CR 151581

FINAL REPORT

SHUTTLE EXPERIMENTAL RADAR FOR GEOLOGICAL EXPLORATION (SERGE)

ANTENNA AND INTEGRATION CONCEPT DEFINITION STUDY

F77-23

OCTOBER 7, 1977

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lyndon B. Johnson Space Center
Houston, Texas

Ball Brothers Research Corporation

Aerospace Division

BOULDER, COLORADO 80306

Report F77-23

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Prepared for

NASA Lyndon B. Johnson Space Center
Houston, TX 77508

Contract NAS9-15363

Prepared by:

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FOREWORD

The Shuttle Experimental Radar for Geological Exploration (SERGE) Antenna and Integration Concept Definition Study was conducted for NASA's Lyndon B. Johnson Space Center by Ball Brothers Research Corporation under contract NAS9-15363. The Johnson Space Center Technical direction for the SERGE study was provided by Mr. Harold A. Nitschke and Mr. Curtis J. LeBlanc. The Principal Investigator for SERGE is Dr. Charles Elachi of the Jet Propulsion Laboratory.

This report presents the final technical results of the study, using material presented at the Concept Definition Review on August 3, 1977 and the Final Presentation on September 26, 1977. The study covers the concept definition of the SERGE Antenna, feed system, supporting structure and pallet interfaces, and the thermal coverings. The other SERGE hardware, the transmitter, electronics, optical recorder, etc., are provided by the Jet Propulsion Laboratory. SERGE is planned to fly on the second space shuttle mission, OFT-2. The OFT-2 mission management for payloads is provided by Johnson Space Center.

The study leader was Mr. John Kierein with major contributions from Messrs. Gary Sanford, Tom Metzler, Jack James, Don Yagi, and Dan McMann.

The title of the SERGE experiment is currently under review. It has also been know as the All Weather Surface Observation Experiment (AWSOE) and the Shuttle Imaging Radar-A (SIR-A).

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BASELINE CONFIGURATION

The baseline configuration of the SERGE Antenna, feed system, supporting structure and thermal coverings is shown in the figure. The system consists of two major assemblies, the installation truss assembly and the strongback truss assembly.

The installation truss assembly is a free standing trusswork that mounts to the OFT-2 pallet at 4 points using adjustable interface fittings. These fittings provide adjustment to mate to the pallet hardpoints and provide vernier pointing adjustment for the antenna. The truss joints are covered with multilayer inslation (MLI) and the entire trusswork is covered with teflon impregnated quartz cloth (TIQC) for thermal protection. The truss will be shipped in two pieces and assembled prior to mounting to the pallet.

The strongback truss assembly includes the strongback truss which supports the 7-way coax corporate feed and seven antenna panel array. The front face of the antenna array is covered by the TIQC and the entire rear of the assembly is covered with both MLI and TIQC for thermal protection. The strongback truss assembly mounts to the installation truss assembly at four points. Shimming at these four points provides coarse pointing of the antenna. The strongback truss assembly will be shipped as a single unit.

Both truss assemblies are constructed of graphite reinforced epoxy with aluminum joints to provide a lightweight structure of sufficient stiffness to meet the fundamental frequency requirements for structure mounted to a pallet.

The pallet is shown centered on the long dimension of antenna array. The pallet location in the shuttle payload bay allows this positioning for a seven panel array to fit the allowable envelope between the EVA envelope at the hatch fromthe cabin to the bay and the access envelope to the Development Flight Instrumentation pallet near the aft of the bay.

The preferred SERGE electronics location is identified to reduce the length of feed line to the antenna. The electronics are provided by JPL.

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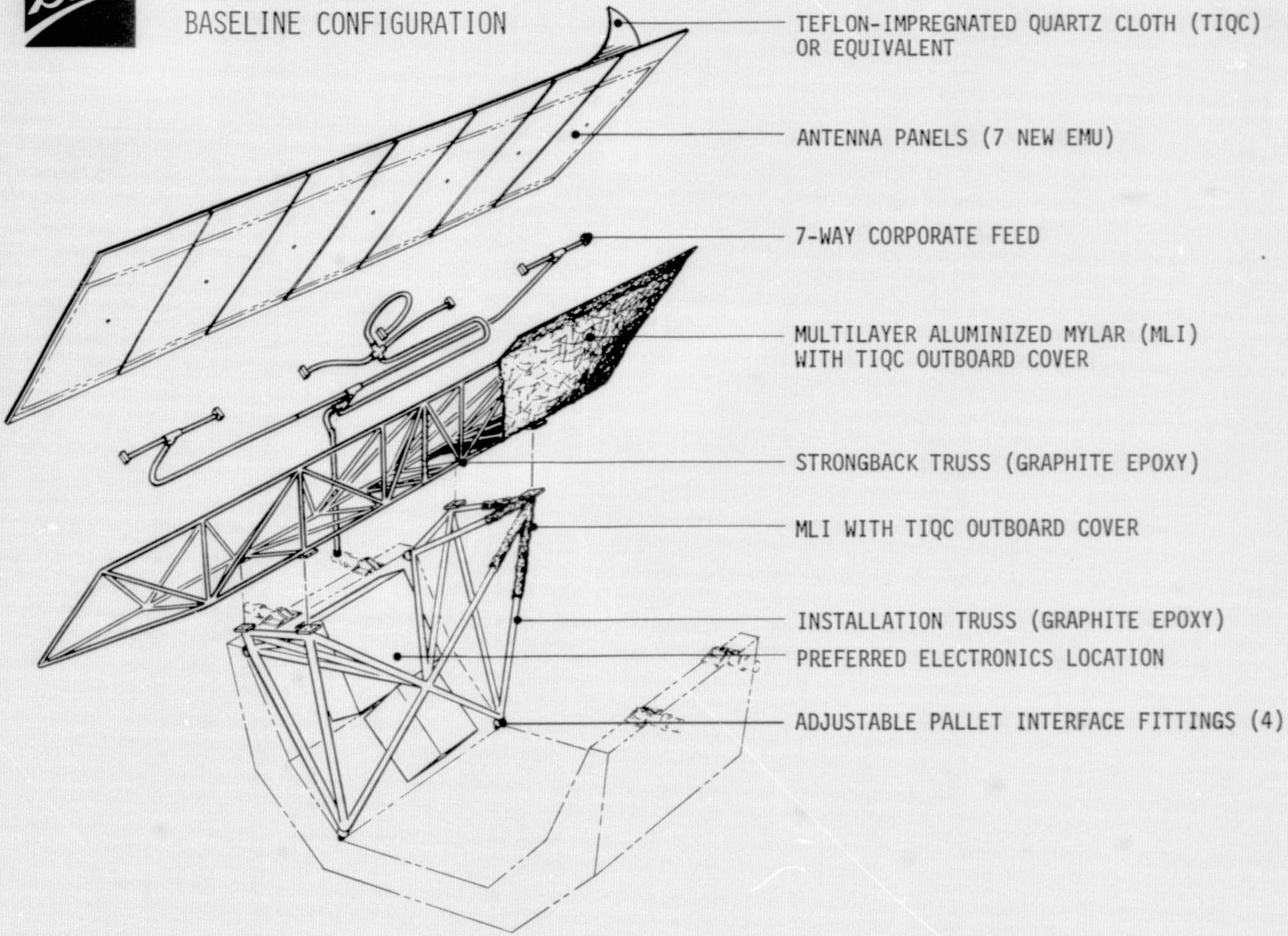
SERGE ANTENNA
BASELINE CONFIGURATION



MAJOR FUNCTIONAL REQUIREMENTS

The major functional requirements are listed. The 33 dB gain requirement is met using a seven panel array of SEASAT engineering model panel design with a coax cable corporate feed to these panels. The power is split to these panels with a "natural" taper of unequal power division to provide for lowering the sidelobes in the horizontal E-plane to the required level. This caused the horizontal beamwidth to marginally exceed the initially specified 2°. The beamwidth requirements were subsequently changed to 2.2° as the reduced sidelobes were determined to be more important than the smaller beamwidth.

Orbiter interface requirements were taken from the Shuttle System/Cargo Standard Interface Specification. One of the driving requirements was the necessity of reducing the radio frequency interference levels in the payload bay. This was accomplished by mounting the antenna high in the bay.

Pallet mounted structure was required to have a fundamental frequency greater than 25 hertz. This requirement necessitated the use of graphite reinforced epoxy structural members in the strongback truss.

The low cost considerations resulted in the use of existing-design engineering model panels from the SEASAT program and a low-cost coax feed system.

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SERGE ANTENNA
MAJOR FUNCTIONAL REQUIREMENTS

- 33 dB GAIN
- 1.4 to 2.2 DEGREE HORIZONTAL PLANE BEAMWIDTH
- -14.5 dB SIDELOBES IN ALL PLANES
- MEET ORBITER INTERFACE SPECIFICATION REQUIREMENTS
    - ESPECIALLY RFI
- 25 CPS FUNDAMENTAL FREQUENCY
- LOW COST

MAJOR RESULTS

The baseline configuration chosen is predicted to meet all RF performance specifications at low cost and weight. The gain will be marginally better than the specification and the sidelobes well below the specification.

The structural fundamental frequency is predicted to be 28.5 hertz. This provides a 3.5 hertz margin over the required 25 hertz. The individual panels have a predicted fundamental frequency of 15 hertz with a nine point attachment to the strongback truss. These panels are relatively light weight components of the system and are not required to meet the 25 hertz requirement of the primary structure of the strongback truss and installation truss assembly.

Thermal effects on panel flatness deviation and pointing at the antenna were found to be small in the relatively benign environment of the earth-pointing payload bay.

The peak amount of radio frequency interference coming from the backside of the antenna panels into the payload bay is estimated at 1 volt per meter at the center of the bay, half the allowable level. This peak amount occurs only if the transmitter transmits at 1500 watts. The level is greater nearer the antenna and smaller farther away.

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SERGE ANTENNA
MAJOR RESULTS

- RESULTS
  - MEETS ALL RF PERFORMANCE SPECS.
    - GAIN: 33.1 DB
    - E-PLANE BEAMWIDTH $< 2.2°$, SIDELOBES -15 DB
  - WEIGHT LESS THAN 400 LBS.
    - ESTIMATED 370 LBS.
  - MAJOR STRUCTURE FUNDAMENTAL FREQUENCY 28.5 Hz
    - PANELS $\sim$ 15 Hz
  - THERMAL DISTORTION $\sim$ .1 INCHES MAXIMUM DEVIATION FROM PLANE
  - THERMAL EFFECTS ON POINTING $<$ .03 INCHES FROM PALLET REFERENCE (MUST ADD ORBITER DEFLECTIONS)
  - RFI IN P/L BAY APPROXIMATELY 1 V/M PEAK

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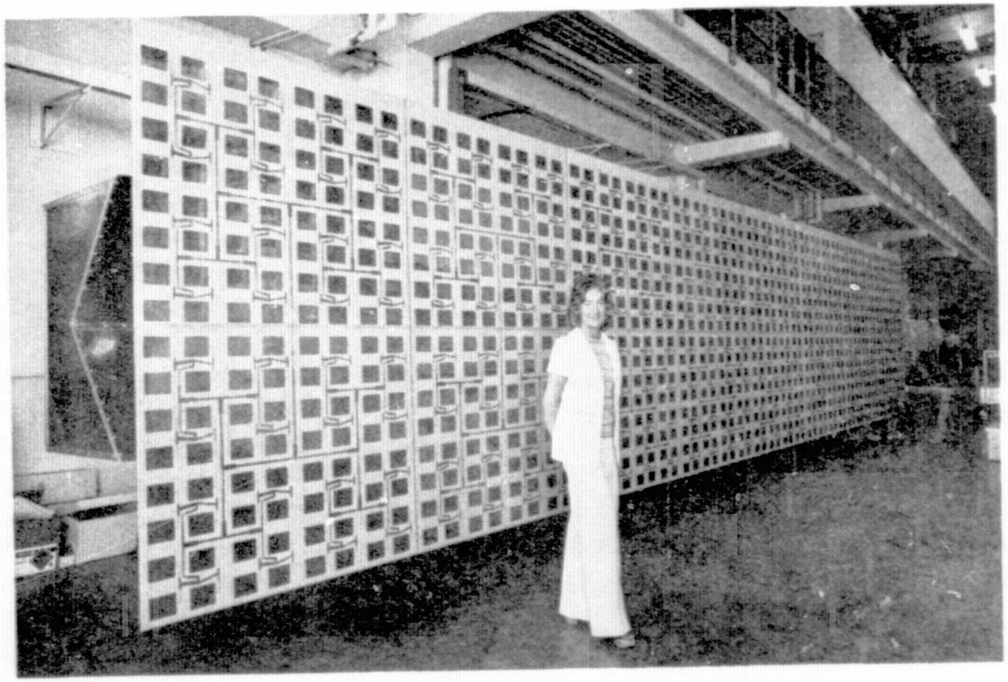
EARLY ELECTRICAL ENGINEERING MODEL

One of the candidate panel designs for SERGE, and the design finally chosen, was that of the engineering model unit (EMU) panels of the SEASAT program. The array gain measured was for an eight panel array rather than the SERGE seven panel array. Note that the H-plane (vertical in the photograph) sidelobe levels are well below the specified levels due to built-in H-plane power taper. The E-plane (horizontal) sidelobes were reduced for SERGE by building in a power taper from panel-to-panel in the seven way power division feed network to the panels. This, plus the use of seven rather than eight panels caused the E-plane beamwidth to increase form 1.7° to 2.1°.

EARLY ELECTRICAL ENGINEERING MODEL



MEASURED PERFORMANCE

PANEL GAIN = 25.9 DB

ARRAY GAIN = 34.9 DB*

SIDELOBES
- E-PLANE - -13.0 DB
- H-PLANE = -17.0 DB

BEAMWIDTH
- E-PLANE = 1.7°
- H-PLANE = 6.1°

*ARRAY GAIN WITH LOSSLESS FEED NETWORK.

PROTOTYPE PANEL - SEASAT FLIGHT MODEL

Another major antenna panel candidate was the flight model of the SEASAT panels. A prototype of this panel is shown in the figure. It differs from the EMU panel in that the feed on the flight unit is a coaxial cable network to eight points on the panel. This resulted in a marginally greater gain per panel, but was much more costly to manufacture than the EMU panel.

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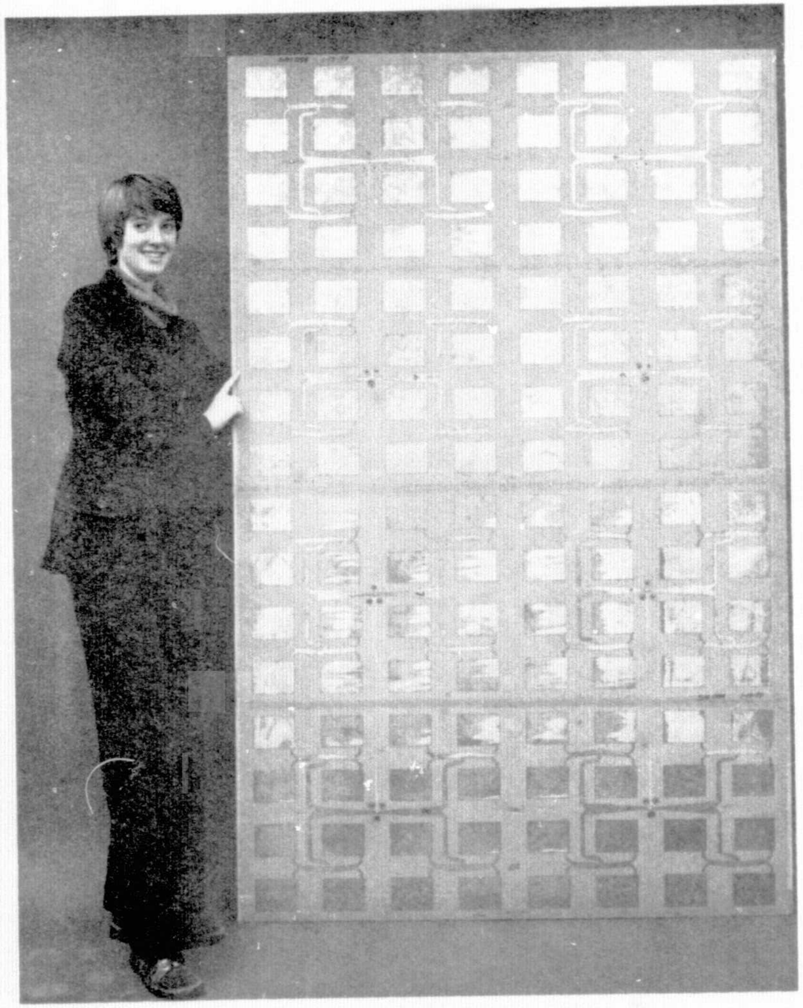
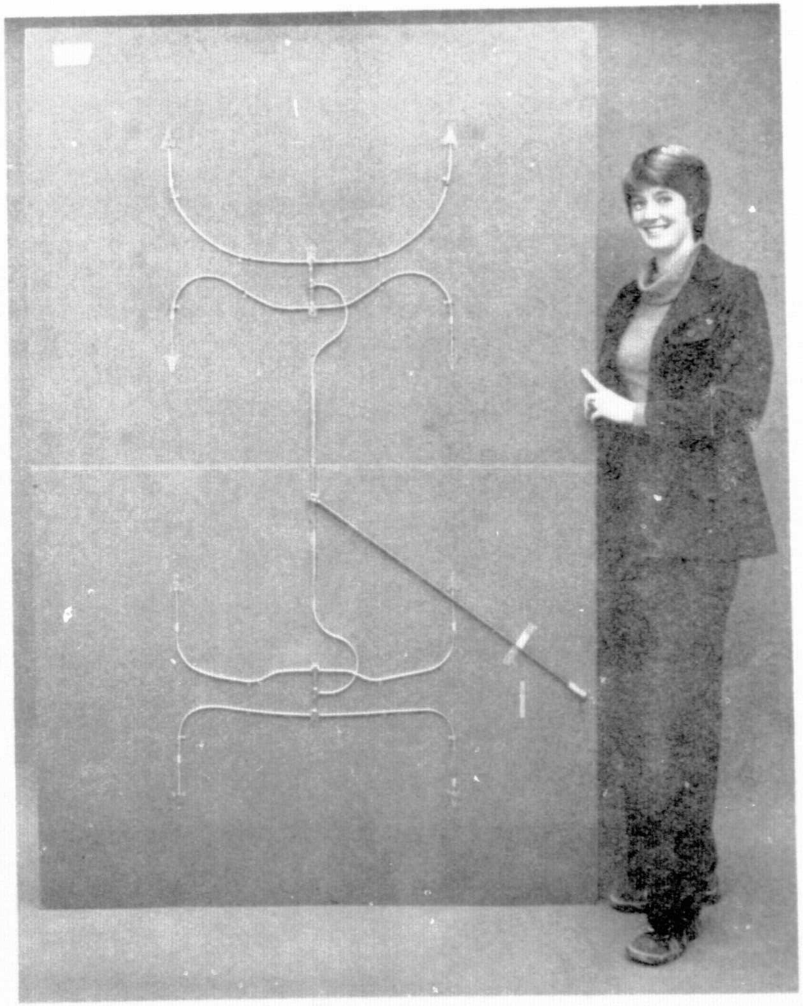
PROTOTYPE PANEL



CIRCUIT SIDE



GROUND PLANE SIDE

PANEL CONSTRUCTION

The EMU panels have a stronger construction than the SEASAT flight panels. Both panels are of honeycomb construction, but the EMU panels have the fiberglass side of the ground plane facing the inside of the sandwich which provides a stronger bond to the honeycomb core. The flight panels have the copper side of the ground plane facing the core in order to marginally improve the gain. Since the gain requirements are not so great for SERGE as SEASAT, and the panels are launched in a deployed configuration, the stronger EMU panels are of a better construction for the SERGE application.

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SERGE ANTENNA
PANEL CONSTRUCTION

COMPONENT \ PANELS	SEASAT EMU	SEASAT FLIGHT
CIRCUIT SHEET	G-10 EPOXY FIBERGLAS w/1 oz COPPER	SAME; SILVERPLATED WITH CHROMATE CONVERSION COAT
CORE	3/8" HEXCEL HRP 2.2 lb/ft^3 1/4" THICK	1/4" HEXCEL HRH 10 1.5 lb/ft^3 1/4" THICK
ADHESIVE	NARMCO 1113-2 .030 lbs/sq ft	HEXCEL HEXABOND III .015 lbs/sq ft
GROUND PLANE	G-10 EPOXY FIBERGLAS w/1 oz COPPER	SAME; COPPER, SILVERPLATED .0003 to .0008 WITH CHROMATE CONVERSION COAT
	FIBERGLAS TO CORE	COPPER-SILVER TO CORE
PANEL FEED	MICROSTRIP FROM ONE FEED POINT	MICROSTRIP FROM 8 POINTS; COAX TO THE 8 POINTS FROM ONE FEED POINT

EMU PANEL STATUS

Twelve EMU panels were manufactured. Gain measurements were made on 10 of them. Only six of the 12 have been found to be in good condition, the others having been damaged or destroyed in development testing of concepts for attaching bracketry, feed lines, and connectors. Since the EMU panels were not built to flight quality control or drawings, their usefulness as flight hardware would require considerable rework. However, the existence of good gain measurements gives confidence in the performance of the design.

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SERGE ANTENNA
EMU PANEL STATUS

SERIAL NUMBER	GAIN	STATUS
1	NOT MEASURED	DAMAGED - HOLES CUT, BRACKETS ADDED, ETC.
2	26.15	MISSING - PROBABLY DAMAGED
3	25.65	GOOD
4	25.85	GOOD
5	25.65	GOOD
6	25.85	MISSING
7	25.85	GOOD
8	26.0	MISSING
9	25.8	GOOD
10	26.15	GOOD, REPAIRED PATCH
11	26.05	DAMAGED - HOLES CUT, BRACKETS ADDED
12	NOT MEASURED	DAMAGED - GROUND PLANE IN - NO CONNECTOR

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EMU PANEL REWORK REQUIRED

The facing chart indicates the rework which would be required to be performed on the existing EMU panels to configure them for SERGE and certify them for flight status. Even if this rework were performed, the resulting panels would not have the quality control and materials traceability of newly manufactured panels. There is also the danger that the panels might be damaged in the reworking. Some of the rework would require developmental testing to devise methods of removing brackets and connectors without damage.

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SERGE ANTENNA
EMU PANEL REWORK REQUIRED

- REPLACE CONNECTORS
- REMOVE BRACKETS
- TRIM
- ROUND CORNERS AND EDGES
- INSPECT, CLEAN, REWORK COPPER TAPE AND REPAIRS
- OUTGASSING TEST
- TREAT COPPER
- BUILD SPARES AND/OR FLIGHT UNITS

PANEL SELECTION

A trade study to select antenna panels for the SERGE mission was performed. Panels newly manufactured to the EMU design were selected, based mainly upon cost. An additional candidate antenna panel considered was a new design of panels sufficiently smaller than the SEASAT panels such that 8 panels could fit in the envelope and thus utilize the more conventional 8-way power divider. The other options considered were Flight SEASAT panels and the use of reworked existing panels. A significant input to the panel selection trade study was the confidence achieved in this study in the 7-way power division feed network selected.

The SEASAT panels have a vented core honeycomb to preclude multipactor (or corona). The existing EMU panels have a smaller vent size than the Flight panels. The new EMU panels to be built will use the larger vent size.

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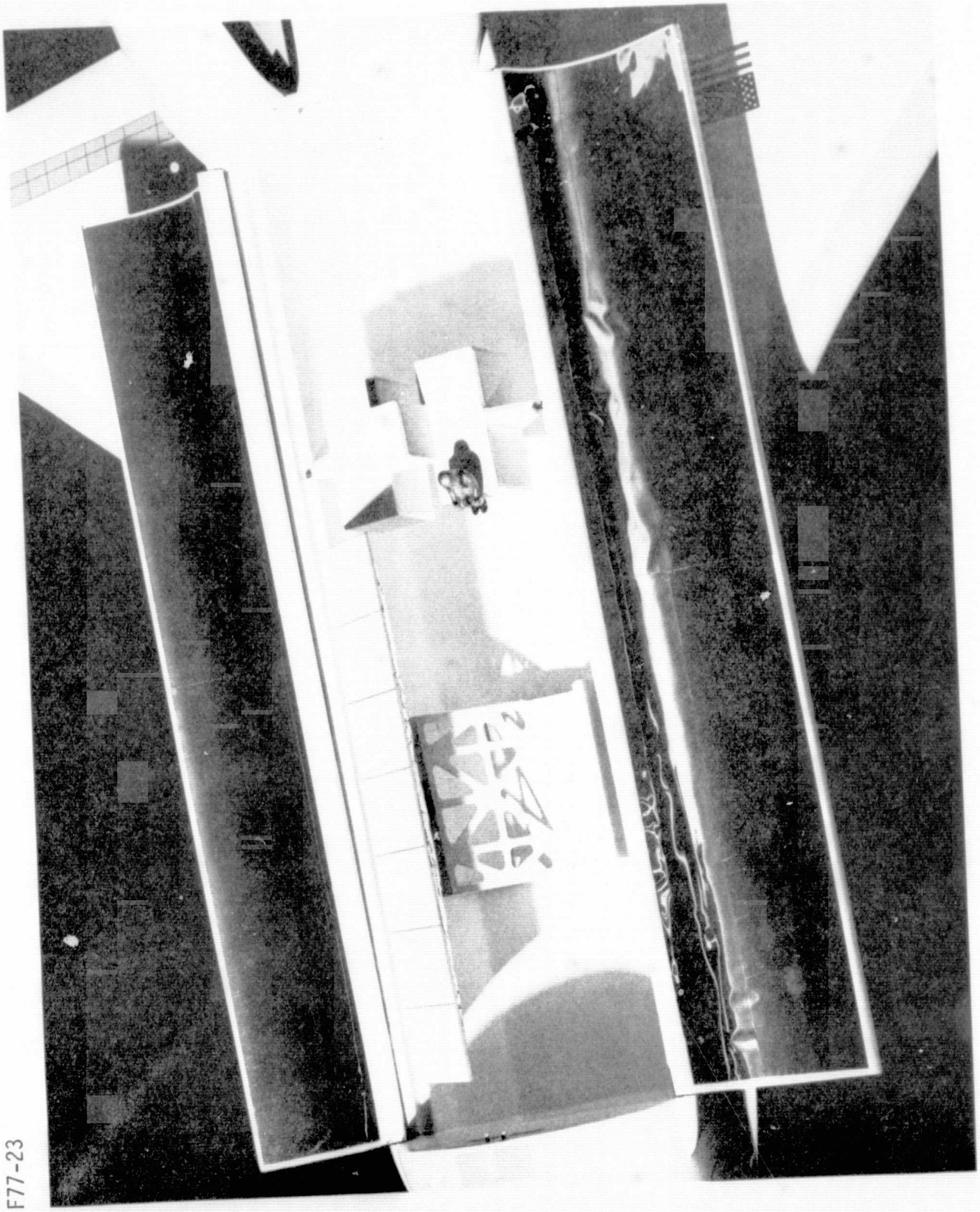
SERGE ANTENNA PANEL SELECTION

PANELS / REQUIREMENT	7 EXISTING EMU	7 NEW EMU	7 FLIGHT SEASAT	8 NEW SMALLER
NUMBER EXISTING	6	0	3 (?)	0
NUMBER REQUIRED (INCLUDING SPARES)	10	10	10	11
REWORK	YES	NO	YES	NO
Q.C./MATERIALS TRACEABILITY	NO	YES	YES	YES
POWER DIVIDER	7-WAY	7-WAY	7-WAY	8-WAY
E-PLANE SIBELOBES/BEAMWIDTH	MARGINAL	MARGINAL	MARGINAL	MARGINAL
GAIN	32.9 to 33+	32.9 to 33+	34.1	33.3 to 33.6
VENT SIZE	SMALL	OK	OK	OK
ADDITIONAL DESIGN	SMALL	SMALL	MED TO HI	MED
MFG. COST	LOWEST (?)	LOW	HIGHEST	LOW
PROVEN DESIGN	YES	YES	YES	NOT YET

MECHANICAL ANALYSES

The mechanical analyses included trade studies of the location of the antenna in the bay, mounting concepts, materials, truss junction concepts, concepts for panel attachment to the truss and feed attachments, pallet adjustable fitting concepts, clearance analysis, and weight and C.G. determinations.

The facing photograph shows a model of the antenna mounted high in the payload bay on the OFT pallet between the DFI pallet and the cabin bulkhead. This was the general location finally selected. The antenna is pointed 50° away from the orbiter Z-axis.



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LOW IN THE BAY LOCATION

This photograph shows the antenna mounted low in the bay on a pallet, another concept considered. In this location, reflections of sidelobes from orbiter surfaces caused potentially high RFI levels in the bay.

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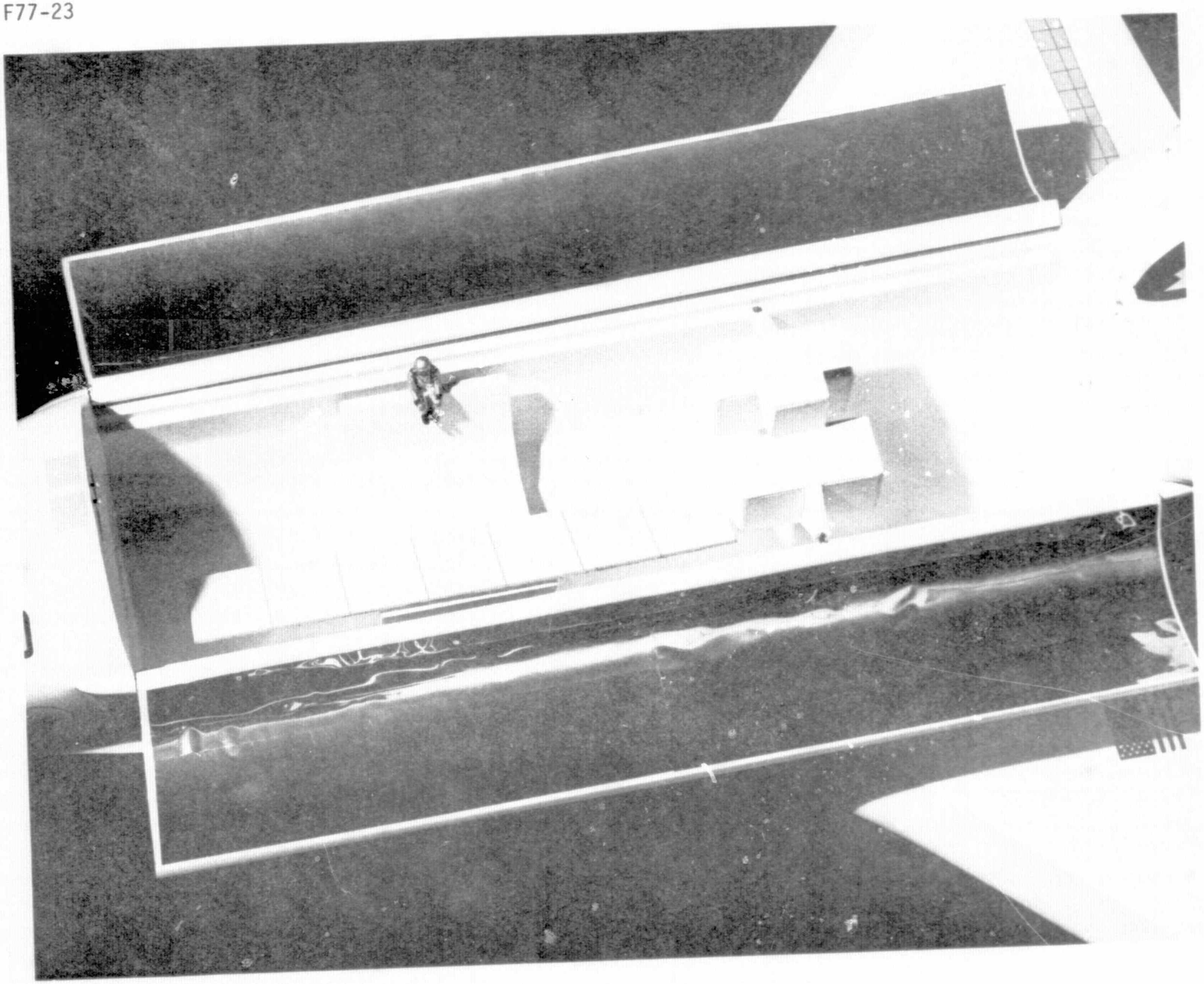

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DIRECT MOUNT TO ORBITER

This photograph shows a concept initially considered. The direct mounting to the orbiter resulted in excessive weight of supporting structure and was rejected early in the study.

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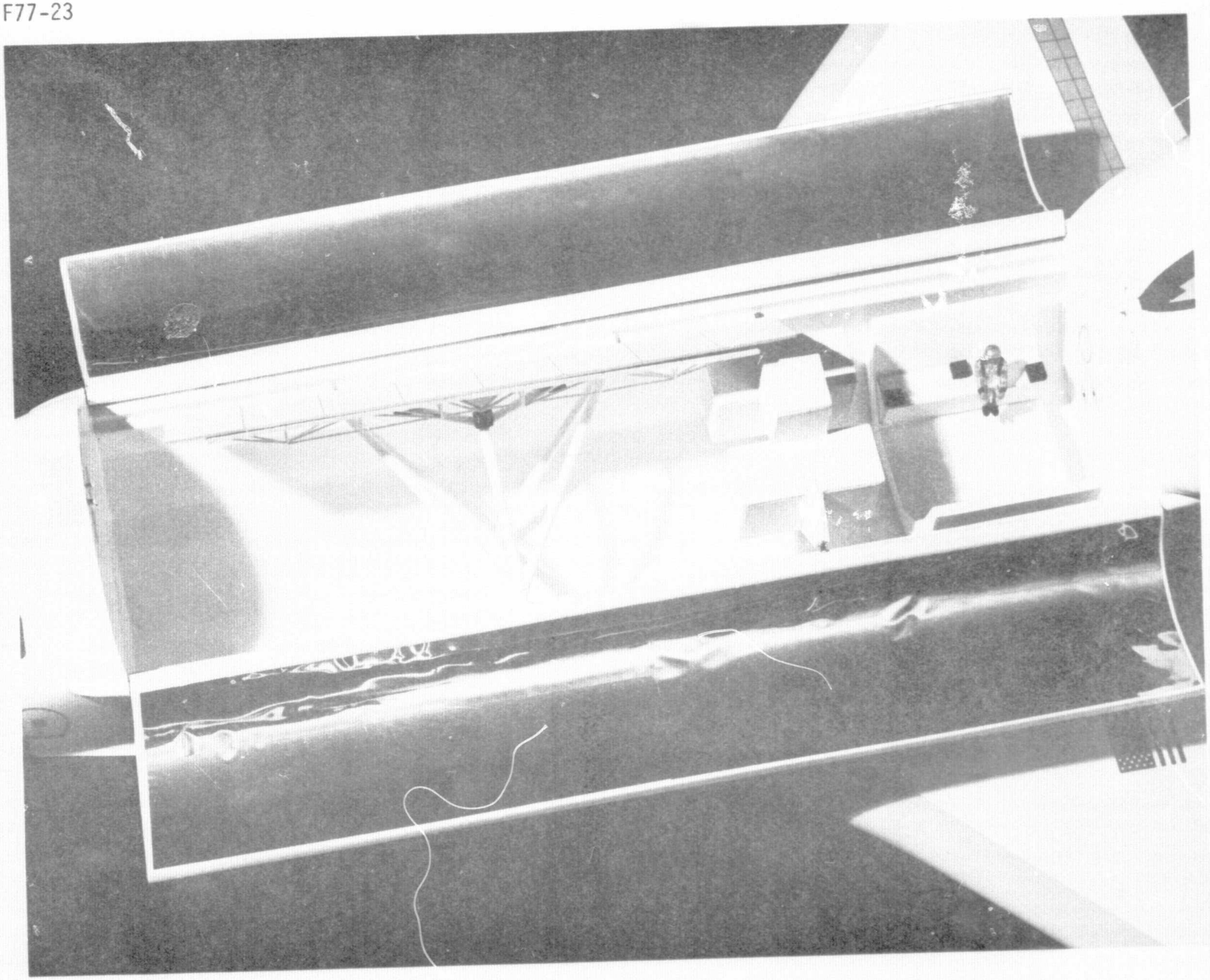

GENERAL ARRANGEMENT TRADEOFF

The arrangement selected was the pallet high mount configuration based mainly on considerations for reducing the levels of potential RF interference in the bay. As a result of the selection, the SERGE electronics location was re-arranged on the pallet to move it to the same site of the pallet as the antenna thus reducing the length of feed line needed.

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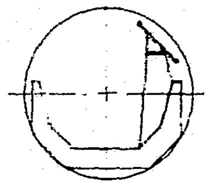
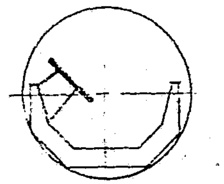
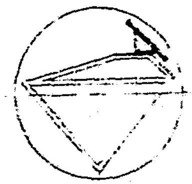
SERGE ANTENNA
GENERAL-ARRANGEMENT TRADEOFF

	 PALLET/HI	 PALLET/LO	 SANS PALLET
WEIGHT	ACCEPTABLE	BEST	PROHIBITIVE
STRUCTURAL STIFFNESS	ACCEPTABLE	BEST	X
THERMAL ENVIRONMENT	ACCEPTABLE	BEST	X
FEED (ELECTRONICS)	POOR*	BEST	X
ANTENNA PERFORMANCE	GOOD	GOOD	X
RF INTERFERENCE	BEST	POOR	X

*PALLET/HI ELECTRONICS-FEED RATING WILL BE AS GOOD AS FOR PALLET/LO IF SERGE ELECTRONICS ARE MOVED TO STARBOARD (ANTENNA) SIDE.

STRUCTURAL FORM TRADEOFF

Box and truss structures were considered as structural forms for the support structure. Truss structures were selected mainly because of the reliability of analyses of this type of structure.

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SERGE ANTENNA
STRUCTURAL-FORM TRADEOFF

	ANTENNA STRONGBACK AND INSTALLATION STRUCTURES	
	TRUSS	BOX
STIFFNESS/WEIGHT	ACCEPTABLE	ACCEPTABLE
STRENGTH/WEIGHT	ACCEPTABLE	ACCEPTABLE
ACCESS--PALLET HARD POINTS	BEST	ACCEPTABLE
ACCESS--OTHER EQUIPMENT	BEST	POOR
FABRICABILITY	BEST	ACCEPTABLE
THERMAL CONTROL	EQUAL	EQUAL
COST (LABOR)*	ACCEPTABLE	BEST
RELIABILITY OF ANALYTICAL RESULTS	BEST	POOR

*BASED ON GRAPHITE-EPOXY TRUSS AND SHEET-METAL BOX STRUCTURES

STRUCTURAL MATERIALS TRADEOFF

Although graphite epoxy had the highest cost, it proved to be the only material for the strongback trusswork capable of meeting the 25 hertz structural requirements due to its high stiffness to weight ratio. This is discussed in the strucutral dynamics section of the report in more detail. As weight considerations became more important later in the study, the lighter weight of the graphite epoxy structure also became a more attractive feature of its selection.

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SERGE ANTENNA

STRUCTURAL-MATERIALS TRADEOFF (REF. TRUSSES)

	ALUMINUM	GRAPHITE	STEEL	TITANIUM
STIFFNESS/WEIGHT	POOR	BEST	POOR	POOR
STRENGTH/WEIGHT	ACCEPTABLE	BEST	POOR	POOR
MATERIALS COST	ACCEPTABLE	HIGH	LOW	ACCEPTABLE
THERMAL CONTROL	ACCEPTABLE	BEST	POOR	POOR
FABRICABILITY	GOOD	ACCEPTABLE	GOOD	GOOD
AVAILABILITY	GOOD	ACCEPTABLE	GOOD	GOOD

GENERAL ARRANGEMENT

The general arrangement of the trusses and panels on the OFT pallet is depicted in the figure. The pallet hardpoints used are identified and dimensions given.

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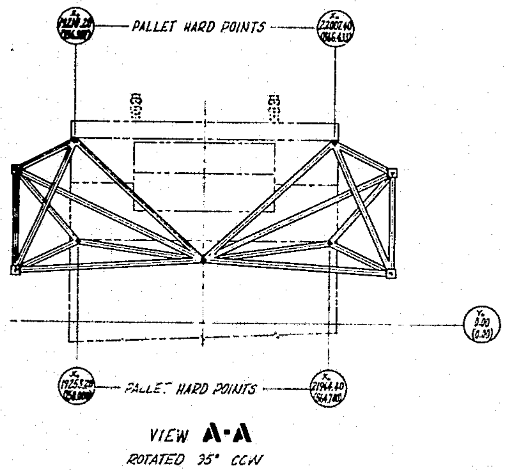
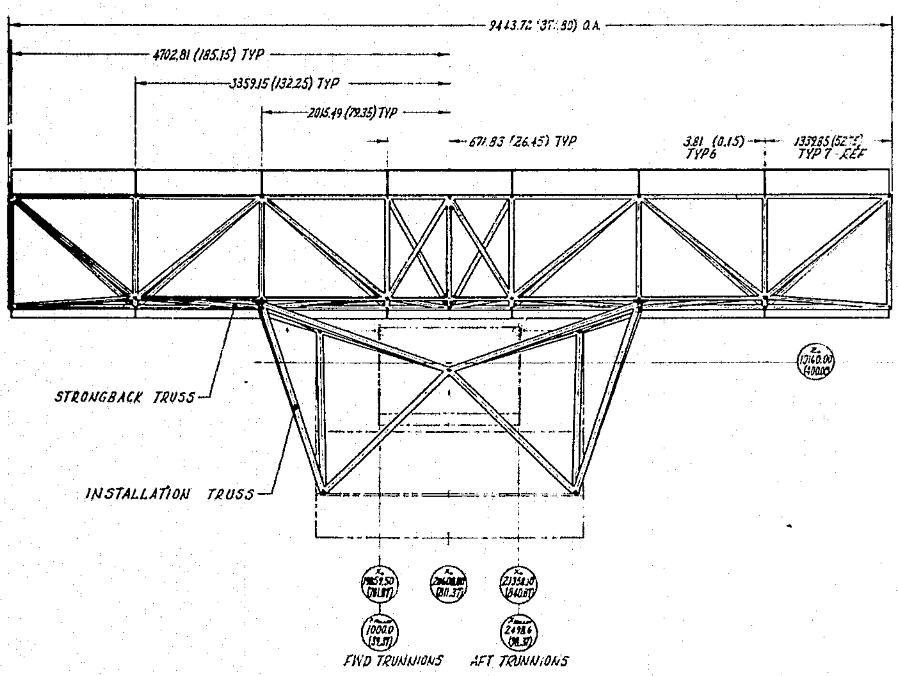
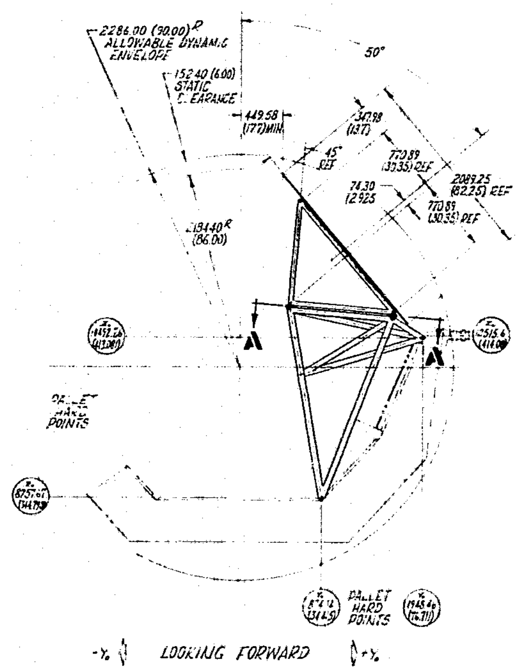
SERGE ANTENNA

GENERAL ARRANGEMENT







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TYPICAL TRUSS JUNCTION END FITTINGS

The truss member junction concept is illustrated. The end fittings have clevis members to permit truss assembly. Two bolts may be used to attach each end fitting to the junction rather than the single bolts shown in order to make a more rigid junction.

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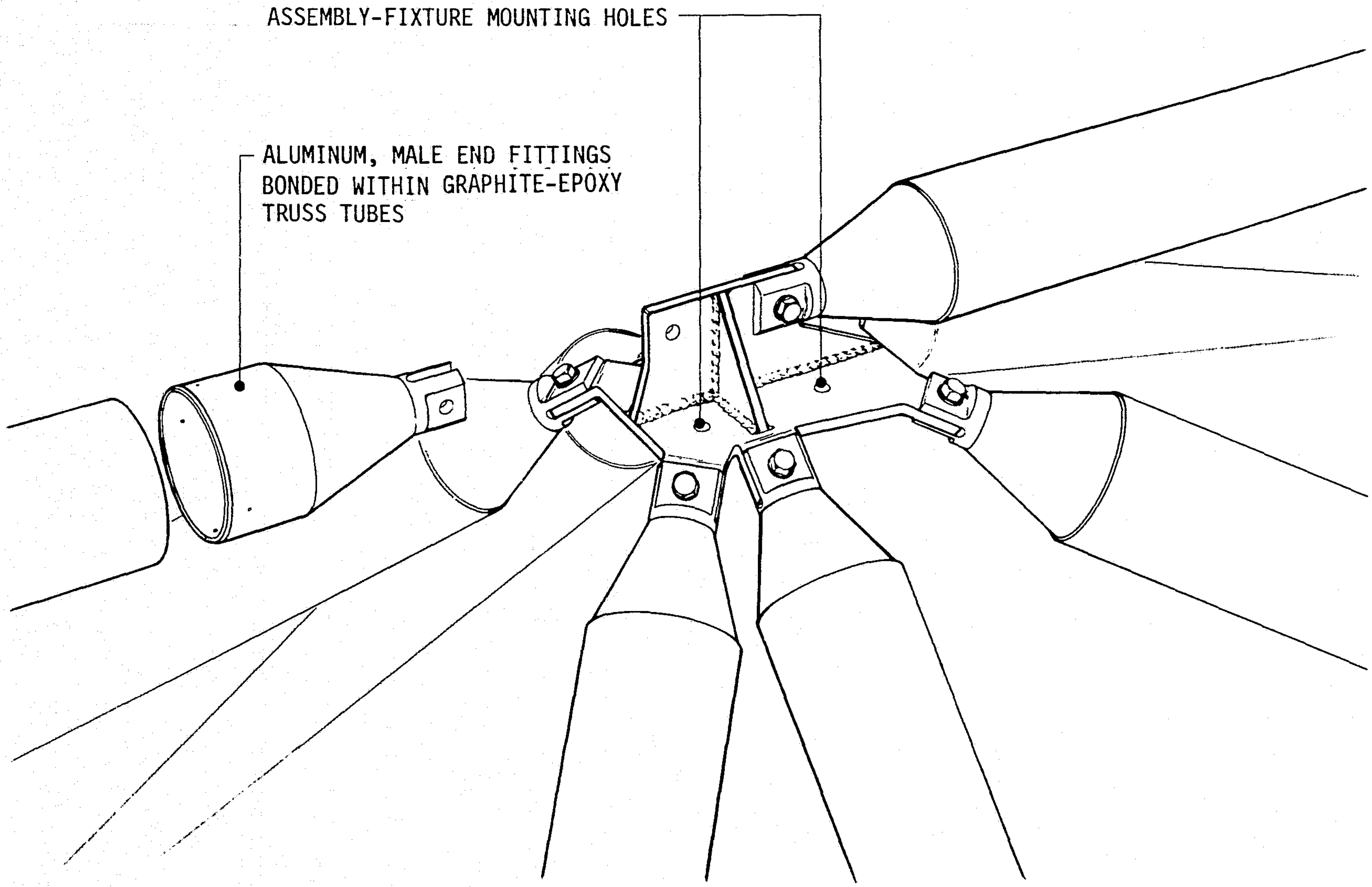
SERGE ANTENNA
TYPICAL TRUSS JUNCTION AND END FITTINGS



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TYPICAL TRUSS JUNCTION AND END FITTINGS

Another truss junction is illustrated, this one at the interface between the strongback truss and the installation truss. Handling fixtures for lifting the strongback and lowering it to the installation truss on the pallet will interface with this junction.

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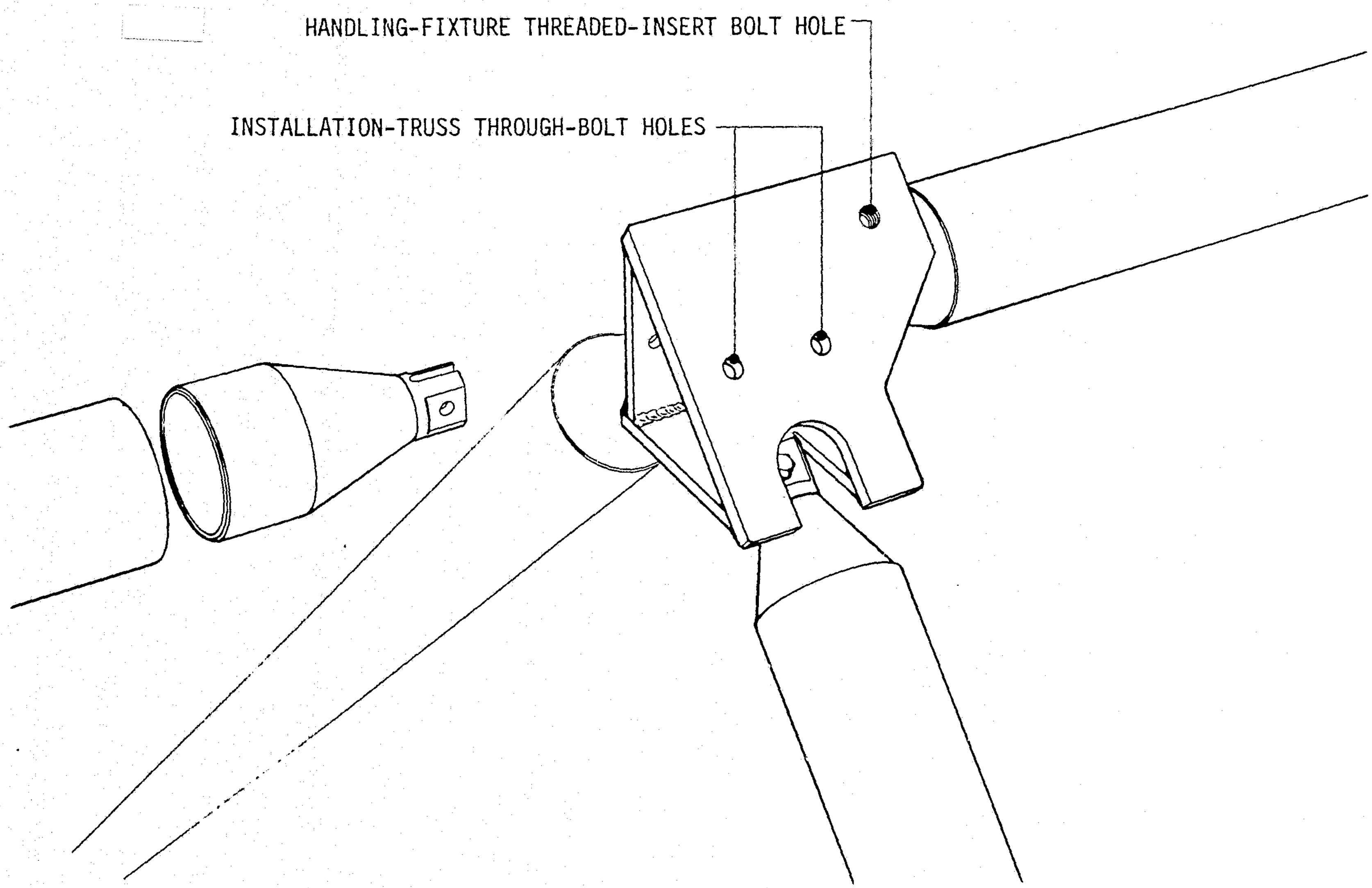
SERGE ANTENNA

TYPICAL TRUSS JUNCTION AND END FITTINGS



PANEL ATTACH FITTINGS

The panels will be attached to the strongback truss using a thermally non-redundant mounting concept similar to that used to attach the SEASAT panels to its trusswork. This concept permits differential expansion of the trusswork and panels and reduces distortions.

The panel attach fittings will be bonded to the back of the panels. A pattern will be etched away from the ground plane to allow bonding to the fiberglas substrate, making a stronger bond.

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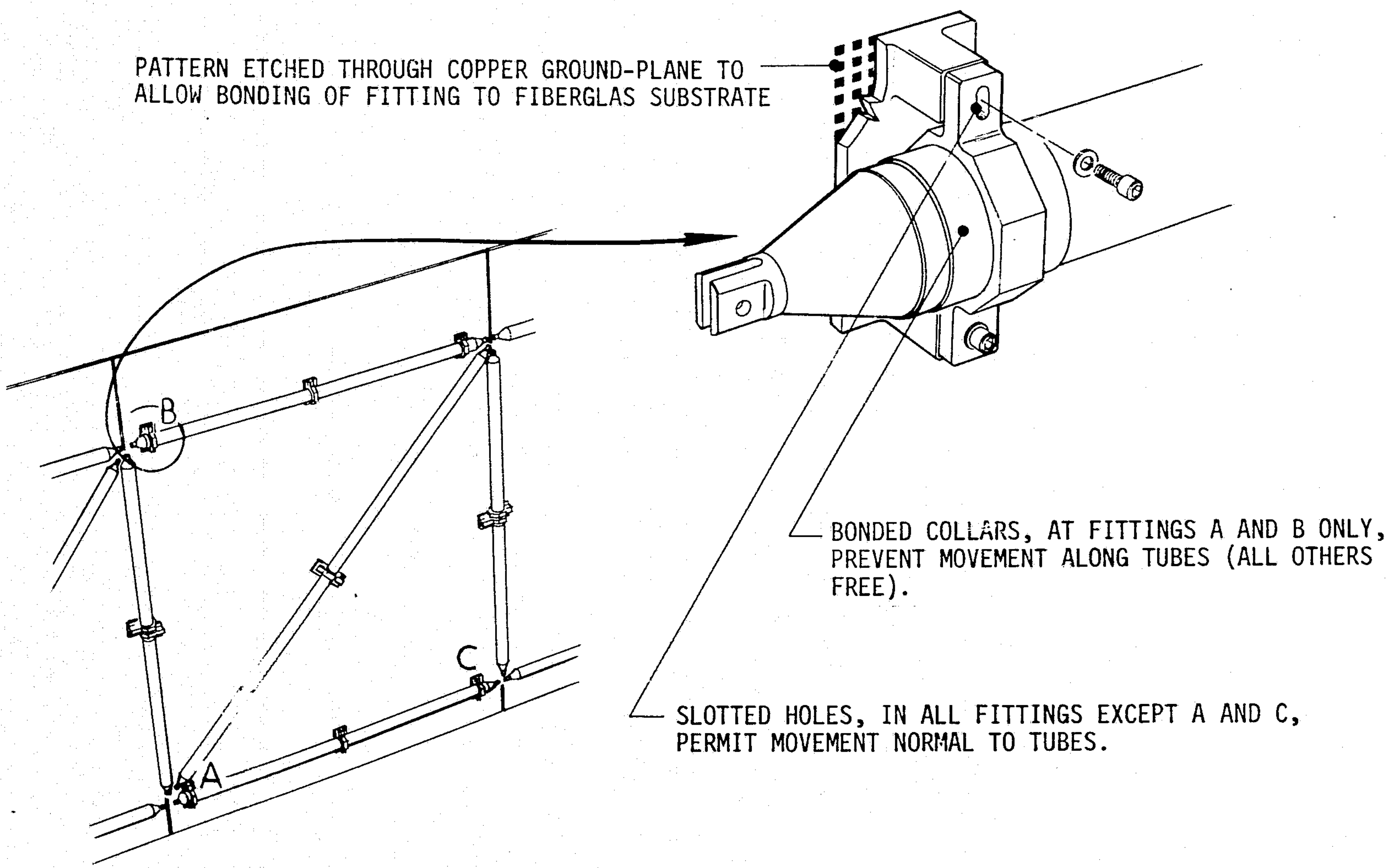
SERGE ANTENNA
PANEL ATTACH FITTINGS



RF FEED ATTACH FITTINGS

The RF coax cable feed will be attached in a manner which allows the cable to expand without producing a load on the trusswork. A short length of flexible coax cable will interface between the panel connector and the larger coax cable to protect the interface from loads.

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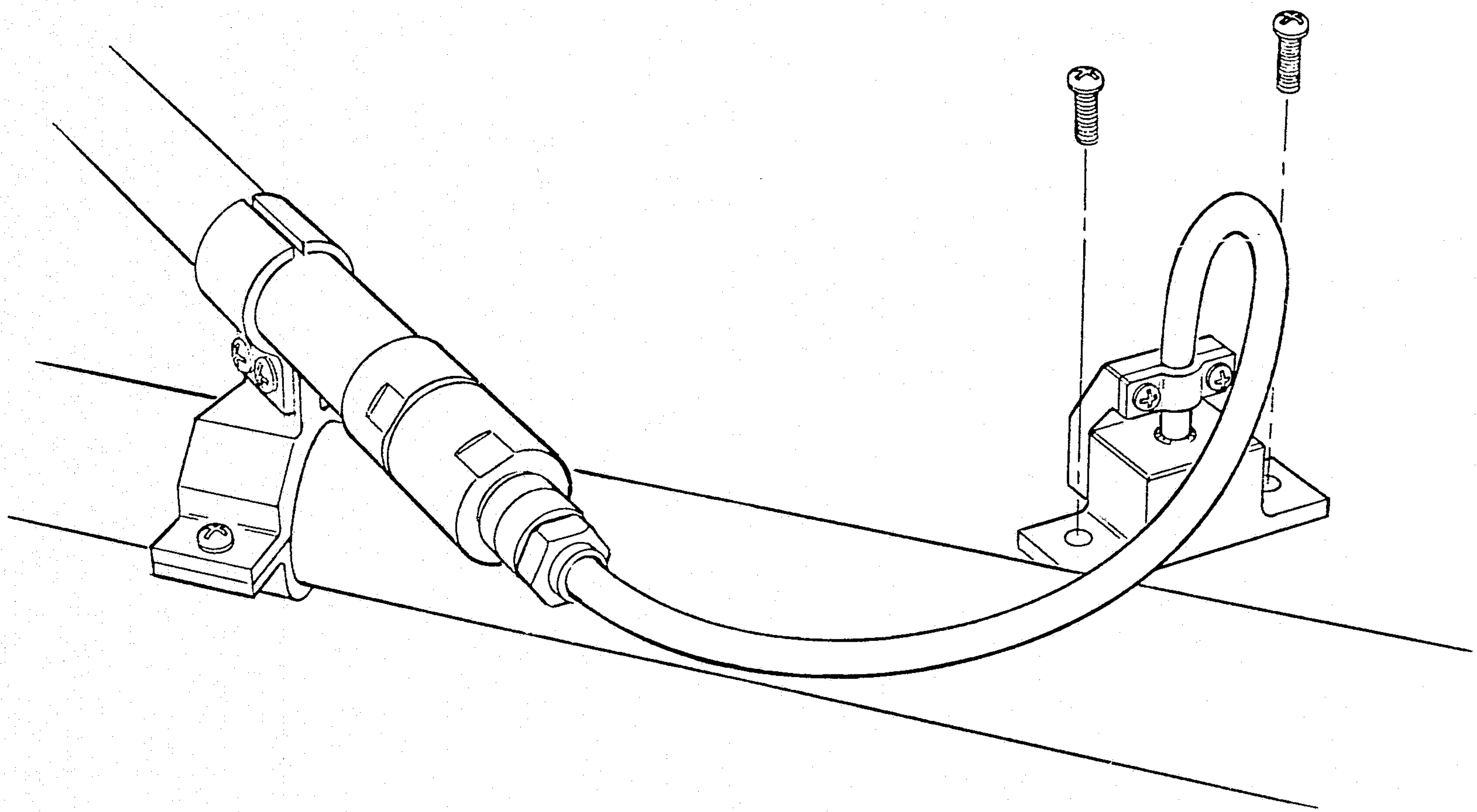
SERGE ANTENNA
RF-FEED ATTACH FITTINGS



ADJUSTABLE PALLET INTERFACE FITTINGS

An adjustable pallet interface fitting will be provided to mate to the pallet hardpoints. The adjustment will allow the interface ball to be located at the socket. It will also provide fine pointing capability (± ½°) after the antenna has been coarsely aligned to within ½° of the pointing direction by shims at the strongback to installation truss interface. This capability will allow the antenna to meet the ± 0.2° pointing accuracy requirement with respect to the pallet trunnions in a one-g environment.

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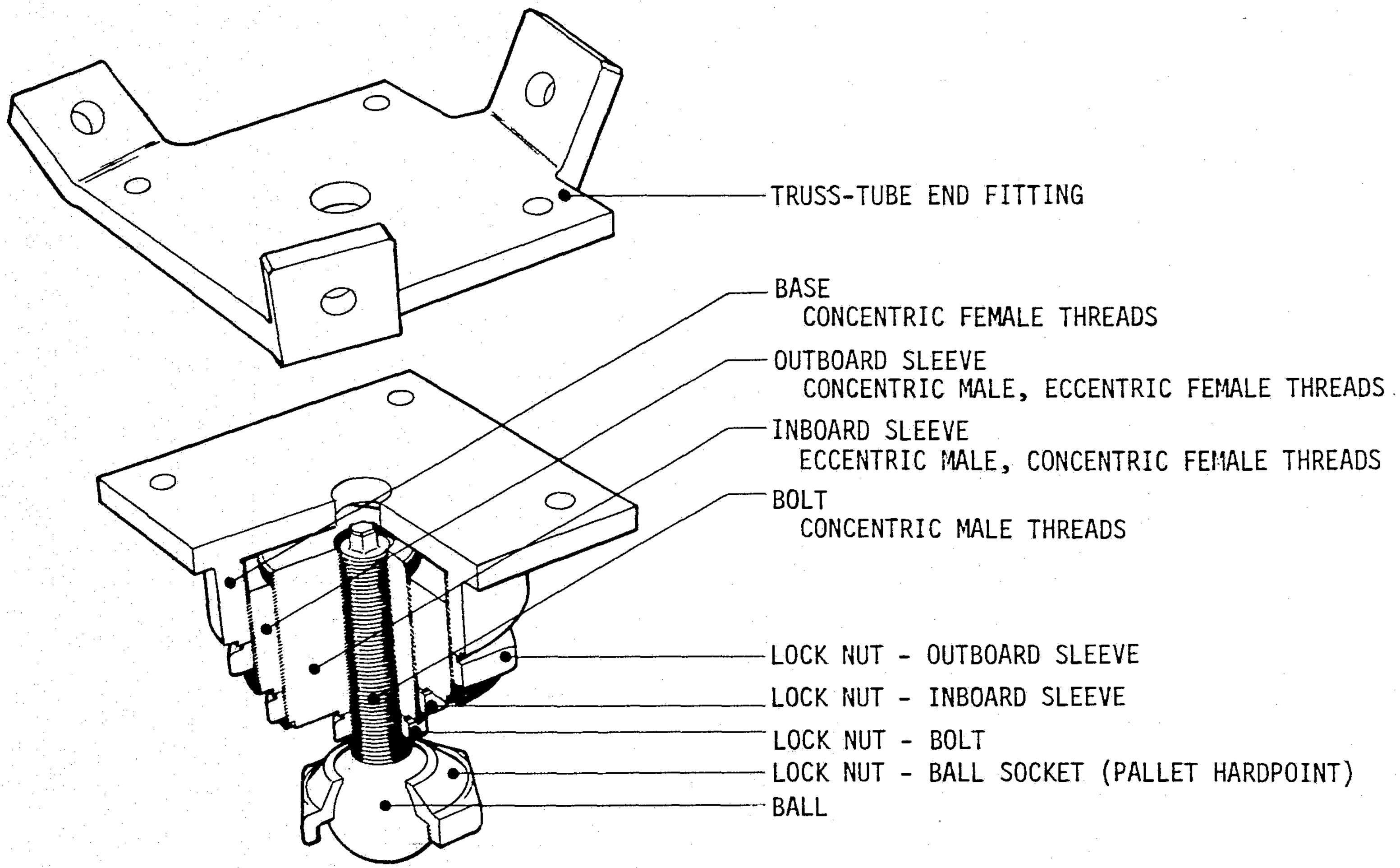
SERGE ANTENNA
ADJUSTABLE PALLET-INTERFACE FITTINGS (4)



CLEARANCE ANALYSIS - INSTALLED STATIC POSITION

A clearance analysis was conducted to verify that orbiter distortions due to thermal "hotdogging" and ascent and landing dynamics did not result in mechanical interference with the antenna. The next 4 figures show that under static conditions thermal distortion conditions, ascent conditions, and landing conditions no interferences result. The most critical case is the ascent condition.

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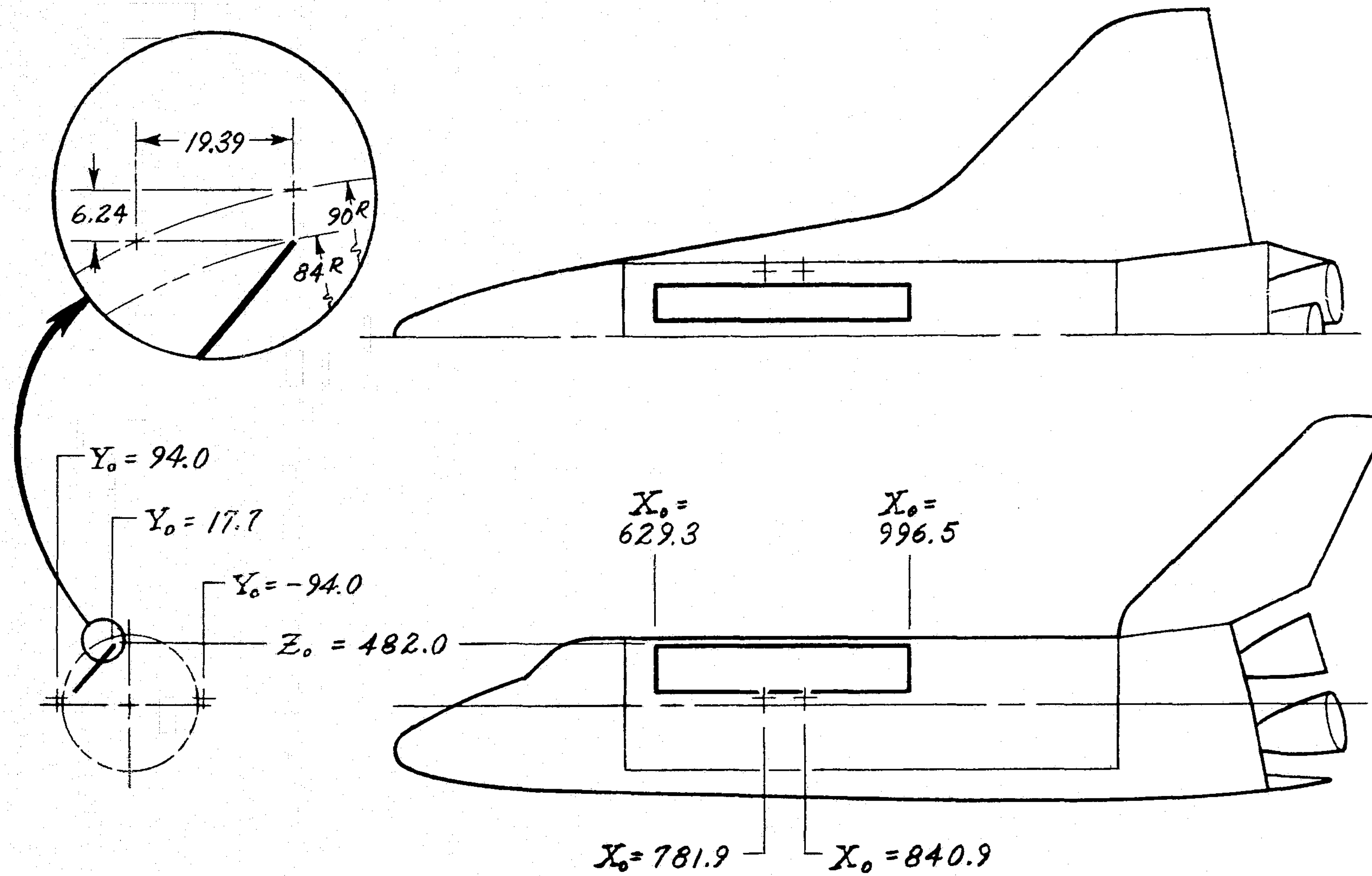
SERGE ANTENNA
INSTALLED STATIC POSITION



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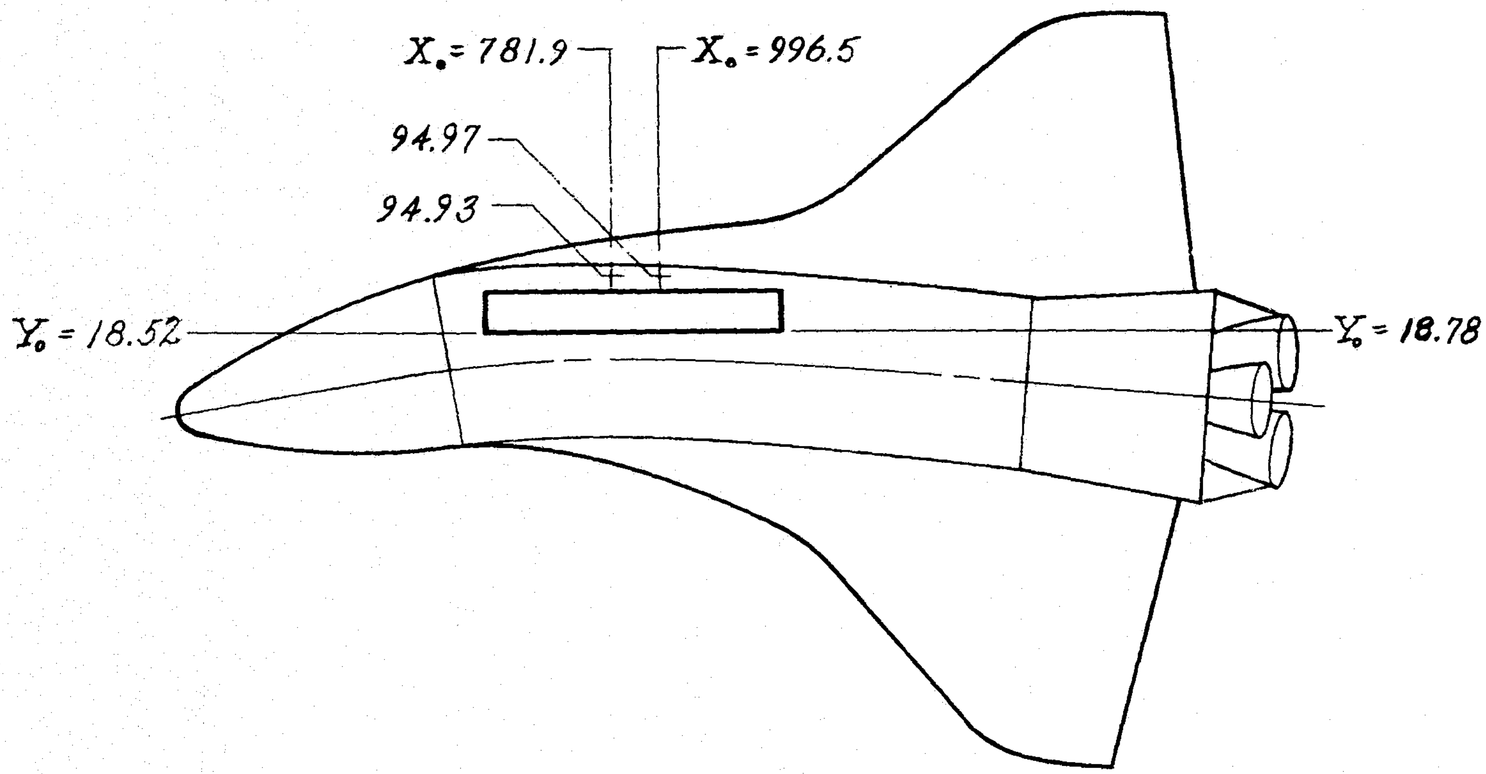
SERGE ANTENNA
ORBITER THERMAL DISTORTION - 6-HOUR HOLD

REDUCES LATERAL CLEARANCE (REF. UNDISTORTED ENVELOPE):

- FROM 19.39 to 18.57 INCHES AT TOP/FWD ANTENNA CORNER
- FROM 19.39 to 18.31 INCHES AT TOP/AFT ANTENNA CORNER



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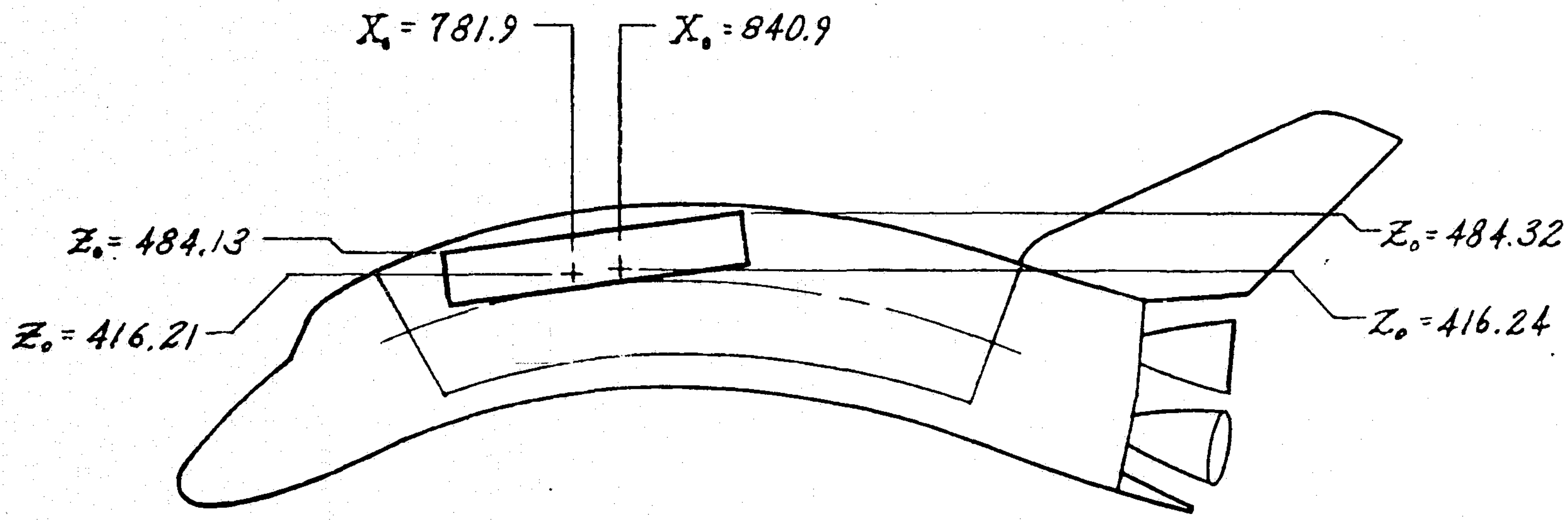
SERGE ANTENNA
ORBITER DYNAMIC DISTORTION - ASCENT

REDUCES VERTICAL CLEARANCE (REF. UNDISTORTED ENVELOPE)

- FROM 6.24 to 4.11 INCHES AT TOP/FWD ANTENNA CORNER
- FROM 6.24 to 3.92 INCHES AT TOP/AFT ANTENNA CORNER



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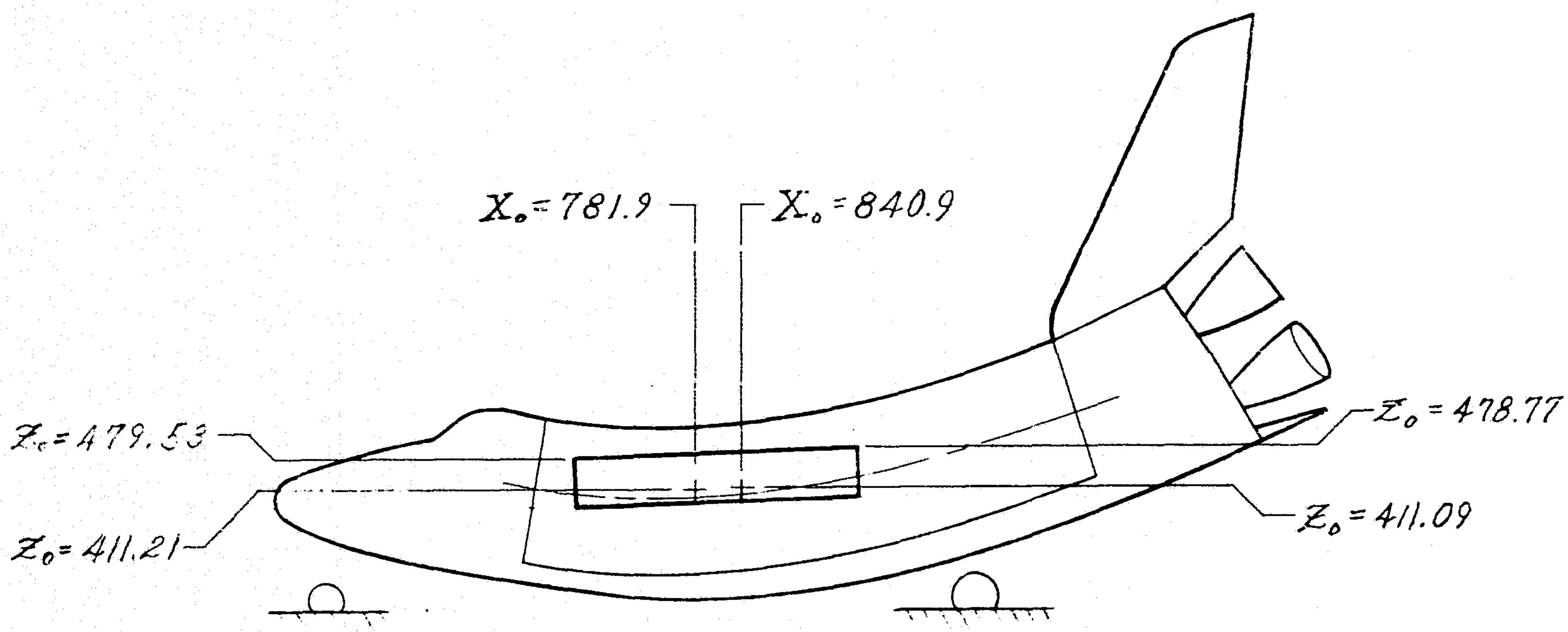
SERGE ANTENNA
ORBITER DYNAMIC DISTORTION - LANDING

INCREASES VERTICAL CLEARANCE (REF. UNDISTORTED ENVELOPE)

- FROM 6.24 to 8.71 INCHES AT TOP/FWD ANTENNA CORNER
- FROM 6.24 to 9.47 INCHES AT TOP/AFT ANTENNA CORNER



ESTIMATED WEIGHT BREAKDOWN

The estimated weights for the baseline configuration are given in the chart. The 10% uncertainty is utilized to account for potential uncertainties in calculations. The margin is for potential design changes which could result in weight growth. The target weight (best estimate plus uncertainty) is slightly less than 170 Kg (370 lbs). The not-to-exceed weight (including margin) is 181.3 Kg (400 lbs).

The approximate C.G. location corresponding to the best estimate weight is also given in the chart.

F77-23
SERGE ANTENNA
ESTIMATED WEIGHT BREAKDOWN

	KILOGRAMS	(POUNDS)
ANTENNA PANELS (7 NEW EMU)	34.9	77.0
FEED FITTINGS (7)	0.3	0.7
COAX "PIG TAILS" WITH CONNECTORS (7)	0.6	1.4
PRIMARY COAX WITH CONNECTORS (18.4 m x 28 mm DIA)	20.4	45.0
POWER DIVIDERS (1 3-WAY + 4 2-WAY)	0.8	1.7
ELECTRONICS COAX WITH CONNECTORS (1.2 m x 28 MM DIA)	1.6	3.6
CABLE ATTACH FITTINGS (APPROXIMATELY 50)	3.4	7.5
THERMAL FRONT-FACE COVER (20.4 m^2 TIQC)	5.3	11.8
TOTAL ANTENNA	67.3	148.7
STRONGBACK TRUSS TUBES (84.1 m x 38.1 mm DIA)	25.2	55.7
JUNCTION AND TUBE-END FITTINGS (25 JUNCTIONS)	7.3	16.1
INSTALLATION TRUSS MOUNTING PLATES (4)	0.9	2.0
BOLTS, NUTS, ADHESIVE, ETC.	2.5	5.5
THERMAL BALNKET (30.7 m^2, 5 LAYERS MLI + 1 TIQC)	10.7	23.6
TOTAL STRONGBACK TRUSS	46.6	102.9
INSTALLATION TRUSS TUBES (27.6 m x 50.8 mm DIA)	11.2	24.6
JUNCTION AND TUBE-END FITTINGS (9 JUNCTIONS)	15.4	34.0
STRONGBACK TRUSS MOUNTING PLATES (4)	0.9	2.0
BOLTS, NUTS, ADHESIVE, ETC.	4.2	9.3
ADJUSTABLE PALLET-INTERFACE FITTINGS (4)	2.9	6.4
THERMAL SLEEVES (8.2 m^2, 5 LAYERS MLI + 1 TIQC)	3.1	6.9
TOTAL INSTALLATION TRUSS	37.7	83.2
TOTAL ANTENNA SYSTEM, BEST ESTIMATE	151.6	334.8
UNCERTAINTY (10%)	15.2	33.5
TOTAL ANTENNA SYSTEM, TARGET WEIGHT	166.8	368.3
MARGIN	14.5	31.7
TOTAL ANTENNA SYSTEM, NOT-TO-EXCEED	181.3	400.0

C.G. LOCATION - ORBITER STATION	MM	INCHES
Xo	20608.8	811.4
Yo	1053.9	41.5
Zo	10908.3	429.5

STUDY CONCLUSIONS - MECHANICAL

The chart summarizes the major conclusions of the mechanical portion of the study.

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SERGE ANTENNA
STUDY CONCLUSIONS - MECHANICAL

- "HIGH" POSITION ON STARBOARD SIDE OF PALLET
- TRIANGULAR-SECTION, 7-BAY, 1.5 INCH DIA. GRE-TUBE STRONGBACK TRUSS
- "STAND-ALONE", 2.0 INCH DIA. GRE-TUBE INSTALLATION TRUSS WITH FIELD JOINT
- ALUMINUM JUNCTION AND END FITTINGS, BOTH TRUSSES
- 4-POINT, HARD-BOLT INTERFACE BETWEEN TRUSSES
- 4-POINT, ADJUSTABLE-POSITION PALLET INTERFACE FITTINGS
- COARSE POINTING AT BOLT INTERFACE AND FINE POINTING AT PALLET INTERFACE
- POINTING REFERENCES TO BE OPTICAL FLAT ON ANTENNA AND PLANE OF PALLET TRUNNIONS, IN 1 G, AT LEVEL IV INTEGRATION
- NON-REDUNDANT, ALUMINUM, PANEL ATTACH FITTINGS
- LOAD ISOLATION OF RF-FEED DIVIDERS VIA HARD-CLAMP TRUSS FITTINGS
- LOAD ISOLATION OF PANEL RF-FEED FITTINGS VIA LOOPED PIG TAILS
- SHIPMENT OF ANTENNA, EXCEPT INSTALLATION TRUSS, AS ONE ASSEMBLY

RF ANALYSIS

The RF objectives of the SERGE Antenna Study were to:

1) Define the antenna to be flown
2) Establish mounting configuration based on antenna performance and Shuttle interface requirements
3) Define the panel feed system and establish performance levels
4) Project performance of the selected SERGE Antenna configuration

Several studies were undertaken by BBRC to accomplish these objectives. The results are summarized in the following section. First the selected configuration and projected performance is outlined with more detailed trade-off studies considered in the following order: panel study, mounting configuration, feed system, thermal blanket effects and gain-loss budget.

The SERGE antenna consists of seven new EMU panels for which the electrical design and efficiency have been demonstrated during the SEASAT program. The panels are interconnected by a 7/8" coax corporate feed providing both amplitude taper on the outer four panels and equal phase illumination to all panels. A high-in-the-bay mounting configuration improves the electrical performance and reduces unwanted radiation within the payload bay.

SERGE ANTENNA
RF ANALYSIS

PROJECTED PERFORMANCE

The facing table lists nominal expected performance levels. It should be noted that the E plane beamwidth criteria has been modified to accommodate the required E plane taper for 14.5 dB sidelobes.

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SERGE ANTENNA PROJECTED PERFORMANCE

CRITERIA	SPECIFICATION	PROJECTED PERFORMANCE
OPERATING FREQUENCY	1,275 MHz	1,275 ± 3 MHz
BANDWIDTH	± 11 MHz	+12/-14 MHz
VSWR	1.5:1	1.5:1
PEAK POWER	1,500 WATTS	>1,500 WATTS
GAIN	33.0 dB	33.18
BEAMWIDTH E-PLANE	2.2°	2.1
BEAMWIDTH H-PLANE	6.2° ± .1°	6.2°
SIDELOBES E-PLANE	14.5 dB	15.0 dB[1]
SIDELOBES H-PLANE	14.5 dB	17.0 dB
POLARIZATION PURITY	-20 dB	-26 dB
PHASE ERROR	<20° ± 5° OFF-BORE SIGHT	< 5°
DEVIATION FROM QUADRATURE FIT	2.0°	.5°
RFI	2 V/M	1 V/M[2]

1)GRATING LOBE AT 47°
2)ESTIMATED LEVEL AT CENTER OF PAYLOAD BAY

PANEL STUDY

The selection of EMU panels was based on low cost and risk both in the design and manufacturing stages of this program. The electrical performance is acceptable and has been thoroughly established. Due to element spacing the EMU array exhibited a 14.5 dB grating lobe at 47° from boresight in the E-plane.

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SERGE ANTENNA
PANEL STUDY

- PANEL SELECTION:

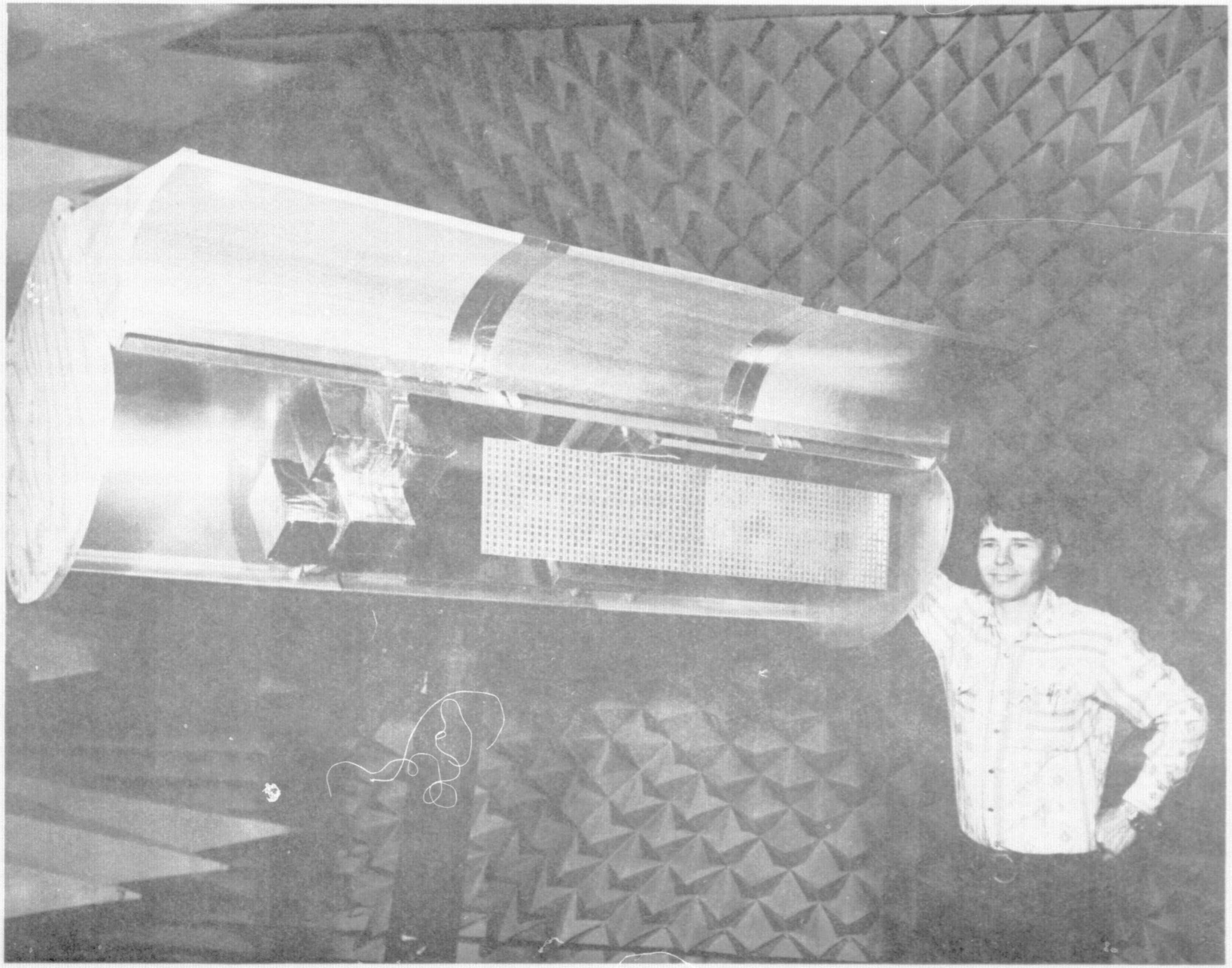
TRADE-OFF CRITERIA		EMU PANELS	FLIGHT PANELS	NEW PANELS
ELECTRICAL:	GAIN	ACCEPTABLE	GOOD	?
	SIBELOBES	GRATING LOBE	GOOD	GOOD
	DESIGN RISK	LOW	LOW	HIGH
MECHANICAL:	COMPLEXITY	EXCELLENT	POOR	GOOD
	RESONANT FREQ.	GOOD	POOR	GOOD
	DESIGN RISK	LOW	HIGH	LOW
DEVELOPMENT COSTS		LOW	LOW	HIGH
MANUFACTURING COSTS		LOW	HIGH	LOW

- CONCLUSION: SEVEN EMU PANEL CONFIGURATION WILL MEET ALL SYSTEM SPECIFICATIONS WITH THE EXCEPTION OF 16 dB INTEGRATED SIDELOBES. THE SPECIFICATION WAS SUBSEQUENTLY CHANGED TO REFLECT 16 dB INTEGRATED SIDELOBES WITHIN 40° OF THE BORESIGHT, MAKING THE GRATING LOBE AT 47° ACCEPTABLE.

MOUNTING CONFIGURATION 1/10 SCALE MODEL

Due to the proximity of the SERGE antenna to potential reflecting surfaces within the Shuttle bay, it was necessary to evaluate the antenna performance in its operating environment. As shown in the facing figure, BBRC built a 1/10 scale model of the SERGE antenna and Shuttle bay. Pattern tests were conducted with the antenna mounted in a high configuration as depicted, and also mounted on the opposite side of the bay in a low mounting configuration.

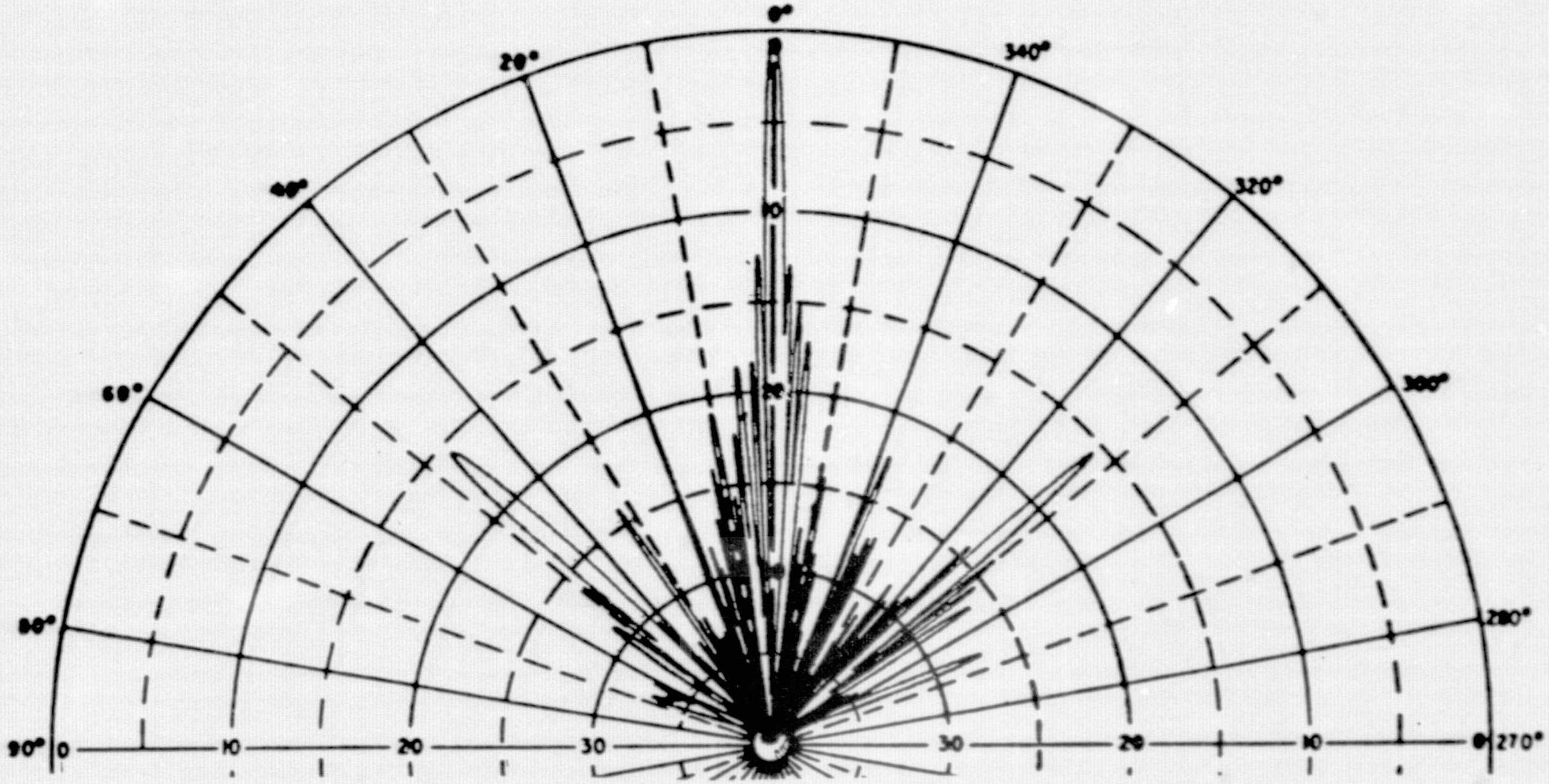
F77-23



MOUNTING CONFIGURATION PATTERN TESTS

Test patterns were first obtained for the 1/10 scale SERGE antenna under free space conditions. These results were compared to patterns recorded with the antenna mounted both high in the bay and low in the bay. The scale model antenna operated at a frequency of 12.7 GHz providing patterns scaled to the payload bay model. The measured patterns are shown on the following four charts. As only minor variations were detected in the E-plane, only H-plane patterns are shown for comparison.

F77-23
SERGE ANTENNA
1/10 SCALE TEST
E-PLANE
NO MODEL



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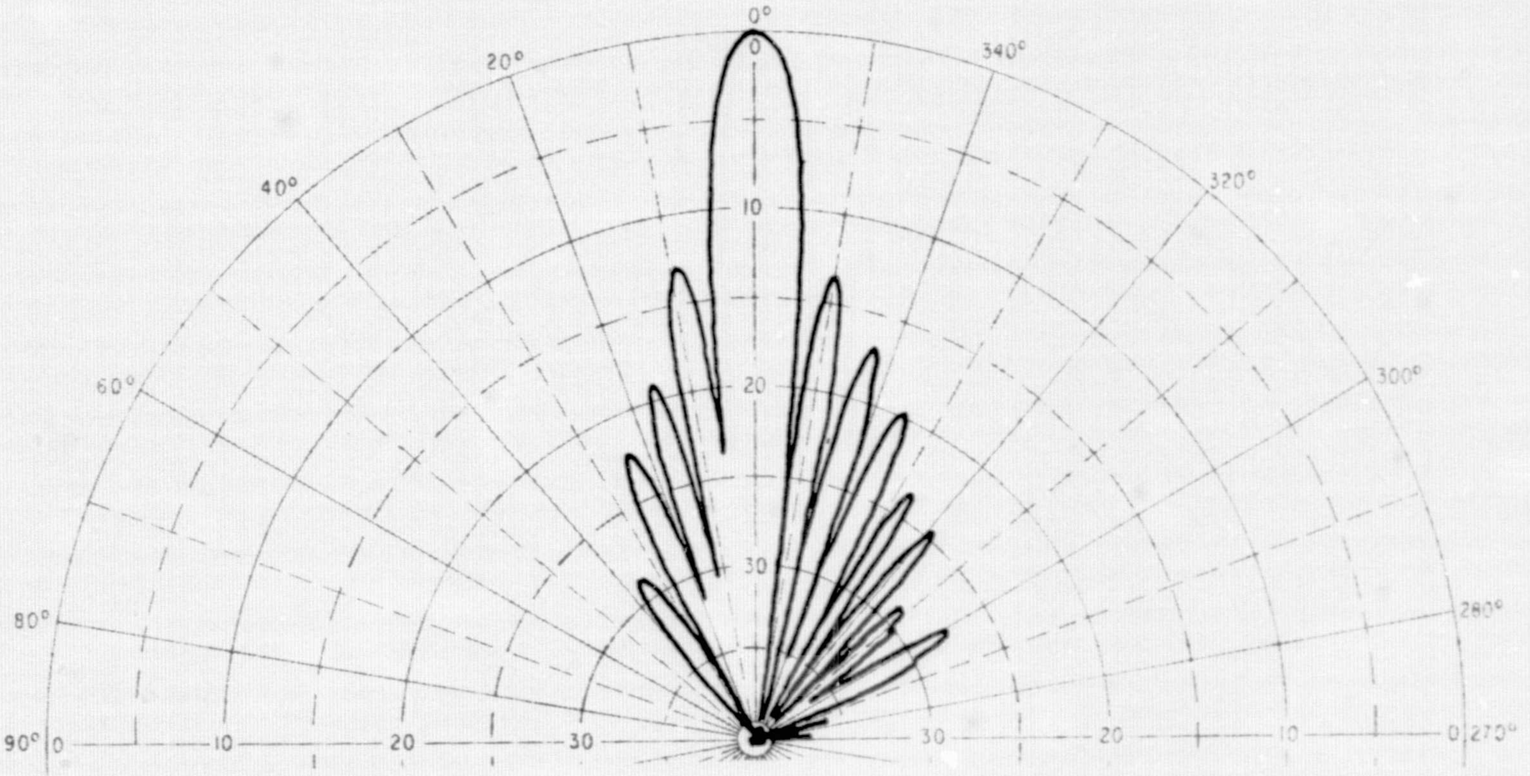
SERGE ANTENNA

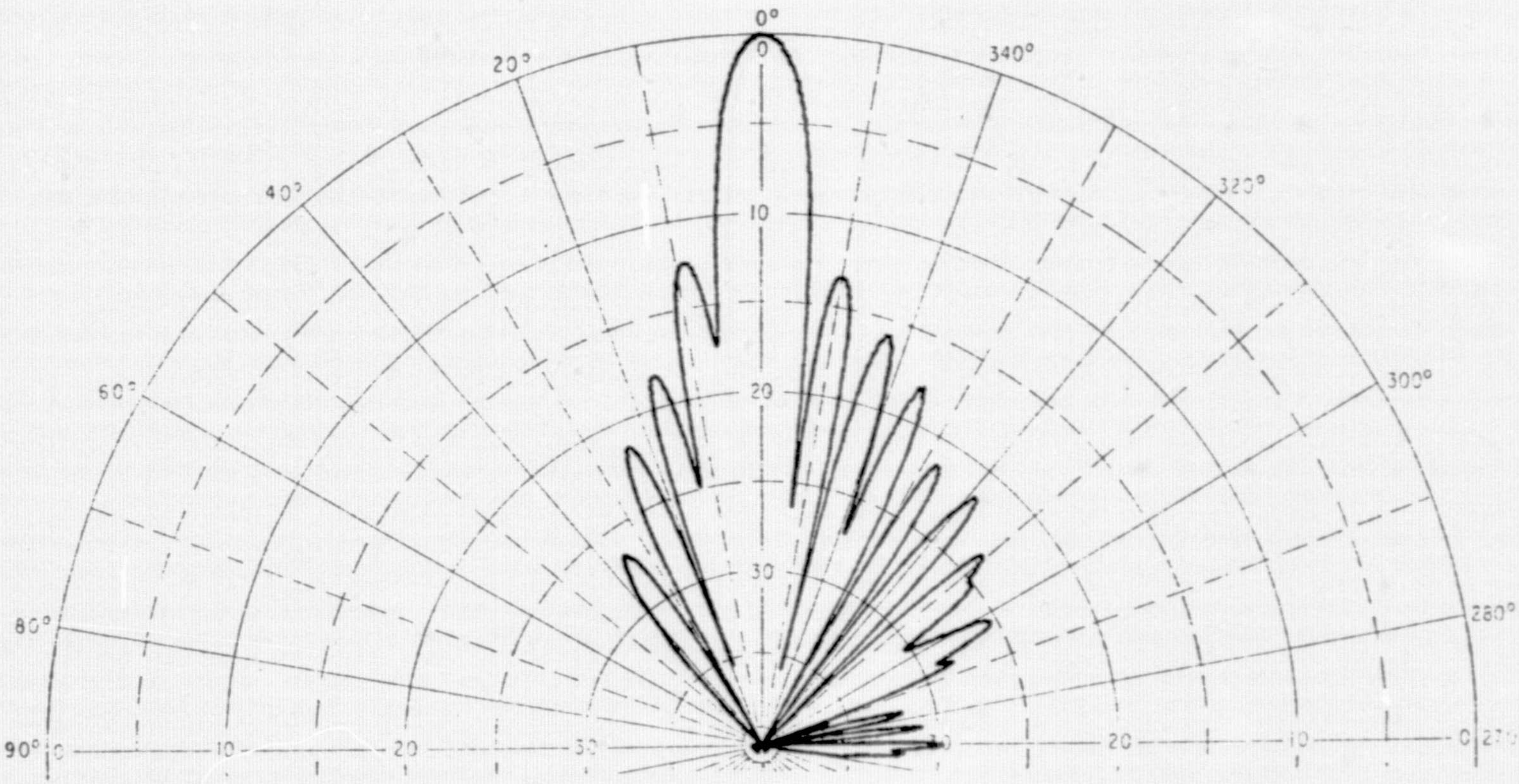
1/10 SCALE

H-PLANE

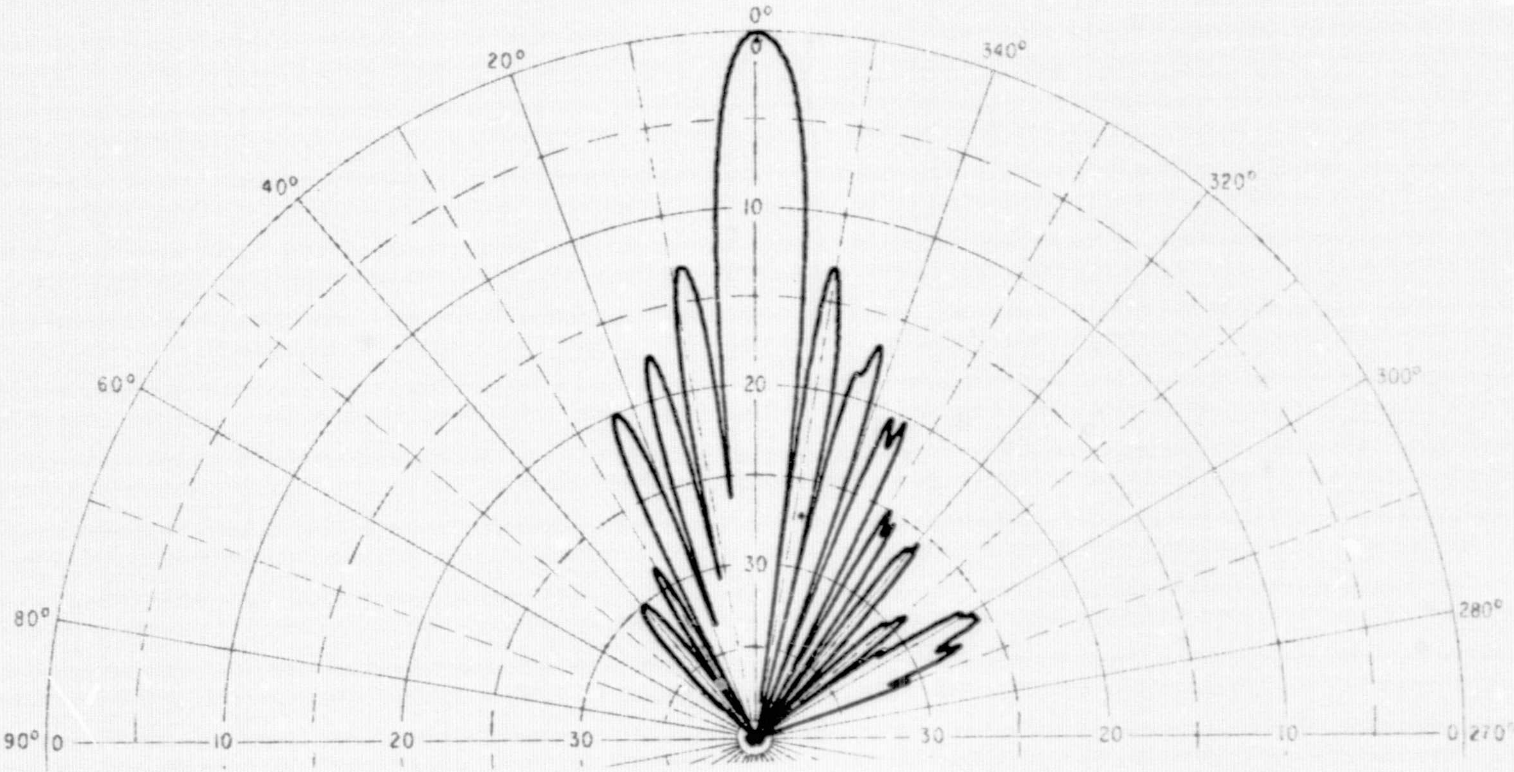
NO MODEL



F77-23
SERGE ANTENNA
1/10 SCALE
H-PLANE
LOW MOUNT



F77-23
SERGE ANTENNA
1/10 SCALE
H-PLANE
HIGH MOUNT



MOUNTING CONFIGURATION
TEST RESULTS

The 1/10 scale model results are summarized in the opposite table. In terms of beamwidth and first sidelobe levels, there appears to be little impact on the antenna in either the high or low configuration. Further study indicates that in the low configuration, outer sidelobes increase three to five dB and null filling occurs. Tests also indicated that in the high mount, minor aberrations in sidelobes are due to reflections off the Shuttle's outer thermal radiator panels and not due to reflections from within the Shuttle bay.

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SERGE ANTENNA
1/10 SCALE
TEST RESULTS

H-PLANE

ANTENNA POSITION	BEAMWIDTH* 3dB	BEAMWIDTH* 8dB	SIDELOBES (dB) LEFT	SIDELOBES (dB) RIGHT	GRATING LOBES (dB) LEFT	GRATING LOBES (dB) RIGHT
NO MODEL	6.1^o	9.3^o	-13.0	-13.8	----	-----
HIGH	6.0^o	9.1^o	-13.0	-13.0		
LOW	6.2^o	9.0^o	-12.5	-13.0		

E-PLANE

NO MODEL	1.5^o	1.9^o	-12.5	-13.0	15.5	16.0
HIGH	1.4^o	1.9^o	-12.0	-12.5	15.0	18.0
LOW	1.5^o	1.9^o	-12.2	-12.8	14.7	15.5

*BEAMWIDTH READINGS SUBJECT TO $.2^o$ INTERPRETATION ERROR

MOUNTING CONFIGURATION RFI

In the low-mounted configuration increased sidelobe levels indicated significant reflections within the Shuttle bay. To estimate the electric field intensity within the bay, the analysis as shown on the facing page was performed. The estimated level of 10 volts/meter exceeds specification.

With the high mount, only radiation due to currents on the backside of the panels will be detected within the bay. Near field patterns of a single EMU panel were measured with major attention focusing on the back side radiation. A similar analysis applied to these near field measurements yield an estimated electric field intensity of 1 V/m at the center of the Shuttle bay.

Based on pattern performance and a reduction in the RFI level by 20 dB the high configuration was selected.

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SERGE ANTENNA
RFI CONSIDERATIONS

- SPECIFICATION

  ELECTRIC FIELD INTENSITY < 2 V/m

- OBSERVED FIELD LEVELS IN LOW CONFIGURATION

  INTERIOR REFLECTIONS INCREASE SIDELOBES 2-5 dB

  3 dB INCREASE FIFTH SIDELOBE IMPLIES REFLECTED SIGNAL OF 25 dB DOWN FROM PEAK LEVEL OR 4.74 WATTS

  ASSUME THAT THE INTERIOR SPECULAR REFLECTIONS ORIGINATE FROM AN APERTURE EQUAL IN SIZE TO THE SERGE ANTENNA. THE POWER DENSITY AT THIS APERTURE IS .26 WATTS/M^2.

  PLANE WAVE APPROXIMATION--POWER DENSITY = E^2/η

  $$E \approx 10 \text{ V/m}$$

- OBSERVED FIELDS EXCEED SPECIFICATION

SIDELOBE STUDY - FEED SYSTEM AMPLITUDE TAPER

The specification of 14.5 dB sidelobes in all planes requires that power tapers be applied in both the E and H-planes. The EMU panel is designed with an H-plane taper and achieves 17 dB sidelobes in this plane. A power taper can be applied by the panel feed system such that the power is distributed to the panels achieving a step-wise taper across the aperture in the E-plane. Computer analysis of various step-tapers using the measured EMU pattern as the element factor were conducted during this study. A summary of the projected array performance for various step tapers is shown.

The "natural" taper developed for the SERGE 7-way power division to the 7 panels which presents the least development costs and risks requires further explanation. Four equal 2-way power divisions and one equal 3-way power division implements the required amplitude distribution. After initially splitting the input power in half, 50 percent of the total power is used to feed the center three panels. This power undergoes a 3-way power division such that the center three panels are each illuminated with 1/6 of the total power. The remaining power is equally divided by three 2-way power divisions. The outer four panels thus are illuminated at 1/8 the total power each. This is the selected distribution to be used on the SERGE antenna.

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SERGE ANTENNA SIDELOBE STUDY

TAPER	BEAMWIDTHS 3 dB	BEAMWIDTHS 8 dB	FIRST SIDELOBE LEVEL (dB)	GRATING LOBE LEVEL (dB)	DIRECTIVITY LOSS (dB)
NONE	1.22°	1.88°	-13.0	-17.2	---
COSINE	1.27°	2.05°	-15.0	-17.2	-.03
16 dB TCHEBYSCHEFF	1.22°	2.05°	-16.0	-17.2	-.02
"NATURAL" TAPER	1.33°	2.00°	-15.0	-17.2	-.05

CONCLUSION:

- REQUIRED 14.5 dB SIDELOBES CAN BE OBTAINED, BUT BEAMWIDTH SPECIFICATION WILL BE EXCEEDED. CAN E-PLANE BEAMWIDTH SPECIFICATION BE INCREASED TO 2.2 degrees?
- GRATING LOBE WILL EXIST AT 47 DEGREES IN E-PLANE OF EMU ARRAY. MEASUREMENTS INDICATE A -14.5 dB LEVEL AT 1.275 Ghz.

FEED SYSTEM REQUIREMENTS

Gain and sidelobe level specification dictate that the selected component feed system be able to obtain low insertion loss while providing a stepped amplitude taper across the array.

Nominally the power level to the center three panels should be 7.8 dB below the input level with the outer four panels, 9.0 dB below the input level.

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SERGE ANTENNA
FEED SYSTEM REQUIREMENTS

PARAMETER	REQUIREMENT	EXPECTED PERFORMANCE
INSERTION LOSS (INPUT PORT TO PANEL)	.8	.62 DB
INPUT VSWR	1.5:1	1.5:1
POWER DIVISION	-9.03 -7.78	-9.0 $\pm\Delta$ -7.8 $\pm\Delta$
BANDWIDTH	± 11 MHz	± 11 MHz
CENTER FREQUENCY	1275 MHz	1275 MHz
INPUT POWER	1500 WATTS PEAK 90 WATTS AVG.	
PHASE ERROR (BETWEEN PANEL PORTS	± 5°	± 5°
INTERFACE CONNECTOR	TBD	

FEED SYSTEM POTENTIAL TRANSMISSION LINES

Air-loaded 7/8" coax was selected for the main distribution lines after the first power division, with a dielectrically-loaded 7/8" coax up to that point. System tests which will be discussed later in this report confirm that a coax corporate feed can achieve the insertion loss values indicated. The coaxial system presents low design risks and low manufacturing costs when compared to suspended substrate or waveguide.

The 3 dB multipactor margin in the coaxial configuration is based on a dielectrically-loaded 7/8" input cable with the first power divider also dielectrically-loaded. The 7/8" air dielectric cable will handle 1900 to 2000 watts into a matched load before multipactor breakdown occurs. If the system peak instantaneous power is such that a 3 dB multipactor margin can be maintained, it would be advantageous both in terms of reduced insertion loss and development costs to use an air-loaded input section rather than the dielectrically-loaded coax. Multipactor considerations also require the use of HN type connectors rather than N type.

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SERGE ANTENNA
POTENTIAL FEED SYSTEMS

	7/8" COAX	SUSPENDED SUBSTRATE	WAVEGUIDE
ELECTRICAL			
Insertion Loss	.62	.5	.3
Phase Sensitivity (ppm/°C)	Excellent	Good	Good
Multipactor Margin	3DB	3 DB	3 DB
Design Risk	Low	Low +	High
MECHANICAL			
Complexity	Low	Fair	High
Weight	50 lbs.	25 lbs.	100 lbs.
Vacuum Venting	Fair	Good	Good
THERMAL			
Power Dissipation	Fair	Good	Good
MANUFACTURING COSTS	Low	High	Fair

FEED SYSTEM BASELINE CONFIGURATION

A schematic figure of the corporate feed is shown as well as orthographic projections of the actual layout. The cable connecting the radar electronics to the antenna is not shown.

In the proposed baseline configuration power enters directly into a reactive coaxial power divider. This unit is an off-the-shelf item which has been modified to be dielectrically loaded and has HN type connectors. The vendor (Microlab) indicates these modifications can be made with no deterioration in performance. Air-loaded 7/8" coax cable with male HN connectors is used to interconnect similar power dividers as shown to obtain the required distribution. Just before entering each panel a short length of 3/8" flexible cable is used to protect from potential mechanical loads at the panel to strongback attachment.

The cables will be phased by adjusting length D such that all parts are fed in phase. Cable D is shown in the orthographic projections as a loop perpendicular to the plane of the antenna.

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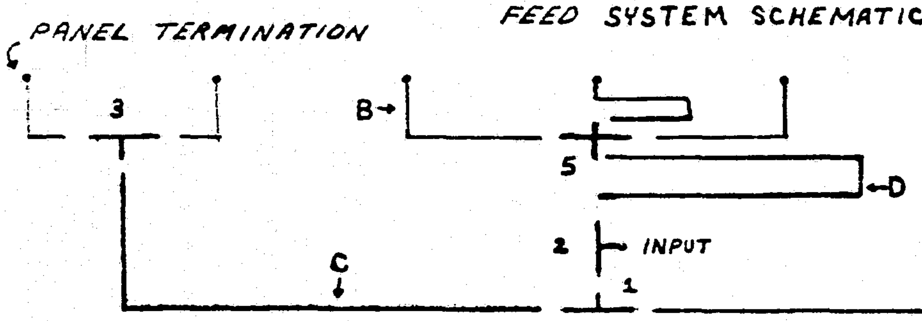
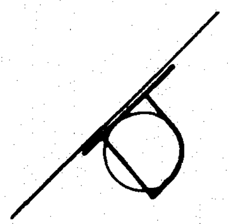
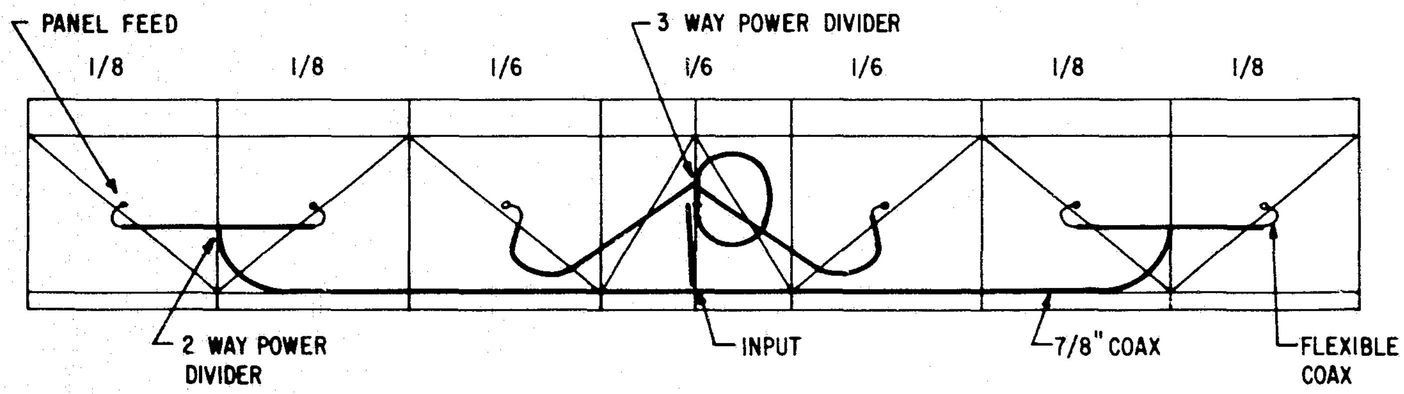
SERGE ANTENNA
BASELINE CORPORATE FEED

FEED SYSTEM SCHEMATIC



1-4 = 2 WAY POWER DIVIDERS
5 = 3 WAY POWER DIVIDER
A-D = 7/8 COAX





COMPONENTS	MANUFACTURER
COAX 7/8" HCC-78-50-J	CABLEWAVE
HN CONNECTORS MODIFIED 738250	CABLEWAVE
COAX 3/8" F382	FLEXCO
MODIFIED D2-2TN POWER DIVIDER	MICROLAB
MODIFIED D3-2TN POWER DIVIDER	MICROLAB

FEED SYSTEM PROTOTYPE TEST

A prototype feed system consisting of Andrews HJ5-50 7/8" coax-cable with 75AN connectors and Microlab D2-2TN power dividers was constructed as shown. This system did not model the 7/8" input cable or the short flexible cable at the panels.

The major objective of this test was to confirm calculated system insertion loss values.

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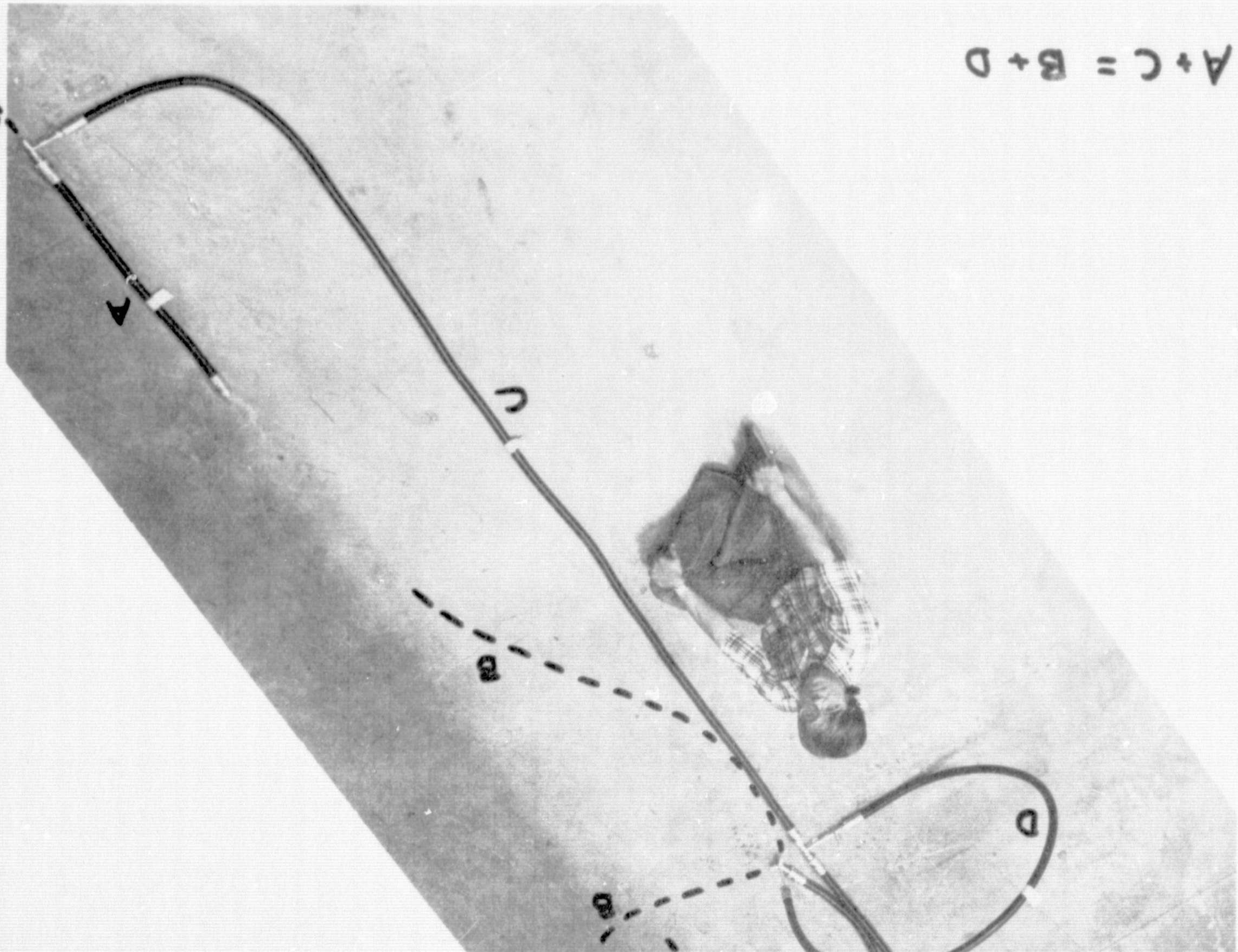

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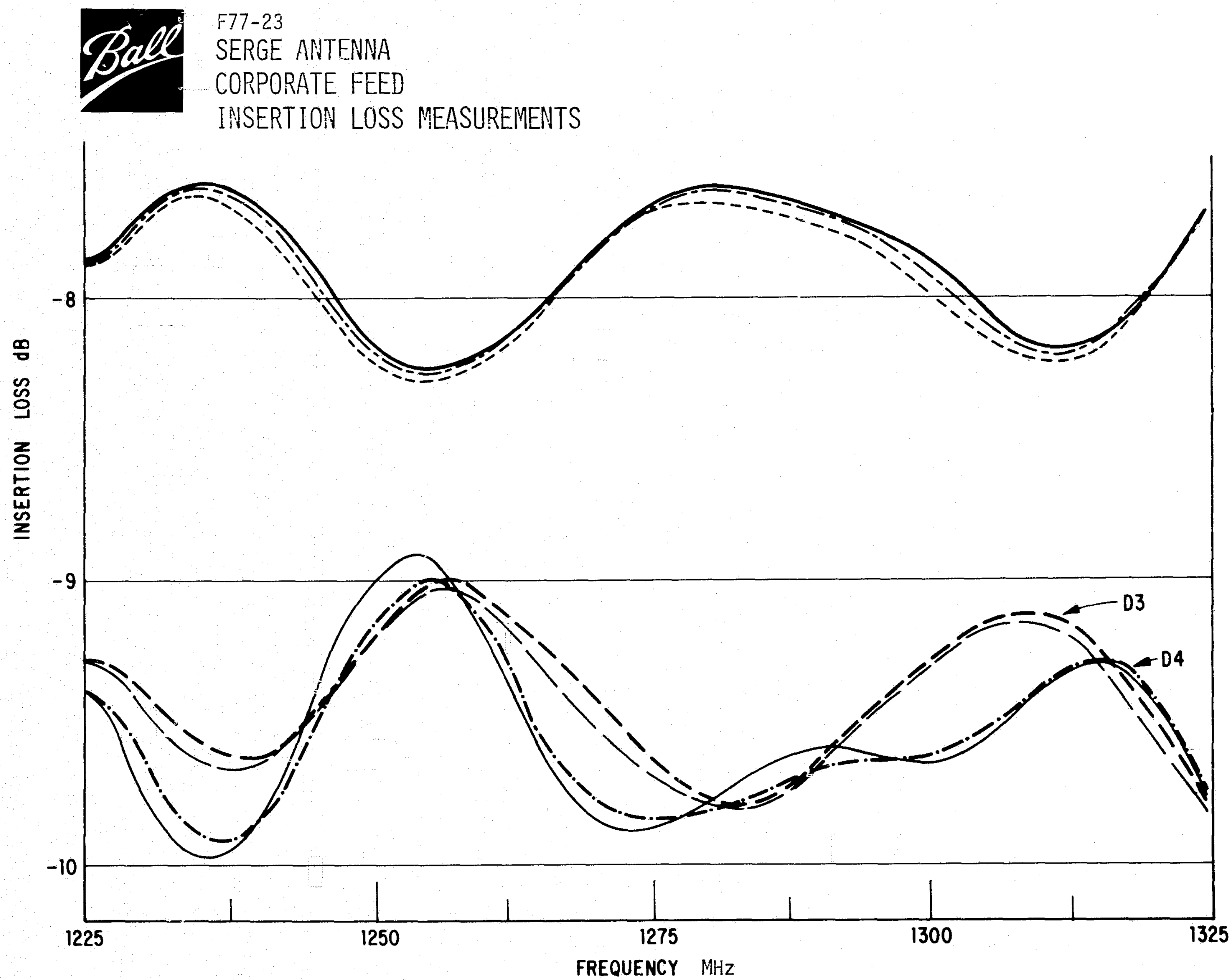
CORPORATE FEED INSERTION LOSS MEASUREMENTS

The insertion loss through each of the seven output ports was measured on a network analyzer with all other ports terminated in matched loads. Output cables A or B were connected to the port being measured. Thus each port measurement simulated the actual length of transmission line to be used in the flight system.

Measured data is depicted on the facing page. Note that the required power split was generally obtained across the band.


F77-23
SERGE ANTENNA
CORPORATE FEED
INSERTION LOSS MEASUREMENTS
INSERTION LOSS dB
-8
-9
-10
D3
D4
1225
1250
1275
1300
1325
FREQUENCY MHz

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CORPORATE FEED INSERTION LOSS

Using the measured data, the system insertion loss was calculated by summing the output from each port. Mismatch loss was negligible across the band. The input VSWR with all ports terminated did not exceed 1.15:1.

Measured insertion loss for the prototype system was .3 dB. Perhaps more important than this low insertion loss is the fact that the insertion loss was predictable based on measured values for the component elements.

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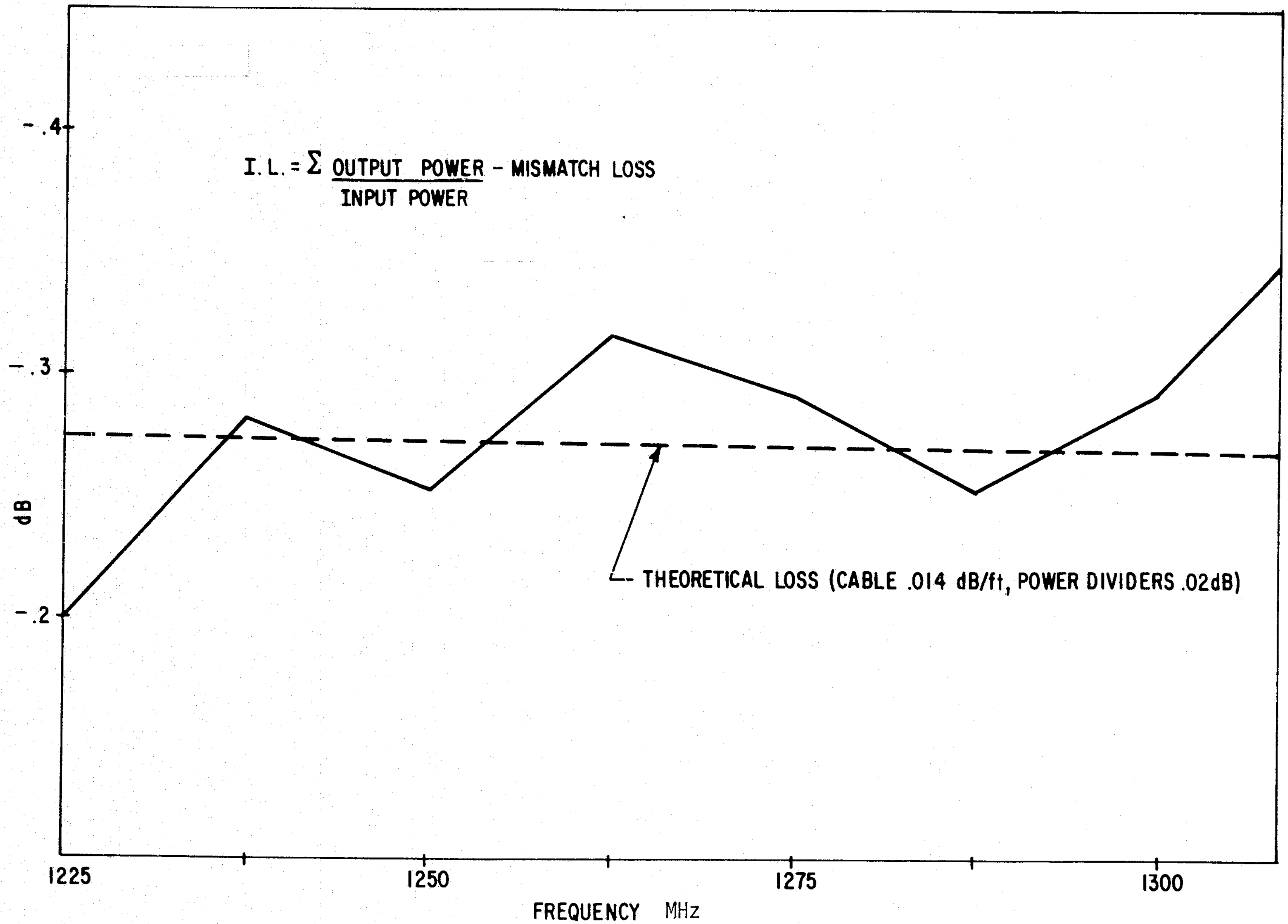
SERGE ANTENNA
CORPORATE FEED INSERTION LOSS



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FEED SYSTEM LOSS BUDGET

Based on the prototype tests, a refined estimate was made of the potential corporate feed loss budget. Including the dielectrically loaded input section and the short flexible cable at each panel, predicted insertion loss is nominally .6 dB.

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SERGE ANTENNA
CORPORATE FEED LOSS BUDGET

COMPONENT	LENGTH	LOSS DB/FT	TOTAL LOSS DB
INPUT LINE (7/8") (DIELECTRICALLY LOADED)	4.5'	.035	.16
POWER DIVIDER			.03
POWER DIVIDER			.03
CABLE RUN	11.9'	.015	.18
POWER DIVIDER			.03
CABLE RUN	2.3'	.015	.04
3/8" FLEX JUMPER AND PANEL CONNECTION	1.0'	.12	.15
TOTAL LOSS			.62

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FEED SYSTEM POTENTIAL COAX CABLES

A survey of potential vendors found two cables (Cablewave HCC-78-50-J, Andrews H55-50) acceptable for main transmission lines. Flexco manufactures cables suitable for the input and flexible panel connections, but these may be available only in large quantities. The vendor is further checking stock and alternate sources will be contacted.

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SERGE ANTENNA
POTENTIAL COAX CABLES

LARGE DIAMETER COAXIAL CABLES

COMPANY	PART NO.	CONSTRUCTION	DIAMETERS OUTER ID	DIAMETERS OUTER OD	DIAMETERS INNER ID	WEIGHT LB/FT	ATTENUATION dB/FT	PEAK POWER 1 ATM (kW)	AVERAGE POWER(kW)	MULTIPACTOR LEVEL (W)	R_{MIN}	PHASE STABILITY (ppm/°F)	CONNECTORS	AVAILABILITY
CABLEWAVE	SLA-78-50J SPIRAFIL	POLYETHYLENE HELIX, 7/8" ALUMINUM	.758	.875	.310	.39	.018	58.8	1.5	1900	9"	5	EIA, N MODIFY FOR HN	STOCK
	HCC-78-50J WELLFLEX	POLYETHYLENE HELIX COPPER 7/8", 1-5/8"	.794	1.00	.354	.55	.015	76.7	1.7	1900	10"	Same	Same	Same
			1.564	1.830	.473	.89	.009	278	1.85	>4000	20"	--	EIA only	--
	1-78-50 RIGID	TEFLON STUDS 7/8"	.785	.875	.341	.60	.012	61	1.5	2000	No Bends	--	EIA and Adaptors	Same
	HCC-R-50J WELLFLEX	1/2" HELIX	.338	.484	.155	.16	.03	15.3	.55	380	5"	5	N, EIA	Same
ANDREWS	H55-50	7/8" HELIX POLYETHYLENE	--	1.11	--	.54	.014	44	1.8	1800	10"	Same	N, EIA	Stock
TIMES	AS50716P	TFE-SPLINE	.642	.716	.248	.216	.025	48.4	6.5	1650	9"	12	N, EIA	50,000' only
FLEXCO	S642	TFE-SPLINE 7/8"		1.025	--	.525	.018	384	1.8	---	5.13	12	N, EIA, TNC	OUT
	S542	TFE-SPLINE 3/4"		.875	--	.475	.020	250	2	--	4.37	--	N, EIA, TNC	STOCK
	F382	TFE SOLID 3/8"		.420	--	.100	.12	--	.9	SOLID DI-ELECTRIC	1.85	--	HN, N TNC	STOCK
	F682	TFE SOLID 7/8"		1.025		-	.035	---		SOLID DI-ELECTRIC	5"	--	HN,N	---

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FEED SYSTEM POWER DIVIDERS

Two alternate power divider concepts will be approached by BBRC in parallel. The actual performance levels of "baseline" Microlab dividers with HN type connectors and dielectric loading is not known. Modifications will be needed to increase the average power capability of the device. These design risks indicate alternate approaches should be studied.

BBRC has developed and tested a prototype 7/8" diameter reactive power device. EIA instead of HN connectors can be used and the device will easily handle the average power. Tests of this alternative indicate performance will equal the standard Microlab D2-2TN device tested in the prototype feed system.

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SERGE ANTENNA
COAX POWER - DIVIDER TRADE-OFF

		MODIFIED MICROLAB/ FXR D2-2-TN	7/8" RIGID LINE POWER DIVIDER
ELECTRICAL			
	VSWR	1.1:1	1.1:1
	POWER DIVISION	3.0 ± .1 DB	3.0 ± .1 DB
	INSERTION LOSS	.03 DB	.03 DB
	AVERAGE POWER DERATED FOR SPACE ENVIRONMENT	50 WATTS	250 WATTS
	MULTIPACTOR LEVEL	PROBABLY ACCEPTABLE	2000 WATTS
MECHANICAL			
	CONNECTORS	MODIFIED HN CONNECTORS	EIA
	DIELECTRIC	SOLID POLYETHYLENE	AIR
	COMPLEXITY	FAIR	GOOD
THERMAL			
	POWER DISSIPATION	POOR	GOOD

THERMAL BLANKET

Astro-quartz, the thermal cover used on SEASAT, tends to flake and could be a source of particulate contamination on the SERGE flight mission. A teflon impregnated quartz cloth material (Beta cloth) is planned to be used to line the Shuttle bay and meets the reflectivity criteria for surfaces in the bay without particulate generation. This material was tested and has little effect on gain or resonant frequency. Beta cloth will be a suitable material to use as a thermal blanket on the SERGE antenna.

F77-23

SERGE ANTENNA
THERMAL BLANKET

- OBJECT - DETERMINE THE EFFECT OF TEFLON IMPREGNATED QUARTZ CLOTH ON ARRAY PERFORMANCE
- PROCEDURE - THERMAL BLANKET WAS PLACED IN INTIMATE CONTACT AND ON 2" STANDOFFS ACROSS AN EMU QUARTER PANEL. CHANGES IN PANEL RESONANT FREQUENCY AND GAIN WERE NOTED.
- RESULTS -

	INTIMATE CONTACT	2" STANDOFFS
RESONANT FREQUENCY SHIFT	NO CHANGE	NO CHANGE
GAIN	-.05 DB	-.05 DB

- CONCLUSION - BLANKET MAY BE PLACED DIRECTLY ON ARRAY APERTURE WITH A .05 DB DECREASE IN GAIN.

F77-23

THERMAL BLANKET/PAINT

Results from SEASAT tests demonstrate the major problems a painted thermal cover would pose to the SERGE program. Beta cloth is superior in terms of overall system performance.

F77-23

SERGE ANTENNA
THERMAL BLANKET/PAINT

- SEASAT TEST RESULTS ON SG113 PAINT
  - FREQUENCY SHIFT 15 - 20 MHz
  - GAIN LOSS OF .1 TO .2 DB
- IMPACT ON SERGE PROGRAM
  - NEW ARTWORK REQUIRED FOR FREQUENCY COMPENSATION
  - DECREASE IN GAIN MARGIN
  - UNEVEN PAINT SPREAD MAY CAUSE LOCALIZED IMPEDANCE SHIFTS
- CONCLUSION
  - USE THERMAL BLANKET

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LOSS BUDGET UPDATE

Theoretical gain of 7 EMU panels equally illuminated is 34.35 dB.

Several sources of loss can be established and are tabulated on the facing page. Nominal corporate feed and thermal blanket losses have been measured. Directivity losses due to E-plane taper and array distortion are based on computer analysis. Mismatch losses are accounted for under frequency and temperature effects.

Predicted array gain is 31.1 to 31.2 dB.

C-2

F77-23

SERGE ANTENNA
LOSS BUDGET UPDATE

- THEORETICAL ARRAY GAIN

EMU PANEL GAIN	25.9
ARRAY FACTOR	+ 8.45
GAIN	34.35

- LOSS FACTORS

CORPORATE FEED		-.62
MECHANICAL AND THERMAL DISTORTION		- .2
FREQUENCY AND TEMPERATURE EFFECTS		- .2
E-PLANE TAPER LOSS		- .1
THERMAL BLANKET		-.05
	TOTAL	-1.17

- PREDICTED GAIN

THEORETICAL GAIN	34.35
LOSS	-1.17
GAIN	33.18

STRUCTURAL ANALYSIS - OBJECTIVE

Structural analysis activities in this study were governed to a great extent by the design objective defined on the facing page. This requirement influenced practically all aspects of the recommended structural design including the selection of materials and the definition of specific configurations.

The design that is recommended herein evolved from a series of iterative analyses which isolated and identified what is regarded to be a highly efficient application of material, configuration and mounting arrangement. Results of interest from a number of those analyses are summarized on the following pages.

- OBJECTIVE - TO DEFINE A MOUNTING STRUCTURE FOR THE SERGE ANTENNA THAT WILL EXHIBIT A FUNDAMENTAL RESONANT FREQUENCY GREATER THAN TWENTY-FIVE HERTZ, AT THE PRIMARY STRUCTURE LEVEL.

DISCUSSION

The various types of structural analysis that were covered in this study are outlined on the facing sheet.

Structural math models were generated at intermediate steps in the design development process. These models were used to conduct trade-off studies and to determine the resonant frequency levels associated with each step.

Math models representing the final design configuration were used to determine loads, stresses and displacements resulting from various design loading conditions. Thermal distortion effects were also determined with these models.

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SERGE ANTENNA
DISCUSSION

- MATERIALS
- STRUCTURAL MODELS
  - CONFIGURATION
  - STUDIES
- RESONANT FREQUENCIES
- DESIGN LOADING CONDITIONS
- MAXIMUM LOADS/STRESSES
- MAXIMUM DISPLACEMENTS
- CONCLUSIONS

MATERIALS

Graphite reinforced epoxy tubing was selected as the material for both the strongback and installation trusses. The selection was based on numerous trade-off studies which included aluminum tubing as a candidate material. The studies showed that, given the same weight and configuration, considerably higher frequency levels could be obtained with GRE than with aluminum.

The selection of the antenna panels (SEASAT type EMU) was influenced only slightly by structural considerations.

F77-23

SERGE ANTENNA
MATERIALS

- STRONGBACK TRUSS
  - GRAPHITE/EPOXY (GRE) COMPOSITE TUBES
  - 1 1/2 INCH DIA. x 0.063 INCH WALL
  - $E = 19 \times 10^6$ LB/IN^2
  - $W = 0.055$ LB/IN^3
- INSTALLATION TRUSS
  - GRAPHITE/EPOXY TUBES
  - 2 INCH DIA. x 0.063 INCH WALL
- ANTENNA PANELS
  - FIBERGLASS/EPOXY HONEYCOMB COMPOSITE
  - $E = 2.5 \times 10^6$ LB/IN^2
  - $T_{EQ} = 0.20$ INCH

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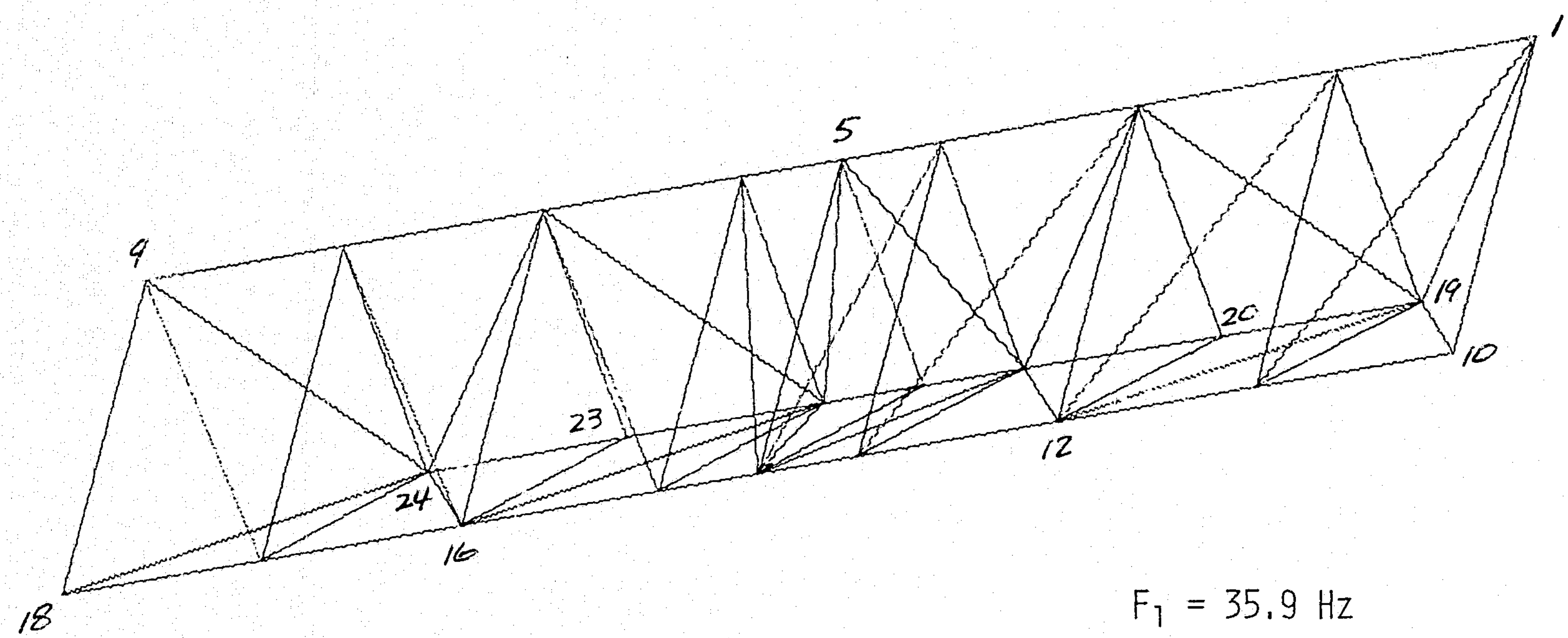
STRONGBACK MODEL

The structural math model of the strongback truss is shown on the facing page. The fundamental resonant frequency associated with this configuration, using 1½ inch diameter GRE tubing, is 35.9 Hz, as noted. Mounting points at nodes 12, 16, 20 and 23 are required to obtain this frequency level.

F77-23
SERGE ANTENNA
STRONGBACK MODEL



$F_1 = 35.9$ Hz

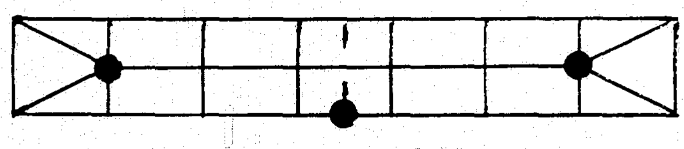
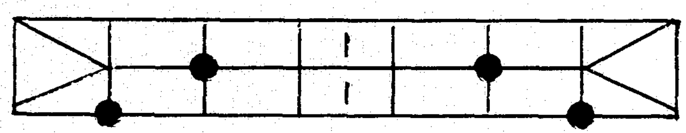
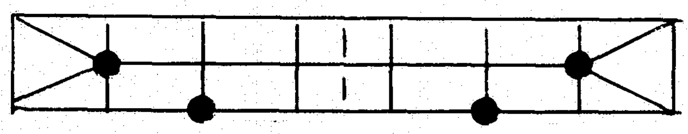
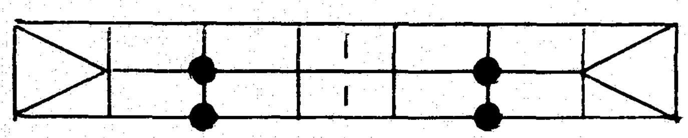
NO. OF MEMBERS = 69
NO. OF NODES = 25
NO. OF DΦF = 75

STRONGBACK MATERIAL/MOUNTING STUDY

A comparison is made of strongback resonant frequency levels obtained with GRE tubing (2 in. dia.) and with aluminum tubing (1 in. dia.). The comparison is based on equal weight and similar configuration.

It is evident that higher frequencies can be obtained using GRE tubing. This is due to the higher stiffness-to-weight (E:w) of GRE. It is also apparent in this comparison that the 25 Hz requirement itself would be difficult to achieve with aluminum.

F77-23
SERGE ANTENNA
STRONGBACK MATERIAL/MOUNTING STUDY

CONFIGURATION	FREQUENCY (Hz)	
	ALUM. TUBE 1 IN. DIA X 0.065	GRE TUBE 2 IN. DIA X 0.065
	11.9	22.5
	16.7	31.4
	19.2	36.2
	21.0	39.5
	(W = 245 LB.)	(W = 260 LB.)

STRONGBACK MOUNTING STUDY

The influence of mounting arrangements on strongback frequency levels is shown on the facing chart. The strongback material in each case is 1½ inch diameter GRE tubing. It can be seen that the four-point mountings are preferable to a three-point mounting.

The highest frequency (35.9 Hz) is obtained with a four-point over/under mounting arrangement at the second in-board joint points. This is the arrangement that is recommended for the SERGE structure.

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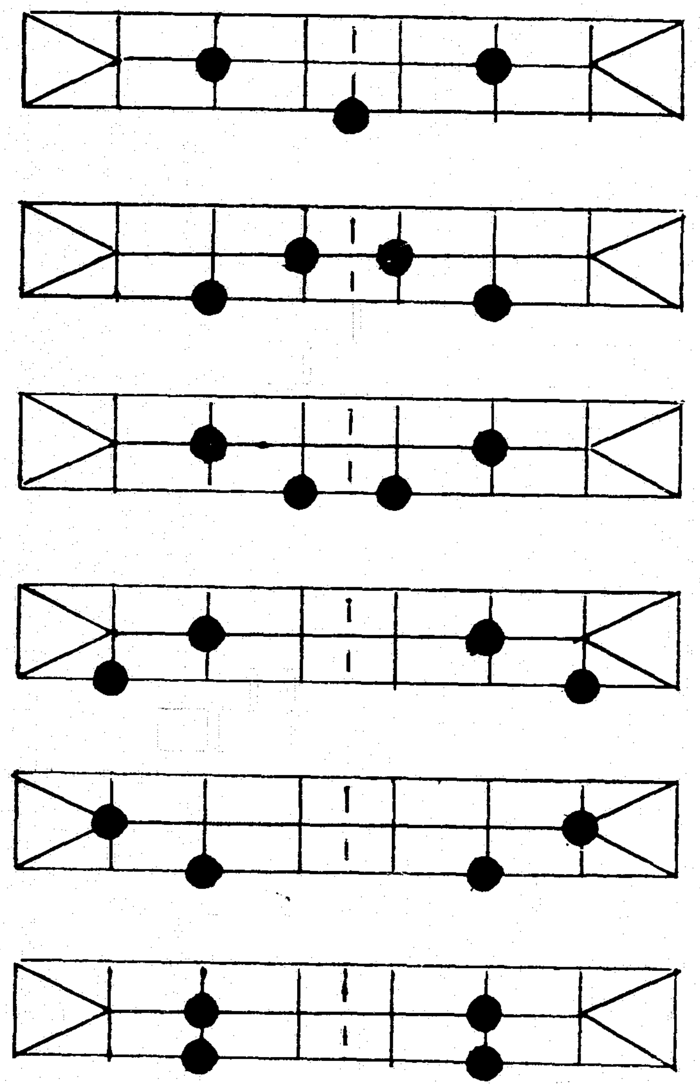
SERGE ANTENNA
STRONGBACK
MOUNTING
STUDY

MOUNTING | FREQUENCY (Hz)



20.6

23.8

25.6

28.6

33.1

35.9

NOTE: ANTENNA PANELS RIGID, LUMPED MASS

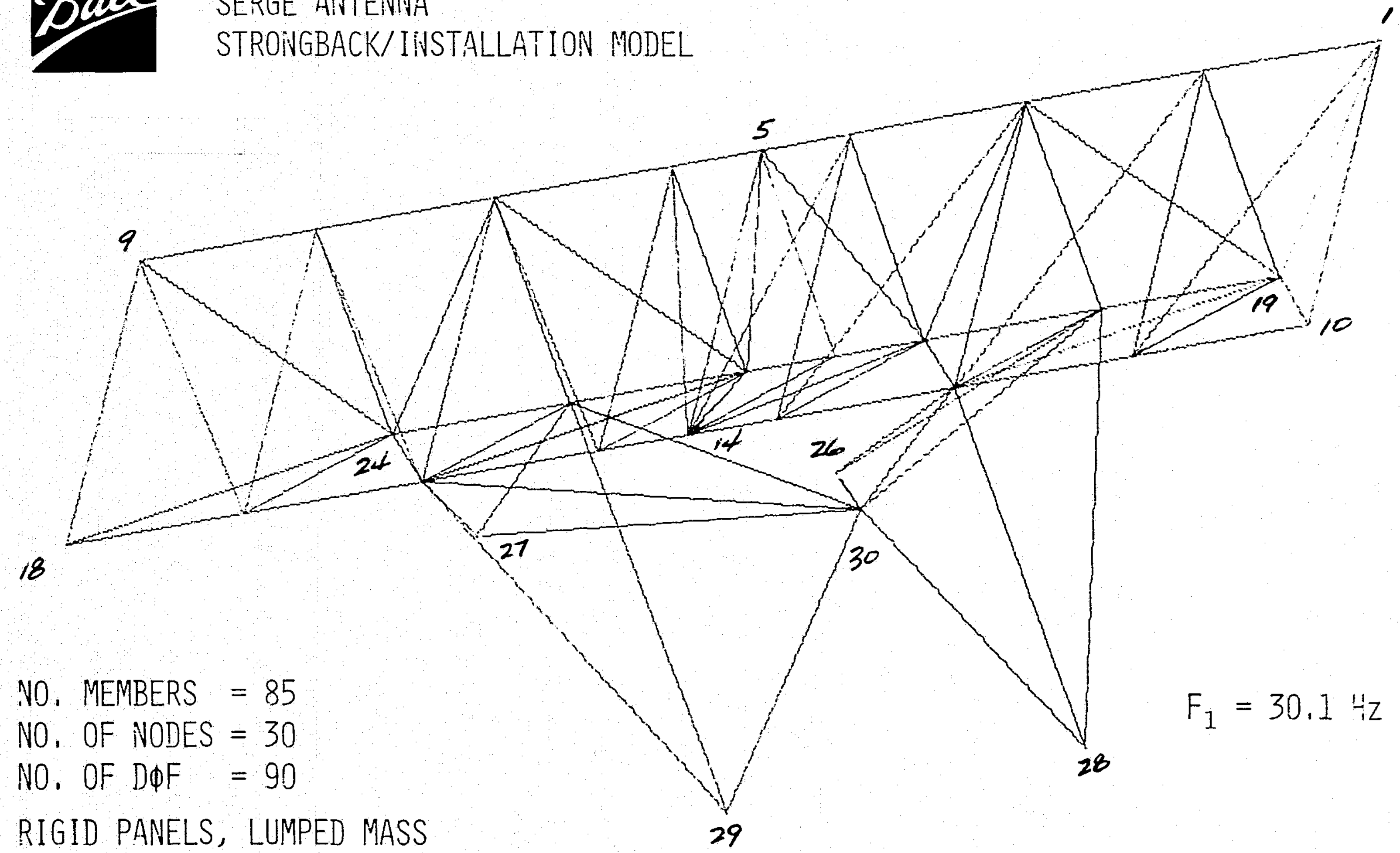
STRONGBACK/INSTALLATION MODEL

The structural math model of the combined strongback-installation truss structure is shown on the facing page. These structures are joined at node 12, 16, 20 and 23 of the strongback truss. Interface points joining the installation truss to the pallet are at nodes 26, 27, 28 and 29. The resonant frequency for this configuration, using 2 inch diameter GRE tubing for the installation truss, is 30.1 Hz, as noted.

F77-23

SERGE ANTENNA

STRONGBACK/INSTALLATION MODEL



NO. MEMBERS = 85

NO. OF NODES = 30

NO. OF DϕF = 90

RIGID PANELS, LUMPED MASS

F_1 = 30.1 Hz

INSTALLATION TRUSS STUDY

Aluminum tubing was also considered as a candidate material for the installation truss. Two variations in installation truss configuration, using 3 inch diameter aluminum tubing, produced resonant frequency levels slightly lower than that obtained with GRE.

However, the lower density and smaller diameter of the GRE tubing make it possible to obtain a GRE installation truss that is approximately 60% lighter than its aluminum counterpart. Hence, a GRE installation truss is recommended for the SERGE structure.

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SERGE ANTENNA
INSTALLATION TRUSS STUDY

- "LONG STRUT" CONFIGURATION 3 INCH DIA. ALUMINUM TUBES 26.1 Hz

- "SHORT STRUT" CONFIGURATION 3 INCH DIA. ALUMINUM TUBES 28.4 Hz

- BASELINE CONFIGURATION 2 INCH DIA. GRAPHITE/EPOXY TUBES 36.1 Hz

NOTE: STRONGBACK ATTACHED. ANTENNA PANELS RIGID, LUMPED MASS

STRONGBACK/INSTALLATION/ANTENNA MODEL

The complete strucutral math model of the SERGE Antenna structure incorporates flexible antenna panels. The seven panels are each indepen-dnet of the other, as in the actual structure, and thus have no continuity across their boundaries.

For this model all modes below 28 Hz (approximately 35 modes) are local antenna panel modes which involve negligible participation of the primary (truss) structure. The first structural mode occurs at 28.5 Hz; the mode shape being similar to the first mode obtained with the rigid panel model.

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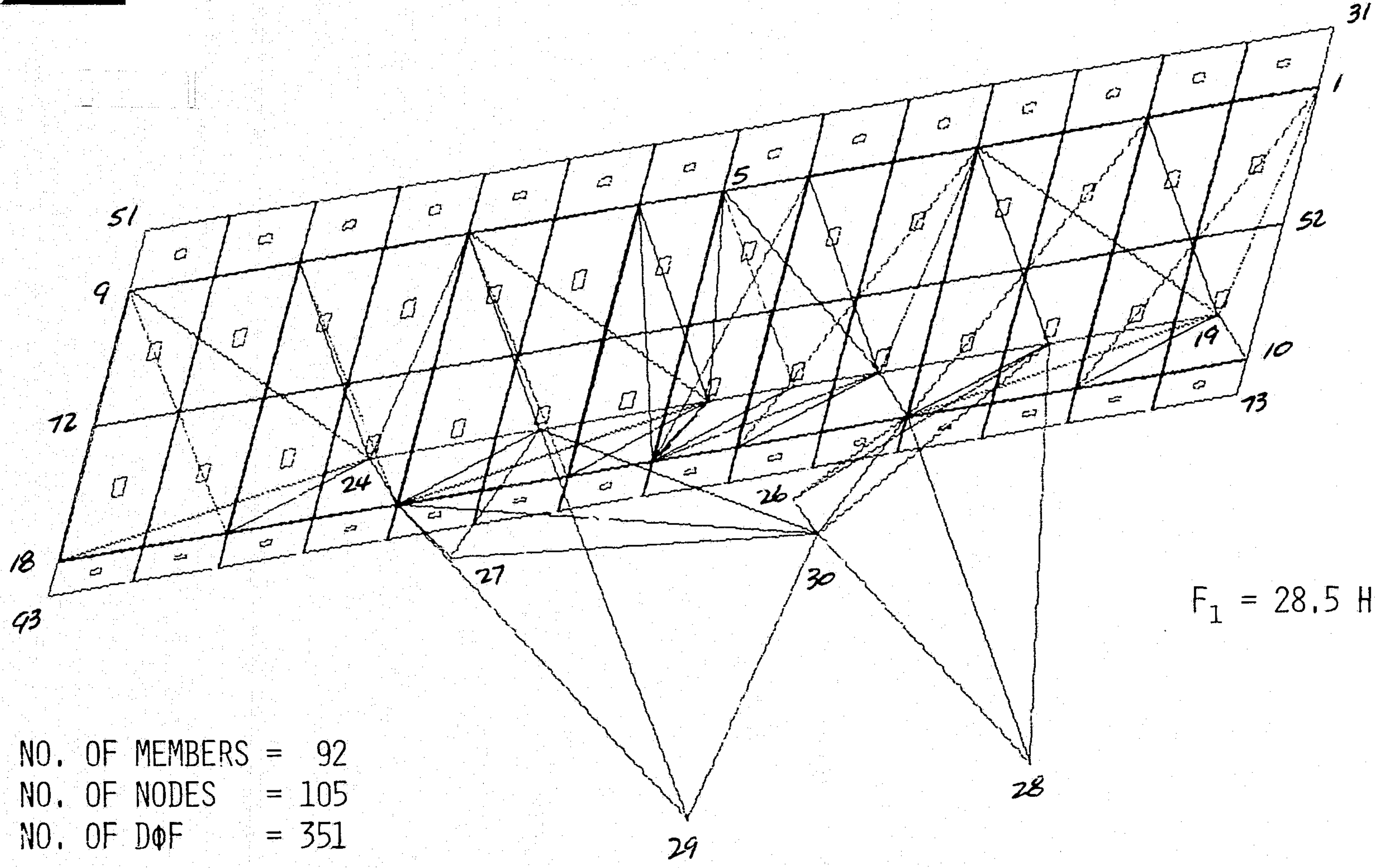
SERGE ANTENNA

STRONGBACK/INSTALLATION/ANTENNA MODEL



F_1 = 28.5 Hz

NO. OF MEMBERS = 92

NO. OF NODES = 105

NO. OF DΦF = 351

FLEXIBLE PANELS

ANTENNA PANEL MODEL

The antenna panel math model incorporates flexural properties of both the panel and the adjacent strongback members. Since the lower modes of panel vibration involve no coupling of strongback joint motion, translational constraints are applied at the joint points; nodes 6, 10, 26 and 30.

With the panel mounted to the strongback joint points and at the mid-points of the five truss members (9-point mounting), the resulting resonant frequency is 15 Hz, as noted.

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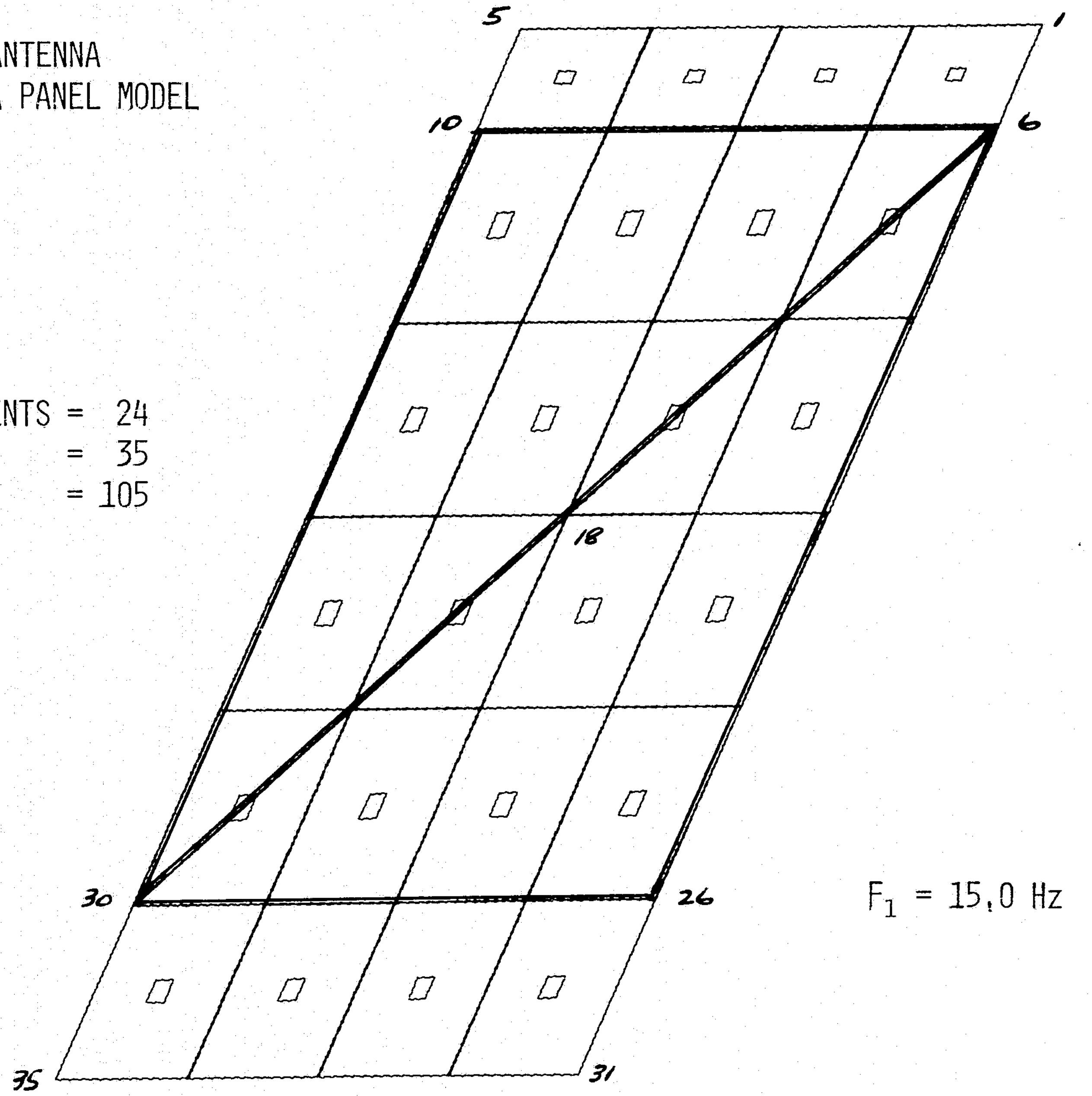
SERGE ANTENNA

ANTENNA PANEL MODEL



NO. OF PANEL ELEMENTS = 24

NO. OF NODES = 35

NO. OF DΦF = 105

F_1 = 15.0 Hz

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PANEL MOUNTING STUDY

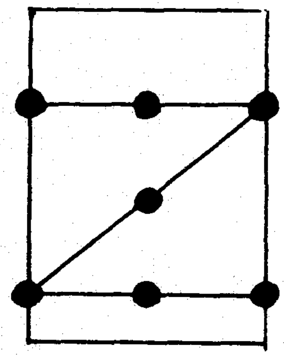
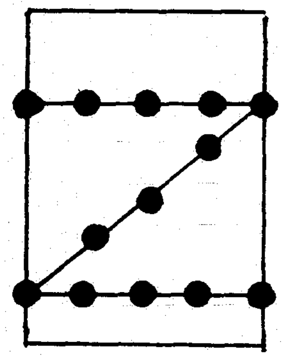
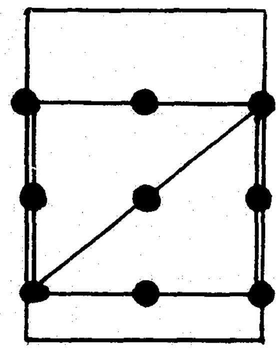
A comparison is shown of antenna panel resonant frequencies for three basic variations in panel mounting arrangement. Each of the variations utilize adjacent members of the strongback.

The nine point mounting arrangement uses all of the available adjacent members; including the partition (side) rails that are omitted in the other arrangements. This mounting provides an improvement in resonant frequency of about 35%.

Extensive additions to both the panel and strongback structures will be required to produce panel frequencies significantly greater than 15 Hz.

F77-23
SERGE ANTENNA
PANEL MOUNTING STUDY

NOTE: ANTENNA PANELS FLEXIBLE.
LUMPED MASS.

MOUNTING		FREQUENCY (Hz)
	7 MOUNTS	10.9
	13 MOUNTS	11.6
	9 MOUNTS USE SIDE RAILS	15.0

FUNDAMENTAL RESONANT FREQUENCIES

The vibration analyses conducted in this study indicate the recommended SERGE Antenna design will have a frequency of 28.5 Hz, at the primary structure level, and will thus be in compliance with the specified requirement of 25 Hz or greater.

At the component level, the antenna panels will have a frequency of 15 Hz.

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SERGE ANTENNA
FUNDAMENTAL RESONANT FREQUENCIES

- <u>PRIMARY STRUCTURE</u>
  - STRONGBACK + RIGID PANELS — 35.9 Hz
  - STRONGBACK + RIGID PANELS + INSTALLATION TRUSS — 30.1 Hz
  - STRONGBACK + FLEXIBLE PANELS + INSTALLATION TRUSS — 28.5 Hz
- <u>ANTENNA PANEL</u> — 15.0 Hz
- <u>REQUIREMENTS</u>
  - PRIMARY STRUCTURE — ≥ 25 Hz
  - COMPONENT STRUCTURE — N/A

DESIGN LOADING CONDITIONS

Design limit load factors that were specified for design are noted on the facing page. The load factors cover lift-off and landing conditions.

The recommended design was evaluated for four of the more severe load factor combinations, which are shown. Math models that were generated previously for frequency determinations were utilized in this analysis.

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SERGE ANTENNA
DESIGN LOADING CONDITIONS

- DESIGN REQUIREMENTS

EVENT	LIMIT LOAD FACTOR (G)		
	NX	NY	NZ
LIFT-OFF	0.4/-4.5	±3.3	3.1/-3.5
LANDING	±2.5	±2.5	6.5/-2.6

- CONDITIONS INVESTIGATED

EVENT	LIMIT LOAD FACTOR (G)		
	NX	NY	NZ
LIFT-OFF (3)	-4.5	3.3	-3.5
LIFT-OFF (4)	-4.5	-3.3	-3.5
LANDING (5)	2.5	2.5	6.5
LANDING (7)	-2.5	-2.5	6.5

MAXIMUM LOADS/STRESSES/DISPLACEMENTS

Maximum loads and stresses were determined for various members of the structure and, as anticipated, found to be relatively low in magnitude. Maximum displacement levels were also evaluated and, likewise, found to be relatively insignificant.

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SERGE ANTENNA

MAXIMUM LOADS/STRESSES/DISPLACEMENTS

• STRONGBACK MEMBER (19-20) LOAD	671 LB
STRONGBACK MEMBER (19-20) STRESS	2360 LB/IN^2
• INSTALLATION MEMBER (26-12) LOAD	774 LB
INSTALLATION MEMBER (26-12) STRESS	2020 LB/IN^2
• PANEL MEMBER (7) LOAD	2.65 IN LB/IN
PANEL MEMBER (7) STRESS	650 LB/IN^2
• TRUSS DISPLACEMENT	
X-AXIS	0.026 IN
Y-AXIS	0.071 IN
Z-AXIS	0.054 IN
• PANEL DISPLACEMENT	
Y-AXIS	0.25 IN

NOTE: 1.) ALL VALUES SHOWN ARE LIMIT VALUES

2.) DISPLACEMENTS ARE IN LOCAL COORDINATE SYSTEM.

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MAXIMUM TRUSS/PALLET INTERFACE LOADS

The maximum pallet interface load was determined to be less than 1,100 lbs., limit. This load is not expected to create any problems for either pallet attachment hardware or the pallet itself.

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SERGE ANTENNA

MAXIMUM TRUSS/PALLET INTERFACE LOADS

• UPPER INTERFACE (26,27)	
X-AXIS REACTION	960 LB
Y-AXIS REACTION	625 LB
Z-AXIS REACTION	635 LB
• LOWER INTERFACE (28,29)	240 LB
X-AXIS REACTION	-935 LB
Y-AXIS REACTION	-1080 LB

NOTE: 1.) ALL VALUES SHOWN ARE LIMIT VALUES.

2.) LOADS ARE IN LOCAL COORDINATE SYSTEM.

STRUCTURAL MARGINS OF SAFETY

Material strength data (allowables) used in this analysis were taken from tests that were performed on the SEASAT program. However, all of the referenced tests were of the non-destructive type. This resulted in the calculation of very conservative margins of safety throughout the analysis.

A summary of member margins of safety is shown on the facing page. Very high margins are available despite the above described conservatism; confirming that stiffness considerations rather than strength dictate the recommended design.

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SERGE ANTENNA

STRUCTURAL MARGINS OF SAFETY

- ALLOWABLE LOADS
  - GRE TUBES, TENSION(1) — 1000 LB
  - 1 1/2 INCH DIA. GRE TUBES, COMPRESSION — 2150 LB
  - 2 INCH DIA. GRE TUBES, COMPRESSION — 3990 LB
  - PANELS, BENDING(2) — 11 IN LB/IN
  - PALLET INTERFACE — (N/A)

- MARGINS OF SAFETY(3)
  - 1 1/2 INCH DIA. GRE TUBES
    - TENSION — >+250%
    - COMPRESSION — >+150%
  - 2 INCH DIA GRE TUBES
    - TENSION — >+300%
    - COMPRESSION — >+300%
  - PANELS, BENDING — >+200%
  - PALLET INTERFACE — (N/A)

NOTES:

1.) BASED ON SEASAT TEST OF 1/2 INCH DIA. GRE TUBES

2.) BASED ON SEASAT TESTS

3.) BASED ON ULTIMATE FACTOR OF SAFETY OF 1.25 x LIMIT LOAD

STRUCTURAL CONCLUSIONS

The SERGE Antenna design recommended by this study meets the specified requirements for both frequency and strength.

F77-23

SERGE ANTENNA

STRUCTURAL CONCLUSIONS

- FUNDAMENTAL FREQUENCY OF PRIMARY STRUCTURE EXCEEDS 25 Hz.
- DESIGN MARGINS OF SAFETY EXCEED 150%.

THERMAL DESIGN CONCEPT

The thermal design concept for SERGE is intended to minimize thermal distortion while keeping all components within their allowable thermal units. It is RF compatible, light weight, easily fabricated and installed, and meets all the OFT Shuttle constraints for thermal control surfaces.

The front of each antenna panel is covered with a single layer of teflon impregnated quartz cloth (Beta cloth). This layer provides improved thermal properties without noticeable RF interference. A coat of white paint could have served the same purpose thermally, but would have caused RF distortions.

To minimize the thermal gradient across the antenna panel face sheet, and to eliminate the transient shadowing of the strongback truss, a multilayer insulation blanket is proposed to cover the back of the panels and the entire strongback structure. This blanket assembly will consist of five (5) layers of doubly aluminized mylar separated by dacron netting. The outer layer will be Beta cloth. It is estimated that this blanket will have an effective emissivity of at most .02.

The graphite tubes that make up the truss members for the installation structure will be covered with a single layer of Beta cloth to limit the transient temperature swings caused by shadowing. The vicinity of the aluminum end fittings will have a five (5) layer blanket like the strongback, to further limit transient excursions of temperature. This greater protection is required at the joints because of the higher linear coefficient of thermal expansion (LCTE) for the aluminum, and it is expected that these joints will be the biggest contribution to thermal distortion in the installation structure.

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SERGE ANTENNA
THERMAL DESIGN CONCEPT

- PANEL FRONT SURFACE
  - SINGLE LAYER OF TEFLON IMPREGNATED QUARTZ CLOTH
- PANEL REAR SURFACE, RF FEED, STRONGBACK STRUCTURE
  - 5 LAYERS OF .25 MIL DOUBLY ALUMINIZED MYLAR SEPARATED BY DACRON NETTING
  - OUTER LAYER OF TEFLON IMPREGNATED QUARTZ CLOTH
- INSTALLATION STRUCTURE
  - GRAPHITE TUBES - SINGLE LAYER OF TEFLON IMPREGNATED QUARTZ CLOTH
  - ALUMINUM FITTINGS - SAME AS STRONGBACK STRUCTURE

NODE LOCATIONS FOR STRONGBACK AND PANELS

The SERGE strongback thermal model consists of sixty-nine (69) graphite epoxy truss nodes (400-468), and twenty-five (25) aluminum joint nodes (500-524). The graphite epoxy nodes have conductive couplings to the joint nodes and radiative couplings to the insulation and panel back nodes. No attempt was made to estimate possible conductive paths between the truss member and the panel attach bracket. This path is expected to be quite small in relation to other heat paths to the truss members.

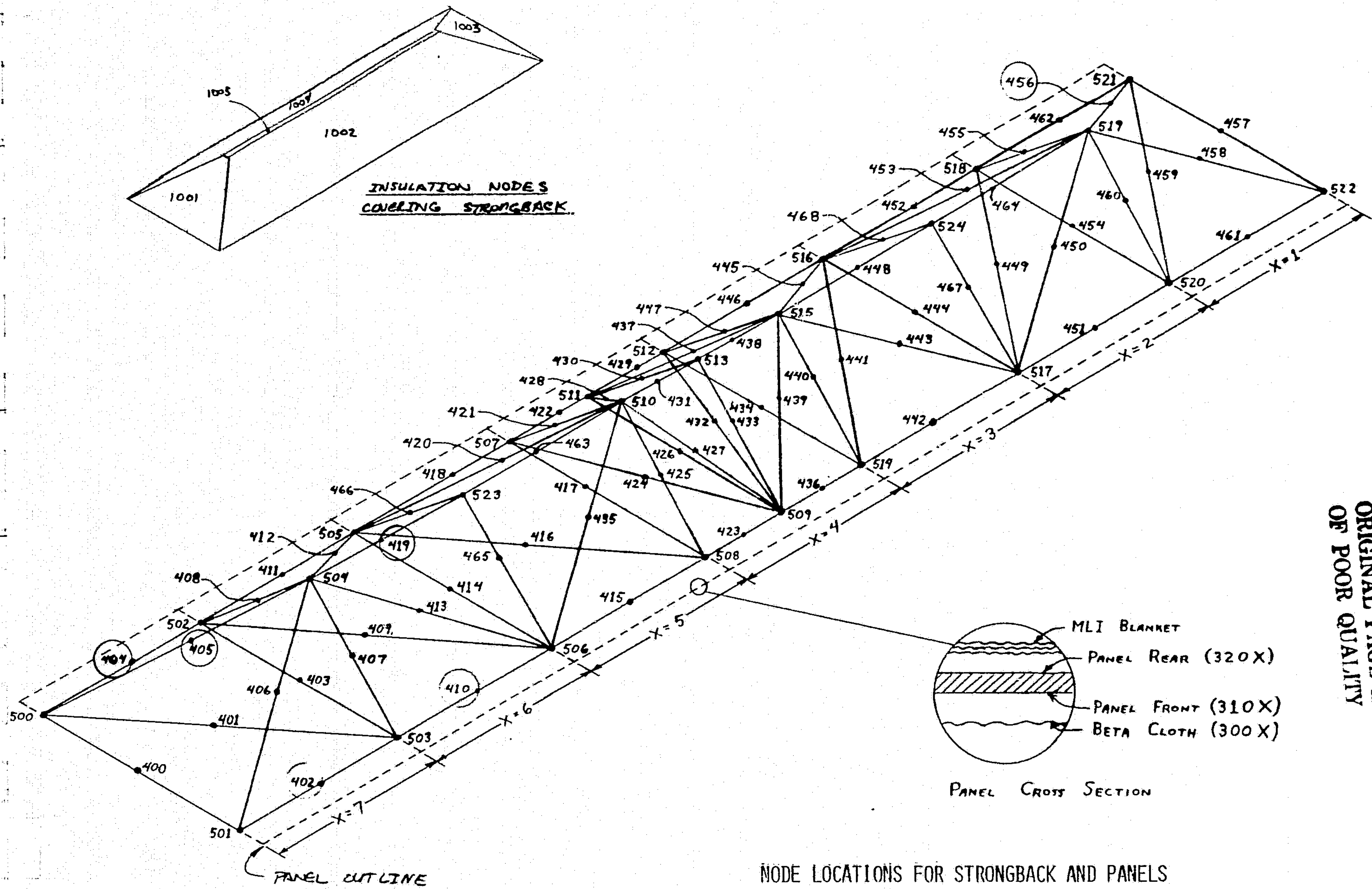
The aluminum joints have only conductive paths to the truss nodes. All radiative couplings would be small, because of the low emissivity of chromacoated aluminum and the small surface area involved. Also, the temperature differences are quite small.

The MLI blanket over the truss and panel backs is treated in five (5) massless nodes. The effective emissivity through the blanket is assumed to be .02. External heat loads (direct solar, albedo, and earthshine), reflected heat loads and reflecting view factors for the MLI blanket were calculated using BBRC thermal analysis programs.

Each panel is divided into two (2) nodes, a face sheet node and a rear sheet node. These two nodes are coupled conductively. The Beta cloth covering the face sheet of each node is modeled as one massless node.

NOTE: The circled node numbers indicate temperature versus time plots included later in this report.

F77-23
SERGE ANTENNA
NODE LOCATIONS FOR STRONGBACK AND PANELS



NODE LOCATIONS FOR STRONGBACK AND PANELS

INSTALLATION STRUCTURE NODE BREAKDOWN

The installation structure thermal model consists of sixteen (16) graphite epoxy truss members, nine (9) aluminum joints and sixteen (16) insulation nodes. The graphite epoxy members exchange heat conductively with the joint nodes and radiatively with the insulation nodes.

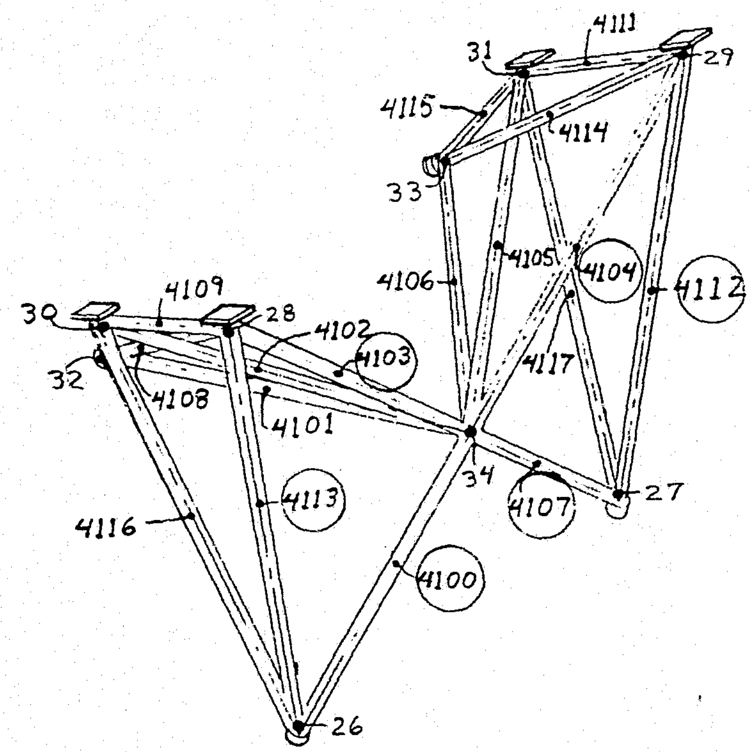
The insulation nodes have external fluxes and reflecting view factors calculated by the BBRC thermal program.

The installation truss is assumed to be conductively isolated from the strongback truss and pallet. This was necessary at the pallet because the temperature history for the pallet is not known. This assumption will not be of significant consequence except in the immediate vicinity of the mounting flanges. Also, the same assumption at the strongback interface will not seriously affect the predicted temperatures distribution. This is because the current designs for these fittings indicate a poor conduction path the the temperature differential is expected to be small.

Since the graphite epoxy truss members are only covered by one layer of Beta cloth which was assumed ~40% transparent to the solar spectrum, 40% of the direct solar and albedo energy on the insulation layer was transferred to the truss member itself.

NOTE: The circled node numbers indicate temperature versus time plots included later in this report.

F77-23
SERGE ANTENNA
INSTALLATION STRUCTURE NODE BREAKDOWN



NOTE: THE INSULATION NODES ARE 100 LESS THAN THESE NUMBERS

INSTALLATION STRUCTURE NODE BREAKDOWN

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INSTALLATION STRUCUTURE TEMPERATURE VERSUS TIME

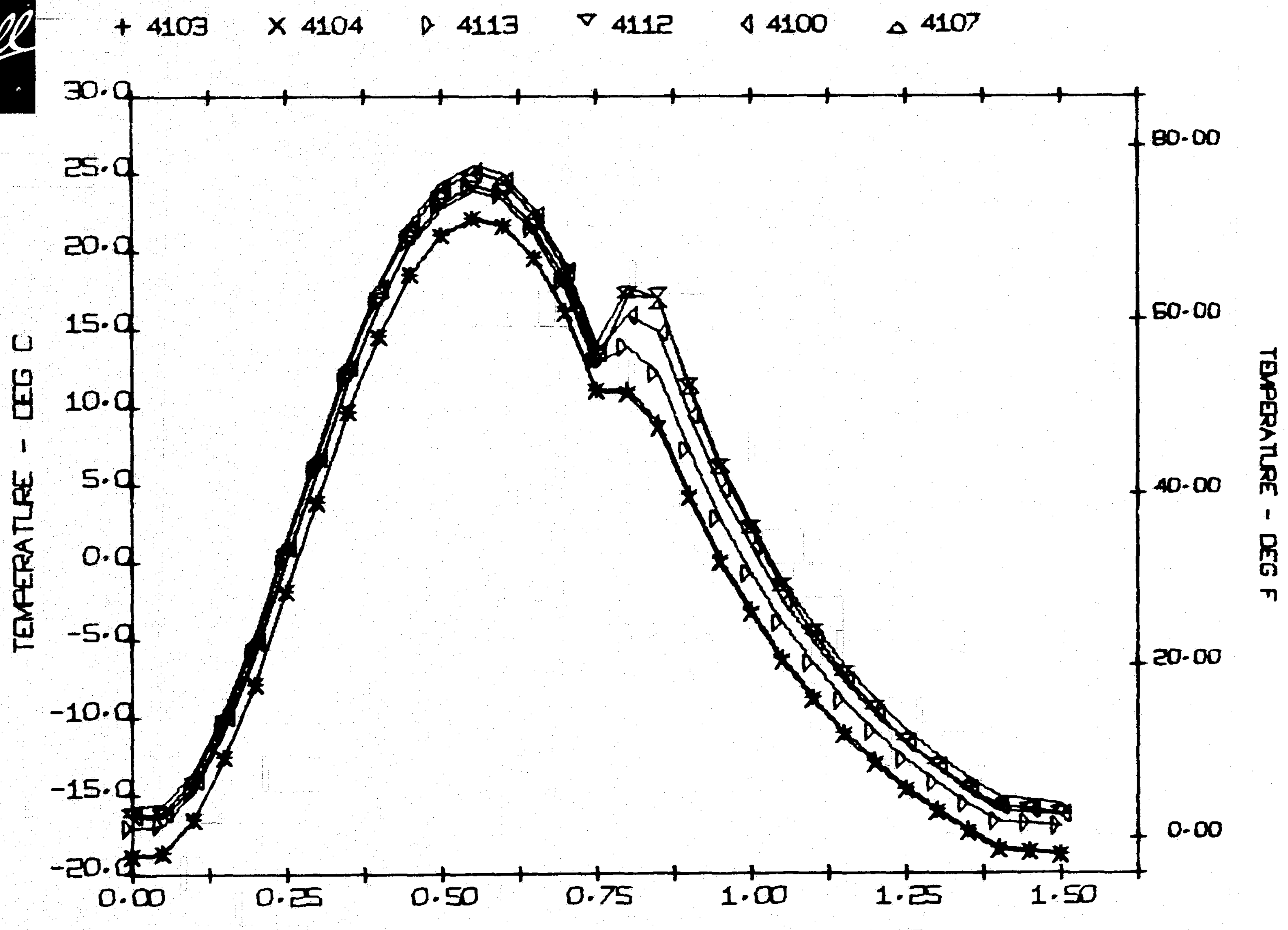
The plot gives the predicted transient temperatures for selected installation truss nodes. Time zero represents the dawn terminator passage. The orbit period is assumed to be 1.51 hours (150 NM orbit).

The temperatures increase as the Shuttle moves into the sunlit portion of the orbit. The increase in temperature is due to the increasing albedo flux. The jump in temperature at ~.75 hrs. is due to momentary direct solar flux into the bay. The temperatures then decrease during the shadowed portion of the orbit.

The orbit angle used in the analysis ($\beta = 0°$) should give worst case temperatures because as the orbit angle increases, in a positive β direction, the front of the antenna is exposed to less and less direct solar radiation and the albedo decreases.

F77-23

SERGE ANTENNA - INSTALLATION STRUCTURE TEMPERATURE vs. TIME



INSTALLATION STRUCTURE TEMPERATURES

INSTALLATION STRUCTURE DIFFERENTIAL TEMPERATURES

Differential temperatures were calculated between various installation truss members. These differential temperatures give an indication of the amount of thermal distortion that can be expected.

It can be seen that the differential temperatures are, in general, less than 5°C. This small value, in a graphite epoxy structure, immediately indicates small thermal distortion values associated with the installation structure.

However, temperature differences between the installation truss and the pallet will be a factor in the total distortion of the antenna plane. This is due to the fact that the pallet is aluminum (with a LCTE of $\sim 13 \times 10^{-6}$ in/in °F) and the installation structure is $\sim$90% graphite epoxy and 10% aluminum (with an equivalent LCTE of $\sim 1.3 \times 10^{-6}$ in/in °F). This factor of 10 difference in the LCTE will lead to thermal distortions, even with low values for the differential temperatures between the two.

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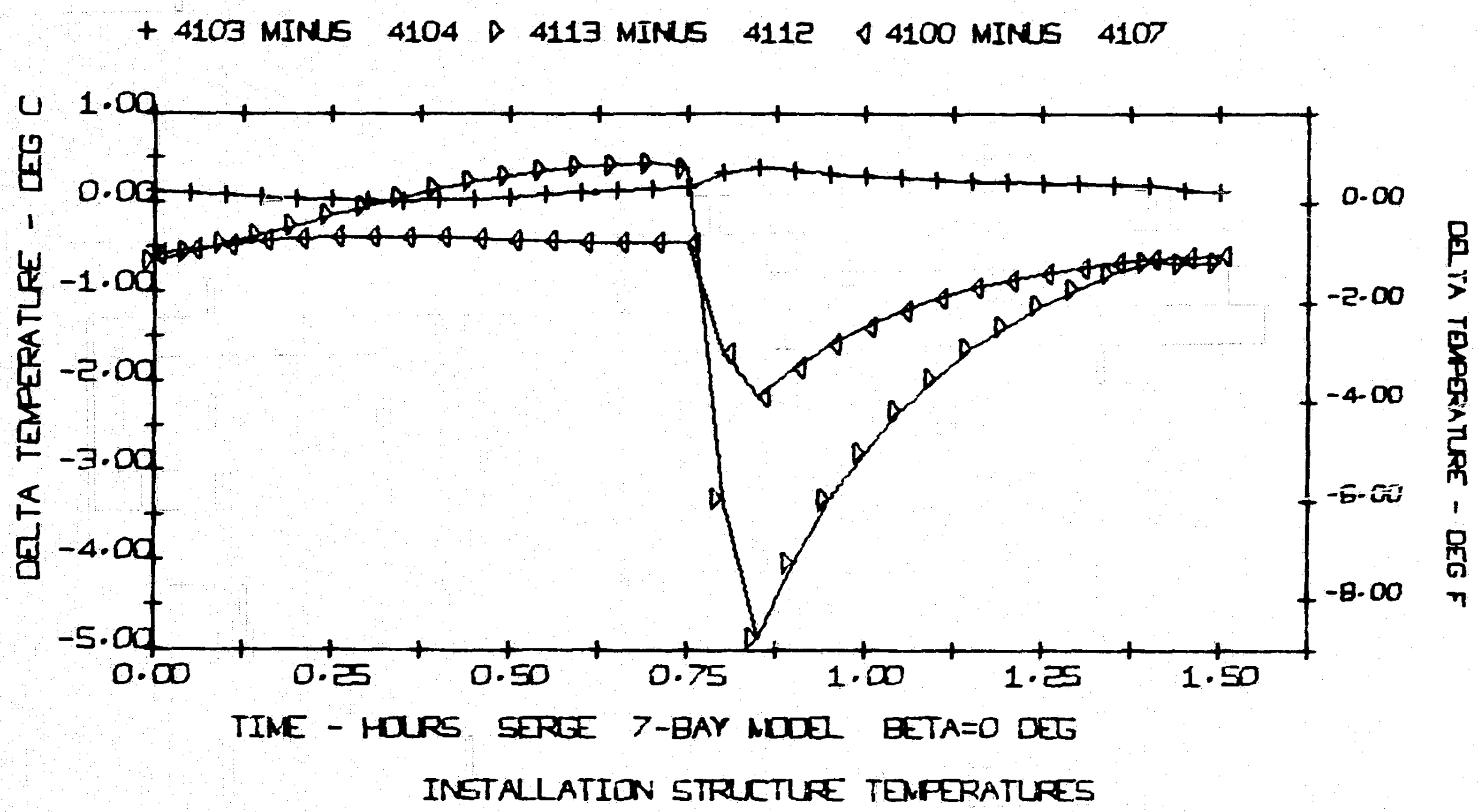
SERGE ANTENNA

INSTALLATION STRUCTURE DIFFERENTIAL TEMPERATURES



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STRONGBACK STRUCTURE TEMPERATURES VERSUS TIME

Typical strongback structure temperatures are presented in the plot. The variations over a typical orbit are less than 3°C for most members. The temperature fluctuations are kept small because the structure is protected from most transient shadowing effects by the MLI and antenna panels.

Structural members near the bottom of the truss (402,410) run at a somewhat warmer temperature than the other truss members. This is due to their "protected" position nearer the Shuttle bay, giving them a reduced exposure to the cold space environment. The coldest members are those at the top of the truss (404, etc.) that have the greatest exposure to space.

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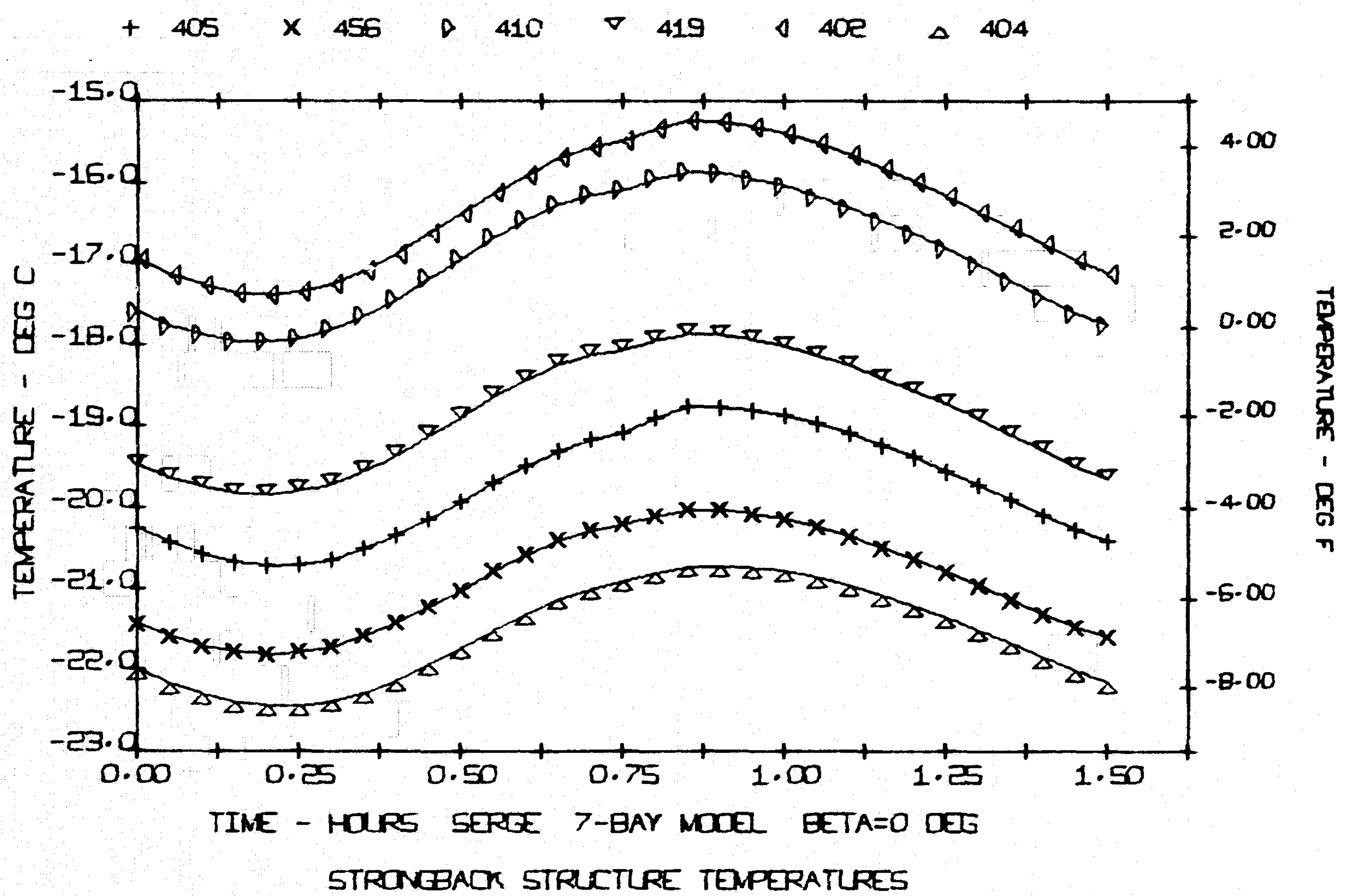
SERGE ANTENNA
STRONGBACK STRUCTURE TEMPERATURES vs. TIME



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STRONGBACK DIFFERENTIAL TEMPERATURES VERSUS TIME

The strongback differential temperatures are quite low, with the maximum (~5.5°C) between the upper and lower antenna support longerons (402 and 404). Since the strongback is mostly graphite/epoxy, with a low LCTE, the expected thermal distortions are quite small.

The low strongback differential temperatures are a result of the relatively benign thermal environment of the Shuttle bay, and the protection the truss receives from the MLI blanket and antenna panel/ Beta cloth combination.

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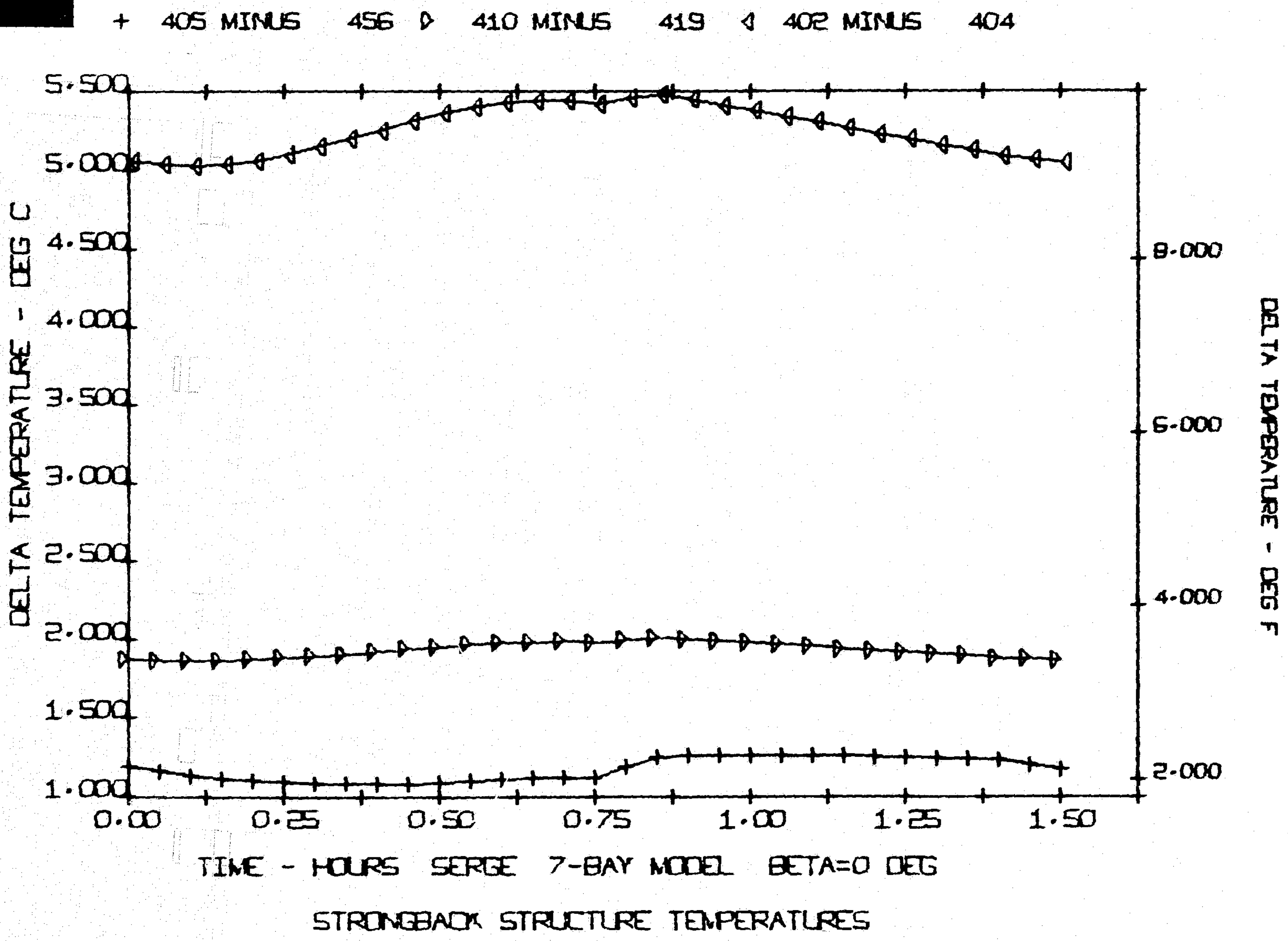
SERGE ANTENNA
STRONGBACK DIFFERENTIAL TEMPERATURES vs. TIME



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PANEL TEMPERATURES VERSUS TIME

Panel temperatures for one orbit are shown in the figure. Except for brief periods during orbit sunrise and sunset the Beta cloth covering the antenna panel receives no direct solar radiation. This is due to blockage by Shuttle bay surfaces. Since the antenna points toward nadir it receives earthshine and albedo radiation. The variation in the amount of albedo radiation during an orbit accounts for the variation in panel temperature from a low of about -34°C (just prior to sunrise) to a high of ~ -10°C (near orbit noon).

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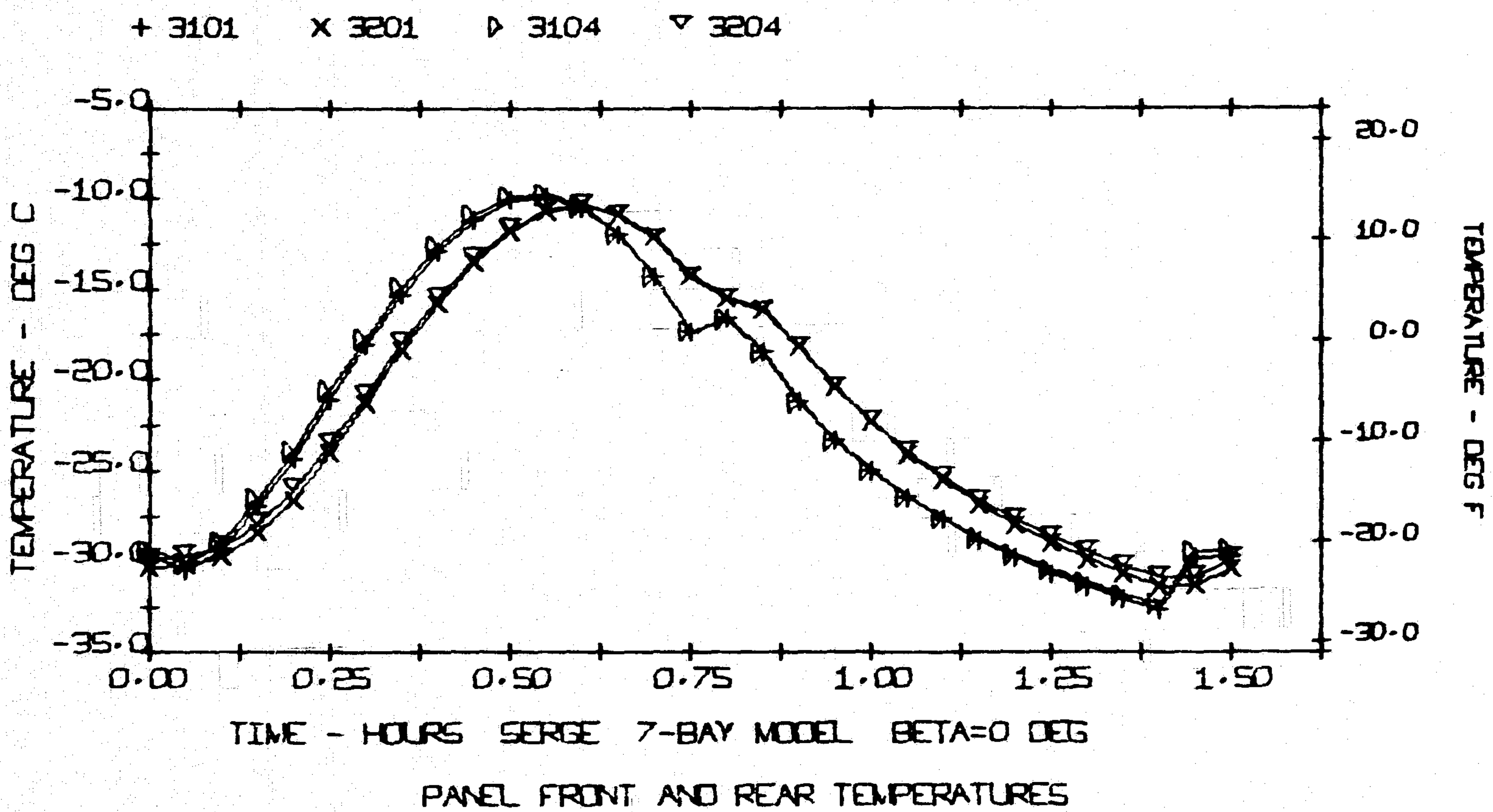
SERGE ANTENNA
PANEL TEMPERATURES vs. TIME



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PANEL DIFFERENTIAL TEMPERATURES VERSUS TIME

Panel differential temperatures (front minus rear) are shown in the figure. The maximum is approximately 3°C which is well under the differential required to introduce significant panel warpage. Test's made on SEASAT-Type panels indicate that a differential temperature of 8°C produces a thermal distortion of only .4 cm. The design goal is to keep the distortion less than .635 cm.

A negative orbit angle (β) would produce higher ΔT's across the panel, but only at large negative β angles would the ΔT approach the 12.7°C needed to exceed the .635 cm warpage goal.

The spikes occuring in the plot at $t \cong .75$ hrs. and $t \cong 1.4$ hrs. is due to momentary rapid heating of the panels by direct sunlight just prior to entering the earth's shadow and just after emerging from it.

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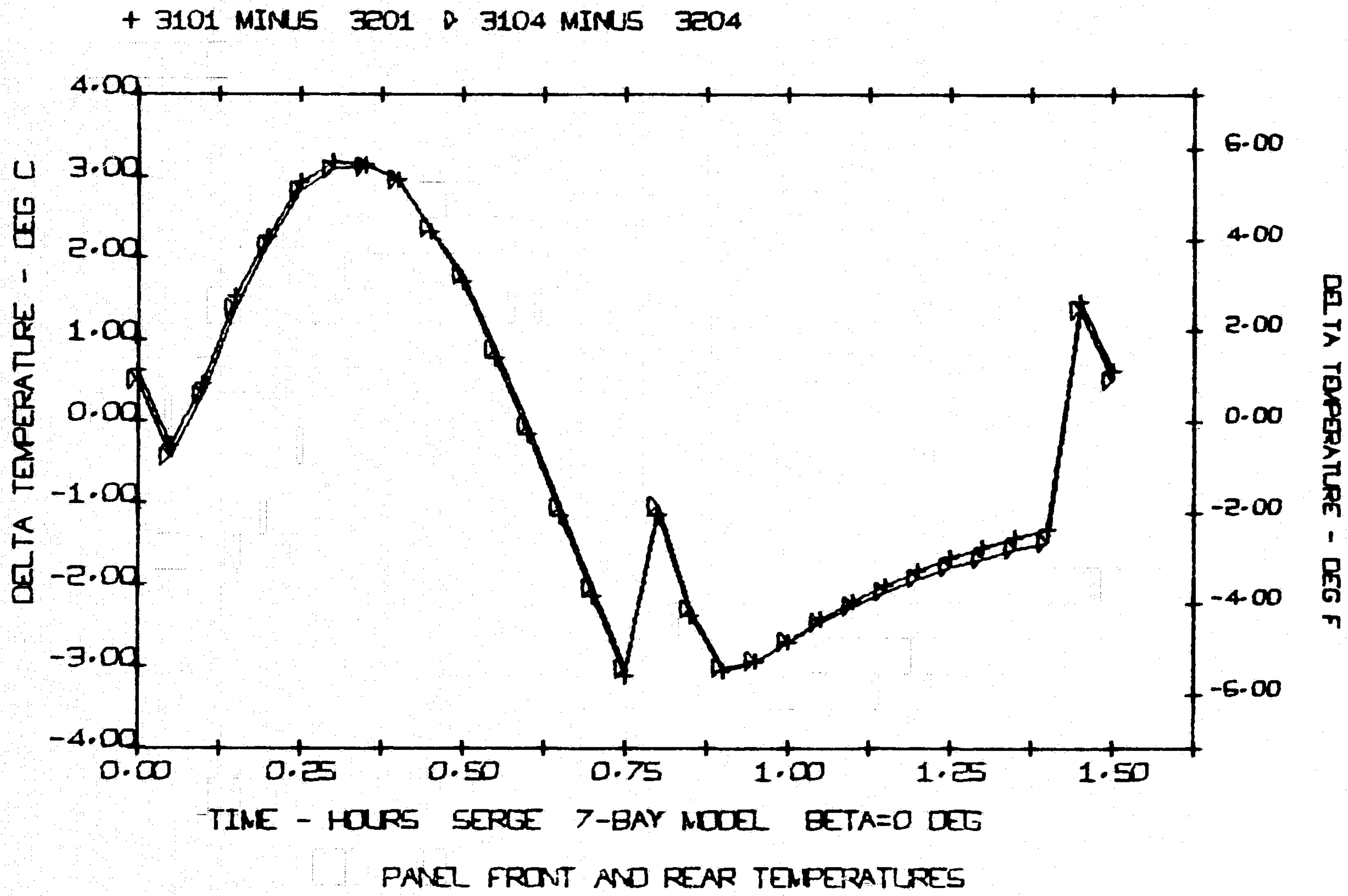
SERGE ANTENNA
PANEL DIFFERENTIAL TEMPERATURES vs. TIME



THERMAL DISTORTION

Thermal distortion due to temperature variations in the strongback and installation truss were quite small. The maximum deviation of the antenna plane from the Gaussian best fit plane was .02 cm. The design goal was to keep the deviation (δ) from the best fit plane less than .635 cm.

Thermal distortions predicted for the pallet-installation structure interface were somwhat larger (.229 cm), but still were well within the allowable range.

In all cases the effect of thermal distortion on the antenna pointing was negligible (< .03°). Therefore, thermal distortion is not expected to be a major factor in the SERGE antenna performance

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SERGE ANTENNA
THERMAL DISTORTION

- FABRICATION TEMPERATURE OF 70°F (R.T.)
- TRUSS TEMPERATURE CHANGE INCLUDED
- PALLET TEMPERATURE CASES
  - 70°F ($\Delta T = 0$)
  - 140°F ($\Delta T = +70$)
  - 0°F ($\Delta T = -70$)
- DISTORTION
  - POINTING ERROR OF BEST-FIT PLANE (θ)
  - MAXIMUM DEVIATION FROM BEST-FIT PLANE (δ)
- RESULTS

PALLET TEMP.	θ (DEG.)	δ (CM)
70°F	0.003	.020
140°F	0.028	.229
0°F	0.023	.203

- MAXIMUM ALLOWED 0.2 .635
- CONCLUSION - NO DISTORTION PROBLEMS

SUMMARY AND CONCLUSIONS

The major conclusions of this concept definition study are summarized in the facing chart.

The baseline configuration defined in the study has the SERGE antenna panel array mounted on the OFT-2 pallet sufficiently high in the bay that negligible amounts of radiation from the beam are reflected from orbiter surfaces into the Shuttle payload bay. The array is symmetrically mounted to the pallet along the array long dimension with the pallet at the center. It utilizes a graphite epoxy trusswork support structure. The antenna panels are of SEASAT engineering model design and construction. The antenna array has 7 panels and a 7-way anturally tapered coax corporate feed system. The assembly mounts to the pallet at four places with adjustable attachments fittings.

The performance of the system is predicted to exceed 33 dB gain, have -15 dB sidelobes in the E-plane and even lower in the H-plane, and have an E-plane beamwidth less than 2.2°, all within performance specification. The entire assembly will be controlled to weigh less than 400 lbs. and in the baseline configuration is estimated to weigh less than 370 lbs. The primary support structure is predicted to exceed the specified greater than 25 hertz fundamental frequency, although individual panels will have 15 hertz fundamental frequency. The thermal effects are predicted to be minimal.

SERGE ANTENNA
SUMMARY AND CONCLUSIONS

- BASELINE CONFIGURATION
  - MOUNT ON PALLET HIGH IN BAY
  - PALLET CENTERED ON PANEL LONG DIMENSION
  - GRAPHITE-EPOXY SUPPORTING STRUCTURE
  - 7 PANELS, NEW BUILD, EMU CONSTRUCTION
  - COAX FEED, 7-WAY POWER DIVISION
  - ADJUSTABLE PALLET ATTACHMENTS
- PERFORMANCE
  - 33 DB GAIN, -15 DB SIDELOBES, $< 2.2^\circ$ E-PLANE BEAMWIDTH
  - $<$ 400 LBS.
  - 28.5 Hz STRUCTURE FUNDAMENTAL FREQUENCY, 15 Hz PANELS
  - MINIMAL THERMAL EFFECTS ON POINTING AND PANEL DISTORTION

OTHER AVAILABLE DATA

In addition to this final report, the thermal and structural dynamics analytical models have been provided to the technical monitor for use in integrated orbiter/pallet/payload analyses. Preliminary design drawings were also provided.

Also, in addition to this technical information, a separate report of the expected cost and schedule for the manufacture, test, and integration of the baseline configuration was provided to the technical monitor.

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SERGE ANTENNA

OTHER AVAILABLE DATA

- THERMAL MODEL
- STRUCTURAL DYNAMICS MODEL
- PRELIMINARY DESIGN DRAWINGS