Air Force Test Center

War-Winning Capabilities … On Time, On Cost

Benefield Anechoic Facility (BAF)

412TW EWG

772d Test Squadron

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Integrity - Service - Excellence

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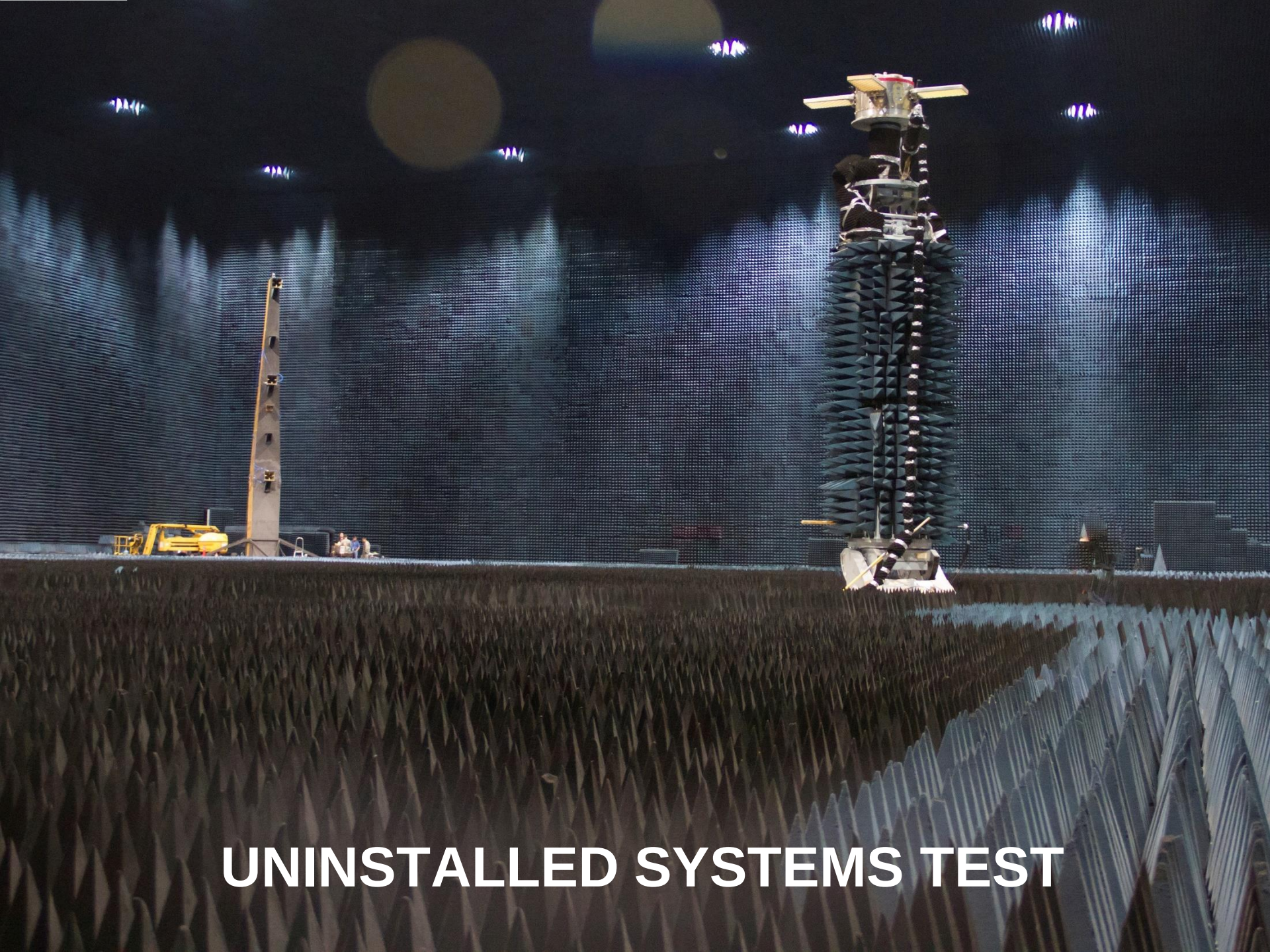
LARGE AIRCRAFT INSTALLED SYSTEMS TEST

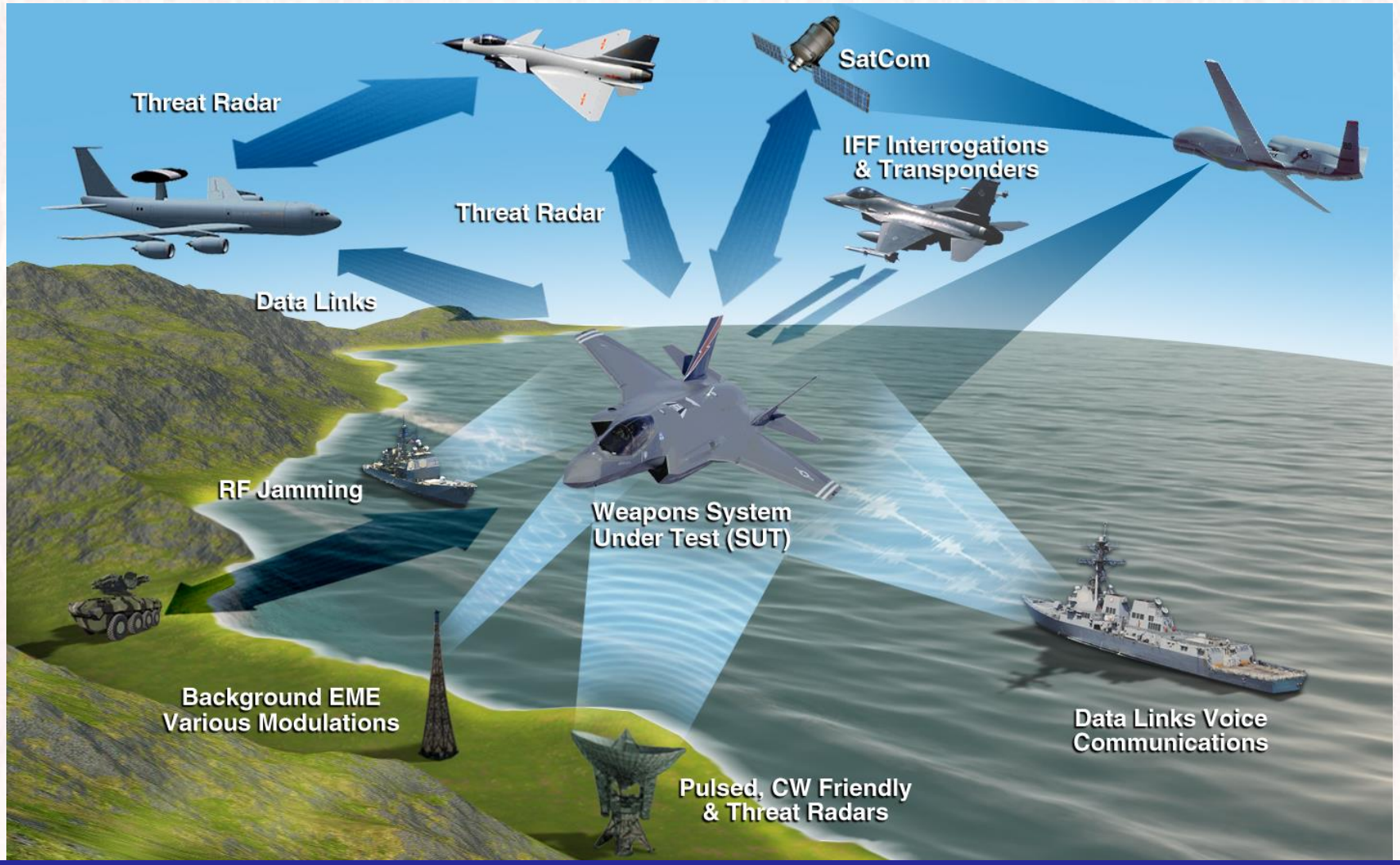
an·e·cho·ic (anəˈkōik) - free from echo ("an anechoic chamber“)

SMALLER AIRCRAFT INSTALLED SYSTEMS TEST



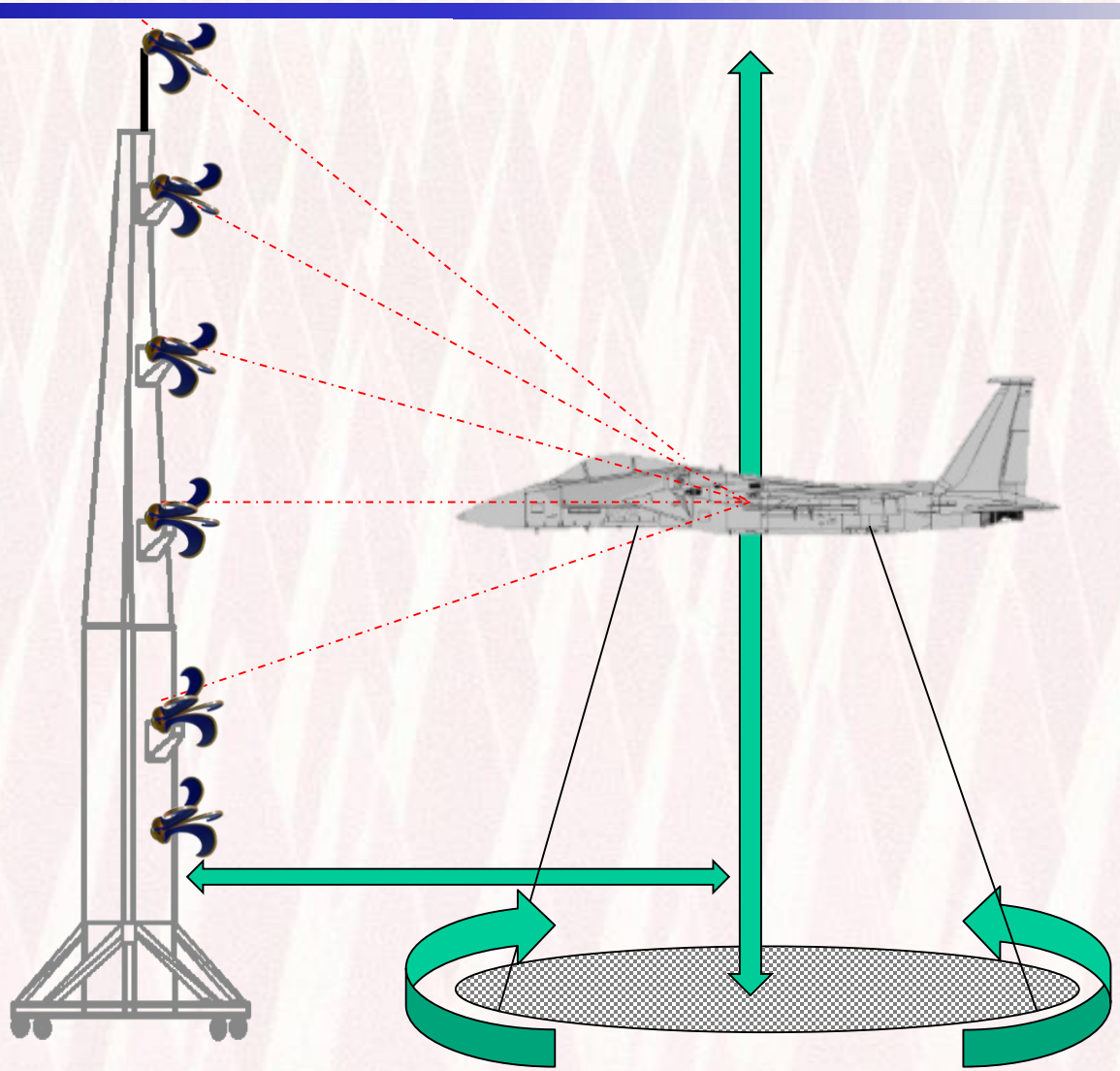
UNINSTALLED SYSTEMS TEST

Electronic Warfare/Information Operations Systems Test



In the BAF the SUT is put in the "real world" *free-space* RF Spectrum

Electronic Warfare/Information Operations Systems Test



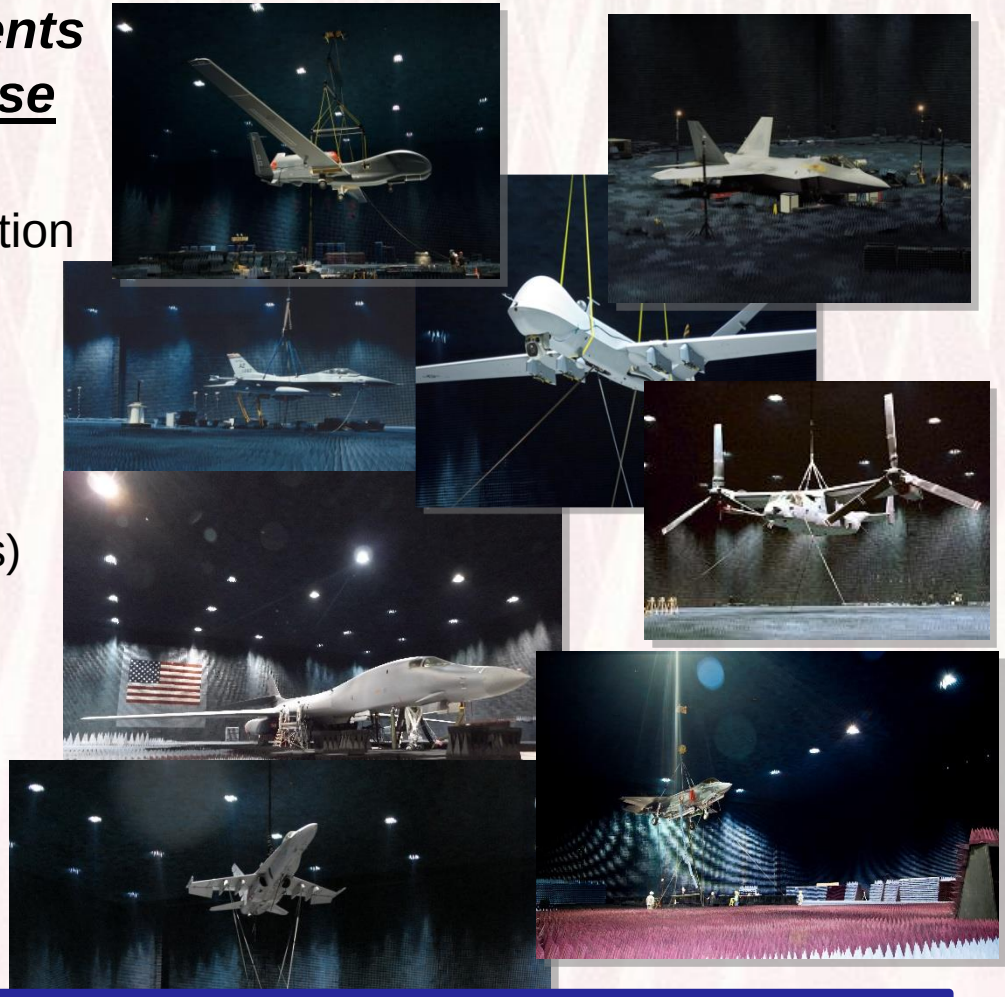
The installed components are uniquely characterized on its platform

Typical Systems Tested

The BAF RF infrastructure supports the <u>diverse</u> requirements of <u>diverse</u> RF systems on <u>diverse</u> platforms

- Electronic Warfare (EW) / Information Operations (I/O)
  - Radar Warning Receivers
  - Electronic Support (ESM)
  - SIGINT/ELINT/COMINT
  - Electronic Attack (EA) (Jammers)
- Radar systems
- Antenna systems for all types of avionics and systems
- Data Links, IFF, NAVAIDS, and Satellite Communication
- Commercial systems

<u>Manned and Unmanned Systems</u>

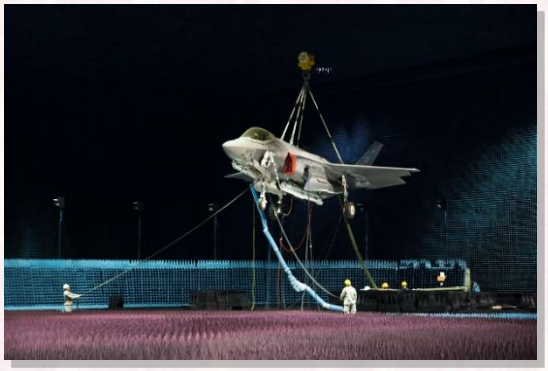


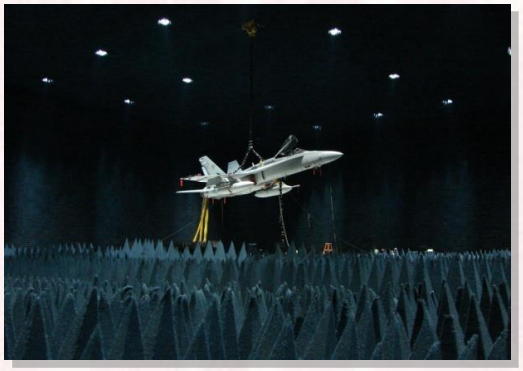
A benefit to most RF systems

Applicable T&E Requirements

Typical EW/IO Test Requirements that can be satisfied:

- Dense EME – EW threat detection, identification, processing, response, SA
- Electronic countermeasures (ECM) functionality
- Technique development and effectiveness (future capability)
- Radar characterization and electronic counter-counter measures (ECCM)
- Antenna performance – installed or uninstalled
- Electromagnetic Environmental Effects (E^3) – EMI/EMC, URE, HIRF, EMCON
  - Sub-system interoperability/compatibility testing – intra/intersystem isolation
  - Suitability and survivability

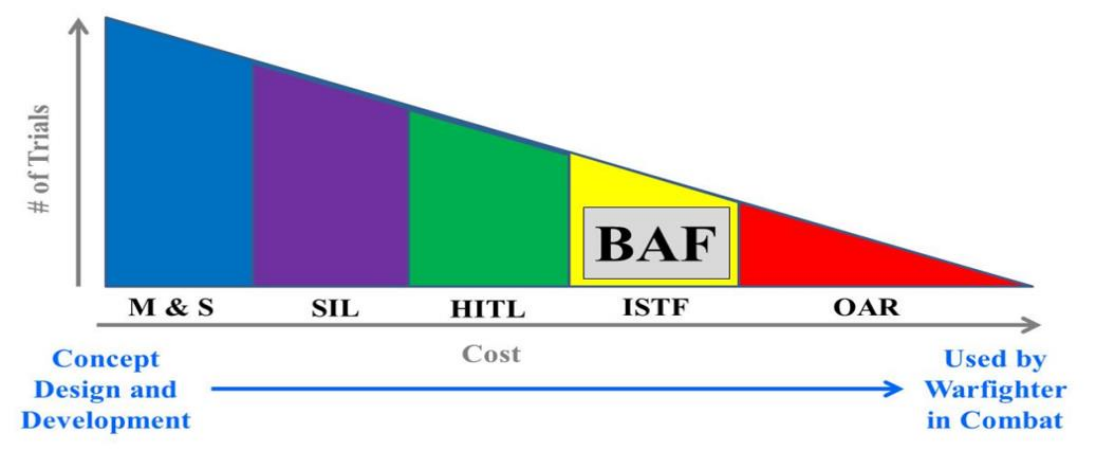




Understood performance prior to the OAR or *deployment*

Why test in the BAF?

Value-added Ground Test



- Builds a robust, complete and integrated test strategy – in line with Defense Acquisition Guidebook and sound systems engineering practices
- "Nothing in, nothing out, nothing but the designed repeatable test environment"
  - significant test control - repeatable test conditions – real-time feedback with data
  - secure environment to test system "War Modes"
  - no issues with regulatory emission restrictions
- Bend the chamber to the desired test environment – to your design

Reduces cost, schedule and performance risk

Why test in the BAF?

Value-added Ground Test

- Allows real-time refinement of:
  - test points to support investigation of results or performance problems
  - allows disciplined engineering approach to problem resolution or system characterization
  - Test condition expansion
  - beyond flight test range asset availability or limitations
  - flight test data collection limitations
- Overcomes limitations of flight-line ground tests
- Reduces risk before flight tests
  - better baseline of installed system performance
  - timely problem identification and resolution
  - optimized flight test plan
  - reduces costly and high-visibility re-flies
- ***Test before you flight test – Significant amount of valuable data quickly…***

Real-time connectivity and data as in SIL with the aircraft

What is the BAF?

- **Completed in 1989 for B-1B**
- **BAF Physical Layout (chamber)**
  - 264 Ft L X 250 Ft W X 70 Ft H
- **Two 40-ton hoists**
- **Unique 175-ton 80-ft diameter turntable**
- **Power, Cooling (air and liquid), Hydraulics available**
- **Quiet Zone Isolation (typically)**
  - 500 MHz* ≥ 72dB
  - 1.0 GHz ≥ 84dB
  - 2.0 GHz ≥ 96dB
  - 3.0-18.0 GHz ≥ 100dB

  Characterized for each test configuration

  * Below 500 MHz special techniques may be used to optimize range for specific SUT
- **RF Shielding Effectiveness**
  - To/from outside environment ≥ 100dB

"Virtual range" within four walls

Summary

Highly capable and robust T&E infrastructure to support the DoD, industry and our allies

- Developmental Test (DT)
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  - Digital Integrated Air Defense System (DIADS) driven OT relevant scenarios
- Secure test environment for sensitive signals (SAP, SCI…) to support DT and OT Battle-Space environment or when restricted by regulatory agencies
- Reduces cost, schedule and performance risk

Test doesn't cost, it pays!

DISCUSSIONS AND BAF TOUR

BAF CAPABILITY DISCUSSIONS

Dense and Complex EME Generation

Highly sophisticated – high fidelity and complex Electromagnetic Environment (EME) signal generation - radiated free-space to the customer's requirement

- Combat Electromagnetic Environment Simulator (**CEESIM**) – Threat and Friendly EW signals from 0.1 – 18 GHz)
  - Threat "activity" can be computed by DIADS, follows modeled doctrine and air picture based on SUT ingress
- Joint Communications Simulator (**JCS**) and others – Communication, Navigation and Identification (**CNI**) signals and command and control (C^2), Data links (simulated and external re-radiation)
- **GPS** simulation and external GPS re-radiation systems
- **Radar** targets and **ECM** (for ECCM tests)
- Radiated Susceptibility High Intensity Radiated Field (**HIRF**) System
- Additional **special assets** as required by customer objectives

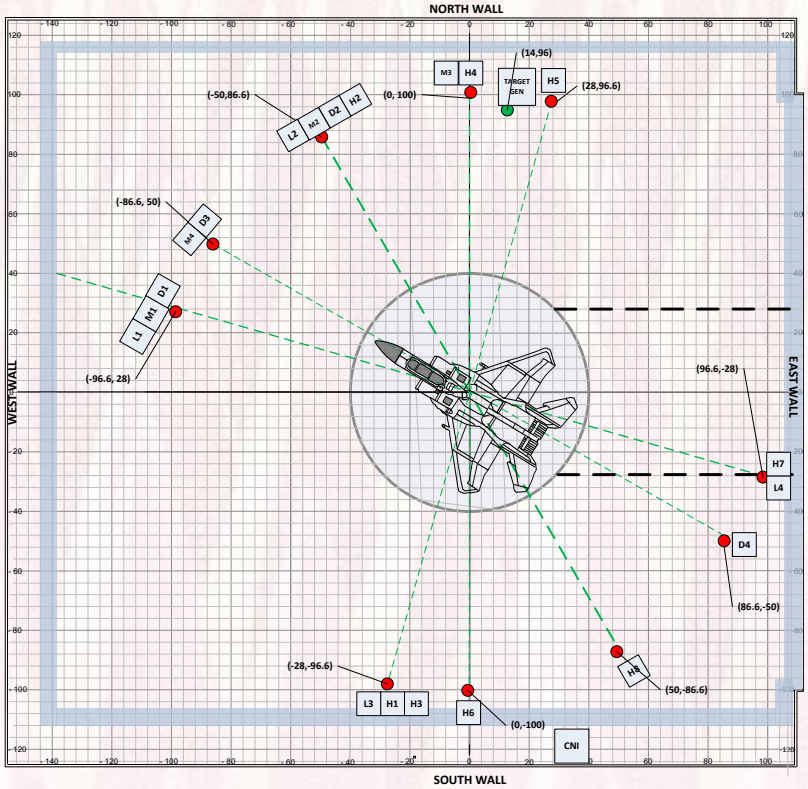
Create and see the EME Picture at the BAF first

EW Threat Laydown Example

- Threat height adjustable typically ~7 – 35 ft
- 26 carts (locations) - Determines AoA (360°)
- 36 Channels in 3 bands
  - High: 6 to 18 GHz – 12 channels
  - Mid: 2 to 6 GHz – 20 channels
  - Low: .1 to 2 GHz – 2 channels, .4 and .5 to 2 GHz – 2 channels
  - Includes 4 Dual carts with 4 each of the mid- and high-band channels

- Aircraft on turntable or hoisted and rotatable
- Threats are assigned to channel locations
  - Selected based on test design and threat requirements
  - Dedicated or multiplexed for density
  - Dynamically reassigned as required
- Threat timing controlled by designed test conditions
  - Scripted, DIADS driven or manual
  - 1 v. 1, 1 v. many (all at once or in specified sequence)
- All transmit signals verifiable with real time pulse monitoring & recording (RF and digitally)
- All chamber free space emission is monitored and recorded as required

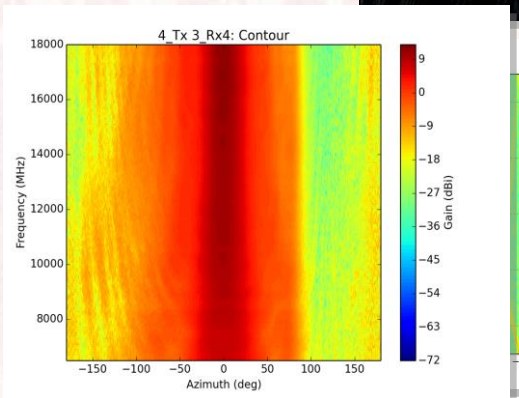
- Laydown may include background signals
  - Comm, Nav, and ID (CNI)
  - Radar Targets
  - Jammers
  - Other…

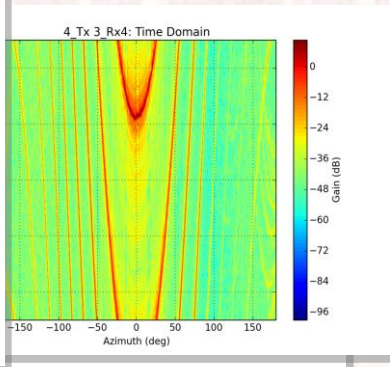


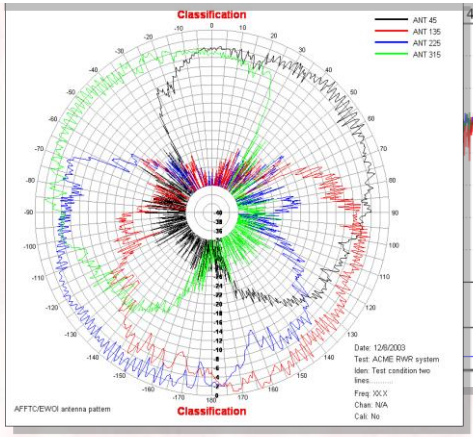
Antenna Pattern Measurements

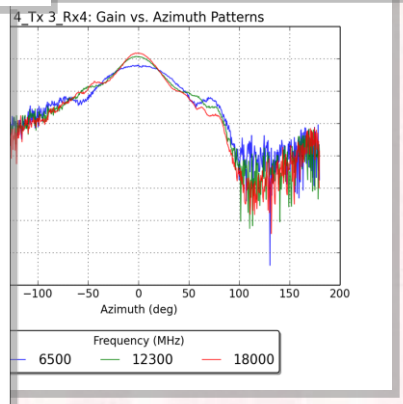
Our measurement expertise and resources provide stand-alone and installed characterization of passive and active antennas

- Frequency range 0.1 to 18 GHz
- Rapid automated data collection
  - Multiple frequencies, angles, and polarizations - collected within a single sweep or rotation
- Phase and amplitude collection
- Polarizations - RHCP, LHCP, vertical, horizontal, dual polarization, slant, axial ratio (rotating linear)
- 360° azimuth; ± Y° elevation (static) on hoist or turntable (Y° = SUT dependent limit)
- 4π steradian (spherical) coverage with antenna positioners





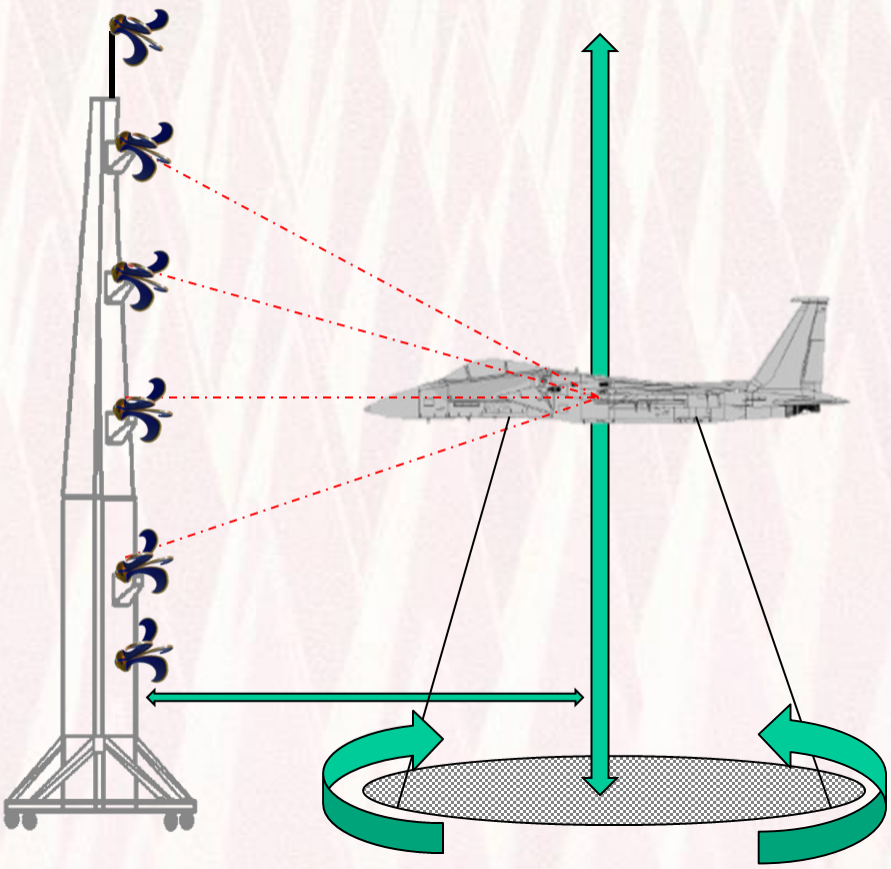




Antenna Pattern Measurements

For fighter-sized aircraft, UAVs, weapons…

- Conical antenna patterns, continuous azimuth, discrete elevation
  - Typical Elevation between +19 and -26 degrees, this can be expanded on a case-by-case basis
- Multiple frequencies, polarizations (H and V), and elevations collected in single pattern rotation
  - 8-16 SUT antennas tested at a time
- Data corrected for AUT location offset from the center of rotation
  - Free space loss delta, range antenna amplitude taper
  - Data corrected to SUT antenna's local coordinate system
    - Takes the "chamber geometry" out of the measurement

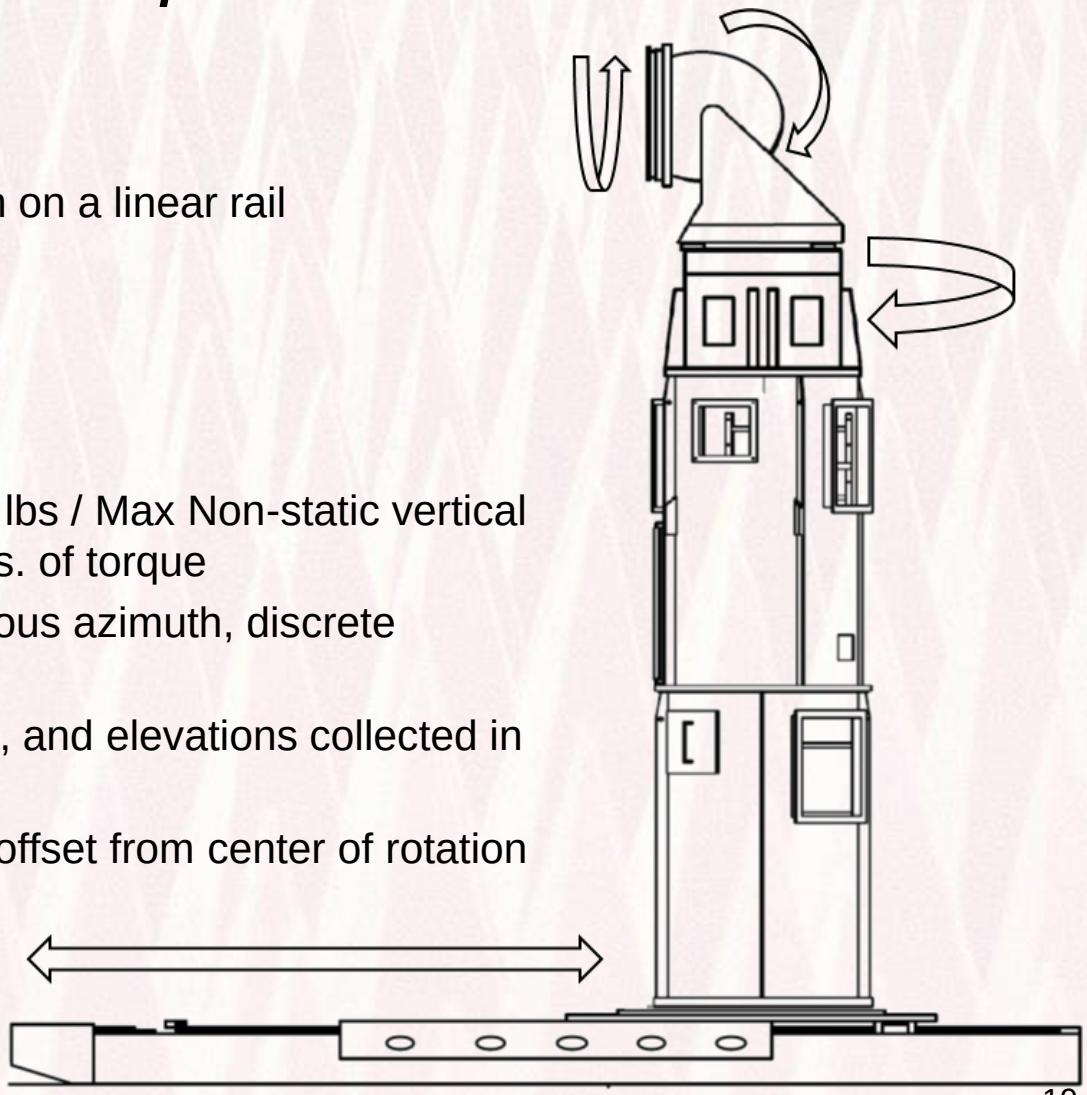


The installed SUT is uniquely characterized on its platform

Antenna Pattern Measurements

Configurable Positioning Data Acquisition Control System (CPDACS)

- Height with Riser Stacks: 23 ft
- Azimuth over Elevation or Azimuth on a linear rail
  - Upper Az: ± 200º
  - Elevation: -45º to +92º
  - Lower Az: ± 200º
  - Linear Rail: 0 in. to 162 in.
- Max Static Vertical Load: 100,000 lbs / Max Non-static vertical Load: 45,000 lbs. and 90,000 ft-lbs. of torque
- Conical antenna patterns, continuous azimuth, discrete elevation
- Multiple frequencies, polarizations, and elevations collected in single swing
- Data normalized for AUT location offset from center of rotation



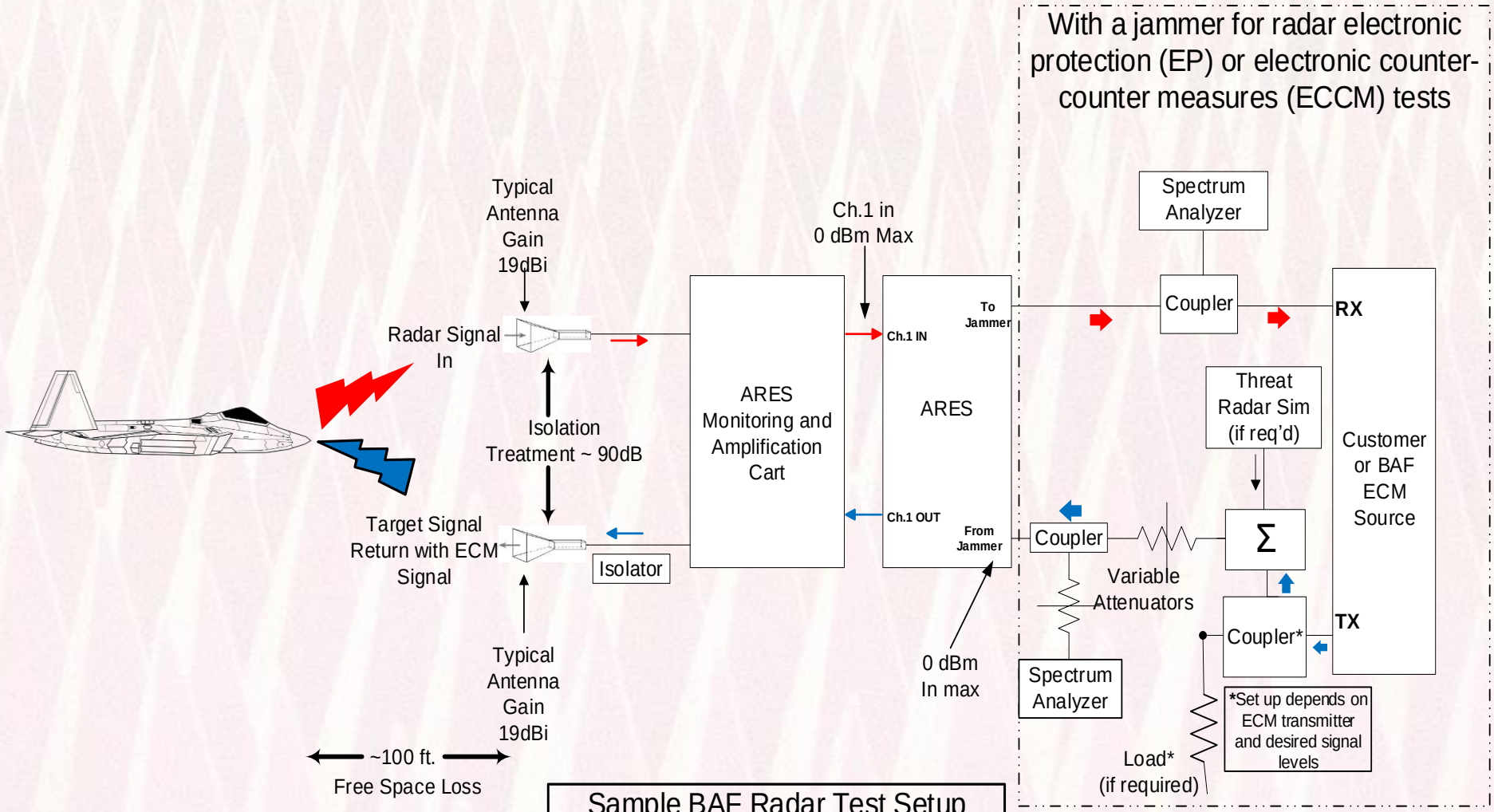
Radar Testing

Provides radar systems test capabilities and radar target generation

- Radar targets
  - DRFM based responses to SUT radar emissions
  - Provides range, range rate, and Doppler
  - 300 MHz – 40 GHz
    - Two (2) channels at .3 – 18 GHz and Two (2) channels 8 – 12 GHz
    - One (1) channel at 18 – 40 GHZ (uses one of the .3 – 18 GHz channels)
- Jammer responses – ECCM or Electronic Protection tests
  - Non – coherent provides noise (e.g., Spot or Barrage, AM, Swept)
  - External Coherent ECM Hosting (2 GHz – 18 GHZ)
    - Accepts ECM from jammer and processes it out coherently with the radar target
    - Provides range (time delay and attenuation) and Doppler shifted signal to jammer
- Returns slaved to radar scanning – adjustable threshold
- Free space or direct injection
- Data Capture and Playback Capability

RF Compatibility, Electronic Protection and Survivability

Radar Testing



Sample BAF Radar Test Setup

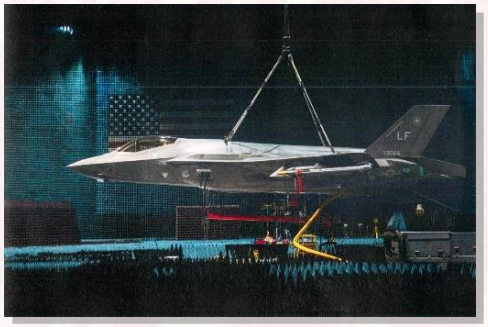
ARES = Advanced Radar Environment Simulator

RF Compatibility, Electronic Protection and Survivability

Electromagnetic Environmental Effects (E^3)

Today's highly integrated weapons systems must operate in challenging EMEs and meet demanding integration and interoperability and survivability requirements (e.g. IAW MIL-STD 464, MIL-STD 461, AFI 91-208, SAE ARP5583)

- Radiated Emissions, EMCON
- Radiated Susceptibility, HIRF, HERO, Shielding Effectiveness
- Conducted Susceptibility via scaled coupled measurements
- Antenna Isolation/Coupling (Inter/Intra-system)
- System Interoperability (RF Compatibility, EMI/EMC)



Ensure interoperability, survivability and mission effectiveness

GPS Simulation and Test

Global Positioning System (GPS) - two systems available for GPS integration, tracking and jamming tests – internally controlled , no regulatory agency approval required

- GPS Retransmission system - Repeats external real world signals - single point
- Advanced Global Navigation Simulator (AGNS)
  - Sixteen RF channels into seven (7) separate L1 and L2 transmit antennas
  - Simulates C/A , L2C, P and P(Y) and M codes for Advanced Encryption Code (AEC)
  - Modernized NAVSTAR Security Algorithm (MNSA) capable
- Controlled Reception Pattern Antenna (CRPA) pattern and nulling effectiveness characterization – Uninstalled and installed antenna pattern measurements
  - Nulling system characterization – GPS anti-jam performance when integrated with antenna electronics

GPS - Critical element for today's systems

RF Monitoring Capabilities

RF monitoring capabilities provide invaluable information for test conduct and control, quality assurance and post-test analyses

- RF Pulse Analyzers – record pulse descriptor words (PDWs)
- Spectrum captures or verification of SUT radars, jammers, or simulators and all RF emissions during test
- Automated Measurement System (AMS) – used for real-time and post-test threat environment verification and recording
- Spatial, Spectral, Temporal and Amplitude Reception System (SSTARS) – characterization of SUT antenna steering (pointing) and beamwidth performance
- ***Customized for each test***

See, control and record the RF environment

Cyber Test

Avionics Cyber Indoor Range Test for Over-the-Air Tests (free-space)

- BAF ISTL co-located and collaborating with 47th Cyber Test Squadron Det 1
- Toolsets allow for the generation of cyber contested environments at ISTL
  - Manipulation of existing traffic
  - Generation of new malicious traffic
  - Fuzzing
- Current 47 CTS Det 1 Operational Tool Set
  - Static and Dynamic Software Analysis (reverse engineer source code)
  - LINK-16, Variable Message Format (VMF) Tactical Datalink, Situational Awareness Data Link (SADL)
  - ACARS over VHF and SATCOM
  - MIL-STD-1553/ARINC429 direct connect
  - MODE S, ADS-B In/Out
  - GPS
- 47 CTS Det 1 Developmental Tools (Late FY21)
  - TCAS
  - MODE 5

Aircraft Ground Support Facilities

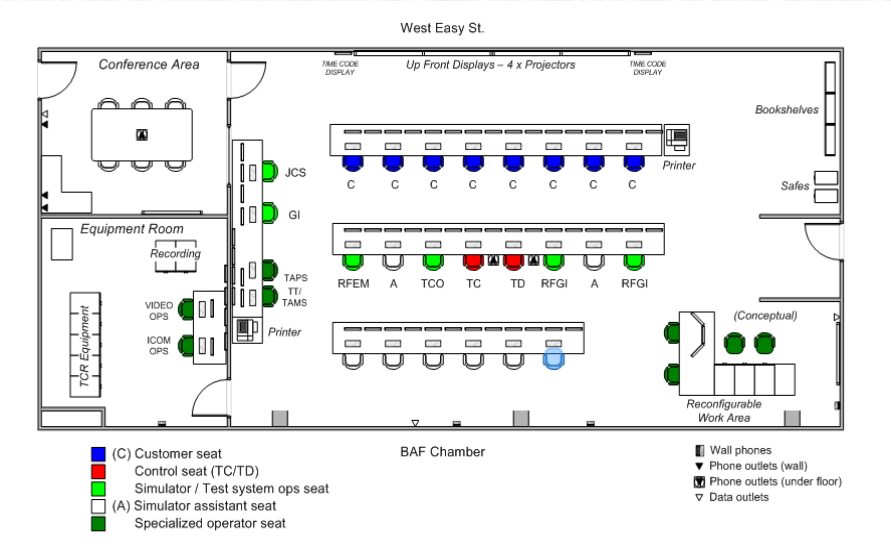
Power, Hydraulics and Cooling – aircraft "flies" in chamber without engines

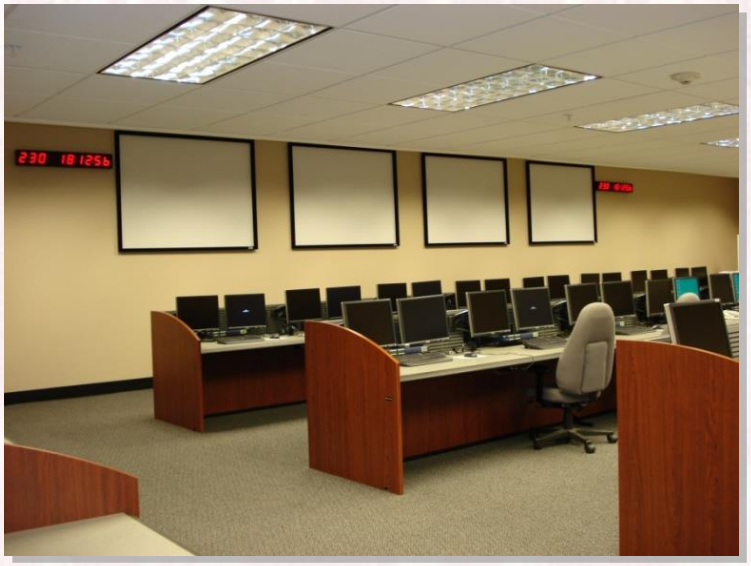
- SUT Electrical Power
  - 270 VDC, 115/230 VAC 400 Hz (Multiple sources), 28 VDC
- Chilled Air Cooling
- Liquid Cooling: PAO (2 loops), Coolanol, EGW and Chilled Water systems
- Hydraulics: 2 loops
- Other electrical for ground support systems and instrumentation
  - 480 VAC (multiple 100 Amp and 200 Amp), 208 VAC, 115 VAC, 28 VDC, 60 cycle
  - 380 VAC 50 cycle

Test Control Room (TCR)

Tests are conducted, controlled and monitored from the integrated TCR

- Test Director
- Test Conductors
- Twenty six (26) stations
  - Test Advisors, engineers
  - Observers
- Intercom to SUT and all test stations
- Digital Video Recording
- Real Time Displays
  - Customer instrumentation and tools – your lab here in the TCR
  - Cockpit
  - Test equipment
  - Avionics buss data
  - RF Environment
  - Test Specific Display (Custom)
- Multiple conference rooms available for customer





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UPGRADES

Recent BAF Upgrades

CEESIM Improvement and Modernization Life Extension (CIMPLEX)

- Digital Generation System (DGS) Upgrade - Improves digital threat programming and generation capacity
  - Benefit: Increased density and versatility
- Advanced Generator Drawer (RF Generation) - DDS-based signal synthesis
  - Benefit: Improved High Fidelity Intrapulse Modulation (HFIM), flexibility, signal fidelity, programmability
- Twelve (12) additional mid-band channels (2 – 6 GHz) in six (6) new dual carts
  - Benefit: Improved laydown geometry and density with 36 total channels with emphasis on new threats

Upgrades On-Contract

Next Generation EW Environment Generator (NEWEG) and CEESIM VPX Integration

- NEWEG is Joint Navy – Air Force program for the Advanced RF Generators for RF threat simulation
- State-of-the Art threat signal simulation
- Focuses on modeling AESA based threats - effectively, accurately & rapidly develop complex threats
  - Direct import of EWIRDB threats
- BAF working CEESIM integration of NEWEG Advanced RF Generators into CEESIM architecture
  - Higher pulse density
  - Faster Calibration
- Schedule: CY2022/23

Upgrades On-Contract

Radar Air to Ground Environment (RAGE) – State-of-the-Art radar target generator for todays modern airborne radars

- RAGE provides multiple dynamic targets in realistic environments
- Ground testing of Air to Ground A/G radar modes
  - Bands 1, 2 & 3 (targets + backgrounds)
  - Provides limited aspects based on physical chamber
- Mission testing with high-density Air to Air (A/A) targets
  - 32+ targets, Bands 1, 2 & 3
  - JEM & RCS models 8 targets, RCS for 32+ targets
- Interleaved A/G & A/A modes bands 1 & 2
- Co-located radar skin returns with threat emitter from target
- Notional Schedule: FY22

Upgrades On-Contract

Mission Systems Test Capability (MSTC) – Augments BAF datalink capabilities for today's weapons systems

- MADL F-35 cockpit, connectivity to JSE
  - Connectivity to virtual battlespace
  - Connectivity to real aircraft in chamber
- Mission testing of multiple Data Links
  - MADL
  - VMF
  - Link 16 Interoperability
- Schedule: FY22

Upgrades On Contract

Closed - Loop Threat Radar Emulations – Uses the Lab Intelligence Validated Emulation (LIVE) models

- Reactively emulates modern RF threat radars – adding closed-loop time dynamic behavior faithfully
  - Intel-validated (MSIC) models
  - Faithfully models the threat radar's emissions
  - Emulates radar's receiver processing and tracking of radar returns
  - ECM waveforms from SUT are processed with emulated radar return
- Capability allows ECM waveform evaluations – not previously available in chamber ISTF level free-space tests
- Complement closed-loop assets available in flight test
- Mission data and ECM optimization prior to flight test or operational deployment
- Schedule: Estimated for CY2022

Future Capability In Planning

120-Ton Hoist – enhances test capabilities and geometry for larger aircraft that are "hoistable"

- Replaces existing 40-ton hoist over the center of the turntable
- Brings new capability that will allow the expansion of test capabilities and test conditions for heavier aircraft
- Schedule: In planning and initial design

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DISCUSSIONS AND BAF TOUR

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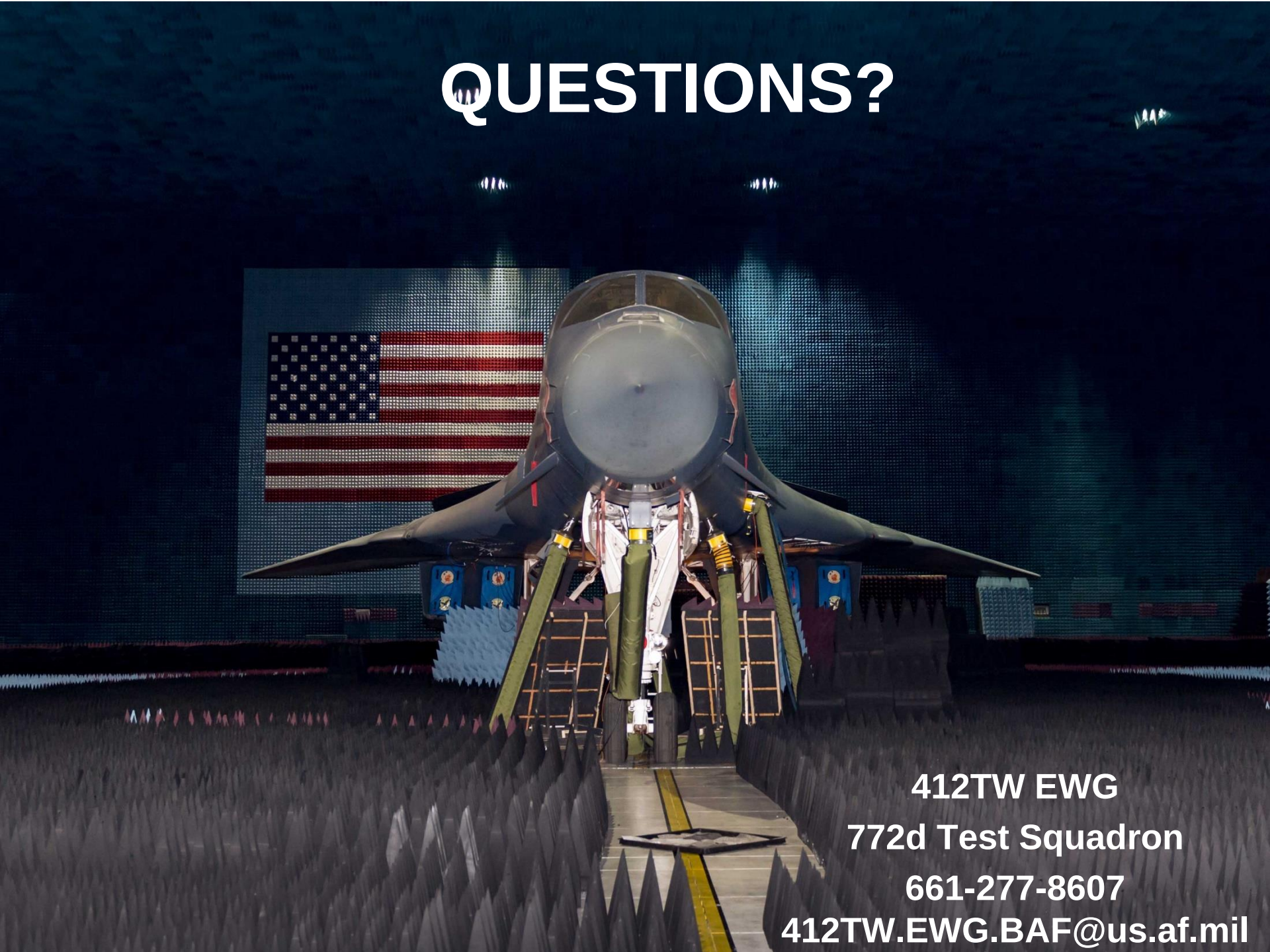
QUESTIONS?



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BAF TOUR

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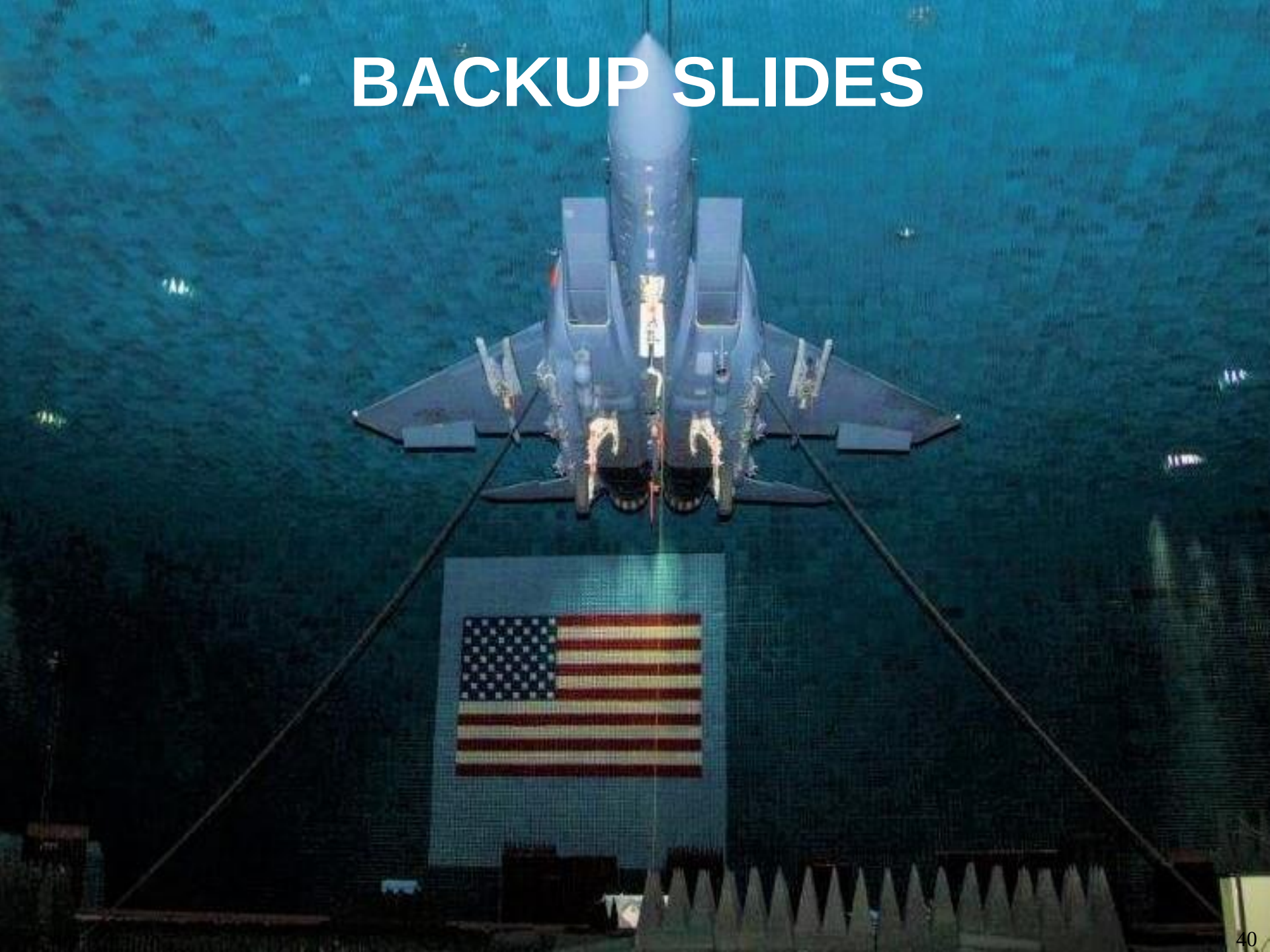
BACKUP SLIDES



BACKUP SLIDES

F-35 Unique Equipment

F-35 requires numerous support systems for full operation during ground test. At this time the F-35 customer must provide these.

- MGTS – MADL (Multifunction Advanced Data Link) Ground Test Set – or BAF MSTC solution
- AVETS – Air Vehicle Engineering Test Station
- Matrix – Monitor for vehicle systems (VS)
- JIMM – Joint Integrated Mission Manager
- JADE – JSF Airborne Data Emulator Hardware
  - Programming support
  - Information on system
- DART – Data Acquisition Recording and Telemetry Pod or Rack
- Mechanical
  - Engineered umbilical strain relief fixture (possible BAF solution)
  - Ability to retract landing gear and close panels with instrumentation

What Does the BAF Provide?

As part of the Air Force Test Center (AFTC), a MRTFB, the BAF provides a State-of-the-Art RF T&E infrastructure:

- An ***exclusively large anechoic chamber*** facility
- Complete RF ***end-to-end installed systems test***
- Dense, high fidelity ***RF threat simulation*** and verification
- ***Electronic countermeasures*** collection, measurement and analysis
- ***Radar target return*** and ECM simulation
- ***Antenna pattern*** measurement
- Inter- and Intra-Systems Electromagnetic (EM) ***Interoperability and Compatibility (EMI/EMC)***
- ***Electromagnetic environmental effects (E^3)*** measurements
- ***Global positioning system (GPS)*** signal generation

Provides the data and/or information a weapons system needs