Externally Mounted Composite Radome / Fairings for Special Mission Applications

FAA Workshop on Modifications and Alterations affecting Composite Parts or Composite Structure

July 19-20, 2016

Gulfstream®
A GENERAL DYNAMICS COMPANY
# Gulfstream Special Mission Experience

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<th>Year</th>
<th>FAA/FAA Approved</th>
<th>Tank / Fuel Capacity</th>
<th>Gulfstream G6</th>
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Gulfstream Special Mission Experience

GI

- TC-4C A-6 Trainer

GII/GIIB

- NASA Shuttle Trainer
- US Military Research Testbed
Gulfstream Special Mission Experience

• GIII
  – Foreign Military Cargo Door Installation

• GIV / G450
  – US Military Cargo Door Installation
  – Foreign Military Signal Intelligence
  – Gov VIP Transport
Gulfstream’s Experience - Special Missions

- GV / G550
  - Foreign Military Signal Intelligence
  - Foreign Military Tracking / Surveillance
  - Domestic / Foreign Atmospheric Research Platforms
  - Gov VIP Transport
Gulfstream’s Experience – Special Missions

Types of Special Mission Modifications / Installations

- Nose Radome
- Forward Fuselage Belly Radome (Canoe)
- Forward Fuselage Upper Fairings
- Forward Fuselage Side Fairings
- Aft Fuselage Lower Fairing
- Empennage Tip Cap Radome
- Tailcone / Ventral Fin
- Wing Stores
Gulfstream’s Experience – Special Missions

- Each Modification has its own unique design challenges
- All radome / fairing modifications require composite material of some type
  - Transmissivity
  - Weight
  - Stiffness
  - Complex Contours
Gulfstream’s Experience – Special Missions

• Most Challenging are Fuselage Belly Radomes or ‘Canoes’
  – Largest
  – Most Complex due to -
    • Mission / Customer Requirements
    • Aircraft Requirements
    • Regulatory Requirements
Radome Structural Design Criteria

• **Customer Driven Requirements**
  – Transmissivity
  – Field of View
  – Maintenance Access

• **Aircraft Driven Requirements**
  – Aerodynamic Loading
    • Flight Envelope / Mission Profile
  – Structural Loading
    • Airframe Deflection
      – Forced Deflection
Radome Structural Design Criteria

Selected Regulatory Requirements

• Design and Construction
  – 25.601 General
  – 25.603 Materials
  – 25.605 Fabrication Methods
  – 25.609 Protection of Structure
  – 25.613 Material Strength Properties and Material Design Values

• Structure
  – 25.301 Loads
  – 25.303 Factor of Safety
  – 25.305 Strength and Deformation
  – 25.307 Proof of Structure
Radome Structural Design Criteria

Selected Regulatory Requirements

Structure - Continued

• 25.365(e) Pressurized Compartment Loads
• 25.571 Damage Tolerance
  • Fatigue Assessment
  • Parts Departing Aircraft
  • Birdstrike – section 25.571(e)(1)
• 25.581 Direct Effects of Lightning
Radome Structural Design Criteria

Policy Statement

- PS-ACE100-2004-10030 Substantiation of Secondary Composite Structures
- PS-ANM-25-17 Structural Certification Criteria for Antennas, Radomes, and Other External Modifications

Advisory Material

- AC 20-107B Composite Aircraft Structure
Radome Structural Design Criteria

Company / Customer Criteria

• Structures not tested to ultimate loads should maintain min. M.S. = 0.25
  – If tested, min would be M.S. = 0.00
  – Ref. MIL-HDBK-516C

• Aero Pressure loads to have ultimate load factor of 2.0
  – May reduce to 1.5 based on previous tests

• Belly pod sizing based on external pressure loads and inertia loading
  – Inertia to include emergency landing and flight inertial
25.603 Material
25.613 Material Design Values

• Material
  – Typically fiberglass or quartz fiber
    • Required for transmissivity characteristics
    • Graphite/Epoxy for non transmission locations
Previous Programs

- Fiberglass material used throughout components
- Other radomes / fairings
- Material testing implemented to validate material data
  - Strength
  - Modulus
  - Strain Cutoffs
  - Critical Environmental Conditions
25.603 Material
25.613 Material Design Values

- Current / Future Programs
  - More sophisticated equipment requiring more advanced material
  - Testing programs developed to generate next generation of design values
  - Material Equivalency testing to existing material databases
  - Extensive use of NIAR facilities/capabilities
25.605 Fabrication

Radome / Canoe Fabrication

• Panels / Shell
  – Solid Laminate or Honeycomb Sandwich
  – Mission Dependent

• Fabrication Processes
  – Well Understood
    • Neither new nor novel
  – In house fabrication process specifications
  – Previously approved
Both classical analysis and FEM are employed.

Laminates are analyzed by typical laminate sizing routines
- Strain cutoffs
- Buckling criteria

FEM Model validation
- Unit loading / classical solutions
- Constraints Checks
- Deflection Checks
- Boundary Conditions
– Maintain minimum M.S. for untested structure
  • Customer/company requirement

– Testing performed to validate analysis and analytical details
  • Fuselage Proof Pressure
  • Attachment fittings
• Belly pods are not pressurized but are attached to pressurized fuselage
• Requirement per 25.365(e) requires any structure outside a pressurized compartment to be able to withstand the sudden release of pressure from fuselage
• Belly pods designs incorporate means of venting the radome in a fuselage decompression event.
25.571 Damage Tolerance

• **Fatigue Assessment**
  – Influence of Canoe / Belly Pod Radome on aircraft fatigue life is addressed
  – Affected sections of airframe are reviewed and updated if required

• **Parts Departing Aircraft**
  – Fuselage Canoe / Belly pod radomes
    • All designs have multiple attachments at frame locations
    • Design incorporates ability to lose connections
    • ‘Get Home’ loading
25.571 Damage Tolerance

• Inspections are established
  – Radome laminate
  – Fittings attaching radome to fuselage
  – Impact damage of composite shell
25.571(e) - Birdstrike

Previous Programs

• Birdstrike testing performed

• Bird will penetrate radome
  – Bird disintegrates on impact
    • Composite fiber toughness shreds the bird
    – No parts separated from test article

• Assessment of penetration
  – Ram air effect due to hole
  – Full aerodynamic pressurization
  – Multiple fitting design
25.581 – Direct Effects of Lightning

- Belly Pod Radomes are generally located in primary strike zone locations

- Segmented diverters are typically utilized
  - Leading edges/extremities
  - Mesh in acreage not in FOV

- Testing
  - High voltage determines attachment location
  - High current validates protection strategy
Summary

• Composite Belly Pod / Canoe Radome designs have been in service on Gulfstream aircraft for over 25 years

• Fiberglass / Graphite Composite material utilized throughout all designs

• Successful Implementation based on
  – Conservative design criteria
  – Sound material selection
  – Proven fabrication methods
  – Reliable structural analysis techniques
  – Systematic inspection
Questions?