End-to-End GPS Multi-Platform Integrated System Testing for MGUE

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Themes

- E2E integrated multi-platform/multi-UE system testing for risk reduction
- Legacy to MGUE transition complexities
- Test COE
- Test standards
- Cost-effective test approaches, e.g. AWFS
- Joint service standards

Outline

- Intro to GPS Modernization and MGUE
- E2E system testing for risk reduction
- Test Center of Expertise (COE)
- Proposed test standards
- Topics in test standards
- Testing to specification
- E2E system testing for UE transition
- AJ testing using AWFS (Dr Sultan Mahmood)
- Joint service standards
- Conclusions

Intro to GPS Modernization and MGUE

- Some features
  - New signals: L1 & L2 M-code, L2 C, L5
  - Flexible NAV messages
    - Improved ephemeris and clock messages
    - New almanac messages
  - Flex power
  - GPS III (L1 C, spot beam, high-speed cross links, integrity, …)
- MGUE
  - YMCA capable Modernized GPS UE which will eventually replace legacy and SAASM-based UE

New interfaces for Hot Start of integrated systems

Integrated System Test (IST)

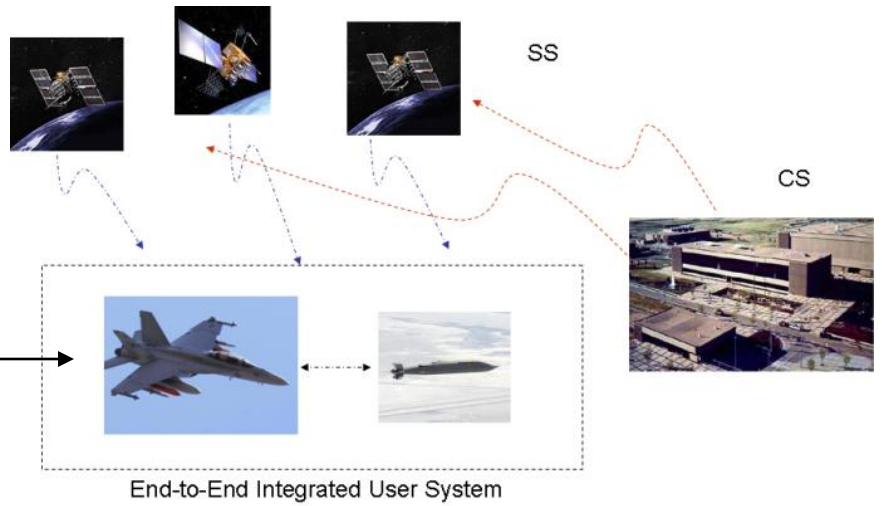
- SAASM testing emphasizes IST, including the SS, CS and representative sets of SAASM receivers
  - IST2-4
- Similar IST test concept is advocated for MGUE
  - MGUE TEMP
- But --- “What is a system?” – see next chart

E2E System Testing for Risk Reduction

- End-to-End (E2E) system is defined as the SS, CS and integrated multi-platform/UE systems
- Integrated System Test (IST) should include testing of the functionality of the interfaces connecting integrated UE systems

Example of Integrated System of Multi-Platform and multi-UE's

Host platform UE supplies initialization function to weapon UE



Test Center of Expertise (COE)

- Led by the GPSW & 746th TS at Holloman AFB
- Cooperative agreement between Air Force, Navy, and Army government test centers:
  - Roles and responsibilities of test centers
  - Cooperation between the test centers
  - Planning for efficient use of limited test resources
  - Identification of any deficiencies in test resources and development of proposals for correction
  - Development of test requirements, test architectures, standards, standardized test plans and procedures for cost-effective testing
- The RTO members of the COE propose an E2E testing service to the GPSW and user services

Proposed Test Standards

- Sets of test documents which need to be developed, with the format and content of each
- Approach for progressive verification, e.g. developmental and component level testing by UE developers, operational, integrated E2E system level testing performed by government labs
- Testing approaches for functional, performance and interface requirements
- Cost-effective testing approaches, e.g. use of PC simulations, use of HITL testing with GPS simulators, range and flight testing
- Standardized testing architectures for different types of UE
- How to test as an “integrated” system when various components are developed and available at different schedules, e.g. making use of simulators
- What performance or test criteria to declare a system as operational
- Development or acquisition of test resources

Topics in Test Standard Documents

- What to include in test standard documents
- Reuse or tailoring of existing standards
- Definitions
- Development of standard scenarios for testing: how many scenarios, how to link requirements to scenarios, how to define a “minimal set” of scenarios to completely cover and test requirements in specification and interface documents
- Standardized test procedures
- Standardized methods to compute deterministic and statistical performance
- Design-in of “testability”
- Automated testing approaches
- Development and use of standard test resources, equipment and facilities

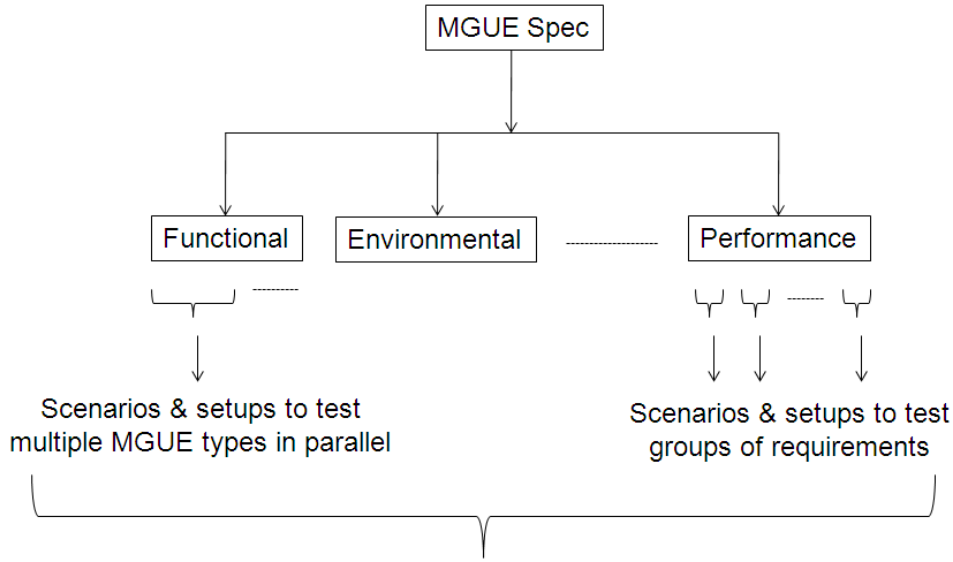
Typical Documents

- Test method
- Diagnostic design specifications
- Manufacturing test requirements design spec
- Design for testability
- Test plan
- Test procedures
- Test equipment
- Operations and maintenance (O&M) manuals

Testing to Specifications

- Some requirements (e.g. functional) may be cost-effectively tested with sets of receivers installed in racks and subject to the same scenarios
- Some requirements (e.g. performance) are UE specific so must be tested in real or simulated operational environment

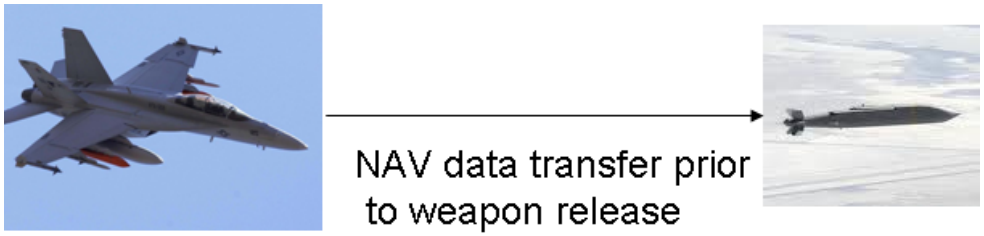
Allocation of spec requirements for testing of many UE in parallel in "equipment racks" vs. UE specific test setups

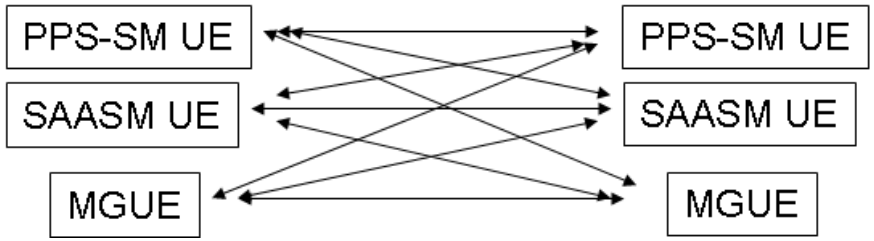


E2E System Testing for UE Transition

- Multiple generations of multi UE may need to interface in an "integrated system," including spot beam capable
- Interfaces for MGUE will also most likely change
- MGUE and all interfaces need to be interoperable and backward compatible

E2E integrated systems need to be interoperable and backward compatible with multi generations of UE





Also spot beam UE

AJ testing using AWFS

Dr. Sultan Mahmood
AFMC AAC/EB, Eglin AFB, FL

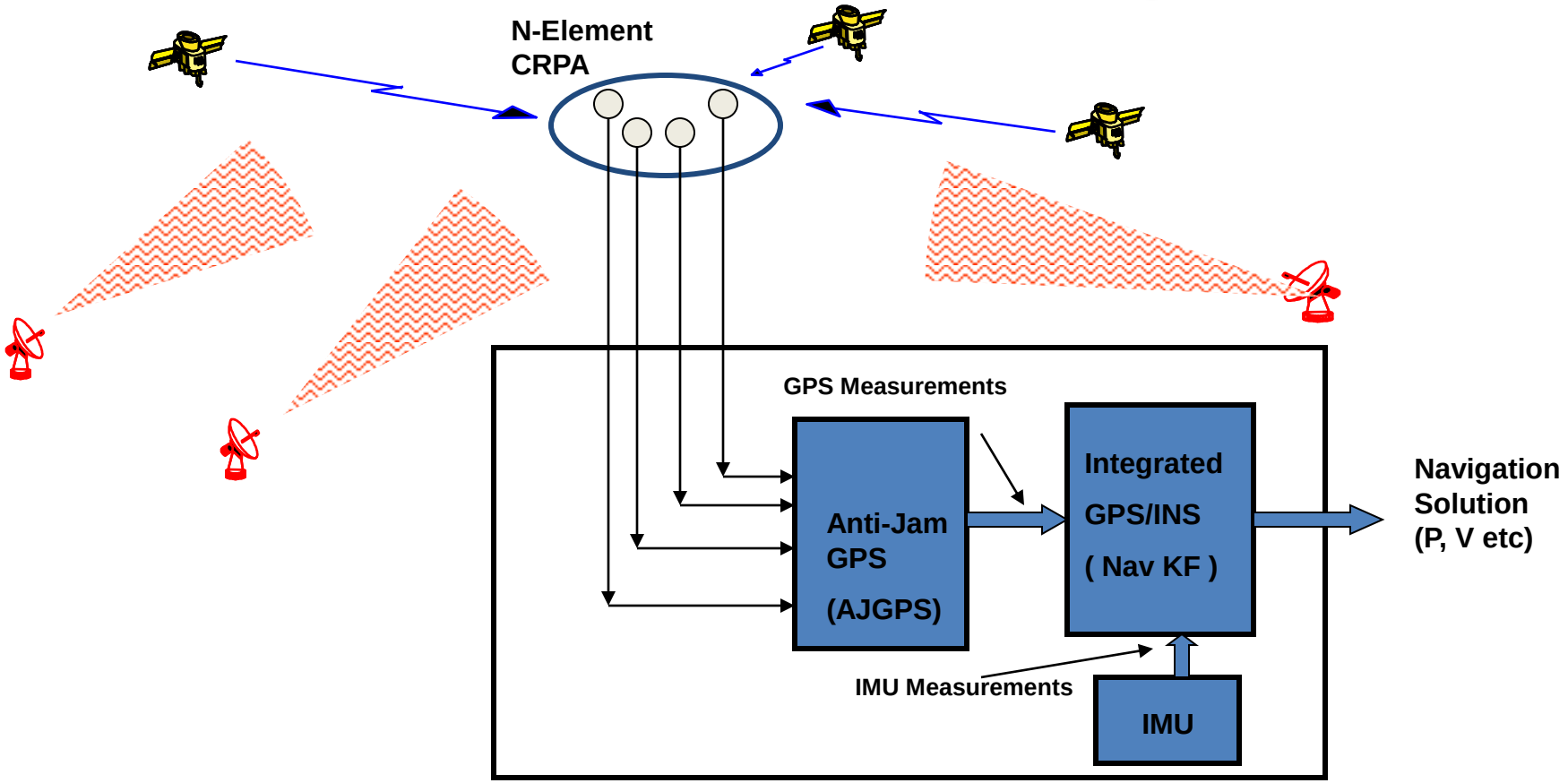
Cost Effective Test Approaches

- **Stand-Alone and Integrated MGUE Performance Testing Under Dynamics and Jamming:**
  - Lab Testing: Hardware-In-The-Loop (HITL) Using Antenna Wave-Front Simulator (AWFS)
  - Van/Flight Testing Using AWFS
  - Integrated Weapon and Aircraft Testing Using AWFS
    - Test Various Hot Start Data Requirements
    - Test Mixed Mode Receiver Operations

Testing for MGUE Specs and Inter-Operability

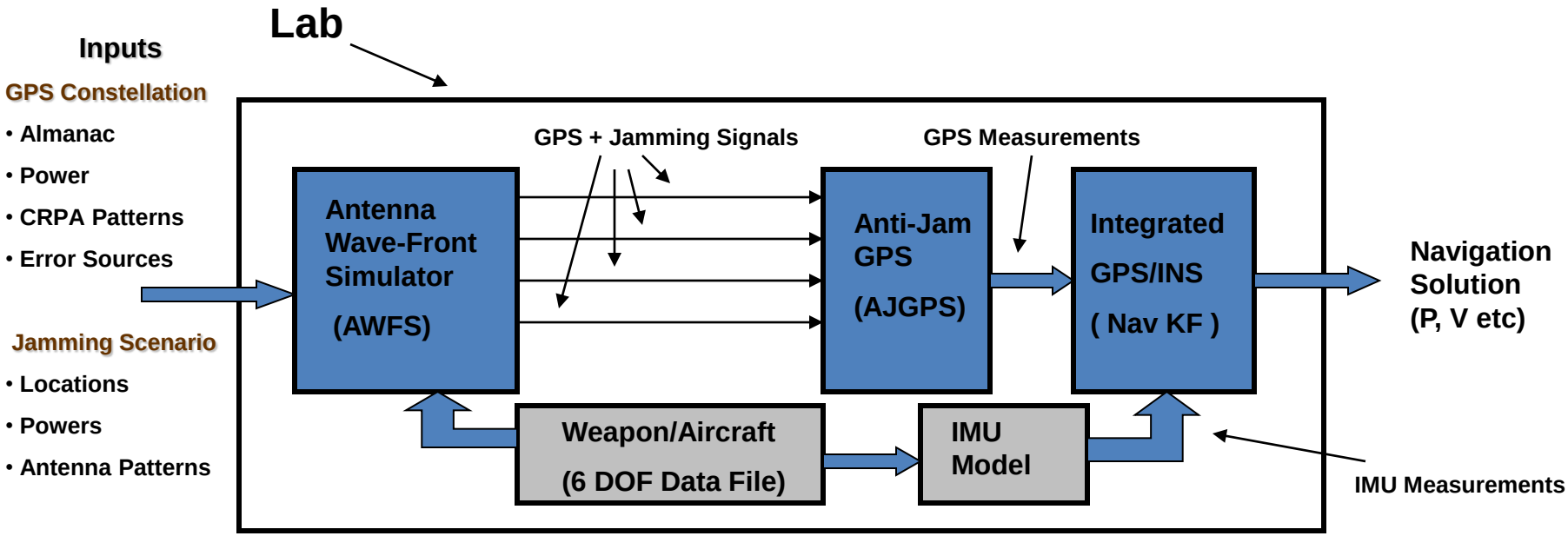
- Stand-Alone or Integrated Tests
- Requirements for Standardized Tests:
  - Realistic Dynamics and Flight Trajectories
  - Realistic GPS SV and Jammer Motion, Power Profiles
  - Environment (Temp, Vibration)
  - EMI/EMC
  - Realistic Initialization Data for Hot Start, Transfer Alignment, Differential Corrections etc
  - Developmental or Operational Navigation/AJ etc Software
  - Multiple Host/Weapon Receiver Combinations
    - Legacy
    - SAASM
    - M-Code or YMCA
  - Multiple Power Levels (Standard, Flex, Spot Beam)
  - Ability to conduct Excursions, and What Ifs

Conventional Ground Testing (Van)



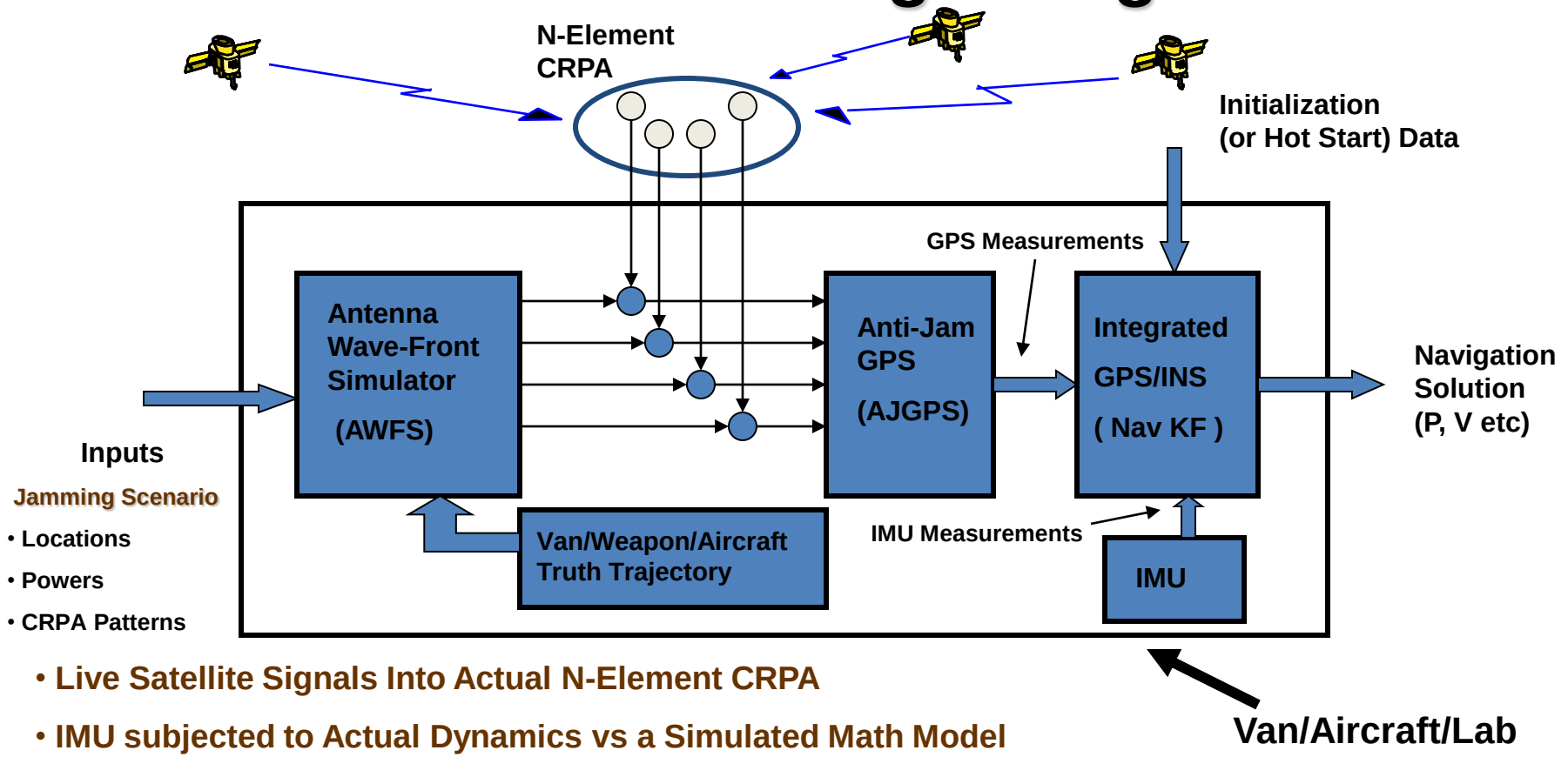
- Live Satellite Signals Into Actual N-Element CRPA
- Live Jammers Into Actual N-Element CRPA
- Frequency Clearance, Jammer Scenario Set-Up Issues

HITL – Using AWFS



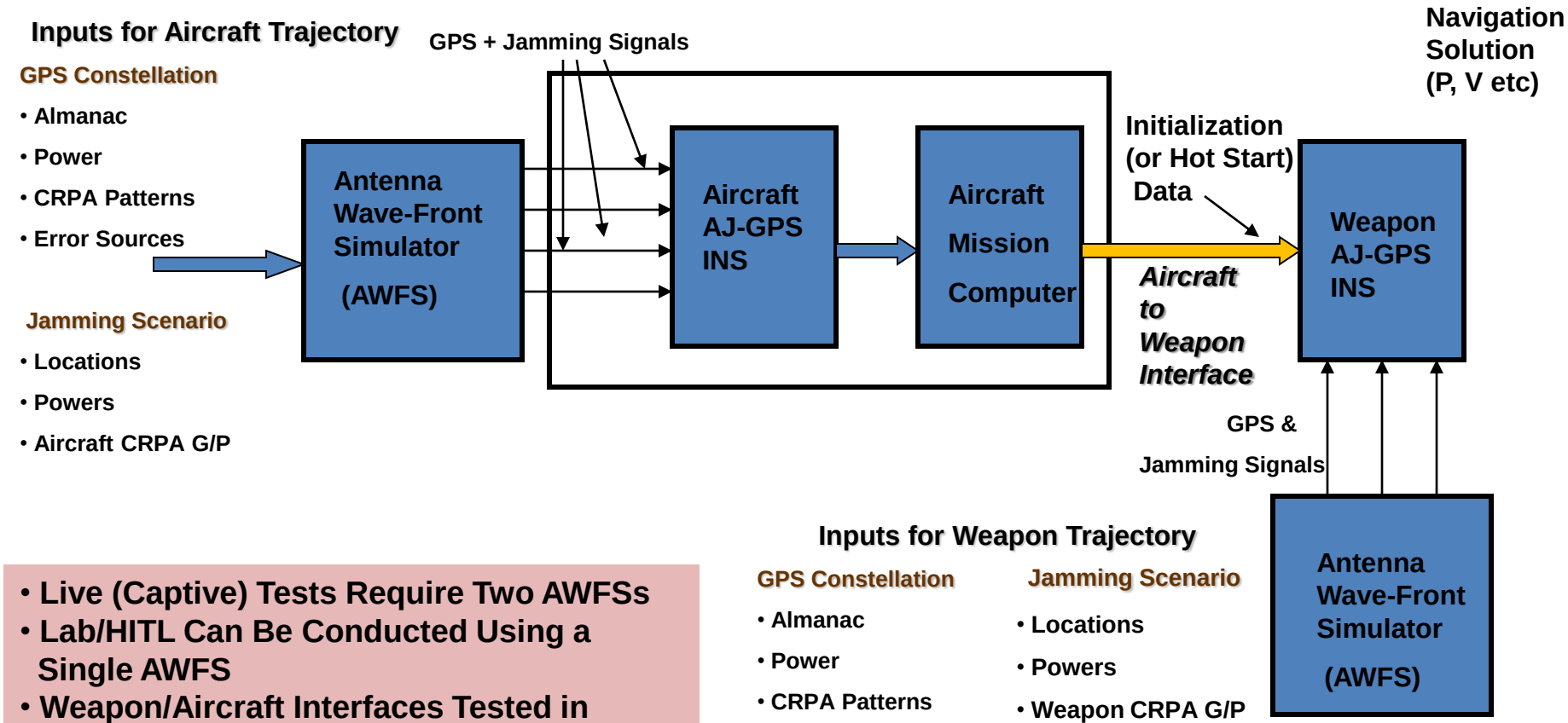
- Simulated GPS and Jammer Signals as Received by Each CRPA Element
  - CRPA Antenna Element Model Includes Body Masking Effects
- AJGPS System Excited with RF Signals From Simulated GPS and Jammers
- Simulated IMU Measurements
- 6 DOF Generates Actual Weapon/Aircraft Dynamics and Flight Trajectories, Initialization Data

Ground and Air Testing Using AWFS



- Live Satellite Signals Into Actual N-Element CRPA
- IMU subjected to Actual Dynamics vs a Simulated Math Model
- Jammer Scenario and CRPA Model Used in AWFS
  - AWFS Generates Actual Jammer RF as Received at Individual Elements
- AJGPS System Excited with Actual GPS and Jammer Signals

Integrated Weapon/Aircraft Testing Using AWFS



- Live (Captive) Tests Require Two AWFSs
- Lab/HITL Can Be Conducted Using a Single AWFS
- Weapon/Aircraft Interfaces Tested in Operational Environments

Conclusions

- Integrated System Test (IST) should include testing of interfaces and generations of UE multi-platform/multi-UE integrated systems
- GPS Test Center of Expertise (COE) offers a means to coordinate and manage the large test effort needed
- Need test standards!
- Need cost effective test approaches, e.g. AWFS
- Recommend Joint Service Standards