Aptima®
Human - Centered Engineering
www.aptima.com

# Model-based Organization Manning, Strategy, and Structure Design via Team Optimal Design (TOD) Methodology


Georgiy Levchuk
Kari Chopra
Michael Paley
Yuri Levchuk
David Clark

**Aptima, Inc.**



***10-th CCRTS Mac Lean, VA, June, 2005***
**Track 1:** ***C2 Modeling and Simulation***

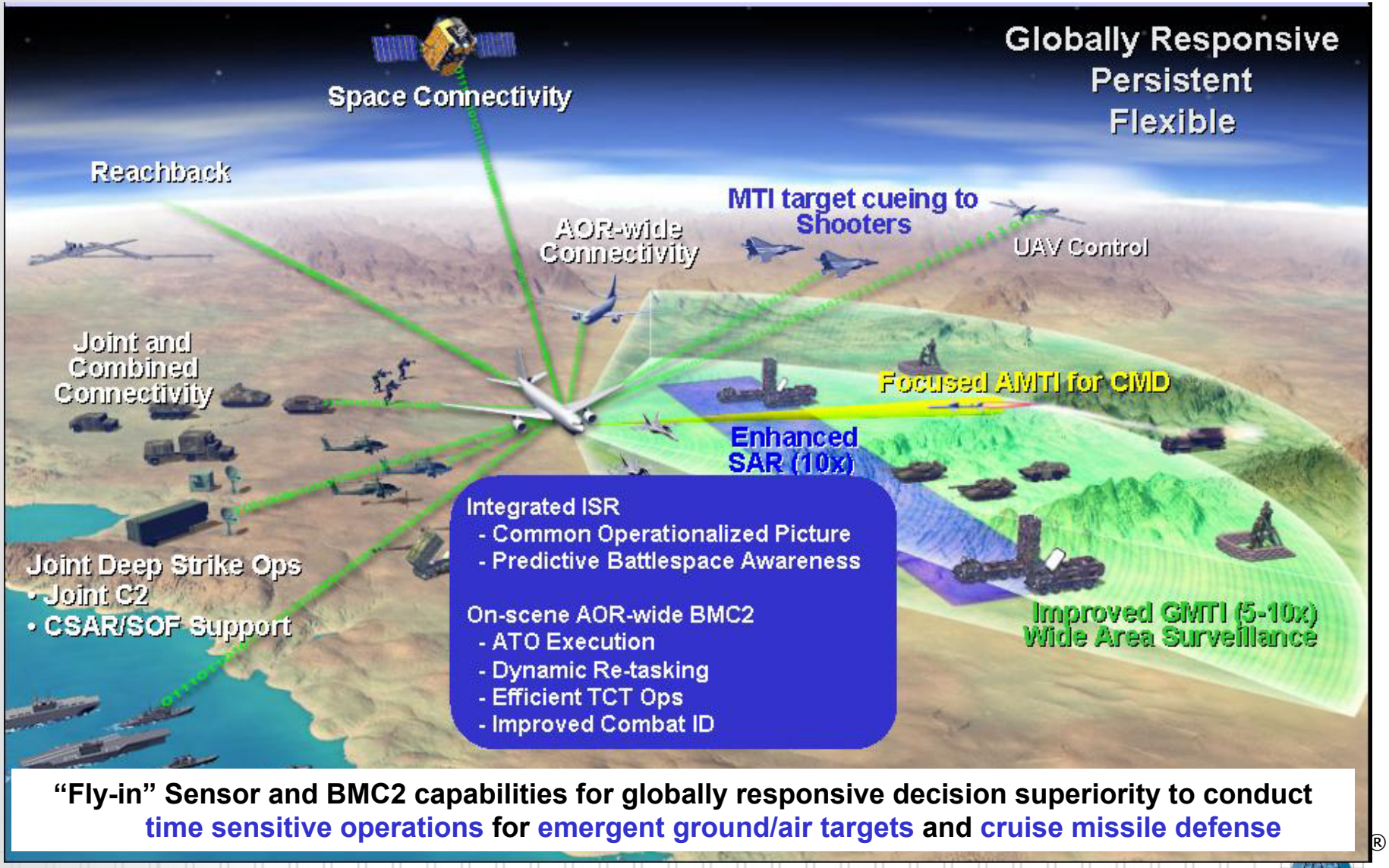


© 2005, Aptima, Inc.

# Outline

- Problem statement
- Design formalism
- Solution methodology
- Team Optimal Design (TOD) optimization and simulation
- Example of results

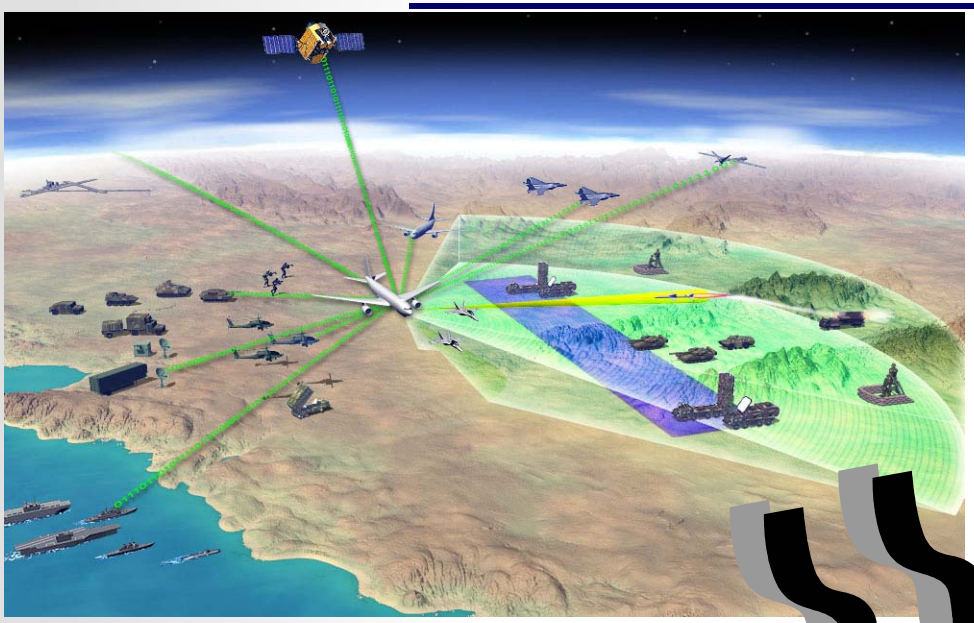
# E-10 MC2A Vision



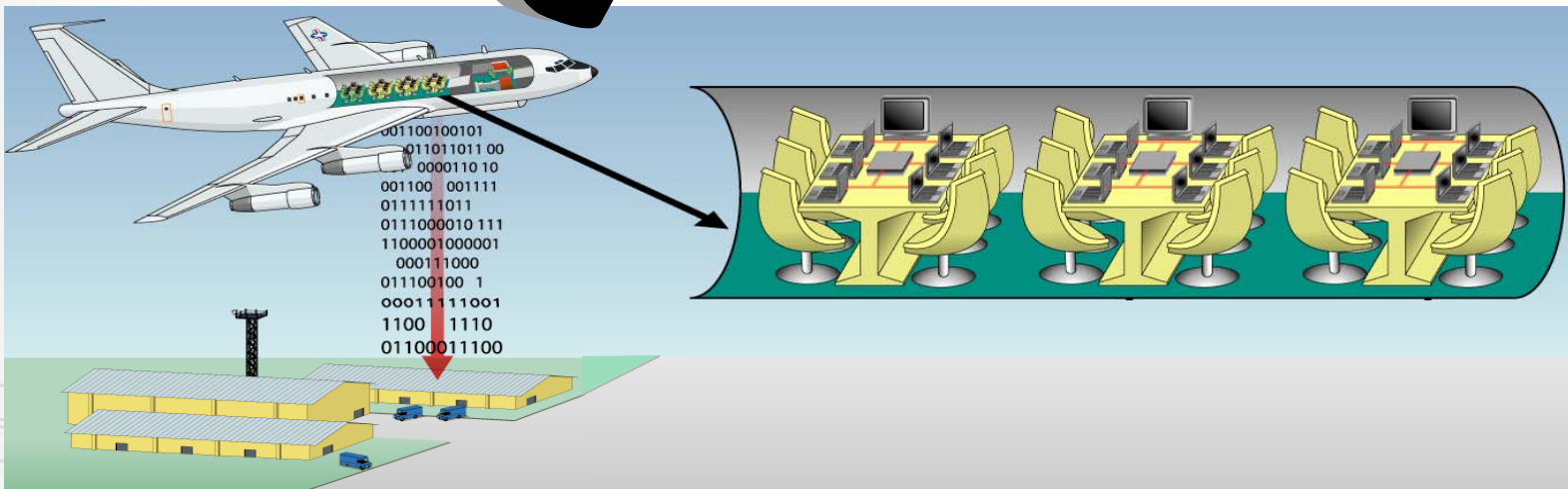

**"Fly-in" Sensor and BMC2 capabilities for globally responsive decision superiority to conduct time sensitive operations for emergent ground/air targets and cruise missile defense**

Aptima®
Human - Centered Engineering

# Questions Along the Development Path

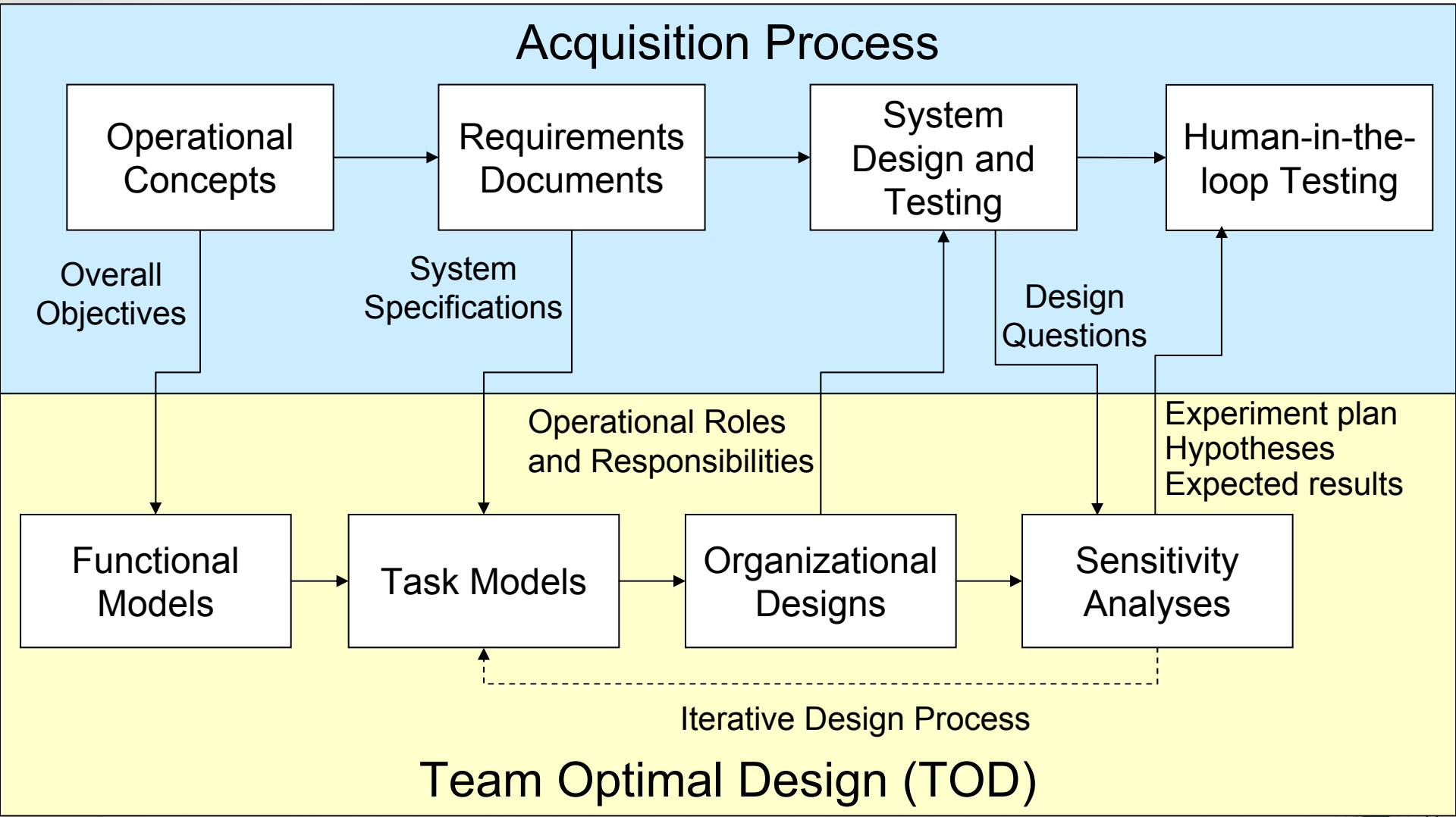


- How do you bridge the gap between operational concepts and system development?
- Does a process exist to conduct trade-off or sensitivity analyses?
- What mechanisms are in place to provide traceability and repeatability of methods?



Aptima®
Human - Centered Engineering

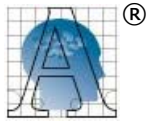
# General Relationship Between Acquisition and TOD



Aptima®
Human - Centered Engineering

# Modeling & Simulation Analysis Benefits

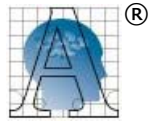
- Evaluate **operational structures**
  - Expectations for crew size and composition
  - Predictions for human-in-the-loop testing
  - What-if analysis for mission parameters
  - Initial training requirements
- Evaluate **organizational structures**
  - Optimized organizational structures and processes
  - Integrated organizational solutions
  - Additional crew and training requirements
- Evaluate **system design**
  - Link system design to operational requirements
  - Interface design
  - Performance metrics
- Cost Effective
  - Model early in the program life cycle to avoid costly redesign later



Aptima®
Human - Centered Engineering

# TOD in the System Development Process

- Objective
  - Transition **functional system requirements** into **specifications for operator in the loop testing**
- Approach
  - Mission task model development
  - **Optimized design** of mission crew composition and organization
  - **Sensitivity analyses** to explore system design options
  - Incorporate subject matter expert inputs and review
- Results
  - Global view of human-machine system performance
  - Definition of **number** and **types** of operators
  - Organizational **structures** and **expected performance** parameters
  - **Diagnosis** of potential problems shapes operator in the loop tests

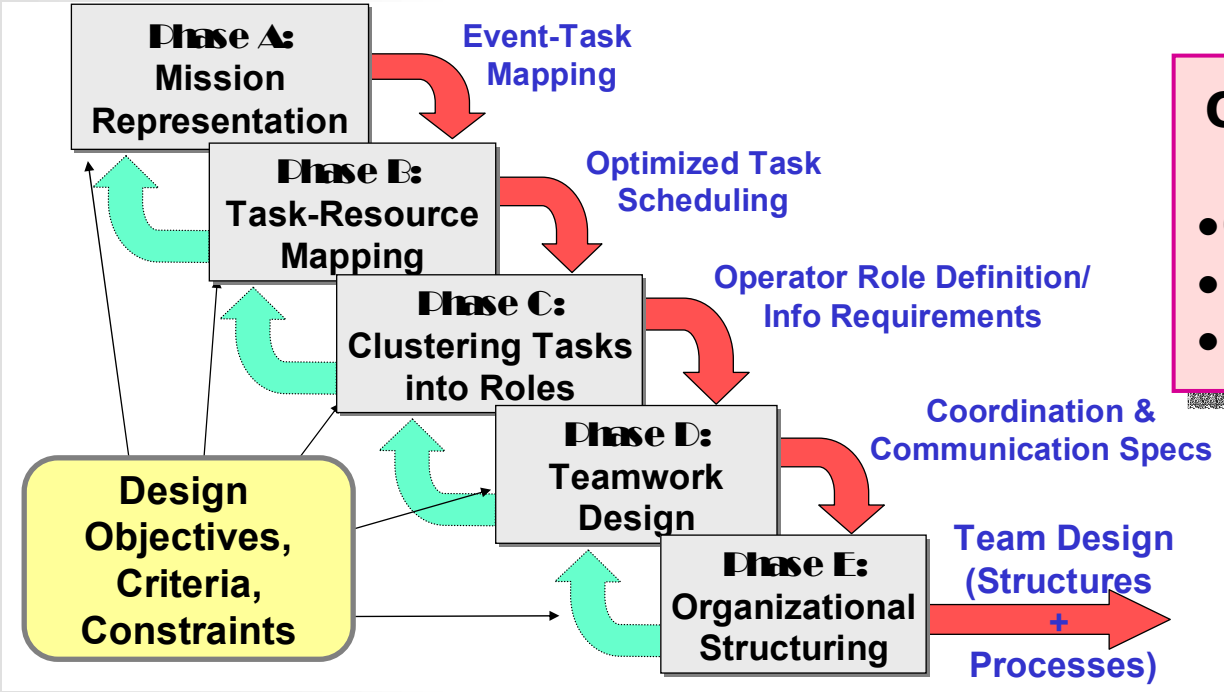


# Design Formalism

**Modeling attributes:**

- The **tasks** that must be accomplished and their interrelationships (the "mission")
- The external **resources** needed to accomplish those tasks (e.g., information, raw materials, or equipment), and
- The human **agents** (decision makers) who will constitute the team

# Team Optimal Design (TOD) Model



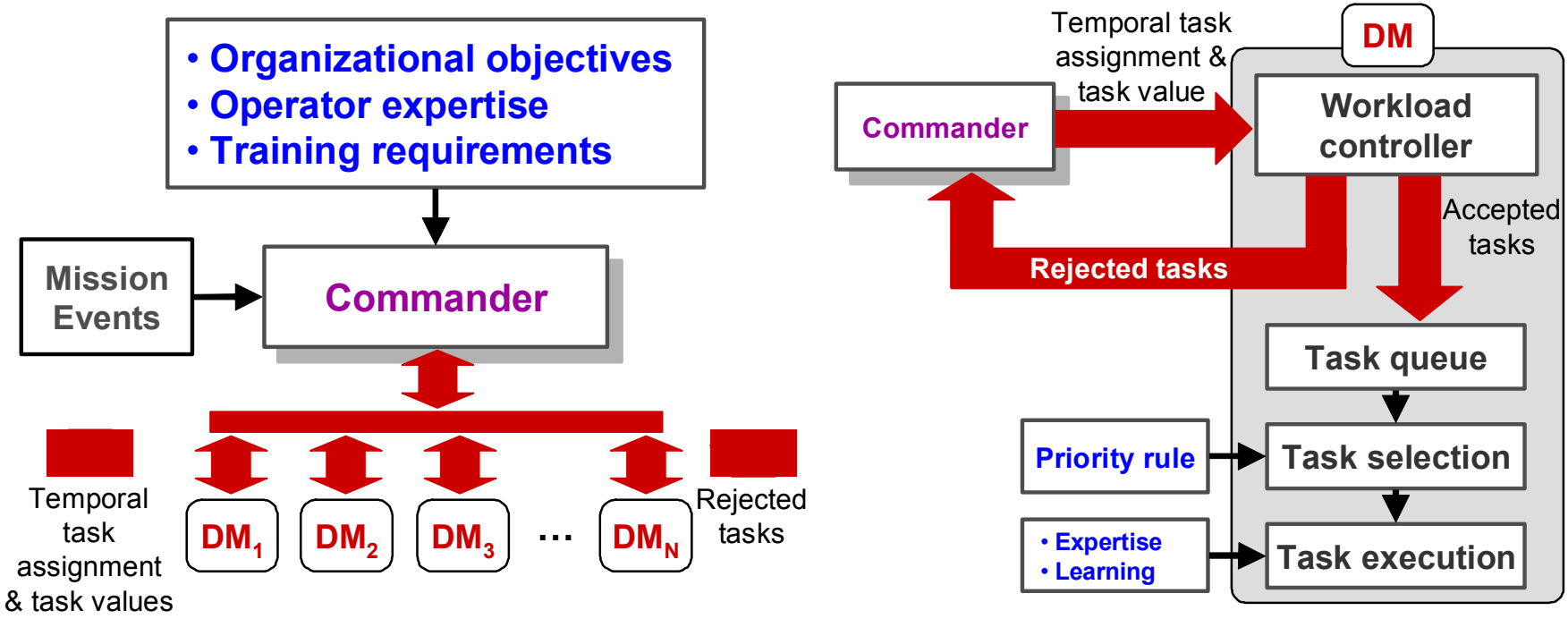

**Optimization of team manning based on**

- Operator workload
- Execution accuracy
- Execution delays

- Normative methodology
- Relies on operator-task allocation heuristics to determine operator profiles
- Relies on SME judgment to frame the design problem
  - decompose an overall mission (or goal) into specific tasks
  - specify the relationships between tasks
  - specify the resources needed to complete the tasks
  - specifying the criteria to be optimized for the team, and
  - specifying the task scheduling and communication rules employed by human agents modeled in TOD.

Aptima®
Human - Centered Engineering

# TOD Simulation Architecture




(a) Commander architecture

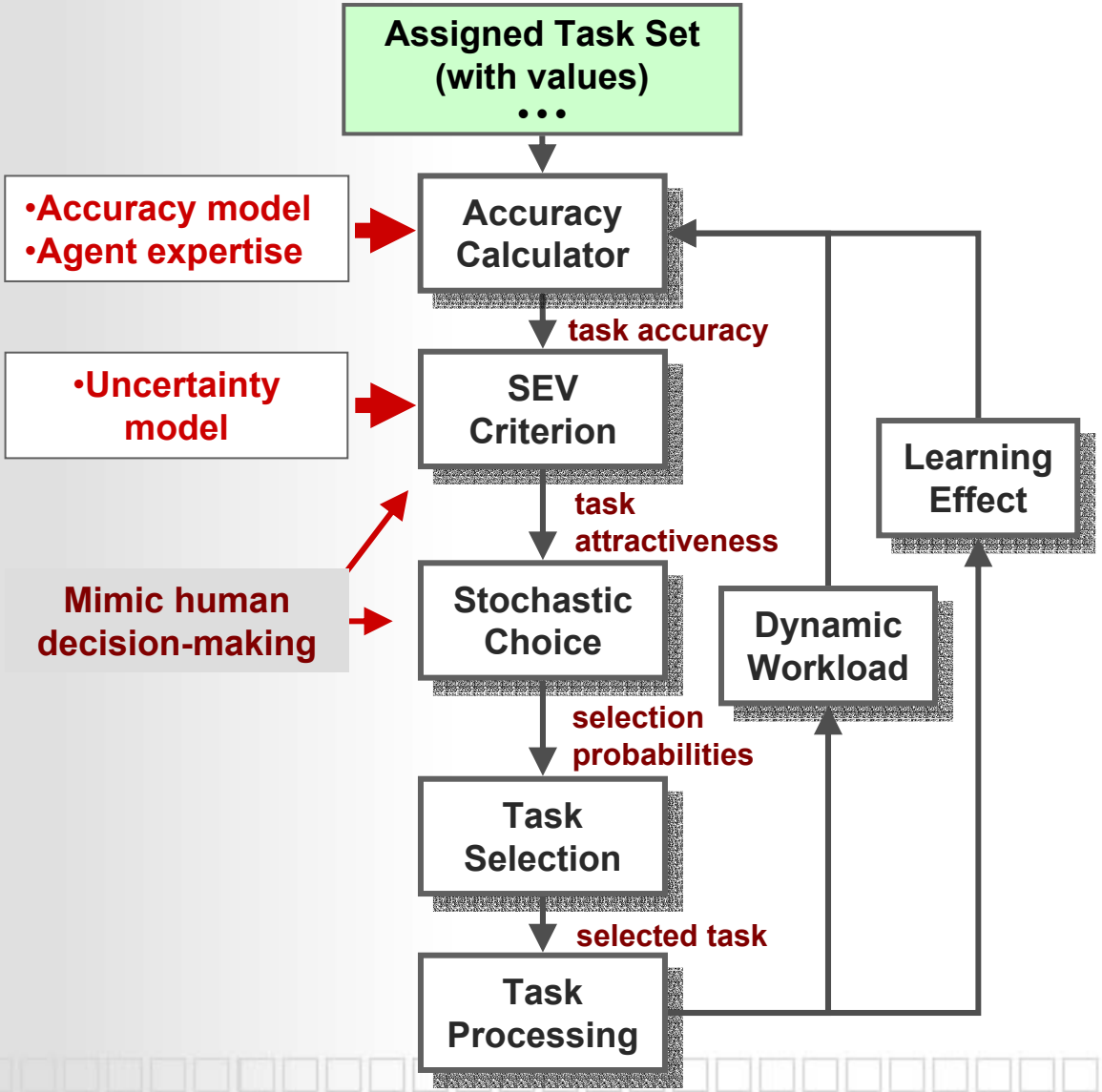
(b) Operator model

**Model:**

- Teamwork
  - Interactions among operators (agents)
- Taskwork
  - Individual task selection and execution

Aptima®
Human - Centered Engineering

# Task Selection & Execution in TOD




**Modeling variables:**

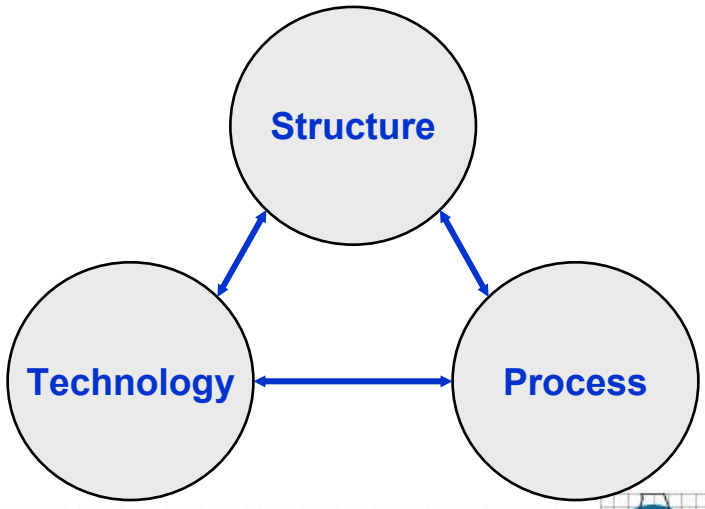
- Operator **Workload**
  - Depends on load of tasks executed
  - Accumulated (latent) effect over time
  - Affects task execution efficiency
- Operator **Competence**
  - Initial expertise
  - Task execution pattern affects the competence
    - Effect of **learning**
    - Model **memory**
  - Mitigates impact of workload on task execution
- Task **Accuracy**
  - Efficiency of task execution
  - Depends on
    - Operator workload
    - Operator competence

Aptima®
Human - Centered Engineering

# E-10 Organizational Modeling: Objectives

- Develop a Battle Management Configuration to support a wide variety of missions
- Define operational roles for E-10 (MC2A) operations
  - Who does what, when, where, and how -- to assure maximum efficiency and effectiveness?
- Results will contribute to Program Objective Memorandum (POM) Manpower Estimates and system requirements definition

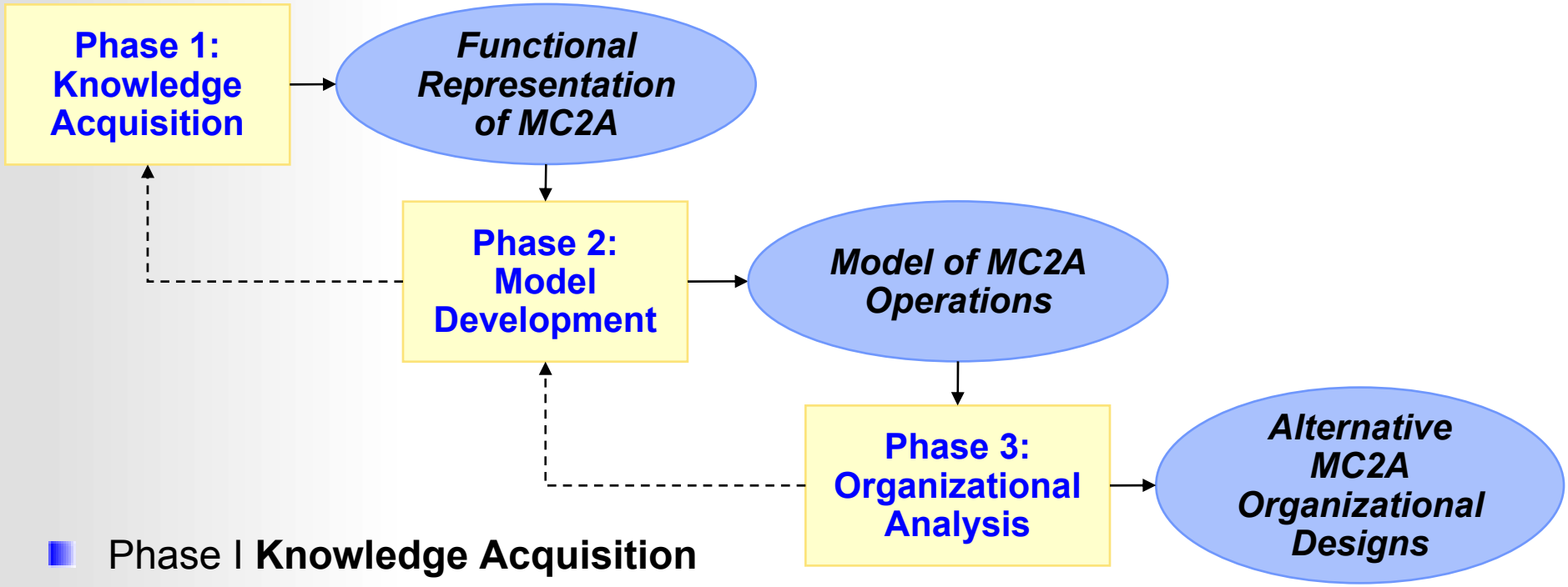
**Ensure Fit Between MC2A Core Components**



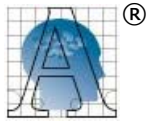

®

Aptima®
Human - Centered Engineering

# MC2A Organizational Modeling: Process




- Phase I **Knowledge Acquisition**
  - Extensive coordination with subject matter experts
- Phase 2 **Model Development**
  - Specification of task-flow diagrams
  - Link tasks to scenario events
- Phase 3 **Organizational Analysis**
  - Information clustering for role specification
  - Definition of crew composition



Aptima®
Human - Centered Engineering

# TOD Process

## Objectives:

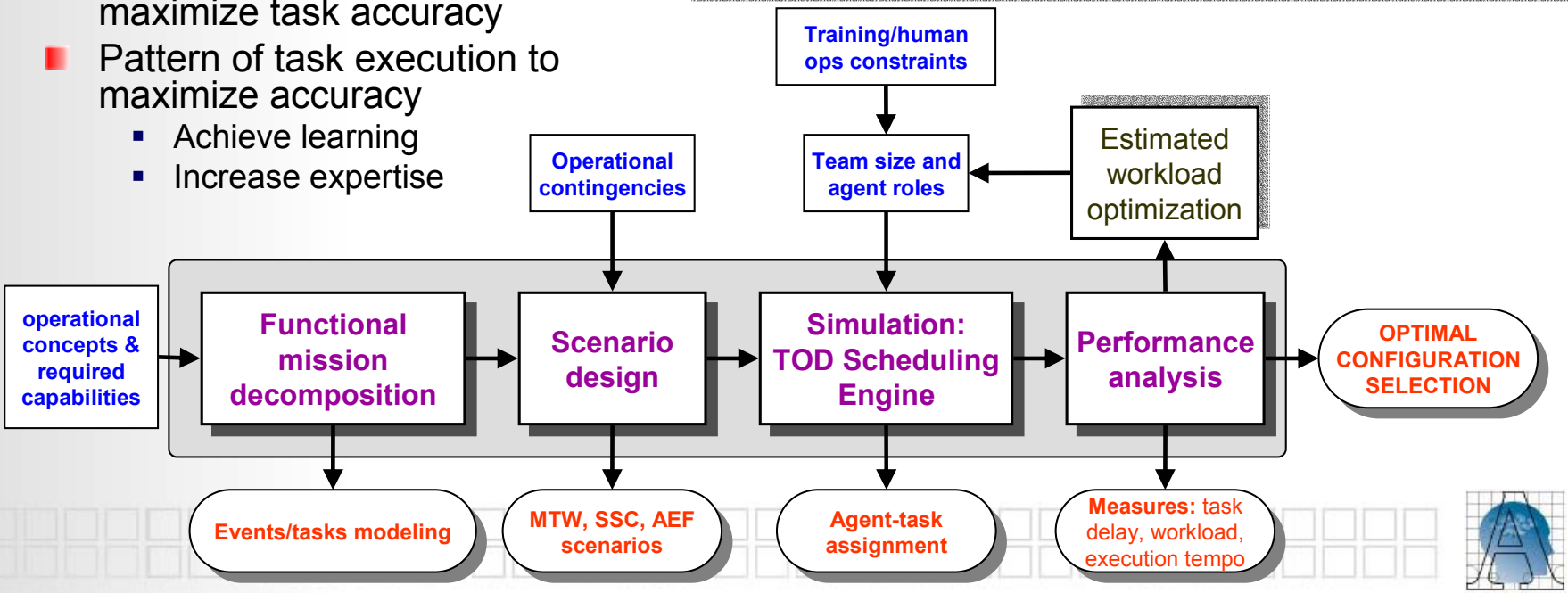
- Minimize workload
  - Operator-needs analysis
  - Balance across operators
- Minimize delays
  - Tradeoff between availability of operators and communication delays
- Maximize execution efficiency
  - Sustain workload to maximize task accuracy
  - Pattern of task execution to maximize accuracy
    - Achieve learning
    - Increase expertise

## Design variables:

- Manning: **Team composition**
- Communication structure: **Who talks to whom**
- Operator roles: **Who does what**

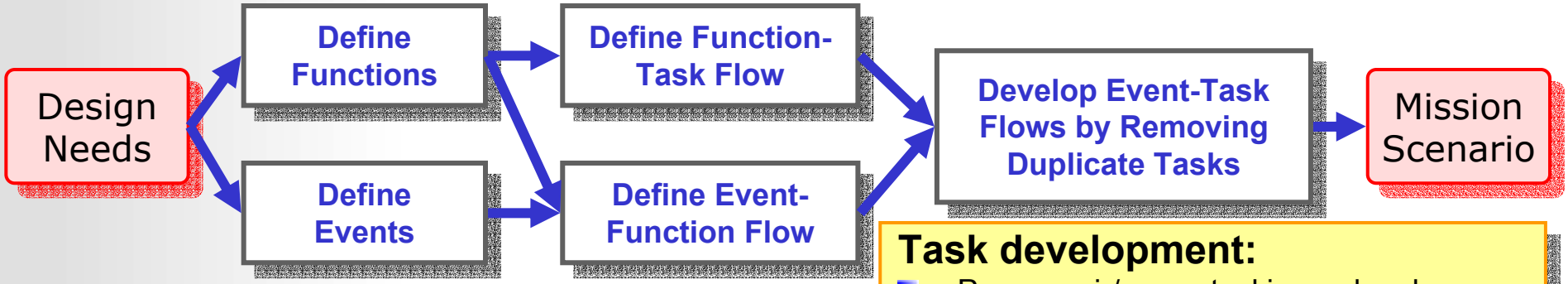
## Find impact on performance from:

- Optimized task assignment
- Technology insertion
- Improved backup potential
- Greater breadth and depth of skill/expertise



Aptima®
Human - Centered Engineering

# Example: Scenario Development

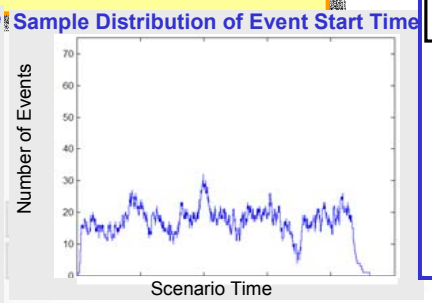


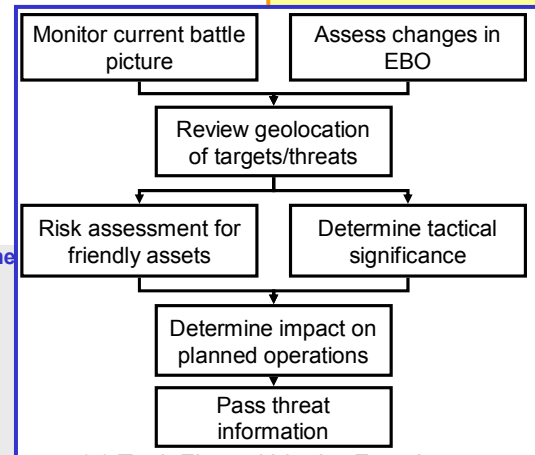

## Function development:

- Basic surveillance routine
- Coverage assessment
- Modify sensor tasking
- Dynamic sensor management
- Target development
- Radar service request
- Process indications and warning
- Perform Cross-Cueing
- Jamming/Electronic Support
- Nominate dynamic target list

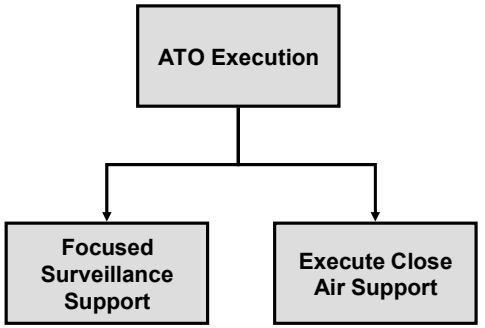
## Task development:

- Process air/space tasking order changes
- Determine availability of alt. sources
- Respond to unforeseen abort
- Identify alternative resources for mission
- Notify affected aircraft/units of surface coordinating measure changes
- Identify likely friendly targets
- Prioritize targets

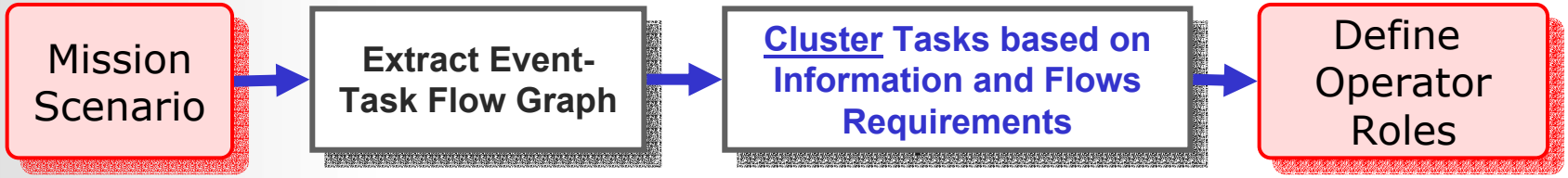

(a) Task Flow within the Function "Assess Active Threats"




(b) Functional Flow within the Event "Task XCAS to CAS"

Aptima®
Human - Centered Engineering

# Example: Roles Definition



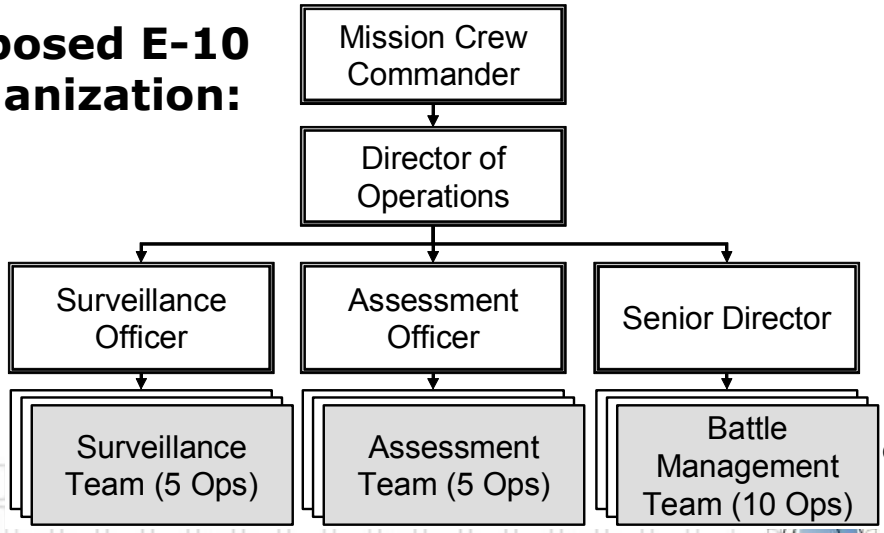

**Task clusters:**

- External coordination
- Schedule re-planning
- Link management
- Identification
- Sensor control
- Threat management
- Asset coordination
- Data management
- Track & target coordination
- Situation assessment
- Collection management
- Target development
- Surveillance
- …

**Roles:**

- ***Command*** – mission command and leadership
- ***Assessment*** – interpretation of operational picture
- ***Battle Management*** – command and control of operations
- ***Surveillance*** – generation of operational picture
- ***ISR Allocation*** – control of ISR assets (constellation)

**Proposed E-10 organization:**

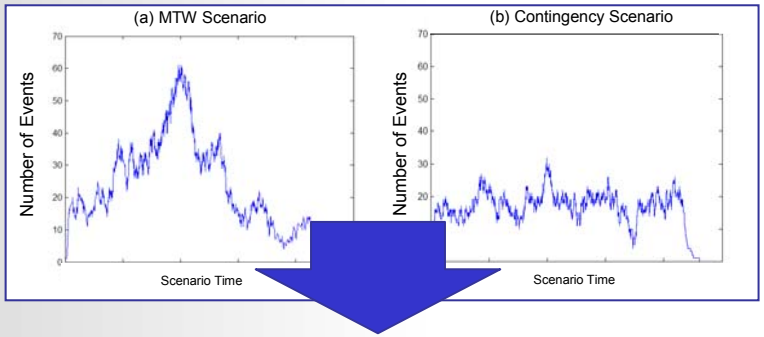


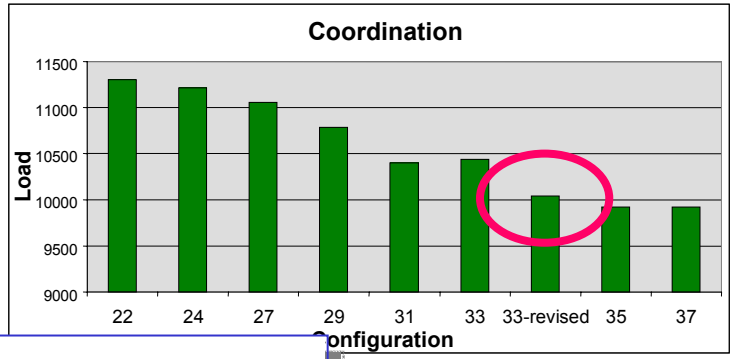

| Crew design | Task delay | Coordination | Workload |
|---|---|---|---|
| Model-based | 40.36 | 5877 | 44.41 |
| Integrated | 31.35 | 4889 | 44.27 |
| Percent improvement | 22.32% | 16.81% | 0.31% |

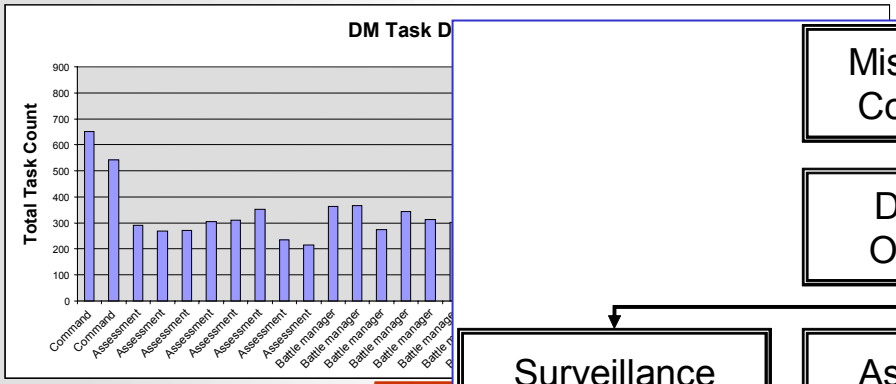
®

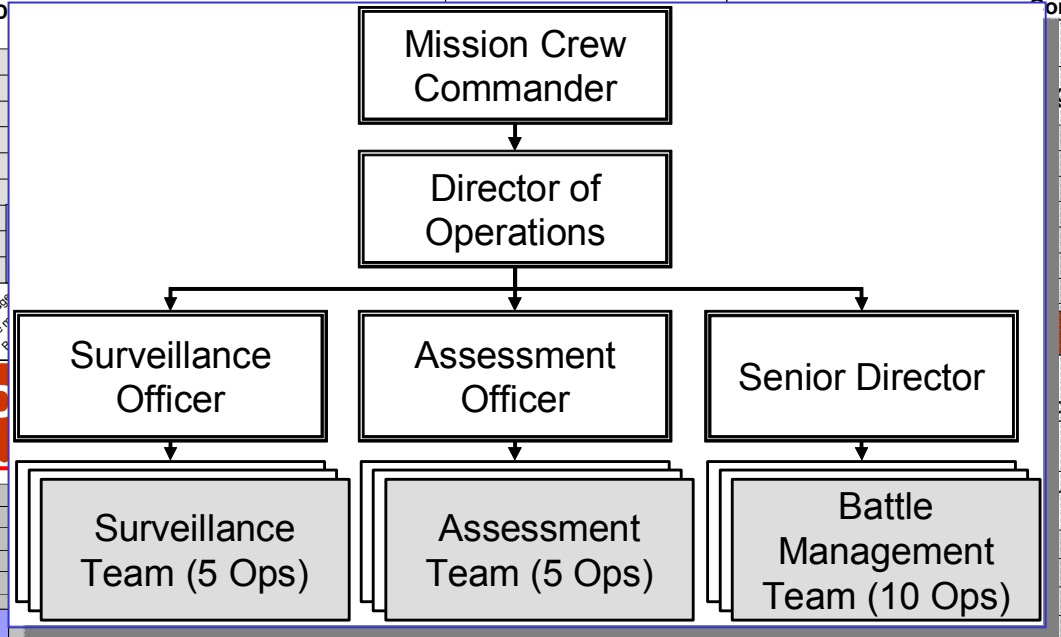
Aptima®
Human - Centered Engineering

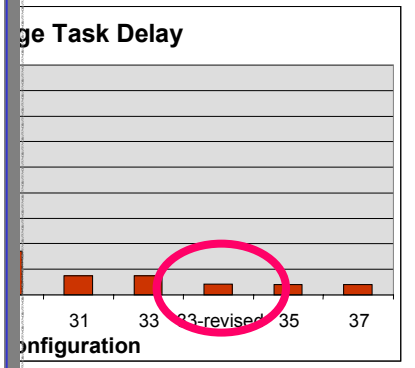
# Example: Simulation Results

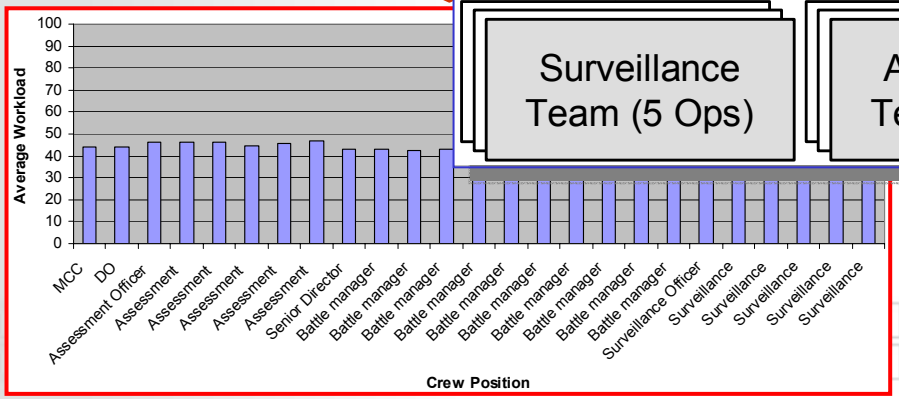


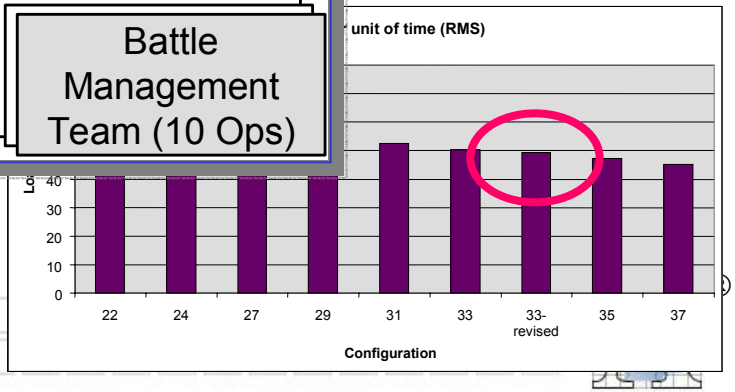



# Conclusions

- Developed organization design methodology based on mission-function-event-task decomposition
  - Model teamwork and taskwork
  - Individual task execution and selection optimization
  - Task execution effectiveness based on expertise and limited-memory learning
- Applied to design crew for E-10 aircraft
  - Developed contingency-based missions
  - Design organizations for specific missions and for all considered essential missions with specific tempo

Aptima®
Human - Centered Engineering

# Future Work: Model-Based Tutoring System