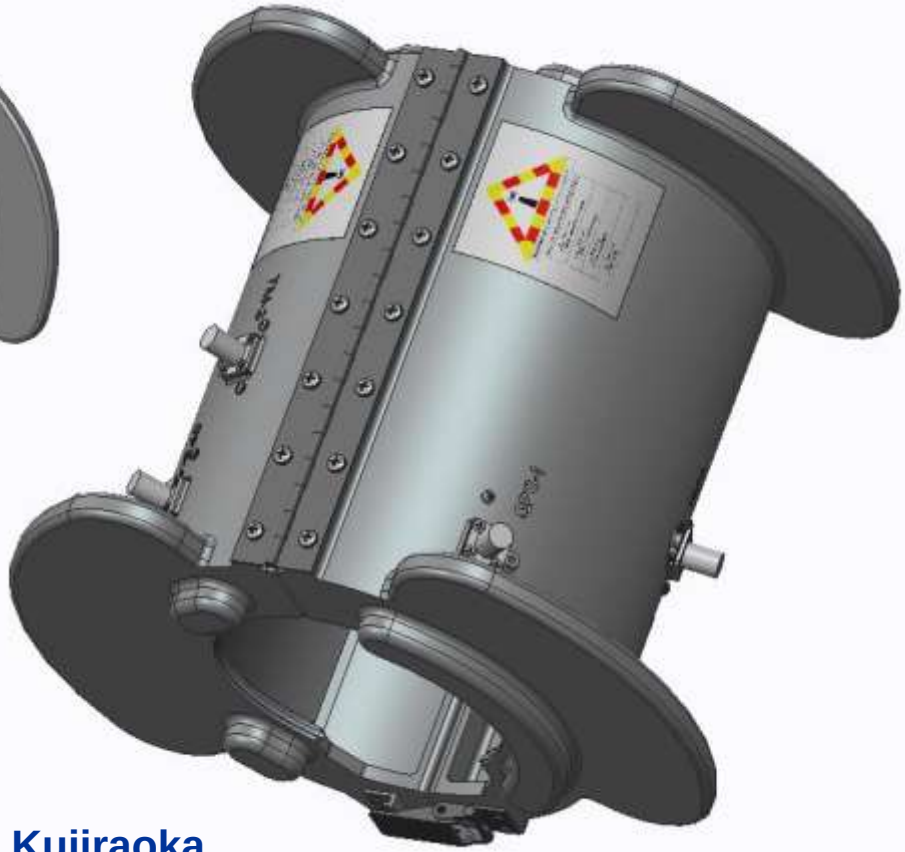
# Advances in the Development of Missile Telemetry Test Sets:
# Utilizing 3D Printing for Rapid Prototyping and Manufacturing



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**NAVAIR- Pt. Mugu CA**
**14 May 2015**

# Agenda

- Background
- Requirements
- Manufacturing Process
- 3D Printed Coupler Lifecycle
- Summary
- Lessons Learned

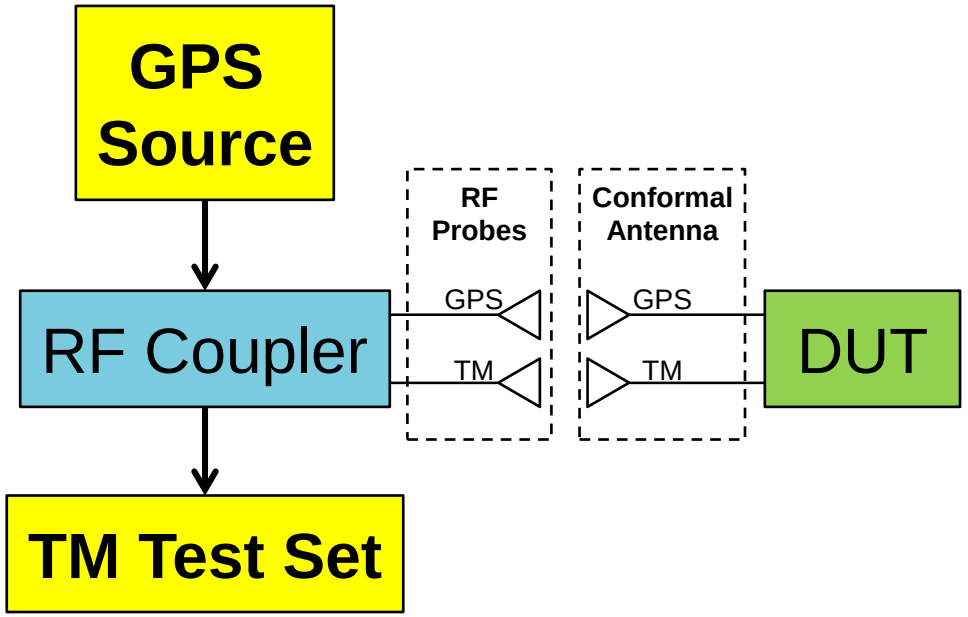
# Background: Test Asset

- **Flight Asset Telemeter**
  - **Tri-Band System**
  - **Conformal Antenna**
    - GPS: L-Band
    - TM: S-Band
    - TM: C-Band
  - **On-board TSPI (JAMI)**

- **Overall Need**
  - **To perform reliable and repeatable functional and acceptance tests on telemeters (in the Stand Alone and All Up Round Missile configurations)**

# Background: Test Setup

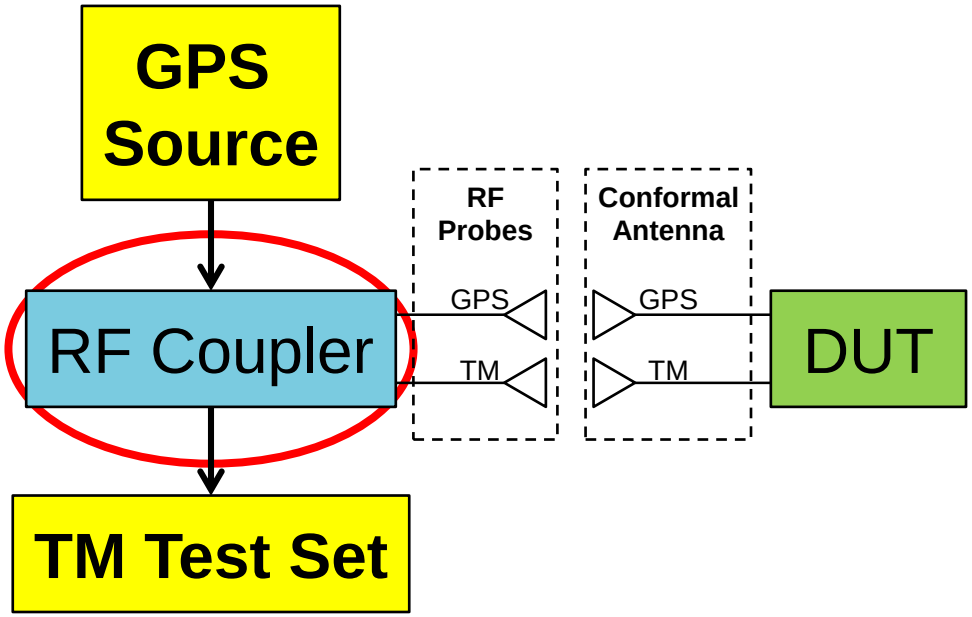
- **Interface Diagram**
  - **RF Coupler: Interface**
    - GPS Port (Input port)
    - TM Port (Output port)
  - **Telemeter Section (DUT)**
    - Conformal Antenna
      - TM Antenna Elements
        **Linear Polarization**
      - GPS Antenna Elements
        **Circular Polarization**
  - **GPS Source**
    - Positional and Timing Data
      - Live or Simulated
  - **TM Test Set**
    - Demodulate Telemeter Data




**Successful Functional Test Increases Data Confidence**

# Background: RF Coupler

- **RF Coupler Capabilities**
  - **Radiation Shield**
    - Enclosed Environment
    - Mitigate RF Leakage
  - **Go / No-Go Testing**
    - Test-Sets
  - **Voltage Monitoring**
    - Peak Detectors
  - **Antenna Element Validation**
    - Fabrication Check
- **In-House Uses**
  - Fabrication Verification
  - Acceptance Testing
    - Antenna & Telemeter
  - Qualification Testing

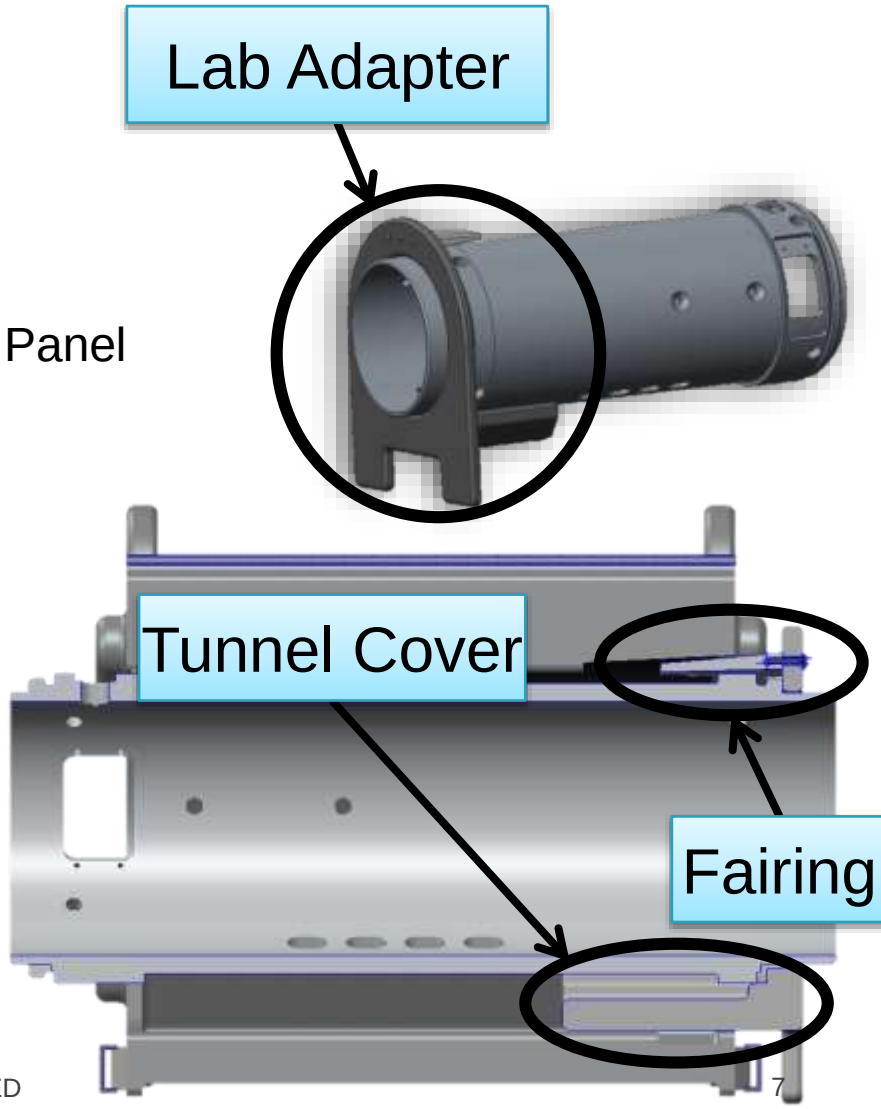


# Requirements: RF

- **Radio Frequency Requirements**
  - **Near Field Coupling**
    - Couple to acceptable power level
      - Avoid saturating / under-powering test-set
      - Provide isolation between TM & GPS probes
  - **RF Probes**
    - Utilize Microstrip antenna elements
      - Repeatable process
      - No tuning required
      - Durable design
  - **RF Leakage**
    - Attenuate RF leakage levels
      - Safely transmit indoors
      - Absorb extraneous RF energy
    - Provide HERO, HERP, HERF instructions

# Requirements: Mechanical

- **Mechanical Requirements**
  - **Repeatable clocking mechanism**
    - Ease of alignment
  - **Respectful to "Keep-out" regions**
    - Tunnel Cover, Fairing, Connector Panel
  - **Multi-purpose scenario**
    - In-lab, production line, flight deck
  - **Modular Design**
    - Permit RF probe swapping
    - Refurbish friendly
  - **Robust Body**
    - Survive four foot drop
    - TNC damage protection
  - **Fabrication Ease**
    - Overnight print



# Manufacturing Process: Machining

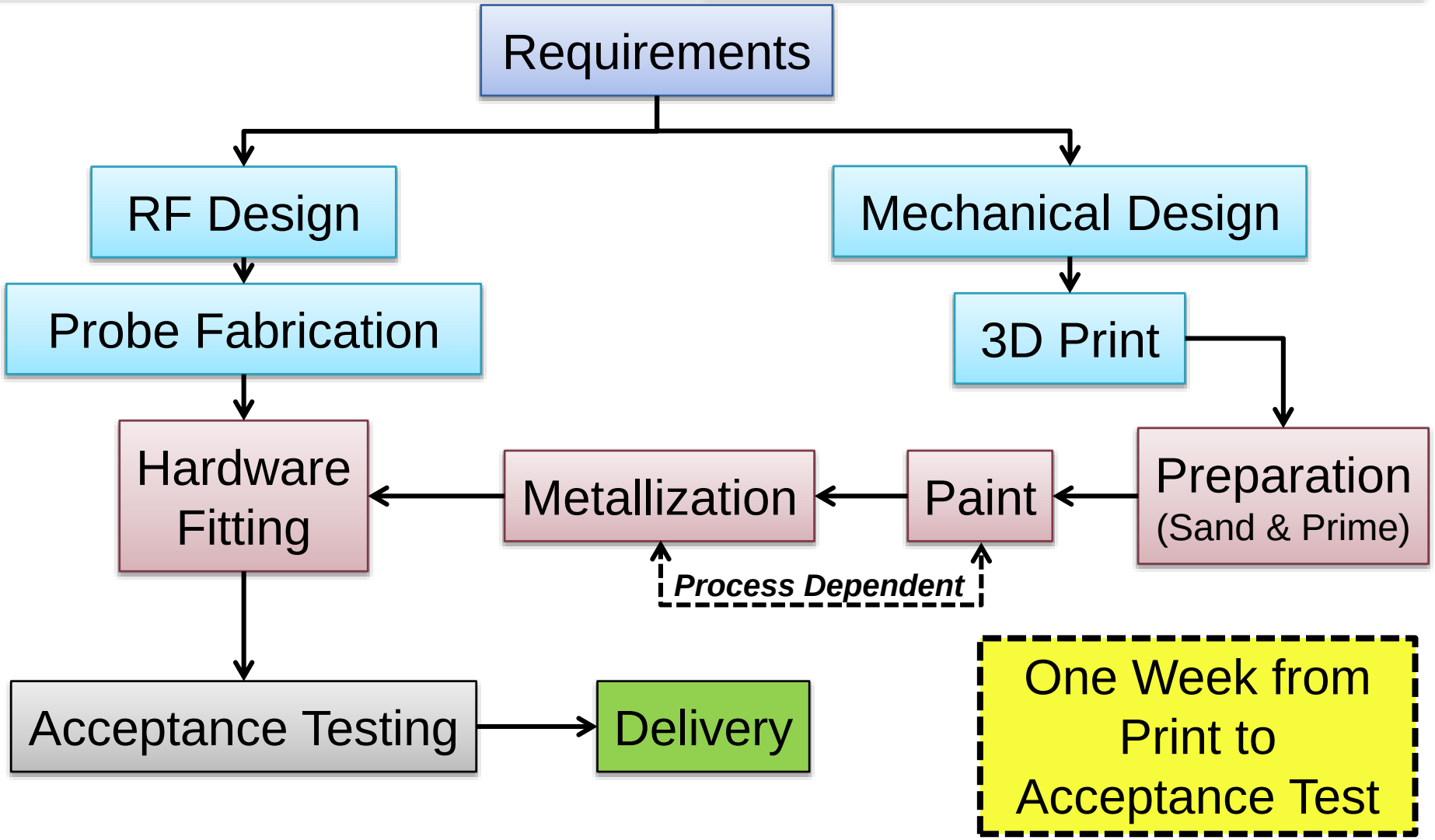
- **Traditional Coupler Manufacturing**
  - **Machine Shop**
    - Complexity
      - Drives cost & schedule
      - Demands simple “cylindrical” design
    - Material dependent
      - Lead time for special metal requirements
    - Requires qualified machining operators
      - NRE costs
    - Welding multiple pieces
      - Warped welding (Alignment Risk)
    - Specialized tooling
      - Complex shapes demand special tools
    - Weight
      - Material thickness and dimensions increase overall weight

# Manufacturing Process:
## Additive Manufacturing (3D Printing)

- **Advances in RF Coupler Manufacturing**
  - **Additive Manufacturing**
    - Requires one operator
    - One piece design
    - Complex shape capability
      - Bends, Screw Holes, Flanges, Edges
    - Multiple material types
      - Acrylonitrile-Butadiene-Styrene (ABS)
      - Polycarbonate
      - Nylon
    - Quick turn-around time
      - Under a day to manufacture
    - Limited by tray size

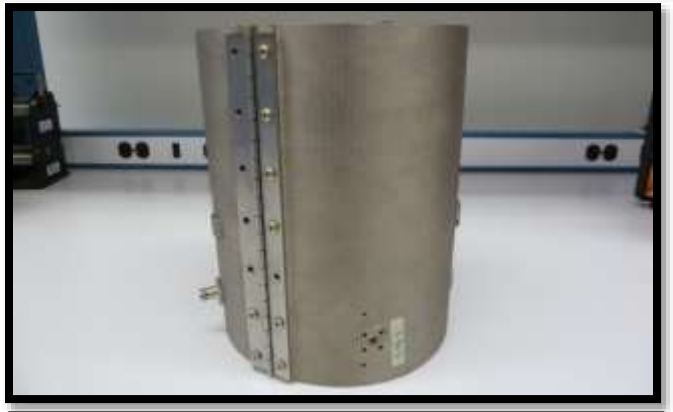
Stratasys:
Fortus 360mc

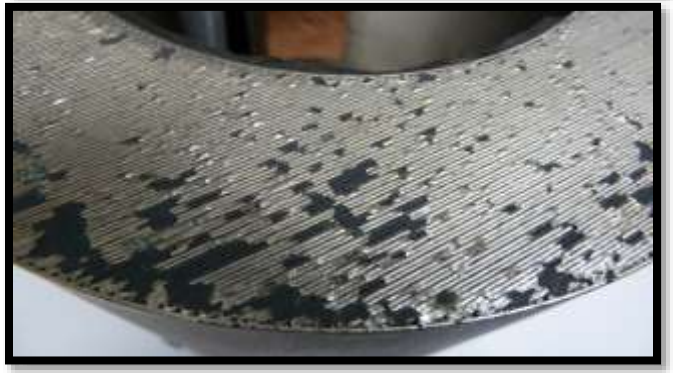
# 3D Printed Coupler Lifecycle



# Metallization:
## Process 1

- **Electro-plating**
  - **Benefits**
    - Continuous metallization
      - RF Shielding
    - Various metals available
      - Ni, Cu, Ag, Au
    - Inexpensive (material dependent)
    - Repeatable
    - Aesthetically pleasing finish
  - **Drawbacks**
    - Variable process
      - Cracking
      - Chipping
      - Pealing
    - Oxidizes without treatment
    - Labor intensive preparation





# Metallization:
## Process 2

- **Copper tape**
  - **Benefits**
    - Cost effective
    - Readily available
    - No preparation required
    - Low Profile
    - Electrically conductive
    - Conductive adhesion
    - Flexible
    - Texture independent
  - **Drawbacks**
    - Edges are hard to work with
    - Wrinkles over uneven surface
    - Layering produces overlaps
    - Mainly for interior application

# Metallization:
## Process 3

- **Silver Coated Copper Conductive Coating**
  - **Benefits**
    - High conductivity
    - Durable
    - Rub off resistant
    - Corrosion resistant
    - Strong adhesion
  - **Drawbacks**
    - HAZMAT material
    - Requires multiple coatings
    - Pre application preparation
    - Relatively expensive

# Painting

**Painting Process**

- Post Print Cleaning
- Surface prep.
  - Sanding
  - Filling
  - Sanding
- Paint

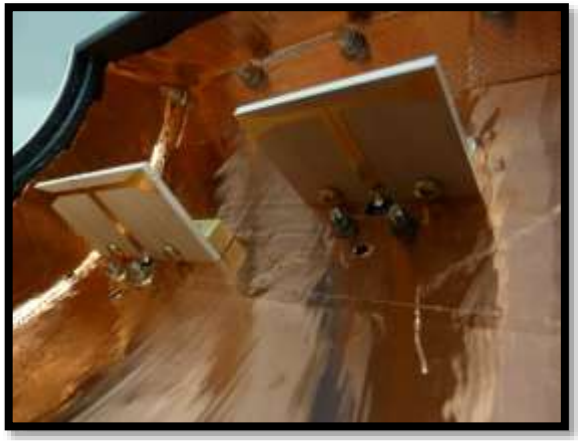
**Results**

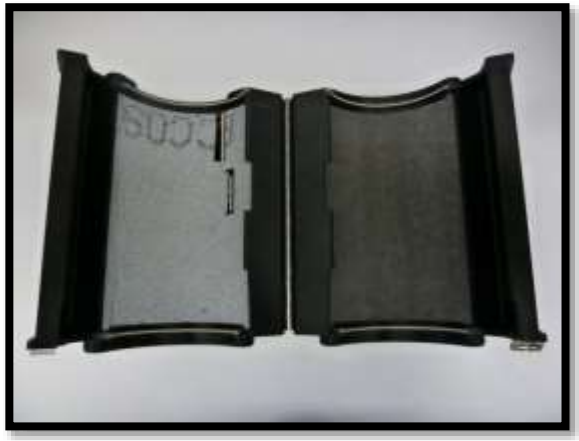
Pre-Paint

Post-Paint

# Hardware

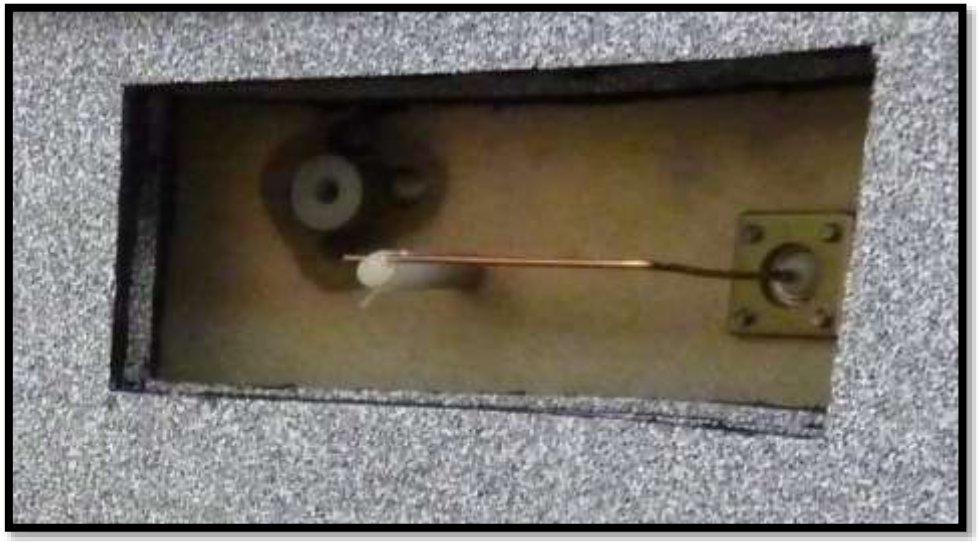
- **RF Hardware**
  - **RF Probes**
  - **RF Absorber**
  - **Dielectric Protective Cover**
  - **EMI Gasket**
  - **50 Ohm TNC Terminations**
- **Mechanical Hardware**
  - **Metal Probe Lids**
  - **RF Probe Supports**
  - **TNC Connectors**
  - **Hinge**
  - **Latches**
  - **Nuts and Bolts**





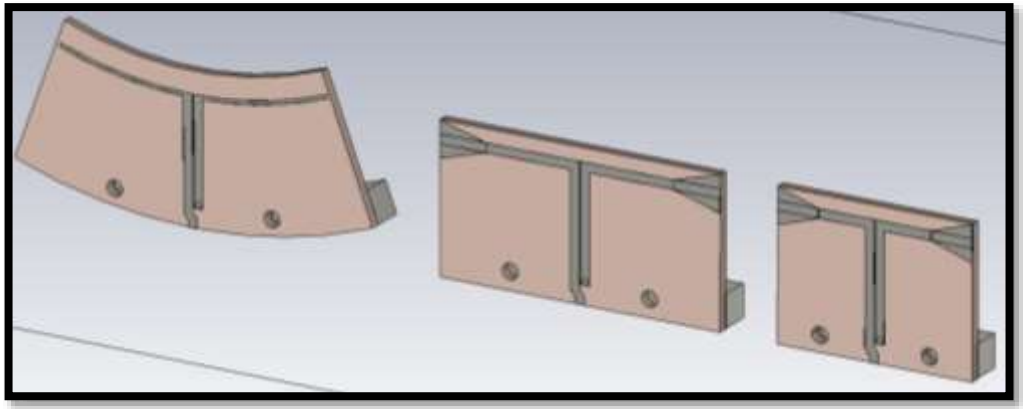
# Hardware: RF Probes

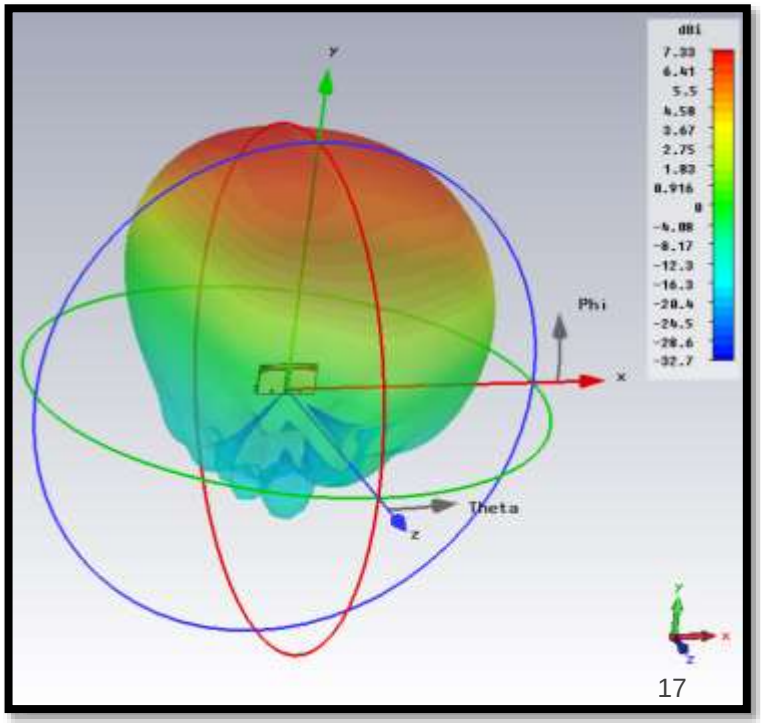
- **Legacy Couplers**
  - **“Coat Hanger” Probe designs**
    - Folded mono-pole antenna
      - Inefficient
      - Not repeatable
      - Prone to damage
      - Requires absorber window tuning for better coupling



# Hardware: RF Probes

- **Current Couplers**
  - **Printed Microstrip Antenna Probes**
    - Dipole Architecture
    - “Donut” pattern produces sufficient gain
    - Continuous ground directs gain pattern towards DUT
      - Provide stronger coupling



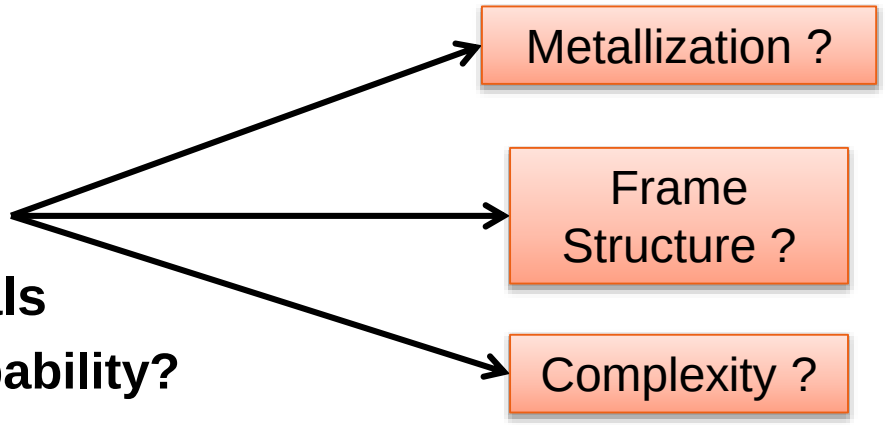


# Summary

- **Three Units Designed and Developed Successfully**
  - Ready for in-lab and field use
- **Acrylonitrile-Butadiene-Styrene (ABS) utilized for printing**
  - Readily available
  - High impact resistance
  - Dimensional Stability
- **Fabrication**
  - **Time**
    - Additive manufacturing significantly reduced fabrication time
      - One week vs. several months
  - **Cost**
    - Reduced labor and tooling costs
- **Functionality**
  - Retained form, fit, and function of traditional RF coupler architecture

# Lessons Learned

- **Understand application**
  - **Will determine RF leakage requirements**
    - Low Power vs. High Power
      - HERO, HERP & HERF
- **Design considerations**
  - Prototype vs. End-use product
- **Determining 3D printer materials**
  - **Does the printer have the capability?**
    - Stratasys: Fortis
      - ABS & Polycarbonate – available capability
      - Nylon – additional $10,000 upgrade
    - Build envelope
      - Is the printer capable of printing the part?
    - Print quality issues
      - Shape Complexity, Curved surface
      - Latent issues (cracking)



# Thank You!

**Point Mugu**

- Rick Davis
- Ryan Doyle
- Chris Ironhill

**China Lake**

- Miriam Horning
- Bob Troublefield

# Questions?