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Software for Space, Defense & Intelligence

NDIA Systems Engineering Conference - 2013

M&S Applied to Improved Test Planning & Analysis
Methods in the DT & OT Execution Phase

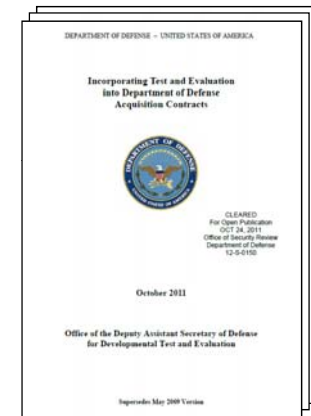
Oct 30, 2013

DOD, AT&L, DTE, DOT&E Policy Directives



Current mandates from offices of: DOT&E & DT&E/TRMC

- Smarter Test Planning methods - Scientific Test and Analysis Techniques (STAT)
 - Design of Experiments
 - Other M&S and Statistical based methods
- DAG directed use of M&S in T&E
- Initiatives to push OT and DT considerations to the beginning stages of systems requirements development
- Initiatives to perform OT as early in the DT cycle as possible
- TRMC initiative - Identify high-payoff areas for potential savings



DoDI 5000.2

DoDI 5000.2; Enclosure 5

- **ES.1** - The PM, in concert with the user and test and evaluation communities, shall coordinate developmental test and evaluation (DT&E), operational test and evaluation (OT&E), LFT&E, family-of-systems interoperability testing, information assurance testing, and modeling and simulation (M&S) activities, into an efficient continuum, closely integrated with requirements definition and systems design and development. The T&E strategy shall provide information about risk and risk mitigation, provide empirical data to validate models and simulations, evaluate technical performance and system maturity, and determine whether systems are operationally effective, suitable, and survivable against the threat detailed in the System Threat Assessment.
- Adequate time and resources shall be planned to support pre-test predictions and post-test reconciliation of models and test results, for all major test events.
- **ES.3.1** - Projects that undergo a Milestone A decision shall have a T&E strategy that shall primarily address M&S, including identifying and managing the associated risk, and that shall evaluate system concepts against mission requirements.
- **ES.4.7** - Appropriate use of accredited models and simulation shall support DT&E, IOT&E, and LFT&E.

DAG – Chap 9 – T&E

From Defense Acquisition Guidebook – Chapter 9 – Test & Evaluation – May 2010

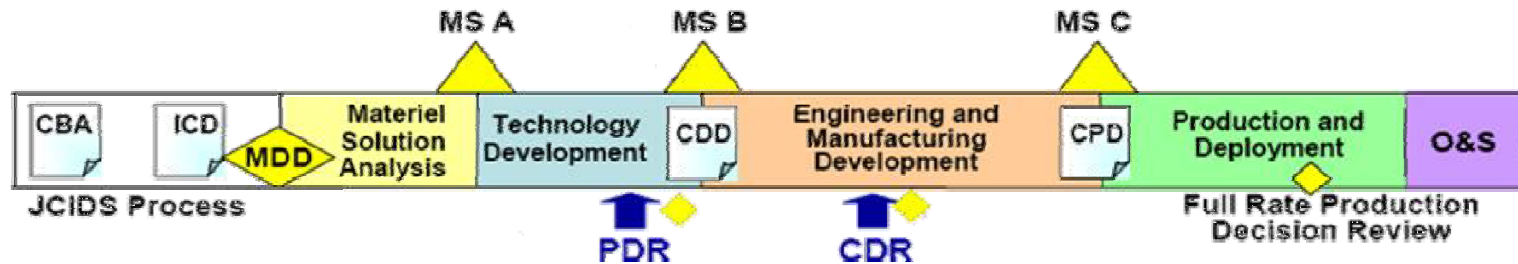
- For T&E, the appropriate application of M&S is an essential tool in achieving both an effective and efficient T&E program.
- T&E is conducted in a continuum of live, virtual, and constructive environments.
- DoD Components have guidelines for use of M&S in acquisition, especially T&E. These guidelines are intended to supplement other such resources.
- The program manager should have an M&S strategy to the T&E Working-level Integrated Product Team (T&E WIPIT) that develops the program's M&S strategy that should be documented in the program's Systems Engineering Plan and the Test and Evaluation Strategy Test and Evaluation Master Plan. Some DoD components require planning for M&S to be documented in a separate M&S Support Plan.
- This M&S strategy will be the basis for program investments in M&S.
- M&S should be planned for fully across the program's life cycle, modified and updated as required to ensure utility as well as applicability to all increments of an evolutionary acquisition strategy.
- A program's T&E strategy should leverage the advantages of M&S.
- M&S planning should address which of many possible uses of M&S the program plans to execute in support of T&E.
- Models and simulations can be used in planning to identify high-payoff areas in which to apply scarce test resources.
- References using M&S can help identify cost-effective test scenarios and reduce risk of failure.
- During conduct of tests, M&S might provide adequate surrogates to provide stimulation when it is too impractical or too costly to use real world models. This is particularly likely for capability testing or testing to equate that is part of a systems-of-systems, or for testing that requires unique loads or in extreme server modes, or for testing for system's responsibility.
- M&S can be used in post-test analysis to help provide insight, and for interpolation or extrapolation of results to untested conditions.

DOT&E TEMP Guidebook

DOT&E TEMP Guidebook – Feb 27, 2012

- **M&S for Test Planning, Pretest Predictions, and Evaluation - Guidance**
 - The Modeling and Simulation (M&S) section should address how M&S will be employed in the overall test strategy and how the M&S will be verified, validated and accredited (VVA). Specifically, the TEMP should identify M&S expected to be used, the intended use, any data requirements, the test objectives to be addressed and/or how test scenarios will be supplemented with M&S, the planned VVA effort, and who will conduct the VVA effort (ref. DoDI 5000.8). The TEMP should list any specific test events required for VVA of the M&S. The resources for the specific test events will be included in Part II.
 - M&S is used throughout developmental, operational and live fire testing. M&S can support evaluation of requirements, trade studies, test planning, pre-test predictions, evaluation of system performance, and other uses. It includes a broad set of tools including spreadsheet models, high-fidelity digital models, and hardware and computer in the loop facilities.
 - **M&S for Test Planning and Prediction**
 - M&S is frequently used in test planning and pre-test predictions. M&S will be used as a basis for data emerging from test and prediction. Description for it to use. What level will have pre-test prediction? VVA pre and post test will be based on M&S.
 - **M&S for Evaluation**
 - Another common intention is that M&S can support the evaluation of system performance. The TEMP should describe how M&S will be used as a basis for evaluating any program against an external or internal criteria or to determine any Critical Operational Performance (COP) for specific systems. It includes, or references, results from the testing of the system to the degree of confidence M&S, VVA or other means to be achieved through M&S. Why M&S being used for safety/criticality pre-test testing?

STAT in the Execution Phase



Planning

Test Planning

- Gross system trades
- Detailed system trades
- Process knowledge
- Selection of factors
- Sensitivity of factors
- Design of Experiments
- Other statistical methods

Execution

Detailed Test Planning

- Test-point requirements
- Test-point resources
- Route planning
- Sequencing and choreographing vehicles and resources

Test Execution

- Quick-look reconstruction
- Measures of performance assessment
- Test-point attainment verification
- Post-test data package visualization supplement

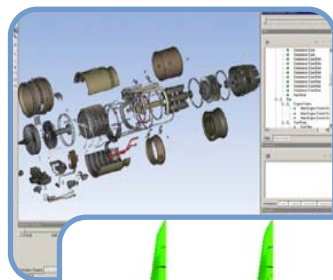
Post Test Analysis & Verification

- **Increasing complexity of mission systems**
- **Increasing mission software complexity**
- **Budget constraints (living with overruns to date)**
- **Low test-point density ?**
- **High re-fly rates ?**
- **Challenge of achieving test-point parallelization**
- **Challenge of communicating capability attainment along with test-point completion**
- **Post-test facing ever increasing data quantity**
- **Verification complexity**

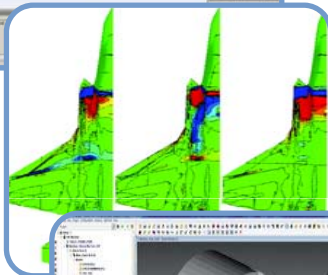
T&E Compared to Other Eng Disciplines



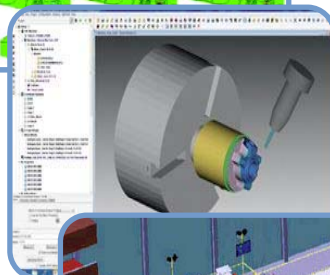
- Product life-cycle & engineering disciplines taking advantage of well established computer aided engineering (CAE) methods



Design



Analysis



Manufacturing



Assembly



Training



Operations



Maintenance

T&E Execution Phase Detailed Planning Tools



- Great opportunity in the T&E discipline to reap similar benefits by using CAE-like methods in test-event design, execution & post-flight analysis

ID	Label	Expected Results	Pass
1	Verify Test Plan		
2	Verify Test Plan		
3	Verify Test Plan		
4	Verify Test Plan		
5	Verify Test Plan		
6	Verify Test Plan		
7	Verify Test Plan		
8	Verify Test Plan		



■ Traditional methods

- Excel
- PowerPoint
- Word
- Custom MATLAB
- “Planes-on-sticks”
- “Flying wrist watches”



- **“Planes-on-a-stick” is a common method for detailed mission systems test plan route design**



- **Available aircraft & condition of systems**
- **Readiness of software block version**
- **Sequencing of subsystem tests for parallelization**
 - Modes, targets, emitters, integrated operation, ...
- **Choreographing of multiple aircraft tests**
 - Aircraft, targets, emitters, operating conditions
- **Sequencing to minimize fuel usage and tanker use**



Detailed Test Event Planning – closer look



Test Plans



Test-point details



Requirements
Objectives
Resources
Evaluation Criteria
MOPS
...



Test Cards



Test point details
Requirements
Objectives
Resources
Evaluation Criteria
MOPS
...

Data Links

Test point details
Requirements
Objectives
Resources
Evaluation Criteria
MOPS
...

Radar

Test point details
Requirements
Objectives
Resources
Evaluation Criteria
MOPS
...

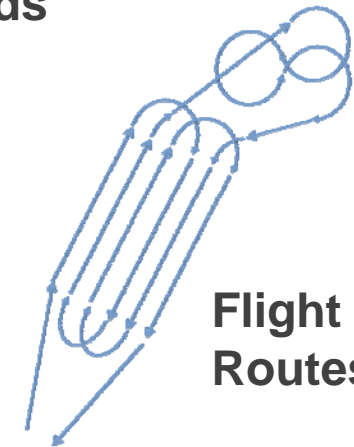
EW

Test point details
Requirements
Objectives
Resources
Evaluation Criteria
MOPS
...

EO/IR



Mission Deck Test Cards



Flight Routes

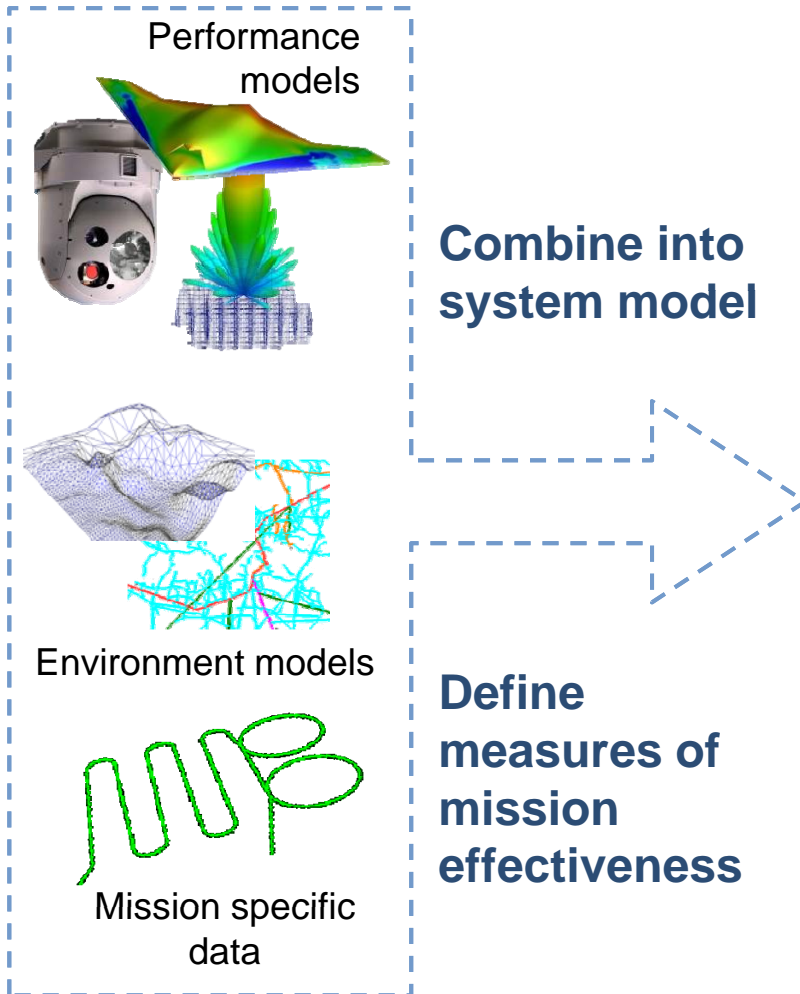
How can we:

- Ensure test-point success?
- Fly more test-points per flight?
- Reduce planning cycle time?
- React quickly to evaluate anomalies?
- Capitalize on “white-space” effectively?
- Streamline communications?
- Reduce program test costs?

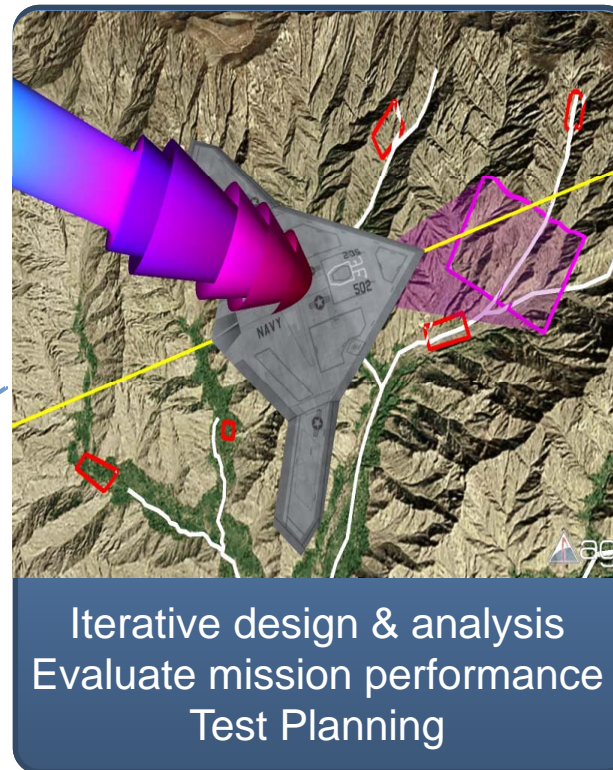
M&S for Interactive Detailed Test Design



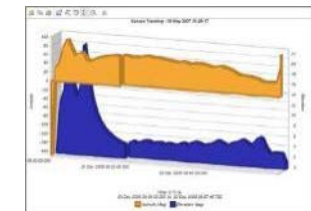
**Build/import models
Characterize system**



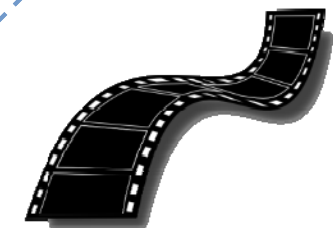
**Run simulations and
evaluate performance**



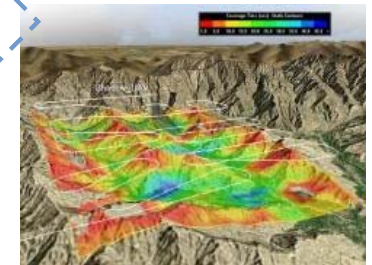
**Convey
results**



Reports & graphs

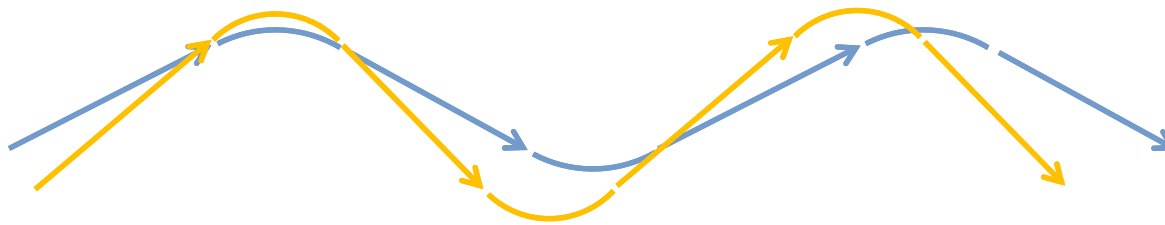


Video



Mission results or
status

- Which route is “better” ?



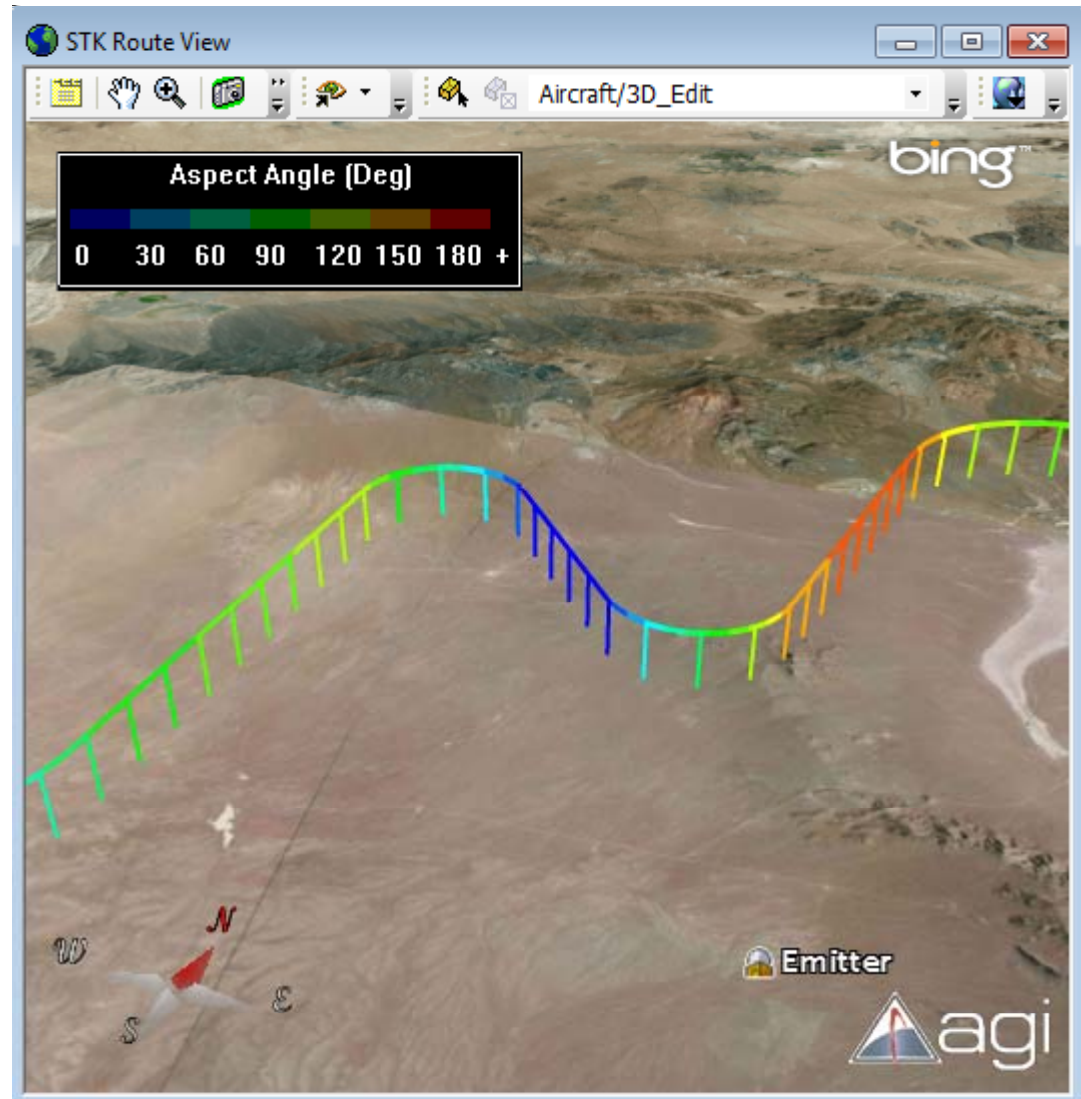
Comm emitter

Test Event Route Assessment

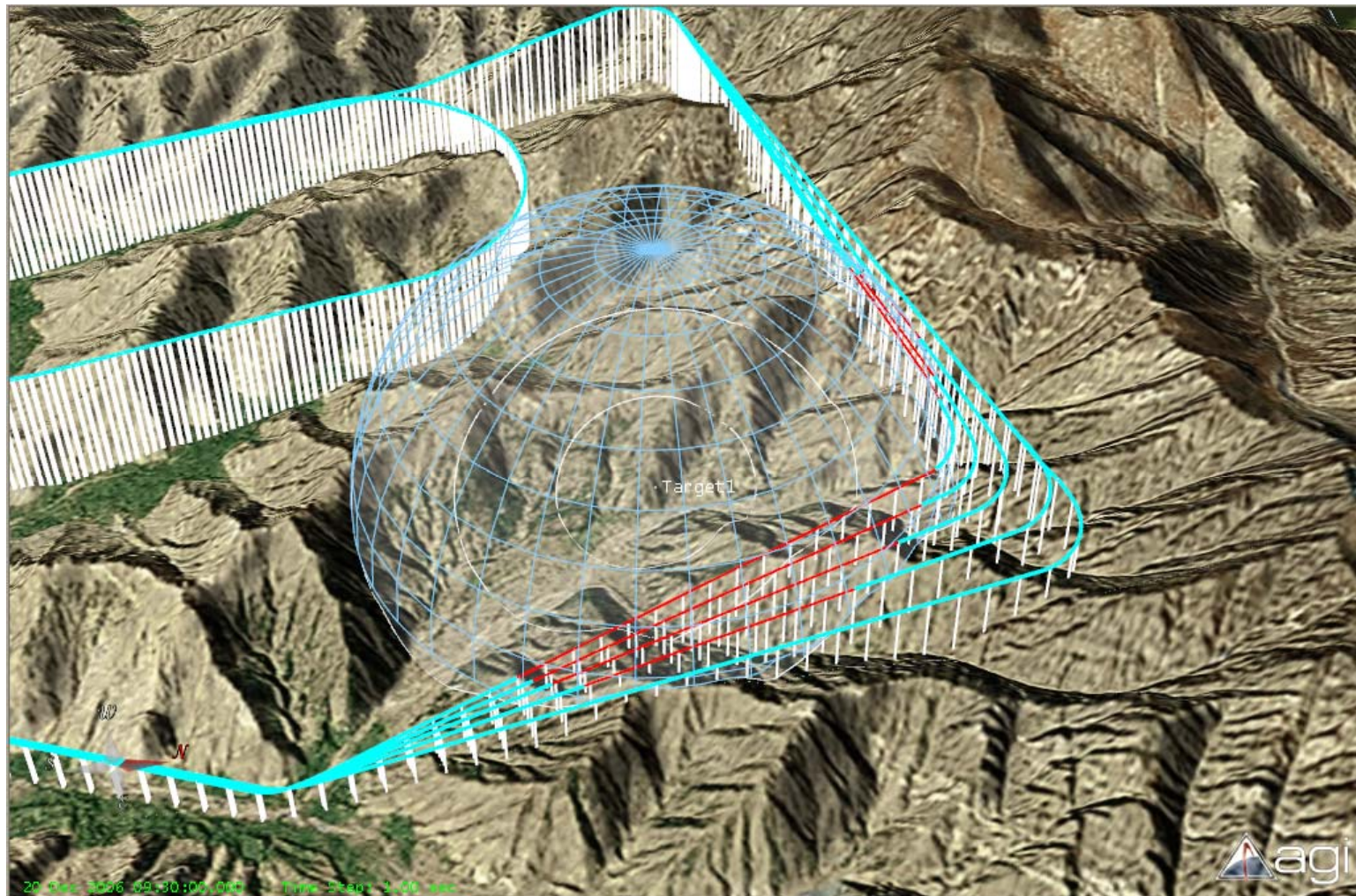


■ Interactive route design

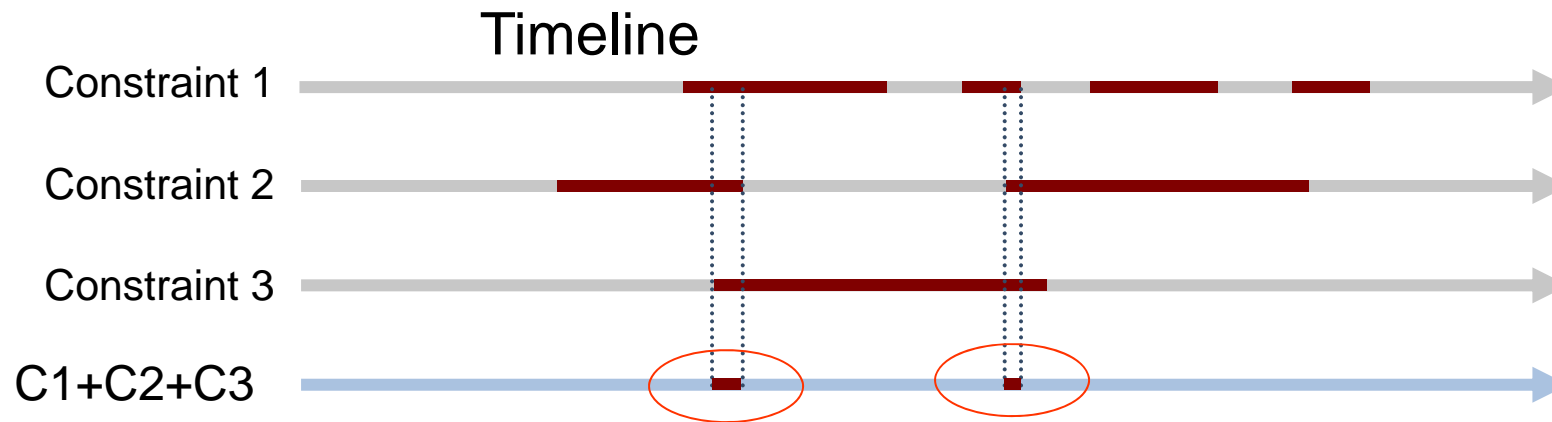
- Fuel remaining
- Aspect angle
- Comm performance
- Telemetry assurance
- Dynamic geometry
- Lighting directionality
- RF directionality
- Safety of flight
- Multi-ship choreographing
- Number of test-points



Route Design / Optimization

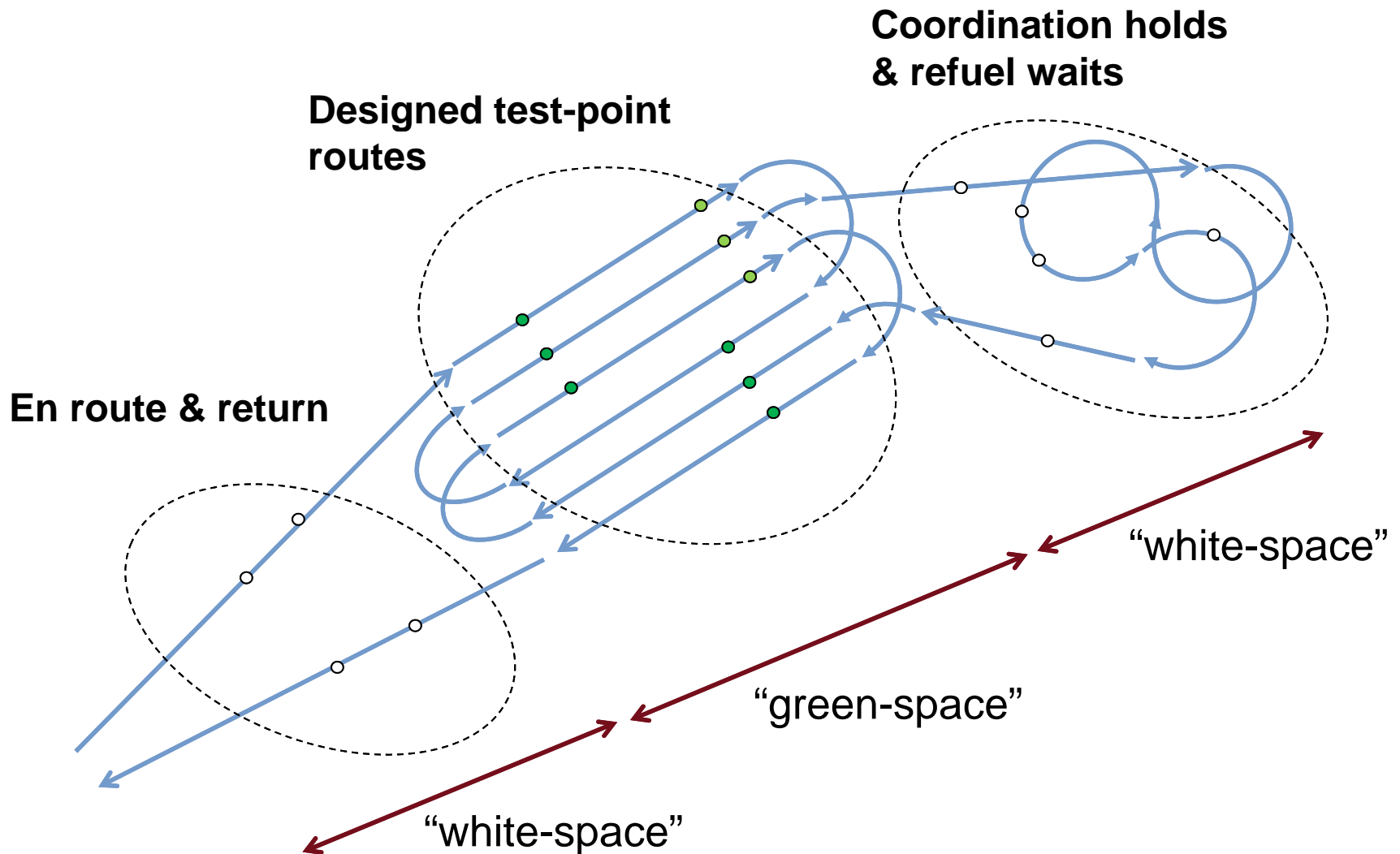


Multi-Constraint Prediction



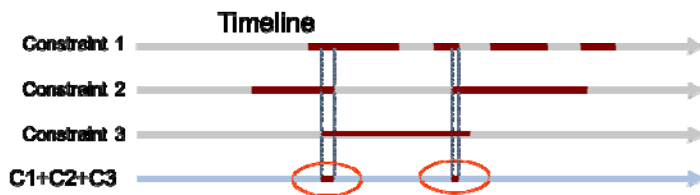
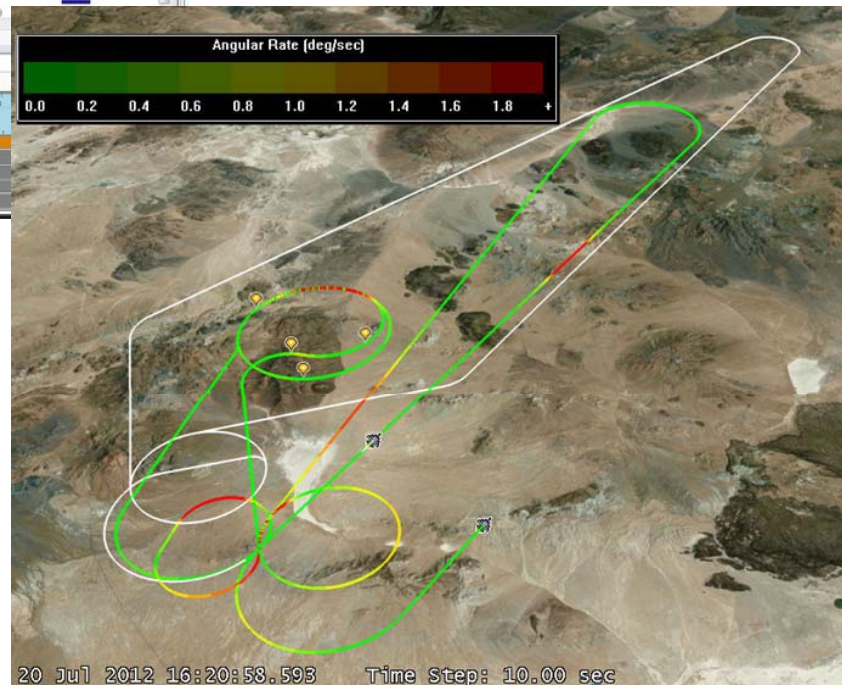
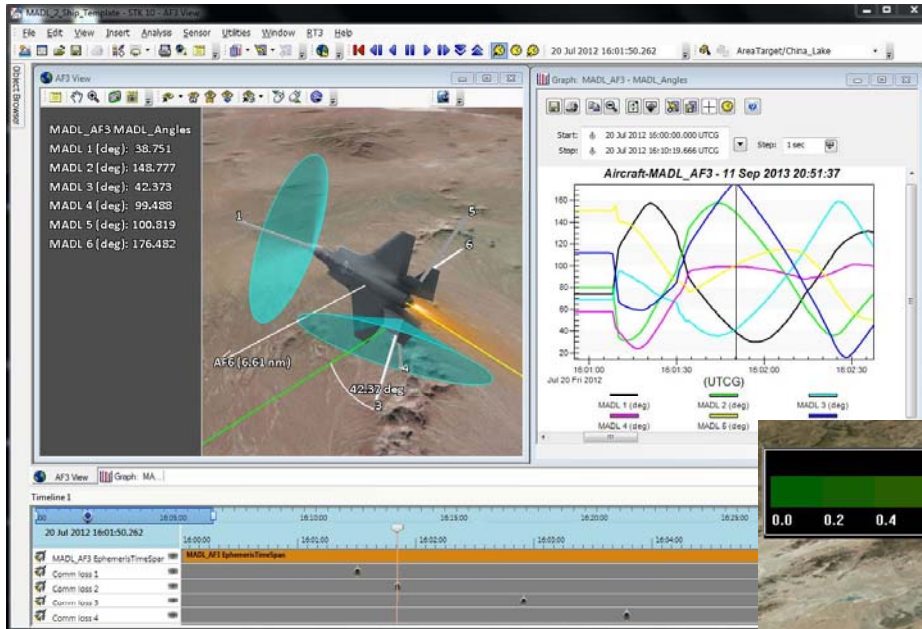
- **Determination of “multi-constraint” satisfaction times**

Increasing Test-point Density per Flight



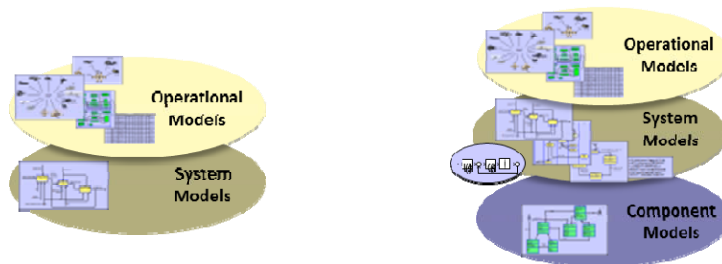
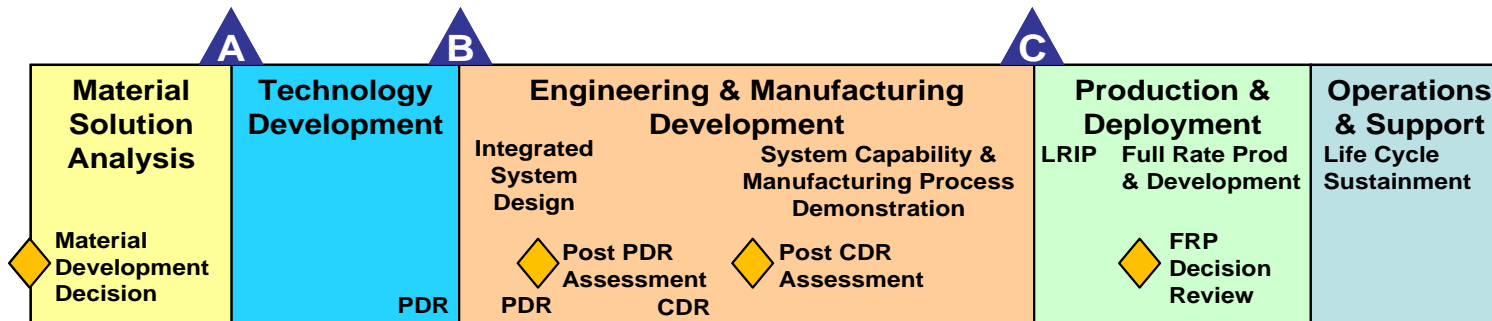
- **Quick import of telemetry data**
- **Colorized routes based on:**
 - Various operating parameters
 - Various performance parameters
 - AGI generated analytical parameters
 - Events
- **Markers on routes or ground (static and time-based)**
- **Supplemental composable routes to assess variations on effectiveness**
- **Analytically derived supplemental visual aides**
 - Vectors, angles, range lines, head-up data displays, parameter graphs
- **Flight playback (quick forward/reverse scroll)**

Post-Flight Analysis



- **How do you do this?**
- **Is it too late for my program to do this?**
- **How much time does this take?**
- **How detailed do my models need to be?**
- **What is the implementation cost?**
- **Is it worth the effort?**

MBE Initiation & Evolution – (When?)

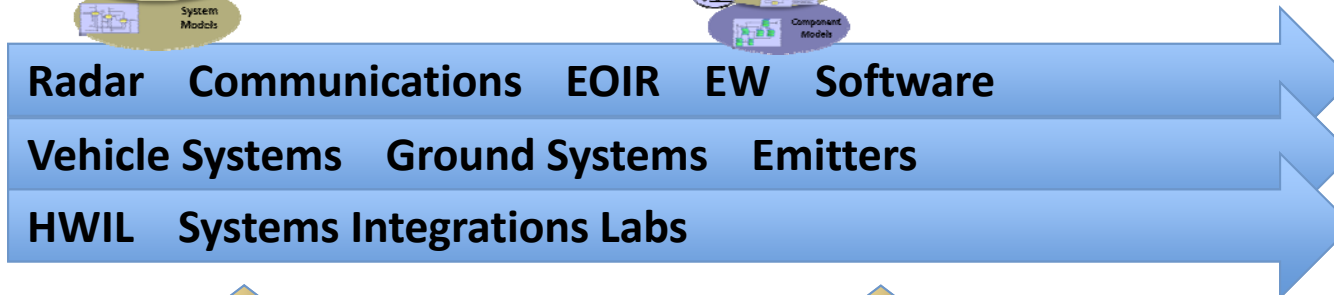
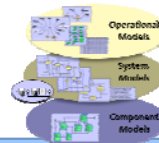
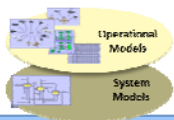
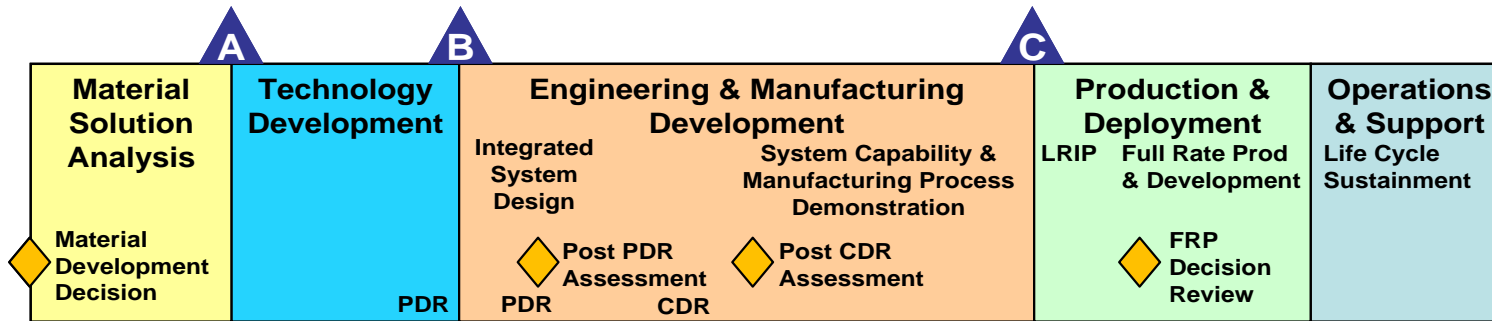


Radar Communications EOIR EW Software

Vehicle Systems Ground Systems Emitters

HWIL Systems Integrations Labs

MBE Initiation & Evolution – (When?)



↑

MBE planned early and carried through to T&E

↑

Systems modeling specific to T&E Execution Phase

T&E Tool Kit Formulation Example – (How?)



Program Test Requirements

- Air Veh performance description
- Physical 3D model
- sensor attach points
- xmtr and rcvr attach points
- Radar spec's description
- EOIR sensors specs
- Comm antenna's specs
- Comm & sensor operating constraints
- Telemetry descriptions
- Data descriptions
- Sensor operating modes & constraints
- Ground handling comm needs
- Typical flight paths (takeoff to op alt)
- Operating flight paths, and comm needs
- Multi-use of sensors and resource loading
- Active sensor targeting CONOPS
- Operating procedures wrt wind conditions
- Payload & bus loading & constraints
- Imaging modes relative resource loading
- Sensor use rules –vs- flight conditions



M&S Configurations

STK objects:
 Vehicle model
 Solid model
 Sensors
 Antennas



AMM changes

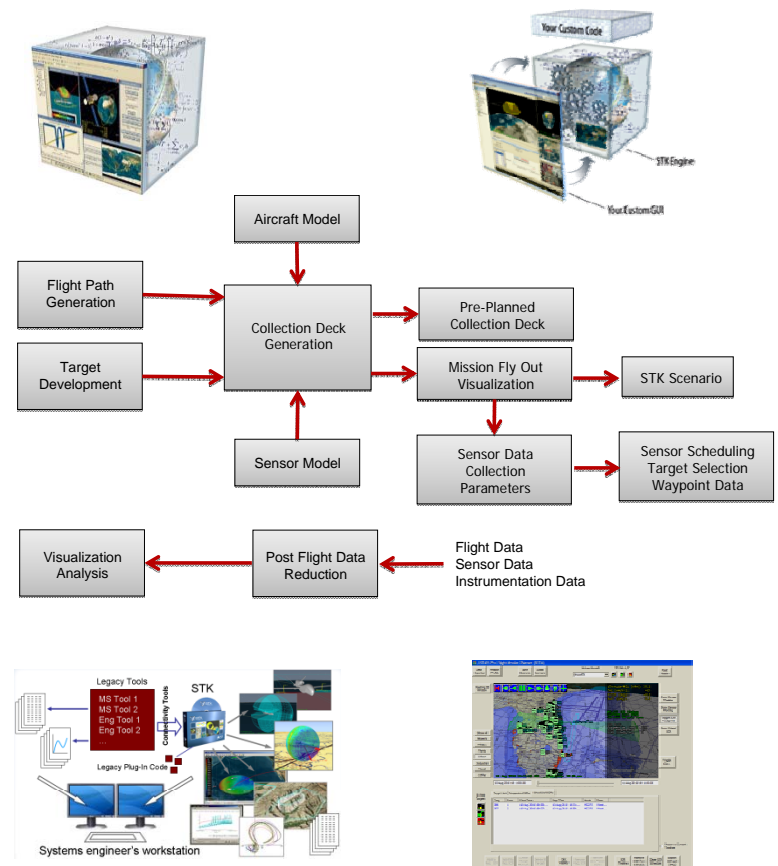
STK data readers

STK system trades

Custom work-flow UIs:

Target scheduling
 Comm link assessment
 Test points assessment
 ...

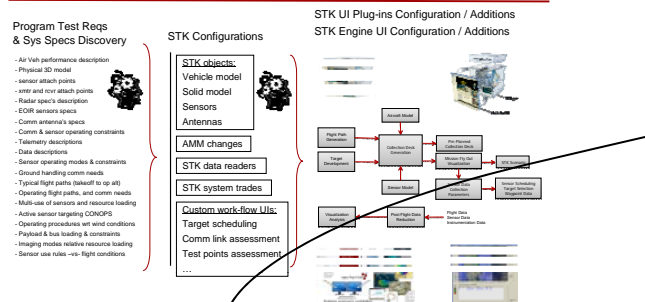
Specifically Configured M&S Tool Set for T&E Execution



Program Specific Implementation – (How?)

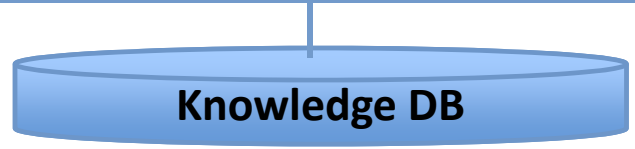
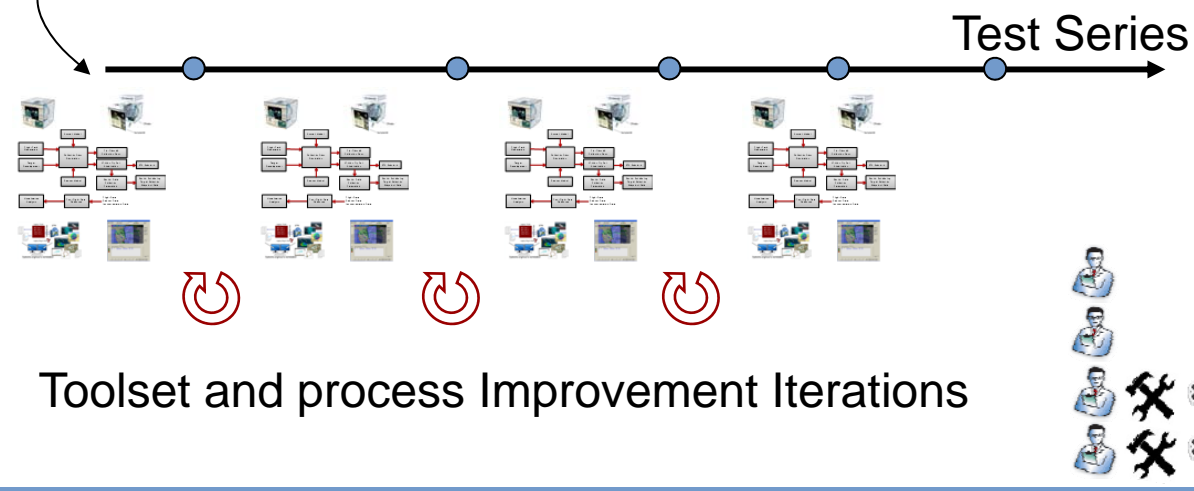


MBE Development for Test Planning



Design/Planning Tool Development

- STK Configuration
- System/Subsystem Characterization
- Workflow Specific UI Development
- Implementation & Iterative Improvement



Summary of Proven ROI Potential – (Why?)



▪ Efficiency of Test Force operations

- Reduced time for test-force process elements
 - Test-plan process, test-card development process, post-test process \$\$
- Shortened and more effective meetings, pre-flight reviews, etc. \$

▪ Effectiveness and efficiency of test flights

- Improved robustness of test-card designs – validation against test plan objectives \$
- Increased number of test-points per flight \$\$\$\$\$
- Improved scheduling of refuel operations \$\$
- Positive overall test-force flight schedule impact \$\$
- Enabling the complicated choreographing of four-ship flights \$\$\$

▪ Communications within the program and with customer

- Illustration of complex concepts and issues at all stages of the execution T&E lifecycle \$
- Enable greater collaboration \$
- Shortened and more effective meetings, pre-flight reviews, etc. \$\$
- Positive impact to test-point sign-off activities \$\$

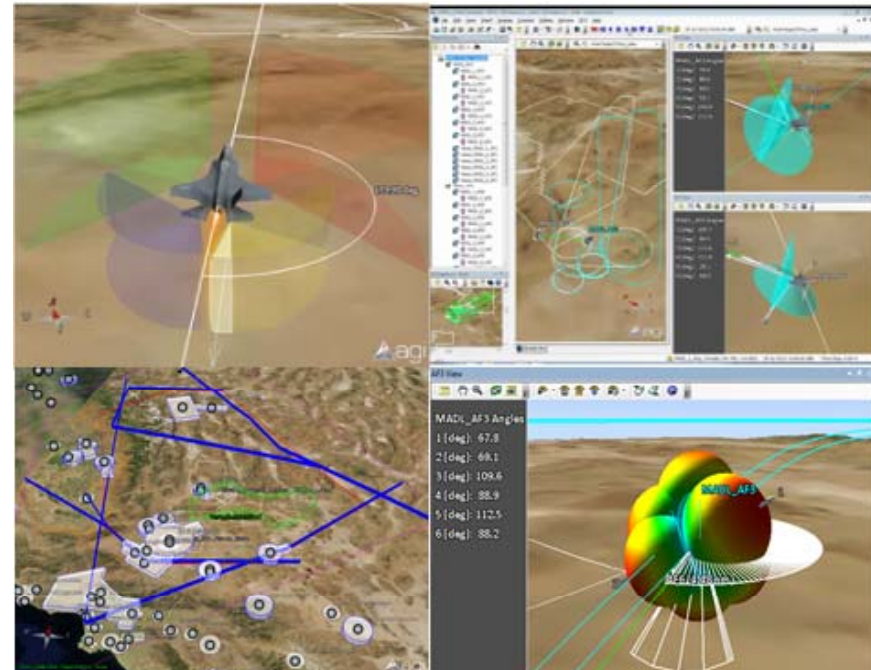
▪ Flight safety

- Rich material enabling added insight to pre-flight briefings
- Robust treatment of multi-ship flight choreographing and event scheduling

F-35 Flight Testing - Case Study

Problem: Flight test planning is largely manual, relying on talent and intuition of experienced engineers.

Solution: Use STK MS&A Environment to improve flight test efficiency, effectiveness and repeatability.



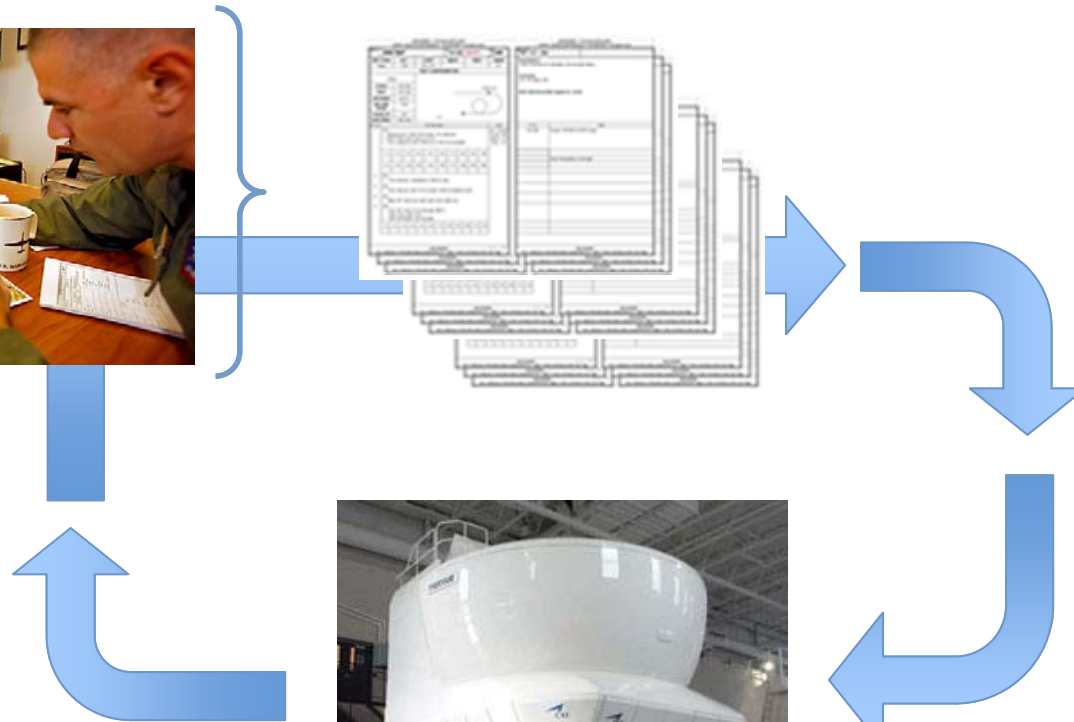
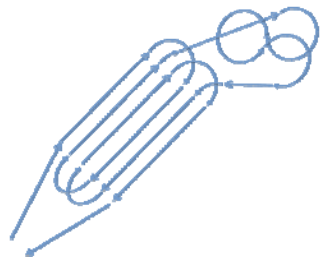
Outcome: Proof-of-Concept demonstrated improved flight test plans, designs and analysis for mission systems testing.

**Accelerated & optimized test planning,
Increased flexibility in test event execution and
Faster post-test analysis**

Optimizing Simulator Time – (Why?)



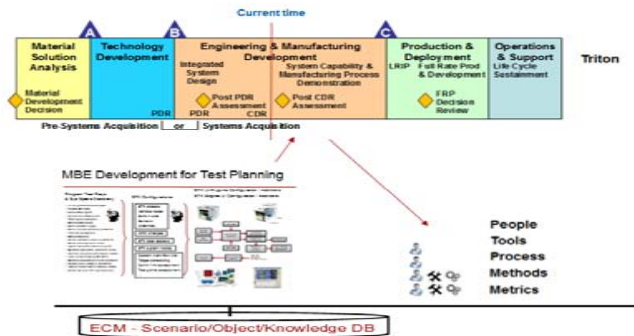
Mission Deck Test Cards



New Metrics Factored into Test Plan Cost & Schedule Forecast – (Why?)



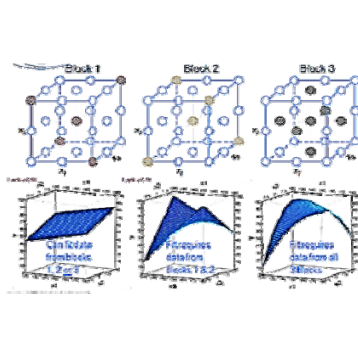
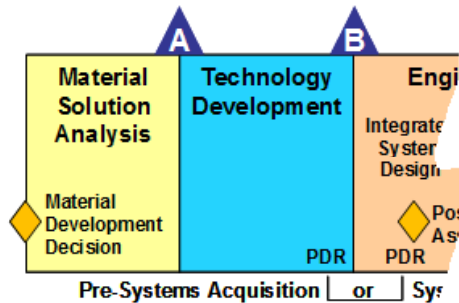
Execution Phase Program



New improved metrics

- Test-points per flight
- Re-flight rate
- Practitioner's efficiency

New Start Program



STAT/DOE yields "right sized" Test Plan

New metrics factored in to plan

Improved Cost & Schedule Forecast

- **Nimble M&S can be effectively used in test execution**
- **Methods can usually be applied at any point in the cycle given the significant ROI potential**
- **Benefits attained with requisite level model fidelity**
- **COTS tools can enable and accelerate implementation**
- **New methods and metrics can be applied to improve future programs**

Questions?