Alternate Propulsion Module

Executive & Discriminator Summary

I R & D M-16S

Prepared By: M. Werner
December 20, 1991

Approved By: M. R. Simms

MARTIN MARIETTA
MANNED SPACE SYSTEMS

01.ES.MPW.911220

Objective, Groundrules & Assumptions M-16S

Objective: To Define an Alternate PM for NLS Reference

Groundrules & Assumptions:

- Groundrules Furnished by MSFC, Except as noted below
- OEPSS Issues Included as Applicable
- Core Tank has 5 Ft LH2 Tank Stretch Aft
- Aft Skirt is part of Propulsion Module (No Aft Skirt on Core Tank for Commonality with NLS Reference)
- NLS Reference as Described by Data Book Dated May 28, 1991, with Changes based on MSFC Groundrules
- Individual Helium Systems to Facilitate 4/2 Pod Checkout as LRU (MSFC Groundrule Change)
- 4/2 Pod 1.5 Stage Controlled by Gimballing only 4 Engines (MSFC Groundrule Change)
- Core Stage Assembled at MAF Using 'Ship & Shoot' Philosophy

MSFC Discriminators - Alternate PM

- <u>Cost / Flight</u>

1. Final Assembly, Stacking & Checkout Cost
2. Maintenance Cost
3. Loading & Launch Cost
4. Manufacturing Cost
5. Assembly Cost
6. Acceptance Testing

- <u>Non-Recurring Cost</u>

7. Vehicle Design & Development Engineering
8. Development Testing
9. Verification Testing
10. Handling Equipment
11. Manufacturing Development

- <u>Construction of Facilities</u>

12. Launch Facilities
13. Test Facilities

- <u>Design Capability</u>

14. Weight
15. Aerodynamic Drag
16. Usable Propellant

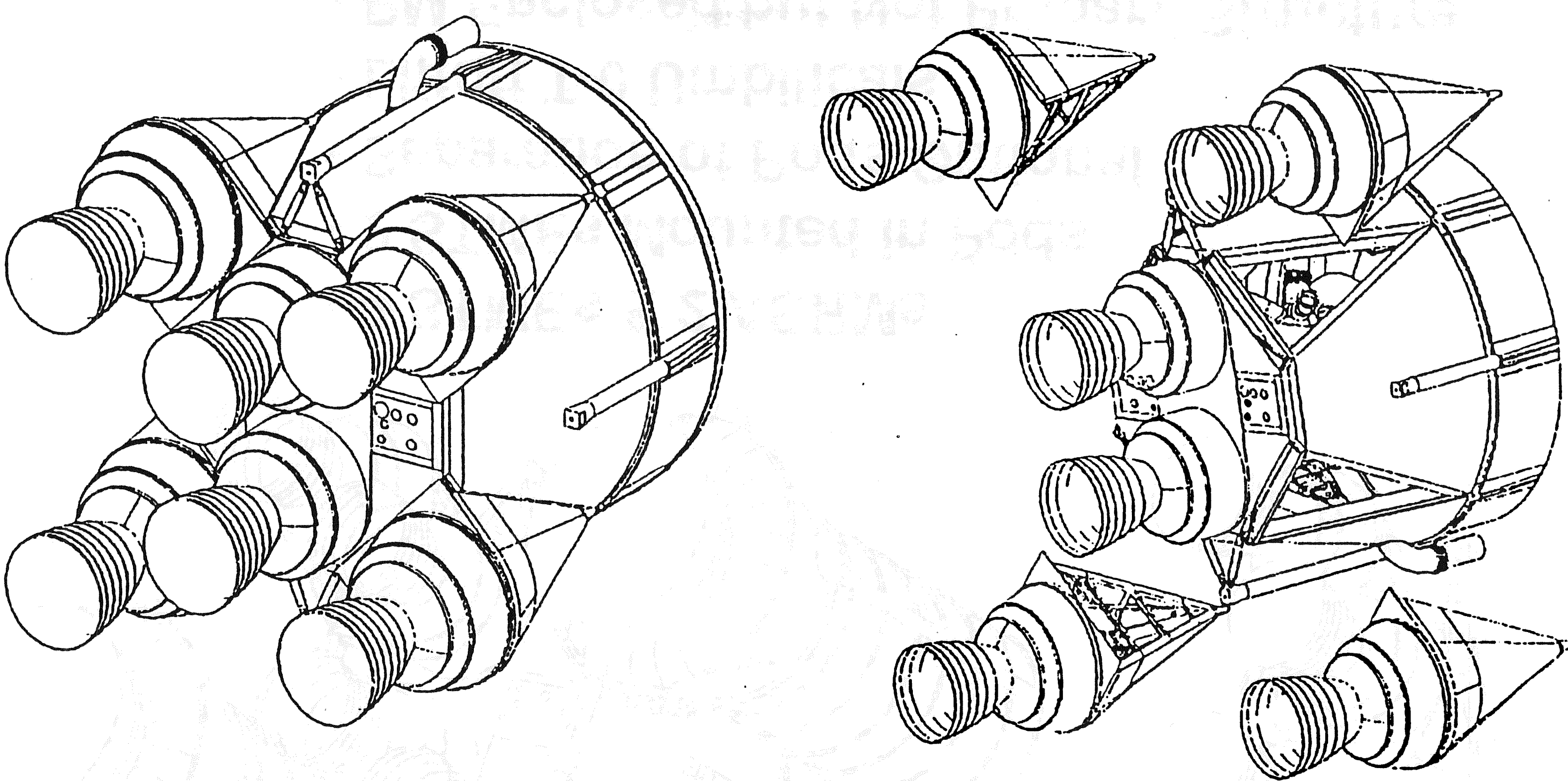
- <u>Mission Reliability</u>

17. System / Subsystem Complexity
18. Confidence Level

- <u>Dependability</u>

19. Maintainability
20. Launch Schedule Reliability

4/2 Single Pod - 1.5 Stage



- 6 STMEs, 4 Booster & 2 Sustainer
- Each Booster Engine Mounted in Jettisonable Pod
- Pod Self-Contained with He, EMA, Controls & Power
- Liftoff T-0 Umbilicals
- PM Enclosed but Not Primary Structure

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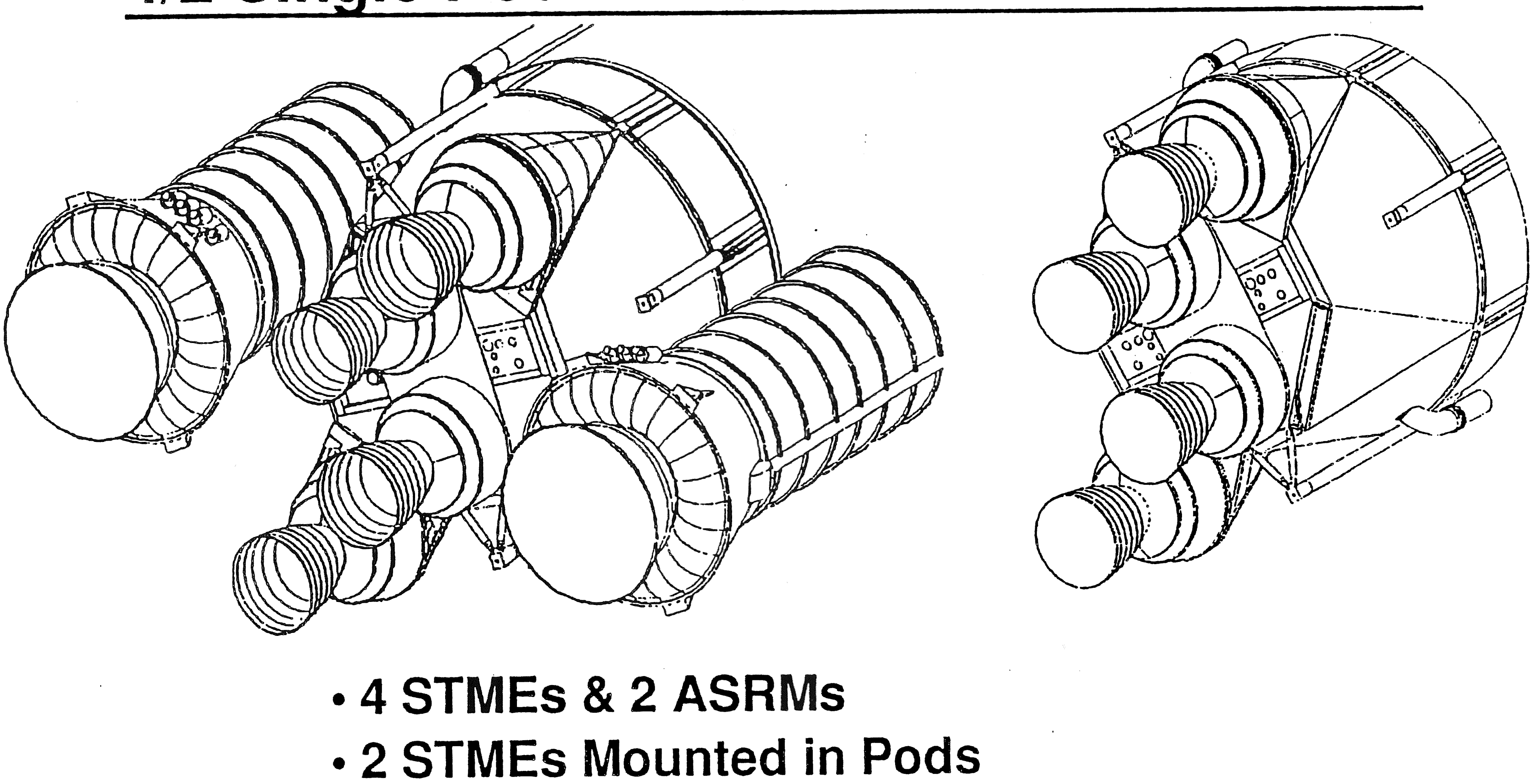
4/2 Single Pod - HLLV

M-16S



- 4 STMEs & 2 ASRMs
- 2 STMEs Mounted in Pods
- Separation of Pods Optional
- Liftoff T-0 Umbilicals
- PM Enclosed but Not Primary Structure

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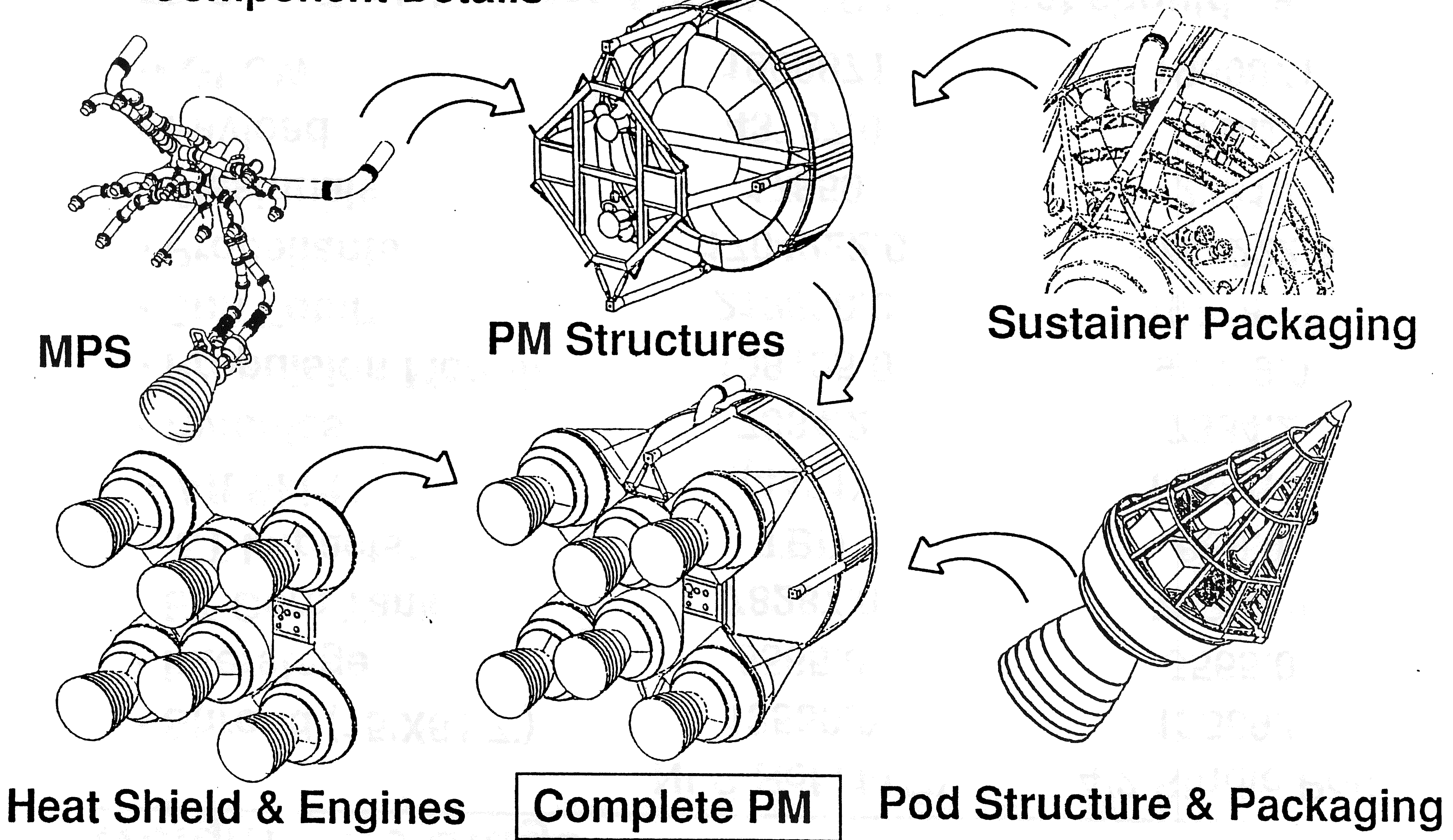
4/2 Single Pod - 1.5 Stage

• Component Details



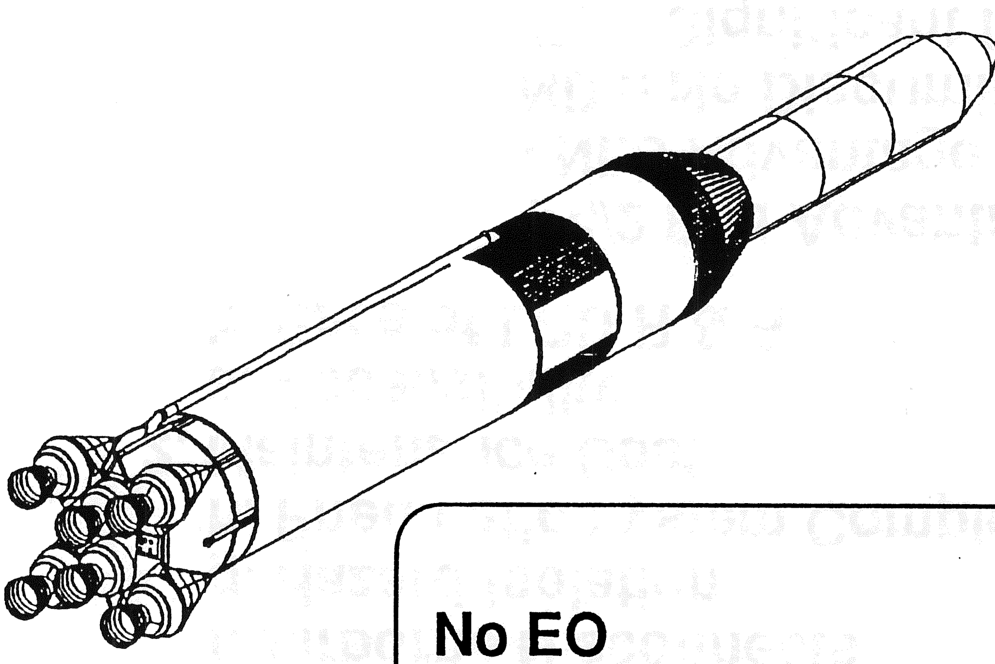
Weight - 1.5 Stage M-16S

	NLS Ref (11/7)	4/2 Single Pod
• Shroud (15'X61.7')	13569.0	13569.0
• Interstage	5565.0	5565.0
• ET Core Tank	78287.0	78287.0
- ET Impacts*	TBD	869.0
- Aft Skirt*	(4421)	(4421.0)
• Avionics	7334.2	7334.2
• Propulsion Module	108125.0	96579.0
• Sub Total*	212880.2	197782.6
• Propellants	1704222.0	1704222.0
- Residuals	17859	21310
• Payload	43767.0	TBD
•• GLOW	1960871	1960871

* ET Core Tank Includes 4421 lbs Aft Skirt that should be part of PM (NLS May be Double Booked)

Performance - 1.5 Stage

M-16S



	NLS Ref.		4/2 Pod
No EO	49893	⟷	52294
Sequenced	---		52541
Sustainer EO	37369	⟷	39504
Keep Booster (XX sec)	---		TBD
Booster EO	TBD	⟷	42597
Booster Jettison @ LO	---		45212

Cost / Flight — M-16S

	4/2 Pod
1. Final Assembly, Stacking & Checkout Cost	
a. Accessibility	⊞
b. Degree of Serial Processing	ND
c. Number of Active Systems	ND
d. Number of Flanged Joints	-
e. Holddown Complexity	+
f. Airborne Disconnects	-
g. Hazard Isolation	ND
h. Pneumatic System Complexity	-
2. Maintenance Cost	
a. Accessibility	⊞
b. Ease of LRU R & R	⊞

+ 4/2 Pod Advantage
- NLS Advantage
ND = No Discriminators
▒ = Significant Discriminator

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Cost / Flight (cont.) M-16S

	4/2 Pod
3. Loading & Launch Cost	
a. Number of LCCs	ND
b. Fill/Drain Complexity	ND
c. Number of Active Systems	ND
d. Propellant Conditioning Complexity	ND
4. Manufacturing Cost	
a. Amount of Touch Labor	⊞
b. Commonality with ET	ND
c. Commonality between HLLV / 1.5 Stage	⊞
d. Impact of ET Production Process	ND
e. Component Cost	ND
5. Assembly Cost	
a. Assembly Sequence Complexity	⊞
b. MPS Interfaces for Separation	-
c. Degree of Serial Operations	+
d. Amount of Touch Labor	⊞
6. Acceptance Testing	
a. System Level of Testing	⊞

Non-Recurring Cost — M-16S

	4/2 Pod
7. Vehicle Design & Development Engineering	
a. System Complexity	+
b. Complexity of Boattail Structure	[+] (significant)
c. MPS Complexity	ND
d. Number of Components	+
e. Number of Common Parts	+
f. Use of Existing Design	ND
g. Off-the-shelf Hardware	ND
h. Degree of new tank design	ND

+ 4/2 Pod Advantage
- NLS Advantage
ND = No Discriminators
[shaded box] = Significant Discriminator

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Non-Recurring Cost (cont.)

	M-16S 4/2 Pod
8. Development Testing	
a. Propellant Conditioning Requirements	ND
b. Separation Mechanism Testing	[+]
c. Number of Test Articles	+
d. Number of Required Tests	+
e. Special Test Equipment	+
9. Verification Testing	
a. Thrust Structure Test Requirement	+
b. Separation Test Requirement	[+]
c. Number of Parallel System Tests	[+]
d. Number of Required Tests	+
e. Number of Test Articles	+
10. Handling Equipment	
a. Assembly Complexity	-
b. Number of Unique Modules to Handle	+
11. Manufacturing Development	
a. New Tooling Cost	ND

Construction of Facilities — M-16S

	4/2 Pod
12. Launch Facilities	
a. Degree of MPS Design Changes	ND
b. Pad / Flame Trench Mods	ND
c. MLP Common of Design HLLV / 1.5 Stage	+
13. Test Facilities	
a. MPS Test Facility Impacts	-
b. Integrated Vehicle Static Test Req'm'ts	ND
c. Separation Test Facility Req'm'ts	[+]
d. Structural Test Facility Req'm'ts	+

+ 4/2 Pod Advantage
- NLS Advantage
ND = No Discriminators
☐ = Significant Discriminator

Design Capability (P/L to Orbit) M-16S

	4/2 Pod
14. Weight	
a. Residuals	[-]
b. Inert Weight of Boattail	+
c. ET Weight Impacts	TBD
15. Aerodynamic Drag	
a. Performance Impact (Weight)	ND
16. Usable Propellant	
a. Allowable Tank Stretch	ND

+ 4/2 Pod Advantage
- NLS Advantage
ND = No Discriminators
[ ] = Significant Discriminator

Mission Reliability — M-16S

	4/2 Pod
17. System / Subsystem Complexity	
a. Total Number of Parts	ND
b. Separation Complexity (Problems)	⊞
c. Holddown Complexity	+
d. Ground Structural Loads Capability	+
e. Thermal Loads Capability	ND
f. Number of Airborne Disconnects	-
g. Number of Ground Disconnects	ND
18. Confidence Level	
a. Design Maturity	ND
b. Potential for Failure Propagation	+
c. Reduction of Common Mode Failures	⊞
d. Structural Integrity of Mods to ET	ND
e. Structural Design	ND

+ 4/2 Pod Advantage
- NLS Advantage
ND = No Discriminators
▩ = Significant Discriminator

	4/2 Pod
19. Maintainability	
a. Test & Checkout Requirements	▩+
b. Potential for Work Around	ND
c. Ease of LRU R & R	▩+
20. Launch Schedule Reliability	
a. Propellant Loading/Precond Margins	ND
b. Number of Components	-
c. Number of Active Systems	ND
d. Number of LCCs	ND
e. Sensitivity to Uncontrolled Parameters	+

+ 4/2 Pod Advantage
- NLS Advantage
ND = No Discriminators
▩ = Significant Discriminator

Discriminator Summary M-16S

- Significant Positive Discriminators for the 4/2 Single Pod
  - Maintenance Accessibility for Fabrication & Checkout
  - PM 'Simplicity', Specifically for the Separation System
  - Reduction in Testing Costs for the Separation System
  - Reduction in Production Costs using the Pod Assembly Line
  - Commonality in MLP Interfaces for the 1.5 Stage & HLLV
  - LRU Concept for Pod During Launch Facility Operations

- Significant Negative Discriminators for the 4/2 Single Pod
  - High Residual Propellant Weights, However, Redesign of the Feedline Routing & Relocation of Disconnects could Reduce the Residuals

Core Stage OEPSS Items

M-16S

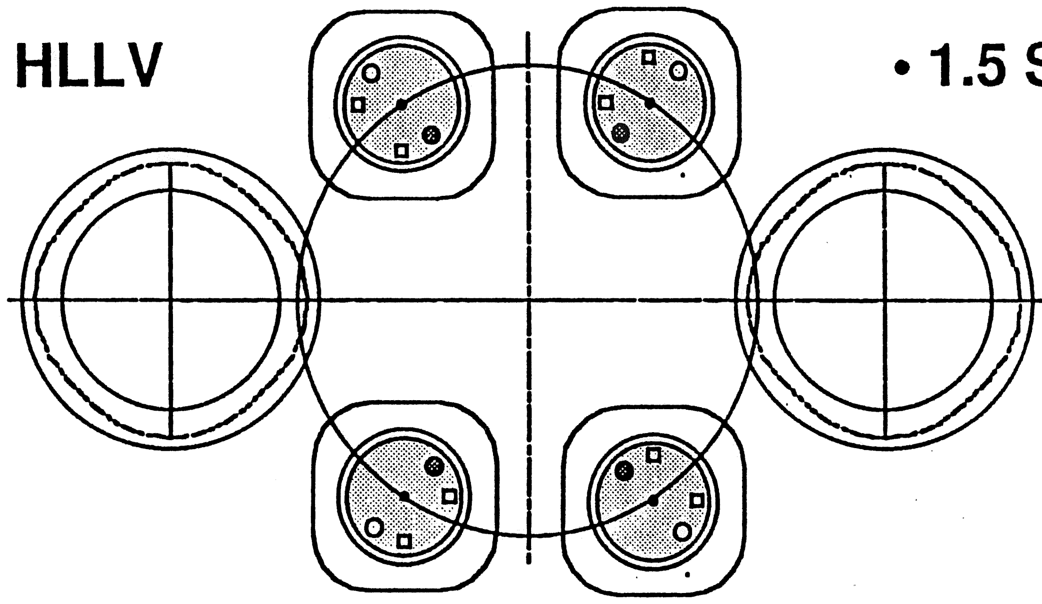
OEPSS Item	Cycle 0 B/L	Cycle 1	Studied
• Item 1 Closed Aft Compartment	-	-	X
• Item 2 Hydraulic System	X	-	-
• Item 3 Ocean Recovery	X	-	-
• Item 6 Accessibility	-	-	X
• Item 7 Sophisticated Heat Shielding	-	-	X
• Item 8 Excessive Components	-	X	-
• Item 9 Lack of Hardware Integration	-	X	-
• Item 11 Pneumatic System	X	-	-
• Item 12 Gimbal System	X	-	-
• Item 14 Ordnance Operations	-	X	-
• Item 15 Retractable T-0 Umbilicals	X	-	-
• Item 16 Pressurization Systems	X	-	-
• Item 17 Inert Gas Purge	-	-	X
• Item 18 Excessive Interfaces	-	X	-
• Item 19 Helium Spin Start	X	-	-
• Item 20 Conditioning / Geysering	X	-	-
• Item 21 Preconditioning System	X	-	-
• Item 23 Hardware Commonality	-	-	X
• Item 24 Propellant Contamination	-	X	-
• Item 25 Multi-Stage Prop Systems	X	-	-

Summary - 4/2 Single Pod M-16S

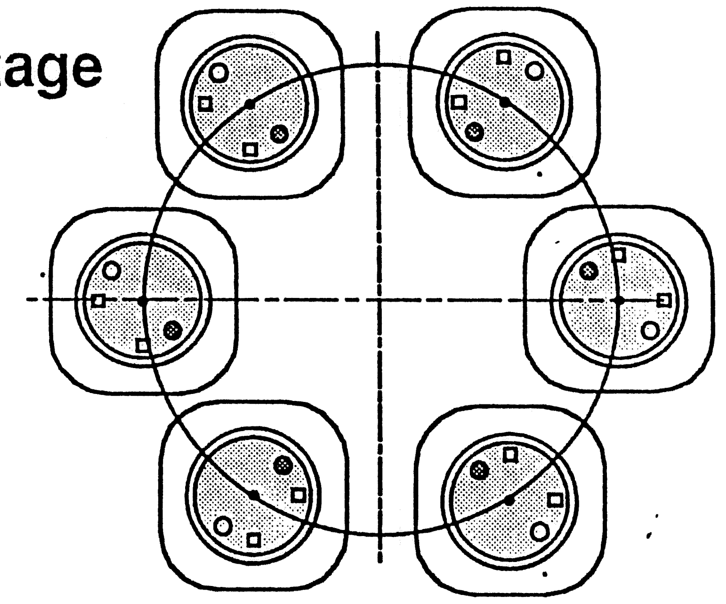
- 4/2 Single Pod Concept is Feasible as an Alternate to NLS
- Both Eng Arrangements Common, Except for SRB Location
- PM 11.5 Klbs Lighter than NLS (11/7/91)
- 1.5 Stage Payload 2100 Lbs More than NLS (SEO)
- Engine Out Capability Enhanced by Jettisoning Failed Engine Pod at Time of Failure
  - Staging Difficult Between 20 to 130 Seconds
- Pod Concept Allows Offsite Assembly as LRU
  - LRU Concept Improves Launch Facility Operations
  - Pod is Ground Transportable
- Feedline Propellant Residuals Too High
  - Redesign F/L with External LO2 & Relocated Disconnects
- Simplified Holddowns Improves Stacking
- Palletized Packaging Accessible from OML
- MLP Commonality between 1.5 Stage & HLLV

Recommendations M-16S

• HLLV



• 1.5 Stage



• Single Pod Concept Should be Expanded to Study 6 Separate Pods with Engines Arranged on OML

- Jettison Any Pod / Engine at Time of Failure
- HLLV with Additional Engine Clearance
- 3 Point Holddowns with Symmetrical Loads
- Design for Engine Growth

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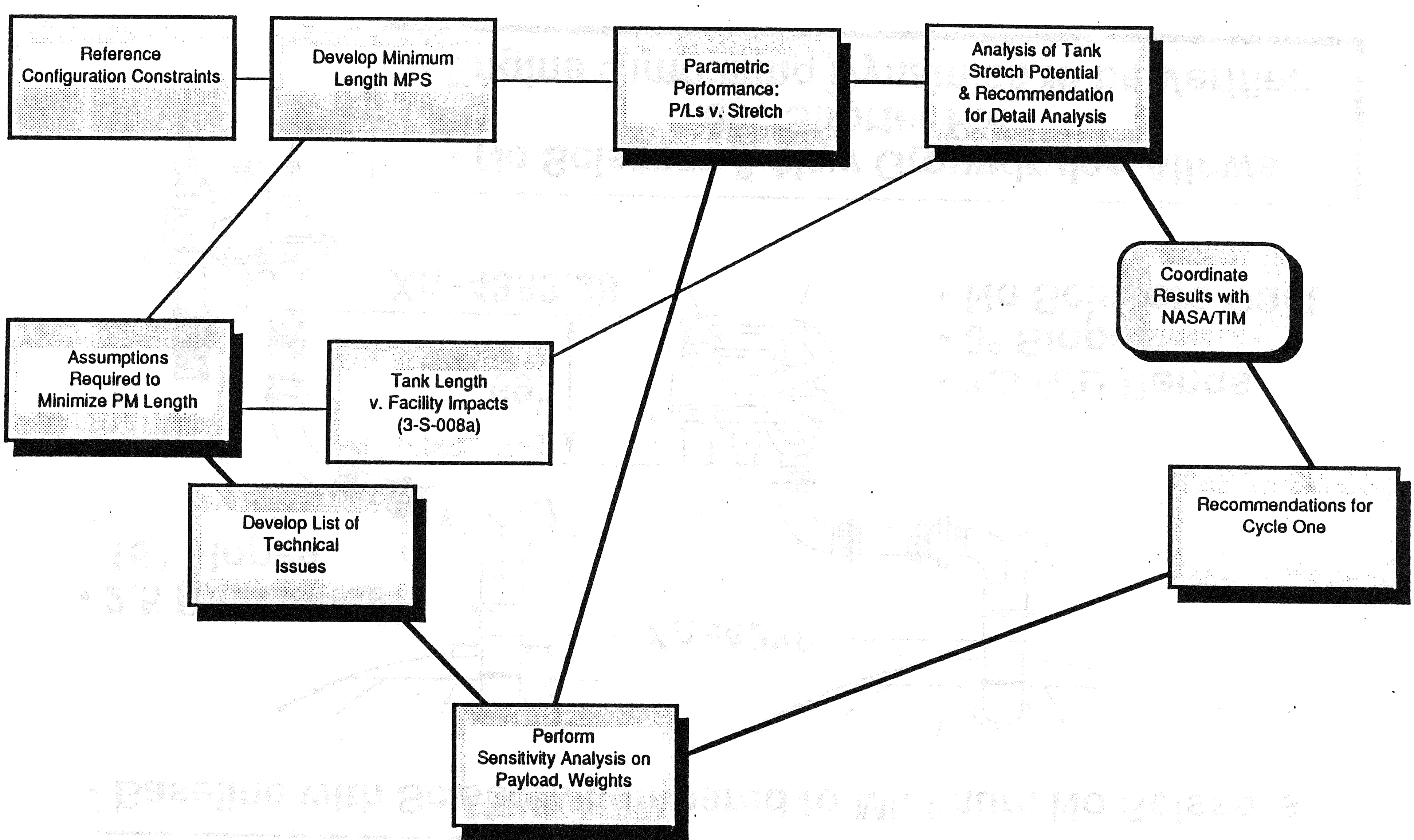
Maximum Tank Stretch Study

3-P-001

Summary

December 20, 1991

3-P-001 MAXIMUM TANK STRETCH STUDY



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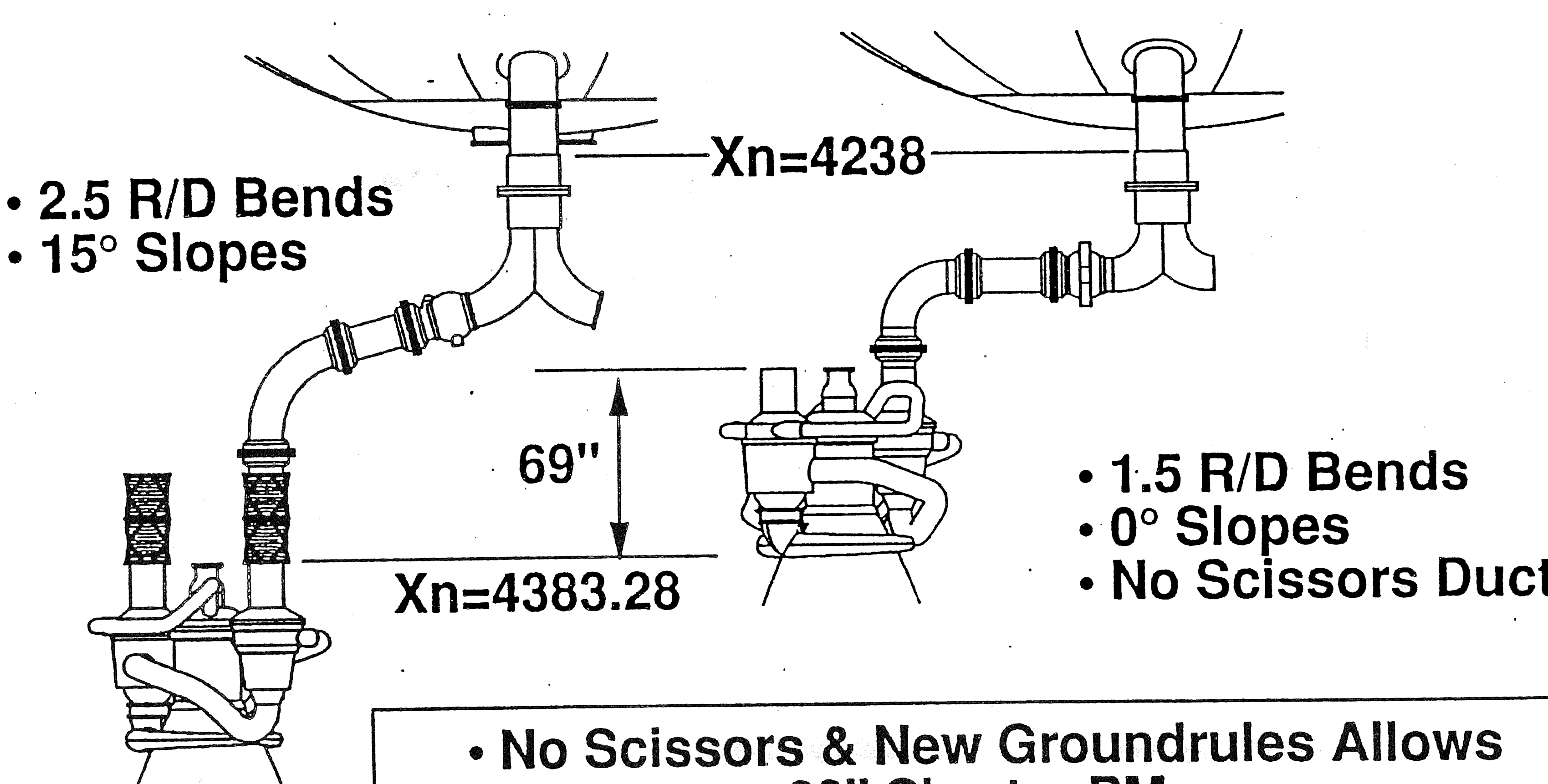
3-p-0016ra

LH2 F/L Comparison - Booster

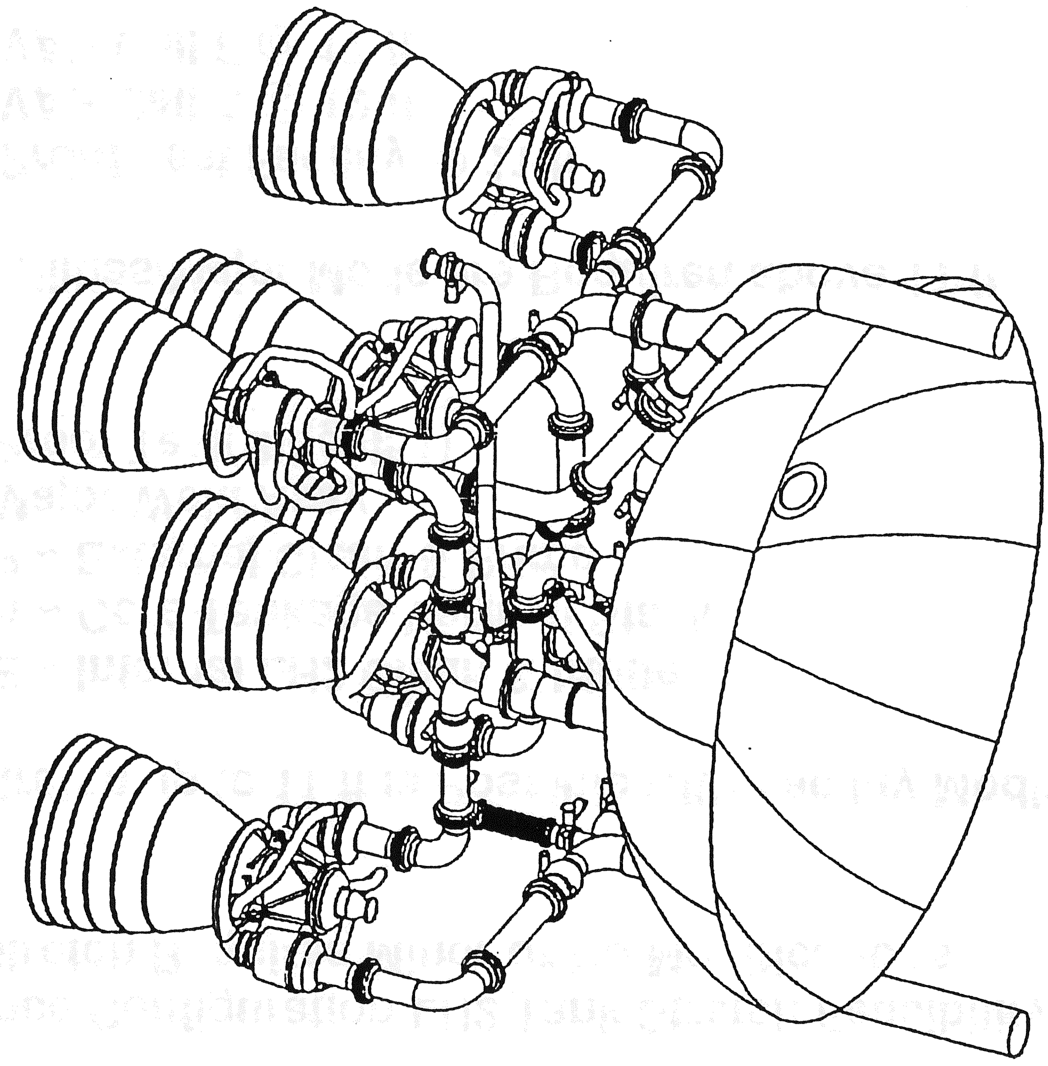
- Baseline with Scissors compared to Minimum No Scissors



- No Scissors & New Groundrules Allows 69" Shorter PM
- Engine Gimballing Dynamics to be Verified

MPS Arrangement

- Minimum MPS Arrangement with No Scissors & 0° Slope



MPW.911206

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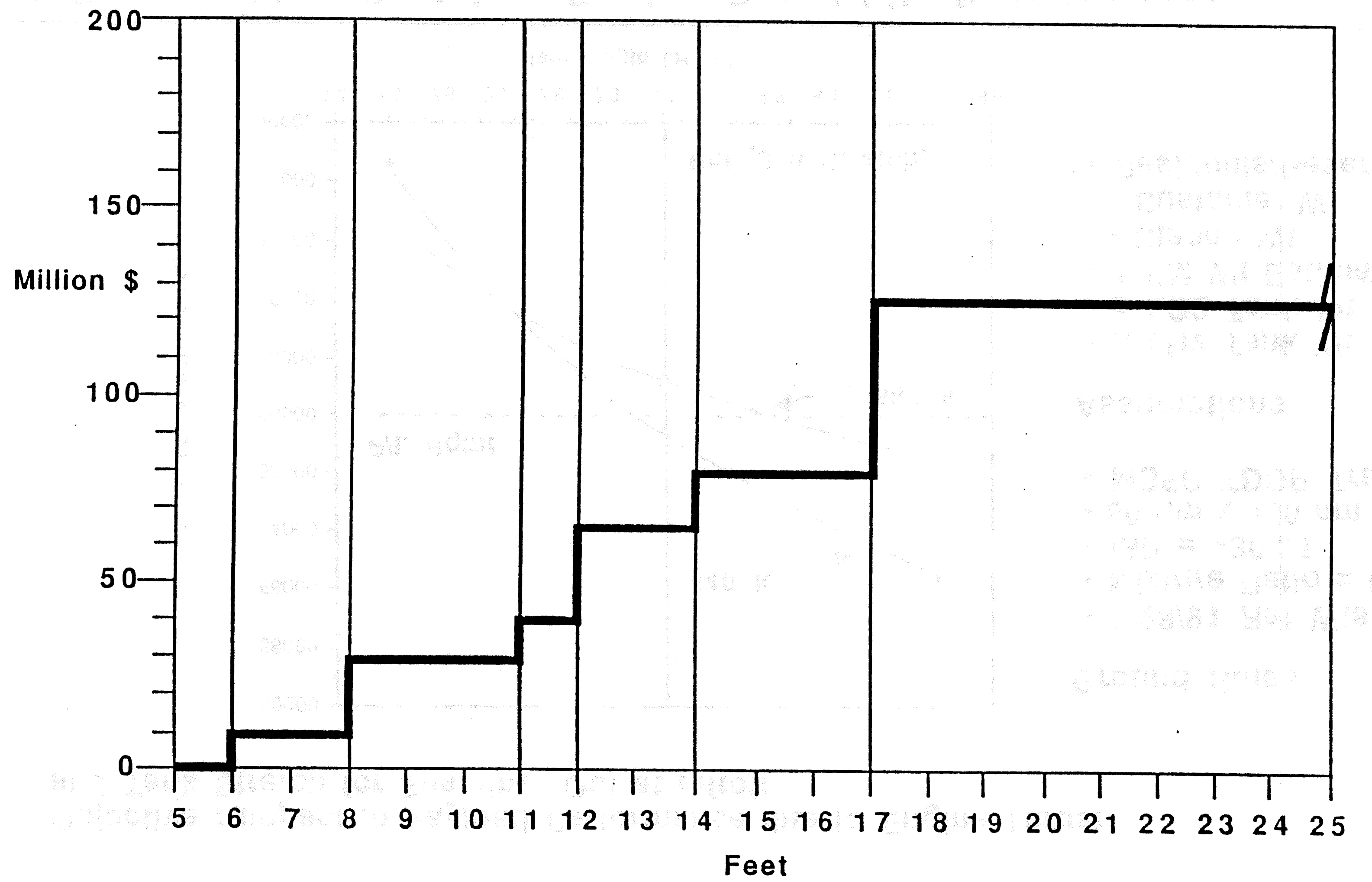
Summary 3-S-008A

- 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)

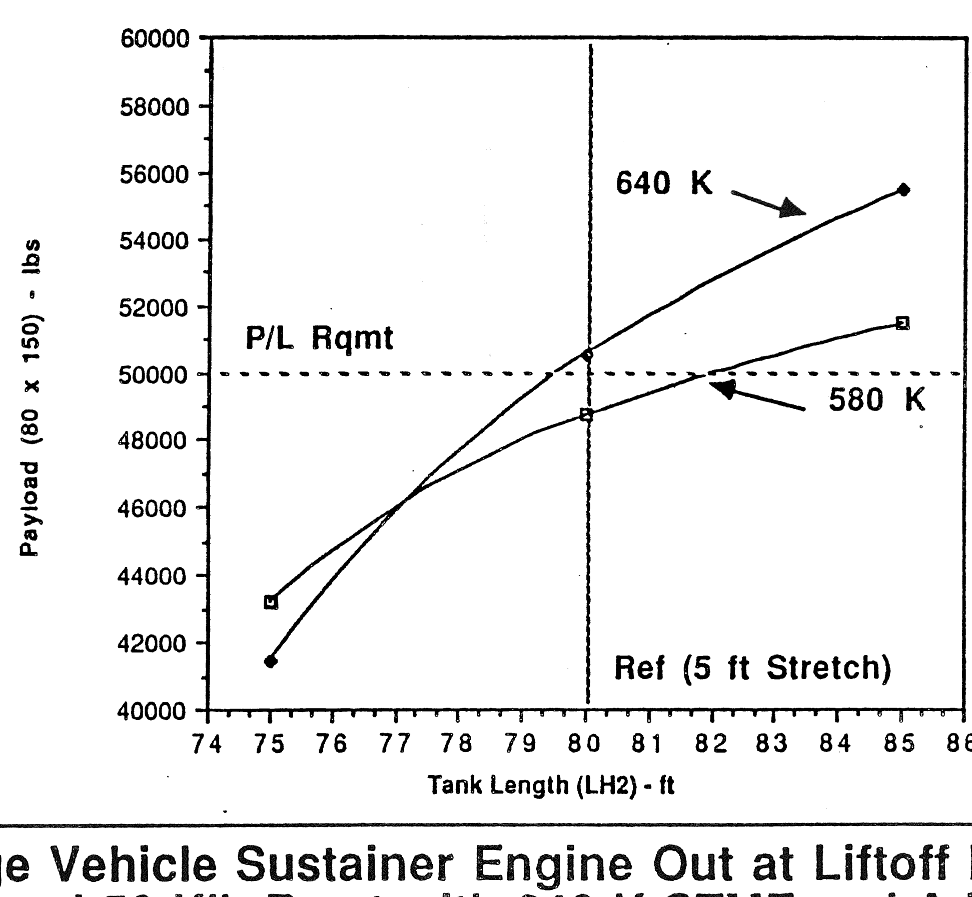
- New Facilities/Major Mods are Required above 11 ft
  - New Proof Test Facility @ 11 ft
  - New VAB Cell A @ 12 ft
  - New VAB Cell E @ 17 ft

NLS Core Tankage Stretch Summary



1.5 Stage Vehicle Performance Impacts

Objective : Impact to Payload Performance due to Engine Thrust and Tank Stretch for Sustainer Out at Liftoff



Ground Rules

- 5/28/91 Ref Wts
- Mixture Ratio = 6.0
- ISP = 430.25
- 80 nm x 150 nm
- MSFC TDDP Traj

Assumptions

- Δ LH2 Tank Wt Estimated
- Δ LO2 Tank Wt Estimated
- Δ PM Wt Estimated
  - Staged Wt
  - Sustainer Wt
- Residuals/Reserves Adj

1.5 Stage Vehicle Sustainer Engine Out at Liftoff Performance Can exceed 50 Klb Rqmt with 640 K STME and Addnl 5 ft Stretch

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Maximum Tank Stretch - Conclusions

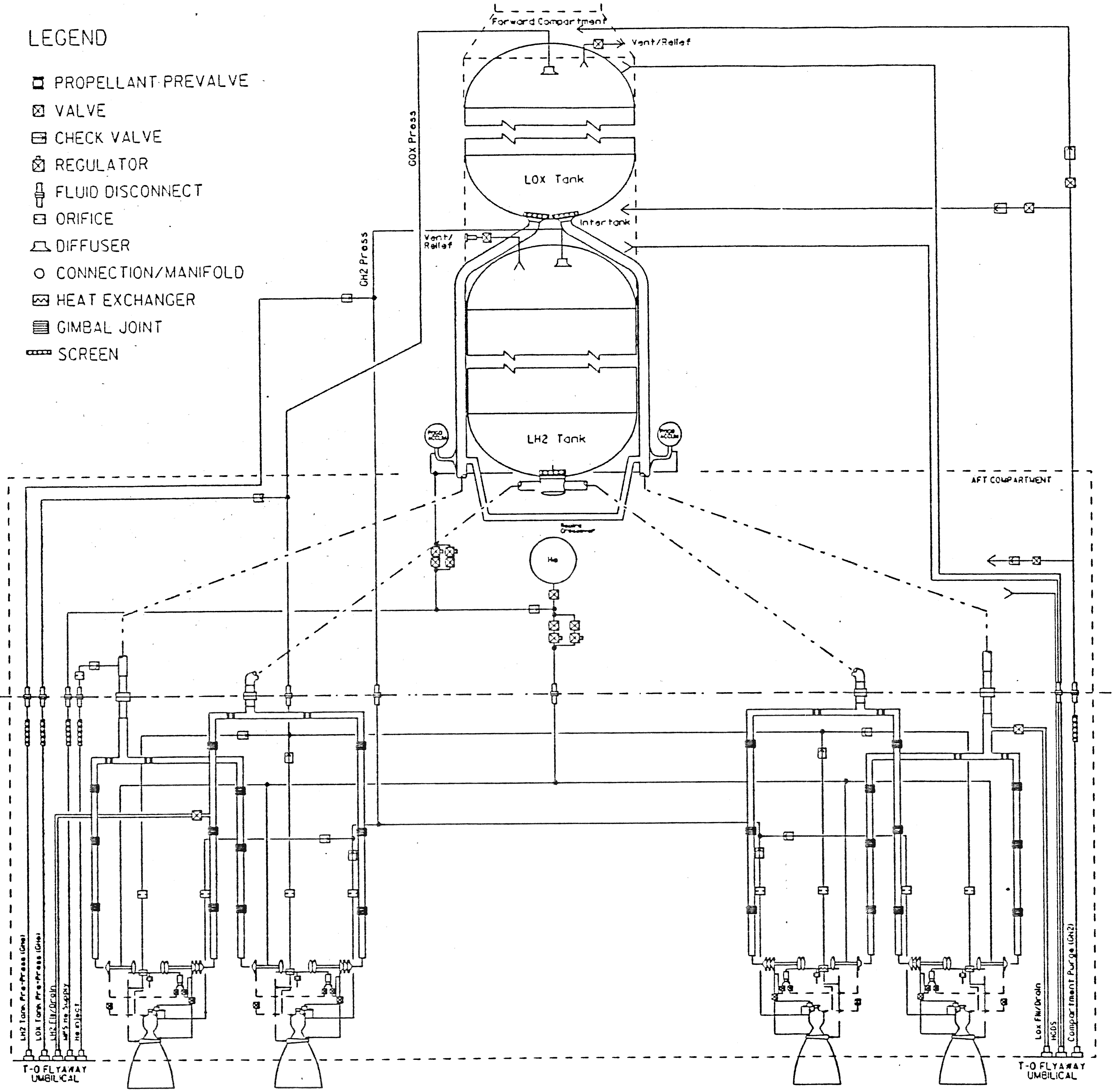
- LH2 Tank Can Be Stretched Aft 10-11 Ft Without Major Facility Impacts
- LH2 Tank Can Be Stretched Aft 10-11 Ft. Without Major Change In Feedline Concept
- A LH2 Tank Stretch Of 10 Ft. Can Potentially Provide A Payload Increase Of About 3000 Lb. Over The NASA 1.5 Stage Reference Vehicle
- Issues Associated With Shortened Boattail Structural Design And Packaging Must Be Resolved To Verify Stretched Tank Performance Improvements

Recommendations For Cycle 1 — 3-P-001

- Using The Revised NLS Cycle 1 Propulsion Module Reference Configuration

- Cycle 1 Recommendations Relevent To Stretched Tanks

  - Re-Confirm Minimum MPS Length Using Cycle O Ground Rules
  - Develop Minimum Length PM Structural Arrangement
  - Develop Subsystem (TVC, Avionics, Pneumatic) Packaging For Minimum Length PM
  - Develop Staging Concept Details For Minimum Length PM And Analyze
  - Develop MPS Arrangement (Internal vs. External LO2 Feedlines For Minimum Length PM
  - Analyze Feedline Movement During Engine Gimballing (Develop Feedline Gimbal Requirements)
  - Develop Minimum Length Propulsion Module Mass Properties
  - Calculate Payload Performance Of Stretched Tank/Minimum Length PM Vehicle



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NLS MPS Schematic
HLLV Configuration

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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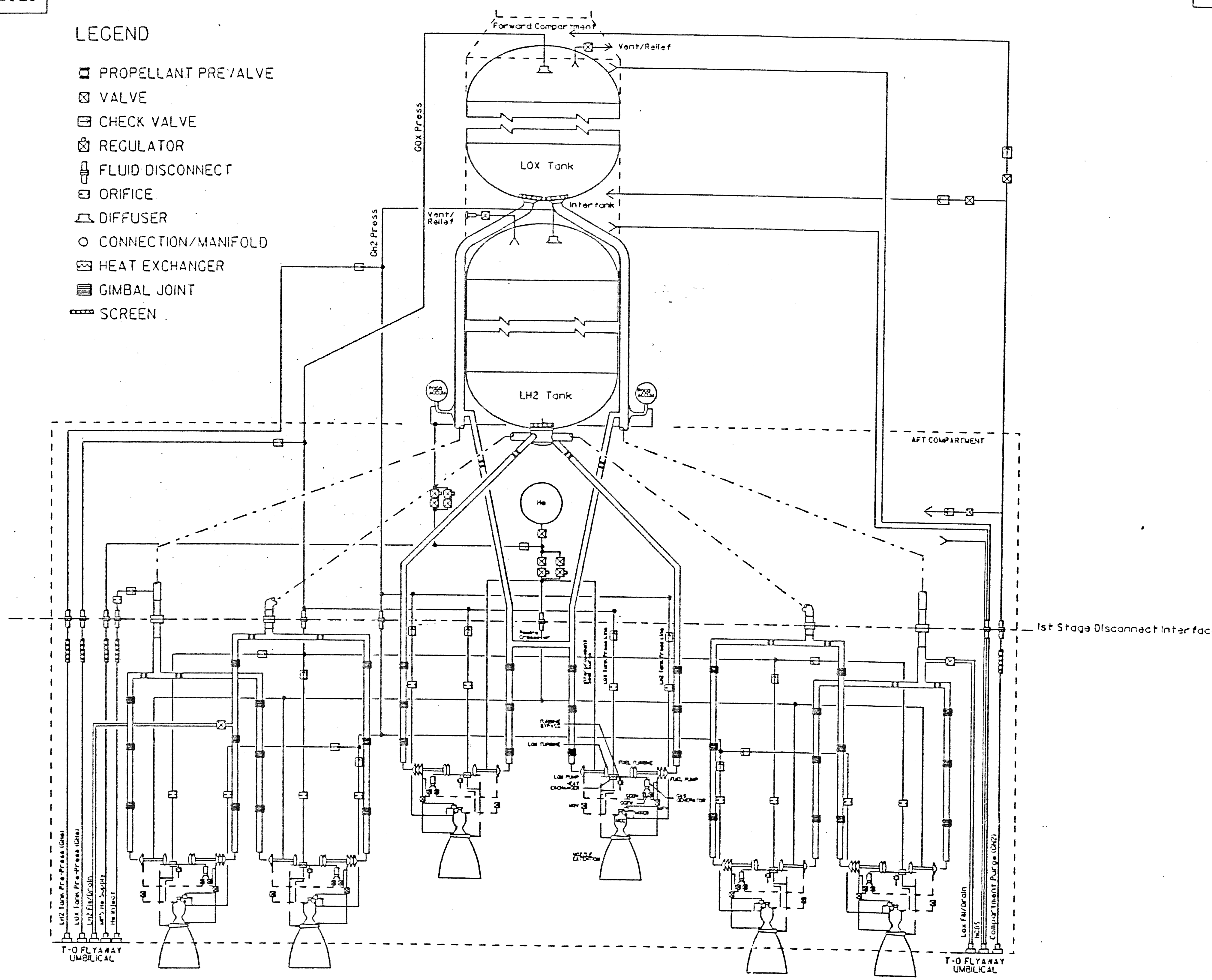

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NLS MPS Schematic
1.5 Stage Config.
First Stage

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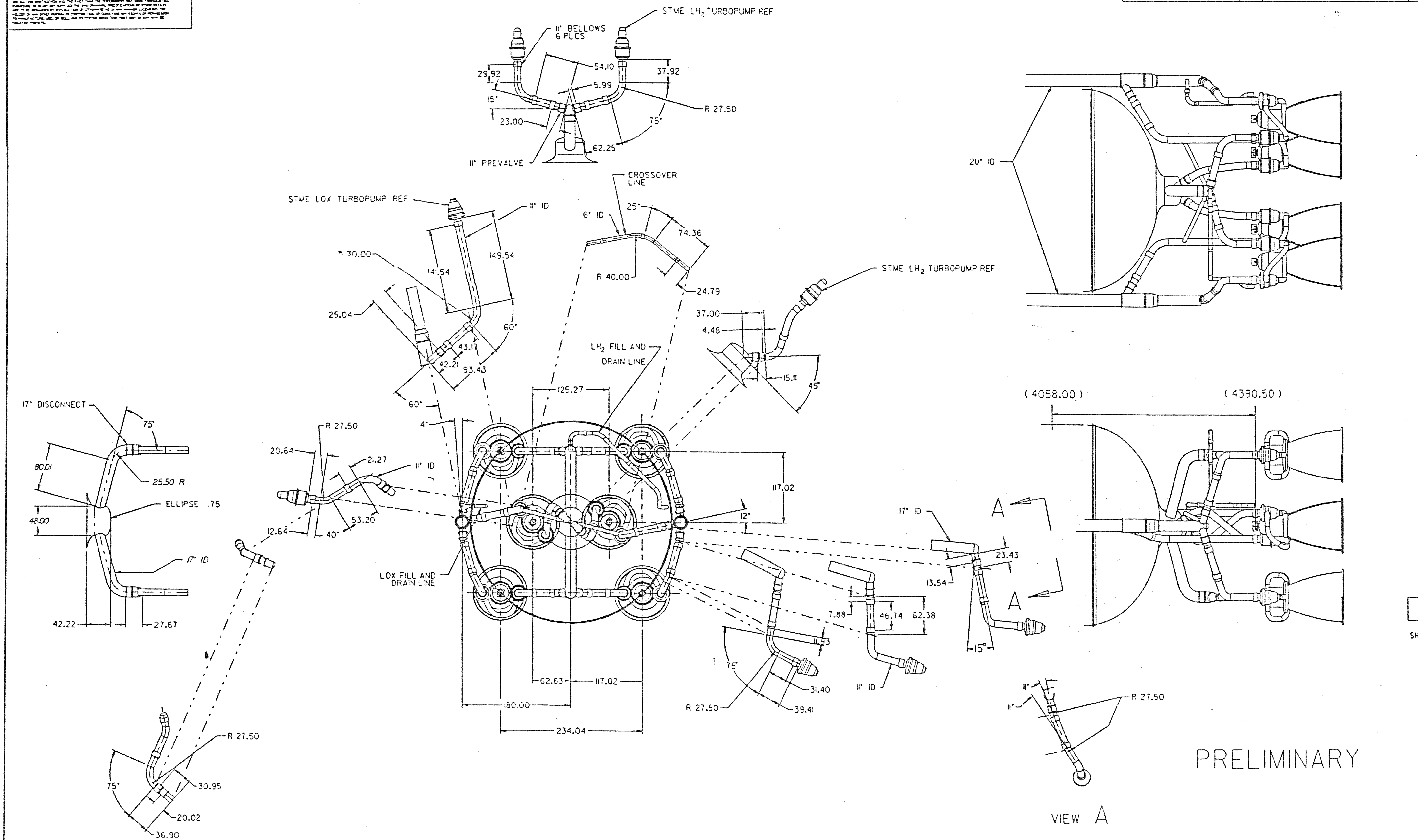

PRELIMINARY

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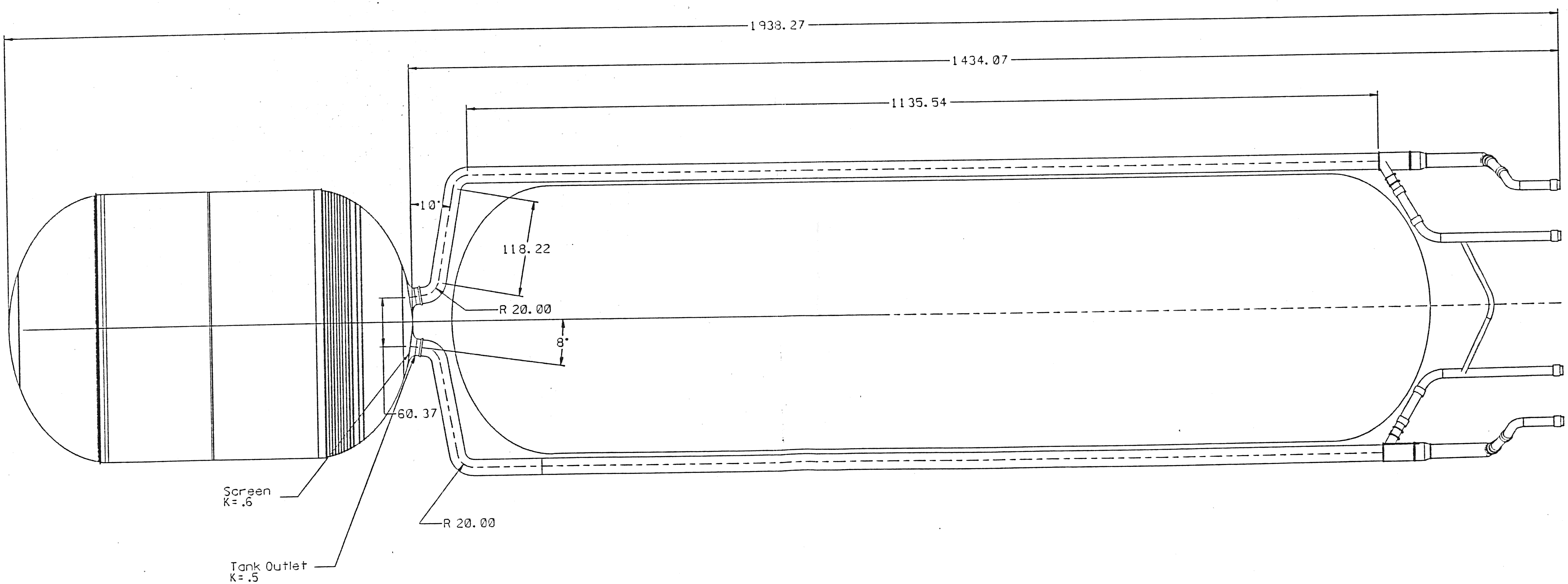
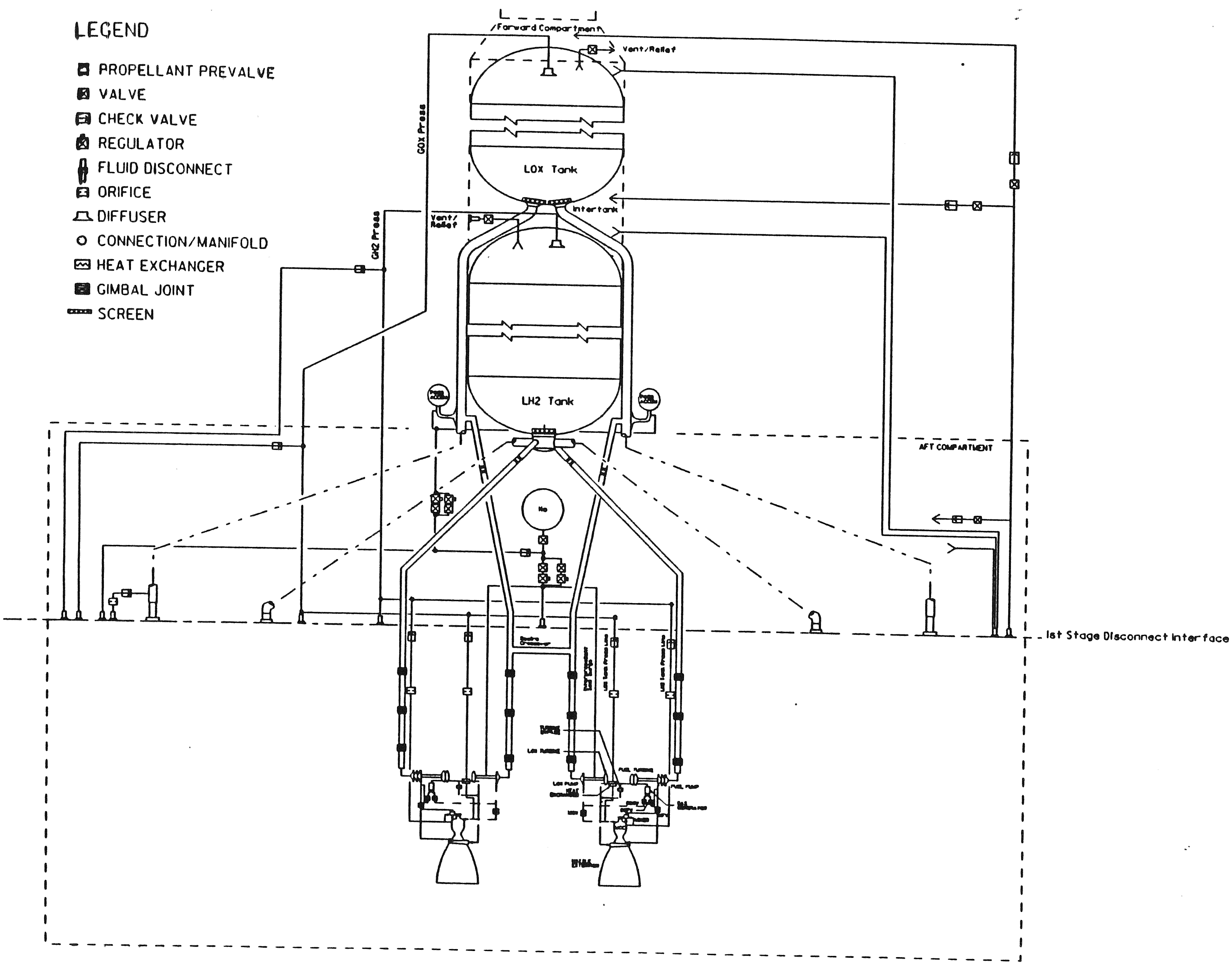
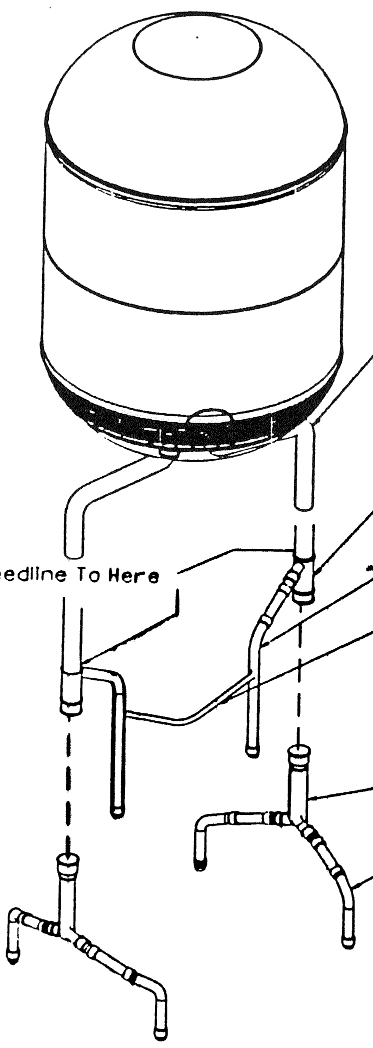
APPLICATION		MATERIAL / HEAT TREATMENT / FINAL PROTECTIVE FINISH		SCALE: 1/75 / UNIT WEIGHT	DWG SIZE D / SHEET OF



1938.27
1434.07
1135.54
10°
118.22
R 20.00
8°
60.37
Screen
K=.6
R 20.00
Tank Outlet
K=.5



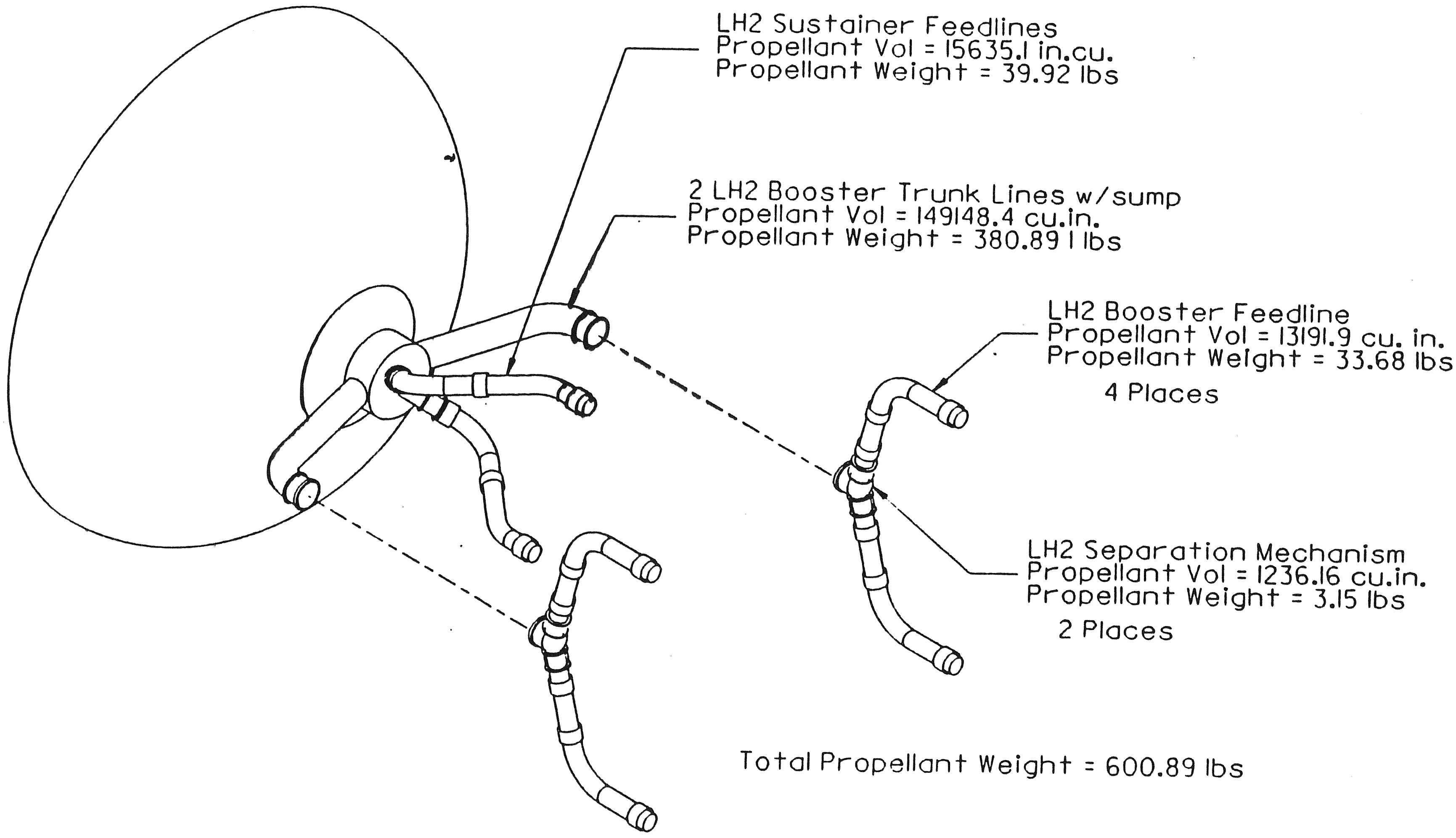
(9-27-91) NLS MPS Schematic
1.5 Stage Config.
Post Separation



Line		Weight	RESIDUALS
20 In. LOX Trunk Line Propellant Vol = 425598.8 cu. In. Propellant Weight = 17520.64 lbs.	x 2 =	35041.2 lbs.	
LOX Disconnect Propellant Vol = 9390.28 cu. In. Propellant Weight =386.53 lbs.	x 2 =	773.06 lbs.	773.06 lbs.
11 In. LOX Sustainer Line Propellant Vol = 26060.5 cu. In. Propellant Weight = 1072.73 lbs.	x 2 =	2145.46 lbs.	2145.46 lbs.
LOX Crossover Line Propellant Vol = 5324.88 cu. In. Propellant Weight = 219.18 lbs.	x 1 =	219.18 lbs.	219.18 lbs.
Core Feedline Propellant Weight		38178.9 lbs.	3137.7 lbs. (Left @ Cut-Off)
17 In. LOX Branch Line Propellant Vol = 30260.52 cu. In. Propellant Weight = 1245.62 lbs.	x 2 =	2491.24 lbs.	2491.24 lbs.
11 In. LOX Booster Line Propellant Vol = 16761.7 cu. In. Propellant Weight = 689.96 lbs.	x 4 =	2759.84 lbs.	2759.84 lbs.
Booster Feedline Propellant Weight		5251.08 lbs.	5251.08 lbs. (Propellant Lost At Staging)
GRAND TOTAL		42050 lbs.	
		TOTAL UNUSABLE In Feedline	8388.78 lbs.

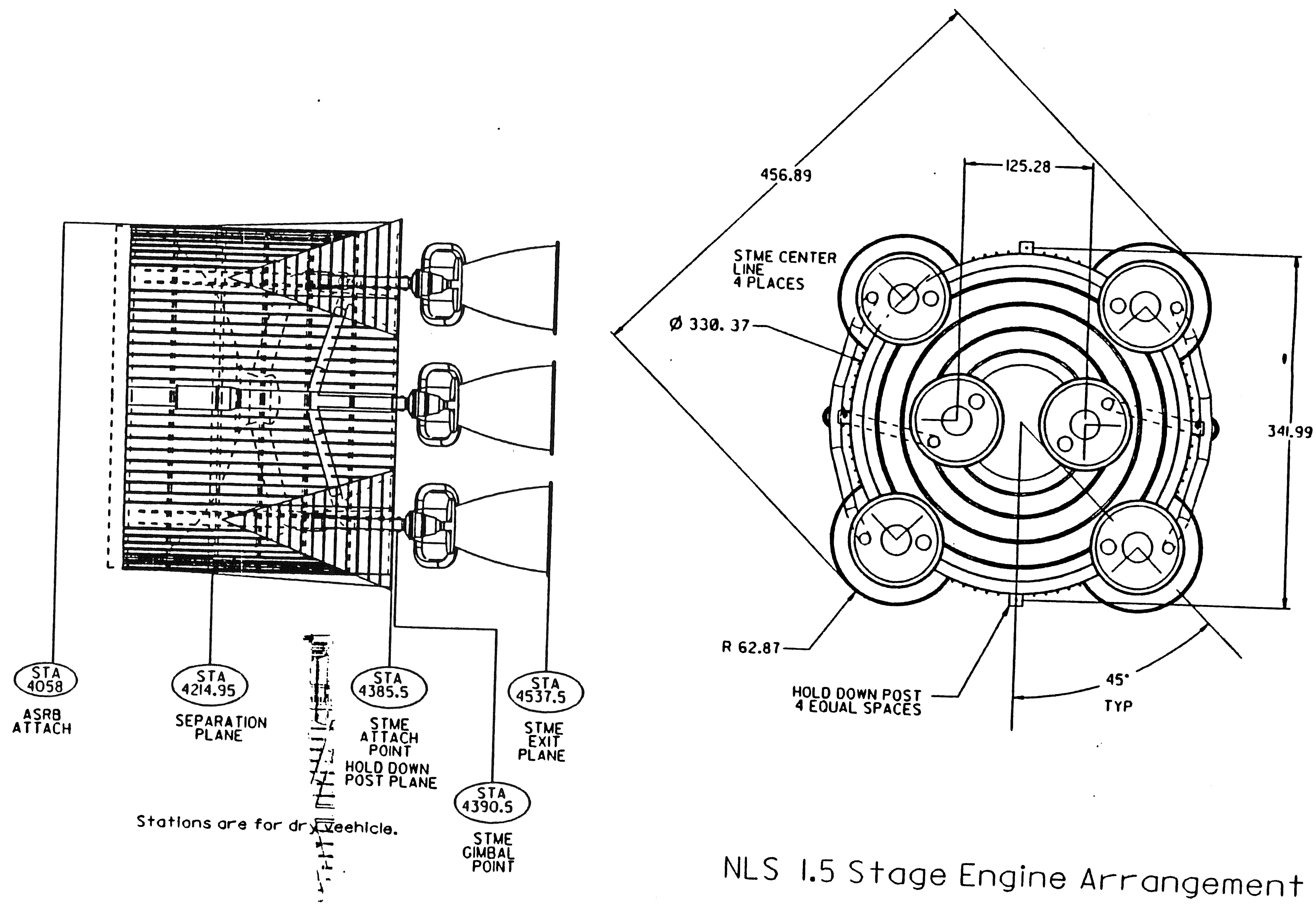
1.5 STAGE LOX FEED SYSTEM PROPELLANT WEIGHT ASSESSMENT

D.Davis EP55
10-2-91



1.5 STAGE LH2 FEED SYSTEM PROPELLANT WEIGHT ASSESSMENT

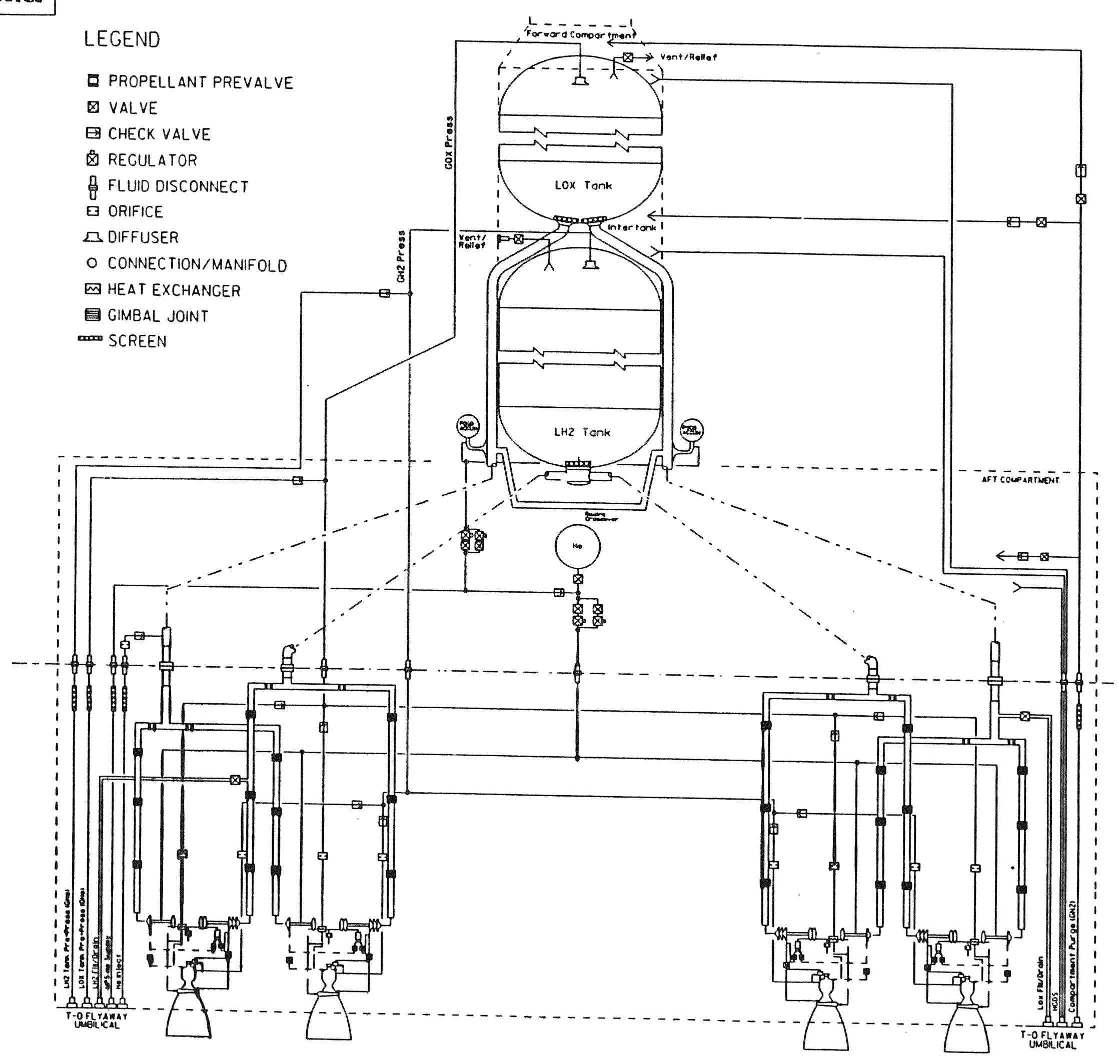
D.Davis EP55
9-18-91



NLS 1.5 Stage Engine Arrangement

9-17-91

Danny Davis EP55



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NLS MPS Schematic
HLLV Configuration

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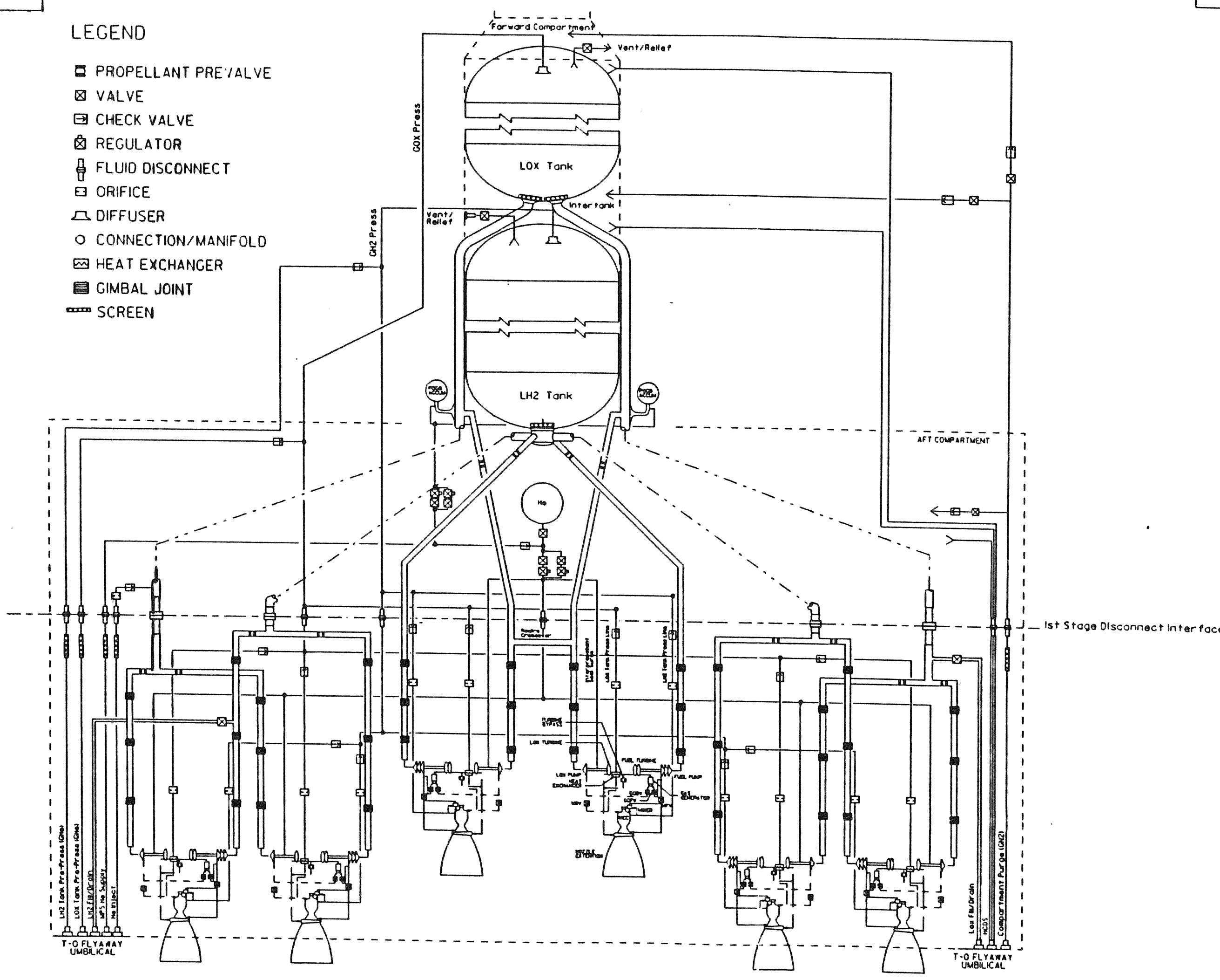

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NLS MPS Schematic
1.5 Stage Config. First Stage

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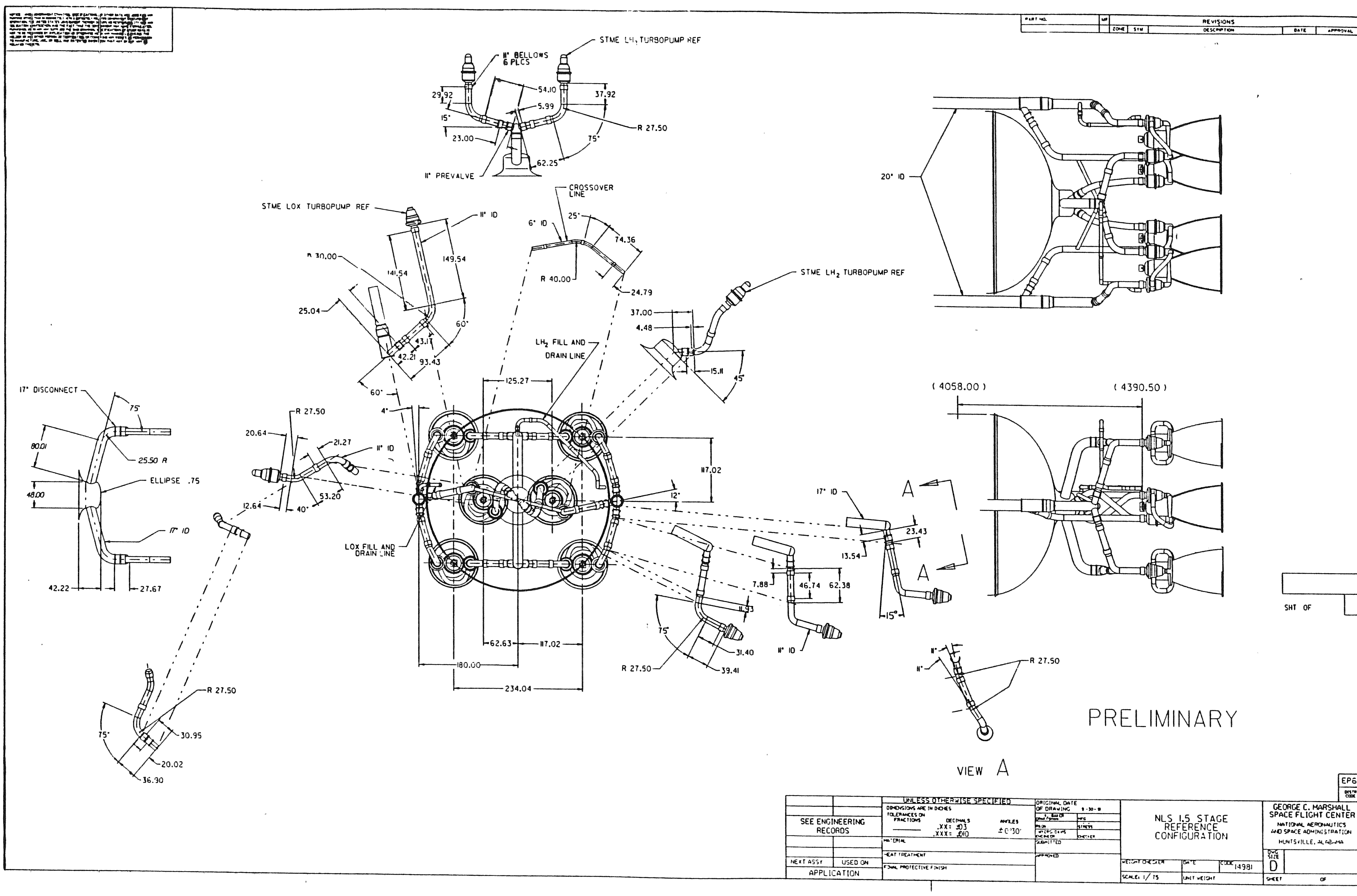
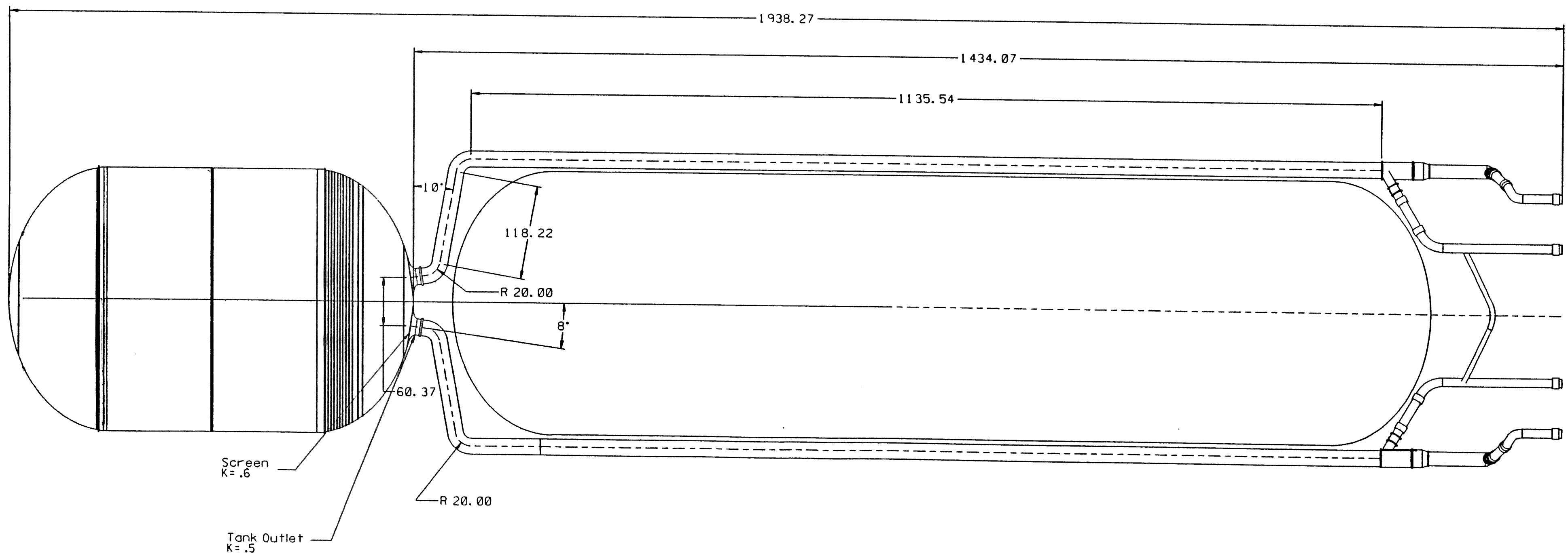


11" BELLOWS 6 PLCS
STME LH2 TURBOPUMP REF
11" PREVALVE
STME LOX TURBOPUMP REF
11" ID
CROSSOVER LINE
6" ID
STME LH2 TURBOPUMP REF
LH2 FILL AND DRAIN LINE
17" DISCONNECT
ELLIPSE .75
17" ID
LOX FILL AND DRAIN LINE
20" ID
(4058.00)
(4390.50)
SHT OF
PRELIMINARY
VIEW A
EP64
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
SEE ENGINEERING RECORDS
NEXT ASSY
USED ON
APPLICATION
MATERIAL
HEAT TREATMENT
FINAL PROTECTIVE FINISH
NLS 1.5 STAGE REFERENCE CONFIGURATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA
14981
D
SCALE: 1/15
REVISIONS


1938.27
1434.07
1135.54
10°
118.22
R 20.00
8°
60.37
Screen
K= .6
R 20.00
Tank Outlet
K= .5