Integration of Operational Simulations with Physics-Based Models for Engineering Analysis

Stephen Guest
Henson Graves

October 2009

Outline

- Engineering Analysis and Requirements
- Integration of Operational Simulations with physics based models – an effective approach
- Examples
- Use of MBSE for Integration
- Conclusion

Engineering Analysis is Performed to:

- Understand requirements
- Determine feasibility
- Evaluate proposal design
- Solutions verification

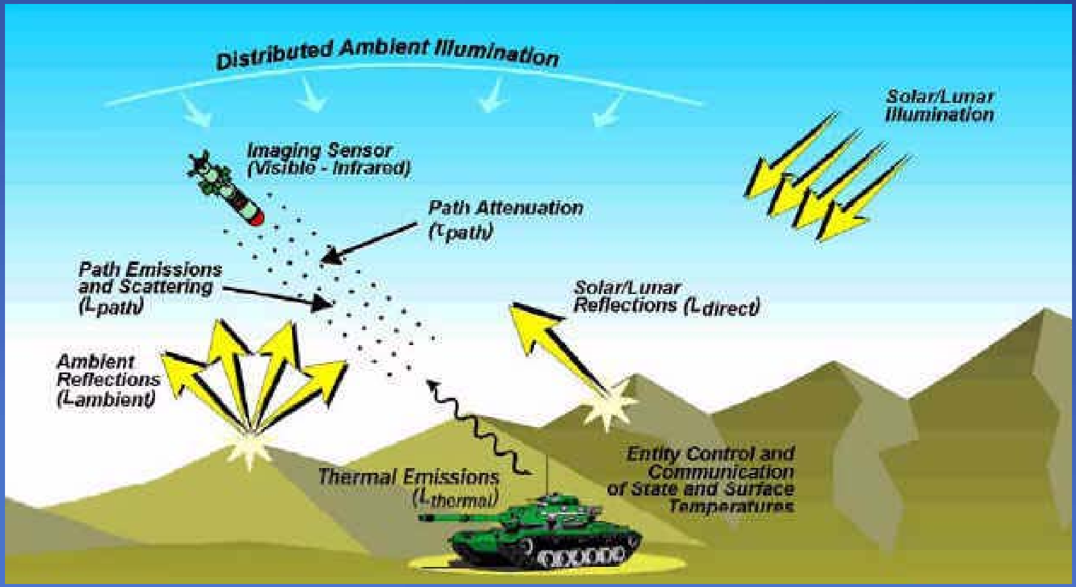
May be for new systems or upgrades

Results of Analysis

- Provide quantitative prediction of behavior with evidence to back it up
- Examples
  - Aircraft performance
  - Sensor analysis
  - Mission effectiveness

Problems Encountered in Analysis

- System behavior is complex and depends on complex interactions with the environment
- Need for component models with appropriate levels of fidelity
- Availability of test data for modeling and verification of certain behaviors



SensorPrime from Presagis

Operational Simulations Integrated with Physics Based Simulations

- Operational simulations integrated with physics based simulations include
  - Behavioral models of vehicles interacting with 3D synthetic environment
  - Physics based models of sensors, atmosphere, ballistics, etc.
- Results - perform experiments, collect data, do analysis
  - Must understand fidelity of models
  - And aggregate integrated results as basis for evidence

Problem - M&S is Not Traditionally at the Core of Product Development Processes

- Simulations of air vehicle and subsystem are in common use, but
- Without integration of detailed avionics/system/subsystem models with operational simulation,
- Simulation results are not available in time to affect the design process

Feasibility, Cost, and Accuracy Have Changed Drastically Over Last Few Years

- Hardware/Software improvements
  - Of course it means the cliché of increased performance and lower costs
  - But what it really means is that I can run it on my laptop
  - Increased performance provides opportunity for more useful/higher fidelity models
  - SDKs and XML provide wide ranging interface capabilities

Sensor Display Simulation

First example – sensor slew performance analysis

- We needed to evaluate a sensor's capability to track a target for a given mission/scenario
- Couldn't acquire detailed sensor performance data for the analysis
- So we built the operational scenario and integrated with a perfect sensor tracking model

Sensor simulation results

- Simulation executed and sensor locked to target
- Platform jitter not modeled (important assumption)
- Motion data of sensor captured and max/min rates and accelerations calculated
- End results indicated that the basic aircraft motion does not drive sensor performance requirements (although stabilization with platform jitter may)

Sensor tracking simulation

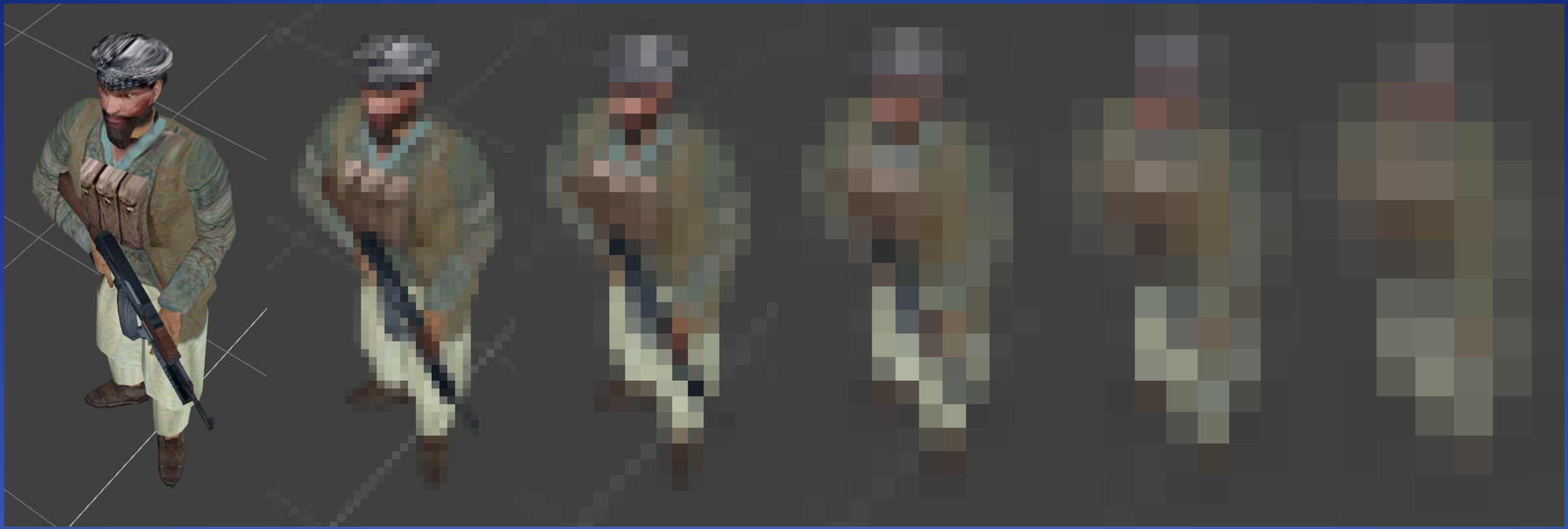
Second example – sensor resolution analysis

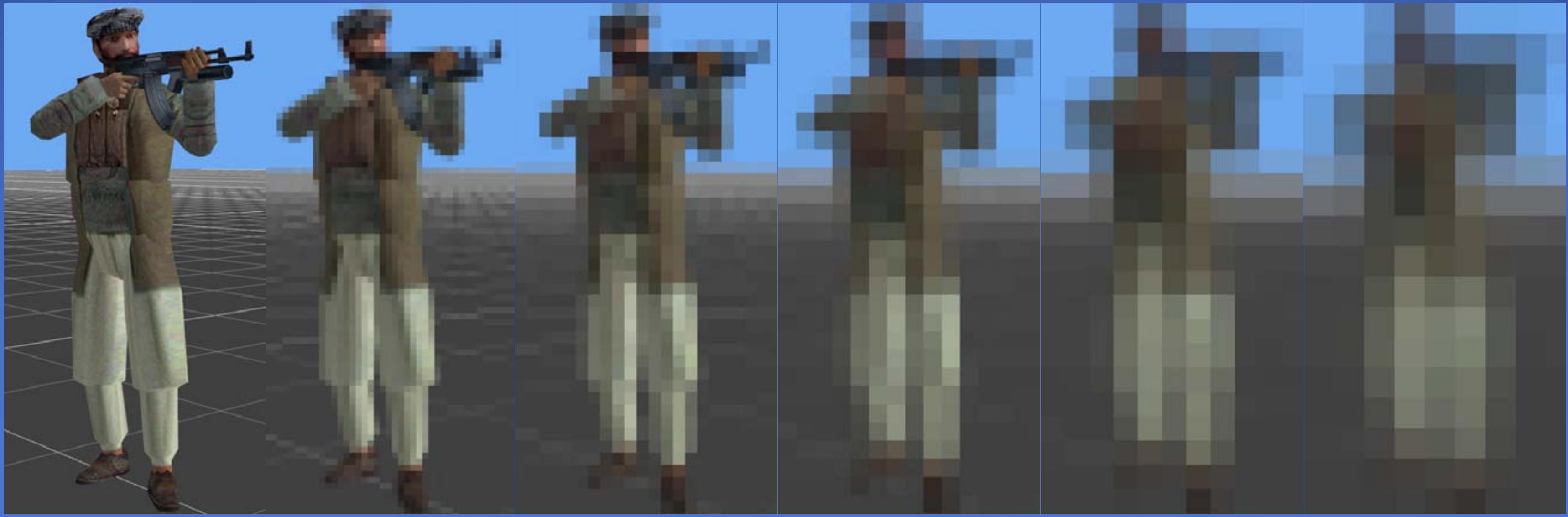
- We wanted to get a feel for what sensor resolution/FOV was needed for target recognition based on
  - Mission profile
  - Multiple resolutions and
  - FOVs (zoom/magnification)
  - Sensor degradation (blur, persistence, etc.)
  - Display characteristics

Resolution Analysis (cont'd)

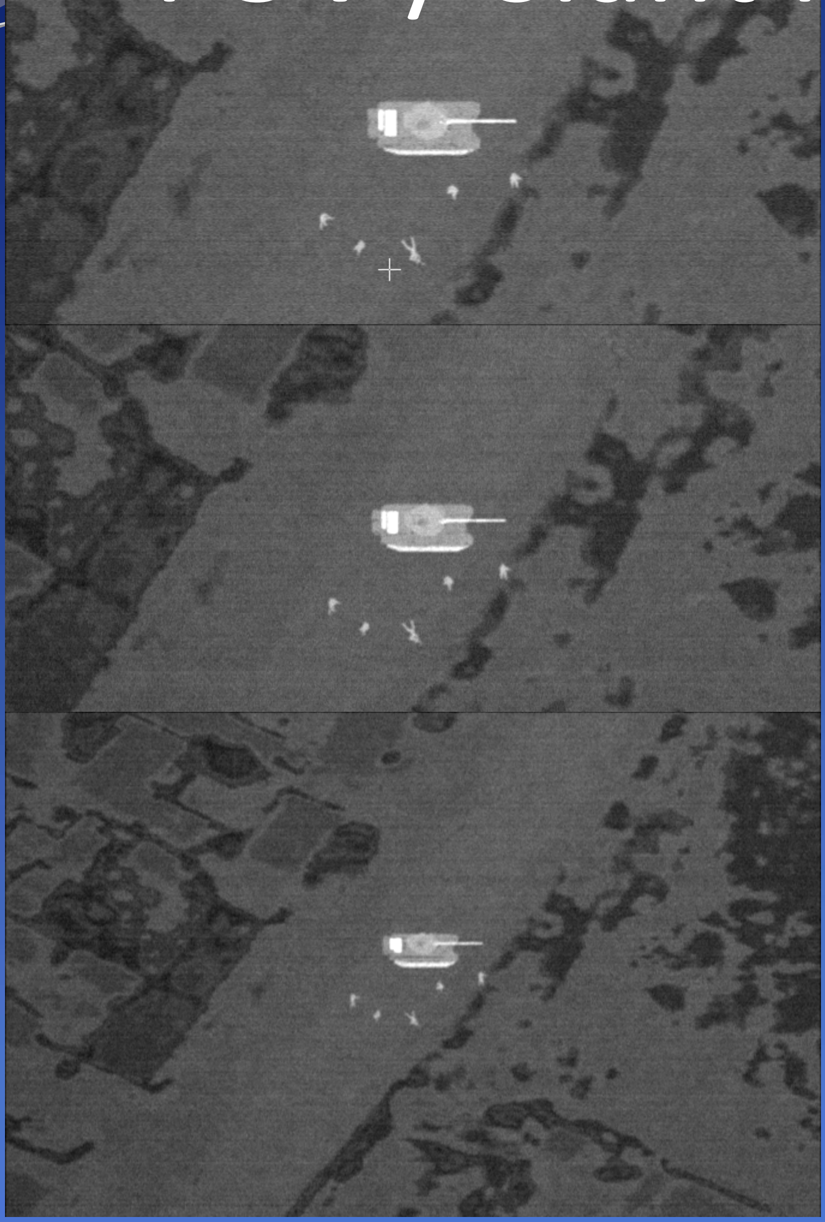
- We could use models like Johnson criteria
  - Certainly valid but not satisfying
  - Provides disconnected subjective results
- Or just build a sensor simulation and evaluate the results
  - Provided direct results - but can still be subjective as one person may make positive identification while another may not

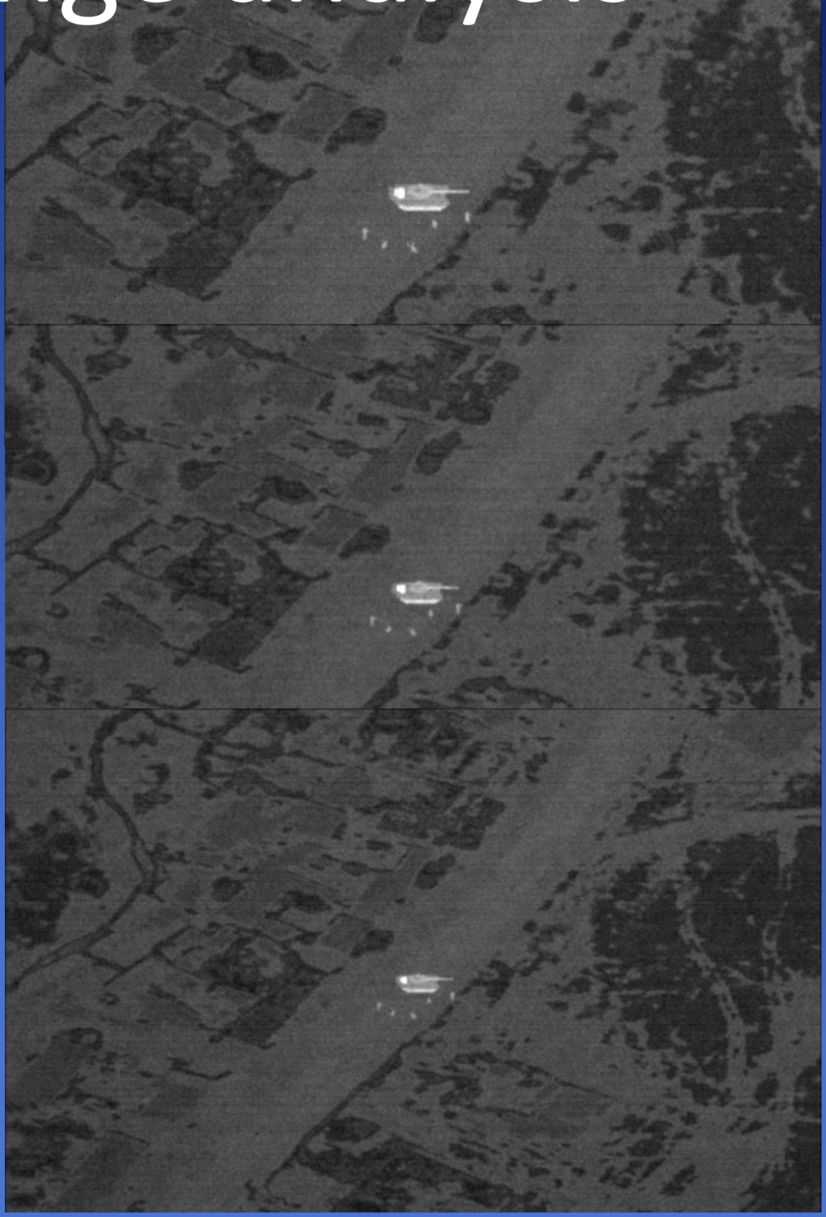
Resolution Analysis





FOV / Slant range analysis



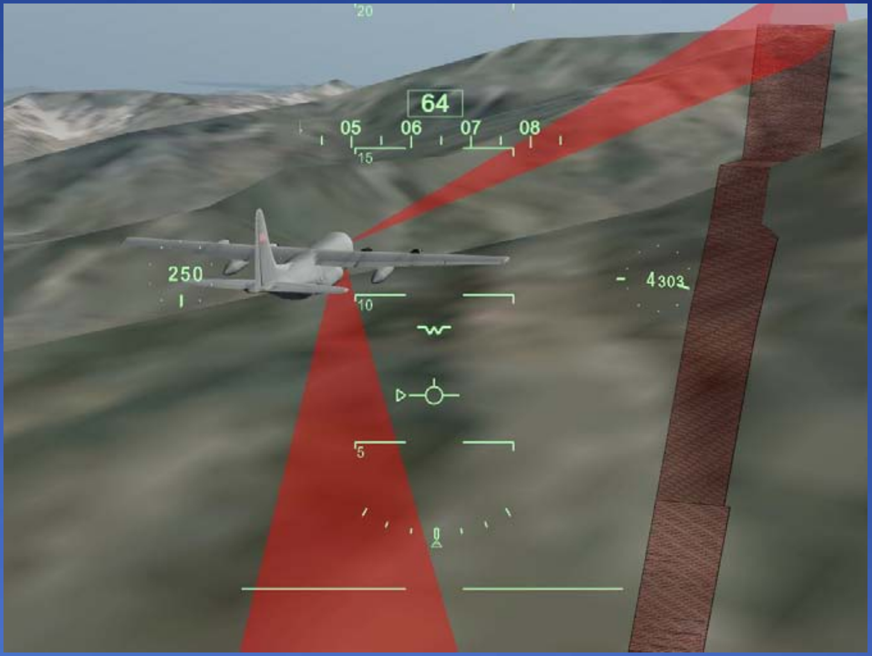


Use of MBSE for Integration

- In order to better establish the link between system simulations and operational simulations, we are investigating the use of MBSE and SysML to define the interfaces and auto-generate code
- This helps
  - Build re-useable and detailed executable design models cost effectively
  - Obtain quantitative analysis results
  - Incorporate the results into the design process

Leveraging SysML Integration

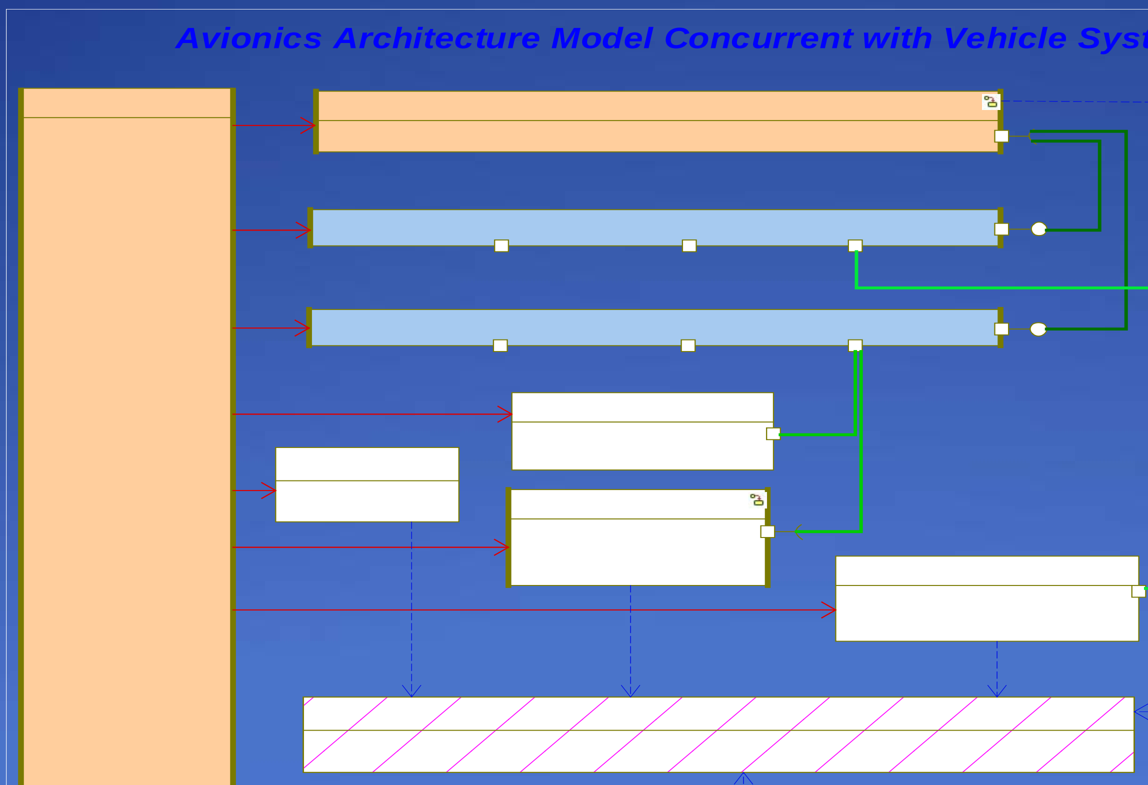
- We used the simulation environment configured with
  - Performance model of aircraft
  - Sensor models
  - Mountains, obstacles, weather, …
- To understand and refine the requirements
- To understand design constraints
  - Aircraft performance
  - Radar performance
  - In specific operational scenarios



Aircraft with radar altimeter and terrain detection radar

Integration of a 1553 Bus with a Terrain Following Simulation

…, and integrated with Simulation



… behavior defined by state charts, uses message table, with statistical assumptions about performance

Conclusions

- The integration of physics based simulations within an operational simulation can be practical
- Building and assembling models, executing distributed simulations, collecting data, and performing analysis within an integrated environment is relatively inexpensive.
- Leveraging an MBSE approach simplifies the creation of an executable architecture and reusable frameworks