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Multispectral/Multi-sensor Simulation for V&V across the EMS

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Agenda

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Why is a Multispectral/Multi-sensor Integration Lab Needed

What Stimulators Must be Part of a Multispectral/Multi-sensor Integration Lab

Integration of Multiple Stimulators into a Single Multispectral/Multi-Sensor Lab

Creating a Coordinated Simulation/Stimulation

Architecture of Synchronizer/Controller

Multi-ship Multispectral Integration Labs

Closing the Loop

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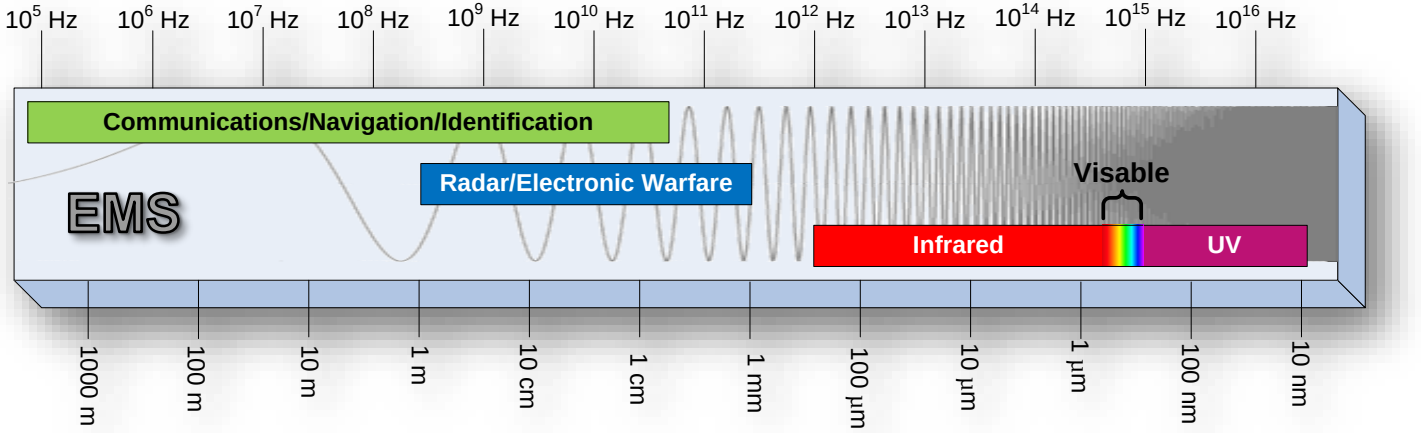
Why is a Multispectral/Multi-sensor Integration Lab Needed

- Because modern aircraft have sensors that cover the EMS



- A Multispectral integration lab can provide all these sensors a unified representation of the environment

- What Testing/Training Capability can a Multispectral Integration Lab Provide?
  - Systems Integration Lab (SIL) for Avionics V&V
  - Mission Data Load Programming
  - Mission Rehearsal
  - Testing of Sensor Fusion

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Why is a Multispectral/Multi-sensor Integration Lab Needed (cont'd)

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- Sensor fusion has become widespread and is fielded on aircraft such as:
  - F-22
  - F-35
  - GRIPEN E
  - Rafale
  - Eurofighter Typhoon

- Sensor fusion is making its way into unmanned systems as well
  - Sense and Avoid
- Types of sensor fusion systems requiring testing
  - Multi-sensor Track Fusion
  - Multi-sensor Information Fusion
  - Multi-sensor Target Identification Fusion
  - Multi-sensor Image Fusion
- To completely test sensor fusion, each sensor must be provided with an accurate and coherent view of the simulated environment for a wide variety of different testing conditions

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Why is a Multispectral/Multi-sensor Integration Lab Needed (cont'd)

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Testing of multi-sensor fusion requires the verification of:

- Sensor management and control
- Fusing of sensor data into coherent tracks
- Rejection of false tracks
- The pilot's interaction with system, reduction in workload

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What Simulators Must be Part of a Multispectral/Multi-sensor Integration Lab

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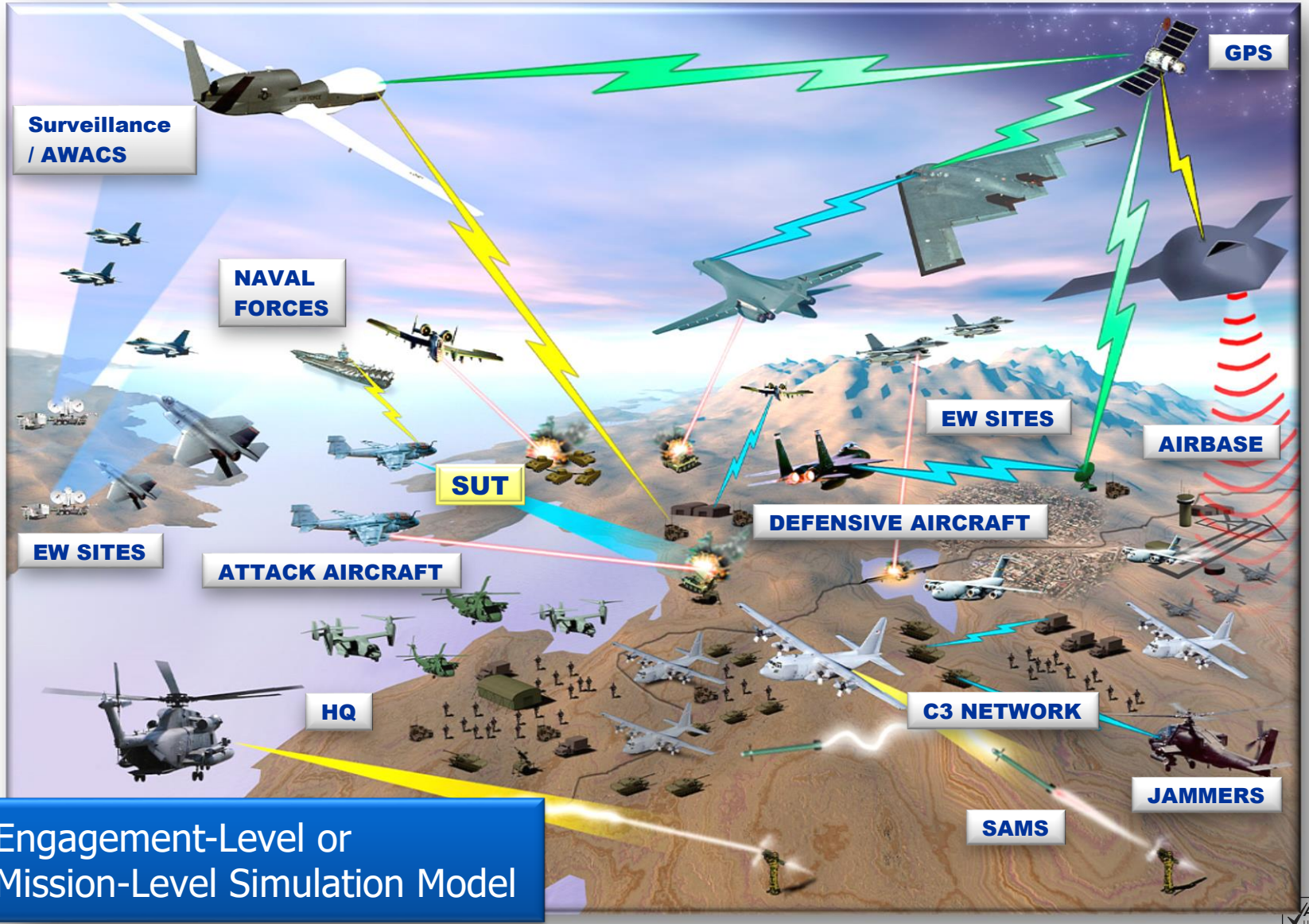

Engagement-Level or Mission-Level Simulation Model

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What Simulators Must be Part of a Multispectral/Multi-sensor Integration Lab

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Electronic Warfare	• Both for ES and EA
Radar/Lidar	• Radar Target Generation and EA Simulation • Potential to Support Radar Imaging (SAR)
Communications/ Navigation/Identification (CNI)	• IFF • Data links
GPS/INS	• Including GPS Jamming
IR/EO	• Missile Warning Systems • IR Countermeasure Systems

All being tightly coordinated to produce a coherent and consistent view of the simulated environment

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What Simulators Must be Part of a Multispectral/Multi-sensor Integration Lab

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- Not all sensor systems are required to be physically present in the integration lab
- The sensor along with is environment can be emulated and the resulting data stream from the sensor generated by a simulator
  - The emulation of the sensor and its environment must be to high-enough fidelity to permit accurate data fusion
- To provide some clarification the following terminology will be used:
  - Stimulators provide stimulus to all or part of sensor system that is physically present in the integration lab and the sensor generates its normal data stream
  - Emulators emulate both the sensor system and the environment when the sensor system is not physically present in the integration lab and provide the accurate data stream that that sensor system would provide
  - Both Stimulators and Emulators will be referred to as Simulators in this presentation
- A “Hybrid” lab may contain a mixture of real sensor systems being physically stimulated and fully emulated sensors

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What Other Must be Part of a Multispectral/Multi-sensor Integration Lab

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- Instrumentation
  - Data Bus Monitoring/Recording
    - Records internal bus traffic to allow the performance of the system to be assessed in real-time
    - Facilitates post-test analysis
  - Environmental Recording
    - Records and analyzes the EMS environment provided to the SUT
      - Signal Measurement Systems to record and monitor the RF environment presented to EW, Radar and Communications Systems
      - Data/Video Recording Systems for imaging data provided to IREO sensors
- Analysis Tools
  - Real-Time Analysis Tools
    - To monitor data being recorded by the instrumentation during test execution
  - Post Test Analysis Tools
    - Historical data recorded by Synchronizer/Control System and individual simulators that contains time-tagged events of what each simulator was being commanded to do during the execution of the script

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Integration of Multiple Simulators into a Single Multispectral/Multi-Sensor Lab

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All simulators that will be part of a Multispectral/Multi-sensor Integration Lab …

Must be capable of Real-time performance	• The time to execute the simulation and present the sensor with its input is equivalent to the elapsed time
Must have a constant, known, latency	• Where latency is defined as time between a command for an event to happen to the time when the result of the event is present at the sensor
Must be capable to being synchronized to a central time server	• Example IRIG, PTP Precision Time Protocol
Should use common databases and models where needed	• Terrain and Feature Databases (DTEF, DFAD) • Models of targets (ex faceted models used for both Visual/IR and Radar RCS simulation) • Motion models
Must provide an easy way to develop the models for the simulator	• A high degree of integration is desirable with a common look and feel across simulators • May require the Integration of multiple editing tools, potentially from different simulator suppliers

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Integration of Multiple Simulators into a Single Multispectral/Multi-Sensor Lab (cont'd)

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All simulators that will be part of a Multispectral/Multi-sensor Integration Lab …

Must be capable of being controlled remotely by a central synchronizer/controller

- Synchronizer/Controller executes a common master script that defines the test scenario
- Commands are then pushed out control to each simulator

Should use a Common Message Set to reduce the number of unique messages that must be sent

- Reduces overhead of controlling large number of simulators (messages only have to be sent once)
- Creates NRE for each simulator to support the common message set
- Example message set:
  - *Simulator State Control Messages*
  - *Player Position/Orientation Updates*
  - *Scenario Events*
  - *Issues with a common message set (one off interface for each simulator)*

Should support a common method of rapidly distributing messages to all Simulators

- Via a high speed, low-latency, data bus
- Ethernet (note switches in the data distribution path may introduce some uncertainty)
- Reflective Memory (SCRAMnet)

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Creating a Coordinated Simulation/Emulation

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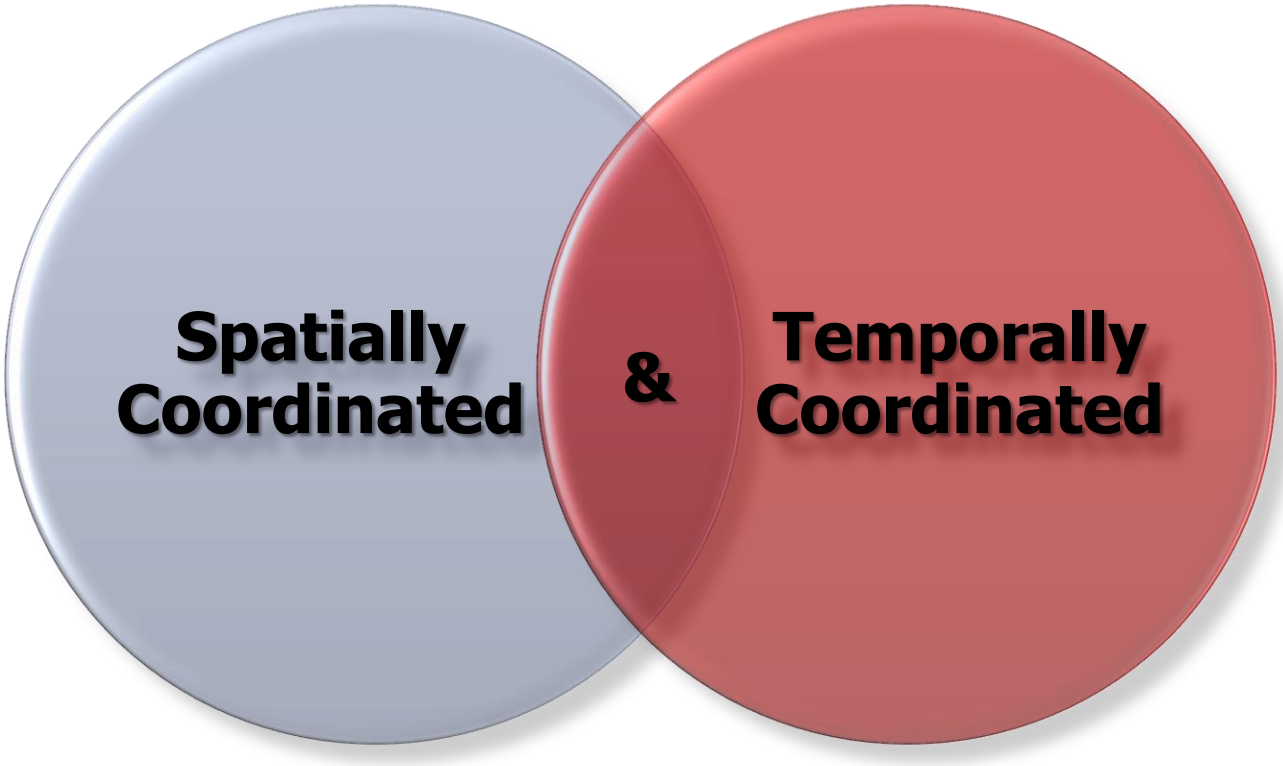
In order to provide a truly coordinated picture to all of the sensors, that will allow sensor data to fuse properly, the simulation/emulation must be …



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Creating a Coordinated Simulation
Spatially Coordination

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- All simulated players must be in the same spatial location at the same time for each simulator regardless of simulator geometry update rates (Spatial Concurrence)

- Need for Common Motion Model running on all simulators
  - Will ensure that all simulators have players in same location at the same time
  - An example of a model that can be used is the PVAJ (Position/Velocity/Acceleration/Jerk) model

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Creating a Coordinated Simulation
Temporally Coordination

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- All simulators/emulators require a common view of time
  - Central time server distributes time data to all simulators
  - Must be capable of providing the time to each simulator with a minimum of skew
  - Account for propagation delay of time data to each simulator
- How tightly synchronized do the individual simulators need to be (Temporal Concurrence)?
  - This is a function of the SUT's processing needs and the characteristics of the central time server
  - Must account for longest initialization time of simulators so that it knows when the slowest initializing simulator is done and execution can start
    - Simulators can report when initialization is complete
  - Must accounting for differences in message processing time (Latency)
- Events in the scenario must occur at the same time for each simulator/emulator
  - Events must be sent to each simulator far enough in advance to account for the latency of the highest latency simulator

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Architecture of The Synchronizer/Controller
Major Elements

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The Synchronizer/Controller System will include

Computer Systems

- Initialize each simulator and prepare for script execution
- Allow the operator to build and run the script for the test scenario that is common to all simulators
- Execute applicable models

Timing Network

- Provide a master clock source to all simulator within the lab
- Time at each simulator has a minimum of skew

Data Networks

- Provide synchronization and control of each of the simulators during the execution of the scenario

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Architecture of The Synchronizer/Controller
Block Diagram

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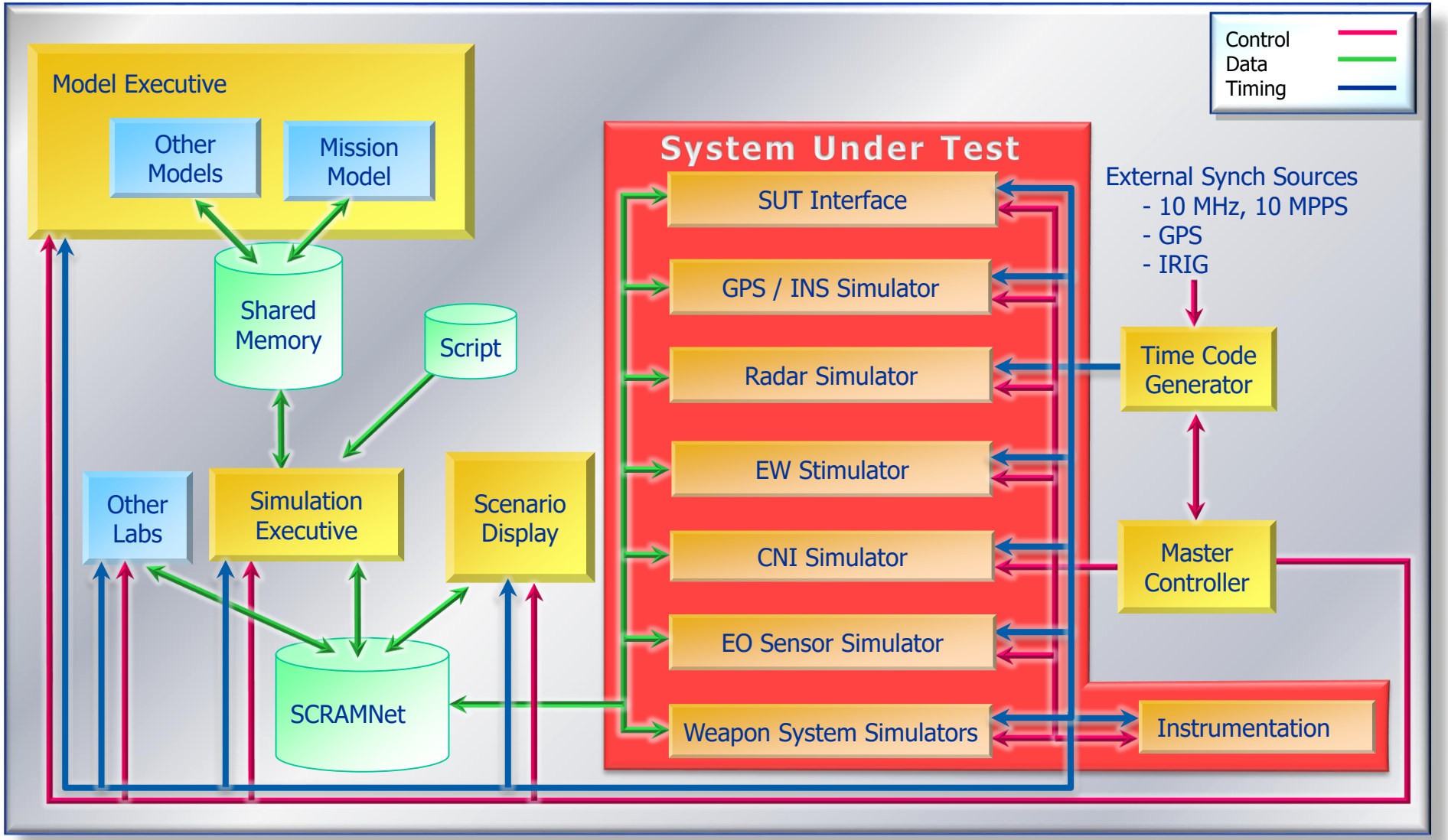

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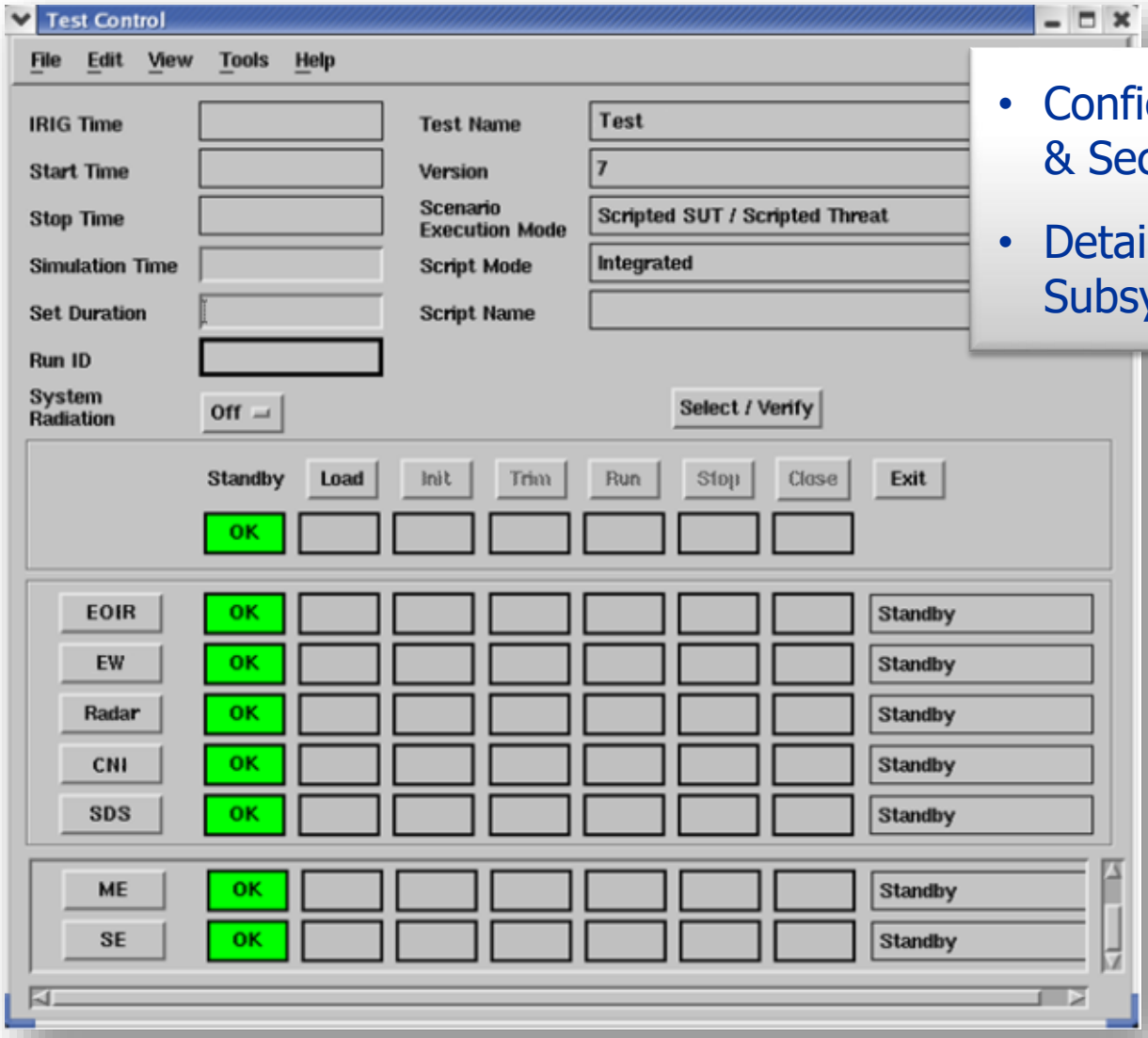
Architecture of The Synchronizer/Controller

Example Master Control Dialog



- Configurable Control – Primary & Secondary Systems
- Detail Indicators & Combined Subsystem Status

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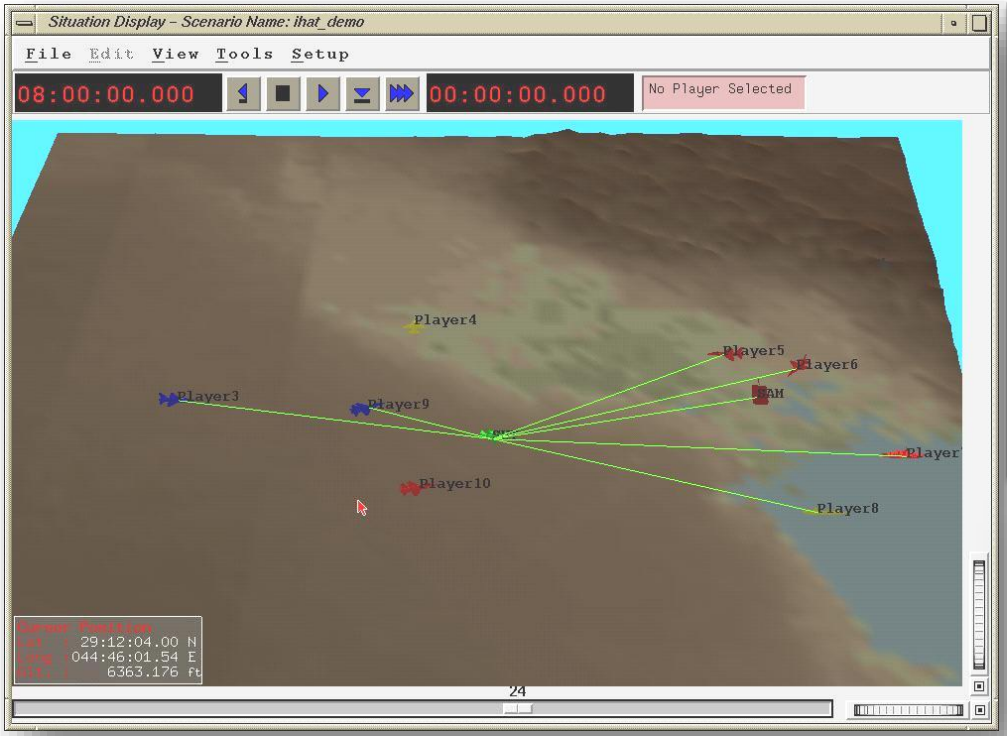
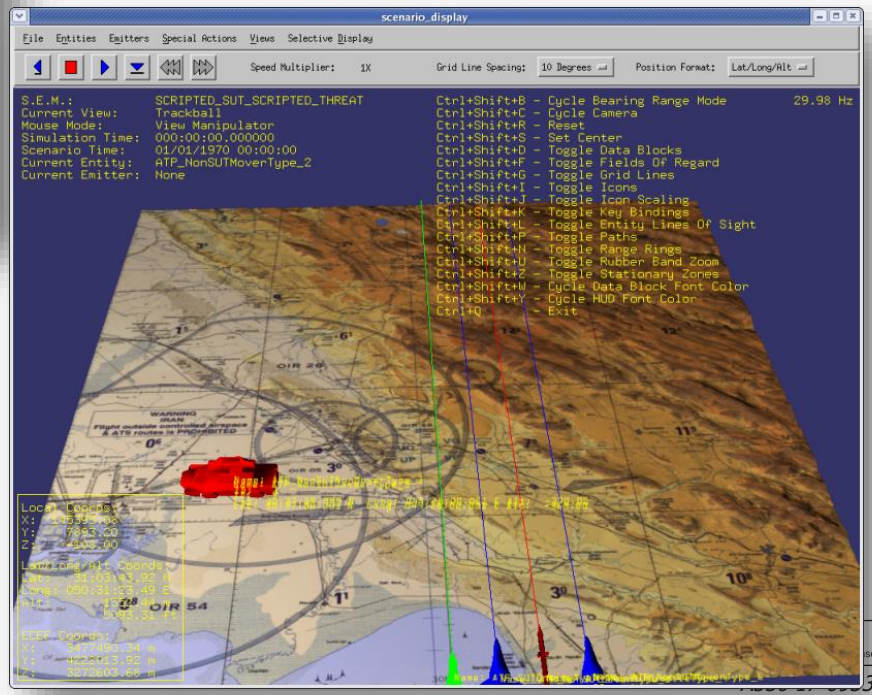
Architecture of The Synchronizer/Controller

Situation Display for Operator Control



- Player Situation Display
- 2-D Entry of Player Locations
- GUI Dialogs for Data Entry
- Graphical Model Data Entry of Flight Paths & Engagement Zones
- 2-D / 3-D Review of Scenario Data



Multi-ship Simulation

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Why is providing stimulus to multiple Systems Under Test required?

- To support Multi-ship (multiple aircraft) precision geolocation testing
- To support cooperative jamming testing

Multi-ship Labs May Require Data Link Simulation

- Typically, multi-ship coordination is accomplished through data links (either direct or satellite links)
- Will require the simulation of the data traffic between ships

How to Perform Multi-ship Simulation across multiple labs

- Requires a high degree of synchronization between labs
- Synchronizing across labs
  - *Use one Synchronizer/Controller System to control both labs*
  - *Use two separate Synchronizer/Controller Systems that are tightly synchronized*

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Closing the Loop

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Human/Pilot in the Loop

- Once the latency (or lag) of the system starts to get large (greater than 100 milliseconds), the human in the loop will begin to notice.
- Therefore, latencies must be kept low

Models in the Loop

- Provide higher fidelity models or model aspects of the threat environment not present
  - *Mission Models*
  - *IADS Model*
  - *Missile Fly-out Models*
  - *Realistic Aircraft Motion Models*

Closing the loop with Electronic Attack Systems

- If the instrumentation provided with the lab has the ability to measure and characterize the jamming response of SUT
- Then the stimulus being provided to jammer by the EW simulator can be appropriately adjusted to how the threat would respond to jamming

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Conclusions

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- This presentation has shown that through tight synchronization and control of multiple simulators within a multispectral lab, true multispectral simulation can be provided
- Northrop Grumman has provided very capable Synchronization/Control Systems (SCS) that have served as the cornerstone of many Multispectral/Multi-sensor Integration Labs
- Northrop Grumman has also provided many of the simulator and instrumentation systems needed for a multispectral lab
  - CEESIM for EW and Communications signal simulation
  - RISS for Multicolor IR and UV simulation
  - Signal Measurement System for Recording the RF Environment

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