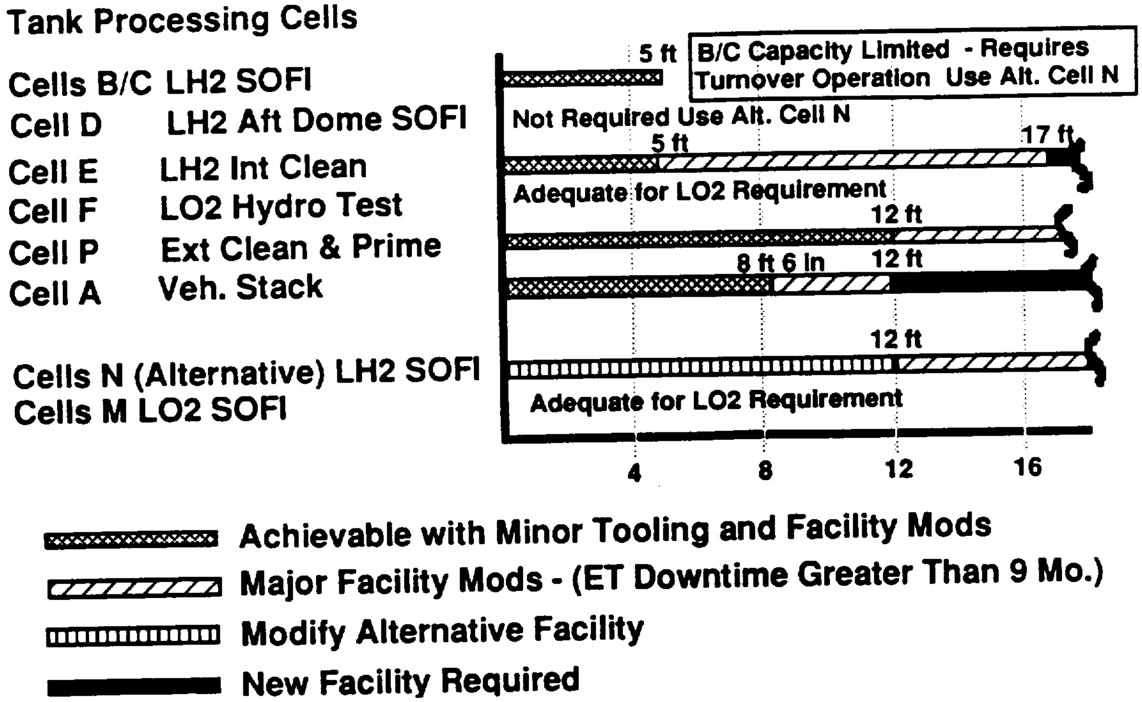
Conclusions

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

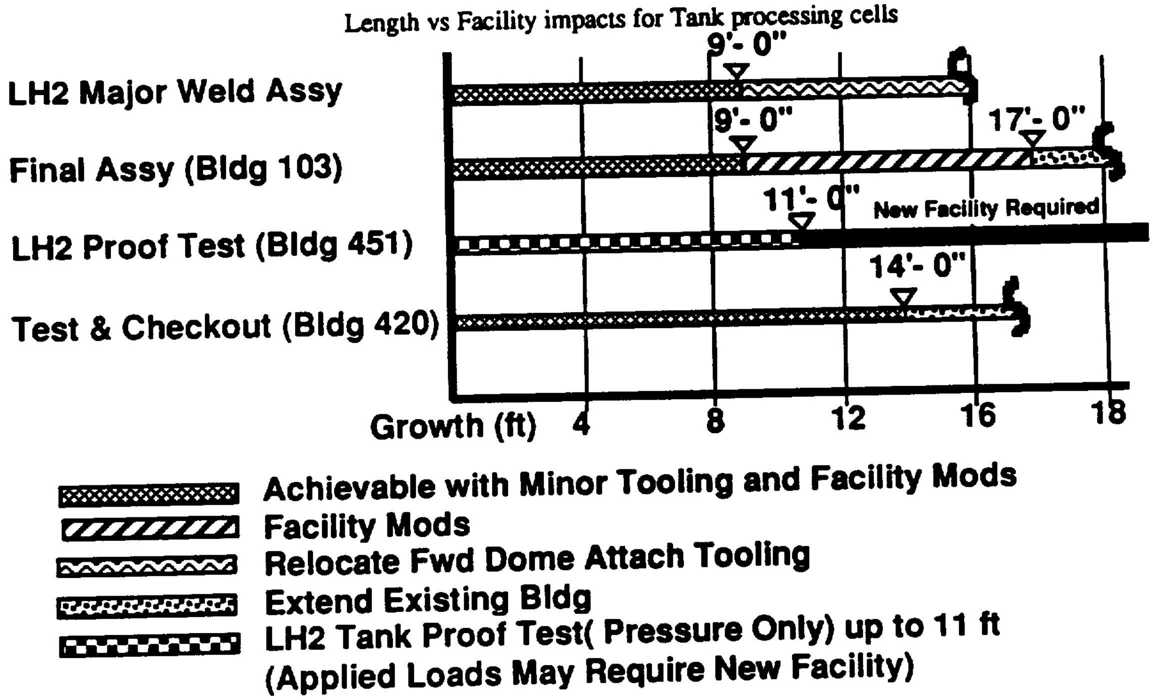
Recommendations

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

Tank Processing Cells



Length vs Facility impacts for Tank processing cells



Length vs Facility impacts for Assembly Facilities

Additional Information

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

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3-S-008B
(CV-STR-20B)
LH2 Tank Impact vs. Ullage Pressure Trade Study

Prepared By : Tom Severs
(504) 257-5226

Approved By: R. Simms

Rev: Initial
Date: January 8, 1992

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MANNED SPACE SYSTEMS

TJS-B1-139a

Objective and Approach 3-S-008-B

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.

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TJS-B' a

Approach (Continued) 3-S-008-B

- 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.

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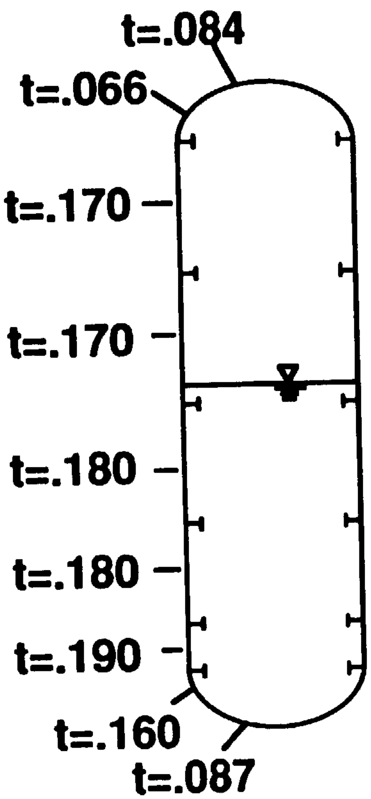
TJS-B1-139a

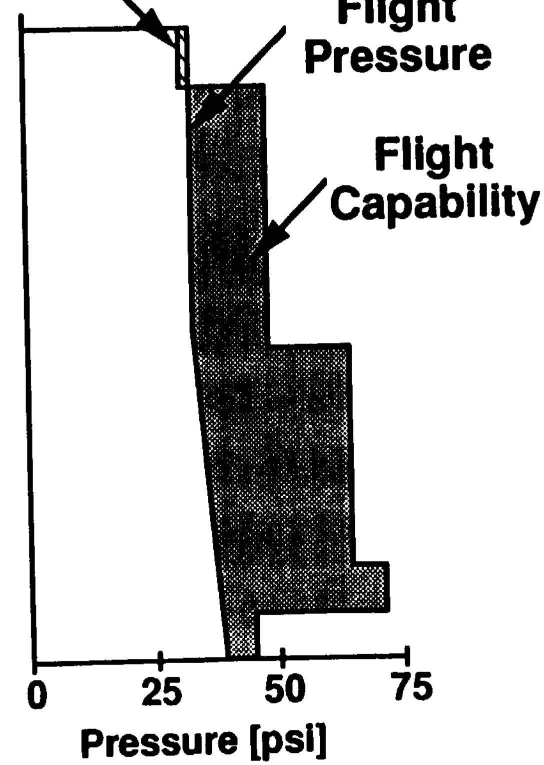
Ground Rules & Assumptions 3-S-008-B

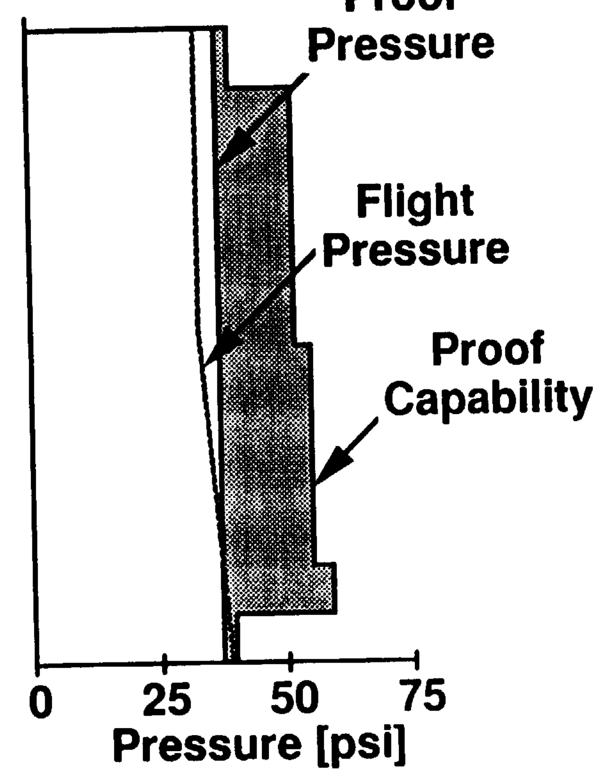
- Nominal tank configuration as per MSFC Cycle 0 definition as per 10/9/91. (34 psi maximum ullage pressure)
- The study addresses tank membrane and weld land requirements only, stiffener size and pitch, and frame size and pitch is from the reference configuration.
- Thicknesses are taken to a zero margin 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







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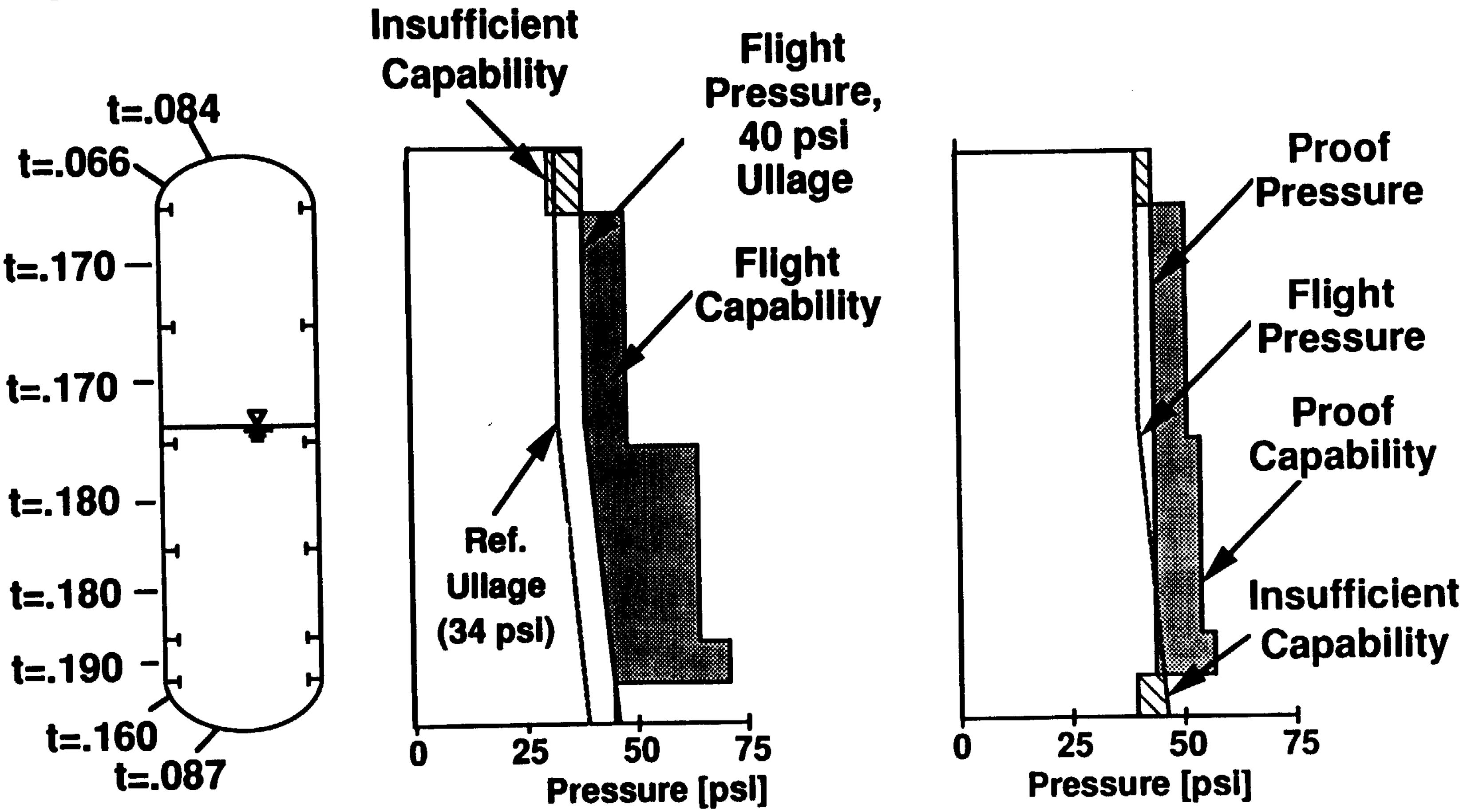
TJS-B1-139a

Ullage Pressure Req't vs. Capability 3-S-008-B

40 psi Ullage



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TJS-B1-

Max. Design Pressures 3-S-008-B

Location	Ref. Cond.	Ref. Config. Capability	Max. Ullage Pressure [psig]					
			34 psi	40 psi	50 psi	60 psi	70 psi	80 psi
Fwd Dome	Flight	32.0	34.0	40.0	50.0	60.0	70.0	80.0
	Proof	41.0	38.3	44.3	54.3	64.3	74.3	84.3
Bbls 3 & 4	Flight	46.2	34.0	40.0	50.0	60.0	70.0	80.0
	Proof	52.4	38.3	44.3	54.3	64.3	74.3	84.3
Bbls 1 & 2	Flight	67.6	39.0	45.0	55.0	65.0	75.0	85.0
	Proof	55.5	38.3	44.3	54.3	64.3	74.3	84.3
Barrel 1a	Flight	71.3	39.0	45.0	55.0	65.0	75.0	85.0
	Proof	58.6	38.3	44.3	54.3	64.3	74.3	84.3
Aft Dome	Flight	46.5	40.2	46.2	56.2	66.2	76.2	86.2
	Proof	41.0	38.3	44.3	54.3	64.3	74.3	84.3

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MANNED SPACE SYSTEMS

TJS-B1-139a

Delta Membrane Thicknesses 3-S-008-B

Thicknesses in Inches

Location	Ref. Config. Thickness	Max. Ullage Pressure [psig]					
		34 psi	40 psi	50 psi	60 psi	70 psi	80 psi
Fwd Dome	.066 to .084	.007	.029	.066	.103	.140	.177
Bbls 3 & 4	.170	.000	.000	.014	.051	.088	.124
Bbls 1 & 2	.180	.000	.000	.000	.029	.061	.094
Barrel 1a	.190	.000	.000	.000	.019	.051	.084
Aft Dome	.160 to .087	.000	.007	.040	.072	.105	.137

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MANNED SPACE SYSTEMS

TJS-B' a

Weld Land Thicknesses 3-S-008-B

Thicknesses in Inches

Location	Ref. Config. Thickness	Max. Ullage Pressure [psig]					
		34 psi	40 psi	50 psi	60 psi	70 psi	80 psi
Fwd Dome	.066 to .084	.204	.237	.294	.352	.411	.470
Bbls 3 & 4	.170	.204	.237	.294	.352	.411	.470
Bbls 1 & 2	.180	.229	.264	.323	.382	.440	.499
Barrel 1a	.190	.229	.264	.323	.382	.440	.499
Aft Dome	.160 to .087	.236	.271	.330	.388	.447	.506

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MANNED SPACE SYSTEMS

TJS-B1-139a

Membrane Delta Weight [Lbs.] 3-S-008-B

Location	Delta Wt. 34 psi	Delta Wt. 40 psi	Delta Wt. 50 psi	Delta Wt. 60 psi	Delta Wt. 70 psi	Delta Wt. 80 psi
Fwd Dome	92	380	866	1351	1837	2322
Fwd Barrels	0	0	714	2602	4489	6326
Aft Barrels	0	0	0	1383	2966	4598
Aft Dome	0	92	525	945	1378	1797
Sub-Total	92	472	2105	6281	10669	15044
Contingency (8 %)	7	38	168	502	854	1203
Total	99	510	2273	6783	11523	16247
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.

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Manufacturing Impacts 3-S-008-B

- 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

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MANNED SPACE SYSTEMS

TJS-B1-139a

Manufacturing Impacts 3-S-008-B

- **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

3-S-008-B

- 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.

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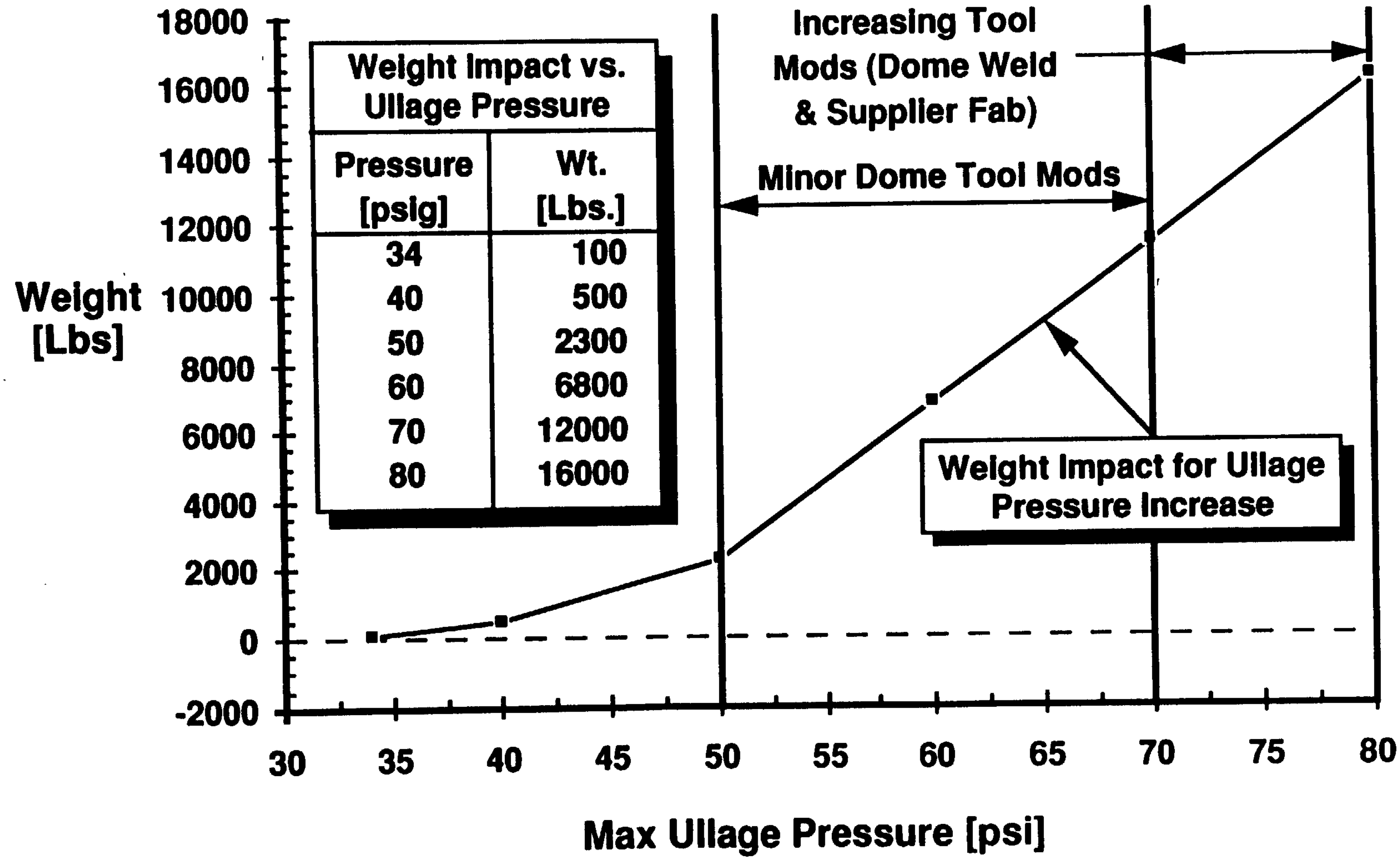
MANNED SPACE SYSTEMS

TJS-B1-139a

Summary

3-S-008-B



Weight Impact vs. Ullage Pressure

Pressure [psig]	Wt. [Lbs.]
34	100
40	500
50	2300
60	6800
70	12000
80	16000

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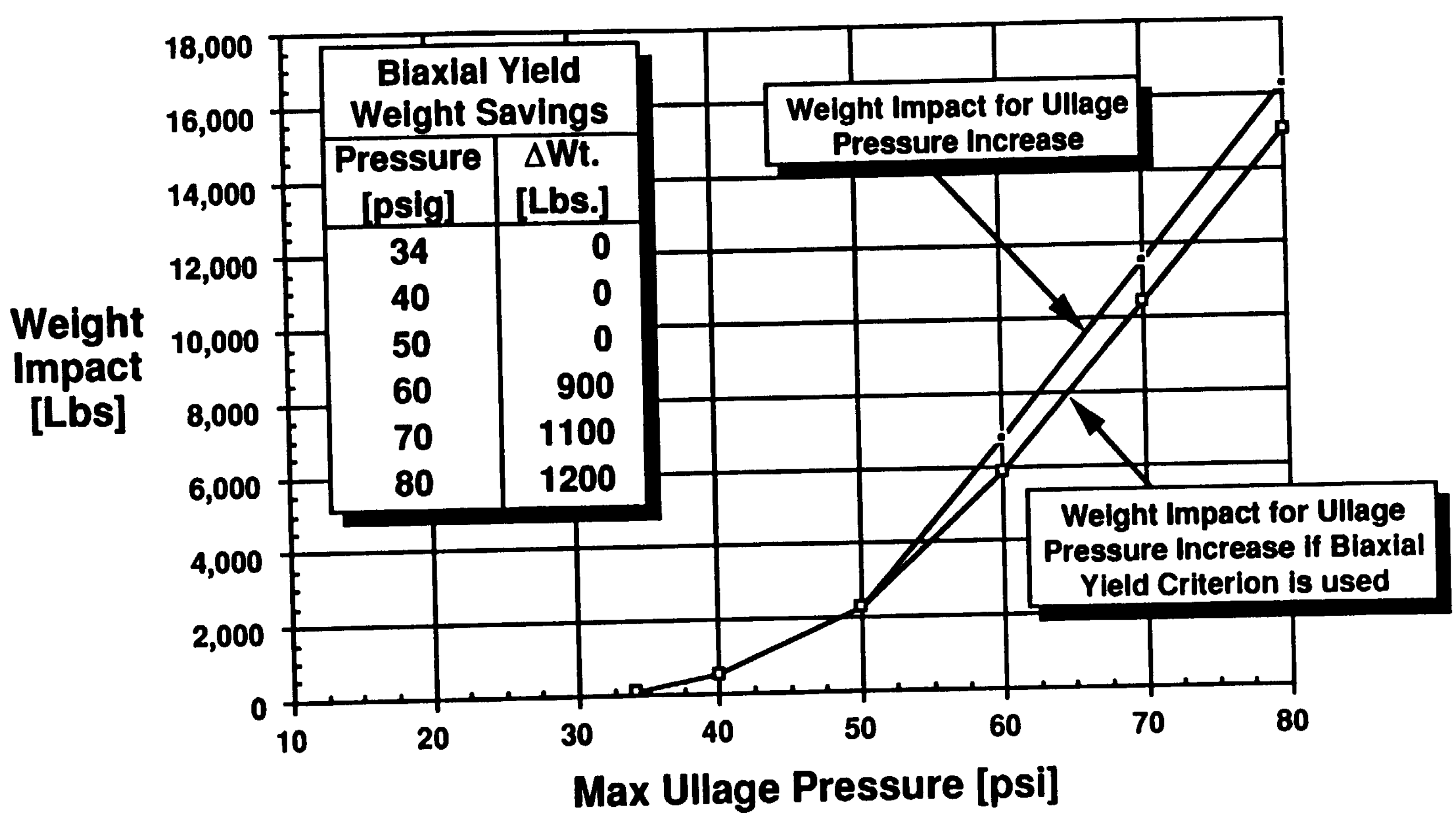
MANNED SPACE SYSTEMS

TJS-B1

Biaxial Yield Theory Savings

3-S-008-B



Biaxial Yield Weight Savings	
Pressure [psig]	ΔWt. [Lbs.]
34	0
40	0
50	0
60	900
70	1100
80	1200

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MANNED SPACE SYSTEMS

TJS-B1-139a

Issues Identified During Study — 3-S-008-B

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

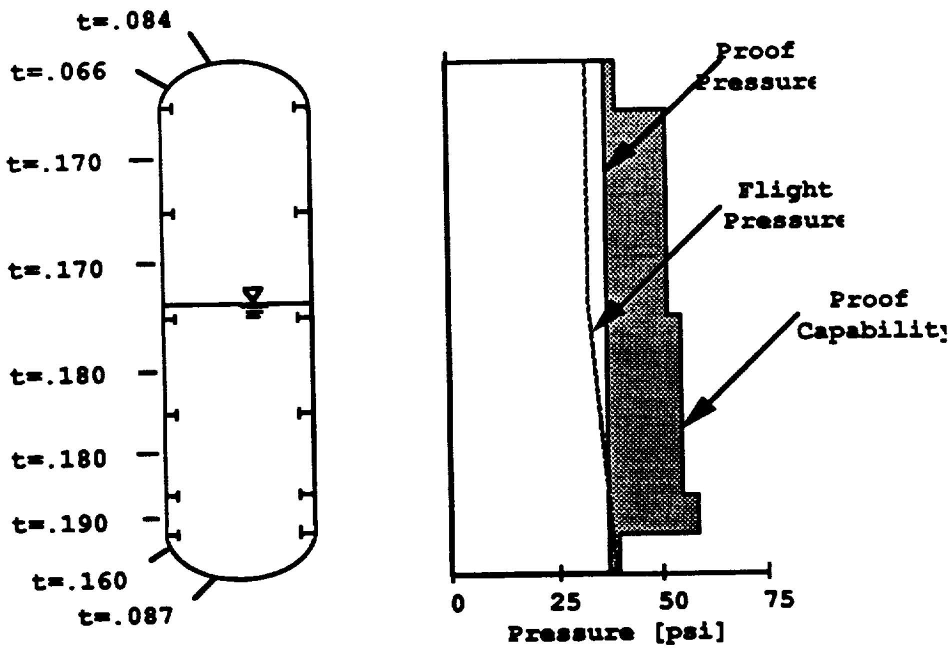
The weight impact is roughly 450 Lbs. per psi. No tooling impacts are identified until ullage pressures reach 50 psig. Major tooling impacts occur once ullage pressures exceed 70 psig. There is no weight savings for ullage pressure below the baseline pressure because the skin is sized for compression, 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.

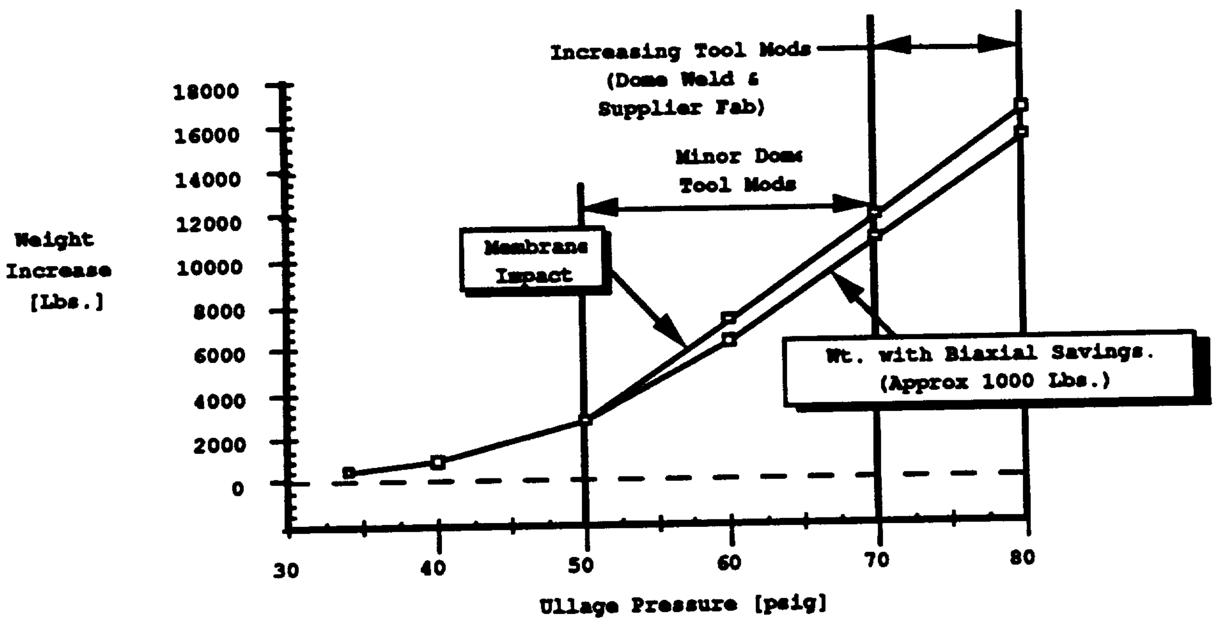
Conclusions

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

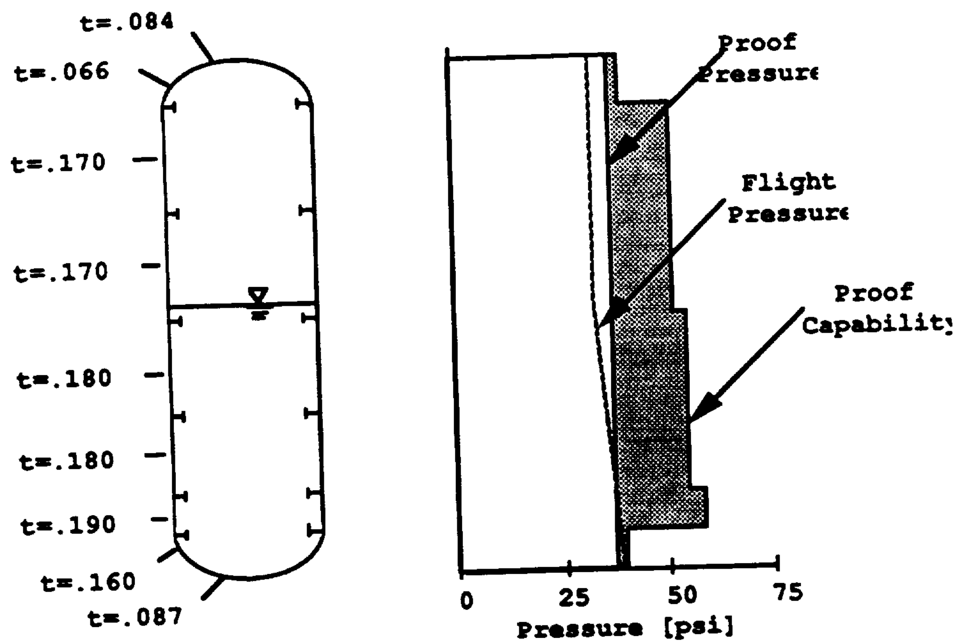
The weight impact is roughly 450 Lbs. per psi. No tooling impacts are identified until ullage pressures reach 50 psig. Major tooling impacts occur once ullage pressures exceed 70 psig. There is no weight savings for ullage pressure below the baseline pressure because the skin is sized for compression, 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.

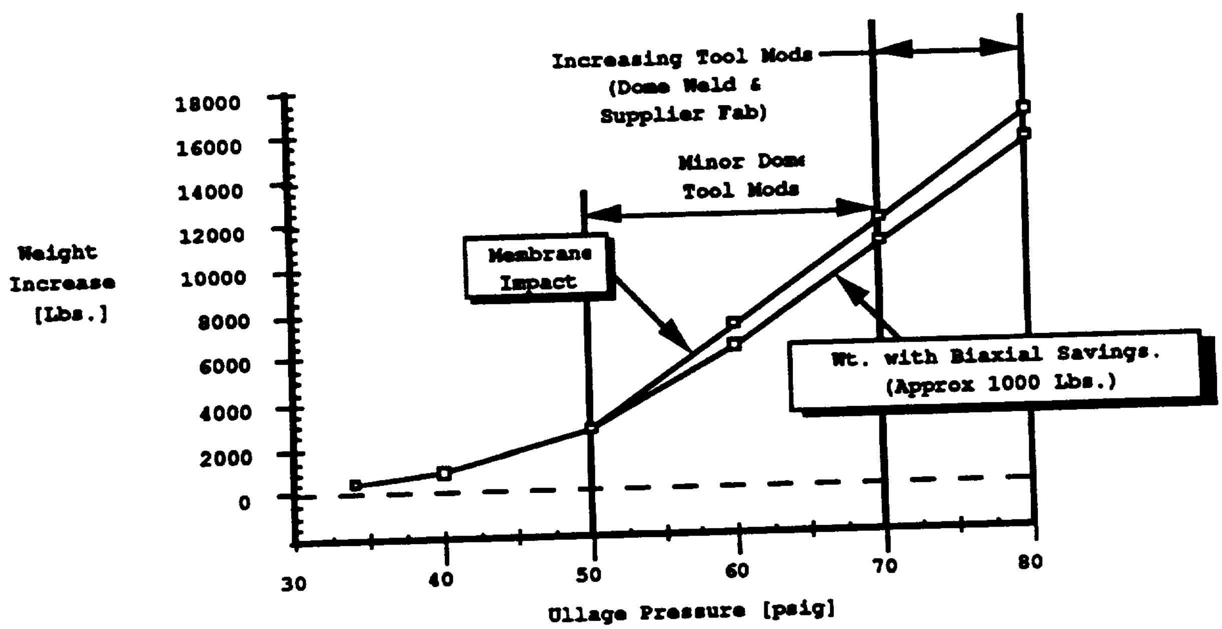
Conclusions

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

See 3-S-001B Trade Study

Prepared By: Dilip Dudgaonkar
(504)257-0076

Approved By: M.R.Simms

Rev: Initial
Date: January 8, 1992

MARTIN MARIETTA
MANNED SPACE SYSTEMS

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 sensititivities
e) Prepare conclusions and recommendations

Key Study Results

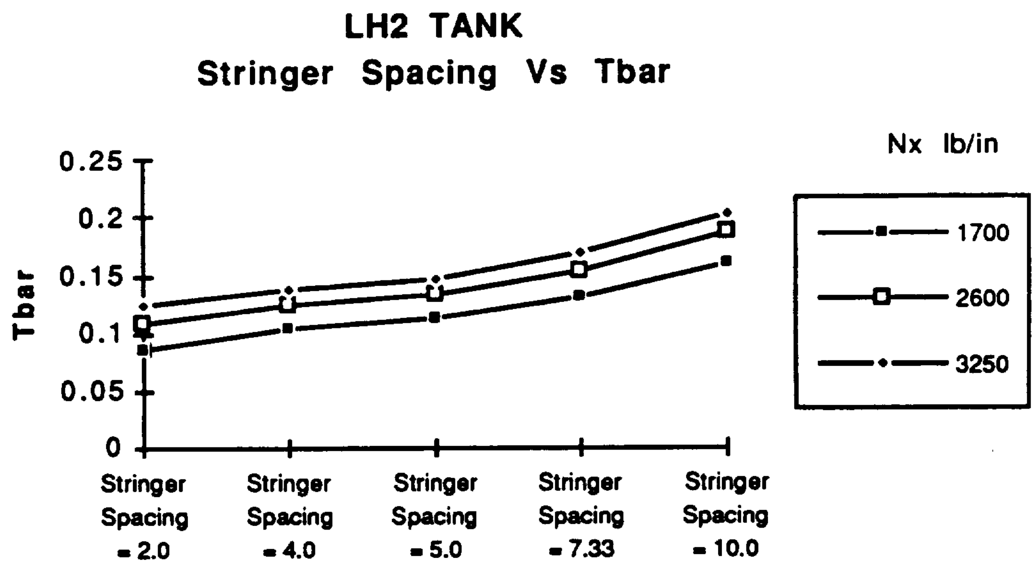
The current internal T section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight (tbar) trend shows that an optimum occurs at a stringer pitch of 2.0 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

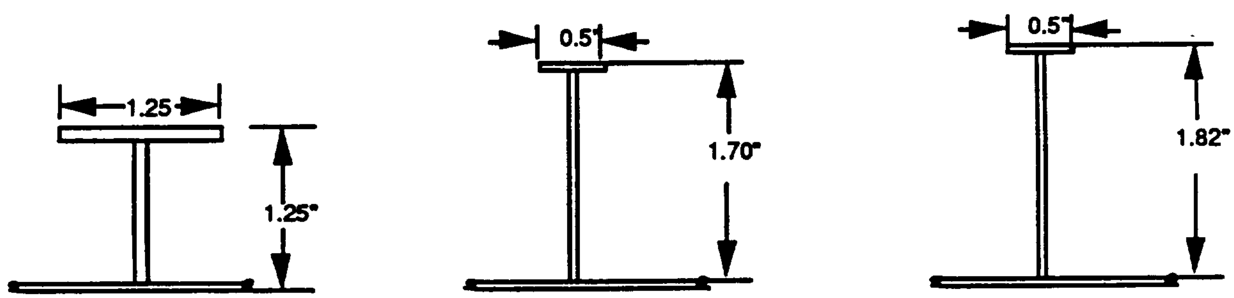
Conclusions

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 varing frame spacing on the stiffener pitch.





Current Design	Optimized Design Nx=2600 lb/in	Optimized Design Nx=3250 lb/in
Stringer Spacing=10.832"	Stringer Spacing=2.0"	Stringer Spacing=2.0"
Frame Spacing=26.7"	Frame Spacing=26.7"	Frame Spacing=26.7"
Tskin=0.170	Tskin=0.061	Tskin=0.067
Tbar=0.193	Tbar=0.108	Tbar=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 sensititivities
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

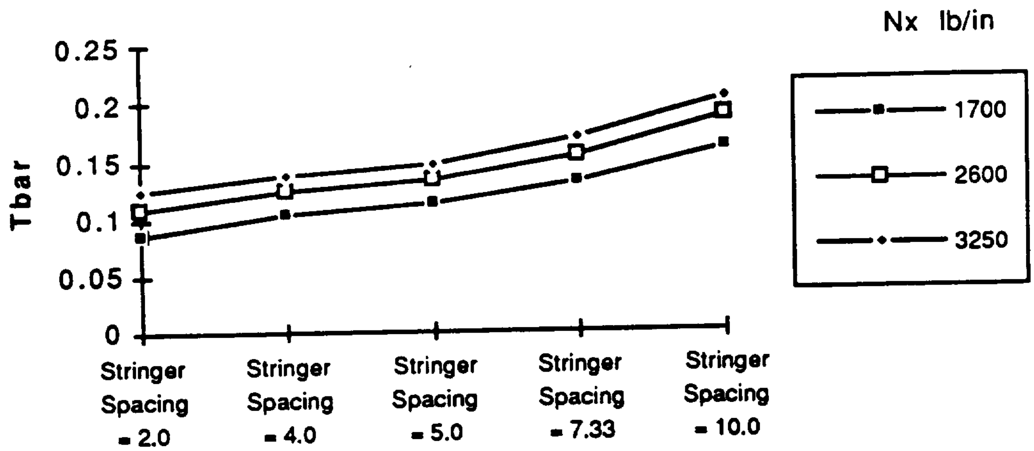
Conclusions

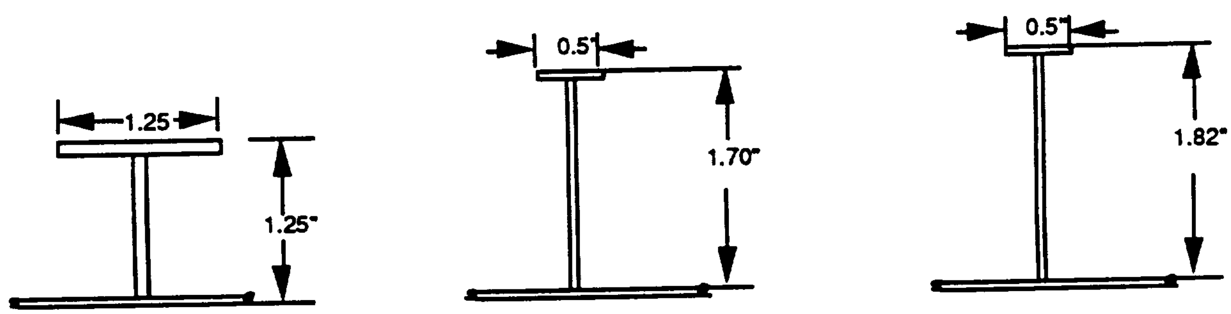
Weight sensitivity data was generated by varying the stringer pitch while maintaining the the reference configurations integrally machined longitudinal tee stiffened panel approach. The Panda II optimized configuration developed offers weight savings compared to the baseline configuration but is not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

LH2 TANK
Stringer Spacing Vs Tbar





Current Design	Optimized Design Nx=2600 lb/in	Optimized Design Nx=3250 lb/in
Stringer Spacing=10.832"	Stringer Spacing=2.0"	Stringer Spacing=2.0"
Frame Spacing=26.7"	Frame Spacing=26.7"	Frame Spacing=26.7"
Tskin=0.170	Tskin=0.061	Tskin=0.067
Tbar=0.193	Tbar=0.108	Tbar=0.123

Additional Information

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

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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

Approved By: M.R.Simms

Rev: Initial
Date: January 8, 1992

GMR.91352

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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.

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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.)

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Groundrules & Assumptions (Cont.)

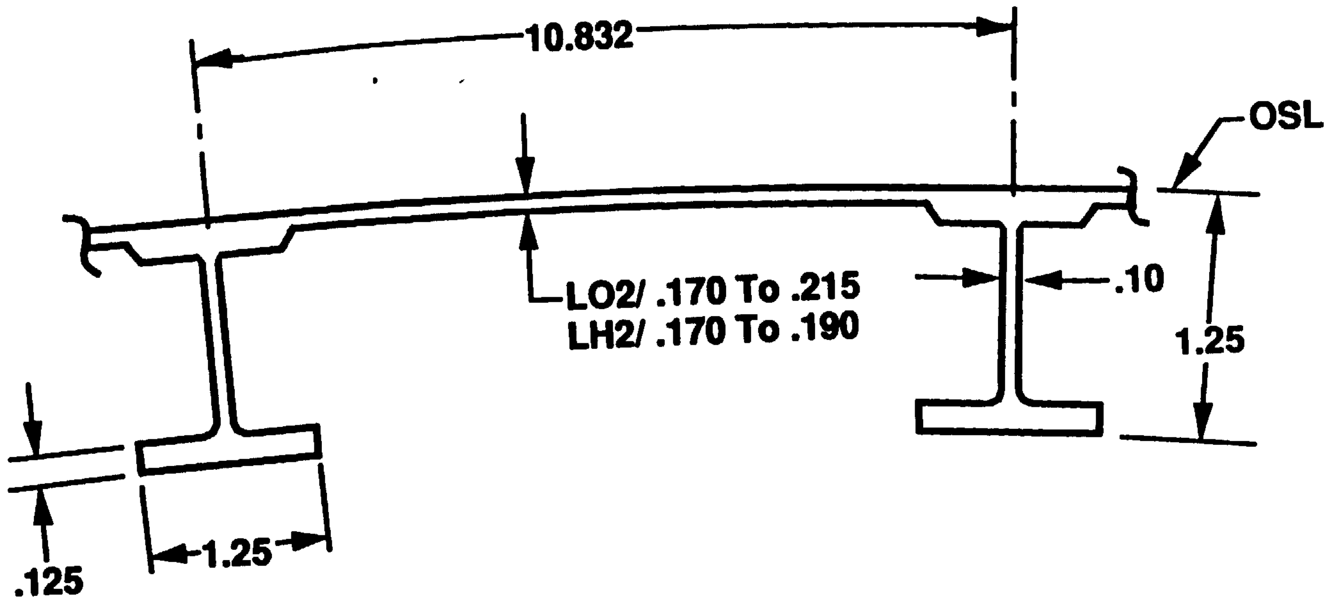
- Weldalite Not Considered.
- Dimensions Based On ROM Sizing.

Key Issues/Evaluation Criteria

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

Evaluation Criteria		Rationale
Manufacturing/Producibility		Producibility Is A Major Factor In Concept Selection. Selected Option Should Not Impact NLS Manufacture On ET Tooling.
Weight Impact		Any Additional Weight Must Be Traded Against Loss Of Payload Lift Capability.
Costs	Non-Recurring	Minimal DDT&E Desired.
	Recurring	Low Cost Per Flight Desired For Expendable HLLV

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 Consistant With Maximum Axial Load.

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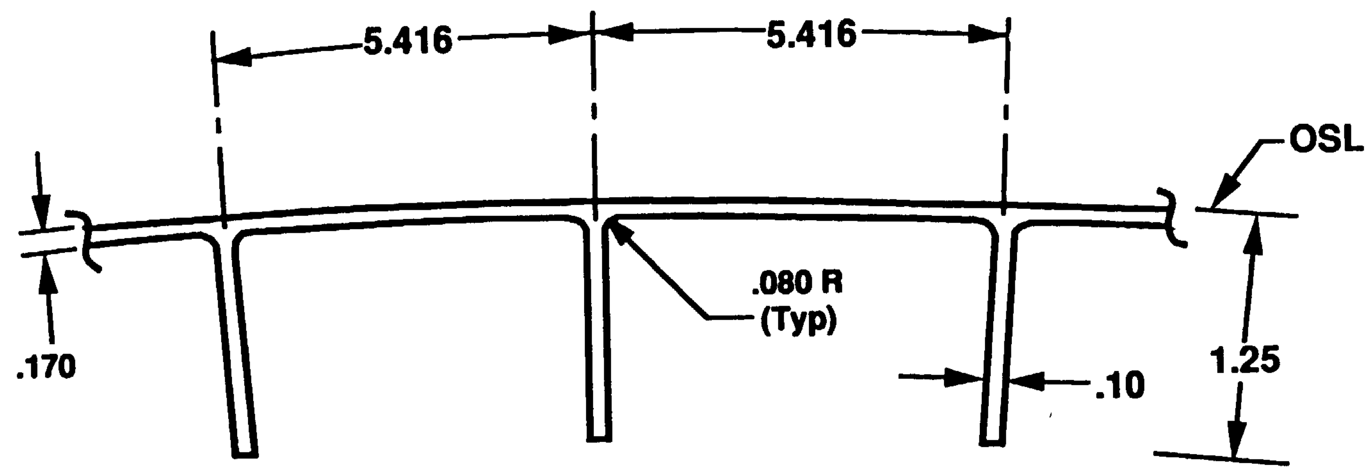
Option 2 - Machined Blade-Stiffened Panel (LO2 & LH2)



- 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.

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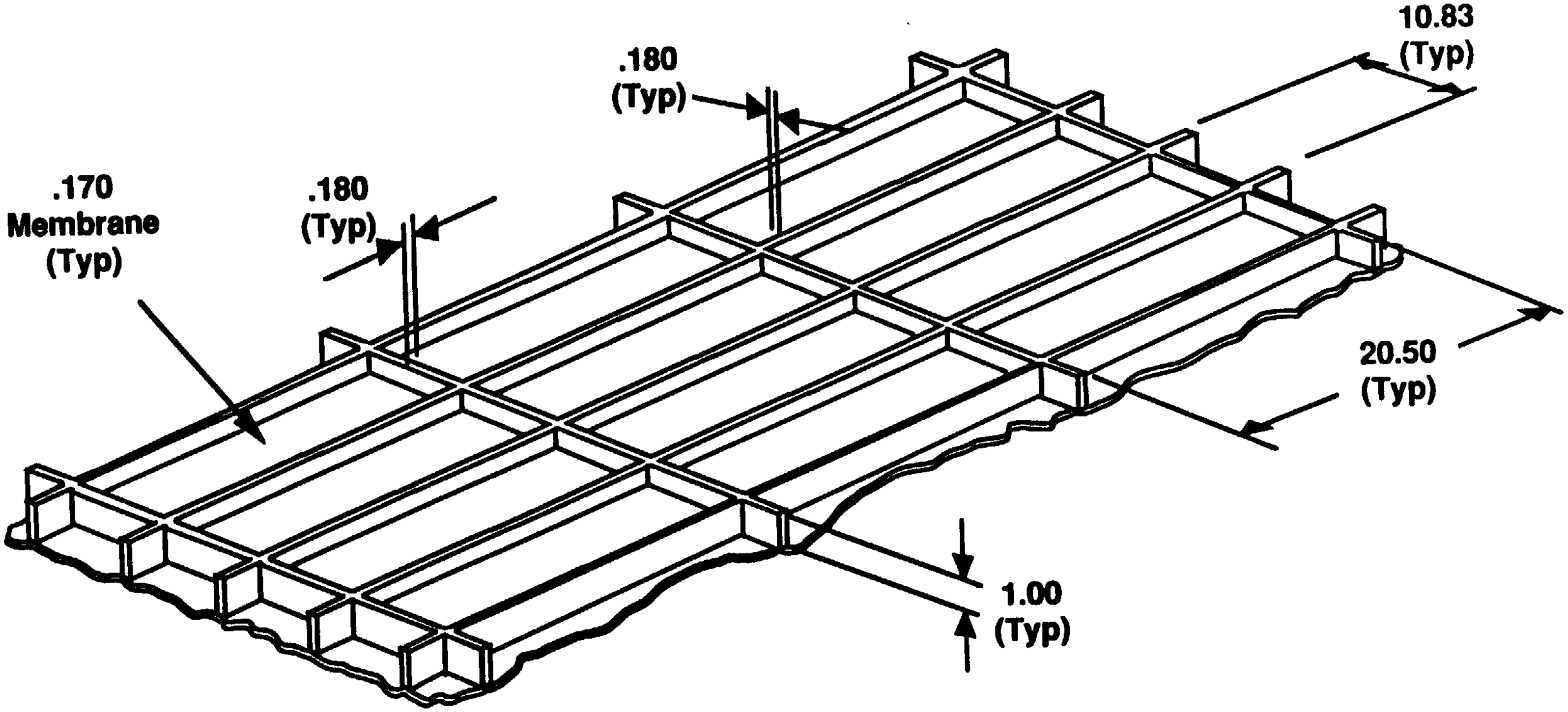
Option 3 - Machined Waffle Panel (LO_2 & LH_2)



- Integrally Machined Waffle Panel With Longitudinal & Transverse Stiffening.
- New Processes And Tooling Required.
- Designed For Maximum Axial & Bending Loading Conditions.

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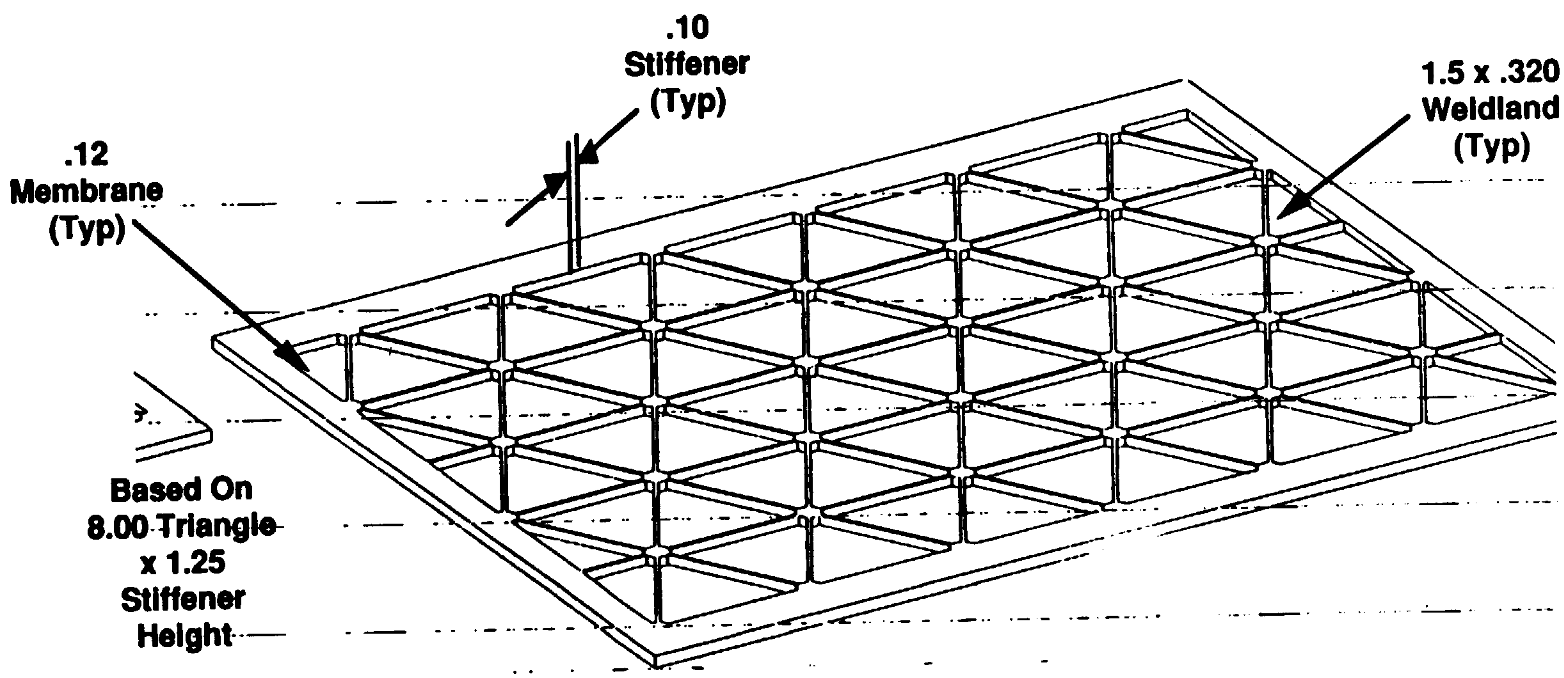
Option 4 - Machined Isogrid Panel (LO2 & LH2)



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

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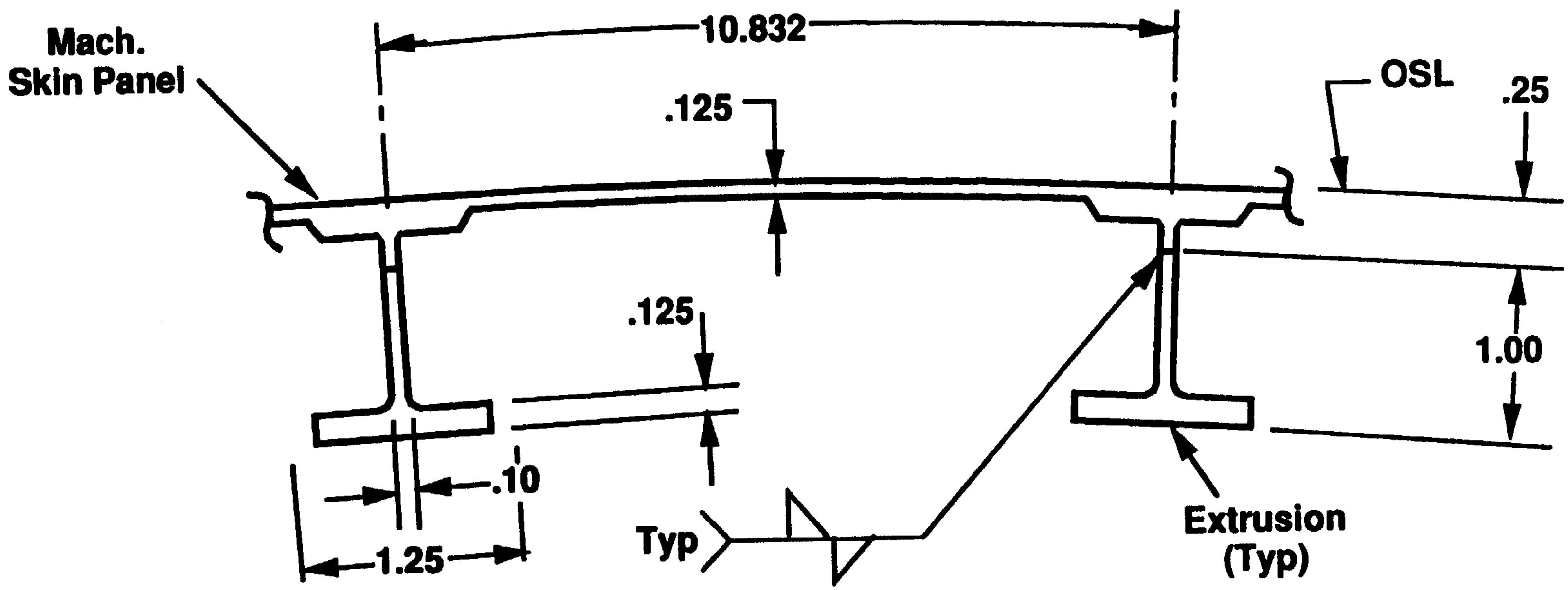
Option 5 - Welded Panel (LO2 & LH2)



- 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.

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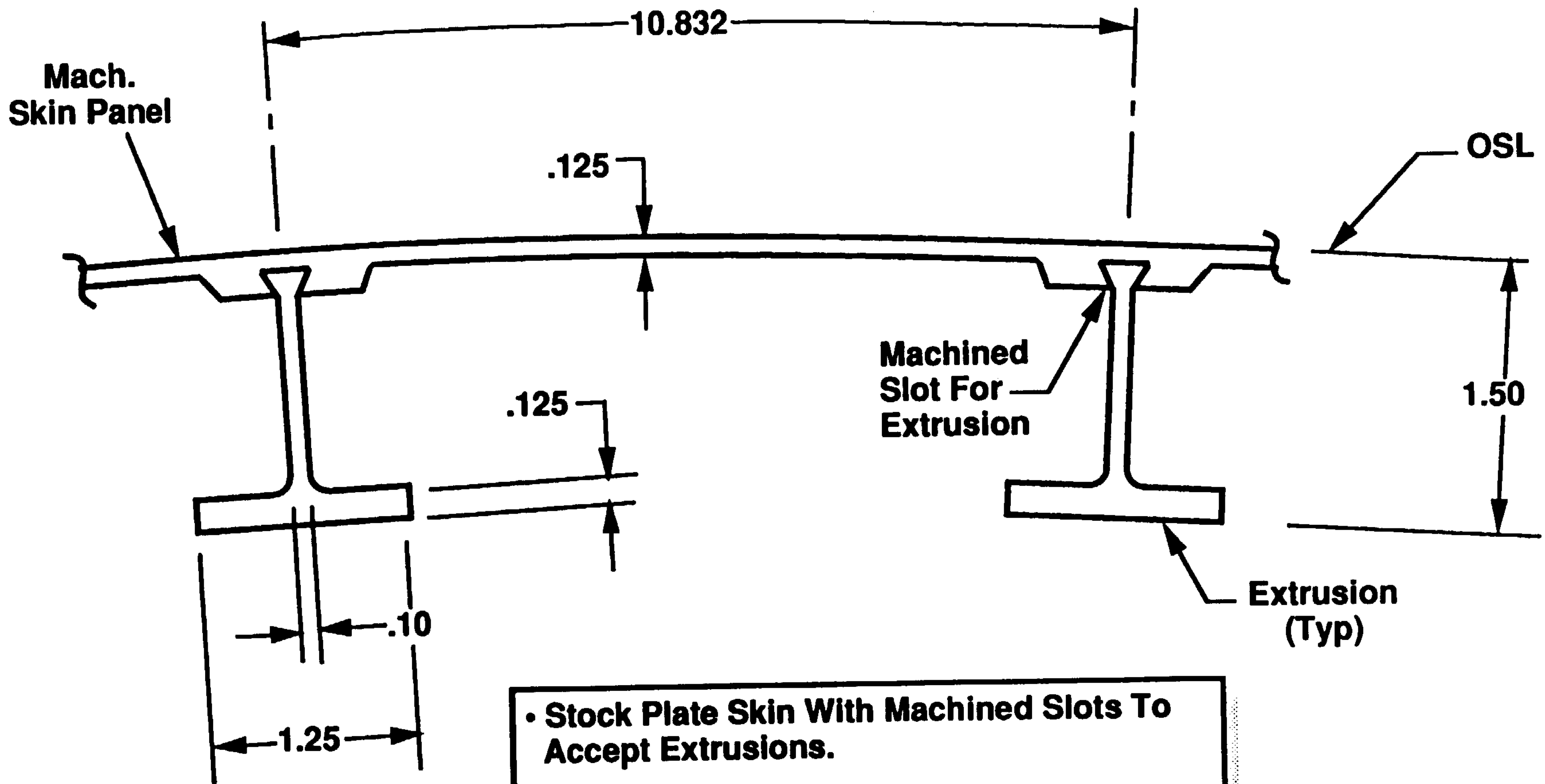
Option 6 - Mechanically Fastened Panel (LO_2 & LH_2)



- 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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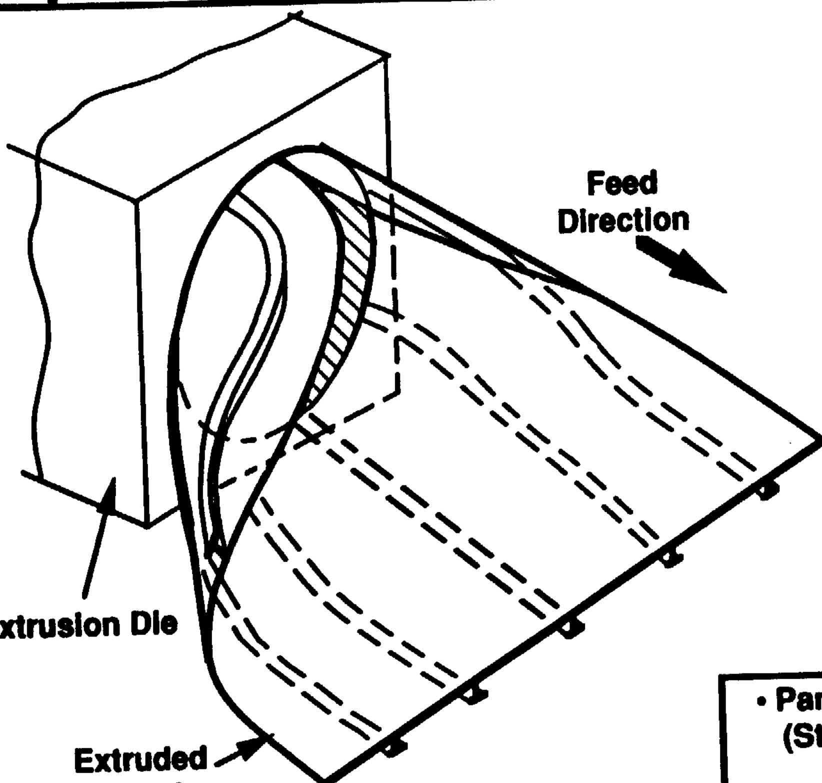
Option 7 - Extruded Panel (LO2 & LH2)



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.

- 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.

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

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Manufacturing/Producibility Summary

	Barrel Weld Assembly	Mechanical Assembly & Installation To Tank	Intermediate Frame Attachment
Option 1 (Baseline)	Baseline	Baseline	Baseline
Option 2 Machined Blade Stiffened Panel	Same As Baseline	(-) Requires Separate Frame Attach. Brkts.	(-) Complex Bracket Arrgt. Required.
Option 3 Machined WafflePanel	(-) Some High Development WorkTo Adapt ET Tooling. Higher Weld Costs.	(+) Fewer Intermediate Frames Required.	(+) Less Complex Bracket Arrgt. Required
Option 4 Machined Iso-Grid Panel	(-) Some High Development WorkTo Adapt ET Tooling. Higher Weld Costs.	(+) Fewer Intermediate Frames Required.	(+) Less Complex Bracket Arrgt. Required
Option 5 Welded Panel	Same As Baseline	(-) Some High Development WorkTo Adapt ET Tooling. Higher Weld Costs.	Same As Baseline
Option 6 Mechanically Fastened Panel	Same As Baseline	(-) Some High Development WorkTo Adapt ET Tooling.	Same As Baseline
Option 7 Extruded Panel	Same As Baseline	Same As Baseline	Same As Baseline

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Weight Impact Summary

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

Costs Impact Summary

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

* Insufficient Data Exists To Effectively AssessThis Option.

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Evaluation Summary

	Weight Impacts	Cost Ranking	Manufacturing/ Producibility Impacts	Other Impacts
Option 1 (Baseline)	P.O.D.	1	None	Good Synergism With E.T.
Option 2 Machined Blade Stiffened Panel	8 % Decrease	2	Sim. To Baseline, But Req. Sep.Frame Attach. Brkts. Some High Development WorkTo Adapt ET Tooling.	—
Option 3 Machined WafflePanel	5 % Increase	5	Some High Dev.Work To Adapt ET Tooling. Higher Weld Costs.	Fewer Intermediate Frames Required.
Option 4 Machined Iso-Grid Panel	12 % Decrease	3	Some High Dev.Work To Adapt ET Tooling. Higher Weld Costs.	Fewer Intermediate Frames Required.
Option 5 Welded Panel	Same As Baseline	6	Some High Development WorkTo Adapt ET Tooling. Higher Weld Costs.	Good Synergism With E.T.
Option 6 Mechanically Fastened Panel	1 % Increase	4	Some High Development WorkTo Adapt ET Tooling.	Good Synergism With E.T.
Option 7 Extruded Panel	Same As Baseline	* TBD	New Processes And Tooling Required.	Good Synergism With E.T.

* Insufficient Data Exists To Effectively AssessThis Option.

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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.

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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 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.

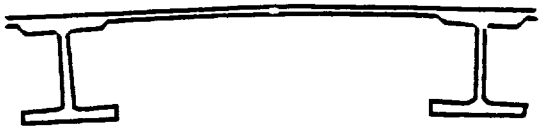
Conclusions

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

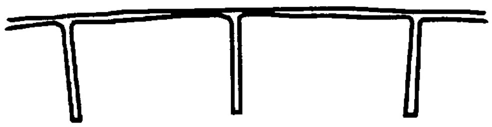
Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:

- Option 1 - M/C Panel With Tee Stiffeners (Baseline)
- Option 4 - Machined isogrid panel.
- Follow the progress and development of Option 7



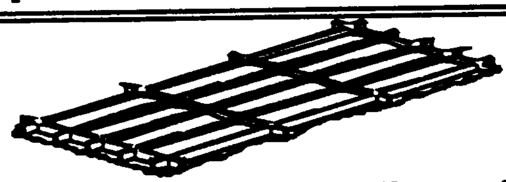
Option 1 - Baseline Panel (P.O.D.)

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



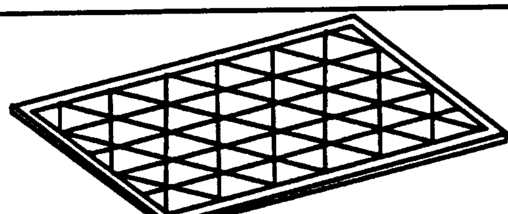
Option 2 - Mach.Blade-Stiff. Panel

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



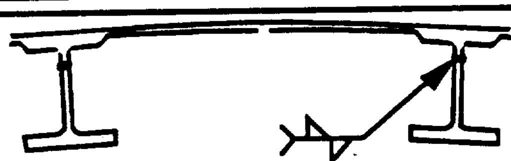
Option 3 - Machined Waffle Panel

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



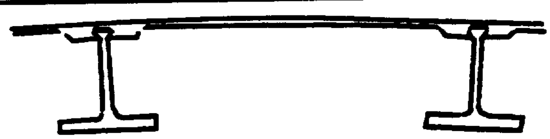
Option 4 - Machined Isogrid Panel

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



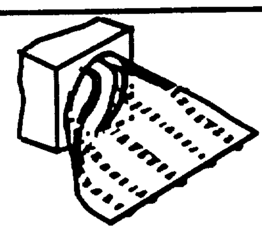
Option 5 - Welded Panel

- Machined Panel With Welded Extruded Tee-Stiffening.
- Similar To External Tank.
- New Processes And Tooling Required.
- Design Consistant 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.

6.2.6.4.6 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 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.

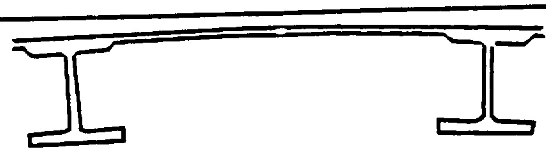
Conclusions

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

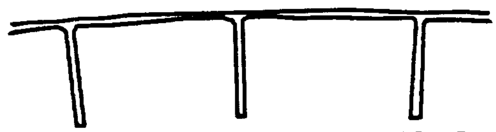
Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:

- Option 1 - M/C Panel With Tee Stiffeners (Baseline)
- Option 4 - Machined isogrid panel.
- Follow the progress and development of Option 7



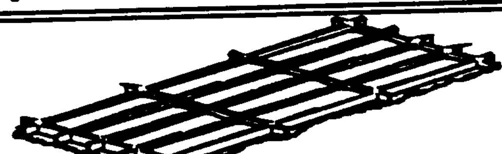
Option 1 - Baseline Panel (P.O.D.)

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



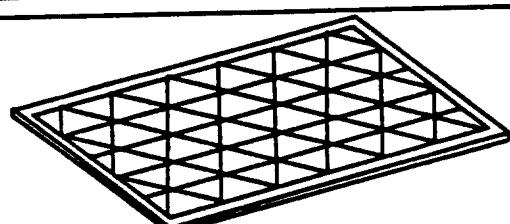
Option 2 - Mach.Blade-Stiff. Panel

- Machined Panel W/ Blade-Stiffening.
- May Not Utilize ET Processes And Tooling.
- Design Consistant 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.

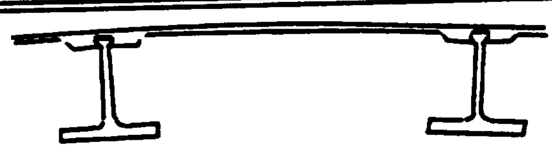


Option 4 - Machined Isogrid Panel

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

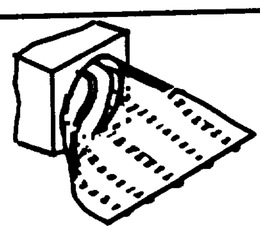
Option 5 - Welded Panel

- Machined Panel With Welded Extruded Tee-Stiffening.
- Similar To External Tank.
- New Processes And Tooling Required.
- Design Consistant 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.

3-S-009A
(CV-STR-19A)
Intertank Commonality Assessment

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

Approved By: M.R.Simms

Rev: Initial
Date: January 8, 1991

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NLS Intertank Commonality CV-STR-19A

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

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DAT.91'

Groundrules CV-STR-19A

- Intertank Structure Definition Per MSFC Reference Layout NLS-0001 Dated 10/9/91
- NLS Ref Intertank Used As The HLLV Intertank For This Study

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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

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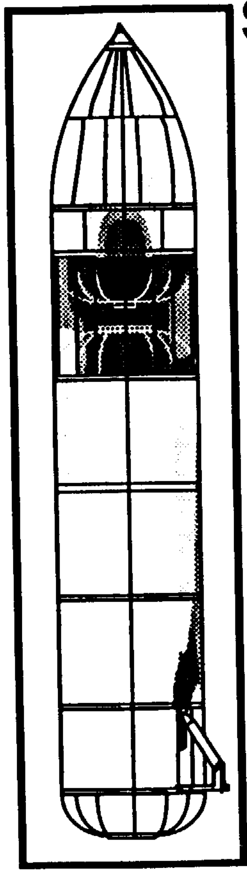
DAT.91'

Design Loads Comparision CV-STR-19A



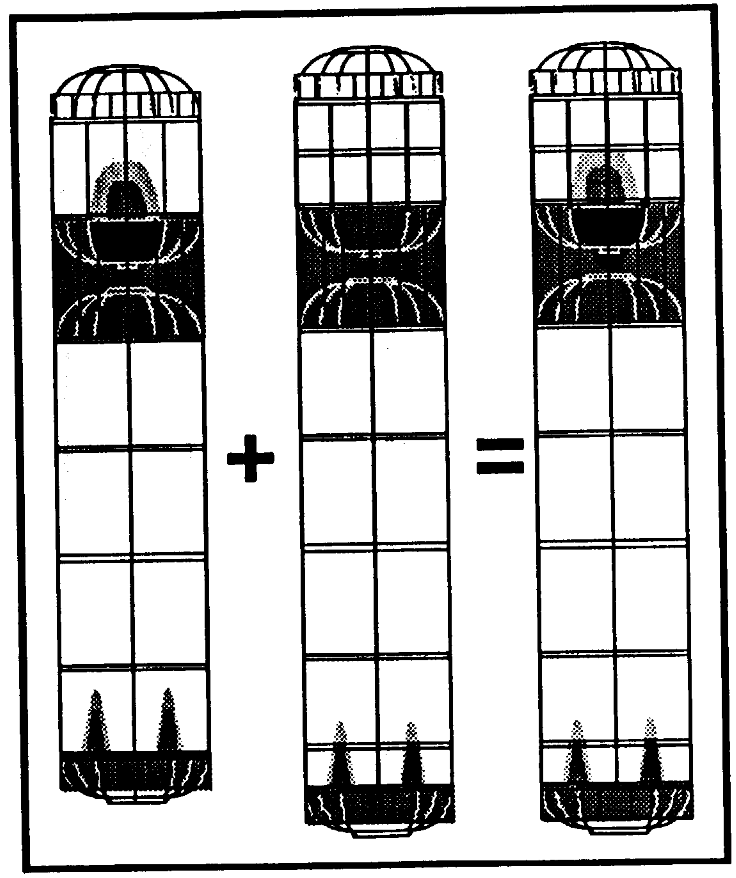
Standard ET

Shell Axial Design Loads – Limit

Loads – lb/in

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

ET-Derived Core Tankage



HLLV 1.5 Stage Common Core

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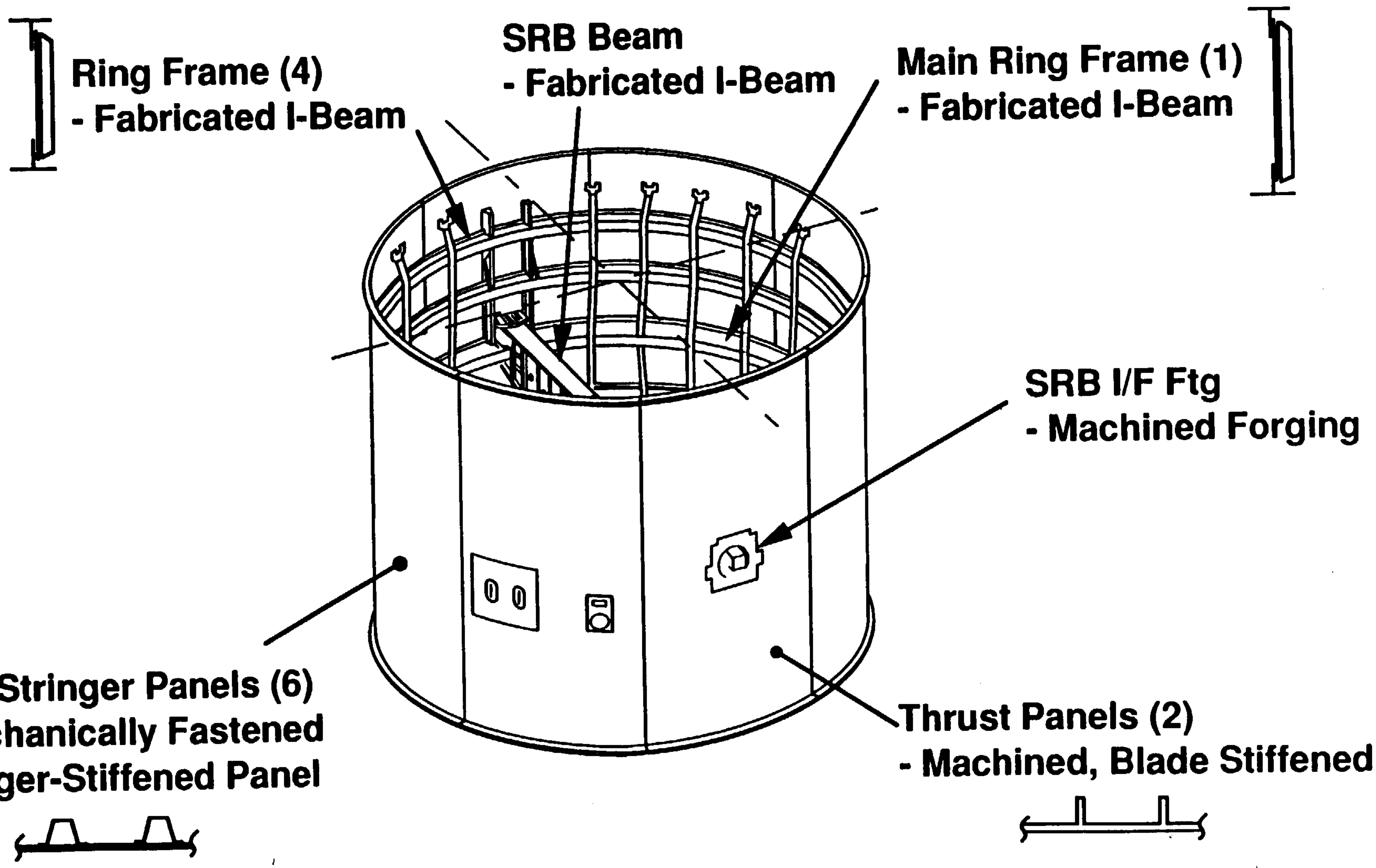
- **ET Intertank Definition**

ET Intertank Arrangement CV-STR-19A



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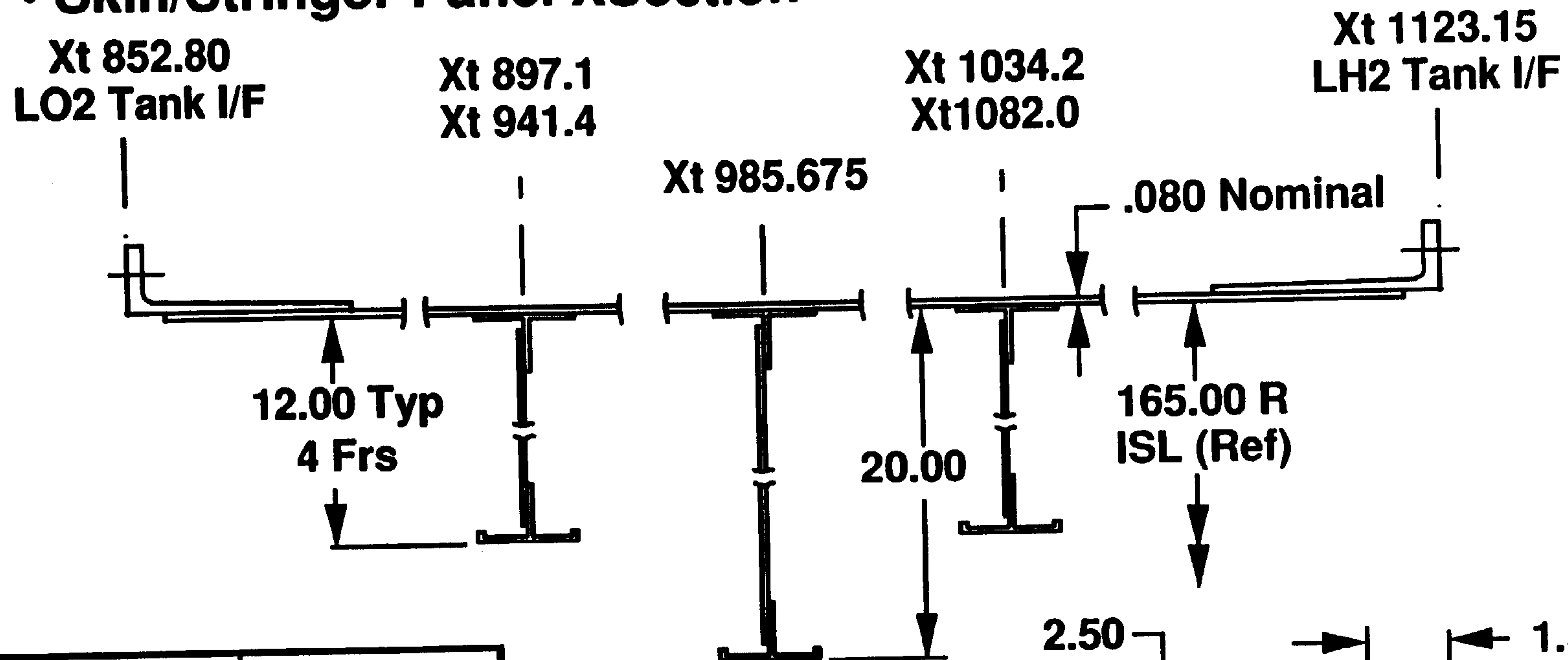
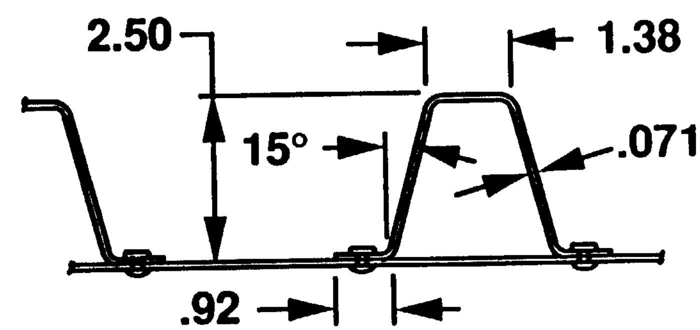
ET Intertank Structure CV-STR-19A

- Skin/Stringer Panel XSection



Frame	XSect Area
Xt 897.1	1.51 in sq
Xt 941.4	1.96 in sq
Xt 985.675	6.05 in sq
Xt 1034.2	2.24 in sq
Xt 1082.0	1.69 in sq



Nominal Stiffener Detail

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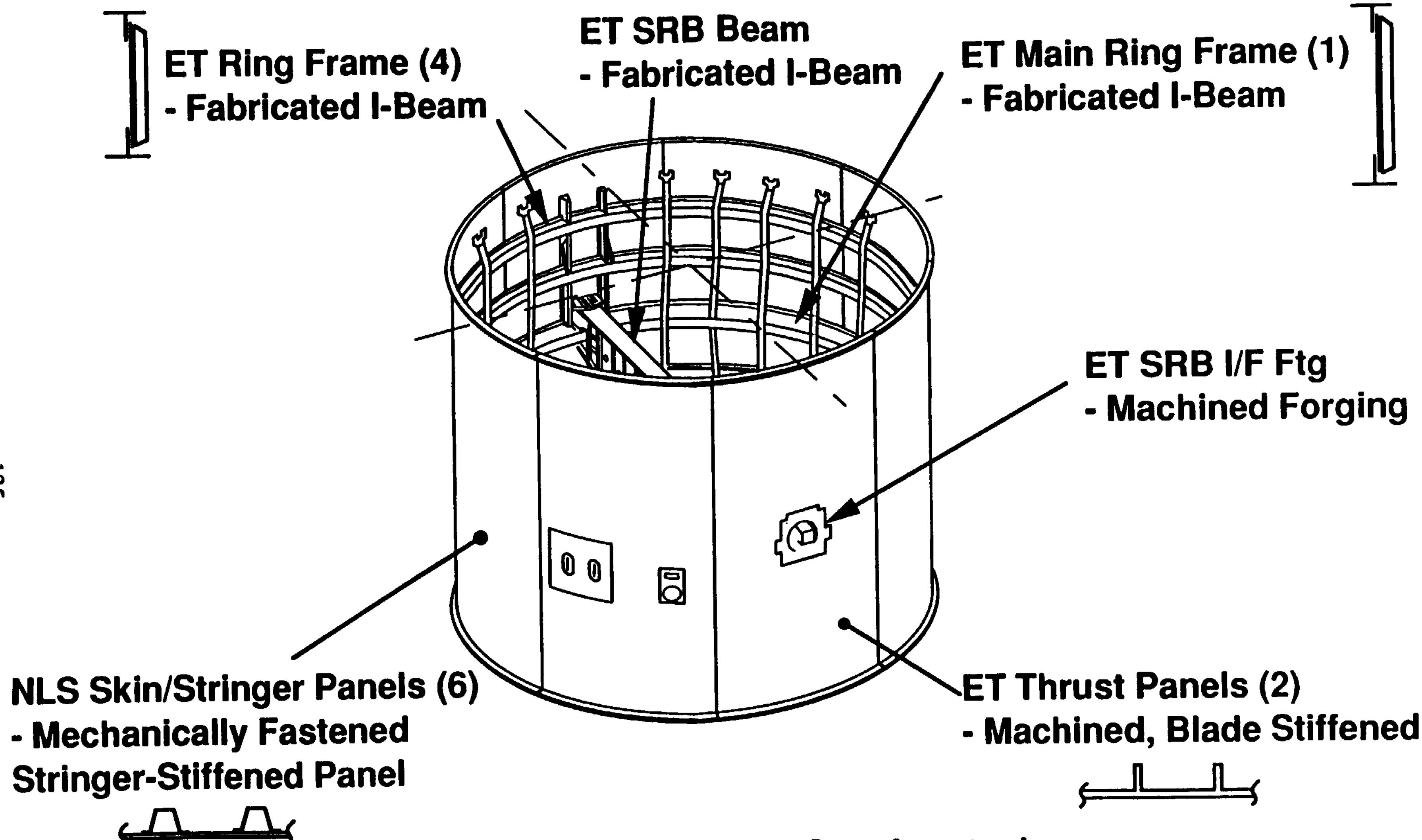
DAT.91'

Standalone HLLV Intertank* CV-STR-19A



* Same As NLS Common Core Intertank

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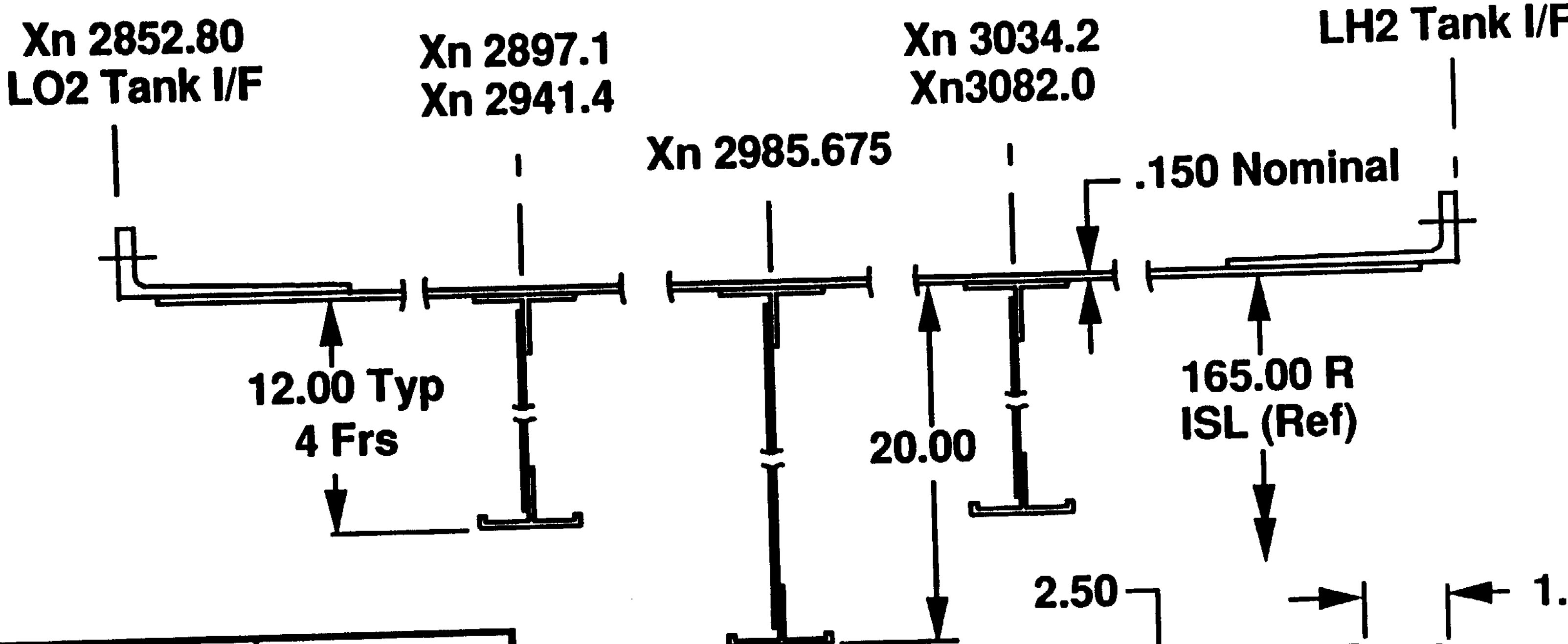
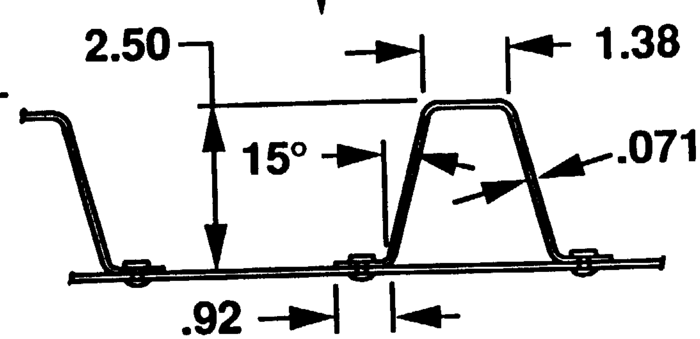
Standalone HLLV Intertank CV-STR-19A

- Skin/Stringer Panel XSection





Nominal Stiffener Detail

Frame	XSect Area
Xn 2897.1	1.51 in sq
Xn 2941.4	1.96 in sq
Xn 2985.675	6.05 in sq
Xn 3034.2	2.24 in sq
Xn 3082.0	1.69 in sq

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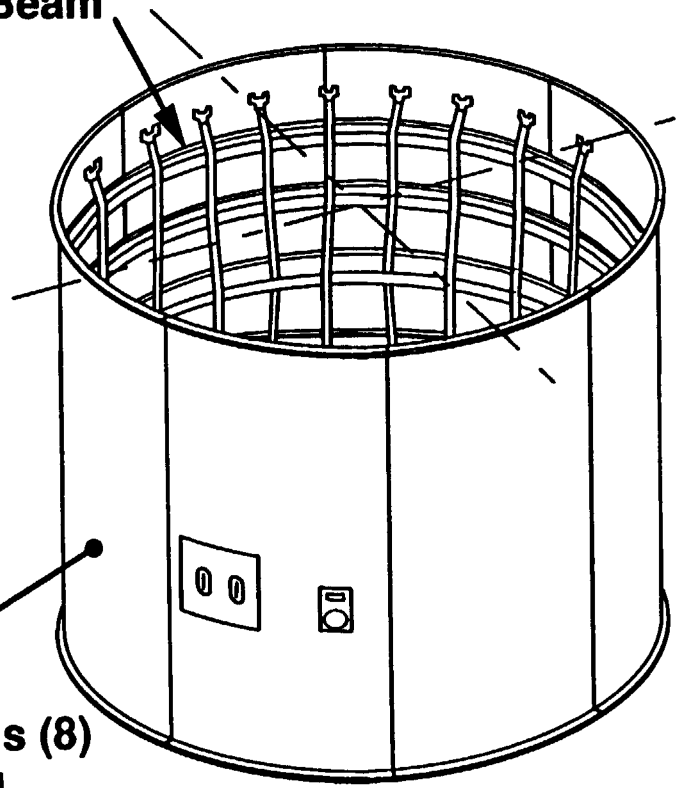
DAT.91'

Standalone 1.5 Stage I/T CV-STR-19A

ET Ring Frame (5)
- Fabricated I-Beam



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

DAT.91297

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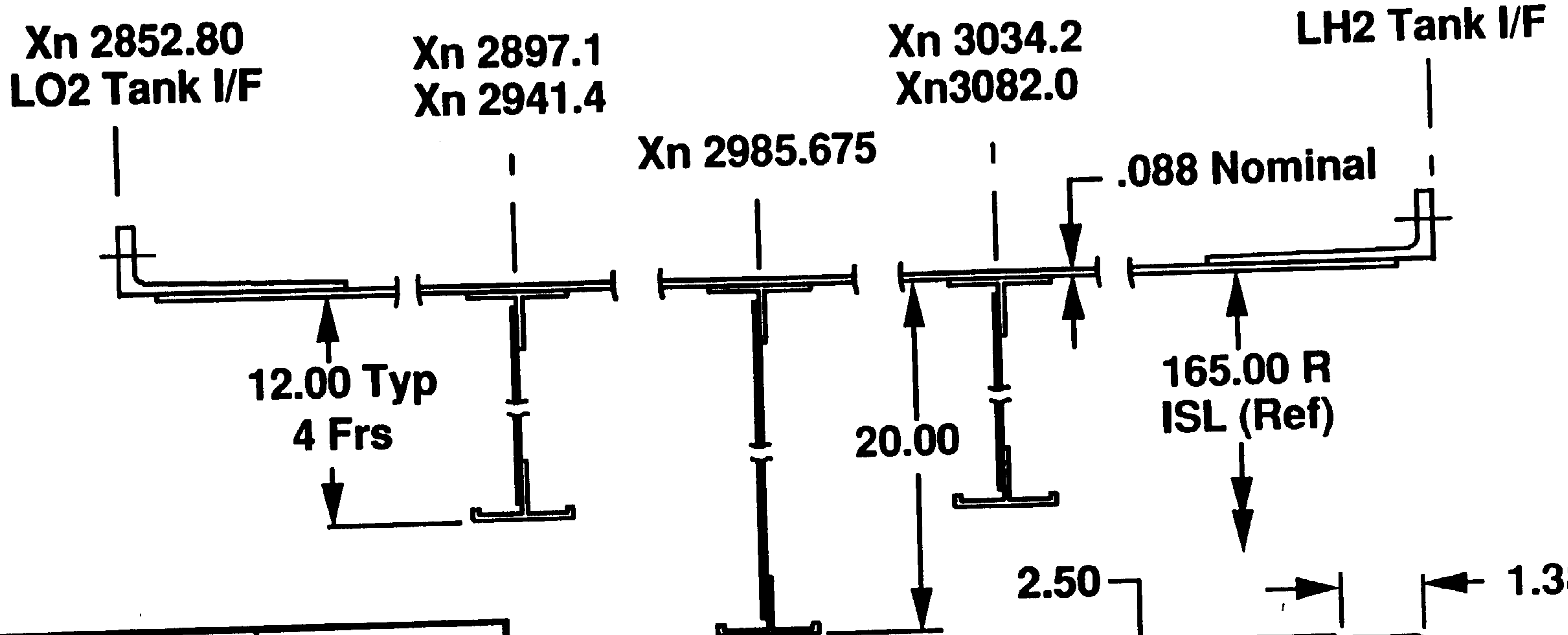
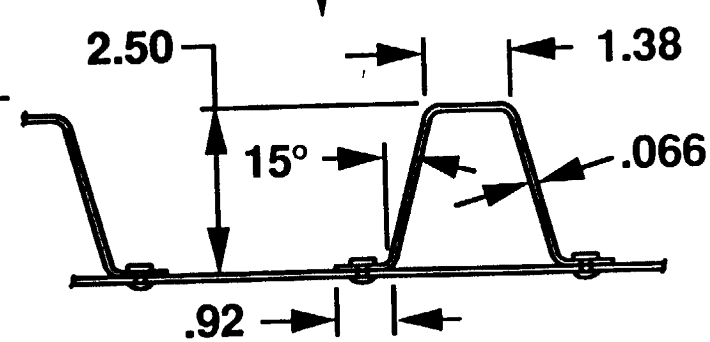
Standalone 1.5 Stage Intertank CV-STR-19A

• Skin/Stringer Panel XSection





Nominal Stiffener Detail

Frame	XSect Area
Xn 2897.1	2.14 in sq
Xn 2941.4	2.14 in sq
Xn 2985.675	2.14 in sq
Xn 3034.2	2.14 in sq
Xn 3082.0	2.14 in sq

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Weight Estimates

CV-STR-19A

Hardware	ET 120	HLLV Ref	1.5 Stage Ref	1.5 Stage
Panel Assy	7563.10	9256.66	9256.66	5014.80
Panel # 1	653.20	920.97	920.97	626.85
Panel # 2	615.30	900.03	900.03	626.85
Panel # 3	676.60	900.03	900.03	626.85
Panel # 4	1906.10	1906.10	1906.10	626.85
Panel # 5	1907.30	1907.30	1907.30	626.85
Panel # 6	642.90	900.63	900.63	626.85
Panel # 7	619.30	900.63	900.63	626.85
Panel # 8	542.40	920.97	920.97	626.85
Frames	1532.70	1609.20	1609.20	1058.20
SRB Ring Frame (2985)	625.80	625.80	692.70	211.64
Ring Frame (2897)	203.20	203.20	203.20	211.64
Ring Frame (2941)	220.20	220.20	220.20	211.64
Ring Frame (3034)	259.70	259.70	259.70	211.64
Ring Frame (3082)	223.80	233.40	233.40	211.64
SRB Beam & Fittings	1952.60	1952.60	0.00	0.00
Misc. Hardware	1077.50	999.61	1199.69	1173.40
Sub-Total Dry Wt	12125.90	13818.15	12065.55	7246.40
Contingency (5%)	606.30	690.91	603.28	362.32
Total Dry Wt	12732.20	14509.06	12668.30	7608.72

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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 $\pm$Y Fabricated Panels
- Systems Installation Tool (T06A7424) Would Require Modification Only If Frame Depths Increased

- Intertank Commonality Assessment

Intertank Commonality — CV-STR-19A

Part	Title	Part Status			1.5 Stage Modification
		ET	HLLV	1.5 Stg	
P3	Panel # 3	E	N	U	Resized For 1.5 Stage Loads
P4	Panel # 4 (-Y)	E	E	U	Thrust Panels Replaced By Skin/Stringer Panels On 1.5 Stage. Common Panels ±Y
P5	Panel # 5 (+Y)	E	E	U	
P6	Panel # 6	E	N	U	Resized For 1.5 Stage Loads
P7	Panel # 7	E	N	U	Resized For 1.5 Stage Loads. Idendical To Panel # 2
P8	Panel # 8 (-Z)	E	N	U	Resized For 1.5 Stage Loads. Idendical To Panel # 1
B1	SRB Beam	E	E	-	SRB Beam Omitted

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

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MANNED SPACE SYSTEMS

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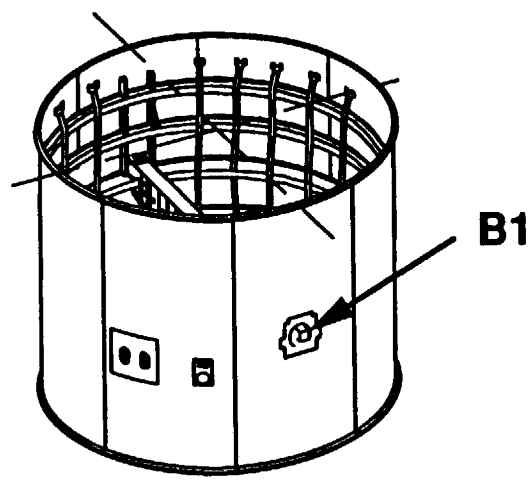
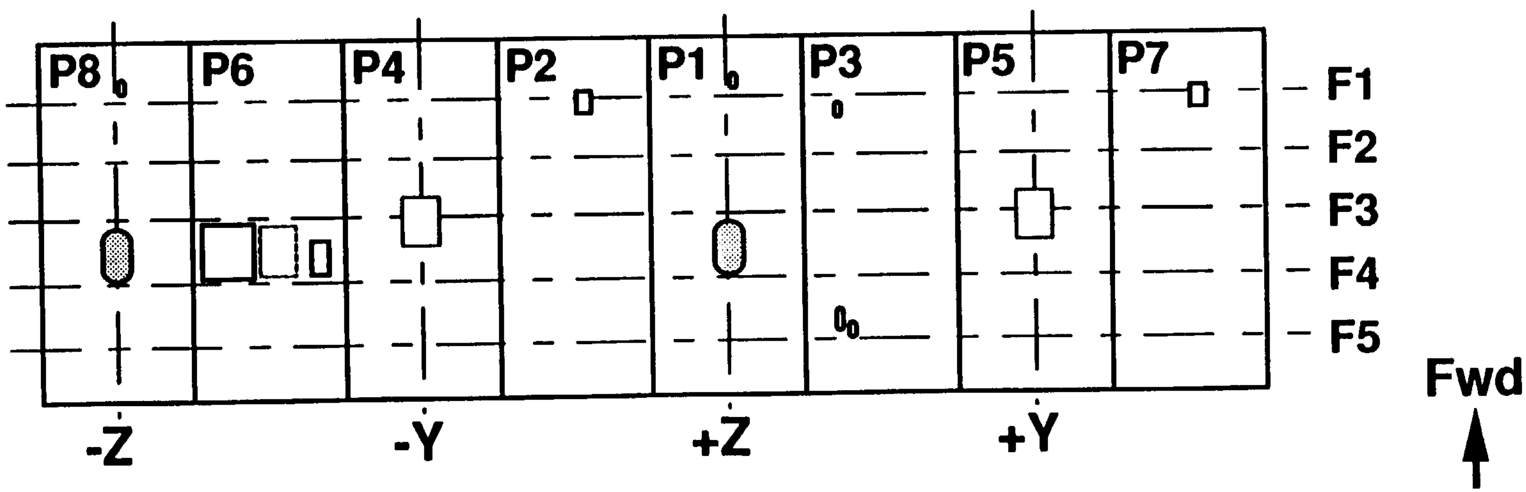
Intertank Commonality CV-STR-19A





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Intertank Commonality

CV-STR-19A

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

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

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Evaluation Summary CV-STR-19A

Critera	Common Core		Unique	
	HLLV	* 1.5 Stage	HLLV	1.5 Stage
Weight	14509	12668	14509	7608
# Of New Major Assys	4	1	4	6
# Of New Instls	1	1	1	1
Tooling Assy Impacts	NLS Ref	As Ref	As Ref	Minor Assy Tool Impacts
Test	STA Reqd	Verified By Analysis	STA Reqd	STA Reqd

* Unique For 1.5 Stage Only, On NLS Common Core

DAT.91297

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Conclusions CV-STR-19A

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

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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

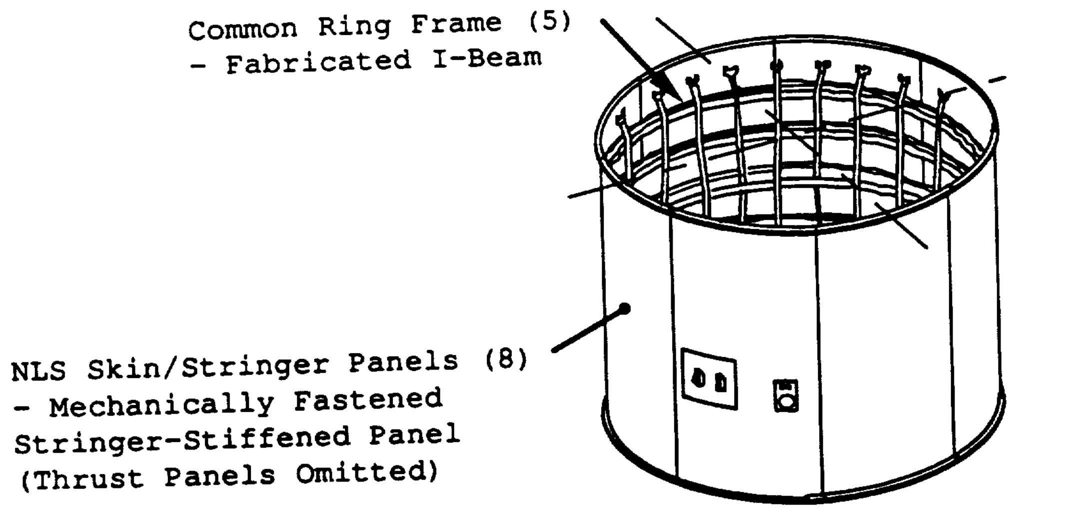
The standard HLLV intertank was identified as almost identical to the common core NLS intertank, indicating that ASRB loads are the prime driver. A significant weight saving of over 5 Klbs can be achieved by designing a standalone 1.5 Stage intertank. This requires an additional STA which adds DDT&E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

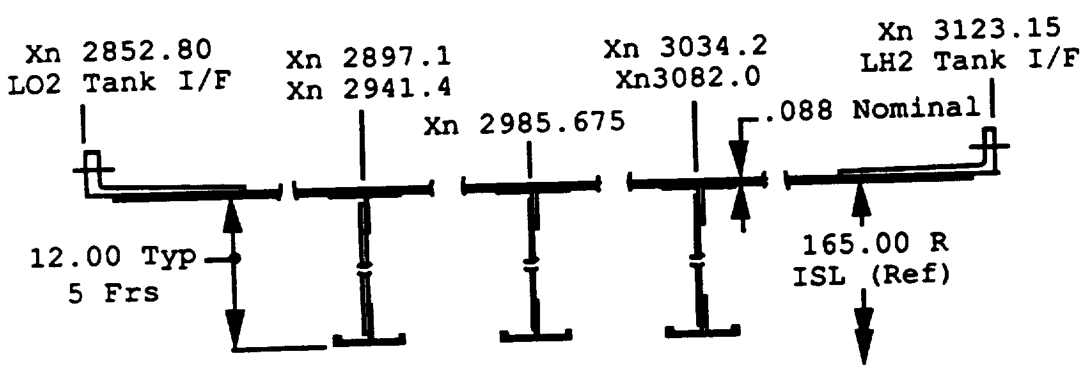
Conclusions

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

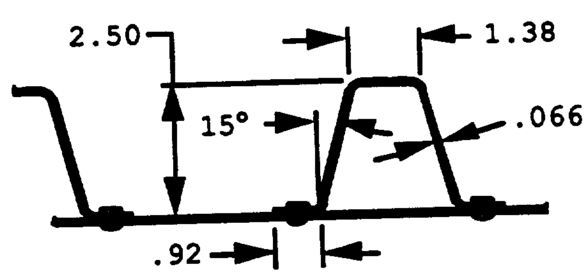
During Cycle 1 a more in depth study should be performed to confirm 1.5 Stage intertank weight savings. This study should also incorporate results from trade study on stiffener pitch sensitivity (see 5.2.5.4.3).





Skin/Stringer Panel XSection

Intertank	Weight
NSTS	12152
HLLV	14509
1.5 Stage	7608



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

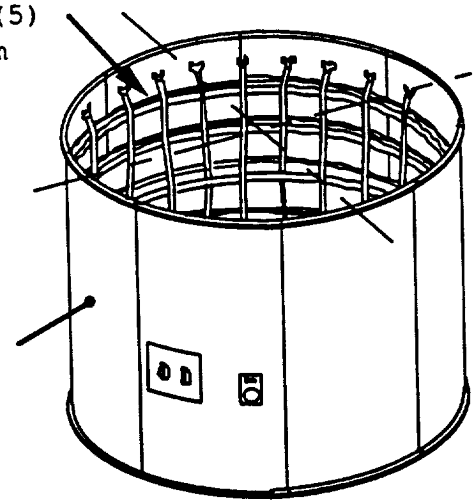
The standard HLLV intertank was identified as almost identical to the common core NLS intertank, indicating that ASRB loads are the prime driver. A significant weight saving of over 5 Klbs can be achieved by designing a standalone 1.5 Stage intertank. This requires an additional STA which adds DDT&E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

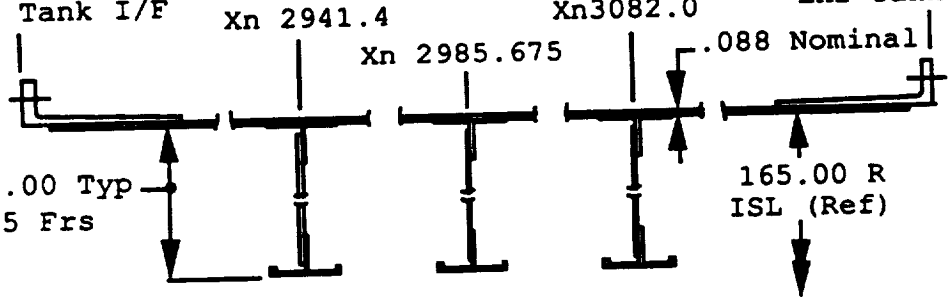
Conclusions

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

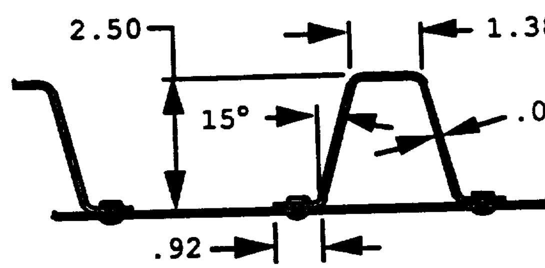
During Cycle 1 a more in depth study should be performed to confirm 1.5 Stage intertank weight savings. This study should also incorporate results from trade study on stiffener pitch sensitivity (see 6.2.5.4.3).





Skin/Stringer Panel XSection

Intertank	Weight
NSTS	12152
HLLV	14509
1.5 Stage	7608



Nominal Stiffener Detail

1.5 Stage Standalone Intertank

Additional Information

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

See 3-S-001B Trade Study

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

Approved By: M.R.Simms

Rev: Initial
Date: January 8, 1992

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MANNED SPACE SYSTEMS

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.

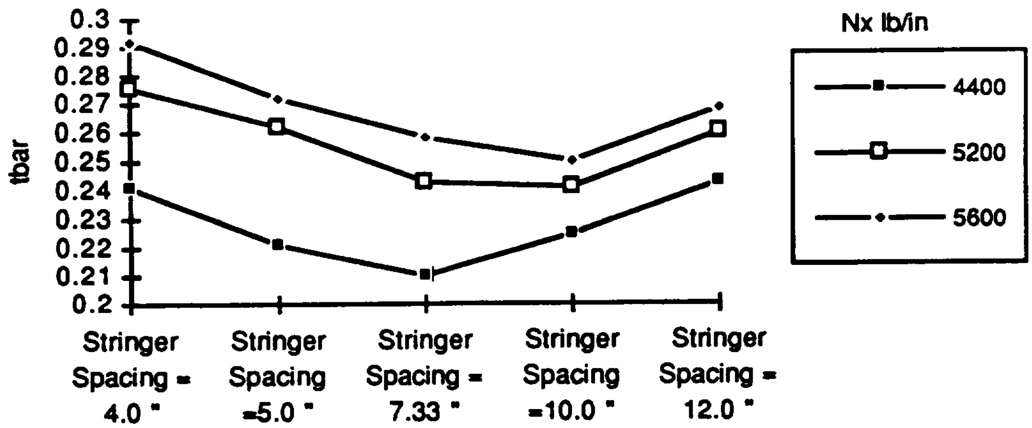
Conclusions

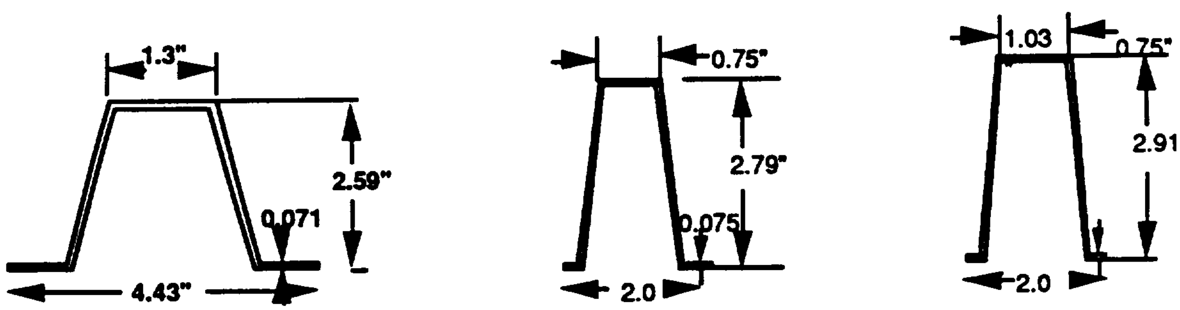
Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. The modified Panda II optimized configuration is lighter compared to the baseline configuration. However modifications to produce a practical 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 Vs tbar





Current Design	Panda II Optimized Design (Nx = 4400 lb/in ult)	Panda II Optimized Design (Nx = 5200 lb/in ult)
Stringer Spacing = 7.33"	Stringer Spacing = 7.33"	Stringer Spacing = 10.0"
Frame Spacing = 45.0"	Frame Spacing = 45.0"	Frame Spacing = 45.0"
Tbar=0.238"	Tbar=0.21"	Tbar=0.241

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 sensititivities
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.

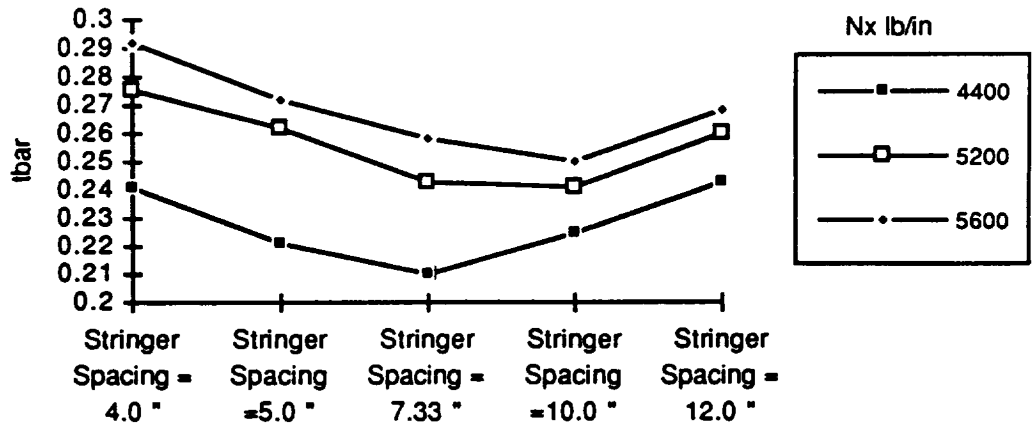
Conclusions

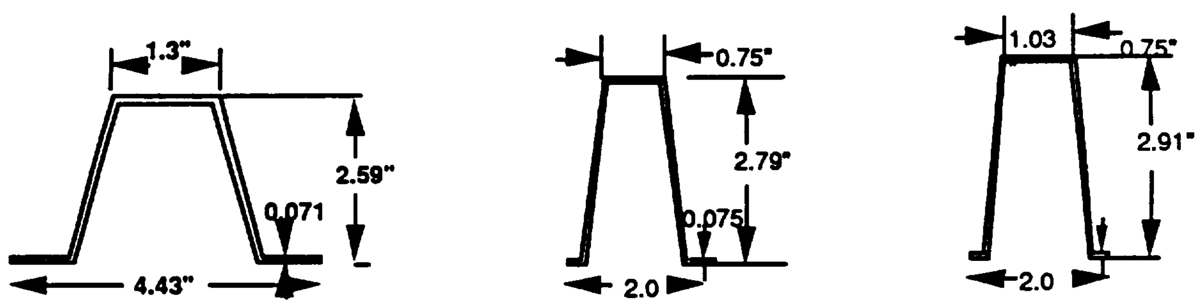
Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configuration skin/hat section fabricated construction approach. The modified Panda II optimized configuration is lighter compared to the baseline configuration. However modifications to produce a practical 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 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)
Stringer Spacing = 7.33"	Stringer Spacing = 7.33"	Stringer Spacing = 10.0"
Frame Spacing = 45.0"	Frame Spacing = 45.0"	Frame Spacing = 45.0"
Tbar=0.238"	Tbar=0.21"	Tbar=0.241

Additional Information

Details of this study are contained in Doc #MMC.NLS.SR.001.Book 1

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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

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TJS-B1-137

Objective and Approach 3-S-010-A

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.

Approach (Continued) 3-S-010-A

- 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 — 3-S-010-A

- 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.)

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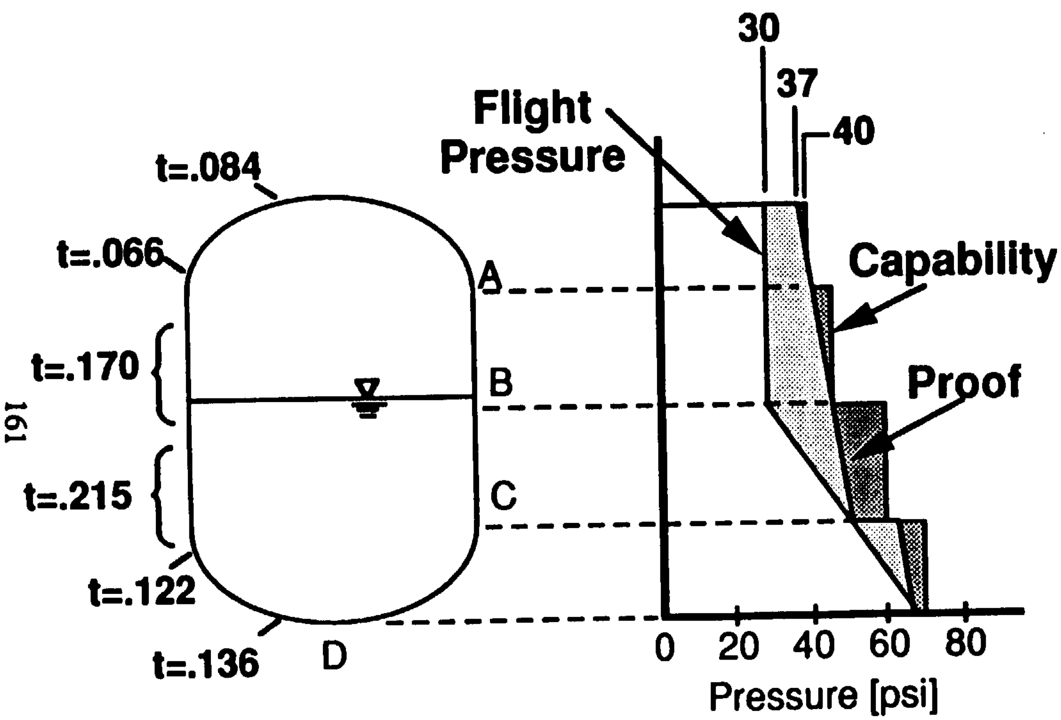
TJS-B

Ullage Pressure Req't vs. Capability 3-S-010-A



Location	Pressures [psi] Ref. Config. Capability	Proof Test
Fwd Dome	40.0	41.3
Fwd Barrel	46.2	45.8
Aft Barrel	58.5	50.3
Aft Dome	70.6	67.4

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TJS-B1-137

Proof Test Requirements

- Max. Design Pressures Based on Proof Test

Location	Ref. Config. Capability	Max. Ullage Pressure [psig]					
		30 psi	40 psi	50 psi	60 psi	70 psi	80 psi
Fwd Dome	40.0	41.3	51.3	61.3	71.3	81.3	91.3
Fwd Barrel	46.2	45.8	55.8	65.8	75.8	85.8	95.8
Aft Barrel	58.5	50.3	60.3	70.3	80.3	90.3	100.3
Aft Dome	70.6	67.4	77.4	87.4	97.4	107.4	117.4

Delta Membrane Thicknesses 3-S-010-A

Thicknesses in Inches

Location	Ref. Config. Thickness	Max. Ullage Pressure [psig]					
		30 psi	40 psi	50 psi	60 psi	70 psi	80 psi
Fwd Dome	.066 to .084	.005	.042	.078	.115	.152	.189
Fwd Barrel	.170	.000	.035	.072	.109	.146	.183
Aft Barrel	.215	.000	.007	.043	.080	.117	.154
Aft Dome	.122 to .136	.000	.025	.062	.099	.135	.172

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Weld Land Thicknesses [Inches] 3-S-010-A

Location	Ref. Config. Thickness	30 psi	Max. Ullage Pressure [psig]				
			40 psi	50 psi	60 psi	70 psi	80 psi
Fwd Dome	.200	.200	.274	.327	.381	.434	.487
Fwd Barrel	.320	.320	.320	.351	.405	.458	.511
Aft Barrel	.360 to .387	.320	.322	.375	.429	.482	.535
Aft Dome	.320	.320	.413	.467	.520	.573	.627

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TJS-B1

Membrane Delta Weight [Lbs.] 3-S-010-A

	Reference Wt.	Delta Wt. 30 psi	Delta Wt. 40 psi	Delta Wt. 50 psi	Delta Wt. 60 psi	Delta Wt. 70 psi	Delta Wt. 80 psi
FWD DOME	1,225.90	65.60	551.05	1,023.37	1,508.82	1,994.27	2,479.71
FWD BARREL[1, 2]	2,473.16	0.00	475.91	979.01	1,482.11	1,985.21	2,488.31
AFT BARREL[1, 2]	3,205.16	0.00	95.18	584.69	1,087.79	1,590.89	2,093.99
AFT DOME	2,226.50	0.00	328.00	813.45	1,298.90	1,771.22	2,256.67
SUB-TOTAL	9,130.72	65.60	1,450.14	3,400.52	5,377.61	7,341.59	9,318.68
CONTINGENCY (8 %)	730.46	5.25	116.01	272.04	430.21	587.33	745.49
TOTAL	9,861.18	70.85	1,566.15	3,672.56	5,807.82	7,928.91	10,064.18
	Wt. Factor[3]	1.00	1.11	1.25	1.40	1.54	1.69

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.

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Additional Results

3-S-010-A

- 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

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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

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TJS-B1

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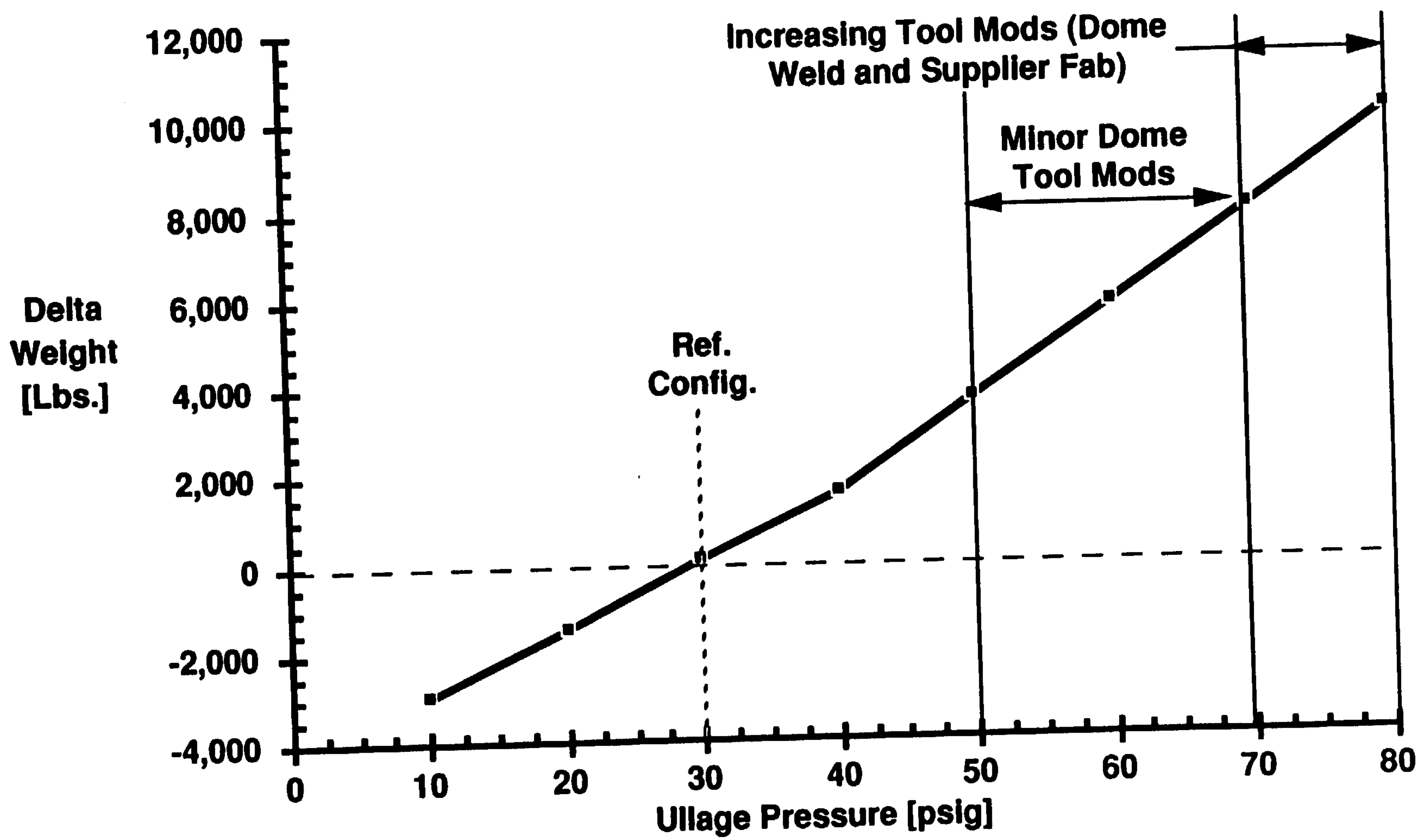
Summary

Weight Impact for an Ullage Pressure Reduction



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TJS-B1

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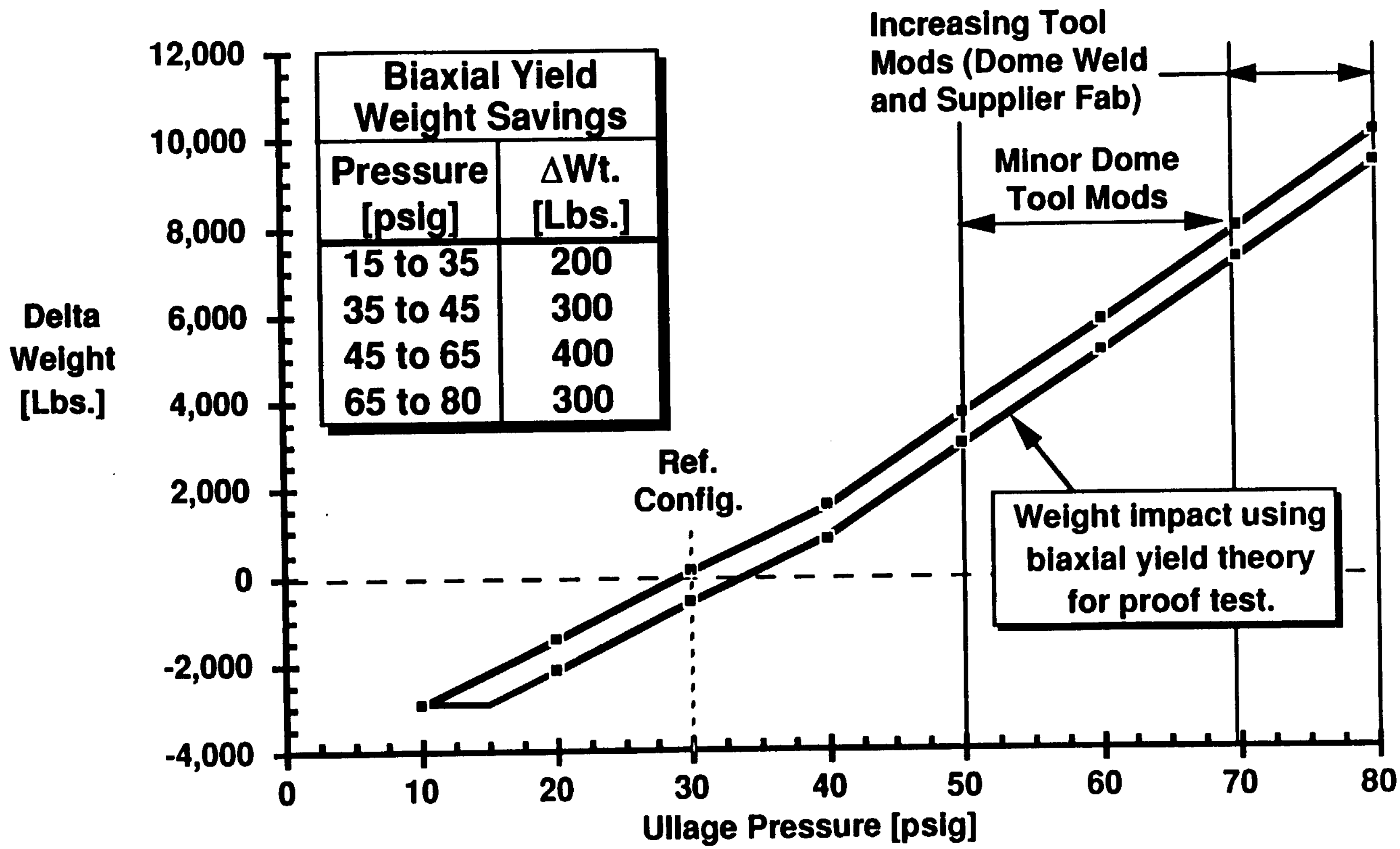
Biaxial Yield Theory Savings

3-S-010-A



Biaxial Yield Weight Savings	
Pressure [psig]	ΔWt. [Lbs.]
15 to 35	200
35 to 45	300
45 to 65	400
65 to 80	300

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Summary

3-S-010-A

- 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.

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Issues Identified During the Study 3-S-010-A

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.)

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TJS-B1-137

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

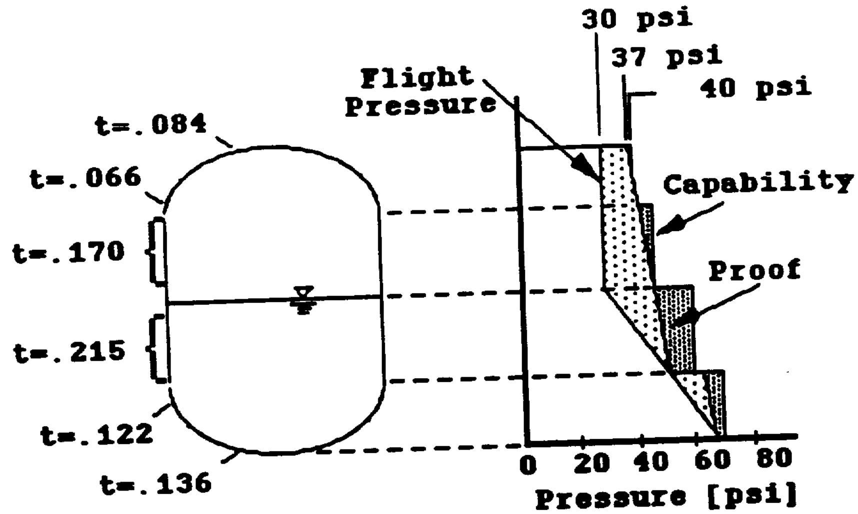
The weight impacts for a specific pressure is approximately 200 Lbs per psi. Minor tooling modifications are necessary for any increase in ullage pressure. Major tooling impacts occur once ullage pressures exceed 40 psig. There is a weight reduction to the LOX tank for ullage pressures below 30 psig. 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.

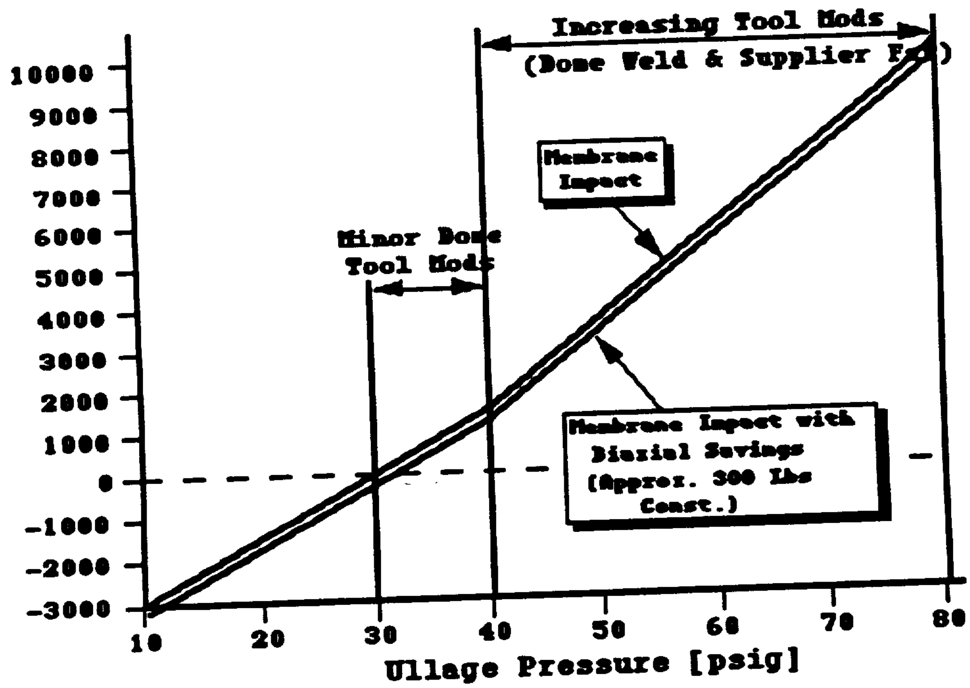
Conclusions

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

6.2.4.4.3 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

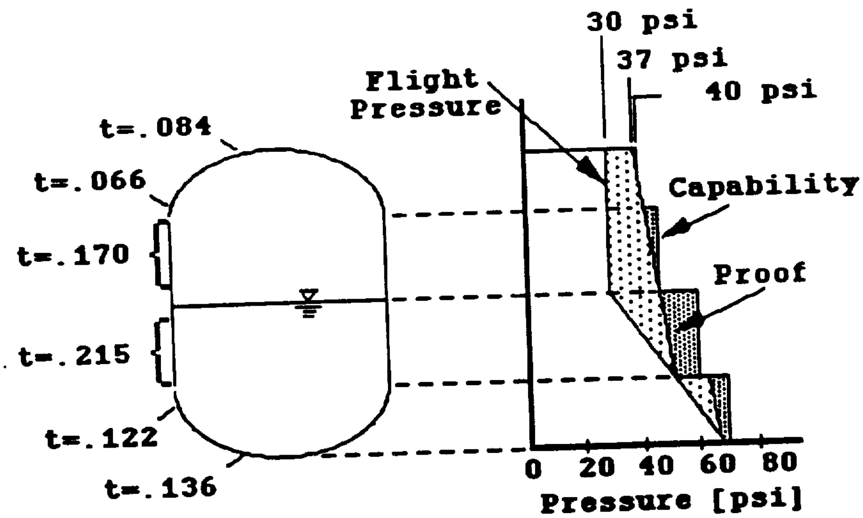
The weight impacts for a specific pressure is approximately 200 Lbs per psi. Minor tooling modifications are necessary for any increase in ullage pressure. Major tooling impacts occur once ullage pressures exceed 40 psig. There is a weight reduction to the LOX tank for ullage pressures below 30 psig. 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.

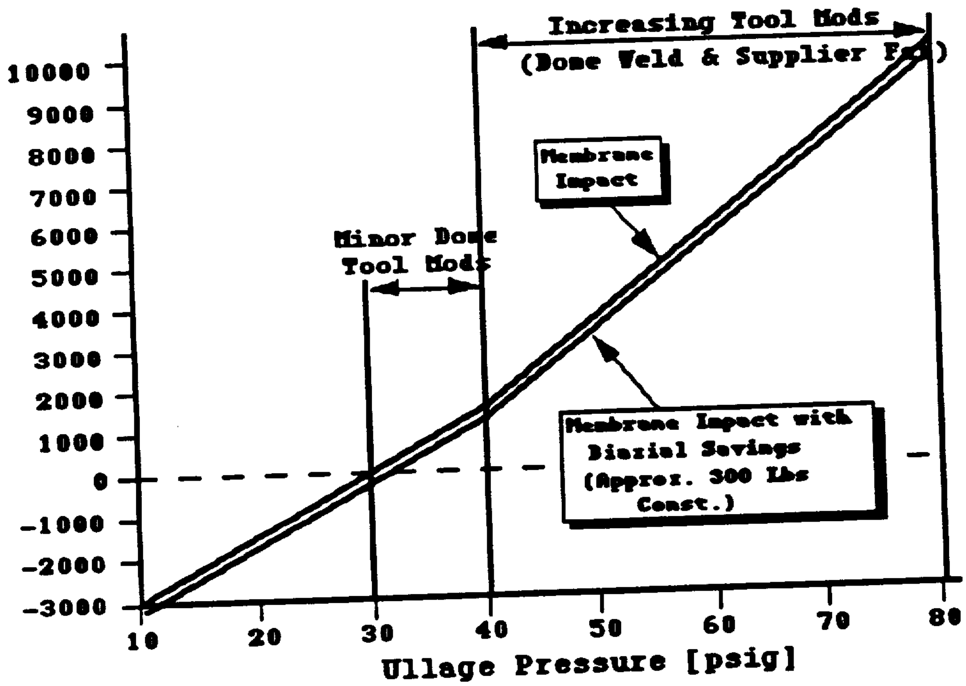
Conclusions

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

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

See 3-S-001B Trade Study

Prepared By: Dilip Dudgaonkar
(504)257-0076

Approved By: M.R.Simms

Rev: Initial
Date: January 8, 1992

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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 sensititivities
e) Prepare conclusions and recommendations

Key Study Results

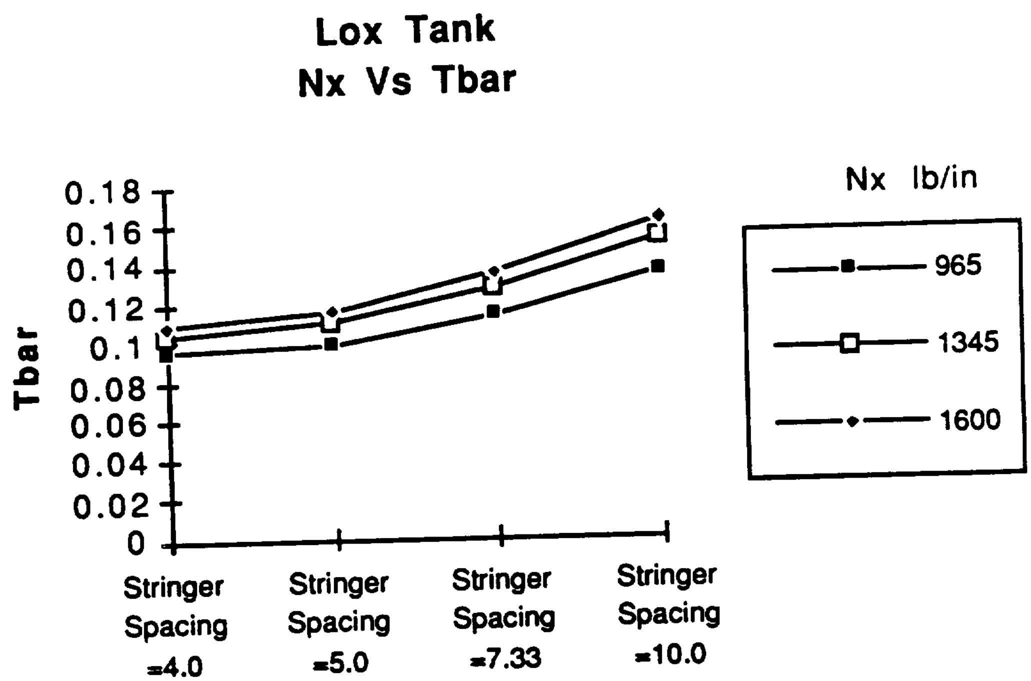
The current internal T section stringers were used as the baseline configuration and Panda II was used to optimize stringer size for varying pitch and load. Ring frame spacing based on the reference configuration was used. The weight (tbar) trend shows that an optimum occurs at a stringer pitch of 4.0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

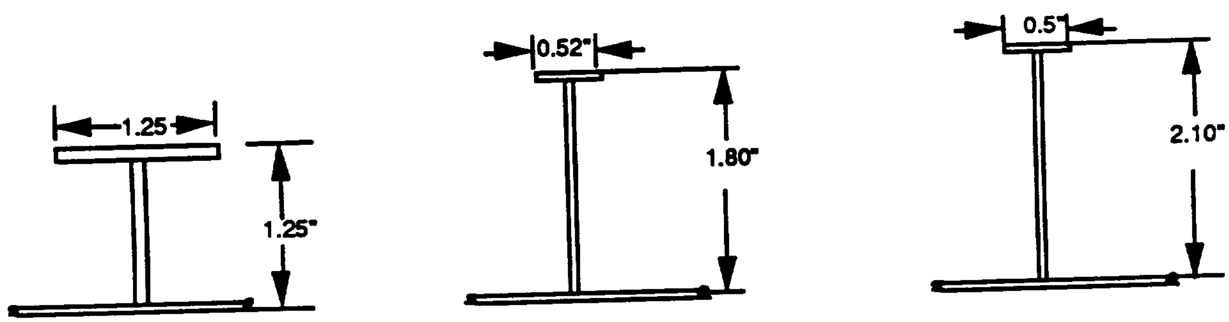
Conclusions

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.





Current Design	Optimized Design Nx=960 lb/in	Optimized Design Nx=1345 lb/in
Stringer Spacing=10.832"	Stringer Spacing=4.0"	Stringer Spacing=4.0"
Frame Spacing=34.9"	Frame Spacing=34.9"	Frame Spacing=34.9"
Tskin=0.170	Tskin=0.067	Tskin=0.075
Tbar=0.193	Tbar=0.0963	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.

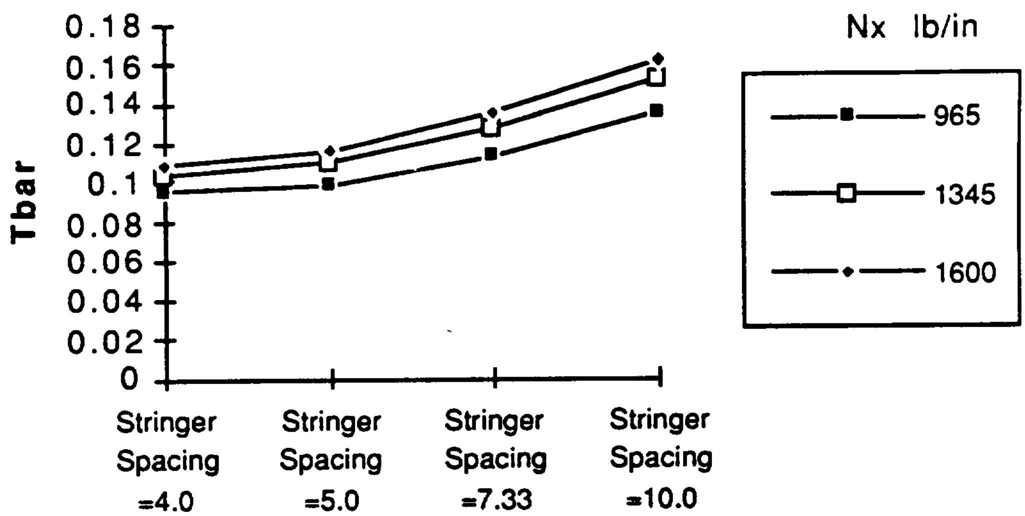
Conclusions

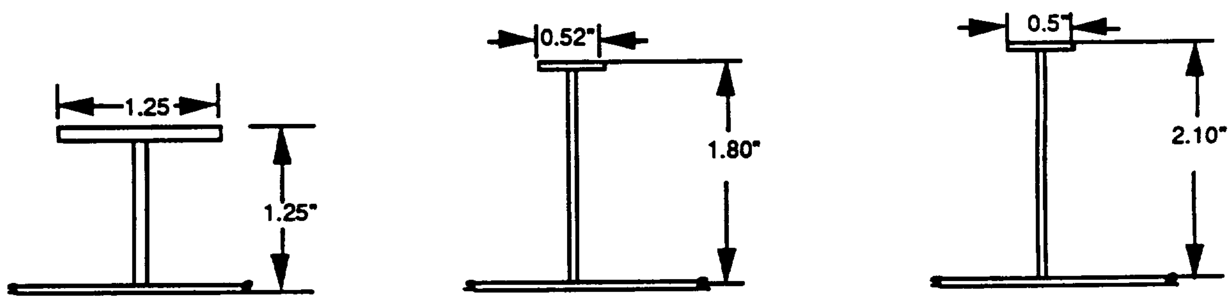
Weight sensitivity data was generated by varying the stringer pitch while maintaining the reference configurations integrally machined longitudinal tee stiffened panel approach. The Panda II optimized configuration developed offers weight savings compared to the baseline configuration. It does however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





Current Design	Optimized Design Nx=960 lb/in	Optimized Design Nx=1345 lb/in
Stringer Spacing=10.832"	Stringer Spacing=4.0"	Stringer Spacing=4.0"
Frame Spacing=34.9"	Frame Spacing=34.9"	Frame Spacing=34.9"
Tskin=0.170	Tskin=0.067	Tskin=0.075
Tbar=0.193	Tbar=0.0963	Tbar=0.1043

Additional Information

Details of this study are contained in Doc #MMC.NLS.SR.001.Book 1

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See 3-S-008D Trade Study

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

Approved By: M.R.Simms

Rev: Initial
Date: January 8, 1992

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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 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.

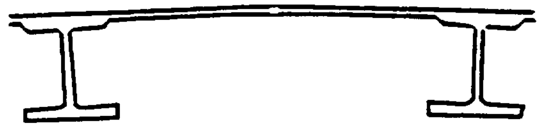
Conclusions

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

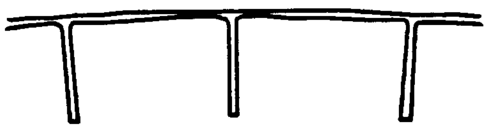
Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:

- Option 1 - M/C panel with tee stiffeners (Baseline)
- Option 4 - Machined isogrid panel.
- Follow the progress and development of Option 7



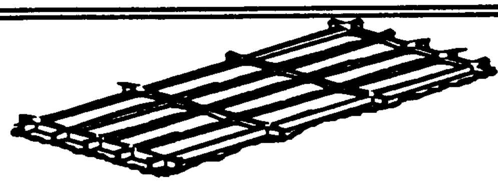
Option 1 - Baseline Panel (P.O.D.)

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



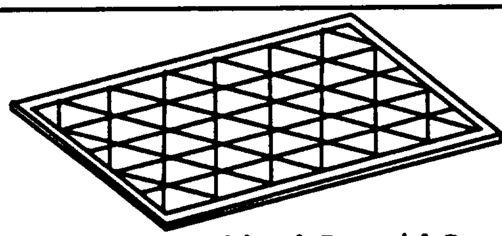
Option 2 - Mach.Blade-Stiff. Panel

- Machined Panel W/ Blade-Stiffening.
- May Not Utilize ET Processes And Tooling.
- Design Consistant 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.

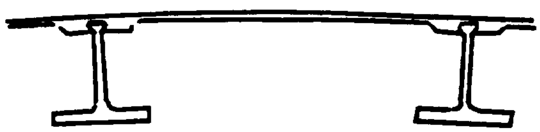


Option 4 - Machined Isogrid Panel

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

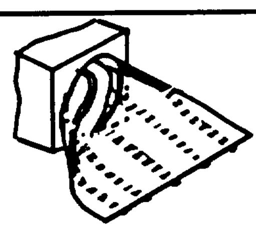
Option 5 - Welded Panel

- Machined Panel With Welded Extruded Tee-Stiffening.
- Similar To External Tank.
- New Processes And Tooling Required.
- Design Consistant 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.

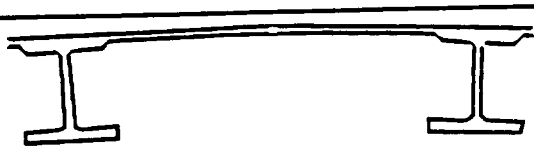
Conclusions

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

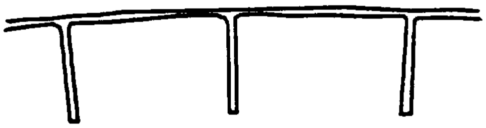
Maintain Option 1 as Baseline. Continue to study the following viable alternative designs during Cycle 1:

- Option 1 - M/C panel with tee stiffeners (Baseline)
- Option 4 - Machined isogrid panel.
- Follow the progress and development of Option 7



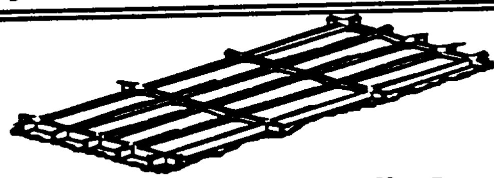
Option 1 - Baseline Panel (P.O.D.)

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



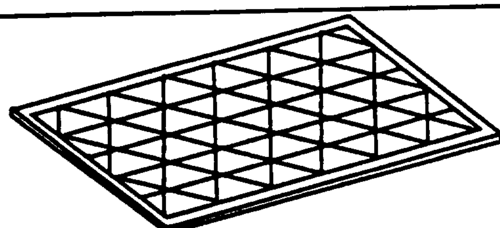
Option 2 - Mach.Blade-Stiff. Panel

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



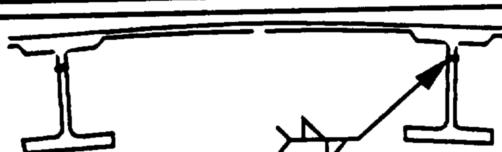
Option 3 - Machined Waffle Panel

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



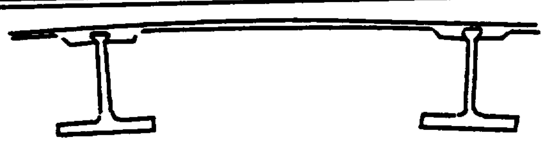
Option 4 - Machined Isogrid Panel

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



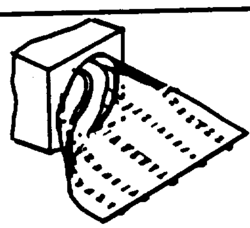
Option 5 - Welded Panel

- Machined Panel With Welded Extruded Tee-Stiffening.
- Similar To External Tank.
- New Processes And Tooling Required.
- Design Consistant 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.

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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

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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

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3-S-011
(CV-STR-22)
Appendix 1

- **Sensitivity To Slosh Damping Reqmt**

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Slosh Damping Sensitivity 3-S-011

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.

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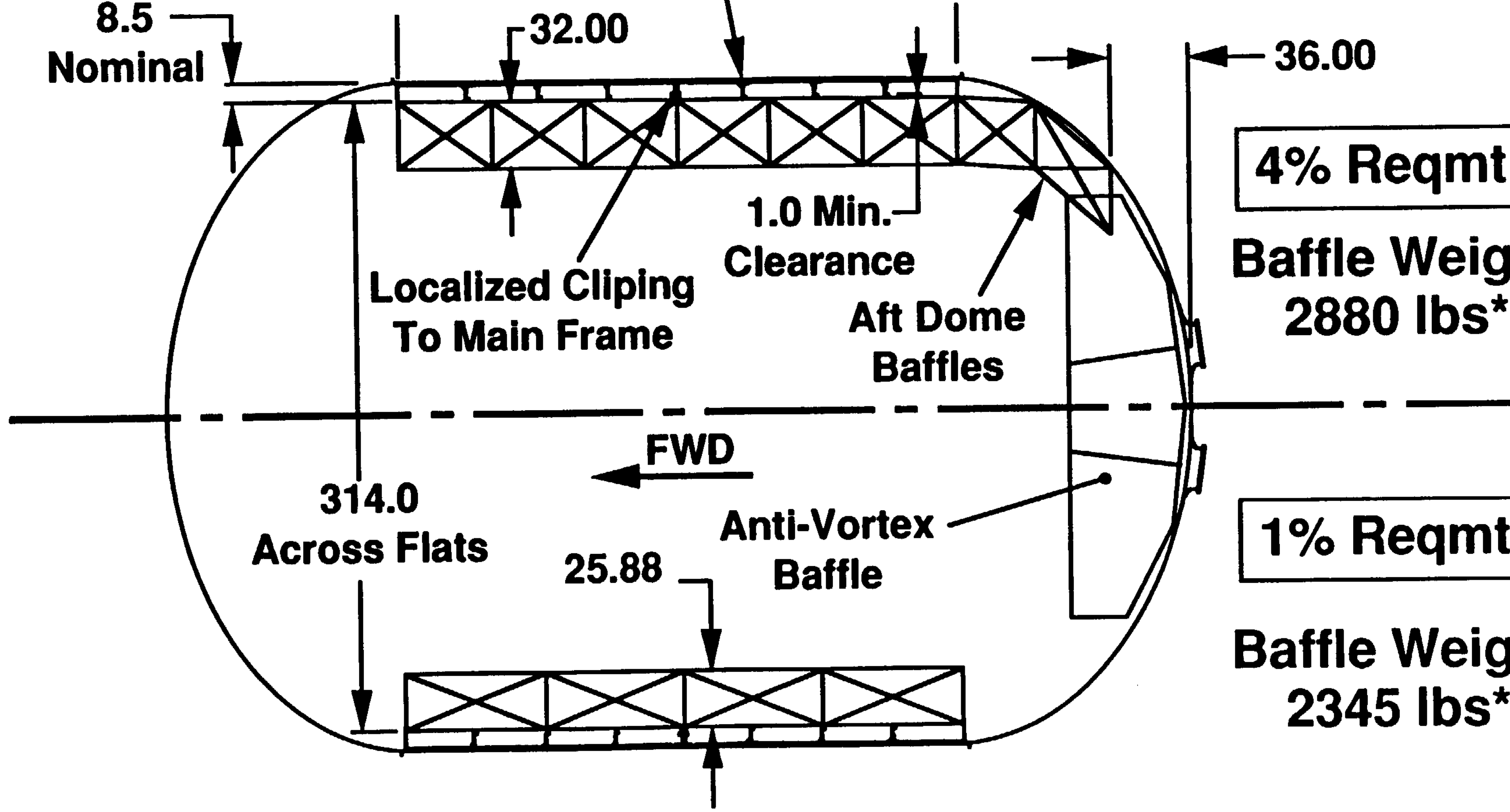
Slosh Baffle Comparisons 3-S-011



4% Reqmt

Baffle Weight 2880 lbs*

1% Reqmt

Baffle Weight 2345 lbs*

* Ref ET Baffle Weight = 1500 lbs

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Conclusions

3-S-011

- 1% Requirement Requires 5 x 25.88 Deep Baffles
- 4% Requirement Requires 9 x 32.00 Deep Baffles
- In Order To Meet The 4% Critera, 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 3-S-011

- Work With Controls Panel To Finalize Damping Requirement For Cycle 1
- Update Cycle 1 Baseline Configuration To Reflect Selected Damping Requirement

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Appendix 2

- **1.5 Stage/HLLV Unique Baffle Configurations**

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Unique Baffle Configurations 3-S-011

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

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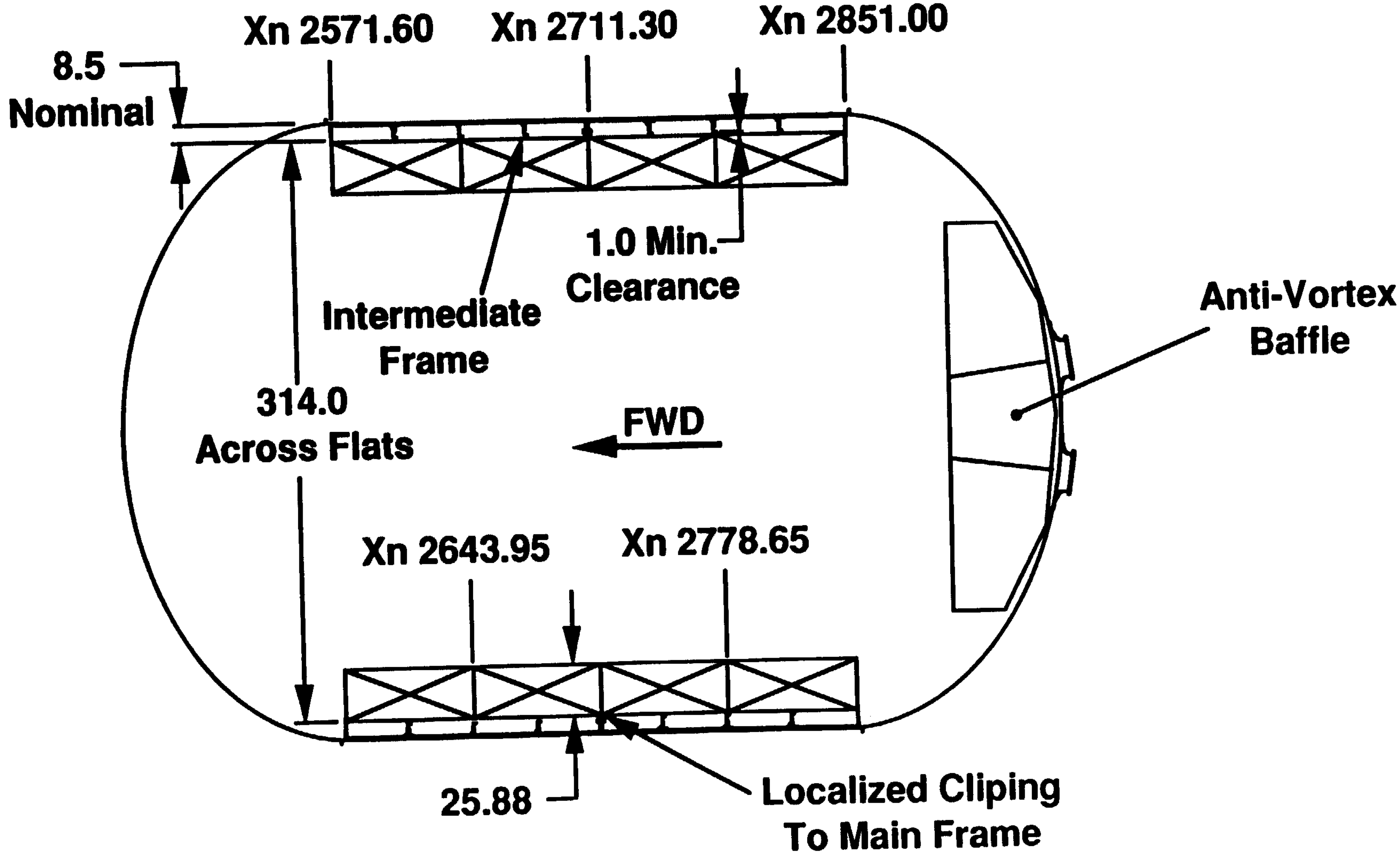
1% 1.5 Stage Slosh Baffle Conf. 3-S-011

- Reference Common Core Configuration



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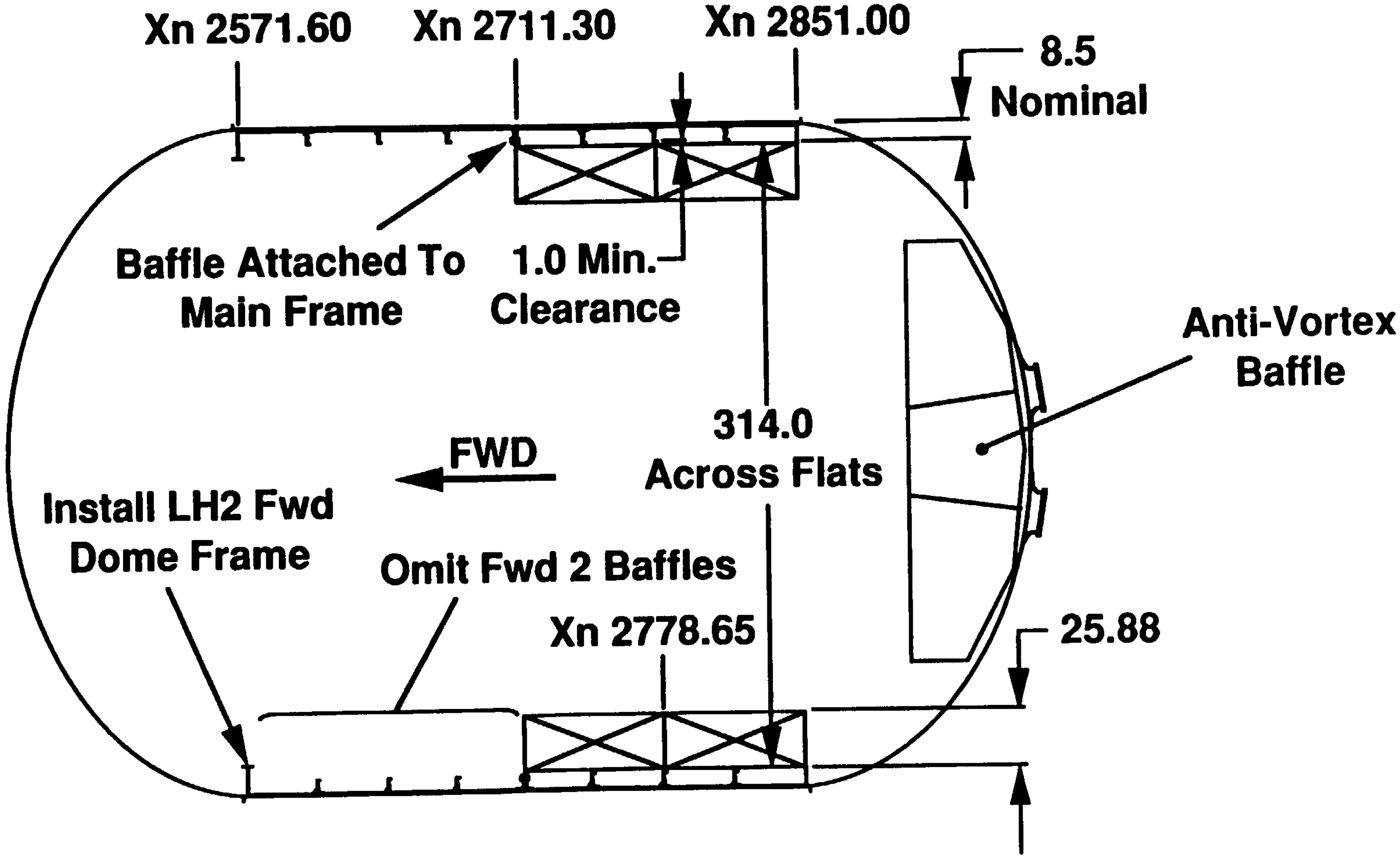
1% HLLV Stage Slosh Baffle 3-S-011



- Weight Impact -492 lbs From Reference

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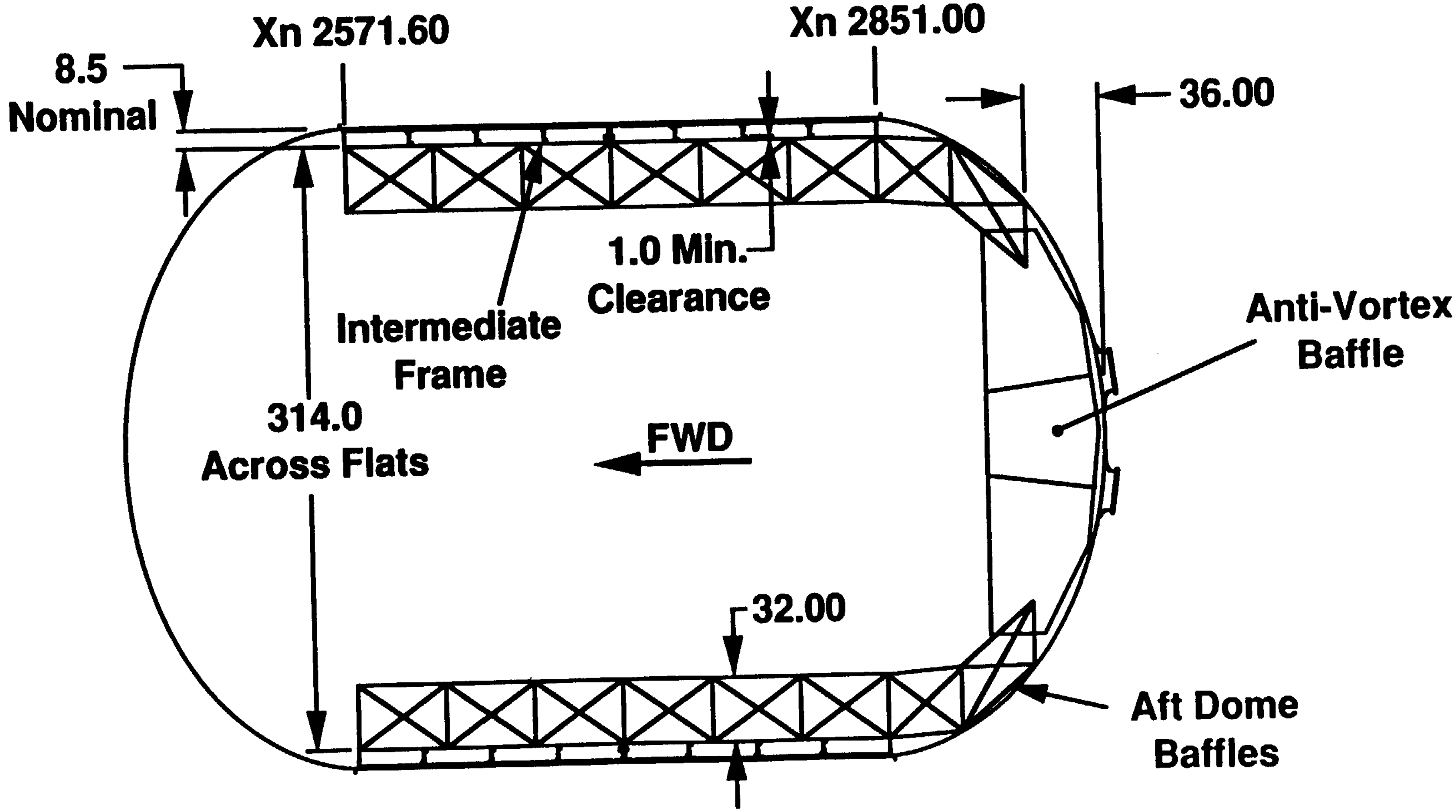
4% 1.5 Stage Slosh Baffle Conf. 3-S-011

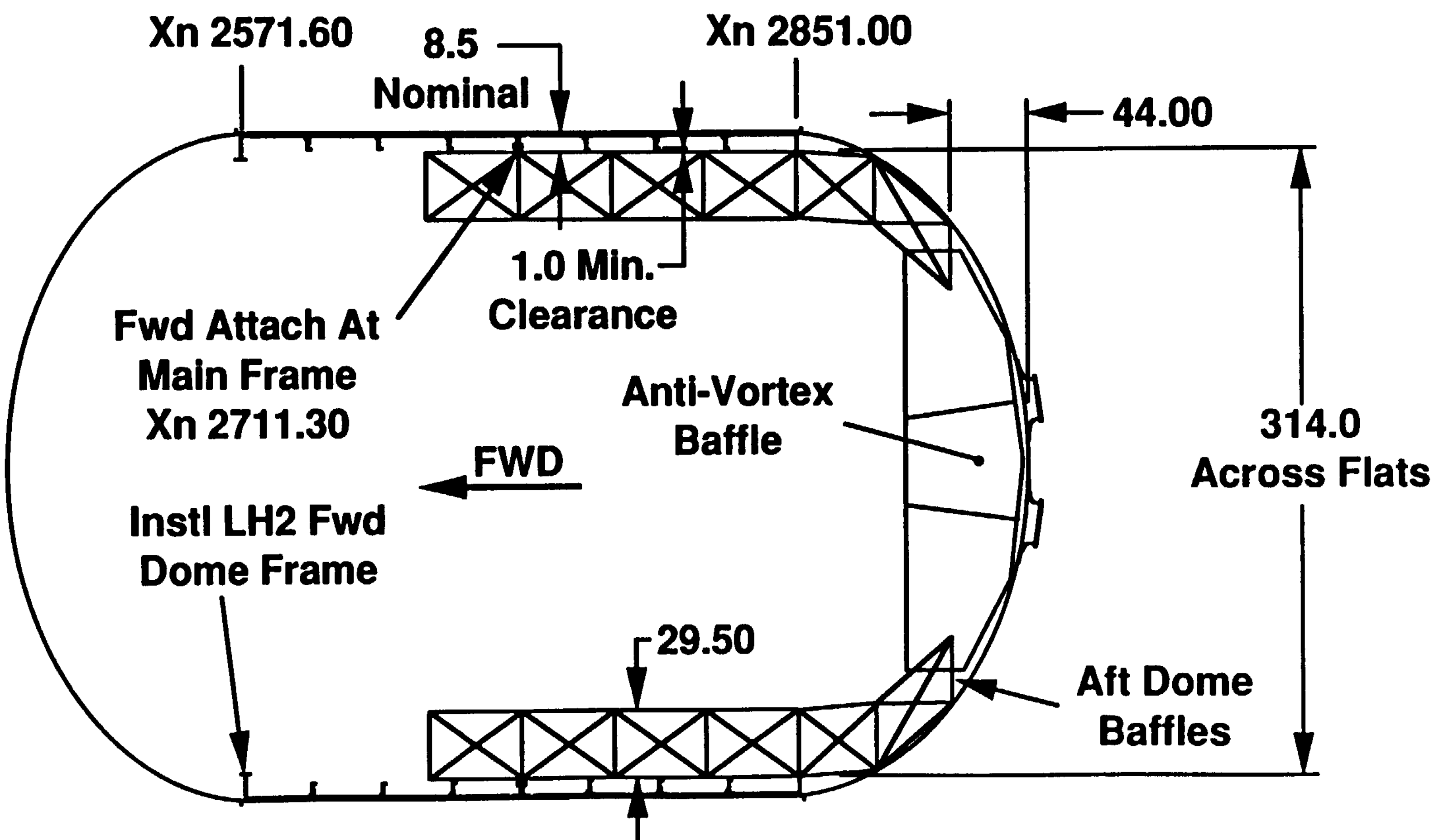
- Recommended Reference Common Core Configuration



DAT.9'

4% HLLV Tank Slosh Baffle 3-S-011

- Unique HLLV Configuration



- Weight Impact -526 lbs From Reference 4% Configuration

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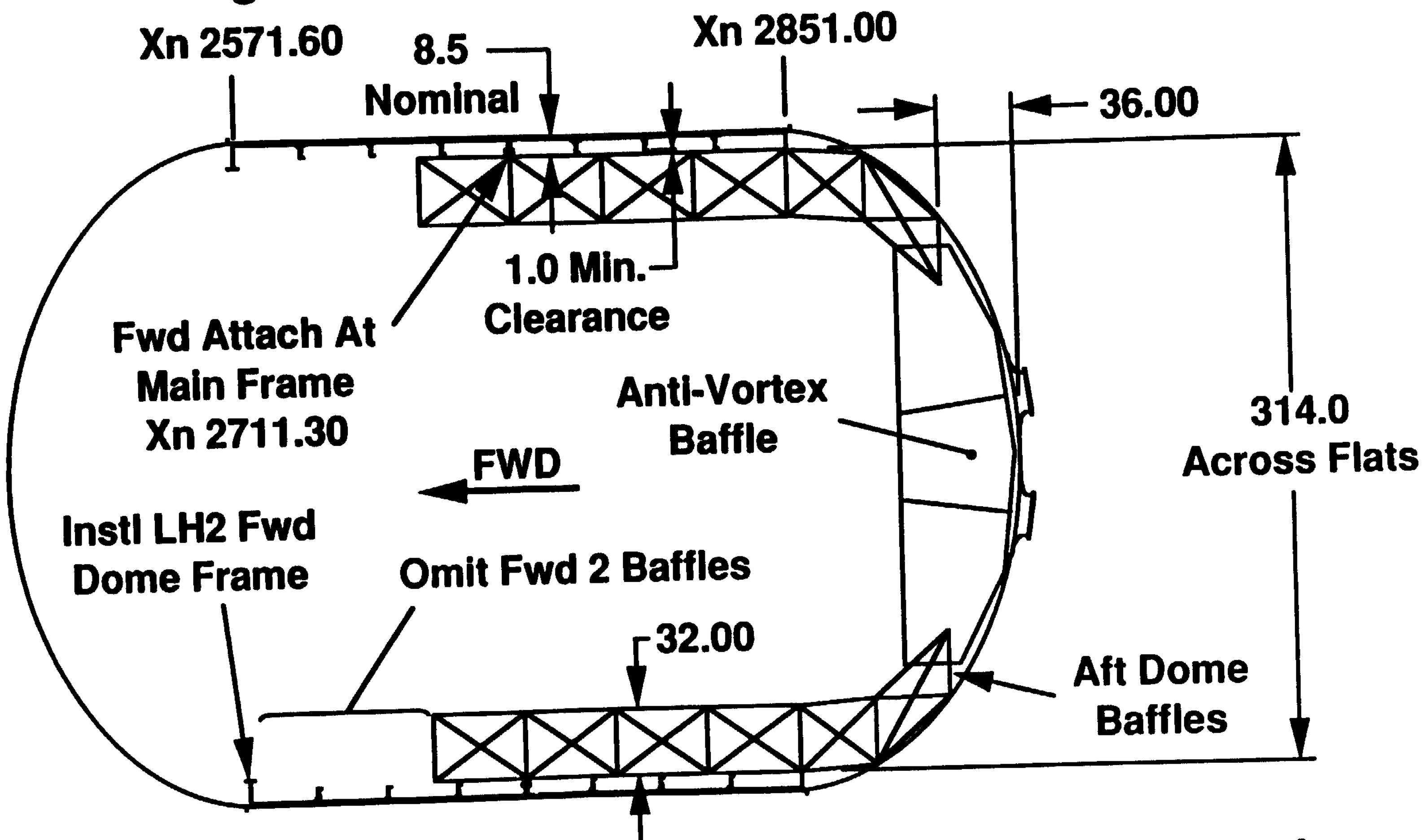
4% HLLV Tank Slosh Baffle 3-S-011

- HLLV Configuration Derived From Common Core



- Weight Impact -417 lbs From Reference 4% Configuration

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DAT.91'

Recommendation 3-S-011

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**

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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

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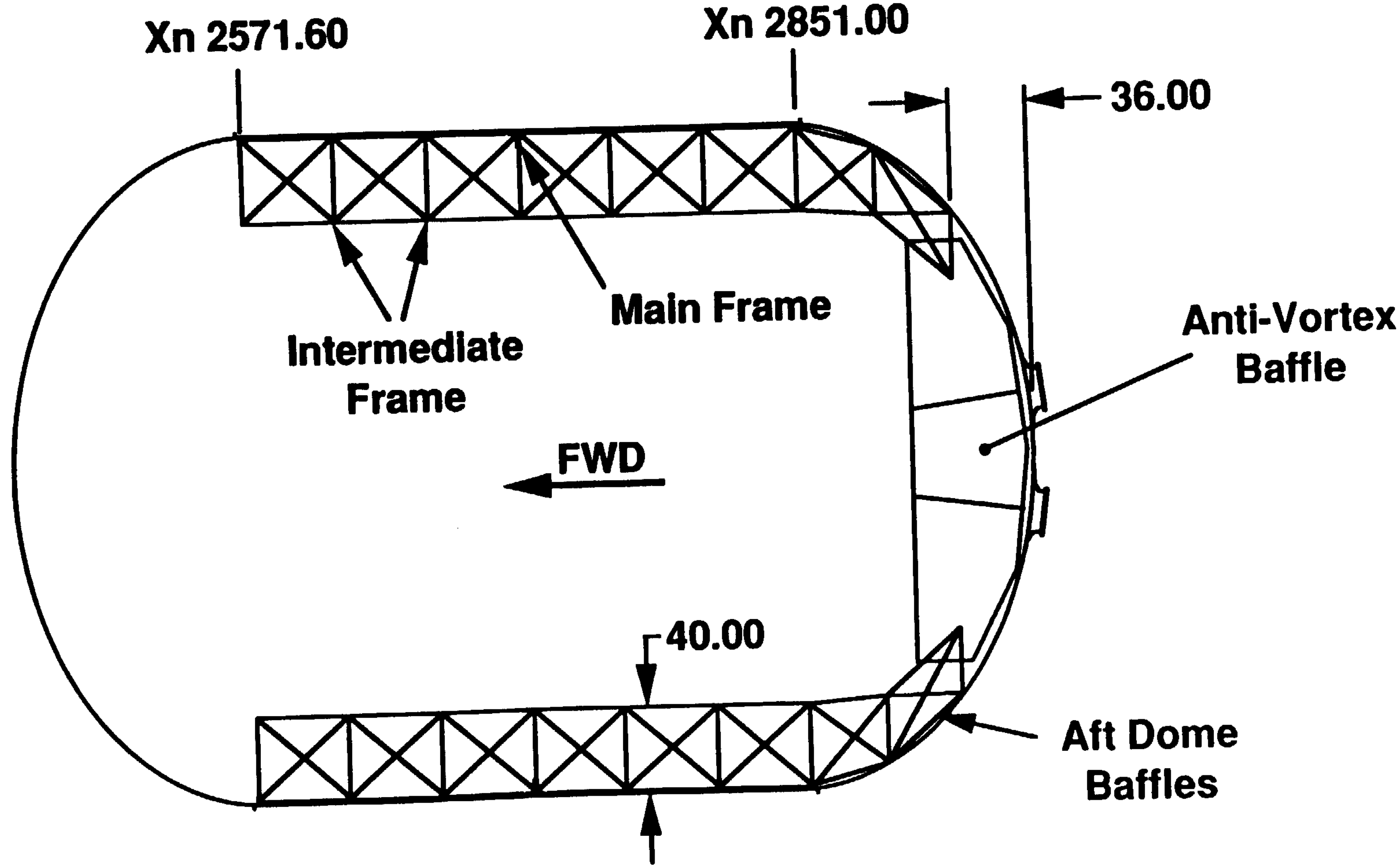
Integral 4% Slosh Baffle Conf. 3-S-011

- Common Core Configuration



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Evaluation — 3-S-011

+ 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 3-S-011

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

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Items For Cycle 1 Study 3-S-011

- Finalize Damping Requirement For Cycle 1 & Update Reference Configuration
- Define & Evaluate An Integral Baffle Design

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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

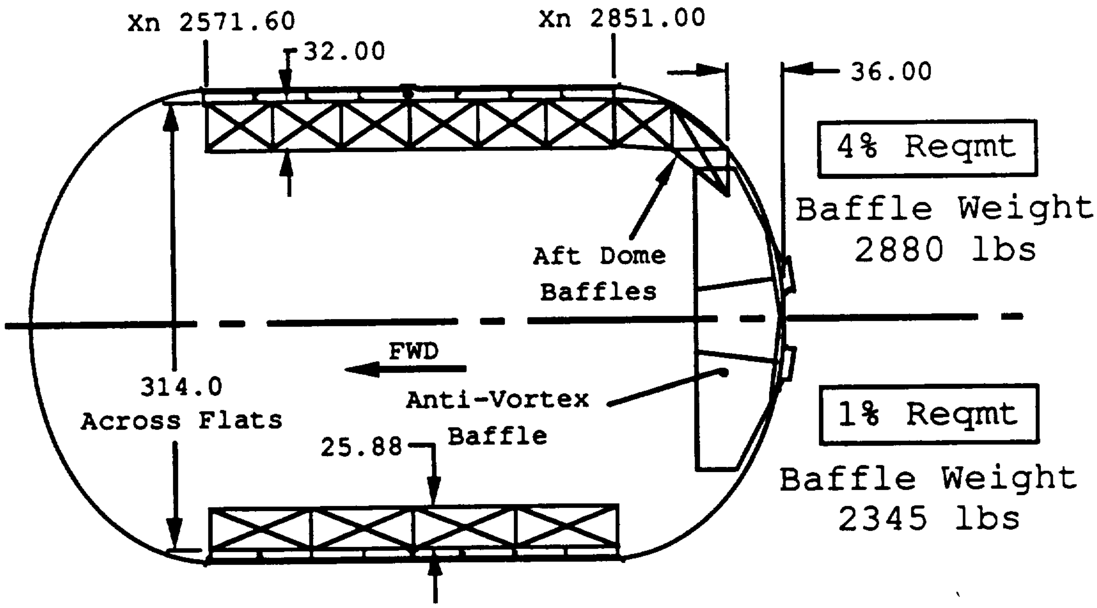
The reference was designed to meet a 1% damping requirement. Recent controls analysis indicates that 4% may be required. A 4% damping capability requires an increase in baffle depth plus an additional 4 baffles. A 4% baffle configuration will add baffles to the aft dome for an overall weight impact of 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 crictical 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

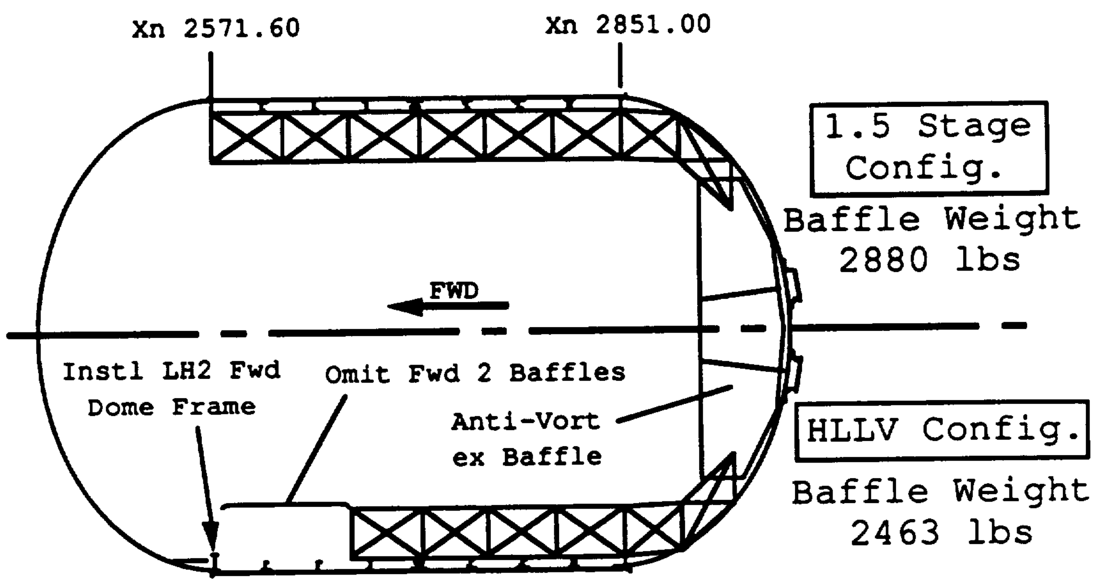
Baffle damping requirements significantly impact the configuration and must therefore be established prior to further design work. The baffle configuration is driven by 1.5 Stage slosh requirements. An integral baffle and frame design appears to be an attractive proposition for an alternative design.

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 Comparision



4% 1.5 Stage - HLLV Configuration Comparision

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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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 crictical 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.

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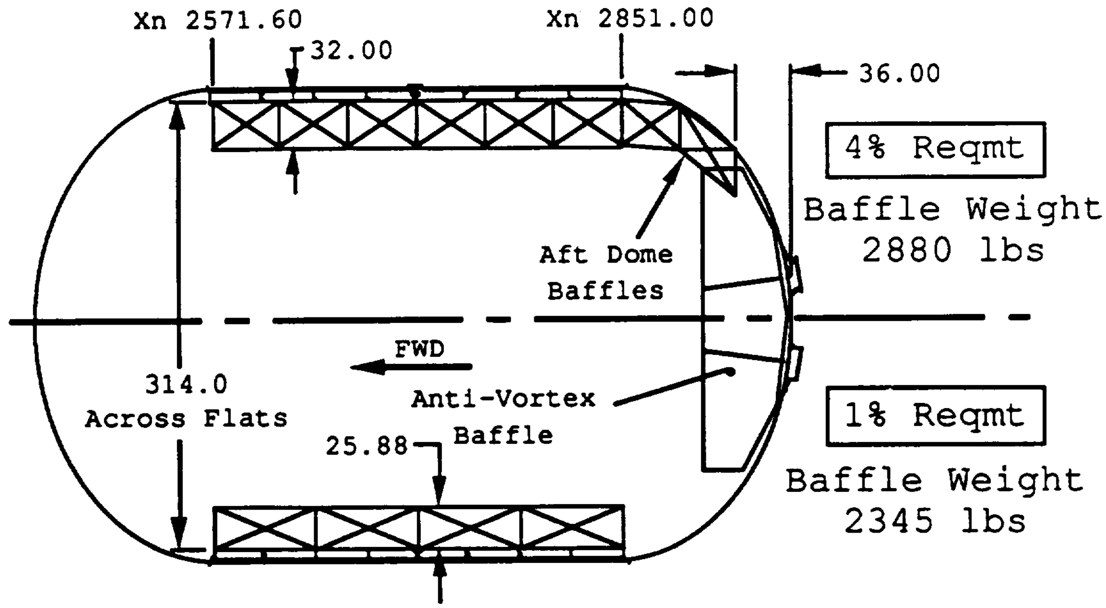
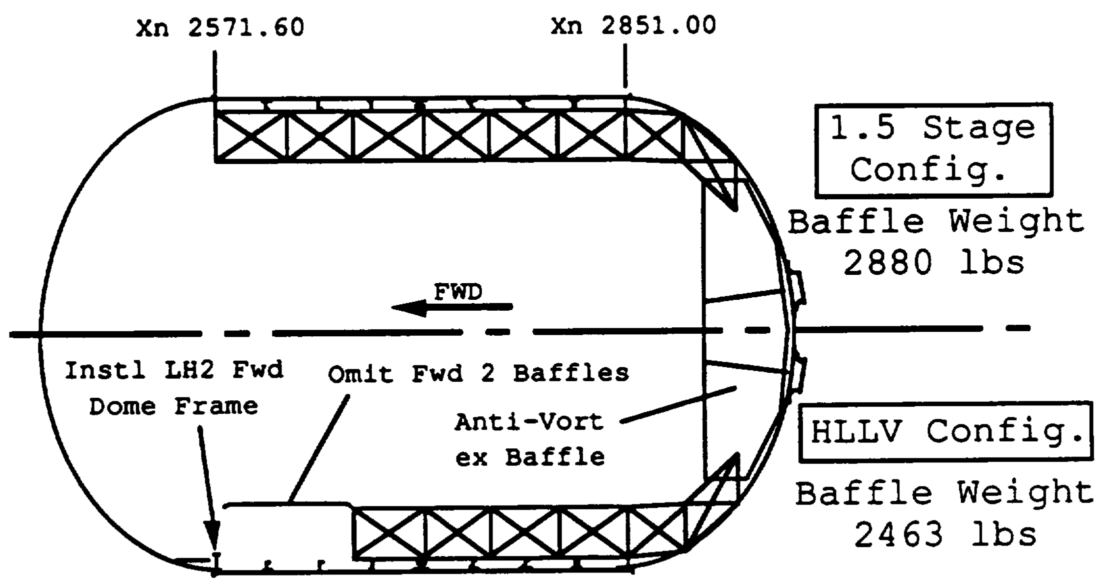
During Cycle 1 finalize the damping requirement and update the baseline configuration. The reference configuration is designed for 1.5 Stage and should remain common unless HLLV weight savings are required. A study should be performed during Cycle 1 to define the weight savings and manufacturing impacts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



1% - 4% Slosh Baffle Comparision



4% 1.5 Stage - HLLV Configuration Comparision

Additional Information

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

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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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Objectives And Approach

Objective

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

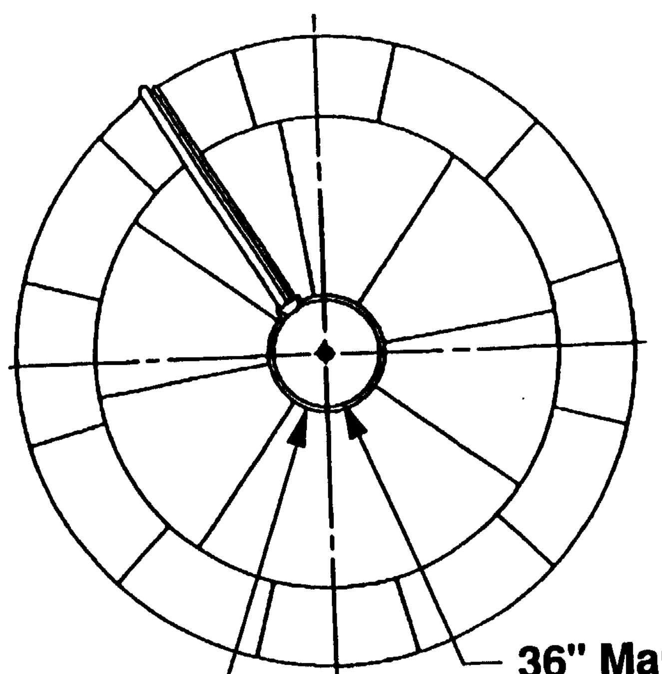
Approach

- 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.

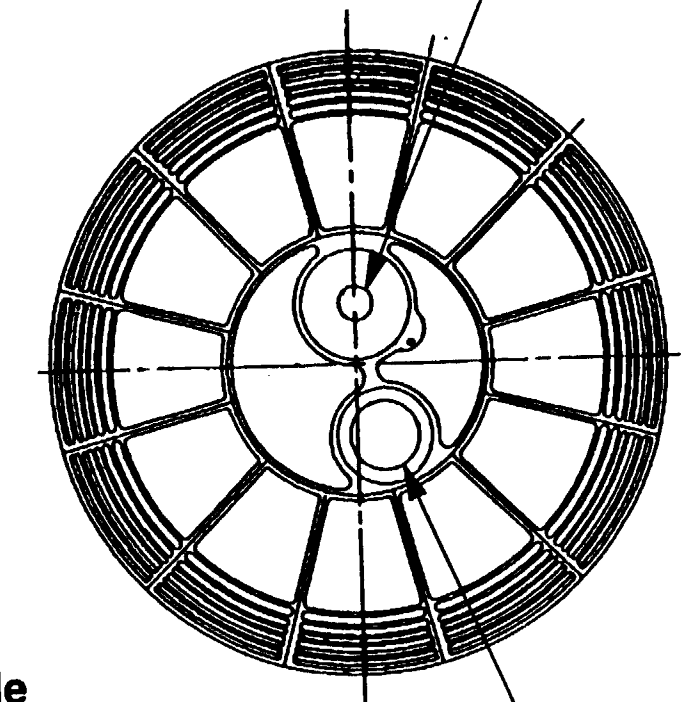
Ground Rules And Assumptions

- 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 LO2



LO2 Fwd Ogive
Cover Plate



Aft Dome

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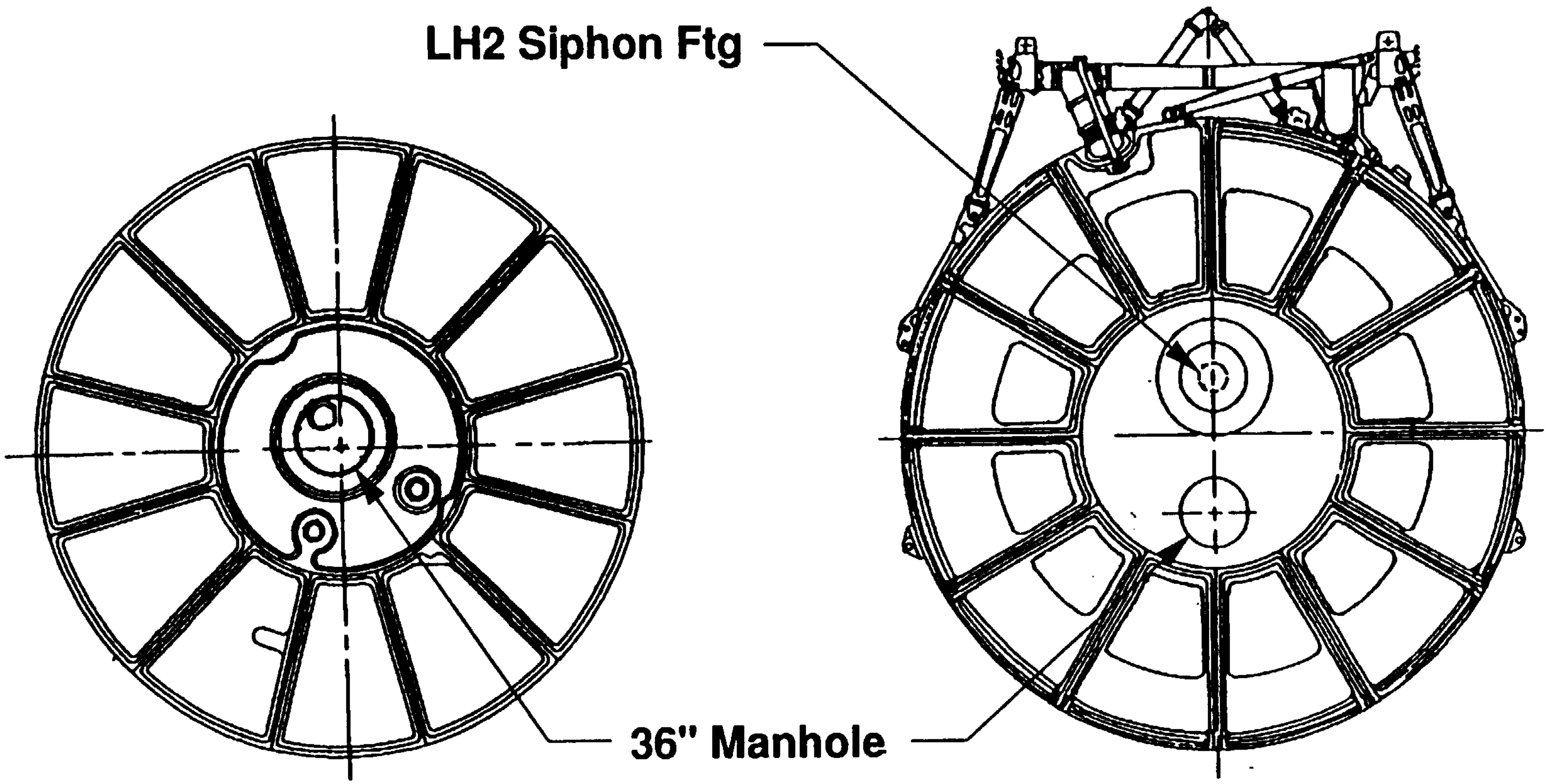
ET Access Capability LH2

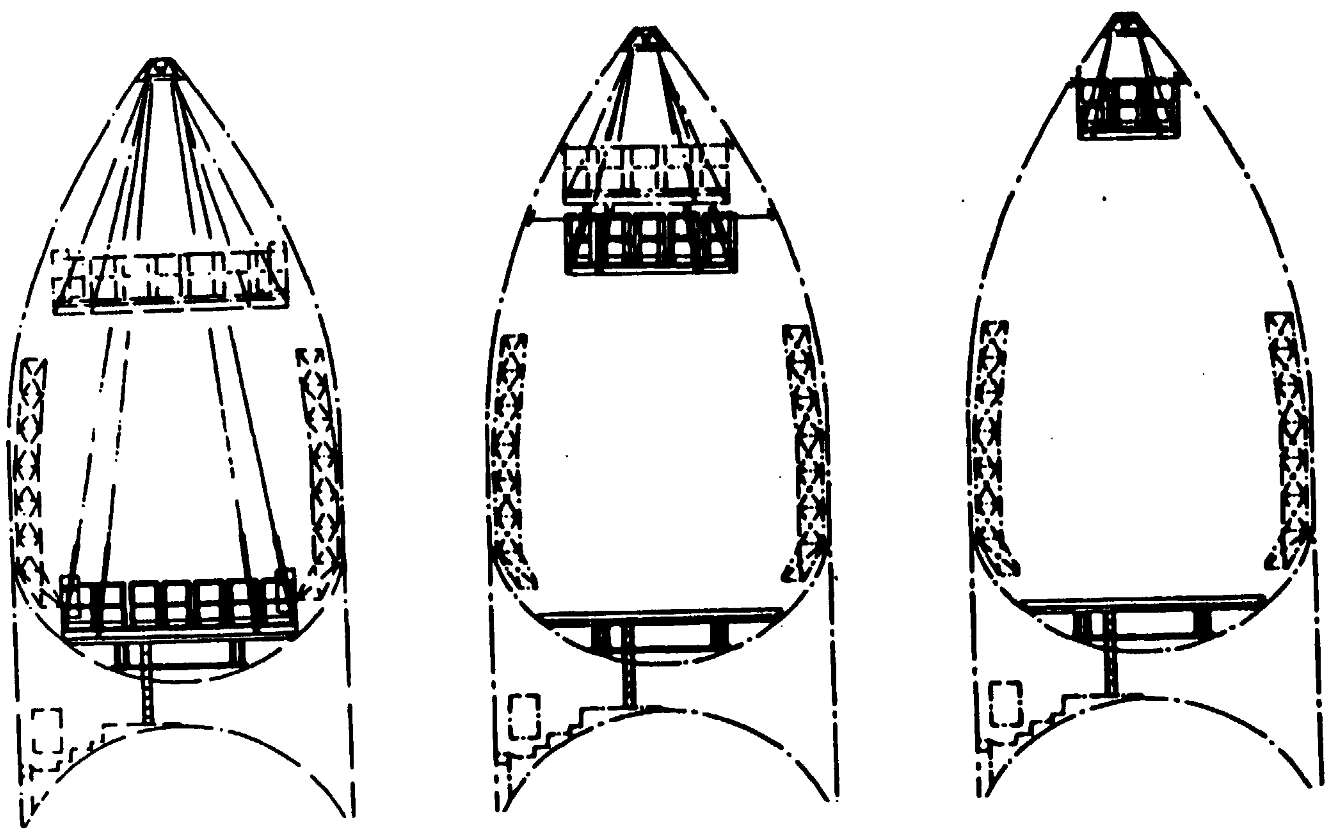
CV-DI-01-A



LH2 Fwd Dome

LH2 Aft Dome

External Tank Access Tooling



LO2 Internal Access Platform Set

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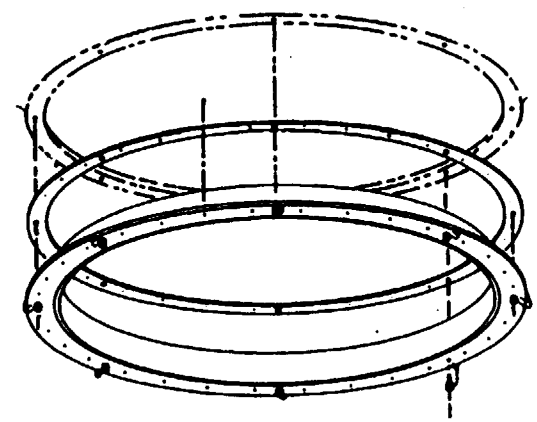
External Tank Access Tooling

CV-DI-01-A

LO2 Aft Dome Access Kit



LH2 Aft Dome Access Kit
(Manhole Protector)

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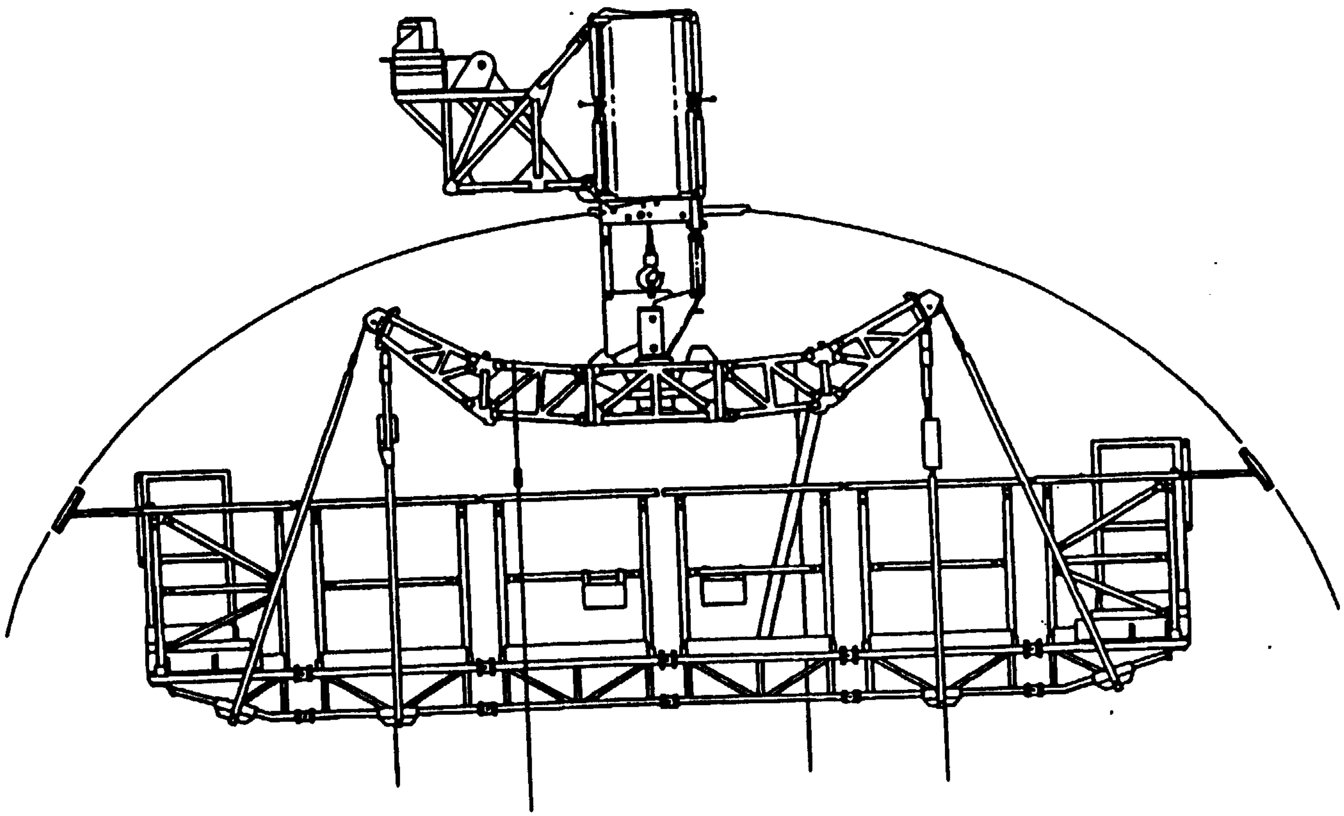
External Tank Access Tooling

CV-DI-01-A



LH2 Internal Access Platform Set

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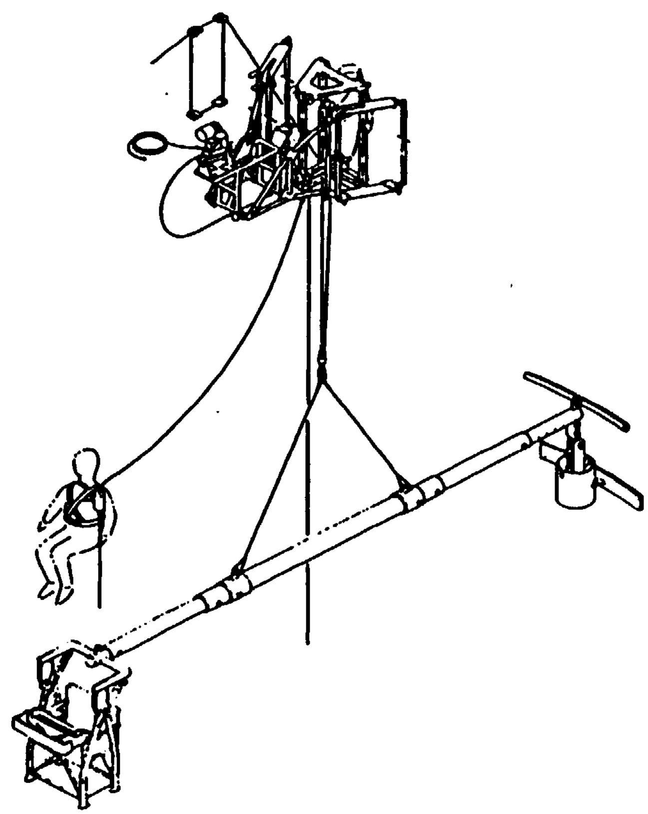
External Tank Access Tooling

CV-DI-01-A



LH2 Tank Internal Access Equipment (1 Man)

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External Tank Access History At KSC

CV-DI-01-A

ET Number	No. Of Entries		Reason For Entry
	LH2	LO2	
1	2	1	Diffuser Changeout
2	1	-	ECO Sensor Changeout
8	-	1	Diffuser Changeout
23,27,29, 32-47	19	-	"Scheduled" ECO Clip Mod
Total	22	2	

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.

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LO2 Access Capability On ET

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

Access Location	Process	Operation
LO2 Fwd Cover Plate	Welding	• Remove Close-out Weld Mandrel.
	Internal Cleaning	• Remove Debris
	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

Access Location		
LO2 Fwd Cover Plate	Cell E (Vertical)	Cleaning Probe Instl
	Cell G,H (Vertical)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Fwd Mast Installation
LO2 Aft Dome	Cell E (Vertical)	LO2 Aft Sensor Mast Instl. Siphon Screen Instl
	Cell G,H (Vertical)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Contingency Access Only

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LH2 Tank Access Capability On ET

CV-DI-01-A

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

Access Location	Process	Operation
LH2 Fwd Dome	Welding	• Remove Close-out Weld Mandrel. • Clean Tank
	Mechanical Assy	• Install 1129 Frame Stabilizer • Install Fwd Sensor Mast Supports. • Clean Up And X-Ray (After Proof Test).
LH2 Aft Dome	——	None

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LH2 Access Capability On ET (Cont)

CV-DI-01-A

During Cleaning ,TPS Application And Final Assy

Access Location		
LH2 Fwd Dome	Cell E (Vertical)	Cleaning Probe Instl
	Cell B,C,D (Vertical)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Contingency Access Only
LH2 Aft Dome	Cell A (Vertical)	Inspect For Condensation
	Cell E (Vertical)	LH2 Aft Sensor Mast Instl. Siphon Screen Instl
	Cell D (Vertical)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Fwd Sensor Mast Instl

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NLS Manhole Size

OSHA Requirements

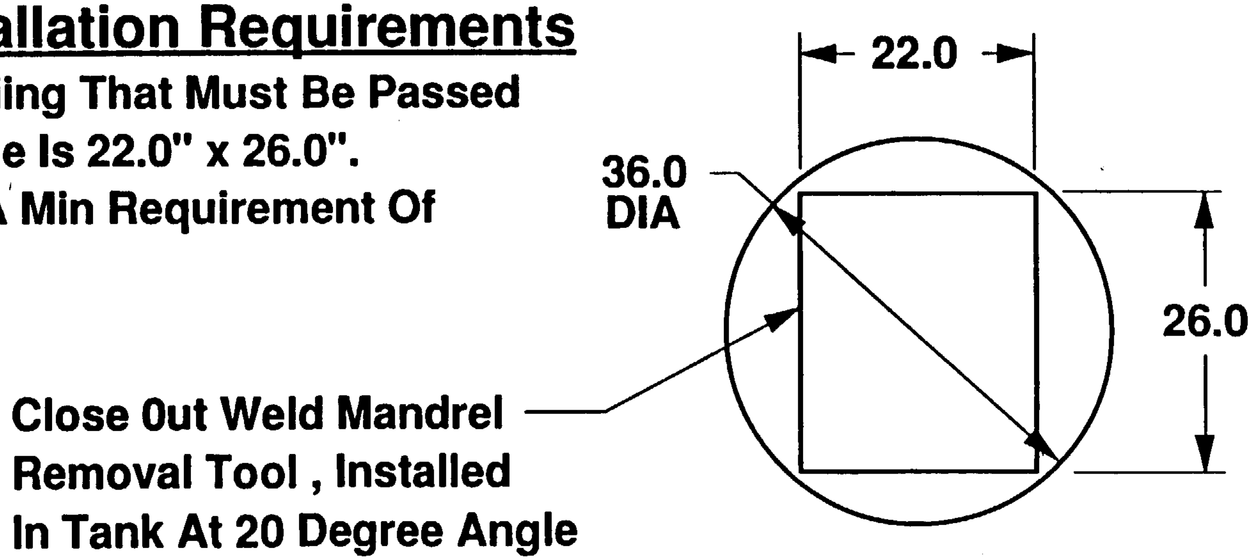
- OSHA Chapter XVII , Section 1910.106 , Para Vb Specifies That Pressure Vessel Be Built In Accordance With The ASME Code For Boiler And Pressure Vessels. Section VIII , Division 2 , Para AD-1020-1 Of The ASME Code Specifies A Minimum Dia Of 15" For Access.

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.



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NLS Core Tank Access Reqmts Summary CV-DI-01-A

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) CV-DI-01-A

During Build At MAF - Based On ET Capability

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

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NLS L02 Tank Access Requirements

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

Access Location	Process	Operation
LO2 Fwd Dome	Welding	• Remove Close-out Weld Mandrel.
	Internal Cleaning	• Remove Debris
	Mechanical Assy	• Complete Instl Of Fwd Slosh Baffle • Tie In Aft Baffle. • Clean Up And X-Ray (After Proof Test).
LO2 Aft Dome	—	None

NLS L02 Tank Access Requirements(Cont) CV-DI-01-A

During Cleaning ,TPS Application And Final Assy

Access Location		
LO2 Fwd Dome	Cell E (Vertical)	Cleaning Probe Instl
	Cell M (Vertical)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Fwd Mast Installation
LO2 Aft Dome	Cell E (Vertical)	LO2 Aft Sensor Mast Instl. Siphon Screen Instl
	Cell M (Vertical)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Contingency Access Only

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NLS LH2 Tank Access Requirements

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

Access Location	Process	Operation
LH2 Fwd Dome	Welding	• Remove Close-out Weld Mandrel. • Clean Tank
	Mechanical Assy	• Install 1129 Frame Stabilizer • Install Fwd Sensor Mast Supports. • Clean Up And X-Ray (After Proof Test).
LH2 Aft Dome	—	None

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NLS LH2 Tank Access Requirements(Cont) CV-DI-01-A

During Cleaning ,TPS Application And Final Assy

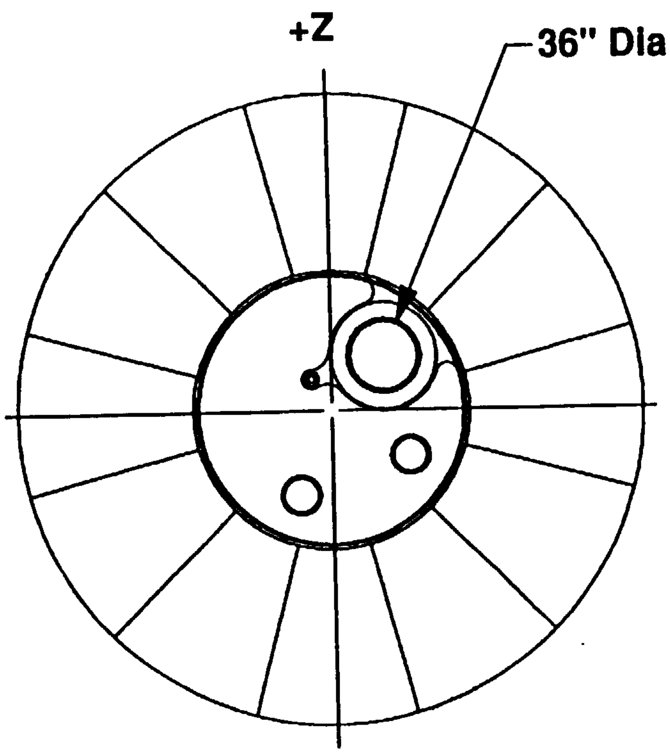
Access Location		
LH2 Fwd Dome	Cell E (Vertical)	Cleaning Probe Instl
	Cell N (Vertical)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Contingency Access Only
LH2 Aft Dome	Cell A (Vertical)	Inspect For Condensation
	Cell E (Vertical)	LH2 Aft Sensor Mast Instl. Siphon Screen Instl
	Cell N (Horizontal)	Heat Duct Instl For TPS Curing
	Final Assy (Horizontal)	Fwd Sensor Mast Instl

Options (NLS L02 Tank)

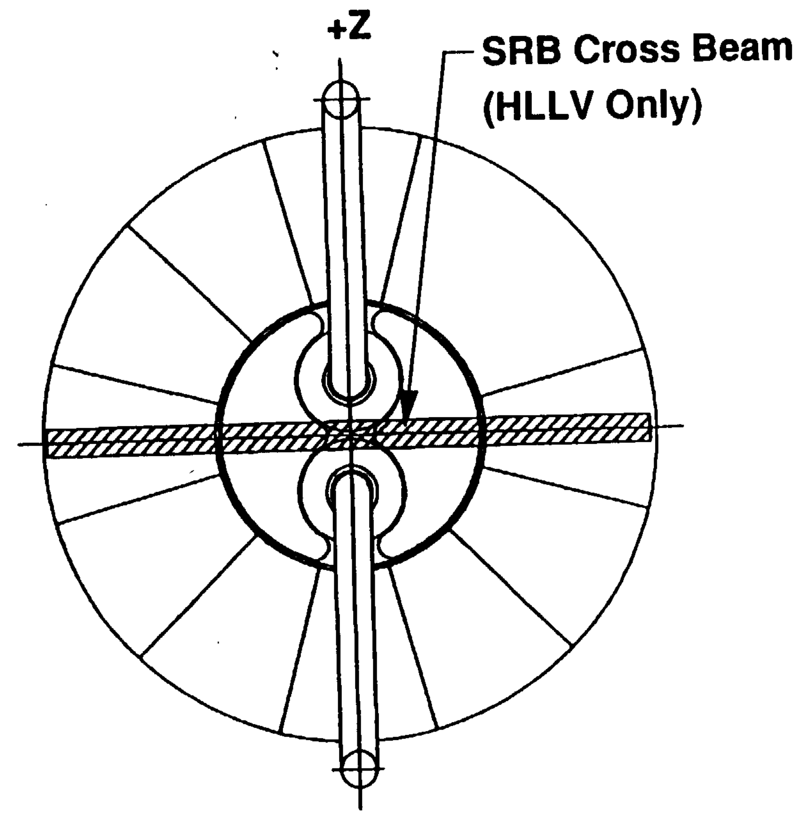
- Option 1- Baseline (MSFC Ref Cycle 0 Design).
- Option 2- Relocate Aft Dome Feedline Penetrations To Allow For The Addition Of A 30" Dia Manhole In Bottom Of Tank. Relocate Fwd Dome Manhole To Match ET.
- Option 3- Design Aft Dome Feedline Penetration To Be Bolted On Which Would Allow Removal For Access. 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)

CV-DI-01-A



Fwd Dome



Aft Dome

No Tank Access Available

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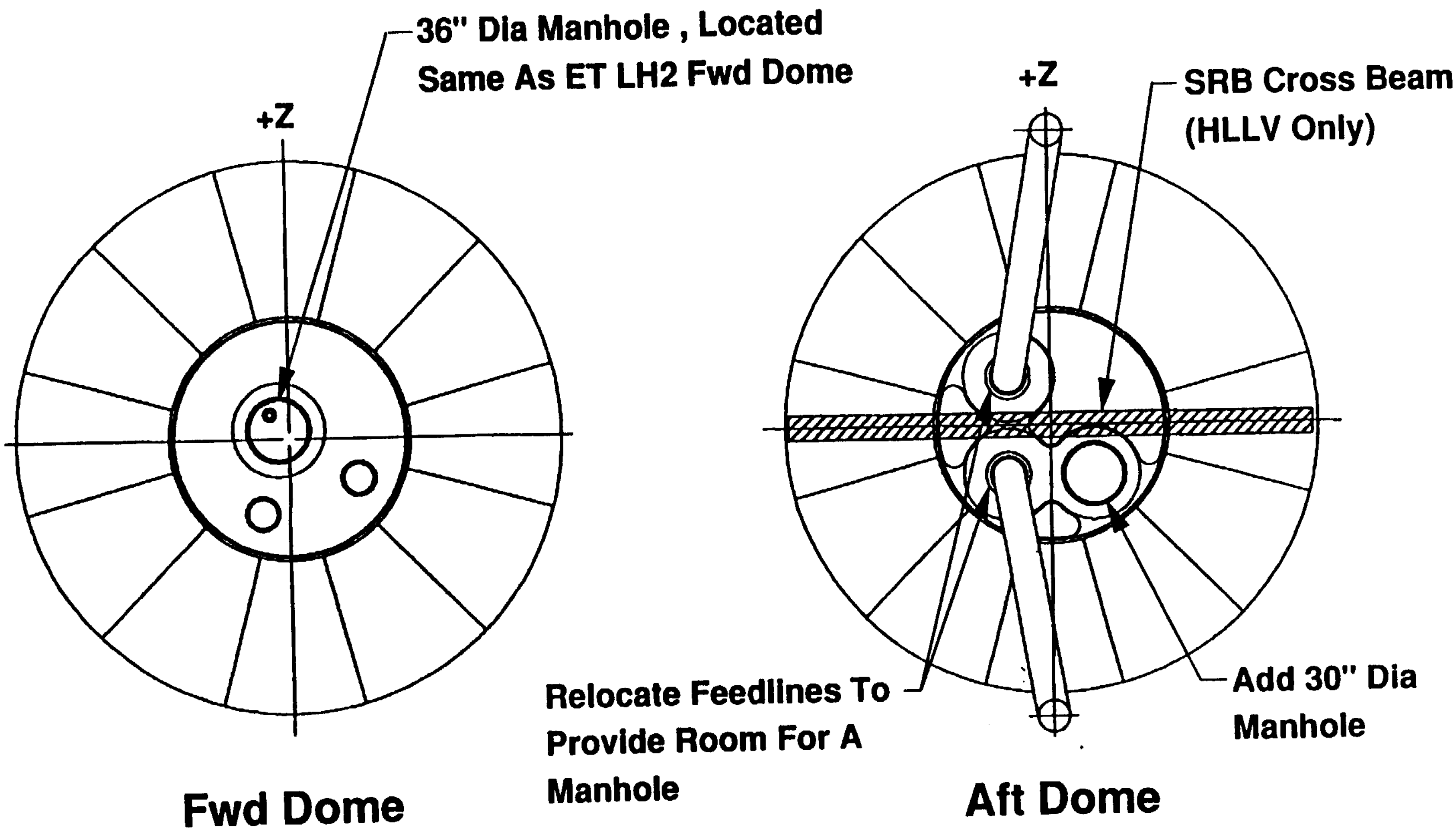
LO2 Option 2



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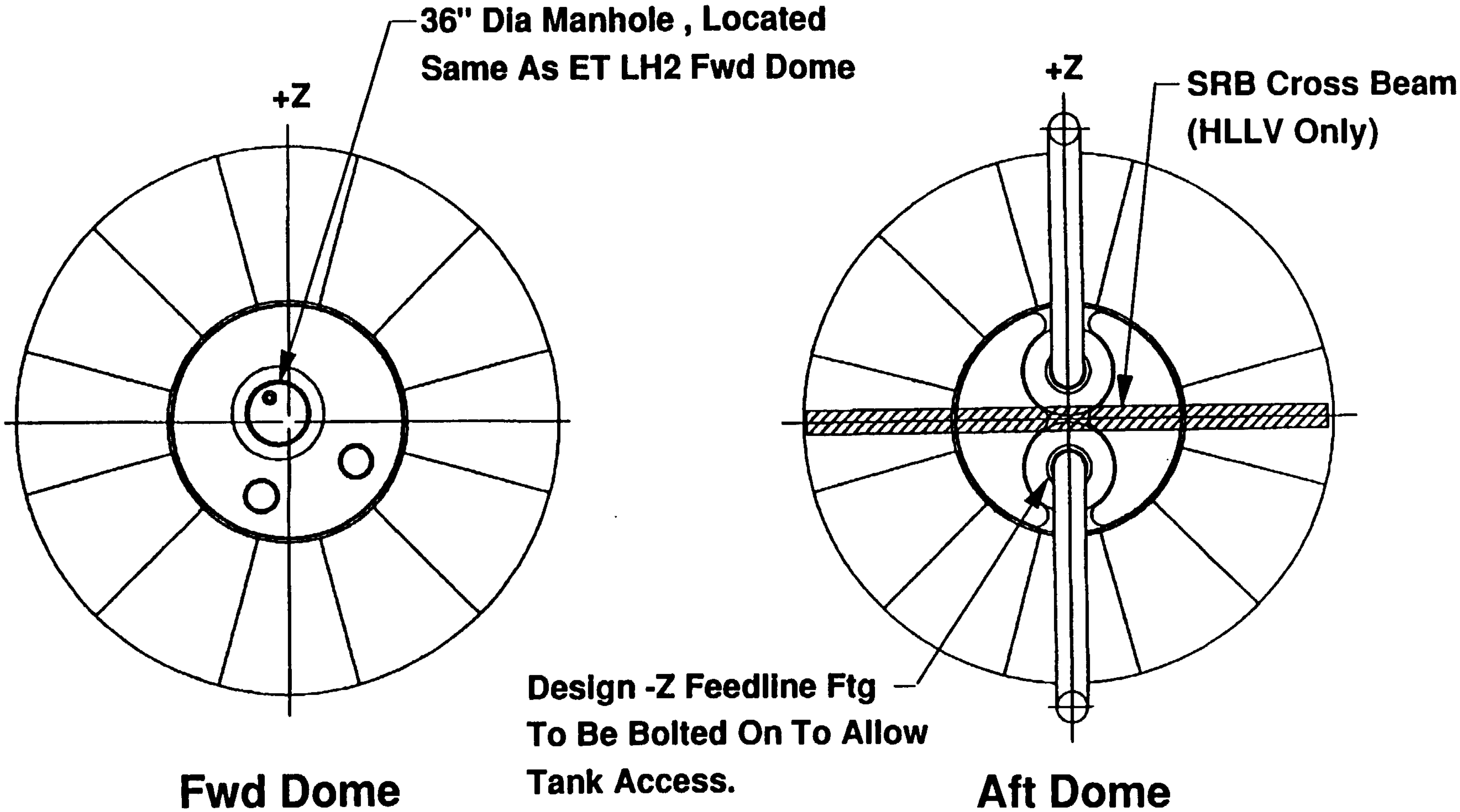
LO2 Option 3



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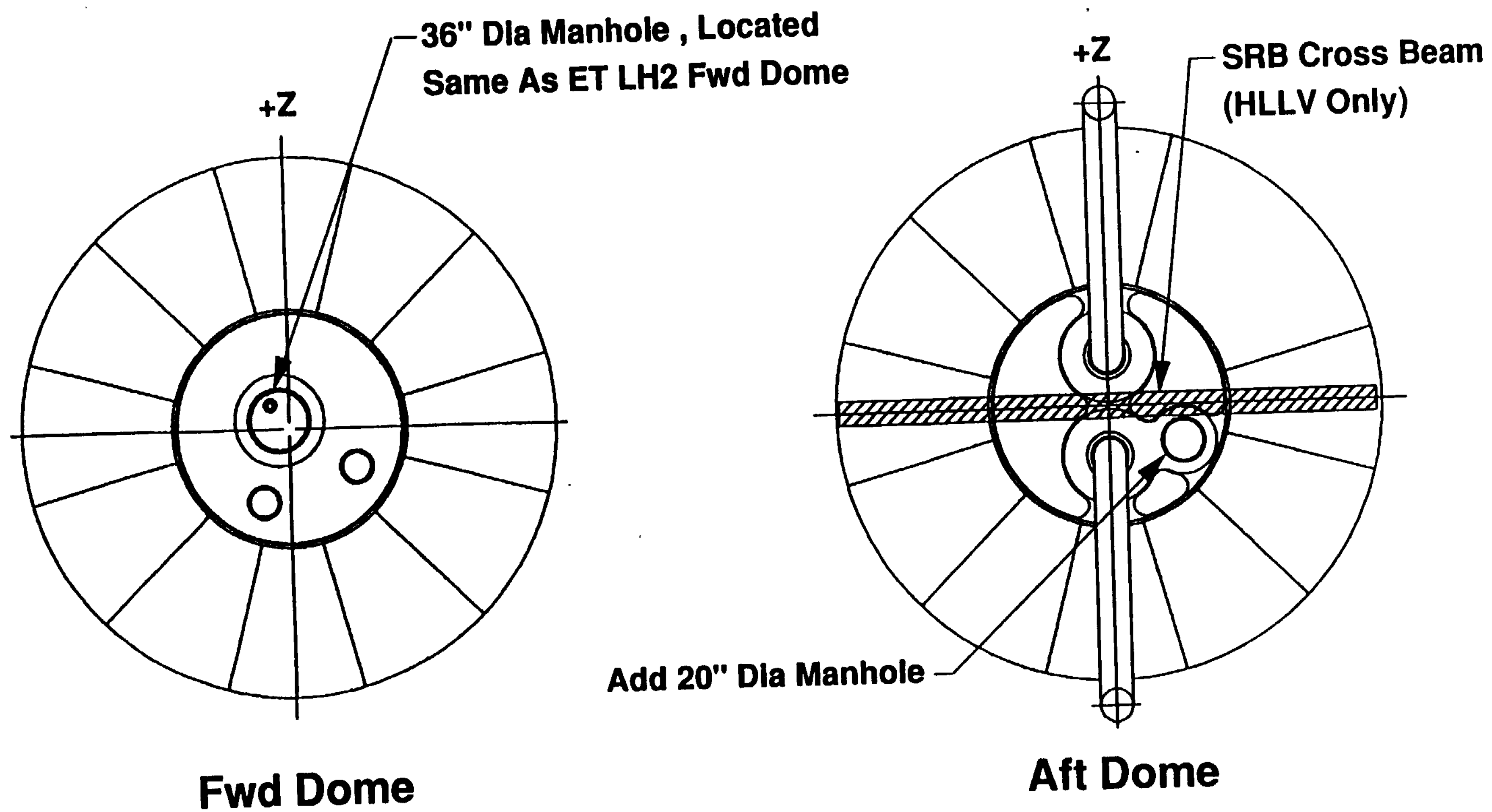
LO2 Option 4



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NLS LO2 Access Option Summary

CV-DI-01-A

BUILD AT MAF

Activity	Option 1	Option 2	Option 3	Option 4
Removal Of Close-Out Weld Mandrel Thru Fwd Manhole (Welding)	Location Of Manhole Requires Mods To Tank Access Tools	Yes	Yes	Yes
Complete Instl Of Fwd Slosh Baffle. Access Thru Fwd Manhole (Mech Assy)				
Tie In Aft Baffle. Access Thru Fwd Manhole. (Mech Assy)				
Clean Up And X-ray. Access Thru Fwd Manhole. (Mech Assy)	Location Of Manhole Requires Mods To Tank Access Tools			
Install Internal Cleaning Probe Thru Fwd Manhole (Cell -E , Vertical)	Location Of Manhole Requires Mods To Cleaning Probe		Yes	Yes
Install Heat Ducts For TPS Curing Thru Both Domes (Cell - M , Vertical)	No Aft Manhole Available	Yes	Requires Removal Of Feedline Fitting And Mods To Aft Heat Duct	Aft Manhole Size Requires Mods To Heat Duct

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NLS LO2 Access Option Summary (Cont)

CV-DI-01-A

	Activity	Option 1	Option 2	Option 3	Option 4
BUILD AT MAF	Install Aft Level Sensor Mast. Access Thru Aft Manhole. (Cell - E , Vertical)	No Aft Manhole Available	Yes	Requires Removal Of Feedline Fitting	Aft Manhole Size Requires Mods To Tooling
	Install Siphon Screen. Access Thru Aft Manhole. (Cell - E , Vertical)	No Aft Manhole Available		No Aft Manhole Available	Aft Manhole Size Req's Redesign Of Siphon Screen
	Install Fwd Level Sensor Mast. Access Thru Fwd Manhole. (Final Assy - Horizontal)	Location Of Manhole Requires Mods To Tank Access Tools		Yes	Yes
KSC Processing	Install Tank Entry Tooling Thru Aft Manhole	No Aft Manhole Available	Yes	Requires Removal Of Feedline Fitting	Aft Manhole Size Requires Mods To Tooling
	Contingency Access Thru Fwd Dome	Unstack Payload And CTV			

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NLS L02 Tank Evaluation Sum (Fwd Dome) CV-DI-01-A

Criteria		Option 1	Option 2	Option 3	Option 4
Can A Common Cleaning Probe Location Be Achived Between ET & NLS		NO	YES	YES	YES
Is There Provisions For Connection Of TPS Cure Heat Ducts		YES	YES	YES	YES
Can Existing Tank Access Platforms Be Utilized Without Modifications		NO	YES (Use LH2 Tooling)	YES (Use LH2 Tooling)	YES (Use LH2 Tooling)
Can Weld Close Out Mandrel Be Removed Thru Fwd Manhole		YES	YES	YES	YES
What Is The Extent Of The Tooling And Facility Mods		MAJOR Rdesign Access Tooling, Relocate Cleaning Probe And TPS Heat Duct	MINOR Use LH2 Access Tooling, Cleaning And TPS Application Hardware	MINOR Use LH2 Access Tooling, Cleaning And TPS Application Hardware	MINOR Use LH2 Access Tooling, Cleaning And TPS Application Hardware
What Is The Estimated Weight Impact		Reference	NONE	NONE	NONE
Is Internal Access Feasible After Tank Stacking At MAF		NO *	YES	YES	NO
Is Contingency Access At KSC Feasible	Before Payload Stacking	NO *	YES	YES	NO
	After Payload Stacking	NO *	NO	NO	NO

* Requires Aft Dome Manhole To Install Access Tooling.

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NLS L02 Tank Evaluation Sum (Aft Dome) CV-DI-01-A

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

* Requires Removal Of Siphon Ftg And Feedline Assy

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Conclusions - NLS L02 Tank Access

CV-DI-01-A

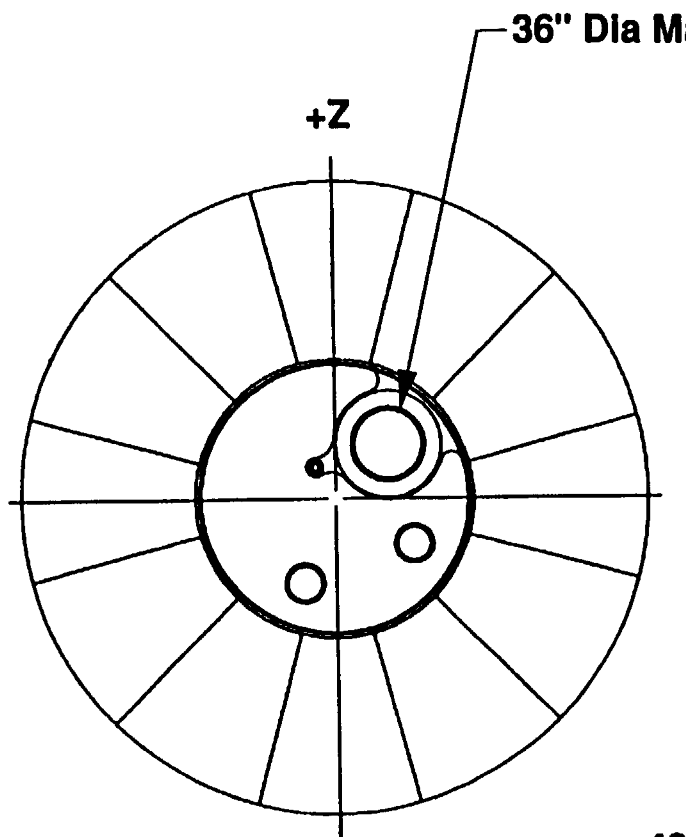
- Option 2 Is Perferred :
  - Allows Tank To Be Manufactured Using Existing ET Tooling And Processes.
  - Provides Internal Access To Tank At MAF.
  - Provides Contingency Access To Tank At KSC Prior To Payload Mating.

Options (NLS LH2 Tank)

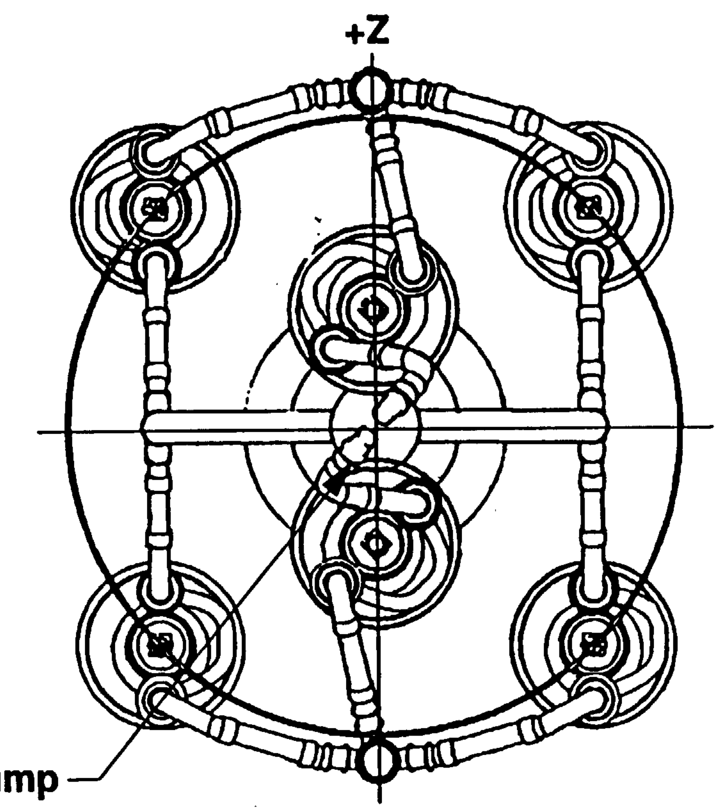
- Option 1- Baseline (MSFC Ref Cycle 0 Design).
- Option 2- Design Aft Dome Sump As "Bolt On" To Allow Access. Relocate Fwd Dome Manhole To Match ET.
- Option 3- Adopt MSFC Alternate Prop Arrangement An Add 30" Dia Manhole To Aft Dome Cap.Relocate Fwd Dome Manhole To Match ET.

LH2 Option 1 (MSFC Cycle 0)

CV-DI-01-A



Fwd Dome



Aft Dome

No Tank Access Available

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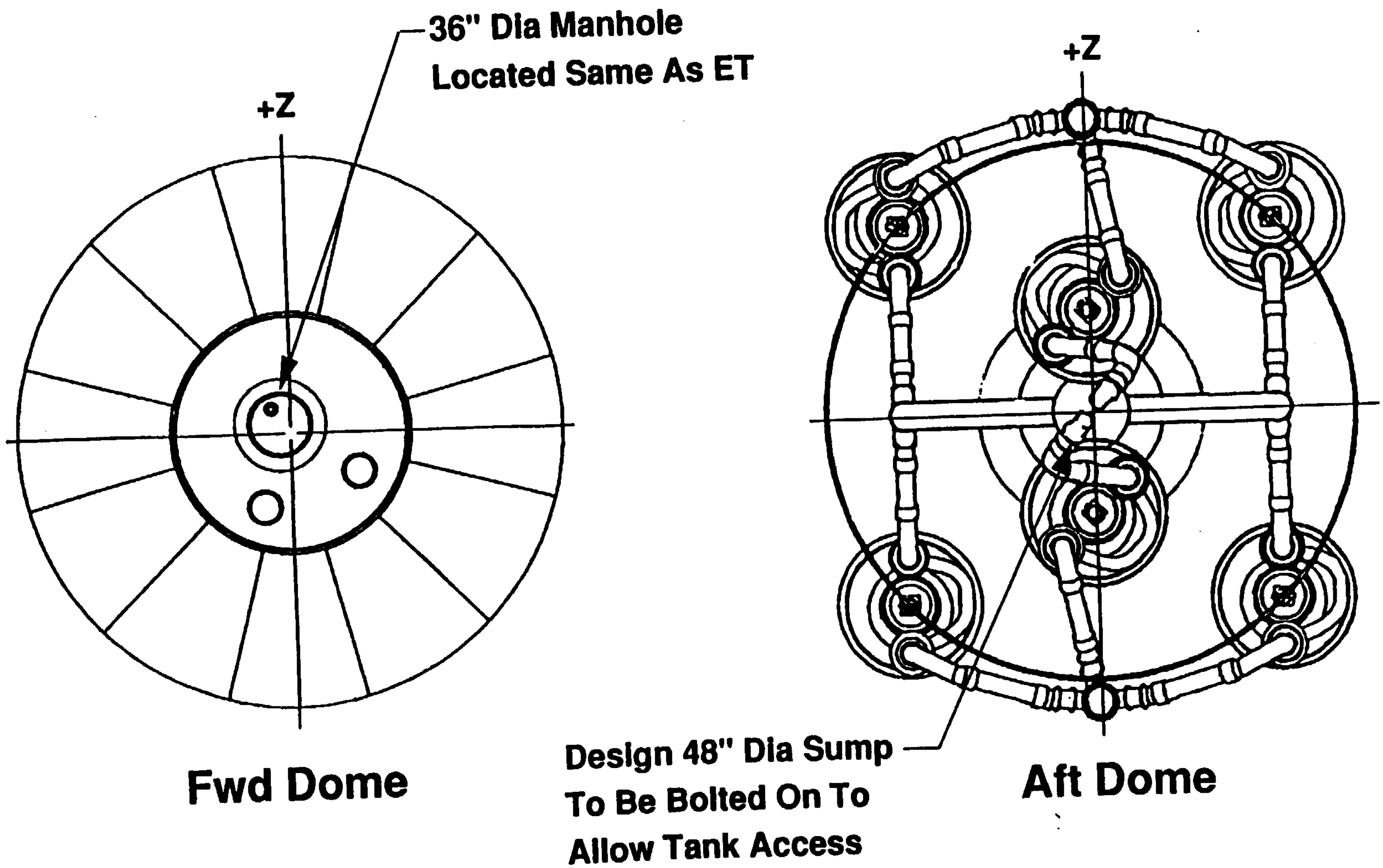
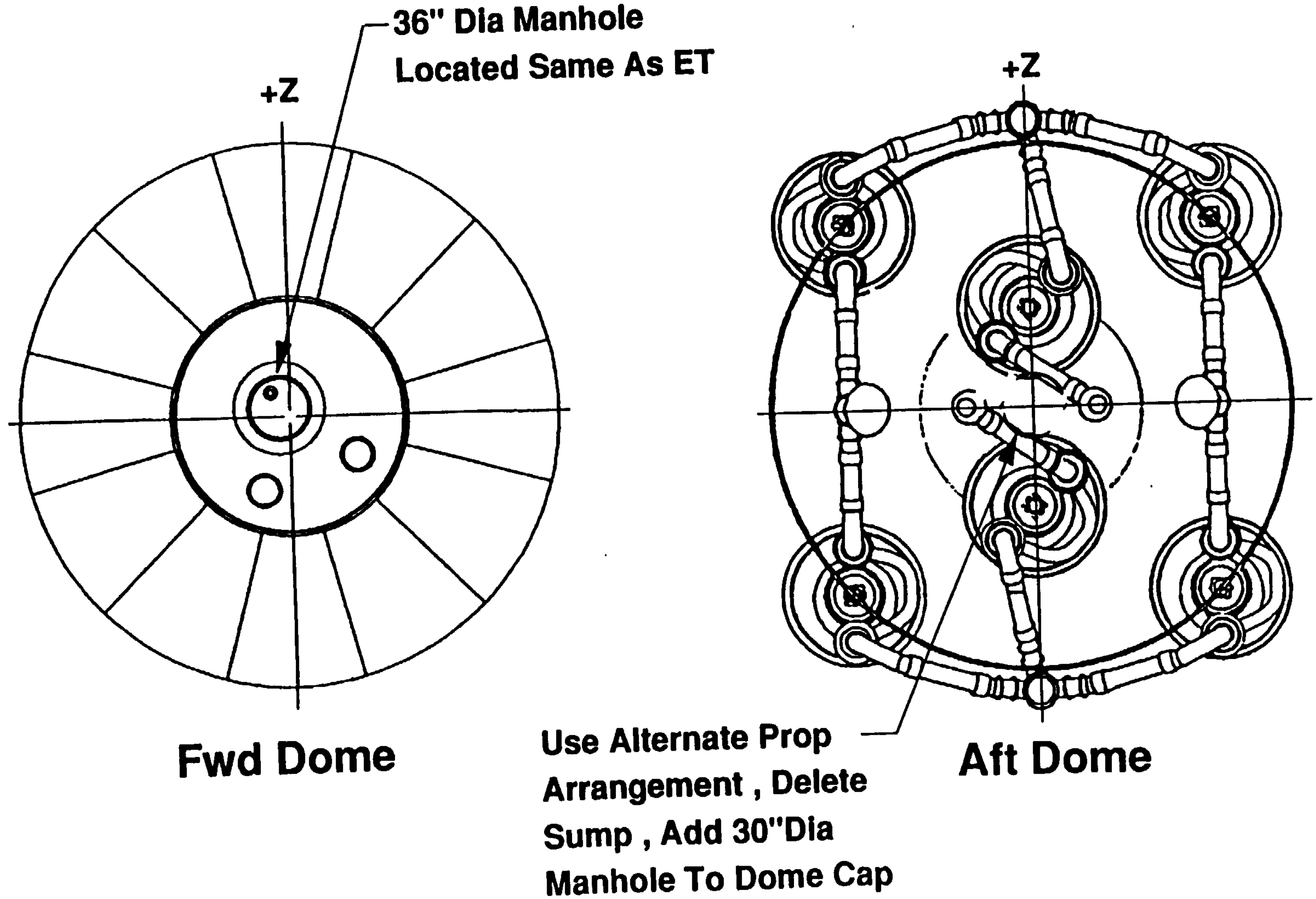
LH2 Option 2


36" Dia Manhole
Located Same As ET
+Z
+Z
Fwd Dome
Design 48" Dia Sump
To Be Bolted On To
Allow Tank Access
Aft Dome

LH2 Option 3



Fwd Dome

Aft Dome

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NLS LH2 Access Option Summary

CV-DI-01-A

BUILD AT MAF

Activity	Option 1	Option 2	Option 3
Removal Of Close-Out Weld Mandrel Thru Fwd Manhole (Welding)	Location Of Manhole Requires Mods To Tank Access Tools	Yes	Yes
Install 1129 Frame Stabilizer. Access Thru Fwd Manhole. (Mech Assy)			
Install Fwd Level Sensor Mast Supports. Access Thru Fwd Manhole. (Mech Assy)			
Clean Up And X-ray. Access Thru Fwd Manhole. (Mech Assy)	Location Of Manhole Requires Mods To Tank Access Tools		
Install Internal Cleaning Probe Thru Fwd Manhole (Cell -E, Vertical)	Location Of Manhole Requires Mods To Cleaning Probe	Yes	
Install Heat Ducts For TPS Curing Thru Both Domes (Cell - N, Horizontal)	No Aft Manhole Available	No Aft Manhole Available	Yes

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NLS LH2 Access Option Summary (Cont) CV-DI-0 ı-A

	Activity	Option 1	Option 2	Option 3
BUILD AT MAF	Install Aft Level Sensor Mast. Access Thru Aft Manhole. (Cell - E , Vertical)	No Aft Manhole Available	Yes	Yes
	Install Siphon Screen. Access Thru Aft Manhole. (Cell - E , Vertical)		No Aft Manhole Available	
	Check For Condensation After Proof Test. Access Thru Aft Manhole. (Cell -A , Vertical)			
	Install Fwd Level Sensor Mast. Access Thru Aft Manhole. (Final Assy - Horizontal)			
KSC Processing	Install Tank Entry Tooling Thru Aft Manhole	No Aft Manhole Available	No Aft Manhole Available	Yes
	Contingency Access Thru Fwd Dome	Unstack Payload And CTV		

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NLS LH2 Tank Evaluation Sum (Fwd Dome) CV-DI-01-A

Criteria	Option 1	Option 2	Option 3
Can A Common Cleaning Probe Location Be Achived Between ET & NLS	NO	YES	YES
Is There Provisions For Connection Of TPS Cure Heat Ducts	YES	YES	YES
Can Existing Tank Acces Platforms Be Utilized Without Modifications	NO	YES	YES
Can Weld Close Out Mandrel Be Removed Thru Fwd Manhole	YES	YES	YES
What Is The Extent Of The Tooling And Facility Mods	MAJOR Rdesign Access Tooling, Relocate Cleaning Probe And TPS Heat Duct	NONE	NONE
What Is The Estimated Weight Impact	Reference	NONE	NONE
Is Internal Access Feasible After Tank Stacking At MAF	NO *	NO *	YES
Is Contingency Access At KSC Feasible	NO *	NO *	YES

* Requires Aft Dome Manhole To Install Access Tooling.

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NLS LH2 Tank Evaluation Sum (Aft Dome) CV-DI-01-A

Criteria	Option 1	Option 2	Option 3
Is There Provisions For Connection Of TPS Cure Heat Ducts	NO	NO	YES
Can Existing Tank Acces Platforms Be Utilized Without Modifications	NO	NO	YES
Can Tank Be Manufactured Using Existing ET Tooling And Processes	NO	NO	YES
What Is The Extent Of The Tooling And Facility Mods	MAJOR NO Tank Opening For TPS Heat Duct, Unable To Access Tank For Final Assy	MINOR Provide Adapter For TPS Heat Duct	MINOR Provide Adapter For TPS Heat Duct
What Is The Estimated Weight Impact	Reference	+20 lbs	-114 lbs
Is Internal Access Feasible After Tank Stacking At MAF	NO	NO	YES
Is Contingency Access At KSC Feasible	NO	NO	YES

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MANNED SPACE SYSTEMS

WRW.NLS.91262

Conclusions - (NLS LH2 Tank Access) CV-DI-0ı-A

- 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 And Recommendations

CV-DI-01-A

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 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 loctn.; delete Sump, Add 30in Dia Manhole in Dome Cap

Key Study Results

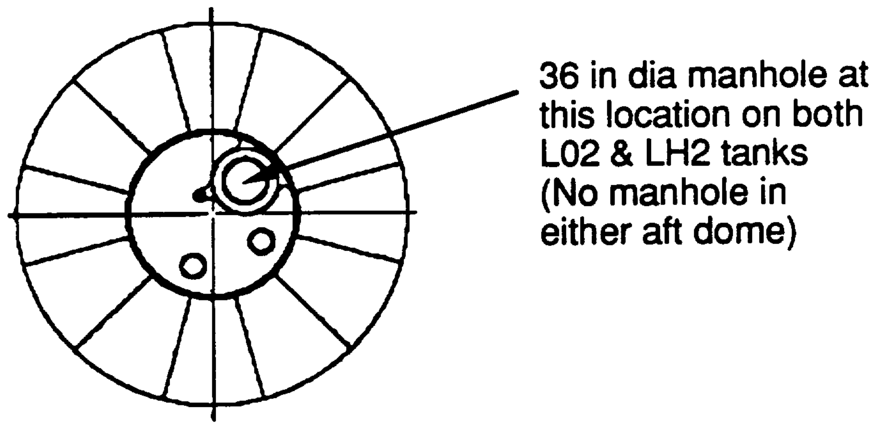
24 tank entries were made on ET at KSC(all on first 30 tanks). MIL-STD-1472 specifies that minimum manhole size is 30 inches. Existing Weld mandrel is 22in x 26in and is removed thru fwd dome. This requires a 36 in dia hole. For build at MAF similar access requirements to ET are required. This requires 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

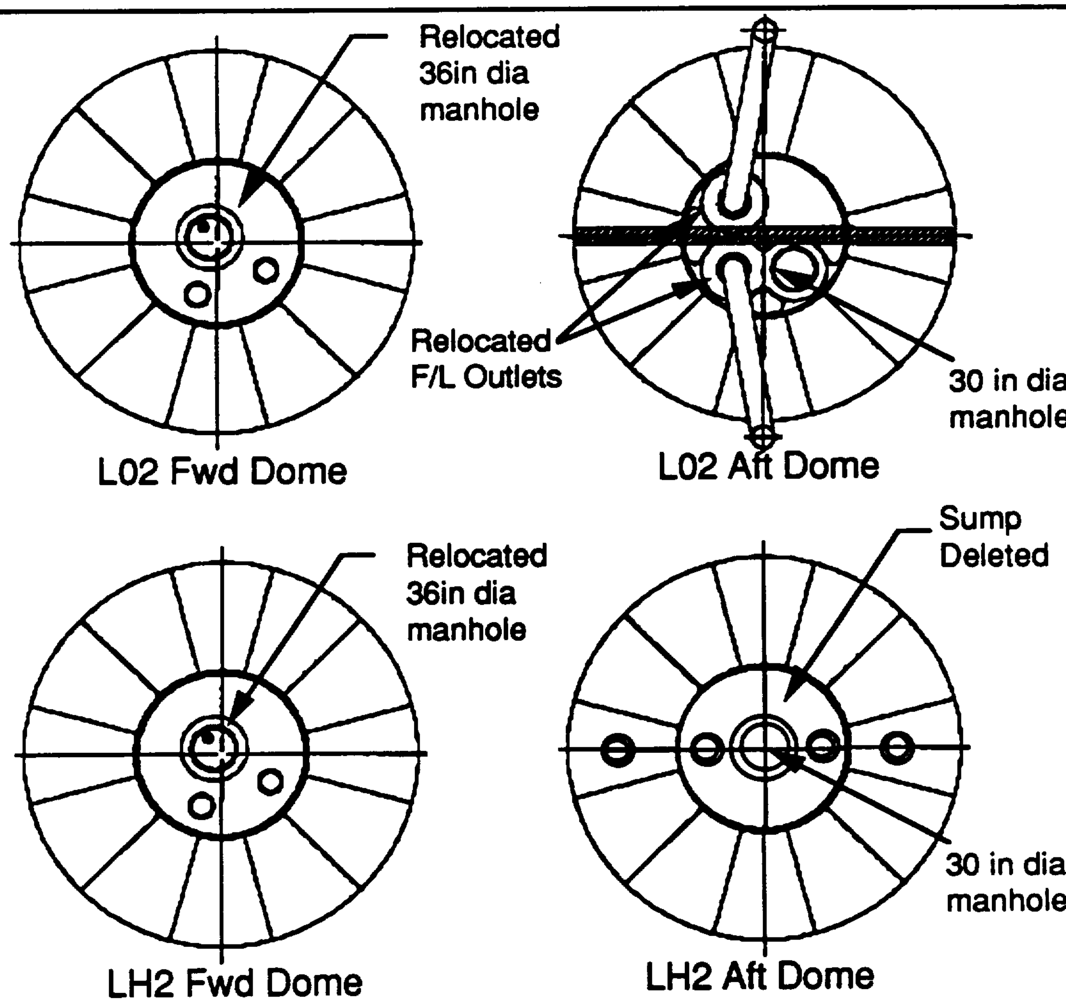
Option 2 is preferred for the L02 tank this option allows the NLS to be manufactured using ET tooling and facilities. It also provides for internal access at MAF and contingency access at KSC.

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 5.2.6.4.1)



NLS Cycle Ø Baseline



Proposed Update to NLS Cycle Ø Baseline

Additioal 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 loctn; 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

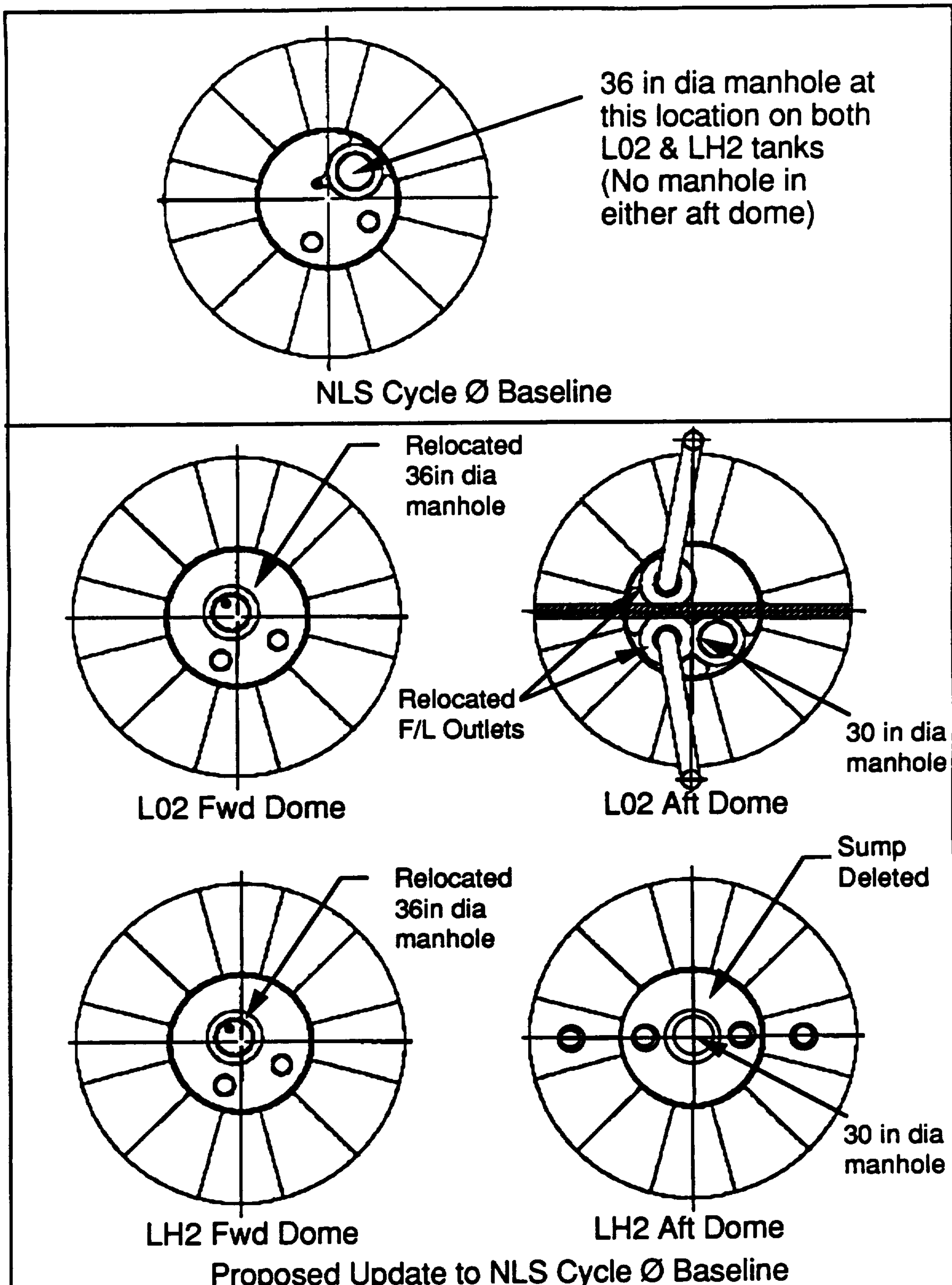
24 tank entries were made on ET at KSC(all on first 30 tanks). MIL-STD-1472 specifies that minimum manhole size is 30 inches. Existing Weld mandrel is 22in x 26in and is removed thru fwd dome. This requires a 36 in dia hole. For build at MAF similar access requirements to ET are required. This requires 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)



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 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

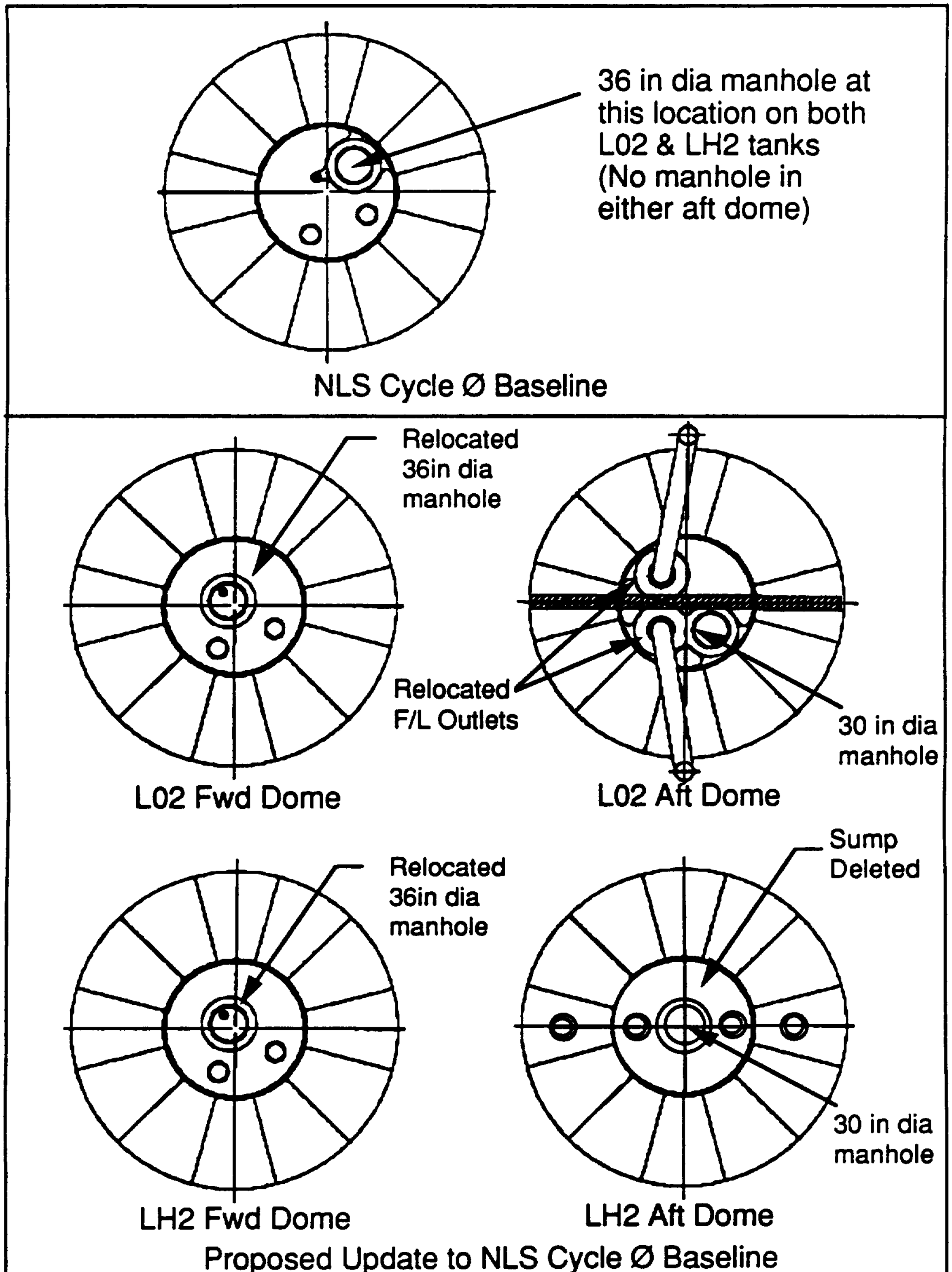
Options Studied - LH2 Tank (Reference only)

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 L02 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)



Additioal 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 loctn; 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

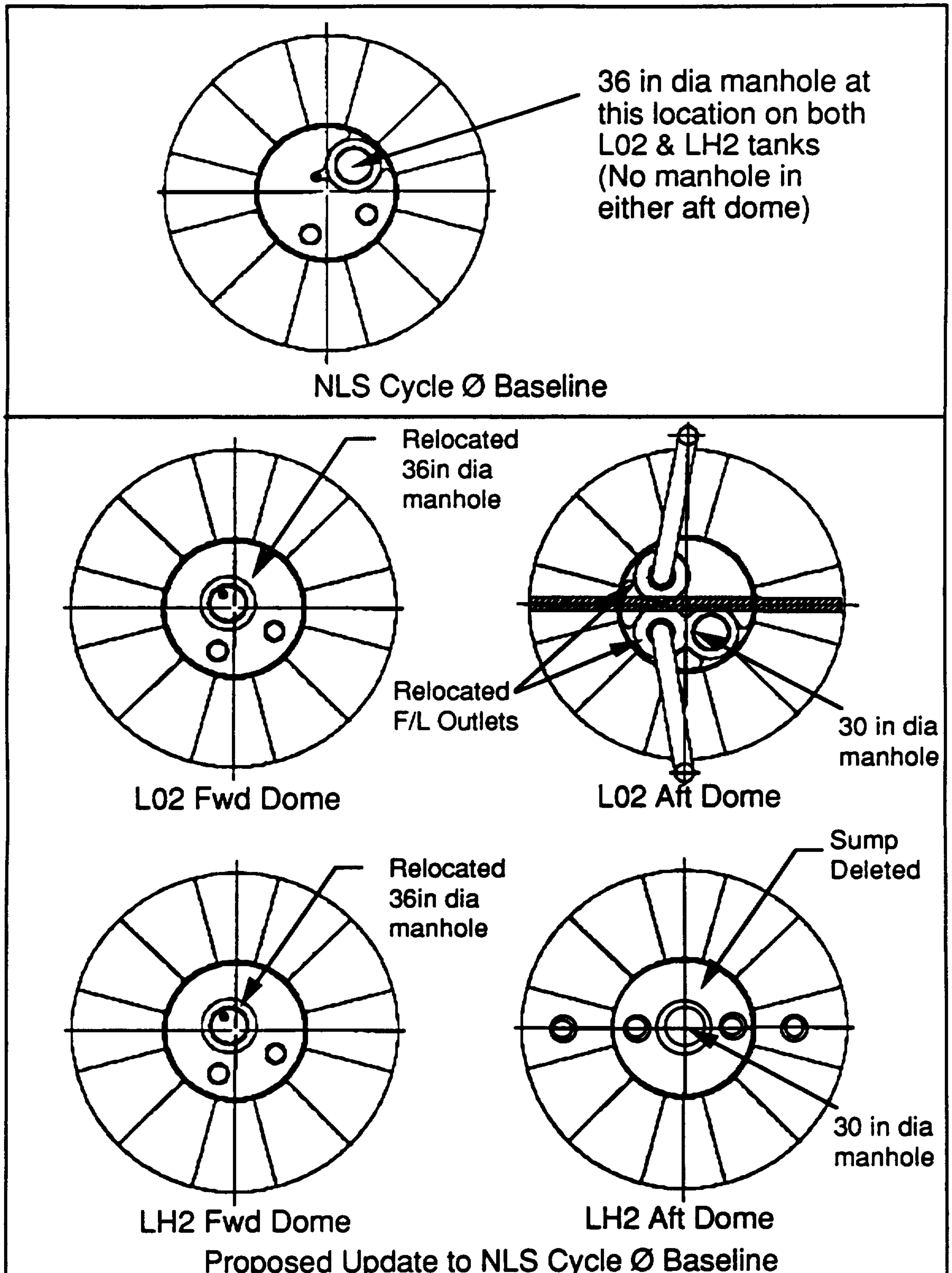
24 tank entries were made on ET at KSC(all on first 30 tanks). MIL-STD-1472 specifies that minimum manhole size is 30 inches. Existing Weld mandrel is 22in x 26in and is removed thru fwd dome. This requires a 36 in dia hole. For build at MAF similar access requirements to ET are required. This requires 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 6.2.6.4.1).



Additional Information

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

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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

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Objective and Approach

CV-DI -01B

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

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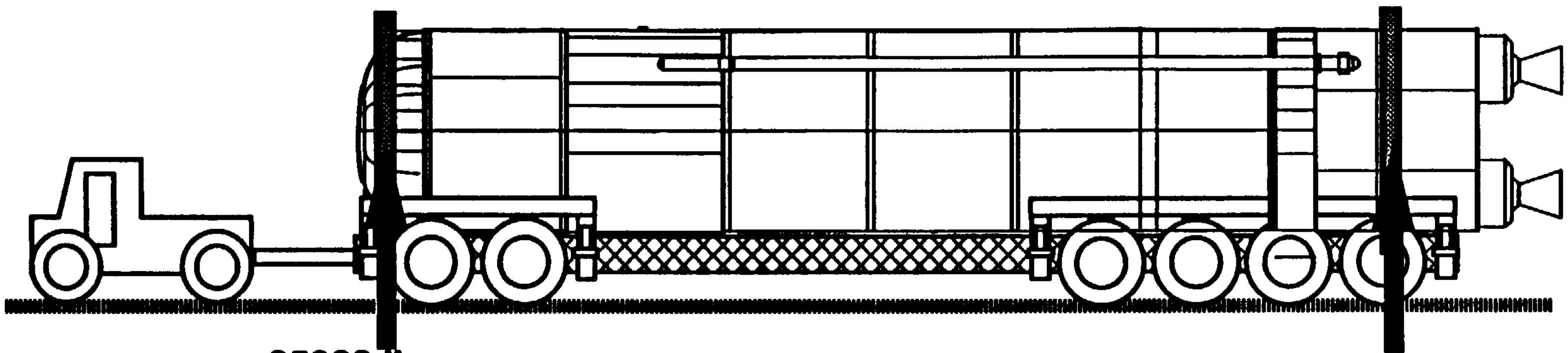
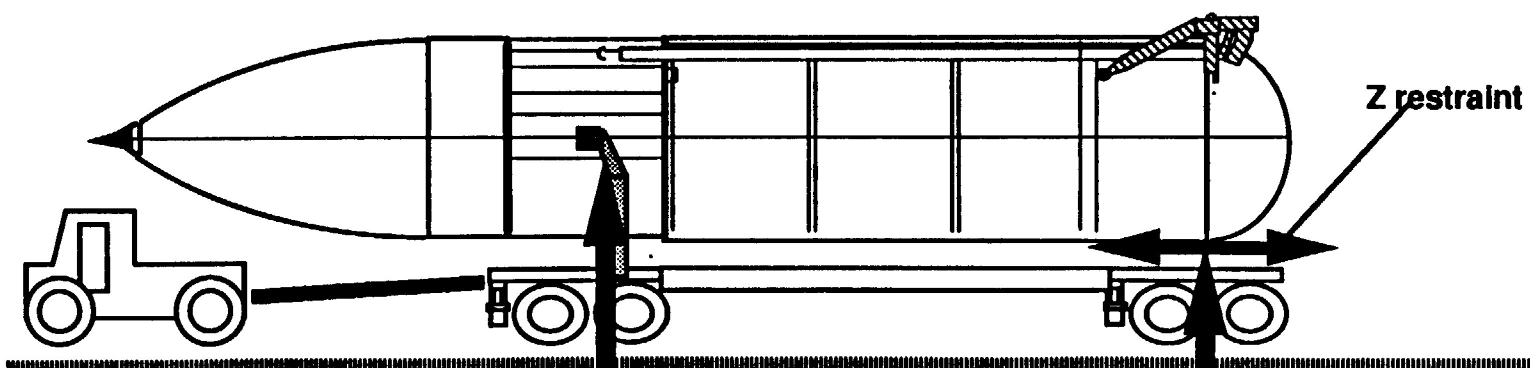
Transporter Comparison

CV - DI -01B





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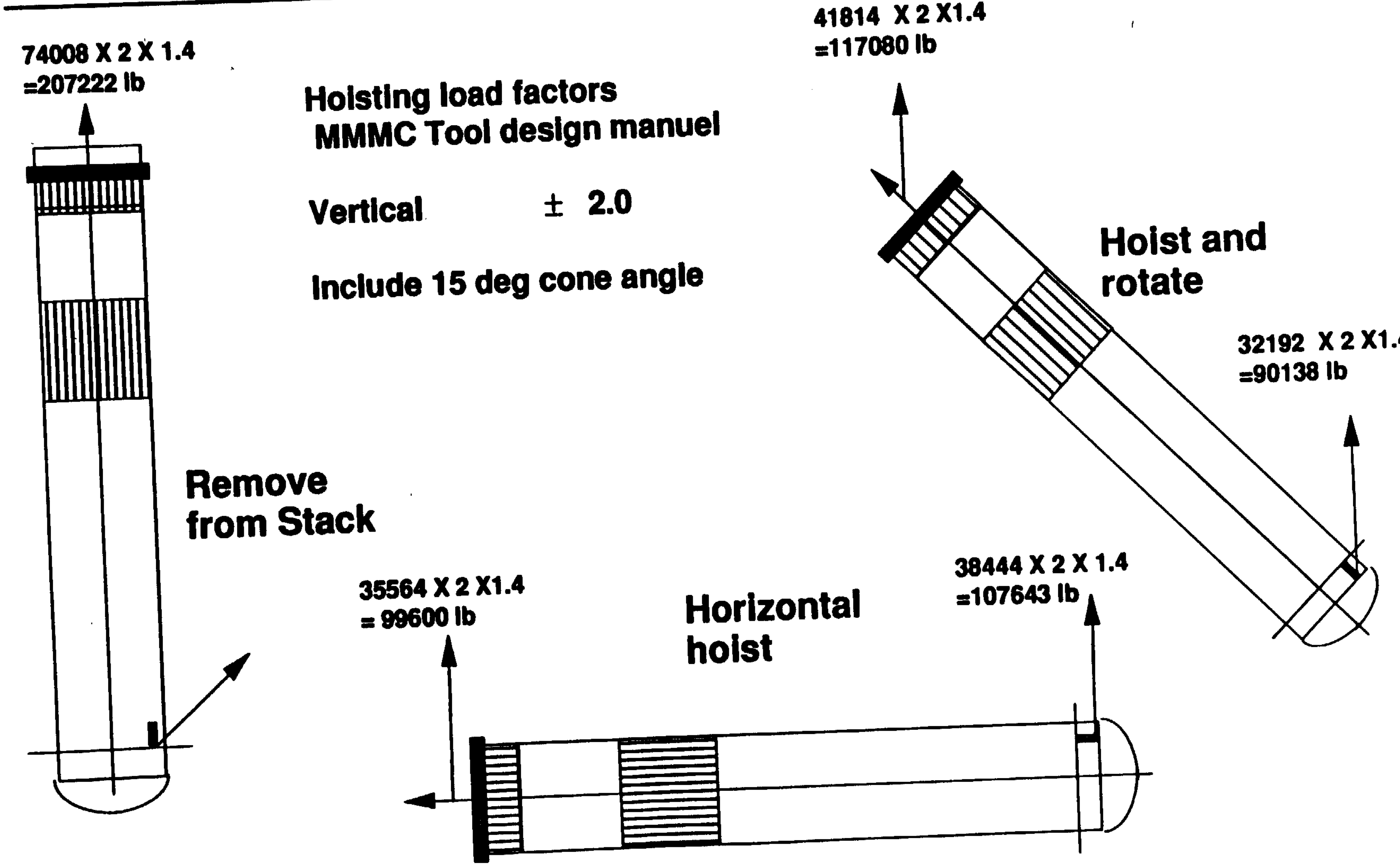
Handling Loads - Hoisting at MAF VAB

CV - DI - 01B

Hoisting load factors
MMMC Tool design manuel

Vertical ± 2.0

Include 15 deg cone angle



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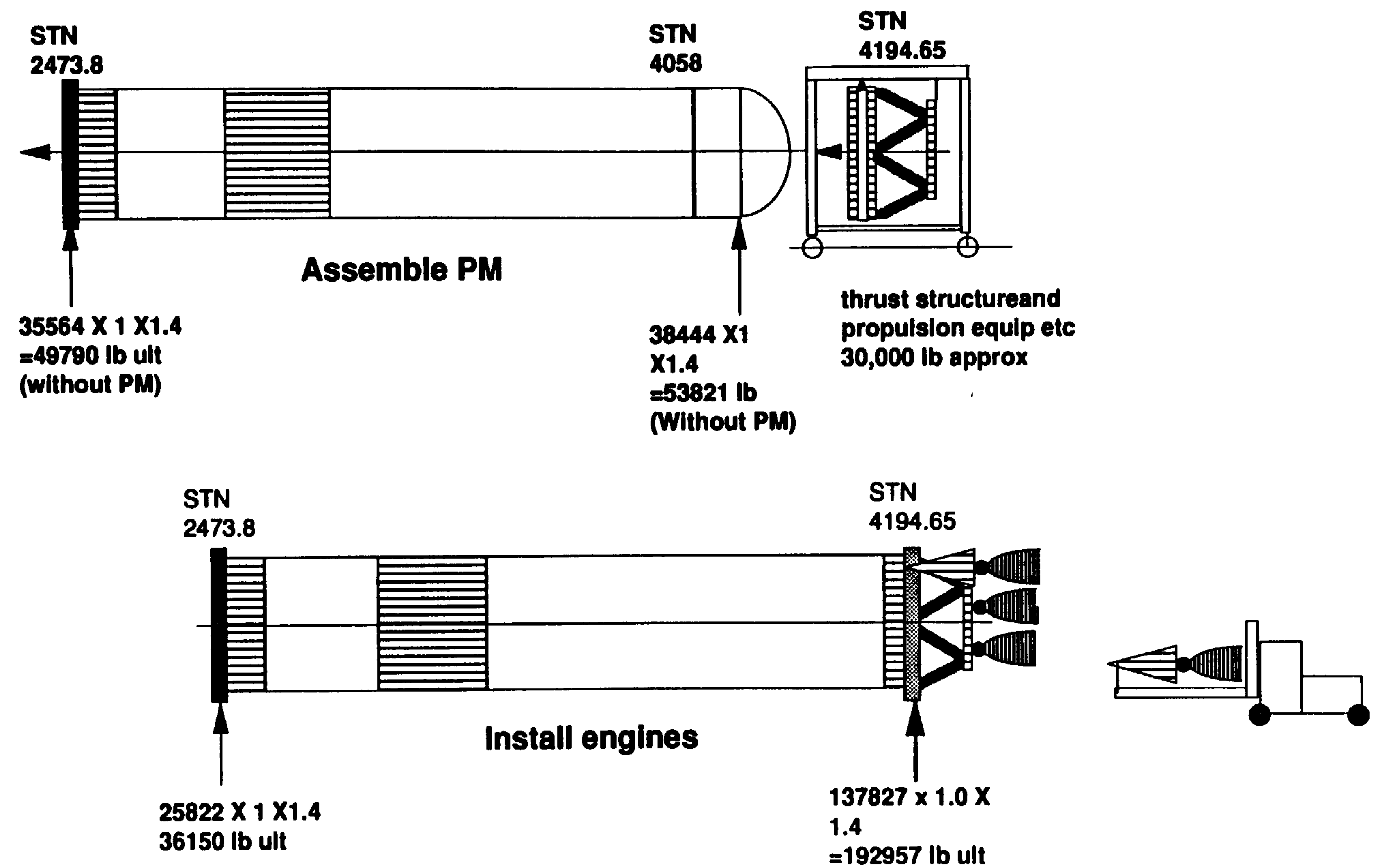
Handling Loads - Final assembly

CV - DI - 01B



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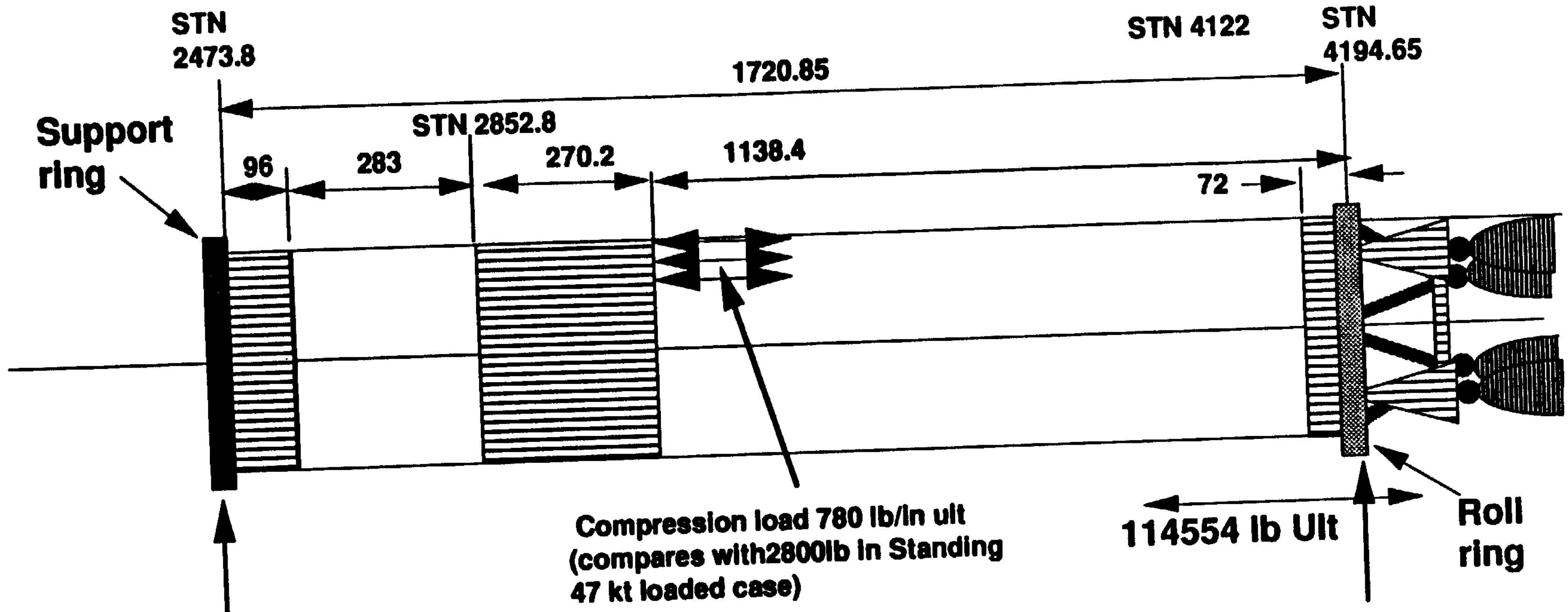
Handling- Complete Vehicle on Barge CV - DI - 01B



25822 X 2.5 X 1.4
=90377 lb ult

137827X 2.5 X 1.4
= 482394lb ult

Transport load factors (Water transport)
Ref SP 8077

Longitudinal	± .5
Lateral	± 2.5
Vertical	± 2.5

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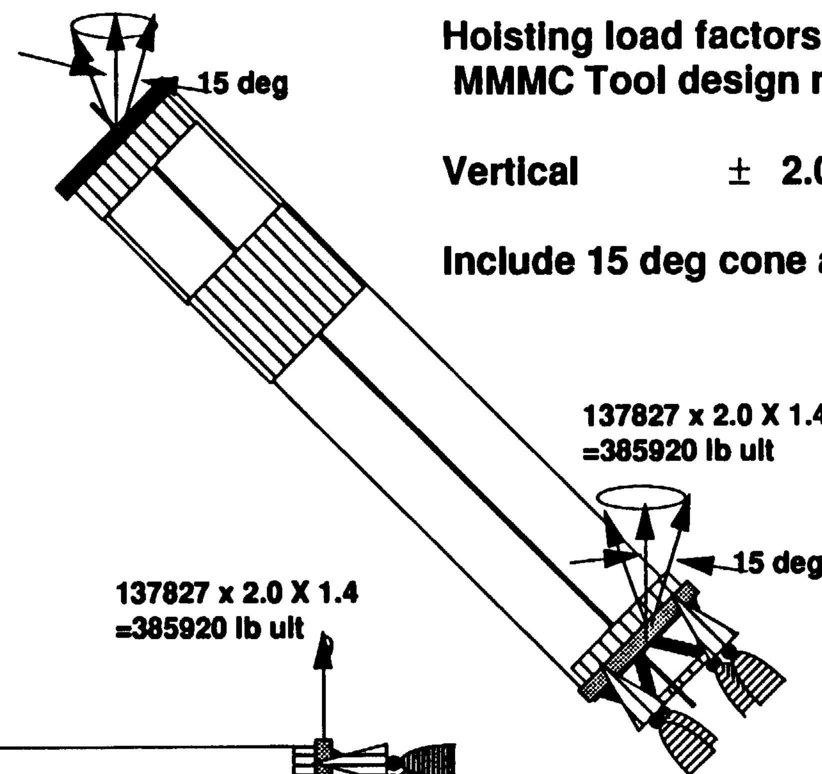
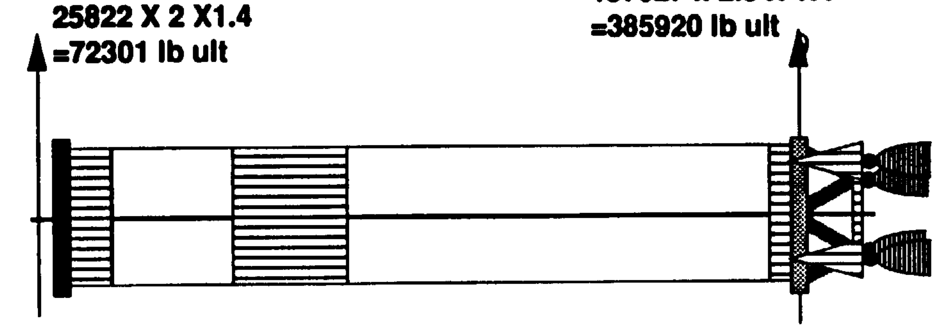
Handling Loads - Hoist at KSC VAB   CV - DI - 01B

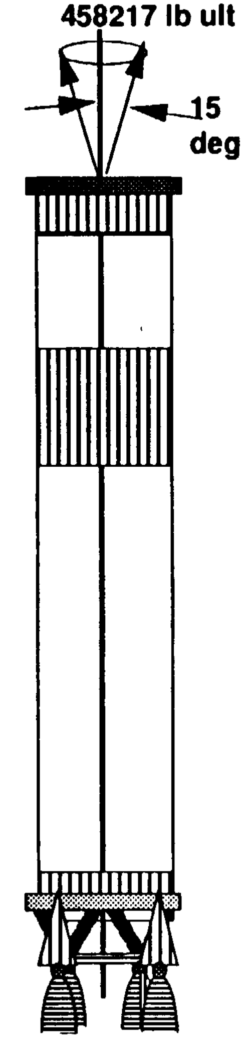


Hoisting load factors
MMMC Tool design manual

Vertical ± 2.0

Include 15 deg cone angle





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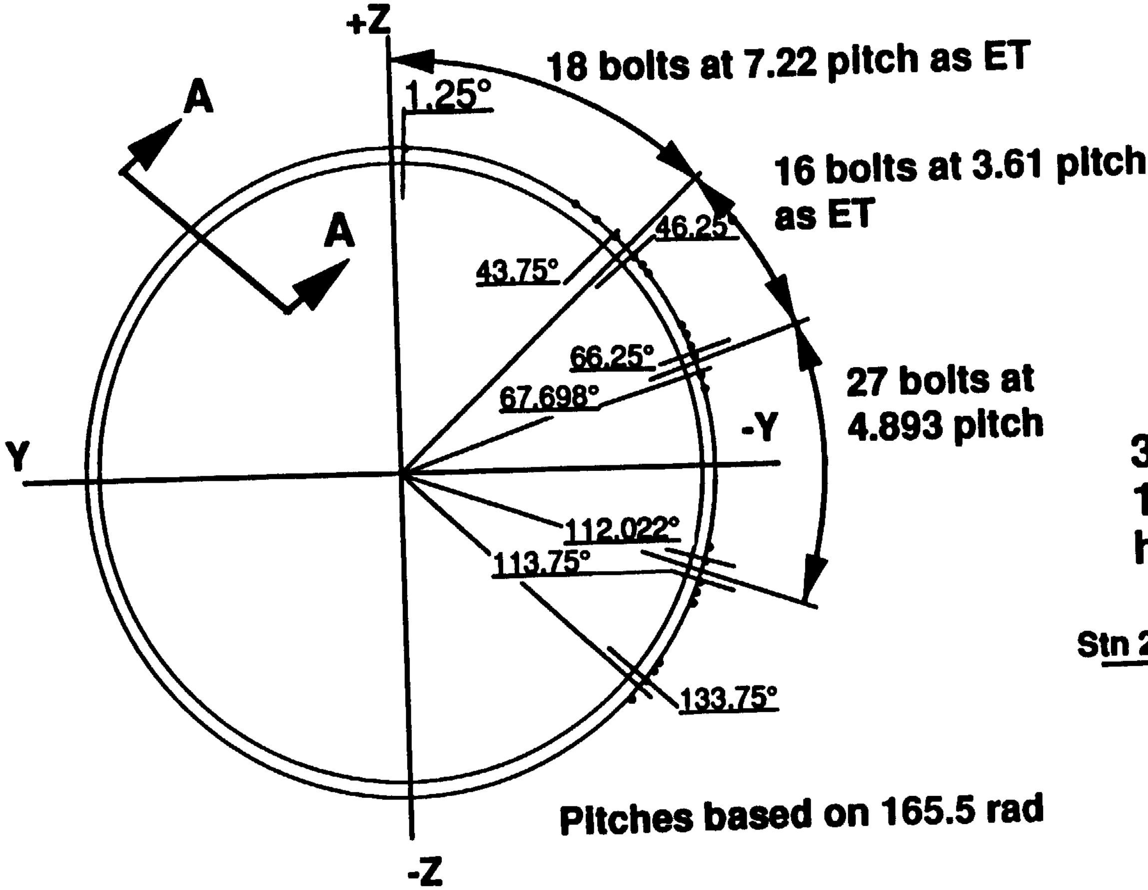
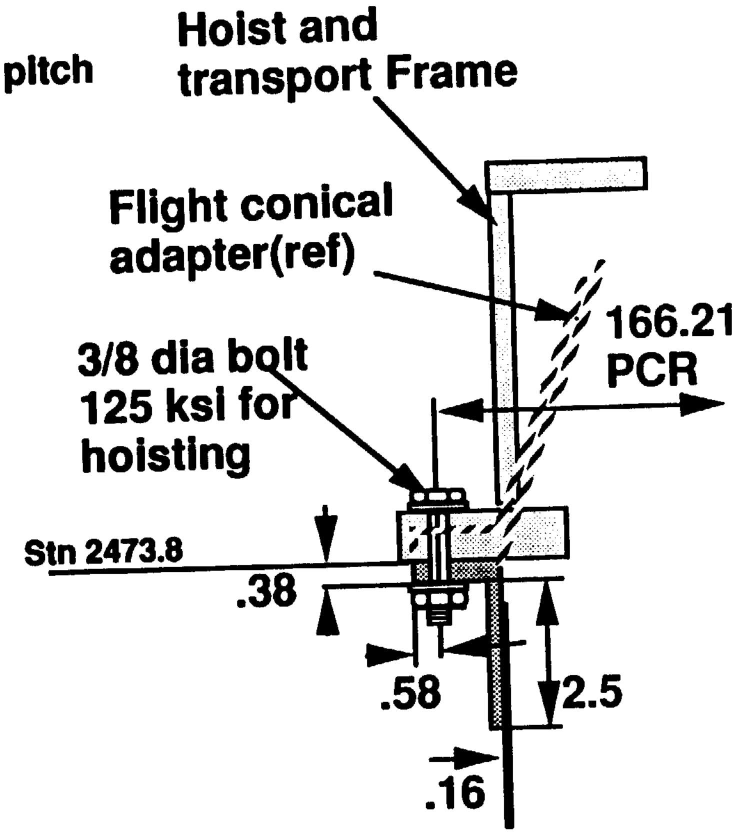
Support At Fwd Skirt

CV - DI - 01 B





Section AA

EXISTING TOOLING BOLT LOCATIONS PER ET
Bolt circle radius = 166.21

ET bolt dia 9/16
Hole dia .61 dia

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Conclusions and Recommendations CV - DI -01B

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 prefered location of the aft transportation ring

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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 andcore 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

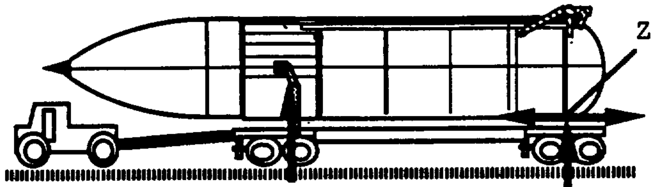
(a) Alternate transportation approach has no impact on ref.configuration core tankage sizing.
(b) Fwd ring can be attached using Fwd skirt/interstage attachment hardware holes.

Study Recommendations

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

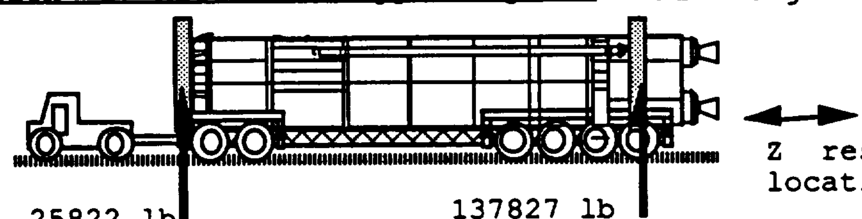
(b) Define with the aft structure panel the preferred location of the aft transportation ring.

Option 1) Et support system ET weight 66000 lb



New transporter needed:
- Heaviervehicle
- Longer vehicle
- lower vehicle clearence for roll rings.(roll rings are needed to provide access to pod engines)

Option 2) Alternate support system NLV weight 163646 lb



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

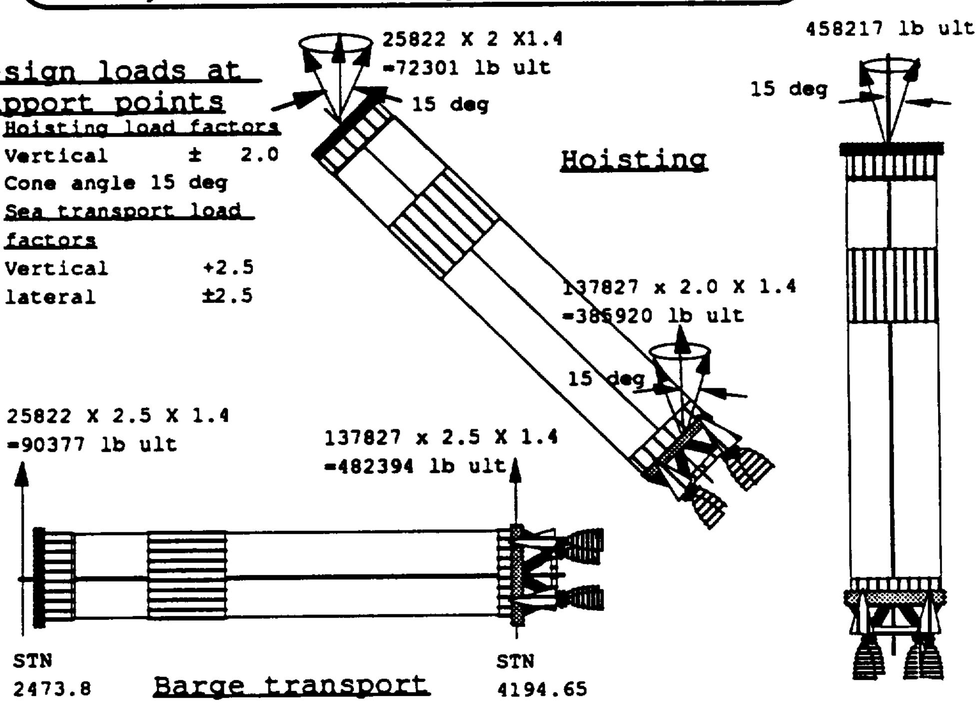
Design loads at support points

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 andcore 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 1.5stage 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.

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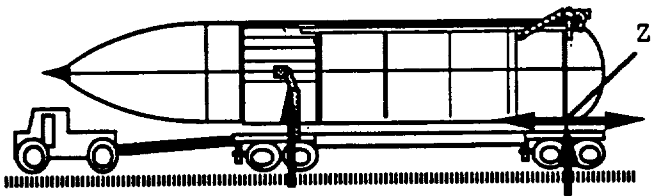
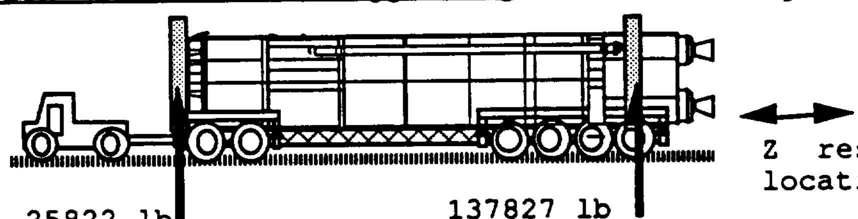


New transporter needed:
- Heaviervehicle
- Longer vehicle
- lower vehicle clearence for roll rings.(roll rings are needed to provide access to pod engines)

Option 2) Alternate support system NLV weight 163646 lb



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

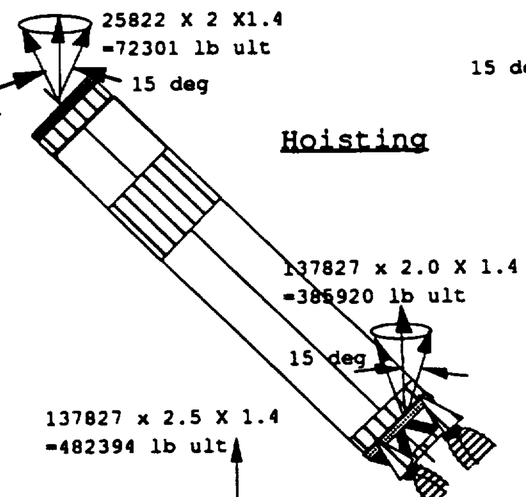
Design loads at support points

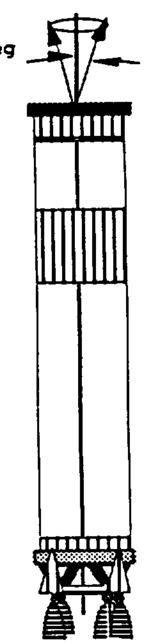
Hoisting load factors

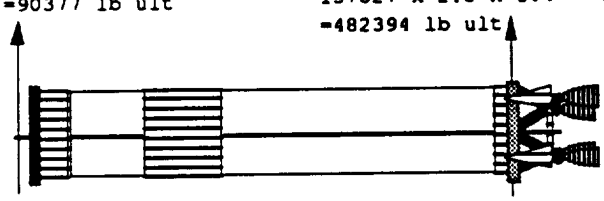
Vertical	± 2.0
Cone angle 15 deg	

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

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Fwd Skirt Design Definition CV-STR-14A

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

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Groundrules & Assumptions CV-STR-14A

Ground Rules

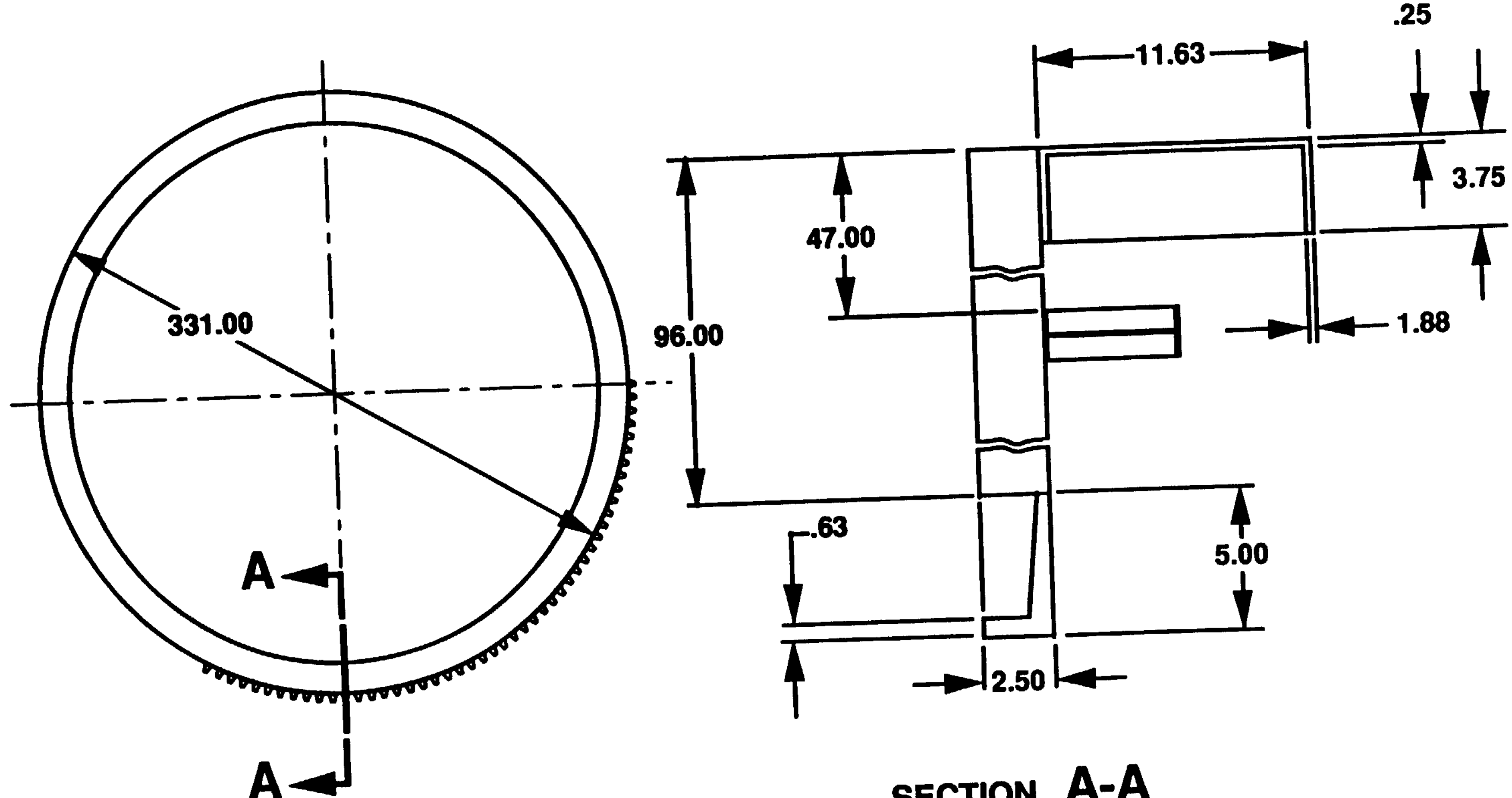
- Forward Skirt Structure Definition Per MSFC Reference Layout NLS-0008 Dated 8/27/91
- Mass Properties As Defined On 10/7/91
- Loads & Factors From Memo To P. Thomson From Bart Graham, Dated 5/10/91

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

Reference Geometry Definition CV-STR-14A

- From NLS Reference Layout NLS -0008 08/27/91



SECTION A-A

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Potential Study Items — CV-STR-14A

- 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

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Recommended Changes

CV-STR-14A

Study Item	Recommendation	Back Up Data	Wt(Lb) Impact	Status
• Alternate I/F Concept	Confirm Option 1 Feasability During Cycle 1	Append 1	- 443	Pending
• Shell Penetration Defn	Add Penetrations	Append 2	N/A	Accepted
• Stringer Pitch Dimension	Revise Method Of Dimensioning	Append 3	N/A	Incorporated
• Potential Use Of ET Tooling To Build Fwd Skirt	Use ET Tooling As Appropriate	Append 4	N/A	N/A
• Sizing Changes	(a) Incorporate 1" Of TPS (b) Incorporate Aft Chord Section	Append 5	+ 213 - 157	Accepted Accepted
• Reference Part Definition	N/A	Append 6	N/A	N/A

Incorp - Now Incorporated In MSFC Baseline Layouts
Accepted - Agreed But Not Yet Incorporated
Pending - Being Evaluated By MSFC

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CV-STR-14A
Appendix 1

- **Alternate Interface Concept**

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Alternate Interface Concepts CV-STR-14A

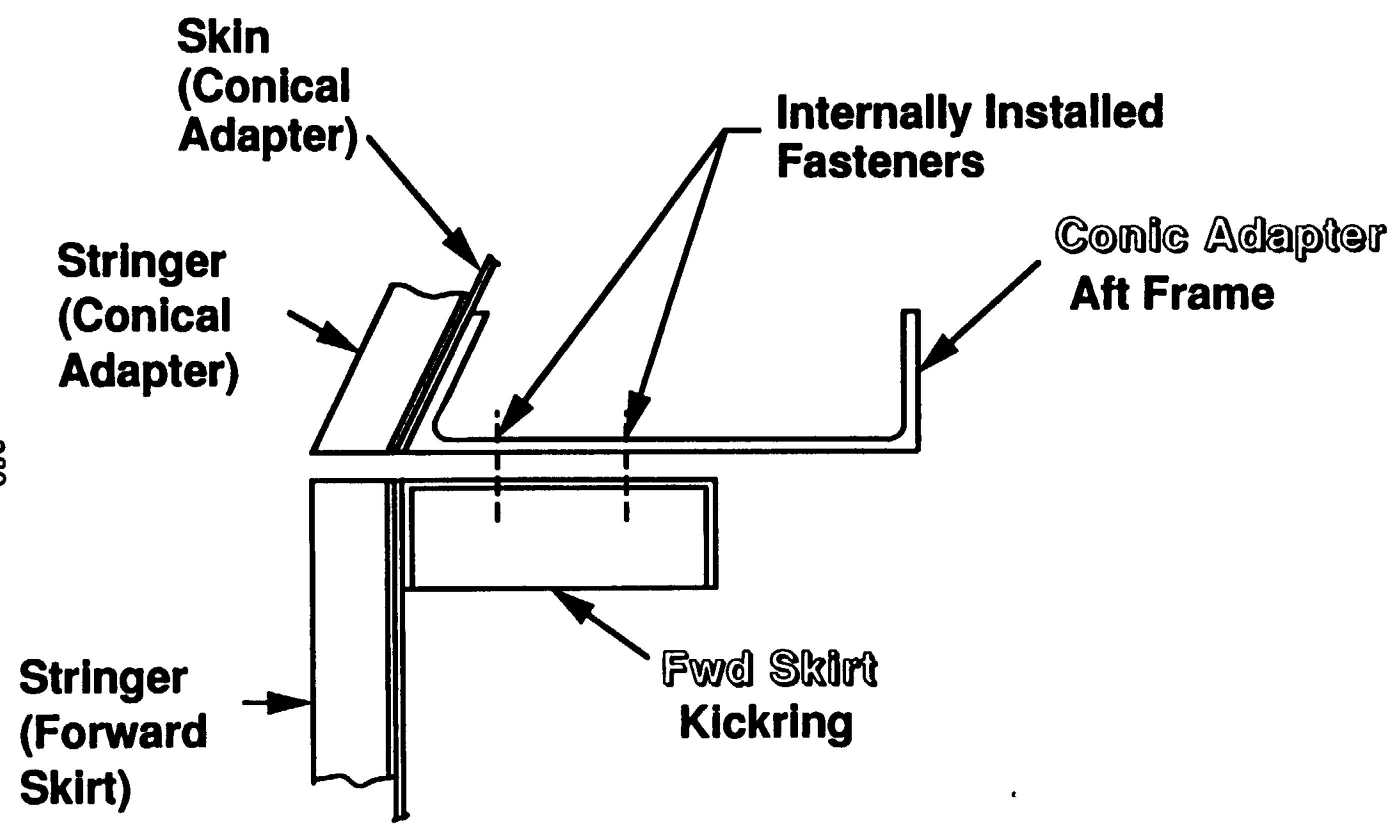
Issue

- 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

Reference Fwd I/F Attach't CV-STR-14A



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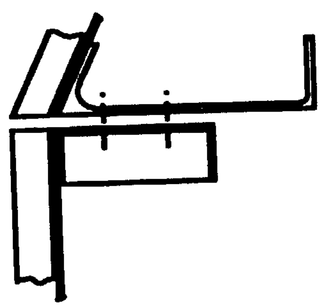
Options Studied

CV-STR-14A

Reference



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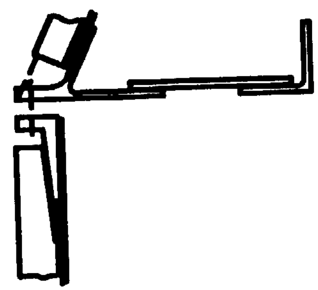

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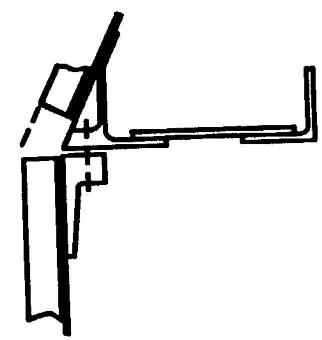

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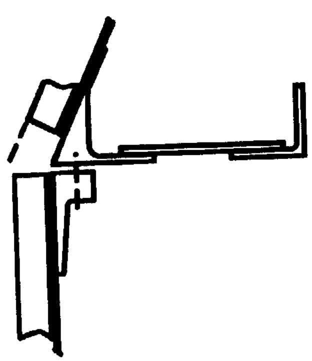

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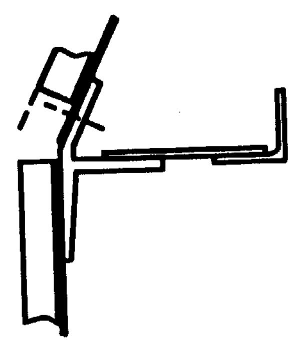

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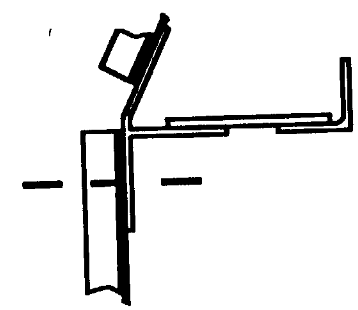

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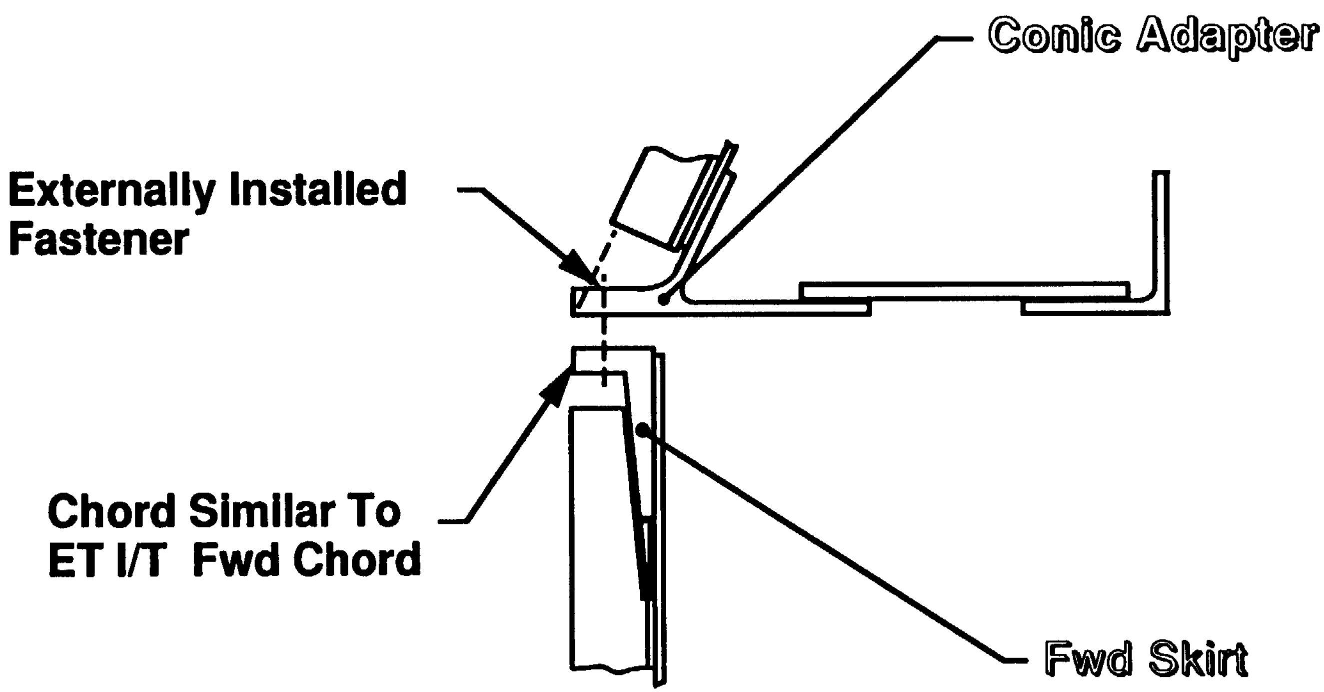
Option 1 - External I/F CV-STR-14A



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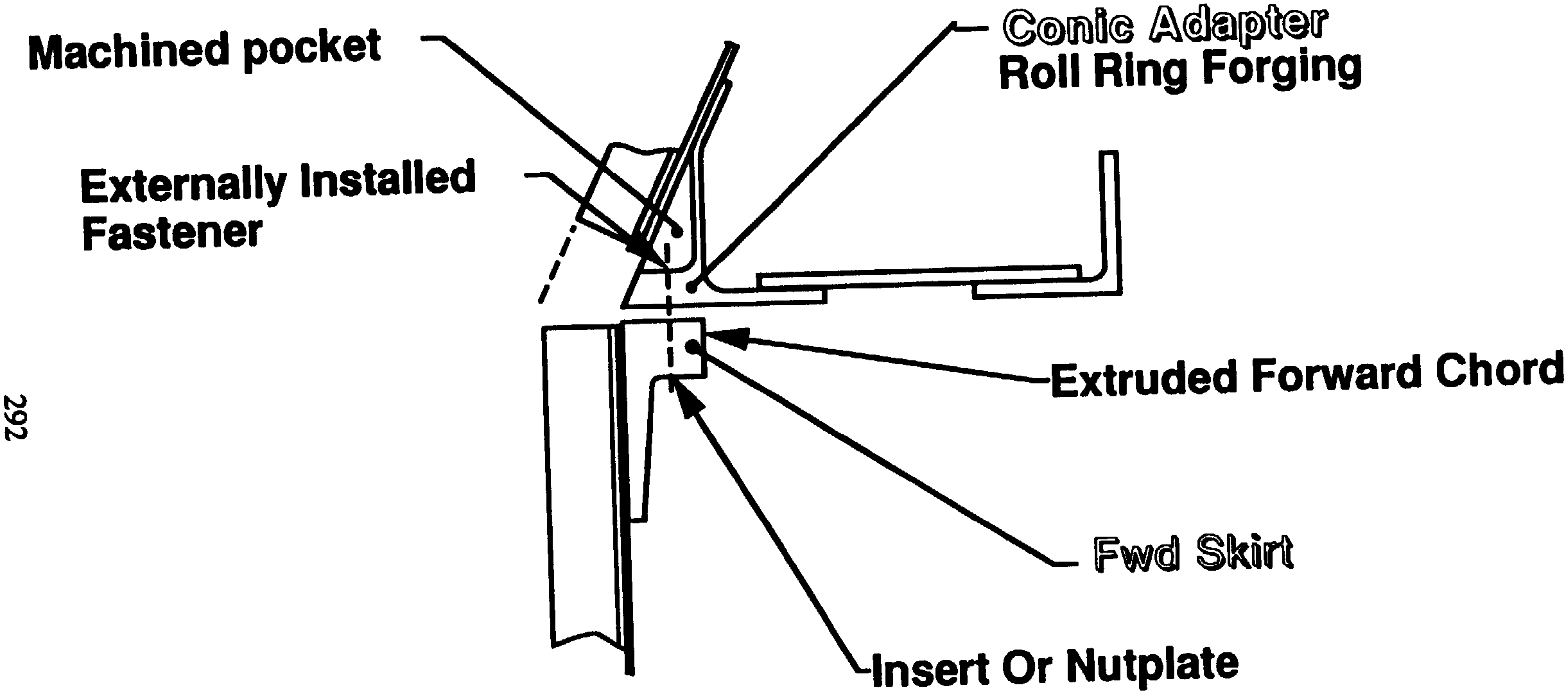
Option 2 - Recessed Ext I/F

CV-STR-14A



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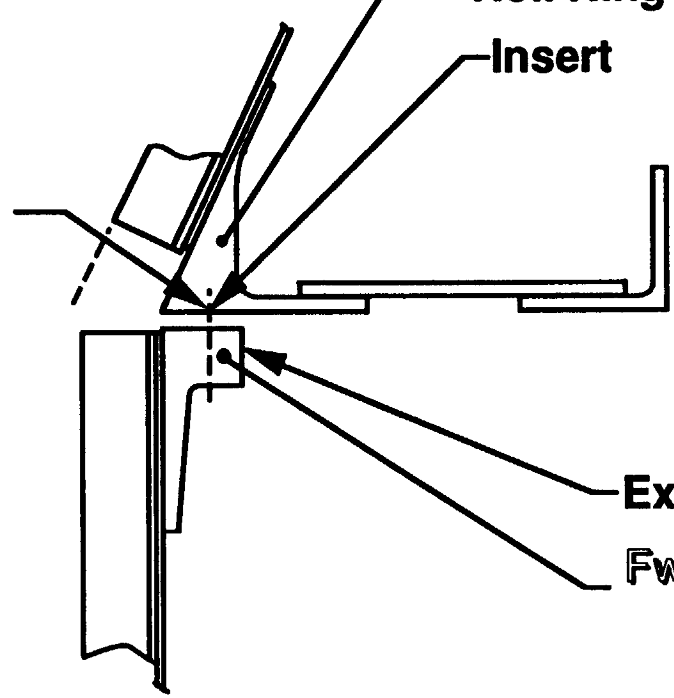
Option 3 - Internal I/F — CV-STR-14A



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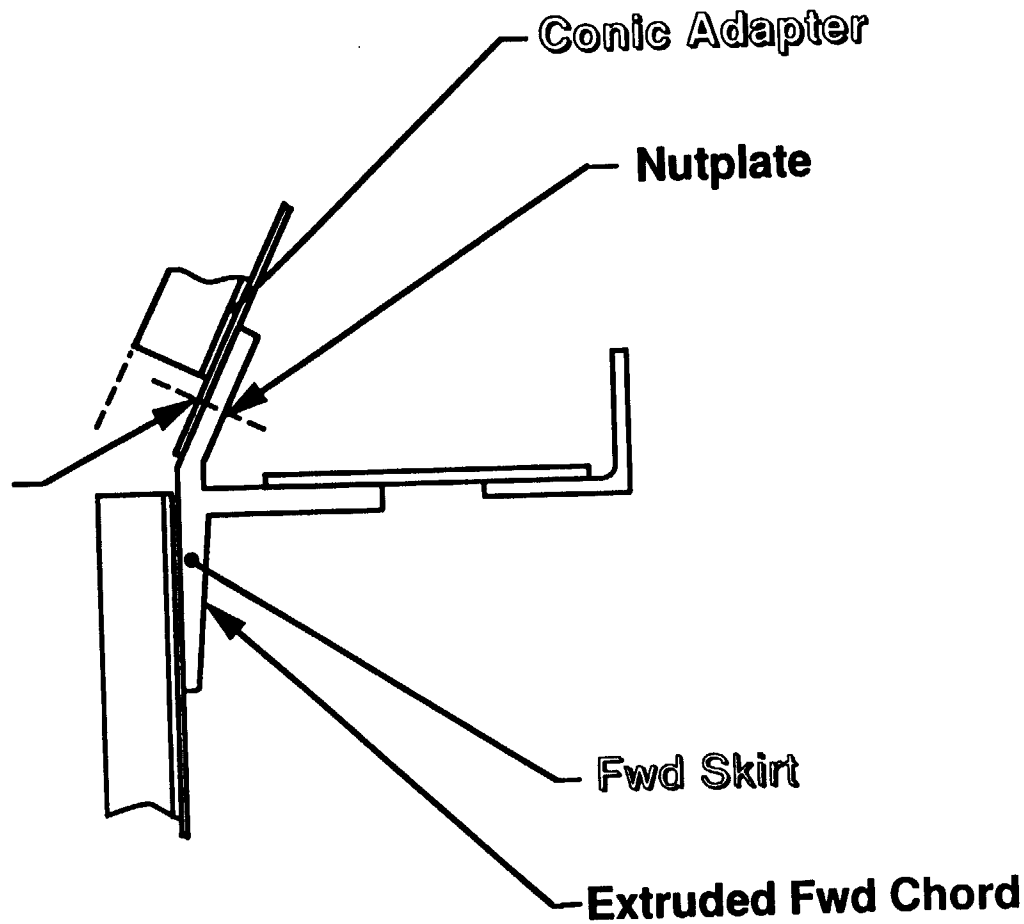
Option 4 - Conical External I/F CV-STR-14A



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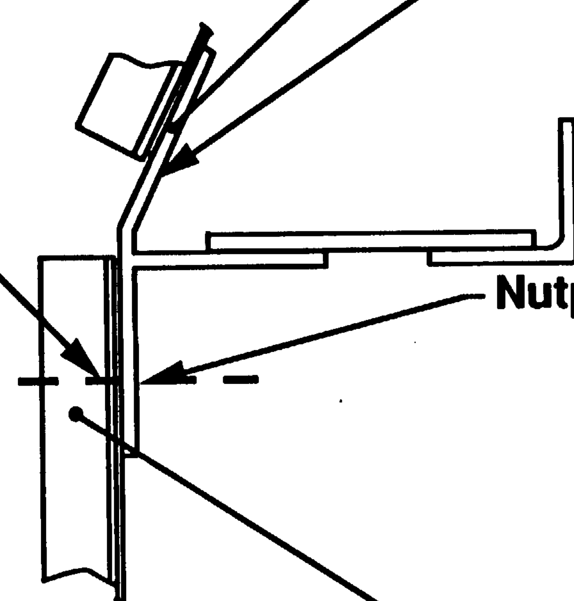
Option 5 - Cylindrical Ext I/F CV-STR-14A



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Option - Eval'n-Coarse Screen CV-STR-14A

Criteria	Reference	Option 1	Option 2	Option 3	Option 4	Option 5
H/W Instn	Internal	External	External	Internal	External	External
I/F Tooling Complexity	Simple	Better Than Reference	Similar to Reference	Similar to Reference	Complex Interface	Complex Interface
Joint Integrity	Poor	Good	Good	Good	Excellent	Exellent
Part Complexity	Reference	Simple Extrusion	R-R Forging Cmplx Mchg	Roll Ring Forging	Simple Extrusion	Simple Extrusion
Backup Ftg's Req'd	Yes Or Redesign Jnt	No	No	No	No	No
Jnt Suscept to Aero Htg	No	Yes	No - Local C/O Req'd	No	No	No
Potential Use of ET Tooling	New I/F Tool Req'd	Pot'l Use of ET Tool'g	New I/F Tool Req'd	New I/F Tool Req'd	New I/F Tool Req'd	New I/F Tool Req'd
Wt Impact to Reference	+ 41 *	- 443	-133	-133	-144	-144

* To Accommodate Bolt Offset

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Conclusions

CV-STR-14A

- 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

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Conclusions &Recommendat'n CV-STR-14A

Conclusion

- Option 1 Is Prefered
  - 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

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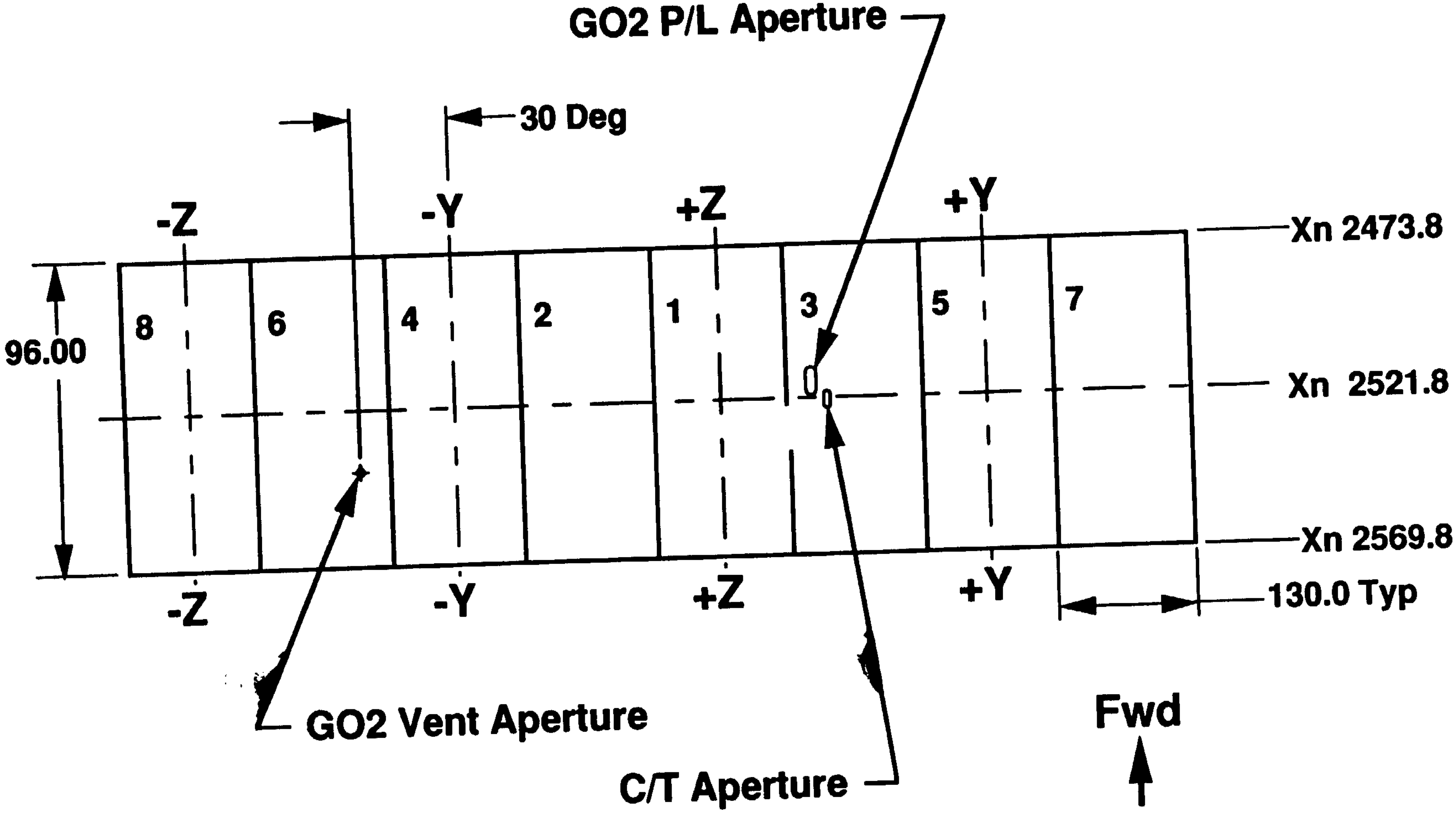
CV-STR-14A
Appendix 2

• Shell Penetration Definition

Shell Penetration Definition CV-STR-14A



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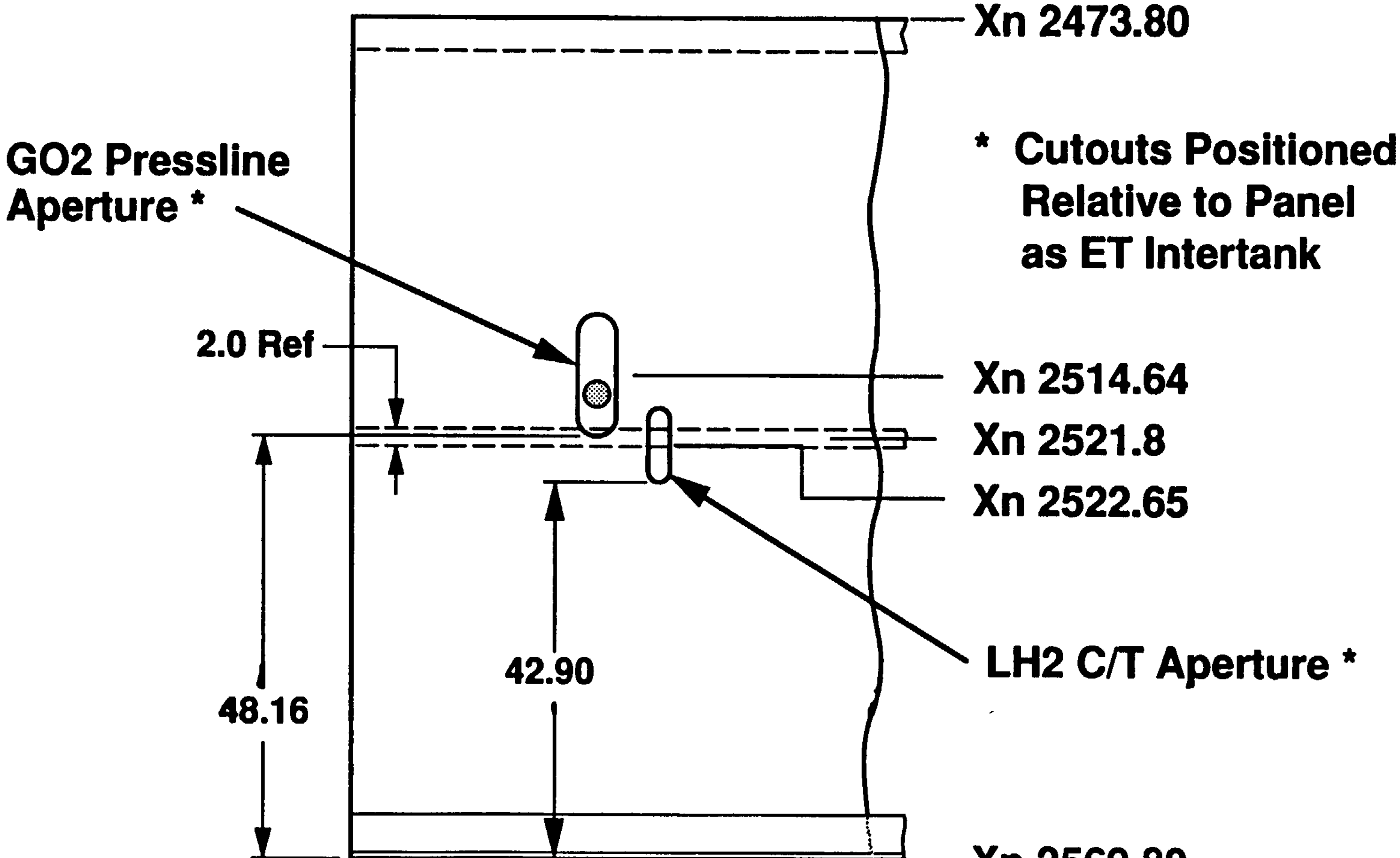
GO2 P/L Penetration CV-STR-14A

Panel #3 - NLS Ref Convfiguration



- Frame at Xn 2521.8 Interferes WithGO2 P/L & LH2 C/T Cutouts

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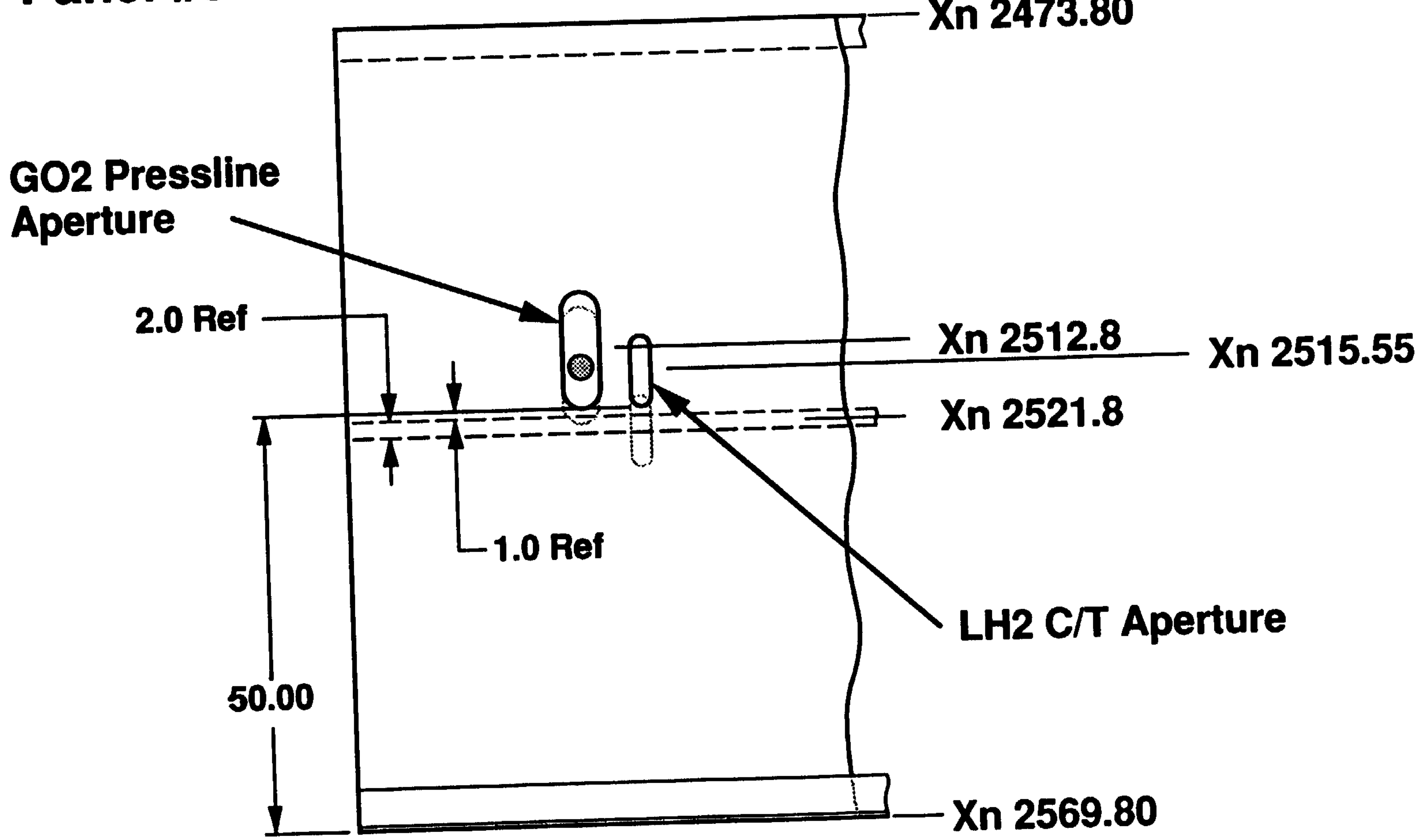
GO2 P/L Penetration

Panel #3 - Alternate Configuration



Position Cutouts & Relocate Pressline As Shown

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GO2 P/L Penetration CV-STR-14A

<u>Conclusion</u>

- Cutouts Positioned Relative to ET Intertank Interfere with Frame

<u>Recommendation</u>

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

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CV-STR-14A
Appendix 3

- **Stringer Pitch Dimensioning**

Stringer Pitch — CV-STR-14A

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

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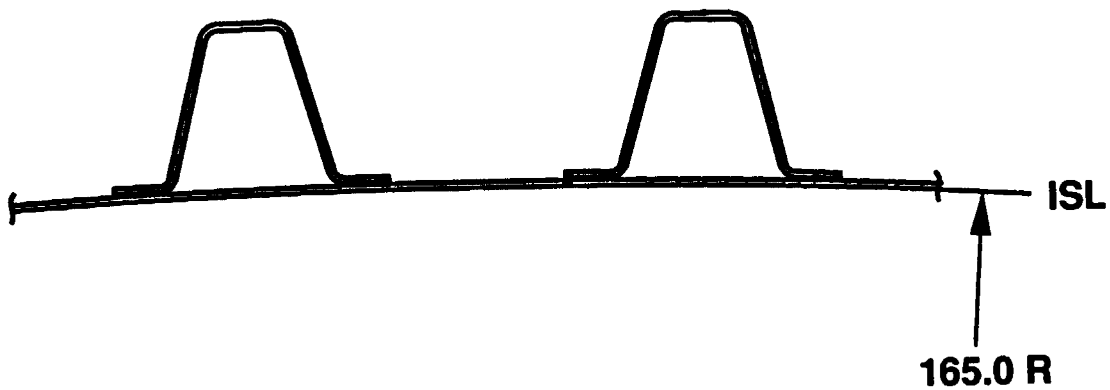
Ref Stringer Geometry

CV-STR-14A



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)

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Appendix 4

- **Use Of ET Tooling**

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Use Of ET Tooling In F/S Build   CV-STR-14A

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

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Use Of ET Tooling In F/S Build CV-STR-14A

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

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No TPS Impacts

CV-STR-14A

Issue

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

Impacts

TPS Thk	Stringer Thk		Skin Thk		Weight Impact	
	Ref.	Reqd.*	Ref.	Reqd.*	Stringer	Skin
.00	.071	.090	.063	.120	+196lbs	+569lbs

- Total Weight Impact +765lbs

* Based On Remtec Heating Data

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CV-STR-14A

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 CV-STR-14A

Issue

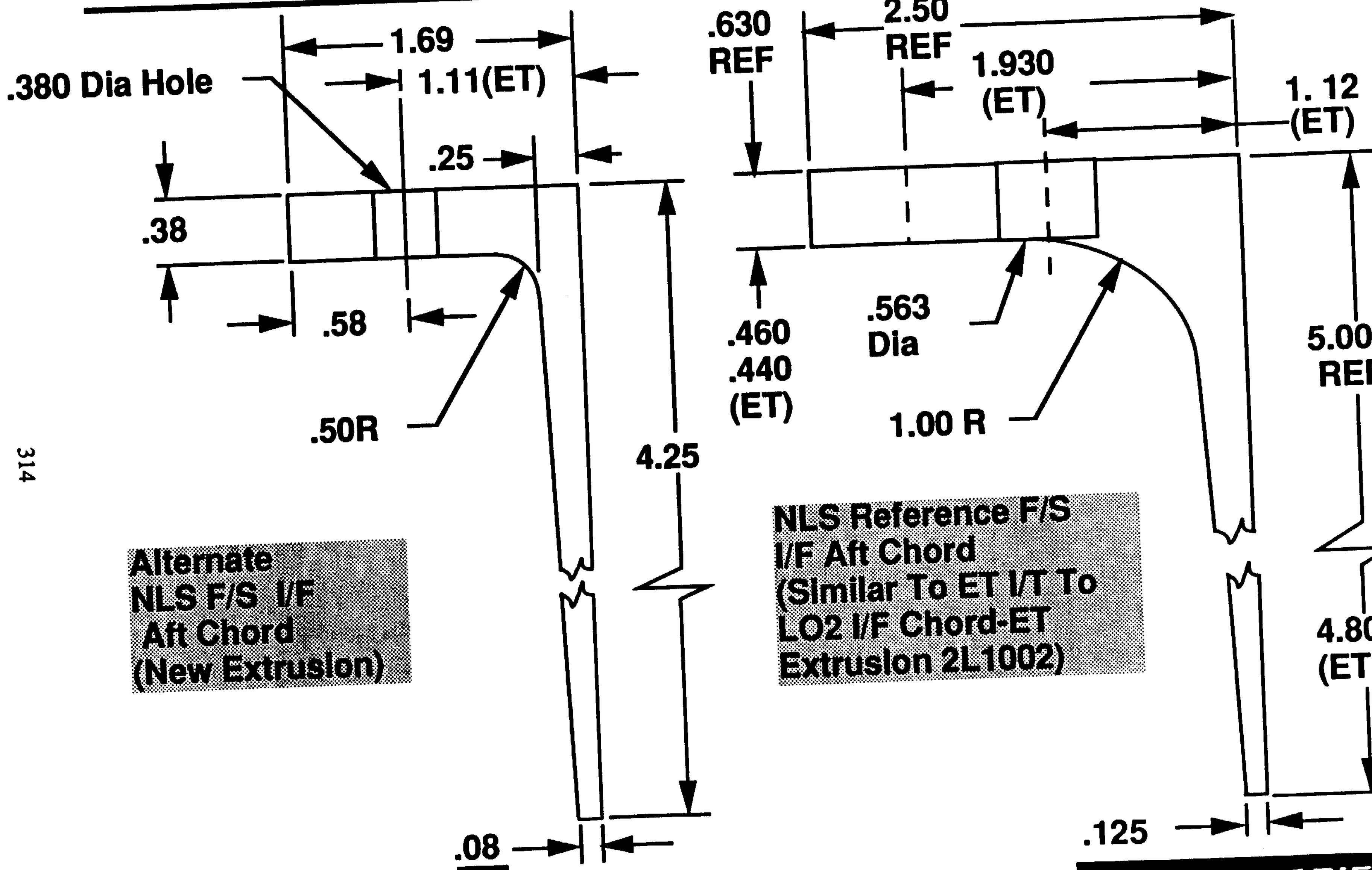
- ET Chord Used On Reference Aft Skirt I/F Is Larger And Heavier Than NLS Structural Requirements Indicated

Objective

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

Alternate Chord Section

CV-STR-14A



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F/S Alternate Chord Sect'n CV-STR-14A

Conclusions

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

Recommendation

- Incorporate Alternate Chord In Cycle 1 Baseline

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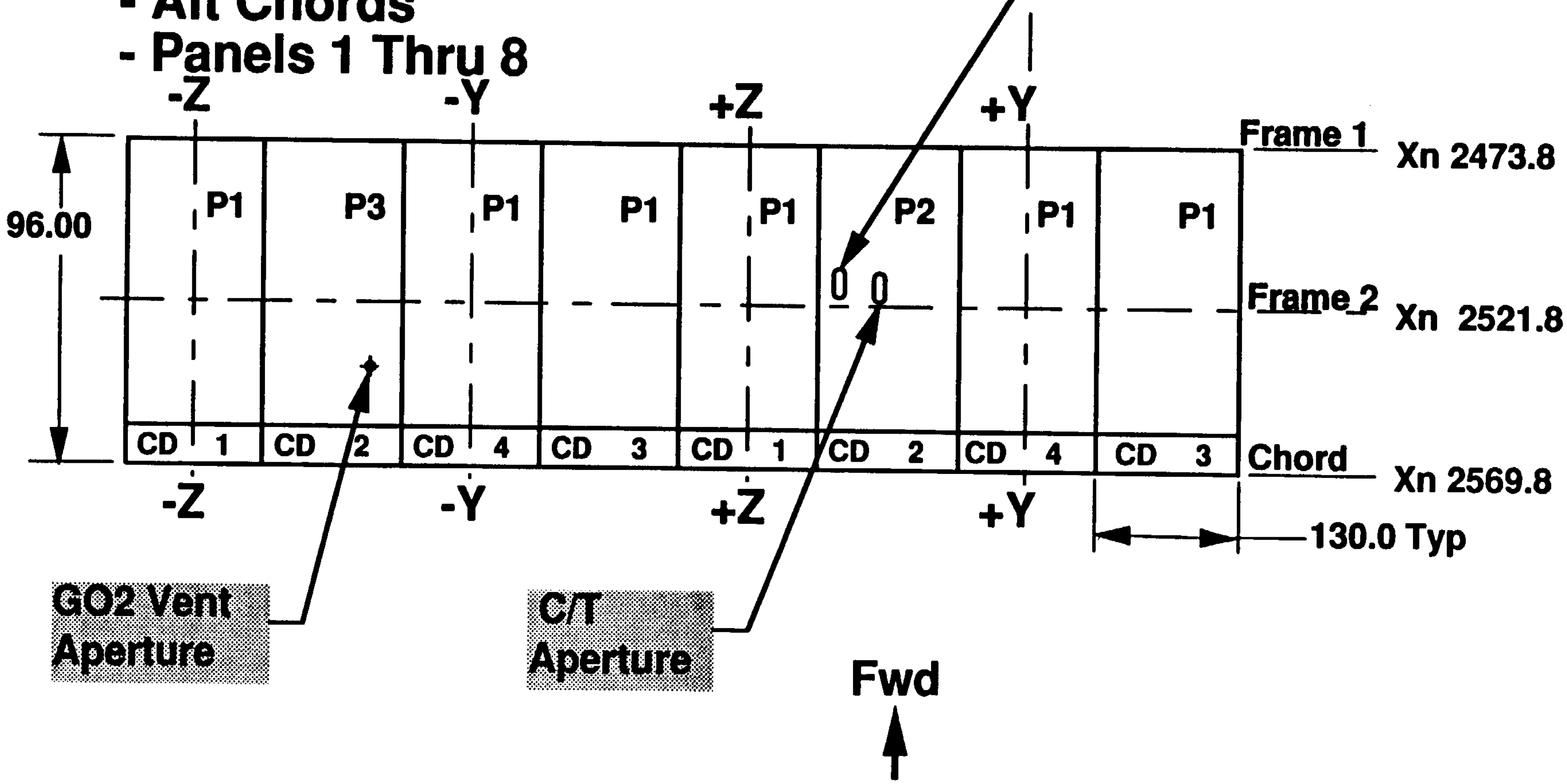
CV-STR-14A
Appendix 6

- **Fwd Skirt Part Definition**

Fwd Skirt Sructural Definition CV-STR-14A

Shell Definition

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



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Fwd Skirt Panel Definition

CV-STR-14A

Part	Title	Part Status			Remarks
		ET	Mod.	New	
P1	Panel 1			√	Panels 1,2,4,5,7 & 8 Are Identical.
P1	Panel 2			√	
P1	Panel 4			√	
P1	Panel 5			√	
P1	Panel 7			√	
P1	Panel 8			√	
P-2	Panel 3			√	Panel 3 Is Unique. Cutouts For C/T, GO2 Press Line Penetrations Are Located In This Panel.
P-3	Panel 6			√	The GO2 Ventline Penetration Is Located In Panel 6

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F/Skirt Aft Chord & Frame Def'n CV-STR-14A

Part	Title	Part Status			Remarks
		ET	Mod	New	
CD 1	Chord, Aft, Panel 1 & 8		√		Similar To ET I/T Forward Chords(I/F I/T To LO2 Tank) (CD 1 – CD 3)
CD 2	Chord, Aft, Panel 3 & 6		√		
CD 3	Chord, Aft Panel 2 & 7		√		
CD 4	Chord, Aft, Panel 4 & 5		-	√	Similar To ET I/T Chord But With Revised Hole Pattern
F1	Frame 2473.8			√	
F2	Frame 2521.8			√	

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Candidates For Further Study — CV-STR-14A

- 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

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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).

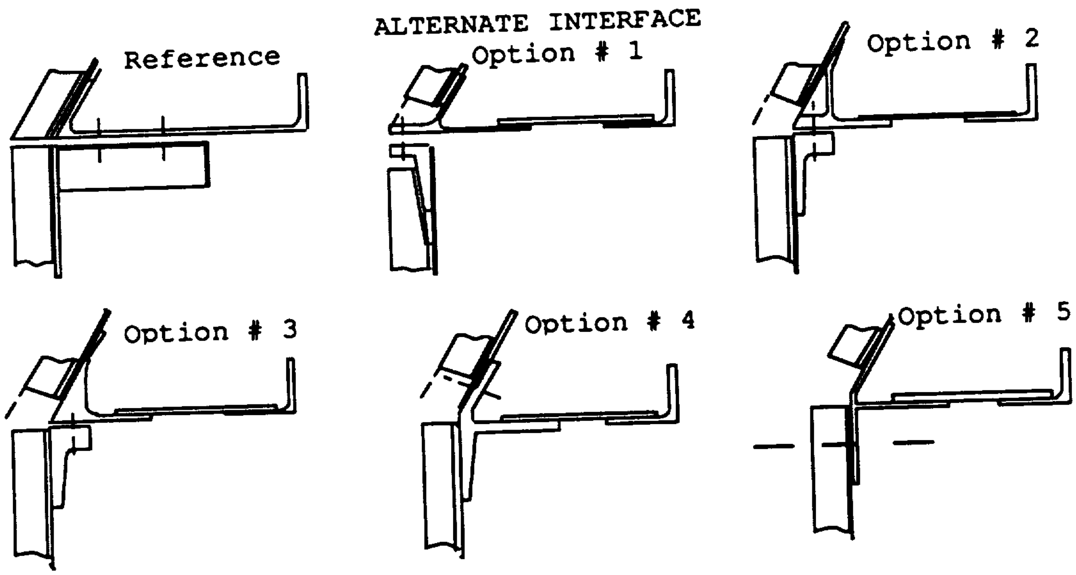
Conclusions

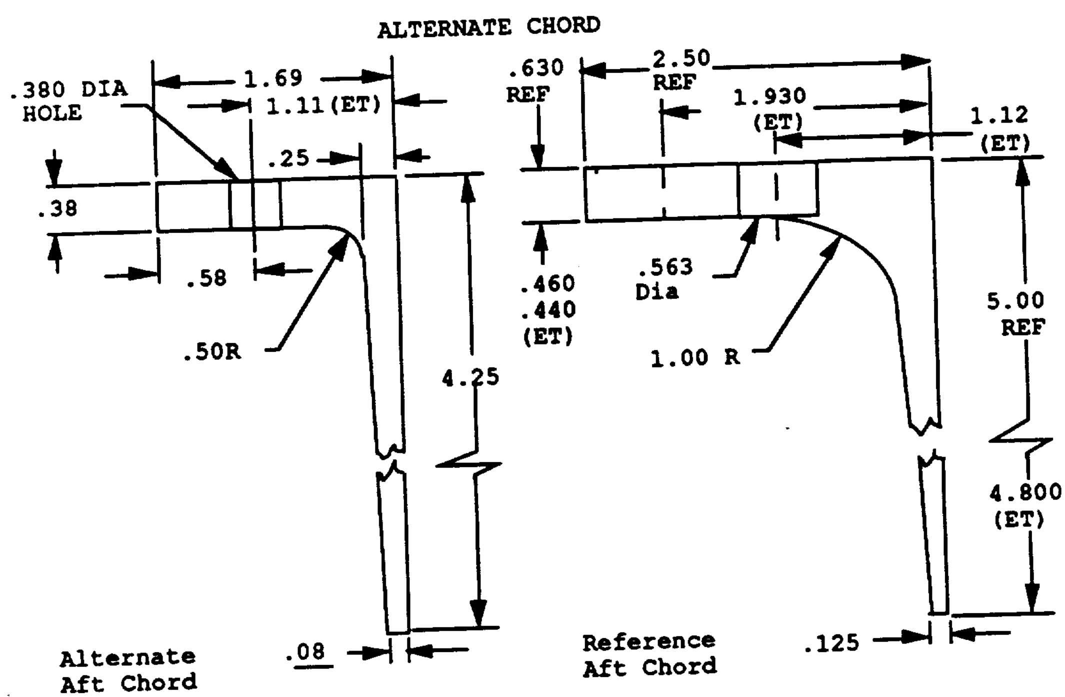
Several enhancements to the Cycle Ø Fwd Skirt structure definition were studied. Incorporation of these enhancements will reduce weight by 600 lbs and improve producibility. In addition, the potential use of ET Intertank tooling for Fwd Skirt fabrication was confirmed.

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.





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.
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 6.2.1.4.3).
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 6.2.1.4.2).

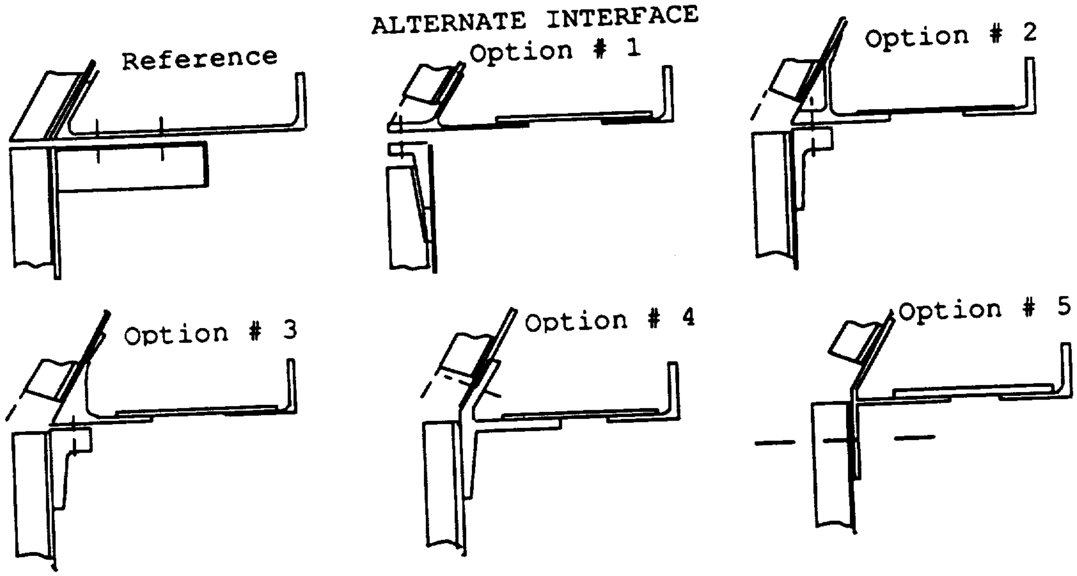
Conclusions

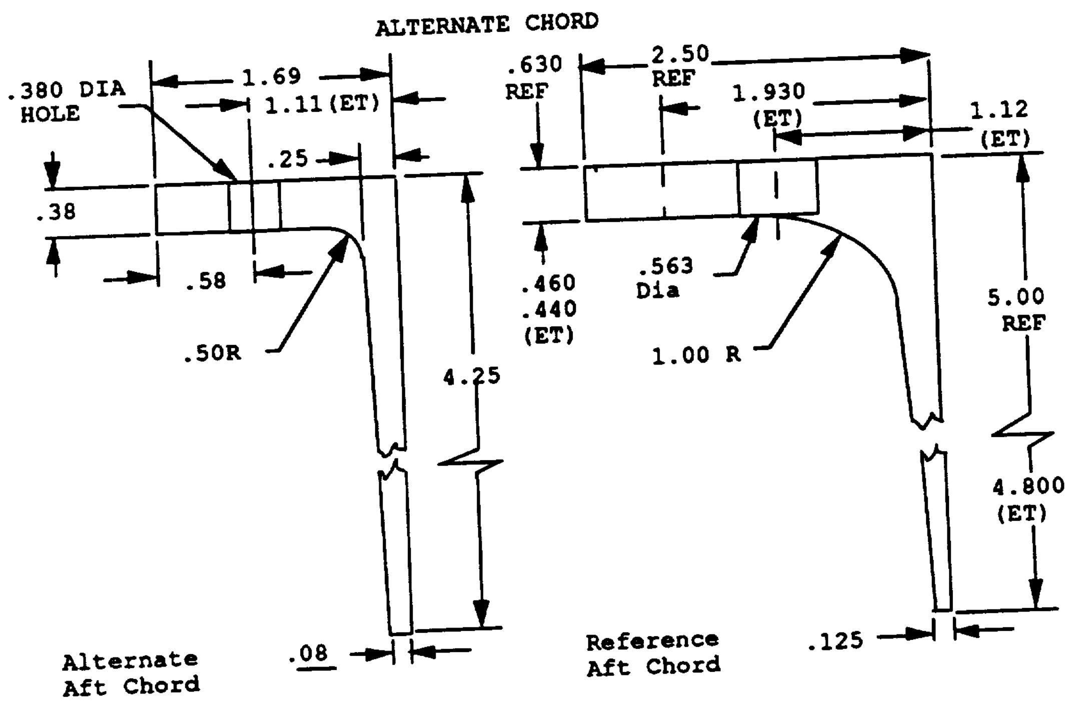
Several enhancements to the Cycle Ø Fwd Skirt structure definition were studied. Incorporation of these enhancements will reduce weight by 600 lbs and improve producibility. In addition, the potential use of ET Intertank tooling for Fwd Skirt fabrication was confirmed.

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.





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

Approved By: M. R. Simms

Rev: Initial
Date: January 8, 1991

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NLS LO2 Tank Definition CV-STR-14B

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

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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 — CV-STR-14B

- 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

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Recommended Changes CV-STR-14B

Study Item	Recomendation	Back Up Data	* Wt. Impact	Status
Barrel/Frame Geom.	Use New Geom & Frs	Append. 1	N/A	Incorp.
Alt. Fwd Chord & Fr.	Change Chord , Fr, & Geom	Append. 2	-47 lbs	Incorp.
Reference Baffle Def.	Incorporate Option 3	Append. 3	774 lbs	Accepted
Anti-Vortex Baffle Def.	Incorporate Into Ref	Append. 4	50 lbs	Accepted
Ext. Hardware I/F's	Incorporate Into Ref	Append. 5	18 lbs	Accepted
Ch./Barrel Weld Lands	M/c Chord Weld Lands	Append. 6	N/A	Incorp.
Ref Part Definition	N/A	Append. 7	N/A	N/A

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

* Weight Impacts Include 8% Contingency

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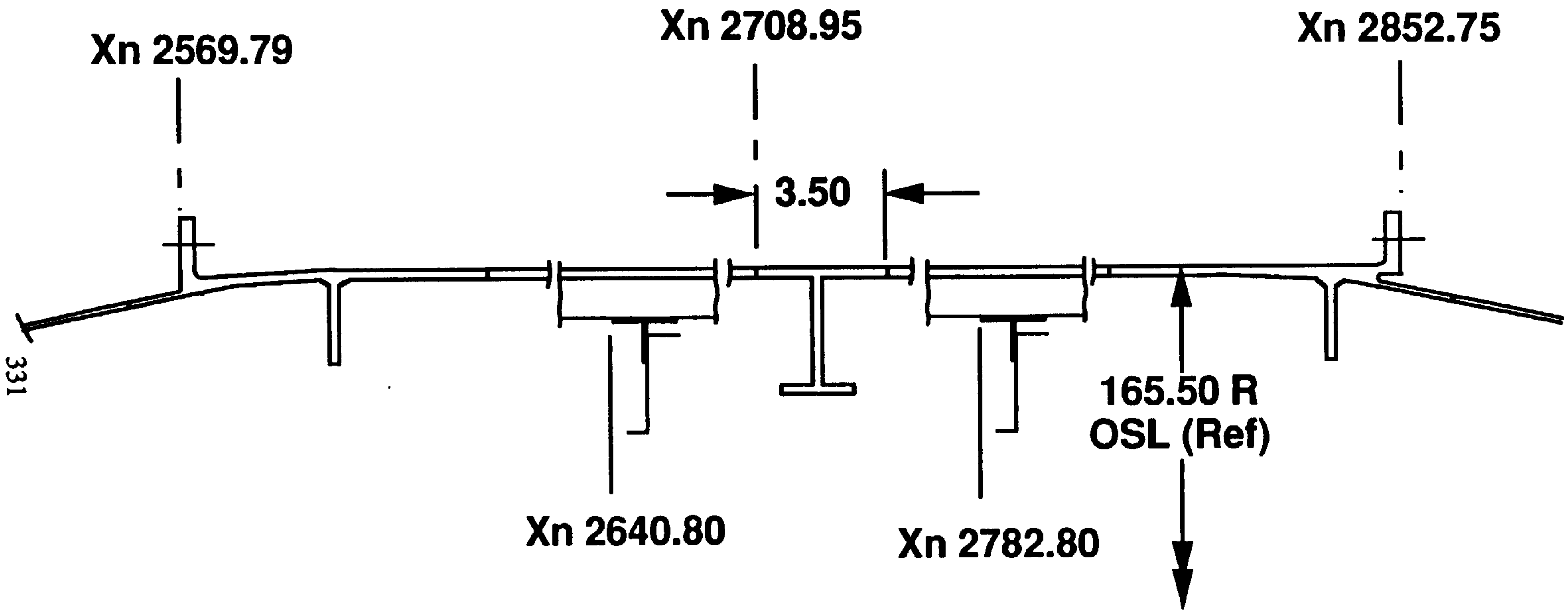
CV-STR-14B
Appendix 1

- **Barrel/Frame Geometry Definition**

Reference Geometry Definition   CV-STR-14B



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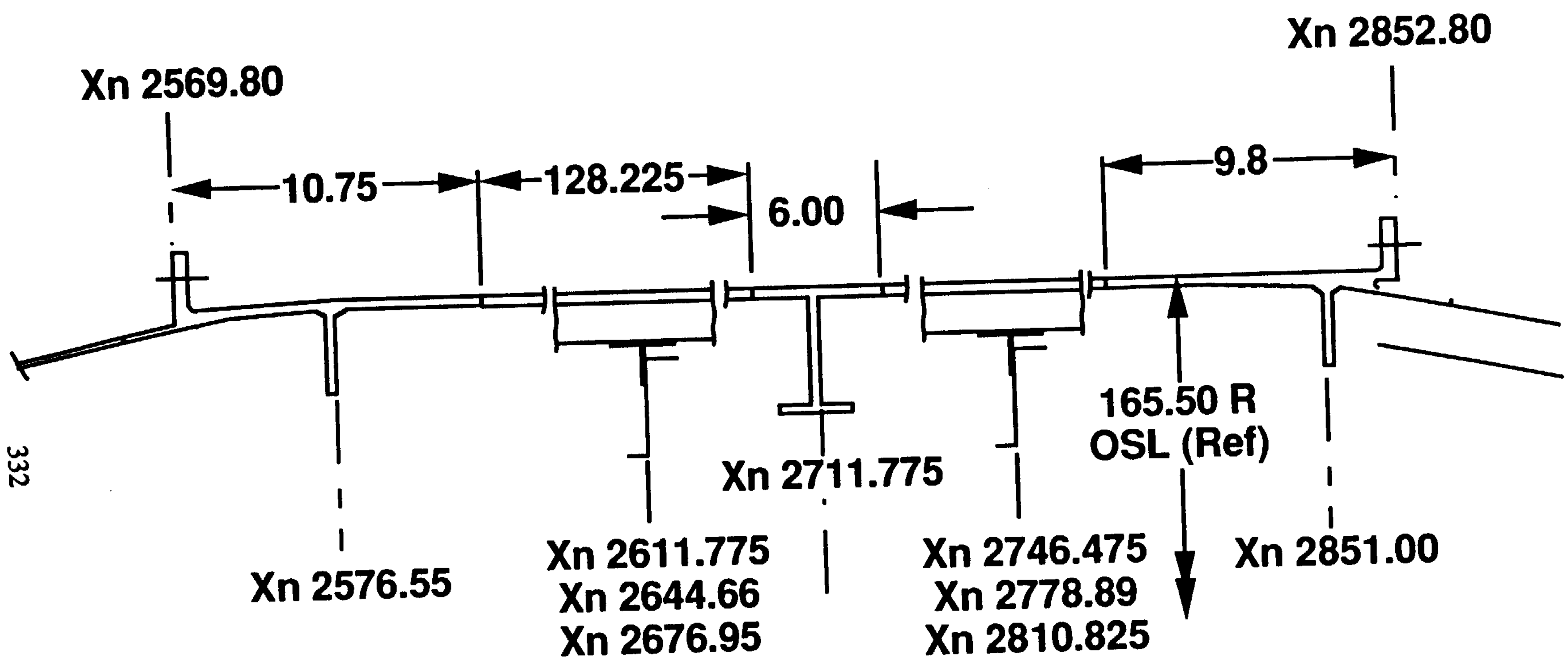
Proposed Geometry Definition CV-STR-14B



Note : See Appendix 2 For Further Update To This Proposed Geometry

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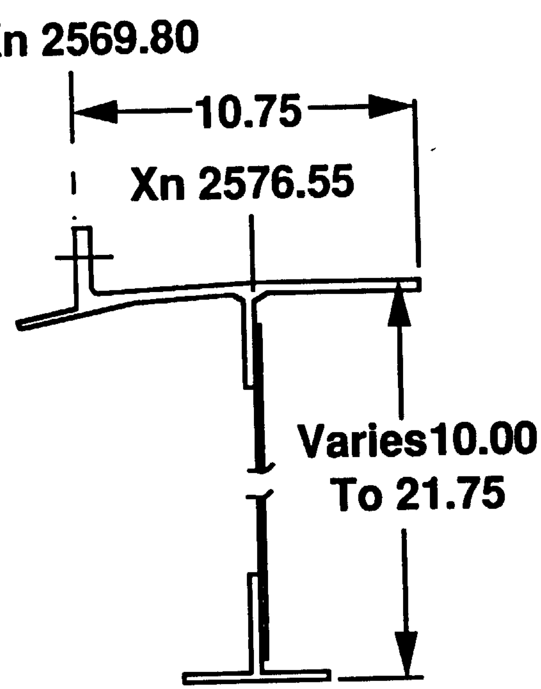
CV-STR-14B
Appendix 2

- **Substitution Of Alternate Fwd Dome Chord & Frame (Including Geometry Update)**

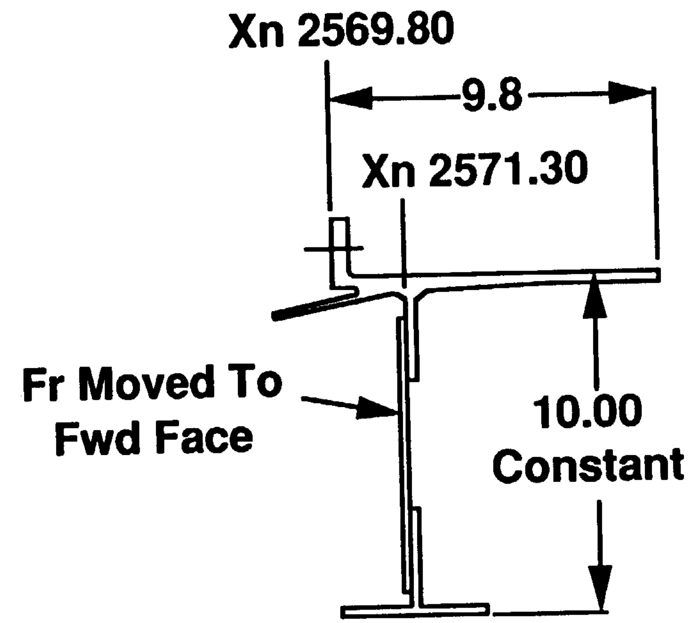
Alt. Fwd Dome Chord & Frame CV-STR-14B

Reference Fwd Dome Chord



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

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)

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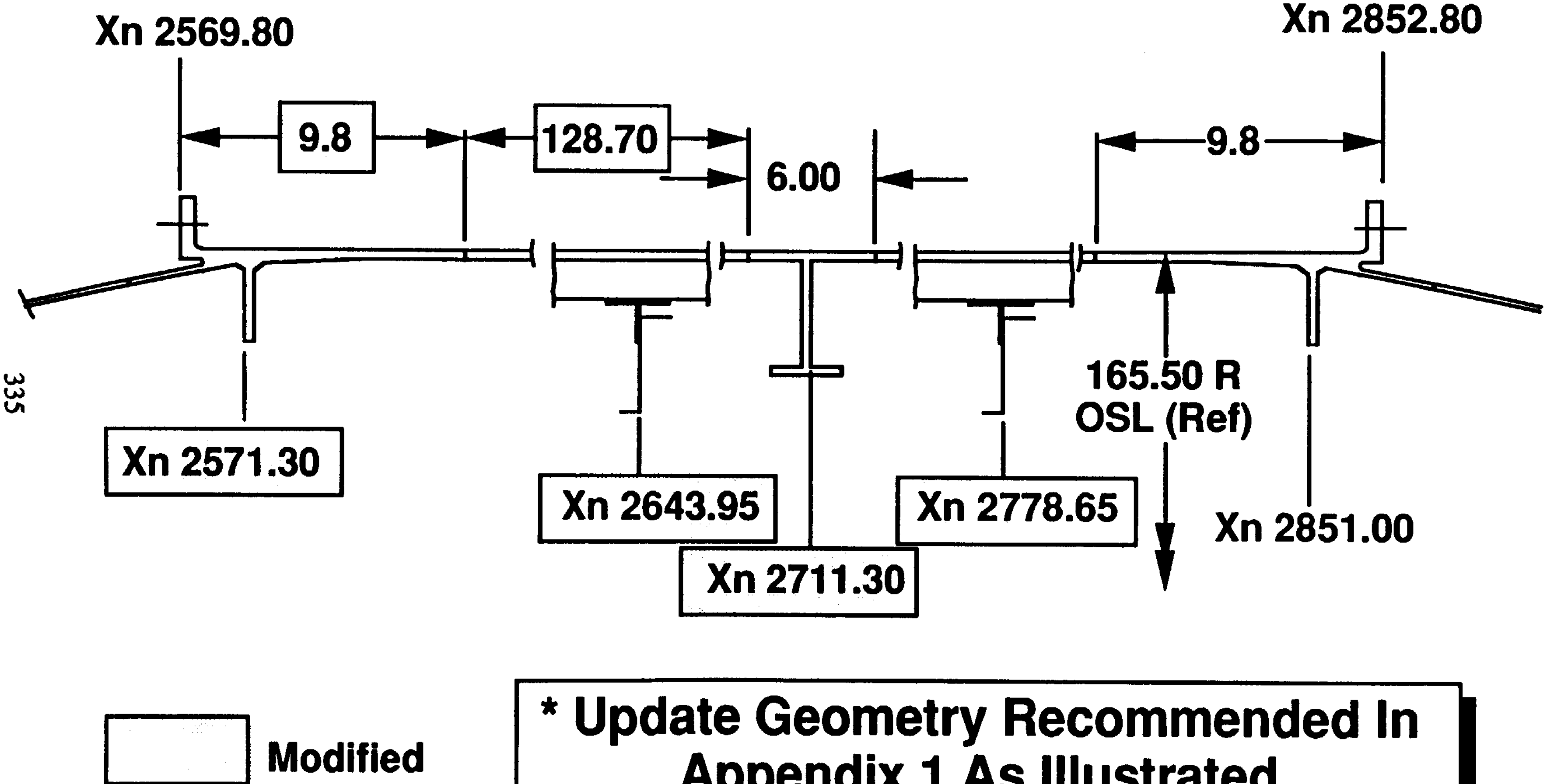
Alt. Fwd Dome Chord & Frame CV-STR-14B

Modified Geometry*



* Update Geometry Recommended In Appendix 1 As Illustrated

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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

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Appendix 3

- **Definition Of Reference Slosh Baffle Design**

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Definition

Definition

- efinition Is ET LO2 Tank Baffles "As Is" onfiguration & ET Slosh Baffle Usage
- Authority Requirements For Slosh idered To Date
- ffle Design Configurations
  - ice "As Is" ET Configuration
  - Baffle - Aft Barrel Only
  - Baffle - Both Barrel Length
  - osh Baffle Definition For Reference
- osh Baffle Approach Using Ring Frames Is Being Studied Under 3-S-011

Damping Criteria — CV-STR-14B

- 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

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Damping Criteria Explanation   CV-STR-14B

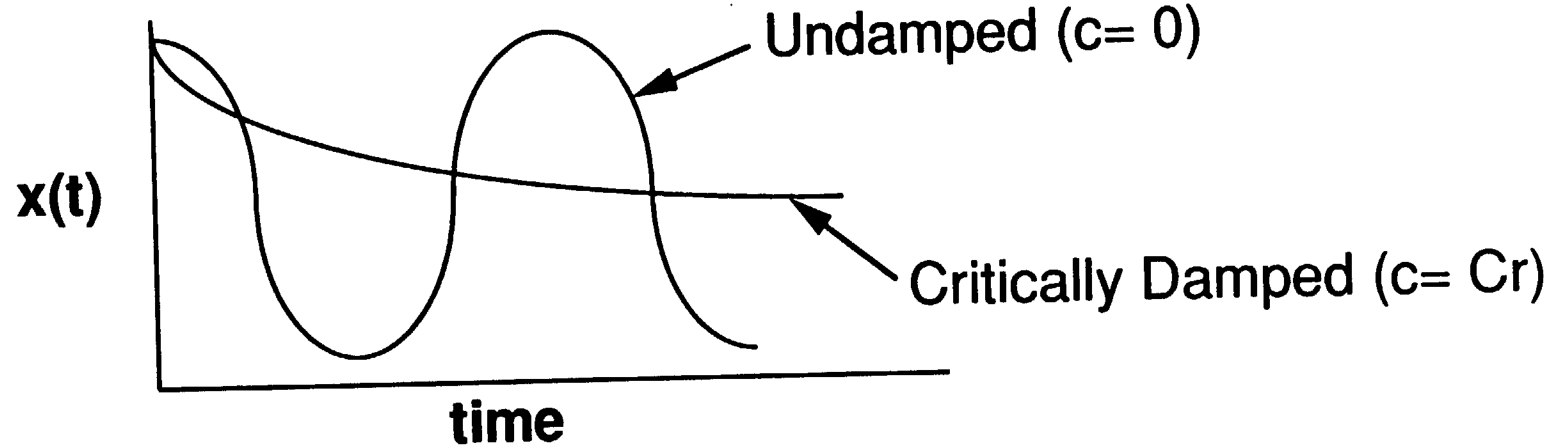
- Simple Single Degree Of Freedom Equation of Motion

$$M\ddot{x} + c\dot{x} + kx = F$$

Natural Frequency = $w = \sqrt{k/M}$

Critical Damping = $Cr = 2k/w$

- 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.: $c = 0.01Cr$

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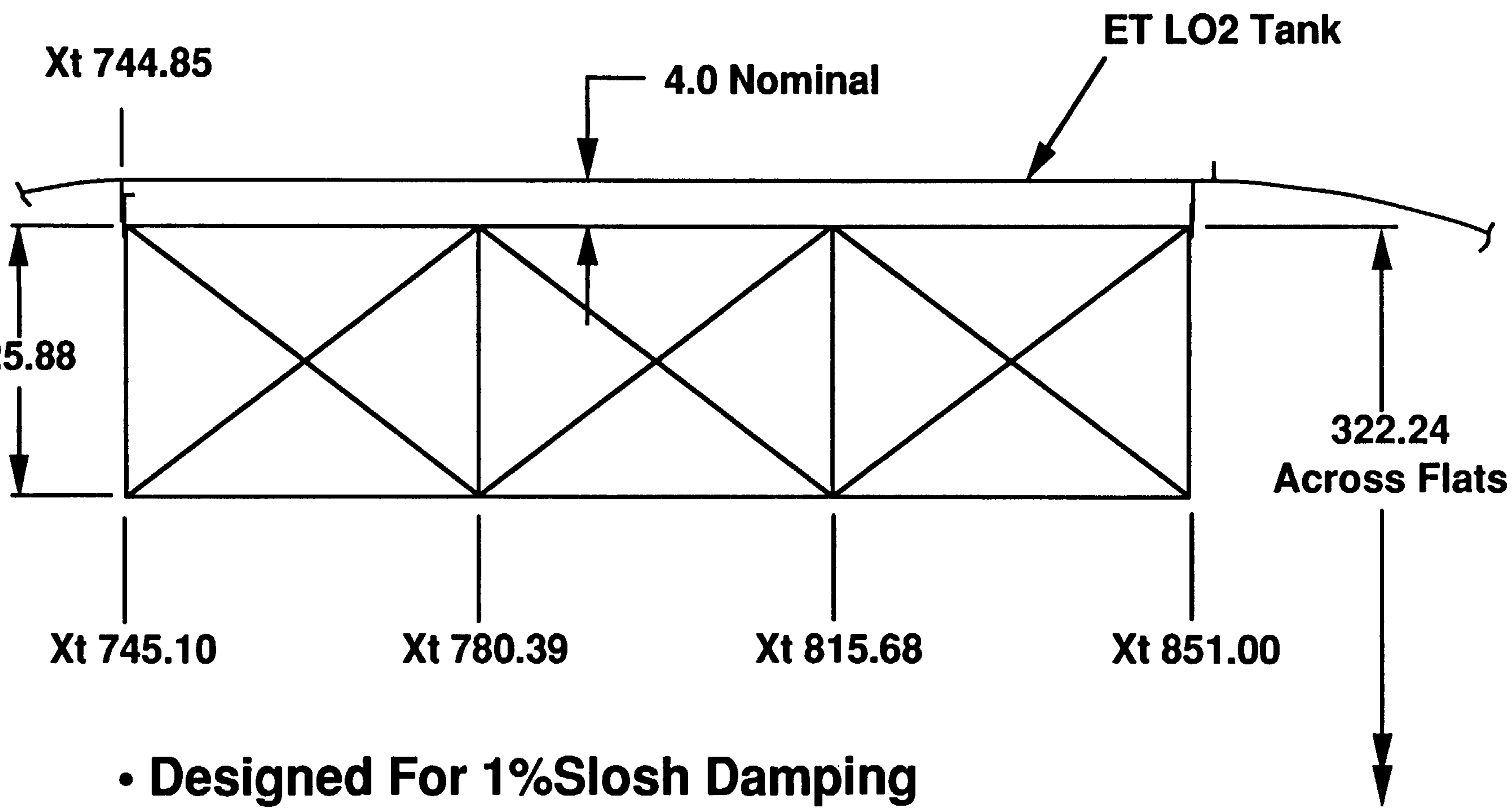
ET Baffle Definition CV-STR-14B



• Designed For 1%Slosh Damping

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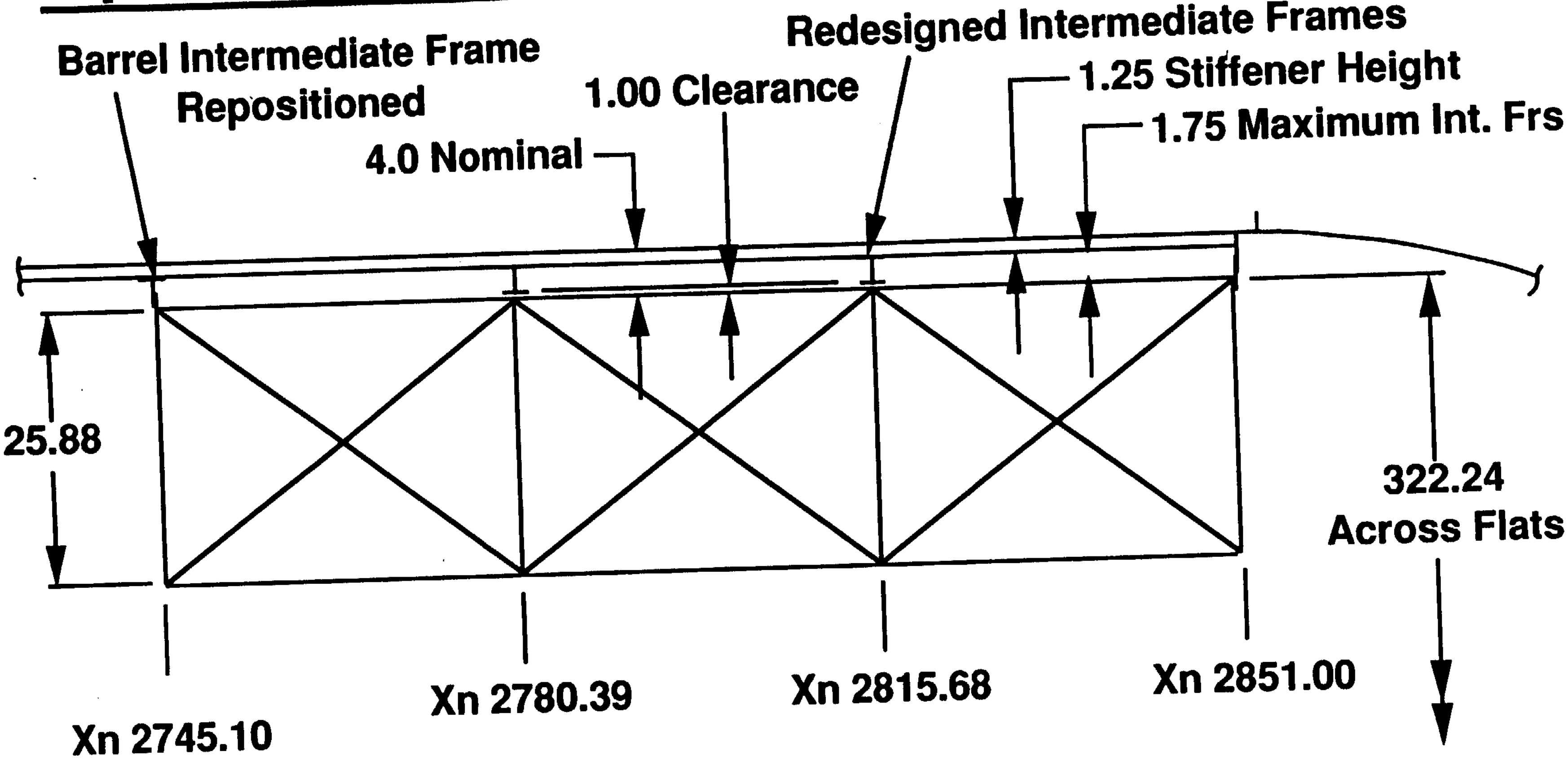
Opt 1, ET Baffles

CV-STR-14B



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

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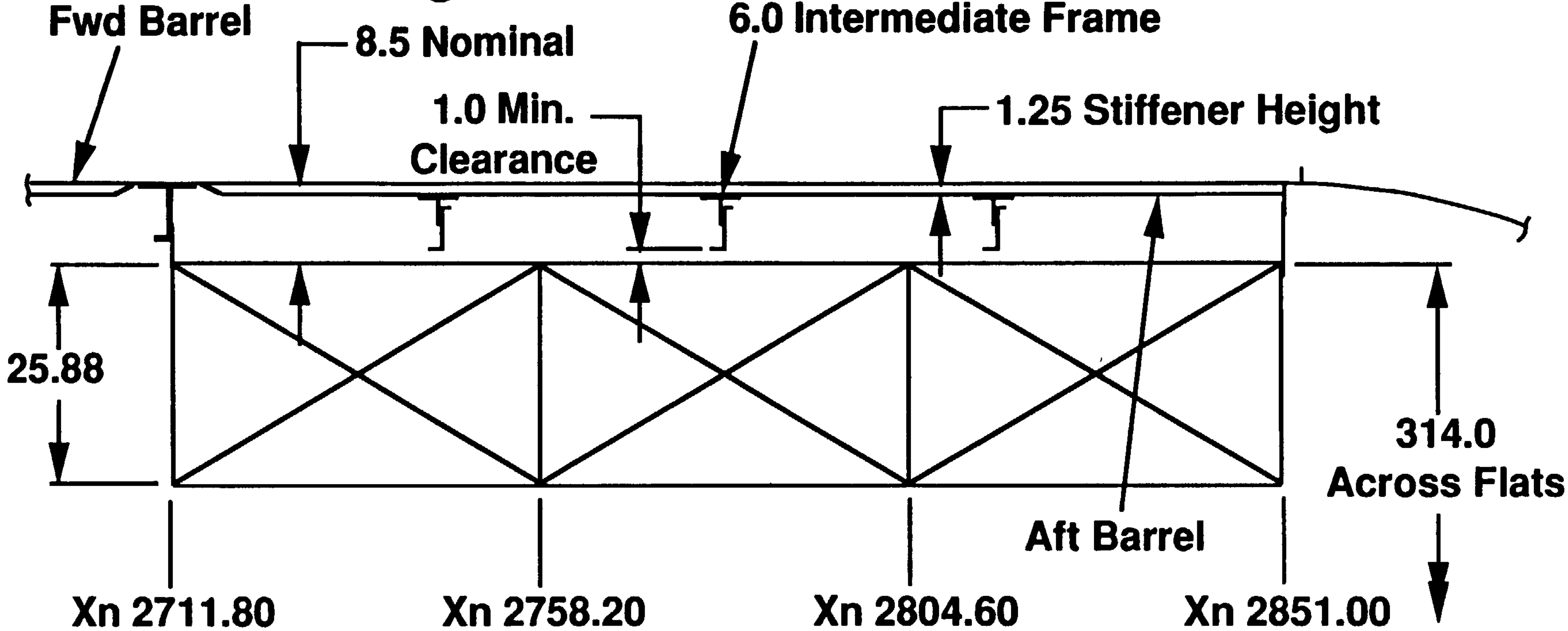
Opt 2 - Extended ET Type Baffles CV-STR-14B

- 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

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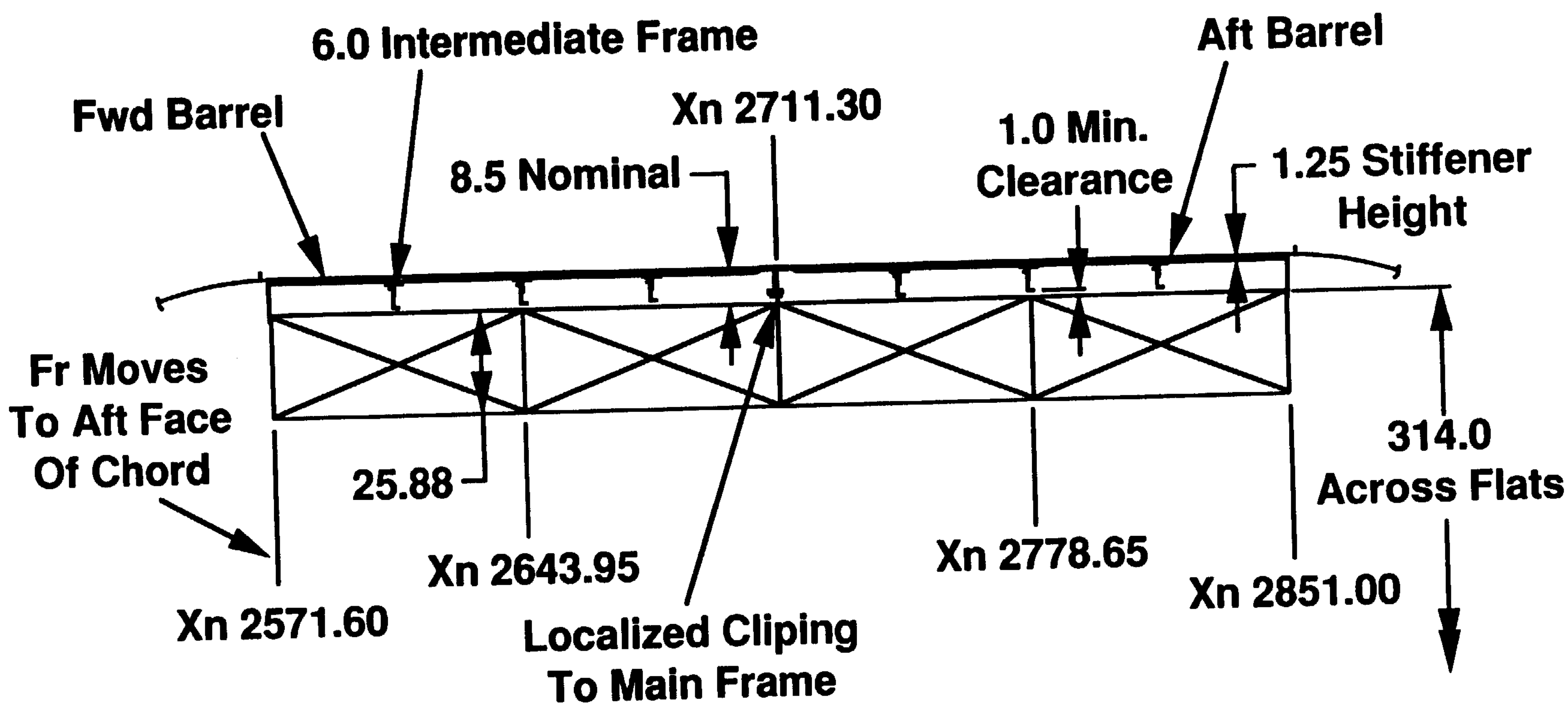
Opt 3 - Extended ET Type Baffles CV-STR-14B



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

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Option Evaluation CV-STR-14B

Opt.	Remarks	Weight Impact	Meets Baffle Reqmts	
			1.5 Stage	HLLV
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

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Recommendation CV-STR-14B

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%

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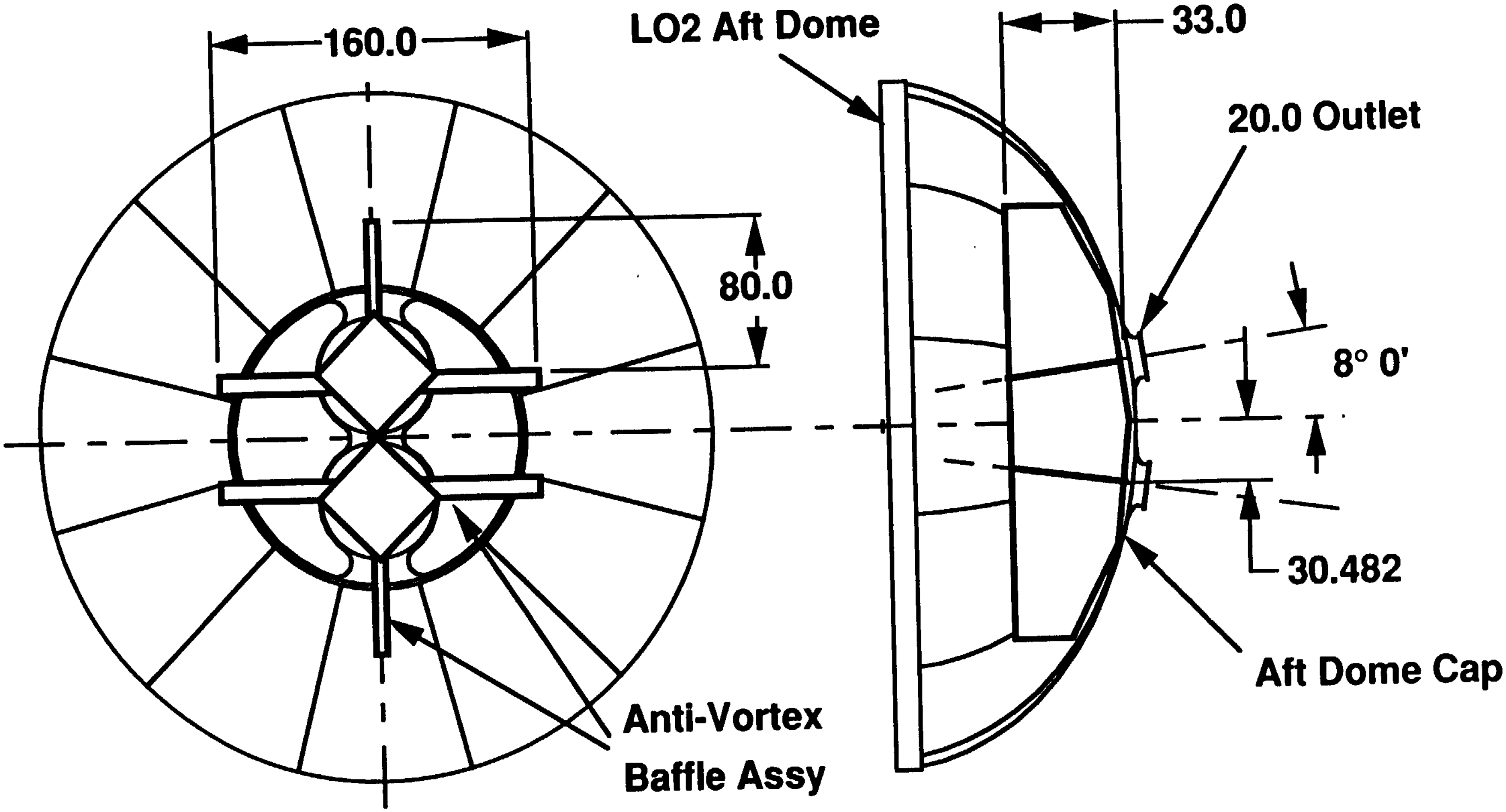
CV-STR-14B
Appendix 4

- **Definition Of Reference Anti-Vortex Baffle**

LO2 Tank Ant-Vortex Definition CV-STR-14B



- 50 lbs Weight Impact To Reference

CV-STR-14B
Appendix 5

- Definition Of External Hardware Mtg Provisions

External H/W Mtg Provisions CV-STR-14B

Objective

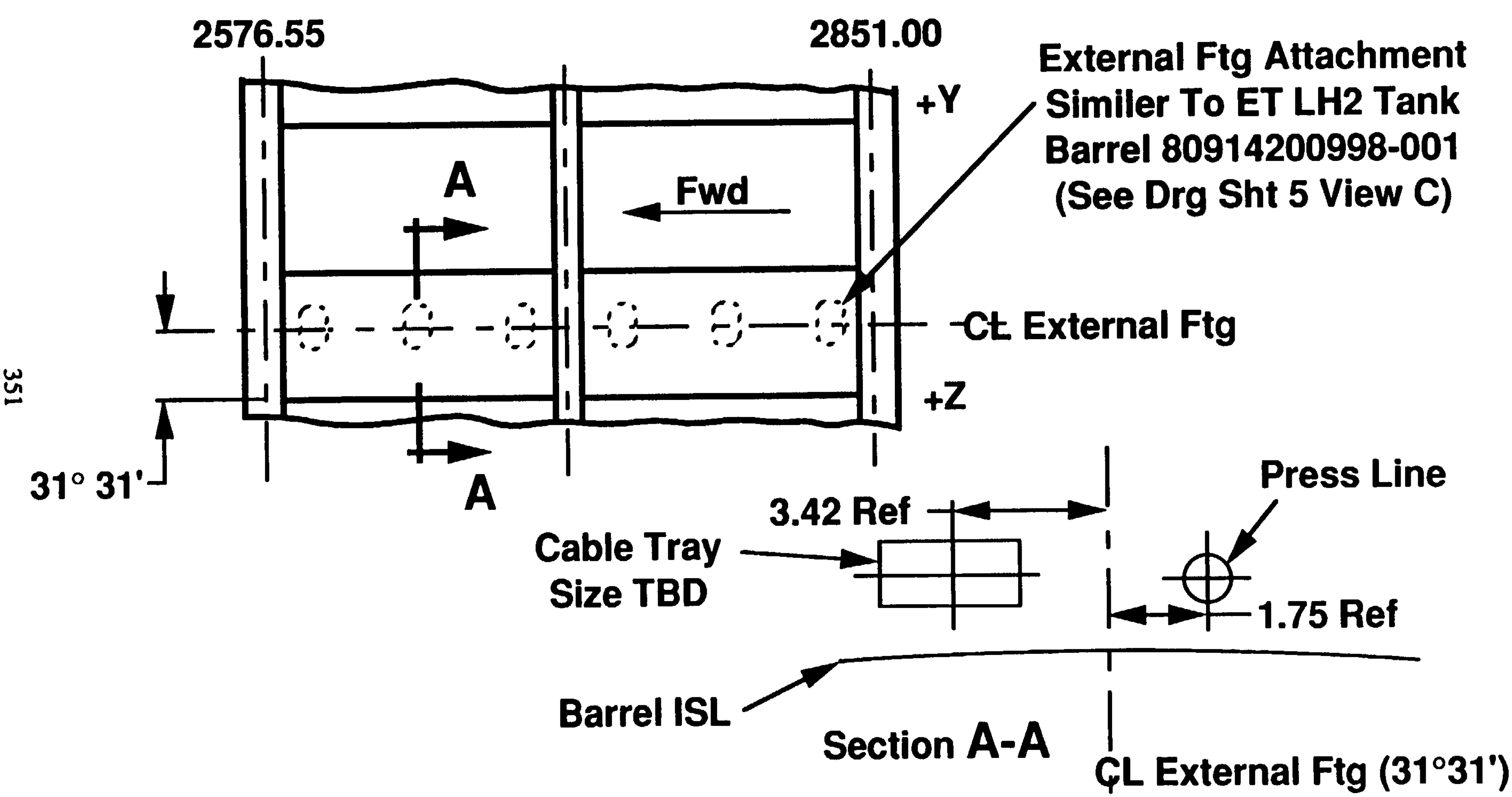
- Define Locations For External Hardware Mounting Provisions On The LO2 Tank

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



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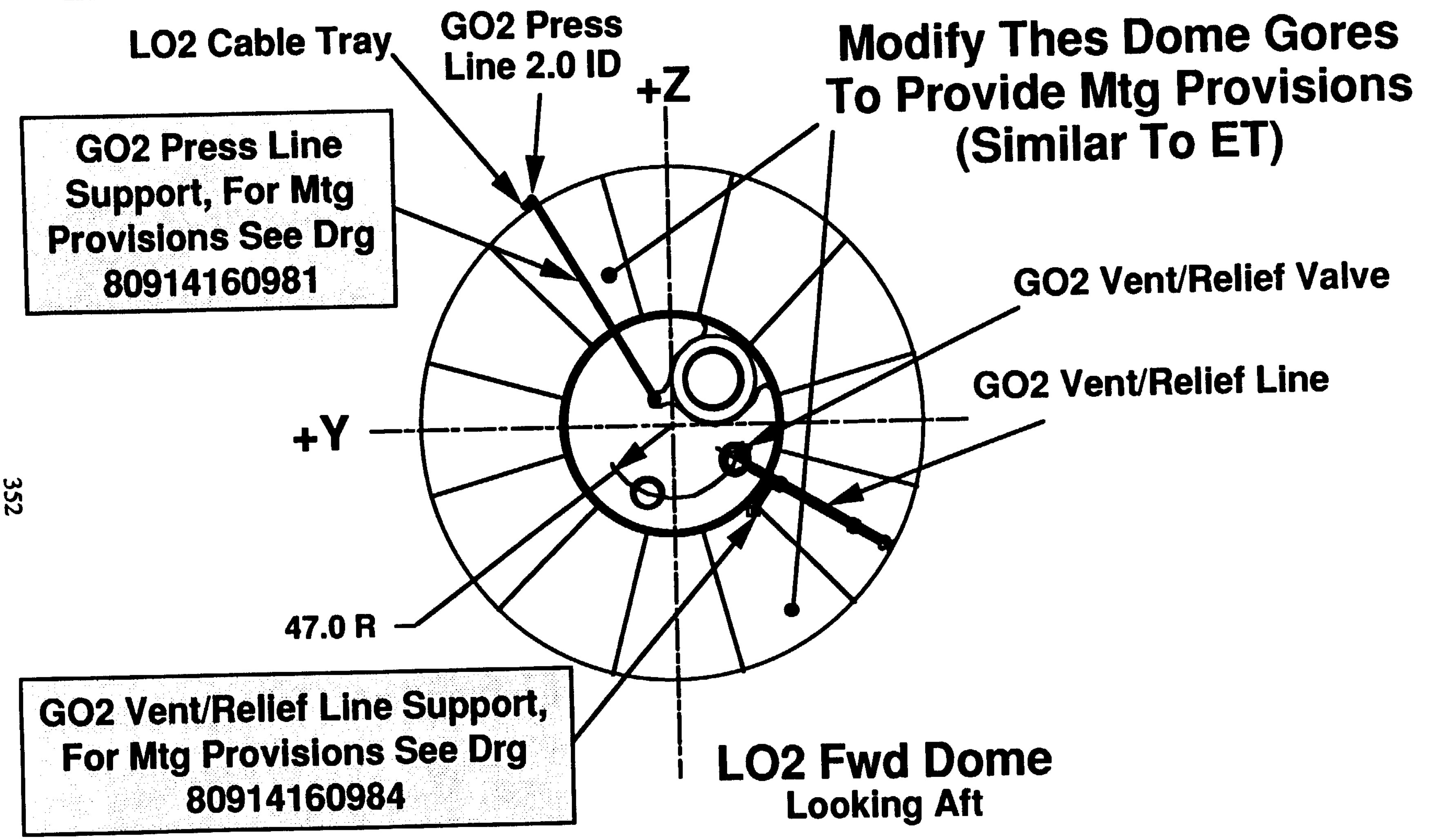
External H/W Mtg Provisions CV-STR-14B



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External H/W Mtg Provisions CV-STR-14B

Recommendation

- Add External Hardware Mtg Provisions To Reference LO_2 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 And Barrel 1
  - Chord Barrel Weld Land = .397; Barrel Weld Land = .32

Recommendation

- Modify Aft LO2 Tank Barrel Weld Land To.387

CV-STR-14B
Appendix 7

- LO2 Tank Part Definition

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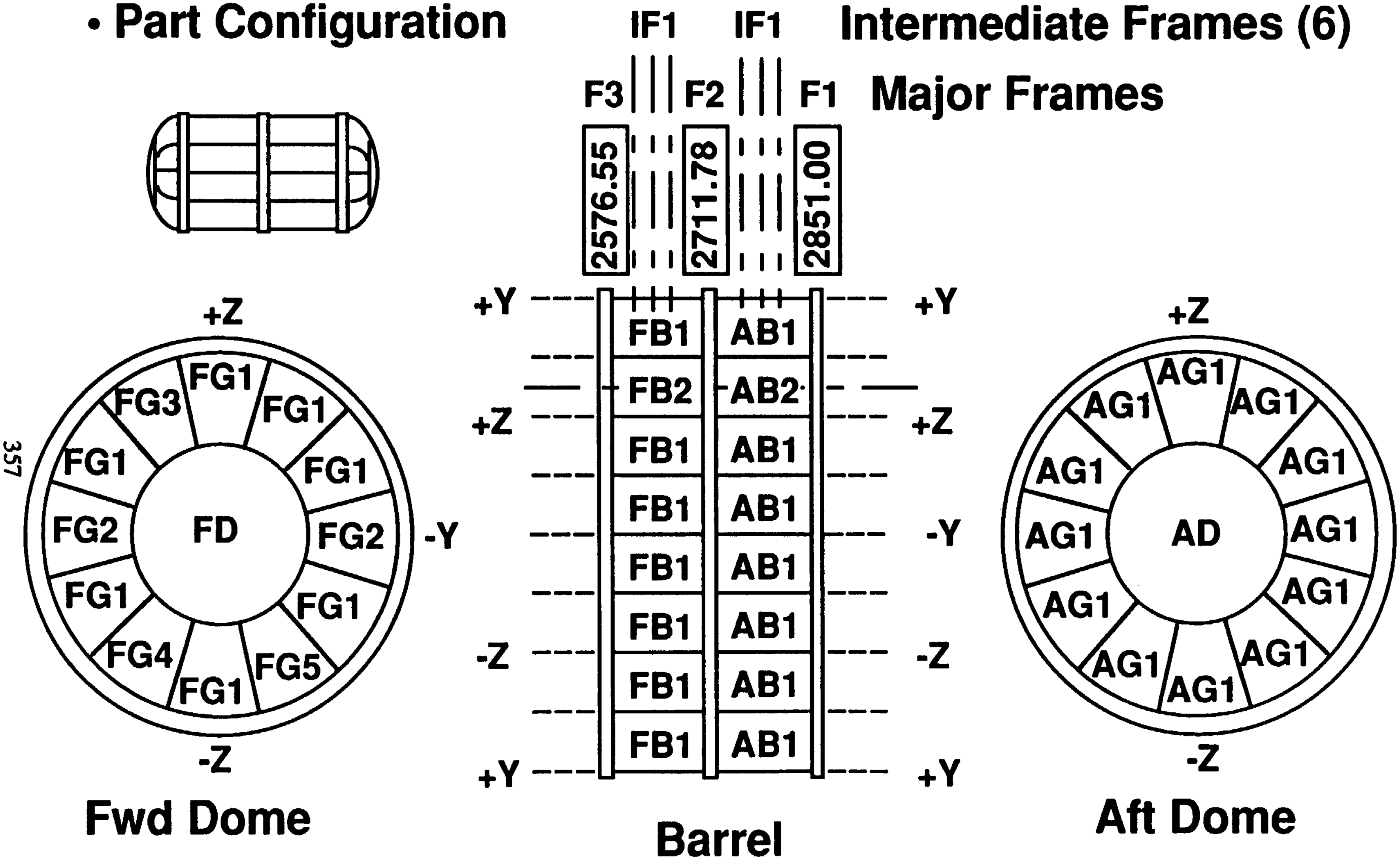
LO2 Tank Shell Definition CV-STR-14B

- Part Configuration



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LO2 Tank Shell Definition Cont. CV-STR-14B

Part	Title	Part Status			Remarks
		ET	Mod.	New	
FD	Fwd Dome Cap	-	-	√	Common To NLS LH2 Tank Fwd Dome
FG1	Dome Gore Plain	-	√	-	Similar To ET & NLS Fwd LH2 Dome Gores, With Membrane Thickness Modified For Proof Test Requirements (FG1–FG5)
FG2	Dome Gore SRB*	-	√	-	
FG3	Dome Gore Press	-	√	-	
FG4	Dome Gore Sensor	-	√	-	
FG5	Dome Gore Vent	-	√	-	
AD	Aft Dome Cap	-	-	√	Requires 2 Feedline Outlets
AG1	Dome Gore	√	-	-	
F1	Frame 2851.0				
	- Outer Chord	√	-	-	ET LO2 Aft Dome Chord
	- Frame	-	√	-	Fr Depth Increased To Meet Baffle Definition
F2	Frame 2711.775	√	-	-	Use LH2 Tank Fr 1377.35

* Selected For Commonality With LH2 Fwd Dome

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LO2 Tank Shell Definition — CV-STR-14B

Part	Title	Part Status			Remarks
		ET	Mod.	New	
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

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LO2 Tank Shell Definition

CV-STR-14B

Part	Title	Part Status			Remarks
		ET	Mod.	New	
IF1	Intermediate Fr (Typical 6 Places)	-	-	√	Unique Size Intermediate Frame, Similar Construction To ET LH2 Tank Intermediate Frames

Candidate Items For Cycle 1 CV-STR-14B

- 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)

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Candidate Items For Cycle 1 CV-STR-14B

- Investigate Barrel Length Requirement & Maximum Manufacting 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

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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.

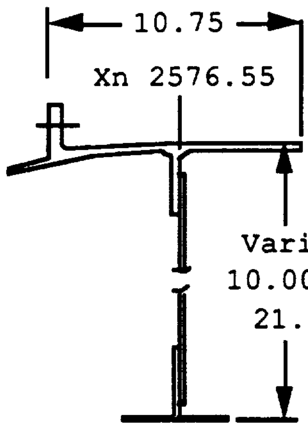
Conclusions

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.

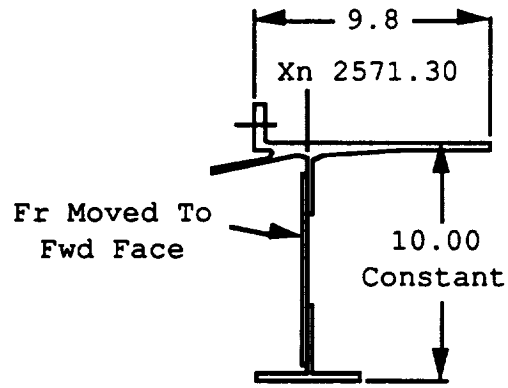
Study Recommendations

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

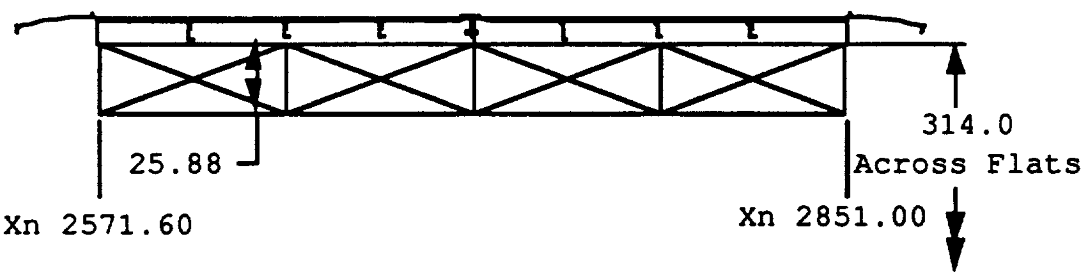
- Revise reference definition to use aft chord & frame in forward location.
- Revise reference slosh baffle to proposed full length configuration.
- Include proposed Anti-Vortex Baffle definition.
- Incorporate the proposed definition of external hardware mtg. provisions.
- Increase barrel weld land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



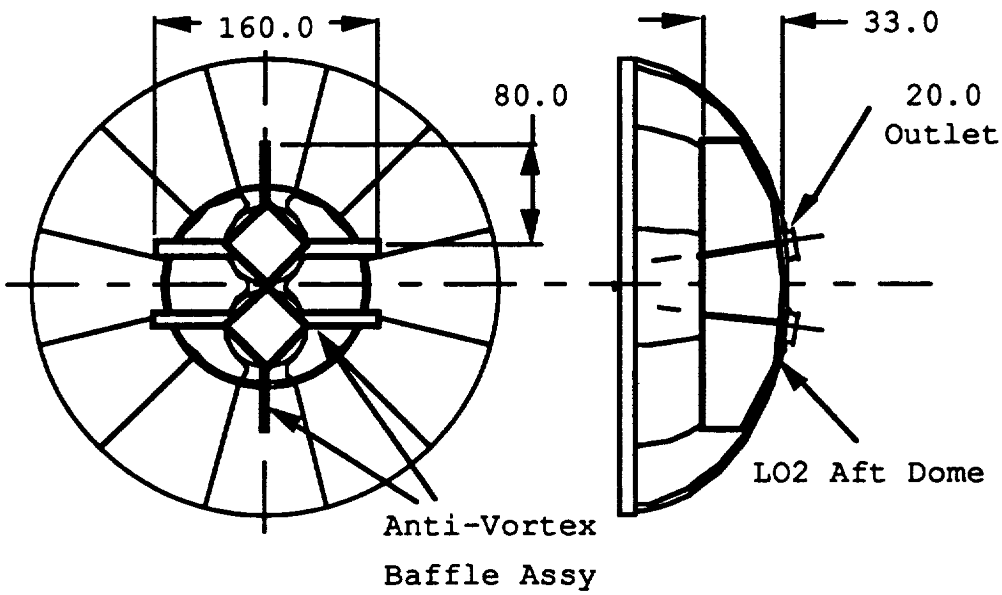
Reference FWD Dome Chord



Proposed FWD Dome Chord



Proposed 1% Slosh Baffle Assembly



Proposed Anti-Vortex Baffle Assembly

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.
(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.

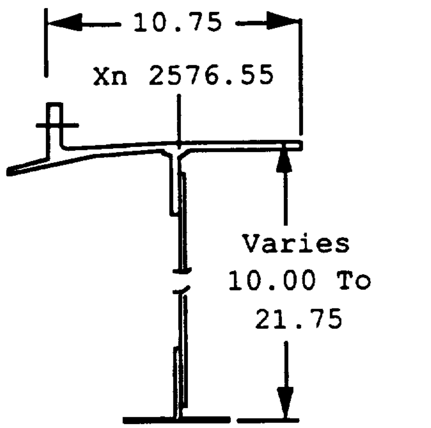
Conclusions

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.

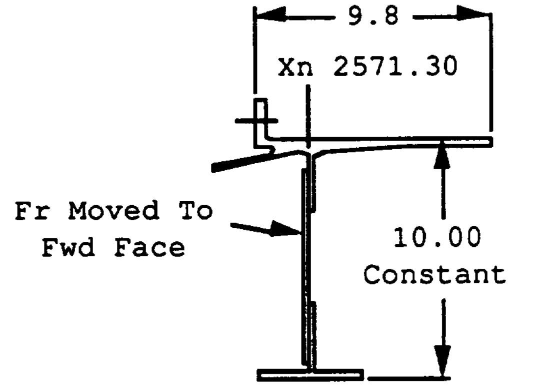
Study Recommendations

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

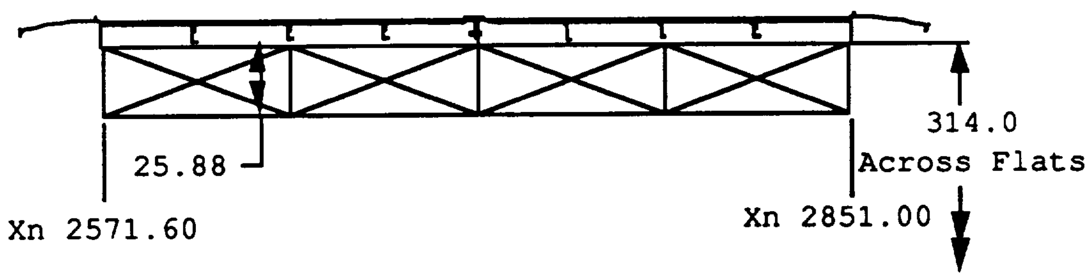
- Revise reference definition to use aft chord & frame in forward location.
- Revise reference slosh baffle to proposed full length configuration.
- Include proposed Anti-Vortex Baffle definition.
- Incorporate the proposed definition of external hardware mtg. provisions.
- Increase barrel weld land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



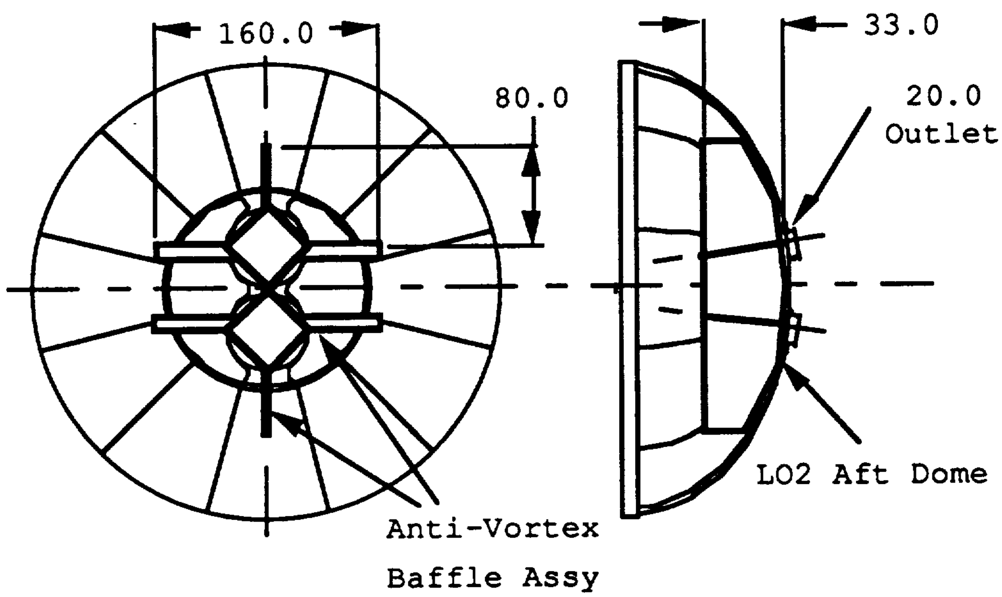
Reference FWD Dome Chord



Proposed FWD Dome Chord



Proposed 1% Slosh Baffle Assembly



Proposed Anti-Vortex Baffle Assembly

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
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Carl W Hedden
(504)257-5507

Approved By: M. R. Simms

Rev: Initial
Date: January 8, 1991

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NLS Intertank Definition CV-STR-14C

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

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Groundrules CV-STR-14C

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

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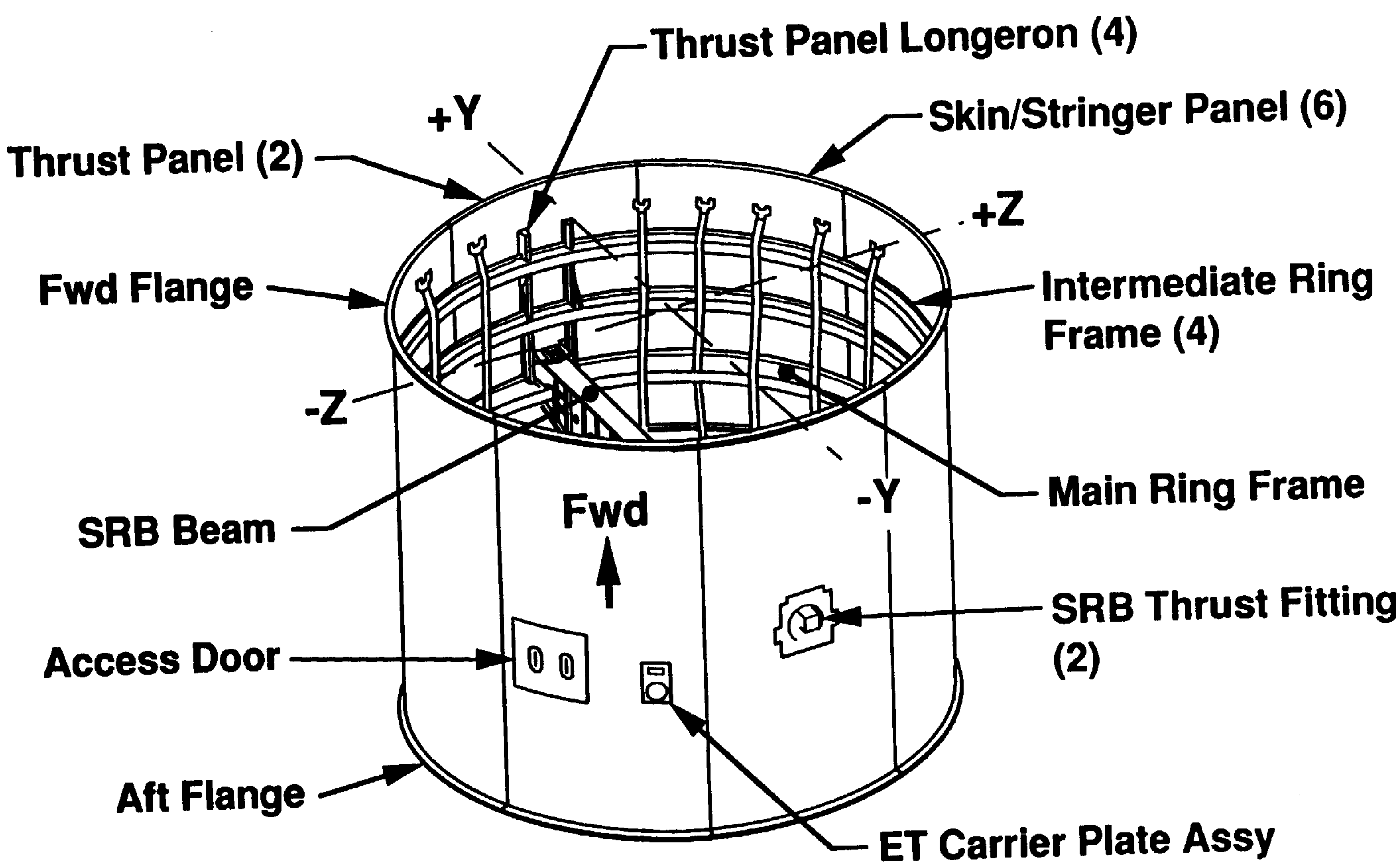
ET Intertank Major Elements CV-STR-14C



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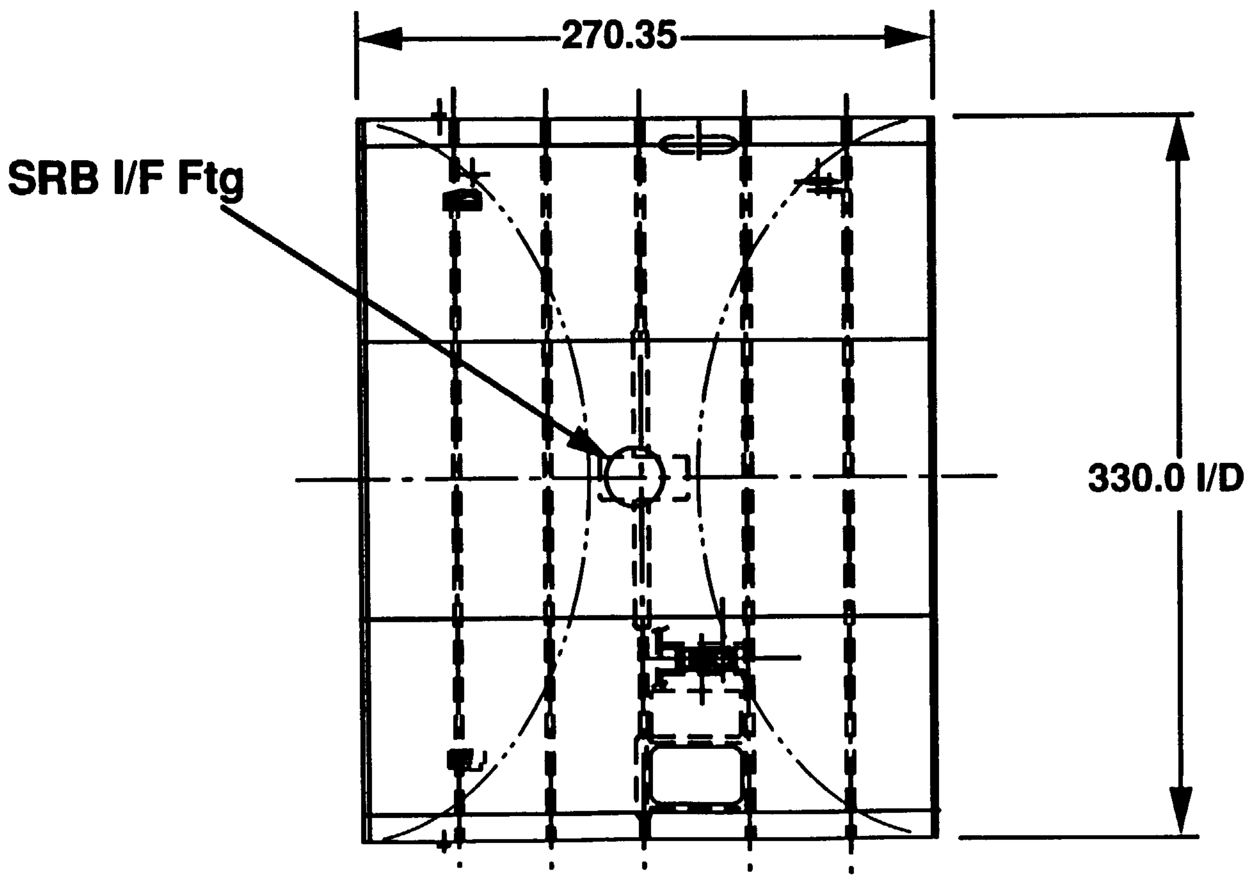
Intertank Geometry CV-STR-14C

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



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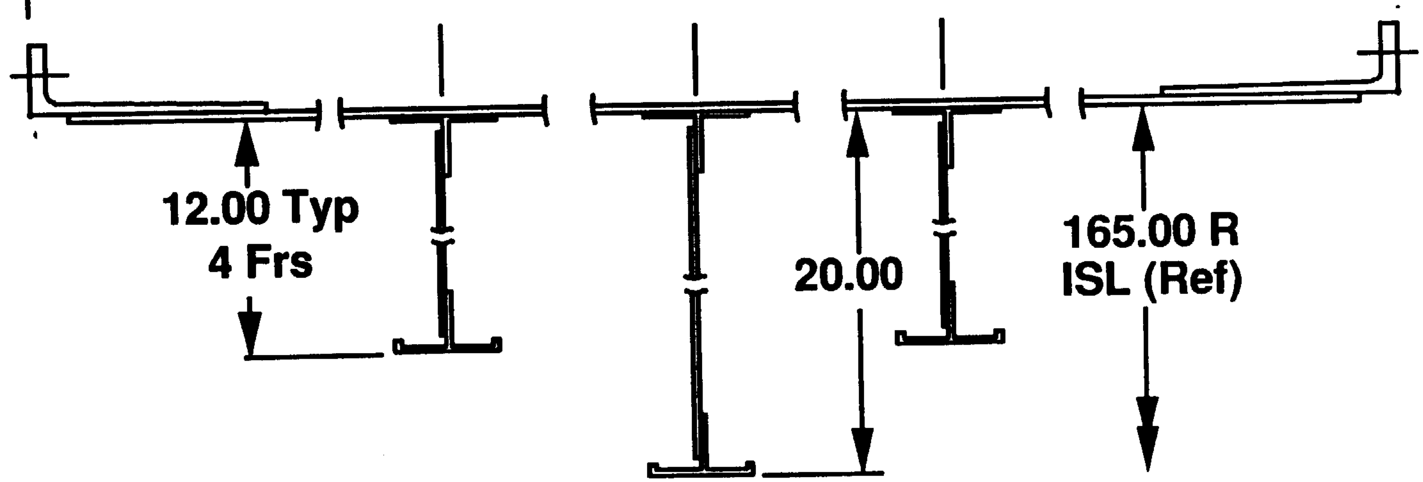
Intertank Geometry

CV-STR-14C

- From Intertank Panel Lead, 10/9/91



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Potential Study Items — CV-STR-14C

- 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

Recommended Changes CV-STR-14C

Study Item	Recomendation	Back Up Data	Wt. Impact	Status
1.5 Stage Fr2985 Mods	Option 4	Append. 1	80	Incorp.
Shell Penetrations	Add Penetrations	Append. 2	N/A	Accepted
Impacts Of No TPS	Incorp. Weight Impact	Append. 3	-172	Incorp.
Purge & Vent	Study Further in Cycle 1	Append. 4	N/A	Accepted
Sizing Mods	Change Skin/Stiffeners	Append. 5	-172	Incorp.
Ref Part Definition		Append. 6	N/A	Incorp.

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

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Appendix 1

- **Fr Xn 2985.675 Mods For 1.5 Stage**

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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 Ommitted 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

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Groundrules & Options CV-STR-14C

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 & Doublers 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

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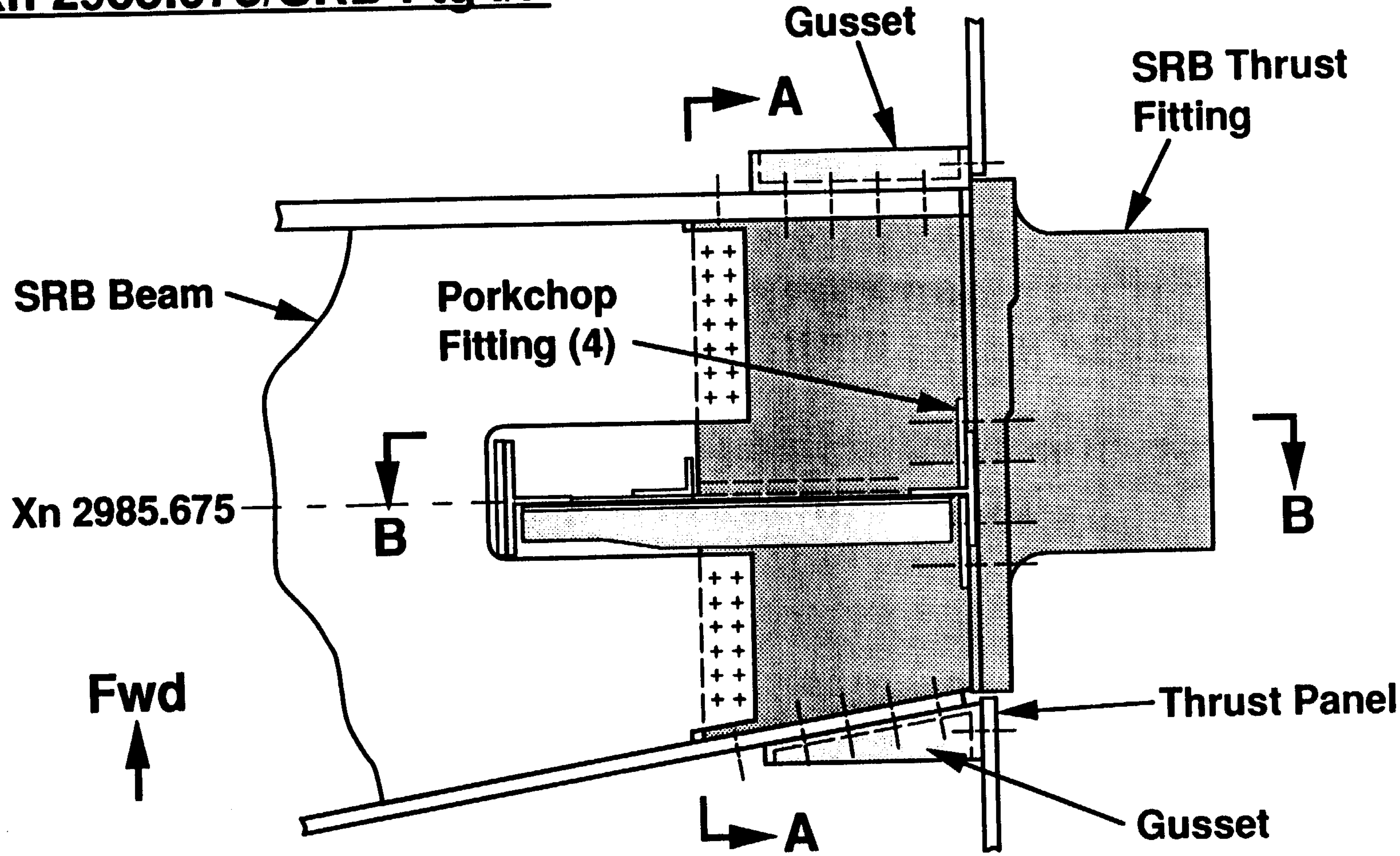
Ref HLLV

CV-STR-14C

Xn 2985.675/SRB Ftg I/F



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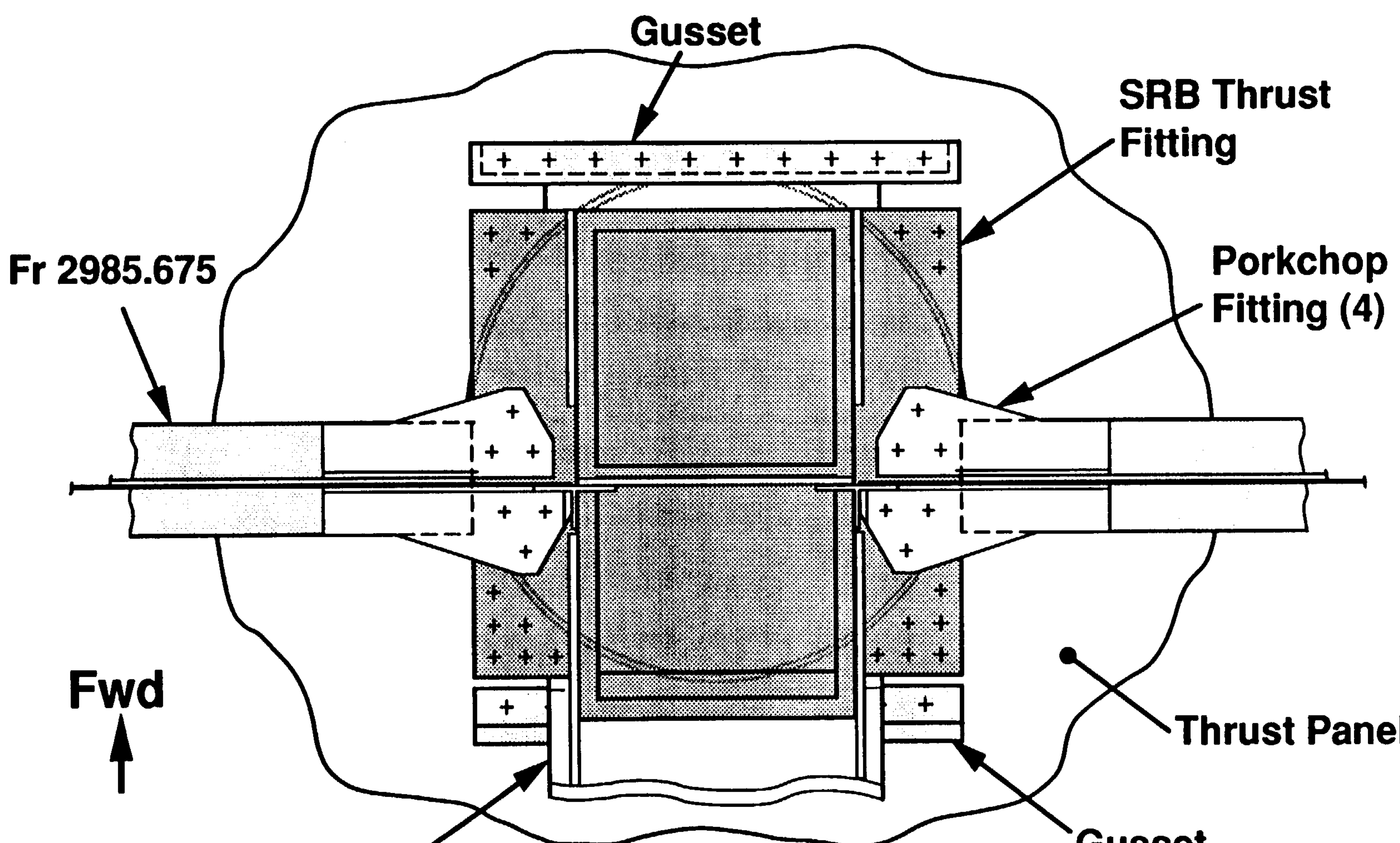
Ref HLLV CV-STR-14C



View A-A

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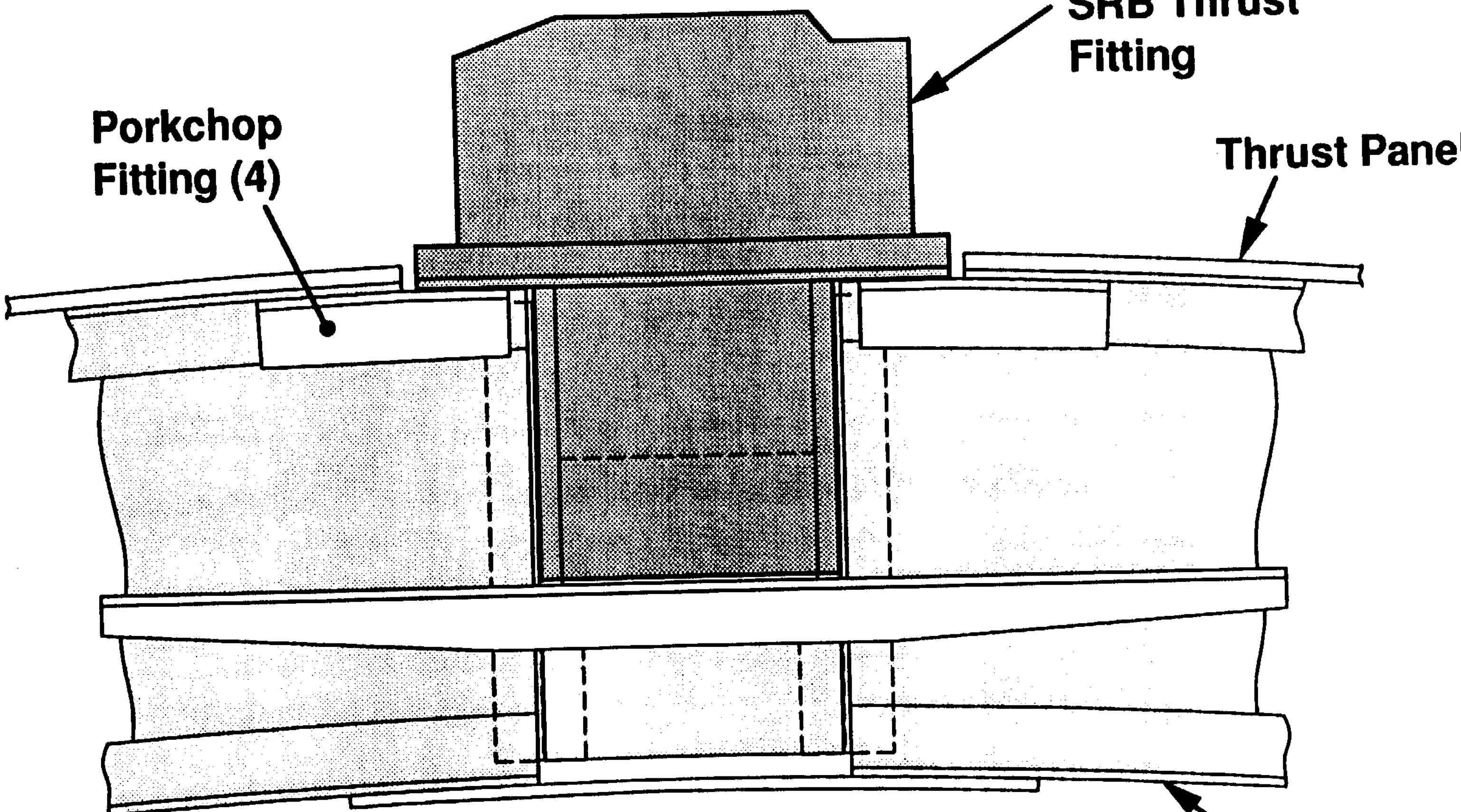
Ref HLLV

CV-STR-14C



View B-B
Looking Aft

- SRB Beam & Gussets not Shown for Clarity

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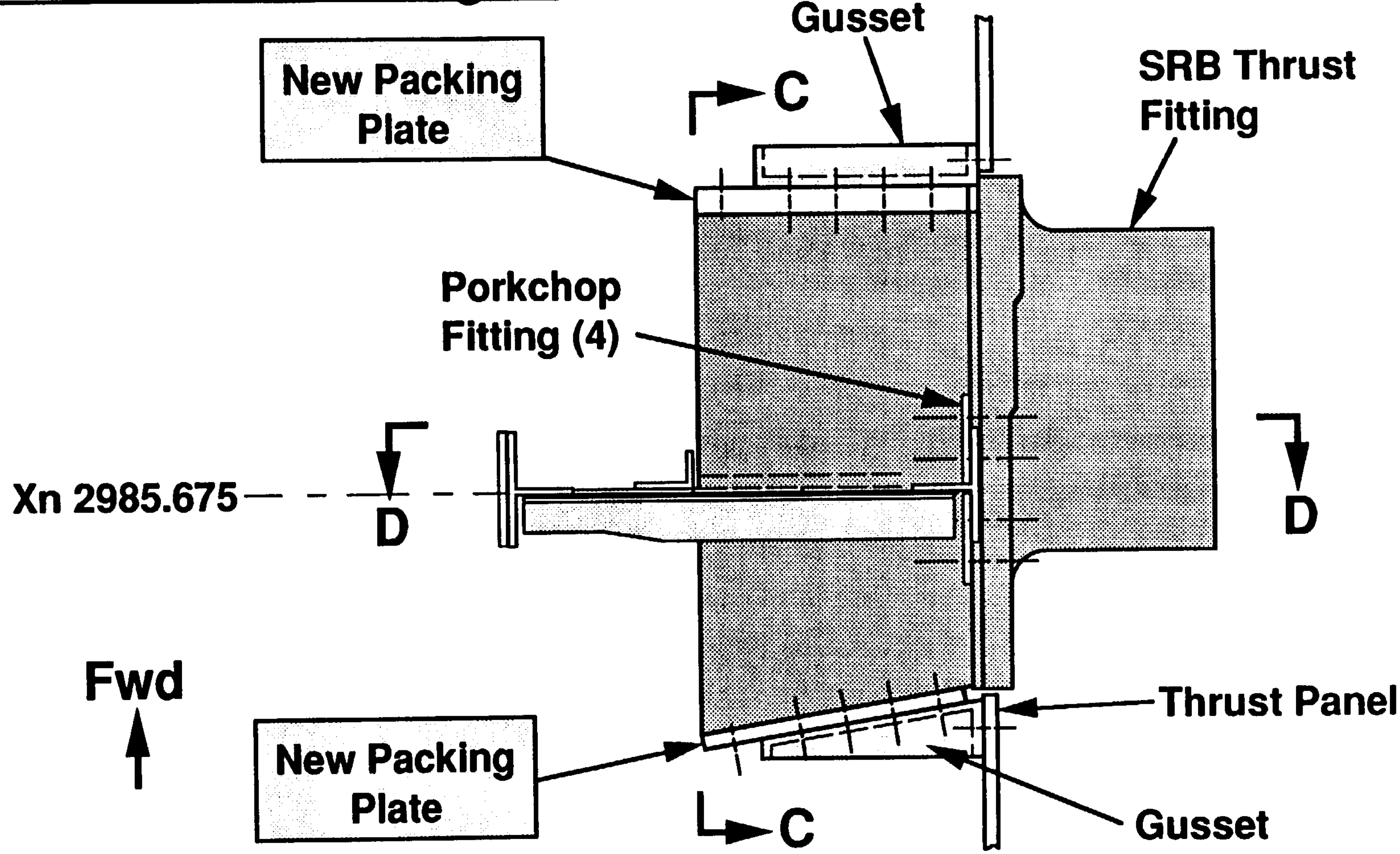
Option 1, Omit XBeam — CV-STR-14C

Xn 2985.675/SRB Ftg I/F



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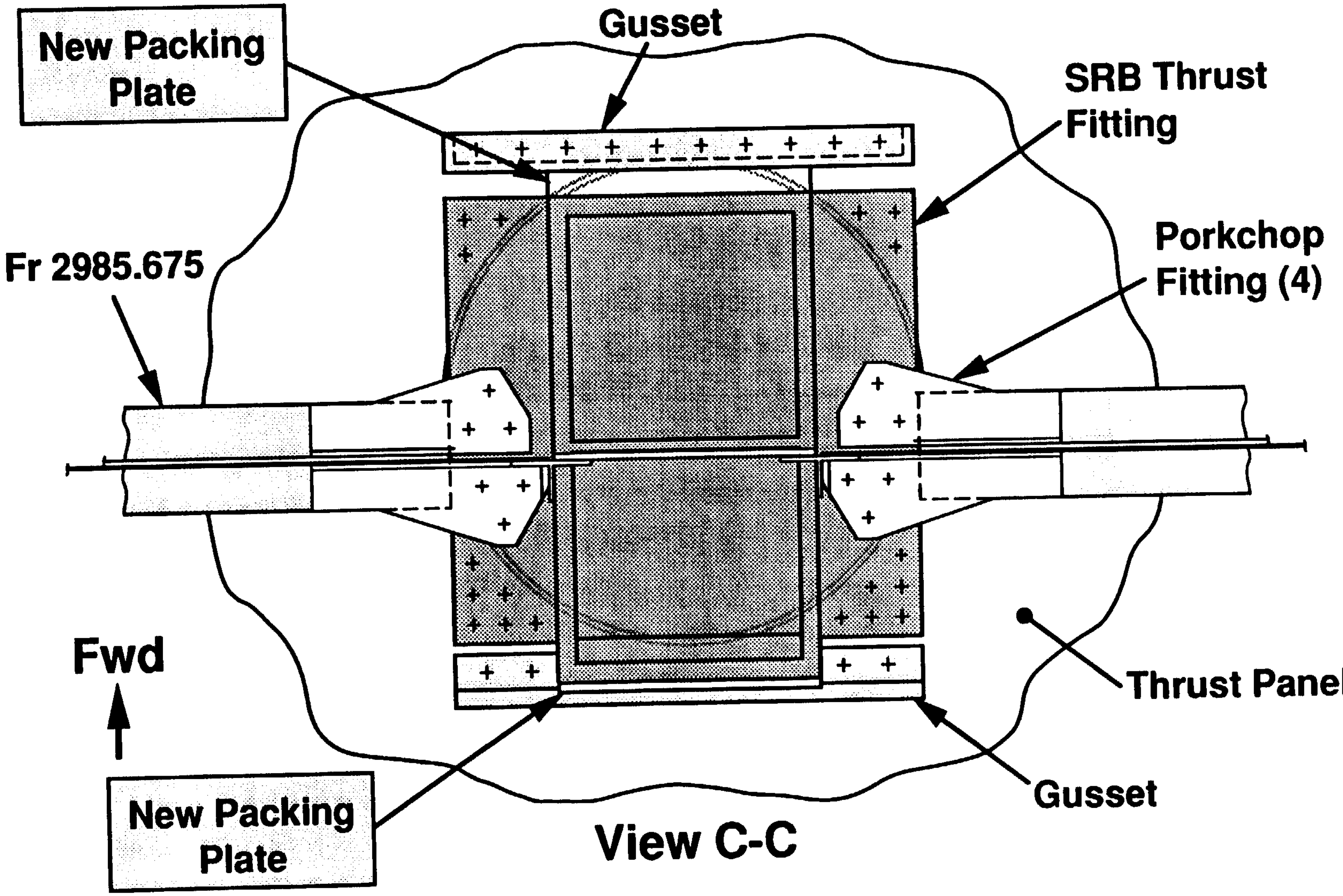
Option 1, Omit XBeam — CV-STR-14C



View C-C

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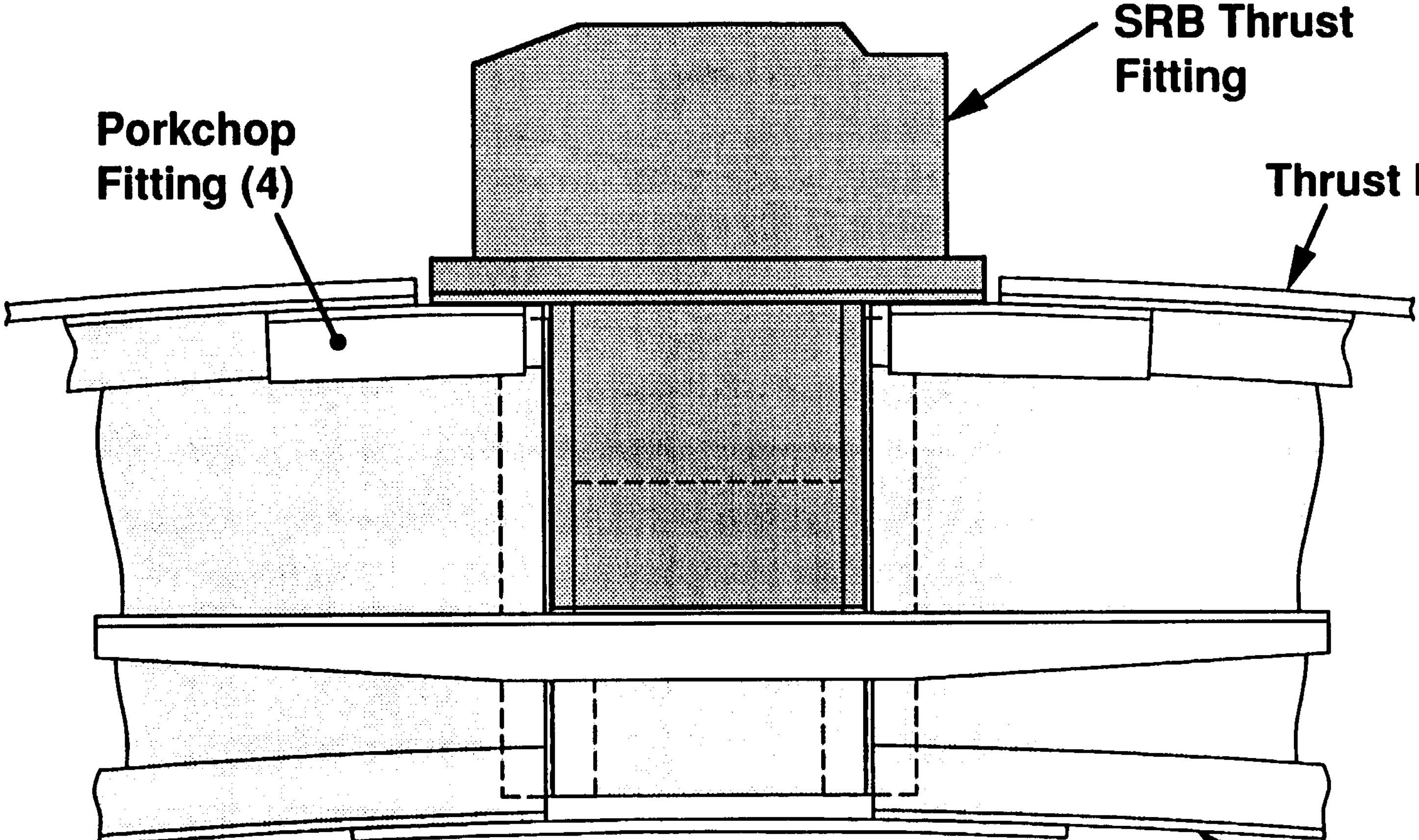
Option 1, Omit XBeam   CV-STR-14C



View D-D
Looking Aft

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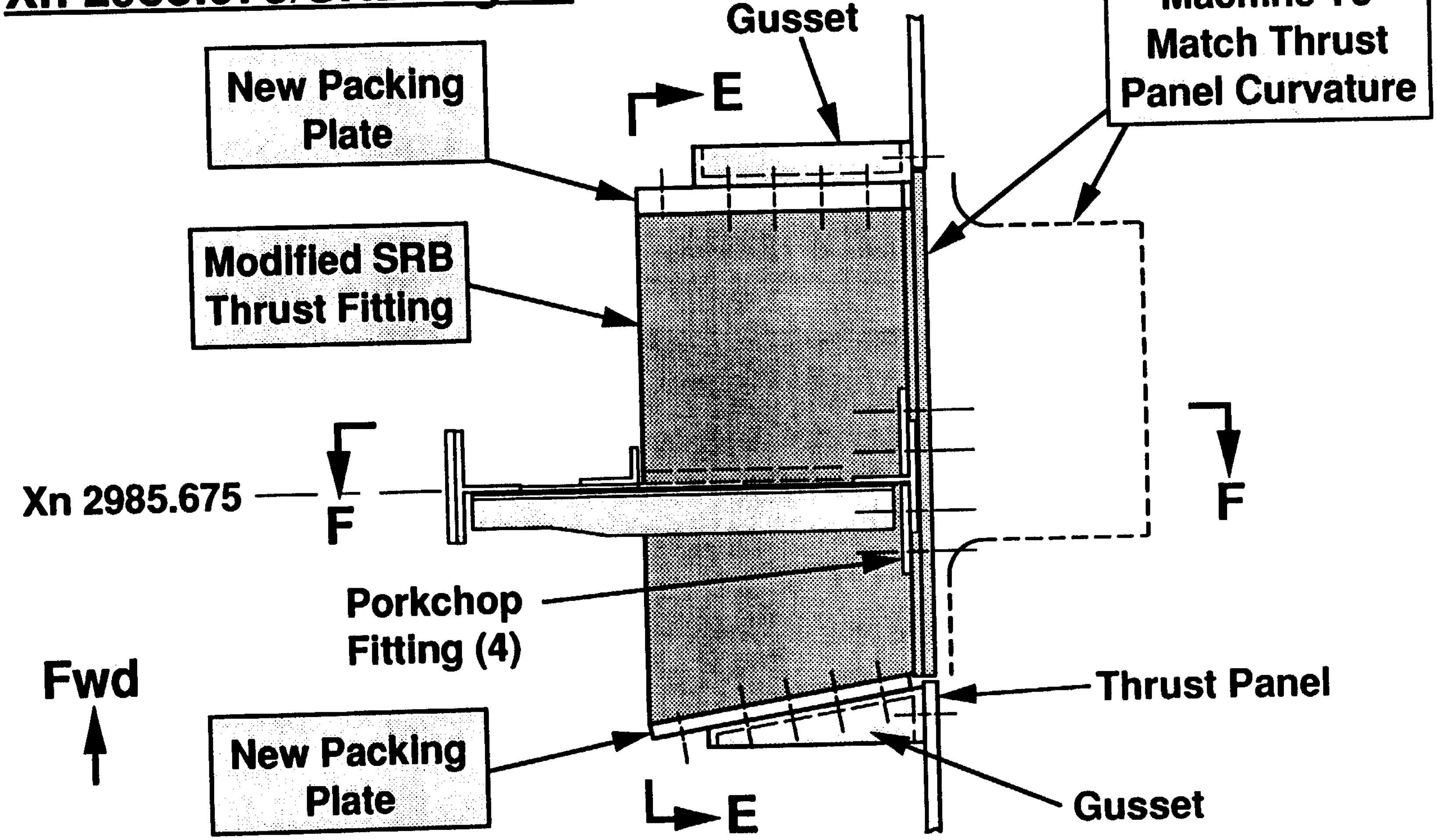
Opt 2, Modified SRB Ftg. CV-STR-14C

Xn 2985.675/SRB Ftg I/F



- Machine Off SRB/SRB Beam Interfaces Not Required

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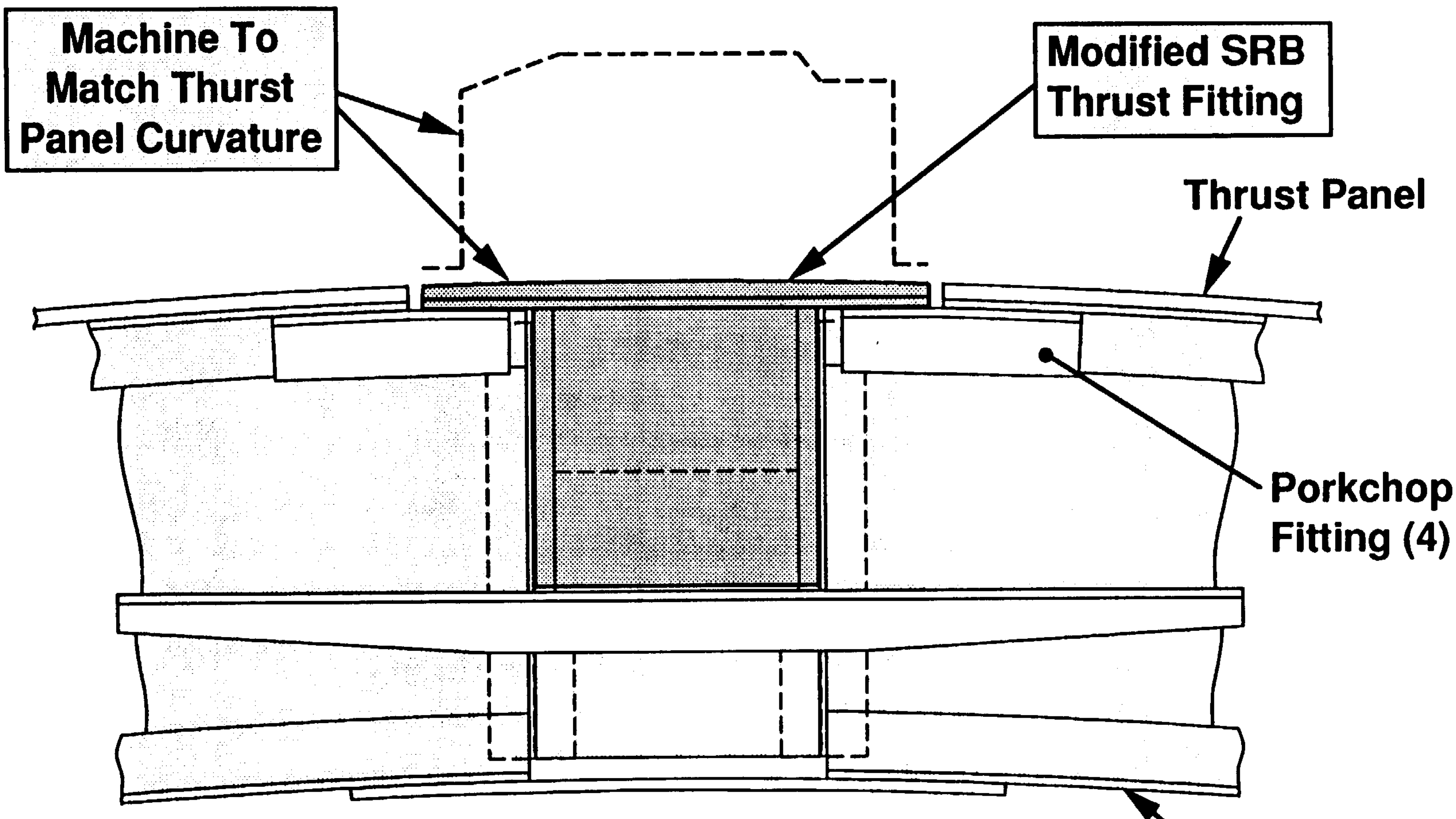
Opt 2, Modified SRB Ftg. CV-STR-14C



View F-F
Looking Aft

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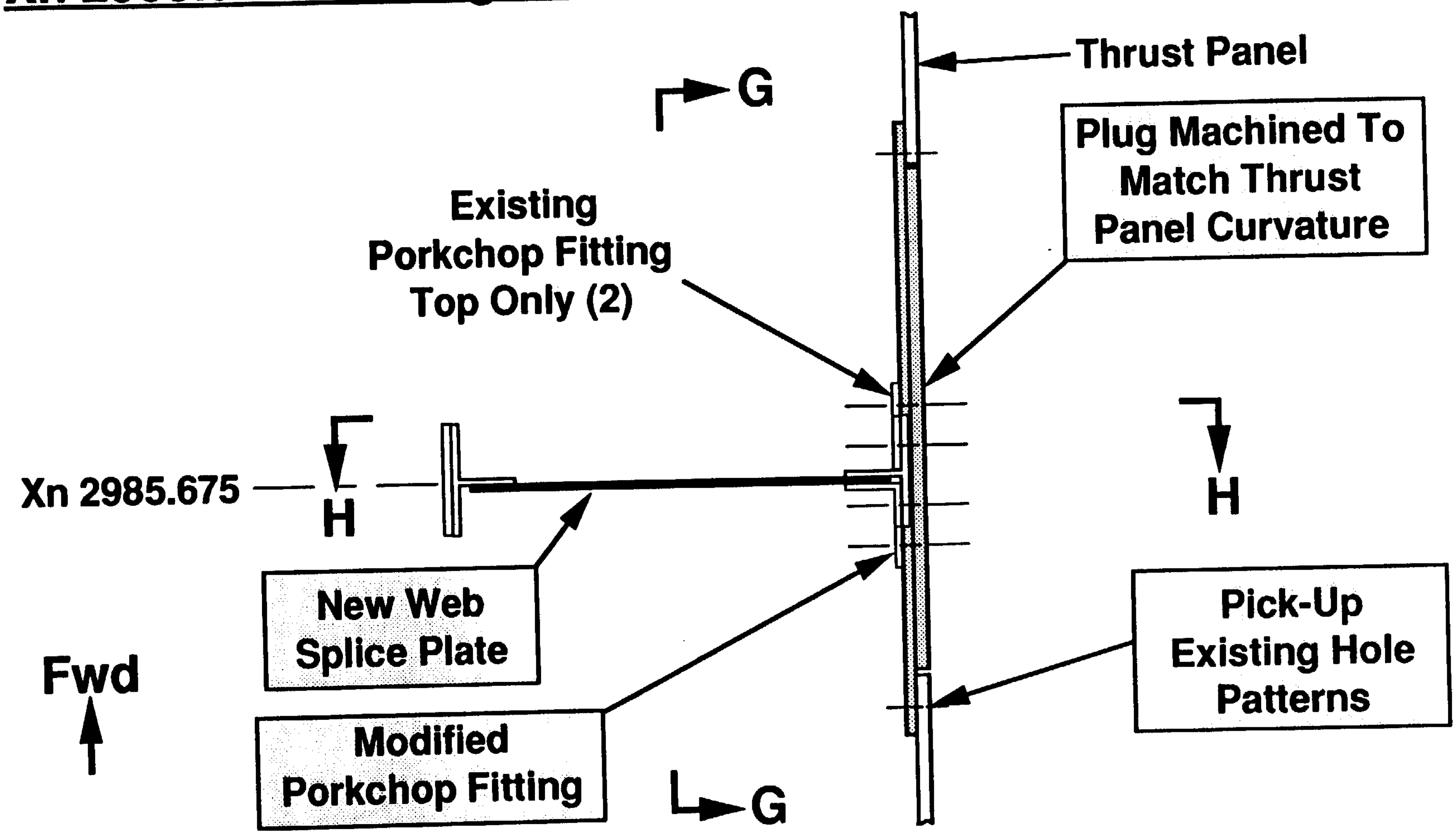
Opt 3, New Fabricated Joint CV-STR-14C

Xn 2985.675/SRB Ftg I/F



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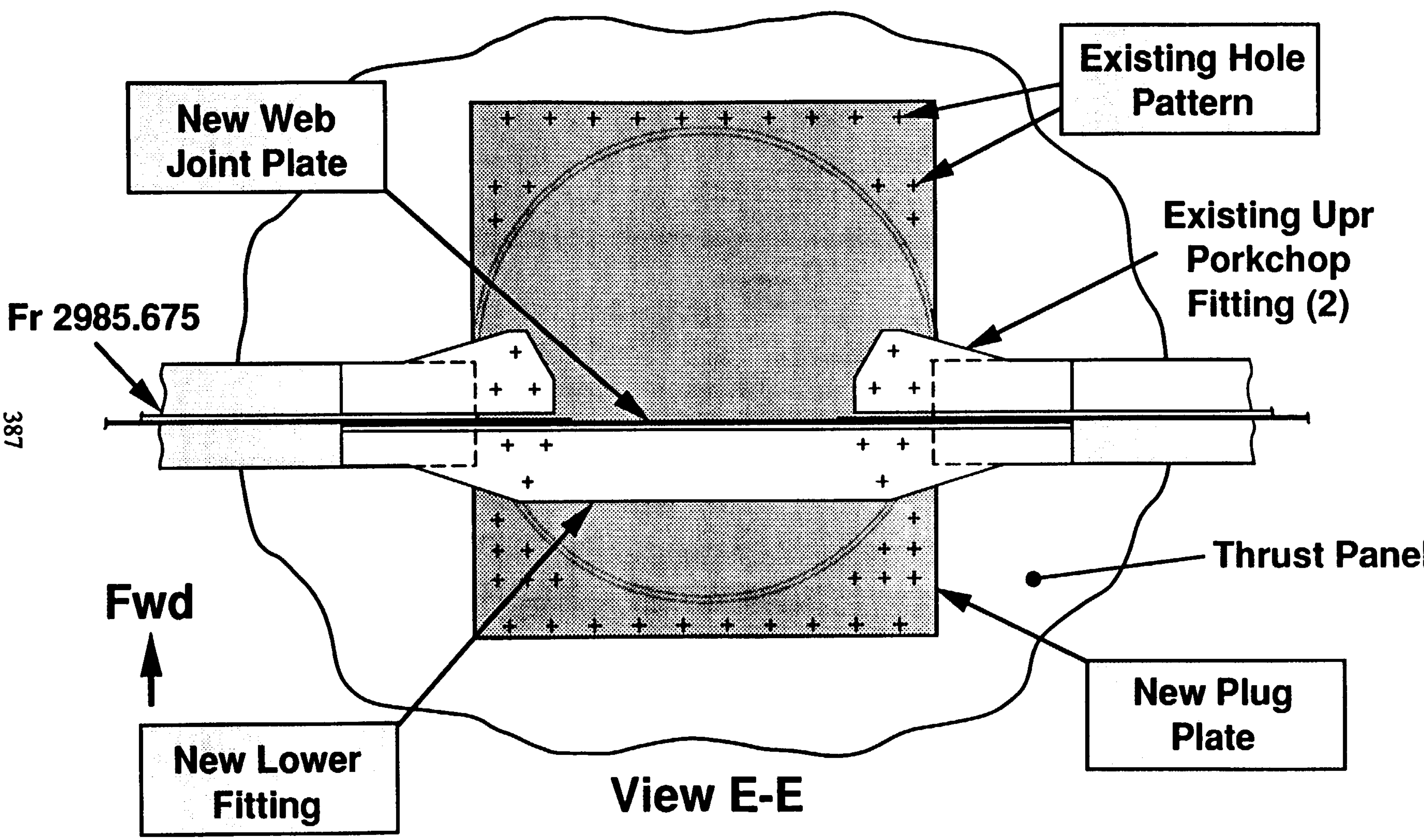
Opt 3, New Fabricated Joint CV-STR-14C



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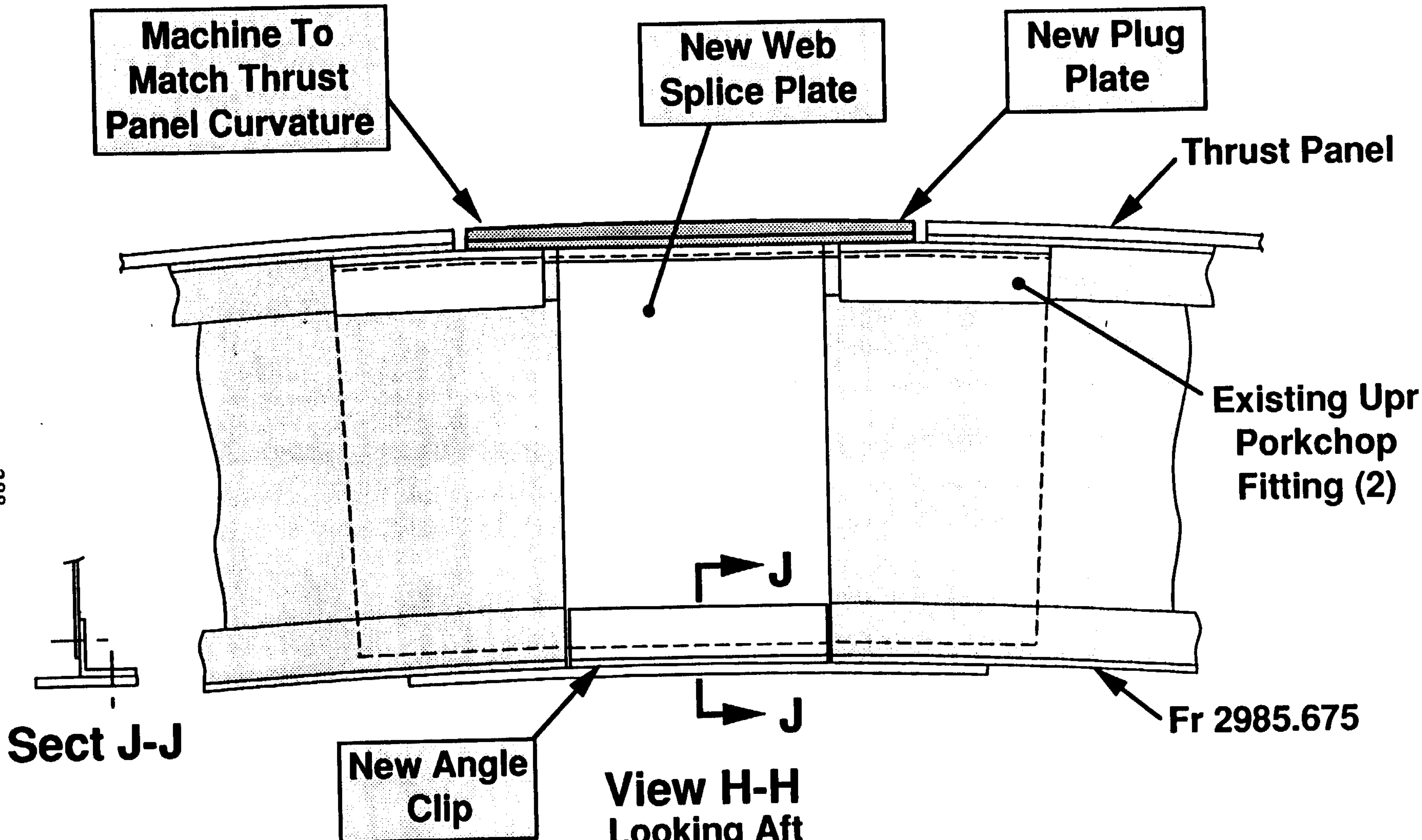
Opt 3, New Fabricated Joint CV-STR-14C



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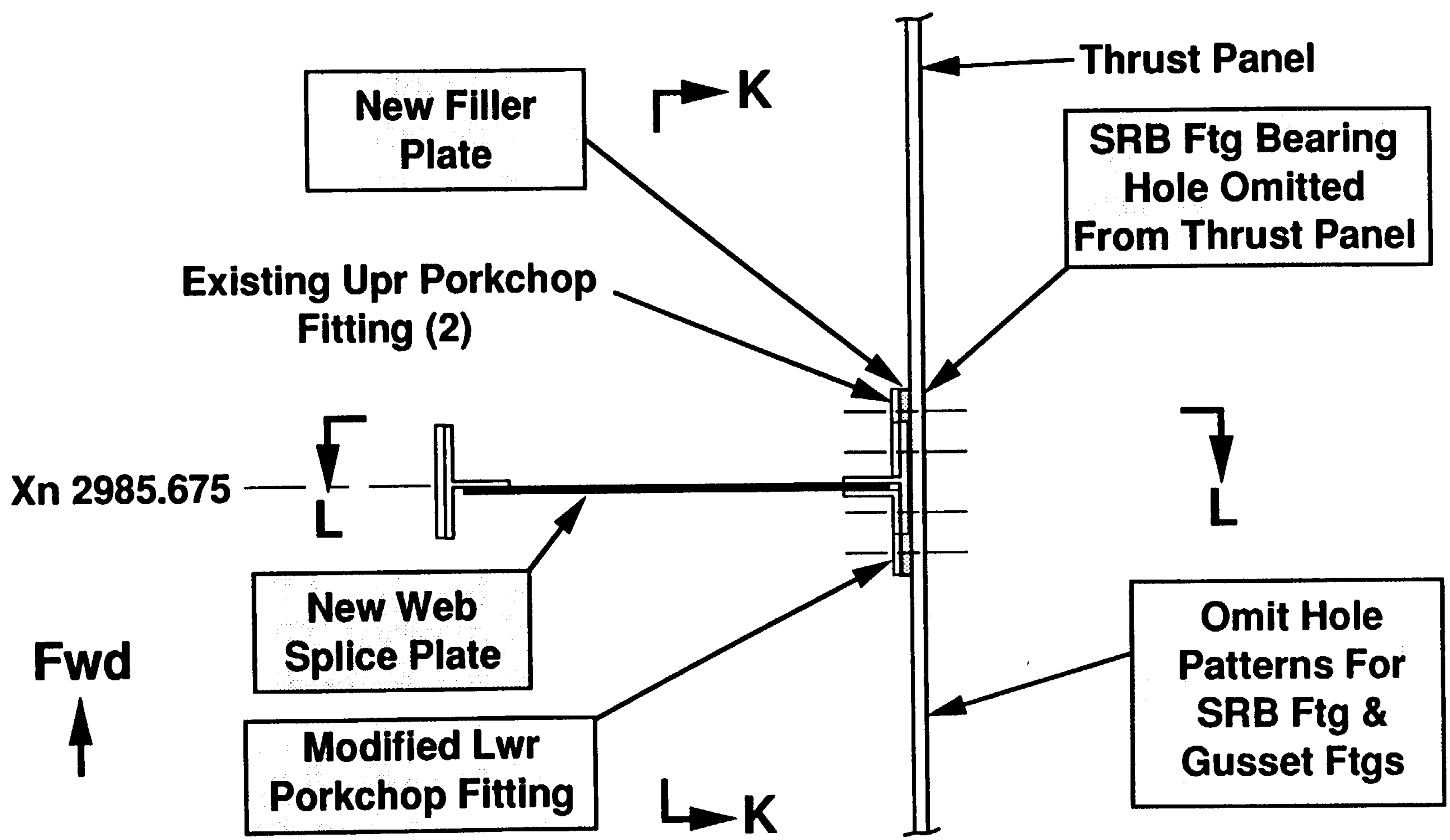
Opt 4, Modified Thrust Panel CV-STR-14C



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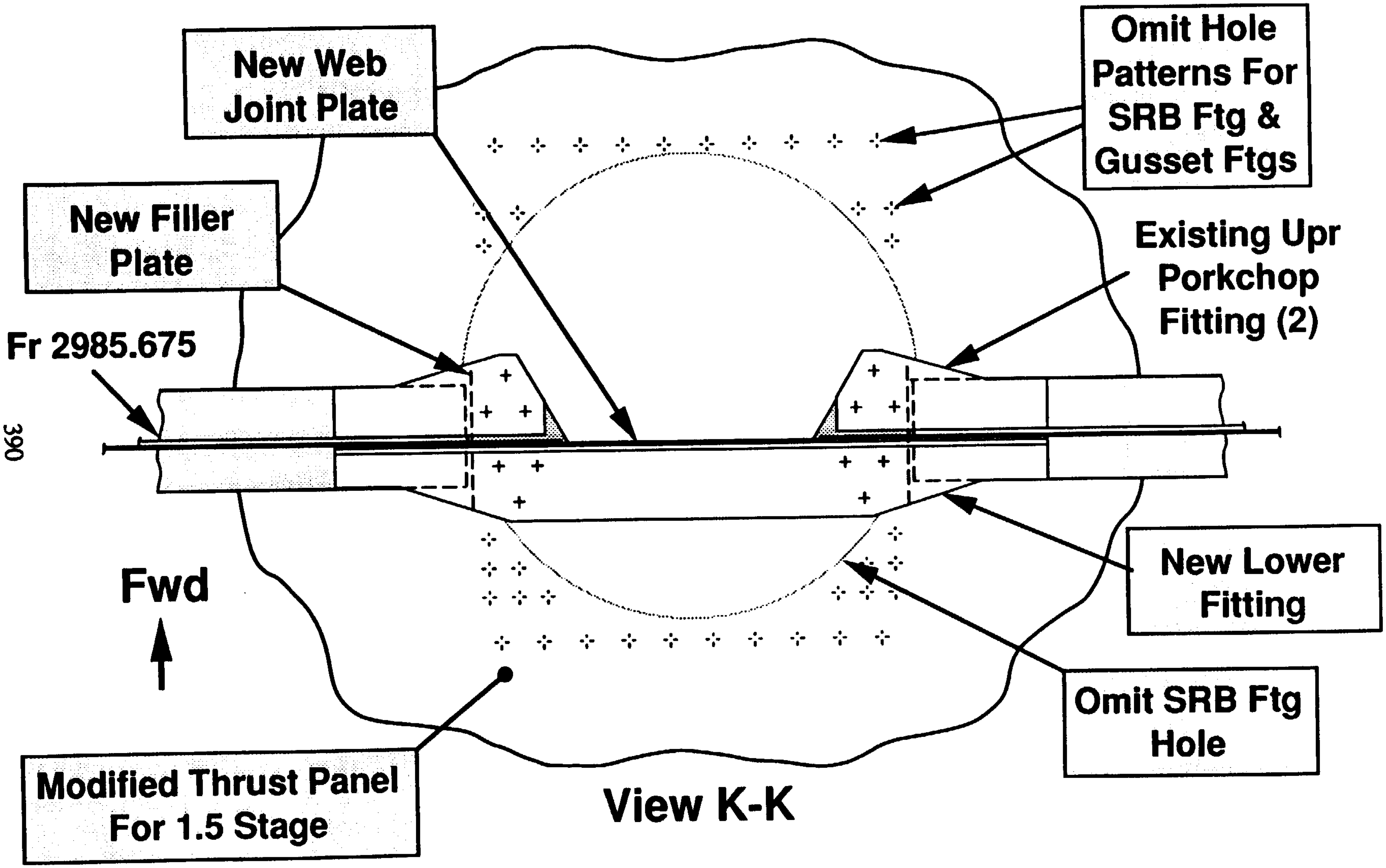
Opt 4, Modified Thrust Panel CV-STR-14C



View K-K

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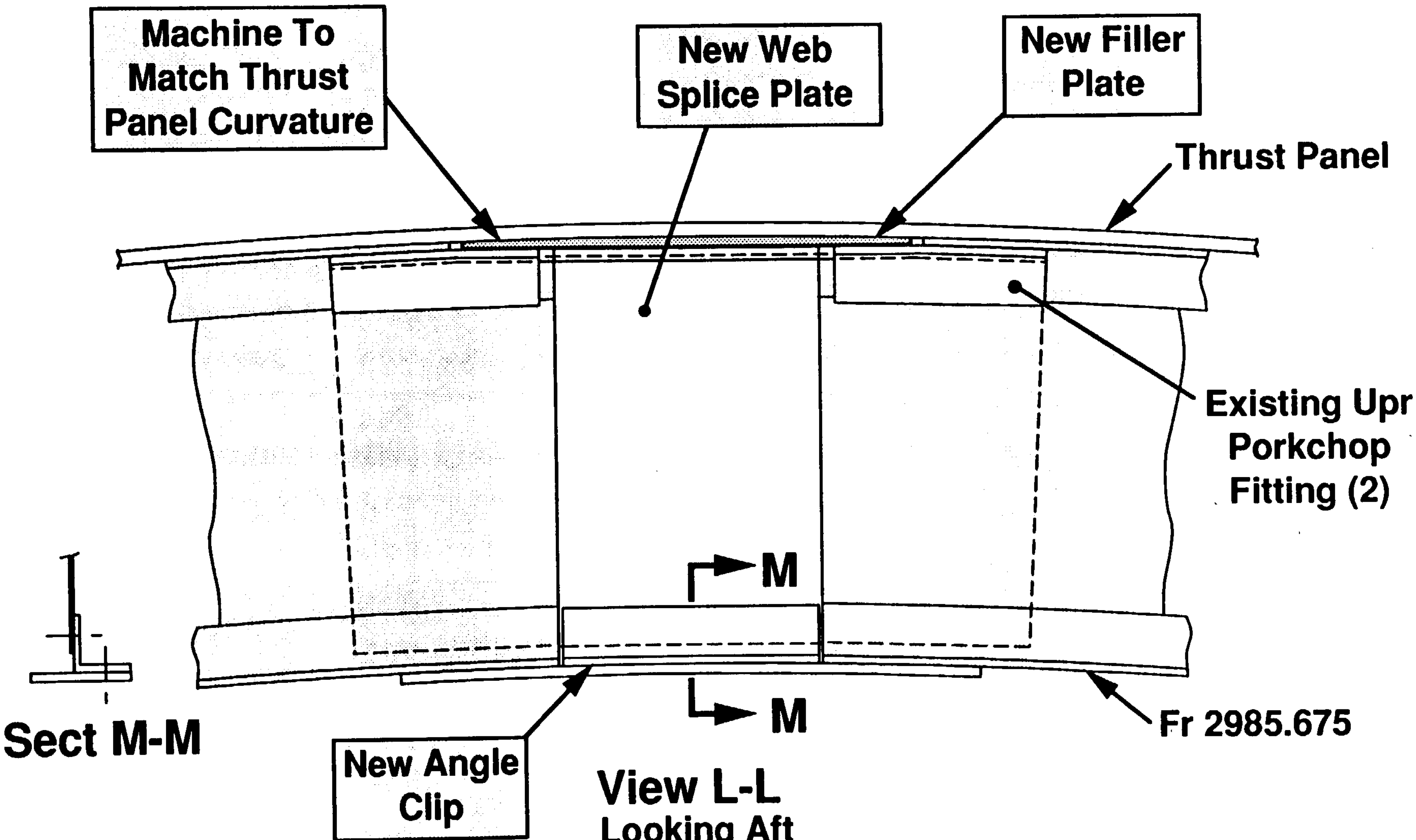
Opt 4, Modified Thrust Panel CV-STR-14C



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Option Evaluation

CV-STR-14C

Opt.	Remarks	Weight Impact*
1	+ Uses ET SRB Ftgs, Porkchop Ftgs, Thrust Panels, & Gussets - Maximum Weight Penalty - Requires New Packing Plates - Complex Assy	775
2	+ Uses ET Porkchop Ftgs, Thrust Panels, & Gussets - SRB Ftgs Require Modifing - Requires New Packing Plates - Complex Assy	323
3	+ Uses ET Upr Porkchop Ftgs &Thrust Panels + Simplified Assy - Requires New Plug Plates & Lwr Ftgs	186
4	+ Lightest Option + Simple Assy - Uses Unmachined Unique Thrust Panel (Make From ET Part) - Requires New Filler Plates & Lwr Ftgs	80

* • 200 lbs Allocated in Ref Config Weights
• Increased Weights Incl 8% Contingency

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Recommendation CV-STR-14C

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

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Appendix 2

- **Intertank Shell Penetrations**

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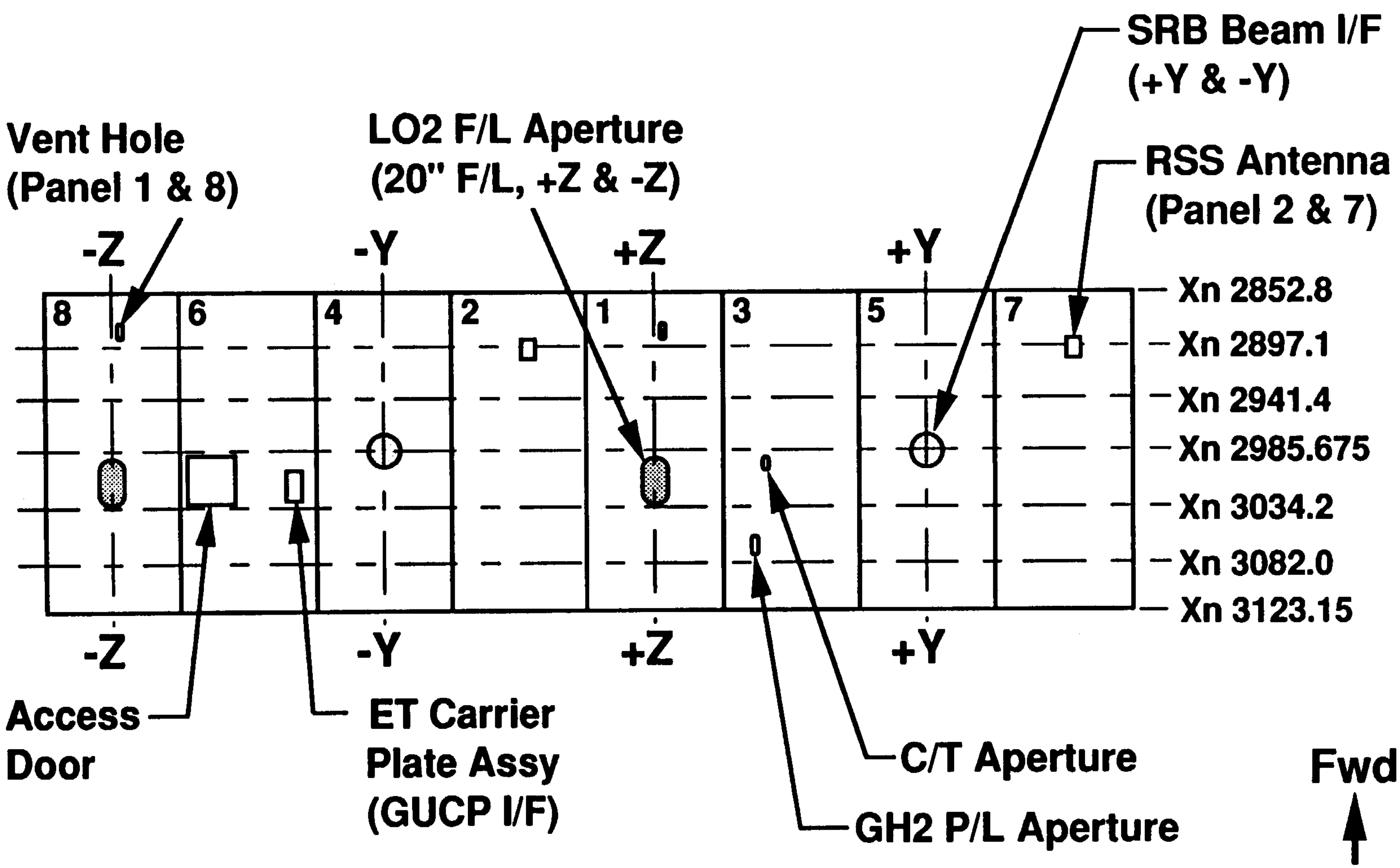
Intertank Penetrations CV-STR-14C



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LO2 Feedline Penetration CV-STR-14C

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

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LO2 Feedline Penetration CV-STR-14C

Issues

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

C-5

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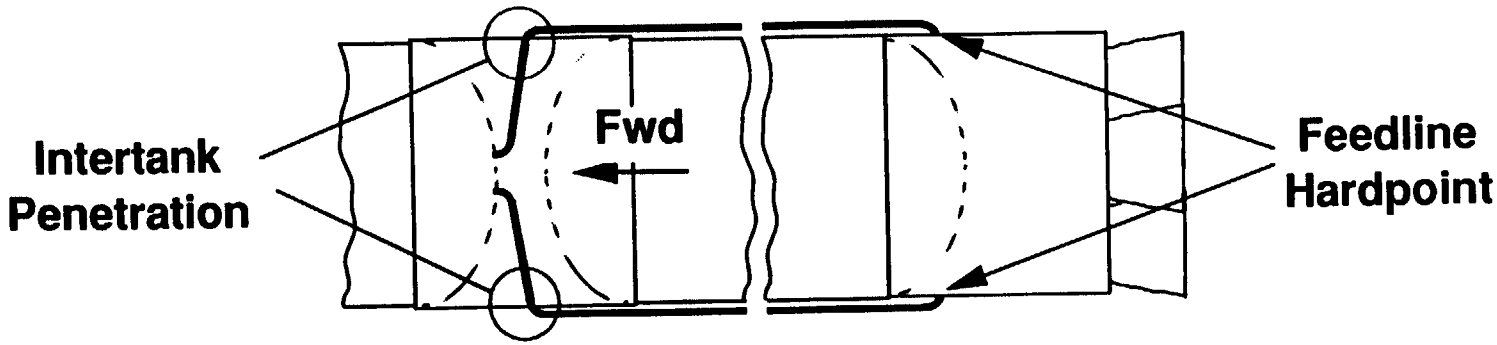
Feedline Loads & Dynamics CV-STR-14C

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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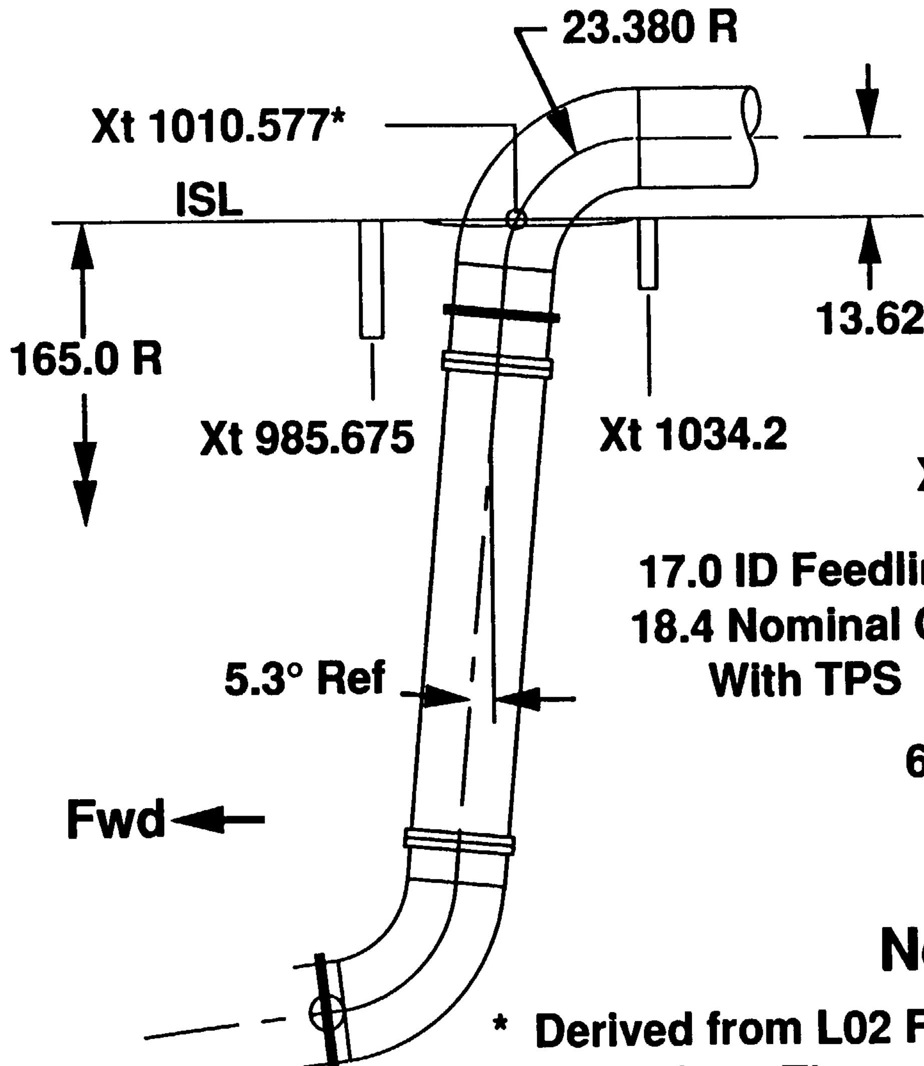
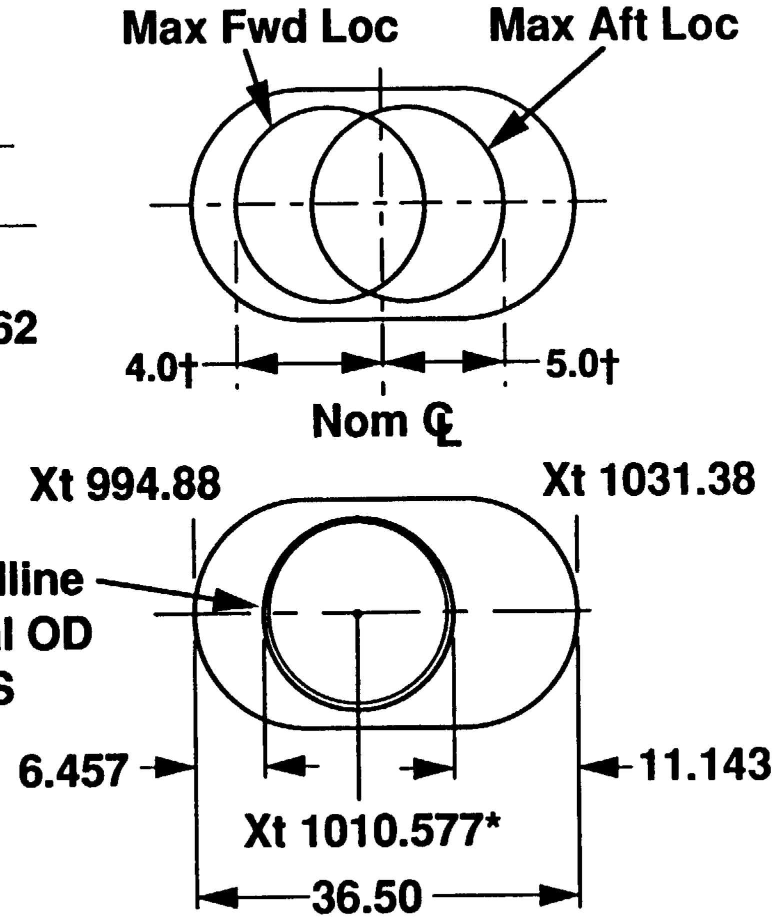
ET L02 F/L Geometry — CV-STR-14C





Nominal Feedline Clearance

* Derived from L02 F/L Motion Study 1-27-86

† Worst Case Thermal Displacement During Fill

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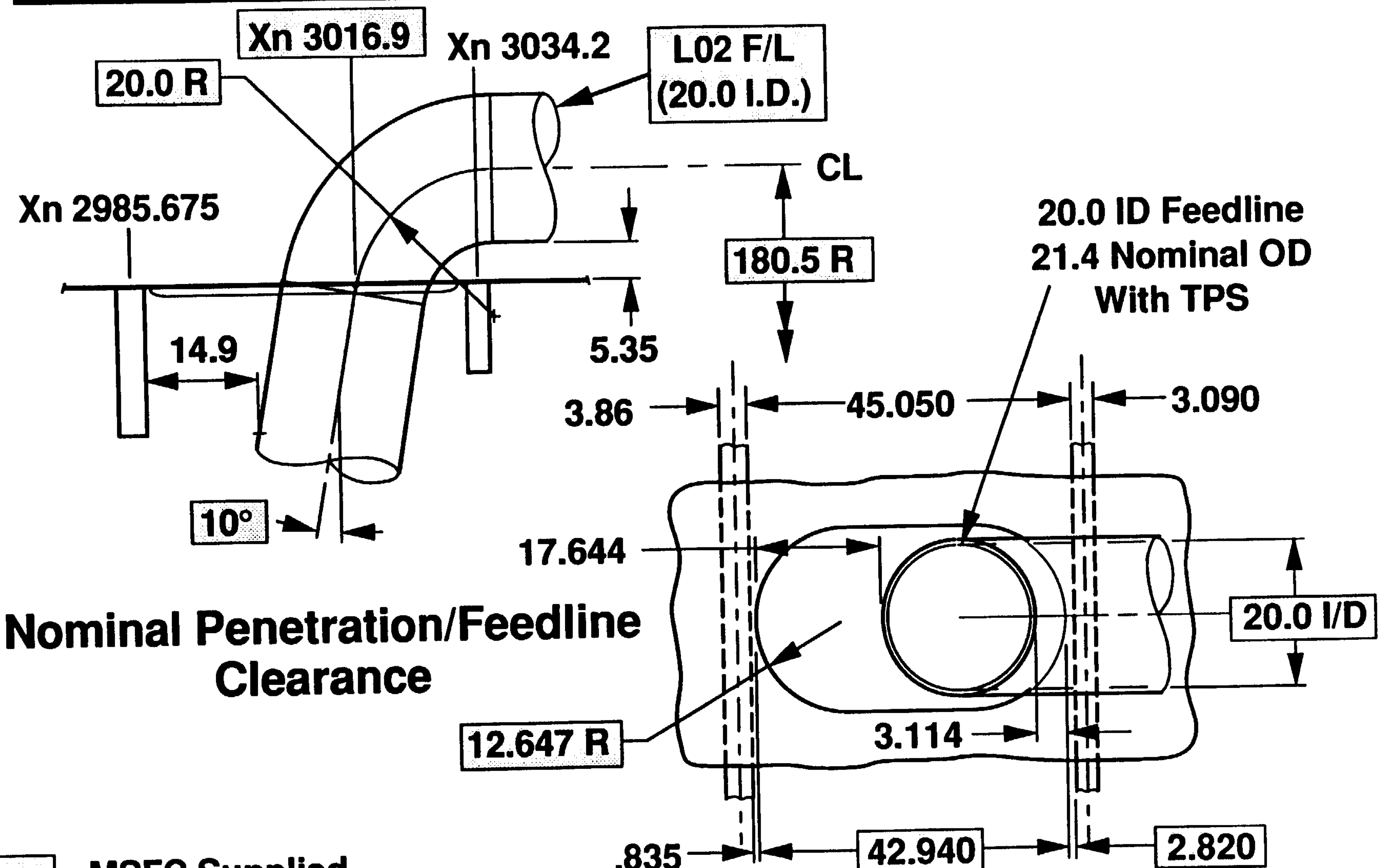
NLS LO2 Feedline Geom. CV-STR-14C



MSFC Supplied

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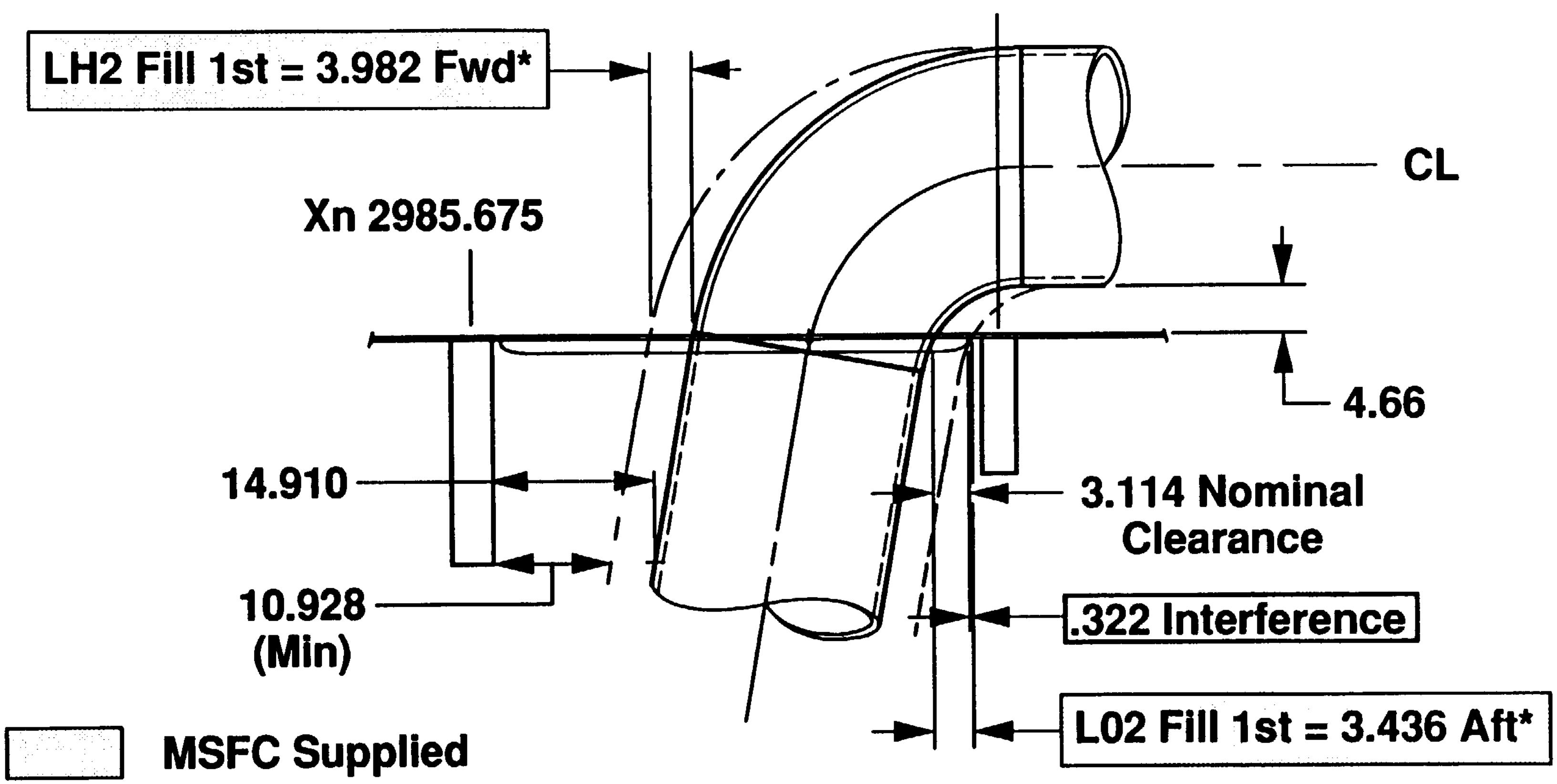
NLS LO2 F/L Penetration CV-STR-14C

Thermal Displacements



* = Thermal Displacement at Fill

Interference Exist With Only Thermal Displacement Applied

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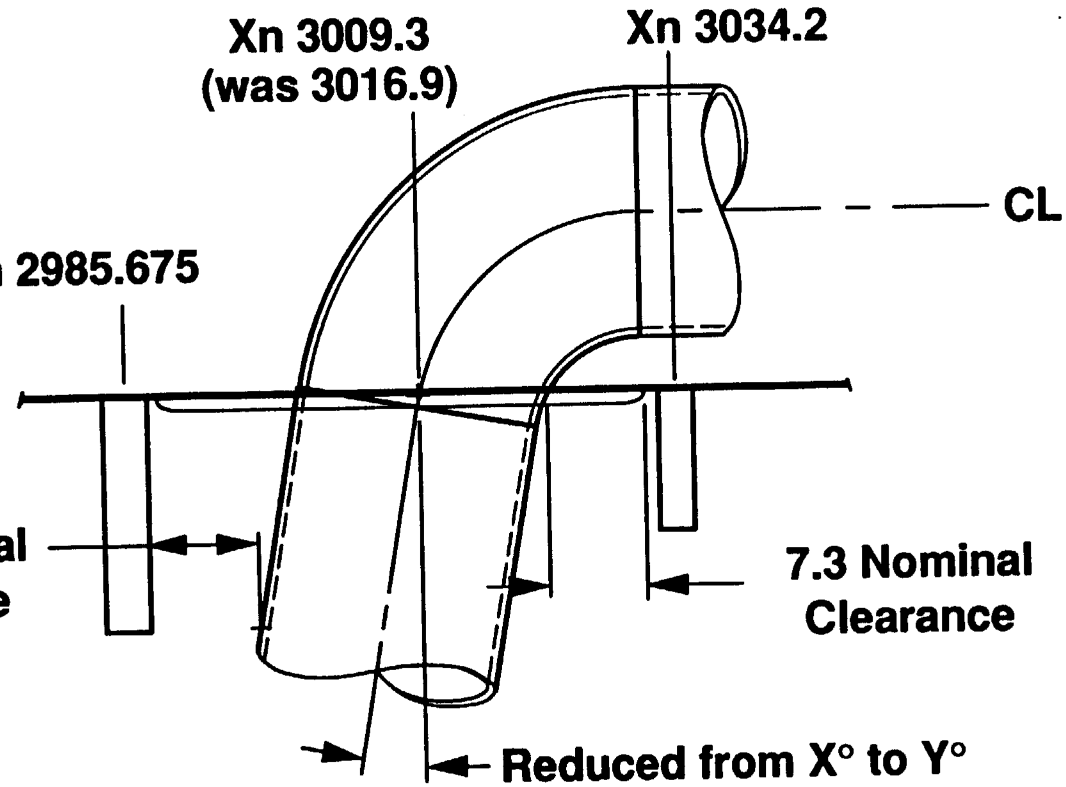
NLS LO2 F/L Penetration CV-STR-14C

Feedline Centralized For Max Clearances



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

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Conclusions CV-STR-14C

- 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

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LO2 Feedline Penetration CV-STR-14C

Items For Further Study

- Reassess Situation Based On Selected Cycle 1 Feedline Configuration
- Detailed Feedline Motion Study

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Appendix 3

- **Intertank Impacts Of No TPS**

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No TPS Impacts CV-STR-14C

Issue

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

Impacts

TPS Thk	Stringer Thk		Skin Thk		Weight Impact	
	Ref.	Reqd.*	Ref.	Reqd.*	Stringer	Skin
.00	.071	.090	.150	.120 §	446 lbs	-618 lbs

- 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)

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CV-STR-14C
Appendix 4

- **Purge And Vent**

Intertank Purge & Vent — CV-STR-14C

Issue

- The Intertank Venting Is Passive And Controlled By 2 Forward Aerovents And The Orifices Around The Subsytem 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

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Intertank Purge & Vent — CV-STR-14C

- Total ET Intertank Vent Area

Vent Item	Area	
	Min.	Max.
Vent Hole	5.66	6.31
Vent Hole	5.66	6.31
LO2 Tank Elect. Conduit Opening	.26	.47
Umbilical Panel	.11	.22
Access Door	.94	1.88
LO2 Feedline Fairing	38.79	43.02
GH2 Pressurization Line	4.16	5.88
LH2 Tank Elect. Conduit Opening	.20	.40
Total	55.78	64.49

60 Sq In Mean Total Vent Area

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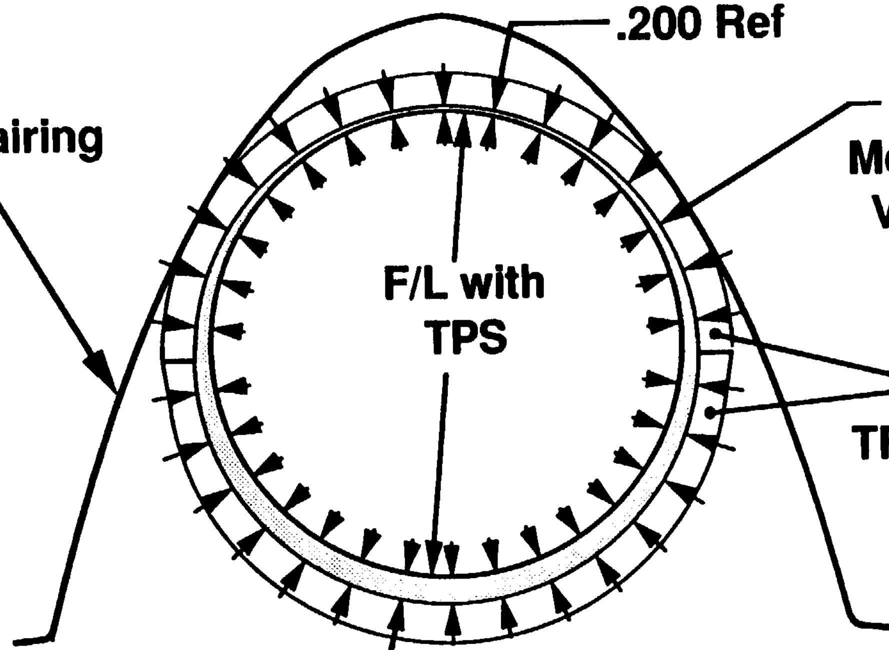
Intertank Purge & Vent CV-STR-14C

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.

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Intertank Purge & Vent CV-STR-14C

- Approx. NLS Reference Intertank Vent Area

Vent Item	Approx. Area (Mean)	
	Duplicate ET Config	Maintain ET Vent Area
Vent Hole	5.99	5.99
Vent Hole	5.99	5.99
LO2 Tank Elect. Conduit Opening	0	0
Umbilical Panel	.17	.17
Access Door	1.41	1.41
LO2 Feedline Fairing	95.46	41.12
GH2 Pressurization Line	5.02	5.02
LH2 Tank Elect. Conduit Opening	.30	.30
Total	94.68	60.0

Intertank Purge & Vent CV-STR-14C

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 Δ p's

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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

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Appendix 5

- **Intertank Sizing Modifications**

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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

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CV-STR-14C
Appendix 6

- **Intertank Part Definition**

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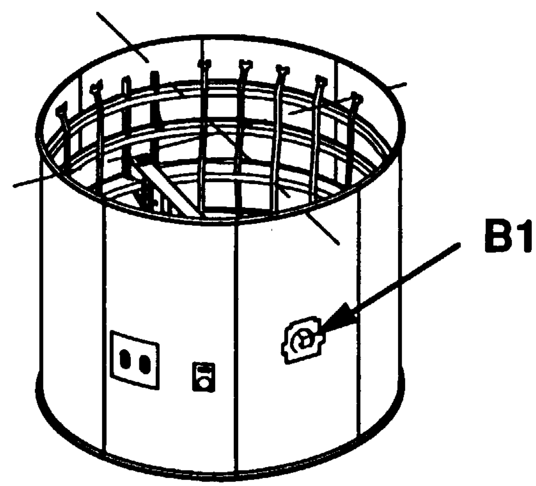
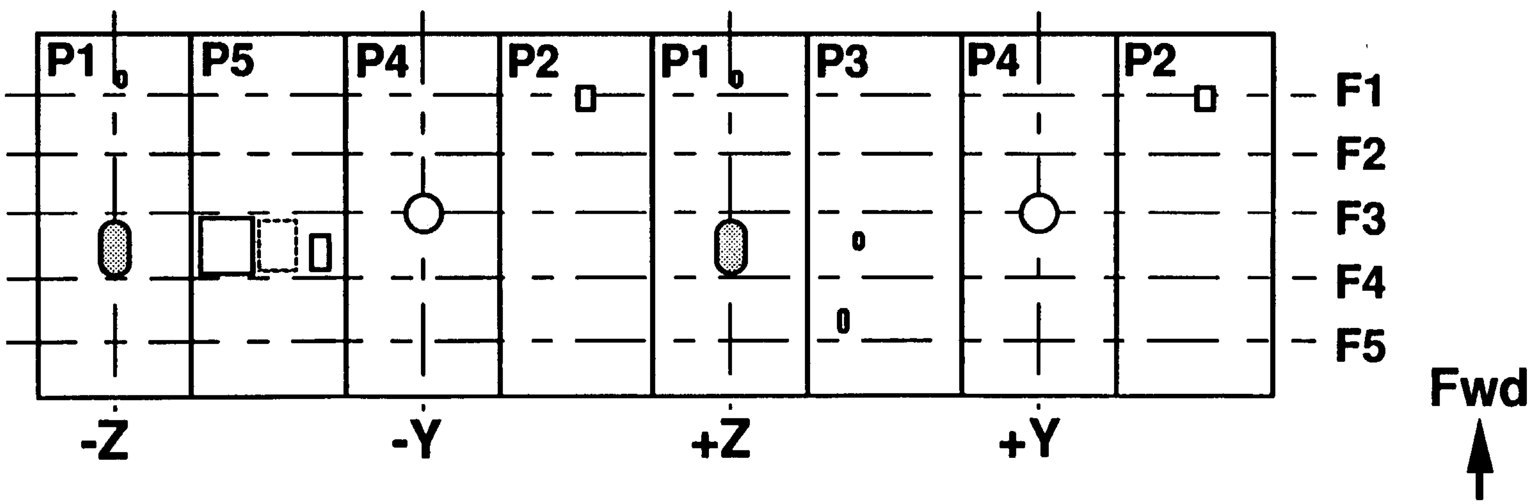
Intertank Part Definition CV-STR-14C





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Intertank Part Definition — CV-STR-14C

Part	Title	Part Status ET	Part Status Mod.	Part Status New	Remarks
F1	Frame 2897.1	√	-	-	
F2	Frame 2941.4	√	-	-	
F3	Frame 2985.675	√	√*	-	1.5 Stage Modified To Complete Fr Without XBeam
F4	Frame 3034.2	√	-	-	
F5	Frame 3082.0	√	-	-	
P1	Panel (±Z)	-	-	√	Resized For NLS Loads
P2	Panel	-	-	√	
P3	Panel	-	-	√	
P4	Thrust Panel (±Y)	√	√*	-	1.5 Stage Modified To Omit SRB Ftg Hole
P5	Panel	-	-	√	HLLV Only
B1	SRB Beam	√	-	-	

* 1.5 Stage Only

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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)

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5.2.5.4.1 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 ommitted (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.

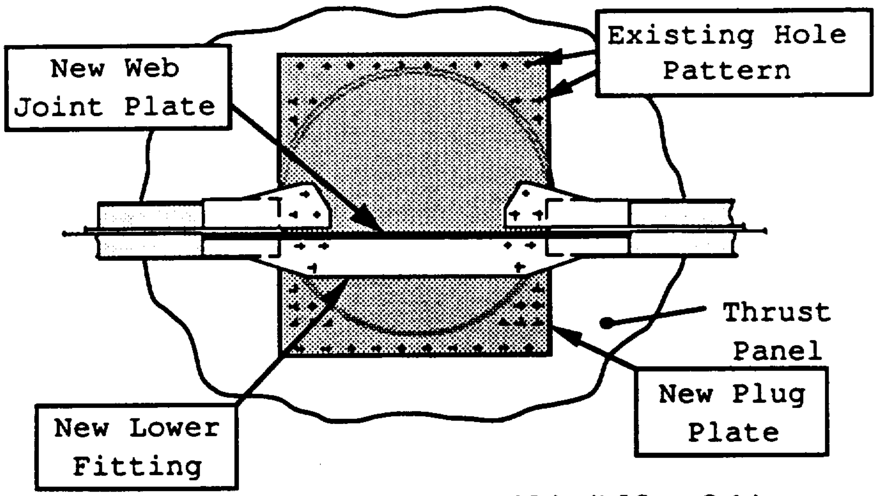
Conclusions

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 idendified for study during Cycle 1.

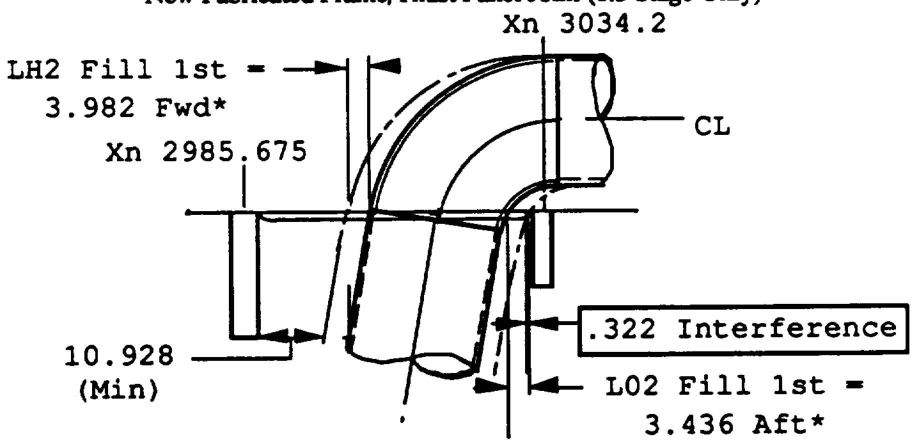
Study Recommendations

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/Thust Panel Joint (1.5 Stage Only)



* Thermal displacement

Reference LO2 Feedline Penetration

Vent Item	Duplicate ET Config	Maintain ET Vent Area
Vent Hole	5.99	5.99
Vent Hole	5.99	5.99
LO2 Tank Elect. Conduit Opening	0	0
Umbilical Panel	.17	.17
Access Door	1.41	1.41
LO2 Feedline Fairing	95.46	41.12
GH2 Pressurization Line	5.02	5.02
LH2 Tank Elect. Conduit Opening	.30	.30
Total	94.68	60.00

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.
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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 idendified 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).
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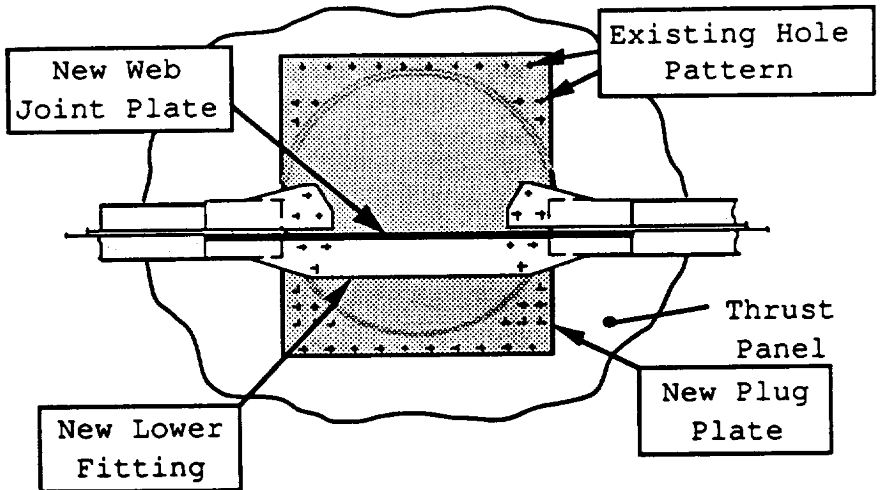
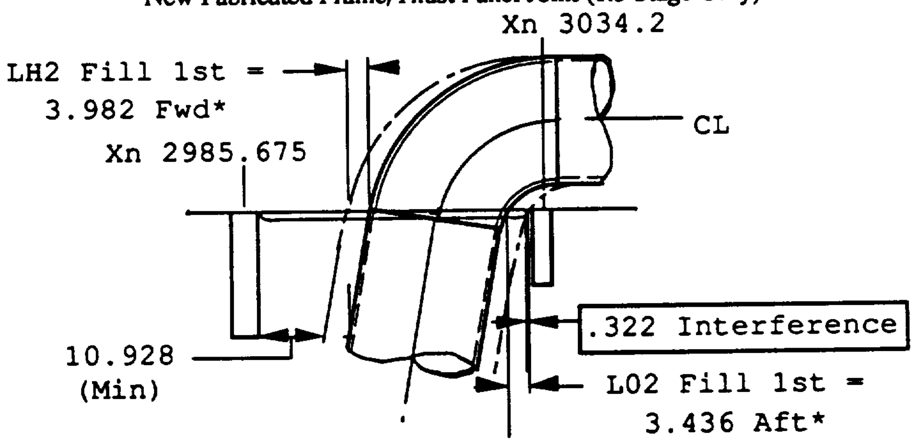
- Study alternate methods of sealing the LO2 feedline penetrations and potential for a fixed vent area (Cycle 1 task).



New Fabricated Frame/Thust Panel Joint (1.5 Stage Only)



* Thermal displacement

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Umbilical Panel	.17	.17
Access Door	1.41	1.41
LO2 Feedline Fairing	95.46	41.12
GH2 Pressurization Line	5.02	5.02
LH2 Tank Elect. Conduit Opening	.30	.30
Total	94.68	60.00

NLS Intertank Vent Area

Additional Information

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

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CV-STR-14D
LH2 Tank Structural Reference Configuration Enhancements

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

Approved By: M.R.Simms

Rev: Initial
Date: January 8, 1991

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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 — CV-STR-14D

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 CV-STR-14D

- 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 & Intallation
- Frame Stablizer Configuration
- Size & Qty Of Intermediate Frames
- Barrel 1A Impacts From PM Assessment
- Vortex Baffle Definition

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Related Tasks — CV-STR-14D

- CV-STR-14G External Hardware Definition
- CV-STR-14H TPS Reference Definition
- CV-STR-16D Transportation & Handling
- CV-DI-01A Tank Access

Recommended Changes CV-STR-14D

Study Item	Recomendation	Back Up Data	* Wt. Impact	Status
Barrel/Frame Geom.	Use New Geom & Frs	Append. 1	N/A	Incorp.
Alt. Fwd Chord & Fr.	Change Chord & Fr	Append. 2	-47 lbs	Incorp.
Ext. Hardware I/F's	Incorporate Into Ref	Append. 3	18 lbs	Accepted
Ch./Barrel Weld Lands	M/c Chord Weld Lands	Append. 4	N/A	Incorp.
Handling Points	Incorporate Option 3	Append. 5	17 lbs	Accepted
Alt Aft Dome Config	Incorporate Into Ref	Append. 6	-35 lbs	Accepted
Level Sensor Instl.	Adopt Opt 2 As Ref	Append. 7	6-15 lbs	Accepted
Ref Part Definition	N/A	Append. 8	N/A	N/A

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

* Weight Impacts Include 8% Contingency

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Appendix 1

- **Barrel/Frame Geometry Definition**

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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

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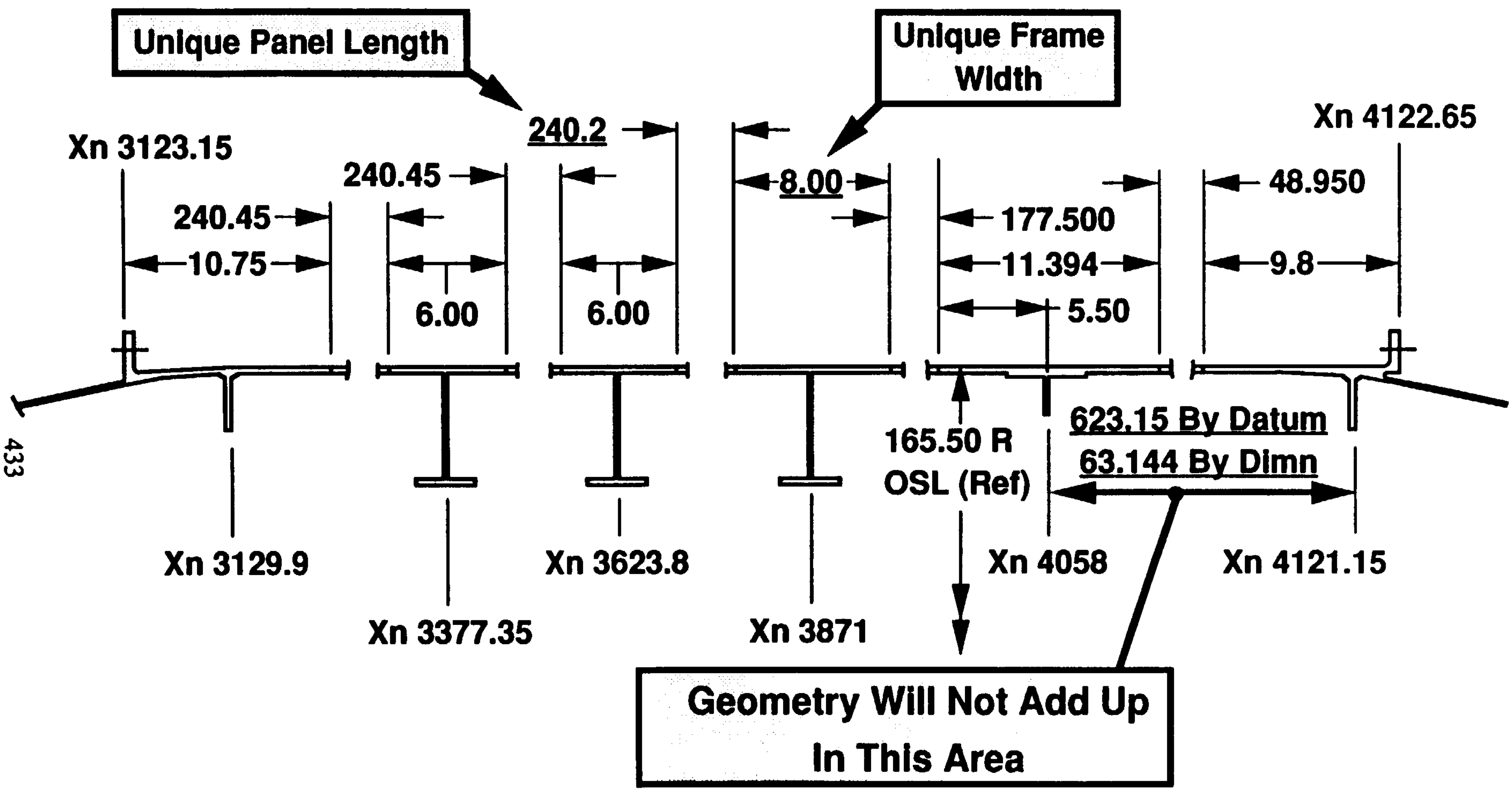
Ref Geometry Definition CV-STR-14D



2 Standard Barrels & Frames

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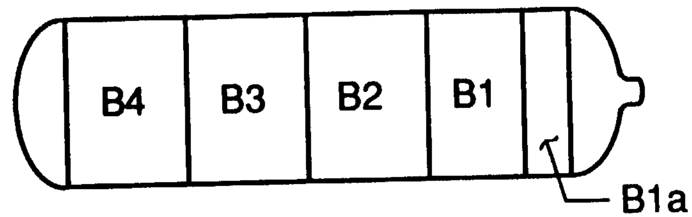
Ref Barrel Commonality CV-STR-14D



	Xn 3129.9 – Xn 3377.35	Xn 3377.35 – Xn 3623.8	Xn 3623.8 – Xn 3871	Xn 3871 – Xn 4058	Xn 4058 – Xn 4120.85
+Y	B3P1	B3P1	B2P1	B1P1	B1aP1
CL of Press Lines & C/T	B4P2	B3P2	B2P2	B1P2	B1aP2
+Z	B3P1	B3P1	B2P1	B1P1	B1aP1
	B3P1	B3P1	B2P1	B1P1	B1aP1
-Y	B3P1	B3P1	B2P1	B1P1	B1aP1
	B3P1	B3P1	B2P1	B1P1	B1aP1
-Z	B3P1	B3P1	B2P1	B1P1	B1aP1
+Y	B3P1	B3P1	B2P1	B1P1	B1aP1

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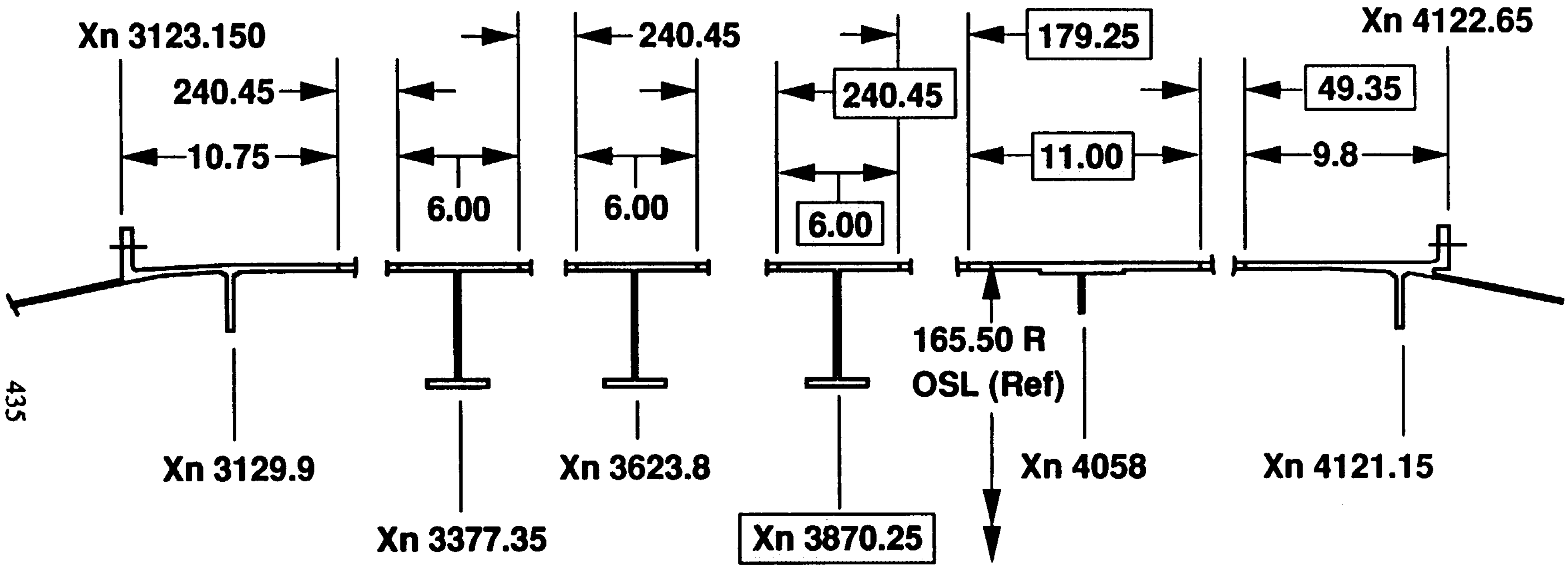
Alternate Geometry Definition CV-STR-14D



Modified

3 Standard Barrels & Frames

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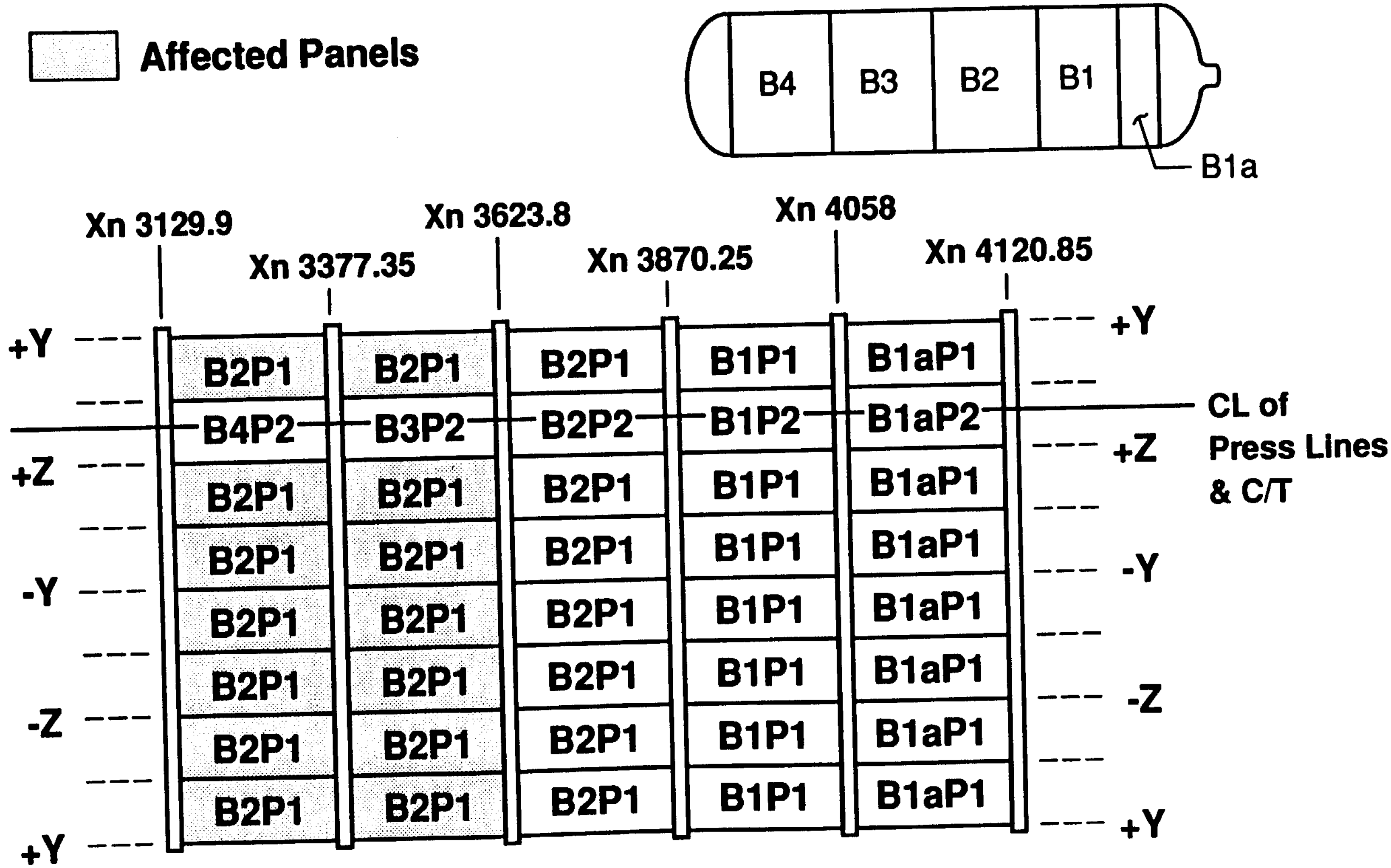
Alternate Barrel Commonality CV-STR-14D



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Recommendation CV-STR-14D

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

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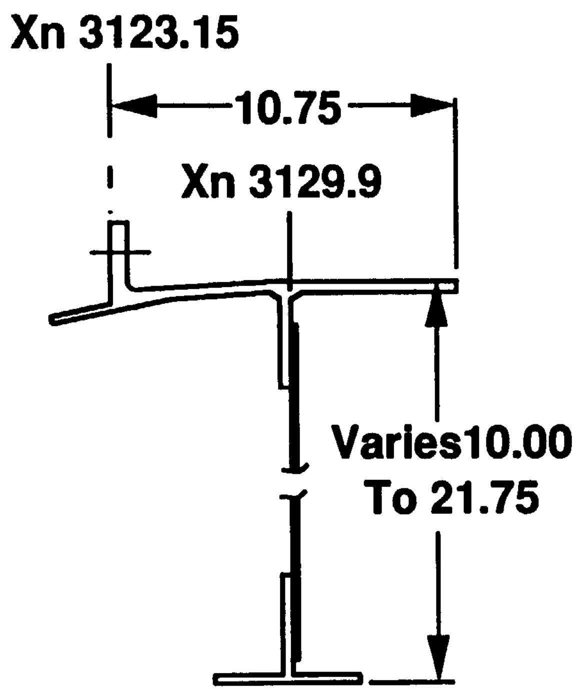
CV-STR-14D
Appendix 2

- **Substitution Of Alternate Fwd Dome Chord & Frame (Including Geometry Update)**

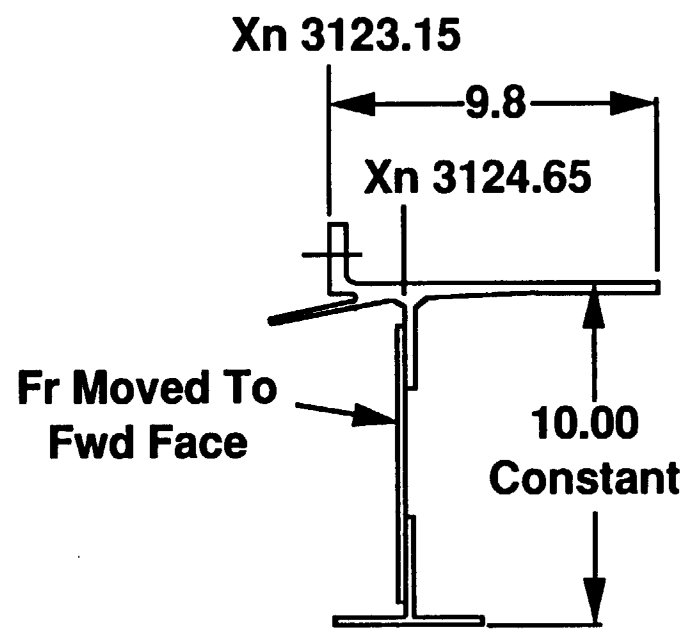
Alt. Fwd Dome Chord & Frame CV-STR-14D

Reference Fwd Dome Chord



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

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)

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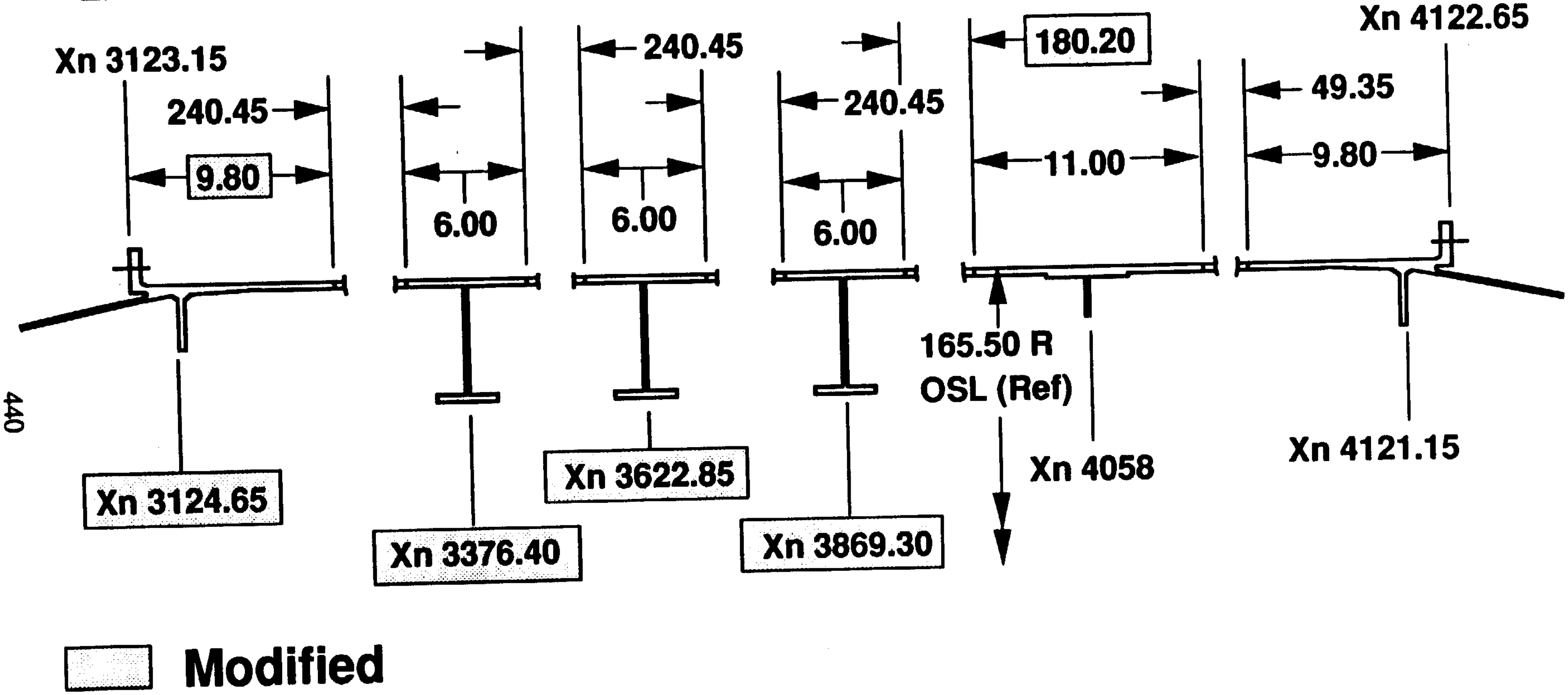
Alt. Fwd Dome Chord & Frame CV-STR-14D

Modified Geometry



Modified Geometry Will Still Permit Increased Barrel Commonality Recommended By Appendix 1

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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

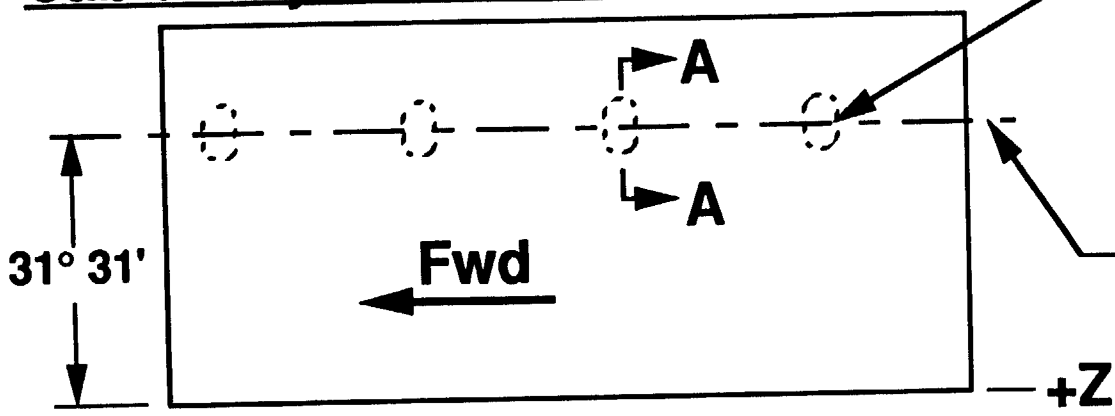
- Define Locations For External Hardware Mounting Provisions On The LH2 Tank

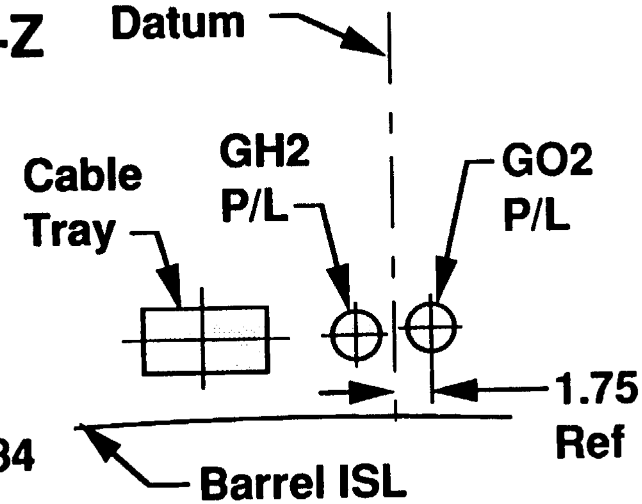
Groundrules (Pending Completion Of CV-STR-14G)

- 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 $\pm$ Z Axis

External H/W Mtg Provisions CV-STR-14D

Cable Tray/Pressure Line Interfaces





Section A-A
(Typ)

Ext Ftg Locations:

Barrel 1a = Xn 4092.6
Barrel 1 = Xn 4028, Xn 3980.8, 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

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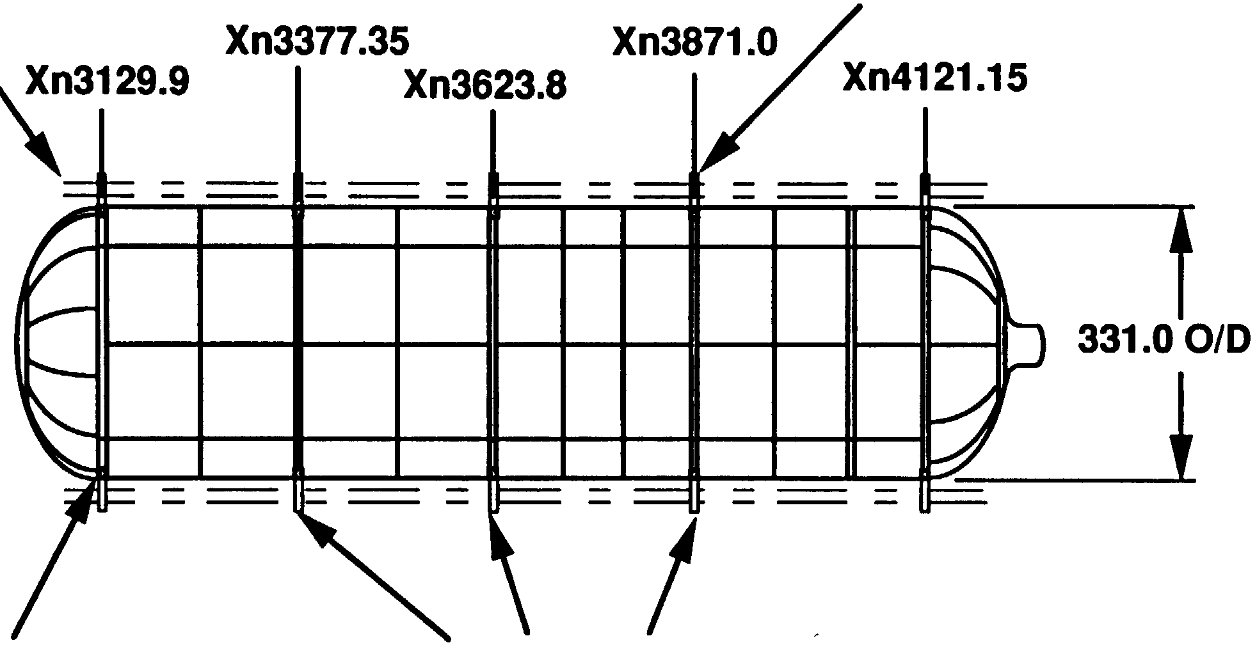
External H/W Mtg Provisions CV-STR-14D

- **Locations On ±Z, Based On Reference Geometry**

LO2 Feedline ± Z Axis

LO2 Feedline Support



Dome Chord Feedline Support Interface Similar To 80914140997 Sh 15 View V

Frame Feedline Support Interface Similar To 80914500961 Sh 4 View R Fr Xn3377.35 80914500961 Sh 13 View BL Frs Xn3623.8 & Xn3871

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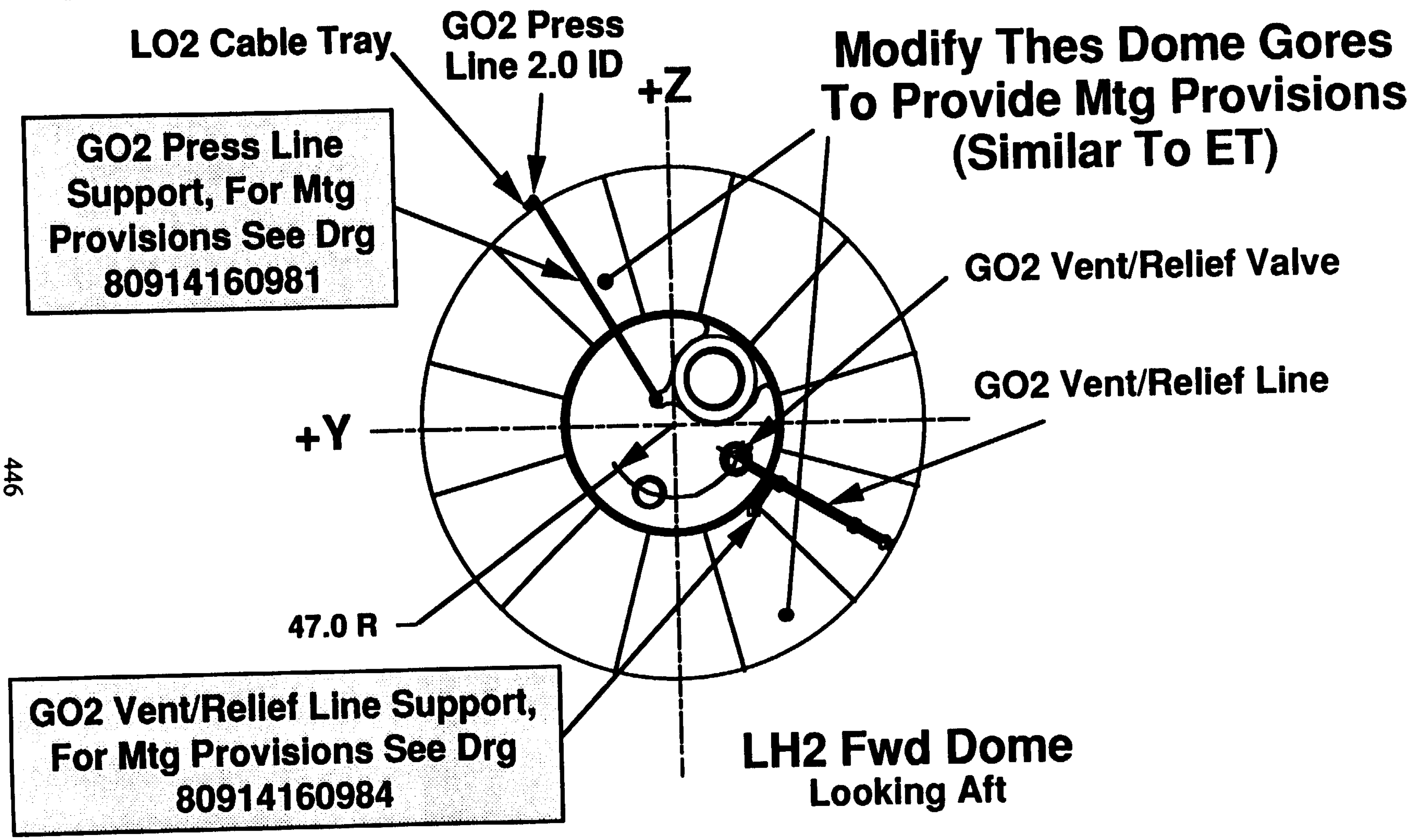
External H/W Mtg Provisions CV-STR-14D



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External H/W Mtg Provisions CV-STR-14D

Recommendation

- Add External Hardware Mtg Provisions To Reference LH2 Tank Definition

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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

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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

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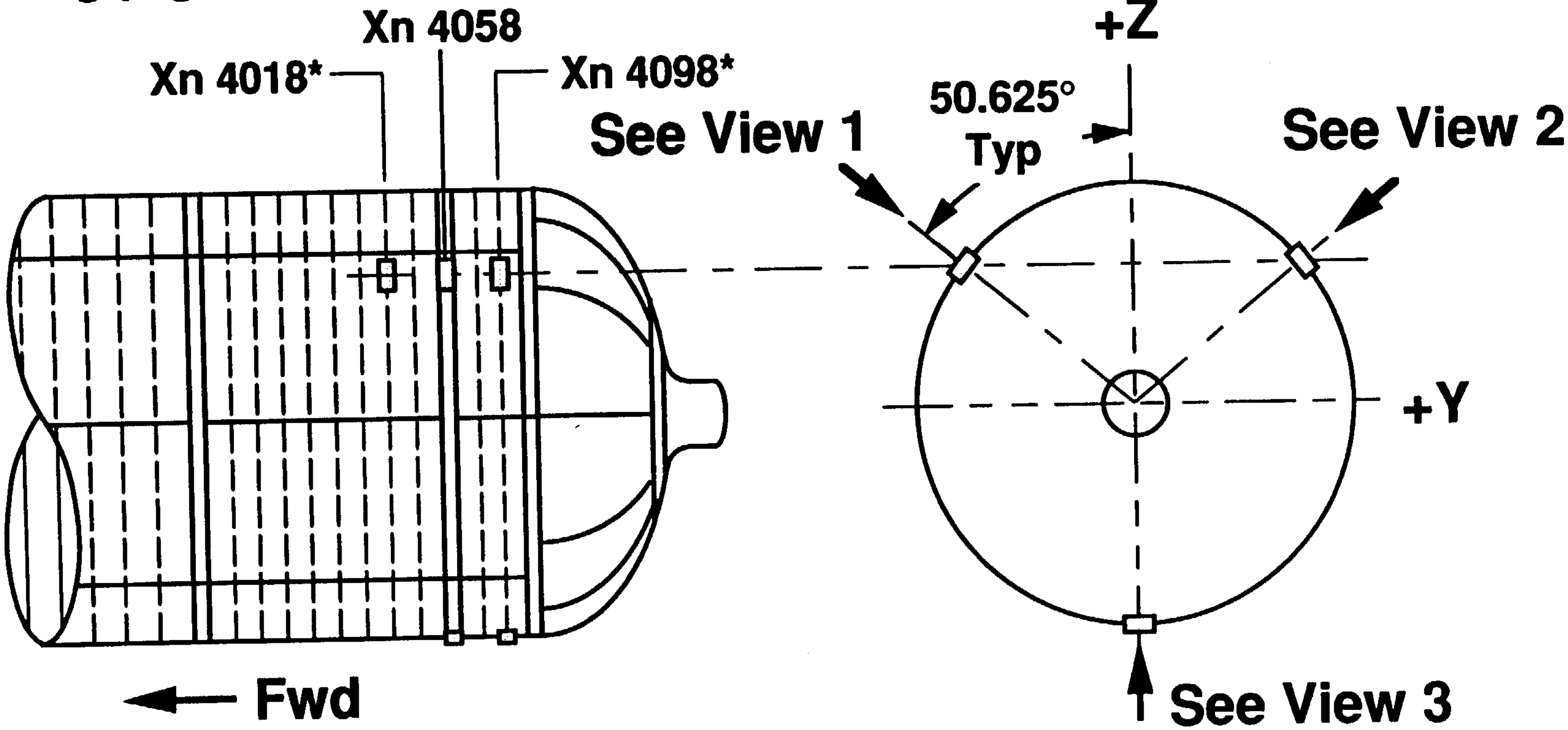
LH2 Tank Handling Points I/F's CV-STR-14D

- 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

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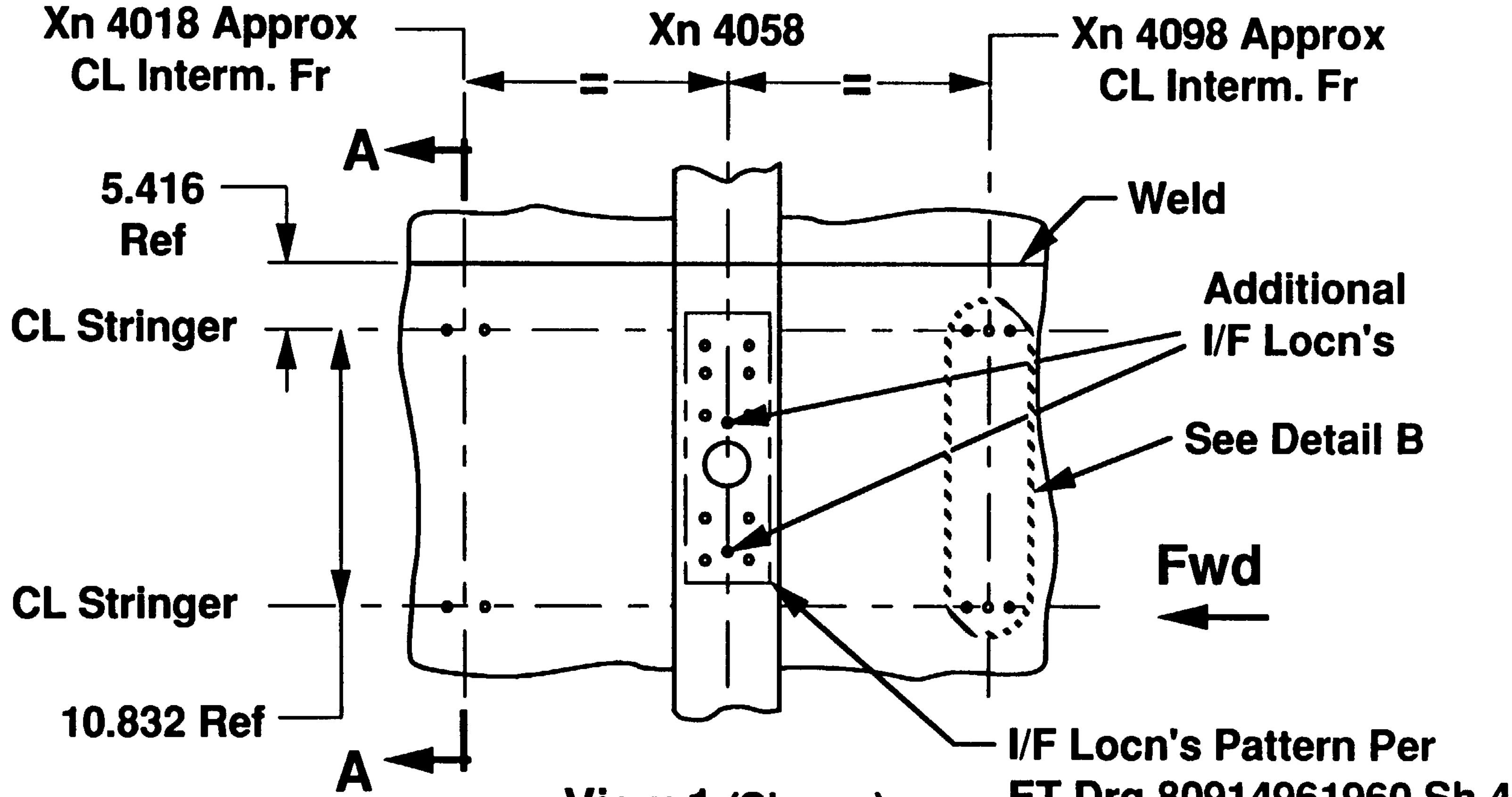
+Z Handling Point I/F's CV-STR-14D



View 1 (Shown)
View 2 (Opposite)
(Handling Tools Not Shown For Clarity)

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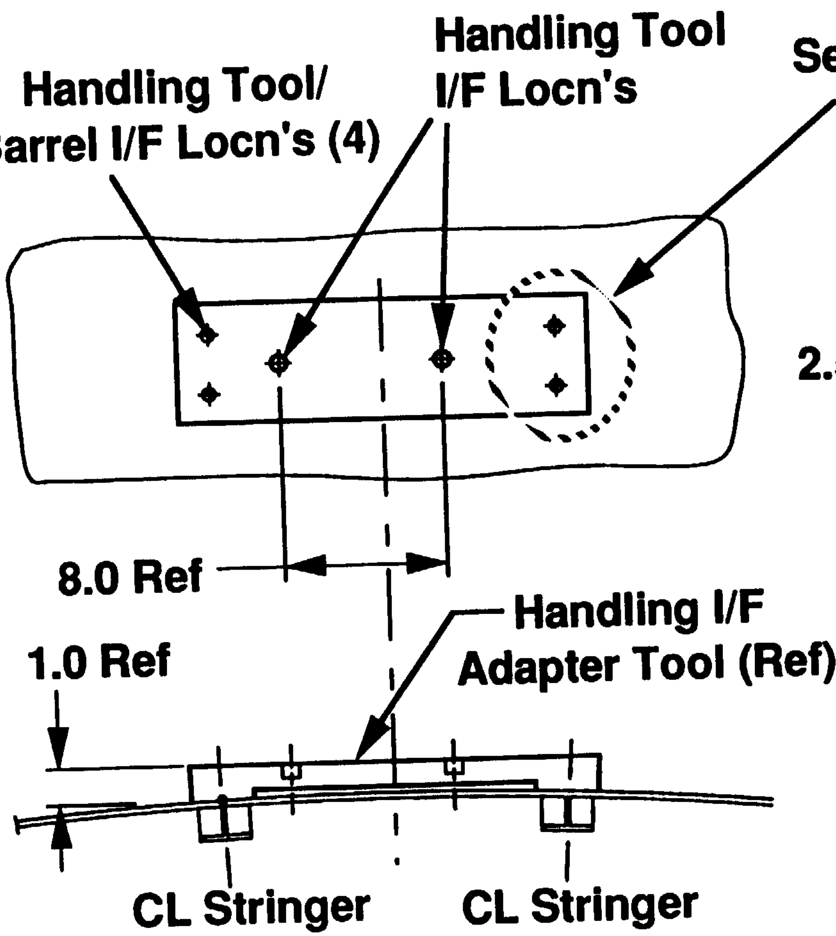
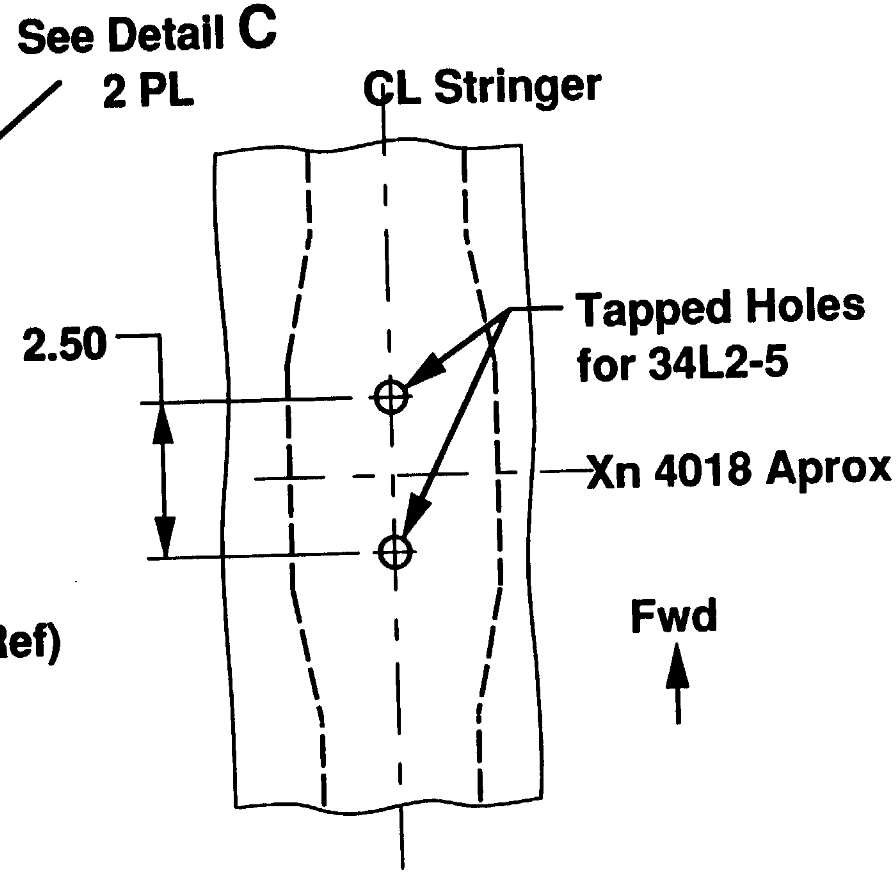
Fwd Handling Point I/F's CV-STR-14D



Section A-A
Rotated



Detail C
(Handling Tool Not Shown For Clarity)

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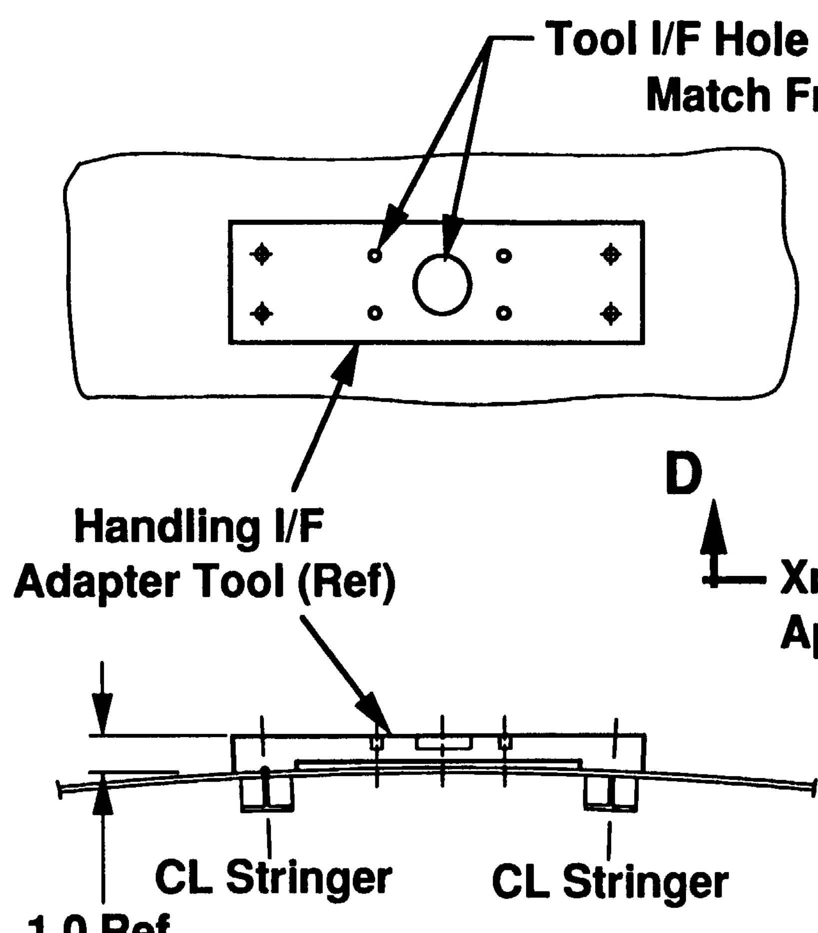
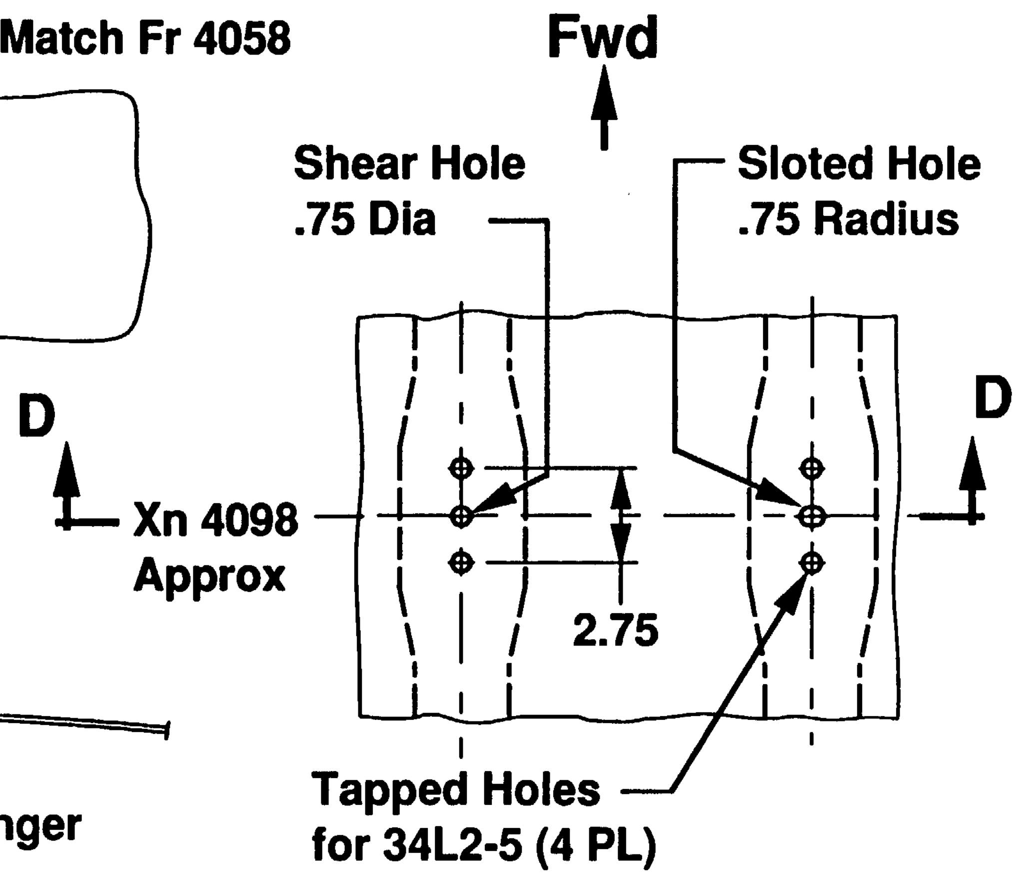
Aft Handling Point I/F's CV-STR-14D



Section D-D



Detail B Rotated
(Handling Tool Not Shown For Clarity)

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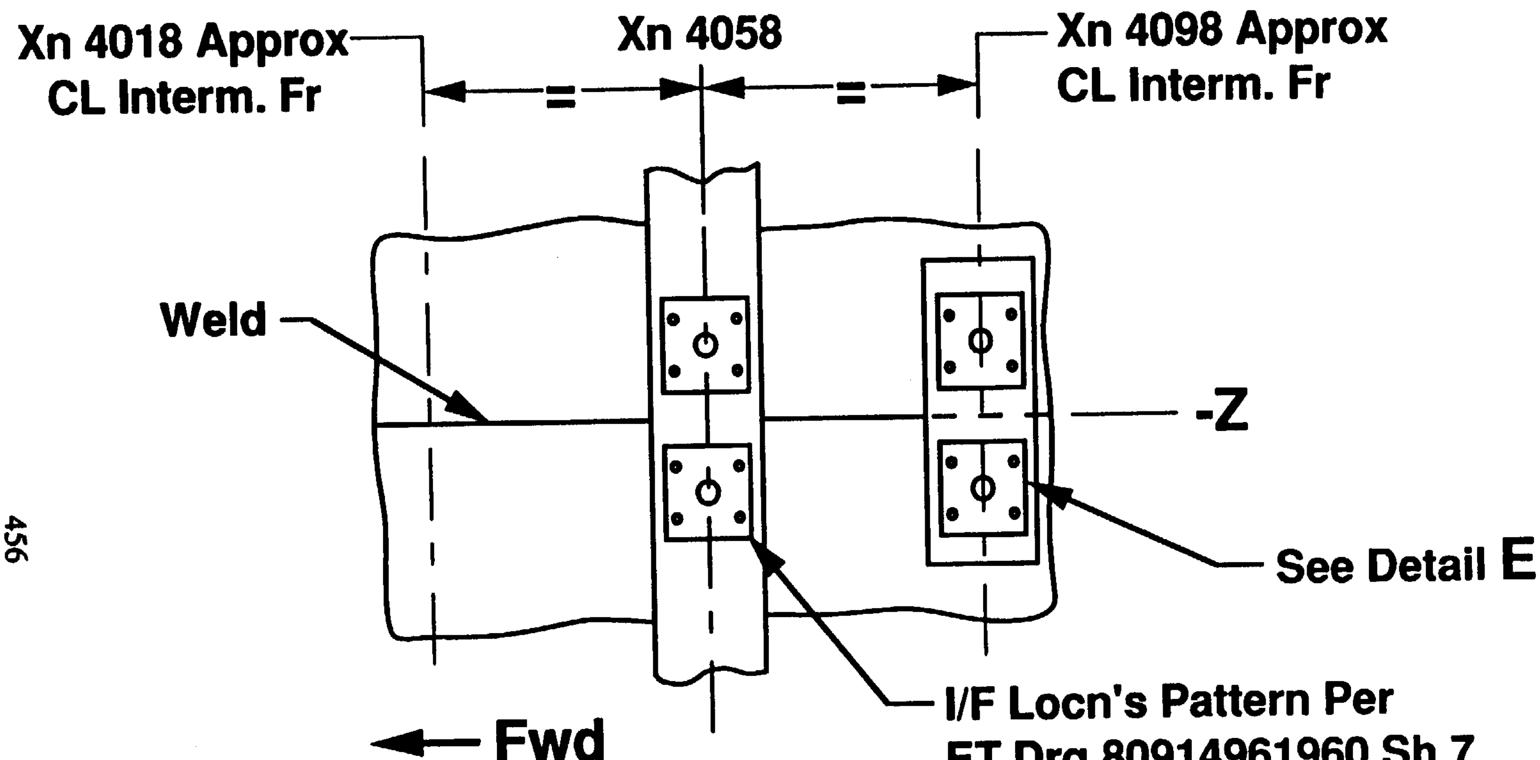
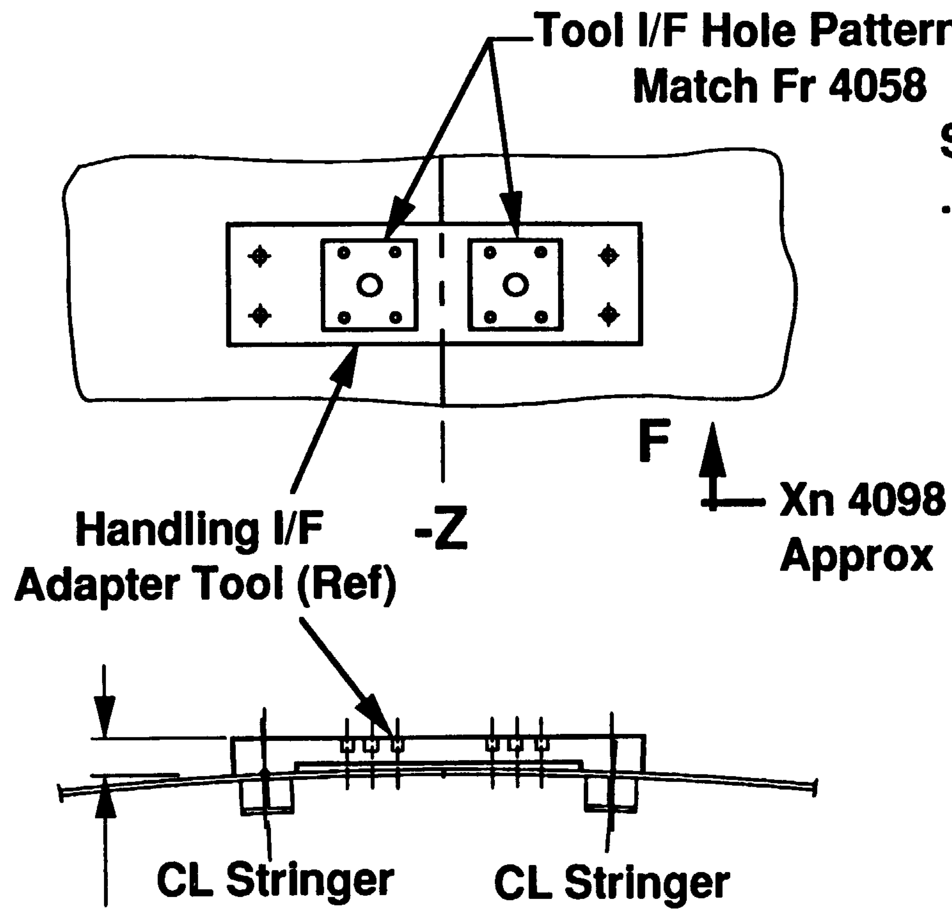
-Z Handling Point I/Fs CV-STR-14D

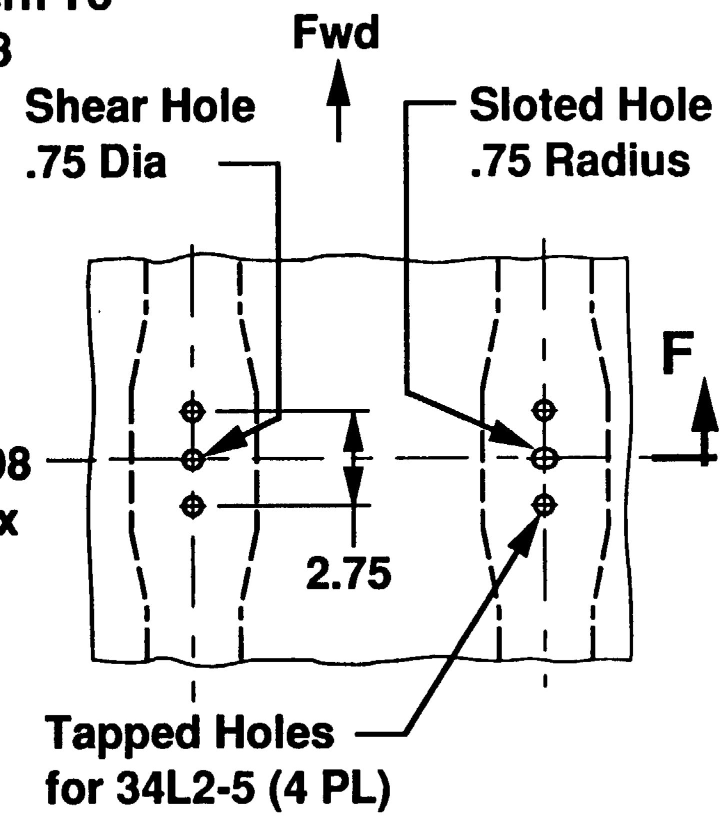


View 3

-Z Aft Handling Point I/F CV-STR-14D



Section F-F



Detail E

Hole Pattern Drilled After Assy Weld
(Handling Tool Not Shown For Clarity)

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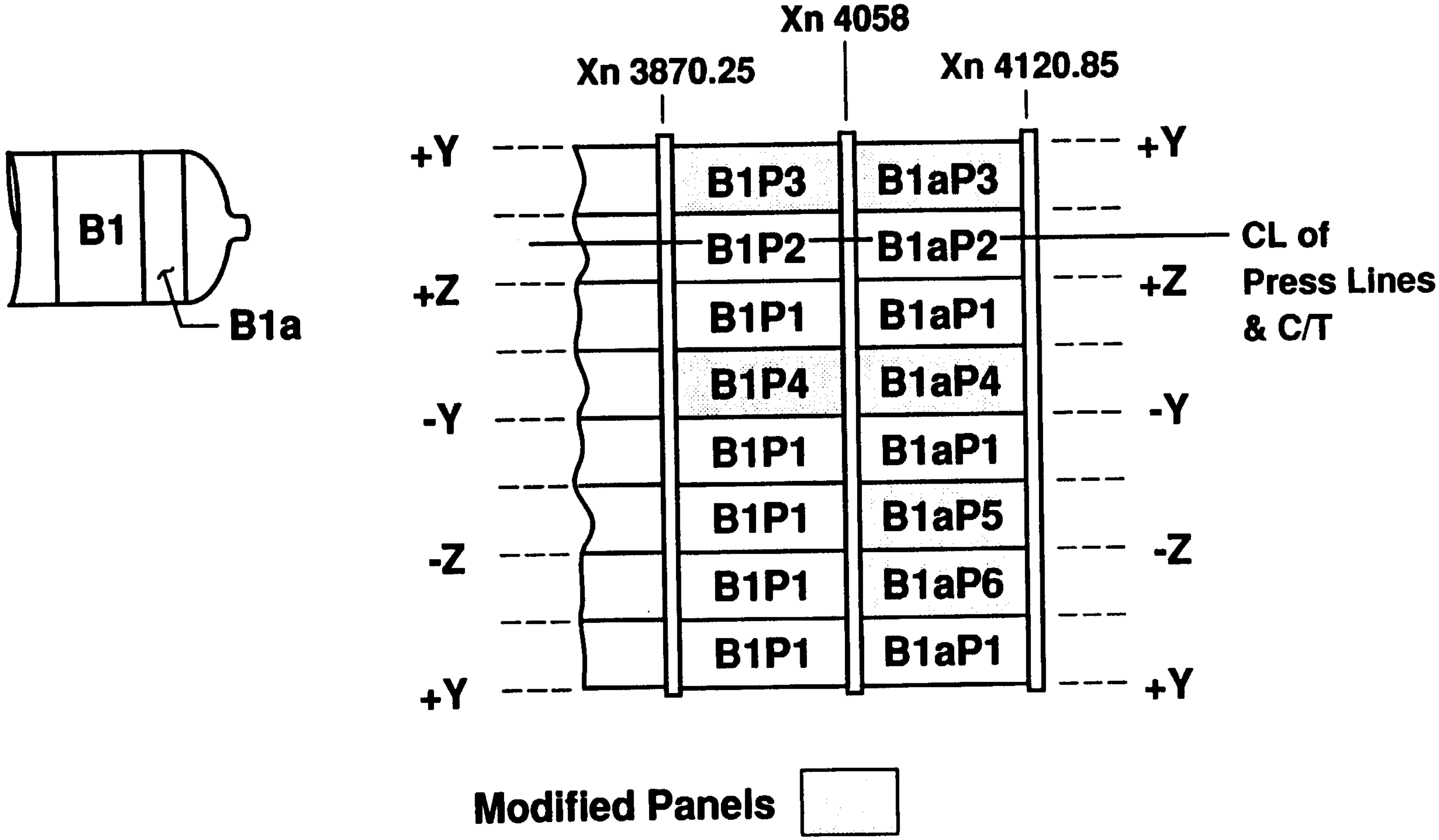
LH2 Tank Handling Points CV-STR-14D

Barrel Panel Commonality Impacts



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LH2 Tank Handling Points — CV-STR-14D

Recommendation

- Incorporate The Transportation & Handling Points As Configured By This Study

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CV-STR-14D
Appendix 6

- **Alternate Aft Dome Configuration**

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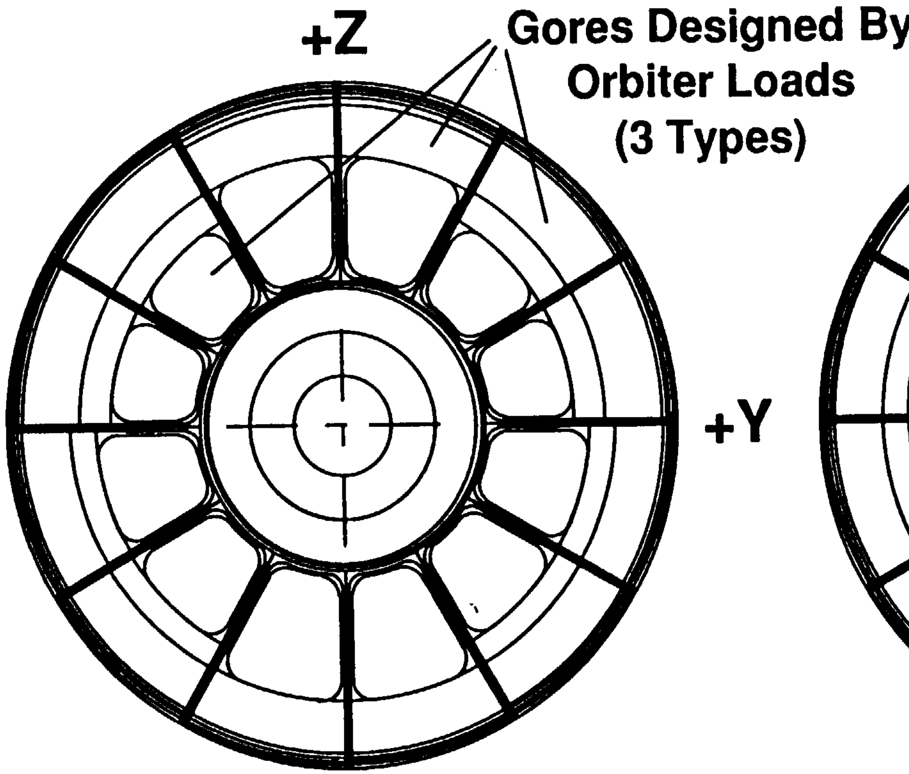
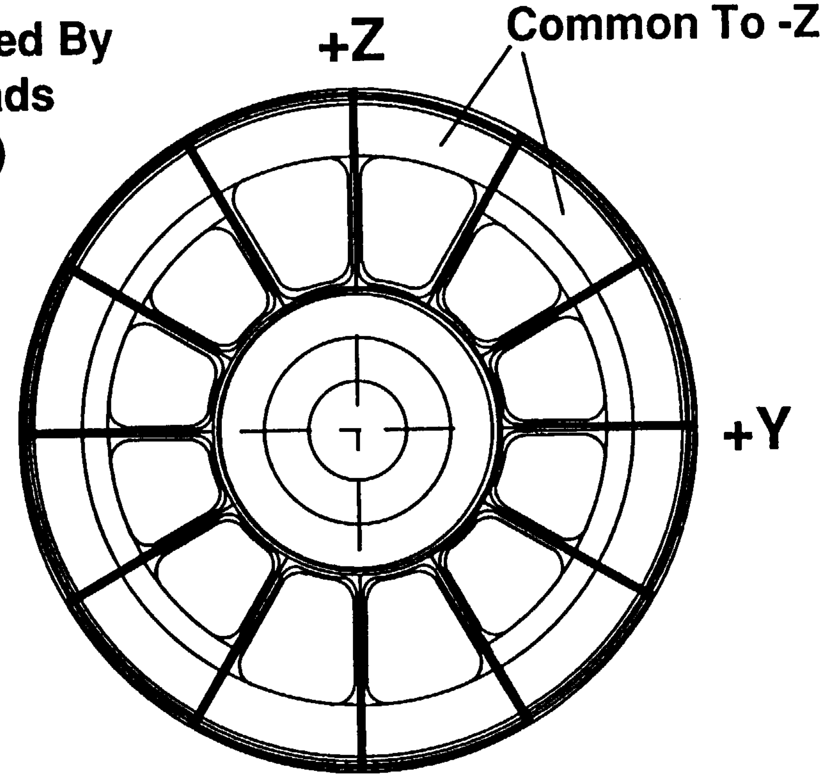
Alternate Aft Dome Config. CV-STR-14D





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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Recommendation CV-STR-14D

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

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CV-STR-14D
Appendix 7

- **Fwd Sensor Installation**

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Fwd Sensor Installation CV-STR-14D

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 CV-STR-14D

Reference - ET Mast

Option 1 - Single Dome Cap Stinger

Option 2 - Dual Stingers, Additional Radial Stinger In Gore

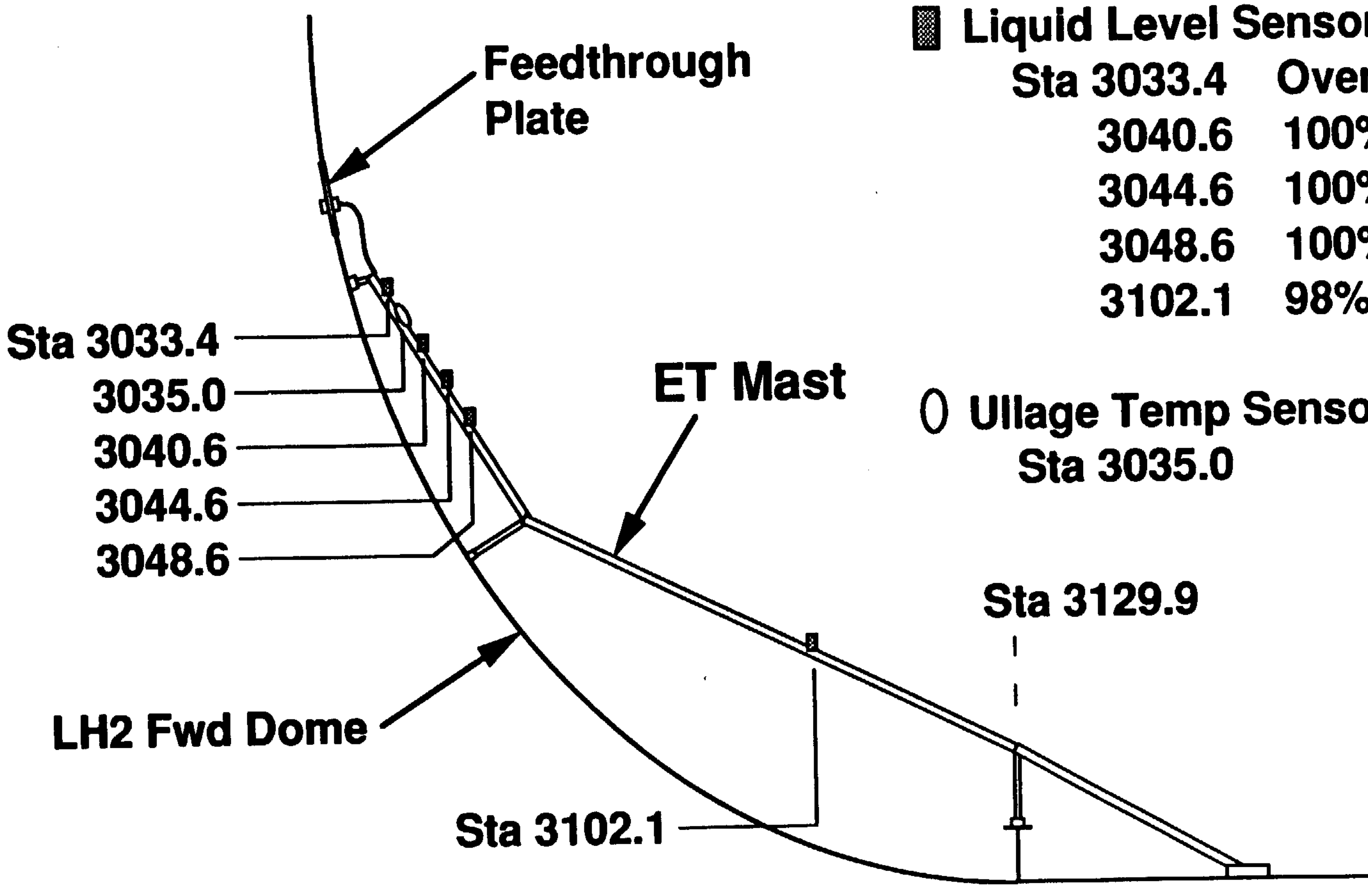
Option 3 - Dual Stingers, Gore Stinger With Vertical Instln

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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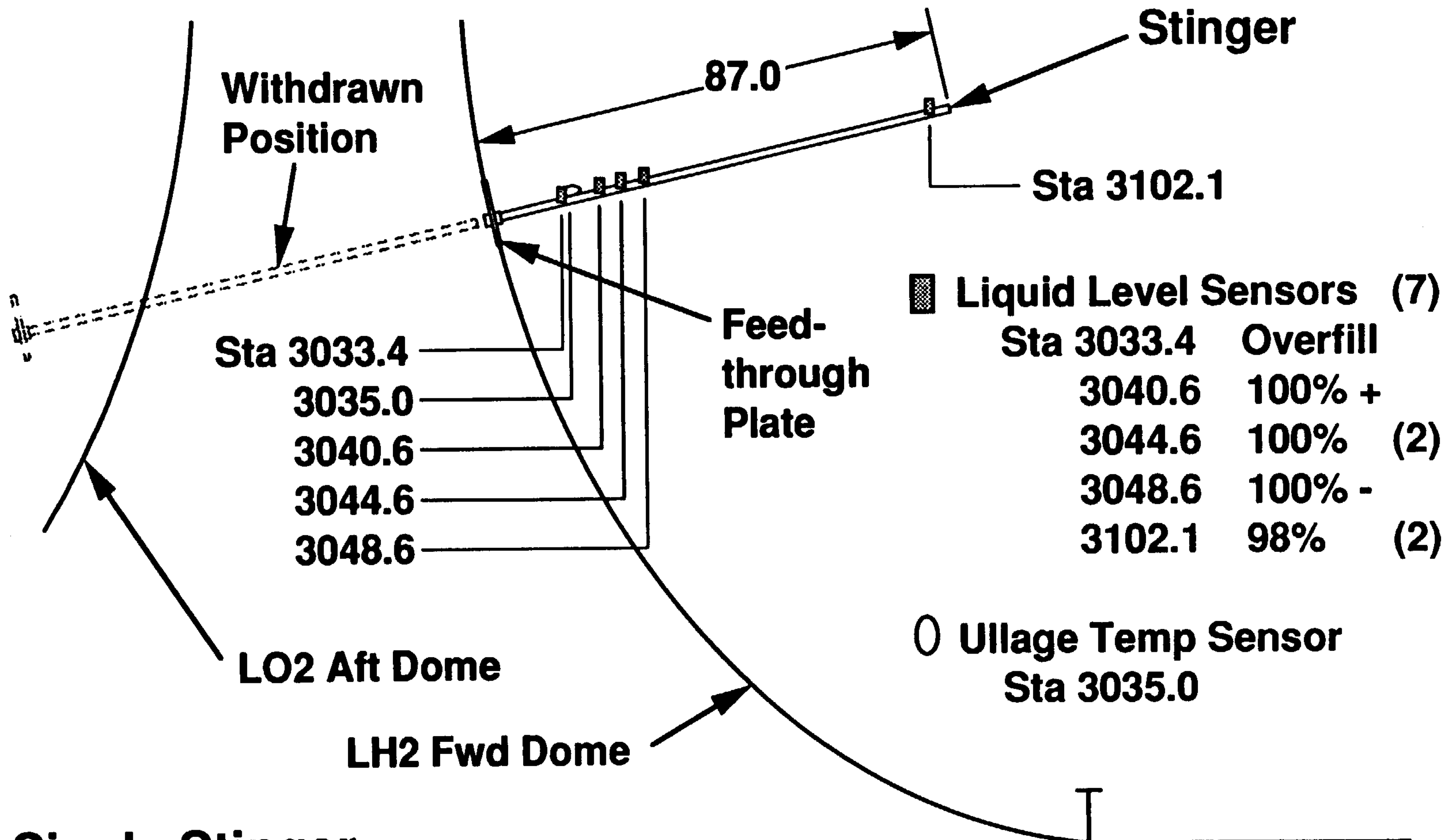
Opt 1 Fwd Sensor Config. CV-STR-14D



- Single Stinger
- Location Based On Utilizing Existing Feedthru Plate Location

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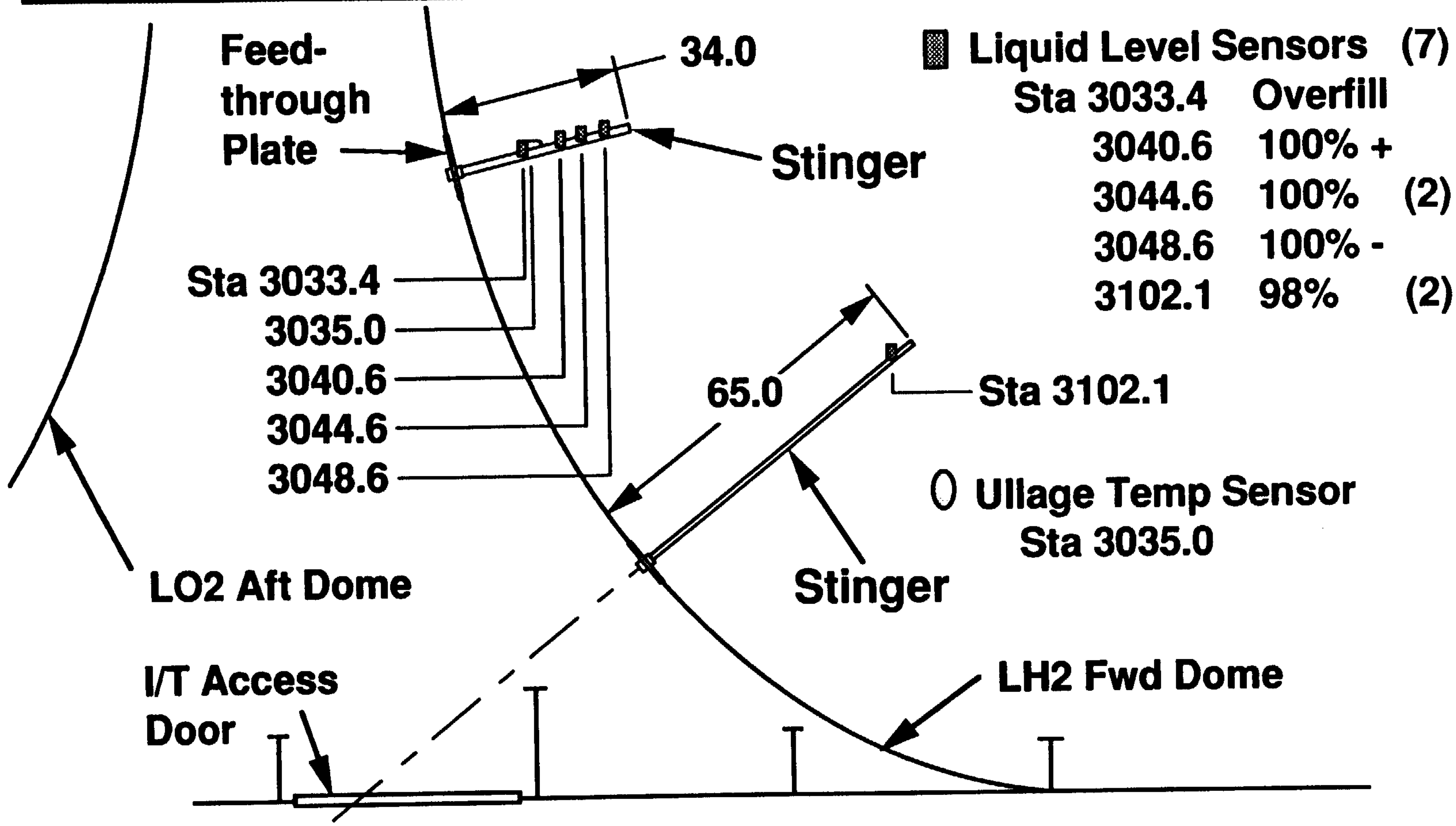
Opt 2 Fwd Sensor Config. CV-STR-14D



- Dual Stinger
- 100% Sensor Utilizes Existing Feedthru Plate Location
- 98% Sensor Located On Unique Stinger

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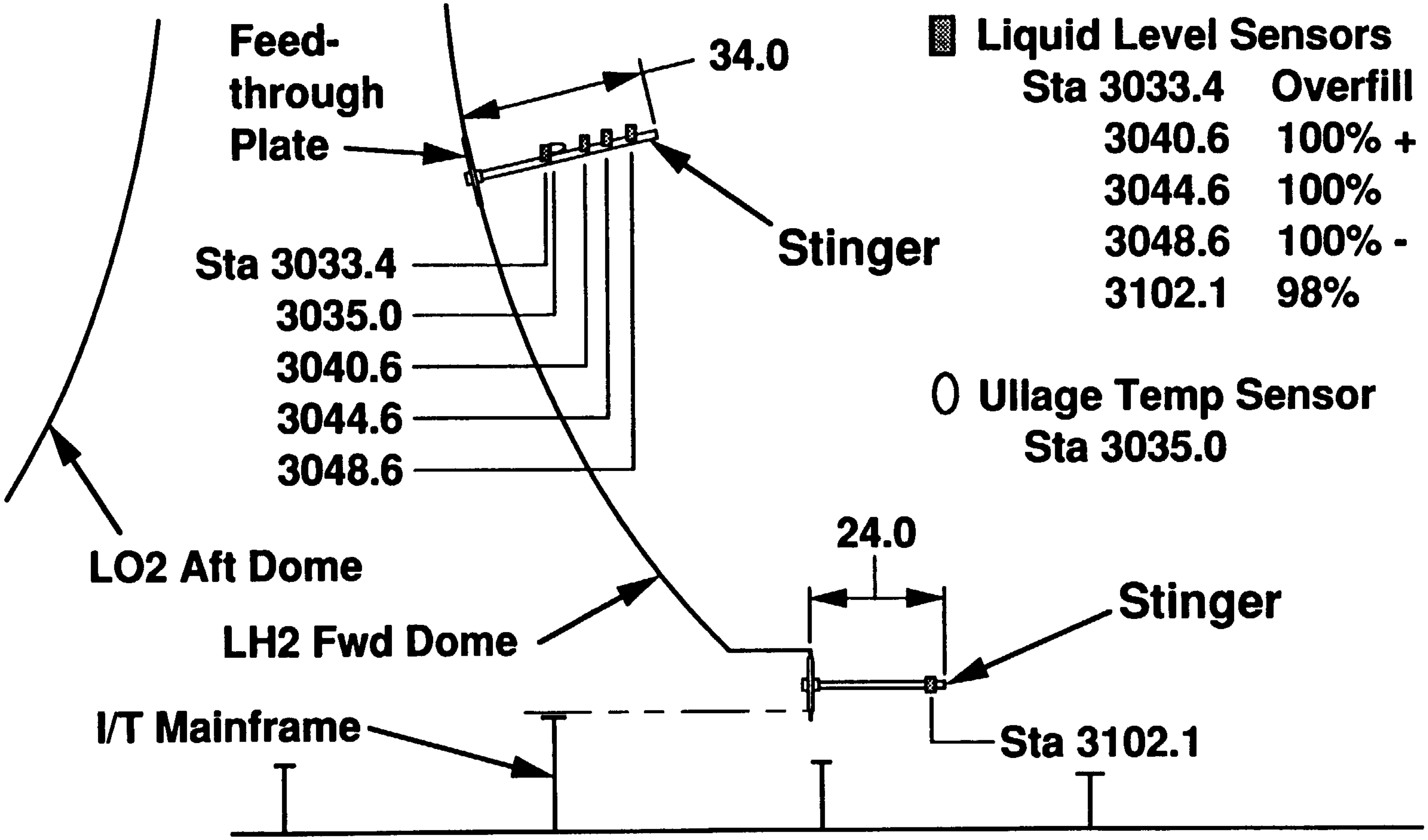
Opt 3 Fwd Sensor Config. CV-STR-14D



▨ Liquid Level Sensors (7)

Sta 3033.4	Overfill	
3040.6	100% +	
3044.6	100%	(2)
3048.6	100% -	
3102.1	98%	(2)

0 Ullage Temp Sensor
Sta 3035.0

- Dual Stinger
- 100% Sensor Utilizes Existing Feedthru Plate Location
- 98% Sensor Located On Unique Stinger

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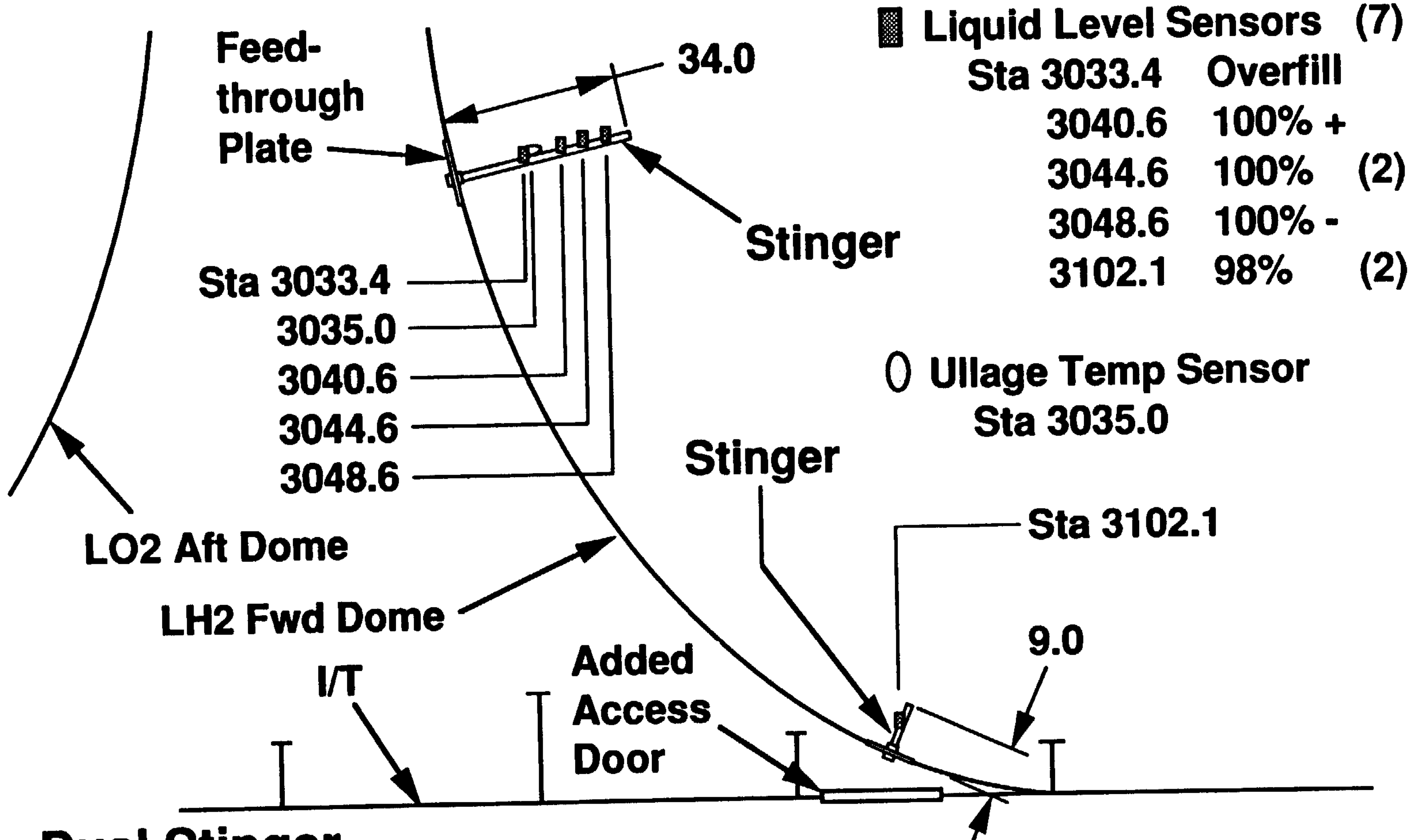
Opt 4 Fwd Sensor Config. CV-STR-14D



- Dual Stinger
- 100% Sensor Utilizes Existing Feedthru Plate Location
- 98% Sensor Located On Unique Stinger

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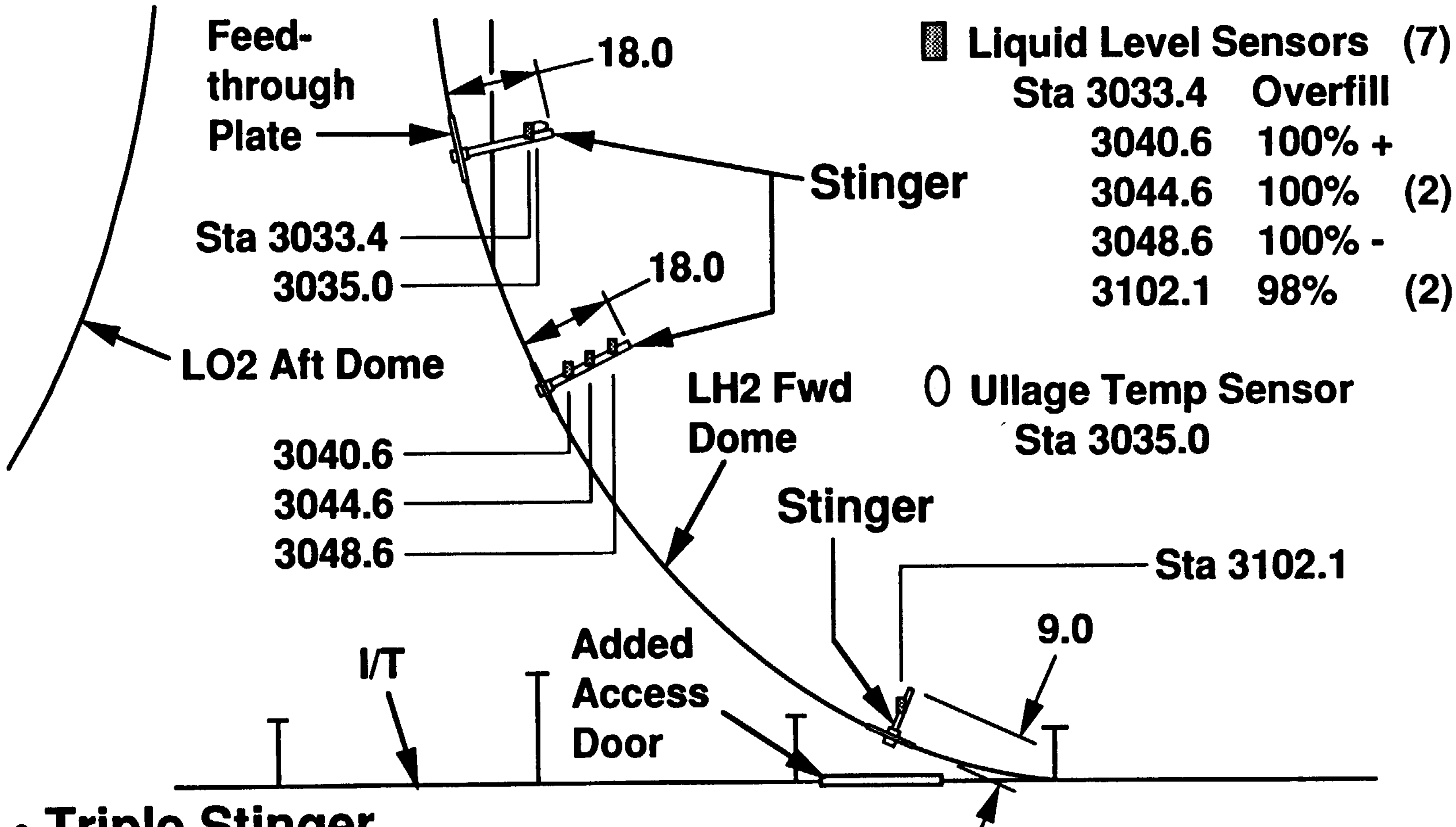
Opt 5 Fwd Sensor Config. CV-STR-14D



- Triple Stinger
- Overfill Sensor Utilizes Existing Feedthru Plate Location
- 100% & 98% Sensor Located On Unique Stingers

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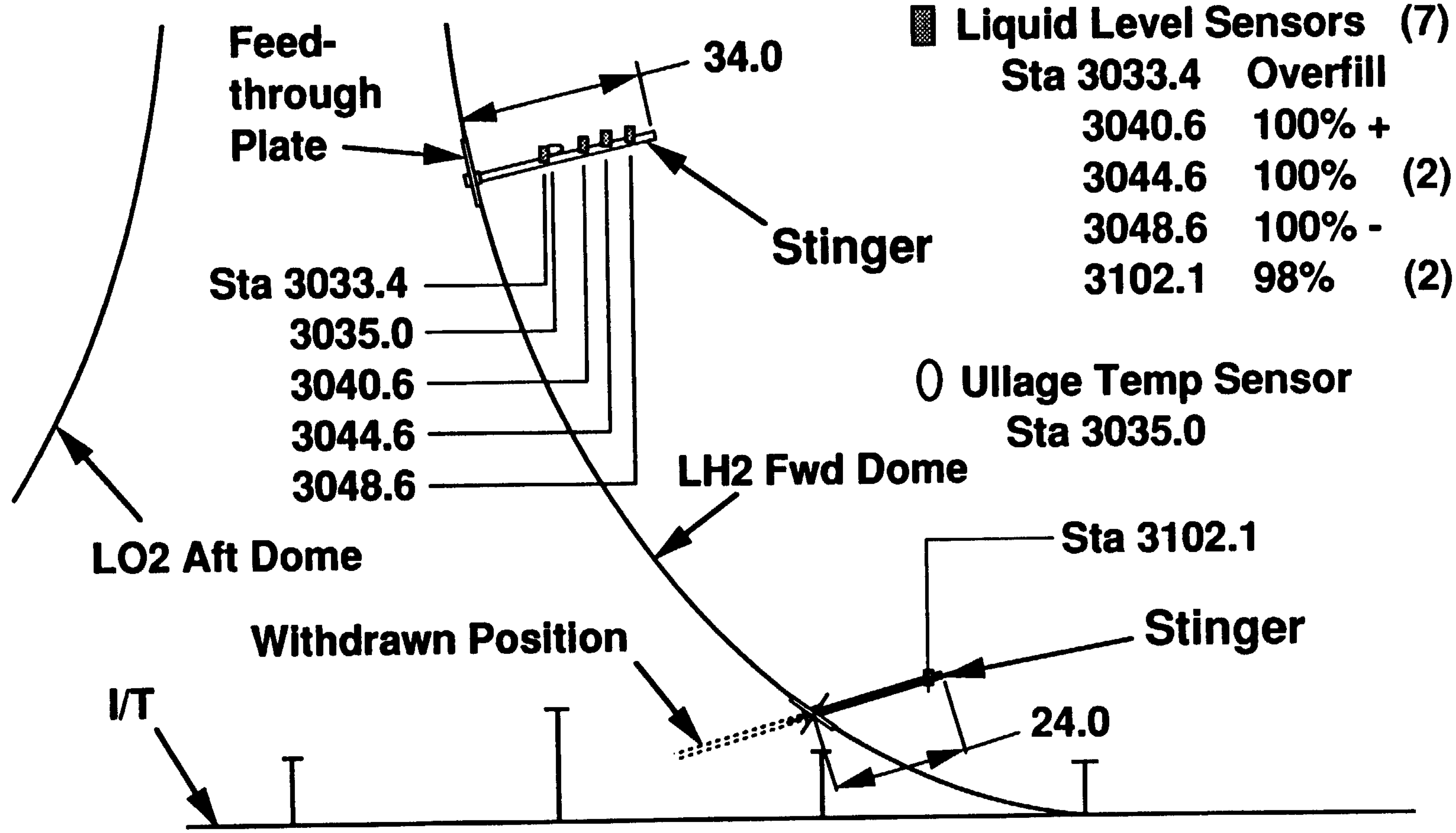
Opt 6 Fwd Sensor Config. CV-STR-14D



- Dual Stinger
- 100% Sensor Utilizes Existing Feedthru Plate Location
- 98% Sensor Located On Unique Stinger

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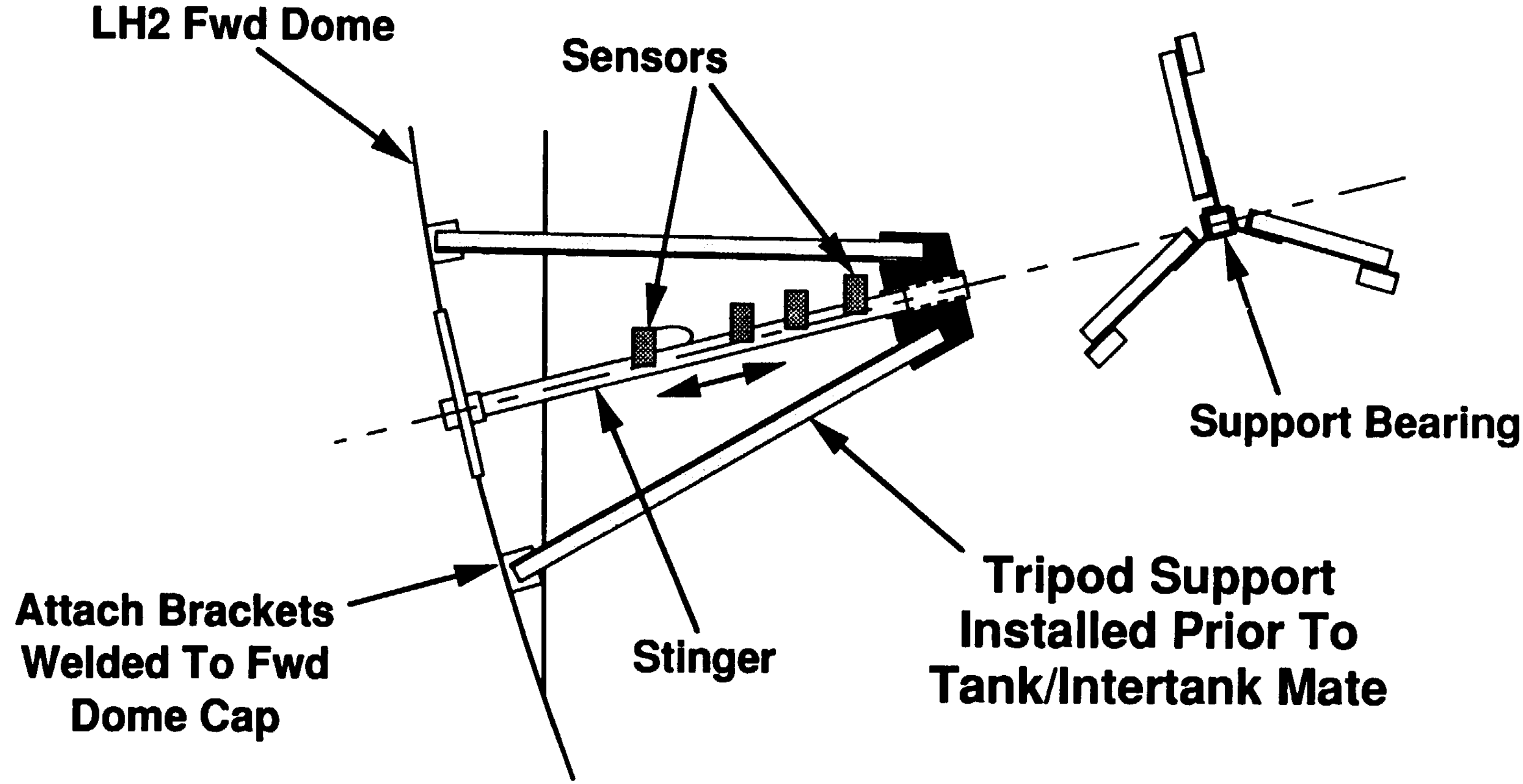
Fwd Sensor Mounting CV-STR-14D

- Optional Tripod Support



Tripod Attached to Inside of Dome Cap

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Fwd Sensor Instn Evaluation CV-STR-14D

Critera	Options		
	Ref	1	2
Instl & Service	- Tank Access Reqd. - Difficult After Stacking	+ No Tank Access Reqd. - Can Not Instl/Service After Stacking	+ No Tank Access Reqd. • 2nd Instl Thru I/T Acess Door
Penetrations	• Existing Feed Thru	• 1 In Dome Cap - Additional 1 In Gore	• 1 In Dome Cap - Additional 1 In Gore
Tank Impacts	• Reference	- Modified Dome Cap & Gore	- Modified Dome Cap & Gore
Design Integrity	+ Uses ET Mast Assy	- 87" Stinger Difficult To Design With Adaquate Stiffness	- 65" Stinger Difficult To Design With Adaquate Stiffness
Weight Impact	• Reference	6 lbs	15 lbs

Major Impacts

• Increased Weights Incl 8% Contingency

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MANNED SPACE SYSTEMS

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Fwd Sensor Instn Evaluation CV-STR-14D

Critera	Options		
	3	4	5
Instl & Service	+ No Tank Access Reqd.	+ No Tank Access Reqd. • Additional Access Thru A 2nd I/T Door	+ No Tank Access Reqd. • Additional Access Thru A 2nd I/T Door
Penetrations	• 1 In Dome Cap - Additional 1 In Gore	• 1 In Dome Cap - Additional 1 In Gore	• 1 In Dome Cap - Additional 2 In Gore
Tank Impacts	- Modified Dome Cap & Gore	- Modified Dome Cap & Gore - Additional I/T Access Door Reqd	- Modified Dome Cap & Gore - Additional I/T Access Door Reqd
Design Integrity	• 34" Stinger May Require Stablizer Suppt - Complex Gore Ftg Reqd	• 34" Stinger May Require Stablizer Suppt	+ Short Stinger Design Disirable For Stiffness
Weight Impact	19 lbs	20 lbs	31 lbs

Major Impacts • Increased Weights Incl 8% Contingency

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MANNED SPACE SYSTEMS

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Fwd Sensor Instn Evaluation CV-STR-14D

Critera	Options		
	6		
Instl & Service	+ No Tank Access Reqd. - Differcult To Gain Access For Instl		
Penetrations	• 1 In Dome Cap - Additional 1 In Gore		
Tank Impacts	- Modified Dome Cap & Gore		
Design Integrity	• 34" Stinger May Require Stablizer Suppt		
Weight Impact	6 lbs		

Major Impacts

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Conclusions CV-STR-14D

- 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 Differcult To Install

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Recommendation CV-STR-14D

Recommendation

- Incorporate Option 2 As Reference

Items For Study In Cycle 1

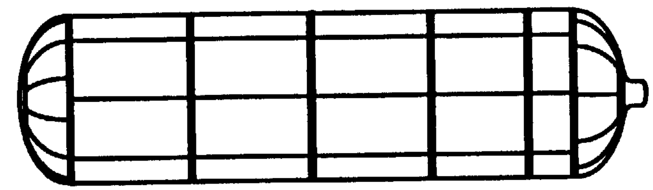
- Establish Sensor Requirements & Locations
  - Can 98% Fill Be Changed To 99%
  - 100% Fill Level For NLS To Be Defined
- Re-evaluate Options Based On Cycle 1 Sensor Locations

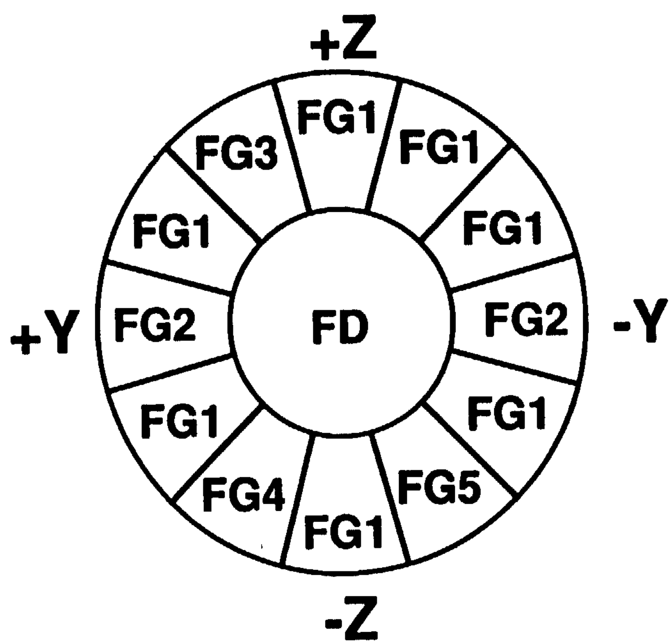
CV-STR-14D
Appendix 8

- **LH2 Tank Part Definition**

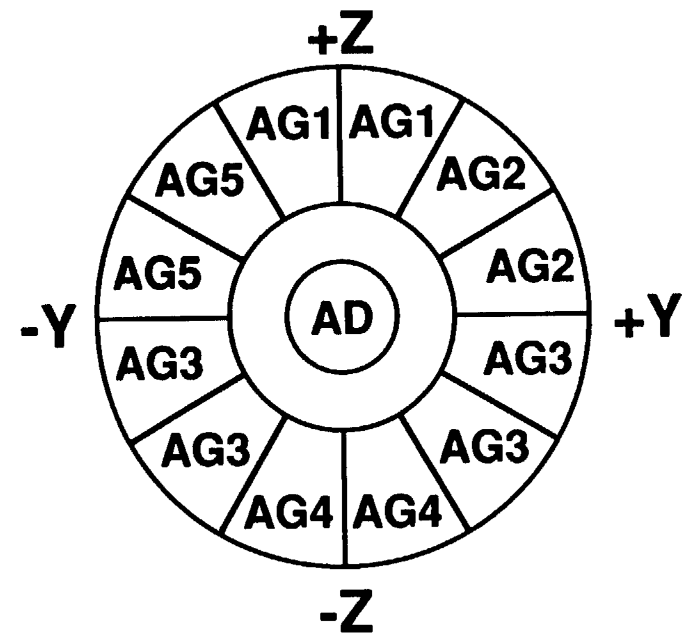
LH2 Tank Dome Configurations CV-STR-14D

- Part Definition





Fwd Dome



Aft Dome

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LH2 Tank Dome Part Definition CV-STR-14D

Part	Title	Part Status			Remarks
		Exist.	Mod.	New	
FD	Fwd Dome Cap	-	-	√	Common To NLS LO2 Tank Fwd Dome
FG1	Dome Gore Plain	-	√	-	Similar To ET Fwd LH2 Dome & NLS Fwd LO2 Dome Gores, With Membrane Thickness Mod For Proof Test Reqmts
FG2	Dome Gore SRB	-	√	-	
FG3	Dome Gore Press	-	√	-	
FG4	Dome Gore Sensor	-	√	-	
FG5	Dome Gore Vent	-	√	-	
AD	Aft Dome Cap	-	-	√	Contains Sump
AG1	Dome Gore	√	-	-	Configuration Could Be Modified As Orbiter Loads Are Eliminated (See Appendix 6)
AG2	Dome Gore	√	-	-	
AG3	Dome Gore	√	-	-	
AG4	Dome Gore	√	-	-	
AG5	Dome Gore	√	-	-	

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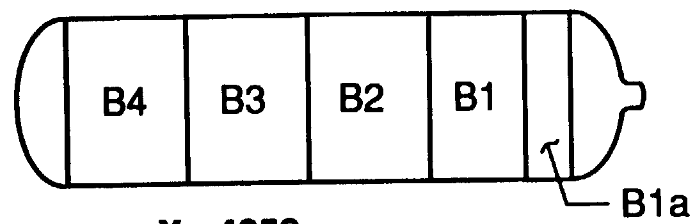
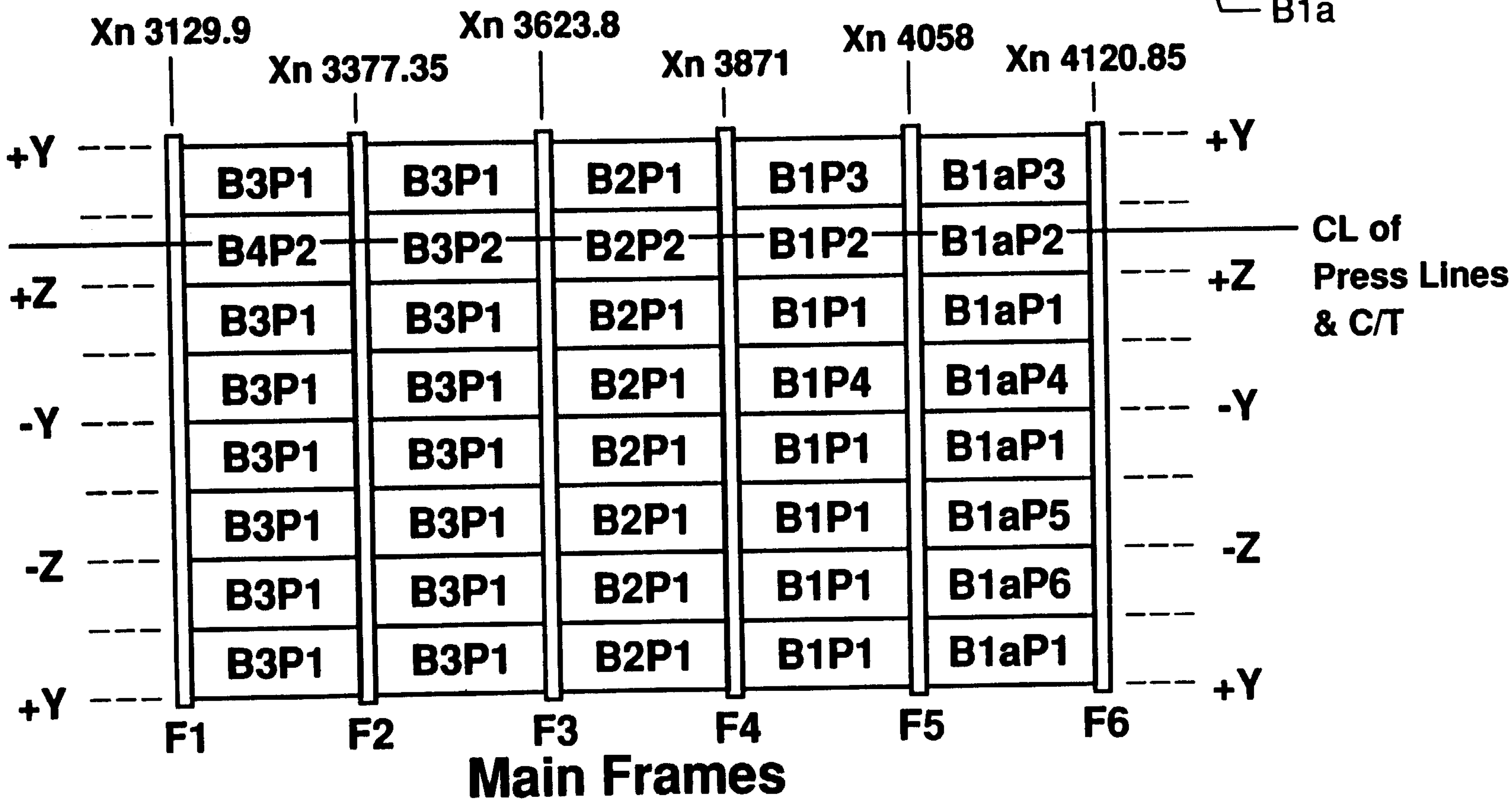
LH2 Tank Shell Definition CV-STR-14D

- **Part Configuration**



Barrel Panels



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LH2 Tank Main Frames CV-STR-14D

Part	Title	Part Status			Remarks
		Exist.	Mod.	New	
F1	Frame 3129.9 - Outer Chord	-	√	-	+ Z Quandrant Modified To Delete Bi-Pod Attach, LO2 Feedline Changed To ± Z Locn
	- Frame Segments	-	-	√	Constant 10.0 Deep Frame
F2	Frame 4058 - Outer Chord	-	-	√	New With ET Fr 2058 SRB I/F's, Orbiter I/F's Omitted
	- Frame Segments	√	-	-	Use ET Fr 2058 Segments*
F3	Frame 3871	-	√	-	Use ET Fr 1623.8 Modified For ± Z LO2 Feedlines

* Segments Could Be Modified Because Of Absense Of Orbiter Loads

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LO2 Tank Main Frames Cont. CV-STR-14D

Part	Title	Part Status			Remarks
		Exist.	Mod.	New	
F4	Frame 3623.8	-	√	-	Use ET Fr 1623.8 Modified For ± Z LO2 Feedlines
F5	Frame 3377.35	-	√	-	Use ET Fr 1377.35 Modified For ± Z LO2 Feedlines
F6	Frame 3129.9				
	- Outer Chord	-	√	-	Use ET Fr TBD Modified For ± Z LO2 Feedlines
	- Frame Segments	√	-	-	Use ET Fr 1129.9 Lower Segment Assys, In Place Of Upper & Lower Segments

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LH2 Tank Barrel Panels — CV-STR-14D

Part	Title	Part Status: Exist.	Mod.	New	Remarks
B1aP1	Barrel Panel	-	-	√	Unique Length Barrel Panel, Based On ET Type LH2 Machined Barrel Panel
B1aP2	Barrel Panel	-	-	√	Similar To B1aP1 With C/T & Press Line I/F's
B1aP3	Barrel Panel	-	-	√	Similar To B1aP1 With Ground Handling & Tooling I/F's (B1aP3–B1aP6)
B1aP4	Barrel Panel	-	-	√	
B1aP5	Barrel Panel	-	-	√	
B1aP6	Barrel Panel	-	-	√	
B1P1	Barrel Panel	-	-	√	Unique Barrel Panel, Based On ET Barrel 1Type LH2 Machined Barrel Panel
B1P2	Barrel Panel	-	-	√	Similar To B1P1 With C/T & Press Line I/F's

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LH2 Tank Barrel Panels CV-STR-14D

Part	Title	Part Status			Remarks
		Exist.	Mod.	New	
B1P3	Barrel Panel	-	√	-	Similar To B1aP1 With Ground Handling & Tooling I/F's
B1P4	Barrel Panel	-	√	-	
B2P1	Barrel Panel	-	√	-	Modified ET Barrel 2 Type LH2 Machined Barrel Panel
B2P2	Barrel Panel	-	√	-	Similar To B2P1 With C/T & Press Line I/F's
B3P1	Barrel Panel	-	√	-	Modified ET Barrel 3 Type LH2 Machined Barrel Panel
B3P2	Barrel Panel	-	√	-	Similar To B3P1 With C/T & Press Line I/F's

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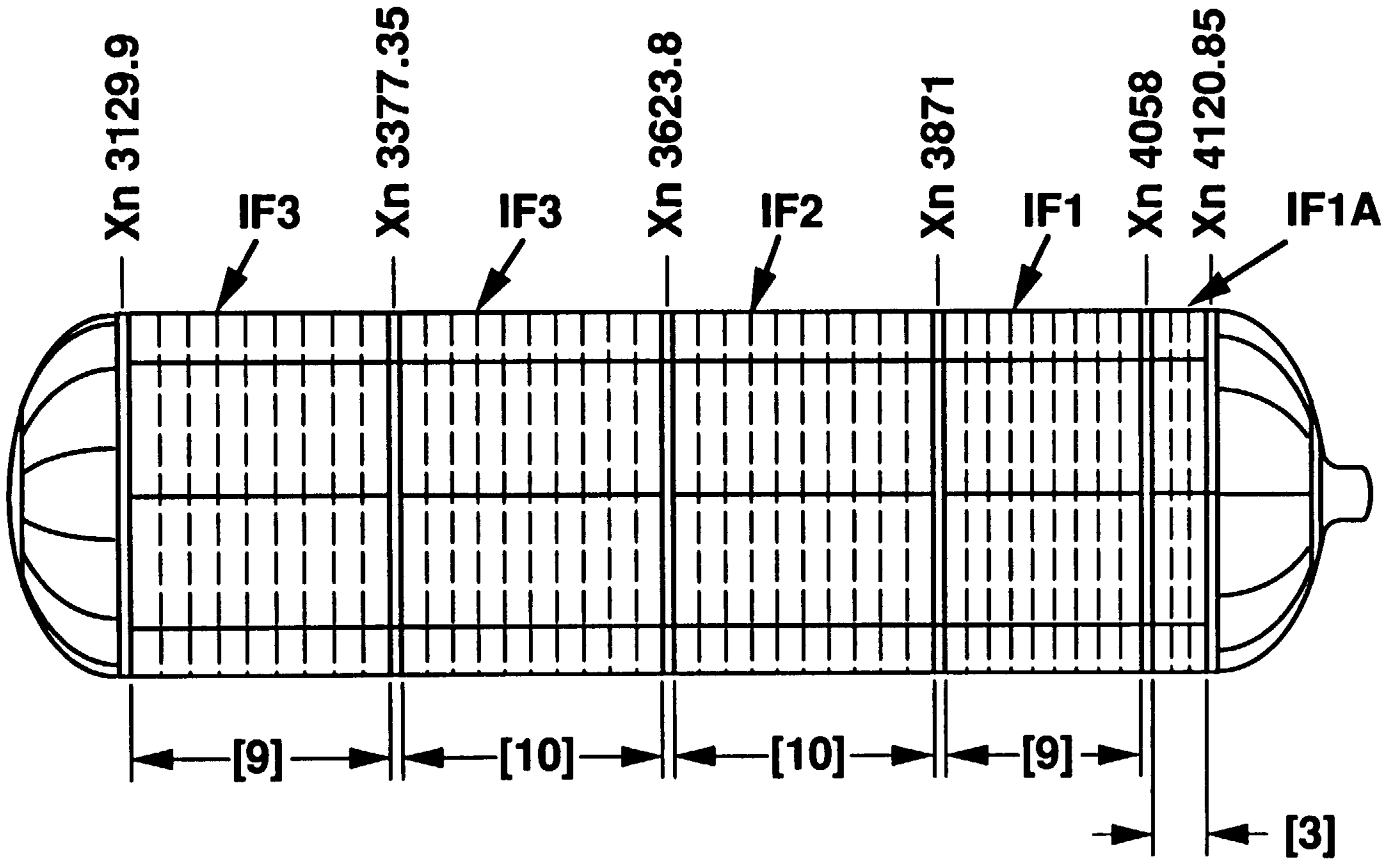
LH2 Tank Intermediate Frs CV-STR-14D



[n] = Number Of Equal Spaces

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LH2 Tank Intermediate Frs CV-STR-14D

Part	Title	Part Status			Remarks
		Exist.	Mod.	New	
IF1A	Intermediate Fr	-	-	√	Unique Size Intermediate Frame, Similar Construction To ET LH2 Tank
IF1	Intermediate Fr	-	-	√	
IF2	Intermediate Fr	-	-	√	
IF3	Intermediate Fr	-	-	√	

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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)

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Items For Cycle 1 Study CV-STR-14D

- 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

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MANNED SPACE SYSTEMS

5.2.6.4.1 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.
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 thats installed externally thru the fwd dome.

Conclusions

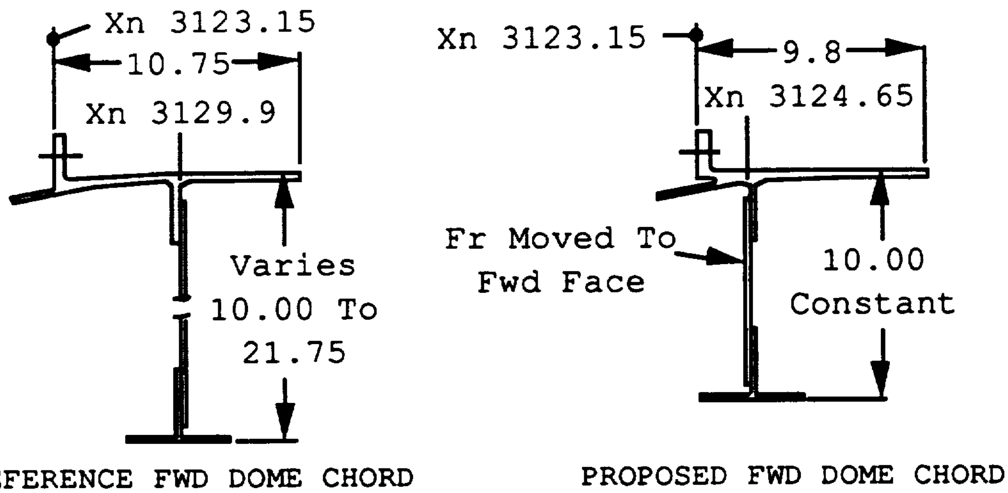
The Cycle Ø definition made use of ET assemblies with some modified components. Weight and manufacturing complexity can be further improved by revising more of these components to better match NLS sizing requirements. These modified components can still be produced on ET tooling with the minor modifications already identified. Installation of level sensors without internal access was determined to be feasible.

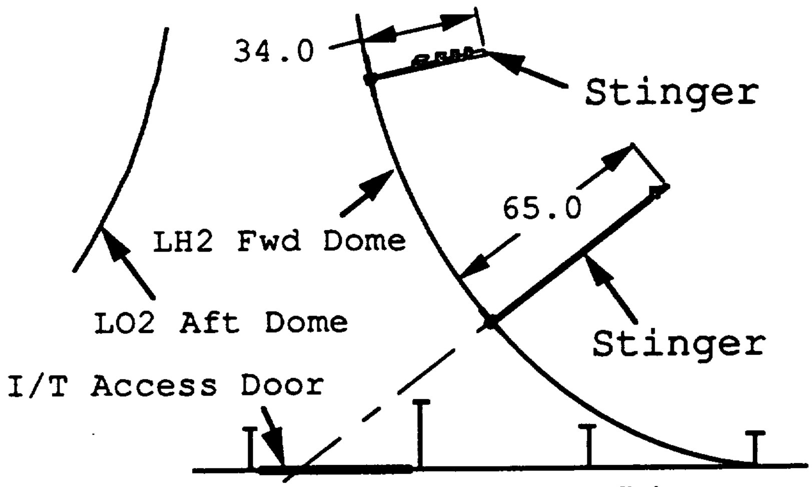
Study Recommendations

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

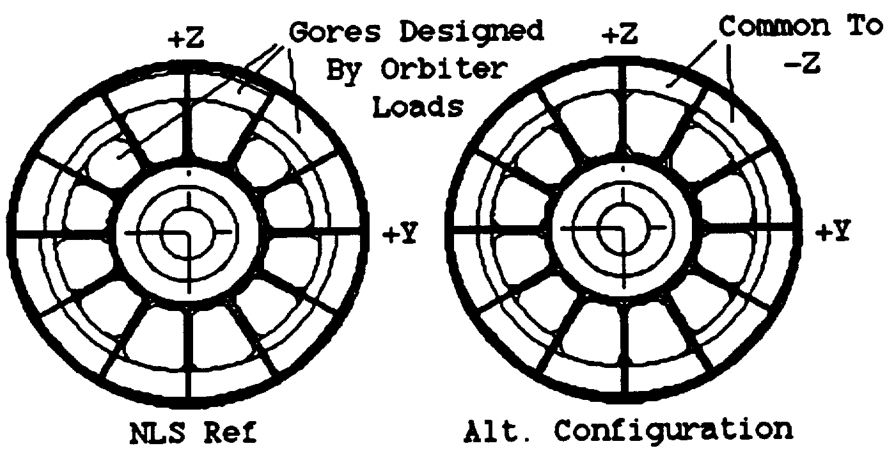
- Revise reference definition to use LO2 aft chord and revised LH2 fwd frame in forward location.
- Incorporate the proposed definition of external hardware mtg. provisions.
- Increase barrel weld land at dome chord welds to .387.

During Cycle 1 further define the level sensor installation and re-evaluate intermediate frame sizing.





Proposed Level Sensor Installation



Proposed Alternate Aft Dome Gore Configuration

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

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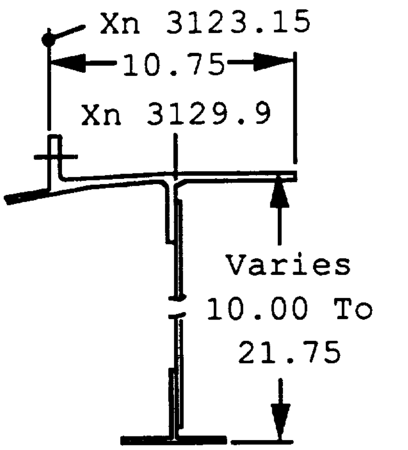
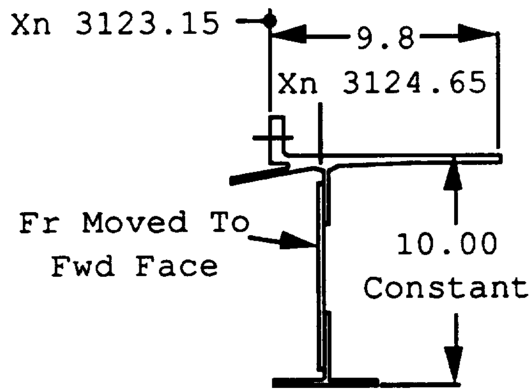
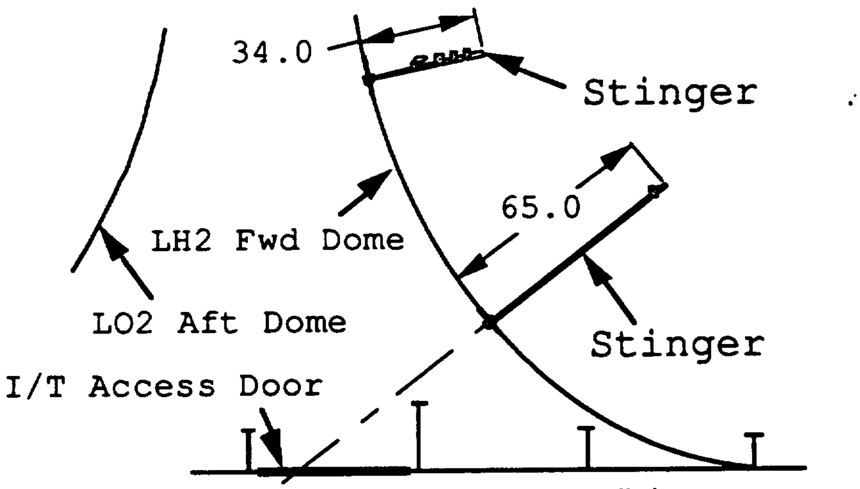
During Cycle 1 further define the level sensor installation and re-evaluate intermediate frame sizing.



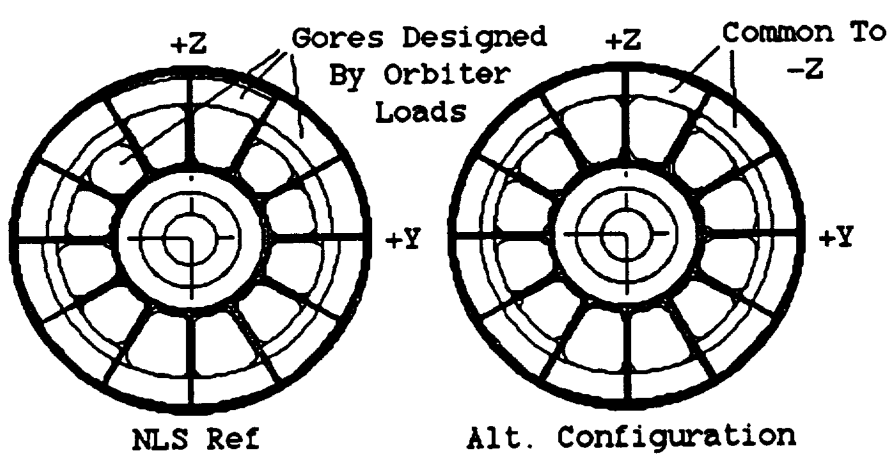
REFERENCE FWD DOME CHORD



PROPOSED FWD DOME CHORD



Proposed Level Sensor Installation



Proposed Alternate Aft Dome Gore Configuration

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

WRW.NLS.91350

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MANNED SPACE SYSTEMS

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

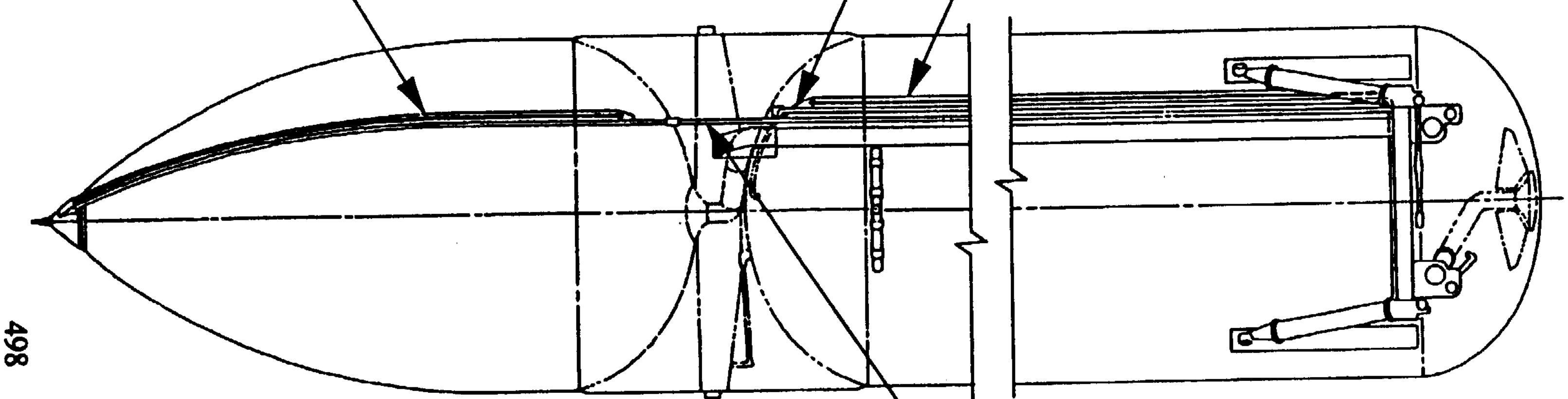
- Investigate STS External Tank Cable Tray And Press Line Design.
- Define Potential NLS Configuration.
- Document Study And Prepare Conclusions.
- Identify Items For Study During Cycle 1.

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.

STS ET Cable Tray & Press Line Def

CV-STR-14G



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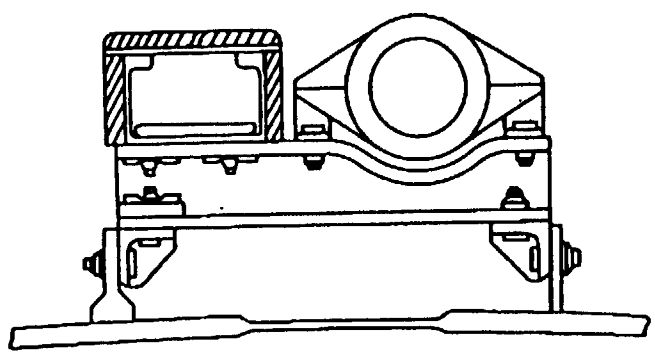
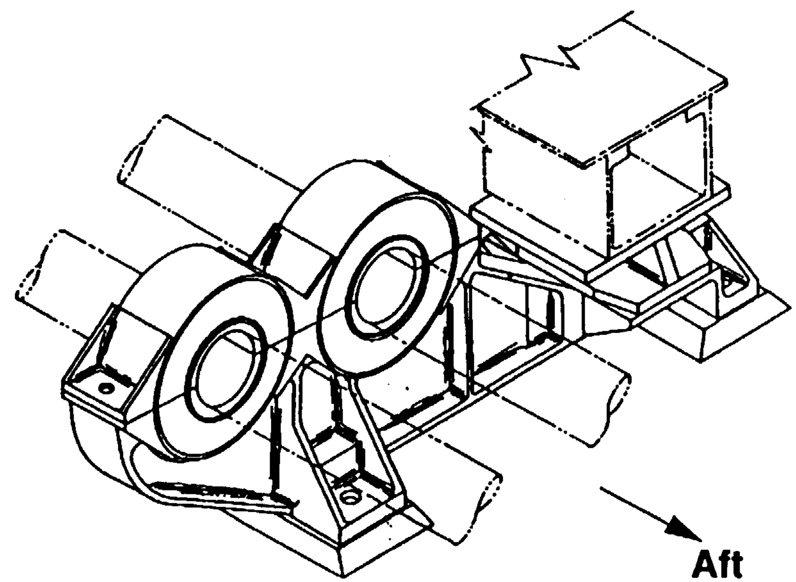
STS ET Cable Tray & Press Line Def CV-STR-14G



Typical LO2 Cable Tray Support Fitting
(View Looking Aft)



Typical LH2 Cable Tray Support Fitting

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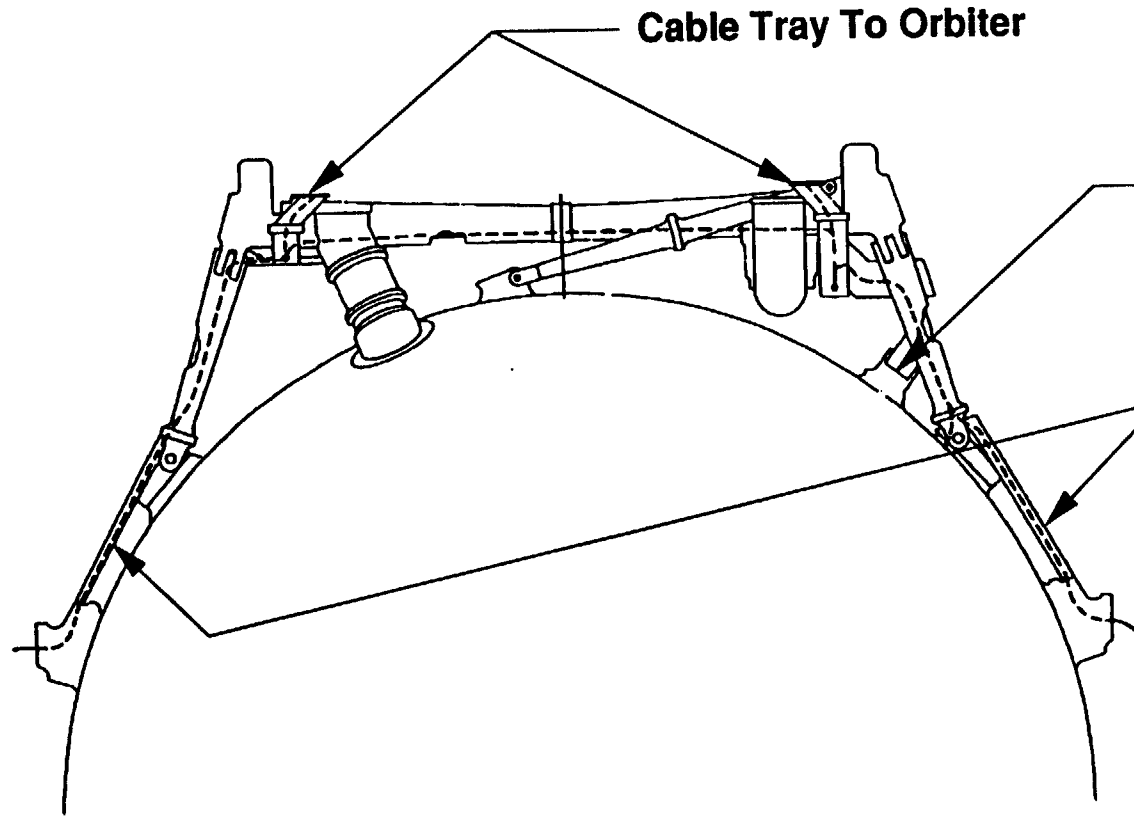
STS ET Cable Tray & Press Line Def

CV-STR-14G



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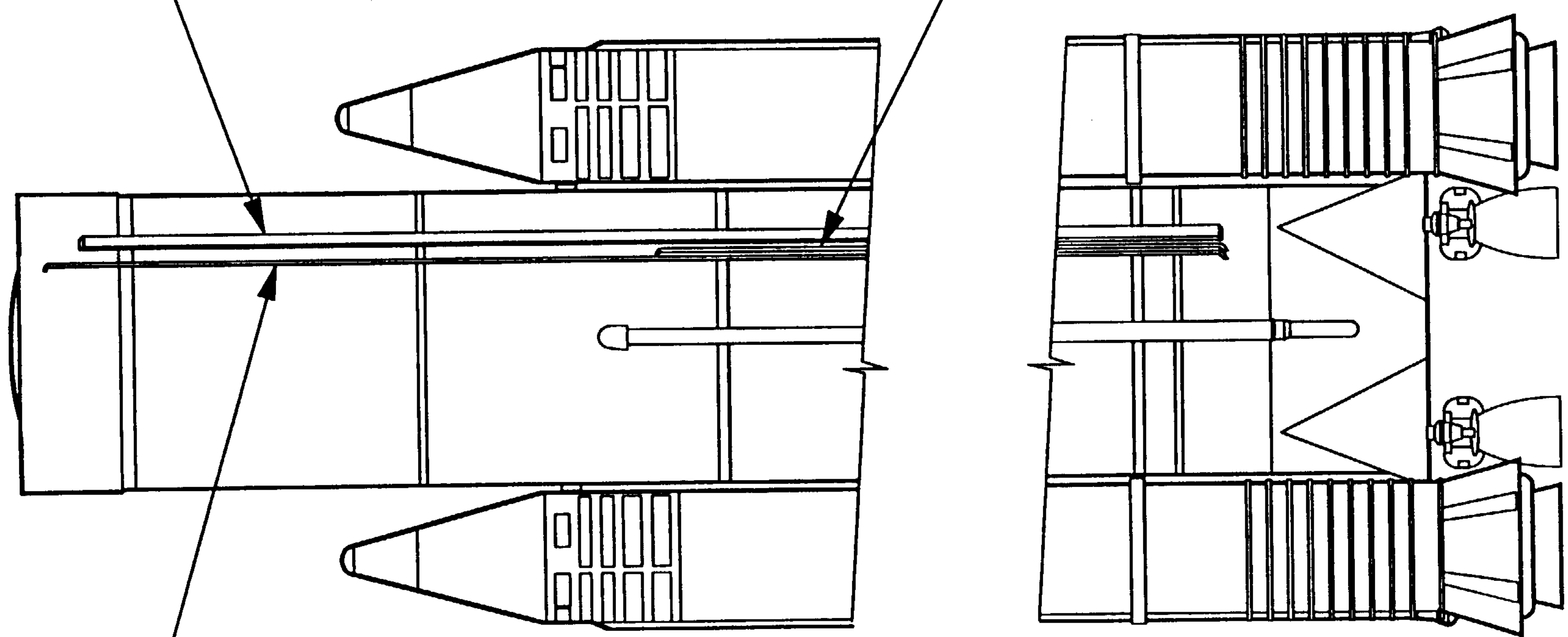
NLS Ref Ext Hwd Configuration



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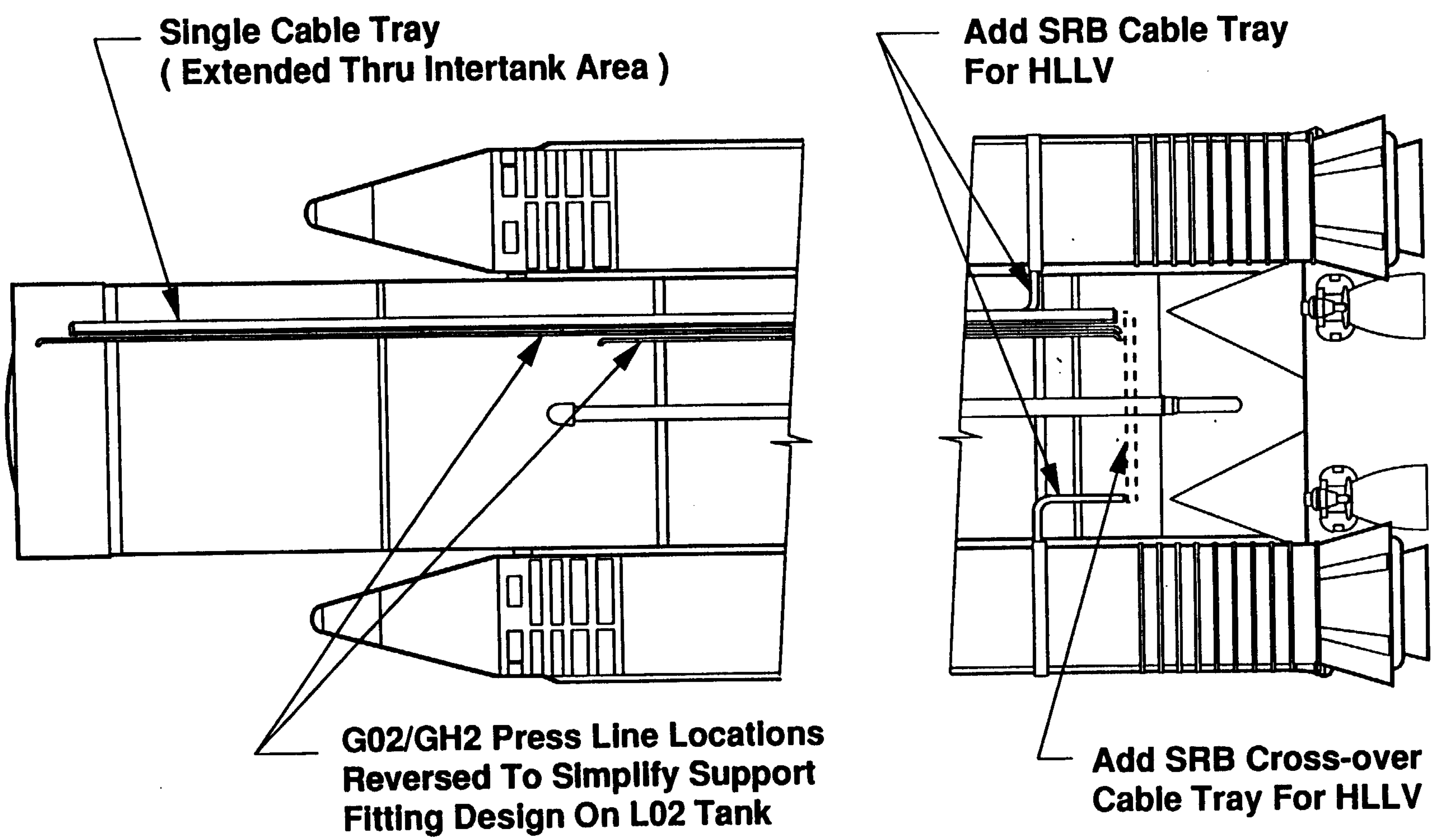
NLS Alternate Ext Hdw Configuration CV-STR-14G



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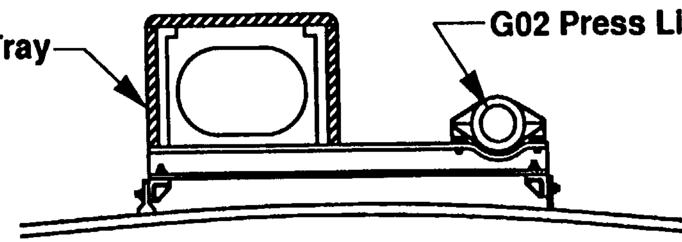
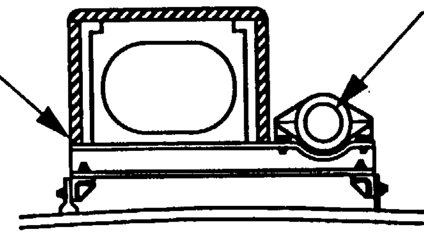
Options Comparision

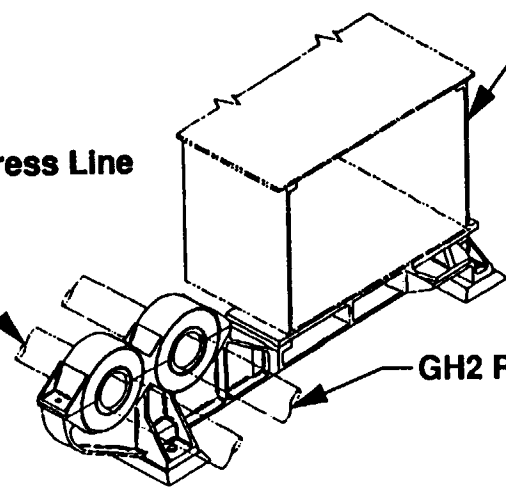
CV-STR-14G



Typical L02 Support Fitting
(View Looking Aft)

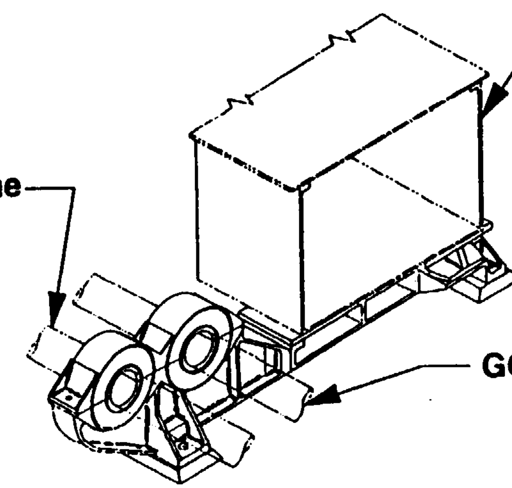


Typical L02 Support Fitting
(View Looking Aft)



Typical LH2 Support Fitting

Ref Configuration



Typical LH2 Support Fitting

Alt Configuration

Swap GH2 / GO2 Press Line Locations
To Simplify Support Fitting Design

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Conclusions And Recommendations CV-STR-14G

Conclusions

- For HLLV Add SRB Cable Tray Extension To LH2 Cable Tray.
- For HLLV Add SRB Cross-over Cable Tray To Aft Skirt Def.
- Swap GH2 / L02 Press Line Locations To Simplify Design Of Support Fittings On L02 Tank.

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

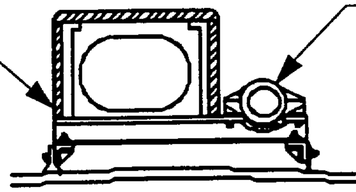
ET cable tray arrangement has separate cable trays on the L02 and LH2 tanks. These are located at different angular locations. The cable trays do not run along the intertank as their purpose is to feed cables into and out of the intertank. On NLS a different situation exist; primary cable routing is 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. 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

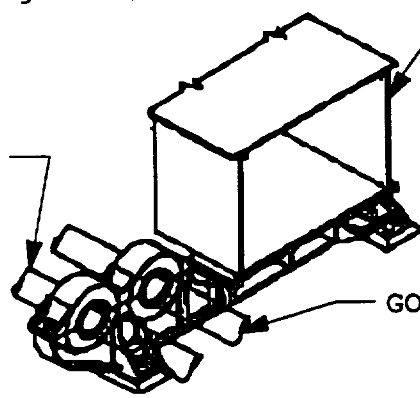
The proposed concept provides a continuous longitudinal cable tray and provides a means for routing cables to the solid rocket boosters.

Study Recommendations

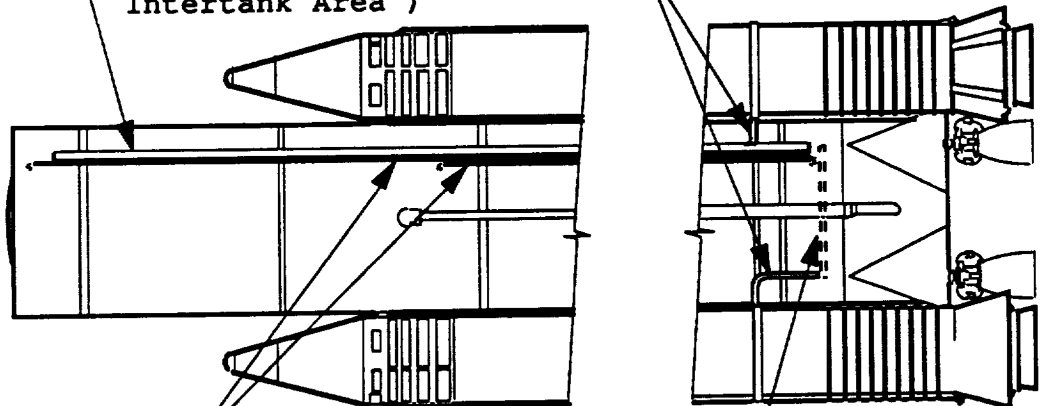
Revise cycle Ø baseline to incorporate the proposed configuration. In cycle 1, study a system tunnel approach and angular location of cable tray/press lines and cable tray size.



Typical L02 Support Fitting
(View Looking Aft)



Typical LH2 Support Fitting



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

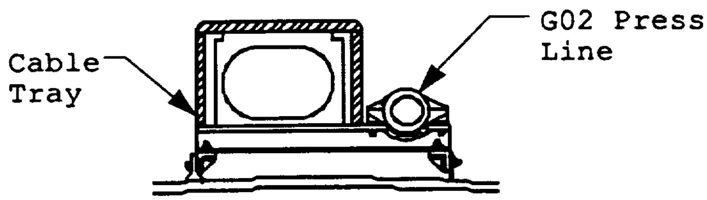
ET cable tray arrangement has separate cable trays on the L02 and LH2 tanks. These are located at different angular locations. The cable trays do not run along the intertank as their purpose is to feed cables into and out of the intertank. On NLS a different situation exist; primary cable routing is 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

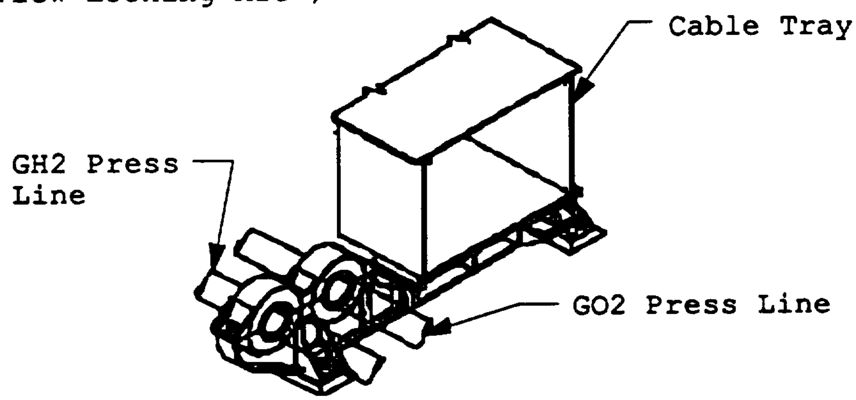
The proposed concept provides a continuous longitudinal cable tray and provides a means for routing cables to the solid rocket boosters.

Study Recommendations

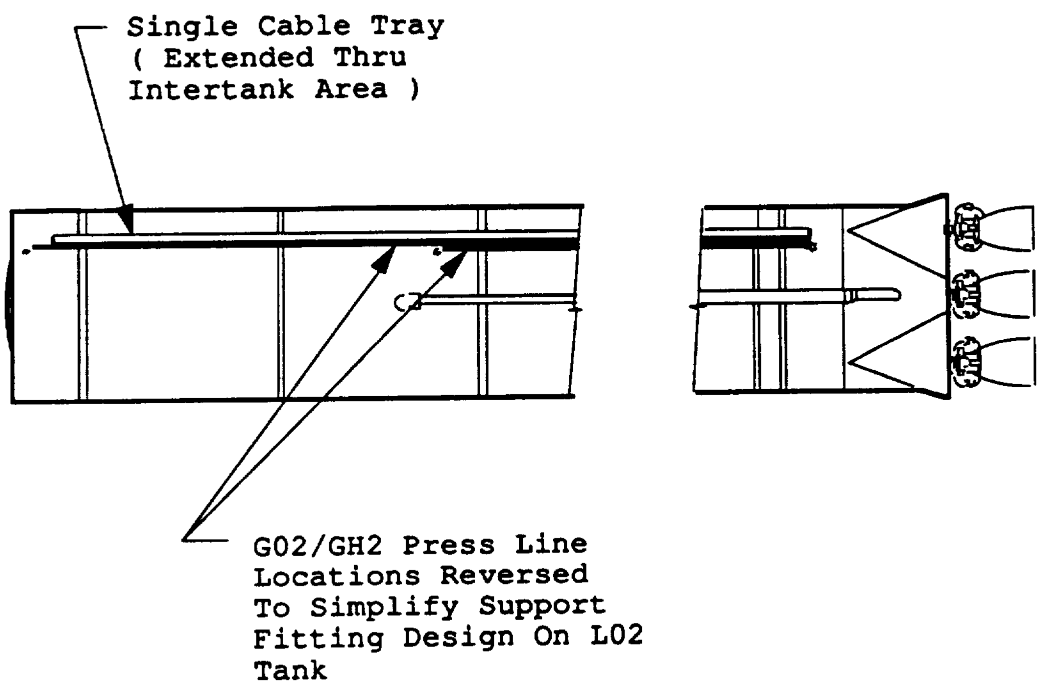
Revise cycle Ø baseline to incorporate the proposed configuration. In cycle 1, study a system tunnel approach and angular location of cable tray/press lines and cable tray size.



Typical L02 Support Fitting
(View Looking Aft)



Typical LH2 Support Fitting



Proposed External Hardware Definition

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

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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 CV-STR-14H

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 CV-STR-14H

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 CV-STR-14H

- 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 CV-STR-14H

- 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)

Evaluation Criteria CV-STR-14H

Criteria	Rationale
Core Vehicle Design	Identify any major vehicle design concerns associated with TPS options
Manufacturing	Assess impact to manufacturing based on structure & TPS design
Operability	Identify operability impacts due to propellant conditioning requirements and ice or liquid air formation
Performance / Weight	Identify relative performance of each option
Cost	Identify any major cost differentials between options

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Study Outline CV-STR-14H

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

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Part 1

Core Element Thermal Evaluation

- Aeroheating
- Propellant Conditioning
- Structural Design & Material Properties
- TPS Manufacturing Issues
- Operational & Safety Issues
- Weight / Performance
- Cost

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Forward Skirt Results

Options - Forward Skirt CV-STR-14H

Option	Rationale
Ref Configuration	Point Of Departure
Option 1 Heat Sink Design	Defines Minimum Structure to Survive Heating Without TPS
Option 2 Nominal TPS thickness=.75"	Partial Heat Sink / TPS Design
Option 3 Nominal TPS thickness=1.0"	Partial Heat Sink / TPS Design
Option 4 Nominal TPS thickness=1.5"	Reference Structure + TPS to protect from Aeroheating affects

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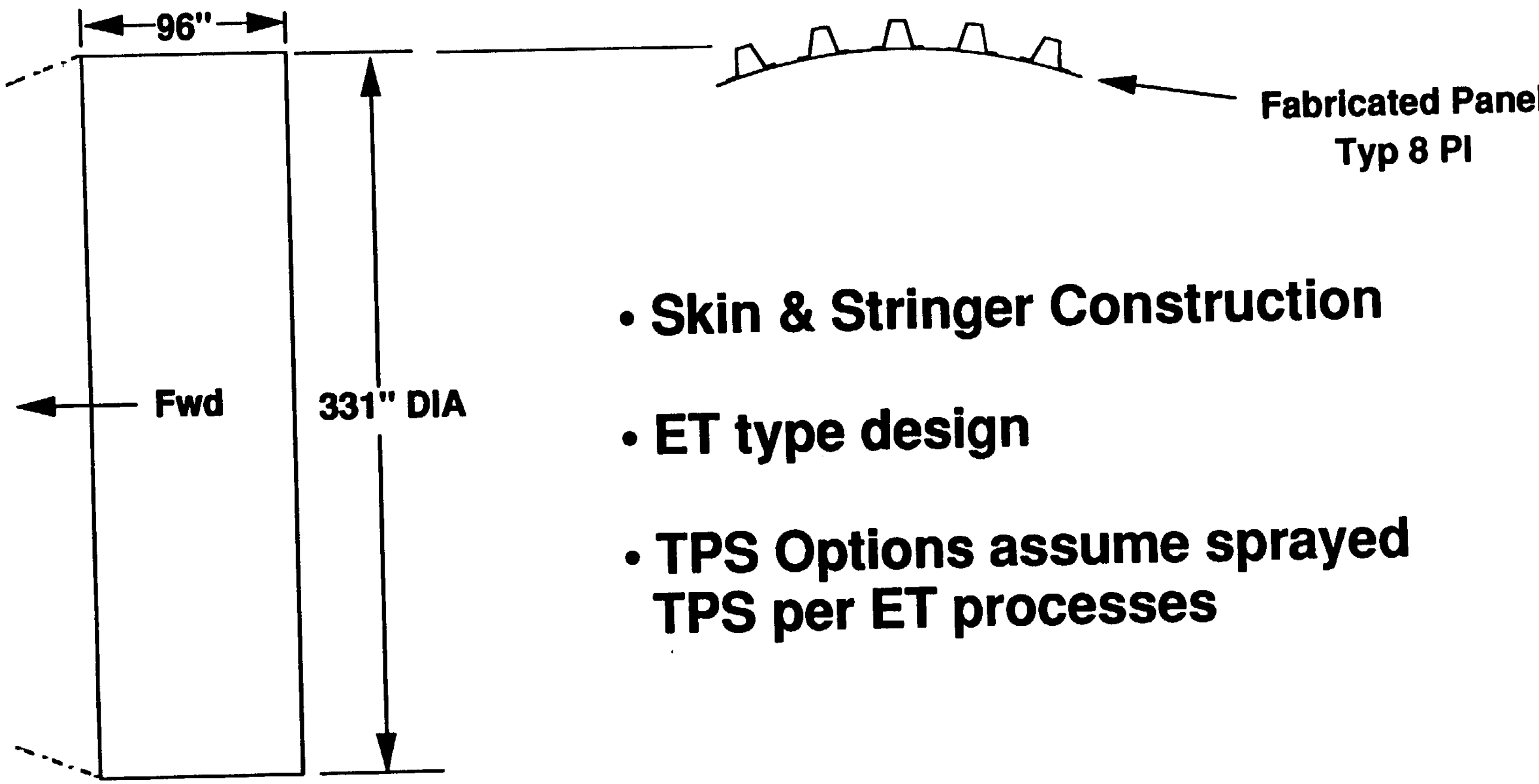
Fwd Skirt - Configuration CV-STR-14H



- Skin & Stringer Construction
- ET type design
- TPS Options assume sprayed TPS per ET processes

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Fwd Skirt - Results CV-STR-14H

	TPS (Nom)	Structure $\bar{t}$ (in)	Structure Wt Δ (lbs)	TPS Wt Δ (lbs)	Total Wt Δ (lbs)
Ref Config	None	.135	0	0	0
Option 1	None	.211	+765	0	+765
Option 2	.75"	.157	+227	+159	+386
Option 3	1.0"	.149	+145	+213	+358
Option 4	1.5"	.136	+21	+319	+340

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Evaluation - Forward Skirt CV-STR-14H

		Ref Config Bare	Option 1 Heatsink	Option 2 Nom TPS=.75	Option 3 Nom TPS=1.0	Option 4 Nom TPS=1.5
Core Vehicle Design		Aeroheating causes Structural failure	Ref	Additional TPS & Thermal Design Required - Minimal Effort		
Manufacturing		Ref	Ref	ET Spray & Closeout Processes No facility/tooling impacts		
Operability		Significant Ice Formation @ LO2 I/F	Significant Ice Formation @ LO2 I/F	Ice worse than ET @ LO2 I/F	Ice same as ET @ LO2 I/F	Less Ice than ET @ LO2 I/F
				Potential TPS damage/repair req'd @ KSC		
Weight Delta (lbs)	Metal	Ref	+765	+227	+145	+21
	TPS	—	—	+159	+213	+319
	Σ	Ref *	+765 *	+386 *	+358	+340
Cost	Non-rec	Ref	Ref	TPS / Thermal Design = $120k		
	Recurring	Ref	Ref	Material Cost = $60k		

☐ Least desireable impacts

* Ice Wt Impact Unknown

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Fwd Skirt Conclusions CV-STR-14H

- 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

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I/T Results

Options - Intertank CV-STR-14H

Option	Rationale
Ref Configuration	Point Of Departure
Option 1 Heat Sink Design	Defines Minimum Structure to Survive Heating Without TPS
Option 2 Nominal TPS thickness=.75"	Partial Heat Sink / TPS Design
Option 3 Nominal TPS thickness=1.0"	Partial Heat Sink / TPS Design
Option 4 Nominal TPS thickness=1.5"	Minimum Structure + TPS to protect from Aeroheating affects

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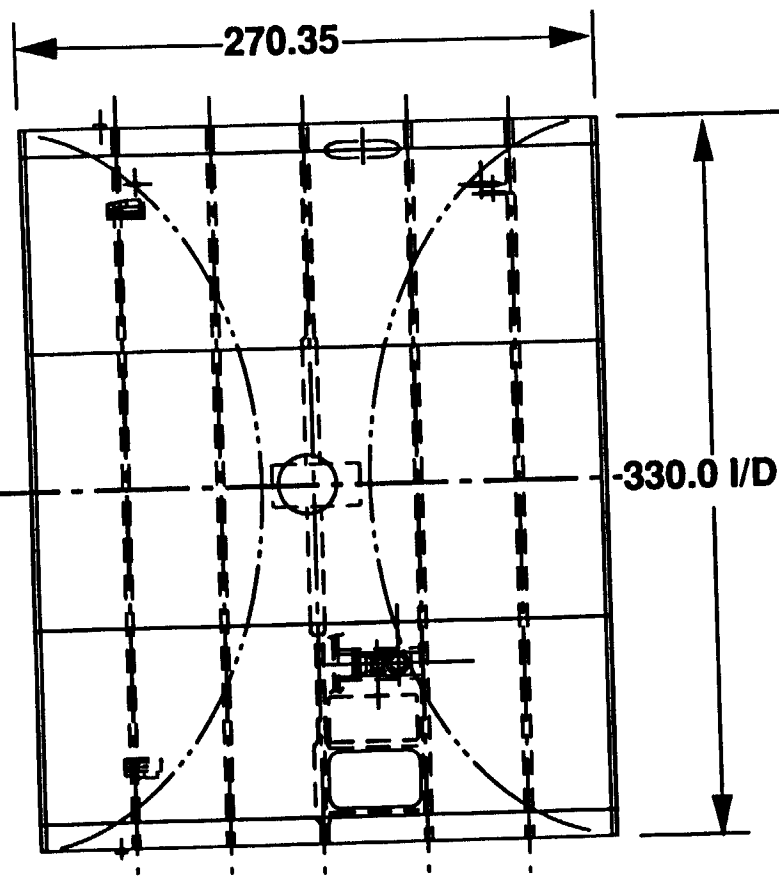
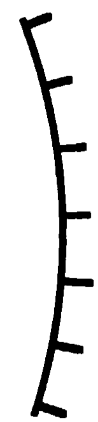
Intertank - Config CV-STR-14H



- ET I/T type design
- All Panels similar to ET
- TPS Options , assume sprayed TPS per ET processes



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Intertank - Results CV-STR-14H

	TPS (Nom)	Structure $\bar{t}$ (in)	Structure Wt Δ (lbs)	TPS Wt Δ (lbs)	Total Wt Δ (lbs)
Ref Config	None	.230	0	0	0
Option 1	None	.222	-173	0	-173
Option 2	.75"	.192	-782	+348	-434
Option 3	1.0"	.186	-915	+464	-451
Option 4	1.5"	.181	-1009	+696	-313

- .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.

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Evaluation - Intertank CV-STR-14H

		Ref Config Bare	Option 1 Heatsink	Option 2 Nom TPS=.75"	Option 3 Nom TPS=1.0"	Option 4 Nom TPS=1.5"
Core Vehicle Design		Ref	Ref	Additional TPS & Thermal Design Required - Minimal Effort		
Manufacturing		Ref	Ref	ET Spray & Closeout Processes No facility/tooling impacts		
Operability		Significant Ice Formation @ LH2 & LO2 I/F's & Liquid Air formation on LH2 Tank		Ice worse than ET @ LO2 & LH2 I/F'S	Ice same as ET @ LO2 & LH2 I/F's	Less Ice than ET @ LO2 & LH2 I/F's
				Potential TPS damage / repair req'd @ KSC		
Weight Delta (lbs)	Metal	0	-173	-782	-915	-1009
	TPS	—	—	+348	+464	+696
	Σ	0 *	-173*	-434*	-451	-313
Cost	Non-rec	Ref	Ref	TPS / Thermal Design = $50k		
	Recurring	Ref	Ref	Prod Ops & Material Cost = $366k		

☐ Least desireable impacts

* Ice Wt Impact Unknown

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I/T Conclusions CV-STR-14H

- 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

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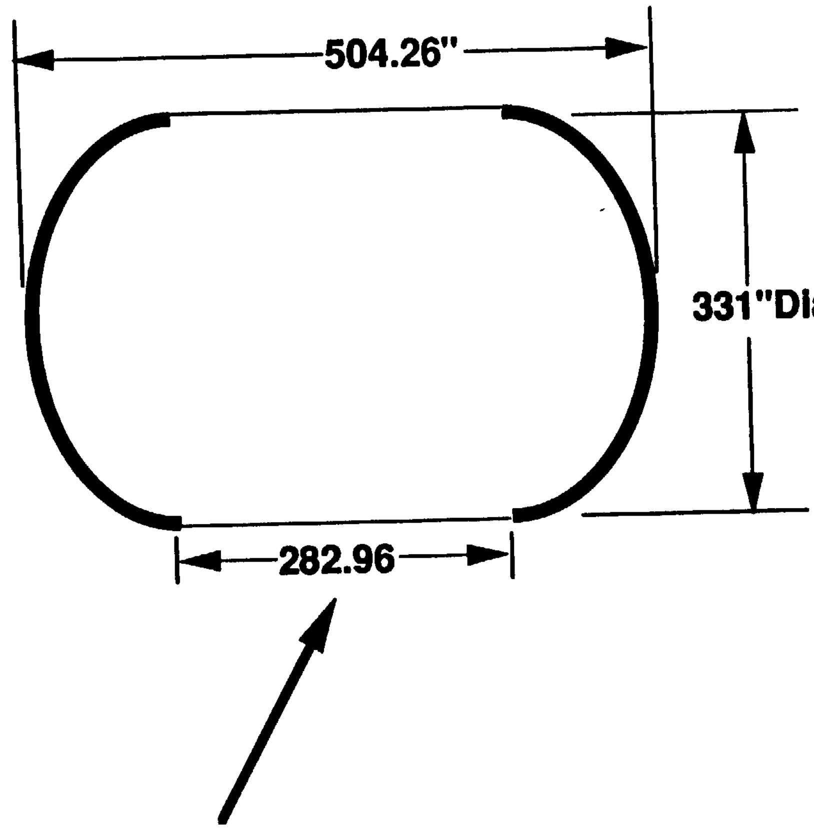
LO2 Tank Results

Options - LO2 Tank CV-STR-14H

Option	Rationale
Ref Configuration .5" TPS on Domes	Point Of Departure
Option 1 Add .5" TPS to Barrel	Adding TPS to Barrel Section Reduces Ice & May Improve Payload
Option 2 Add 1.0" TPS to Barrel	Adding 1.0"TPS to Barrel Section Reduces Ice Even More & May Improve Payload

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

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Results - Stress Analysis CV-STR-14H

- Membrane is Sized by Proof Load for Weld Lands & Exceeds Heat Sink Design Requirements

Lox Barrel	Skin Gauge Ref Config	Skin Gauge for Heat Sink Only
Fwd	.170	.115
Aft	.215	.111

Conclusion - LO2 TPS Configuration is Independent of Membrane Aeroheating effects

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LO2 Results — CV-STR-14H

Payload penalty derivation

Payload penalty derived by combining the following effects :

- Payload reduction due to decreased LOX density , calculated as lost LOX density (lbs) X .075 . The .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

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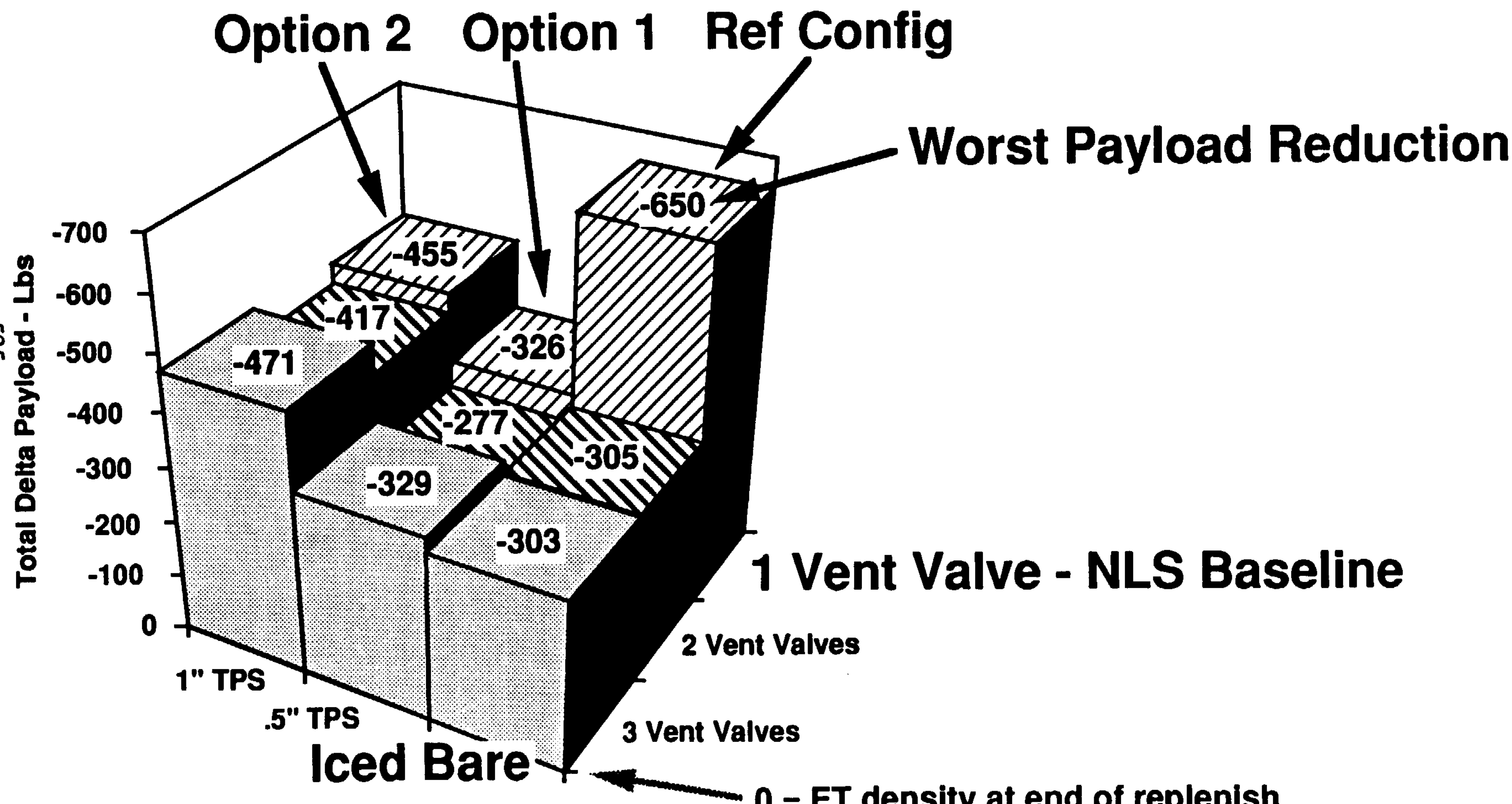
LO2 Payload vs TPS — CV-STR-14H

NLS Baseline Propellant Conditioning Parameters
5000 Gpm, GHe Inject, 5 Hr. Min. Load to Launch



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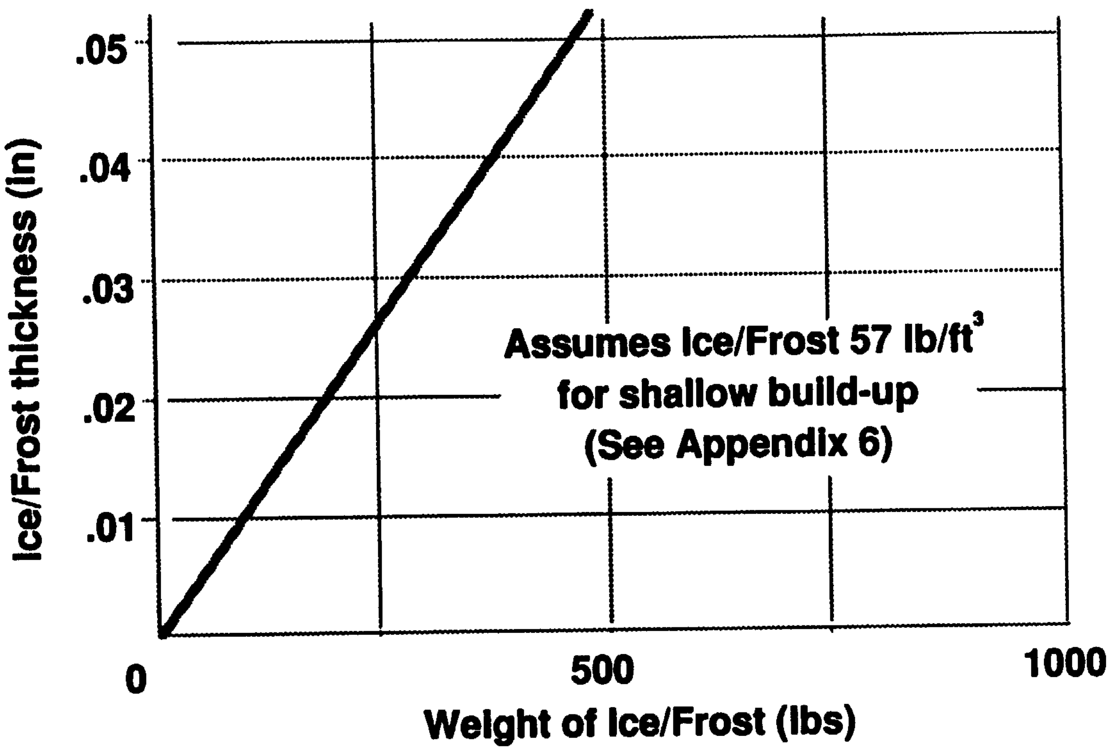
LO2 Ice / Frost Weight CV-STR-14H



- Even thin Ice/Frost build-up generates significant weight
- Actual build-up will depend on weather conditions and variations in TPS thickness

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LO2 Flight Results CV-STR-14H

- 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

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Evaluation - LO2 Tank CV-STR-14H

		Ref Config Bare	Option 1 .5" TPS	Option 2 1.0" TPS
Core Vehicle Design		Ref	Additional TPS Design Required Minimal Effort	
Manufacturing		Ref	ET Spray Processes Mods to Cell M required for LO2 barrel spray	
Operability		Large Ice Formation Problem	Much higher probability than ET of Ice formation on any given day	Ice Formation same as ET
Performance (lbs)		0 Ice Wt Impact Unknown	+324 Ice Wt Impact Unknown	+195
Cost	Non-rec	Ref	TPS Design $50K Cell M Spray Fixture $500K	= $550k
	Recurring	Ref	Production Ops $29K Material $60K	= $89k

☐ Least desireable impacts

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LO2 TPS Conclusions CV-STR-14H

- 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 CV-STR-14H

Option	Rationale
Ref Configuration	Point Of Departure - .5" TPS on Domes & Barrels
Option 2 1.0" TPS on Bbls	1.0" TPS on Barrel Section Reduces Ice & May Improve Payload

Note - Acreage TPS only , no flange or bracket ice / frost closeouts

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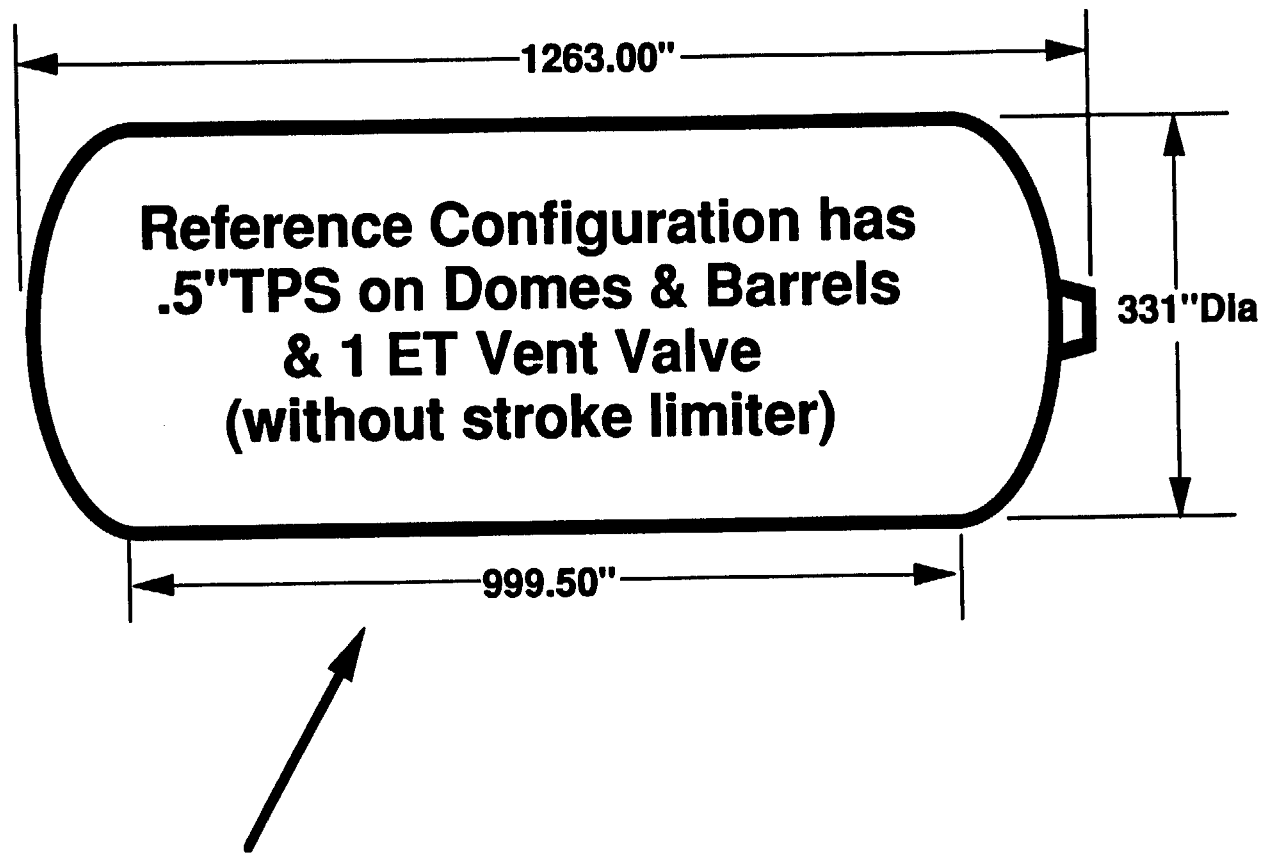
LH2 - Ref Vehicle Config CV-STR-14H



Option 1 has 1.0 TPS on the Barrels

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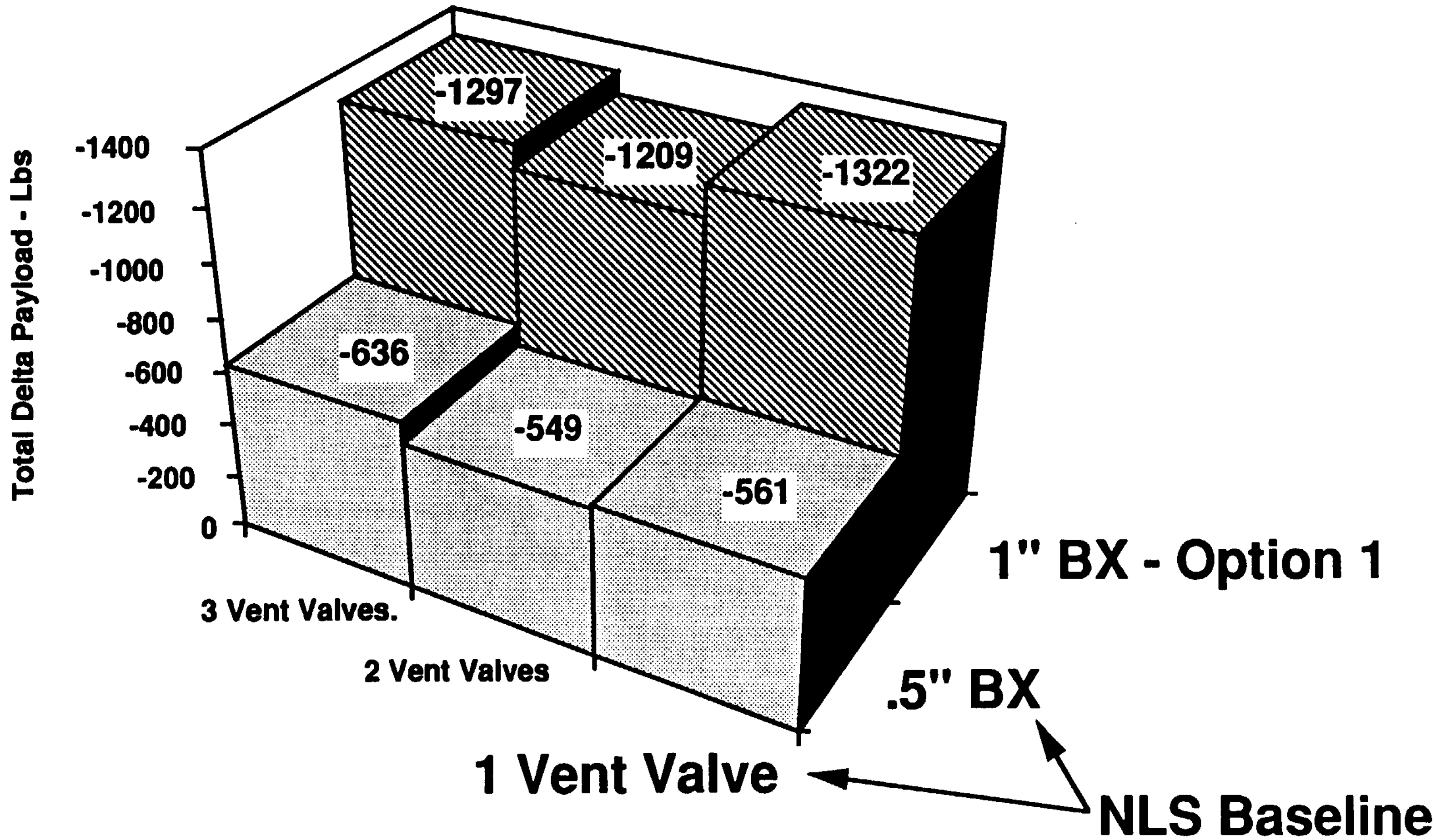
LH2 Payload vs TPS CV-STR-14H

5 Hour Min Load to Launch



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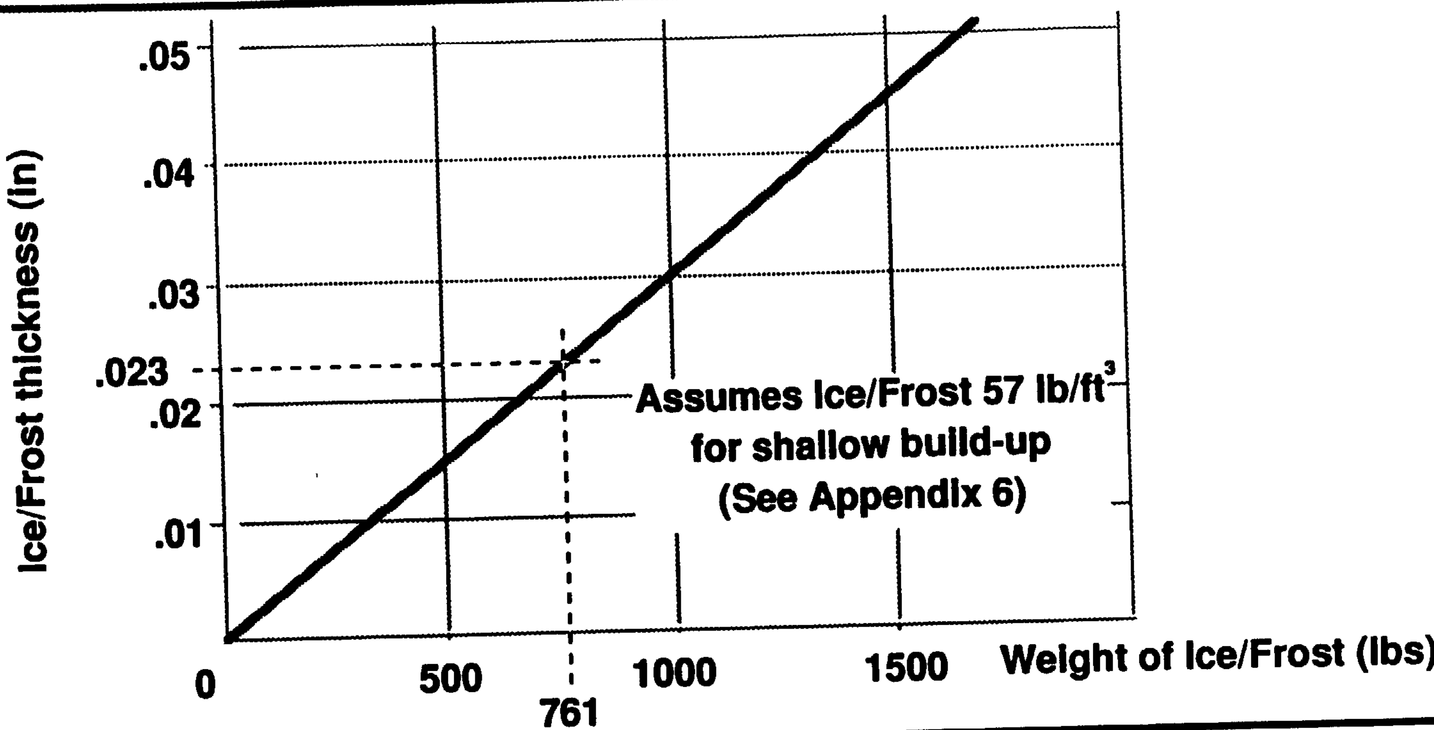
LH2 Ice / Frost Weight CV-STR-14H



- 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

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LH2 Flight Results CV-STR-14H

- 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

Evaluation - LH2 Tank CV-STR-14H

		Ref Config .5" TPS	Option 1 1.0" TPS
Core Vehicle Design		Ref	No Impact
Manufacturing		Ref	No Impact
Operability		Much higher probability than ET of ice formation on any given day	Ice Formation same as ET
Performance (lbs)		0 Ice Wt Impact Unknown	-761 lbs
Cost	Non-rec	Ref	$0k
	Recurring	Ref	Material = $60k

☐ Least desireable impacts

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LH2 Conclusions CV-STR-14H

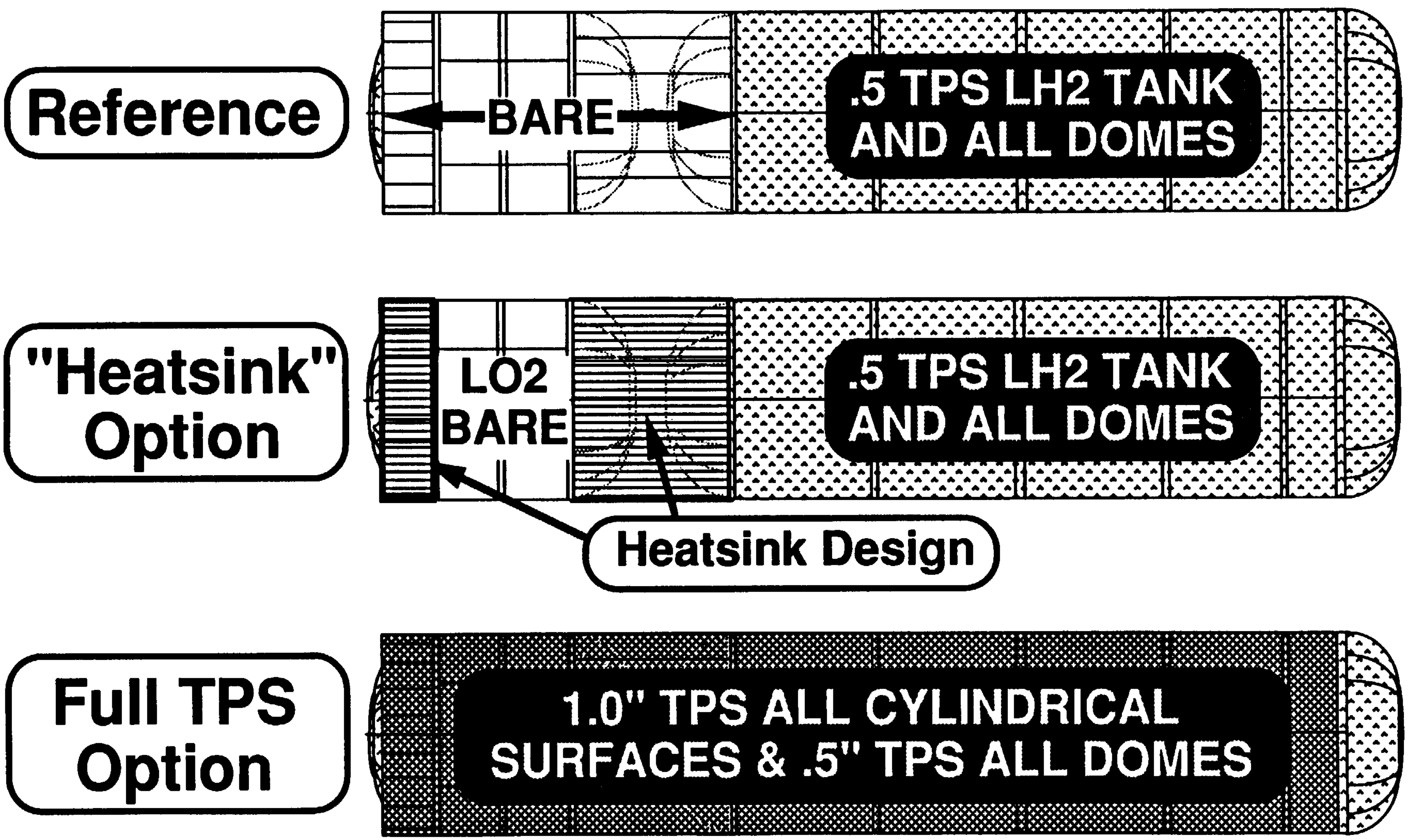
- Both options satisfy known ground & flight requirements
- No significant cost difference between options , but the Reference option does not address additional operational costs associated with Ice formation
- Major uncertainties do exist regarding ice formation and possible retention during flight for configurations with less than the ET configuration of 1.0" nominal TPS.
- Option 1 shows a significant performace 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



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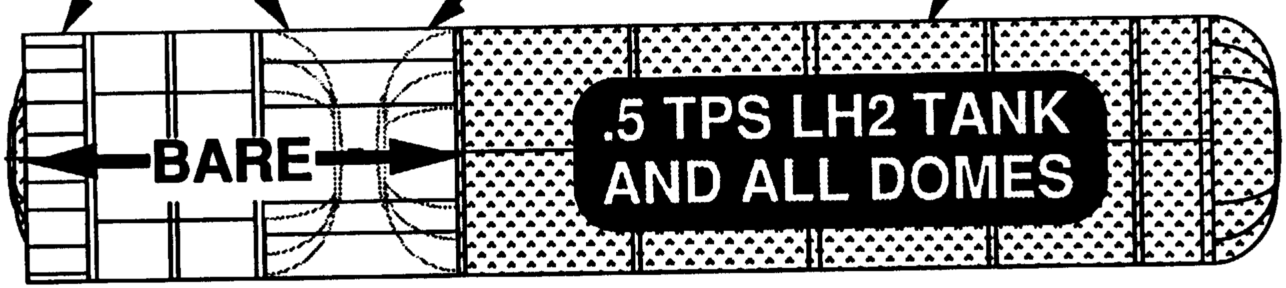
Ref Configuration CV-STR-14H

- 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)



- 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

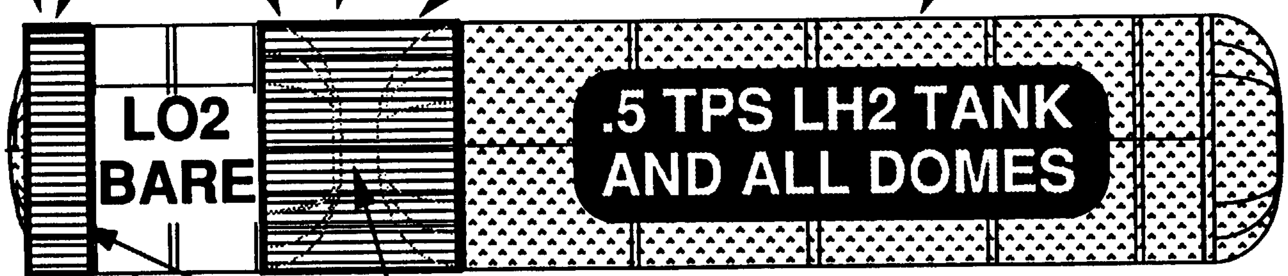
- Ice/Frost formation within 2ft of LO2 I/F

+765 lbs

-173 lbs

- 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)



Compared with Ref Config

Wt + 592 lbs

Cost - No Change

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

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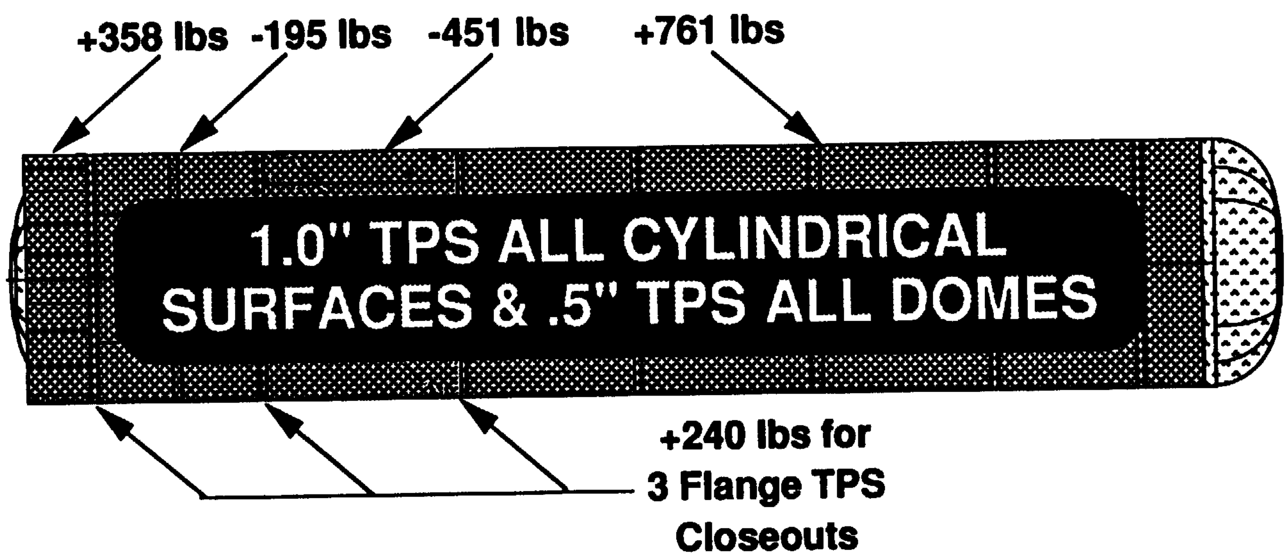
Full TPS Vehicle — CV-STR-14H

- Probability of Ice/Frost & Liquid Air formation on Core is the same as ET to-day
- No Performance, Operations or Safety uncertainty



Compared with Ref Config

+ 713 lbs
+ $.72 M Non-Rec
+ $1.1 M Recurring

- Extra 121 lbs vs "Heatsink" option removes uncertainties due to Ice & Liquid Air
- Cost Increase relatively low

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Evaluation - Core Vehicle CV-STR-14H

		Reference	Heatsink	Full TPS (Nominal 1.0")
Core Vehicle Design		Fwd Skirt Fails due to Aeroheating	Ref	Additional TPS Design required
Manufacturing		Ref	Ref	ET TPS Processes Mods to Cell M required for LO2 barrel spray
Operability		Significant potential for excessive Ice / Frost & Liquid Air Formation		No Ice Problem (same as ET)
Weight (lbs)		0 Ice Wt Impact unknown	+592 Ice Wt Impact unknown	+713 No Ice Problem
Cost	Non-rec	Ref	Ref	= $.72M
	Recurring	Ref	Ref	= $1.1M

☐ Least desireable impacts

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Core Conclusions CV-STR-14H

- 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 +$.72M Non-rec & +$1.1M Recurring

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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.

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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

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Assumptions CV-STR-14H

- 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)

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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

Location	NLS Config	Remtech			Rockwell		
		Body Point	Heating Rate (Btu/ft^2 - sec)	Heat Load (Btu/ft^2)	Body Point	Heating Rate (Btu/ft^2 - sec)	Heat Load (Btu/ft^2)
Fwd Skirt & LO2 Tank	1.5	BP7	.7852	74.51	A7	.76	68.2
	HLLV	BP17	1.122	136.1	B7	1.00	100
Intertank	1.5	BP8	.7569	71.61	A8	.74	66.2
	HLLV	BP17	1.122	136.1	B8	1.0	97.4
	HLLV Shock	BP18	11.1	667.2	B12	19.0	929
LH2 Tank	1.5	BP9	.7298	68.83	A9	.72	62.8
	HLLV	BP19	2.218	205.3	B9	.97	89.7

- Note that only the HLLV heating data were used in the subsequent evaluation section (HLLV rates > 1.5 Rates) to define the reference vehicle

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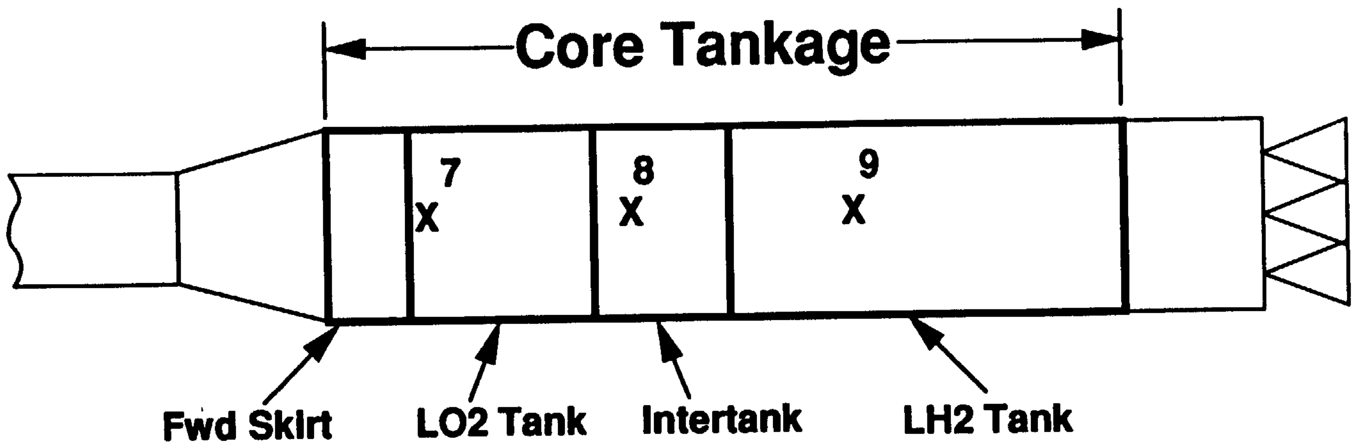
1.5 Stage Bodypoints CV-STR-14H



- Body Point #7 used for both Fwd Skirt & LO2 Tank

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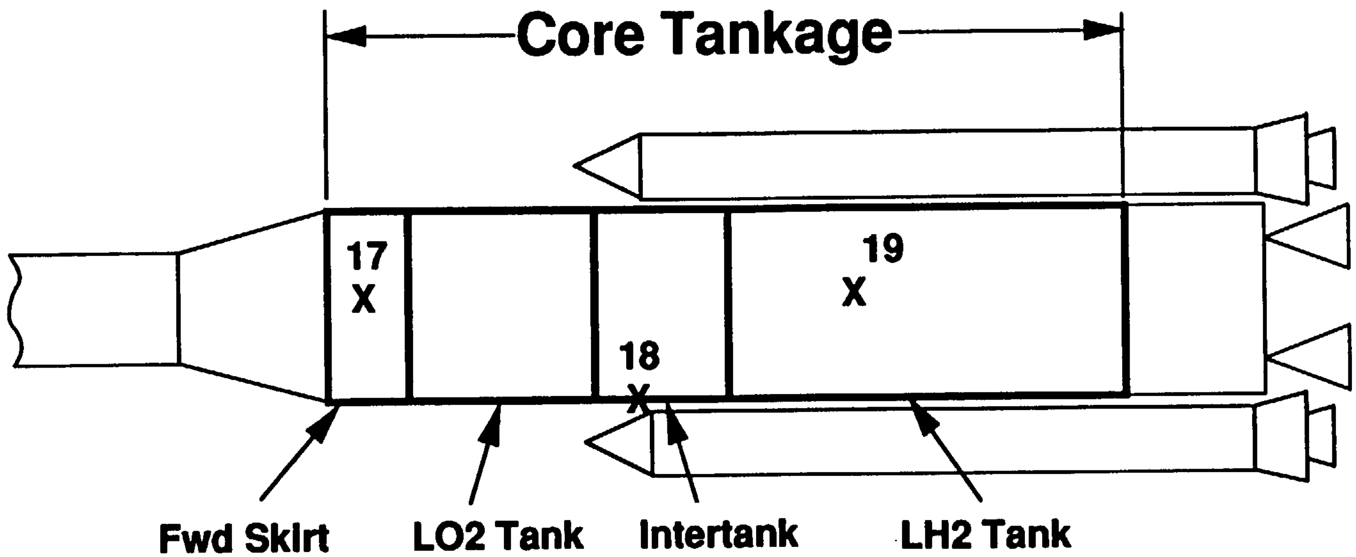
HLLV Bodypoints CV-STR-14H



- 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

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Thermal Analysis Runs CV-STR-14H

Location \ Parameters	Metal Thickness (In) 1.5	Metal Thickness (In) HLLV	TPS Thickness (In)
Fwd Skirt - Stringer	.053	.071	0 , .25 , .50
- Skin	.053	.063	0 , .25 , .50
LO2 - Bare	.1,.13,.16,.23,.3	.1,.156,.16,.23,.3	0
- Insulated	.1 & .3	.1 & .3	.25 , .50
Intertank - Stringer	.071	.071	0 , .25 , .50
- Skin	.15	.15	0 , .25 , .50
- Thrust Panels *	-	-	-
LH2 - Bare **	-	-	-
- Insulated	.1 & .3	.1 & .3	.25 , .50 , 1.0
Element Joints ***	-	-	-

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

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Appendix 2
Fluid Conditioning Data

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LO2 Loading Assumptions CV-STR-14H

- LO2 Tank Volume

- Overall Length	= 504.26"
- Dome Height	= 124.375
- Total Mold Line Volume	= 20,982 ft^3
- Plus Feedline Volume	= 535
- Less Panel/Internals Volume	= 65
- Less Ullage Volume (3.3%)	= 743
- Total Liquid Volume	= 20,709 ft^3

- Barrel Area = 1870 ft^2
- Bubble Volume = 40 ft^3
- Ambient Pressure = 14.65 @ Vent Exit
- Nominal ET End of Replenish Density = 71.13 lb/ft^3
- 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 in^2 (Fully Open)
- GHe Effects Assume Bubble Volume Not Refill-ed 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

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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

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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 CV-STR-14H

- 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

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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

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Appendix 3
Sensitivity Analysis for Propellant Conditioning Variables

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LO2 Sensitivity Analysis CV-STR-14H

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

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Sensitivity Analysis CV-STR-14H

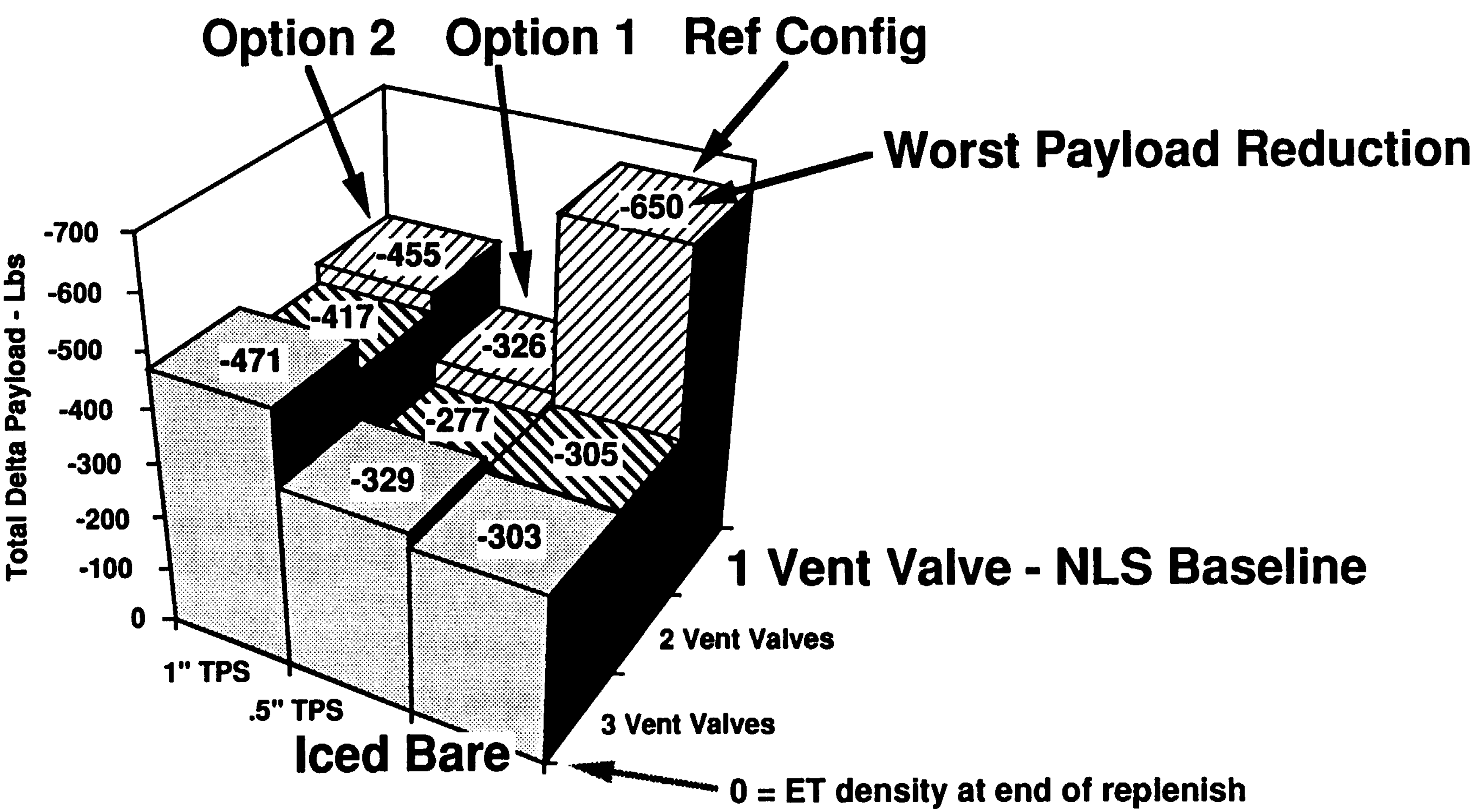
Payload Factor Sensitivity

- **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, 1Vent 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 CV-STR-14H

NLS Baseline Propellant Conditioning Parameters

5000 Gpm, GHe Inject, 5 Hr. Min. Load to Launch



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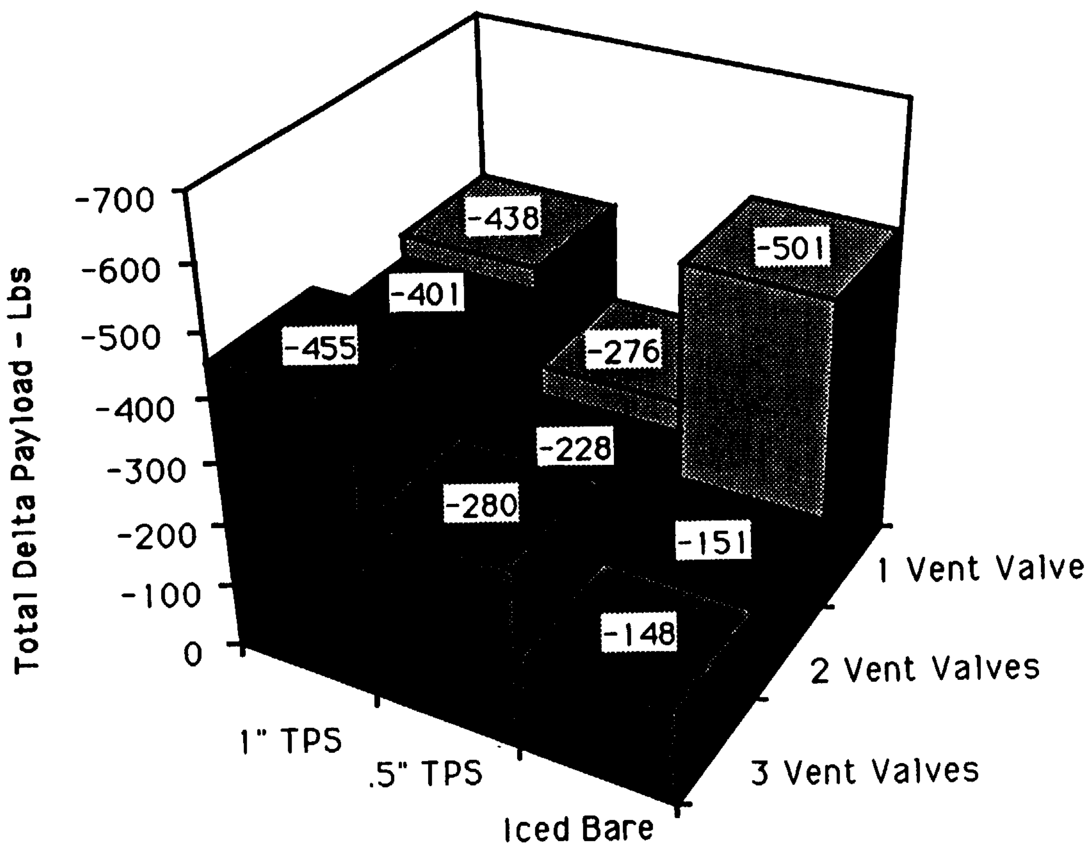
LO2 Sensitivity Analysis CV-STR-14H

No GHe Inject

5000 Gpm, No GHe Inject, 5 Hr. Min. Load to Launch



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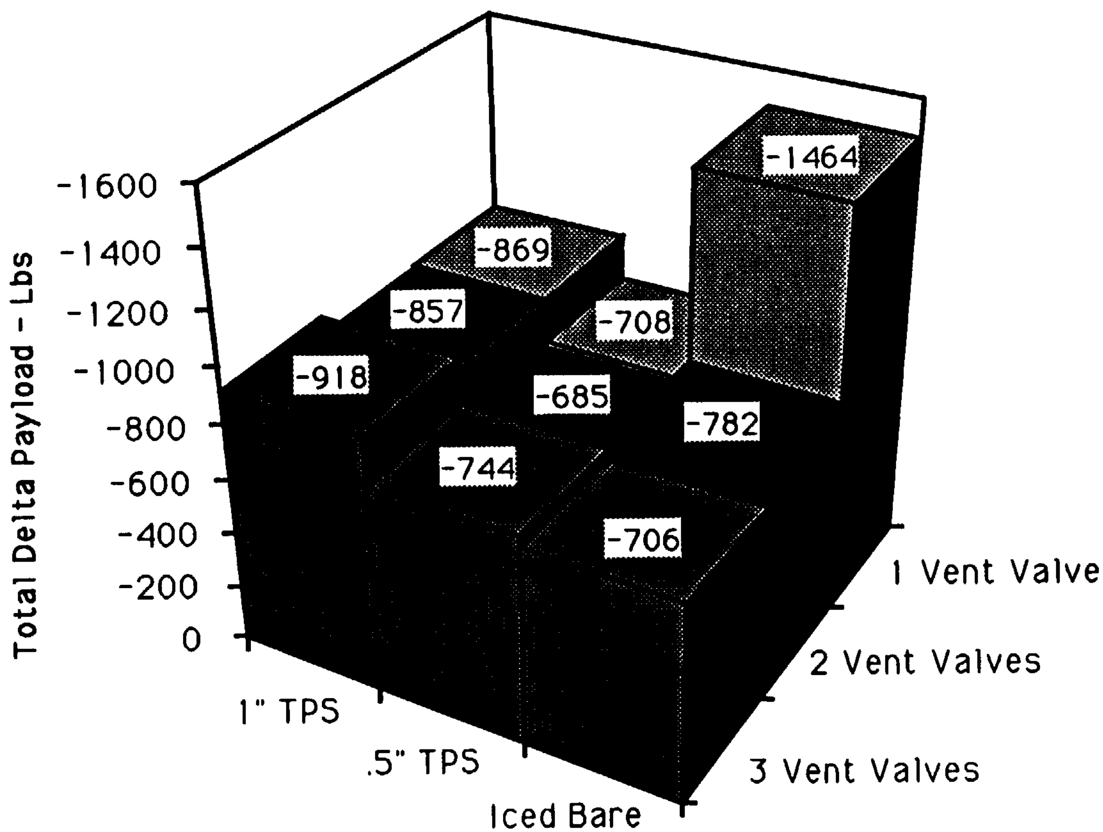
LO2 Sensitivity Analysis CV-STR-14H

No GHe & Reduced Loading Time

5000 Gpm, No GHe Inject, 2 Hr. Min. Load to Launch



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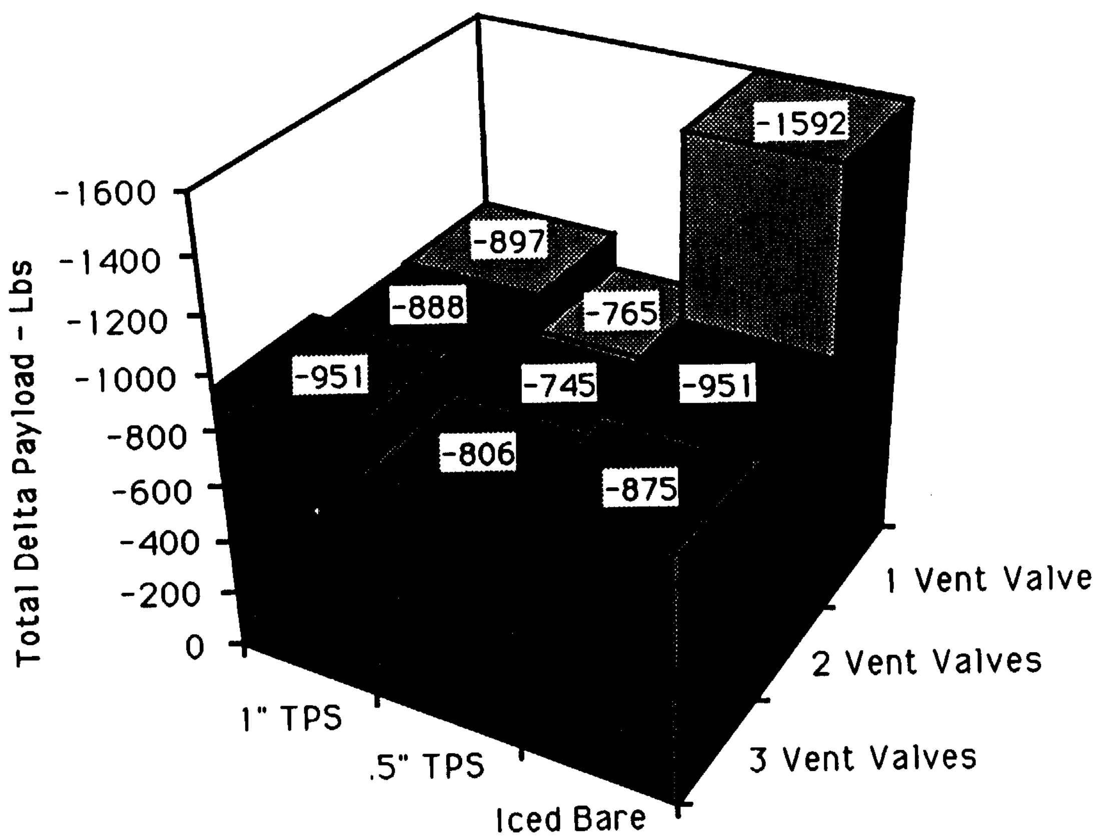
LO2 Sensitivity Analysis CV-STR-14H

Reduced Loading Time

5000 Gpm, GHe Inject, 2 Hr. Min. Load to Launch



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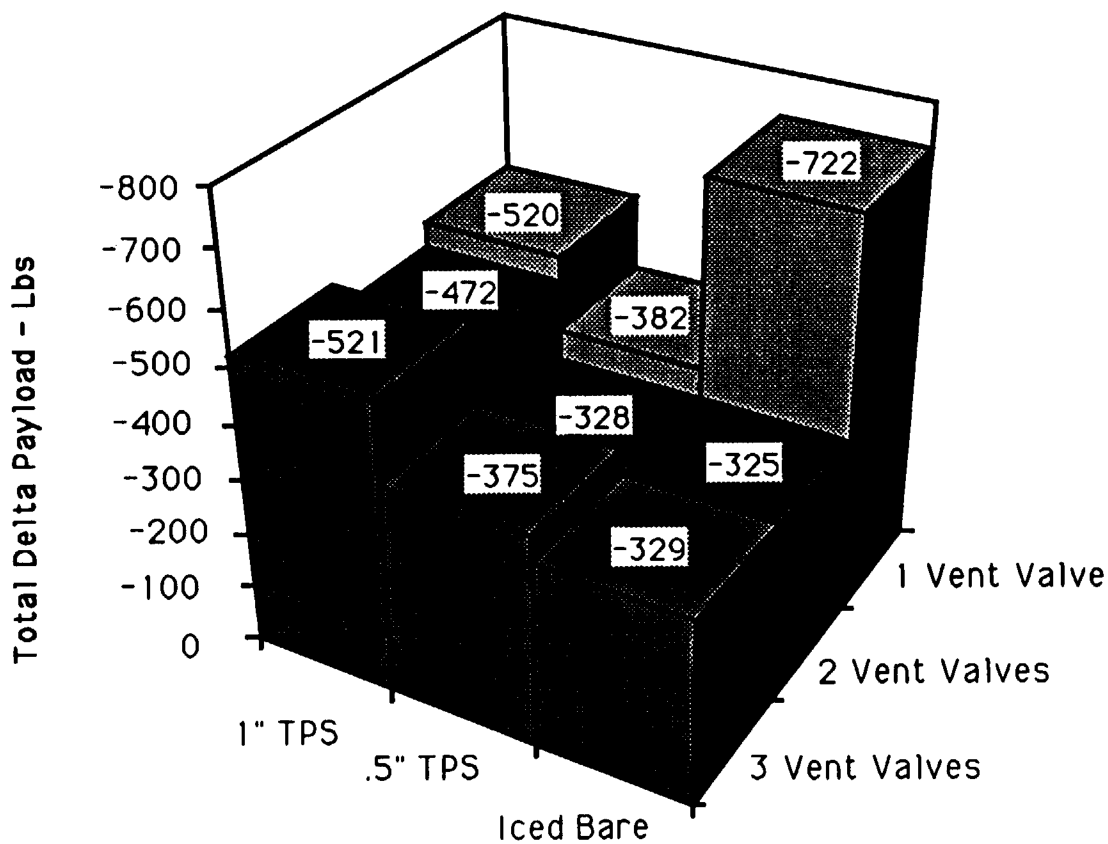
LO2 Sensitivity Analysis CV-STR-14H

ET Fill Rate & Short Fill Time

1400 Gpm, No GHe Inject, 2 Hr. Min. Load to Launch



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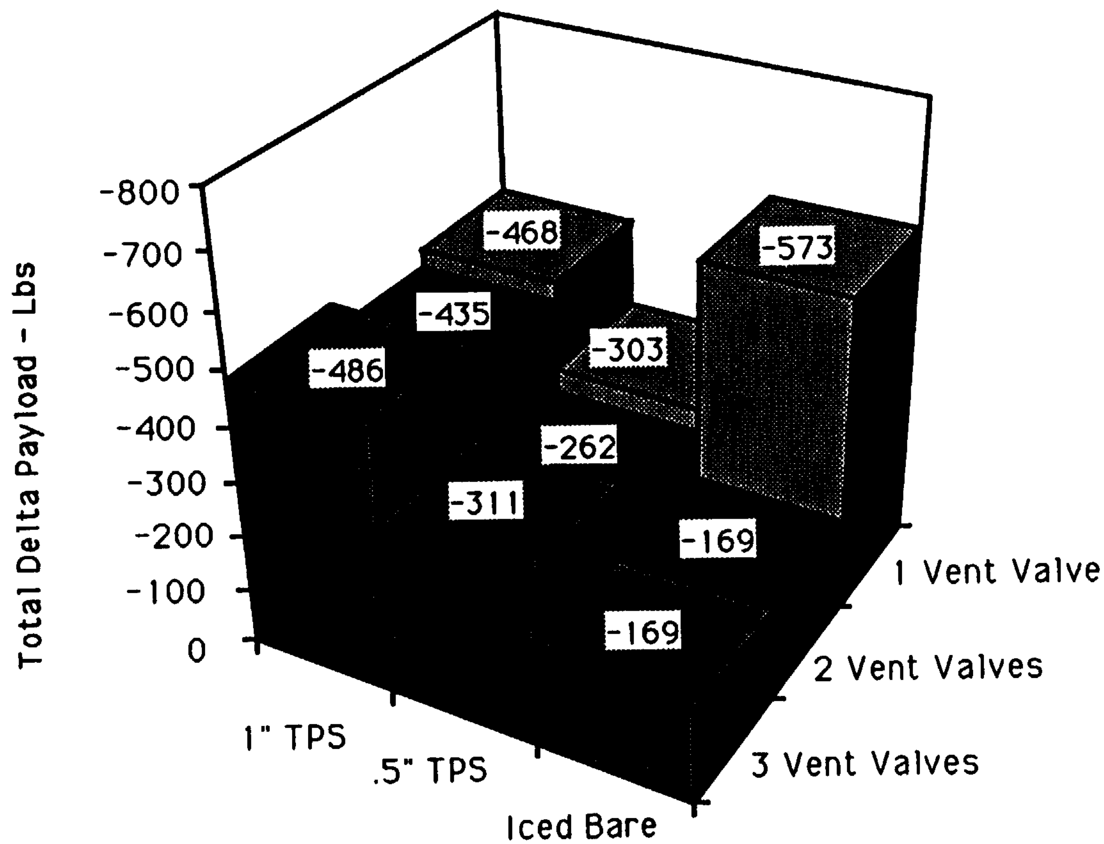
LO2 Sensitivity Analysis CV-STR-14H

ET Fill Rate

1400 Gpm, No GHe Inject, 5 Hr. Min. Load to Launch



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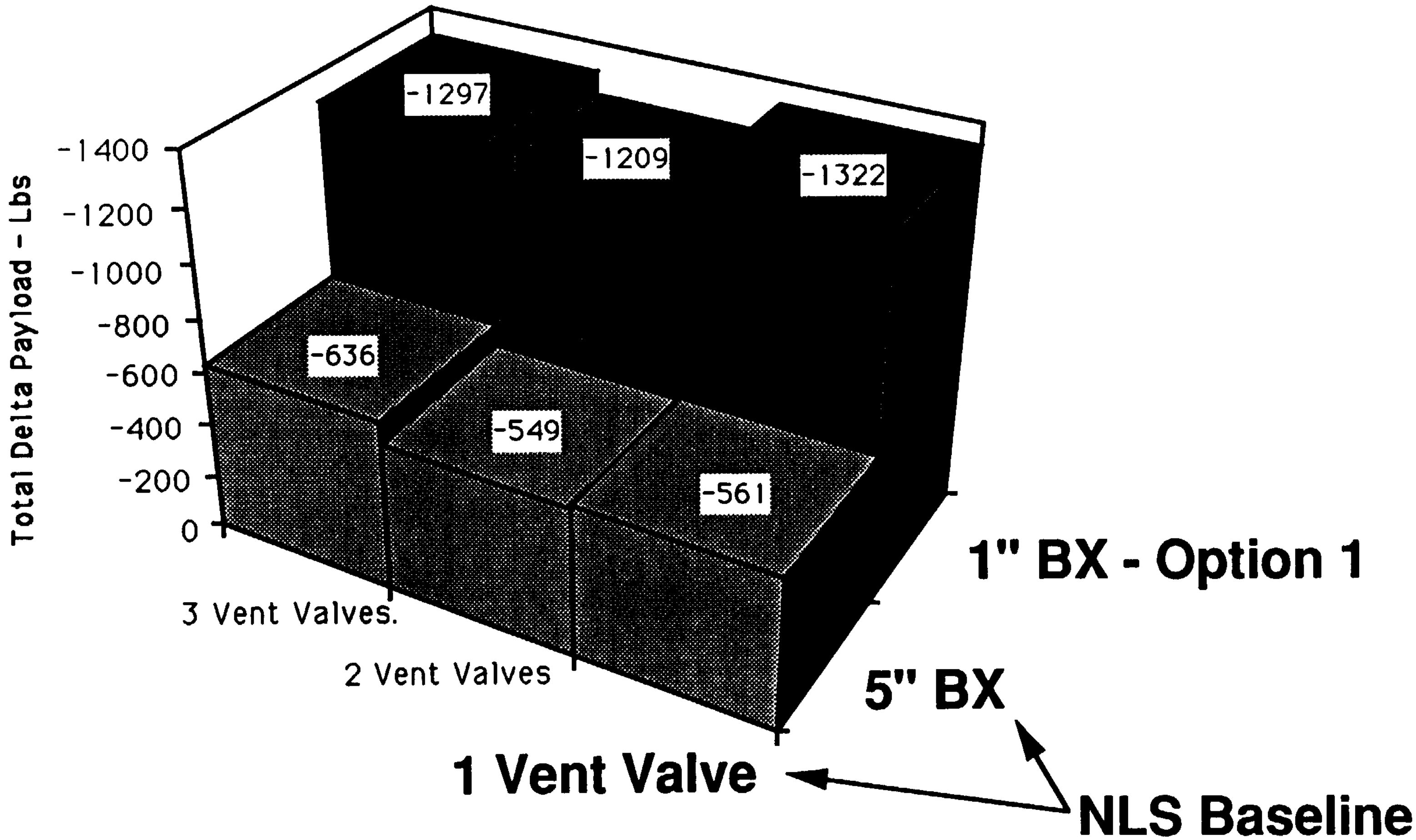
LH2 Payload vs TPS — CV-STR-14H

5 Hour Min Load to Launch



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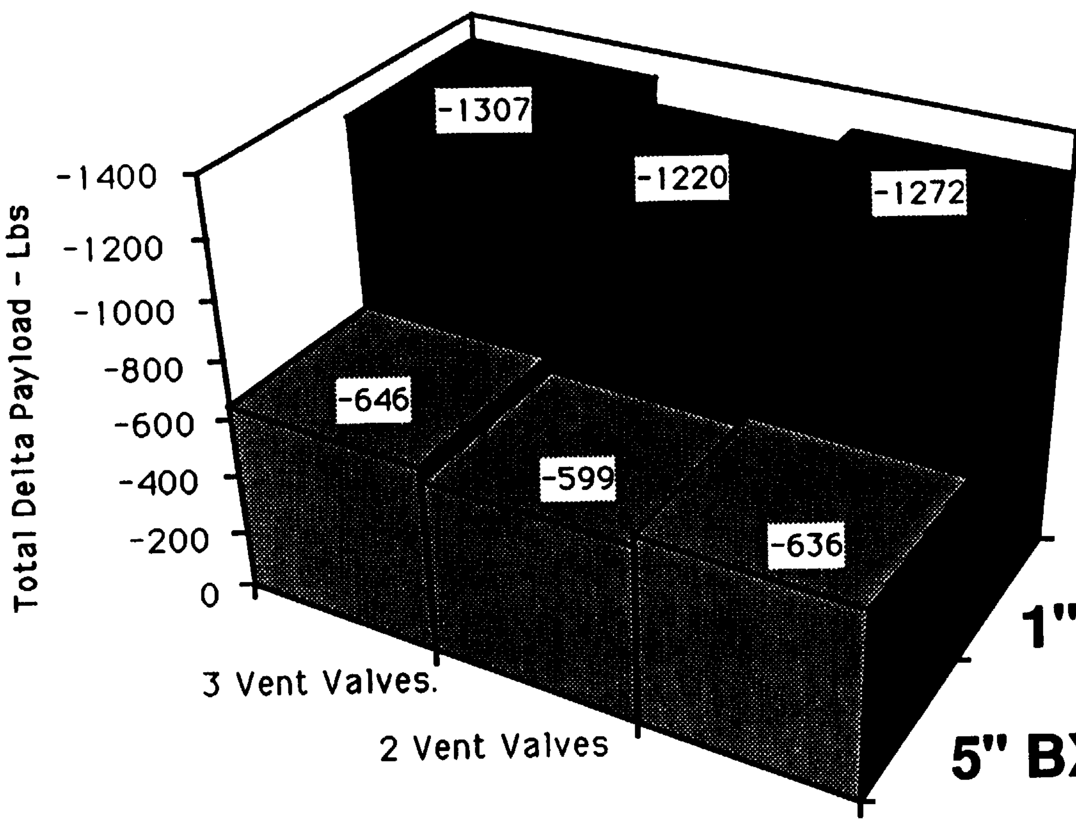
LH2 Payload vs TPS — CV-STR-14H

2 Hour Min Load to Launch



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Appendix 4
TPS Manufacturing

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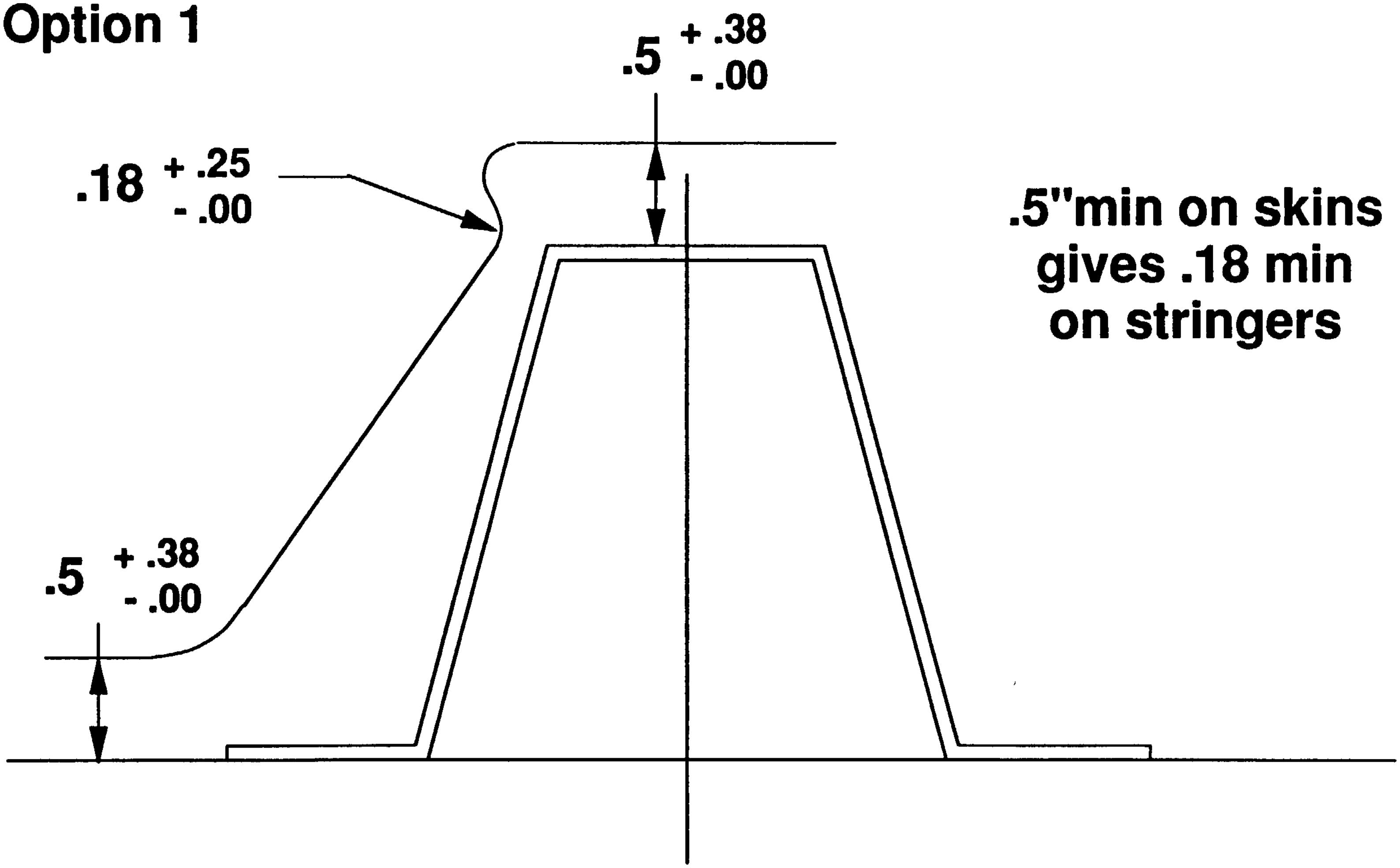
Spray Process CV-STR-14H

- 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



.5"min on skins gives .18 min on stringers

.75" nominal TPS thickness used for mass properties

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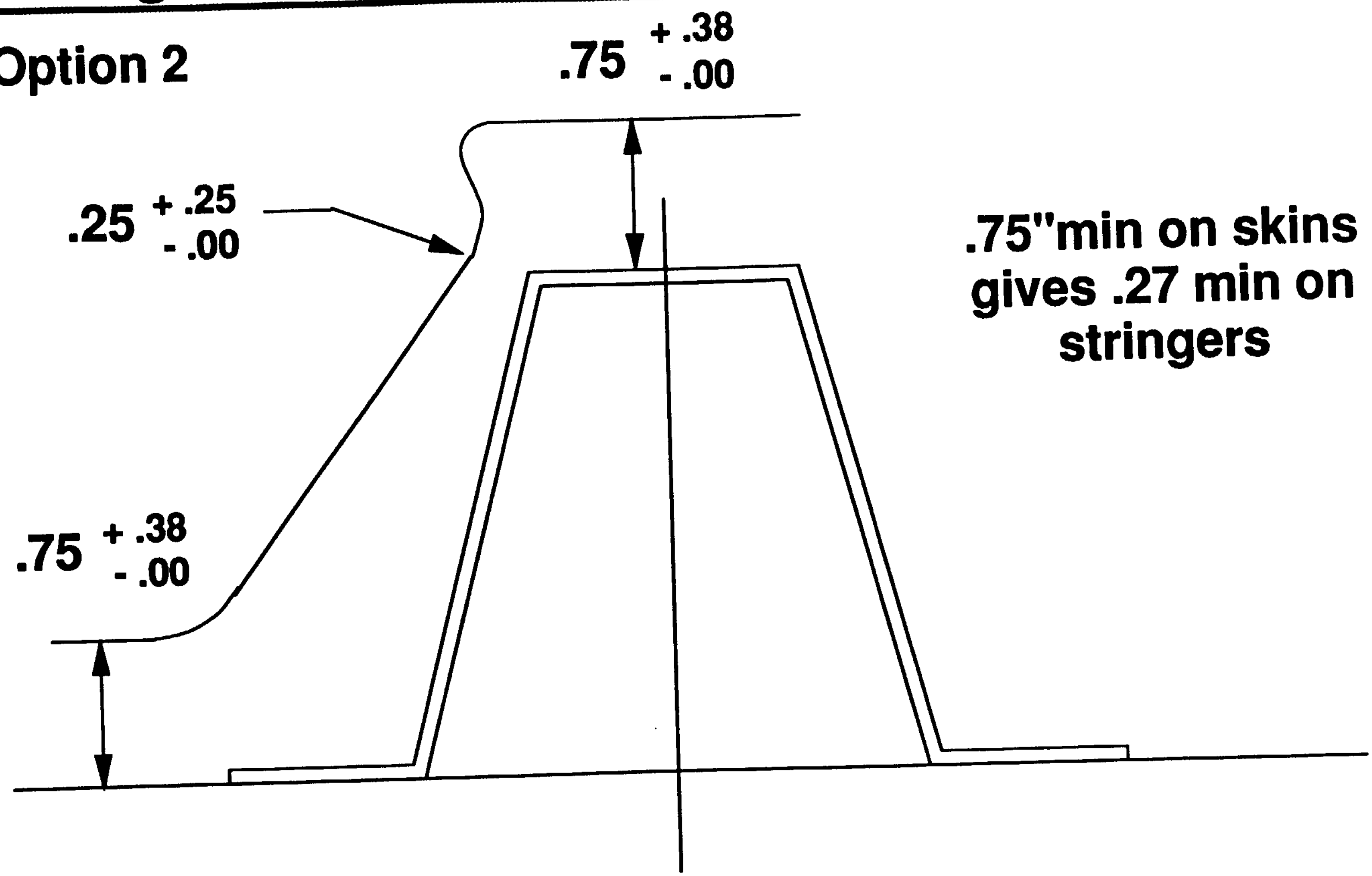
Stringer TPS Profile CV-STR-14H

Option 2



.75"min on skins gives .27 min on stringers

1.0" nominal TPS thickness used for mass properties

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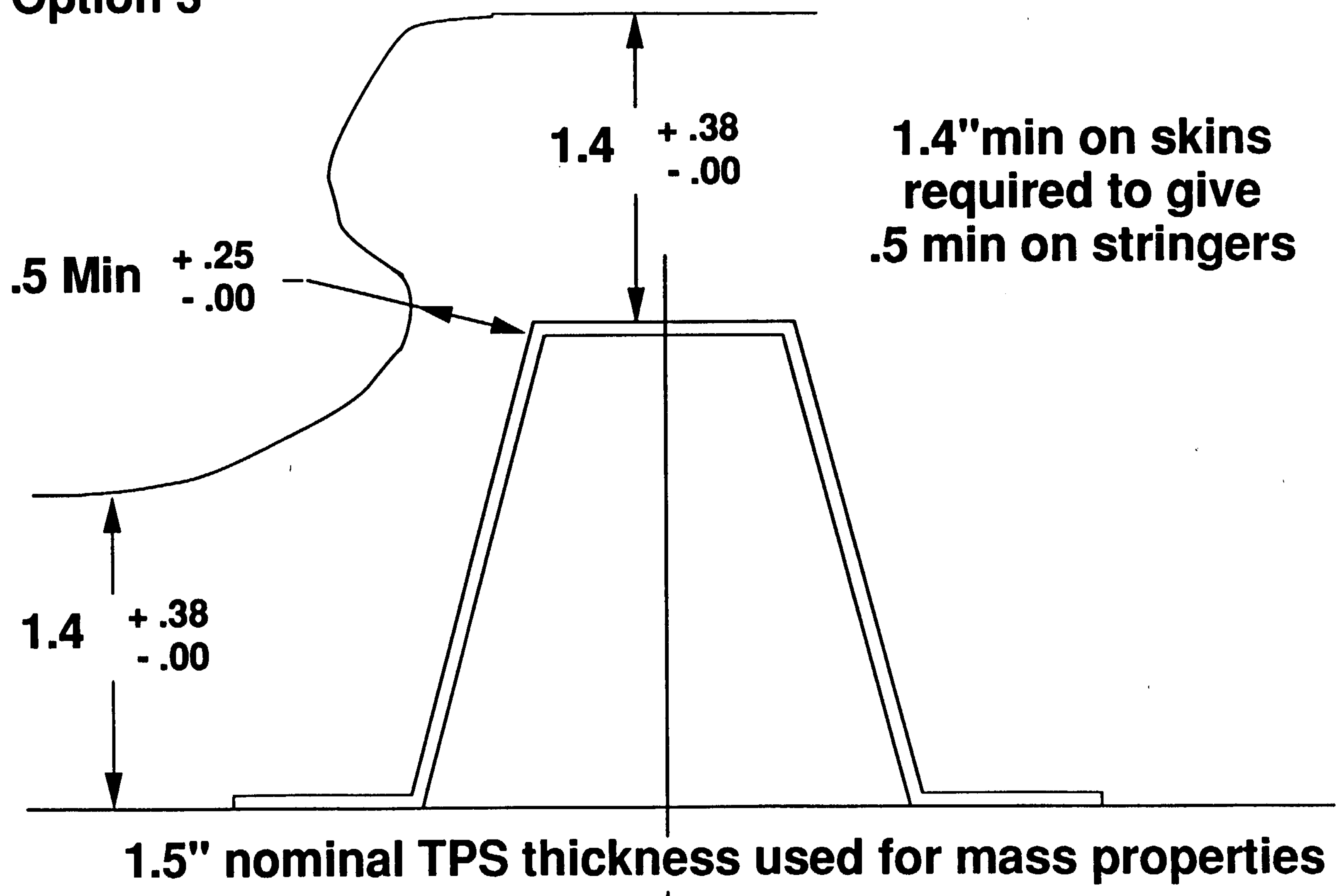
Stringer TPS Profile CV-STR-14H

Option 3



1.4"min on skins
required to give
.5 min on stringers

1.5" nominal TPS thickness used for mass properties

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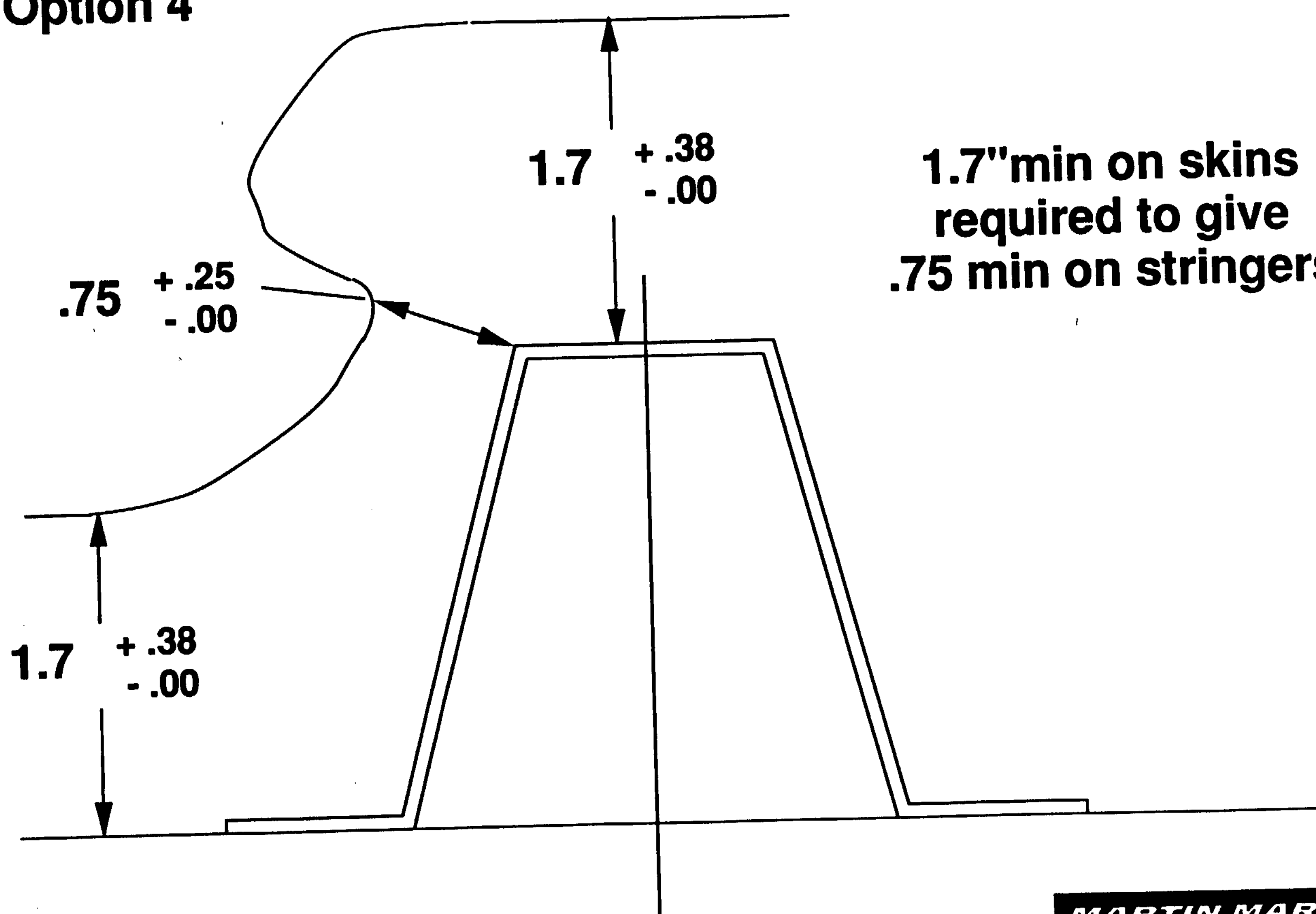
Stringer TPS Profile

CV-STR-14H

Option 4



1.7"min on skins
required to give
.75 min on stringers

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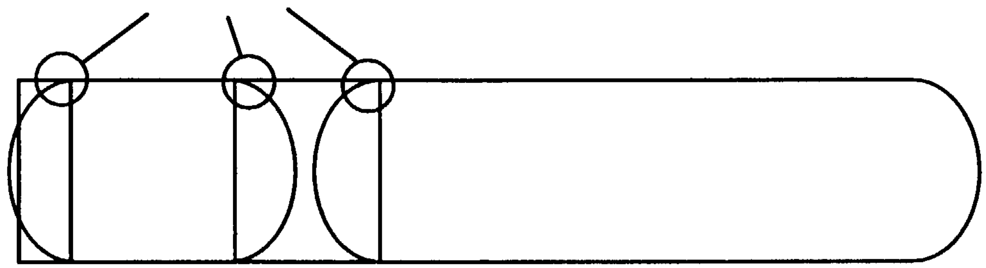
Conclusions — CV-STR-14H

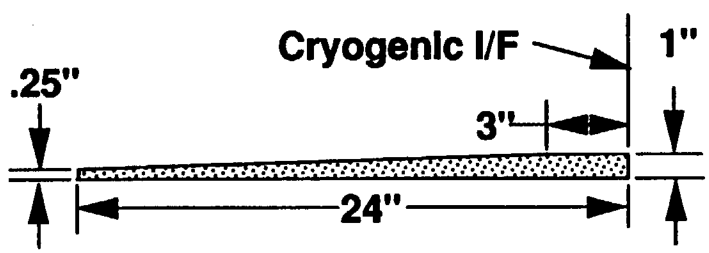
Option 1	Viable option
Option 2	Viable option
Option 3	Viable option
Option 4	Excessive TPS thickness

TPS Closeouts

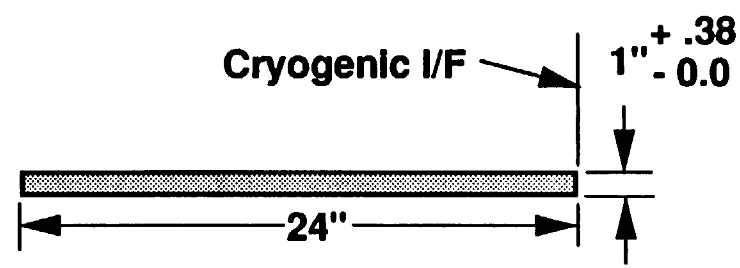
Ice / Liquid Air Suppression CV-STR-14H

Assumes bare Fwd Skirt & I/T





Theoretical TPS Profile



Manufacturing TPS Profile
80 lbs per detail shown

Detail A

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Closeouts CV-STR-14H

<u>Flange Closeouts</u>
- Bolted joints between components
- No TPS required for NLS heating rates
- TPS is required for ice/frost & liquid air prevention
- No flange closeots used in Reference configuration
- Three flange closeouts added to Full TPS option @ 80 lbs per closeout

<u>Fwd Skirt & Intertank Closeouts</u>
- 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

<u>Cable Tray & Propellant Line supports</u>
- 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

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TPS Weights CV-STR-14H

	Reference * TPS Weights (LBS)	MMMSS Config	
		Nom TPS	WT (LBS) **
Fwd Skirt	0	1.0"	213
LO2 Tank	174.8		
- Domes		.5"	161
- Barrels		1.0"	353
Intertank	12.6	1.0"	464
LH2 Tank	825.7		
- Domes		.5"	161
- Barrels		1.0"	1322
Closeouts #	0	N/A	240

* 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.

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Appendix 5
Freon Replacement

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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

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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

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Appendix 6
Ice & Liquid Air Formation

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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

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Ice Sensitivity — CV-STR-14H

- 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

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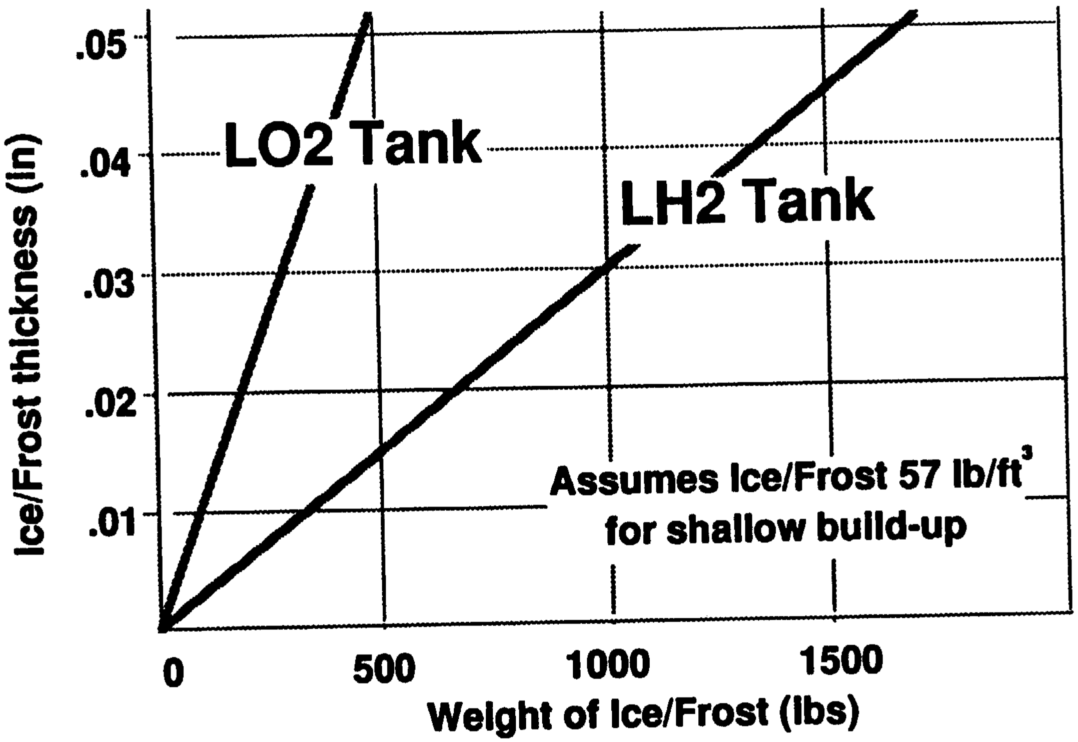
Ice / Frost Weight CV-STR-14H



- Even thin Ice/Frost build-up generates significant weight
- Actual build-up will depend on weather conditions and variations in TPS thickness

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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 antisipated over the Reference option.

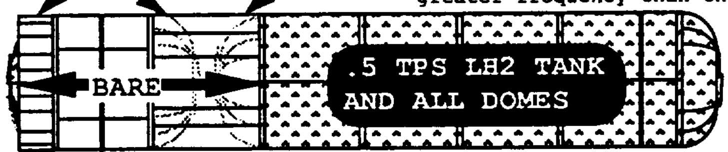
There is an additional performance loss of 121 lbs (vs the Heatsink) assuming 1.0" of TPS on the entire Core. This avoids all the problems associated with ice & liquid air formation. The cost of applying acreage TPS is not felt to be prohibitive to avoid the above system level uncertainties / problems. 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 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)



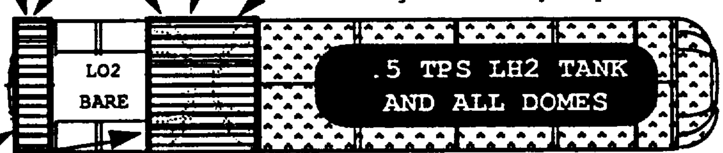
- Significant Potential for Excessive Ice/Frost formation over entire LO2 Barrel

> - **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 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)

+765 lbs -173 lbs



Compared with Ref Config
Wt + 592 lbs
Cost - No Change

Modified Heatsink Design

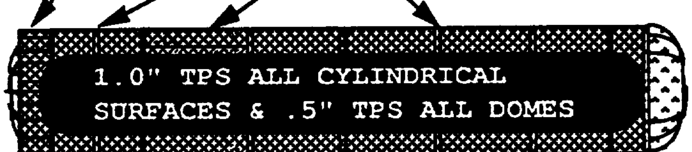
- Significant Potential for Excessive Ice/Frost formation over entire LO2 Barrel

> - **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

+358lbs -195lbs -451lbs +761lbs



Compared with Ref Config
+ 713 lbs
+ $.72 M Non-Rec
+ $1.1 M Recurring

+240lbs for 3 Flange TPS Closeouts

> - **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.

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 antisipated 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 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)

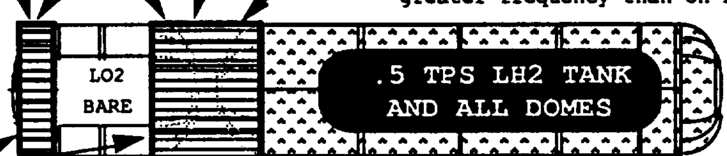
- Significant Potential for Excessive Ice/Frost formation over entire LO2 Barrel

> - 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 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)

+765 lbs -173 lbs



Modified Heatsink Design

- Significant Potential for Excessive Ice/Frost formation over entire LO2 Barrel

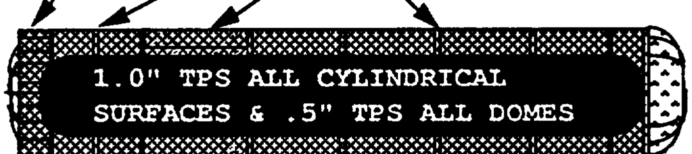
<u>Compared with Ref Config</u>
Wt + 592 lbs
Cost - No Change

> - 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

+358lbs -195lbs -451lbs +761lbs



<u>Compared with Ref Config</u>
+ 713 lbs
+ $.72 M Non-Rec
+ $1.1 M Recurring

+240lbs for 3 Flange TPS Closeouts

> - 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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CV-STR-16A
Core Tankage
Manufacturing 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

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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

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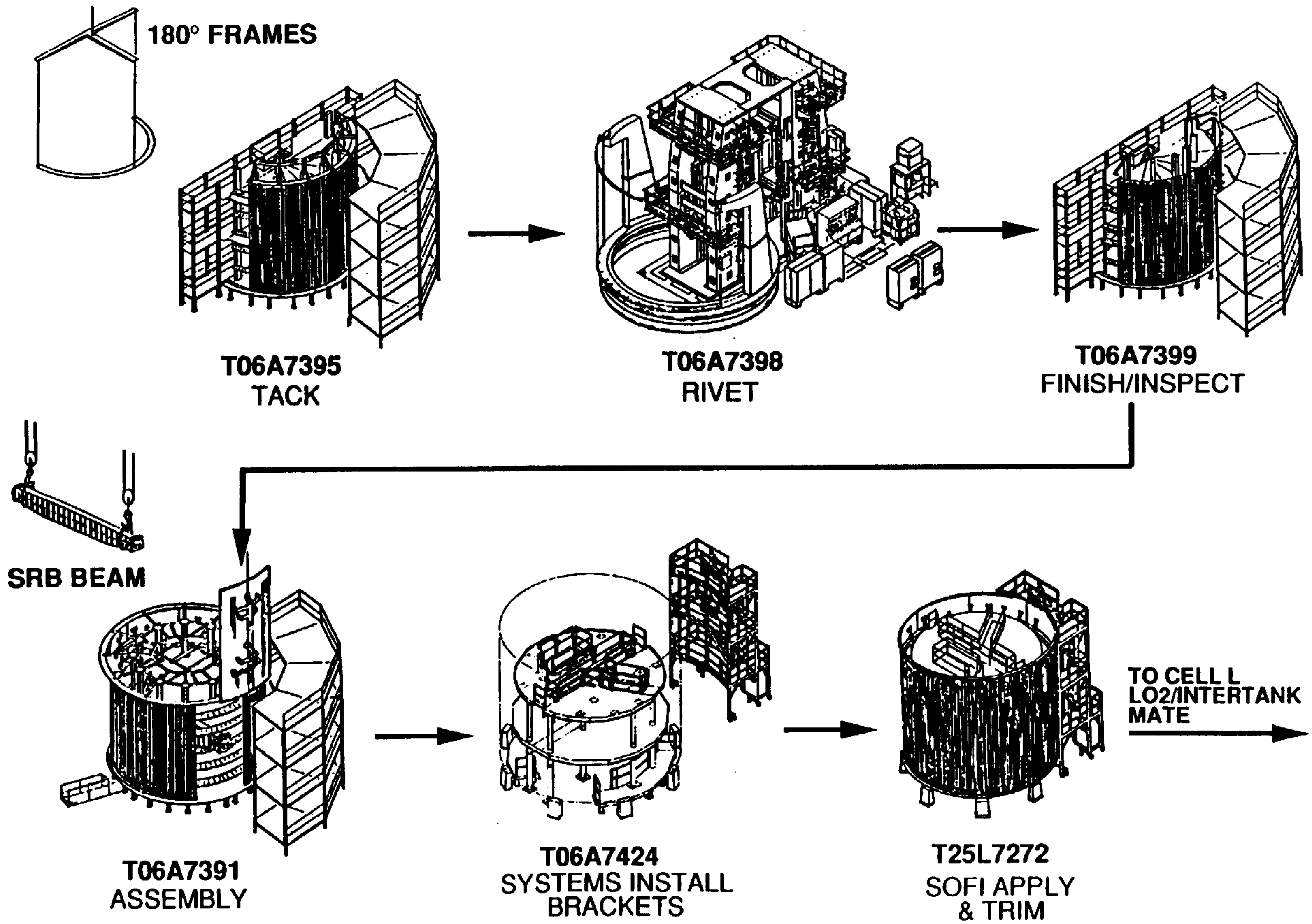
Coretank Manufacturing Flow - Intertank



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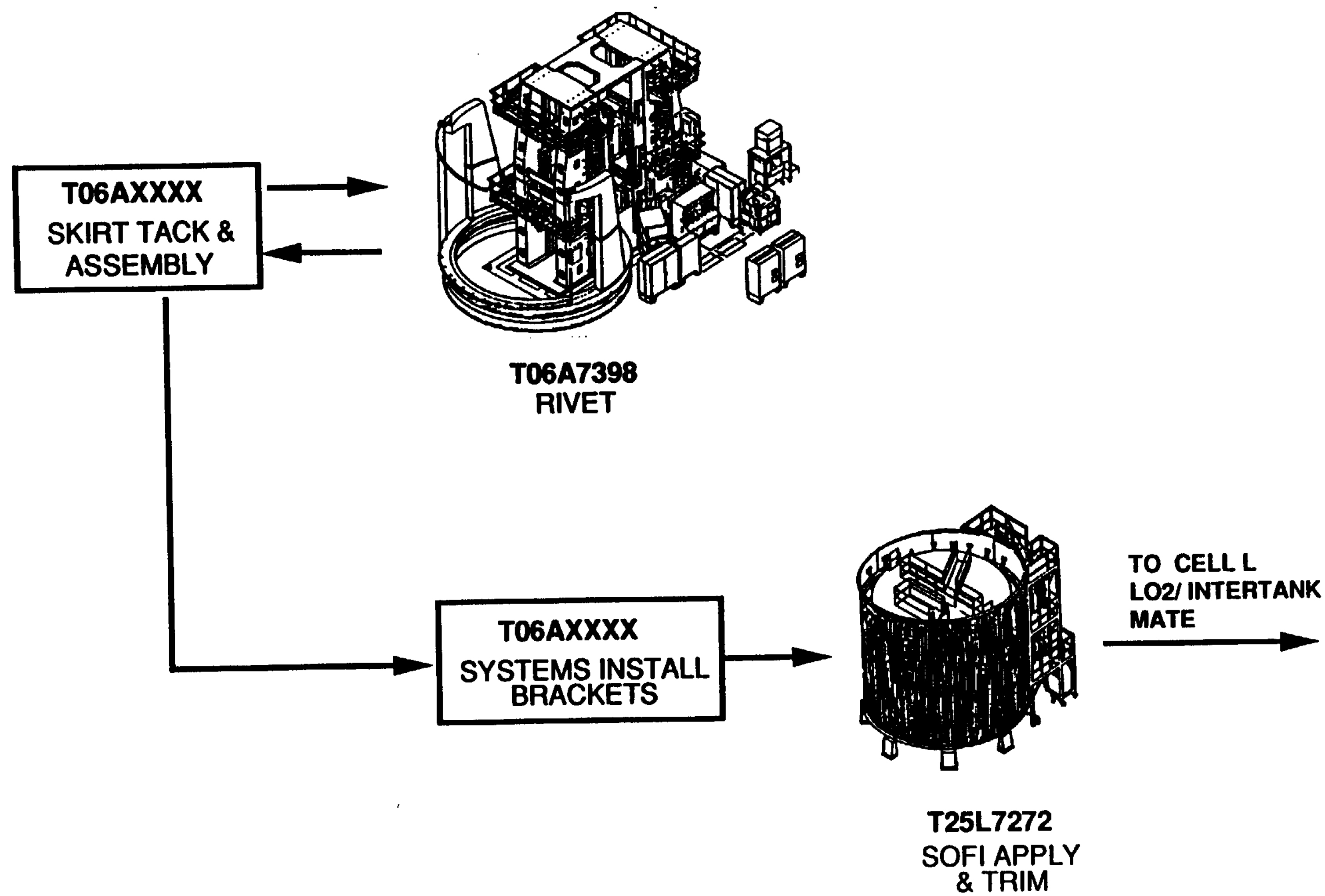
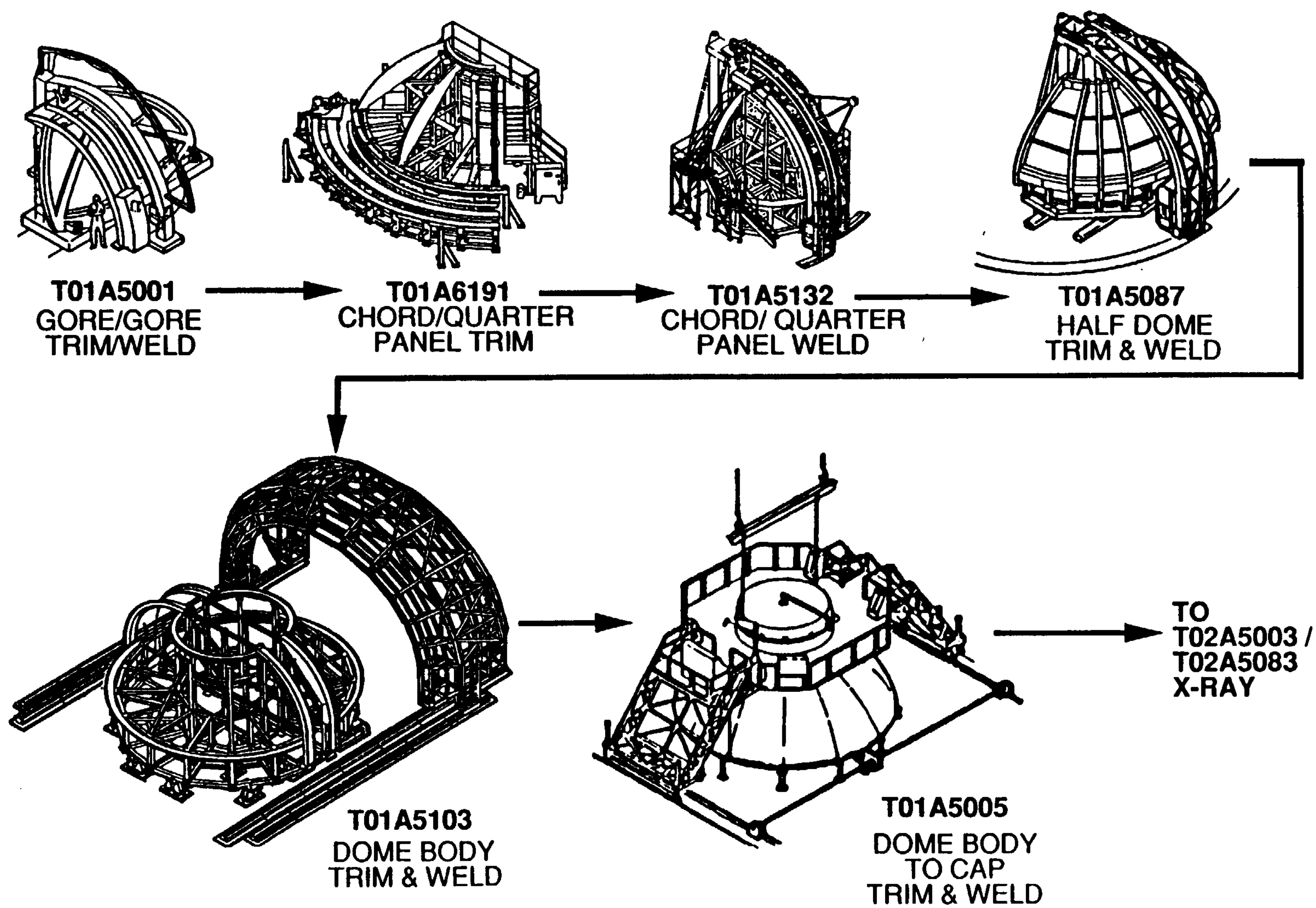
Coretank Manufacturing Flow - Forward Skirt



Coretank Manufacturing Flow - Domes



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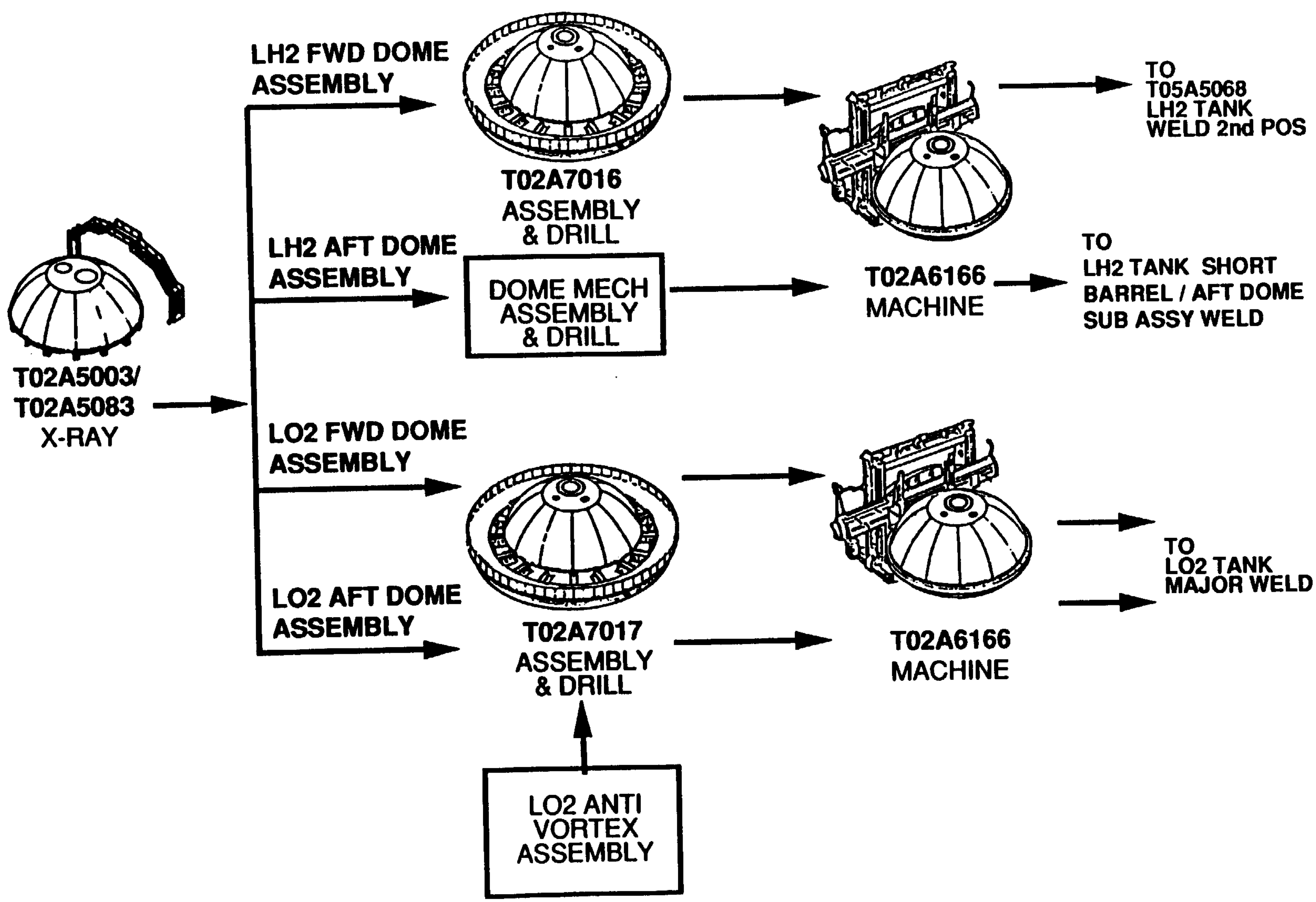
Coretank Manufacturing Flow - Domes (Contd)



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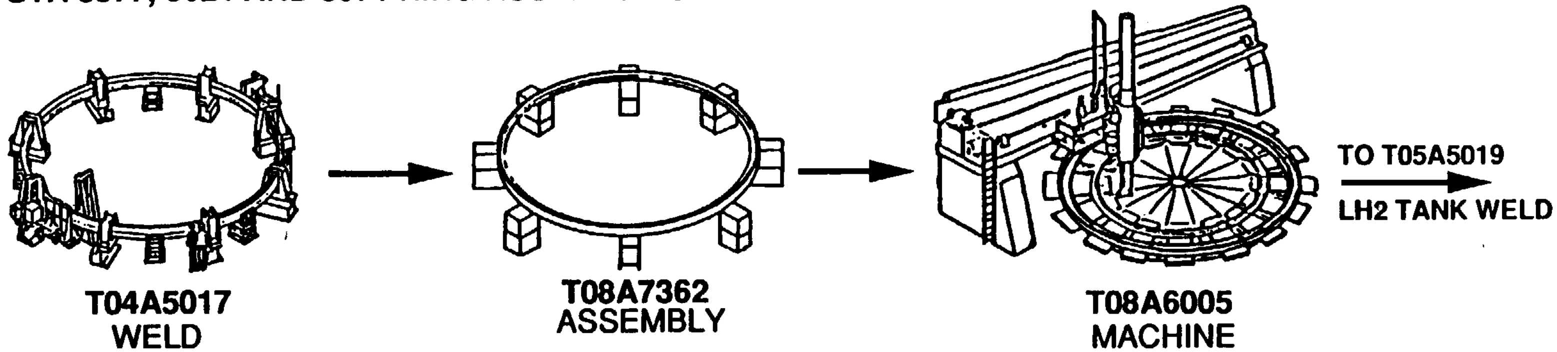
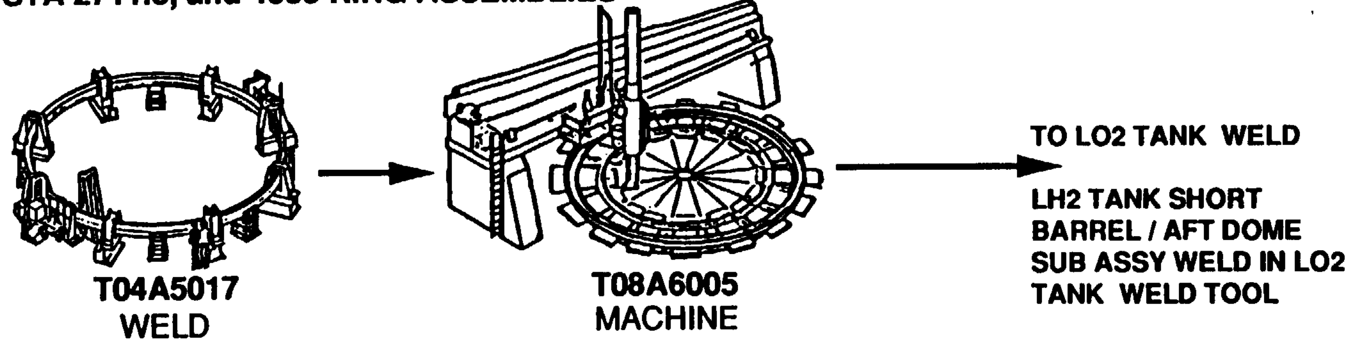
Coretank Manufacturing Flow - Rings

STA 3377, 3624 AND 3871 RING ASSEMBLIES



STA 2711.3, and 4058 RING ASSEMBLIES



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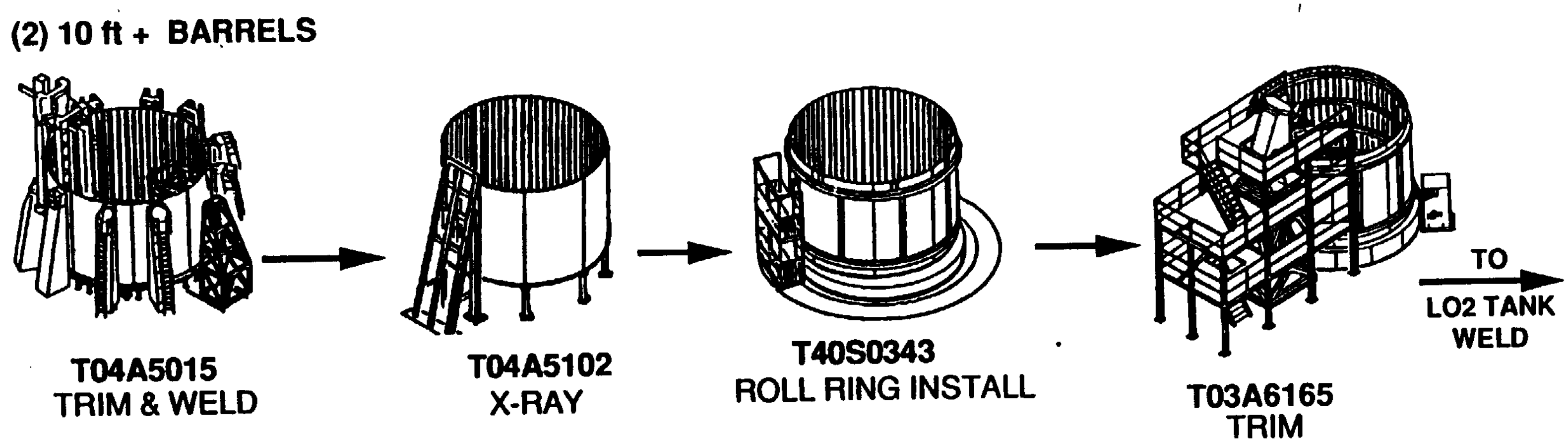
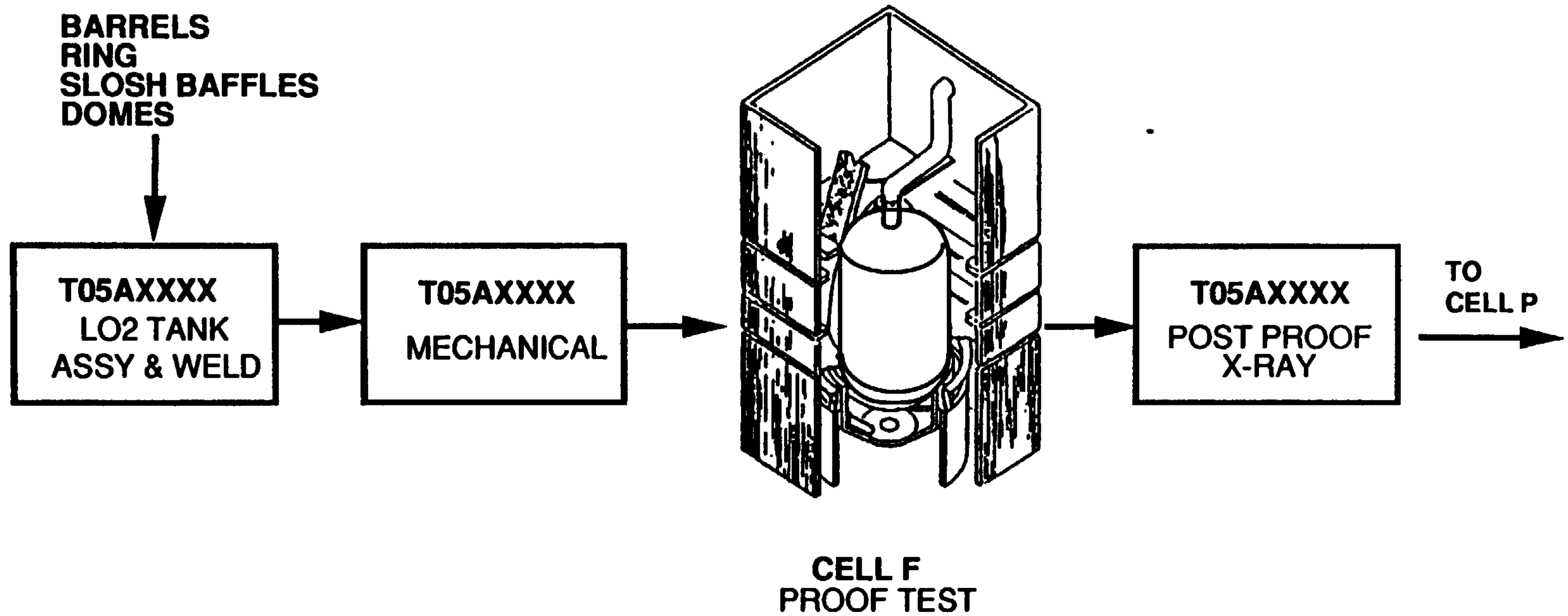
Coretank Manufacturing Flow - LO2 Barrel



Coretank Manufacturing Flow - LO2 Major Weld



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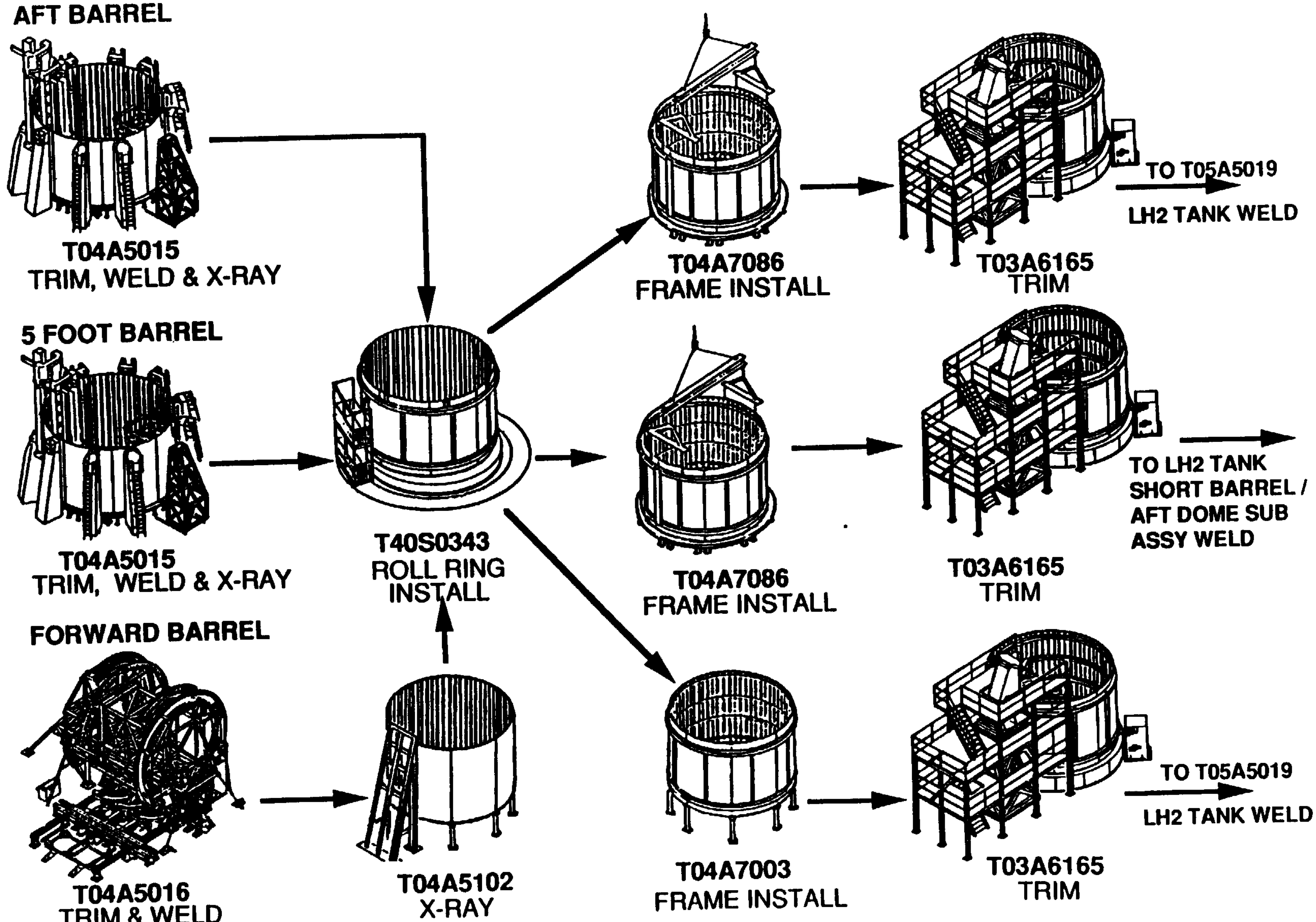
Coretank Manufacturing Flow - LH2 Barrels



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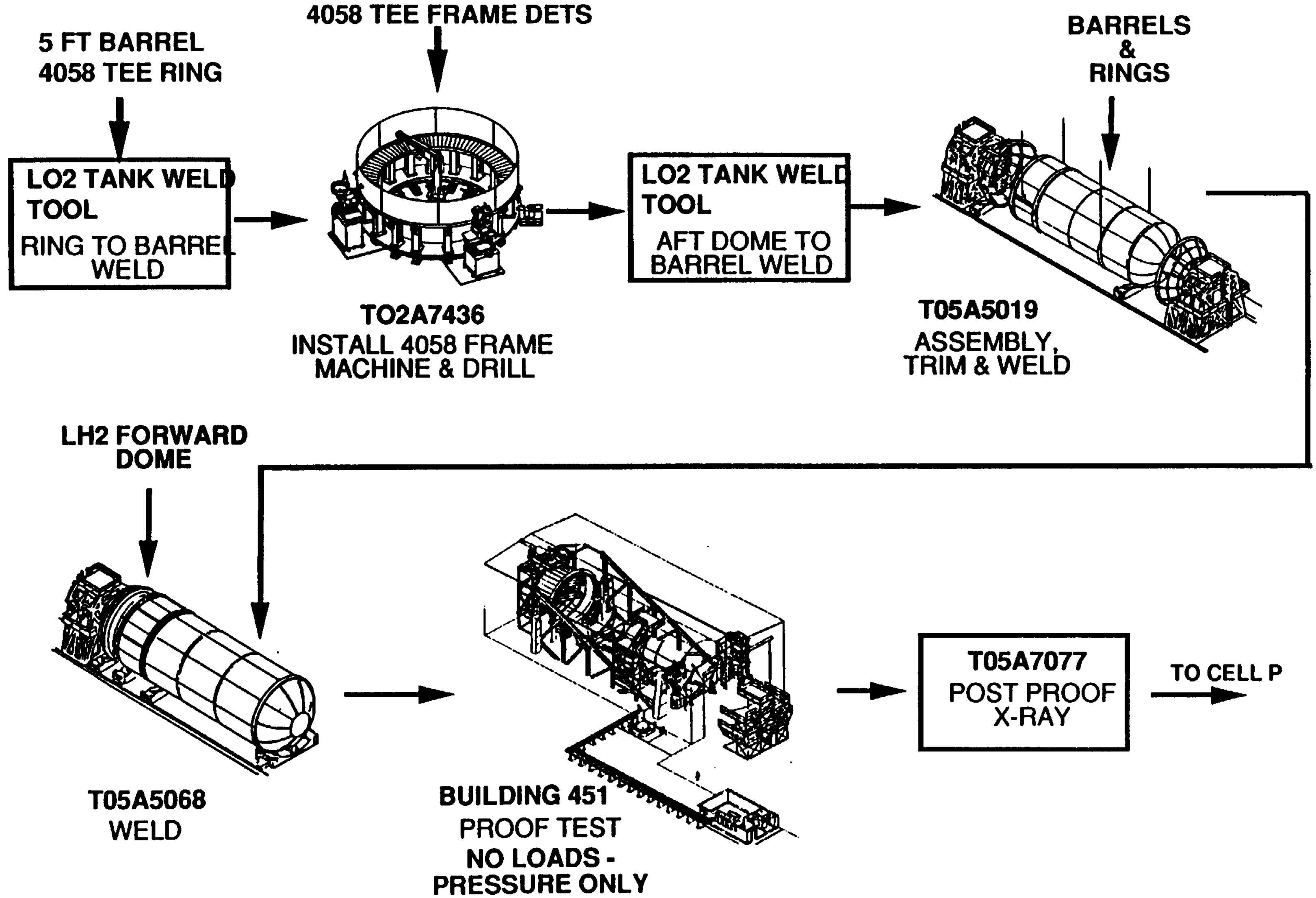
Coretank Manufacturing Flow - LH2 Major Weld



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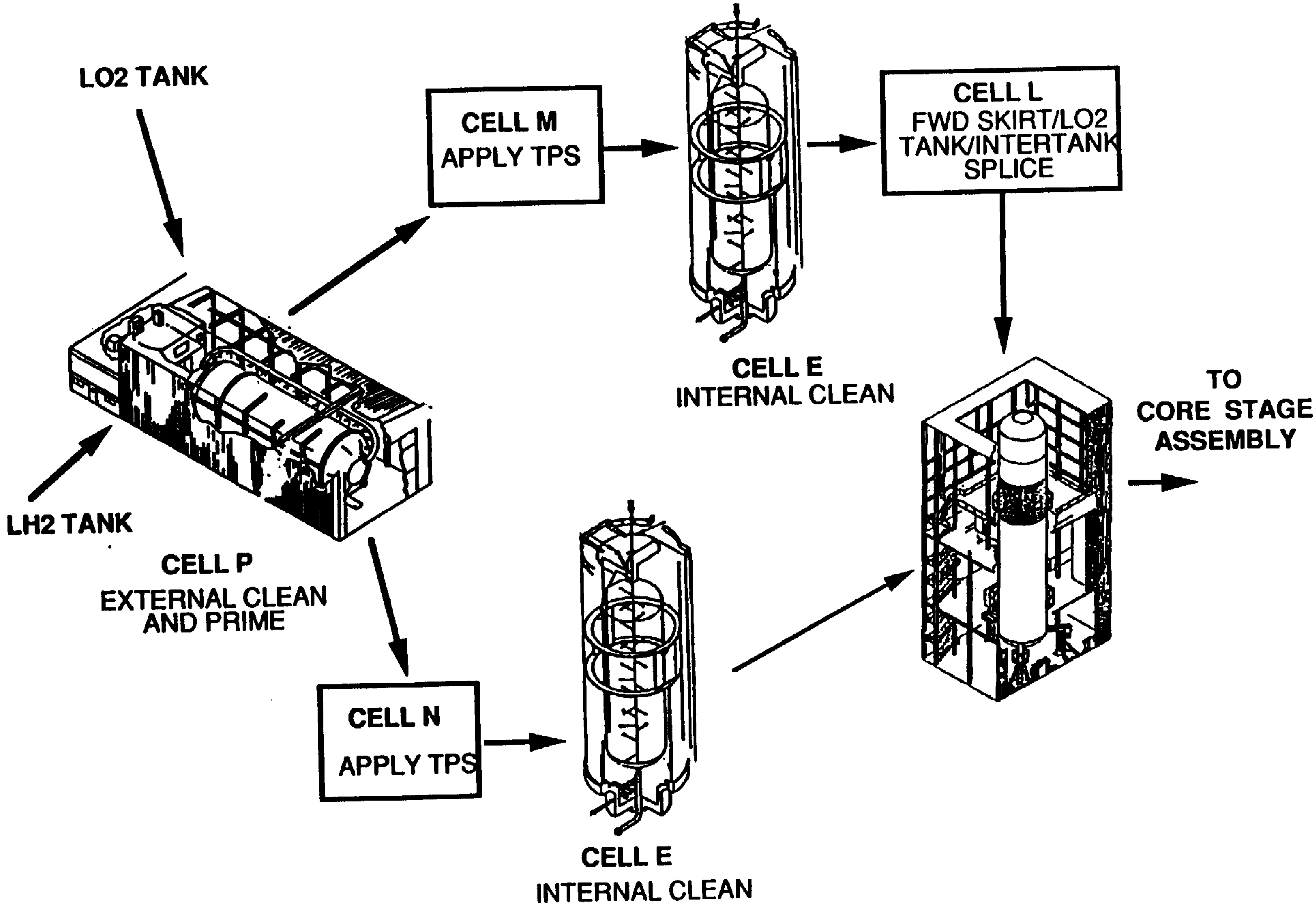
Coretank Manufacturing Flow - Clean, TPS & Stack



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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)

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.

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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

RH 91/12/09

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Core Tankage - Facilities Plan

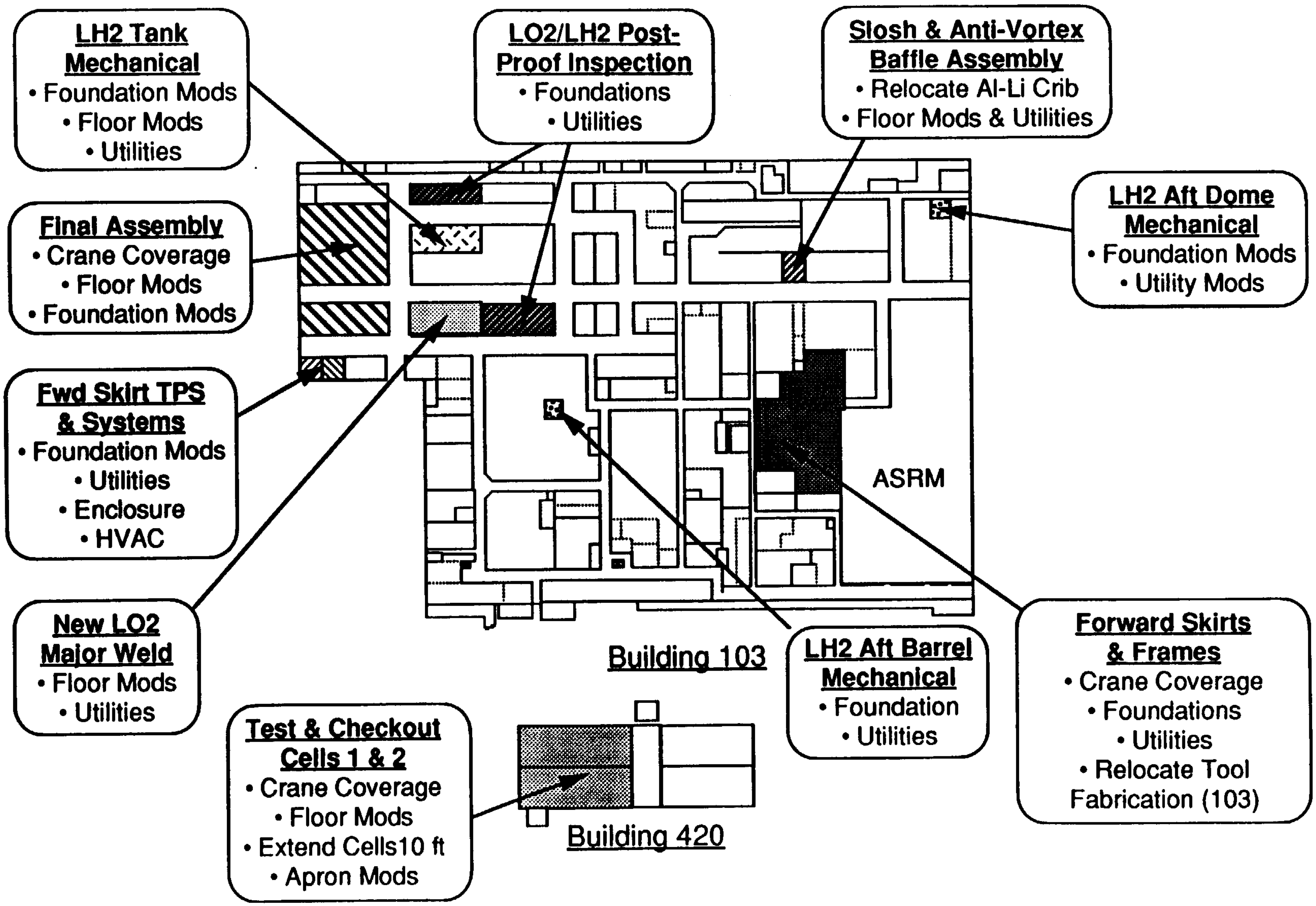
Objective

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

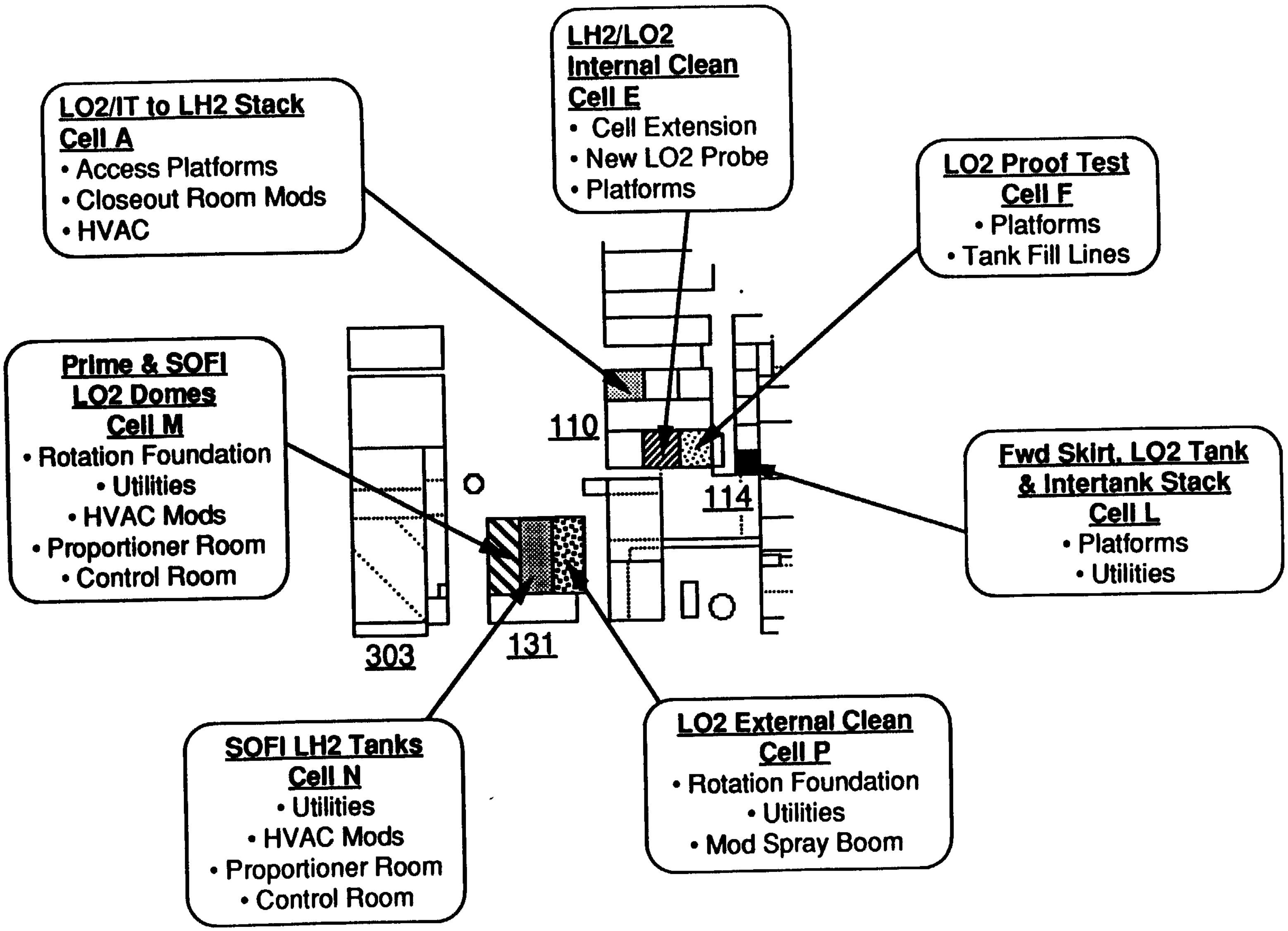
Core Tankage Modifications (103 & 420)



MARTIN MARIETTA
MANNED SPACE SYSTEMS

RH 91/12/09

Core Tankage Modifications (110/114/131)



MARTIN MARIETTA
MANNED SPACE SYSTEMS

RH 91/1

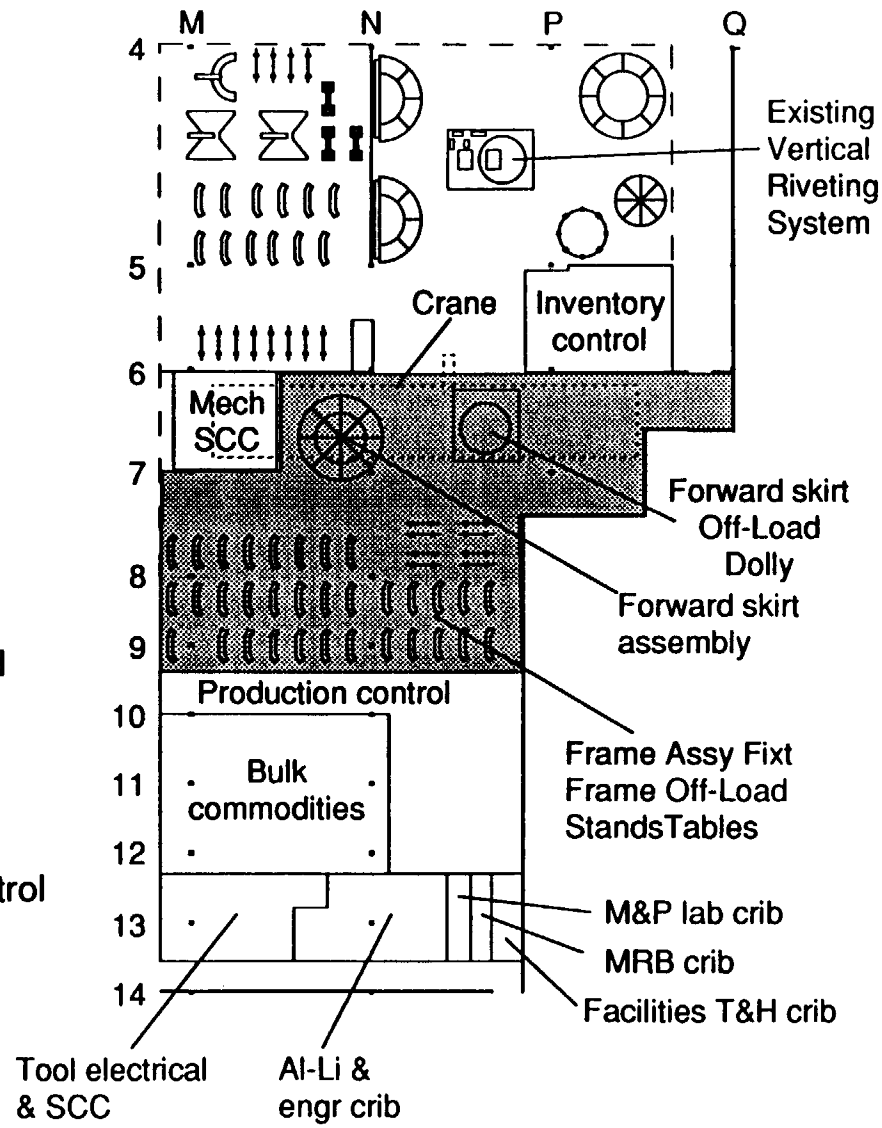
Core Tankage Modifications - 103

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



RH 91/12/09

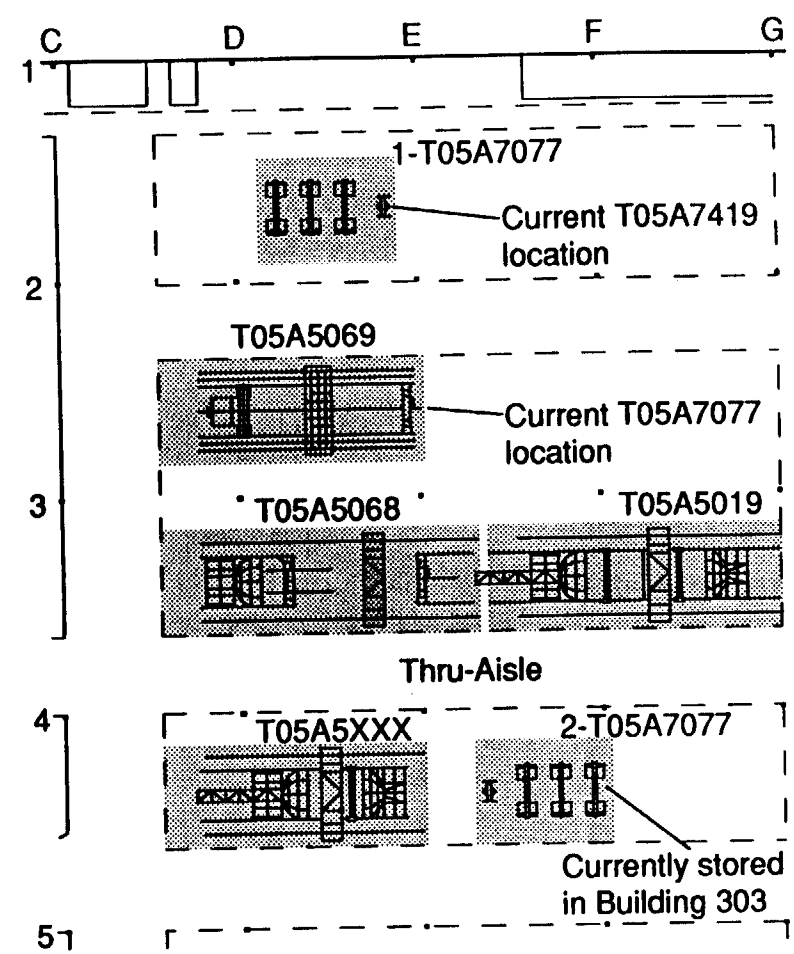
MARTIN MARIETTA
MANNED SPACE SYSTEMS

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



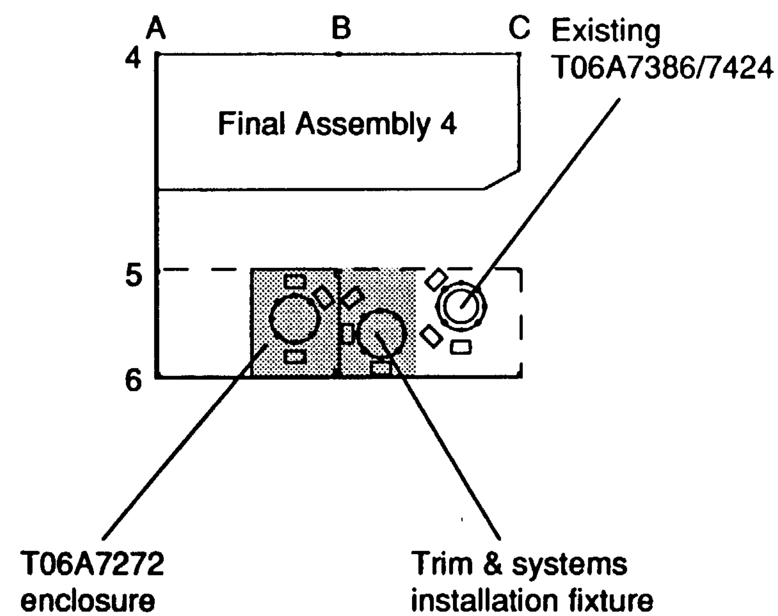
RH 91/1?

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



RH 91/12/09

MARTIN MARIETTA
MANNED SPACE SYSTEMS

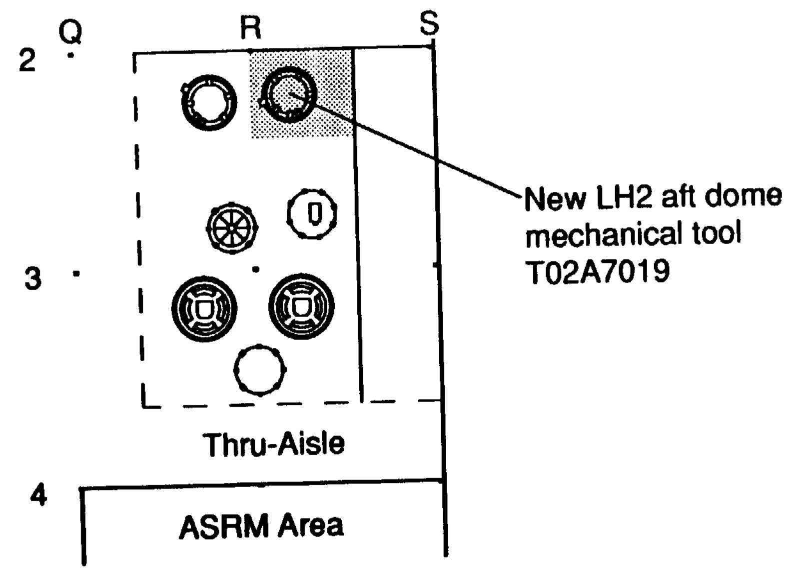
Core Tankage Modifications - 103

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

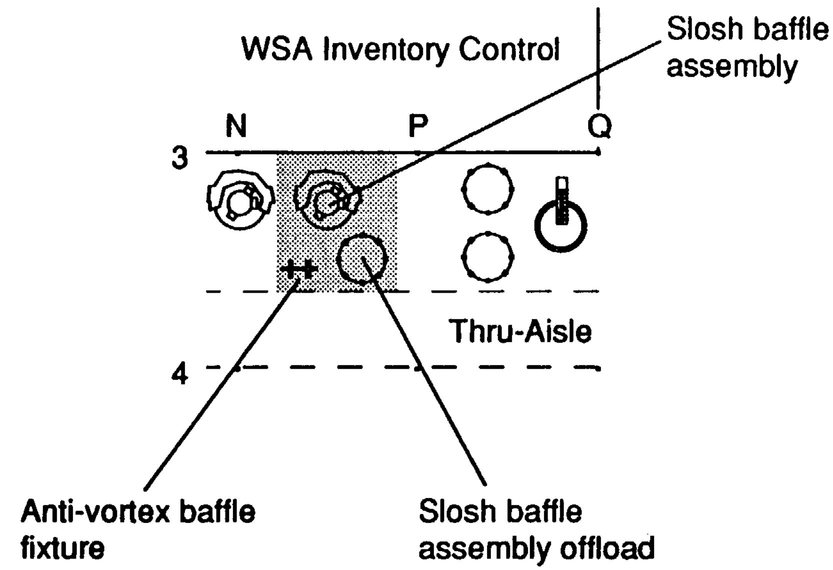


Core Tankage Modifications - 103

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



RH 91/12/09

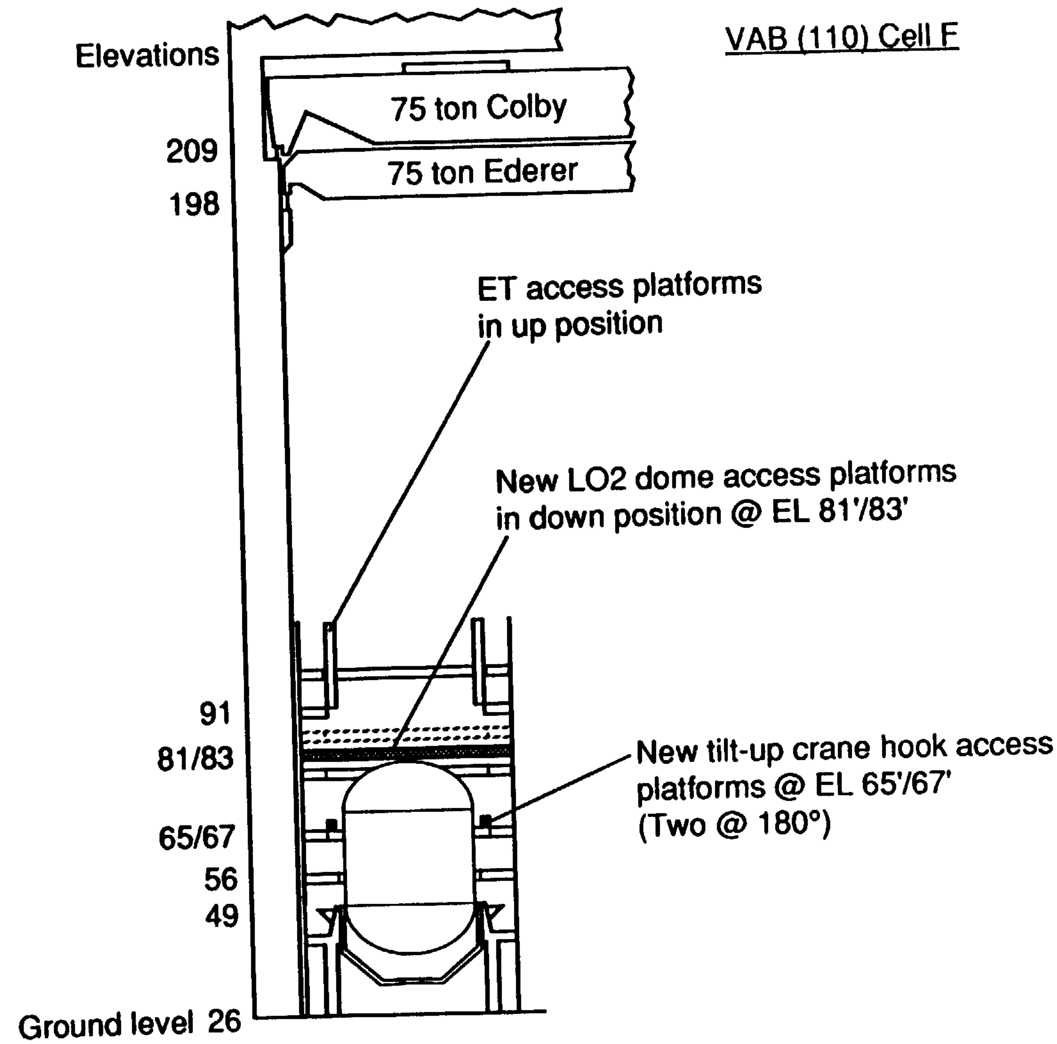
MARTIN MARIETTA
MANNED SPACE SYSTEMS

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.



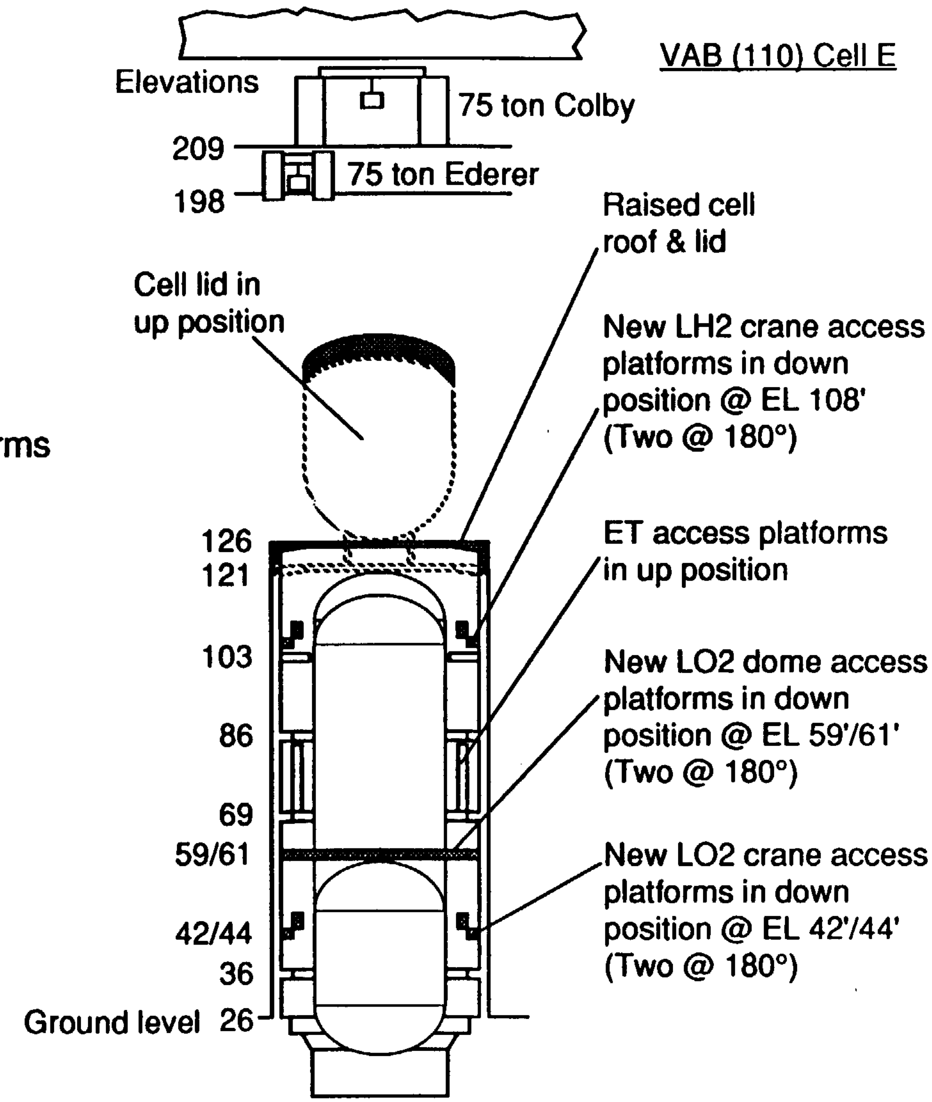
RH 91/12

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



RH 91/12/09

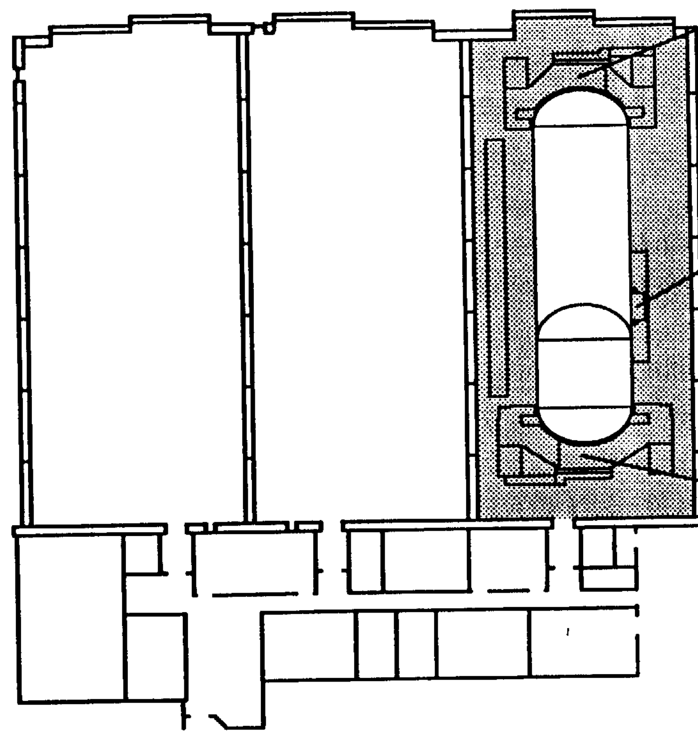
MARTIN MARIETTA
MANNED SPACE SYSTEMS

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

RH 91/1?

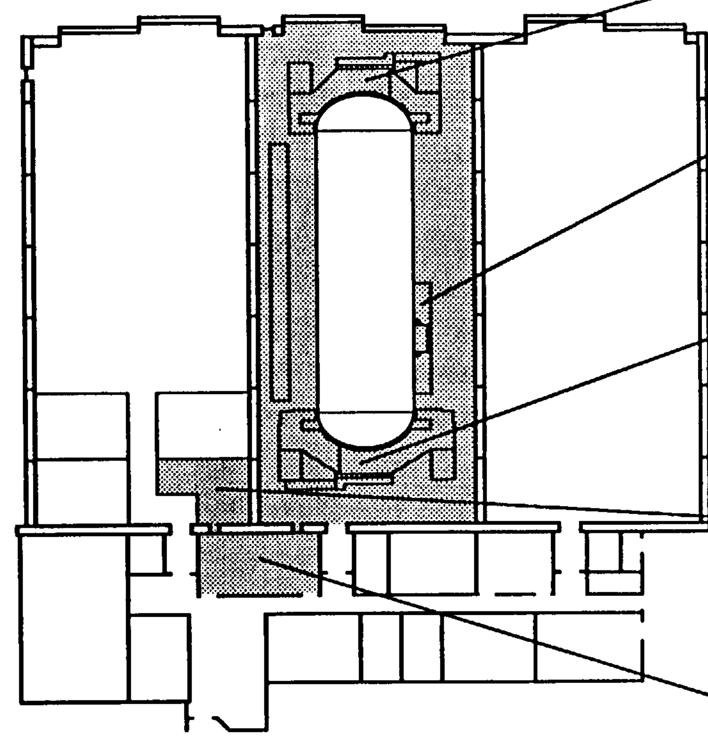
MARTIN MARIETTA
MANNED SPACE SYSTEMS

Core Tankage Modifications - Cell N

Requirement
- SOFI LH2 tanks

Tooling Effort
- New forward dome spray platform
- Relocate aft dome spray platform
- Modify barrel spray carriage & platform

Work Scope
- Platform & spray carriage utilities
- Extend spray carriage floor plates
- Modify for spray control room
- SOFI pot/proportioner room
- SOFI supply lines



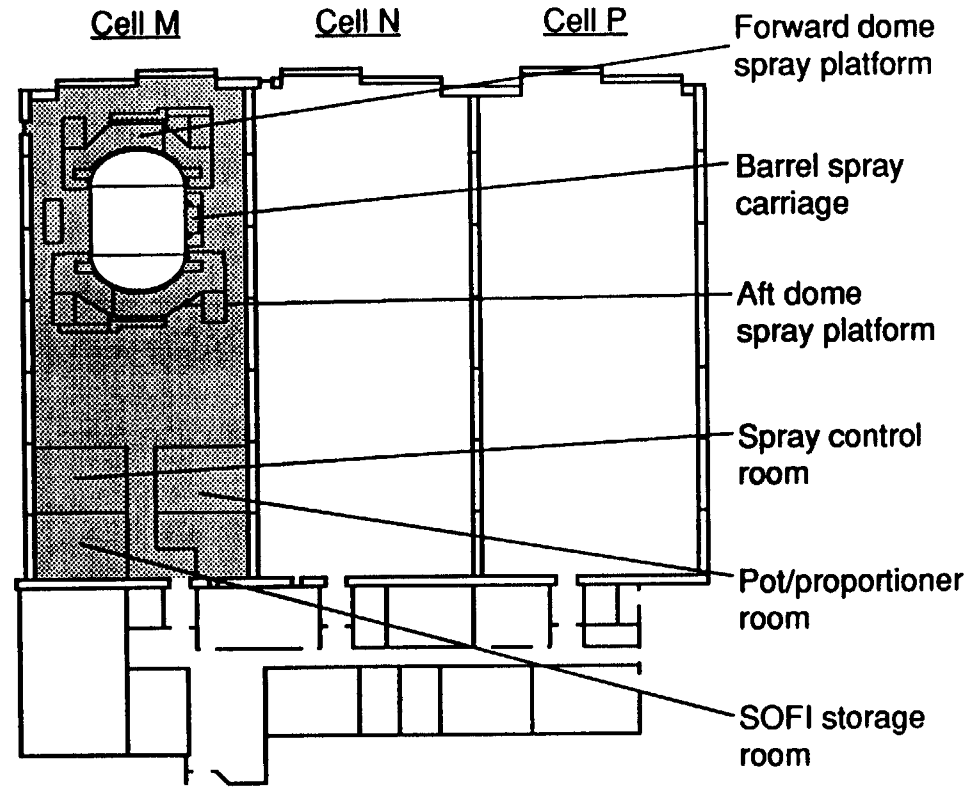
Building 131

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

RH 91/1:

MARTIN MARIETTA
MANNED SPACE 'YSTEMS

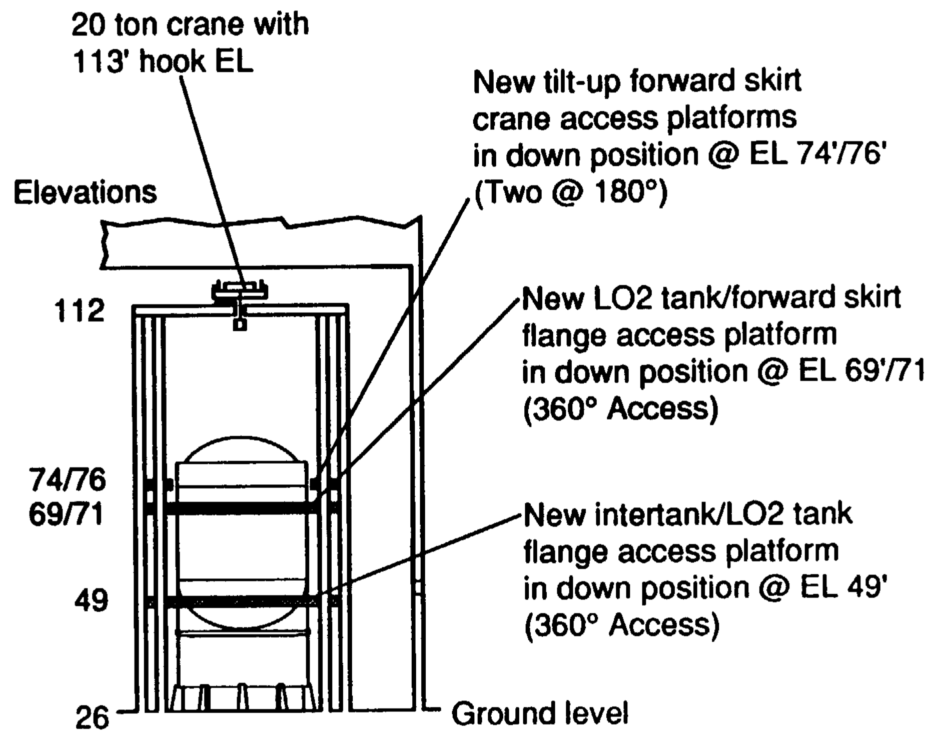
Core Tankage Modifications - Cell L

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



RH 91/12/09

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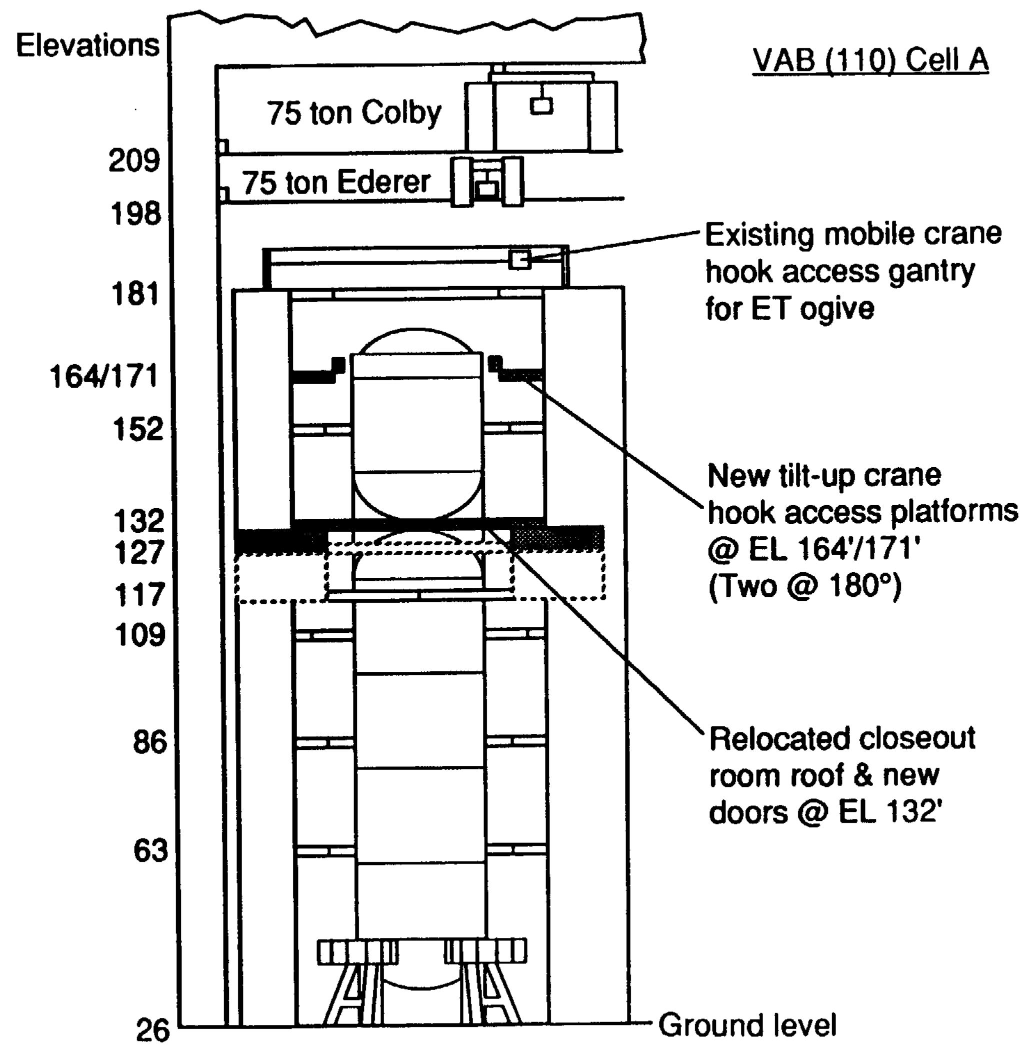
MANNED SPACE SYSTEMS

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



RH 91/1:

MARTIN MARIETTA
MANNED SPACE SYSTEMS

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, 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 addresed 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.

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 addresed 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
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George R. Charron
(504) 257-2917

Approved By: Donald F. Lumley

Rev: Initial
Date: January 8,1992

RH 91/12/09

MARTIN MARIETTA
MANNED SPACE SYSTEMS

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

Tool No.	Description	Modified	New
Domes			
• T02A5006	Dome Fittings & Outlets TWF	x	-
• T02A5007	Roll Ring Barrel Fwd End	x	-
• T02A5008	Dome Cap/LO2 Outlet TWF	x	-
•	Fittings And Outlets TWF	-	x
•	Dome Cap TWF	-	x
• T02A7118	Vortex Baffle Assembly	x	-
•	Dome Cap Machine Fixture	-	x
•	Dome Mech Assy LH2 Aft	-	x
• T02A7045	LH2 Aft Dome Mech 3rd Pos	x	-
• T04A7018	Assy Fixture Aft Dome	x	-
Barrels			
• T07A7005	Baffle Fwd Assy LO2 Basic O/HD	x	-
• T07A7132	Fwd Slosh Baffle 2nd Pos	x	-
• T04A7003	LH2 Int Barrel Frame Inst Tool	x	-
• T04A7086	LH2 Aft Barrel Rd Out & Fr Inst Fixt	x	-
• T04A5015	Barrel Assembly Aft TWF	x	-
• F78-4364	Control System For T04A5015	x	-
• F78-4369	Control System For T04A5015	x	-
• T04A7086	LH2 Aft BBL Inst Fixture	x	-
• T03A6089	Barrel Trim Fixture	x	-
• F78-2326	Control System	x	-
• T04A7003	Barrel Frame Inst Fixture	x	-
• T02A7016	Barrel Mech Assy Fwd SRB	x	-

Core Tankage - Tooling

Tool No.	Description	Modified	New
Major Weld			
• T05A5019	LH2 Tank Assembly TWF	X	-
• T05A5068	LH2 Weld Fixture 2nd Posn Assy Fixt.	X	-
•	LO2 Tank Instl	-	X
• Bldg. 451	LH2 Proof Test	X	-
• F78-2328	Control System For T05A5068	X	-
•	LO2 Weld Fix	-	X
•	X-Ray & Mech. Inst. Fix.	-	X
• T05A7077	Off-Load Rotational Fix.	X	-
Intertank			
• T06A7424 (2)	Access Platform I/T Interior	X	-
Forward Skirt			
•	Skirt Frame Assy fixts	-	X
•	Assembly fixture	-	X
• T06A7398	Vertical Drivmatic Riveting System	X	-
•	System Installation Fixt	-	X
• T30K7272	SOFI Apply & Trim Fixt	X	-
Ancillary Tooling			
• Sling, Dollies, Adapters, Covers		-	X

RH 91/12

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Core Tankage - Tooling

Tool No.	Description	Modified	New
Cells			
• Cell A	Pedestals	x	-
• Cell N	Spray Carriage/Platform	x	-
• Cell P	Access Platform/Rot. Fixture	x	-
• Cell E	Support Tooling	-	x
• Cell K	Dome Prime/TPS	x	x
• Cell F	Support Tooling	-	x
• Cell L	LO2 & Intertank TPS closout Tools	-	x
	System Inst Tooling	-	x
	Forward Skirt Adapter	-	x
	IT- LO2 Tank- Fwd Skirt Splice Tool	-	x
	IT Support Structure	-	x
• Cell M	(4) Rotational Ring Forward	-	x
	(2) Rotational Fix. LO2	-	x
	Access Platform Aft	-	x
	LO2 SOFI Fixt	-	x
	Access Platform LO2 Barrel	-	x
	Control System	-	x
	Access Platform Forward	-	x

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MARTIN MARIETTA
MANNED SPACE SYSTEMS

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 repectively. 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.

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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.

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CV-STR-16D
Transportation and Handling Requirements

Prepared By: Robert L. Gallagher
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(504) 257-1510

Approved By: Donald F. Lumley

Rev: Initial
Date: January 8, 1992

MARTIN MARIETTA
MANNED SPACE SYSTEMS

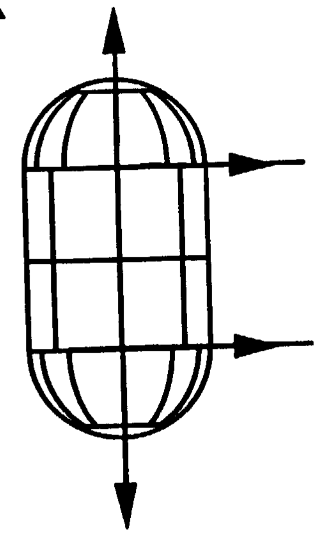
Groundrules And Assumptions

- 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

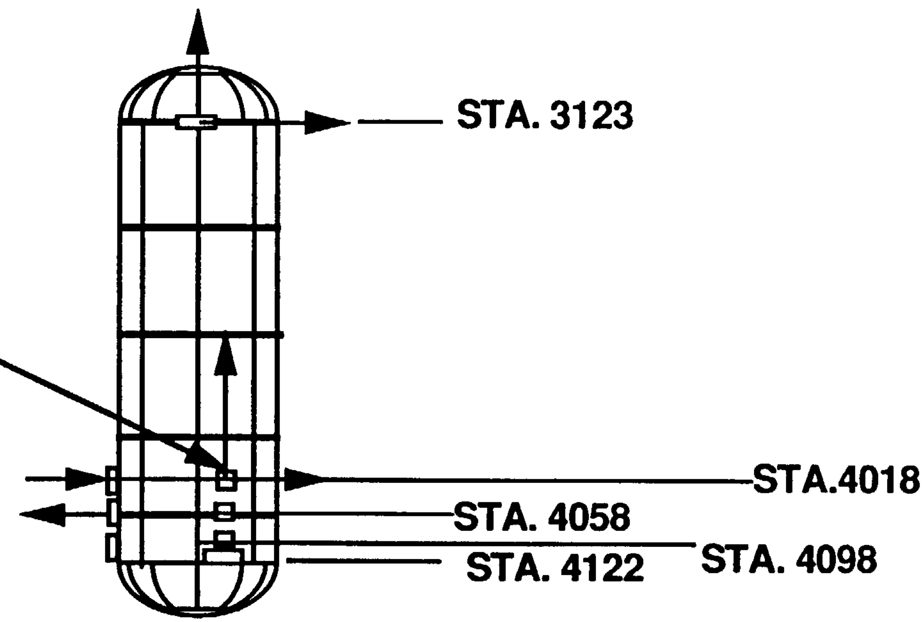
Determine Handling and Transportation Points Required on Core Tankage Subassemblies for Manufacturing of the Core Tankage and IACO/Transportation of the Core Stage.

Study Results -- LO2 Tank



Operation / Lift Position	Lift Point Location (Sta)
Straddle Carrier	Belly Band at 2852.8 & Flg. at 2569.8
Mech. Assy./Horiz., Cells/Vert. Horiz. to Vert.	Flgs. at 2569.8 and 2852.8

Study Results – LH2 Tank



Operation / Lift Position	Lift Point Location (Sta)
Cell E / Vert.,	3 - Fittings Located at 4098 and 4058
Cell A / Vert	3 - Fittings Located at 4018 and 4058
Straddle Carrier	Belly Band Located at 3123.15 and 3865.15 Lateral Support at Flgs.
Cell P / Horiz.	Roll Rings at 3123 and 4122
Horiz. to Vert. & Tank Inversion	Flg. at 3123 and Fittings at 4058 and 4018

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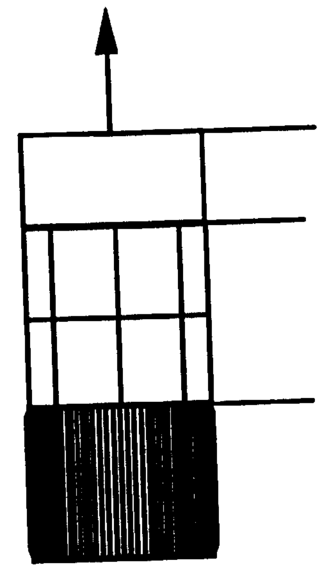
MANNED SPACE SYSTEMS

Study Results – Fwd. Skirt / LO2 /Intertank

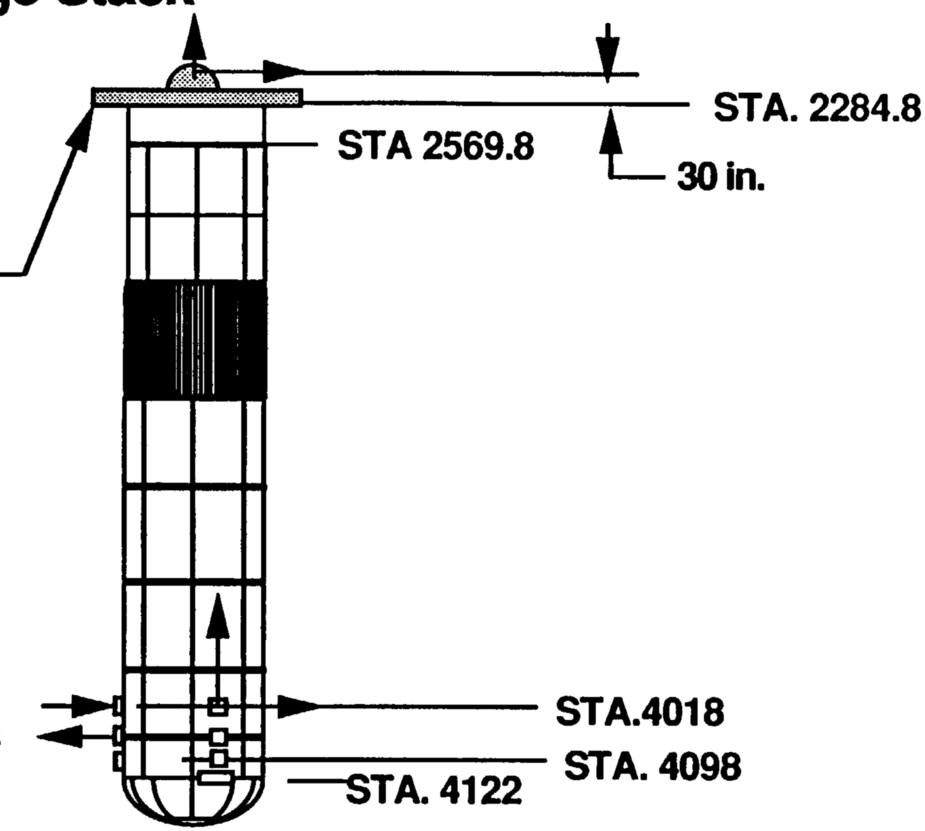


Operation / Lift Position	Lift Point Location (Sta)
To Stack in Cell A	Flg. at 2284.8

Transportation and Handling

CV-STR-16D

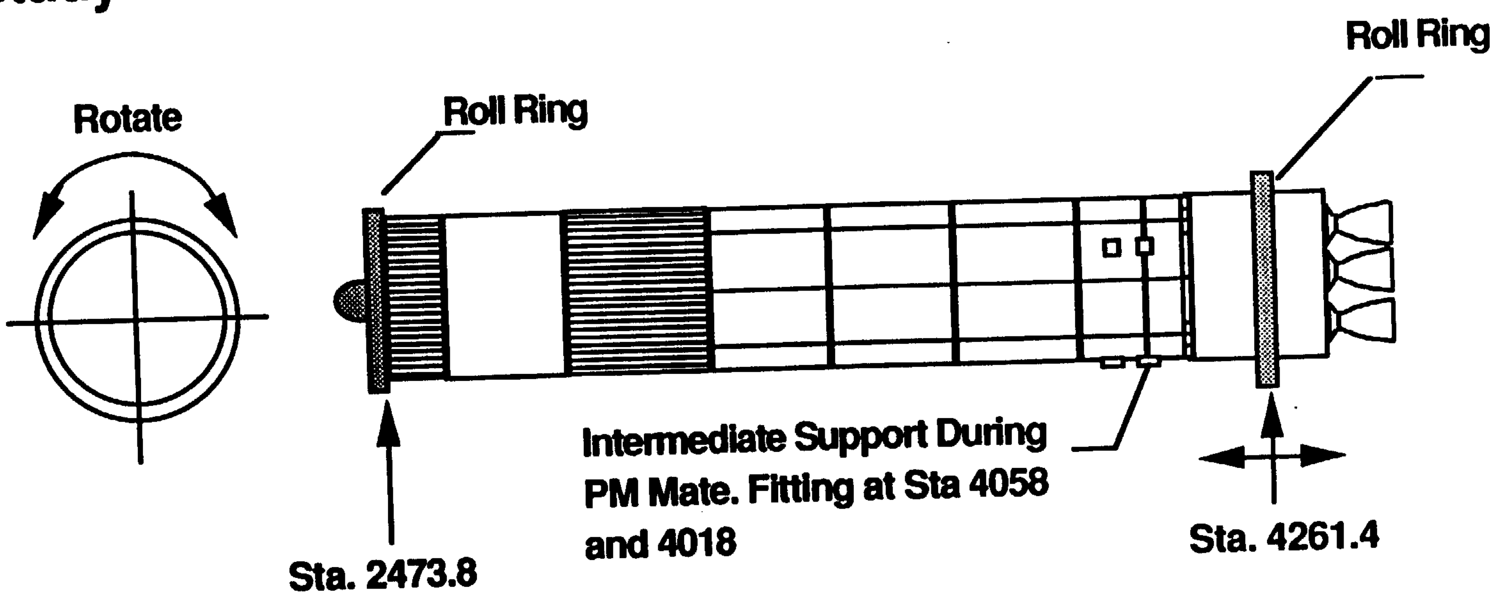
Study Results -- Core Tankage Stack



Operation / Lift Position	Lift Point Location (Sta)
Stack in Cell A, Vert. Support	3 - Places at 4058 and 4018
Lift Fr. Stack and Vert. To Horiz.	Fitting at 2284.8 and 2 Fittings at 4058 and 4018

MARTIN MARIETTA
MANNED SPACE SYSTEMS

Study Results – Core Stage IACO & Ship



Operation / Lift Position	Lift Point Location (Sta)
IACO / Rotate Stage	Support at 2473.8 , Support and Drive at 4261.4
Transportation of Core Stage	Vert., Support on Roll Ring at 2473.8 Fixed Support on Roll Ring at 4261.4. Sea State Loads Apply

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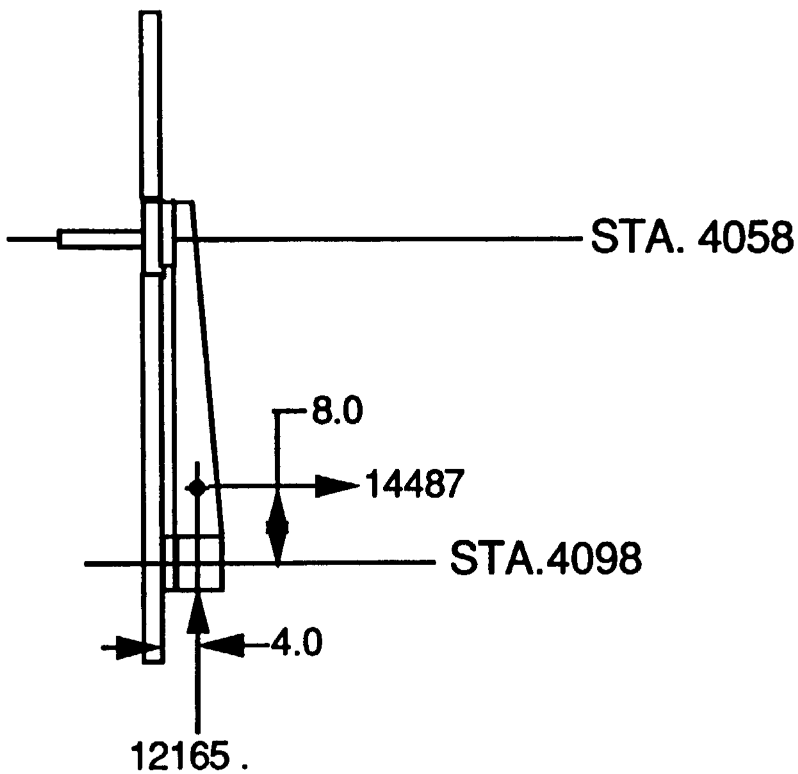
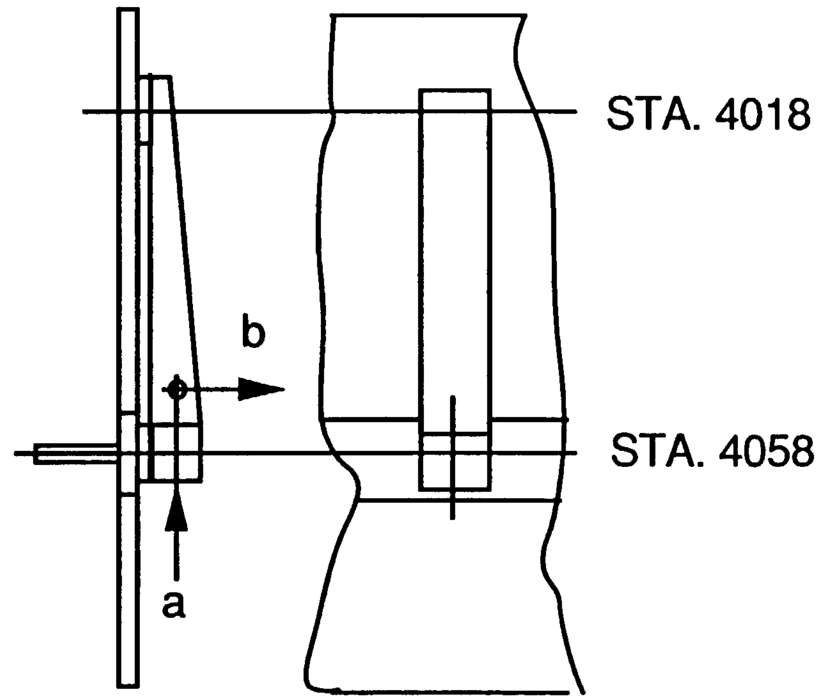
MANNED SPACE SY EMS

Study Results – LH2 Tank Loads



LH2 Tank Only



Core Tankage Stack

Load Case	a	b	Remarks
1	26780	———	Cell A , 3 - Plc
2	———	19166	Horiz. to Vert., 2 - Plcs

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

MARTIN MARIETTA
MANNED SPACE SY 'EMS

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.

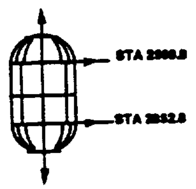
Conclusions

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

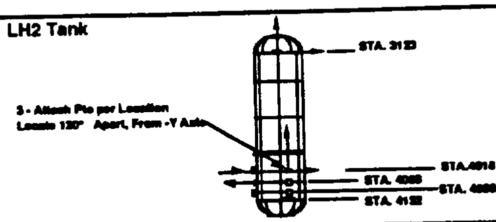
Revise cycle Ø baseline to incorporate the proposed configuration and new transporter requirement. In cycle 1, determine frame and flange sizes, and incorporate attachment holes for tooling adaptors.

LO2 Tank



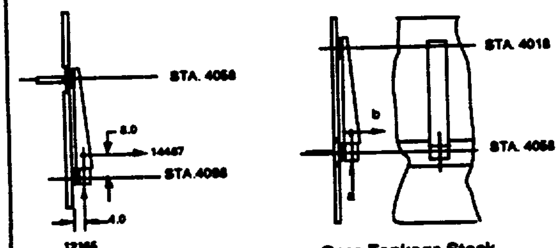
Operation / Lift Position	Lift Point Location (STA)
Straddle Carrier	Belly Band at 2852.8 & Fig. at 2569.8
Mech. Assy./Horiz., Cells/Vert Horiz. to Vert.	Figs. at 2569.8 and 2852.8

LH2 Tank



Operation / Lift Position	Lift Point Location (Sta)
Cell E / Vert.,	3 - Fittings Located at 4058 and 4086
Cell A / Vert	3 - Fittings Located at 4018 and 4086
Straddle Carrier	Belly Band Located at 3123.18 and 3985.18 Lateral Support at Ftgs.
Cell F / Horiz.	Roll Rings at 3123 And 4122
Horiz. to Vert. & Tank Inversion	Fig. at 3123 and Fitting at 4058 and 4011

LH2 Tank Loads

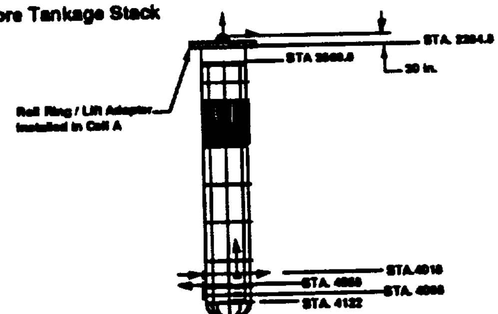


LH2 Tank Only

Core Tankage Stack

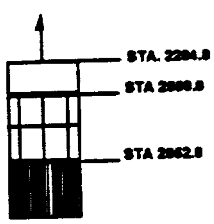
Load Case	a	b	Remarks
1	[illegible]	—	Cell A, 3 - Pins
2	—	[illegible]	Horiz. to Vert., [illegible]

Core Tankage Stack



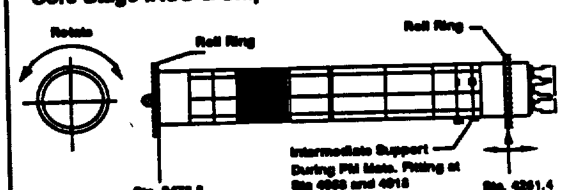
Operation / Lift Position	Lift Point Location (Sta)
Stack in Cell A, Vert Support	3 - Pins at 4058 and 4018
Lift Fr. Stack and Vert To Horiz.	Fitting at 2284.8 and 2 Fittings at 4058 and 4018

Fwd. Skirt / LO2 /Intertank



Operation / Lift Position	Lift Point Location (Sta)
To Stack in Cell A	Fig. at 2284.8

Core Stage IACO & Ship



Operation / Lift Position	Lift Point Location (Sta)
IACO / Rotate Stage	Support at 3472.8 , Support and Drive at 4261.4
Transportation of Core Stage	Vert, Support on Roll Ring at 3472.8 Fixed Support on Roll Ring at 4261.4. Sea State Loads Apply

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

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.

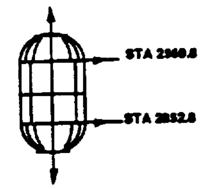
Conclusions

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

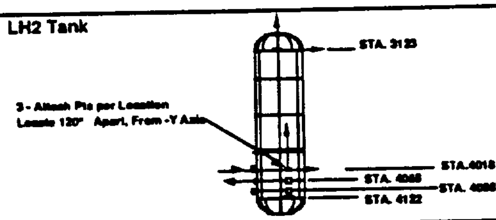
Revise cycle Ø baseline to incorporate the proposed configuration and new transporter requirement. In cycle 1, determine frame and flange sizes, and incorporate attachment holes for tooling adaptors.

LO2 Tank



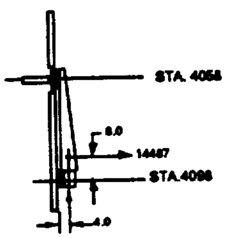
Operation / Lift Position	Lift Point Location (STA)
Straddle Carrier	Belly Band at 2852.8 & Fig. at 2569.8
Mech. Assy./Horiz., Cells/Vert Horiz. to Vert.	Figs. at 2569.8 and 2852.8

LH2 Tank

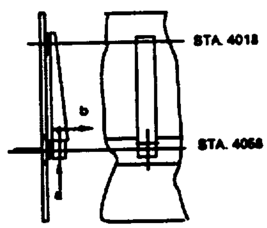


Operation / Lift Position	Lift Point Location (Sta)
Cell E / Vert.,	3 - Fittings Located at 4058 and 4098
Cell A / Vert	3 - Fittings Located at 4018 and 4058
Straddle Carrier	Belly Band Located at 3123.15 and 3985.15 Lateral Support at Figs.
Cell P / Horiz.	Roll Rings at 3123 And 4122
Horiz. to Vert. & Tank Inversion	Fig. at 3123 and Fitting at 4058 and 4011

LH2 Tank Loads



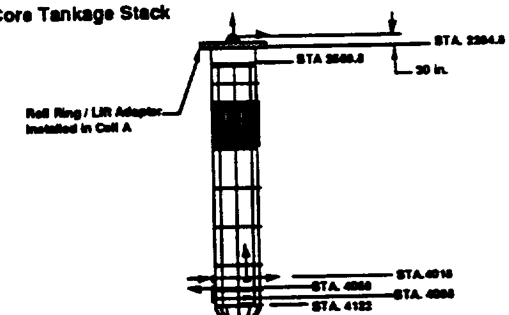
LH2 Tank Only



Core Tankage Stack

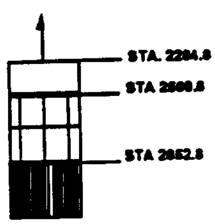
Load Case	a	b	Remarks
1	[illegible]	—	Cell A, 3 - Plcs
2	—	[illegible]	Horiz. to Vert, 3 - Plcs

Core Tankage Stack



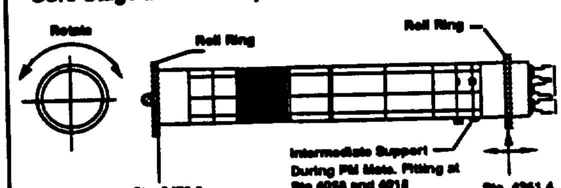
Operation / Lift Position	Lift Point Location (Sta)
Stack in Cell A, Vert Support	3 - Plcs at 4058 and 4018
Lift Fr. Stack and Vert To Horiz.	Fitting at 2284.8 and 2 Fittings at 4058 and 4018

Fwd. Skirt / LO2 /Intertank



Operation / Lift Position	Lift Point Location (Sta)
To Stack in Cell A	Fig. at 2284.8

Core Stage IACO & Ship



Operation / Lift Position	Lift Point Location (Sta)
IACO / Rotate Stage	Support at 2473.8 , Support and Drive at 4261.4
Transportation of Core Stage	Vert, Support on Roll Ring at 2473.8 Fixed Support on Roll Ring at 4261.4. See State Loads Apply

Additional Information

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

CV-STR-17A
Alternate Aft Skirt Configuration

Prepared By : Neil A Duncan
(504)257-0161

Approved By: M.R.Simms

Rev: Initial
Date:January 8,1992

[redacted]

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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

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Approach CV-STR-17A

- 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

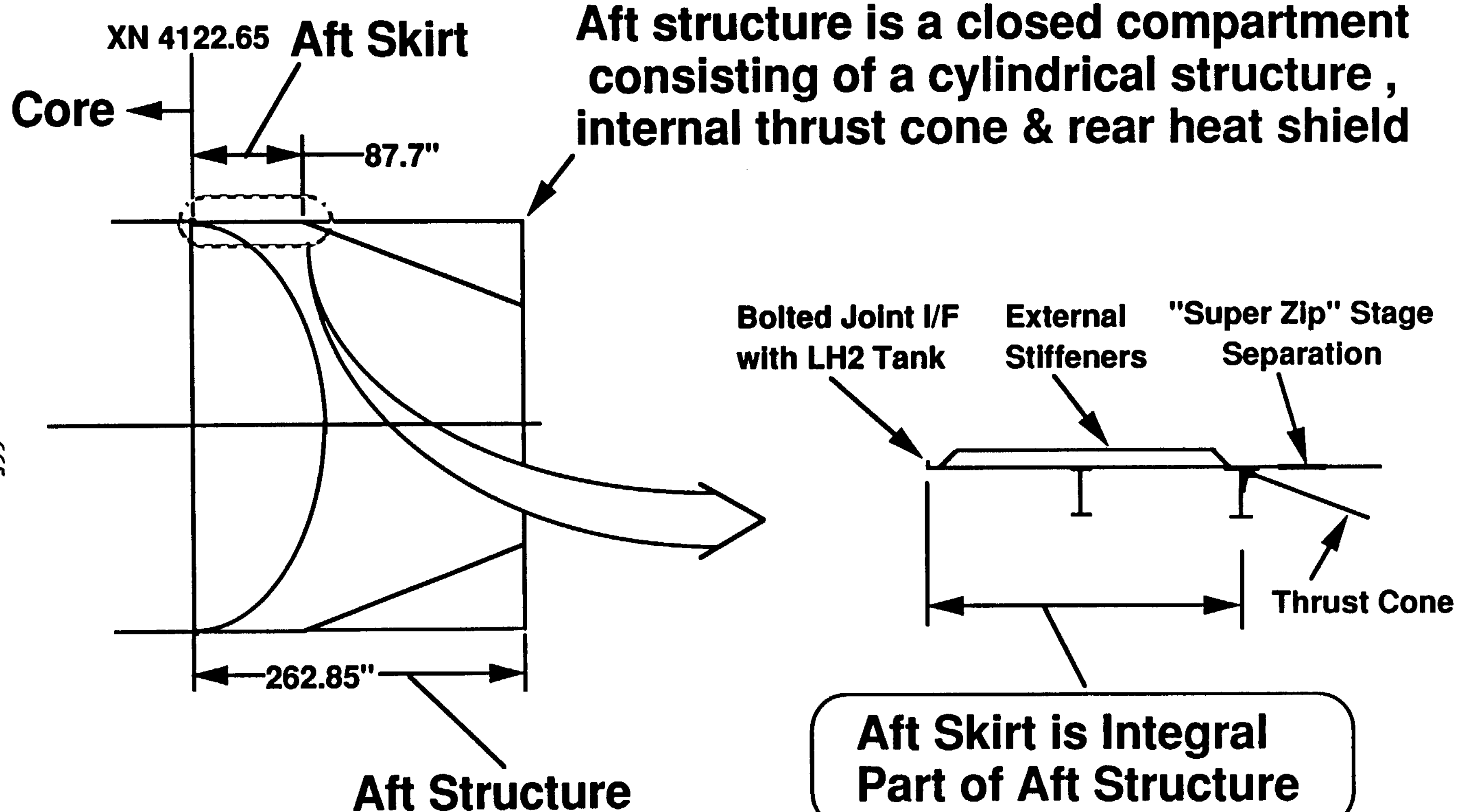
- For Vehicle Definition Use MSFC Reference Definition Dated 8/28/91 , Supplemented by October 9 - 10th Structure Layouts (Config Freeze)
- Maintain MSFC Aft Structure Frame Stations

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



Aft Skirt is Integral Part of Aft Structure

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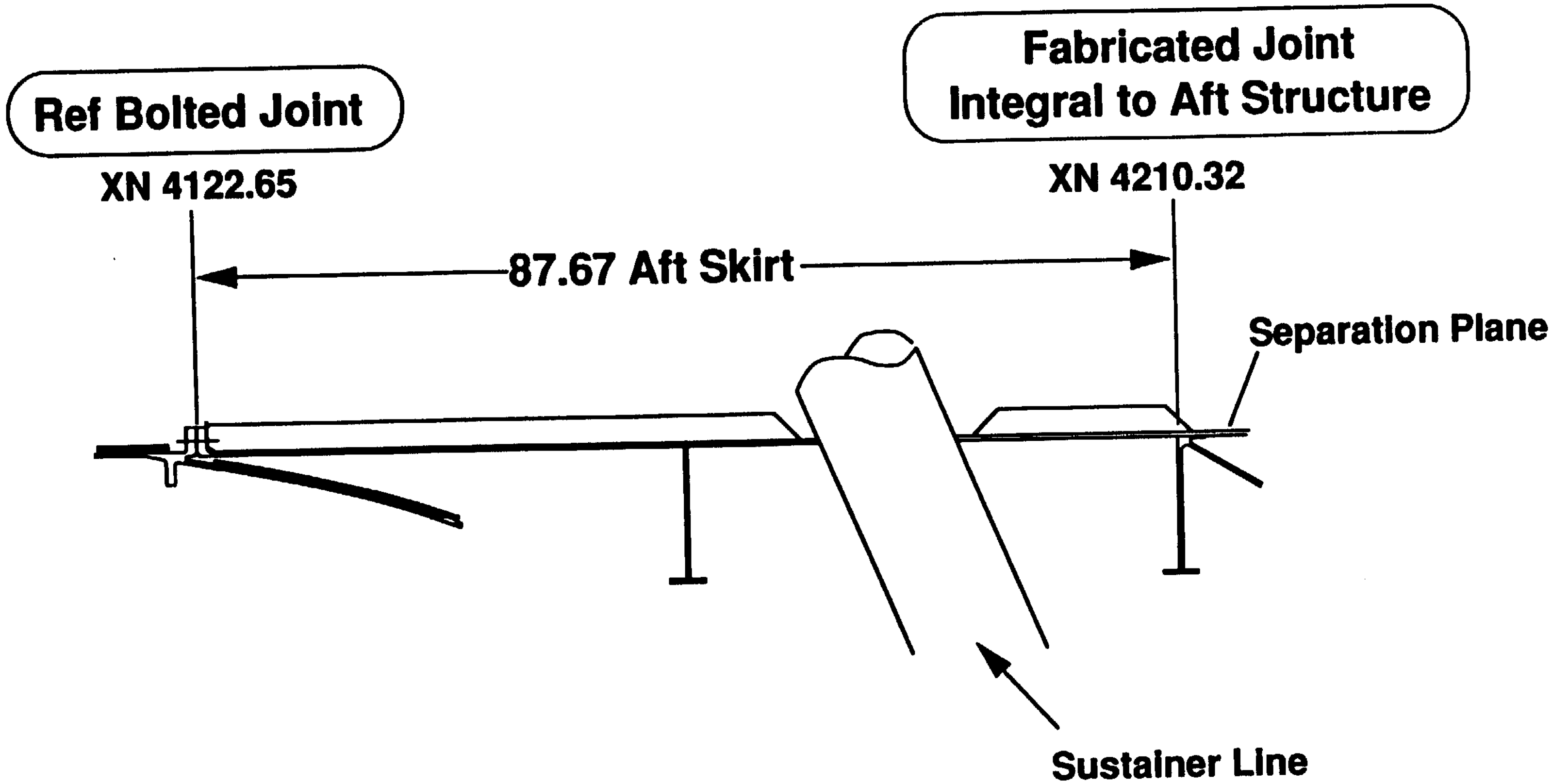
Reference Configuration CV-STR-17A



- Aft Skirt Part of Aft Structure
- 87.67" Long Skirt
- Sustainer Penetration within Aft Structure

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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

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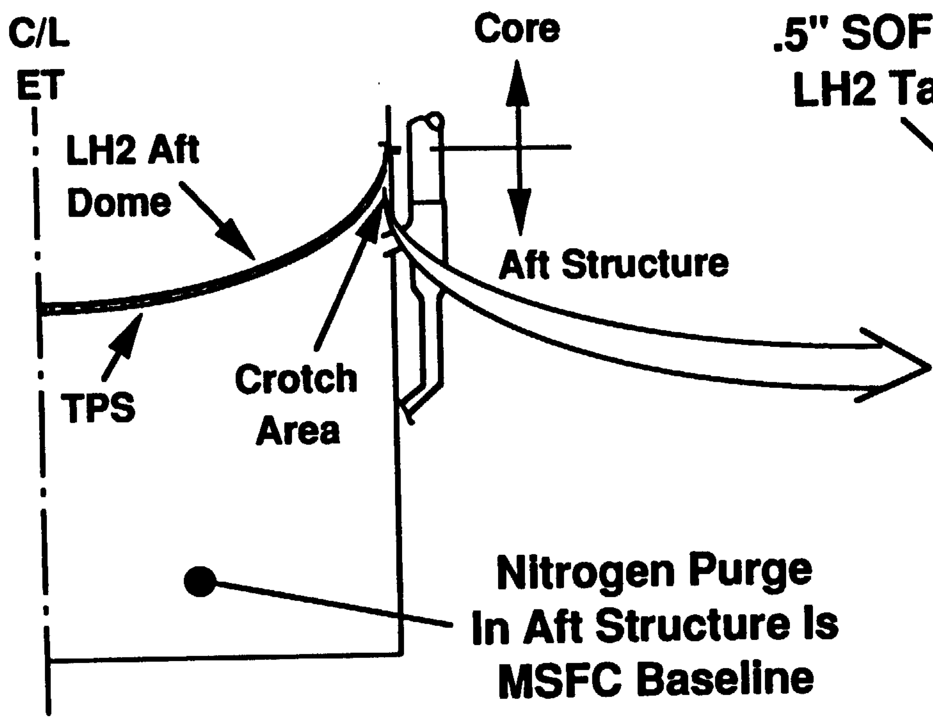
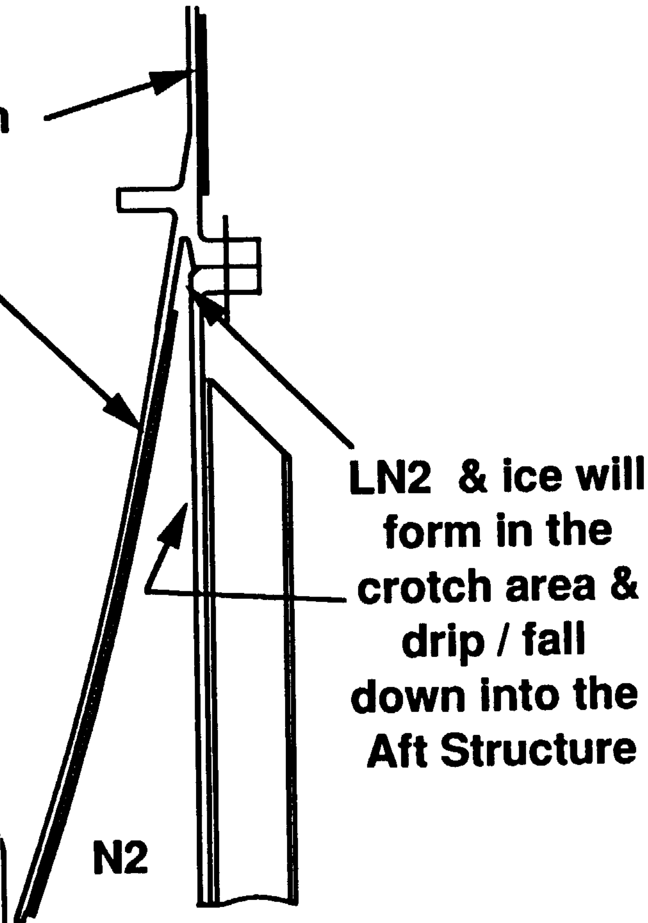
Ref - LN2 Formation CV-STR-17A





Reference Configuration
Core / Aft Skirt Joint

Problems
- LN2 build up inside Aft Structure
- Nitrogen ice debris
- Impact on component design & qual
- Possible venting impact

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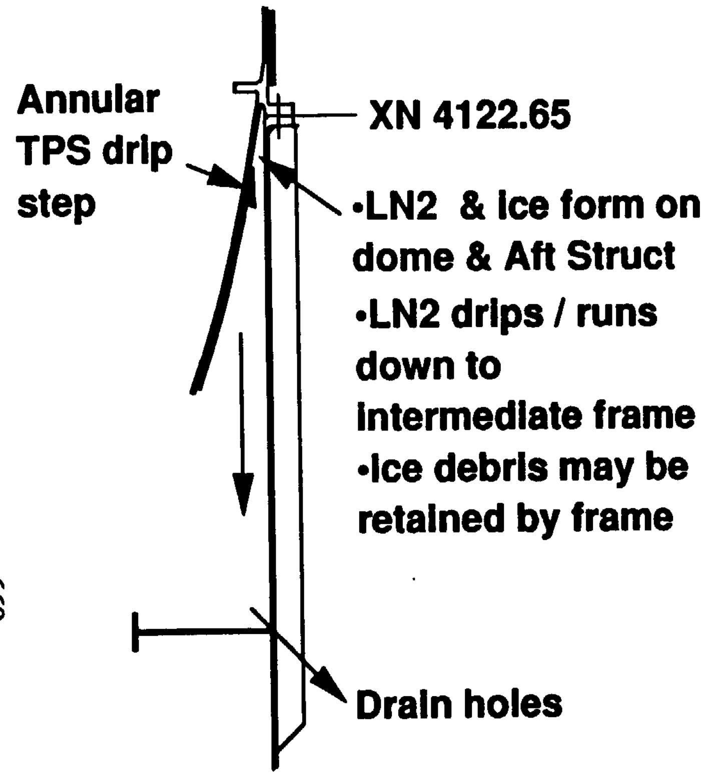
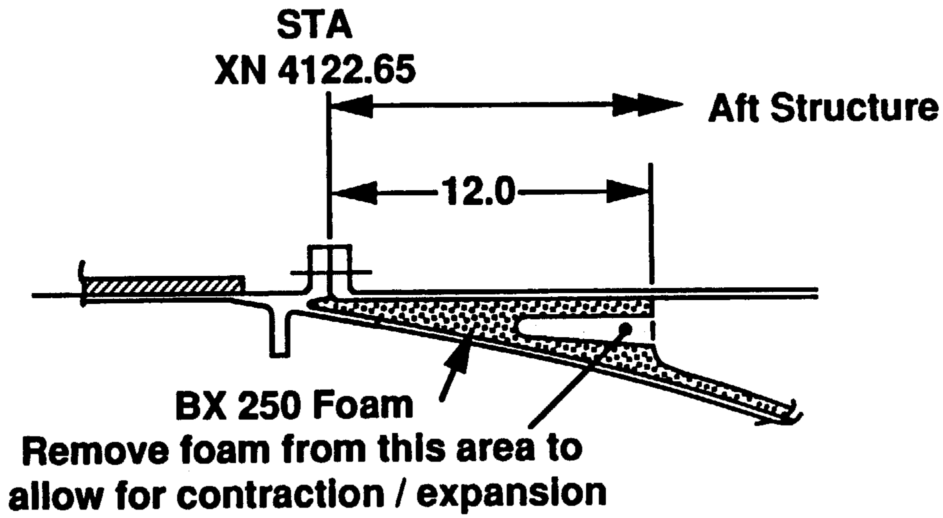
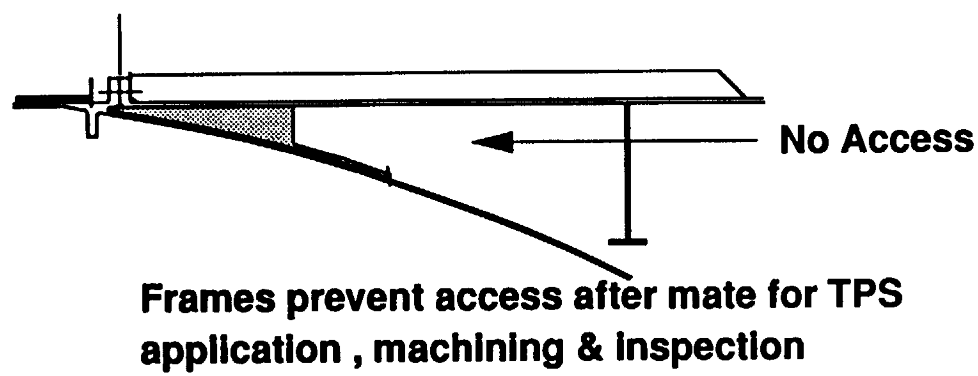
Ref - LN2 Options

CV-STR-17A



#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)

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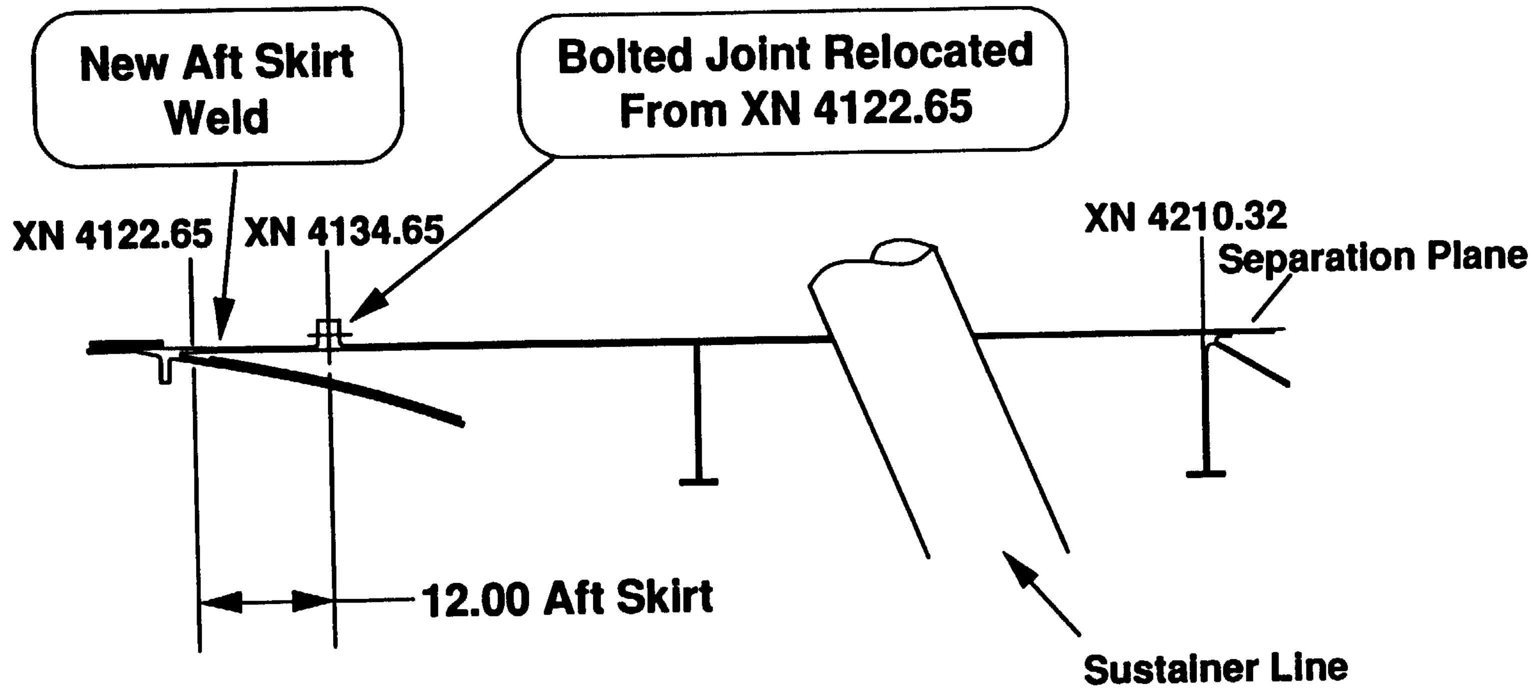
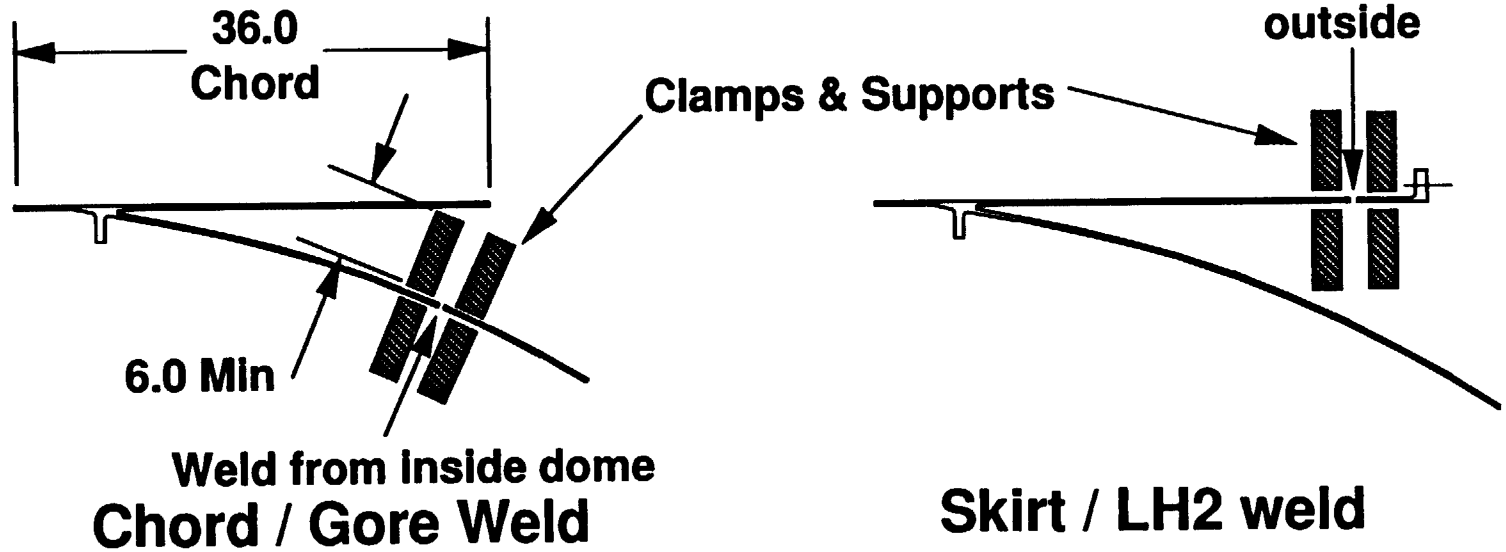
Aft Skirt Welded to Core Vehicle



- Aft Skirt Welded to LH2 Frame
- Part of Core Vehicle
- 12" Long Skirt

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



- Chord Must Be Extended By Almost 2 Ft
- Gore/Dome Weld Must Be Repoitioned (Major Tooling Impact)

Welded Skirt Not Feasible

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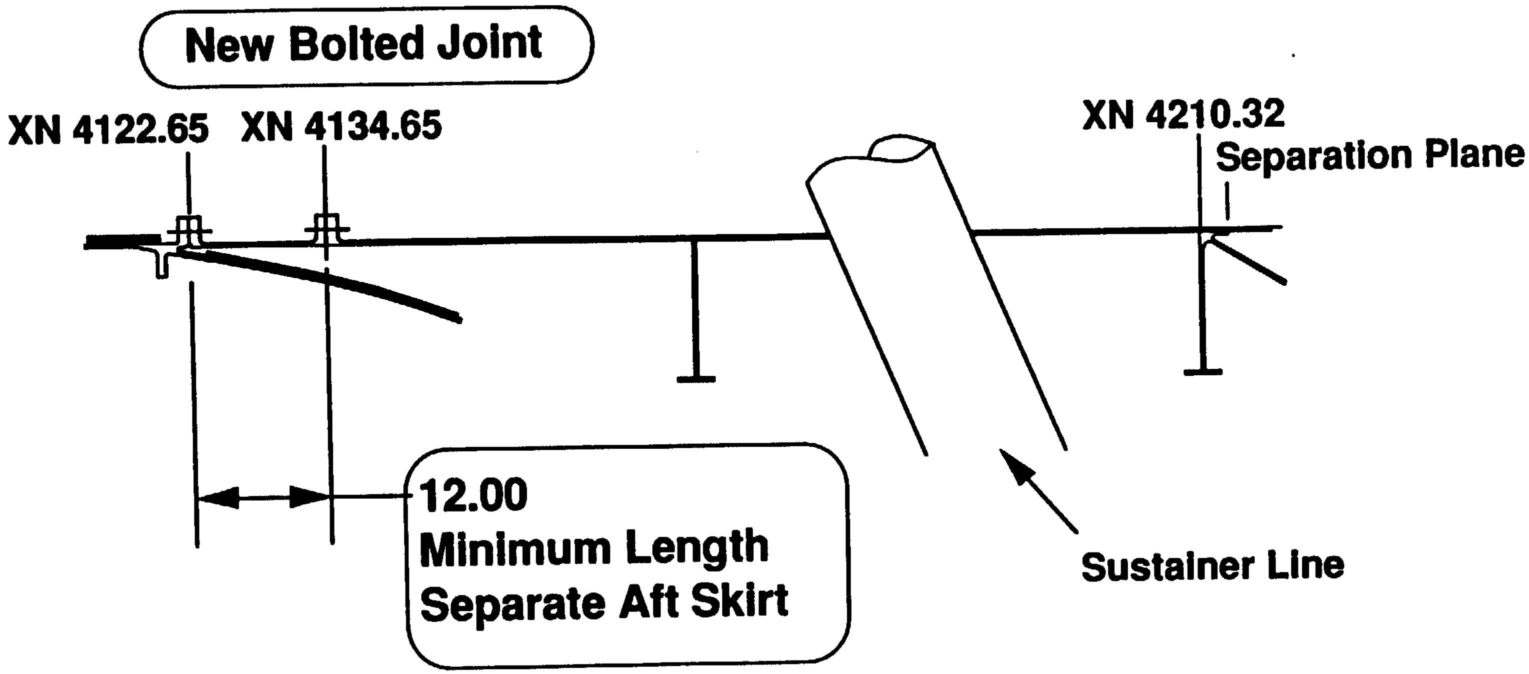
Option 2

CV-STR-17A

Short Bolt-on Skirt



- Separate Aft Skirt
- Part of Core Vehicle
- 12" Long

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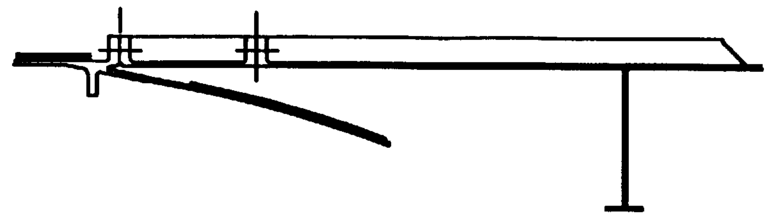
Option 2 - Design & Manuf CV-STR-17A



- 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

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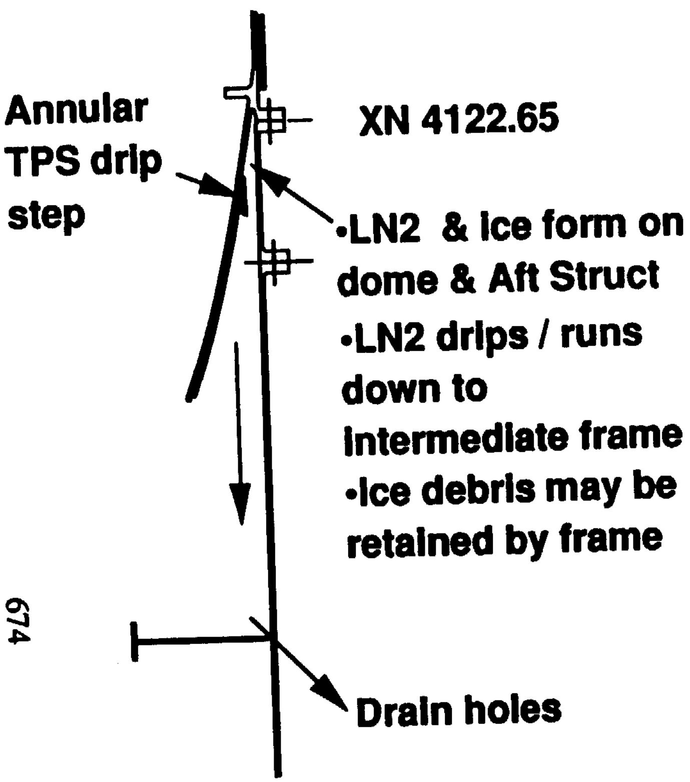
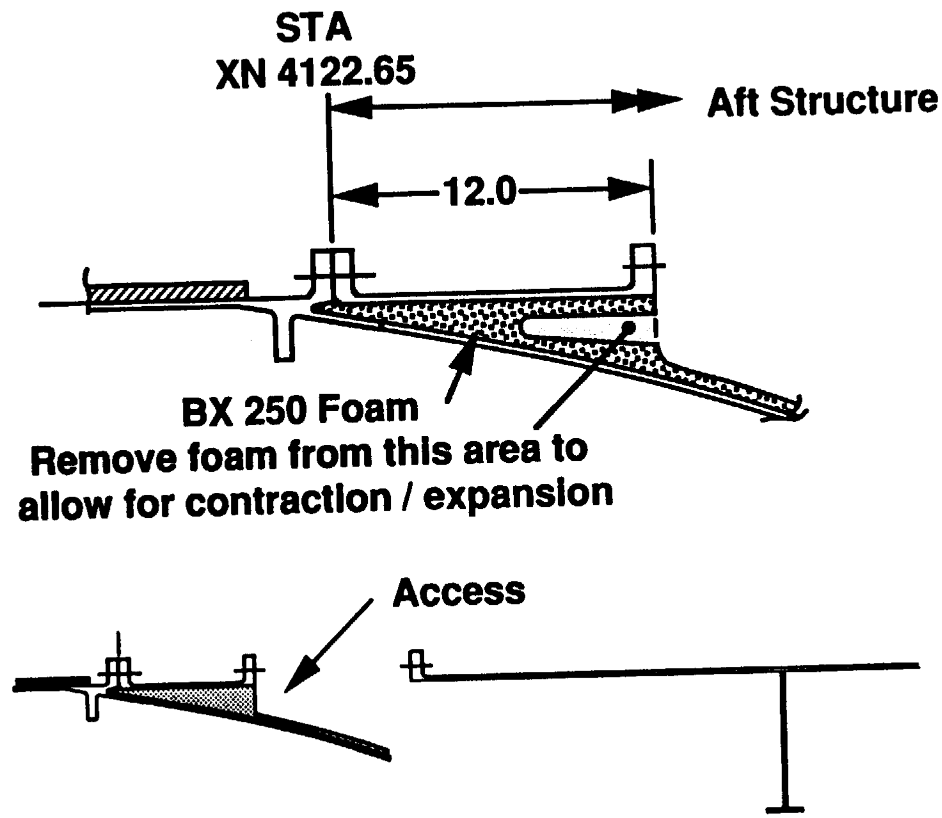
Option 2 - LN2 Options

CV-STR-17A



#1 Catch & Drain LN2



Excellent access for TPS operations prior to Aft Structure mate

#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)

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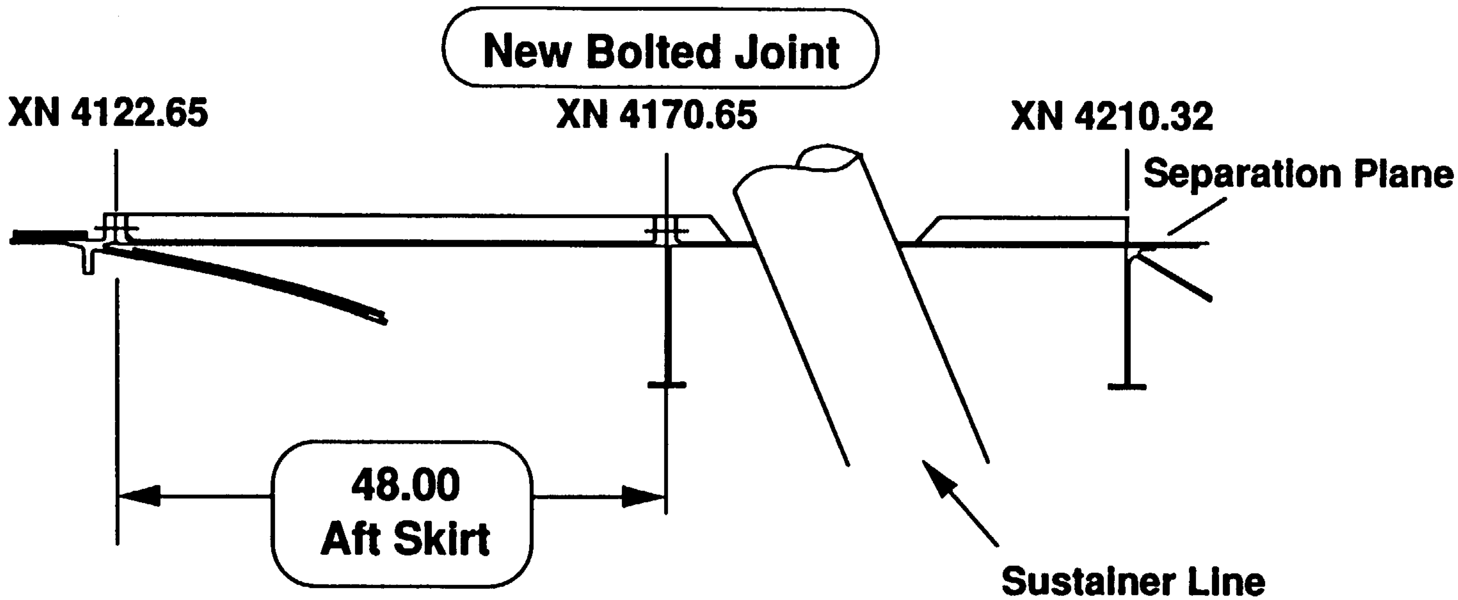
Option 3 CV-STR-17A

Long Bolt-on Skirt



- Separate Aft Skirt
- Part of Core Vehicle
- 48" Long
- Frame at XN 4170.65 is not part of skirt

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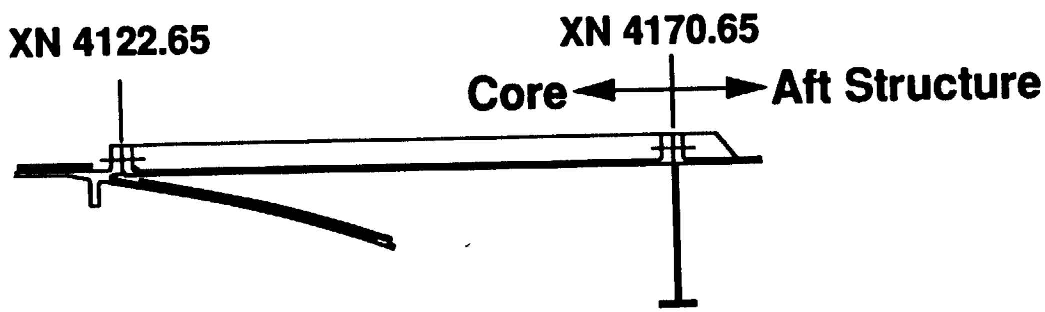
Option 3 - Design & Manuf   CV-STR-17A



- 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)

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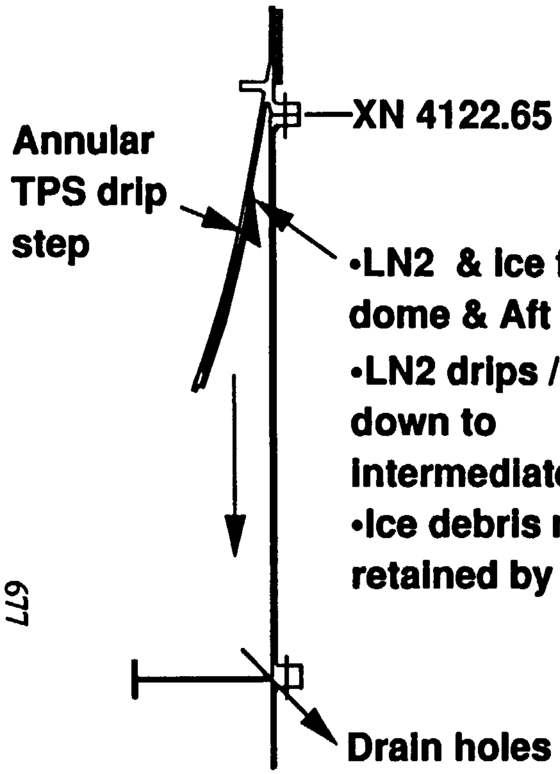
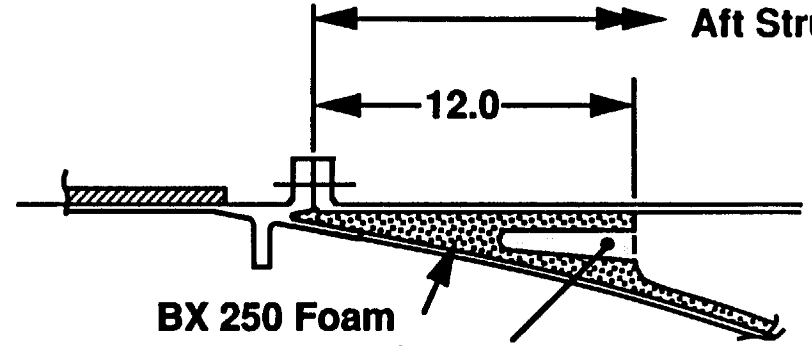
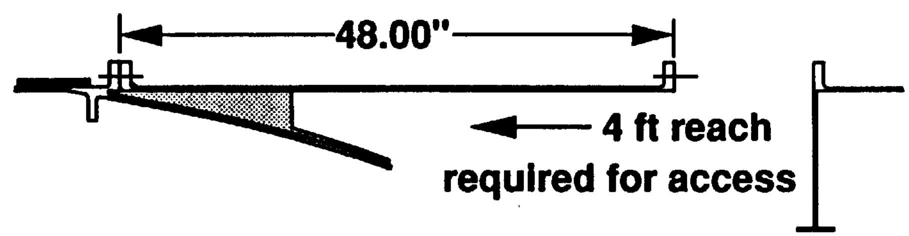
Option 3 - LN2 Options CV-STR-17A



•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





Acceptable access for TPS operations prior to mate

#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)

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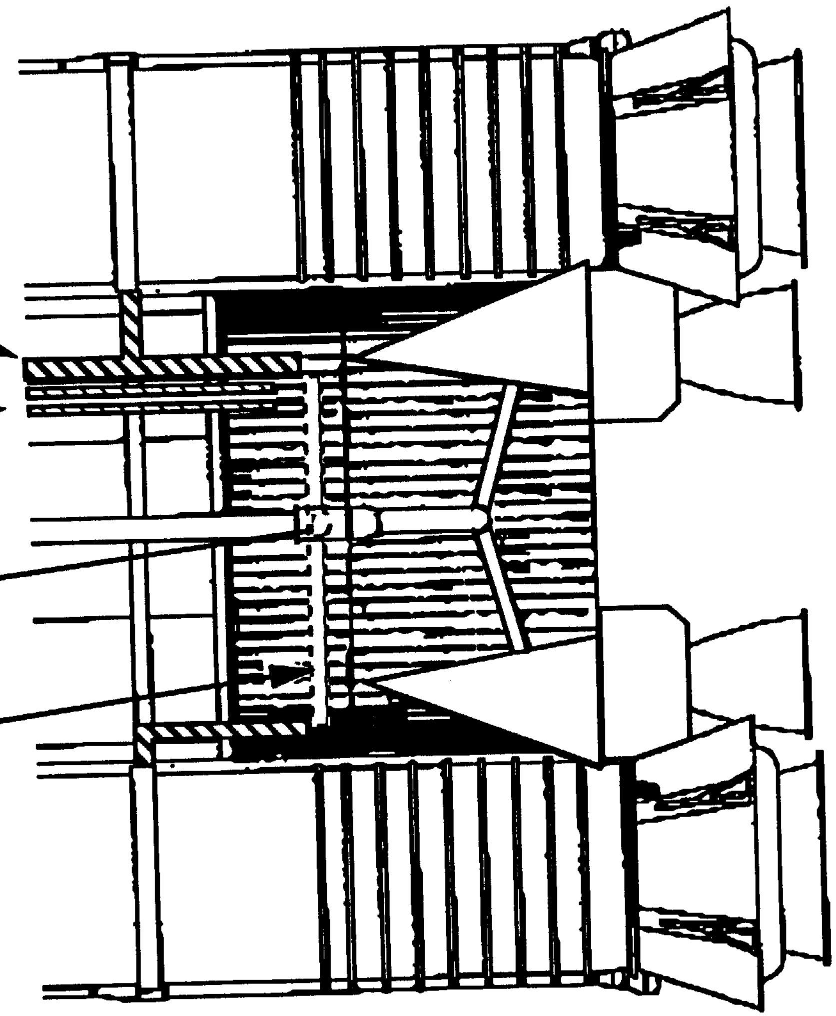
External I/F's



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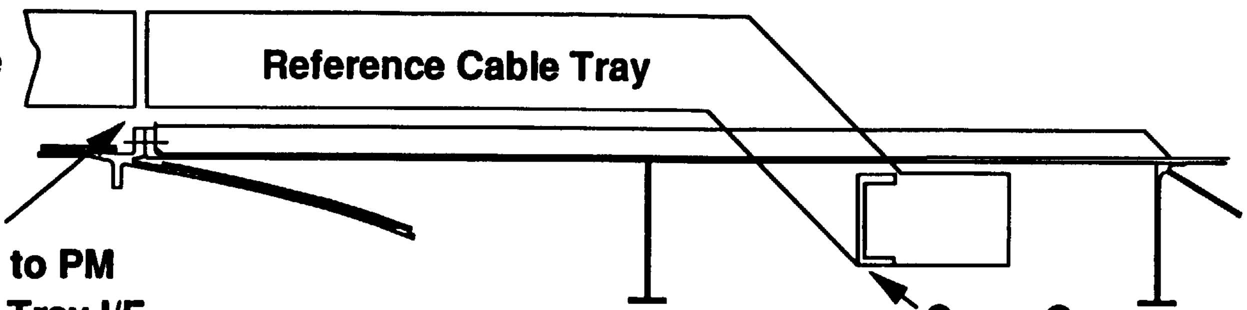
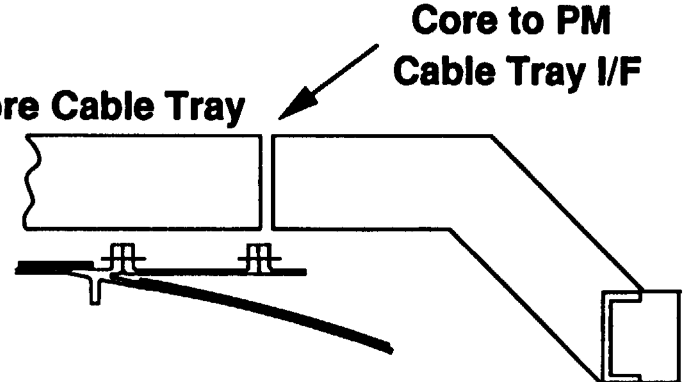
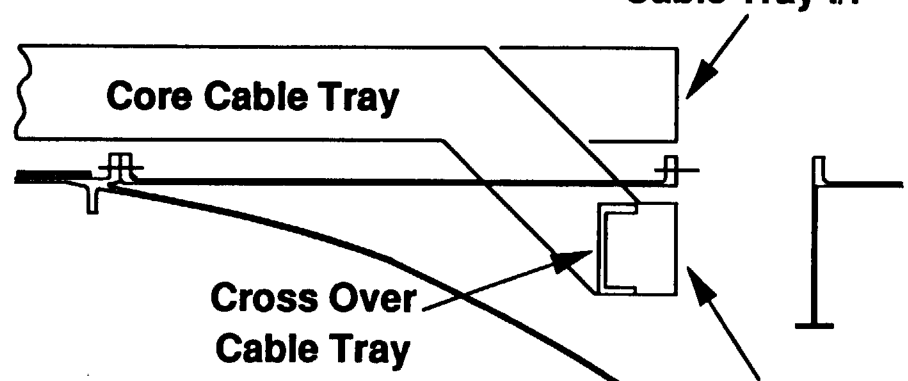
Cable Tray / Skirt I/F's   CV-STR-17A



Reference Configuration



Option 2



Option 3

679

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Evaluation Summary CV-STR-17A

	Ref Config	Option 2 12" Skirt	Option 3 48" Skirt
PM Installation to Core	Adequate	Improved	Improved
No. of Bolted Joints	1	2	2
Load Path Assessment	Good	Less Efficient than Ref	Less Efficient than Ref
LN2 & Ice Formation	Yes- He Purge only Alternate Solution	Foam or He Purge Solutions	Foam or He Purge Solutions
Ease of TPS Crotch Application	Not Possible	Good	Adequate
Instalation of Cross over Cable Tray	After PM Inst'l	After PM Inst'l	Prior to PM Inst'l
Weight Impact	Ref	+ 600 lbs	+ 600 lbs

Preferred

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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

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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.

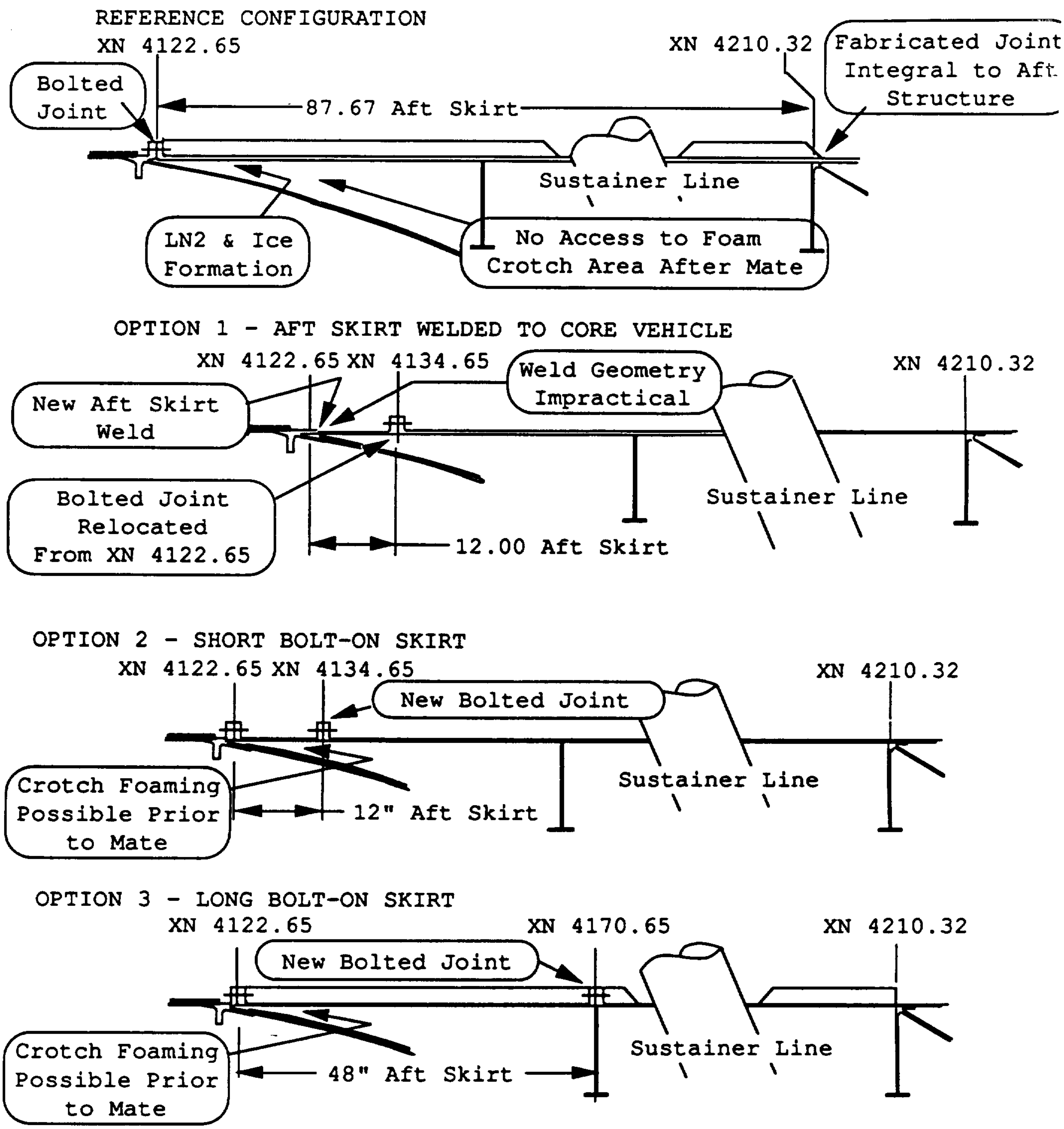
Conclusions

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.



Additional Information

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

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)
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

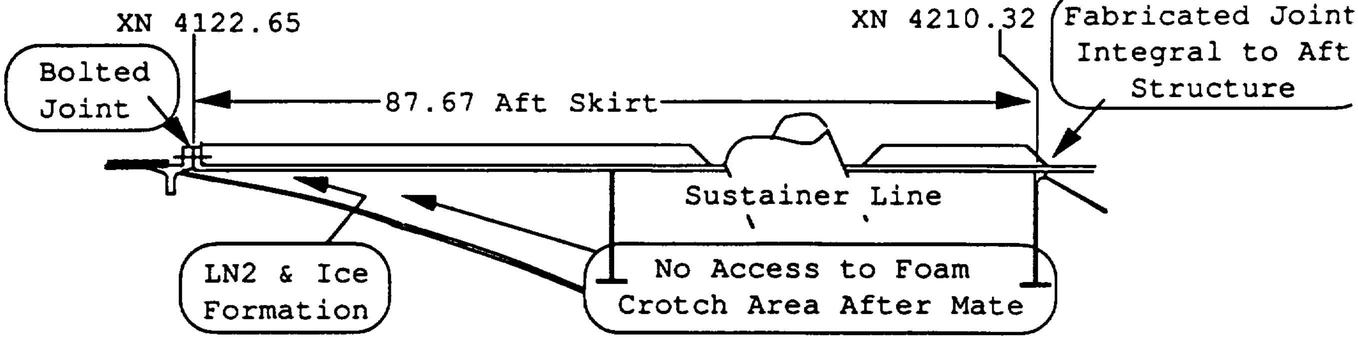
With the exception of Option 1 all Options studied are feasible. Options 2 & 3 offer some increased design flexibility but have associated weight and cost impacts.

Additional analysis is required to make a quantitative assessment of LN2 & Nitrogen ice formation.

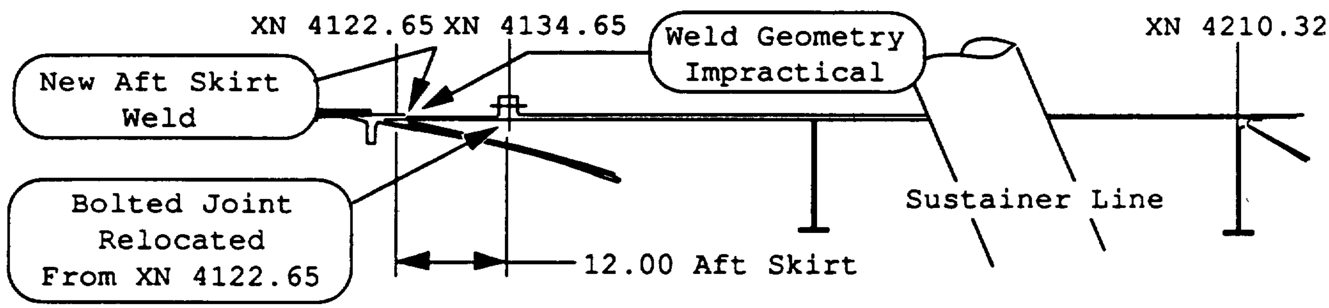
Study Recommendations

Maintain the Reference Aft Skirt configuration. Study the LN2 & ice debris problem further during Cycle 1.

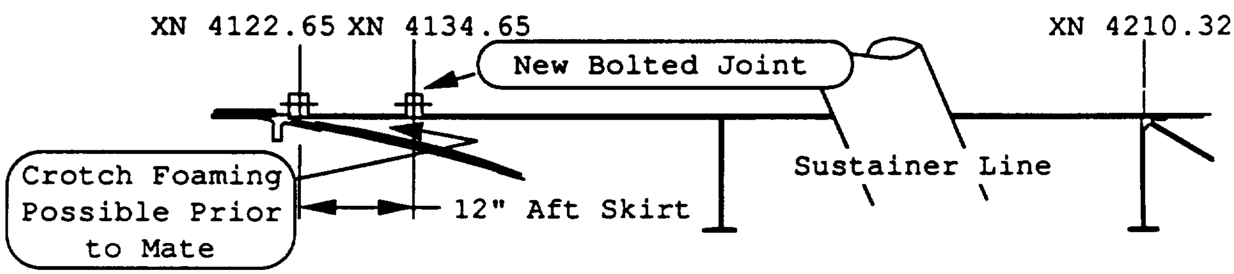
REFERENCE CONFIGURATION



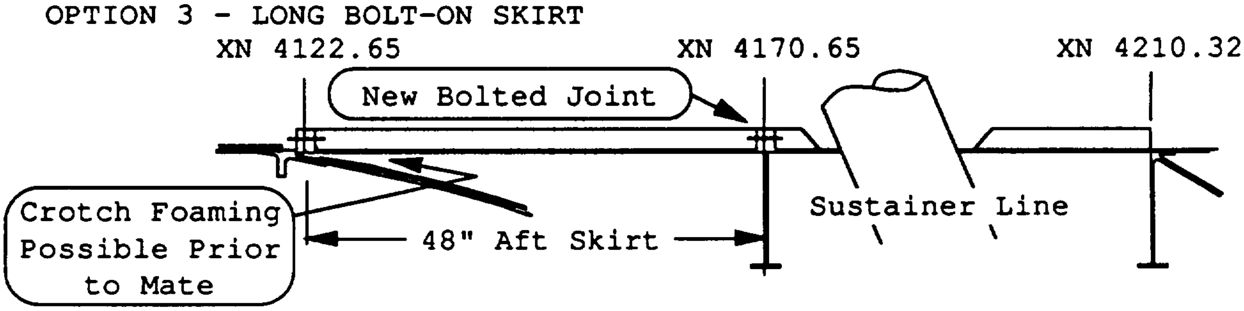
OPTION 1 - AFT SKIRT WELDED TO CORE VEHICLE



OPTION 2 - SHORT BOLT-ON SKIRT



OPTION 3 - LONG BOLT-ON SKIRT



Additional Information

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

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