A Decision Framework for Systems of Systems Based on Operational Effectiveness

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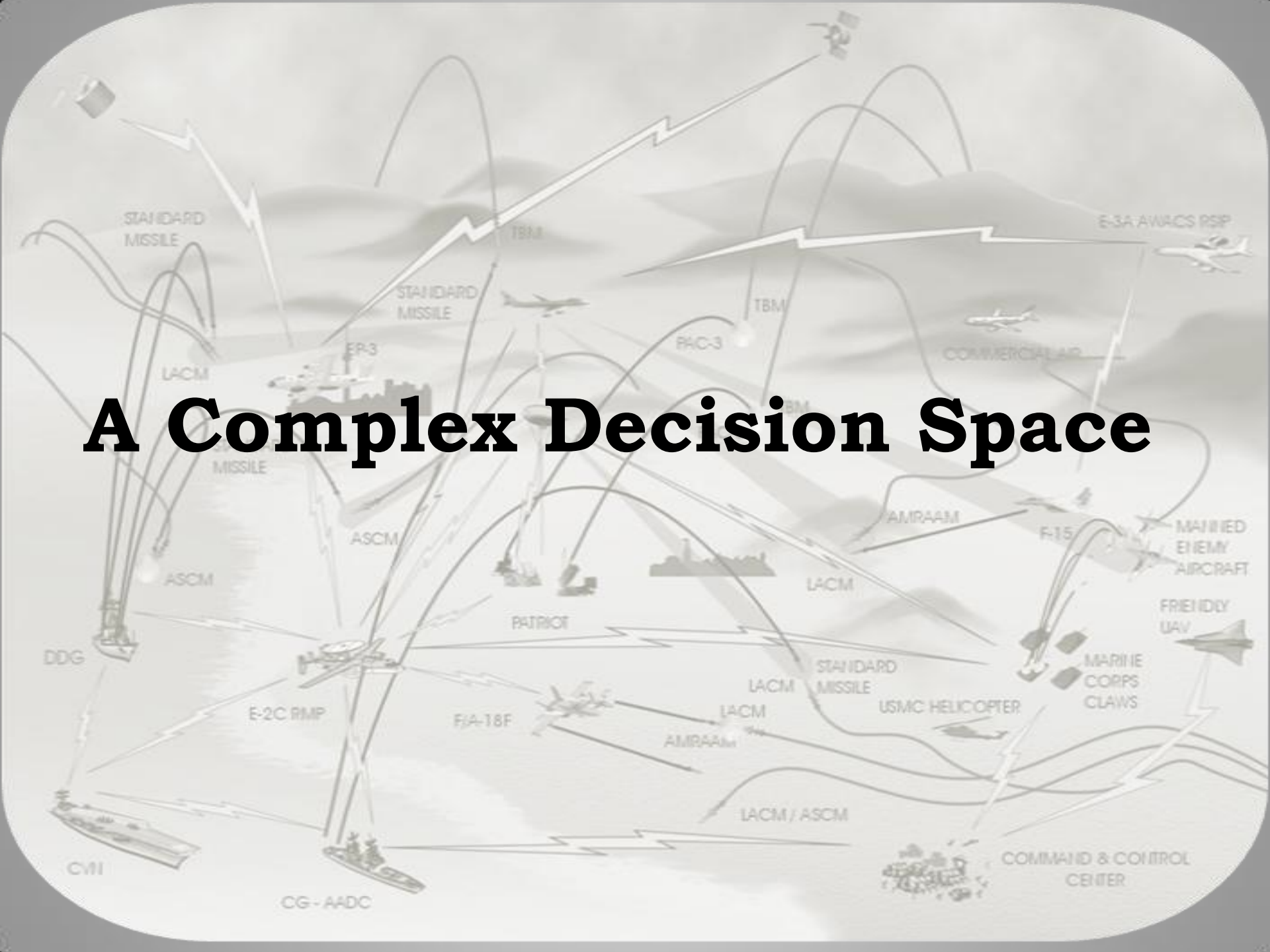
A Complex Decision Space

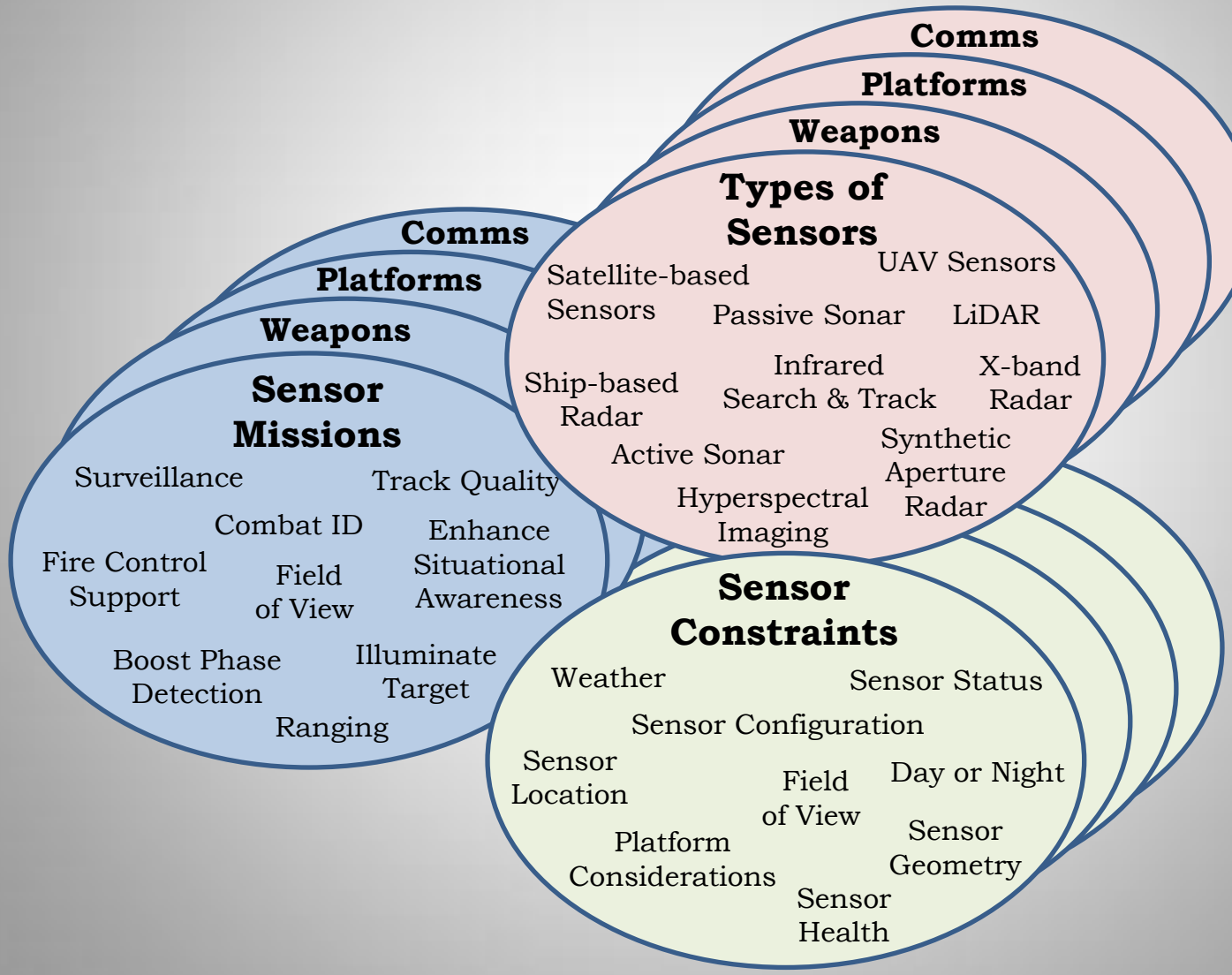


What makes the Decision Space Complex?

- Time-criticality
- Threat complexity
- Prioritization of operational objectives
- Limits to situational awareness
- Changing nature of operation
- Distribution and heterogeneity of warfare assets
- Command and control complexity

Warfare Resources

Leading to Decision Complexity



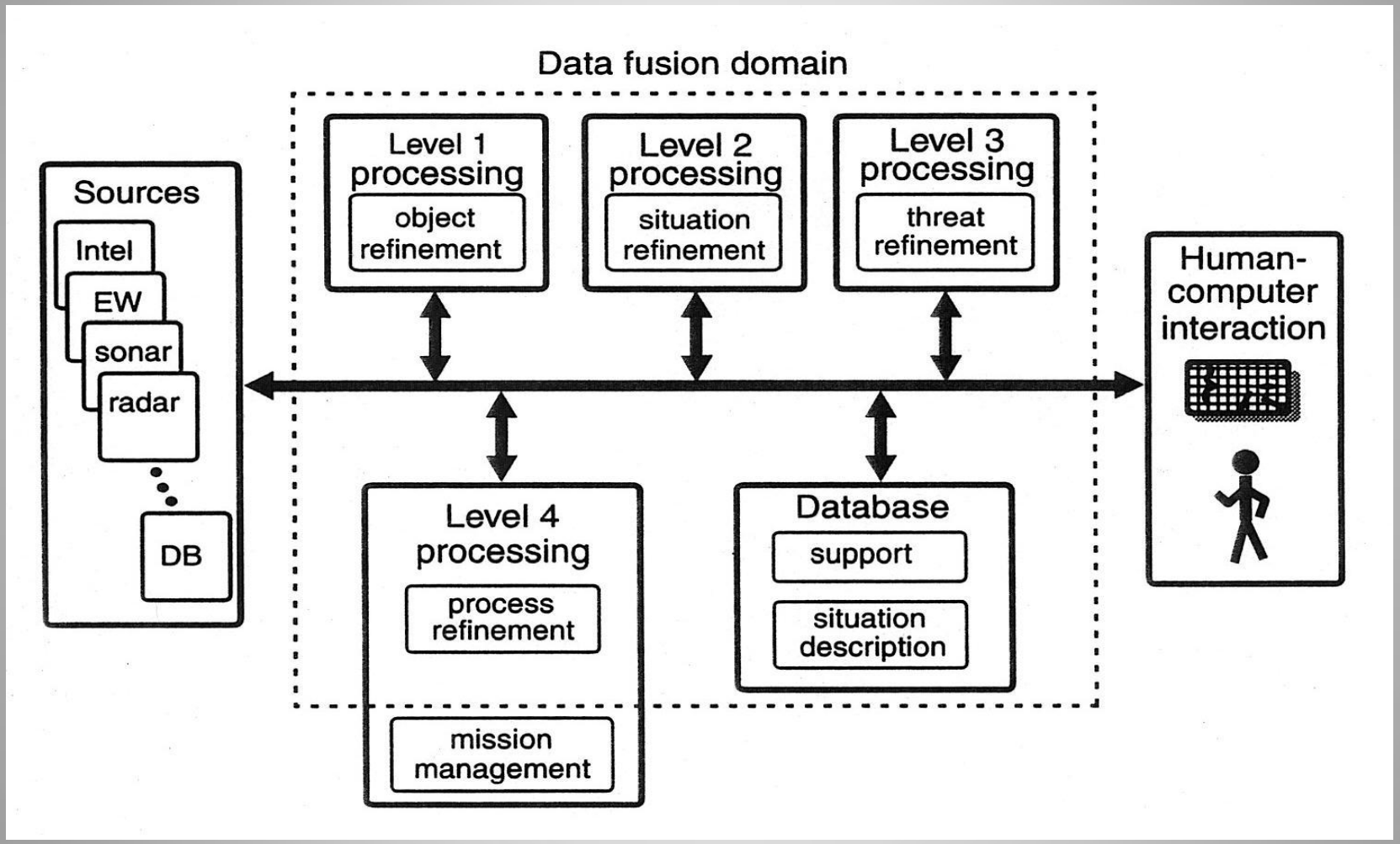
Over-Arching Objective

- To most effectively use warfare resources to meet tactical operational objectives

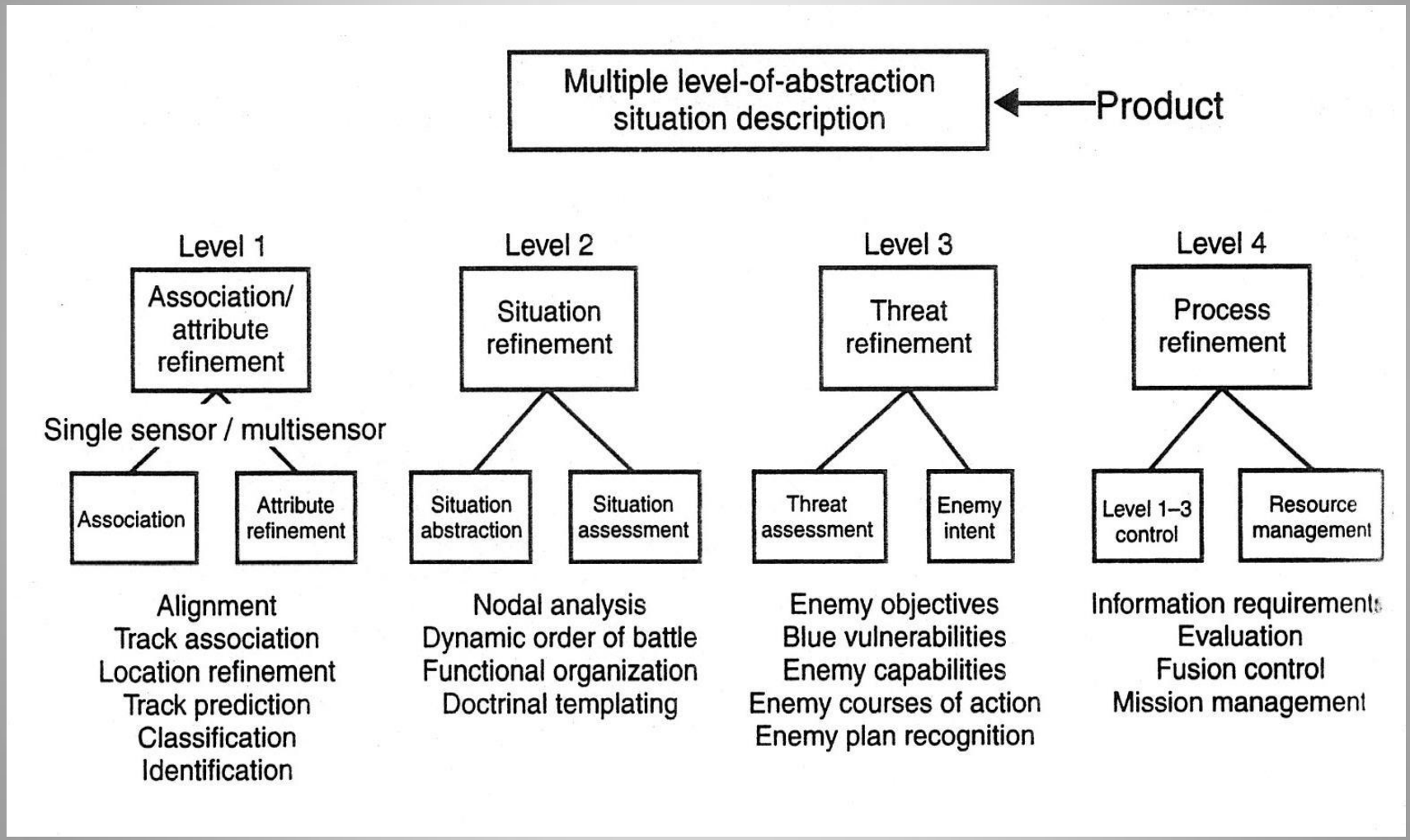
Strategies

- Use warfare resources collaboratively as Systems of Systems (SoS)
- Use an NCW approach to network distributed assets
- Achieve situational awareness to support resource tasking/operations
- Fuse data from multiple sources
- Employ common processes across distributed warfare resources
- Use decision-aids to support C2

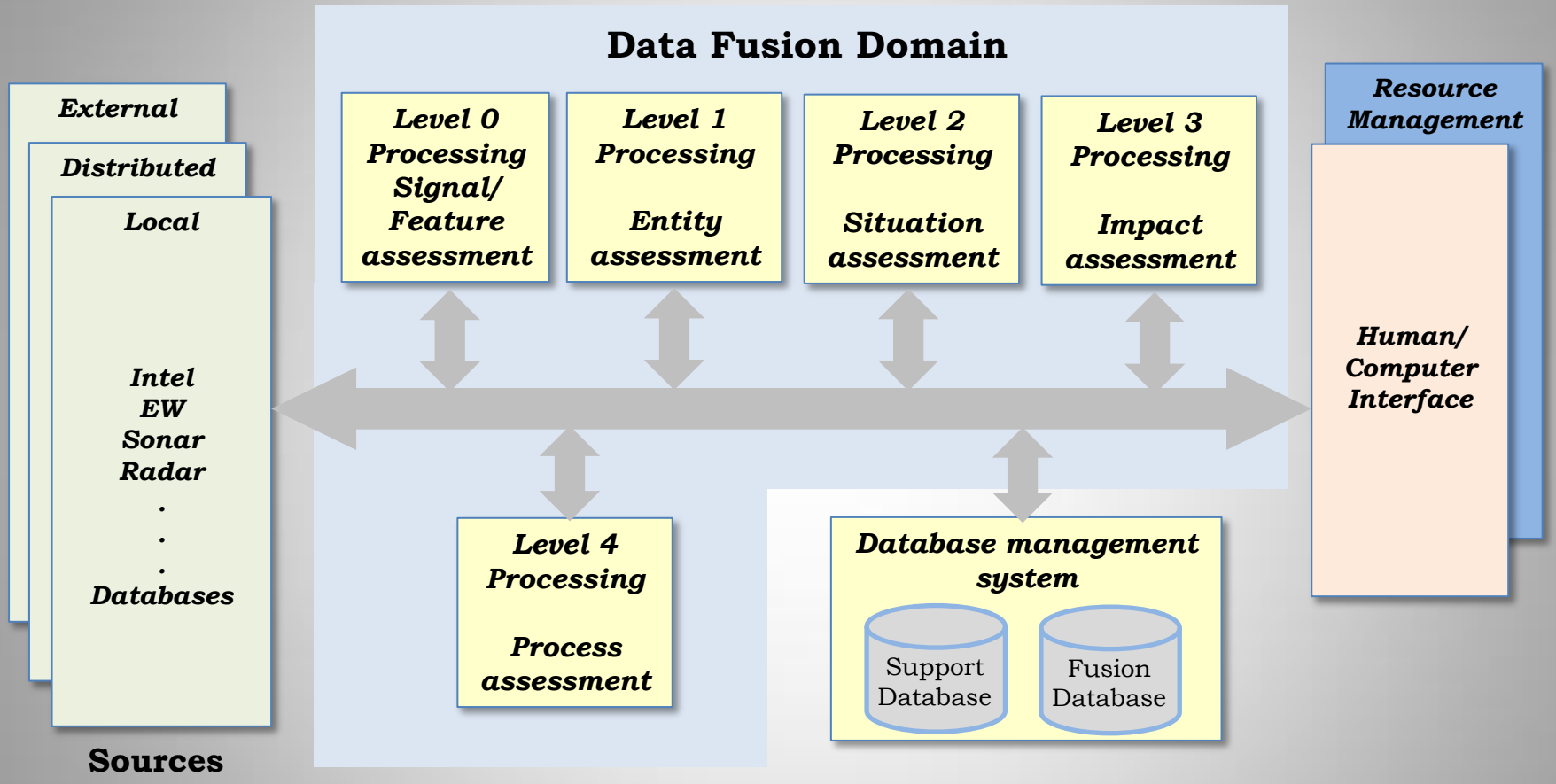
High Level Fusion Model



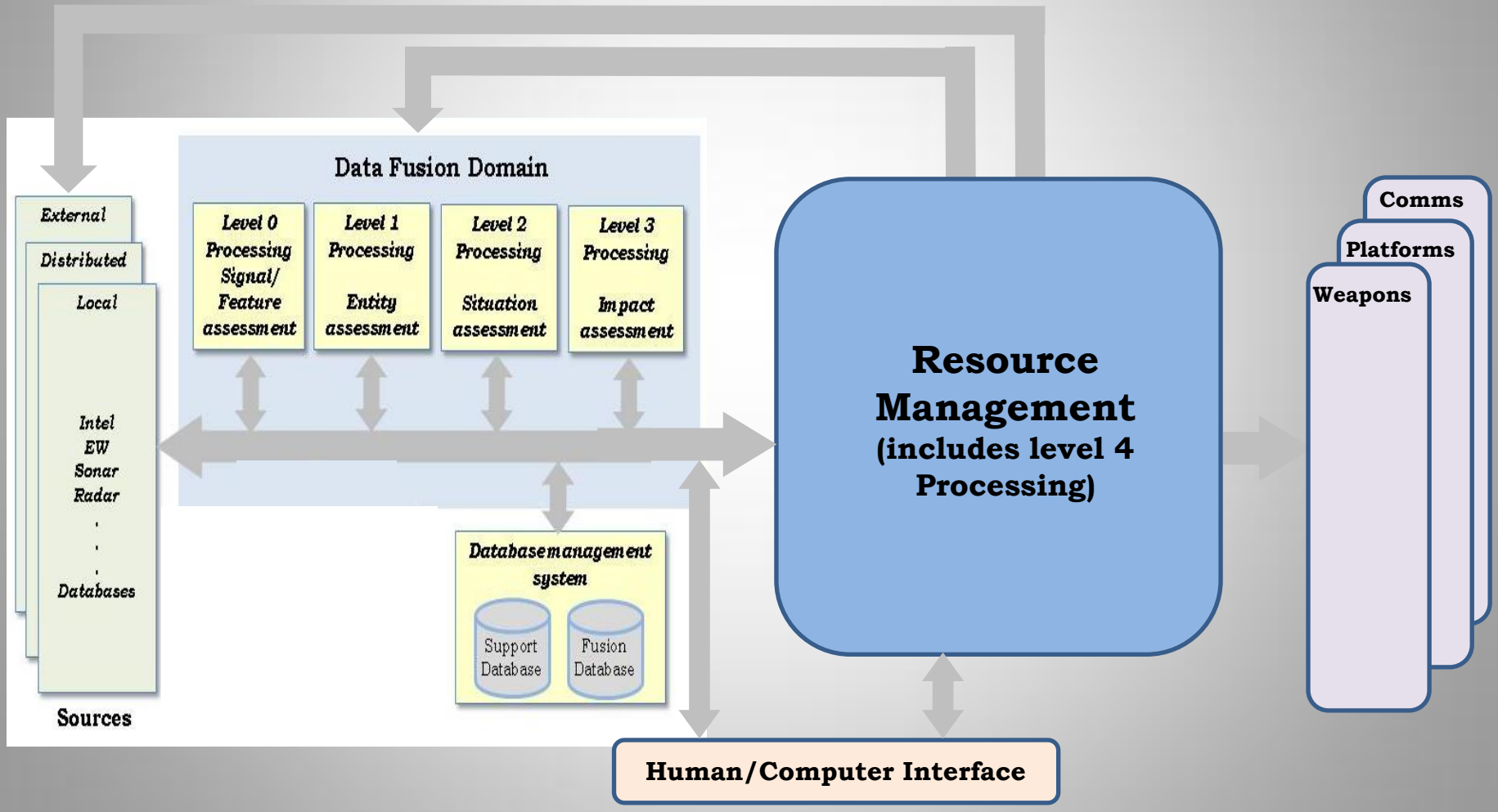
Functionality of the 4 Levels

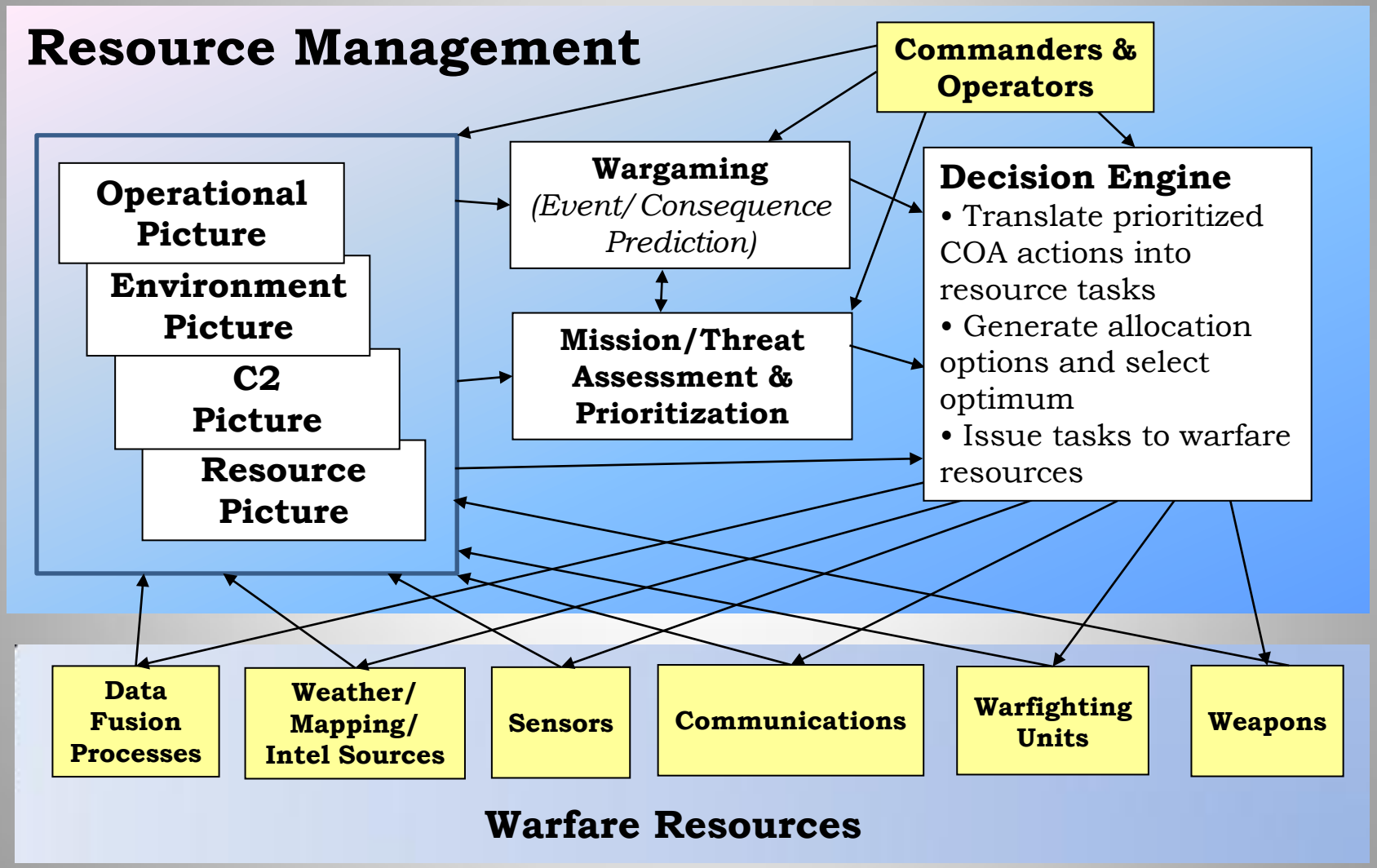


A Data-Centric Framework

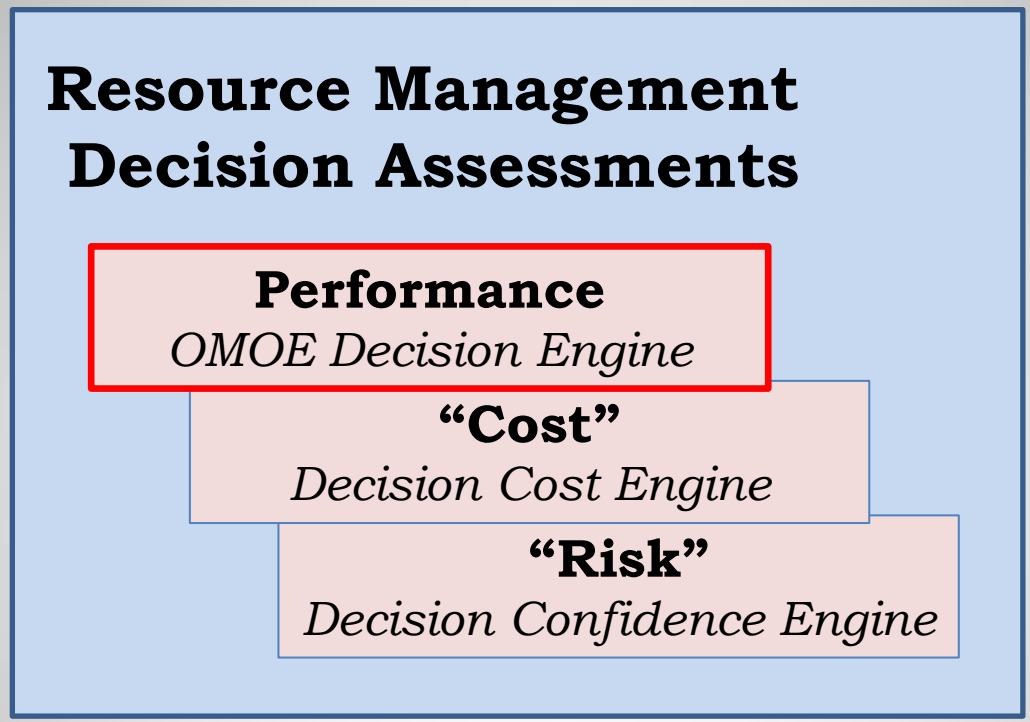


Shift to a Decision-Centric Framework

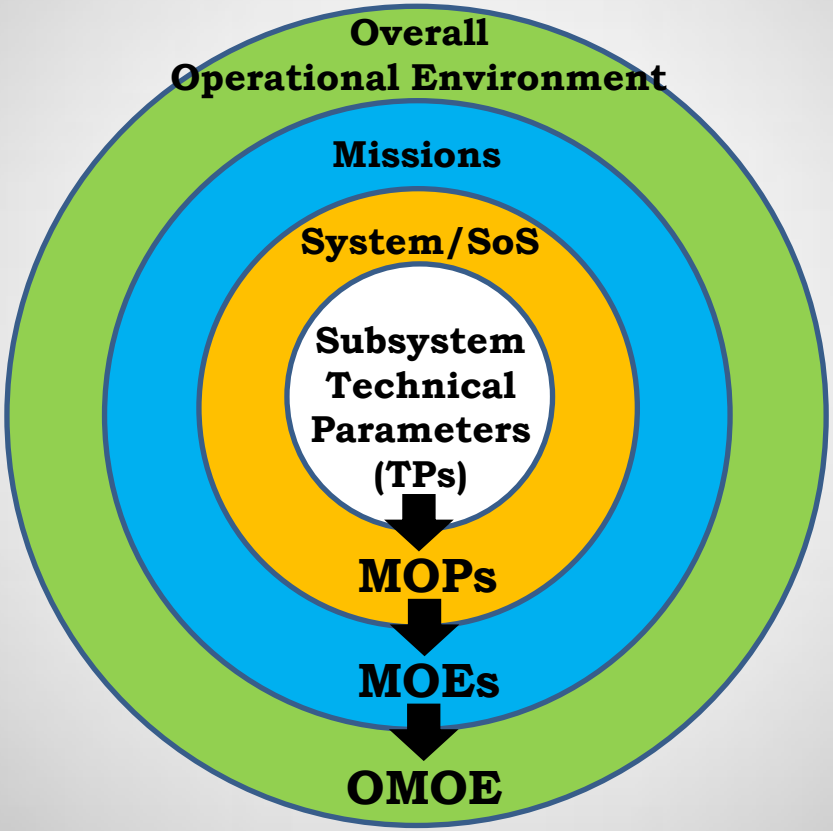



Resource Management
Commanders & Operators
Operational Picture
Environment Picture
C2 Picture
Resource Picture
Wargaming (Event/ Consequence Prediction)
Mission/Threat Assessment & Prioritization
Decision Engine
• Translate prioritized COA actions into resource tasks
• Generate allocation options and select optimum
• Issue tasks to warfare resources
Data Fusion Processes
Weather/ Mapping/ Intel Sources
Sensors
Communications
Warfighting Units
Weapons
Warfare Resources

Applying Systems Engineering Methods to Operational Resource Management


Resource Management
Decision Assessments
Performance
OMOE Decision Engine
"Cost"
Decision Cost Engine
"Risk"
Decision Confidence Engine

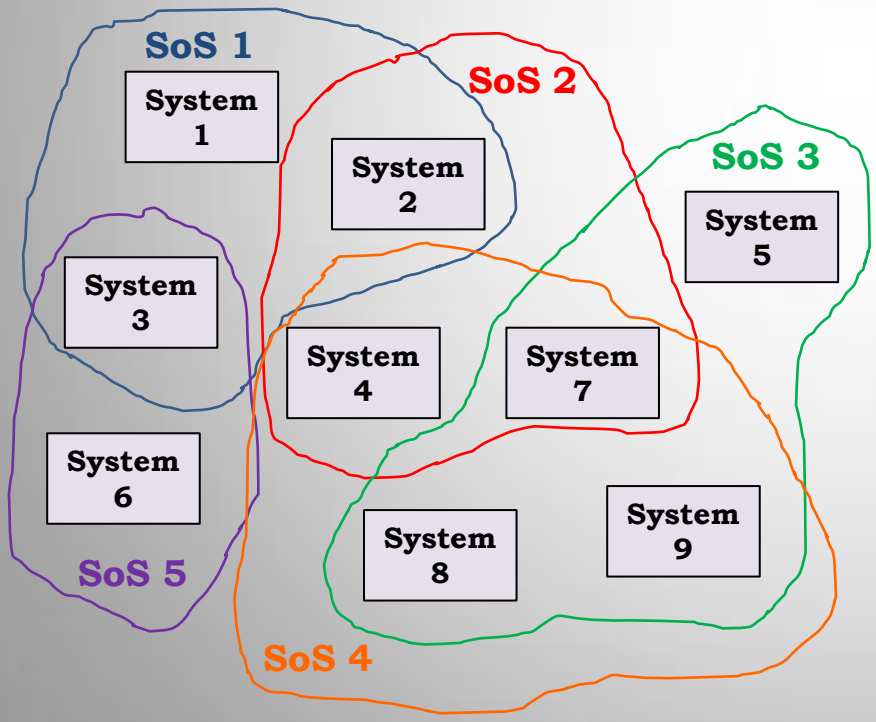
Measuring System Effectiveness & Performance

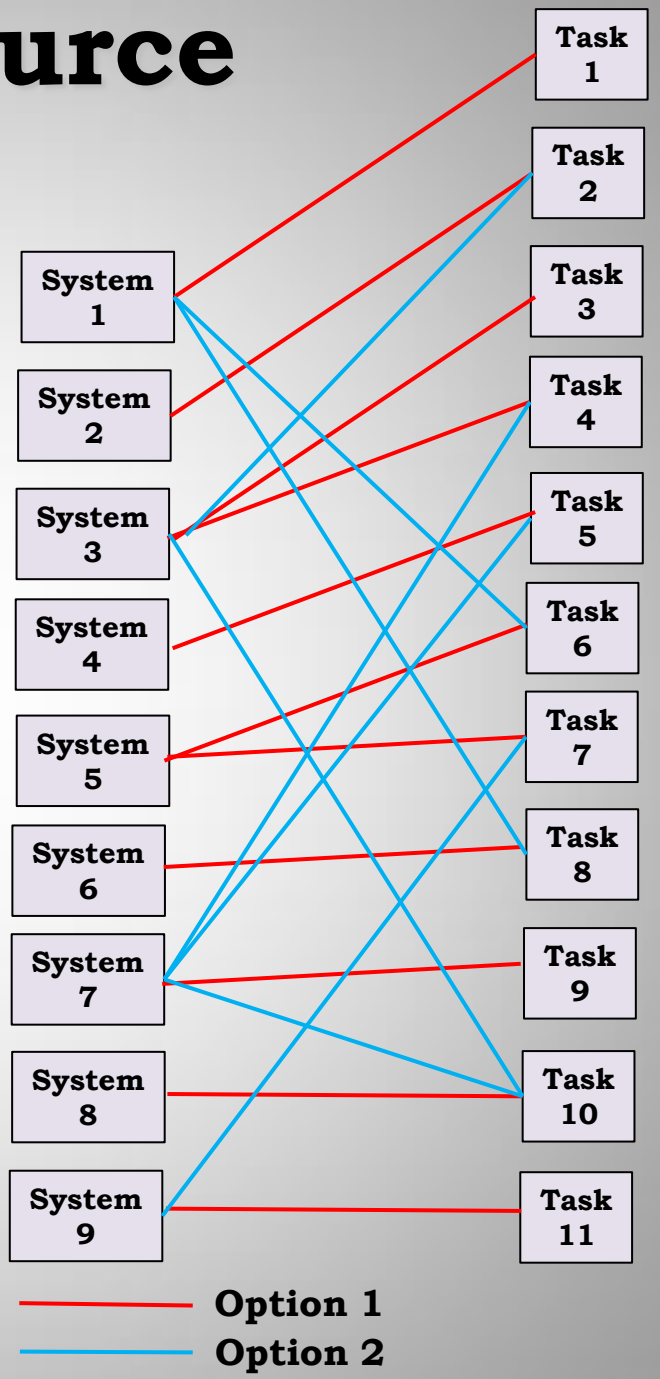


$$OMOE = \Sigma\, w_i\, MOE_i$$

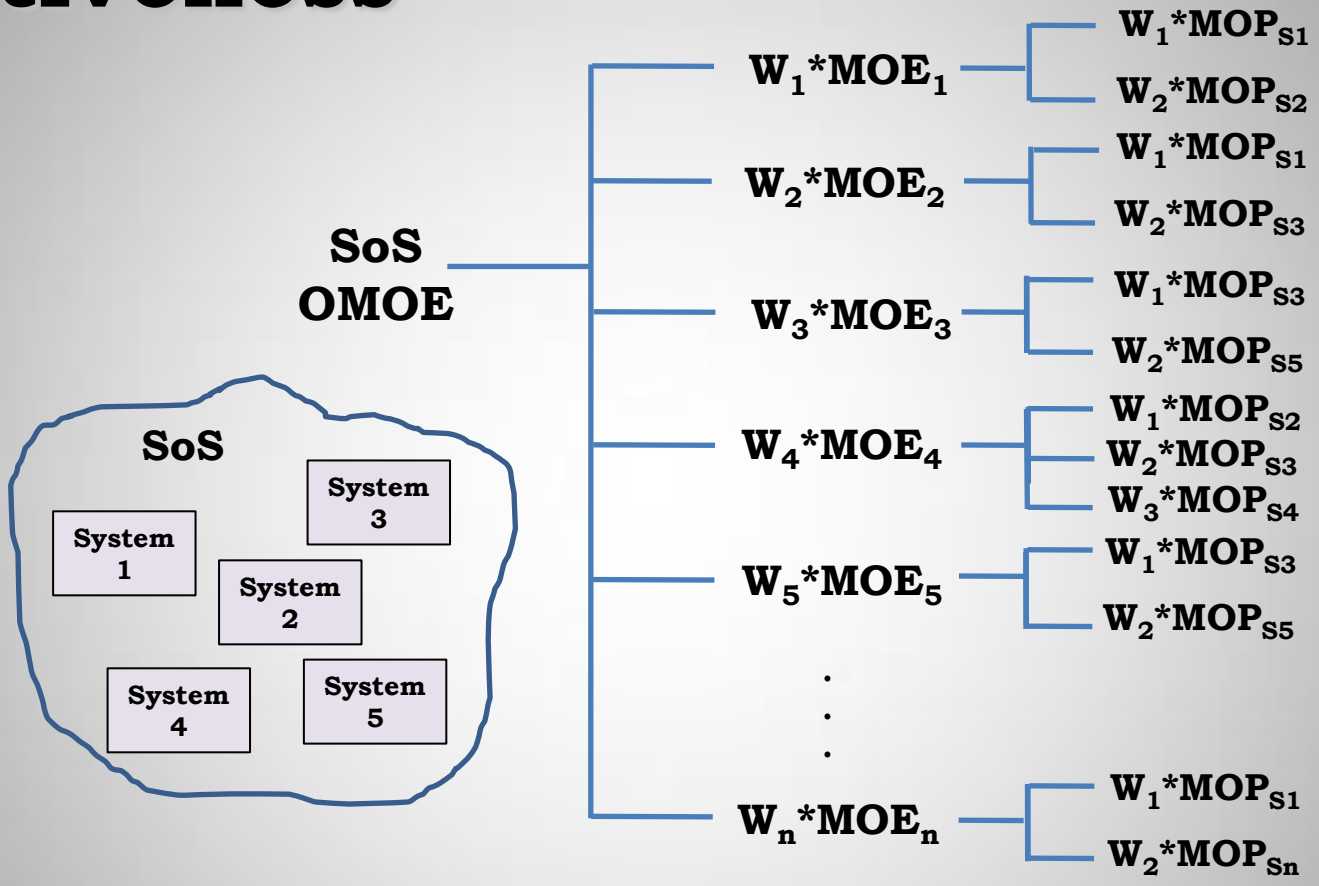
$$MOE = \Sigma\, w_i\, MOP_i$$

Examples of Resource Tasking





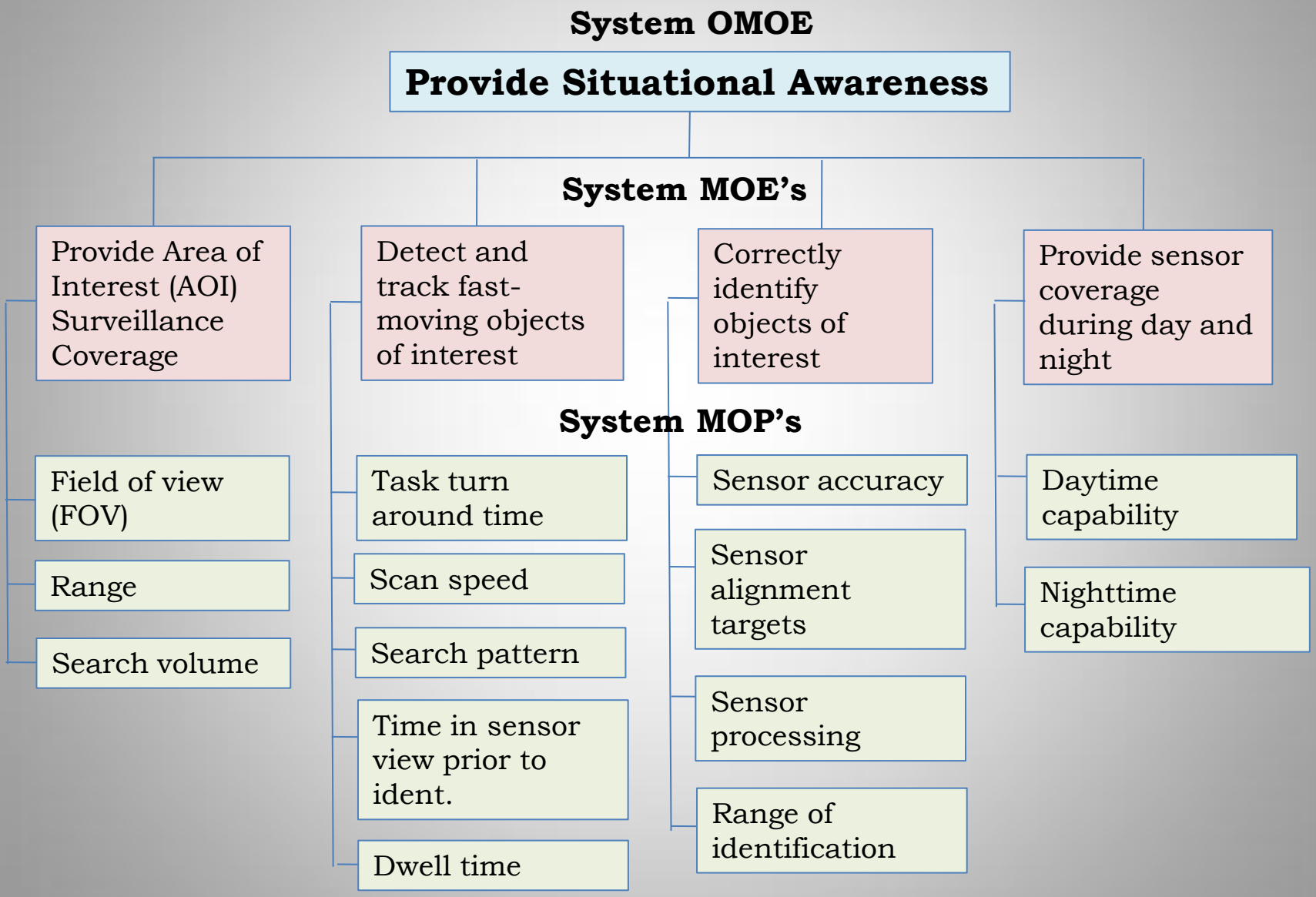
Hierarchy of Performance Effectiveness

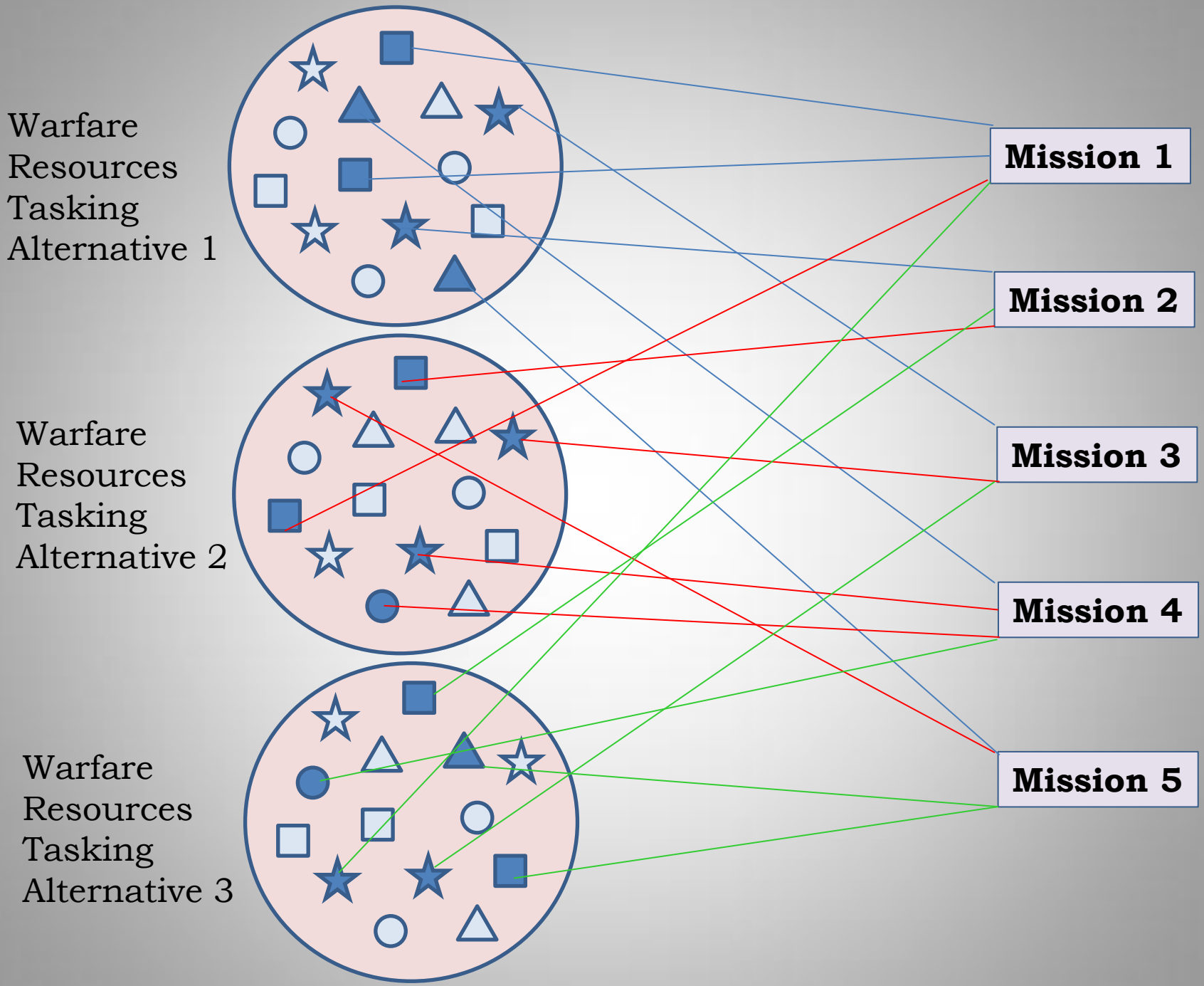


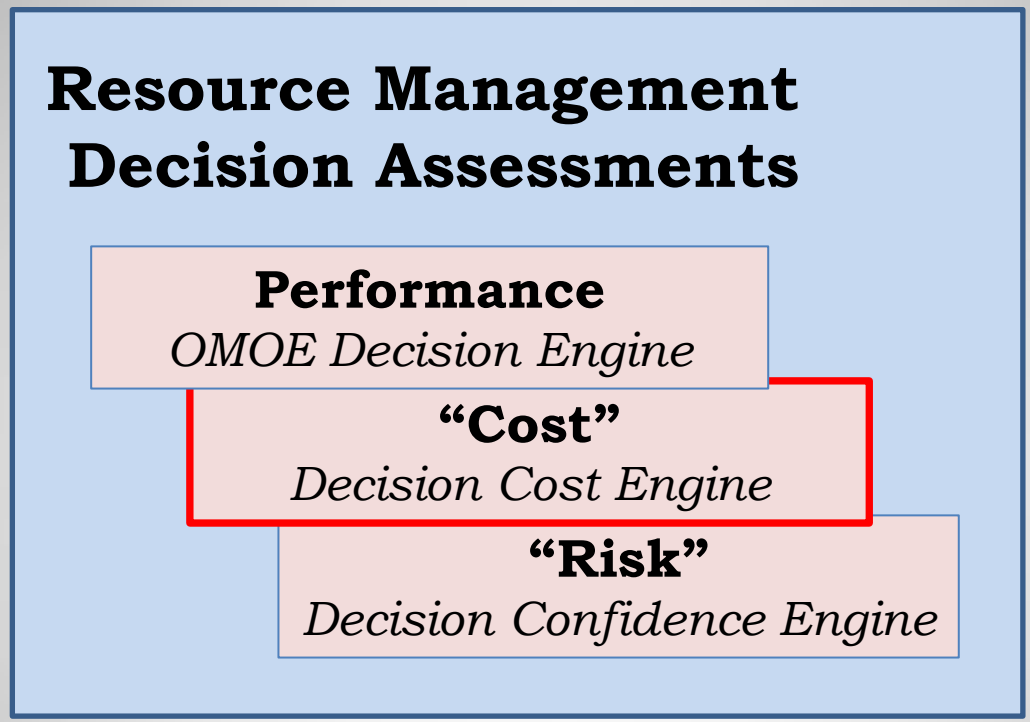
SoS OMOE = $\Sigma\ w_i\ MOE_i$ (Note – these are SoS MOEs)

SoS MOE = $\Sigma\ w_i\ MOP_i$ (Note – these are System MOPs)

Examples of Performance Measures




Warfare Resources Tasking Alternative 1
Warfare Resources Tasking Alternative 2
Warfare Resources Tasking Alternative 3
Mission 1
Mission 2
Mission 3
Mission 4
Mission 5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Cost Considerations for Resource Management

- **Operational Costs** – defensive weapons, fuel, power
- **Maintenance Costs** (due to usage) – preventive maintenance, spares, repairs
- **Safety Costs** – manned vs. unmanned

Remember! For RM, the systems are already developed and paid for—so cost is treated differently

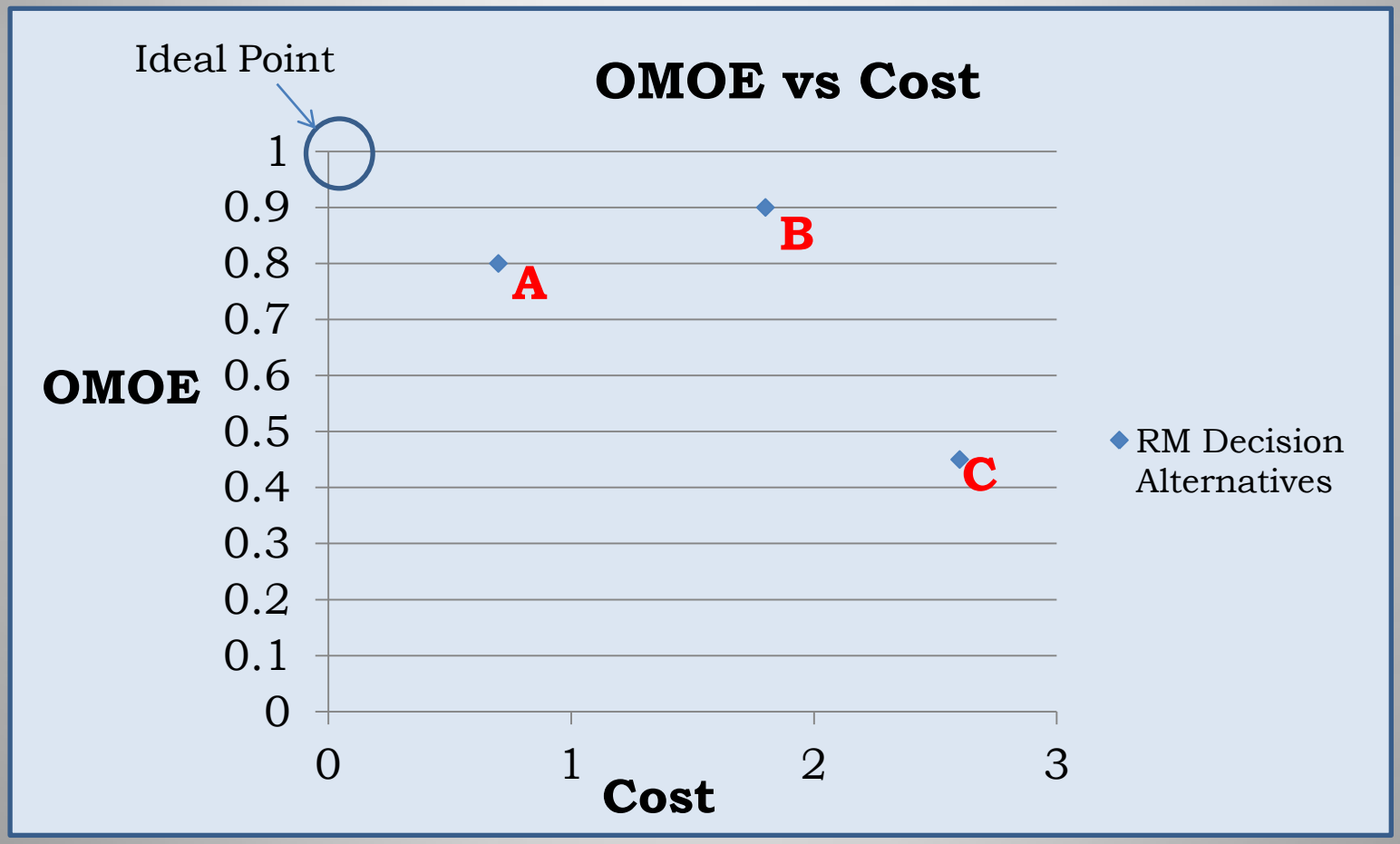
Decision Cost Engine Concept

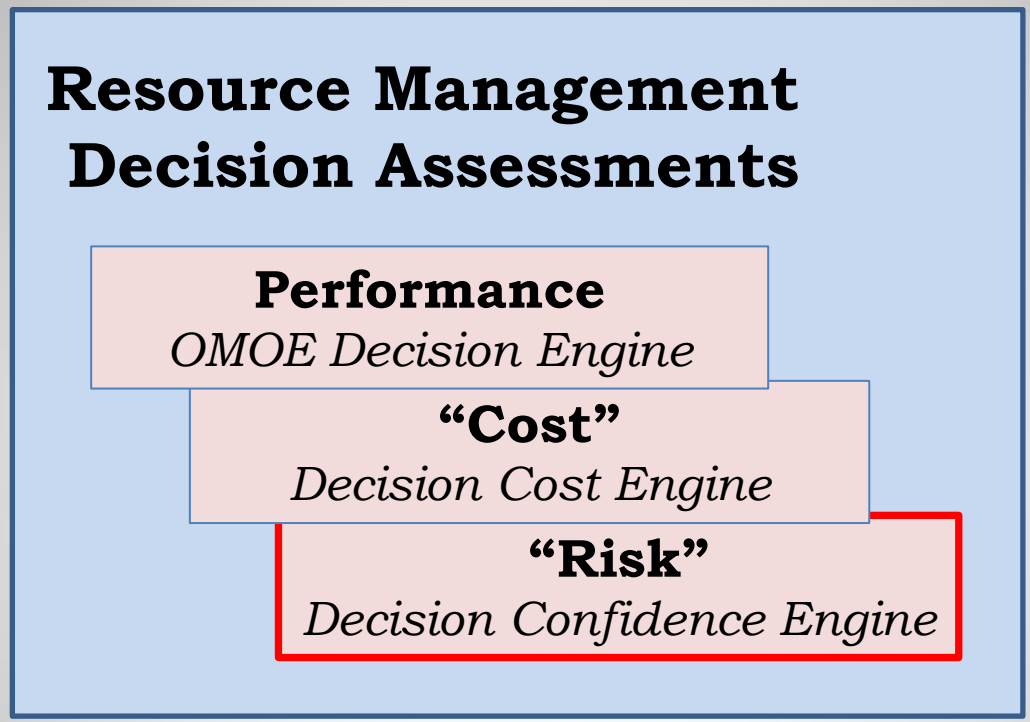
- Provides methods to quantitatively represent the cost associated with the use of each warfare resource
- May provide relative cost levels or values
- Relative values are used to further refine the overall relative ranking of resource tasking decision alternatives

Decision Cost Engine: 3 Concepts

1. **"After the fact"** – shifting OMOE scores up or down based on relative cost levels
2. **"Red Flag"** – associating an "identifier" with very costly warfare resources to highlight decision alternatives that include their use
3. **"Hierarchical Weightings"** – the most comprehensive approach would assign cost ratings to all resources and weightings to compute an overall "cost" for each decision option

Combining Performance and Cost Assessments

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Decision Confidence Engine

- Determines a “level of confidence” associated with each resource tasking option

- Based on:
  - Information reliability (or “goodness”)
  - Data fusion performance
  - Sensor error
  - Communication error
  - Computational error
  - Mis-associations, incorrect identifications, dropped tracks, poor track quality, etc.

Sources of Decision Error

- Sensor Observations (SO)
- Communications (C)
- Data Fusion Processing (DFP)
- Association (A)
- Attribution (At)
- Identification (Id)
- Threat Prioritization (TP)
- Mission Identification/Prioritization (MP)
- Resource Information (Health, Status, Configuration, Location, etc.) (RI)

Notional Decision Confidence Level:

$$P_{\text{Decision Accuracy}} = P_{SO} * P_{C} * P_{DFP} * P_{A} * P_{At} * P_{Id} * P_{TP} * P_{MP} * P_{RI}$$

Decision Confidence Engine (continued)

- Hierarchical probability model – that includes all possible sources of error
- As the operational situation changes, model is updates with error estimates
- Errors are summed hierarchically to calculate an overall confidence level for each resource tasking option

Summary

(comparison of Systems Engineering Assessment with Resource Management)

Decision Assessment for System Design	**Decision Assessment for RM Operations**
System is in design phase	Systems are in operation
To select the most operationally effective design	To select the most operationally effective SoS/resource tasking
Single decision	Continuum of decisions
Projected performance against operational mission requirements	Projected performance against actual operational missions/threats
Cost in terms of estimated $ for acquisition and total lifecycle	Cost in terms of known cost to operate & maintain; safety
Risk in terms of ability to meet requirements	Risk in terms of decision uncertainty or level of confidence

Conclusions

- A decision framework providing decision assessment methodologies can address the complexity involved in effective resource management for tactical operations.
- Applications from Systems Engineering provide methods for operational performance, cost, and risk assessments of resource tasking alternatives.
- Future command and control stands to benefit from adopting a decision paradigm in addition to the traditional data-focused perspective.

Future Work

- Objective hierarchy modeling
- Techniques for generating resource tasking alternatives
- Continued development of the OMOE decision engine, cost decision engine, and decision confidence engine
- Designing warfare resources with an emphasis on being “taskable” and have “multiple uses”