SAND2014-16248PE

# An Model Based Systems Engineering Framework For Evaluation and Improvement of Complex Enterprises

**IFORS 2014**

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**Sandia National Laboratories**

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# Overview

- **Present a framework of analytical capabilities to evaluate the performance of the military enterprise as it transforms to meet future, emerging challenges**
- **Proof of concept by illustrating how to address questions like:**
  - Given a set of possible future challenges, what are the set of capabilities that the military needs to have adequate in order meet future missions? What are the contributions toward those capabilities that come from each of the military enterprise elements
    - *Are these new weapons systems? Offensive or defensive mechanisms? More people? More social education?*
  - Where should the military invest $ and technology to best support the power projection and meet mission needs of the future?



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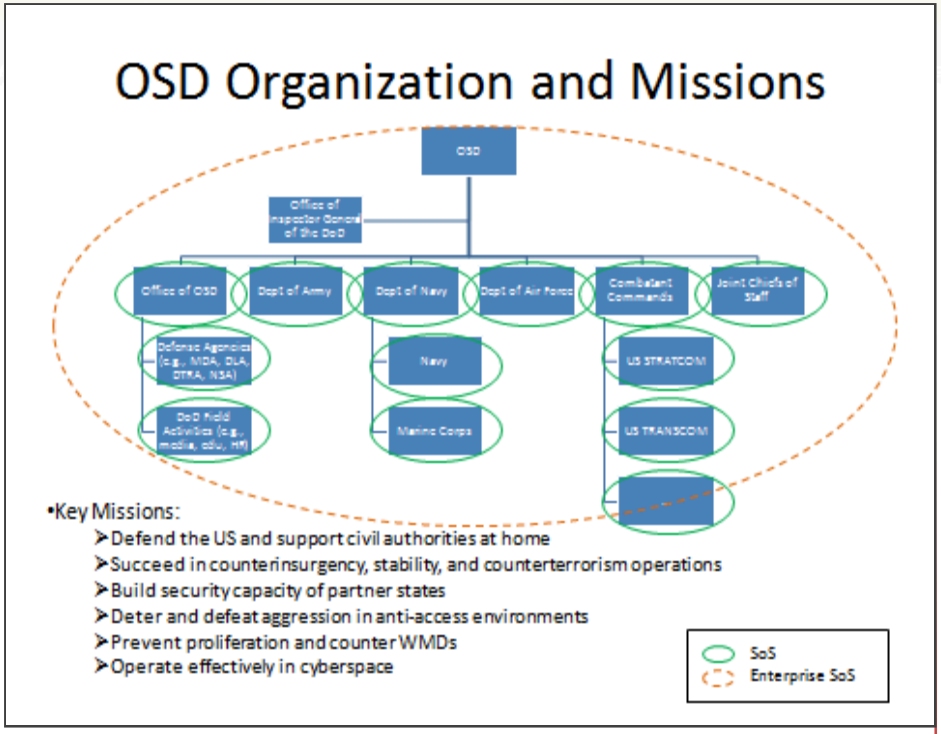
# Complex Adaptive Systems Engineering

**SOURCES of future COMPLEXITY**
- Changing social demographics
- Emerging patterns of globalization
- Shifting economic patterns
- Emerging energy technologies and demands
- Scarcity of food and water
- Emerging effects of climate change
- Natural disasters and Pandemics
- Competition and conflict in the domains of cyber and space
- Hybrid enemies (state and non-state)
- Enemy adaptation (regular, irregular, terrorist tactics)

***Externalities***




**Overview: Research and develop a *Complexity Science* based *conceptual model* of the DoD enterprise that diagrams and decomposes fundamental elements, key relationships, functional analytical needs, and allows for mapping sources of complexity (internal and external) to mission requirements**

*Future Operations in Complex Environments – Dr. Richard Hayes - Assistant Secretary of the Army (Network Information Integration) Mission Command CP Workshop Oct. 2009



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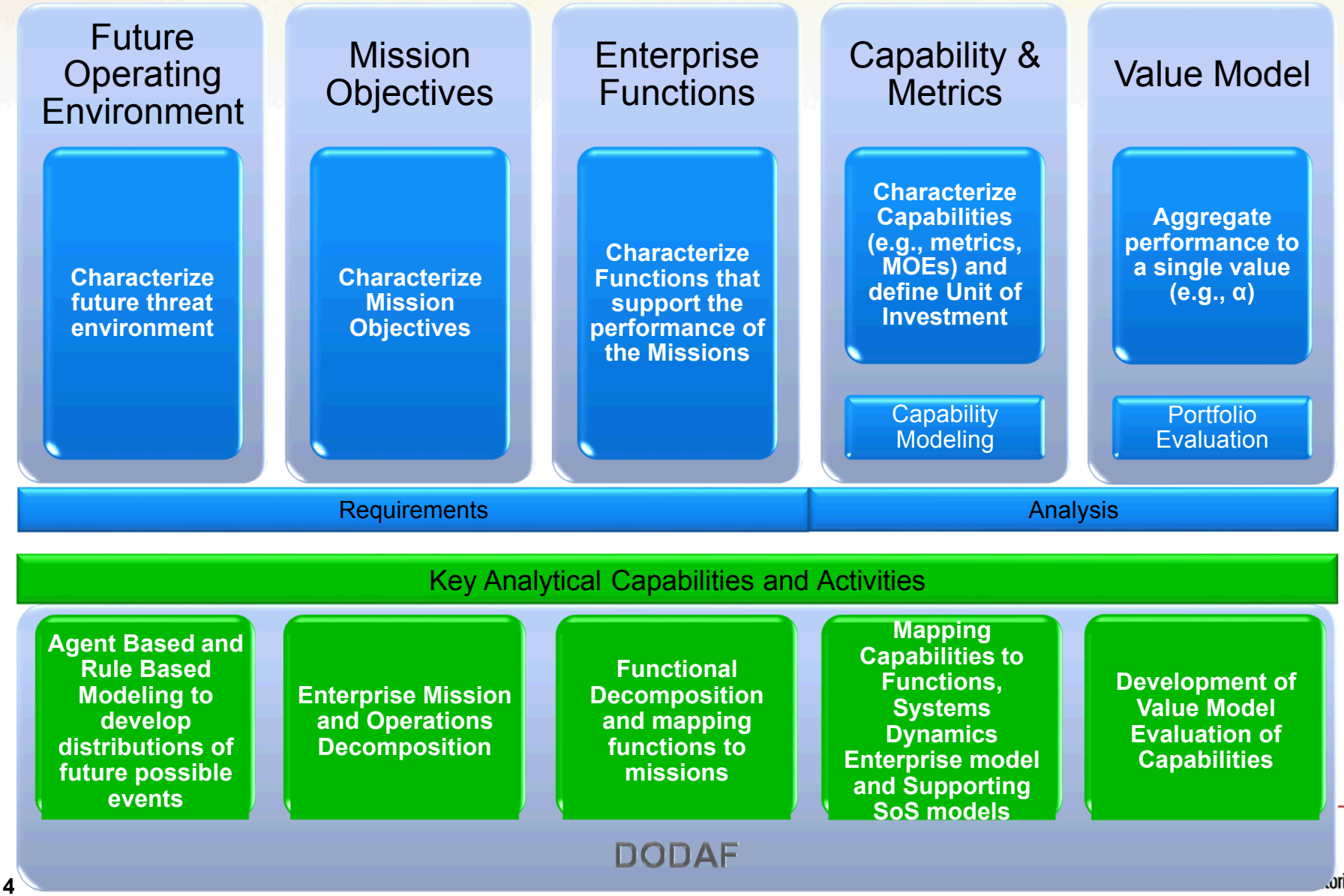
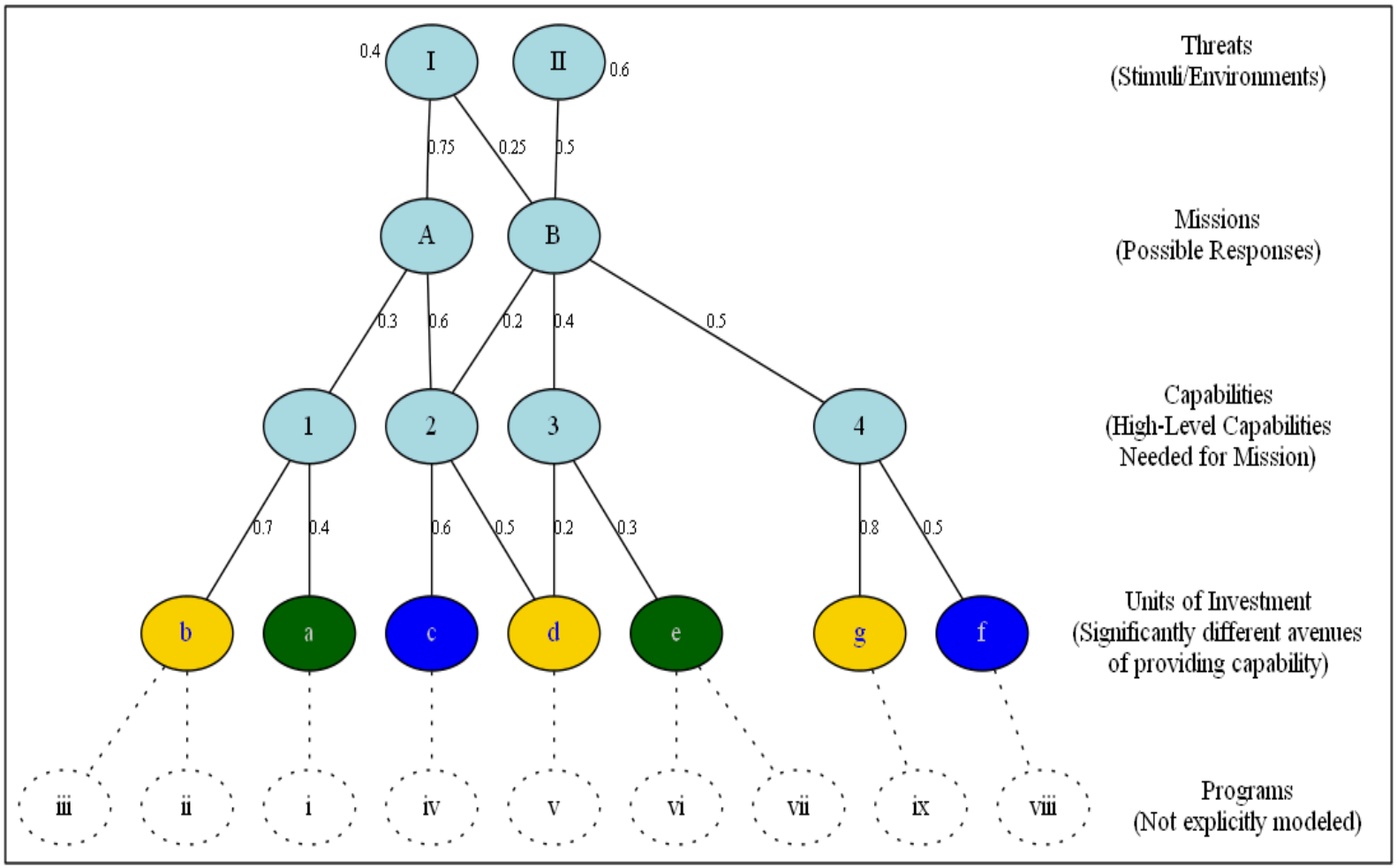
# Enterprise Model Framework



# Graph Organization of Framework




- A Graph representation of the Framework allows for a structured understanding of the relationships between the framework elements/levels
- Modeling and analysis are performed within each framework element and the graph defines analysis connections
- The graph structure in combination with a value model allows for mathematical evaluation of overall framework



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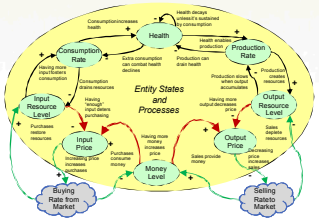
# Framework Elements

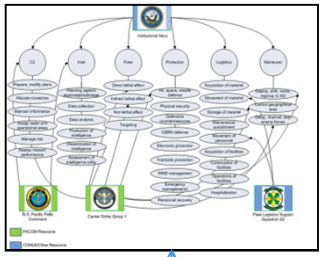
**Agent Based Threat Model**



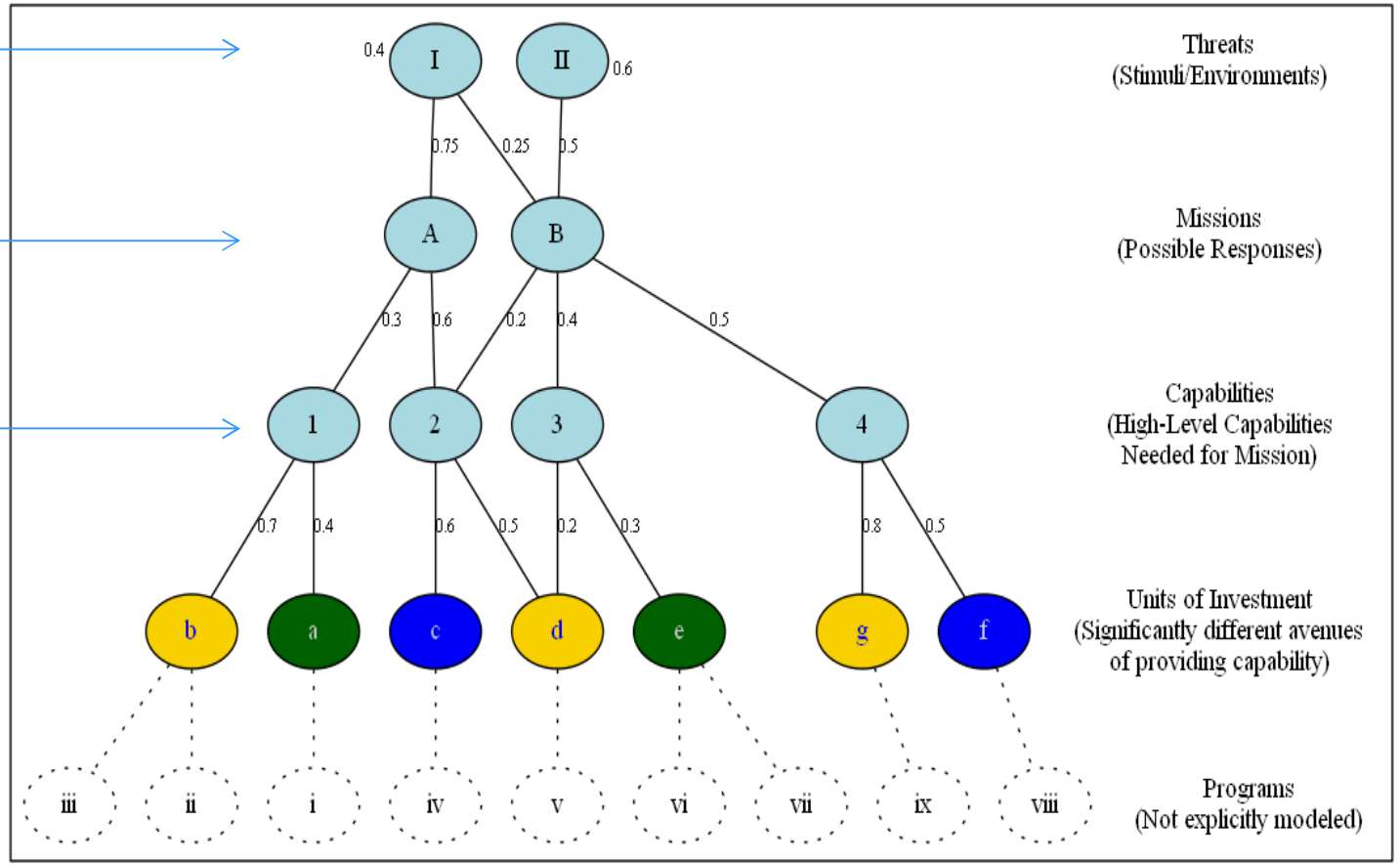

**Mission/Function Decomposition**

| Example: Foreign humanitarian assistance | | | | | |
|---|---|---|---|---|---|
| Joint Functional Capabilities | | | | | |
| Command & Control | Intelligence | Fires | Movement & Maneuver | Protection | Sustainment & Logistics |
| Joint OPLAN/OPORD (How Organizations, People, and Equipment are used) | | | | | |
| Multi service Tactics, Techniques, and Procedures (MTTPs) | | | | | |
| Army | Navy | Marine Corps | Air Force | | |
| Service Specific OPLANs/OPORDs | | | | | |
| Service Specific TTPs | | | | | |

**SD Performance Model**



**Supporting SoS Models**



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# Future Operating Environment

- **Agent Based model used to establish possible future operating environments:**
  - Multiple nation states interacting economically and militarily (e.g. triggers for conflict, consequences, actions/reactions)
  - Allows for explicit introduction of sources of complexity
  - Ties military investment and economic elements together to determine effects on Nation state health
- **Specific future challenges and events occur based on the state of the future operating environment**
- **Model defines distribution of events in future operating environment explicitly incorporating uncertainty**
  - Model a range of possible scenarios
  - Provides input to enterprise model allows for more robust analysis to identify value of capability needs and solutions
  - Results in a distribution of future required missions



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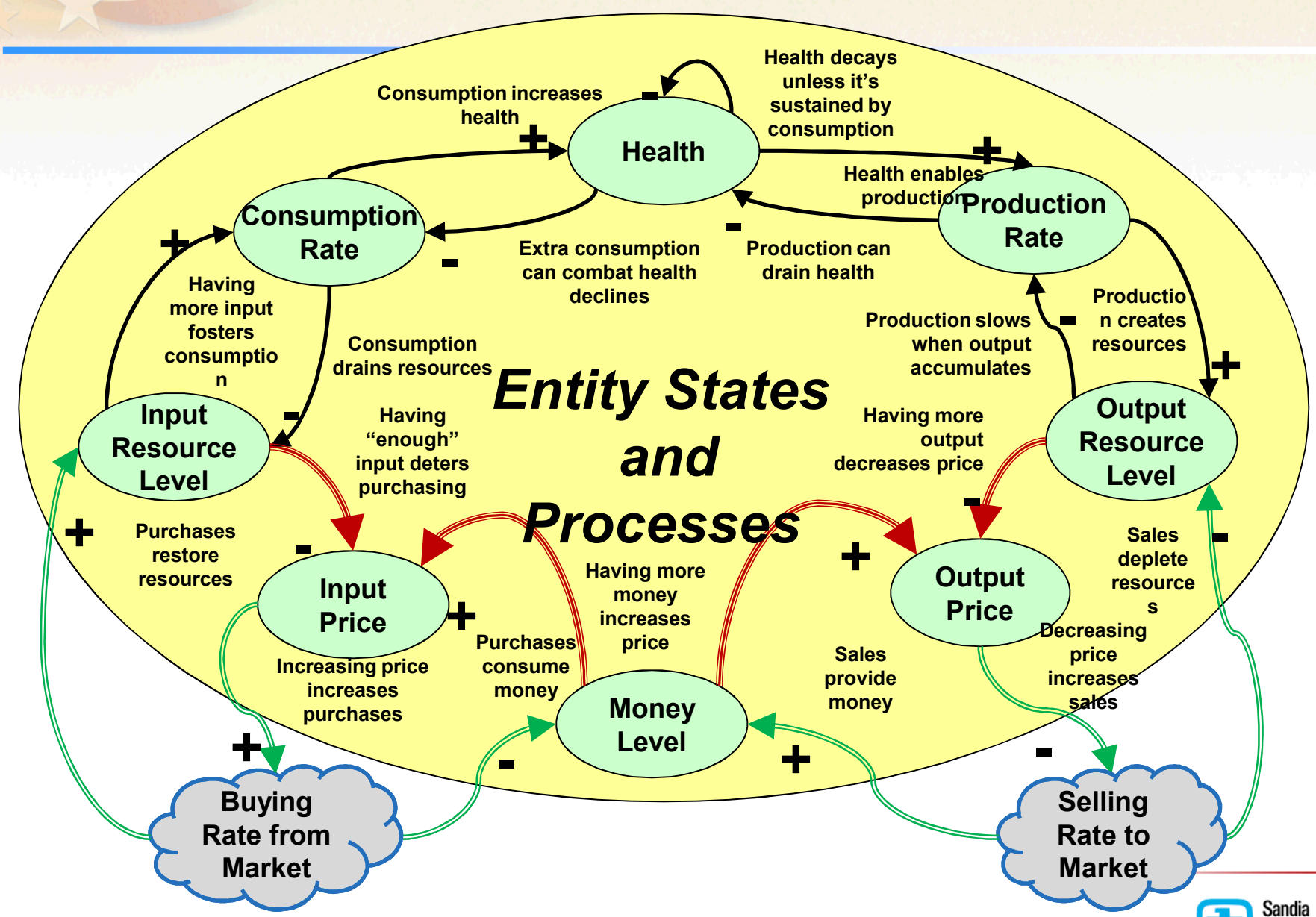
# Agent Based Model Entity Architecture



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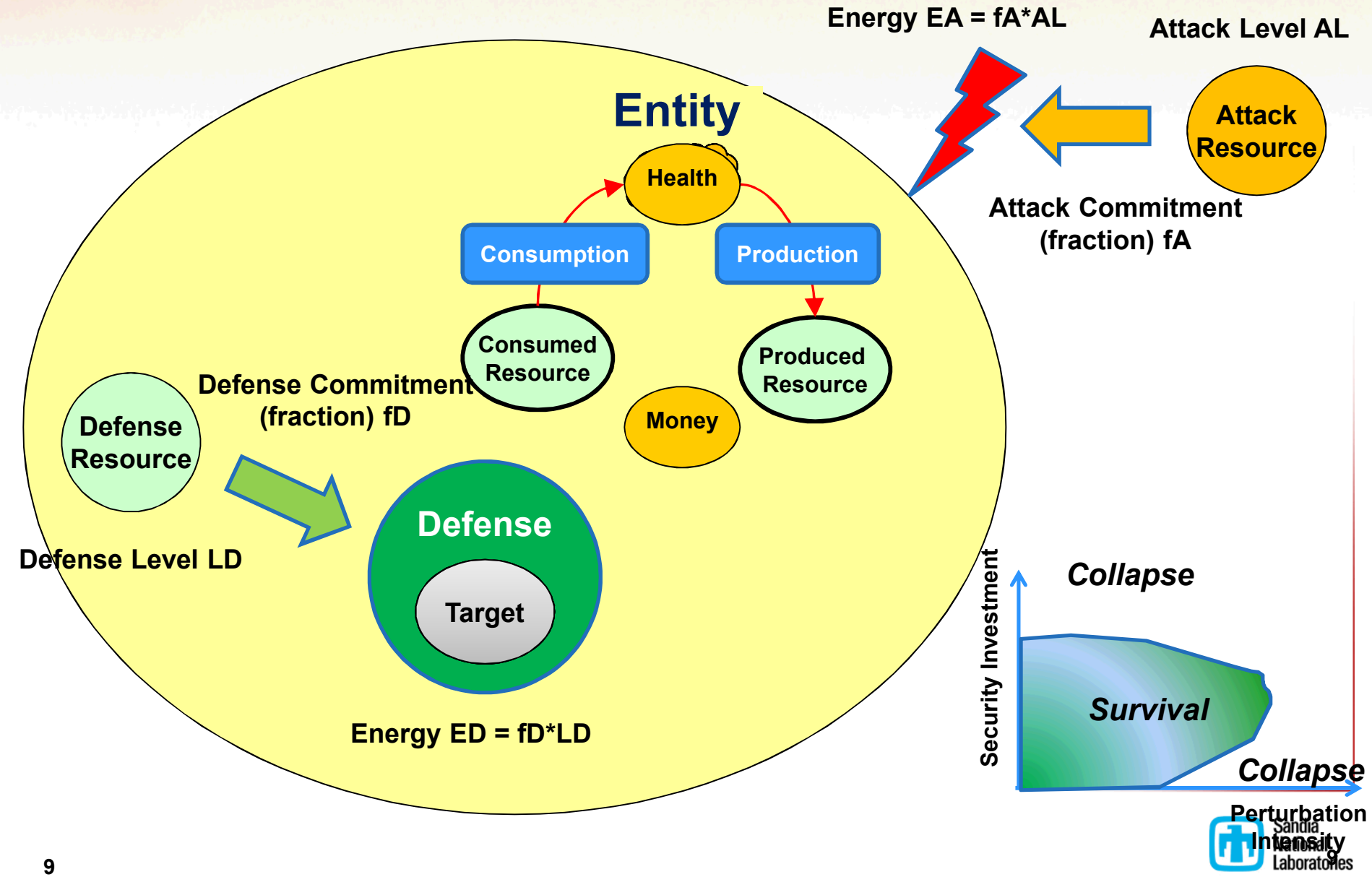
# Agent Based Model Elements



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# Mission & Functional Decomposition

- **Goal: Link the future operating environment to a set of missions, operations, and functional capabilities**
  - Decompose range of possible missions and operations performed by the enterprise
  - Understand lower level sub-functions and required capabilities
  - Capabilities (developed through investment) will be mapped to functions.



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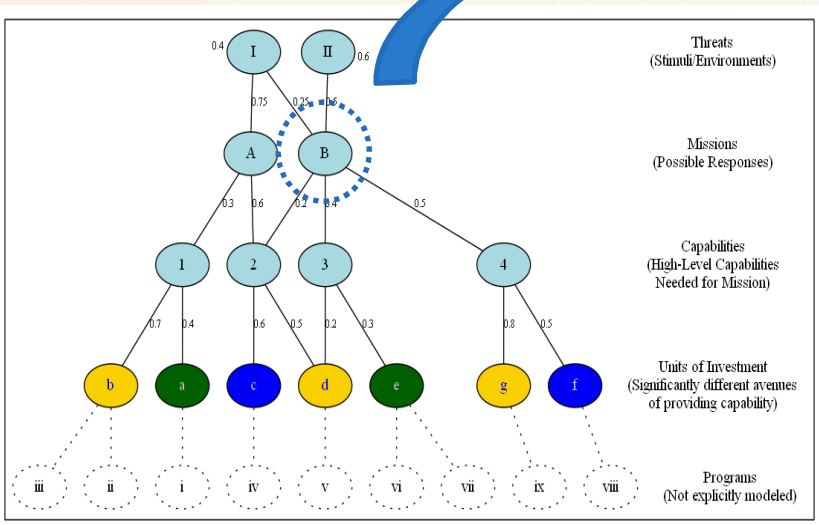
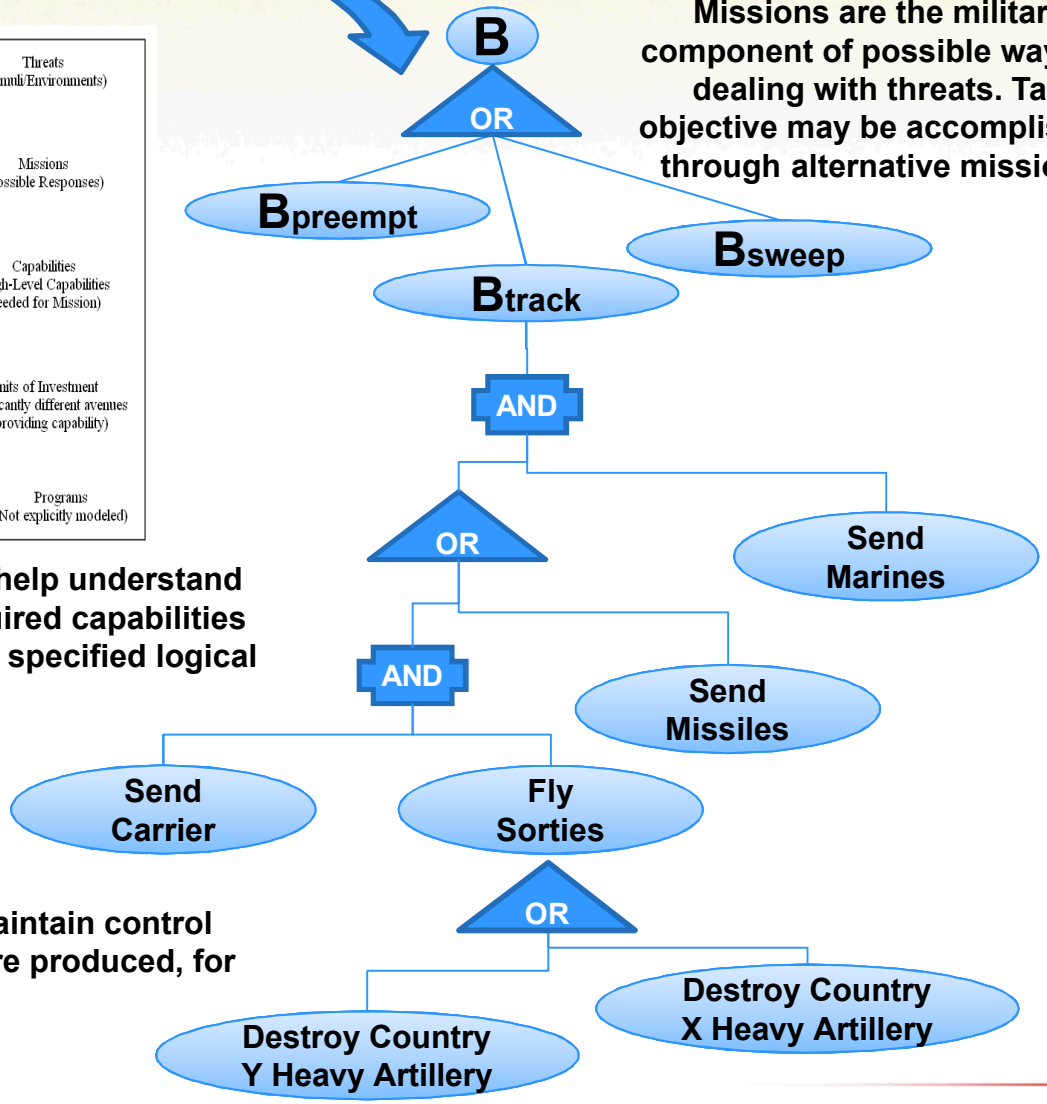
# Mission Decomposition




Missions are the military component of possible ways of dealing with threats. Tan objective may be accomplished through alternative missions

Decomposing missions will help understand required sub-goals and required capabilities for collectively meeting some specified logical conditions.

Mission sub-goals may be abstract (maintain control over territory where critical resources are produced, for example)



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# Themes & Operations: ROMO

## Themes help categorize operations

| THEMES | | | | |
|---|---|---|---|---|
| Peacetime Military Operations | Limited Intervention | Peace Operations | Irregular Warfare | Major Combat Operations |
| Features | | | | |
| Long term<br>Non-doctrine<br>Bilateral or multinational | End state clearly defined<br>Limitations on supporting forces<br>Limited size<br>Limited phasing | Crisis response<br>Contain conflict<br>Limited contingency ops<br>All instruments of national power<br>Asymmetric threats<br>Failing states<br>Collapse of infrastructure<br>Presence of dislocated civilians | State/nonstate actors struggle<br>Irregular forces<br>Warfare among/within people<br>Indirect unconventional methods<br>Special operations conduct most ops | General war<br>Defeat enemy<br>Sieze terrain<br>Multinational interests<br>Doctrine |
| OPERATIONS | | | | |
| Multinational training excercises<br>Security assistance<br>Joint combined exchange training<br>Recovery operations<br>Arms control<br>Counterdrug activities | Noncombatant evacuation<br>Strike<br>Raid<br>Show of force<br>Foreign humanitarian assistance<br>Consequence management<br>Sanction enforcement<br>Elimination of WMD | Peacekeeping<br>Peace building<br>Peacemaking<br>Conflict prevention | Foreign internal defense<br>Support to insurgency<br>Counterinsurgency<br>Combating terrorism<br>Unconventional warfare | Specific named operations<br>Offensive joint operations<br>Defensive joint operations<br>Special operations |

* Campaigns can involve multiple Themes



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# Functional Decomposition

| | | | | | |
|---|---|---|---|---|---|
| Example: Foreign humanitarian assistance | | | | | |
| Joint Functional Capabilities | | | | | |
| Command & Control | Intelligence | Fires | Movement & Maneuver | Protection | Sustainment & Logistics |
| Joint OPLAN/OPORD (How Organizations, People, and Equipment are used) | | | | | |
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| Army | Navy | Marine Corps | Air Force | | |
| Service Specific OPLANs/OPORDs | | | | | |
| Service Specific TTPs | | | | | |

- **Operations require a mixture of Joint Functional Capabilities (JFCs) – units are organized by JFC**
- **Joint OPLANs and OPORDS define how organizations, people, and equipment are orchestrated when conducting a joint operation**
- **Multi-service TTPs detail the tasks associated specific elements of a joint operation**
- **Service specific OPLANs/OPORDs and TTPs define specifics for each service involved in the operation**



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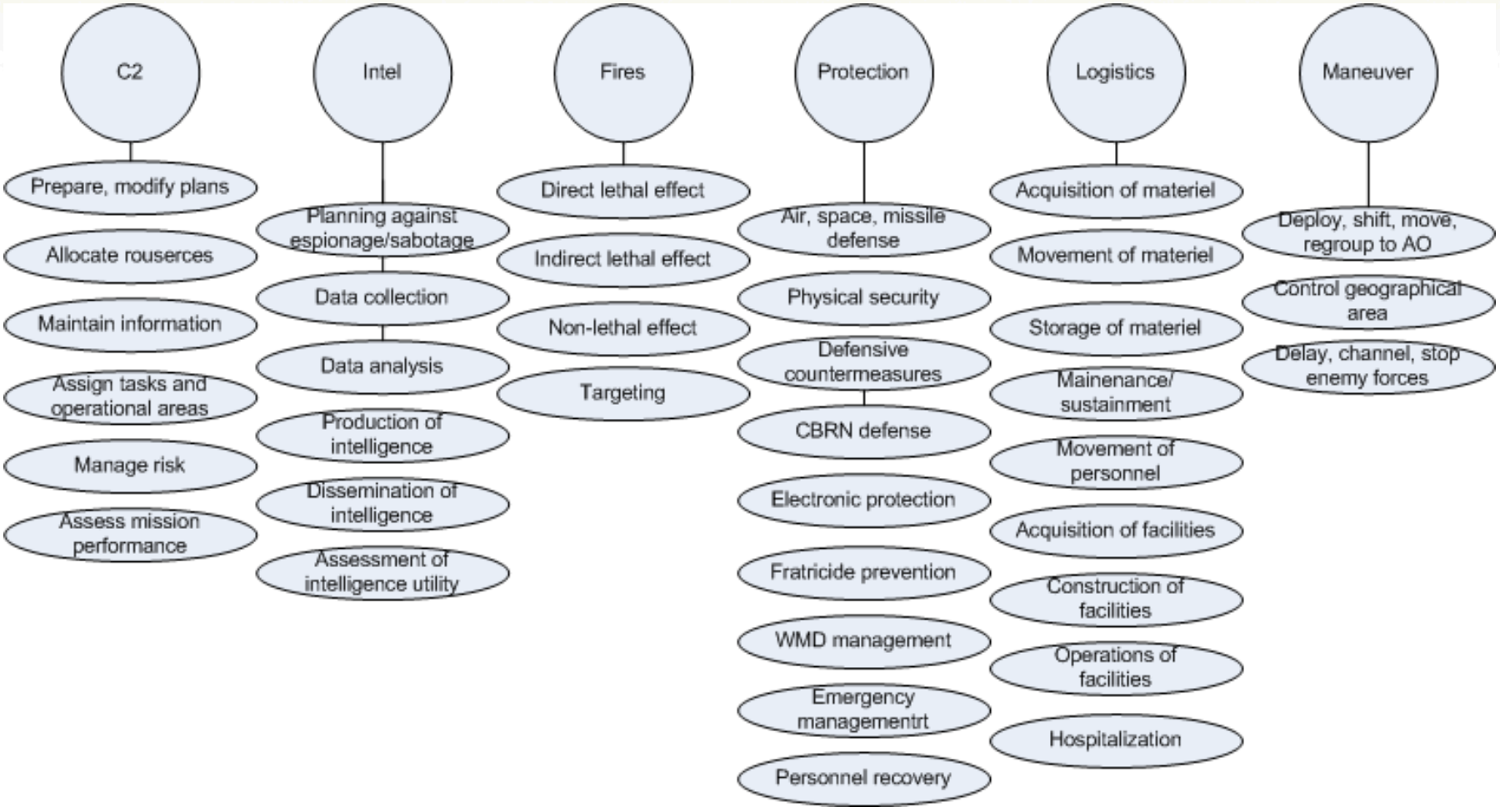
# Functional Decomposition (cont.)



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# Capabilities

- Closely related and complimentary to Mission and Function decomposition
- Defines alternative technologies/solutions and tactics (operations)



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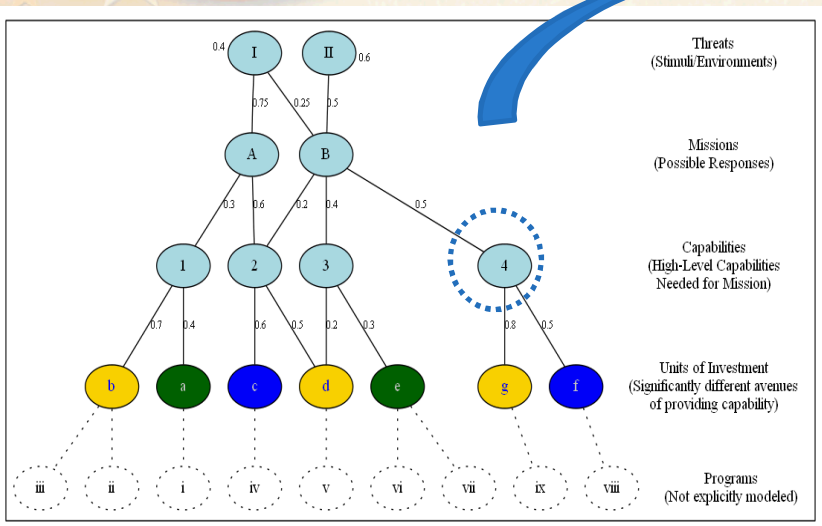
# Capability Alternatives




Strike

OR

Gliders

Ray Guns

Missiles

AND

Capabilities will be mapped to required functions. Units contain capabilities.

Composition rules describe which combinations of units can work together

3

Launch Vehicle

OR

Trident

SLIRBM

Re-Entry

OR

CAV

MLRB

Warhead

OR

Flechette

Penetrator

Some units may support more than one capability

This leads to the final level – the unit of investment, about which decisions are made



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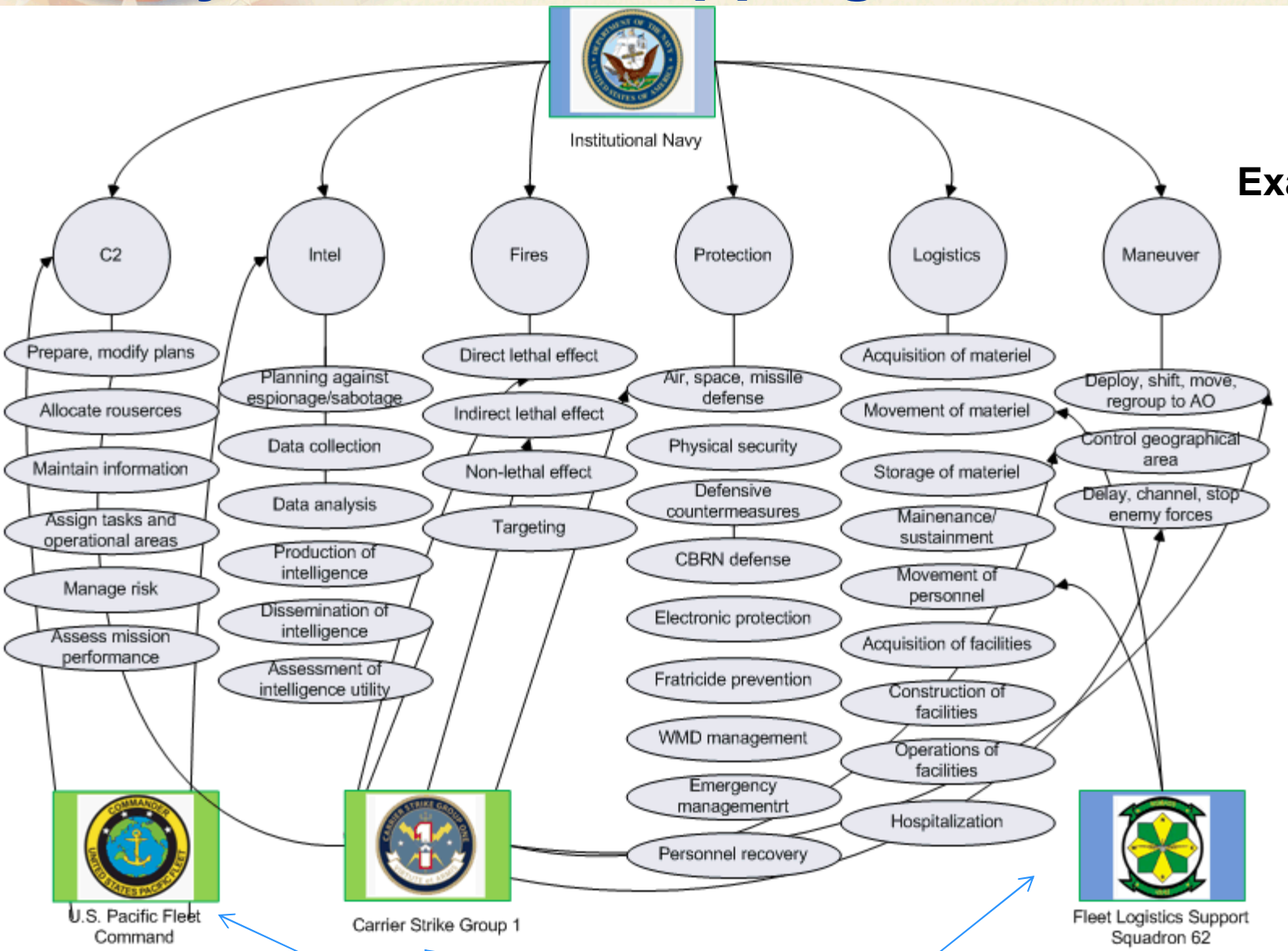
# Navy Unit / JFC Mapping – HADR Example




## Example Metrics

- Range/ Mobility
- Lead Time
- Delay Times
- Time to Perform
- Rate of Movement
- Accuracy
- Completeness
- Durability/ Reliability
- Power
- Cost

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# Value Model

- **Evaluation approach using investment performance metrics against threat environments and capabilities**
- **Small prototype model to demonstrate concept**
  - Simple method of aggregating performance at investment area up to a global fitness metric
  - Simple surrogate-type model of how investment dollars are translated into performance by an investment area; captures concepts of threshold investment and law of diminishing returns
  - Capability to maximize fitness metric under various constraints
- **Future work: demonstrate/incorporate more capability**
  - Rigorous treatment of uncertainty
  - Dynamics (or even any concept of time)
  - Develop method to determine weightings used in framework *(relates to how we compare across different capability types)*



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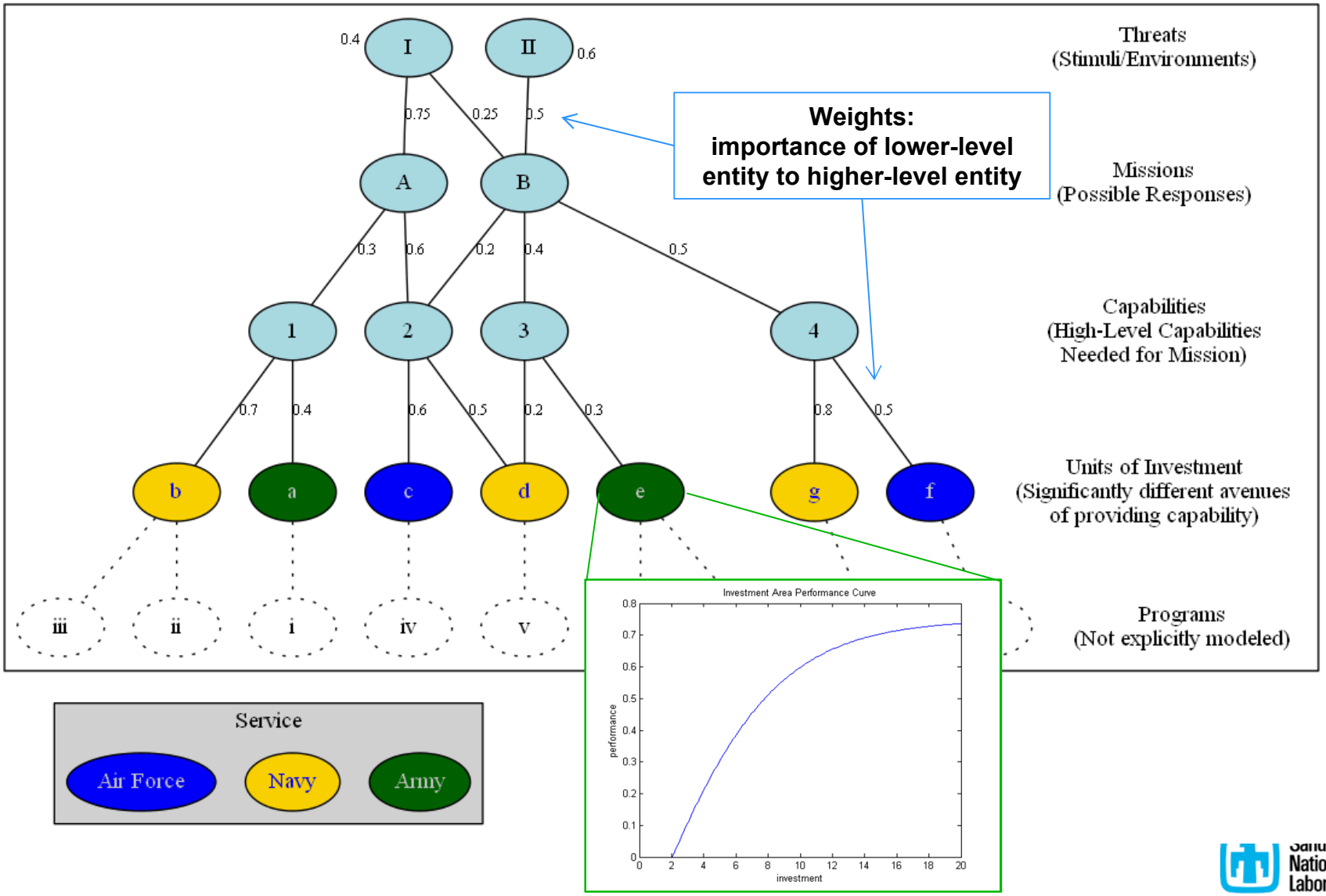
# The System



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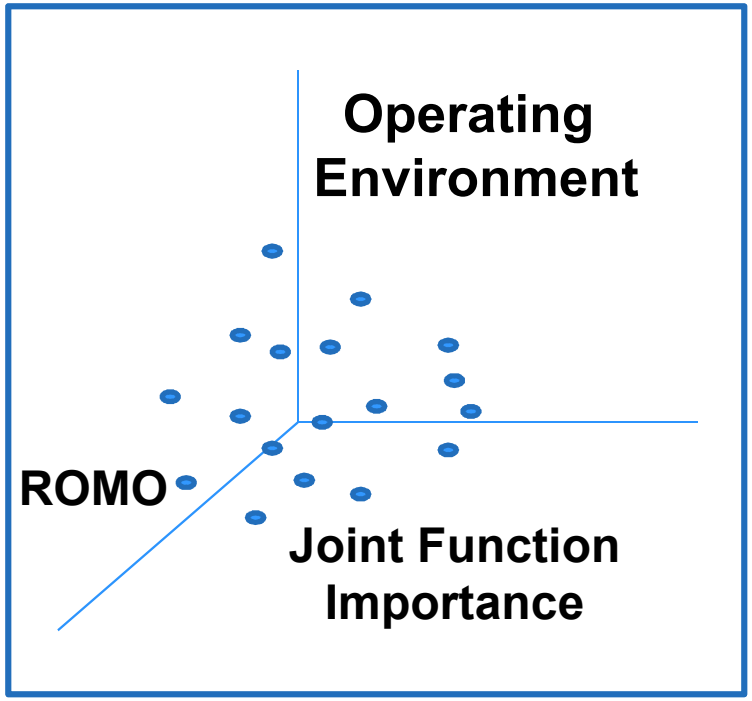
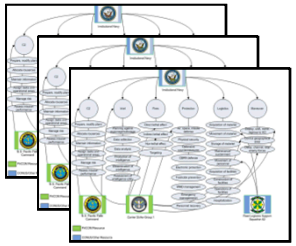
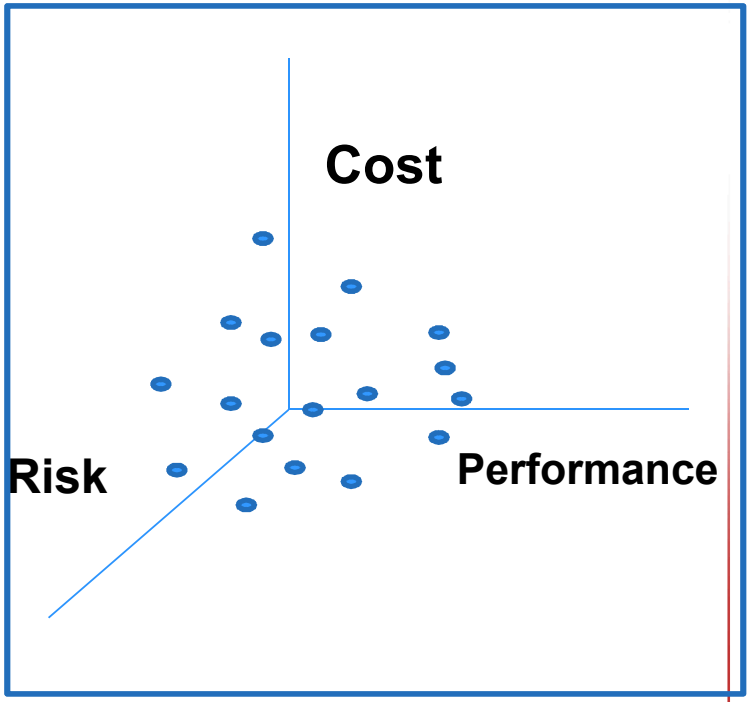
# Input-Output




Systems
Model
Assessment





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# Backup



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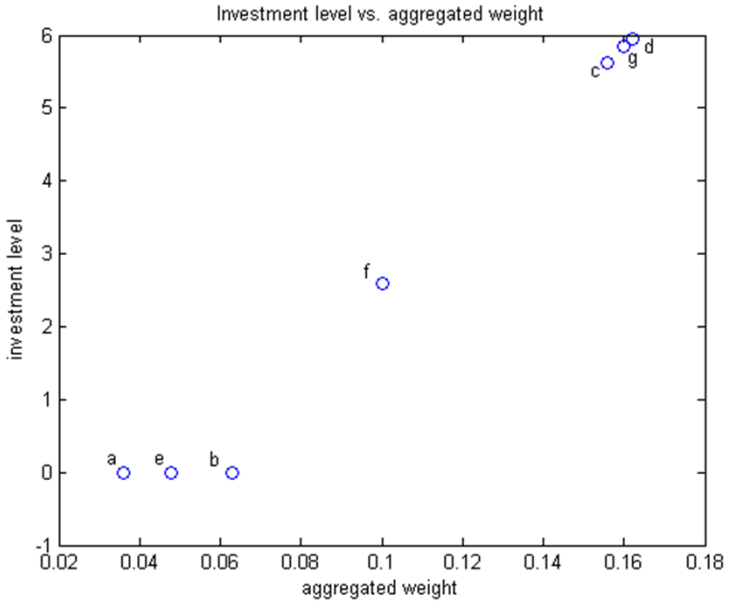
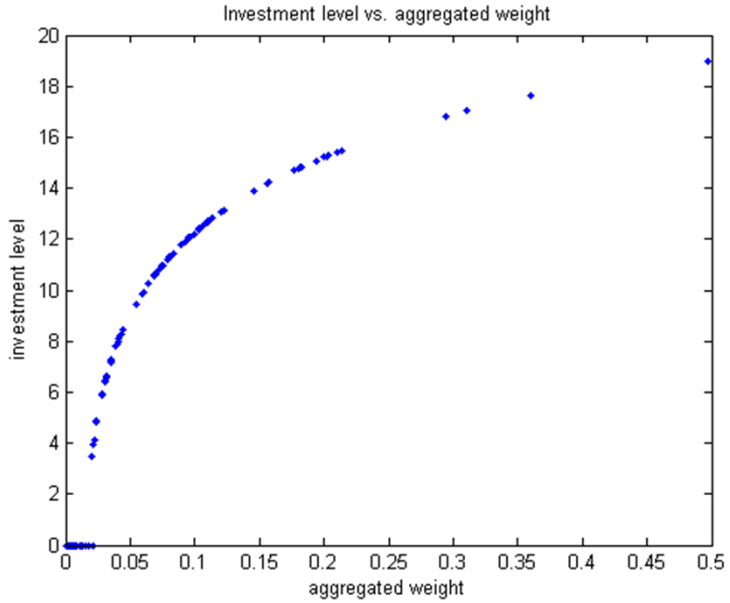
# Scalability




- 7 IAs
- Less than 1 second

- 110 IAs
- About 11 seconds

**(since all IAs currently have the same performance curve, investment vs. aggregated weight should follow a nice clear curve, as above, where investment is zero below some weight and is monotonic increasing and concave down above that threshold.)**



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