Creating the Future Test Range Infrastructure: Wireless Inter-Range Network Environment

Thomas O'Brien
Test Resource Management Center

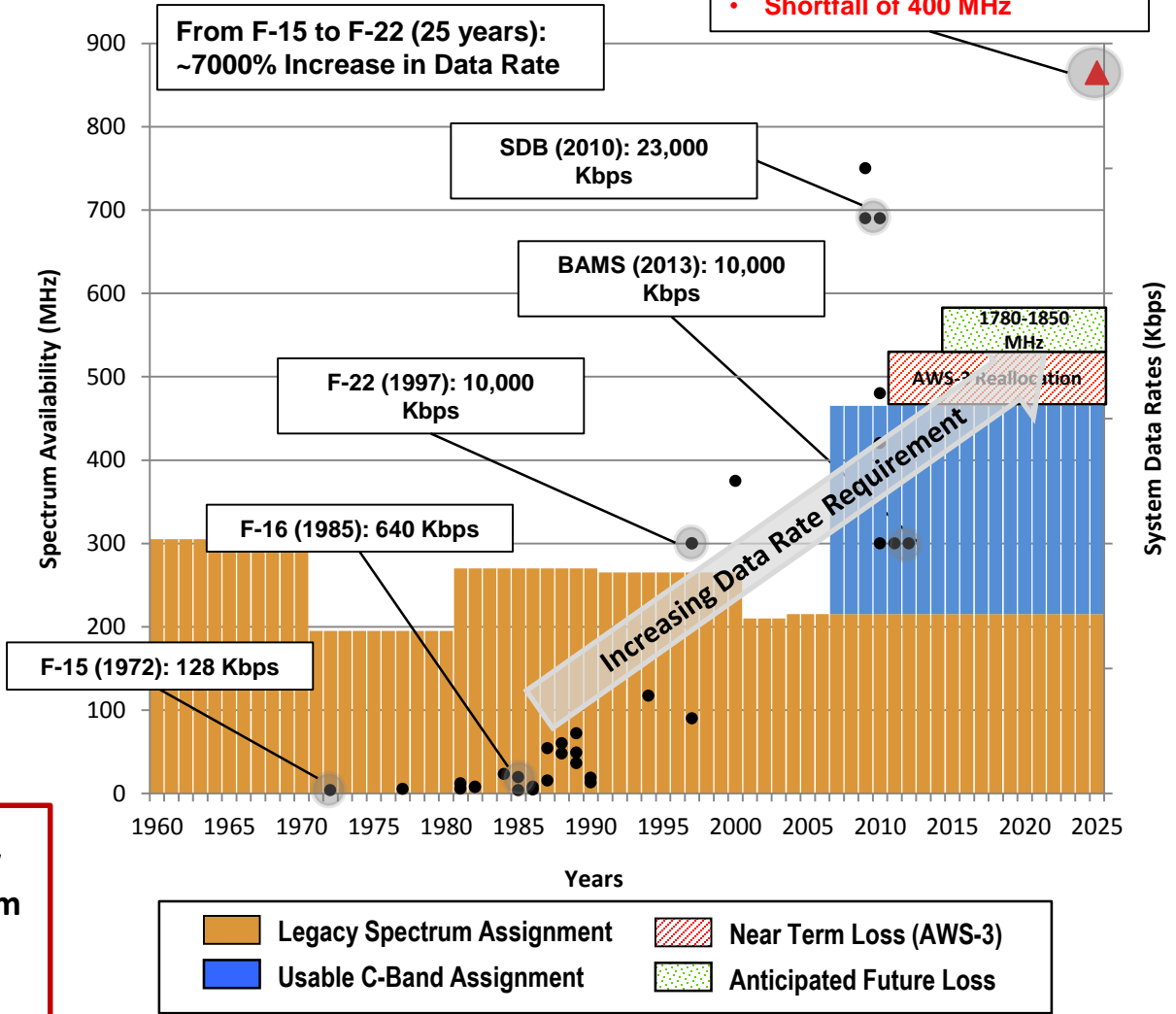**June 28, 2018**

Brief to ETTC 2018

Encroachment to DoD Testing
Spectrum Availability

- **DoD Requirement of 865 MHz by 2025**
- **465 MHz Currently Available**
- **Shortfall of 400 MHz**

- **Increased complexity of weapon systems coupled with decreased availability of telemetry spectrum limits testing at national ranges (complexity of tests, data downlinks)**
  - o Available spectrum will be further reduced by potential loss of 1780-1850 MHz and sharing spectrum with commercial users
- **Large amounts of data collected onboard system and analyzed post-test**
- **Continued investment in advanced RF and network technologies can partially mitigate the loss of spectrum**
  - o Advanced modulation schemes
  - o Networked telemetry
  - o Non-traditional portions of the RF spectrum (e.g. C-band, Ka/Ku-Band)

Increased Weapon System Complexity and Reductions in Available RF Spectrum Limit the Amount and Types of T&E Missions a Range can support

From F-15 to F-22 (25 years):
~7000% Increase in Data Rate

SDB (2010): 23,000 Kbps

BAMS (2013): 10,000 Kbps

F-22 (1997): 10,000 Kbps

F-16 (1985): 640 Kbps

F-15 (1972): 128 Kbps

1780-1850 MHz

AWS-3 Reallocation

Increasing Data Rate Requirement

Spectrum Availability (MHz)

System Data Rates (Kbps)

Years

- Legacy Spectrum Assignment
- Usable C-Band Assignment
- Near Term Loss (AWS-3)
- Anticipated Future Loss

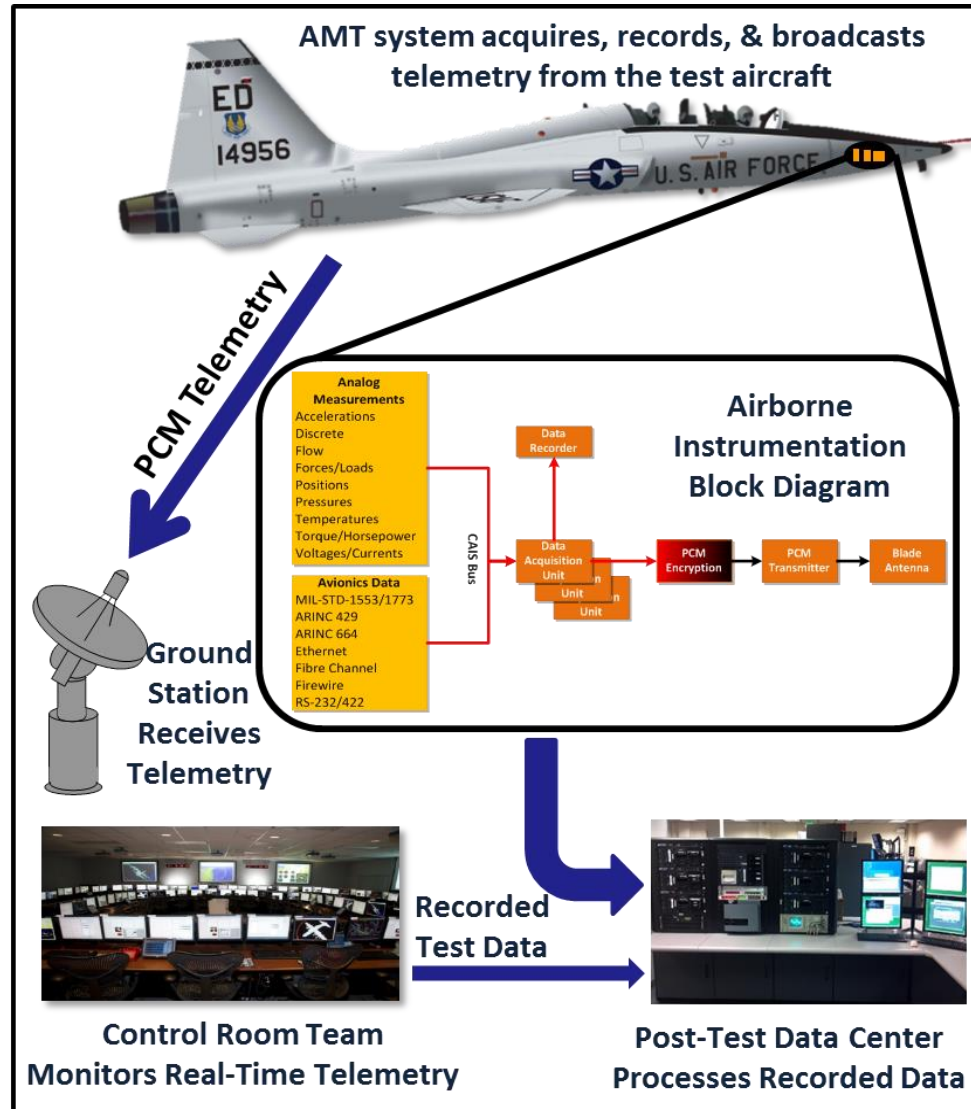# Aeronautical Mobile Telemetry

Telemetry:
The process of <u>measuring at a distance</u>.

Aeronautical Mobile Telemetry (AMT):
The process of making <u>measurements on an aerospace vehicle</u> and sending those measurements to a <u>distant location</u> for recording, display, and analysis.

Why is aeronautical mobile telemetry used?
(1) AMT is the primary source of decision-quality data used to assess aircraft performance
(2) Test efficiency is improved when telemetry data can be monitored in-flight without the need to land for review.
(3) Quality of test runs can be reviewed and repeated if needed
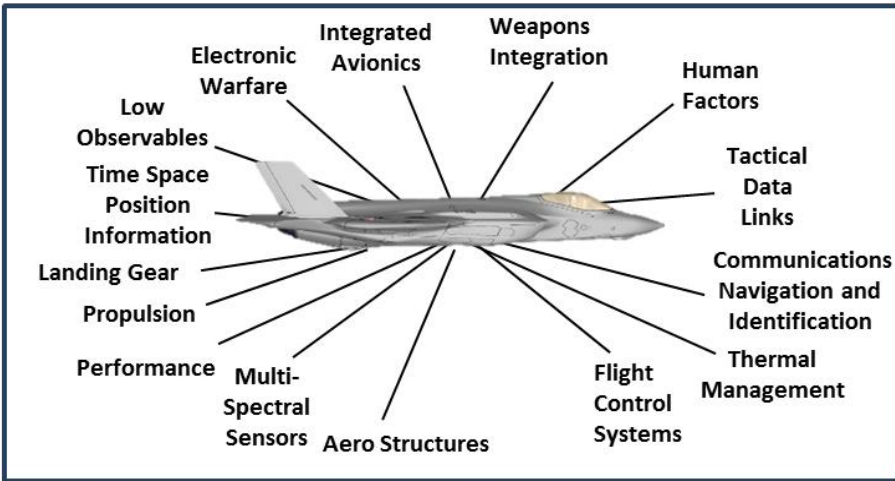(4) Safety of test data monitoring
(5) Preservation of test data in a mishap

AMT system acquires, records, & broadcasts telemetry from the test aircraft

PCM Telemetry

Ground Station Receives Telemetry

Airborne Instrumentation Block Diagram

Analog Measurements
Accelerations
Discrete
Flow
Forces/Loads
Positions
Pressures
Temperatures
Torque/Horsepower
Voltages/Currents

Avionics Data
MIL-STD-1553/1773
ARINC 429
ARINC 664
Ethernet
Fibre Channel
Firewire
RS-232/422

CAIS Bus

Data Recorder

Data Acquisition Unit

PCM Encryption

PCM Transmitter

Blade Antenna

Control Room Team Monitors Real-Time Telemetry

Recorded Test Data

Post-Test Data Center Processes Recorded Data

Aeronautical Mobile Telemetry

Aircraft Technology Improvements Drive the Need for AMT

Labels: Electronic Warfare, Integrated Avionics, Weapons Integration, Human Factors, Low Observables, Time Space Position Information, Landing Gear, Propulsion, Performance, Multi-Spectral Sensors, Aero Structures, Flight Control Systems, Thermal Management, Communications Navigation and Identification, Tactical Data Links

Test Teams Growing to Accomplish More Per Flight

F-22: 2000   F-35: 2010

Existing AMT Challenges

- AMT Spectrum Loss:
    - 35% reduction in AMT spectrum since 1993
    - 25MHz auctioned in AWS-3 (~$45B)
        - 1755-1780MHz
- Airborne Instrumentation Environment:
    - Must be accurate, small, and non-intrusive
    - Some ranges have ~100 unique test articles
        - Manned aircraft/RPVs/stores
        - Limited space available for instrumentation
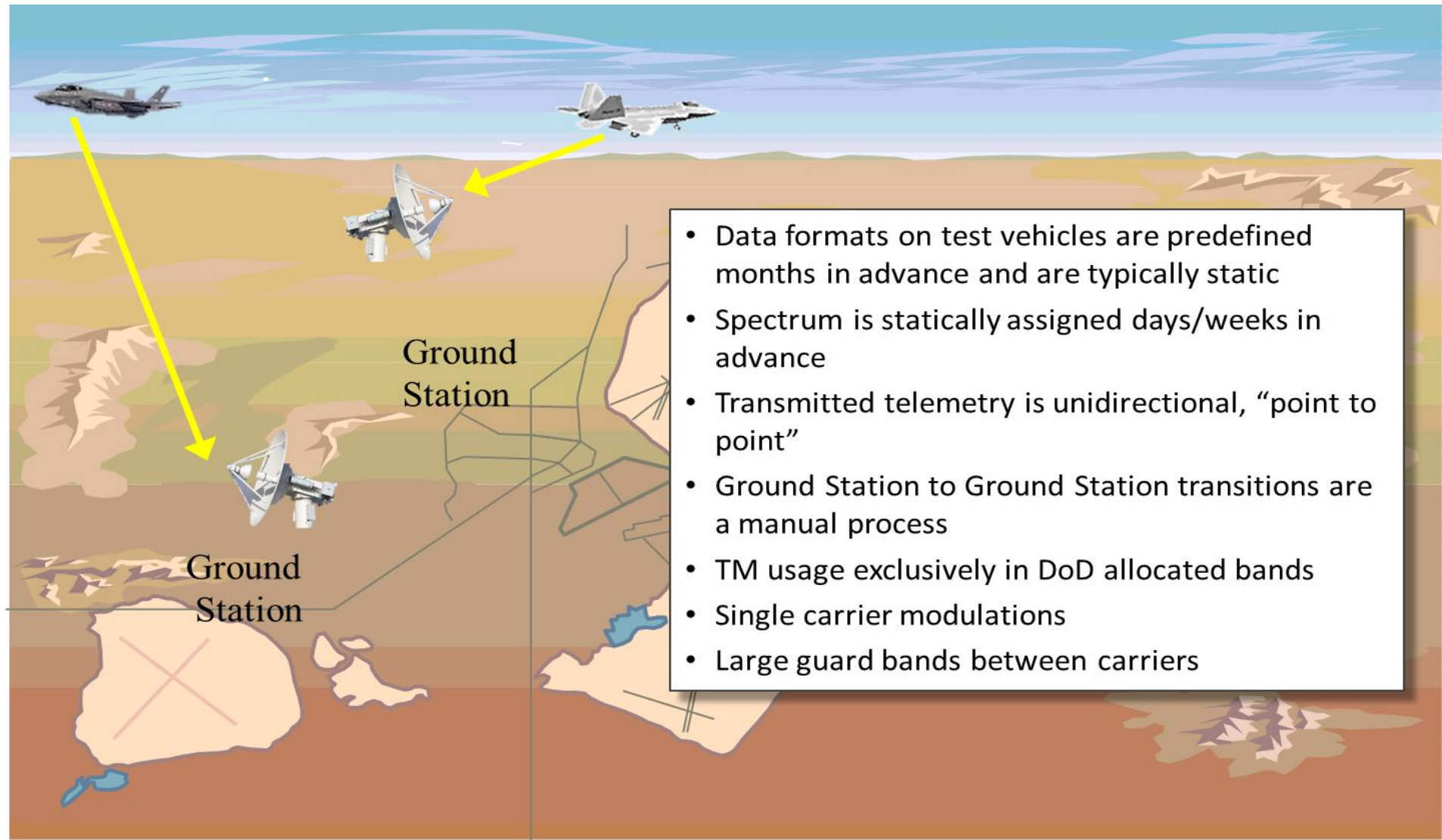   - Cannot affect the performance of the system under test

Challenges to the Current AMT Architecture

- Dedicated AMT RF spectrum for each test mission is not shared; guard bands separating allocations
- Demands for flight test data are exceeding the data acquisition capacity available
    - Video & Avionics systems require much more capacity
- The data telemetered from AMT systems cannot be changed in-flight
- Current AMT systems require separate wiring for time distribution, data, and control

Current AMT Paradigm at Test Ranges

- Data formats on test vehicles are predefined months in advance and are typically static
- Spectrum is statically assigned days/weeks in advance
- Transmitted telemetry is unidirectional, "point to point"
- Ground Station to Ground Station transitions are a manual process
- TM usage exclusively in DoD allocated bands
- Single carrier modulations
- Large guard bands between carriers

Ground Station

Ground Station

Networked Telemetry Paradigm

Network Enabled Instrumentation

- Reconfigurable In-flight
- Ethernet replaces CAIS instrumentation bus
- Generates IP network data
- Reduced cabling & weight
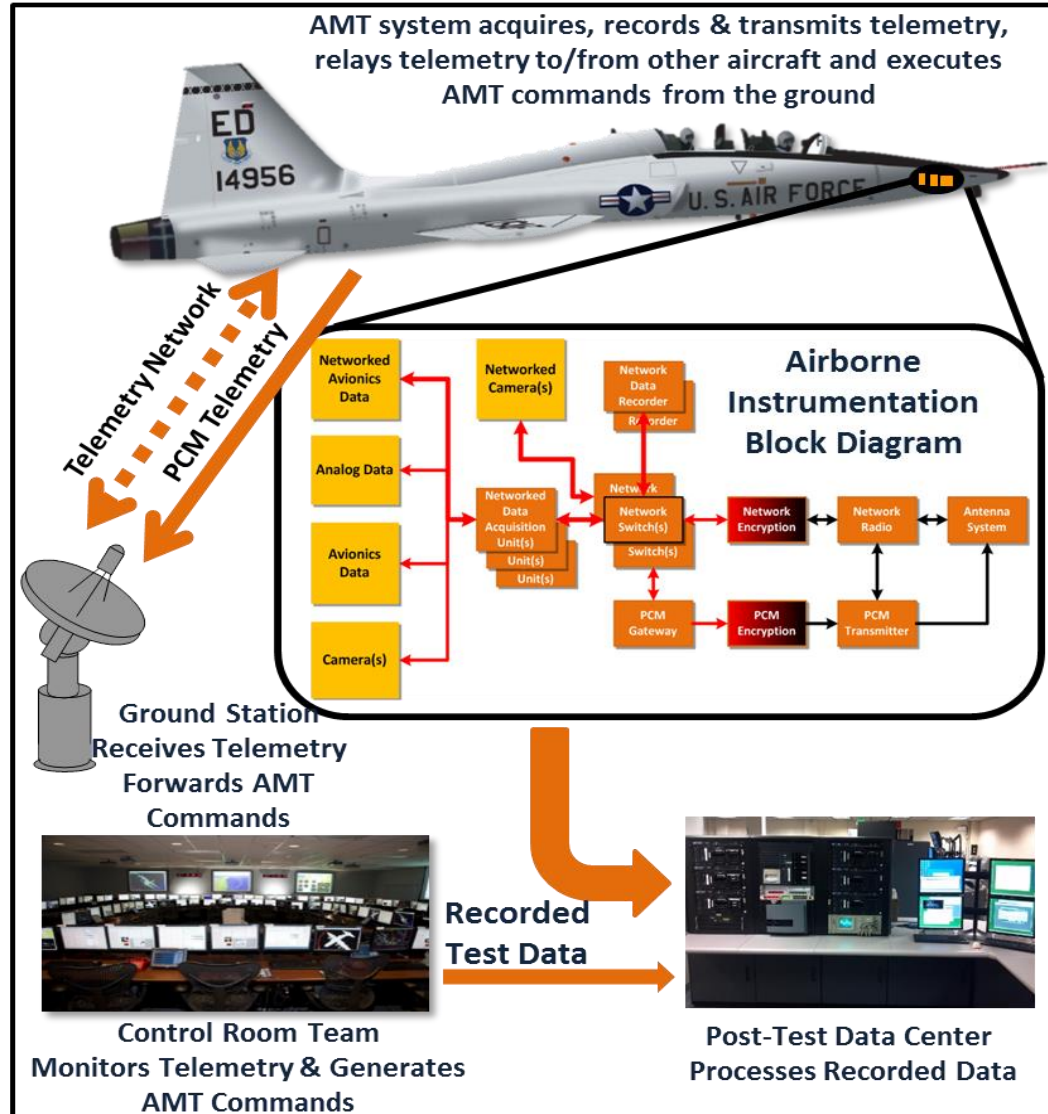- Open architecture

Wireless Telemetry Network

- Multiple test articles share RF spectrum
- Added to existing PCM ground station
- Error correction code increases range
- Remotely manage aircraft instrumentation
- Network Encryption

Control Room Applications

- Secure two-way VoIP "Hot-mike" application
- Modified applications used to process & display network data in the control room
- Store and forward telemetry after dropout
- Change the data that is telemetered

Instrumentation Support Applications

- Instrumentation configuration and control
- Modified AMT ground support applications
- RF Network provisioning & management
- Common metadata for system configuration

AMT system acquires, records & transmits telemetry, relays telemetry to/from other aircraft and executes AMT commands from the ground

ED
14956
U.S. AIR FORCE

Telemetry Network
PCM Telemetry

Airborne Instrumentation Block Diagram

Networked Avionics Data
Networked Camera(s)
Network Data Recorder
RF Recorder
Analog Data
Networked Data Acquisition Unit(s) Unit(s) Unit(s)
Network Switch(s) Switch(s)
Network Encryption
Network Radio
Antenna System
Avionics Data
PCM Gateway
PCM Encryption
PCM Transmitter
Camera(s)

Ground Station Receives Telemetry Forwards AMT Commands

Recorded Test Data

Control Room Team Monitors Telemetry & Generates AMT Commands

Post-Test Data Center Processes Recorded Data

Telemetry Modernization: Integrated Network Enhanced Telemetry (iNET)

- **CTEIP iNET Program is a big step forward in terms of Test Range Modernization**
  - ▸ Focus is on Aeronautical Mobile Telemetry

- **iNET Provides the core set of Network technologies/capabilities**
  - ▸ Provide packetized [Telemetry] data
  - ▸ Request data from the onboard recorder to "backfill" or replace lost or corrupt data initially transmitted over the Serial Streaming Telemetry (SST) link
  - ▸ Change SST data package or format during flight / Reconfigure onboard instrumentation
  - ▸ Select the [Telemetry] data sent down on the network link
  - ▸ Monitor the health and status of the instrumentation system throughout the mission
  - ▸ Request data from the recorder that was not originally transmitted
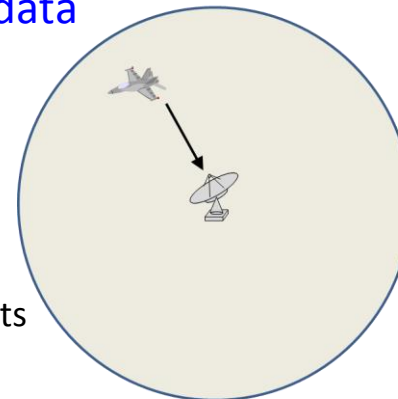 - ▸ Demonstrate Intra- and Inter-Range Seamless Handoff

The Capabilities Provided by iNET are Building Blocks Towards a Highly Integrated, Meshed, Wireless Inter-Range Network Environment

Paradigm Shift in Test Range Infrastructure: Cellular Based Range Telemetry
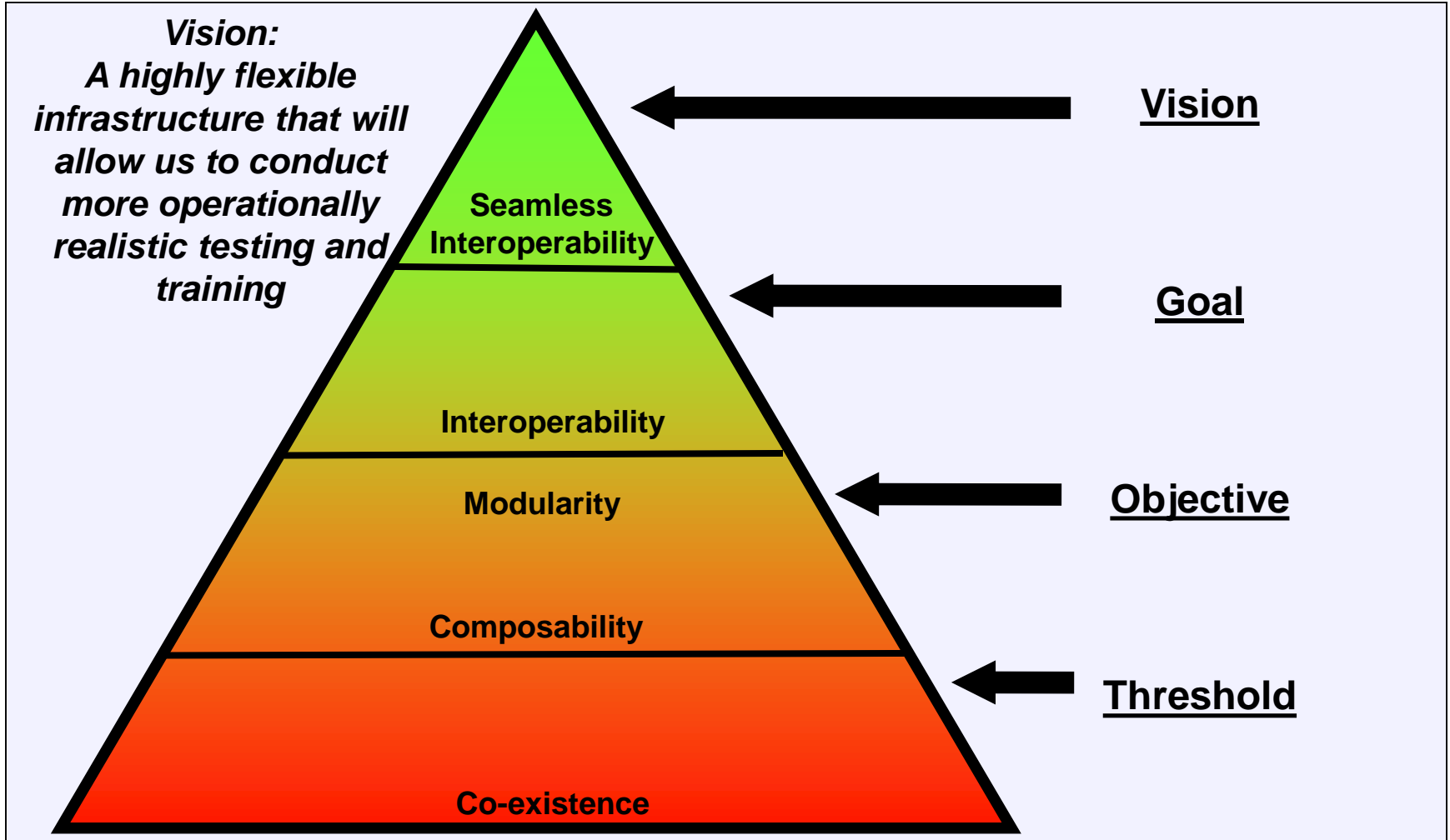
- **Prototype an IP based radio network that leverages the commercial wireless/cellular paradigm where multiple, shorter range ground stations provide telemetry/communications coverage for a large area**

- **Revolutionary (vs Evolutionary) Approach to Modernizing Test Range Infrastructure**
  - Can Leverage and Expand the Capabilities Provided by the iNET Program

- **Addresses Several Issues in Current Range Infrastructure**
  - Inflexibility of transmitted data format
  - Transmission of unnecessary or redundant data
  - Dedication of infrastructure resources
    - Enables "Always on" Approach
  - Inefficient spectrum scheduling and usage
    - Increases opportunity for Spectrum Re-use
    - Enables Support for Additional Test Missions/Events
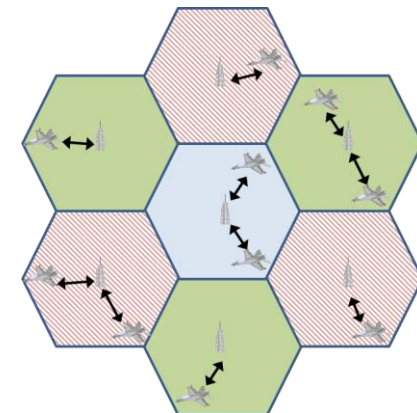
Example of Traditional data transmission method v Cellular Based Approach

Vision:
A highly flexible infrastructure that will allow us to conduct more operationally realistic testing and training

Pyramid levels (top to bottom):
- Seamless Interoperability — **Vision**
- Interoperability — **Goal**
- Modularity — **Objective**
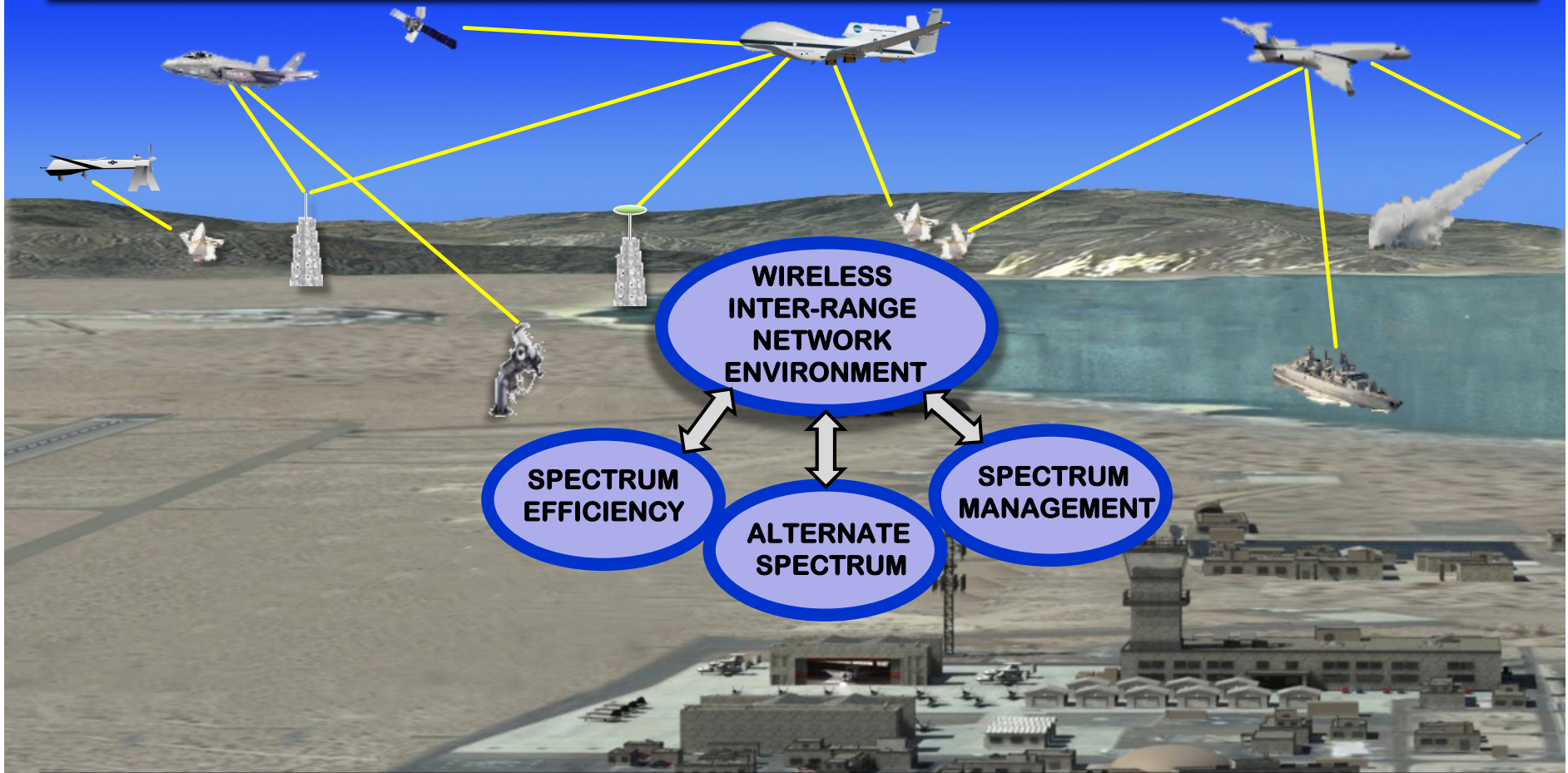- Composability
- Co-existence — **Threshold**

Future Vision for DoD Test Range Infrastructure

Revolutionize the RF test range environment by leveraging network and cellular based technologies to support real-time wireless data communications

WIRELESS INTER-RANGE NETWORK ENVIRONMENT

SPECTRUM EFFICIENCY

ALTERNATE SPECTRUM

SPECTRUM MANAGEMENT

Seamlessly support all range operations 24/7/365 in the most Spectrum Efficient Manner Possible

Summary

- **Increased weapon system complexity coupled with reductions in available RF spectrum limits the amount & types of T&E Missions a Range can support**

- **Continued advancements in RF Technologies and Methodologies are required to increase efficiency**
  - Development/Implementation of Advanced modulation schemes
  - Implementation of Networked Telemetry
  - Expand operations into non-traditional portions of the RF spectrum

- **Evolutionary advancements in RF Technologies will not completely offset the RF Spectrum shortfall**
  - TRMC and the Services have invested in spectrum efficient technologies for many years, increasing data throughput (i.e. Bits/Hertz); The Bits/Hertz from each new technology has started to plateau

- **Leveraging Cellular Based Technologies Provides a Revolutionary approach to Modernize the Test & Training Range infrastructure**

A Paradigm Shift Necessary to Ensure Test Ranges are Poised to Support Future T&E Data Transmission Requirements