FRACTURE CONTROL METHODS
FOR
SPACE VEHICLES

Volume III

Space Shuttle Configurations

By
A.F. Liu and E.J. Mulcahy

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Lewis Research Center
Contract NAS 3-16765
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Contract NAS3-16765
NASA Lewis Research Center
Cleveland, Ohio

August 1974
This volume contains Space Shuttle configuration drawings supplementary to the Space Shuttle structure described in Volume I.
FOREWORD

The work described in this report was performed by the Space Division of Rockwell International Corporation under Contract NAS3-16765, Fracture Control Methods for Space Shuttle Vehicles, for the Lewis Research Center of the National Aeronautics and Space Administration. The investigation was conducted under the technical direction of Mr. Gordon T. Smith of NASA/LeRC. The project study manager at the Space Division of Rockwell International Corporation was Mr. A.F. Liu, with Dr. Paul C. Paris of Del Research Corporation and Dr. Matthew Creager of Del West Associates, Inc., acting as primary technical consultants.

This report consists of three volumes:

Volume I. Fracture Control Design Methods (prepared by A.F. Liu)

Volume II. Assessment of Fracture Mechanics Technology for Space Shuttle Applications (prepared by R.M. Eh'et)

Volume III. Space Shuttle Configurations (prepared by A.F. Liu and E.J. Mulcahy)

Mr. James E. Collipriest, Jr., provided overall technical guidance in the preparation of Volume II. Mr. Edward J. Mulcahy and Mr. A.S. Musicman contributed significantly to the preparation of Section 1.1 (Space Shuttle Vehicle Structural Description) of Volume I. Mr. John Mamon and Mr. F. Stuckenber aid substantially in the preparation of the nondestructive evaluation sections in Volumes I and II. Mr. R.E. O'Brien and Mr. R.M. Ehret contributed, respectively, Section 2.2 (Prevention of Cracks and Crack-Like Defects in Shuttle Vehicle Structure) and Section 2.3.8 (Required Material Properties Data for Space Shuttle Fracture Mechanics Analysis) of Volume I. Dr. Matthew Creager contributed Section 2.3.6 (Failure Under Complex Loading Conditions) and Section 2.3.7.4 (Damage Tolerance Analysis for Pressure Vessels of Volume I and Section 2.2 (Thin Sheet Behavior) and a discussion of fracture behavior under combined in-plane loading in Section 1.2 (Linear Elastic Concepts of Fracture Behavior) of Volume II.

Mr. R.W. Westrup prepared the original proposal response to the RFP and established the basic framework for the study program. The managerial guidance provided by Mr. R.P. Olsen, Engineering Manager, Materials and Processes, Space Division, is acknowledged by the authors.
This volume consists of the preliminary design drawings for the Space Shuttle vehicle structural components. The drawings represent the preliminary design configurations as of (on or before) June 1973.

Figures 1.1.1 to 1.1.4 present the general configuration and locations for major structural components. Figures 1.2.1 to 1.2.3 illustrate the structural parts for the solid rocket booster, and Figure 1.3.1 represents the external tank.

The Space Shuttle orbiter is conveniently divided into six component assemblies:

1. Mid fuselage (Figures 1.4.1 to 1.4.12)
2. Wing (Figures 1.5.1 to 1.5.4)
3. Forward fuselage and crew compartment (Figures 1.6.1 and 1.6.2)
4. Aft fuselage (Figures 1.7.1 to 1.7.5)
5. Vertical stabilizer (Figures 1.8.1 to 1.8.4)
6. Landing gear (Figures 1.9.1 and 1.9.2)

The maintenance accesses are shown in Figures 1.10.1 to 1.10.5.
ILLUSTRATIONS

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America's Space Shuttle transportation system is paramount in furthering this country's knowledge—bringing our tremendous advancements in space sciences back to Earth as direct benefits.

The Shuttle orbiter—the delta-winged flying machine about the size of a medium-range jet—reusable, cargo-carrying, space airplane with workhorse capabilities. Each Shuttle orbiter can fly...
of 100 missions and can carry to orbit as much as 85,000 pounds of payload and up to four crew members and six passengers. It can return 25,000 pounds of payload to Earth.

Rockwell International Corporation's Space Division is integrating the system and developing the Shuttle's payload-carrying orbiter stage under contract to the National Aeronautics and Space Administration.

Figure 1.1.1. Space Shuttle System

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**Orbiter Mid Fuselage**

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Reproducibility of the original page is poor.
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**REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR**

Figure 1.1.2: Space St
VIEW D-D

VIEW C-C

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
VIEW CREW MODULE LOOKING AFT

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Figure 1.1.3.
Figure 1.1.3. Space Shuttle System.
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

VIEW: SRM CASE TO FWD. STRUCT. JOINT
SCALE = 1/2
END VIEW
LOOKING AFT W/O NOSE CONE

DOME ET. LG

DROGUE PARACHUTE RISER
ATTACHMENT
DISCONNECT, 2 REDUNDANT

MAIN PARACHUTE RISER
ATTACHMENT
DISCONNECT, 2 REDUNDANT
TOW LINE ATTACHMENT
(SWIMMER ATTACH)

AVIONICS
- ANTENNA (2)
- MALFUNCTION DETECT SENSORS (2)
- FLASHING LIGHT (2)
- BEACON (2)
- BEACON/FLASHING LIGHT (2)
- BATTERIES (2)

SCALE: NUMERICALLY 1" = 100 INCHES

MAIN PARACHUTE INSTR.
- PARACHUTE PACK, 6 CHUTES
70 FT. DIA., RIBBON TYPE
- RECOVERY CUTTERS
- 2 F. 1St. STAGE, 2 F. 2Nd. STAGE
- FLOATATION BAG
- BATTERY, FLASHLIGHT (4WB/2)
- BASED ON A WT. 160 LBS., 80 MPH

RECOVERY RISER (HOSE LONE RISER ATTACH)
RECOVERY CONTINGENCY

- DROGUE CHUTE INSTR.
- LANDING & PENETRATION BAG, RIBBON TYPE
- RECOVERY CUTTERS, 2 RECOVERY, 2 PENETRATION
- EJECTION BAG, BATTERY
- FLASHLIGHT, (4WB/2)

BOOSTER RECOVERY INSTR.
- SEQUENCER
- BATTERY
- FLASHLIGHT (4WB/2)

FLIGHT RECORDER
(SWIMMER HOLDS)

SEPARATION RETRIEVE
(NOSE CONE)

EJECTION BAG
(DROGUE CHUTE)

FLOATATION BAG
(SWIMMER HOLDS)

DOME CASE

410 SRM CASE (L/TYP.)
VIEW, SCALE 1:40

VI CASE

1358.5 (DOME TO DOME, SRM)

300 300

CENTER GRAIN SEGMENT NO. 2  CENTER GRAIN SEGMENT NO. 3

AFT

142.3 DIA.

ID ROCKET BOOSTER

SIDE VIEW, SCALE 1:40

REPRODUCIBILITY OF THIS ORIGINAL PAGE IS POOR
Figure 1.2.1. Solid Rocket Motor Assembly
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
Figure 1.2.2. Solid Rocket Motor Forward Skirt
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
MANUFACTURING SPICE

150 REF.
TYPE PLACES

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

1358.5 REF.
(DOME TO DOME)
0° NULL POSITION

±8° GIMBAL (SQUARE PATTERN)
(8° INCLUDES 0.4° OVERTRAVE AND 0.5° ALIGNMENT)
DETAIL A
SCALE 1/8
TYP FWD END

OUT FRAME
REQUIREMENTS
1. WEIGHT MARGIN INCLUDED IN CONTROL WEIGHT 2% ON SRM INERT WEIGHT
2. NOZZLE CANT ANGLE = ZERO
3. NOZZLE EXPANSION RATIO 7:1 CONTOURED; T/W AT LIFTOFF = 1.5
4. IS VAC = 266.3 SEC INITIAL NOZZLE EROSION EFFECT TO BE INCLUDED
5. NOZZLE PL = 737 PSI; 360° F. GRAIN TEMPERATURE AND MEOP = 900 PSI
6. MACHINED SURFACES:
   CASE 425
   CLEVIS 63
   O-RING SURFACES & GROOVES 32

Figure 1.2.3, Solid Rocket Motor Case
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

SKIN THICKNESS DIAGRAM
THREE DOTS SHOWN IS TOLERANCE 2.005

SECTION L-L
SCALE: 1/40
AFT DOME - LO2 TANK

AMF
SECTION J-J SCALE: 1/10

DETAIL A
SCALE: 1/4

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

VL78-000024 A
Figure 1.3.1. External Tank Structural Assembly
Figure 1.4.1. Mid Fuselage Structure
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
### NOTES

1. MACHINED LANDS WILL EXIST AT EACH FRAME.

2. SKIN THICKNESSES VARY ON EACH INDIVIDUAL SKIN PANEL

3. ALL DOORS ARE INTEGRALLY STIFFENED DETAILS.

4. ALL SKINS ARE FLAT PANELS

5. ALL STRINGERS ARE TEES AND SPACED AT APPROX 3.25 INCHES

6. ACCESS DOOR AT L. 050 X 1.230 WILL NOT REQUIRE MACHINED RECESSES ON OUTSIDE OF SKIN.
Figure 1.4.3. Mid Fuselage Side Panels
Figure 1.4.4. Mid Fuselage Lower Aft Longeron
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

DIVER C

SECTION 11-11
SCALE 1:10

DOWT FRAME
Figure 1.4.5. Mid Fuselage Lower Aft Longeron
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
1.4.6. Mid Fuselage Lower Aft Skin Panels

NOTES:

1. MACHINED LINES ARE SILL 81 FT AFTER HINGE 31SQ. IN. CIRC. ON OLD
   TAILBLACK
2. SKIN THICKNESSES VARY ON EACH INDIVIDUAL SKIN PANEL
3. ALL SKINS ARE 120 CONTROLED
   COUNTERS
4. ALL OGS ARE 700-1000-700-1000
   SIRED FOR INCLINED SKP

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REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.
Figure 1.4.7. Mid Fuselage Wing Carry-Through
Mid Fuselage Wing Carry-Through Torque Box
PLAN VIEW
SCALE 1:20

OUT FRAME
NOTES:

1. MACHINED LANDS WILL EXIST AT EACH FRAME, SKIN STIFFENER AND BULKHEAD.
2. SKIN THICKNESSES VARY ON EACH INDIVIDUAL SKIN PANEL.
3. ALL SKINS ARE COMPOUND CONTOURED.
4. ALL STIFFENERS ARE TEE AND ARE SPACED 3.25 INCHES APART.

Figure 1.4.8. Mid Fuselage Lower Skin Panels
SECTION C - C
SCALE 1/4

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
Figure 1.4.9. Mid Fuselage Lower Skin Panels
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
Figure 1.4.12. Mid Fuselage Payload Bay Doors
Figure 1.5.1. Wing Structure Subsystem Structural Arrangement
Figure 1.5.2. Wing Assembly Rib Construction
Figure 1.5.3. Wing Assembly Spar Construction
Figure 1.5.4. Elevon Assembly Construction
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

SECTION G - G
STA. 2800

UPPER FUSELAGE STRUCTURE

VIEW K
SCALE 1/1
"Typ for all frames except bounds."
SECTION E - E
STA 4420

SECTION C - C
STA 372.0
SECTION B - B
STA 5040
Notes:

- Crew compartment is floating and is supported at STA 372 and loads are carried on Z axis only. Loads at STA 576 are carried on X and Z axis only. Loads at spread tie X and Y axis only.

- Outer shell is supported by links at STA's 4020, 4420, 4760, 5040 and 5420.

- All flight loads are carried through outer shell only, except loads on Y axis are carried jointly by both structures (cabin and fuselage structure - outer shell).

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Figure 1.6.1. Forward Fuselage Structure

Reproducibility of the original page is poor.
REQUIREMENTS & ASSUMPTIONS
1. LINES PER VLT 70-000-4645
2. INTERIOR ARRANGEMENT PER VLT 70-000-4651

OUTFRAME

INERTIAL

PAYERLOAD

HATCH

PAYLOAD

CABIN AFT BULKHEAD

TYPICAL CABIN FRAME

Figure 1.6.2. Cabin Structure
Figure 1.7.1. Aft Fuselage Structural Arrangement
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
VIEW A-A

SECT D-D

TITANIUM-BORON EPOXY

SECT E-E

TITANIUM-BORON EPOXY

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

T FRAME
Figure 1.7.3. Main Engine Thrust Support Structure

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.
TYPICAL TRUSS MEMBER
BAL. 4V DIFFUSION BOUND-
STAINLESS BORON/EPoxy
TAPES APPLIED TO 4 VR
SURFACES. ONE POLY-
MECHANICALLY FASTENED.

REPRODUCIBILITY OF THIS
ORIGINAL PAGE IS POOR

SECTION C-C

VL70-0.5593 SH.3
Figure 1.7.5. Main Engine Thrust Support Structure
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
Figure 1.8.1 Vertical Stabilizer Fin Assembly
Figure 1.8.2. Vertical Stabilizer Leading Edge Assembly
Figure 1.8.3. Vertical Stabilizer Rudder Assembly
REPENRUCIBILITY OF THE ORIGINAL PAGE IS POOR
Figure 1.9.1. Main Landing Gear
PRESS PORT

ELECTRICAL SUPPORT BOSS
RING PIN NER

HYD & ELECT BRKT SUPPORT BOSS

OUTER CYLINDER

POWER STEERING WITH 5' MAX OVER TRAVEL

5.5' MAX TRAVEL FOR UNLOCKING

LOCK PIN

STEERING COLLAR
- OUTER CYLINDER

MOUNTING SLOTS FOR SENSOR MECH

PISTON PEG SENSOR
MECH REF

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

EXTENDED POS

SECTION F-F
Figure 1.9.2. Nose Landing
Figure 1.9.2. Nose Landing Gear
Figure 1.10.1. Shuttle Area Zone Breakdown
Figure 1.10.2. Shuttle Maintenance Access
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

VIEW LOOKING FWD AT BLKHD STA X, 1307

FOLDOUT FRAME
Figure 1.10.4. Shuttle Maintenance Access
Figure 1, 10.5. Shuttle Maintenance
10.5. Shuttle Maintenance Access