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SURVEY OF GROUND RADOMES

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FOREWORD

This report was prepared by the Development Engineering Branch of Rome Air Development Center, Griffiss Air Force Base, New York. Mr. Robert Curtis, Task Engineer on Task 557901, "Ground Radome Design Techniques," compiled the data presented herein.

The author wishes to acknowledge the cooperation received from Goodyear Aerospace Corporation, North American Aviation, and Electronic Space Structures Corporation in response to requests for data used in the compilation of this survey.

AIR FORCE - Canterbury Press, Rome, N. Y. - 6/8/64 - 133

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SURVEY OF GROUND RADOMES

INTRODUCTION

Since publication of the original "Survey of Ground Radomes" in May 1961, the major development effort in ground radomes has been directed toward increased application of metal space frame structures. This type of construction refers to a structure formed by a three dimensional arrangement of metallic load-carrying members to which are attached thin flexible or semirigid membranes forming the radome wall.

It has been demonstrated in full and scale model testing that very acceptable transmission characteristics may be attained with a metal space frame across a passband extending from approximately 600 to 10,000 mcs. Below this range a dielectric space frame yields better performance characteristics. Above this range, tests have been conducted at K band with acceptable results. The success achieved with these structures may be attributed to the use of the metallic frame plus improved design techniques.

The higher modulus of elasticity of metal makes possible the use of members of reduced cross section. This in turn reduces transmission loss by reducing the "aperture block."

Scattering is reduced by arranging the ribs in a random geometrical pattern and shaping the individual ribs to present a "streamlined" shape to the incident energy. In addition, it has been shown that for cylinders having diameters between approximately one-half to one wavelength, the induced current in dielectric ribs exceeds that in metal cylinders having the same diameters. This indicates a further advantage to be derived from the use of metal ribs.

Although the largest percentage of the structures presented here are metal space frame radomes, there is also reflected an increasing application of foam radomes. Thus far, this technique has been adapted to structures of rather modest dimensions. However, the state of the art in fabricating with foam plastic has advanced to the point where larger structures (i.e., 50' diameter and greater) are practicable.

Sandwich radomes are still employed in limited number for those applications where very stringent transmission requirements justify the additional complexity, expense and narrow passband of this type structure.

The variety of structures and techniques available for ground radomes presents an optimistic picture for the system designer. The choice of a structure is no longer predicated upon a necessity to accept the "lesser of two evils." It is now possible, in most cases, to tailor the radome to the specific requirements, maintaining optimum technical characteristics at reasonable cost.

RADOME CW-424

Geometry

Shape: Smooth, truncated sphere formed by a random geometrical arrangement of spherical polygon panels.

Dimensions:

Spherical Diameter	60' - 10¼"
Base Circle Diameter	50' - 1¾"
Height	48' - 7"

Construction

Type: Sandwich.

Materials: Panels are formed of 0.032" polyester fiberglass laminate skins with 1.5", 40-P-40 (18)¾" cell paper honeycomb core.

Number of Panels: 161

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: 390 man hours.

Field operations required: Bolting of base panel to foundation; interior bolting of adjacent panels for final assembly of shell.

Scaffolding and/or erection equipment: Interior scaffolding and common hand tools.

Sealing: Joints may be caulked or taped to effect final seal.

Maintenance

Exterior surface should be painted and joints recaulked or taped based upon periodic field inspection.

Status

A prototype of this radome was designed and fabricated for testing and evaluation No subsequent procurement has been made.

Electrical Performance

Type Tests: Full Scale.

Antenna: AN/FPS-26

Test Frequency: High - 5900 mc
Medium - 5650 mc
Low - 5400 mc

Results:

	5900 mc	5650 mc	5400 mc
Transmission Loss	0.2 db	0.15 db	0.2 db
Boresight Error	← (Elev - 0.0092° max) / (Az - 0.032 ° max) →		
Maximum Sidelobe Change	+2.6db • -28.0db	+1.9db • -29.4db	+2.7db • -29.7db
Beamwidth	← < 1% Change →		
VSWR	← <10% Increase →		

Figure 1. RADOME CW-424

RADOME CW-620

Geometry

Shape: Faceted, truncated sphere formed by a random geometrical arrangement of triangular panels.

Dimensions:

Spherical Diameter	150'.
Base Circle Diameter	149'.
Height	84'.

Construction

Type: Metal Space Frame.

Materials: The framework is formed from shaped aluminum beams joined by steel hub plates to form an open framework of triangular apertures. These triangular apertures are covered by clamping reinforced plastic laminate membranes to the aluminum beams.

Number of Panels: 590.

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: Unknown.

Field Operations Required: Field bolting of frame members and subsequent attachment of membranes by screws and cap strips.

Scaffolding and/or Erection Equipment: The tools and equipment normally associated with heavy construction are required. Scaffolding may be held to a minimum by working from the frame itself.

Sealing: Gasketing, provided between cap strip, membrane and aluminum beam.

Maintenance

Exterior surface should be painted based upon periodic field inspection

Status

This radome is currently in operational use at Air Force sites.

Electrical Performance

Type Tests: Scale Model.

Scale Factor: 1:13.176.

Antenna: Elliptical Parabolic.

Test Frequency: 5600 mc (UHF full scale)

Results:

Transmission Loss: 0.7² db.
Boresight Shift (Max): 0.2°.
Maximum Sidelobe Change: 6.3db @ -30.4 db
Maximum Beamwidth Change: +3.64% @ -10 db.

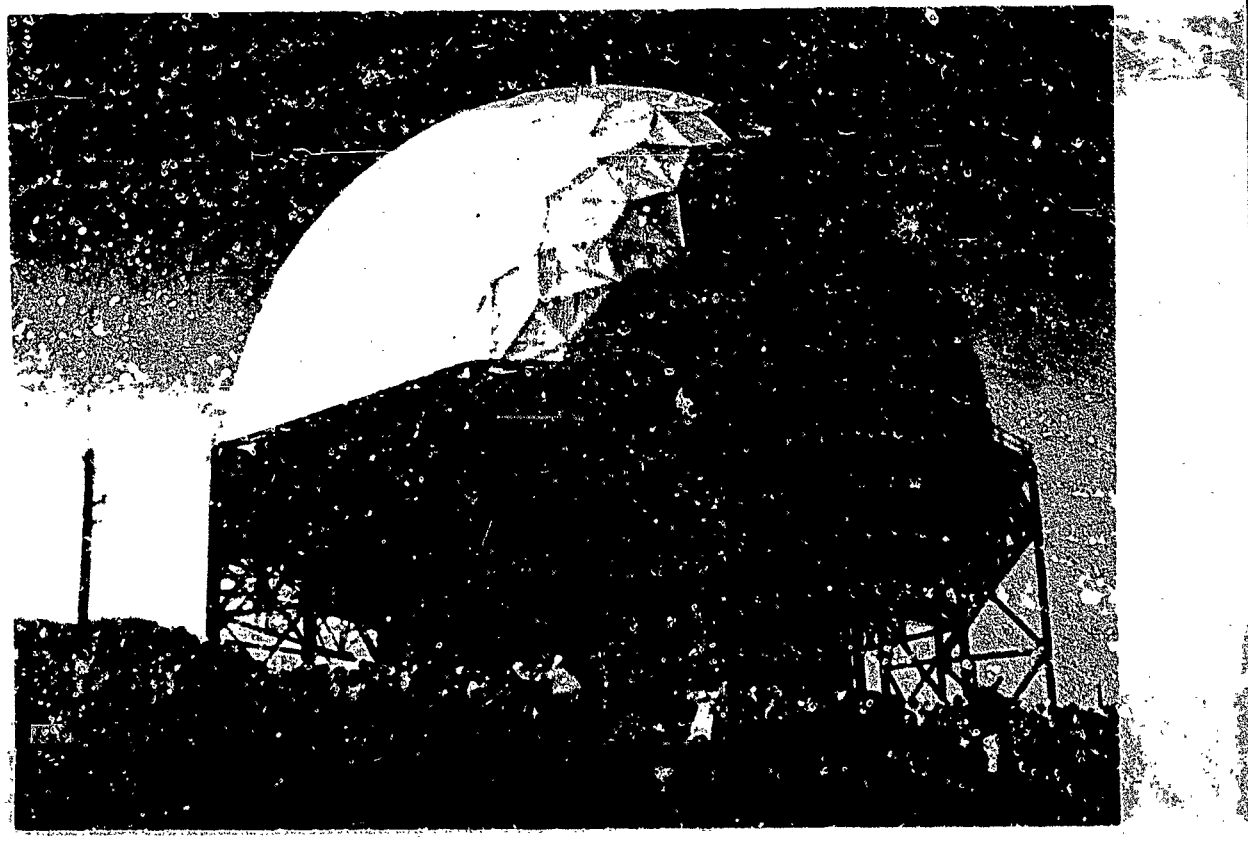

Figure 2. RADOME CW-620

RADOME CW-650

Geometry

Shape: Smooth, truncated sphere formed by a regular geometrical arrangement of polygon panels.

Dimensions:

Spherical Diameter	140'.
Base Circle Diameter	130'.
Height	96'.

Construction

Type: Sandwich.

Materials: The panels are constructed from a paper honeycomb core bonded between two skins of 0.042" thick reinforced plastic laminate. The panel is approximately 6" thick overall and is bounded with a reinforced plastic channel section which provides means for inter-panel attachment.

Number of Panels: 1375.

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: Unknown.

Field Operations Required: Bolting of base panels to base ring and subsequent bolting of remaining panels in position to form complete shell.

Scaffolding and/or Erection Equipment: Extensive interior scaffolding is required to support the shell during erection and to provide staging for the workers. Actual bolting is accomplished with common hand tools.

Sealing: Sealing, if required, may be accomplished by caulking or tape.

Maintenance

Exterior surface should be painted based upon periodic field inspection.

Status

This radome is currently in operational use at Air Force sites.

Electrical Performance

No test data is available for this radome. The following performance characteristics are predicted based upon theoretical calculations and apply only at that frequency for which the radome was specifically designed.

Transmission Loss: .12 db.
Boresight Error. .50 db.
Sidelobe Change: +1.5 db • -25 db.
Beamwidth Increase: +5%.
VSWR: 10%

Figure 3. RADOME CW-650

RADOME CW-694

Geometry

Shape: Faceted, hemisphere formed by a random geometrical pattern of triangular panels.

Dimensions:

Spherical Diameter	93' - 0".
Base Circle Diameter	93' - 0"(-).
Height	45' - 10½".

Construction

Type: Metal Space Frame.

Material: Panel Construction consists of a frame of aluminum beam extrusions welded to corner castings. To the frame is bonded and crimped a skin of polyester resin, fibrous reinforced plastic laminate.

Number of Panels: 540.

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: 500 man hours.

Field Operations Required: Bolting of base ring to foundation; bolting of base panels to base ring; bolting of adjacent panels for final assembly of shell.

Scaffolding and/or Erection Equipment: Interior scaffolding and common hand tools.

Sealing: Radome is sealed by the application of tape to the exterior joint lines.

Maintenance

Exterior surface should be painted and tape replaced based upon periodic field inspection.

Status

Air Force drawings and specifications are available for the manufacture of this equipment.

Electrical Performance

Type Tests: Scale Model.

Model Dimensions: Radome Diameter - 7.14'
Antenna - 3'(circular Parabolic)

Test Frequency: 18000 mc (1380 mc full scale)
8000 mc (614 mc full scale)

Results:

	18000mc	8000mc
Transmission Loss	0.9 db	1.0 db
Boresight Shift	.44 Mils (max)	
Maximum Sidelobe Change	+0.8 db • -20.5 db	+1.2 db • -17.9 db
Half Power Beamwidth	No change.	

RADOME CW-696

Geometry

Shape: Faceted, truncated sphere formed by a random geometrical pattern of triangular panels.

Dimensions:

Spherical Diameter	33' - 0"
Base Circle Diameter	24' - 7"
Height	27' - 6-3/8".

Construction

Type: Metal Space Frame.

Materials: Panels are formed of aluminum frame castings on which are bonded and riveted polyester fibrous glass reinforced, plastic laminate skins.

Number of Panels: 875

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: 110 man hours.

Field Operations Required: Bolting of base ring to foundation; bolting of base panels to base ring; interior bolting of adjacent panels for final assembly of shell.

Scaffolding and/or Erection Equipment: Interior scaffolding and common hand tools.

Sealing: Radome is sealed by the application of tape to the exterior joint lines.

Maintenance

Exterior surface should be painted and tape replaced based upon periodic field inspection.

Status

Air Force drawings and specifications are available for the manufacture of this equipment.

Electrical Performance

Type Tests: Scale Model.

Model Dimensions: Radome Diameter - 7.14'
Antenna - 5' (circular parabolic)

Test Frequency: 9250 mc (2000 mc full scale)
22000 mc (4760 mc full scale)

Results:

	9250 mc	22000 mc
Tramsnission Loss	1.0 db	0.9 db
Boresight Shift	(not measured)	
Maximun Sidelobe Change	+1.6 db • -26.0 db	+1.3 db • -24.7 db
Half Power Beamwidth	No Change.	

RADOME CW-697

Geometry

Shape: Faceted, truncated sphere formed by a random geometrical pattern of triangular panels.

Dimensions:

Spherical Diameter	22' - 0"
Base Circle Diameter	16' - 4¾"
Height	18' - 4¼".

Construction

Type: Metal Space Frame.

Materials: Panels are formed of aluminum frame castings on which are bonded and riveted polyester, fibrous glass reinforced, plastic laminate skins.

Number of Panels: 875.

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: 60 man hours.

Field Operations Required: Bolting of base ring to foundations; bolting of base panels to base ring; interior bolting of adjacent panels for final assembly of shell.

Scaffolding and/or Erection Equipment: Interior scaffolding and common hand tools.

Sealing: Radome is sealed by the application of tape to the exterior joint lines.

Maintenance

Exterior surface should be painted and tape replaced based upon periodic field inspection.

Status

Air Force drawings and specifications are available for the manufacture of this equipment.

Electrical Performance

Type Tests: Scale Model.

Model Dimensions: Radome Diameter - 7.14'
Antenna - 5' (circular parabolic)

Test Frequency: 6200 mc (2000 mc full scale)
9250 mc (3000 mc full scale)

Results

	6200 mc	9250 mc
Transmission Loss	1.0 db	1.0 db
Boresight Shift		.20 Mils (max)
Maximum Sidelobe Change	+1.0 db • -24.6 db	+1.6 db • -26.0 db
Half Power Beamwidth	No Change.	

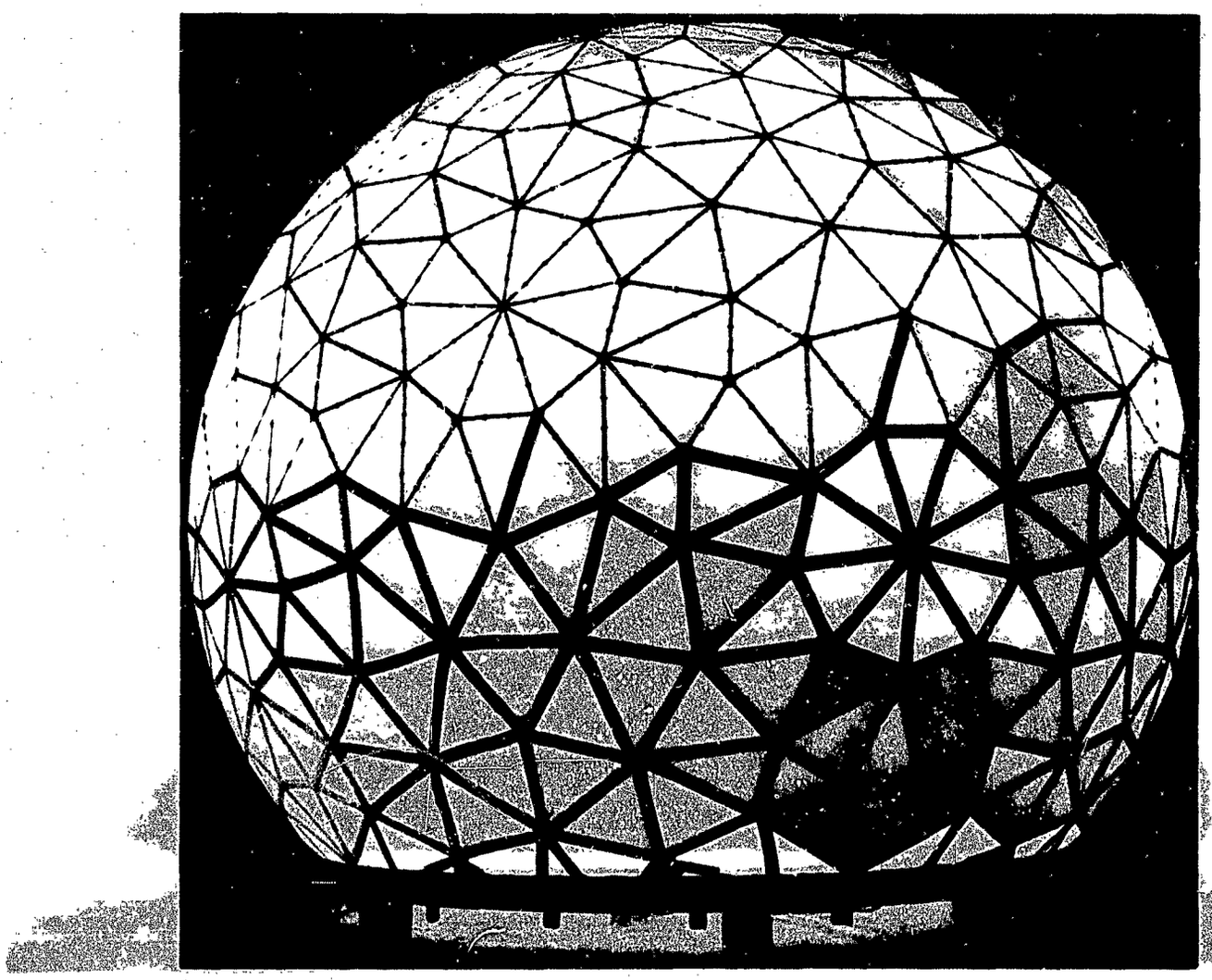

Figure 4. RADOME CW-697

RADOME CW-698

Geometry

Shape: Hemispherically topped cylinder.

Dimensions:

Cylindrical Diameter	10' - 6"OD.
Overall Height	8' - 9"

Construction

Type: Foam Radome.

Materials: Panels are of foam plastic with a nominal thickness of 2-5/8" and density of 6 lbs per ft^3.

Number of Panels:

5 ea cylindrical base panels with bonded aluminum base ring segments.

5 ea spherical segment panel.

1 ea spherical cap panel.

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: 50 man hours.

Field Operations Required: Adhesive bonding of adjacent panels to form continuous structure and the bolting of the shell structure to the foundation thru the aluminum base ring segments.

Scaffolding and/or Erection Equipment: No special scaffolding or tools are required. Adhesive and straps for the field bonding operation are furnished as part of the radome.

Sealing: Bonding of panels provides adequate seal.

Maintenance

Exterior surface should be painted based upon periodic field inspection.

Status

Air Force drawings and specifications are available for the manufacture of this equipment.

Electrical Performance

Type Tests: Full Scale.

Test Frequency: 18000 mc.

Antenna: 3' (circular parabolic)

Results:

Transmission Loss: 0.5 db

Boresight Shift: 1.65 Mils (max)

Maximum Sidelobe Change: +1.0 db • -20.1 db

Half Power Beamwidth: No Change.

NOTE: Radome CW-699 is similar to CW-698 differing only in the following details:

Overall Height: 11' - 9"

Number of Panels: 16 (5 additional cylindrical panels)

FOAM RADOME (17' Diameter)

Geometry

Shape: Smooth, truncated sphere formed by a regular geometrical arrangement of doubly curved polygon panels.

Dimensions:

Spherical Diameter	17' - 0".
Base Circle Diameter	12' - 6".
Height	13' - 11".

Construction

Type: Foam Radome.

Materials: Panels are rigid urethane foam plastic with a nominal thickness of 3".

Number of Panels: 31.

Design Wind Velocity: 126 mph.

Assembly

Approximate Erection Time: 1 week.

Field Operations Required: Adhesive bonding of panels and manual placement to obtain butt joints using special holding clamps until adhesive cures.

Scaffolding and/or Erection Equipment: Simple commerically available scaffolding plus the special holding clamps are required for assembly.

Sealing: Bonding of panels provides adequate seal.

Maintenance

The radome has a non-wettable all weather surface which may require periodic attention.

Status

A number of these have been fabricated by Goodyear Aerospace Corporation for FAA for use with Airport Surface Detection Equipment.

Electrical Performance

Type Tests: Full Scale.

Antenna: FPN-31 (double curvature surface, length 12' - 0", height 3' - 10")

Frequency: 24000 mc.

Results:

Transmission Loss: .45 db.

Boresight Shift: .033°

Maximum Sidelobe Increase: +2.5 db @ -18.2 db.

Maximum Beamwidth Change: +.02°.

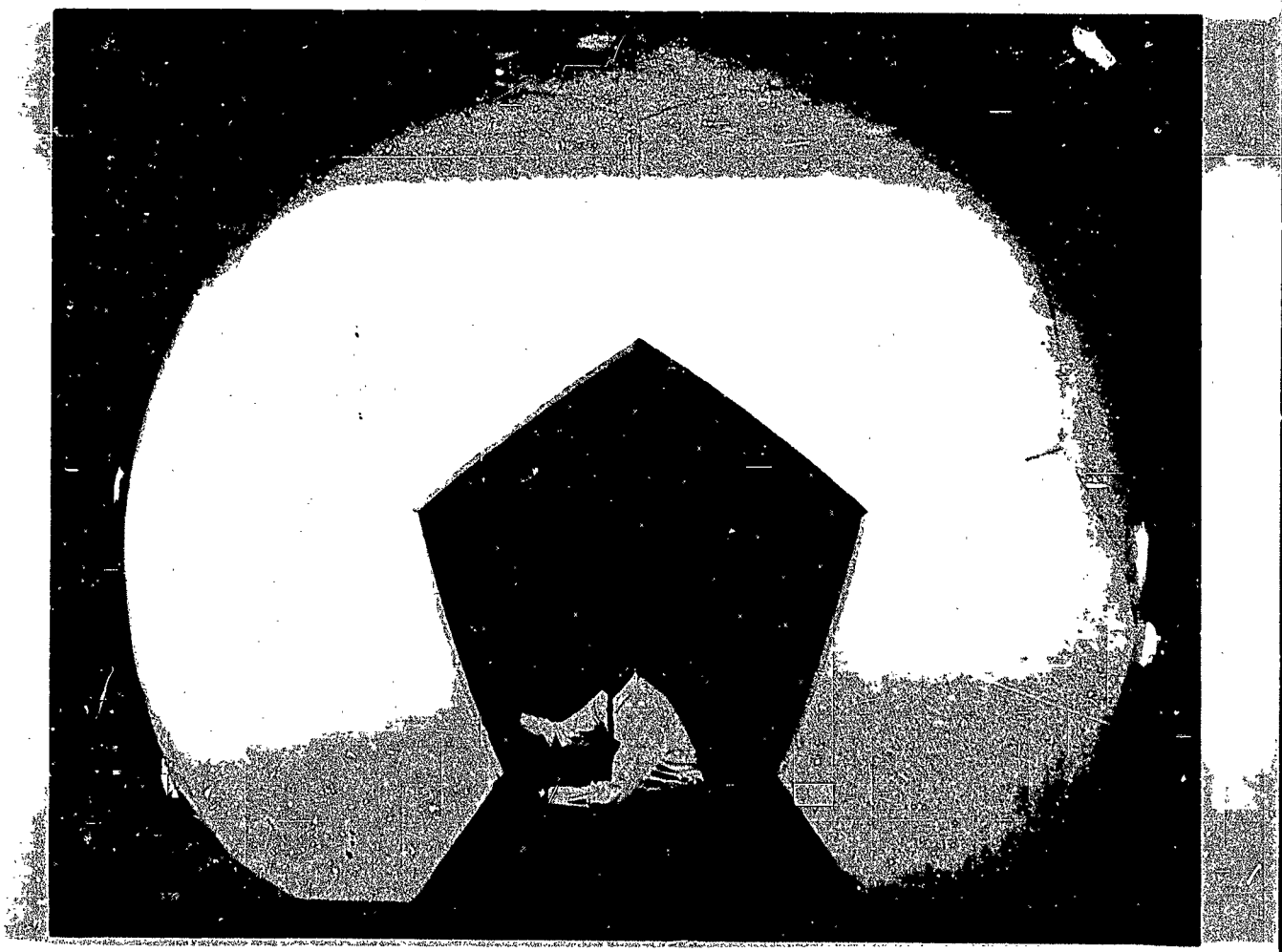

Figure 5. FOAM RADOME (17' Diameter)

FOAM RADOME (10' Diameter)

Geometry

Shape: Smooth truncated sphere formed by a regular geometrical arrangement of doubly curved polygon panels.

Dimensions:

Spherical Diameter	10' - 0".
Base Circle Diameter	7' - 0".
Height	8' - 7½".

Construction

Type: Foam Radome.

Materials: Panels are of rigid urethane foam plastic with a nominal thickness of 2¾" and a density of 6 lbs per ft^3.

Number of Panels: 12.

Design Wind Velocity: 150 mph.

Assembly

Approximate Erection Time: Unknown.

Field Operations Required: Manual placement of panels, field bonding and clamping of panels until adhesive cures.

Scaffolding and/or Erection Equipment: Simple commercially available scaffolding plus normal hand tools appropriate to field bonding operation.

Sealing: Bonding of panels provides adequate seal.

Maintenance

Exterior surface should be painted based upon periodic field inspection.

Status

A number of these structures have been manufactured by Electronic Space Structures Corporation.

Electrical Performance

The following characteristics represent the average electrical properties to be expected up through X-band:

Transmission Loss	< 0.25 db.
Boresight Shift:	0.2 Mils.
Sidelobe Change:	+1.0 db @ -25 db.

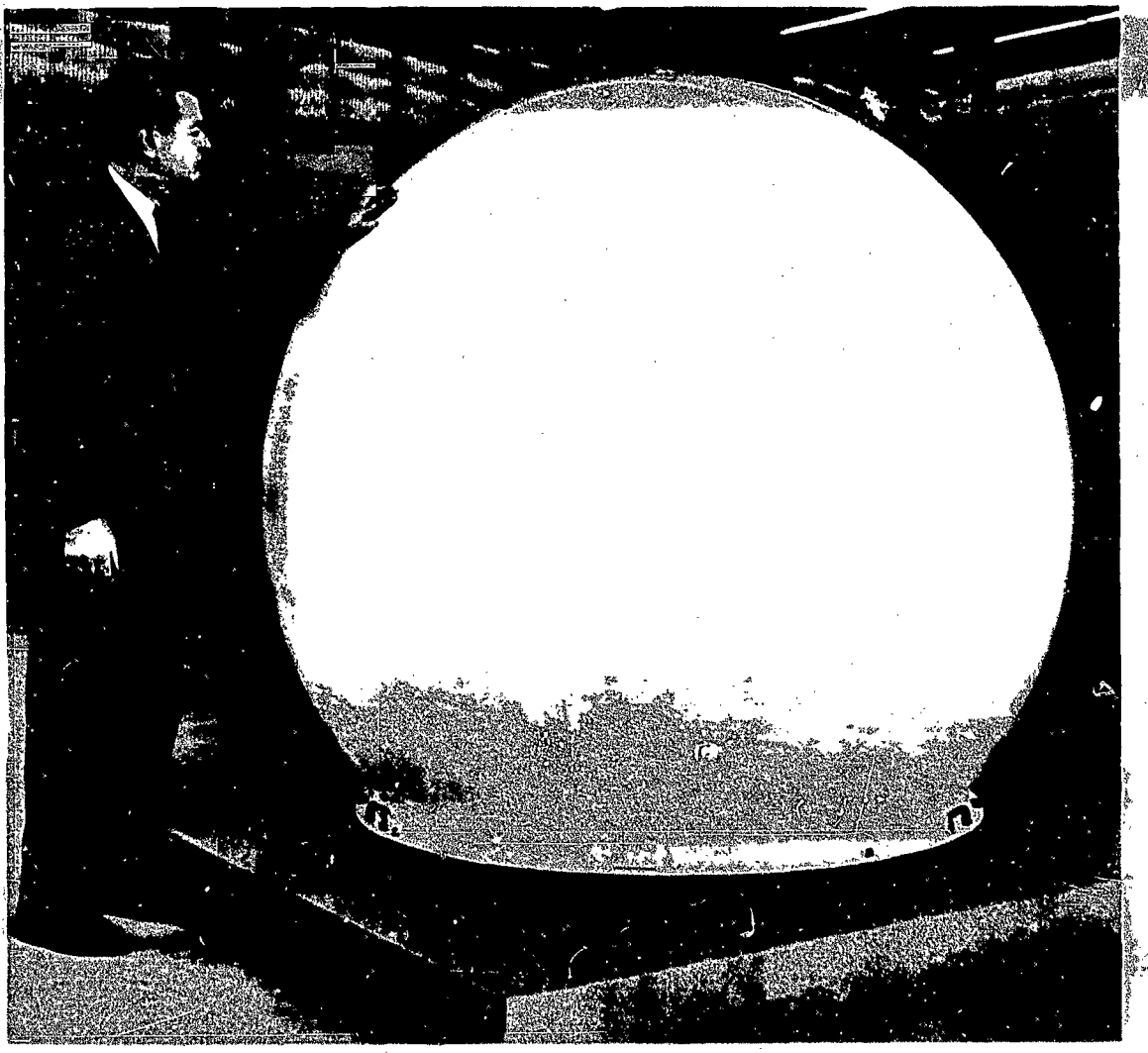

Figure 6. FOAM RADOME (10' Diameter)

FLANGED SHELL RADOME (16' Diameter)

Geometry

Shape: Smooth, truncated sphere formed by doubly curved, lune shaped panels.

Dimensions:

Spherical Diameter	16'.
Base Circle Diameter	11'.
Overall Height	13.8'.

Construction

Type: Flanged Shell.

Materials: The panels are 1/8" thick fiberglass mat reinforced plastic laminate.

Number of Panels: 12 lune shaped panels plus one spherical cap.

Design Wind Velocity: 125 mph.

Assembly

Approximate Erection Time: Unknown.

Field Operations Required: Bolting of panels to one another and the base ring.

Scaffolding and/or Erection Equipment: A minimum of interior scaffolding plus common hand tools.

Sealing: If required, sealing may be accomplished by taping the panel joints.

Maintenance

Exterior surface should be painted based upon periodic field inspection.

Status

This radome has been manufactured by Electronic Space Structures Corporation.

Electrical Performance

The following characteristics represent the average electrical properties to be expected up through S-band:

Transmission Loss	< 0.5 db.
Boresight Shift	0.1 Mil.
Sidelobe Change	+1.0 db @ -25 db.

METAL SPACE RADOME (48' Diameter)

Geometry

Shape: Faceted, truncated sphere formed by a random geometrical pattern of triangular panels.

Dimensions:

Spherical Diameter	48'.
Base Circle Diameter	35.5'.
Overall Height	40'.

Construction

Type: Metal Space Frame.

Materials: The frame members are 6061-T6 aluminum extrusions to which are attached .025" thick, glass fabric reinforced, plastic laminated membranes.

Number of Panels: 875.

Design Wind Velocity: 125 mph.

Assembly

Approximate Erection Time: 260 man hours.

Field Operations Required: Bolting of base ring to foundation; bolting of base panels to base ring; bolting of adjacent panels for final assembly of shell.

Scaffolding and/or Erection Equipment: Interior scaffolding plus common hand tools.

Sealing: Radome is sealed by application of tape to exterior joint lines.

Maintenance

Exterior surface should be painted based upon periodic field inspection.

Status

This radome is one of a number of metal space frame radomes designed and/or manufactured by Electronic Space Structures Corporation. In addition to the previously mentioned CW-697, CW-696, CW-694 and the model described here, this company has designed 55', 110', and 140' metal space frame radomes.

Electrical Performance

The following characteristics represent the average electrical properties to be expected from L-band thru X-band.

Transmission Loss	0.5 db.
Boresight Shift	0.1 Mil.
Sidelobe Change	+1.0 dbe -20.0 db.

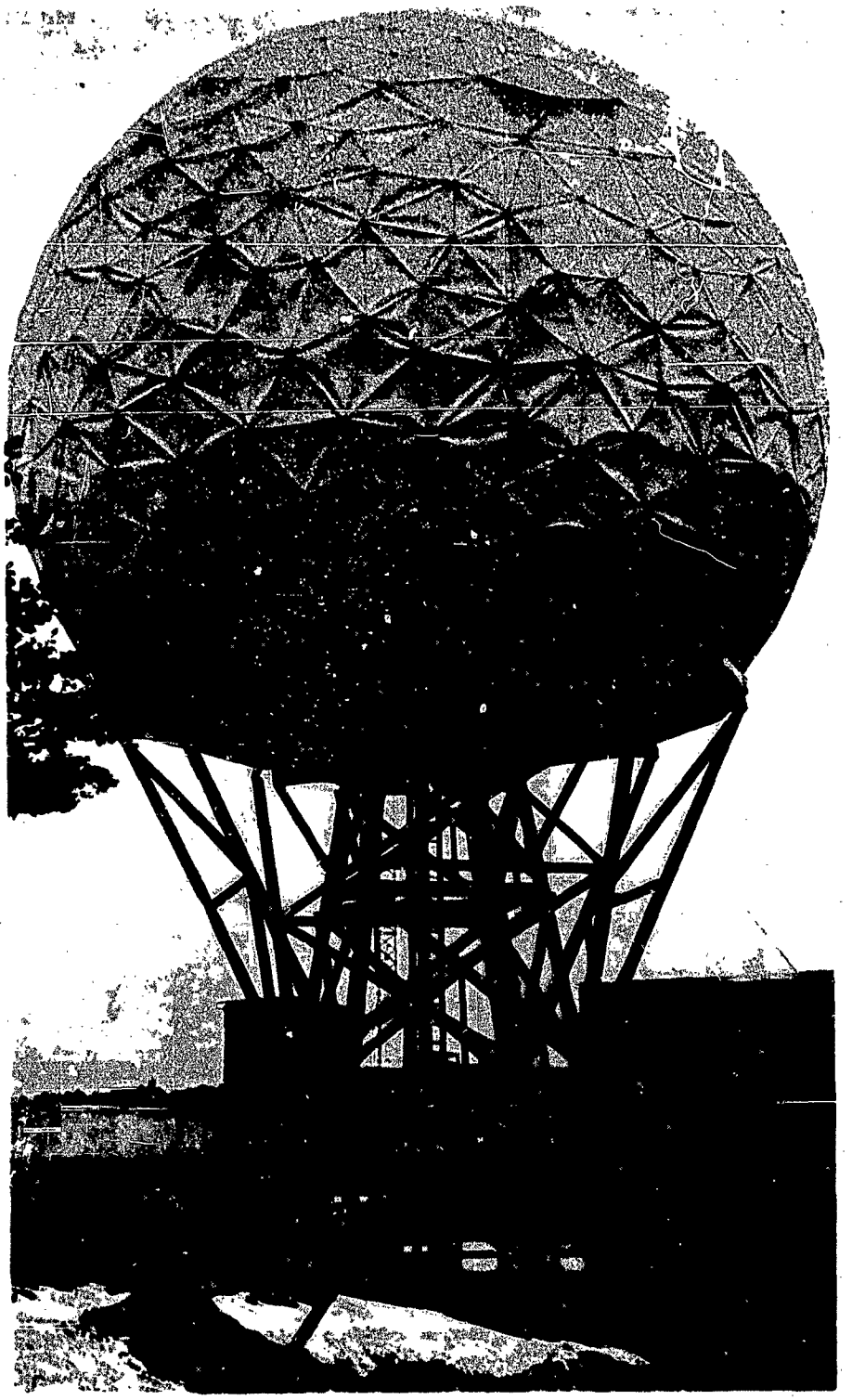

Figure 7. METAL SPACE FRAME RADOME (48' Diameter)

HARDENED RADOME (6.5' Diameter)

Geometry

Shape: Smooth, truncated sphere of monocoque construction.

Dimensions.

Spherical Diameter	6.5'.
Base Circle Diameter	60.25".
Height	67.67".

Construction

Type: Monocoque.

Materials: The monocoque shell is facricated from a glass fabric reinforced plastic laminate.

Number of Panels: The radome is a single continuous shell of uniform thickness.

Design Wind Velocity: This radome is designed to survive in a free stream over-pressure (nuclear blast) of at least 5 psi.

Assembly

Approximate Erection Time: Negligible.

Field Operations Required: Bolting of radome to foundation.

Scaffolding and/or Erection Equipment: No scaffolding is required.

Sealing: None required.

Maintenance

Exterior surface should be painted based upon periodic field inspection.

Status

This radome has been manufactured by Electronic Space Structures Corporation.

Electrical Performance

Type Tests: Full Scale.

Frequency: Ka-Band (10% band)

Results:

Transmission Loss:	.3 db (mid-band)
Boresight Shift:	0.3 Mil (mid-band)
Sidelobe Change:	+1 db.

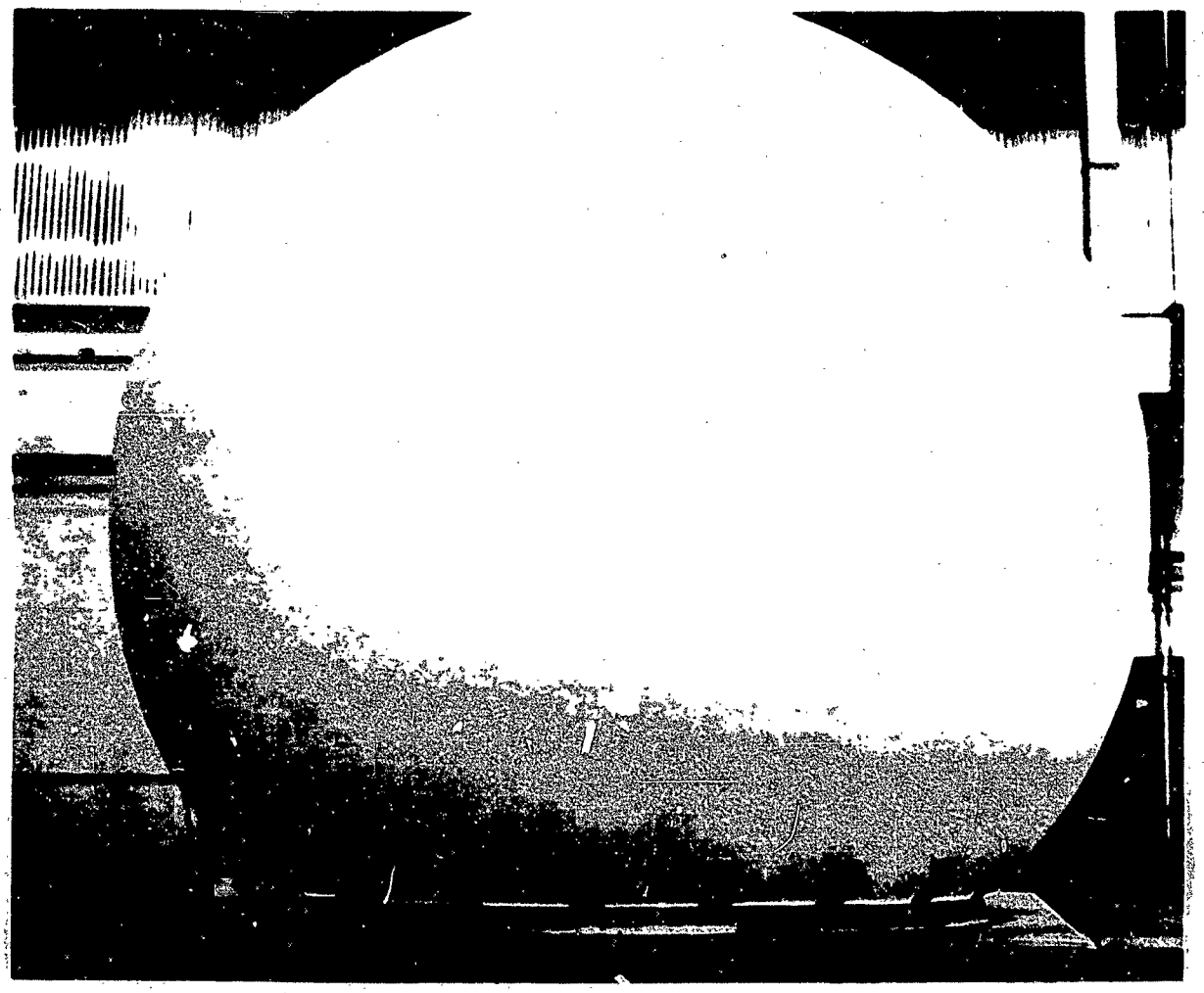

Figure 8. HARDENED RADOME (6.5' Diameter)