

# Development, Validation and Implementation Considerations of a Decision Support System for Unmanned & Autonomous System of Systems Test & Evaluation

Test Week 2010

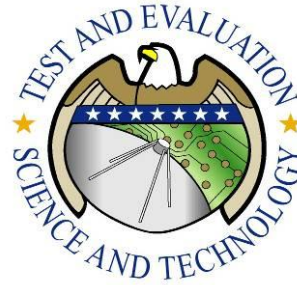
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16 June 2010

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<http://mit.edu/patframe>

# Sponsors

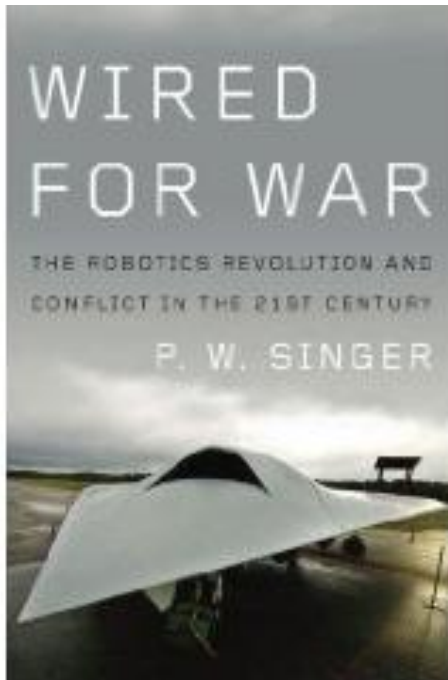
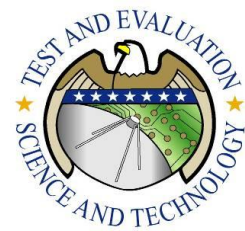


# Desired Transition Partners

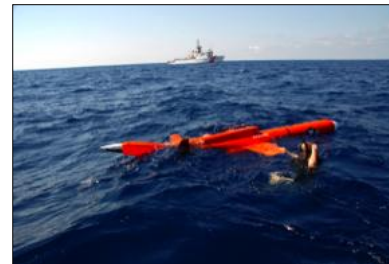




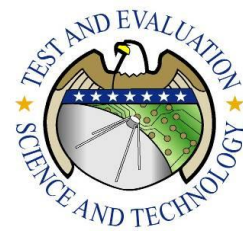
# The Challenge: Science Fiction to Reality



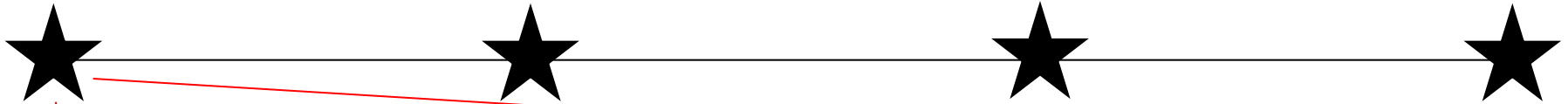
“You will be trying to apply international law written for the Second World War to *Star Trek* technology.”



Singer, P. W., *Wired For War: The Robotics Revolution and Conflict in the 21st Century* (Penguin, 2009)



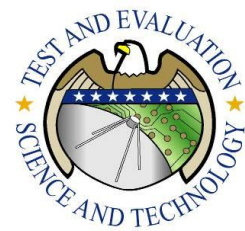
# Scoping the Challenge



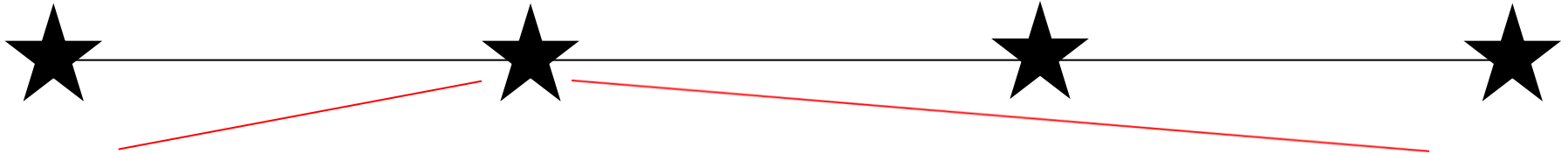
## **2008 Defense Science Board in Regards to Systems of Systems**

- Findings
  - Acquisitions process generally tailored to the development of individual systems, not systems of systems (SoS)
  - Some mission critical testing of SoS capability areas often accomplished for the first time in OT or when deployed
  - Testing all the SoS requirements of all the systems is impossible
  - SoS requires better approaches to requirements definition, resources, and acquisition processes, including judicious T&E
- Recommendations
  - Formulate alternative strategies to adapt current requirements, acquisition and funding processes to enable timely, efficient, and effective T&E of SoS capabilities

Office USD(AT&L), "Report of the Defense Science Board Task Force on Developmental T&E", May 2008



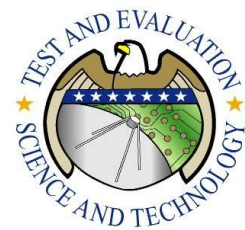
# Scoping the Challenge



## **FY2009-2034 Unmanned Systems Integrated Roadmap**

- Unmanned Systems Investment Areas
  - Reconnaissance and Surveillance
  - Target Identification and Designation
  - Counter-Mine and Explosive Ordinance Disposal
  - Chemical, Biological, Radiological, Nuclear (CBRN) Reconnaissance
- Unmanned Systems T&E Goal
  - Ensure test capabilities support the fielding of unmanned systems that are effective, suitable and survivable

Office USD(AT&L), "FY2009-2034 Unmanned Systems Integrated Roadmap", 2009

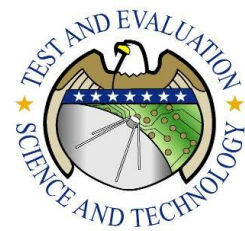


# Scoping the Challenge

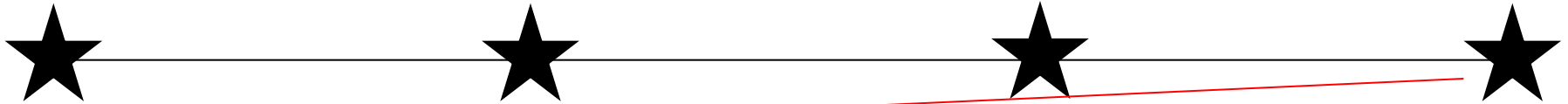


## *USD(DOT&E) T&E Initiatives Memo – Nov 2009*

- New Initiatives for future testing
  - Field new capability rapidly
  - Engage early to improve requirements
  - Integrate developmental, live fire, and operational testing
  - Substantially improve suitability before Initial Operational Test & Evaluation (IOT&E)



# Scoping the Challenge



- **UASoS T&E Need**

- Accelerate test planning by supporting automation of current human-intensive (potentially error-prone) test planning process
- Optimize the joint mission oriented strategy by addressing and balancing multiple criteria
- Predict, detect, and adapt to undesirable emergent behavior

- **S&T Challenge**

- Perform R&D of a multi-dimensional framework for knowledge representation across UASoS
- Perform R&D to develop analyses / simulations across UASoS models
- Develop Decision Support System (DSS) prototype improving test planning

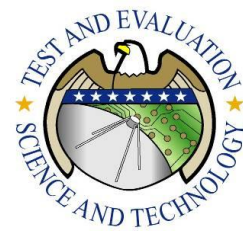


# Meeting the Challenge



- Unmanned and autonomous system of systems (UASoS) is on the horizon for DoD capabilities
- Current Test and Evaluation (T&E) structure needs to be set up to effectively handle UASoS
- TRMC awarded 3 year T&E/S&T contract to MIT, USC & UT Arlington to develop UASoS prototype T&E tool
- Prototype will enable strategic planning and prioritization of UASoS testing (risk, cost, schedule and resources)
- Prescriptive Adaptive Test Framework Decision Support System (DSS)





# PATFrame's Objective

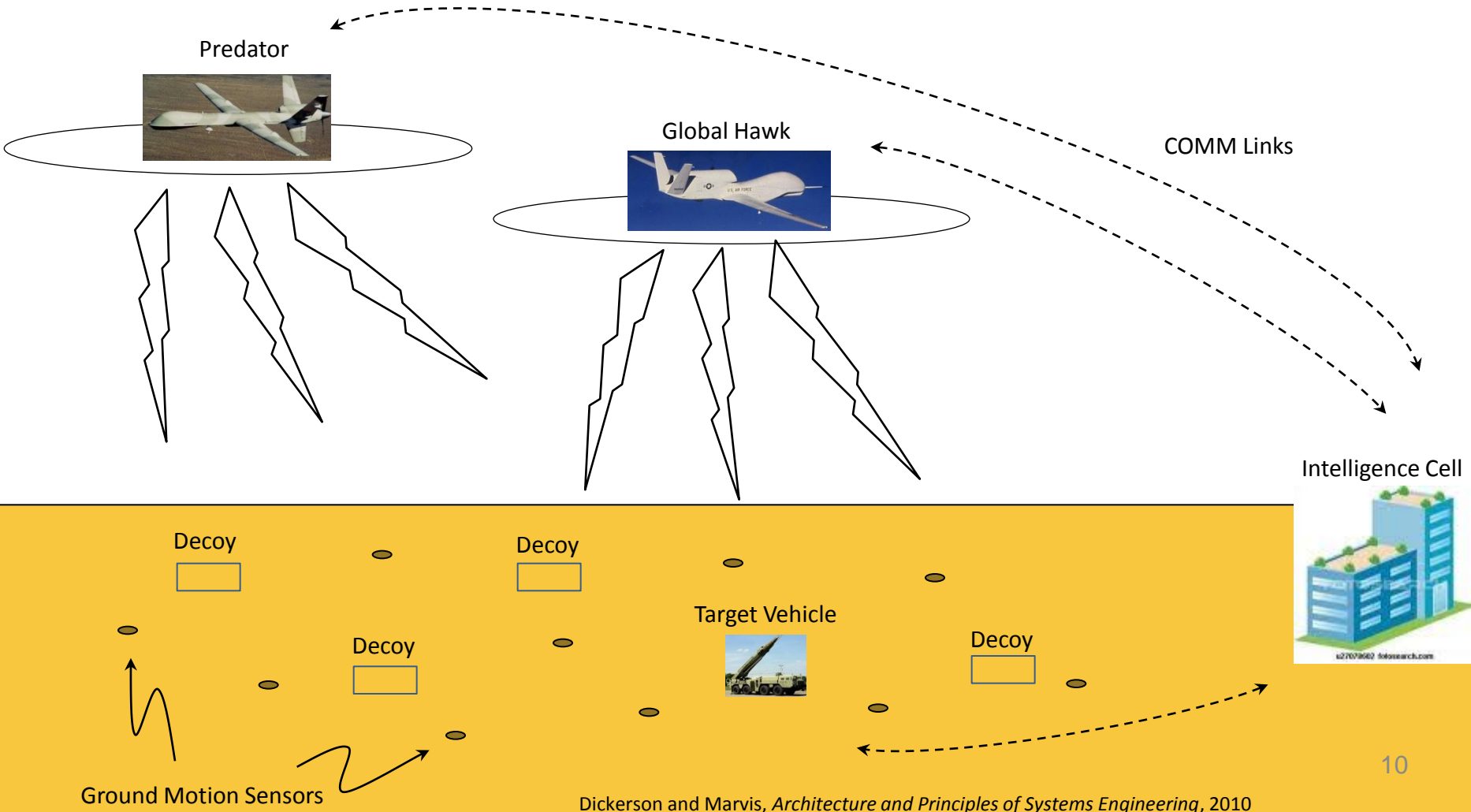
- Research and develop a technology to provide a decision support system encompassing a prescriptive and adaptive framework for UASoS Testing (Air, Land, Sea and Space)
  - The PATFrame prototype will use a software dashboard that will enable improved decision making for the UAS T&E community
  - Addresses UAST focus areas of ***Prescribed System of Systems Environments*** and ***Adaptive Architectural Frameworks***
  - Draws from experts in the following fields
    - Systems of systems
    - Test & evaluation
    - Decision theory
    - Systems engineering
    - Software architectures
    - Robotics and modeling

### Example Scenario #1 – (GH, Predator and MIUGS Sensor Testing)

- Motion sensors sense motion of the target convoy (CUE)
- Global Hawk UAV utilizes GMTI capability follow the convoy
- Predator UAV with EO capabilities can confirm target SCUD launcher
- Performs the CUE, FIND, FIX, TRACK, TARGET functions of kill-chain

### KPP's (For System Under Test – not PATFrame)

- Track missile launcher target vehicle for the maximum amount of time possible
- Identify target vehicle amongst other vehicles with XX% confidence
- Geospatial accuracy of the vehicle within +/- 1 ft
- Quality of communications equipment

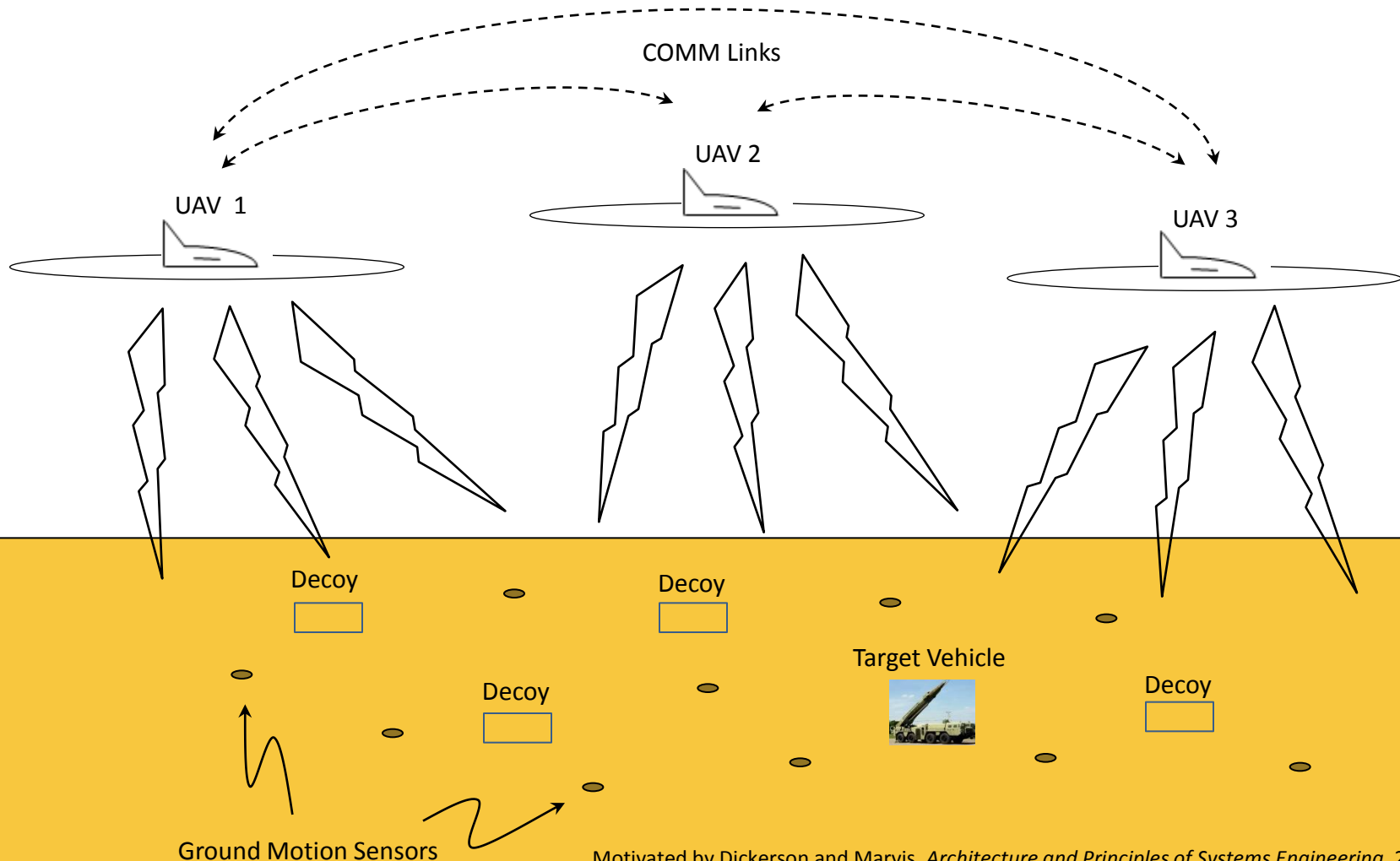


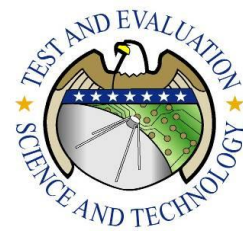
### Example Scenario #2 – (Futuristic UASoS Testing)

- UAVs acting as SoS with near full autonomy tracking target vehicle in convoy
- Ground motion sensors cue the airborne UAVs in order to start the surveillance routine of (FIND, FIX, TRACK, TARGET)
- UAV SoS captures / synthesizes / relays information to geographically separated intelligence cell

### KPP's (For System Under Test – not PATFrame)

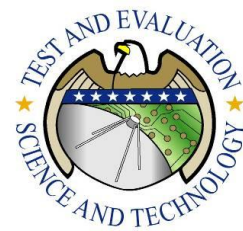
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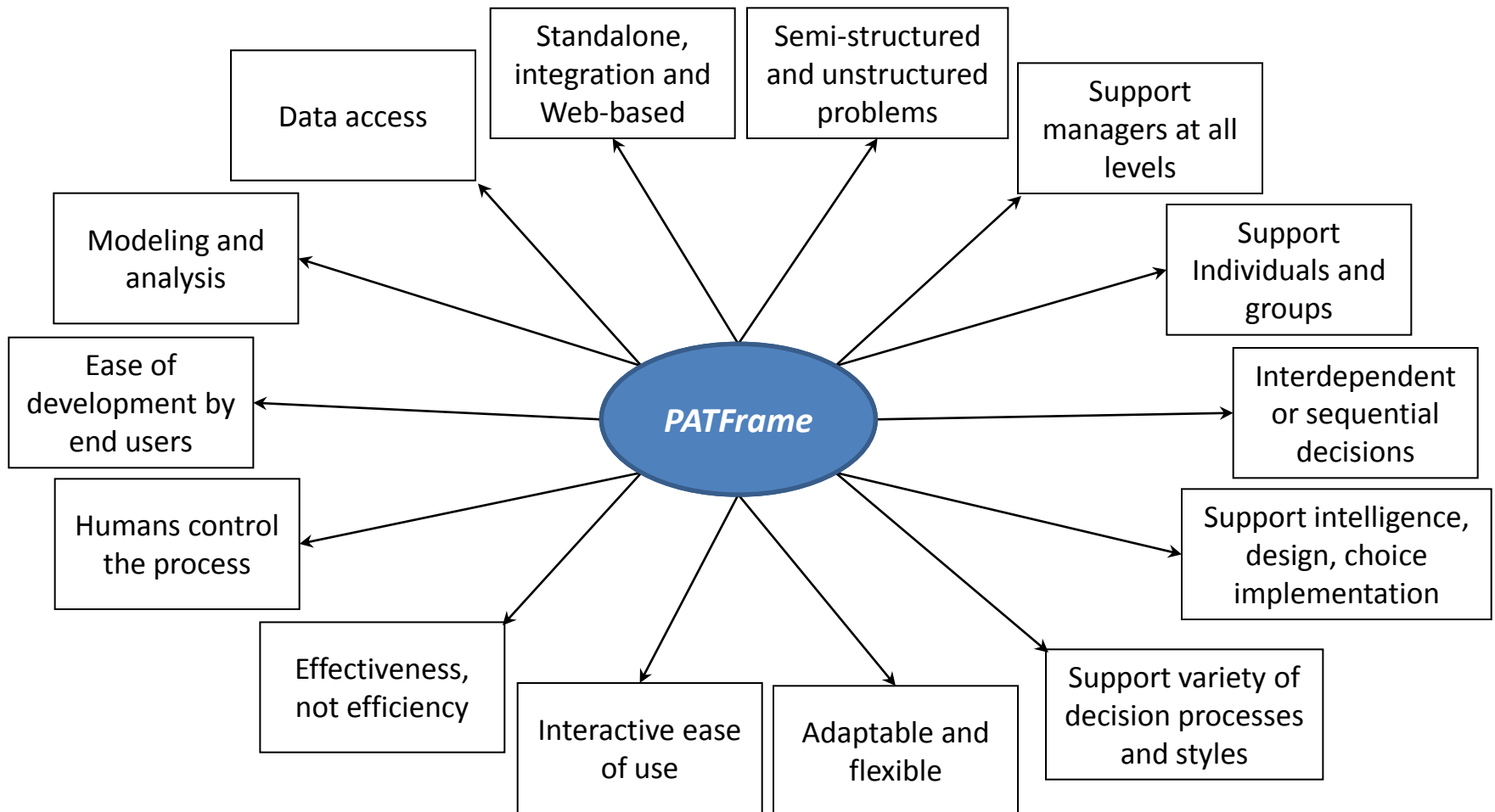


# What Use Cases Provide

- Provide insight into various test applications (threads) for PATFrame that influence design
- Representative use cases being investigated
  - Anticipate undesired behaviors during testing of UASoS
  - Allows for test prioritization using: Real Options, DOE, Value Based Testing and Cost Based Testing
  - Predict effects of autonomous behavior on “ilities”
- PATFrame applicable to all levels of UASoS T&E



# Characteristics & Capabilities of Decision Support Systems



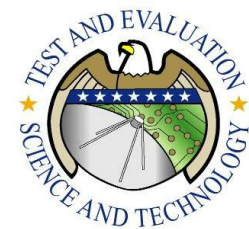
Turban, et al, *Decision Support and Business Intelligence Systems* (2007)



T&E Needs

# Project Description

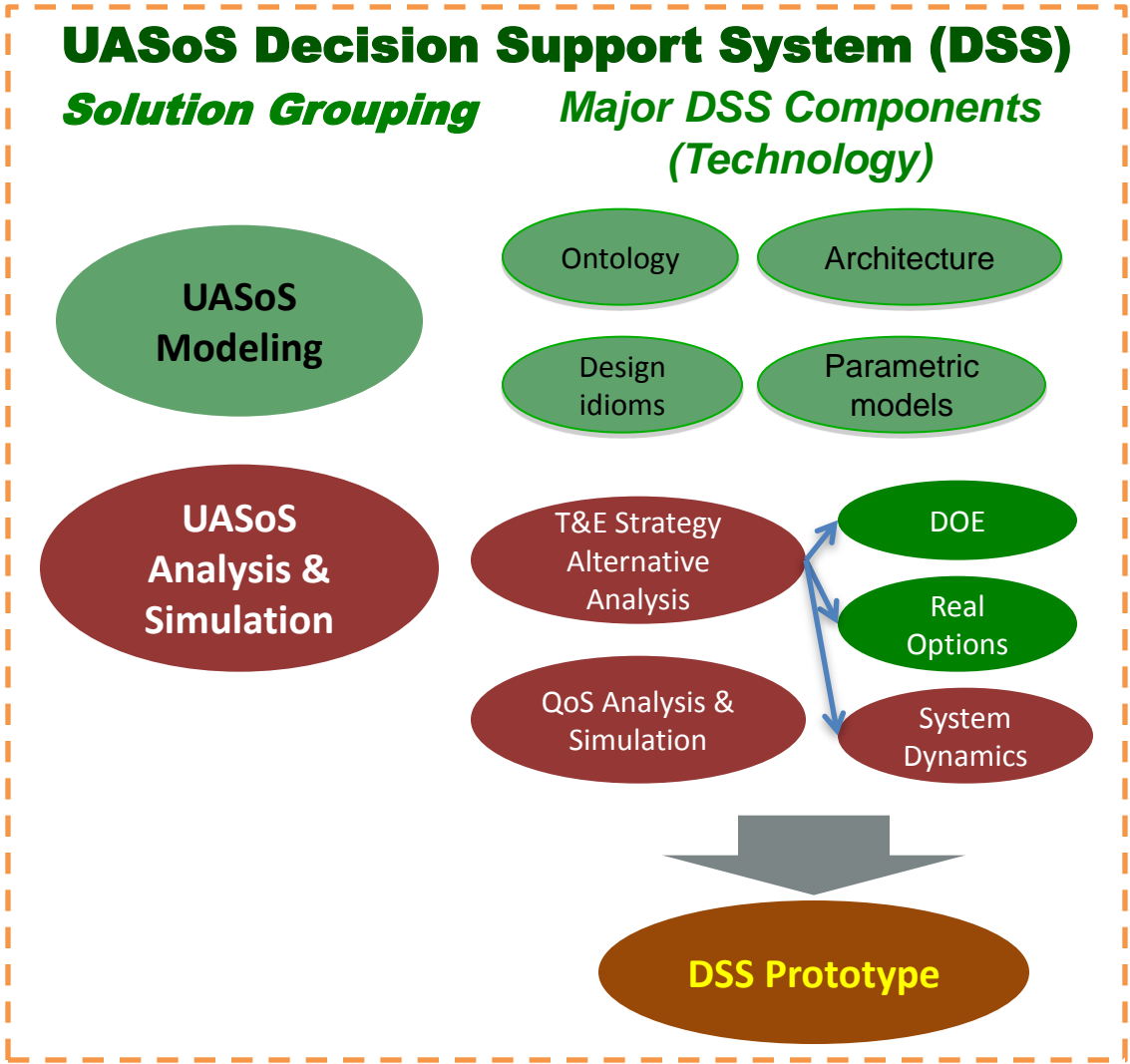
S&T Solutions

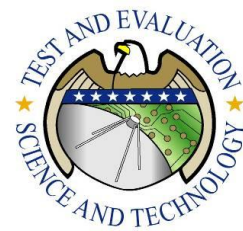


Automate UASoS test planning

Balance multiple criteria in UASoS mission-oriented T&E

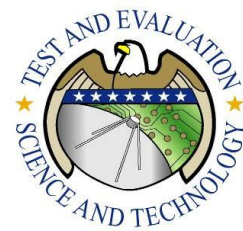
Predict, detect, adapt to undesirable emergent behavior





# Value of PATFrame

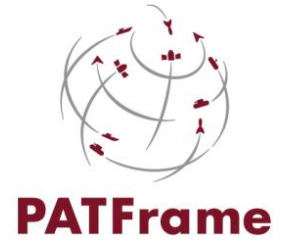
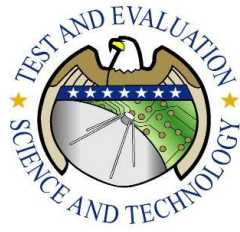
- Addresses challenges associated with the T&E of complex autonomous UASoS
- Overcomes shortfalls of the “As-is” Test and Evaluation enterprise
  - Primarily man-in-the-loop and single system focused
  - SoS testing primarily not conducted until after development
  - Difficulty predicting cost, schedule and resources required
- PATFrame is at the intersection of *unmanned & autonomous* and *systems of systems*
  - Focuses on decision support with applicability to all levels of T&E
  - Understanding of dependencies / relationships of the UASoS
  - Supports safety, suitability, effectiveness and survivability of UASoS



# Conclusion

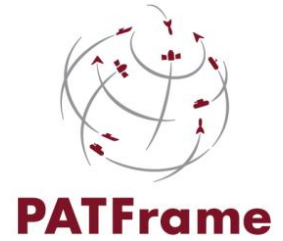
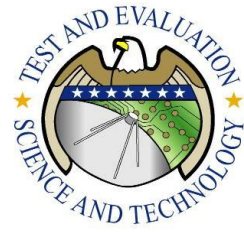
- Unmanned autonomous systems of systems is on the horizon for future DoD capabilities
- DoD is investing in technologies to the allow successful T&E of UASoS
- PATFrame is researching and developing a decision support system envisioned to enable successful T&E planning
  - Cost, schedule and resource allocation
- Future work
  - Elaborate the system requirements for PATFrame
  - Refine the PATFrame system architecture
  - Validate & Verify PATFrame via scenarios (threads)



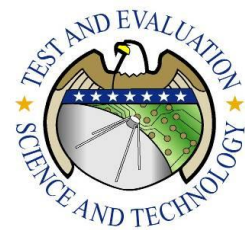


# *Questions / Comments*

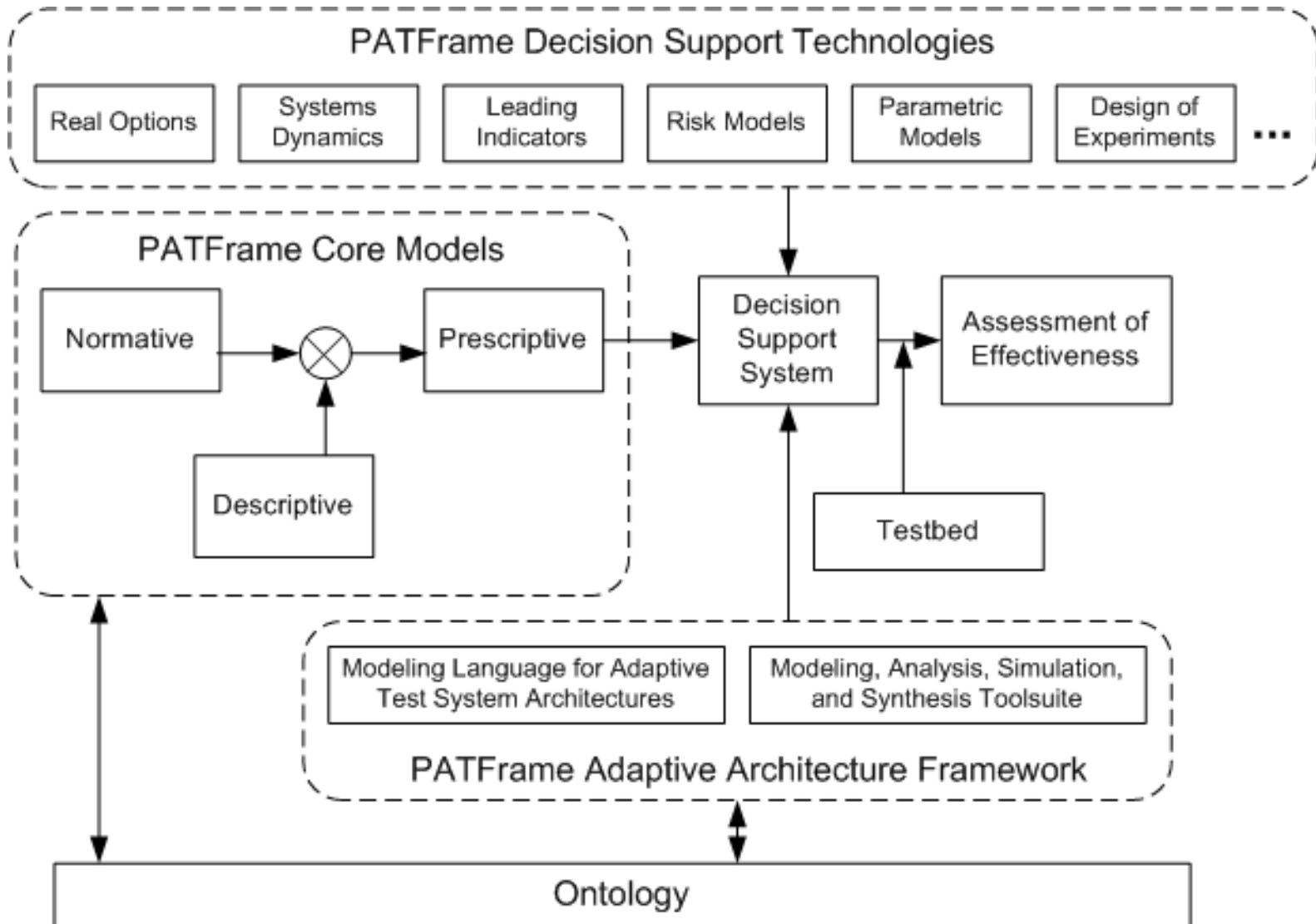
<http://mit.edu/patframe>



# ***Backup Material***

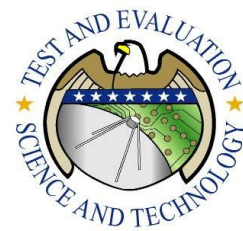


# PATFrame DSS Schematic View





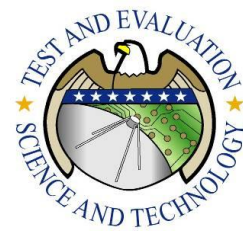
# Use Case: Discover Unwanted Emergent Behavior



- **Use Case Name:** Discover Unwanted Emergent Behavior
- **Goal:** List the optimum set of test cases in order to discover unwanted emergent behaviors in a timely and cost-effective manner.
- **Summary:**
  - Tester characterizes each SoS component system
    - Maturity, size, bandwidth required, energy, autonomy, adaptability, risks to tester, cost to test, complexity, etc.
  - Tester characterizes relationships *between* components in SoS
    - Dependencies, types of interactions, frequency of interactions, spatial, information flow, etc.
  - Tester characterizes test cases
    - Mapping of test cases to component systems & capabilities
    - Cost, risk, safety
  - PATFrame produces an ordered list of test cases, sorted by the probability of exposing an unwanted emergent behavior
- **Stakeholders:** Tester, Test Management, Project Management
- **Actors:** Tester



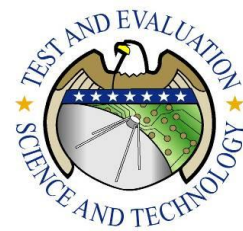
# Use Case: Design of Experiments and Test Prioritization



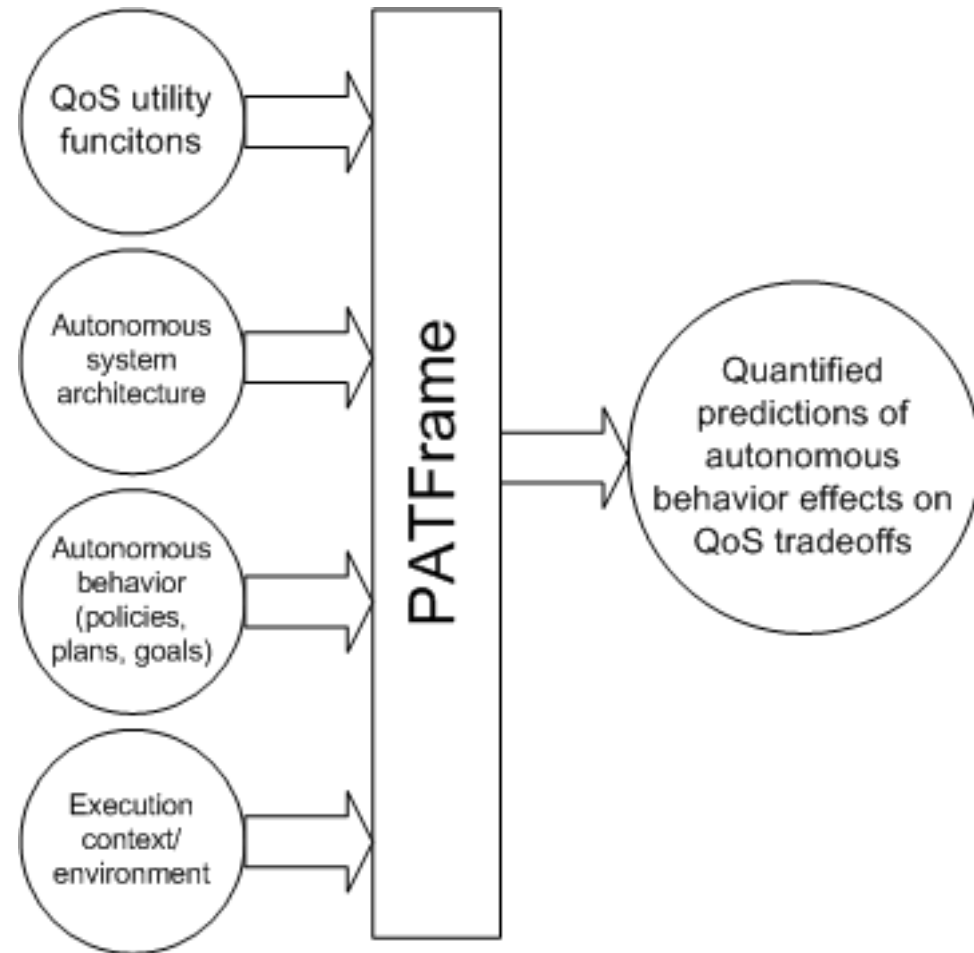
- **Use Case Name:** Prioritize and Define a Battery of Tests for a SoS composed of autonomous UAVs and ground sensors
- **Goal:** Use Design of Experiments (DOE) to plan a set of tests specifically tailored to the unique aspects of an Autonomous System of Systems (emergence, learning behavior, interactions, etc.)
- **Summary:**
  - User inputs information about Systems Under Test, such as requirements, architecture, and UAS-Specific Traits (learning, etc.)
  - User inputs the types of tests available to assess system requirements.
  - User inputs desired confidence intervals and defines criteria for successful SUT performance.
  - User inputs constraints (budget, schedule, and availability).
  - PATFrame proposes a set of tests to perform, including a proposed schedule and the precise number and profile of trials.
- **Stakeholders:** DoD Test Personnel, PATFrame Team, UAST Evaluators, NST Evaluators, InterTec, TRMC
- **Actors:** User (Test Planners, Program Managers, and Schedulers)

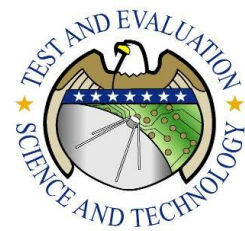


# Use Case: Predict Effects of Autonomous Behavior On QoS



- UAVs in the scenario include several autonomous behaviors
  - Tracking, following, route planning, network planning, etc.
- Behaviors impact the system QoS
  - Reliability, availability, durability, etc.
  - For example, network replanning increases connectivity but consumes more power
- PATFrame uses simulation to determine:
  - What QoS data should be gathered while testing different autonomous behaviors
  - What environmental conditions must be created to trigger different behaviors

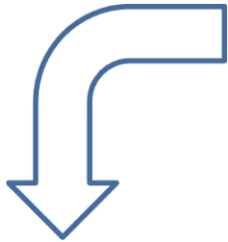




# Alignment of “As-Is” T&E Enterprise

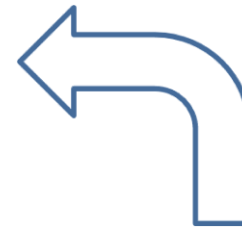
## Strategic T & E Objectives

- DoD 5000.2 Acquisition Cycle
- DoD Developmental Test Regs
- DoD Operational Test Regs
- Service T & E Regulations



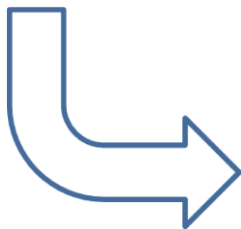
## T & E Metrics

- System Specification Requirements
- Measures of Effectiveness
- Measures of Suitability
- Safety



## Stakeholder Values

- Verification of system requirements – Dev Tester
- Validation of system capabilities – Ops Tester
- Overall system performance in ops - User
- System performs as built - contractor
- Meets requirements w/in cost & schedule – PM



## Tactical T & E Objectives

- DT verification of requirements
- OT validation of capabilities
- Emergent behaviors
- Subsystem interface linkages

