140 C CONFIGURATION
TRAJECTORY NOM NO. 14414.1 (UNFAIRED)

<table>
<thead>
<tr>
<th>TPS</th>
<th>AREA</th>
<th>WT (LB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRSI</td>
<td>6,317</td>
<td>2,966</td>
</tr>
<tr>
<td>HRSI</td>
<td>5,134</td>
<td>7,951</td>
</tr>
<tr>
<td>RCC</td>
<td>409</td>
<td>3,023</td>
</tr>
</tbody>
</table>
| **TOTAL** | **11,860** | **15,984** *

LRSI - COATED SILICA
HRSI - COATED SILICA
RCC - REINFORCED CARBON-CARBON
SIP - NOMEX "E" FELT

* INCLUDES 2044-LB THERMAL SEALS, BULK INS.

Figure 6
LRSI AND HRSI JOINT

BOROSILICATE COATING
(ρ = 0.15 PSF)

HRSI TILE (LI-900 SILICA,
ρ = 9 ± 1 PCF)

0.035 MIN
0.065 MAX

0.50 ± 0.06

FILLER BAR
0.75 ± 0.03

0.06 ± 0.03

0.0075 RTV 560

ALUMINUM SKIN

STRAIN ISOLATOR PAD, NOMEX FELT TYPE "E",
STYLE 2352, NRB, 0.160 THICK

Figure 7
LEADING EDGE STRUCTURAL SUBSYSTEM

WING L.E. RCC PANELS
(22) LH (22) RH

RCC SEAL STRIPS
(22) LH (22) RH

TOTAL AREA - 409 FT²
TOTAL WEIGHT - 1609 LBS
TOTAL NUMBER PARTS - 95 RCC

Figure 8
VERTICAL TAIL
SPACE SHUTTLE ORBITER

INCONEL SANDWICH DESIGN

Figure 9
THERMAL SEAL CONCEPTS

ELEVON - WING

PAYLOAD BAY DOOR - FWD BULKHEAD

ELEVON - FUSELAGE

PAYLOAD BAY DOOR - UPPER CENTERLINE

Figure 10
TPS GEOMETRY TOLERANCE

TILE ORIENTATION & SIZE
- MAX ANGLE BETWEEN LOCAL FLOW & TILE GAPS (NO TILE GAP PARALLEL TO FLOW)
- TILE PLANFORM SIZE - SET BY STRESS REQMNTS

AIRSTREAM

0.050 ± 0.015

+0.010 TO +0.030
-0.010 TO -0.050

AL STRUCTURE

TILE INSTALN TOLERANCES INCREASE TOWARD TAIL & TOP OF ORBITER

WING LOWER SURFACE TILE GAP ORIENTATION

Figure 11
Figure 12
ORBITER ELECTRICAL POWER SUBSYSTEM

FUEL CELL POWER PLANT (FCP) - 3
2-KW MINIMUM 7-KW CONTINUOUS, 12-KW PEAK/FCP
15 MIN DURATION ONCE/THREE HOURS

POWER REACTANT STORAGE/DISTRIBUTION SUBSYSTEM
POWER GENERATION SUBSYSTEM

HYDROGEN DEWARS - 2
23.5 FT³ CAPACITY, 335 PSIA MAX PRESSURE

OXYGEN DEWARS - 2, 12.3 FT³ CAPACITY, 1050 PSIA MAX PRESSURE

FCP SUBSYSTEM
• 14-KW CONTINUOUS/24-KW PEAK
• 27.5 TO 32.5 VDC

REACTANT STORAGE
• 1530-KWH MISSION ENERGY
• 264-KWH ABORT/SURVIVAL ENERGY
• 112 LB O₂ FOR ECLSS
• 92 LB H₂/TANK
• 781 LB O₂/TANK

TOTAL LOADED QUANTITY

Figure 13
**TUBING**

- **MATERIAL**: 21-6-9 (MB0160-035)
- **QUANTITY**: 1570 FEET
- **SIZES O.D.**: 1/4", 3/8", 1/2", AND 5/8"
- **WALL SIZE**: .016

**JOINING METHODS**

- **PERMANENT BRAZE**
- **SEPARABLE FITTINGS**
  - DYNATUBE USED ON FC40 COOLANT, H₂O, O₂, & H₂
  - INDUCTION BRAZE
  - (TUBE END TO FITTING)

**TUBING End to Fitting**

**BRAZE**

- ROCKWELL
- INTERNATIONAL
- APOLLO

**DYNATUBE-RESISTOFLEX**

Figure 14
ELECTRICAL POWER SYSTEM
INSULATION

- LINE INSULATION

1. TUBING RUNS WILL BE INSULATED USING POLYURETHANE FOAM 1/2" THICK, ON PRSD ONLY

2. LINE HEATERS WILL REQUIRE WRAP WITH ALUMINIZED KAPTON TAPE, SPECIFICATION (TBD), ON PGS ONLY

Figure 15
AERU SURFACE CONTROLS

- PDR REVIEW INCLUDED:
  - LAYOUTS
  - ENVELOPE DRAWINGS
  - ICD'S
  - PROCUREMENT SPECIFICATIONS
  - DESIGN REQUIREMENTS
  - INSTALLATION/RIGGING
  - GSE
  - VERIFICATION PLANS
  - SCHEDULES

- TYPICAL ALL OPERATIONAL VEHICLES

Figure 16
ORBITER-ET SEPARATION SUBSYSTEM

Figure 17
CONTROLLER ORGANIZATION
AND REDUNDANCY

Figure 14
SSME HEAT EXCHANGER DETAILS

OXYGEN PRESSURIZATION SYSTEM

FLOW CONTROL SYSTEM

HEAT EXCHANGER TUBE ASSEMBLY

Figure 21
COMPARISON OF SATURN AND SHUTTLE STABILITY LOOPS

Figure 22
POGO SUPPRESSION ACCUMULATOR

FLOW

RECIRCULATION ISOLATION VALVE

GOX OVERFLOW LINE

FLOW

GOX INLET DIFFUSER

THERMAL BALL BLANKET

SURFACE TENSION SCREEN

Figure 24
EXTERNAL TANK

ET/ORBITER AFT ATTACH
ET/ORBITER FWD ATTACH
INTEGRAL STRINGERS
LO₂ SLOSH BAFFLES
LO₂ VENT VALVE & FAIRING
INTER-TANK
LO₂ TANK
LH₂ TANK VENT VALVES
LH₂ TANK
ET/SRB FWD ATTACH

PROPELLANT FEED, PRESSURIZATION LINES

DIAMETER = 331 IN.*
LENGTH = 1846 IN.
PROPELLANT WT = 1.55 x 10^6 LB
INERT WEIGHT = 76,365 LB

*WITHOUT EXTERNAL INSULATION

Figure 25
### LO₂ Tank Analysis

#### Critical Defects

<table>
<thead>
<tr>
<th>Weld</th>
<th>Weld Thickness, in.</th>
<th>Stress Direction</th>
<th>Stress, ksi</th>
<th>Stress Crack Depth, in.</th>
<th>Critical Crack Depth, in.</th>
<th>Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.120</td>
<td>Parallel</td>
<td>5.3</td>
<td>12.4</td>
<td>20.4</td>
<td>Leak</td>
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<tr>
<td>2</td>
<td>0.120</td>
<td>Parallel</td>
<td>2.7/11.6</td>
<td>40/2.5</td>
<td>28/0.75</td>
<td>Leak</td>
</tr>
<tr>
<td>3</td>
<td>0.210</td>
<td>Parallel</td>
<td>0.3/30.1</td>
<td>30/1.75</td>
<td>30/1.75</td>
<td>Leak</td>
</tr>
<tr>
<td>4</td>
<td>0.210</td>
<td>Parallel</td>
<td>11.6/9.1</td>
<td>25/4</td>
<td>25/4</td>
<td>Leak</td>
</tr>
<tr>
<td>5</td>
<td>0.210</td>
<td>Parallel</td>
<td>23/18.2</td>
<td>27/0.75</td>
<td>27/0.75</td>
<td>Leak</td>
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<tr>
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<td>0.210</td>
<td>Parallel</td>
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<td>0.75</td>
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<td>Parallel</td>
<td>18.6</td>
<td>0.75</td>
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<tr>
<td>8</td>
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<td>30.8</td>
<td>0.75</td>
<td>0.75</td>
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<tr>
<td>9</td>
<td>0.210</td>
<td>Parallel</td>
<td>48.3</td>
<td>1.1</td>
<td>1.1</td>
<td>Leak</td>
</tr>
<tr>
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<td>0.210</td>
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<td>5.3</td>
<td>2.5</td>
<td>2.5</td>
<td>Leak</td>
</tr>
</tbody>
</table>

#### LH₂ Tank Analysis

<table>
<thead>
<tr>
<th>Weld</th>
<th>Weld Thickness, in.</th>
<th>Stress Direction</th>
<th>Stress, ksi</th>
<th>Stress Crack Depth, in.</th>
<th>Critical Crack Depth, in.</th>
<th>Failure Mode</th>
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<td>1</td>
<td>0.186</td>
<td>Parallel</td>
<td>23.85</td>
<td>0.266</td>
<td>1.04</td>
<td>Leak</td>
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<td>2</td>
<td>0.175</td>
<td>Parallel</td>
<td>23.85</td>
<td>0.266</td>
<td>1.04</td>
<td>Leak</td>
</tr>
<tr>
<td>3</td>
<td>0.175</td>
<td>Parallel</td>
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<td>0.266</td>
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<td>Leak</td>
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<tr>
<td>4</td>
<td>0.175</td>
<td>Parallel</td>
<td>23.85</td>
<td>0.266</td>
<td>1.04</td>
<td>Leak</td>
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<tr>
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<td>0.175</td>
<td>Parallel</td>
<td>23.85</td>
<td>0.266</td>
<td>1.04</td>
<td>Leak</td>
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<td>Parallel</td>
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<td>0.266</td>
<td>1.04</td>
<td>Leak</td>
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<tr>
<td>7</td>
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<td>Parallel</td>
<td>23.85</td>
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<tr>
<td>10</td>
<td>0.175</td>
<td>Parallel</td>
<td>23.85</td>
<td>0.266</td>
<td>1.04</td>
<td>Leak</td>
</tr>
</tbody>
</table>

---

Figure 26
EXTERNAL TANK

TYPICAL MECHANICAL JOINT

Figure 27
External Tank Propulsion/Mechanical Subsystem LO₂ Propellant Feed

Figure 28
External Tank Propulsion/Mechanical Subsystem Separation Hardware

Figure 29
Figure 30

1. Heat input
2. Bubble formation
3. 
4. 
5. 
6. 
7. 
8. 
HELIUM INJECTION SYSTEM

Figure 31

<table>
<thead>
<tr>
<th>DESIGN FEATURE</th>
<th>INITIAL DESIGN CONCEPT</th>
<th>CURRENT DESIGN</th>
<th>RATIONALE</th>
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<tbody>
<tr>
<td>CHECK VALVES</td>
<td>2-SERIES</td>
<td>4-SERIES/PARALLEL</td>
<td>INCREASED RELIABILITY</td>
</tr>
<tr>
<td>LINE SIZE</td>
<td>1/4&quot;</td>
<td>3/8&quot;</td>
<td>MARGIN FOR GROWTH</td>
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<tr>
<td>FILTER</td>
<td>NONE</td>
<td>ONE</td>
<td>PROTECT CHECK VALVES</td>
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<tr>
<td>COMPONENT LOCATION</td>
<td>NOT DEFINED</td>
<td>INTERTANK</td>
<td>MINIMIZE EFFECT ON VENT VALVE OPERATION</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>8 LB</td>
<td>25 LB</td>
<td>MORE COMPONENTS</td>
</tr>
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</table>

VENT VALVE GHe ACTUATION LINE 1/4" DIA
GHe SUPPLY 3/8" DIA
LOCATED IN THE INTERTANK AREA

LOX Line
ANTI-GEYSER LINE (4" Dia.)
Figure 32

VEHICLE SIMULATION:
- VERTICAL LINE LENGTHS
- LINE DIAMETERS
- HEATING RATES
- TANK OUTLET HARDWARE
- LINE ORIENTATION ANGLES
POINT SENSOR PROPELLANT GAUGING SYSTEM
BASELINE CONFIGURATION

Figure 33
ET/ORBITER FWD STRUCTURAL ATTACH

- BOLT RETAINER
- BEARING CENTERING SPRING (2)
- STRUCT SUPPORT CHANNEL
- REMOVABLE TPS PANEL
- SEPARATION BOLT
- BOLT RETAINER
- SMSI CARTRIDGE
- A-FRAME

Figure 35
ET/ORBITER AFT INTERFACE STRUCTURE

Figure 36

CROSS BEAM

THRUST STRUTS

LO₂ FEEDLINE

LH₂ FEEDLINE

FORWARD
TYPICAL ET ENTRY TRAJECTORIES
FOR MISSION 3A

ENTRY CONDITIONS

1. $\alpha = -130^\circ$ PITCH RATE = 1.3°/SEC
2. $\alpha = -130^\circ$ PITCH RATE = 30°/SEC
3. $\alpha = 130^\circ$ PITCH RATE = -1.3°/SEC

Figure 38
ESTIMATED "FRISBEE" EFFECT ON ET ENTRY

DISPERSION AT 240,000 FT ALTITUDE, N. MI.

TOTAL

DOWN RANGE

UP RANGE

ET TUMBLE RATE, DEG/SEC

Figure 39
SOLID ROCKET BOOSTER

APPROXIMATE WEIGHTS & THRUST

<table>
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<tr>
<th>Item</th>
<th>Weight</th>
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<tbody>
<tr>
<td>GROSS WEIGHT</td>
<td>1,286,560 LB</td>
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<tr>
<td>INERT W</td>
<td>180,510 LB</td>
</tr>
<tr>
<td>THRUST (SL)</td>
<td>2.7M LB</td>
</tr>
</tbody>
</table>

4 SEPARATION MOTORS
20,000 LB THRUST EACH

4 SEPARATION MOTORS
20,000 LB THRUST EACH

DIMENSIONS
LENGTH ... 1790 IN.
DIA ... 146 IN.

Figure 40
Case Design Configuration

Figure 41
Figure 42
SRB/ET SEPARATION SYSTEM

FWD BSM ORIENTATION

INITIATE & CONTROL SEPARATION SEQUENCE

AFT BSM ORIENTATION

FWD STRUCTURAL ATTACHMENT

AFT STRUCTURAL ATTACHMENT ELECTRICAL UMBILICAL

Pc PRESSURE TRANSDUCER

4 BSM EACH SRB

4 BSM EACH SRB

Figure 43
Figure 44
SRB PDR
RECOVERY SUBSYSTEM

NOMINAL TRAJECTORY

APOGEE
h = 210K ft
q = 4 psf
t = 66 sec

HIGH ANGLE OF ATTACK REENTRY MODE
q max = 1160 psf
h = 54K ft
t = 174 sec

SEQUENCE INITIATION, NOSE CAP DEPLOYMENT
h = 19,000 ft
v = 558.3 ft/sec
q = 200.0 psf
t = 234 sec

SEPARATION
t = 0

DROGUE PACK DEPLOYMENT
h = 18,702 ft
v = 653.5 ft/sec
q = 198.8 psf

DROGUE CHUTE INFLATES TO 1ST REEFED CONDITION
h = 18,109 ft (81%)
v = 544.7 ft/sec
q = 196.8 psf

DROGUE CHUTE DISREEFS TO FULL INFLATION
h = 12,404 ft
v = 437.1 ft/sec
q = 155.7 psf
t = 248 sec.

Figure 45
SRB PDR
RECOVERY SUBSYSTEM

DROGUE CHUTE DEPLOYS AFT FRUSTUM WITH MAIN PACKS

FRUSTUM AND DROGUE IMPACT AT ≈ 60 FPS

h = 0212 ft
v = 375.7 ft/sec
q = 129.3 psf
t = 256 sec

MAIN CHUTES INFLATE TO 1ST REEVED CONDITION (15%)

h = 8860 ft
v = 399.8 ft/sec
q = 147.0 psf
t = 270 sec

MAIN CHUTES DISREEF AND INFLATE TO 2ND REEVED CONDITION (40%)

h = 4924 ft
v = 262.6 ft/sec
q = 66.55 psf
t = 270 sec

MAIN CHUTES DISREEF TO FULL INFLATION

h = 3452 ft
v = 153.2 ft/sec
q = 25.61 psf
t = 278 sec

NOZZLE JETTISON

h = 0.0 ft
v = 97.7 ft/sec
q = 11.35 psf
t = 311 sec

SRB WATER IMPACT
RANGE = 125 n. mi.
FOOTPRINT = 10X33 n. mi.
(both)
DETACH PARACHUTES AT IMPACT
DEPLOY TOWING PENDANT

Figure 45 (Concluded)
RECOVERY SYSTEM PACKAGING IN THE NOSE CONE

Figure 46
FIRST VERTICAL FLIGHT

SECOND FLIGHT

THIRD FLIGHT

FOURTH FLIGHT

FIFTH FLIGHT

SIXTH FLIGHT

Figure 47
HAZARD - PRESENCE OF POTENTIAL RISK SITUATION CAUSED BY UNSAFE ACT OR CONDITION (NHB 5300.4 (ID-1))

- HARDWARE FAILURE MODES (FMEA)
- CREDIBLE ACCIDENTS
- HAZARDOUS OPERATIONS OR PROCEDURES
- CREW OPERATIONS AND/OR PROCEDURES

POTENTIAL RISK
- CRITICAL
- CREDIBLE

LOSS OF PERSONNEL

GROUND PERSONNEL AND/OR PUBLIC

LOSS OF OR DAMAGE TO VEHICLE OR FACILITIES

HAZARD REDUCTION
- DESIGN FOR MINIMUM HAZARD
- SAFETY DEVICES
- WARNING DEVICES
- SPECIAL PROCEDURES

CONSIDERATIONS
- NO. SPECIFIC SIMULTANEOUS EVENTS REQUIRED
- TIME CRITICAL - NO TIME FOR CORRECTION
- EXPERIENCE-AIRCRAFT-SPACECRAFT
- TIME OF EXPOSURE

Figure 48
SHUTTLE AND ORBITER
RELIABILITY AND SAFETY ACTIVITIES

Figure 49
GROUND HAZARDOUS GAS DETECTION SYSTEM

SUMMARY

CONTINUOUS MONITORING

YOGENIC & HYPERGOLIC

LAUNCH PAD OP'S

ORBITER HGDS - PORTABLE & FACILITY BASED

SRB PERIODIC HYPERGOLIC PORTABLE

ORBITER HGDS - SELECTED COMPARTMENTS CONTINUOUS MONITORING FOR CRYOGENIC & HYPERGOLIC

GROUND TURNAROUND
- POSTLANDING
- MAINTENANCE

Figure 50
LANDING/DECELERATION
NOSE GEAR INSTALLATION

SECTION A-A
SECTION B-B

Figure 51
REDUNDANT CSC (Conical Shaped Charge)

RDX LSC ASSEMBLY

CABLING

INSULATION

SRM CASE

BASE PLATE

SAFE & ARM DEVICE

CDF MANIFOLD (Contained Detonating Fuse)

CDF ASSY

ELECTRICAL CABLES

Figure 53
MAJOR GROUND TEST PROGRAMS

ORBITER
- STATIC STRUCTURAL
  CREW MOD
- AIRFRAME

<table>
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<tr>
<th></th>
<th></th>
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<tr>
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<tr>
<td>FAB</td>
<td>TEST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- FLIGHT CONTROL
HYDRAULICS LAB

- HORIZ GND VIBR TEST

- AFT FUS VIBROACOUSTIC

- OMS & AFT RCS STATIC FIRING

- FWD RCS STATIC FIRING

CREW ESCAPE SYST
SLED TEST

(First Approach-Landing)
(First Manned Orbital Flight)

Figure 55
Figure 55 (Concluded)
SPACE SHUTTLE AVIONICS SYSTEMS

Figure 56

All these systems to be integrated and tested in the SAIL.
SRB/ET SEPARATION SYSTEM VERIFICATION LOGIC

QUALIFICATION
- FORWARD SEPARATION BOLT
- AFT SEPARATION BOLT
- ELECTRICAL UMBILICAL
- SRB PC TRANSDUCER
- BACKUP CUE ACCELEROMETER MANUAL SWITCH

PLANNED MAJOR TEST
- BSM FIRING BSM IGNITION SYSTEM
- SRM FIRING SRB PC TRANSDUCER SRB THRUST TAILOFF
- SRB STA FWD & AFT STRUCTURAL ATTACHMENTS

COMPONENT TEST
- VAL CHAMBER BSM FIRING BSM PLUME DAMAGE
- BSM IGNITION SYS ALT & BALLISTIC ENVIRONMENT
- SCALE MODEL WIND TUNNEL TEST AERO FORCES & MOMENTS
- STRUCT ATTACH PYRO TESTS FWD & AFT

OTHER
- SOFTWARE VERIF INITIATE & CONTROL SEP SEQUENCE
- COMPUTER SIMULATION SEPARATION DYNAMICS
- COMPUTER SIMULATION MATED FLIGHT CONTROL
- ANALYSIS MASS PROPERTIES

Figure 57
POGO SUPPRESSOR SYSTEM

GIMBAL JOINTS

VEHICLE LO₂ TANK PRESSURANT LINE

FLEX HOSES

GO₂ RECIRCULATION LINE

RECIRCULATION ISOLATION VALVE

GO₂ INLET DIFFUSER

GO₂ OVERFLOW LINE

ACCUMULATOR

PRESSURE TRANSDUCER

LOW PRESSURE OXIDIZER PUMP

HELIX SUPPLY LINE

FLEX HOSES

TO ENGINE PNEUMATIC PACKAGE

HIGH PRESSURE OXIDIZER PUMP

ENGINE LO₂ BLEED LINE

FROM ENGINE PNEUMATIC PACKAGE

GO₂ CONTROL PACKAGE

VENT

HELIX PRECHARGE CONTROL PACKAGE

LO₂ HEAT EXCHANGER ANTIFLOOD VALVE

HEAT EXCHANGER LO₂ DYPASS

HEAT EXCHANGER HOT GAS OUTLET

FAIL-SAFE ISOLATION SQUIB VALVE

BURST DIAPHRAGM

HEAT EXCHANGER

H.E.

LO₂

HIGH PRESSURE OXIDIZER PUMP

Figure 59
POGO INTEGRATION SYSTEM

- POGO INTEGRATION
- STABILITY ANALYSIS

JSC

ROCKWELL SD

POGO INTEGRATION PANEL

- ORBITER STRUCTURAL MODEL
- MATED STRUCTURAL MODEL
- FEEDLINE/SUPPRESSOR MODEL
- MPS POGO STABILITY ANALYSIS
- ORBITER GYBT
- N/GYBT
- MPT
- OMS POGO ANALYSIS
- DEVELOPMENT FLIGHT DATA ANALYSIS

MSFC

ROCKETDyne

MMC

THIOKOL

- SSME MODEL
- SSME TEST
- SUPPRESSOR DEV.

- ET HYDRO MODEL
- FEEDLINE MODEL

LANgLEY RESEARCH CENTER

- 1/6 SCALE VIBRATION TEST
- DYNAMIC FLOWMETER DEV.
- EARLY STABILITY STUDIES

LEWIS RESEARCH CENTER

- ACTIVE SUPPRESSOR TESTS
- ACTIVE SUPPRESSOR ANAL.

KENNEDY SPACE CENTER

- LAUNCH OPERATIONS

NASA HEADQUARTERS

- COORDINATION

Figure 60