

# Portable Laser Guided Robotic Metrology (PLGRM) System

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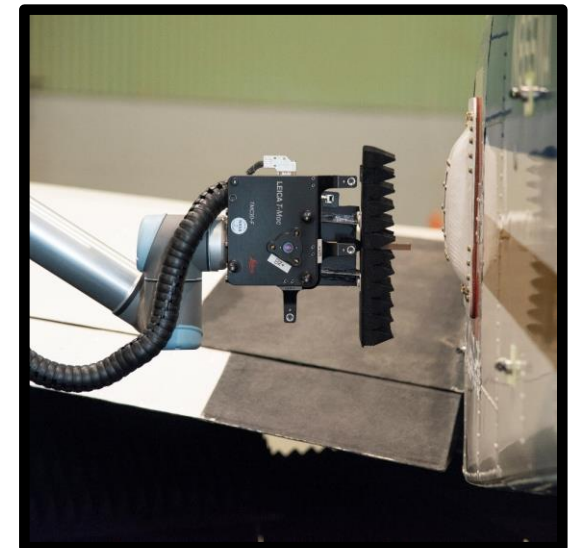
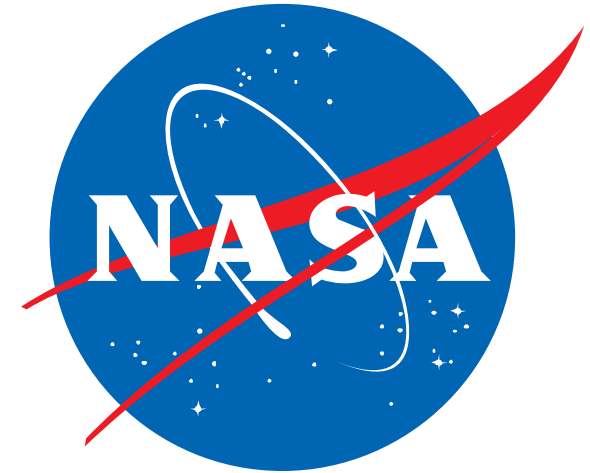


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2019**



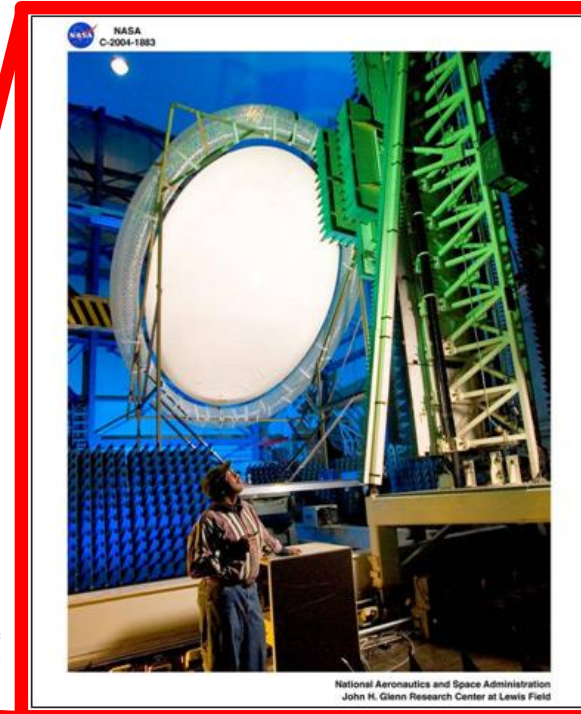
# Overview

- Motivation
- Concept
- Implementation
- Results
- Conclusion



# Installed Antenna Measurements

- Challenging due to wide variety of host platform sizes/shapes
- Can be difficult to bring host platform to existing ranges
- Solution: Develop flexible in-situ antenna metrology system that can be brought to host



# Desired Features

- Portability
  - Easily shipped
  - Deployable by two people
  - Standard wall power
- Flexible measurement system
  - Near/Far Field scanning
  - Safe to operate
  - Solution: collaborative robotics?



# Collaborative Robotics

- Universal Robots UR10
  - 1.3 m reach
  - 10 kg payload
  - Built-in force sensors to operate near humans
    - 150N max
  - Mobile base with LIFTKIT actuator
    - Extends system to 3m vertical reach
  - Arbitrary reach in other directions
- Challenge: accurate probe positioning
  - Robots are repeatable, not necessarily accurate
  - Mobile base: moving coordinate system



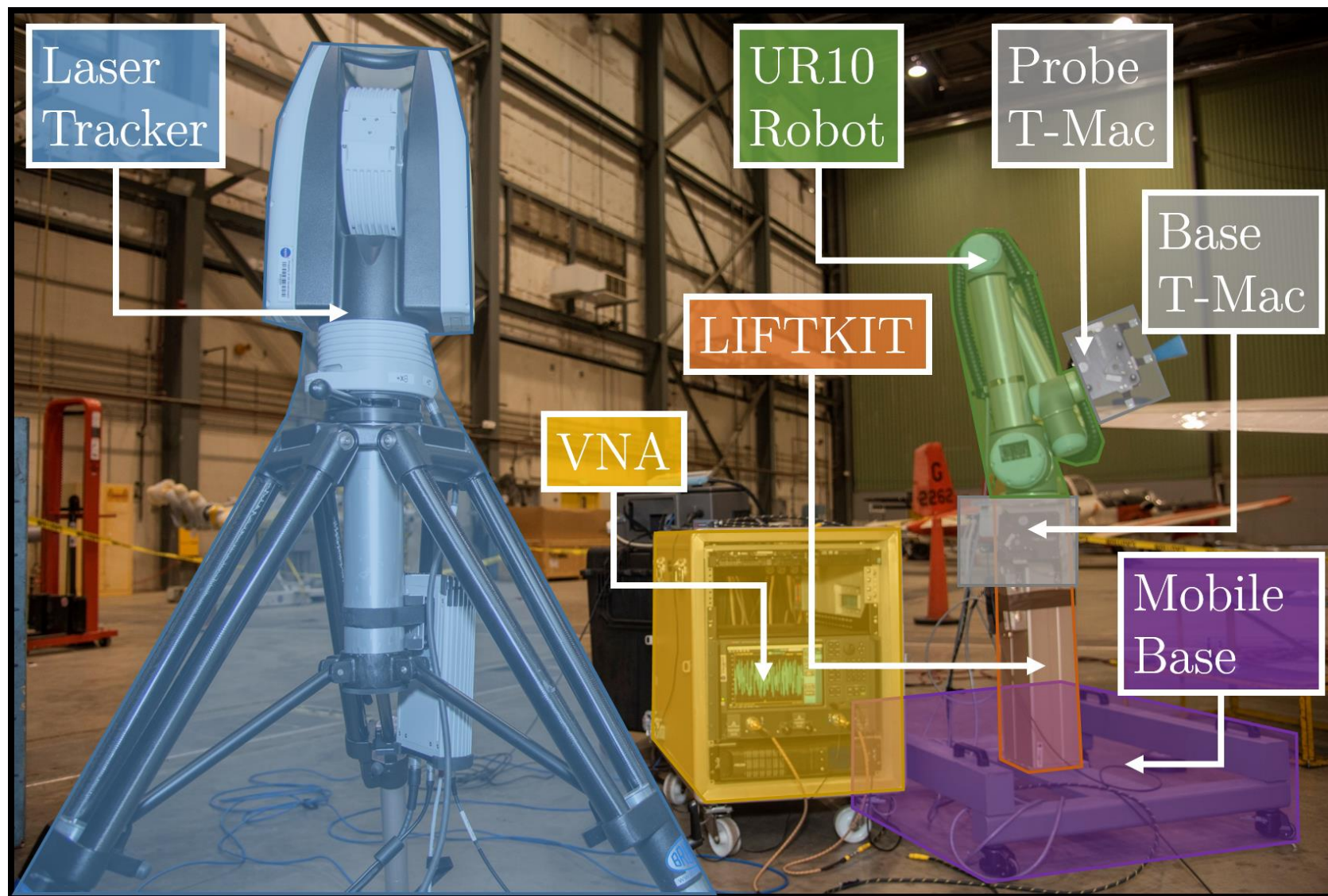
# Solution: Laser Tracker

- Inertial coordinate system (ICS) reference
  - 10's of microns 3D uncertainty
- 3D (position) and 6DOF (position + orientation) targets
- Aligns measurement system to antenna under test (AUT) coordinate system
- Guides robot to scan surface around AUT
  - Corrects for robot base repositioning

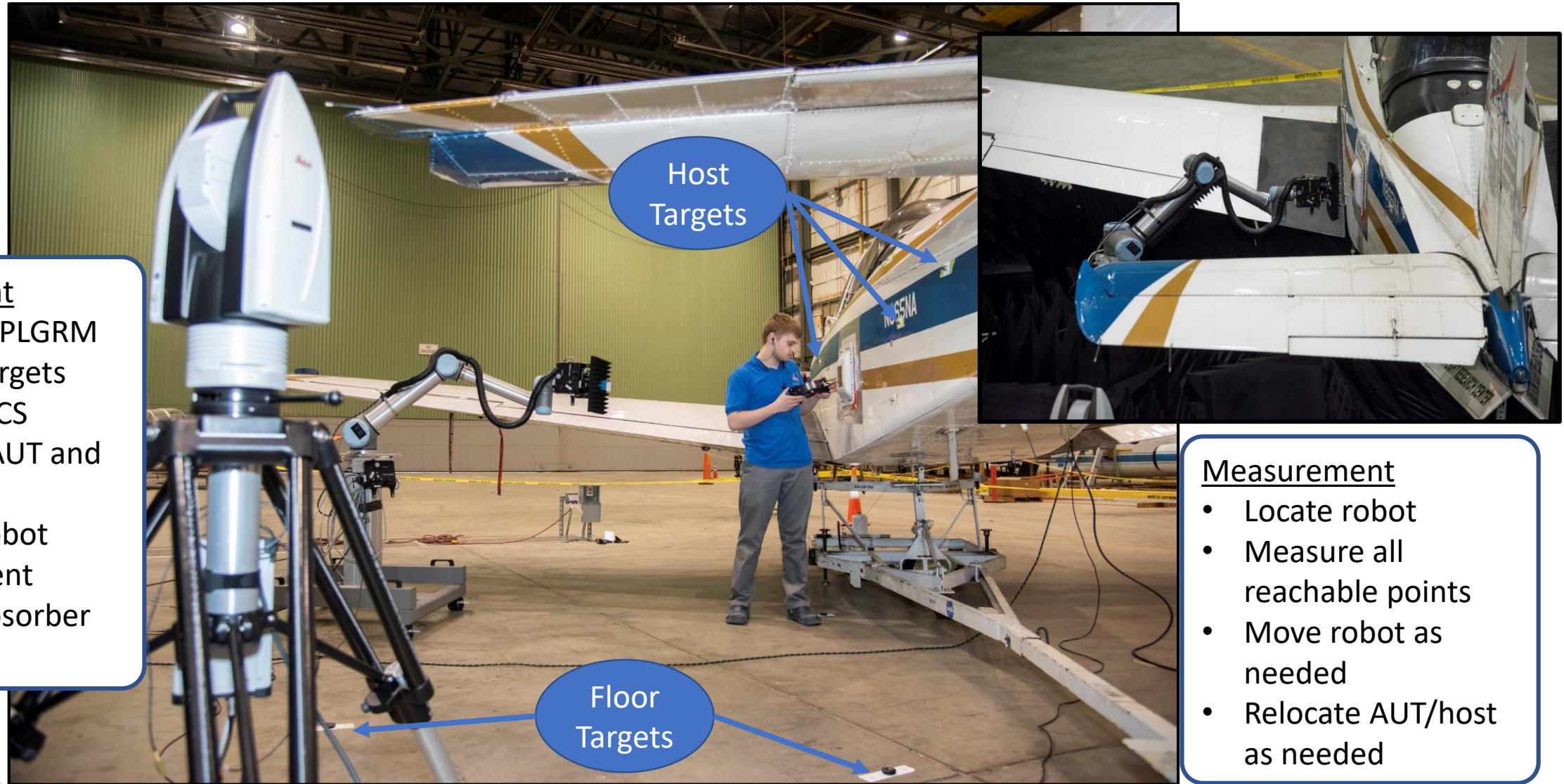


# Portable Laser Guided Robotic Metrology (PLGRM) System

- Laser Tracker: locates ICS
- UR10: probe 6DOF positioner
- LIFTKIT: Robot vertical extension
- Mobile base: coarse positioning
- T-MAC: 6DOF tracking target
- VNA: vector network analyzer



# Measurement Process



## Deployment

- Unpack PLGRM
- Place Targets
- Define ICS
- Locate AUT and host
- Initial robot placement
- Place absorber

## Measurement

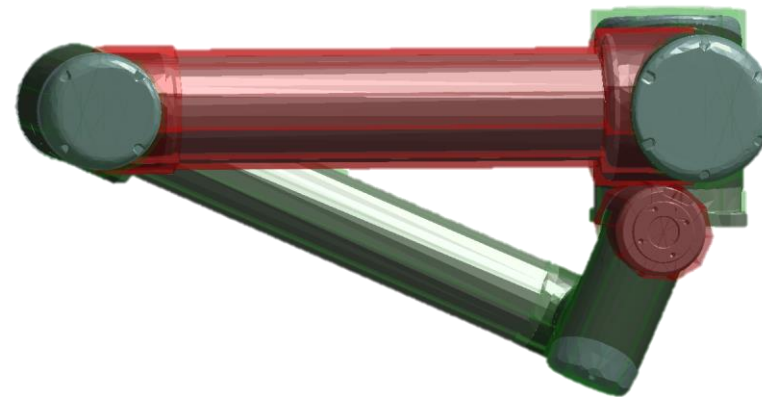
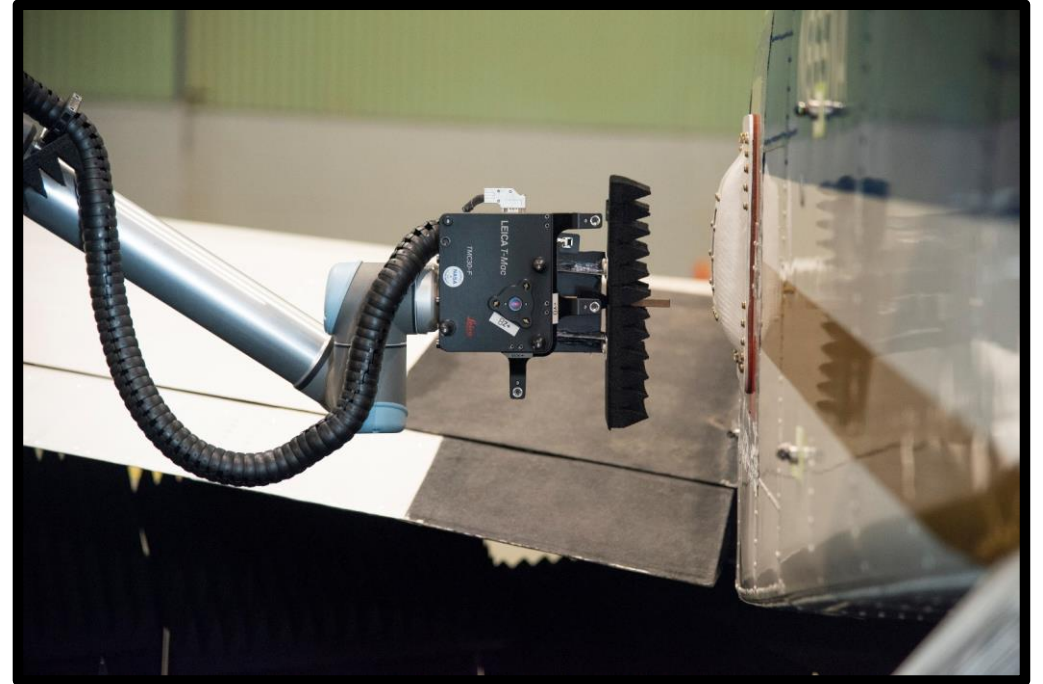
- Locate robot
- Measure all reachable points
- Move robot as needed
- Relocate AUT/host as needed



# Implementation

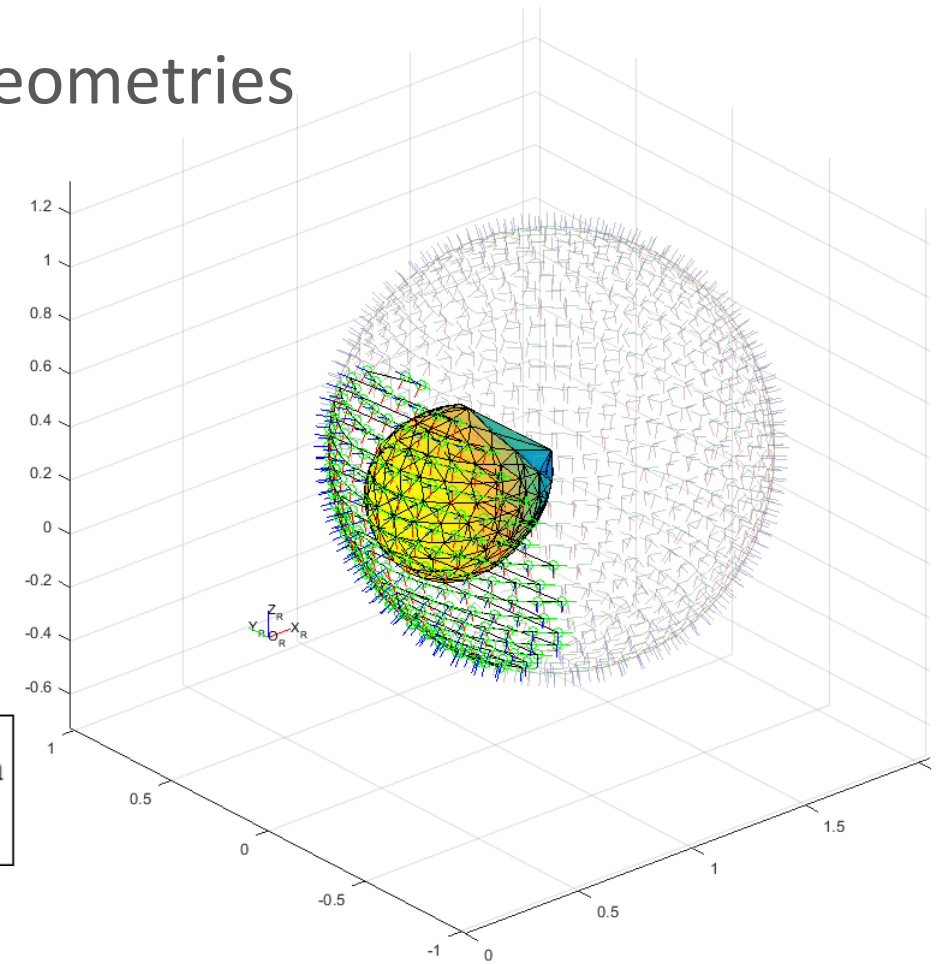
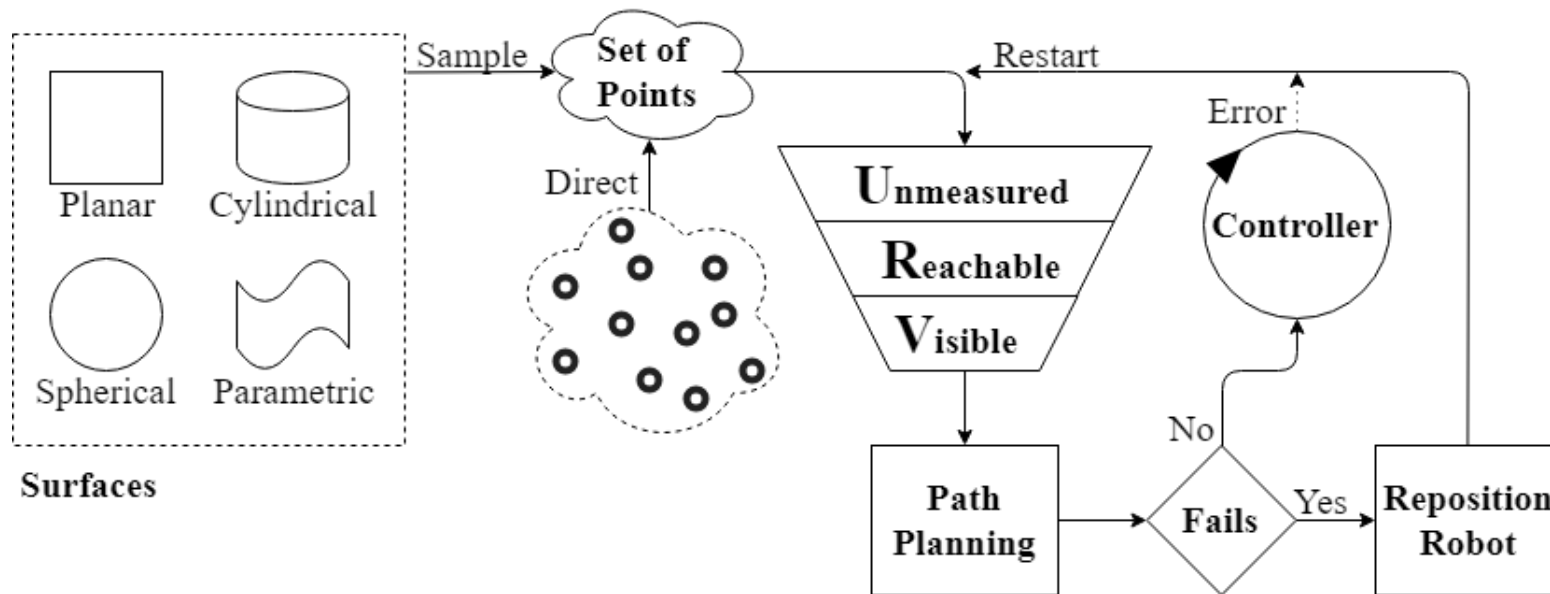
In-house developed software

- ICS and AUT locating
- Motion path planning
- Online path correction
- Protection
  - Robot force limits
  - Collision detection during path planning
  - Especially necessary for near-field measurements
- Planar NF-FF Transform



# Measurement Surface Planning

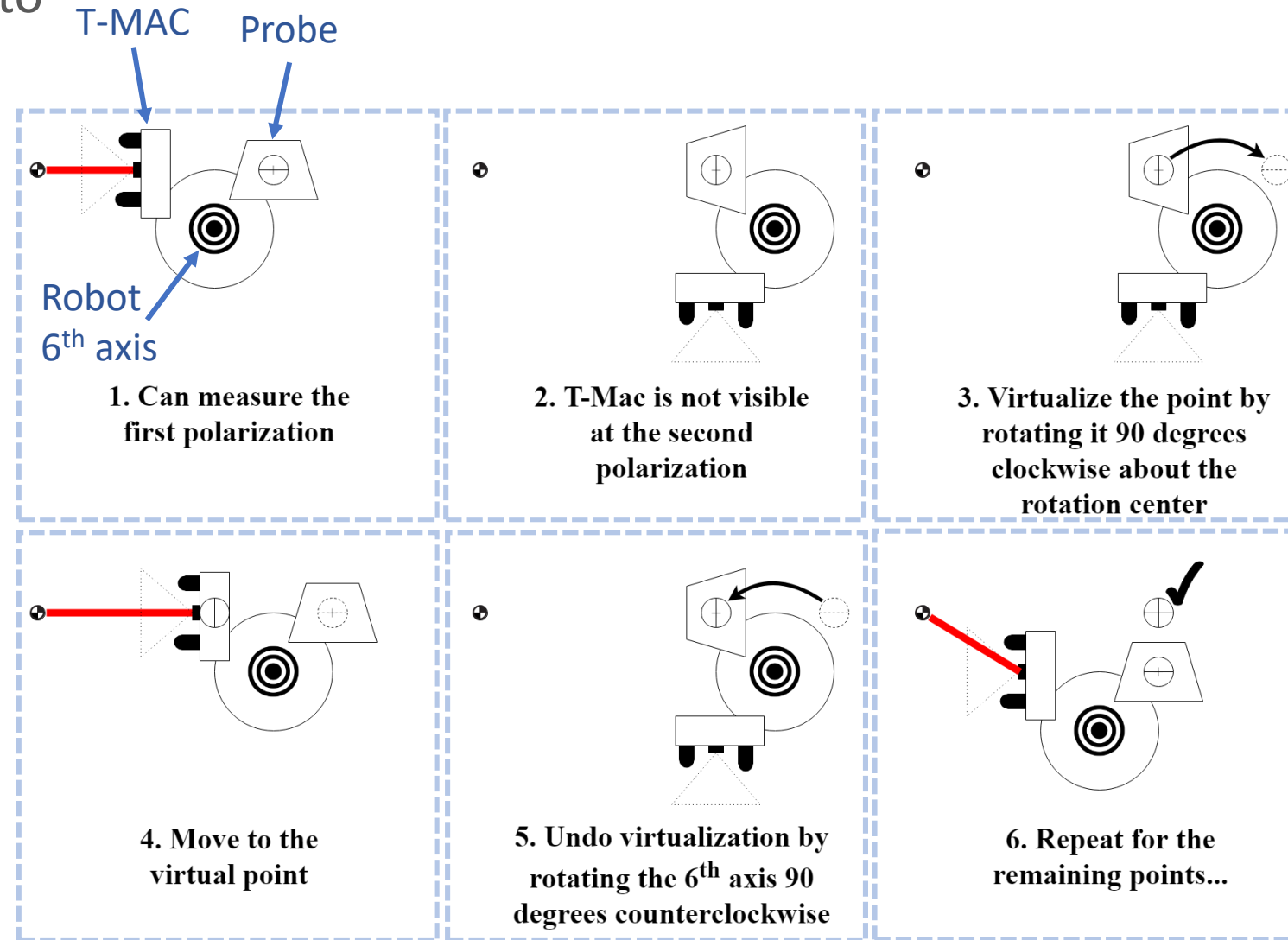
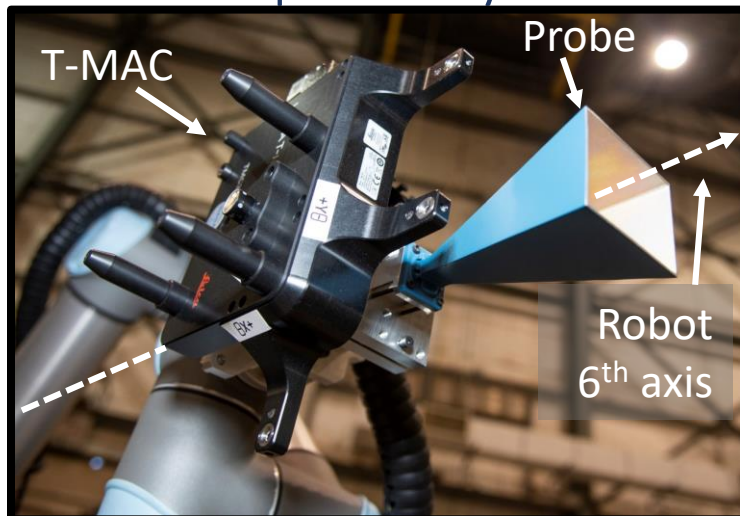
- Algorithm enables larger scan volumes than robot arm reach
- Configurable to near field and far field scan geometries



# Dual Polarization Measurements

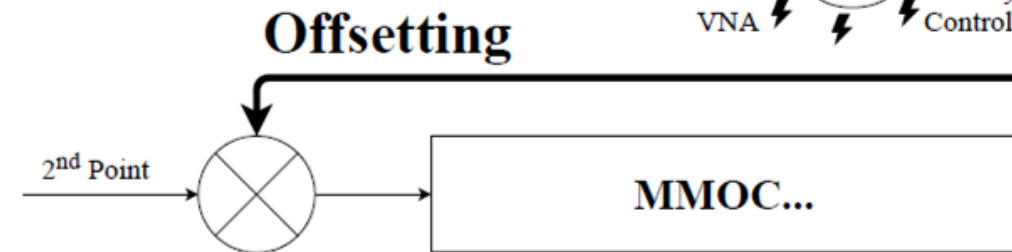
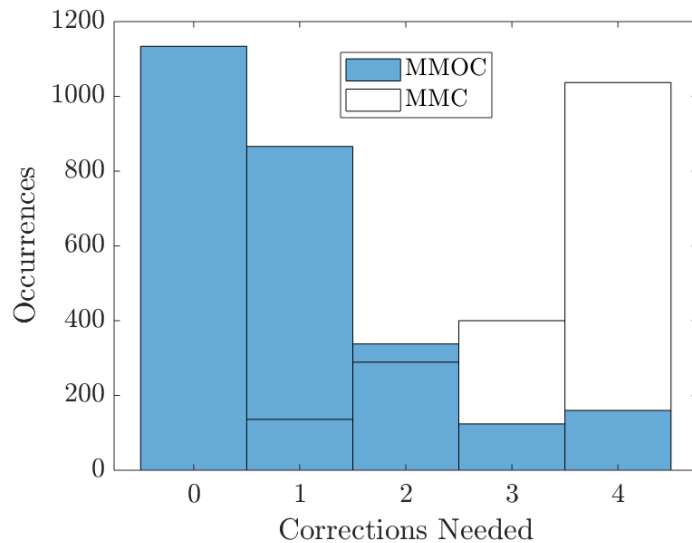
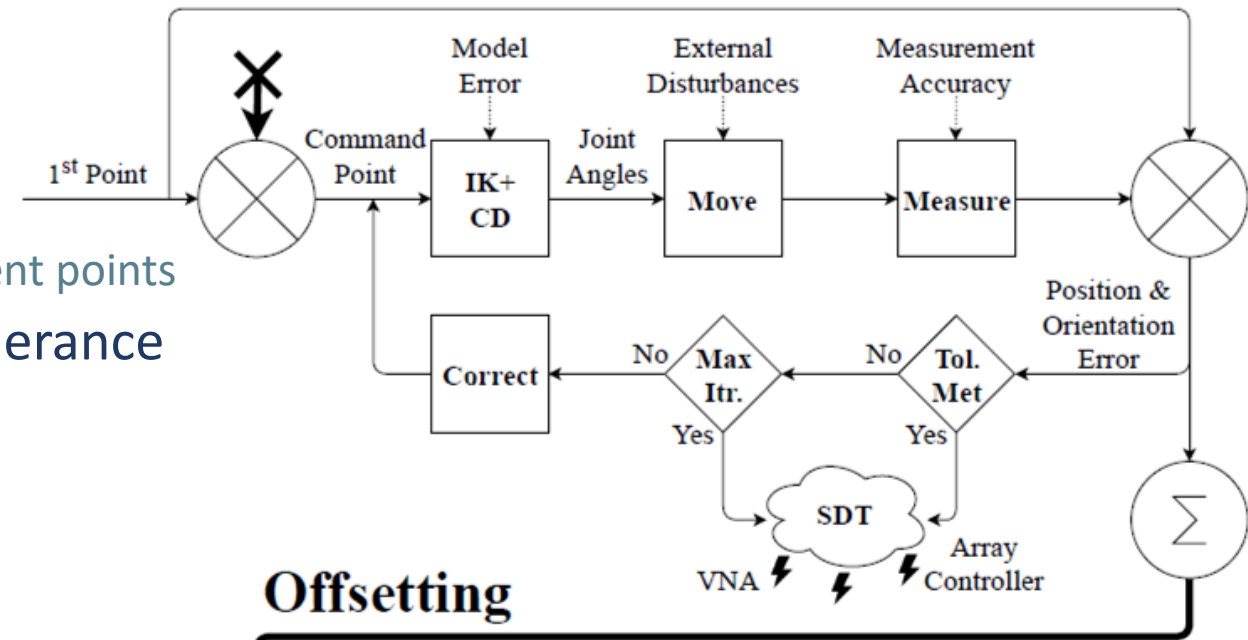
T-MAC target visibility is limited to 90 degree cone

- Two probes
- Dual polarized probe
- Virtual Point Method
  - Rotate Probe 90 degrees
  - Uses repeatability of 6<sup>th</sup> axis



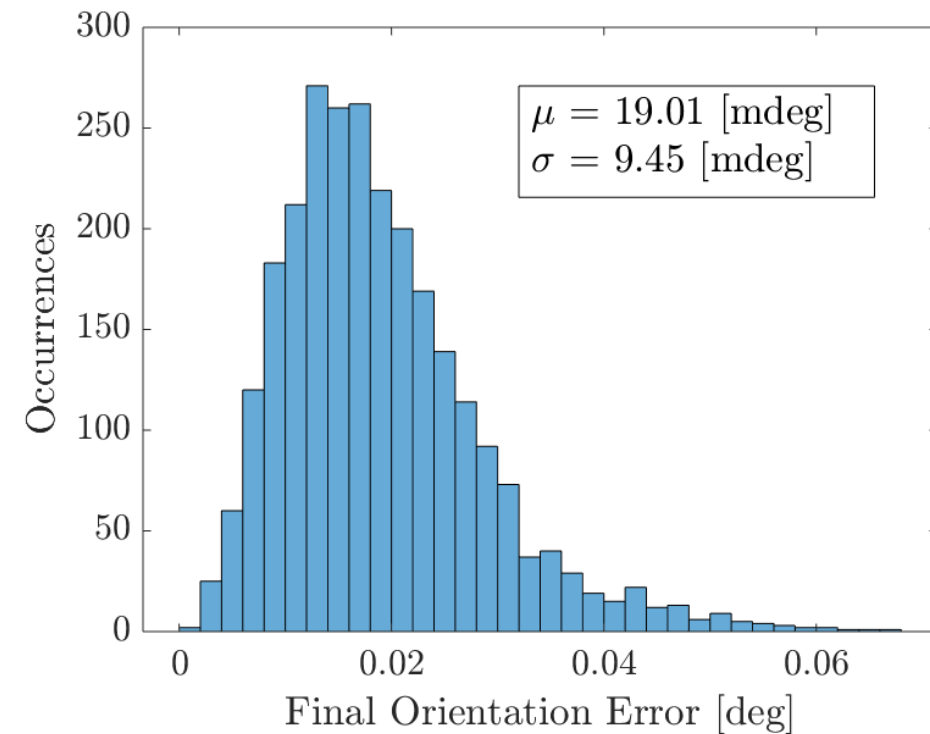
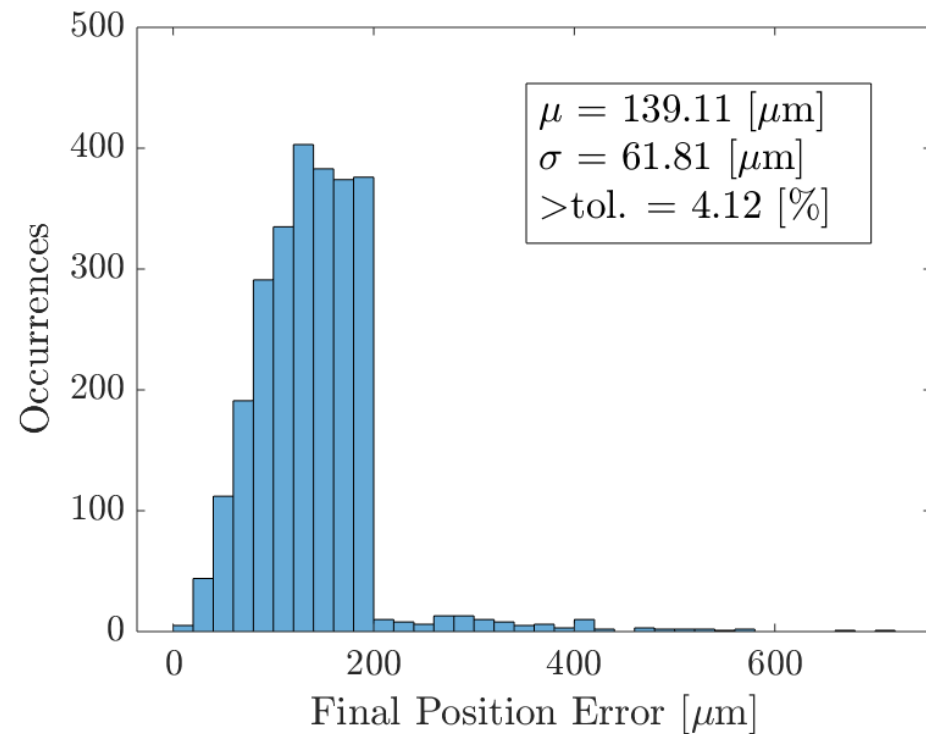
# Measurement Controller

- Algorithms
  - Move Measure Correct (MMC)
  - Move Measure Offset Correct (MMOC)
    - Assumes errors are similar between adjacent points
  - Configurable max iterations & 6DOF tolerance
- Software Defined Trigger (SDT)
  - VNA measurements
  - AUT configuration



# Measurement Controller Performance

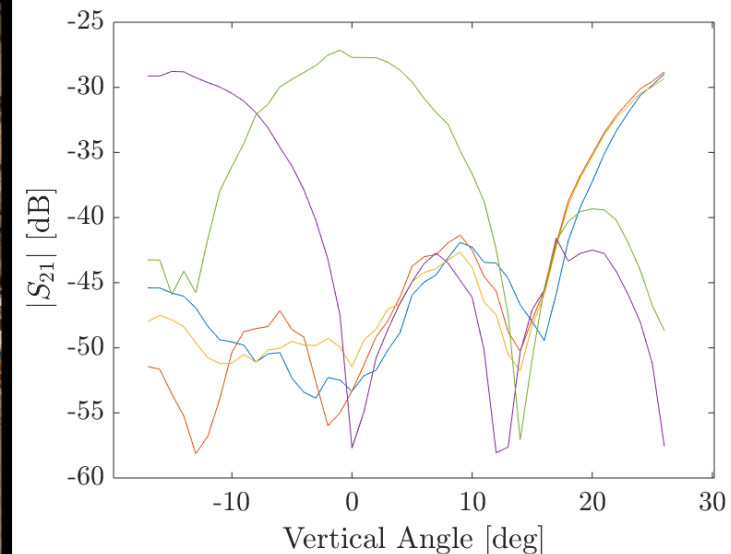
- MMOC Controller configured for Ku-band measurements
  - 200  $\mu\text{m}$  positional tolerance
  - 5 iteration maximum, maintains consistent run time



# Ku band Measurement Results

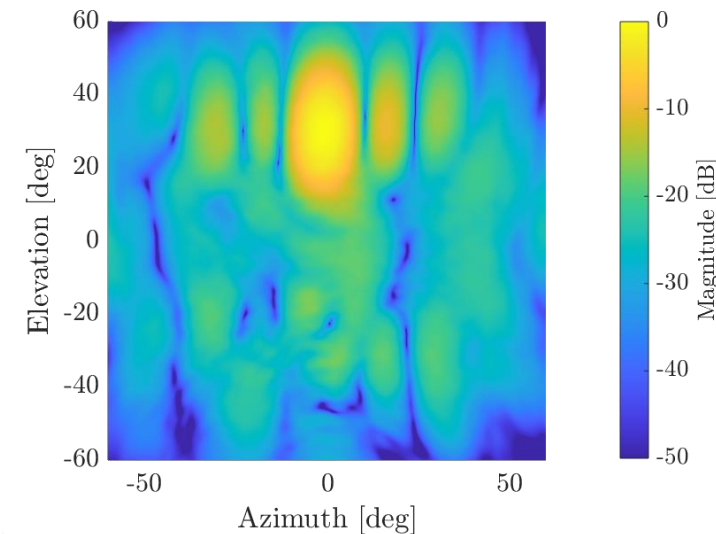
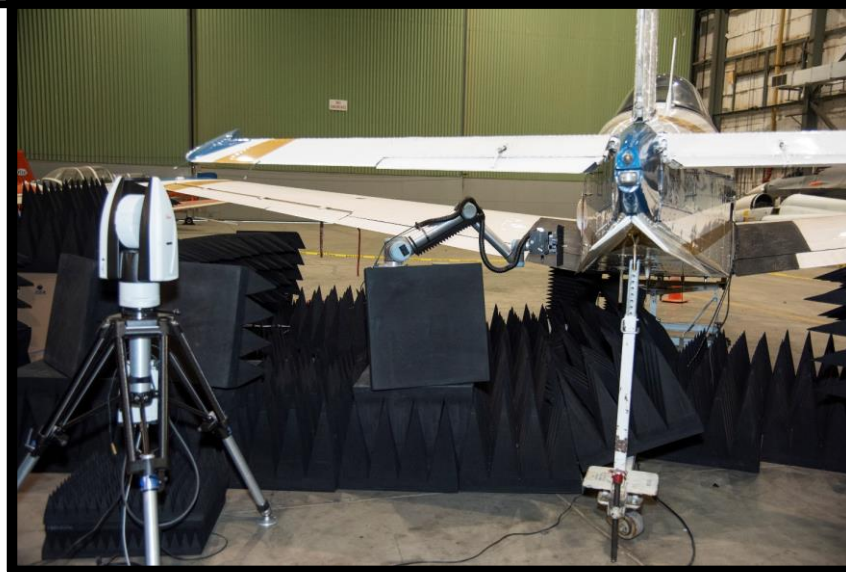
## Spherical Cuts

- 1.7 m radius
- 45 deg cut
- 2 robot moves
- 5 AUT array states
- A few minutes



## Planar NF Scan

- 0.58m x 0.47m planar
- 5244 points
- 1 robot position
- 90 minute scans



# Conclusion & Future Work

- Portable in-situ antenna metrology system developed and successfully deployed
- Laser guided robotics can enable flexible measurements over large and small volumes
- Planned upgrades to improve speed and accuracy
  - Real-time EtherCAT with Laser Tracker
  - Additional calibration, performance analysis
  - Post processing software e.g. cylindrical/spherical NF-FF

