NOTICE

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SPACE FABRICATION DEPARTMENT SYSTEM

QUARTERLY PROGRESS REPORT NO.2

May 17, 1977 - August 26, 1977

NASA/MSFC Contract NAS 8-32472
The Space Fabrication Demonstration System (SFDS) program concluded its second contract quarter year with a quarterly review meeting held at NASA-MSFC on 26 August 1977. This quarterly progress report as agreed upon by NASA-MSFC is comprised of the data presented at this meeting, enclosure (1), supplemented by our previous monthly progress letters, references (a) and (b).

During discussions held with NASA-MSFC in preparation for this quarterly review it was agreed to substitute incremental critical design reviews for the one CDR which was to be held at this time in order to permit continued sequential subsystem design concurrence to occur without impacting the SFDS subsystem assembly and test schedule. These are indicated on Figure 1.

Action items resulting from these meetings still be to satisfied are:

0 Grumman will study the required SFDS assembly alignment tolerances and include these on the final assembly drawing.

0 NASA-MSFC will furnish Grumman with test data on a pin-ended beam test similar to that performed by Grumman for a fixed-ended beam in association with this program.
DISCUSSION

WBS 1.1 PROGRAM MANAGEMENT

Continued detailed review of tasks committed versus tasks completed to date have kept the SFDS program essentially on schedule. Figure 1 - SFDS Master Program Schedule, shows our progress as marked to reflect percent task completion, as applicable. Deviations from and changes made to the schedule are noted below.

WBS 1.2 DESIGN and DEVELOPMENT

1.2.1 Structural Member Development

Process definition includes final selection of recommended thermal coating for the structural truss. Various alternate finishes are still being examined.

Detail truss design and analysis is complete except for completion of the final memo report with conclusions and recommendations for future action.

The material for manufacture of the truss for the truss/joint tolerance tests has been received. The schedule has been updated to reflect the expected test plan and test completion dates.

Data associated with verification of the design of the basic "building block" truss for this reporting period are included in enclosure (1).

1.2.2 Fabrication Facility Design

The schedule has been revised to reflect the completion of detail, dimensioned design layouts of each subsystem. This was done to comply with the agreement reached with NASA-MSFC that Grumman would furnish these for each incremental critical design review in lieu of the design layout drawings we had originally anticipated furnishing.

The configuration layout will be completed upon finalization of each subsystem design layout.

The schedule for the roll forming subsystem has been extended to include completion of the detail design of the rolling mill drive, cap stock feed encoder mounting and cap stock supply reel design. NASA-MSFC has requested that consideration be given to have one of the supply reels include not only simple reload capability but also a self-threading feature to demonstrate how this might be accomplished on a space flight article being used to fabricate large space structure building block trusses.
The schedule for the magazine and dispensing subsystem has been extended to include design consideration of simple cross-brace reloading capabilities for one magazine/dispensing subsystem to demonstrate long range space structure fabrication application has been implemented at the request of NASA-MSFC. Though concurrence with this design is not expected until December, critical long lead items have been released for request for quote in order to expedite purchase, receipt of components, detail parts manufacture and subassembly.

The weld process subsystem detail design completion date has been extended to accommodate the inclusion of six transformers and their related cabling as requested by NASA-MSFC rather than the one transformer originally contemplated. This was done in order to provide a closer match to the SST/payload power supply capabilities. Also included in this schedule extension is the completion of the diagonal brace weld/clamp mechanism.

A mock-up of the truss cut-off has been built and tested. Detail design has been initiated. With completion in October and release to the shop at that time it is expected that detail parts fabrication will be completed on time.

Development testing remains an open item. It will remain so until all subsystem detail designs have been completed and the need for construction of subsystem mock-ups or concept verification tests have been satisfied. Determination of series spotweld electrode life continues.

It is anticipated that the above schedule changes will not impact the overall delivery schedule of the SFDS.

WBS 1.3 FABRICATION and ASSEMBLY

1.3.1 Detailed Parts

Fabrication of detail parts for the roll forming mill continues at the Yoder company. Assembly and test of these subsystem components is anticipated next month.

The magazine and dispensing subsystem components are being held-up pending completion of the detail design layout completion.

1.3.2 Assembly

Composite development forming tests have been completed within the scope of effort defined for this program. Conclusions and recommendations for further in-house development efforts have been generated and are being submitted for corporate management approval.
WBS 1.4 TEST

No tests associated with the final products, the structural member or fabrication facility, were performed during this reporting period.

WBS 1.5 FLIGHT DEMONSTRATION PLANNING

The preliminary Flight Demonstration Program Plan, Cost and Schedule were completed and submitted to NASA-MSFC during this reporting period. We are waiting for comments and/or questions from NASA-MSFC before proceeding with updating materials contained within the report in preparation for the final plan.

CONCLUSION

Satisfactory progress has been accomplished during this reporting period.

Face to face discussion with NASA-MSFC helped to understand their concept of the type and nature of documentation they desired before concurring on developmental subsystem detail design.

RECOMMENDATIONS

Continued close management surveillance by NASA-MSFC and Grumman program management personnel.

Implementation of monthly or bi-monthly meetings for face to face discussions to keep all parties knowledgeable of what is being provided and what is expected so that no further uncertainties may develop.

Should you have any questions or comments with regard to the above or the enclosed, please contact us.

Very truly yours,

GRUMMAN AEROSPACE CORPORATION

Walter K. Muench
SFDS Program Manager

WKM:dm
cc: Distribution NASA-MSFC
    Distribution Grumman
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#### Project Milestones
- **NASA/MSFC Reviews**
- **Grumman Mgmt Qtrly Review**
- **Monthly Reports**
- **Quarterly Reports**

#### WBS Level

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#### Milestones
- **TRUSS DESIGN REQMTS DEFINITION WBS 1 2 1**
- **MATERIALS EVAL/SELECTION WBS 1 2 1 2**
- **PROCESS DEFINITION WBS 1 2 1 3**
- **DETAILED TRUSS DESIGN & ANAL WBS 1 2 1 4**
- **TRUSS JOINT TOL DEVEL TEST PLAN WBS 1 2 1 5**
- **TRUSS JOINT TOL Tests WBS 1 2 1 6**
- **SYSTEMS DEFINITION WBS 1 2 2 1**
- **CONFIG LAYOUT WBS 1 2 2 2**
- **ROLL FORMING SUBSYS WBS 1 2 2 3**
- **MAG/DISP SUBSYS WBS 1 2 2 4**
- **WELD PROCESSING COMP WBS 1 2 2 5**
- **CONTROL COMP WBS 1 2 2 6**
- **TRUSS CUTOFF & SUPPORT SUBSYS WBS 1 2 2 7**
- **DESIGN DEVEL TESTING WBS 1 2 2 8**
- **SYSTEMS DEBUGGING WBS 1 4 1 1**
- **ESTABLISH OPERATING PARAMETERS WBS 1 4 1 2**
- **PRODUCE TRUSS IF FINAL ACCEPTANCE TEST WBS 1 4 1 3**
- **STRUCT MEMBER TEST WBS 1 4 2 1**
- **EVAL TEST RESULTS WBS 1 4 2 2**
- **NONDESTRUCTIVE TESTS WBS 1 4 2 3**
- **DEVELOP MTO DEMO PLAN WBS 1 5 1 1**
- **DEVELOP DETAILED ESTIMATE REQMTS WBS 1 5 1 2**
- **DEVELOP COST ESTIMATES WBS 1 5 1 3**
- **DEVELOP MTO DEMO SCHED WBS 1 5 2 1**

**Figure 1**
### SFDS MASTER PROGRAM SCHEDULE

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- OTRLY
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- BPA FINAL ACCEPTANCE
- CUSTOMER ACCEPTANCE REVIEW
- DELIVER SFDS AT MSFC

#### WBS ITEM

1.1 PROGRAM MANAGEMENT
1.2 DESIGN & DEVELOPMENT
   1.2.1 STRUCTURAL MEMBER
   1.2.2 FABRICATION FACILITY
1.3 FABRICATION & ASSEMBLY
1.4 PRODUCT ASSURANCE TESTS
   1.4.1 FABRICATION FACILITY
   1.4.2 STRUCTURAL MEMBER
1.5 FLIGHT DEMO PLAN

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2105-010W
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STRUCTURAL DESIGN CONDITIONS ONE METER DEEP BEAM

DESIGN CONDITION I – FABRICATION IN ORBITER PAYLOAD BAY
- ORBIT 215 NM 28.5° INCLINATION
- CRITICAL LOAD COND: ORBITER RCS THRUSTER FIRING
- THERMAL CONDITION: ORBITER +Y AXIS EARTH POINTING

DESIGN CONDITION II – SATELLITE SOLAR POWER SYSTEM (SSPS)
- ORBIT: GEOSYNCHRONOUS, SUN ORIENTED
- CRITICAL LOAD COND: STATION KEEPING MANEUVER
- THERMAL COND: SOLAR ARRAY – SUN POINTING
- MW ANTENNA – EARTH POINTING
DESIGN CONDITION I – BEAM FABRICATION IN ORBITER PAYLOAD BAY

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ROLL \( \phi \)  
PITCH \( \theta \)  
YAW \( \psi \)  

ULTIMATE FACTOR OF SAFETY 1.40  
\( \ddot{\phi} = 1.5 \, \text{SEC/SEC}^2 \) USED TO DESIGN BEAM
"BUILDING BLOCK" TRUSS – ONE METER DEPTH
ULTIMATE BENDING MOMENT AT POINT A VS BEAM LENGTH RCS FIRING

MOMENT NM

LENGTH METERS
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<td>TEMP LIMIT, °F</td>
<td>350</td>
<td>360</td>
<td>440</td>
</tr>
<tr>
<td>HANDLING QUALITY DURING FAB</td>
<td>GOOD</td>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>THERMAL COATING</td>
<td>FAIR</td>
<td>EXCELLENT</td>
<td>EXCELLENT</td>
</tr>
<tr>
<td>JOINTING</td>
<td>APPLY COATING TO BASIC MATERIAL IN GRD PROCESS, MUST BE REMOVED FOR JOINING</td>
<td>INCORPORATED INTO RESIN MATERIAL DURING PROCESSING GROUND</td>
<td>INCORPORATED INTO RESIN MATERIAL DURING PROCESSING GROUND</td>
</tr>
<tr>
<td>UV DEGRADATION STATE-OF-THE-ART OF APPLICATION</td>
<td>EXCELLENT</td>
<td>POOR BONDING REQUIRES MELT &amp; CURE</td>
<td>VERY GOOD ULTRASONIC WELD GIVES GOOD SIMPLE ATTACHMENT</td>
</tr>
</tbody>
</table>

*PROPERTIES OF 2024-T3 AND 6061-T6 APPROXIMATELY THE SAME
CANDIDATE THERMAL COATINGS

- **BLACK ANODIZE MIL A-8625**
  - ELECTROLYTICALLY PRODUCED DYED OXIDE COATING
  - THICKNESS .01 TO .1 MILS
  - ABSORPTION TO EMITTANCE RATIO < 1.00

- **SPRAY PAINTS**
  - POLYURETHANE
  - FLUOROCARBON
  - THICKNESS APPROX .8 TO 1 MIL
  - $\alpha = .96, \epsilon = .91$
BEAM ORBITAL ORIENTATION

SOLAR VECTOR

\( \eta = 180^\circ \)

\( \eta = 270^\circ \)

\( \eta = 0^\circ \)
TEMPERATURE DATA $\theta = 180^\circ$

$T_{III} = 78.8^\circ F$

$\alpha_s/\epsilon = .86/.83$

$\theta = 180^\circ$

$\Delta T_{MAX} = T_I - T_{II} = 10.7^\circ F$

$\Delta T_{MAX} = 102 - 52 = 50^\circ F$
\[ \Delta T = 49.1^\circ F \]
\[ \tau = 99.7^\circ F \]
\[ \Delta T = 12.8^\circ F \]
\[ \Delta T_{AV} = 44.2^\circ F \]
\[ \frac{\Delta T}{\tau} = 110.9^\circ F \]

\[ \alpha_{\frac{\Delta T}{\tau}} = 0.86183 \]

**ORBITAL TEMPERATURE RESPONSE**

**SUN VECTOR**

**180°**

**VELOCITY VECTOR**

**MAX TEMP DIFFERENCE INTRANGLE BETWEEN TRIANGLES AREA WEIGHTED**

**BLACK ANODIZE**

**EARTH**
SOLAR BLOCKAGE GEOMETRY

Blockage lasts for 6.1\degree of travel and 95 seconds of time.

Solar rays end of blockage

Solar rays start of blockage

\Delta T = 31\degree F

Direction of motion

w = 3.9\text{ in/min}
DESIGN CONDITION I

- THERMAL STRESSES
- FREQUENCIES AND MODE SHAPES
THERMAL STRESS IN CAP MEMBER DUE TO THERMAL GRADIENT (TEMP, DATUM ASSUMED, 0°F, UNRESTRANDED)

STRESS PSI X 10^2
TEMP OF X 10

1 METER TRUSS
CROSS SECTION WEIGHTED AVER, TEMPERATURE 79.02°F

TEMPERATURE

TENSION

COMPR

STRESS

SUN

2105-86W

20
THERMAL STRESS IN CAP 1 METER TRUSS

+497 PSI (PEAK TENS)

-493 PSI (PEAK COMPR.)

TENSION

COMPRESSION

SUN (NOT TO SCALE)
THERMAL STRESS IN CAP MEMBER (1 1/2M LENGTH) DUE TO THERMAL GRADIENT, FULLY RESTRAINED IN ROTATION ABOUT Y AND Z AXES
DESIGN CONDITION II

- LOADS DATA
- TEMPERATURE DATA
MAXIMUM APPLIED THRUSTER FORCES INCREASED BY DYNAMIC
MAGNIFICATION FACTOR = 2.0, FACTOR OF SAFETY = 1.40
DEFLECTED SHAPE DUE TO TIP LOAD-STRUCTURAL
MODEL

PEAK MEMBER LOAD = -3630 N ULTIMATE
SOLAR REFLECTOR PRELOAD REQUIREMENTS

- REFLECTOR PRELOAD IS SIGNIFICANT DRIVER FOR BEAM DESIGN

- PRELOAD EVALUATED FOR:
  - THERMAL EXCURSIONS
  - SOLAR RADIATION PRESSURE
  - ROTATIONAL ACCELERATIONS
  - NATURAL FREQUENCY
SSPS STEADY STATE TEMPERATURE DISTRIBUTION
FULL SUN
DESIGN CONDITION II

SSPS 1M X 40M BEAM CRITICAL CAP LOAD FUNCTION OF FOLLOWING:

- AXIAL LOAD DUE TO BENDING – STATIONKEEPING
- REFLECTOR PRELOAD
- MANUFACTURING MISALIGNMENT OF 20M X 493M BEAM
- THERMAL GRADIENT/DEFLECTION OF 20M X 493M BEAM
- MANUFACTURING MISALIGNMENT OF THE 1M X 40M BEAM
- THERMAL GRADIENT/DEFLECTION OF THE 1M X 40M BEAM
DESIGN LOADING CONDITION
20M X 493M BEAM

P = 3530 N
W = 1.21 N/m

P

1m BEAM

T1

T2

C0

LIMIT
BENDING MOMENT DUE TO COMBINED LOADS AND INITIAL DEFL 20M X 493M BEAM

BENDING MOM 10^4 NM ULT

C₀ INITIAL DEFL METERS

P = 3530N

W = 1.21 N/M

ΔT°F

2105-083W
BENDING MOMENT DUE TO COMBINED LOADS AND INITIAL DEFL 1M X 40M BEAM

\[ P = 412.5 \text{ LBS LIM} \]
BEAM FAILURE MODES

- 40 M EULER INSTABILITY
- CAP LOCAL CRIPPLING
- 1/2 M CAP TORSION/FLEXURE INSTABILITY
OVERALL STABILITY OF 1M X 40M BEAM

BUCKLING MODE $P_{CR} = 17405N$
(AXIAL PLUS LATERAL)

BUCKLING MODE $P_{CR} = 17405N$
(AXIAL LOAD ONLY)

1M X 40M STRUCTURAL MODEL
(1/2 LENGTH)
MAXIMUM BEAM CAP STRESSES
1M X 40M BEAM

- DESIGN CONDITION I:
  - COMPRESSION STRESS
  - APPLIED LOADS 2506 PSI
  - THERMAL GRADIENT 680 PSI
  TOTAL 3186 PSI

- DESIGN CONDITION II (SSPS):
  - COMPRESSION STRESS
  - APPLIED LOADS 2272 PSI
  - THERMAL GRADIENT 680 PSI
  TOTAL 2962 PSI

- ALLOWABLE AVERAGE COMPR STRESS
  BASED ON STATIC TEST 4421 PSI
ALLOWABLE MANUFACTURING MISALIGNMENT

1M X 40M BEAM

DESIGN CONDITION II:

ULTIMATE CAP LOAD: -856N (-192.5 LBS)
ALLOWABLE CAP LOAD: -1888N (-420 LBS)
PERMISSIBLE MOM: 9777NM (8645 IN LBS)

ALLOWABLE MISALIGNMENT C₀ = 21 METERS
EFFECT OF MANUFACTURING MISALIGNMENT ON BEAM MOMENT (APPLIES IN X-Z PLANE ONLY)*

![Diagram showing the effect of manufacturing misalignment on beam moment.]

\[ \frac{M}{M_C} = 0 \]

\[ C_0/L \times 10^{-3} \]

*MISALIGNMENT IN X-Y PLANE INDUCES TORSION
FATIGUE

- SSPS
  - 30 YEAR LIFE REQUIREMENT
  - GEOSYNCHRONOUS ORBIT – ENTERS AND EXISTS ECLIPSE PHASE TWICE EACH YEAR FOR 45 DAY PERIOD
  - USE SCATTER FACTOR OF 4.0
  - NUMBER OF THERMAL STRESS CYCLES 21600
  - NUMBER OF MECHANICAL STRESS CYCLES – TBD
  - MAXIMUM STRESS (TENSION) + 6752 PSI
  - ENDURANCE LIMIT APPROX 11000 PSI
FATIGUE DATA S-N CURVE NOTCHED $K_T = 2.0$; 2024 – T3

Graph showing the relationship between stress (ksi) and cycles to failure ($N$) for notched conditions.
BEAM DESIGN CONFIGURATION

BEAM BUILDER STRUCTURAL ARRANGEMENT

BEAM BUILDER INSTALLATION IN ORBITER
ONE METER BEAM DESIGN

SPOT WELD

STIFFENER

DIAGONAL BRACE

39 in.

59 in.

1.5 M

1.15 M

(46.57)

(28.4)

TYPICAL TERMINATING TRIPOD - BOTH ENDS

SECTION B-B

SECTION A-A

REF. DRAWING NO. RDH-447-0107

45
BEAM BUILDER STRUCTURAL ARRANGEMENT

- ANVIL SUPPORT STRUCTURE
- MAGAZINE SUPPORT STRUCTURE
- DIAGONAL WELDING UNIT
- VERTICAL WELDING UNIT
- SUPPLY REEL
- ROLL FORMING MACHINES
- MID BULKHEAD
- BOX BEAM (3)
- SUPPORT TRUSS
- PAYLOAD BAY ENVELOPE
- LOWER BULKHEAD
- MID BULKHEAD
- QUILLOTINE (3)

VIEW LOOKING FWD
BASIC DESIGN

STRUCTURAL TEST ON NOV 1976 ESTABLISHES CONFIDENCE IN

FABRICATION FACILITY

FABRICATION ACCURACY REQUIREMENT FOR BEAM DEFINED FOR

CONDITIONS

BEAM DESIGN HAS BEEN DEFINED AND SATISFIES CRITICAL

SPOTWELDING

ROLL FORMING

THERMAL COATTINGS

2024-T3; 2219-T6; 6061-T6

MATERIALS AND PROCESSES SELECTED MEET REQUIREMENTS

II SPS VEHICLE

I FABRICATION IN ORBITER PAYLOAD BAY

DESIGN LOADS AND TEMPERATURES EVALUATED FOR:

CONCLUSIONS
GROUND DEMONSTRATION
MACHINE FABRICATION FACILITY
QUARTERLY REVIEW
AUGUST 26, 1977
DESIGN REQUIREMENTS

- Low cost
- Comply with shuttle payload constraints
- Maximum use of commercial "off-the-shelf" hardware
- Maximum use of existing "state-of-the-art" expertise
- Compatible with future flight test needs
- Fully automated fabrication of truss
WORKING MOCKUPS

- MACHINE CONFIGURATION
- MAGAZINE MECHANISM
- CLAMP & WELD ELECTRODE MECHANISM
- CAP CUTOFF
FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- ROLL-FORMING CAP MEMBER
- MAGAZINE/DISPENSER BRACE MEMBERS
- BRACE ATTACHMENT
- TRUSS CUTOFF AND INTERNAL SUPPORT
- CONTROLS
- SUMMARY
PRINCIPAL MACHINE PROCESSES

- ROLL-FORM CAP MEMBERS
- MAGAZINE STORE PREFAB BRACES
- RESISTANCE-WELD ATTACHMENT
- COMPUTER CONTROL CAP ALIGNMENT
PRINCIPAL SUBSYSTEMS

- ROLL FORMING
- MAGAZINE/CLAMP MECHANISM
- ATTACHMENT
- CUTOFF & SUPPORT
- CONTROLS
FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- ROLL-FORMING CAP MEMBER
- MAGAZINE/DISPENSER BRACE MEMBERS
- BRACE ATTACHMENT
- TRUSS CUTOFF AND INTERNAL SUPPORT
- CONTROLS
- SUMMARY
GROUND DEMONSTRATION MACHINE
PROJECTED WEIGHT DISTRIBUTION

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROLLING MILL</td>
<td>2876 KG</td>
</tr>
<tr>
<td>BRACE DISPENSERS</td>
<td>163 KG</td>
</tr>
<tr>
<td>WELDING SYSTEM</td>
<td>1170 KG</td>
</tr>
<tr>
<td>CONTROL SYSTEM</td>
<td>318 KG</td>
</tr>
<tr>
<td>MATERIALS</td>
<td>210 KG</td>
</tr>
<tr>
<td>SUPPORT STRUCTURE</td>
<td>4081 KG</td>
</tr>
</tbody>
</table>

(6255 LBS) (360 LBS) (2580 LBS) (702 LBS) (482 LBS) (9000 LBS)
PROJECTED AVG POWER DISTRIBUTION

ROLLING MILLS

COMPUTER & INTERFACE

ACTUATORS

WELD SYSTEM

AVG. 2.2 KVA
WELD POWER REQUIREMENTS

12 WELDS (TYPICAL)
EACH LASTS ≈ 17MSEC

AVERAGE POWER OVER
4 WELD SEGMENTS (2.1 KVA)

POWER (KVA)

BAY CYCLE TIME (SEC)

60 40 20
FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- ROLL-FORMING CAP MEMBER
- MAGAZINE/DISPENSER BRACE MEMBERS
- BRACE ATTACHMENT
- TRUSS CUTOFF AND INTERNAL SUPPORT
- CONTROLS
- SUMMARY
ROLL-FORM SUBSYSTEM

- FORM ROLLING MILL
- TOOLING
- SUPPORT STRUCTURE
- DRIVE SYSTEM
ROLL-FORMING CAP MEMBER

FLOWER DIAGRAM

PROGRESSIVE FORMATION OF CAP
# DEVELOPMENT TEST SUMMARY

<table>
<thead>
<tr>
<th>TASK</th>
<th>RESULTS</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESTABLISH 2219-T62, 2024-T3 SPRING BACK</td>
<td>2219-T62 (10 DEG) 2024-T3 (2 DEG)</td>
<td>PRELIMINARY ROLL DESIGN</td>
</tr>
<tr>
<td>REDUCE ROLL STATIONS</td>
<td>STATION REQMTS 8 → 7</td>
<td>ESTABLISH 65-IN LENGTH</td>
</tr>
<tr>
<td>PRELIMINARY CONFIGURATION EVALUATION</td>
<td>• RIPPLED FLANGE • LONGITUDINAL BOW</td>
<td>MODIFY ENTRY AND TRANSITION ROLLS</td>
</tr>
<tr>
<td>CONFIGURATION REFINEMENT</td>
<td>• IMPROVED FLANGE • ELIMINATE BOW</td>
<td>REDESIGN TRANSITION ROLLS</td>
</tr>
<tr>
<td>FLANGE EVALUATION</td>
<td>• MINIMAL WAVE</td>
<td>• ADD CROWN TO FLANGE • PROCEED WITH FINAL DESIGN</td>
</tr>
</tbody>
</table>
EXTERNAL SUPPORT STRUCTURE

- MATERIAL: HOT ROLLED STEEL
- ARC WELD AND BOLTED CONSTRUCTION
- DWG. NO. RDM 447-2070
## ROLLING MILL EQUIPMENT WEIGHT DISTRIBUTION

<table>
<thead>
<tr>
<th>Category</th>
<th>Weight (kg)</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll Housing</td>
<td>857</td>
<td>1890</td>
</tr>
<tr>
<td>Tooling</td>
<td>1048</td>
<td>2310</td>
</tr>
<tr>
<td>Drive</td>
<td>129</td>
<td>285</td>
</tr>
<tr>
<td>Guide &amp; Straightener</td>
<td>381</td>
<td>840</td>
</tr>
<tr>
<td>Other</td>
<td>422</td>
<td>930</td>
</tr>
</tbody>
</table>

**Total** 2836 kg (6255 lbs)
SUMMARY – ROLL-FORMING SUBSYSTEM

- PRODUCED A ROLL-FORMED CAP MEMBER
- YODER ROLLING MILLS ON ORDER
- FINAL TOOL DESIGN UNDERWAY AT YODER
- EQUIPMENT CONFIGURATION CONSISTENT WITH SHUTTLE REQMTS
- SUPPORT STRUCTURE DEFINED

UNDETERMINED

- SUPPLY REEL FINAL CONFIGURATION
FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- ROLL-FORMING CAP MEMBER
- MAGAZINE/DISPENSER BRACE MEMBERS
- BRACE ATTACHMENT
- TRUSS CUTOFF AND INTERNAL SUPPORT
- CONTROLS
- SUMMARY
MAGAZINE & CLAMP MECHANISMS

• BRACE STORAGE & DISPENSER
• ATTACHMENT CLAMP MECHANISM
BRACE MAGAZINE/DISPENSER
PRINCIPAL COMPONENTS

- MAGAZINE STOP ACTUATORS
- BRACE HANDLER ACTUATOR
- VERTICAL MAGAZINE FRAME
- DIAGONAL MAGAZINE FRAME
BRACE FABRICATION

- BLANK MATERIAL
- FORM SECTION
- FORM DIMPLES
- ANODIZE (FLIGHT ARTICLE)
STEPS IN BRACE HANDLING

1. REST POSITION: BRACES IN MAGAZINE

2. TSS SEPARATES BRACE 1 FROM BRACE 2

3. BRACE DISPENSED FROM MAGAZINE

4. BRACE MOVED TO CAP
CLAMP ATTACHMENT MECHANISM

- HOUSING FOR WELD ELECTRODES
- ELECTRODE MECHANISM & ACTUATOR
- BRACE ATTACH CLAMP MECHANISM
- BRACE ATTACH ACTUATOR
- CLAMP ADVANCE ACTUATOR
CLAMP MECHANISM PRINCIPAL FORCES

WELD ELECTRODE FORCE

CLAMP FORCE

BRACE

CAP
SUMMARY – MAGAZINE/DISPENSER SUBSYSTEM

- BRACE DISPENSER MOCKUP FUNCTION TESTED
- BRACE MAGAZINE MODIFIED AS PER PDR
- CLAMP MECHANISM MOCKUP FUNCTION TESTED

UNDETERMINED

- FINAL CONFIGURATION DIAGONAL CLAMP MECHANISM
FACILITY DESIGN

AREAS OF DISCUSSION

• OVERALL CONFIGURATION
• ROLL-FORMING CAP MEMBER
• MAGAZINE/DISPENSER BRACE MEMBERS
  • BRACE ATTACHMENT
• TRUSS CUTOFF AND INTERNAL SUPPORT
• CONTROLS
• SUMMARY
BRACE ATTACHMENT

PRIMARY SYSTEM
- RESISTANCE SPOT-WELDING

ALTERNATES CONSIDERED
- ULTRASONICS
- HOLLOW INTEGRAL RIVET
- INTEGRAL RIVET
- STAPLING
- ELECTRON-BEAM WELDING
- ADHESIVE BONDING
WELD POWER SUPPLY GROUND DEMONSTRATION SYSTEM

- MANUFACTURER - SCIAKY
- QUANTITY - 6
- TYPE - SOLID-STATE A/C
- COOLANT - WATER
- OUTPUT - 63 KV, 4.5 V
- DUTY CYCLE - APPRX. 0.01%
- WEIGHT - 91 KG (200 LBS)
- SIZE - 25.4 x 30.5 x 50.8 CM (10 x 12 x 20 IN.)
WELDING PROCESS SCHEMATIC

ELECTRODE PAIRS (4)

TRANSFORMER (6)

INSULATOR

SHUNT BAR

220V

1/4

4.5V
WELD ELECTRODE LIFE TEST

- MAT'L: 2024-T3 AL ALLOY
- ELECTRODE FORCE: 1334 N (300 LBS)
- SERIES WELD ON 50 MM (2 IN.) CENTERS
- AVG. LEFT ELECTRODE
- AVG. RIGHT ELECTRODE

SHEAR, NEWTONS

NUMBER OF WELDS

896 672 448 224

95 50 100 150 200
SUMMARY – ATTACHMENT SUBSYSTEM

- SERIES ELECTRODE LIFE-TESTS PERFORMED
- ORDERING SIX TRANSFORMERS AS PER PDR
- WELD QUALITY EXCEEDS LOAD REQUIREMENTS
- ELECTRODE SWITCHING SHOWN IN MOCKUP
FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- ROLL-FORMING CAP MEMBER
- MAGAZINE/DISPENSER BRACE MEMBERS
- BRACE ATTACHMENT
- **TRUSS CUTOFF AND INTERNAL SUPPORT**
- CONTROLS
- SUMMARY
TRUSS CUTOFF MECHANISM & SUPPORT STRUCTURE

FUNCTIONS:
- GUIDE TRUSS AFTER ROLL-FORMING
- PROVIDE BACKUP FOR BRACE CLAMP AND WELD
- CUT OFF TRUSS TO PROPER LENGTH
TRUSS CUTOFF MECHANISM

SHEAR

CAP

SUPPORT & GUIDE

SEC A-A
SUMMARY – TRUSS CUTOFF AND INTERNAL SUPPORT SUBSYSTEM

- CUTOFF MOCKUP BEING EVALUATED
- TRUSS SUPPORT CONFIGURATION DEFINED

UNDETERMINED

- FINAL CONFIGURATION TRUSS CUTOFF
FACILITY DESIGN

AREAS OF DISCUSSION
- OVERALL CONFIGURATION
- ROLL-FORMING CAP MEMBER
- MAGAZINE/DISPENSER BRACE MEMBERS
- BRACE ATTACHMENT
- TRUSS CUTOFF AND INTERNAL SUPPORT

CONTROLS

SUMMARY
PERFORMANCE REQUIREMENTS

- Bay Length – 1.5 Meters ± 0.8 MM
- Bay Fabrication Rate – 60 to 300 Sec
- Maximum Cap Length Variation (40-M Beam) – 20 MM
- Rolling Mill Drive Speed – 1.5 to 3.0 Meters/Min
DESIGN GUIDELINES

- MAXIMUM USE OF "OFF-THE-SHELF" COMMERCIAL COMPONENTS
- MINIMUM-COST SYSTEM
- INSURE BEAM STRAIGHTNESS
- HIGH RELIABILITY
PRINCIPAL COMPONENTS

- CENTRAL PROCESSOR
- CAP SYSTEM SERVO
- ASSEMBLY SUBSYSTEM
- OPERATOR CONTROL PANEL
- TELETYPewriter
CONTROL SYSTEM FUNCTIONS

- COORDINATE MOTION OF ROLLING MILLS
- SEQUENCE EVENTS FOR ASSEMBLY AND FASTENING
- EXECUTE OPERATOR INPUT COMMANDS
<table>
<thead>
<tr>
<th>CRITERION</th>
<th>REQUIREMENTS</th>
<th>GOAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay Length (1.5 Meters)</td>
<td>± 0.8 MM</td>
<td>± 0.15 MM</td>
</tr>
<tr>
<td>Bay Fabrication Rate</td>
<td>60 - 300 SEC</td>
<td>100 - 300 SEC</td>
</tr>
<tr>
<td>Maximum Cap Length Variation (40-Meter Beam)</td>
<td>± 20 MM</td>
<td>± 0.15 MM</td>
</tr>
<tr>
<td>Rolling Mill Drive Speed</td>
<td></td>
<td>1.5 - 3.3 M/Min</td>
</tr>
</tbody>
</table>

Performance Summary
SELECTION OF CENTRAL PROCESSOR (PDP8/A)

- Commercially available
- Known high reliability
- Low cost
- Room for expansion
- Extensive software support
- Ease of interfacing

111
CAP POSITION CONTROLS

ON/OFF

FROM CPU

RAMP GEN

CLK

SERVO TRANSLATOR ST-704

MOTOR TACH/RESOLVER SM709

SLOT DETECTOR SPX 1874-1

3

2

3

2

TO CPU

TO CPU INTERRUPT

VE0

TO CPU

UP/DN CNTR
ASSEMBLY SUBSYSTEM SEQUENCE

- SELECT V
- MOVE V TO CAP
- POSITION V ELECTRODE BLKS TO 'A'
- CLOSE SCISSORS
- POSITION ELECTRODES FOR WELD 1
- WELD 1
- OPEN SCISSORS
- MOVE ELECT BLK TO 'B'
- WELD 12
- OPEN SCISSORS
- MOVE ELECT BLK TO 'C'
- WELD 13-24
- OPEN SCISSORS
- RETRACT ELECT BLKS

TIME

TASKS
SOFTWARE HIERARCHY

EXECUTIVE CONTROLLER

ASSEMBLY SOFTWARE
- TASK ACTIVATOR
- COMPLETION
- DETERMINATION
- STATUS MONITOR

CONTROL STATION MONITOR COMMAND STATUS

CAP ROLLING SOFTWARE
- END POSITION
- ON FLY CONTROL
- INTERPOLATION
- RECALIBRATION

SOFTWARE CLOCKS
1 2 3 4 n 2 n 1 n

INTERRUPTS HANDLER
- UPDATE CLOCKS
- POSITIONS
- EMERGENCY
- STOP SHUT DOWN

INTERRUPTS CLOCK FIFO SLOTS POWER FAIL
ASSEMBLY SUBSYSTEM SOFTWARE

- Task Residence
- Task Selector
- Get Next Task and All Parallel Tasks
- Setup Pointer to Next Task
- Wait Queue
- Wait for Any Interlocking Tasks to Complete
- Completion Monitor and Control
- Task Activator
  - Turns Actuators On or Off
- Queue
  - Holds Tasks to Be Made Active
  - 1, 2, 3, ..., 16
SUMMARY

- OVERALL ARCHITECTURE OF CONTROL SYSTEM DEFINED
- MAJOR CONTROL ELEMENTS SELECTED
- EQUIPMENT ORDERED:
  - COMPUTER SYSTEM
  - ROLLING MILL DRIVES
- SOFTWARE DEFINED
- PROCEEDING WITH DETAIL DESIGN, SOFTWARE GENERATION
  AND COMPONENT PROCUREMENT
- UNDEFINED:
  - CONTROL CIRCUITRY FOR ACTUATORS
  - CABLELING AND PACKAGING DETAILS
FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- ROLL-FORMING CAP MEMBER
- MAGAZINE/DISPENSER BRACE MEMBERS
- BRACE ATTACHMENT
- TRUSS CUTOFF AND INTERNAL SUPPORT

SUMMARY
<table>
<thead>
<tr>
<th></th>
<th>Working Mockup</th>
<th>Preliminary Testing Performed</th>
<th>Proven Commercial Process Equipment</th>
<th>Commercial Expertise Utilized</th>
<th>EOR Concurrence</th>
<th>Compatible With Shuttle Power Reclmt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Configuration</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Roll Forming</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Brace Dispenser</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attachment</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Truss Cutout</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FACILITY DESIGN PLAN

• OBTAIN CONCURRENCE WITH MSFC ON DESIGN FOR ALL SUBSYSTEMS

• START FABRICATION AND PROCUREMENT OF DETAIL PARTS

• CONTINUE WITH CONSTRUCTION TO MEET EXISTING PROGRAM SCHEDULE REQUIREMENTS
SFDS QUALITY ASSURANCE

OBJECTIVE: DELIVERY OF A FACILITY FUNCTIONING AT REQUIRED OPERATING CONDITIONS AND RATES THAT REPEATEDLY PRODUCES BEAMS TO ENGINEERING DRAWING REQUIREMENTS

MAJOR QUALITY ASSURANCE TASKS
• FABRICATION OF FACILITY
• EVALUATION OF FABRICATED BEAMS
BEAM EVALUATION

- CONVENTIONAL INSPECTION AND N.D.T. DURING GROUND PHASE
- INVESTIGATE ADVANCED AUTOMATED SYSTEMS FOR FLIGHT APPLICATION
- PRIMARY INSPECTION AREAS
  - ROLL FORMED CAP MEMBERS
  - SPOT WELD ATTACHMENTS
  - BRACE POSITIONING
  - ASSEMBLY ALIGNMENT
BRACE POSITIONING

- EVALUATE TEST BEAMS TO VERIFY
  - BRACE LOCATION ON CAP MEMBER
  - BRACE ALIGNMENT
  - SPOT WELD LOCATION
- UTILIZE CONVENTIONAL DIMENSIONAL INSPECTION
SPOT WELD ATTACHMENTS

- FABRICATE TEST SAMPLES TO VERIFY WELDING PARAMETERS
- PREPARE PROCESS CONTROL TEST SPECIMENS BEFORE AND AFTER BEAM FABRICATION
- VISUAL AND RADIOGRAPHIC EVALUATION OF ATTACHMENTS AT INTERVALS ALONG TEST BEAMS
ASSEMBLY ALIGNMENT

- OPTICAL TECHNIQUE TO MEASURE BOW AND TORSIONAL DISPLACEMENT
- IN PROCESS EVALUATION DURING DE-BUGGING PHASE
- OVERALL MEASUREMENT OF TEST BEAMS
- EVALUATE ADVANCED TECHNIQUES FOR FLIGHT MONITORING