# *Using Conceptual Modeling to implement Model Based Systems Engineering for Program Capability Analysis and Assessment*

*National Defense Industrial Association (NDIA)*
*Systems Engineering Conference*

*October, 29, 2015*

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# Agenda

- Introduction
- MBSE and Acquisition
- DoD Acquisition and use of modeling and simulation
- Problems with Modeling in Acquisition Oversight
- Some Proposed Solutions
- An Approach
- Conceptual Modeling Example – a Threat to the U.S.
- Wrap Up

# Model Based System Engineering

- Model Based System Engineering (MBSE) is able to describe physical processes, along with their attributes, for evaluating acquisition program cost / schedule / performance (CSP)
- MBSE builds on successful techniques from the software engineering community for structuring systems data and aiding development
- Many software tools exist that use MBSE but a **generic conceptual approach** is possible
- Most emphasis on MBSE has been on system/program capability development
- We are looking to expand the rigor of a model-based approach
- Not that much new, just better tools and more experience with:
  - Executable Architectures
  - Model Based Architecture (OMG)
  - Executable DoDAF
  - Simulation-Based Acquisition etc…

We can leverage MBSE to provide analytical insight on system behavior across an acquisition's lifecycle

# MBSE and Acquisition

- MBSE provides a method to organize data to function / purpose over a program's lifecycle
  - Since an MBSE approach is inherently robust and contains the data required to model the processes intrinsic in a capability development, it:
    - Requires a structure for that data that organizes a process with often disparate data into an organized entity
    - Has the prerequisite digital structure to **support modeling capability performance**
- MBSE can be used to help objectively model an acquisition programs macro capability in performance terms and as the Systems of Systems level.
- MBSE can provide clarity on requirements and insight on trades between both functional and performance requirements
- If we view an acquisition lifecycle as a process, with many sub processes also model-able.. then the use of a scalable conceptual framework (MBSE) to organize data is attractive

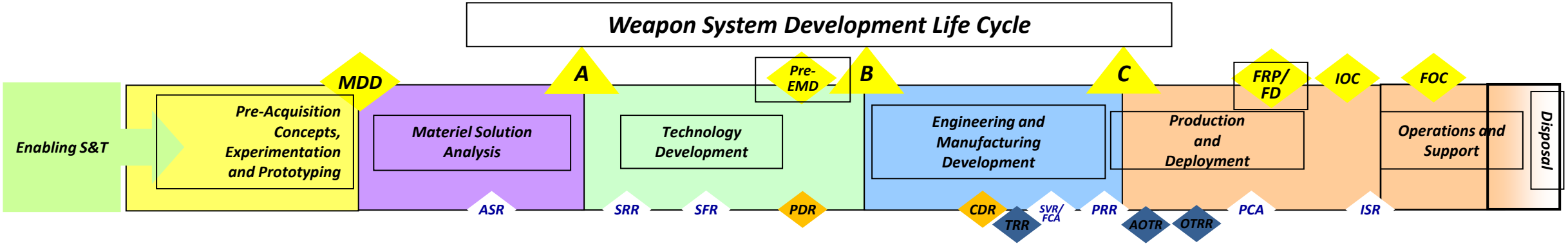
# DoD Acquisition
## use of modeling (and simulation)*

- Defense Acquisition Guidebook (DAG), Chapter 4 is Systems Engineering
  - **Chapter 4.3 Specifically states a key problem area (fidelity) in practice:** *SE requires use of models and simulations from many disciplines and across a hierarchy of perspectives that range from an engineering/technical level up to the campaign/strategic level in order to effectively analyze requirements, design, cost, schedule, performance, and risk.*
  - **Chapter 4.3 also states a key requirement:** *The Program Manager and Systems Engineer should ensure that the program's modeling and simulation activities are coordinated, managed, and controlled such that products are consistent with the system and architecture design at all levels.*

- In practice, modeling use in acquisition and systems engineering in the DoD tends to be fragmented among the various steps in the system lifecycle, often proprietary, and much more pervasive than often appreciated

* Often "modeling" is used to imply "simulation" which is the dynamic execution of a model - usually over time

# DAG Chapter 4 defines the System Lifecycle




AOTR - Assessment of Operational Test Readiness
ASR - Alternative Systems Review
CDR - Critical Design Review
EMD - Engineering and Manufacturing Development
FCA - Functional Configuration Audit
FD - Full Deployment
FOC - Full Operational Capability
FRP - Full-Rate Production
IOC - Initial Operational Capability

ISR - In-Service Review
MDD - Materiel Development Decision
OTRR - Operational Test Readiness Review
PCA - Physical Configuration Audit
PDR - Preliminary Design Review
PRR - Production Readiness Review
S&T - Science and Technology
SRR - System Requirements Review
SFR - System Functional Review
SVR - System Verification Review
TRR - Test Readiness Review

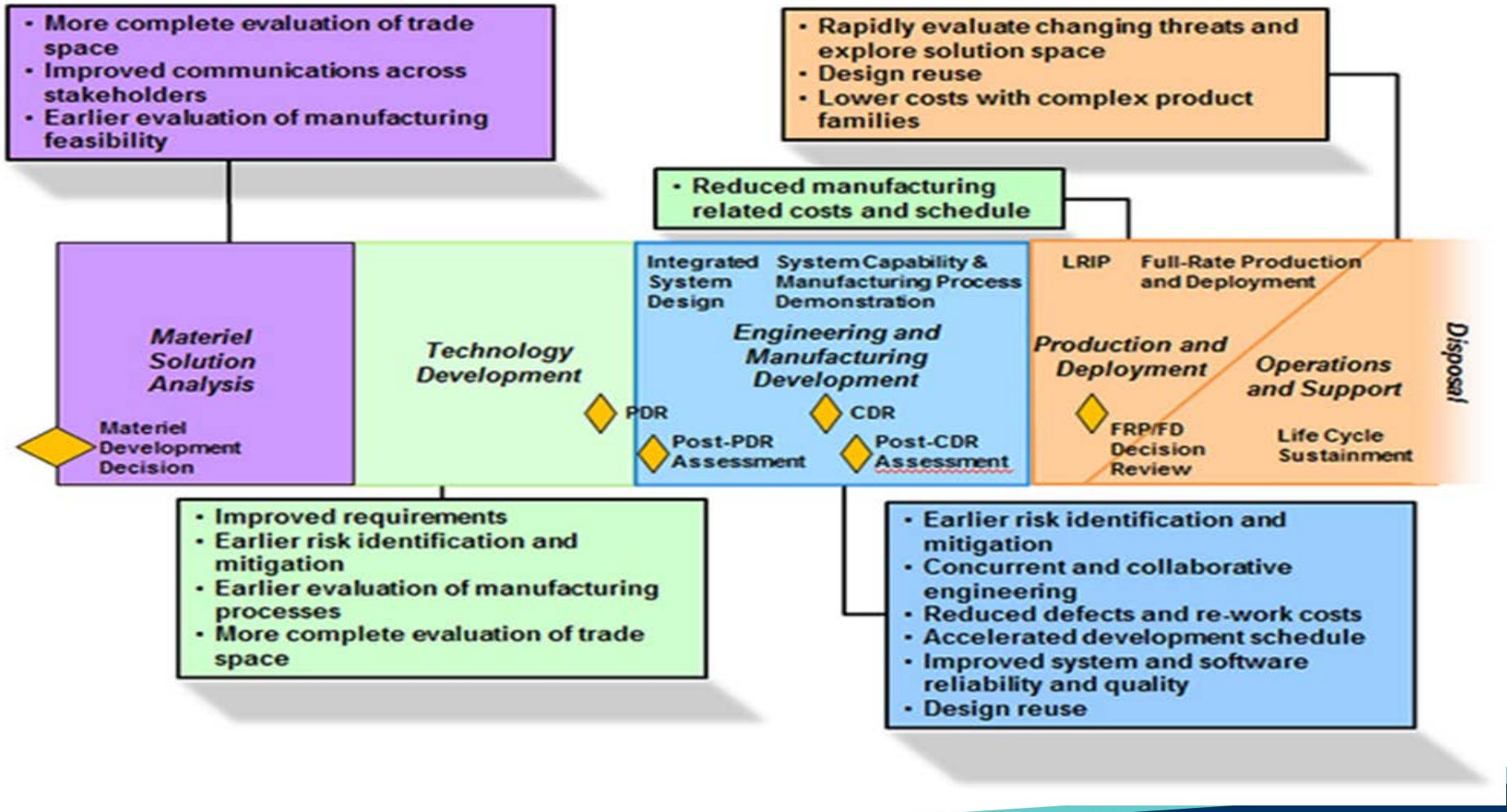
Mandatory technical reviews

Best practice technical reviews and audits

Test reviews (see DAG Chapter 9)

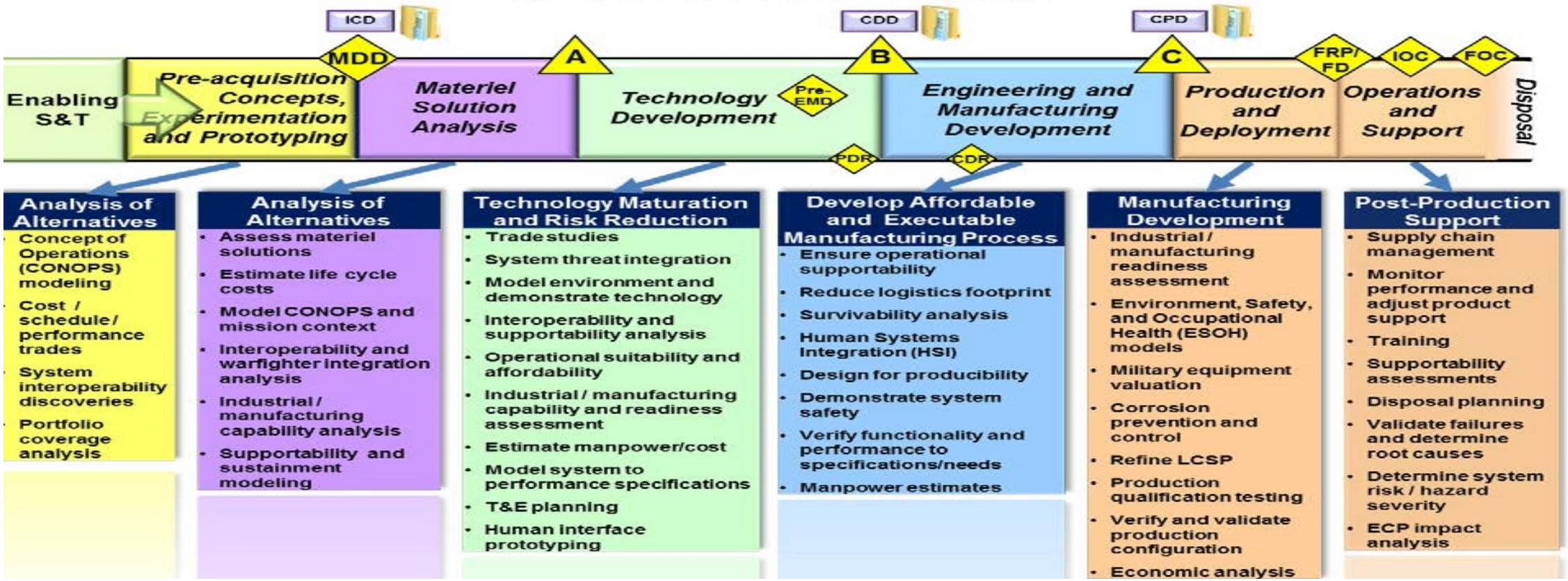
Very much a “top-level” process amenable to process modeling..
and interoperable via a data structure to sub-processes that are more detailed

# DAG Chapter 4.3 notes the benefits of Modeling throughout the System Lifecycle



# Defense Acquisition Guidebook Activities

## that depend on modeling in the DoD Acquisition Life Cycle




Use of modeling, overt or not, is in every facet of the System Lifecycle

# Problems with Modeling in Acquisition Oversight

*Modeling is required and the value of these tools for predictive analysis supporting the 44+ uses: risk, testing, affordability, military effectiveness survivability etc .. is established and noted in policy - So why is it not used more for acquisition decision support?*

- **Resistance to change:** SME evaluation is used extensively for many key considerations, and paper documents are the data source
- **Lack of available digital data:** Contracting is not done with digital harnessing of data in mind.. technical data packages/system models are still evolving, much of the data is required in document form; though much of a system is often designed and manufactured digitally (e.g. CAD/CAM)
- **No common data framework or model throughout the System Lifecycle** or a common data framework between acquisitions – hinders System of System analysis
- **Lack of confidence in results from modeling tools for evaluation purposes** -though high cost, complex systems (aircraft, gas turbine engines, spacecraft, satellites, EW systems, etc.) are extensively designed and tested via modeling tools in the development stages
- **Inability to federate models together from various components of the system** to produce a system model in the fidelity range desired ( performance, military utility, survivability, etc.) That **fidelity** problem form the DAG….
- **System Requirements are derived from modeling** ("Mission Threads", "Operational Scenarios", "CONOPS" etc.) - but do not retain the generating model in many cases!

# Some Proposed Solutions

- **To solve data availability:** Common Data models and frameworks throughout the lifecycle that would support M&S analysis tools:
  - Great idea, but can be costly and often proposed as a centralized, policy driven mandate
  - Industry has headed to self describing schemas for data and data analytics tools to parse between schemas.. Less cost than standardized, universal data models
  - Temptation is to require all potentially useful data to be included - this could make the technical data packages in an acquisition very expensive.

- **To solve fidelity and compatibility problems between disparate models used in various parts of a system lifecycle:**
  - Various proposals for a common technical framework for models and simulations to allow software object level compatibility between them, allowing for reuse and composite "federations" for any purpose:
    - Software integration and interoperability is expensive and slow to react to changes in technology and practice
    - Even data standardization is hard – common data models do not exist!

- **These approaches are used where necessary, but acquisition lifecycle is too large for detailed solutions across all stages to be cost-effective**

*None of these potential solutions are probable without policy driven mandates and would be difficult to implement with competitive bidding*

# Opportunity

## Since the straightforward ways of enabling data and modeling for analysis to support milestone and program decisions are “too hard” what is the alternative?

- System Engineering in general, and as practiced by DoD is changing and new tools, techniques, and types of analysis are being sought for the more complex systems , and systems of systems of today
- Engineers are very familiar with the use of software modeling frameworks and tools to solve complex engineering problems, these are used in every facet of design and production by manufacturers.. Why not government oversight?
- Data is the new interoperability media; a myriad of tools exist for data parsing and interoperability. **(Can help us fix “fidelity”!)**
  - Data set interoperability “up the modeling pyramid” from development level activities to oversight (higher to lower fidelity)
  - Is much easier than software object fidelity changes


A “Scenario” plus the supporting data can be a new interoperable entity

# An Approach(1)

1. Adopt a ***Model-Based/Data-Driven Systems Engineering construct*** to identify essential elements of system information needed to support key known engineering and oversight activities across the life cycle that use modeling and/or simulation, and make that data available for modeling supported analysis across the SLC while leveraging architecture information. A proposed construct would:

   a) Be consistent or at least coherent with DODAF or its successors

   b) Use a generic conceptual approach that allows maximum use of various commercial tools and frameworks

   c) Exploit efficiencies gained by a digital standardized data representation ("System Model") with a companion Standards Profile across the Acquisition Lifecycle – A profile that explains what is currently available digitally or otherwise, and provides requirements for digital acquisition artifacts going forward.

   d) Leverage any Standards activities that gain traction with stakeholders in this area, - emphasizing <u>data interoperability not type conformance.</u>

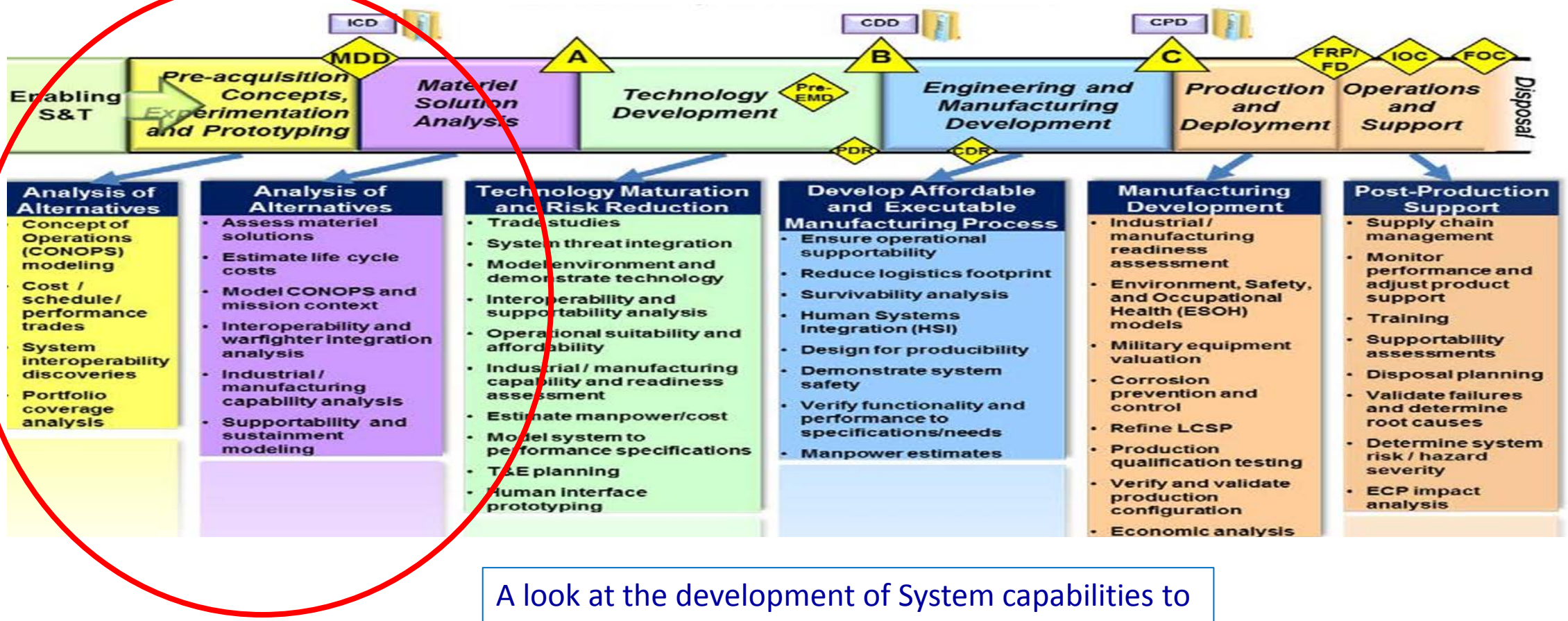
   e) An implementation roadmap to show what data is currently available, and what would need to be required by contracting language/policy etc.

# An Approach(2)

2. Develop a ***Mission Level Analysis Framework for Acquisition Decision-making.***

- Many of the tools, models, simulations, and other artifacts are one-offs, designed for individual parts of the acquisition (components of a vehicle, ship, aircraft, system etc.) and are generally very detailed at a high fidelity
  - They require extensive data to execute and provide engineering quality results on discrete components.
  - While there is a trend towards integrating these components into frameworks commercially, thus enabling reuse, they still operate in the complex engineering modeling and simulation representation level
- To work around these limitations:
  - Develop a conceptual modeling approach to implement an MBSE data framework across an acquisition lifecycle; utilizing existing standards and data models of components of the lifecycle
  - Utilize commercial modeling framework tools (e.g. Eclipse, Model Center, Ansys etc.) to integrate disparate models via data exchange in the framework. This framework should have the capability of developing statistical surrogates at the appropriate level of fidelity that could for example; enable mission suitability analysis via a mission level simulation based on the results of engineering level models

# Conceptual Modeling Example




A look at the development of System capabilities to accomplish a military mission in countering a threat

# Conceptual Modeling Example

- Among other sources, military acquisition programs develop key system capabilities to:
  - Conduct mission operations based on “CONOPS”, and “Mission Threads” etc.
  - Counter external threats based on known and anticipated “Threat Scenarios” (sort of like the Red “Conops”)
  - Assist other systems in their mission performance (Systems of Systems(SoS))

- Requirements for these systems are derived from analysis of these “CONOPS”, “Mission Threads” and “Threat Scenarios”:
  - Often developed by SME’s as textual and graphic “scenarios”, with supporting information
  - Result in textual System Requirements to accomplish or counter them
  - While SoS in nature, often treated like orthogonal system capabilities and requirements

These “Threats”, “Mission Threads”, “CONOPS” etc are **models!**

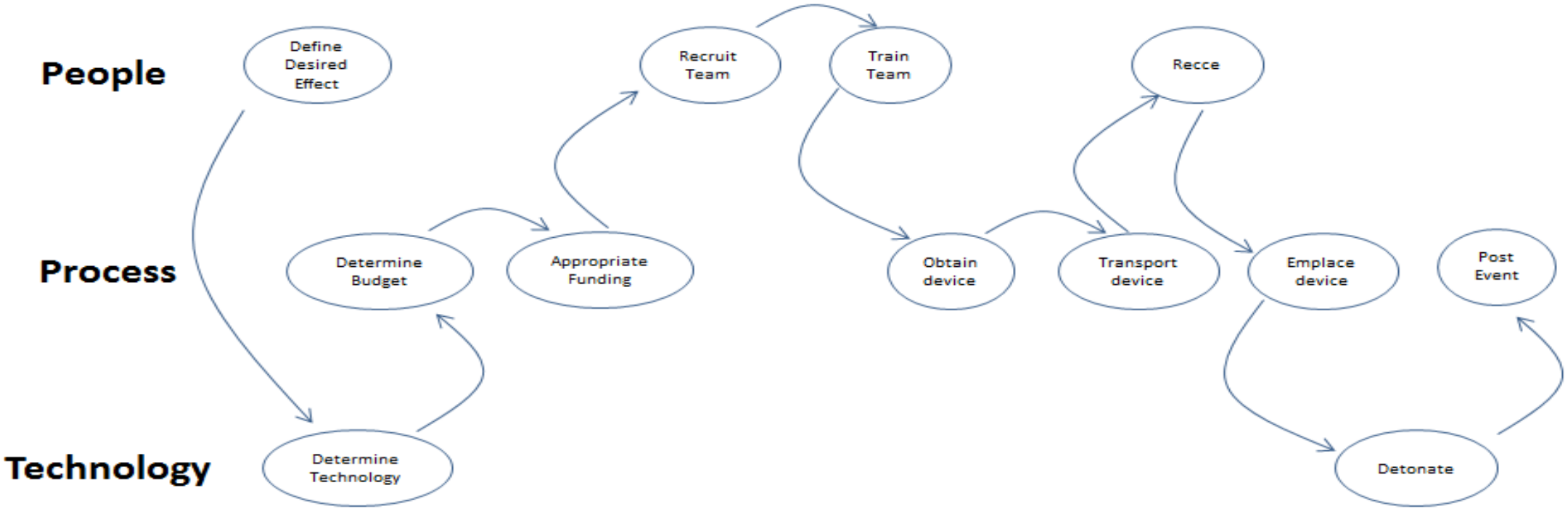
# Systems Engineering Approach
## Viewing the Threat as a process

- **These “Threats”, “Mission Threads”, “CONOPS” etc are scenarios or process models of the threat, mission or operations concept they purport to portray.**
  - If expressed conceptually in a common way commonalities and dependencies can be easily discerned (common frame of reference between scenarios)
  - If expressed as software models interactions and performance can be estimated reliably

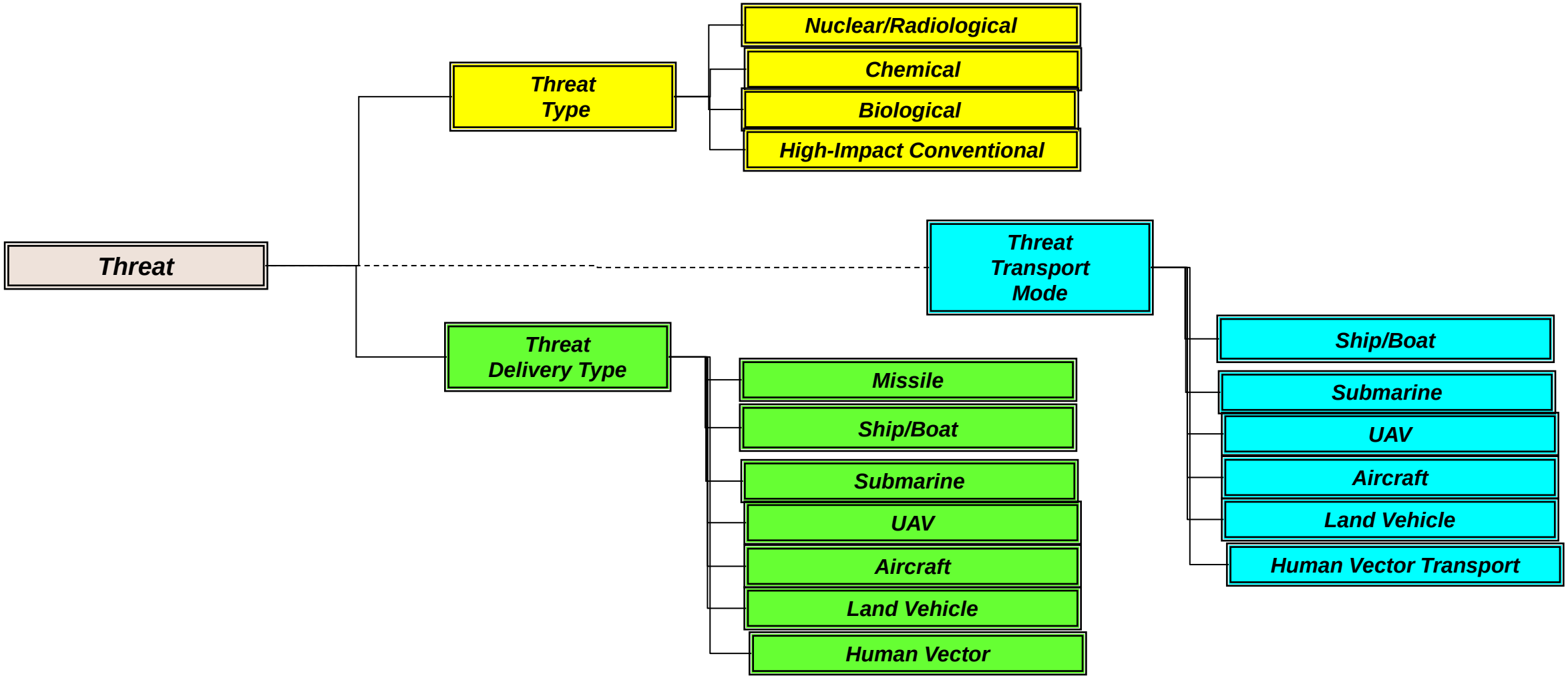
- **As an example; a “Threat” to the U. S. could be countered by “Mission Threads” of U. S. forces to counter the threat, requiring specific counter-capabilities**:
  - The threat could be countered by appropriate “Mission Threads” that will require SoS capabilities that will then need to be decomposed to individual system capabilities
  - By process modeling the threat, we can reverse engineer the capabilities needed to counter
  - By using a conceptual modeling approach to frame the threat, and the counter mission scenarios, we can then organize our scenarios and data in a way to objectively determine capabilities at the capability matching level
  - By further developing the conceptual model to a software model we can access capability performance in countering the threat
  - SoS dependencies can be understood and cataloged more objectively using a process modeling approach. An implemented MBSE approach to this would yield the nth order set of dependencies and interaction between the threat and the counter capabilities at the SoS and down to system levels.

The process modeling approach makes “Threats, “Mission Threads, “CONOPS” etc dynamic modeling scenarios that can more accurately simulate the full range of activities under investigation

# Generic Threat Lifecycle
## (OCONUS threat to U.S.)



# Basic Threat Model

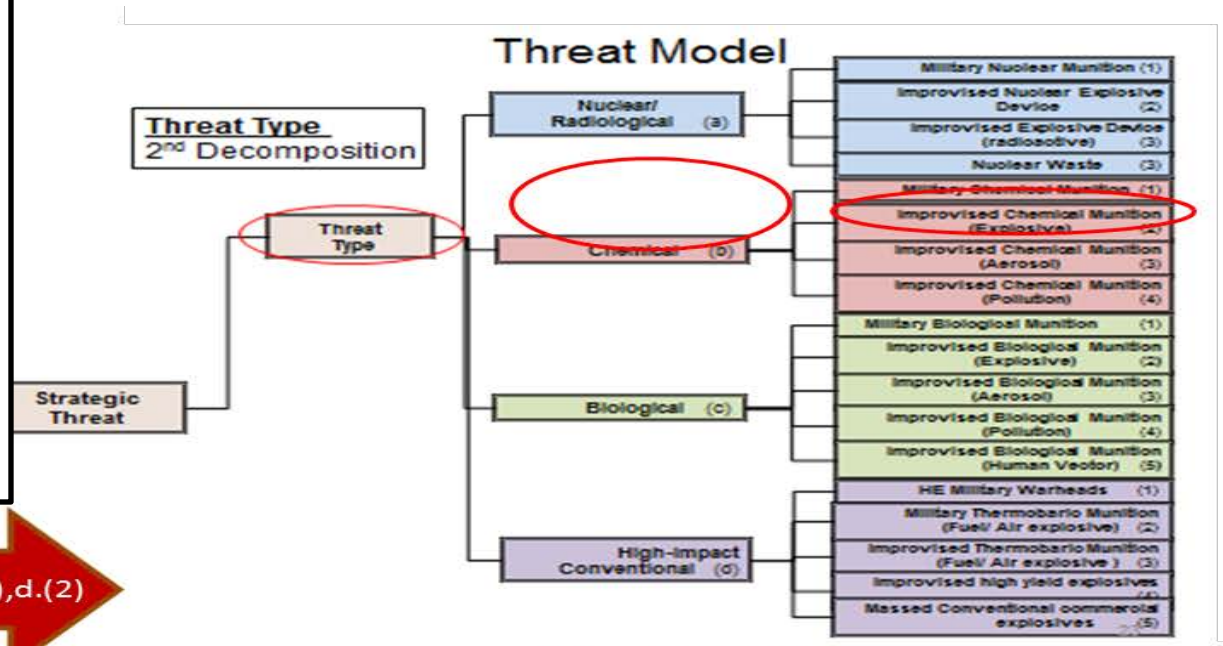


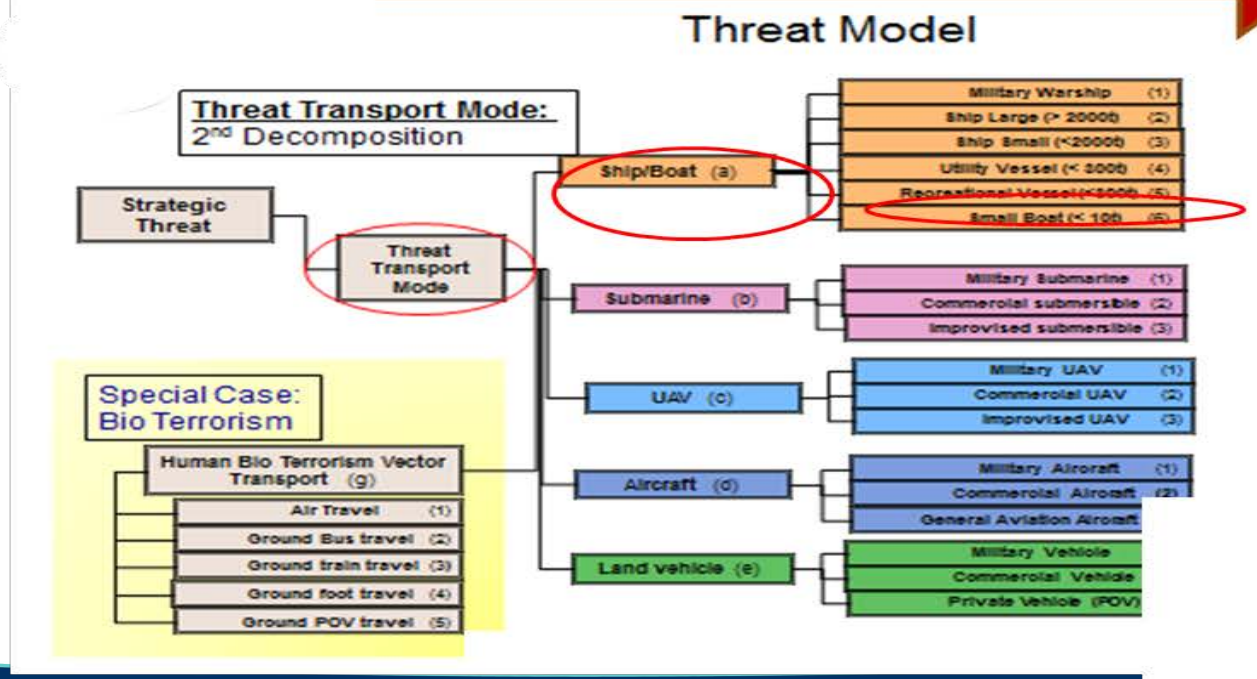

***A Threat is composed of at a minimum:***
*Threat Type, Threat Delivery Type, and Threat Transport Mode*

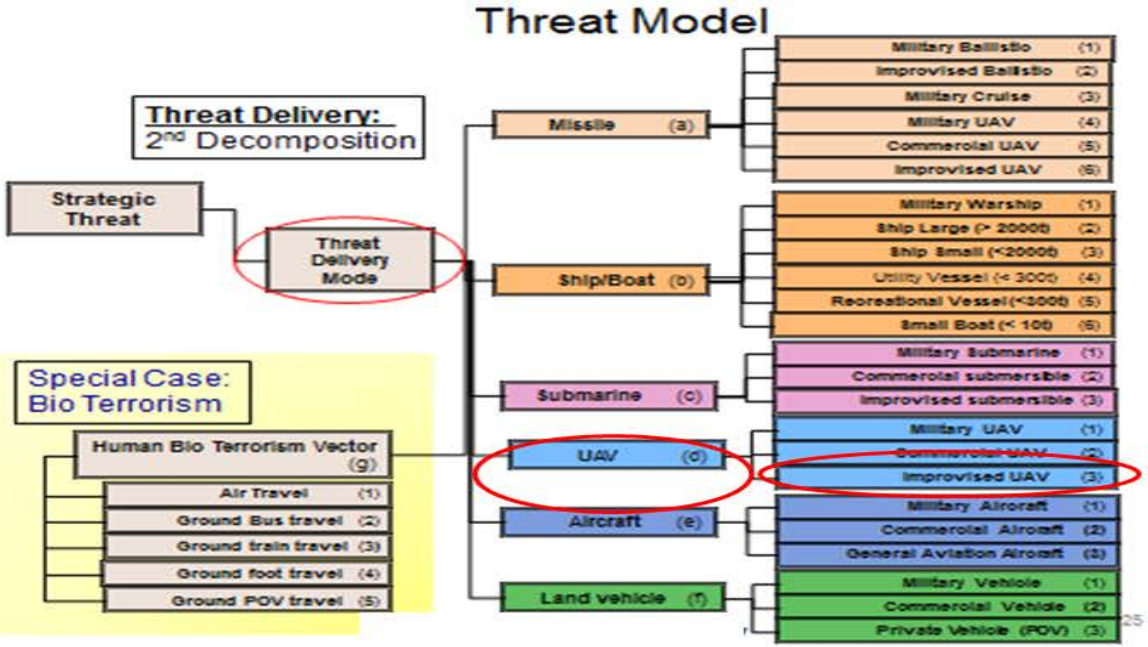
# *Threat Model Example*

- *- A Terrorist group, homebuilt chemical weapon, designed to produce an aerosol mist, small, and designed to produce panic*
- *- Moved from originating country to the delivery assembly area by a motor yacht 60 foot in length, and 53 tons.*
- *- Chemical weapon and sprayer flown from boat near onshore U.S. to target ashore by a commercially available UAV.*

Threat Model b.(3);a.(5),d.(2)



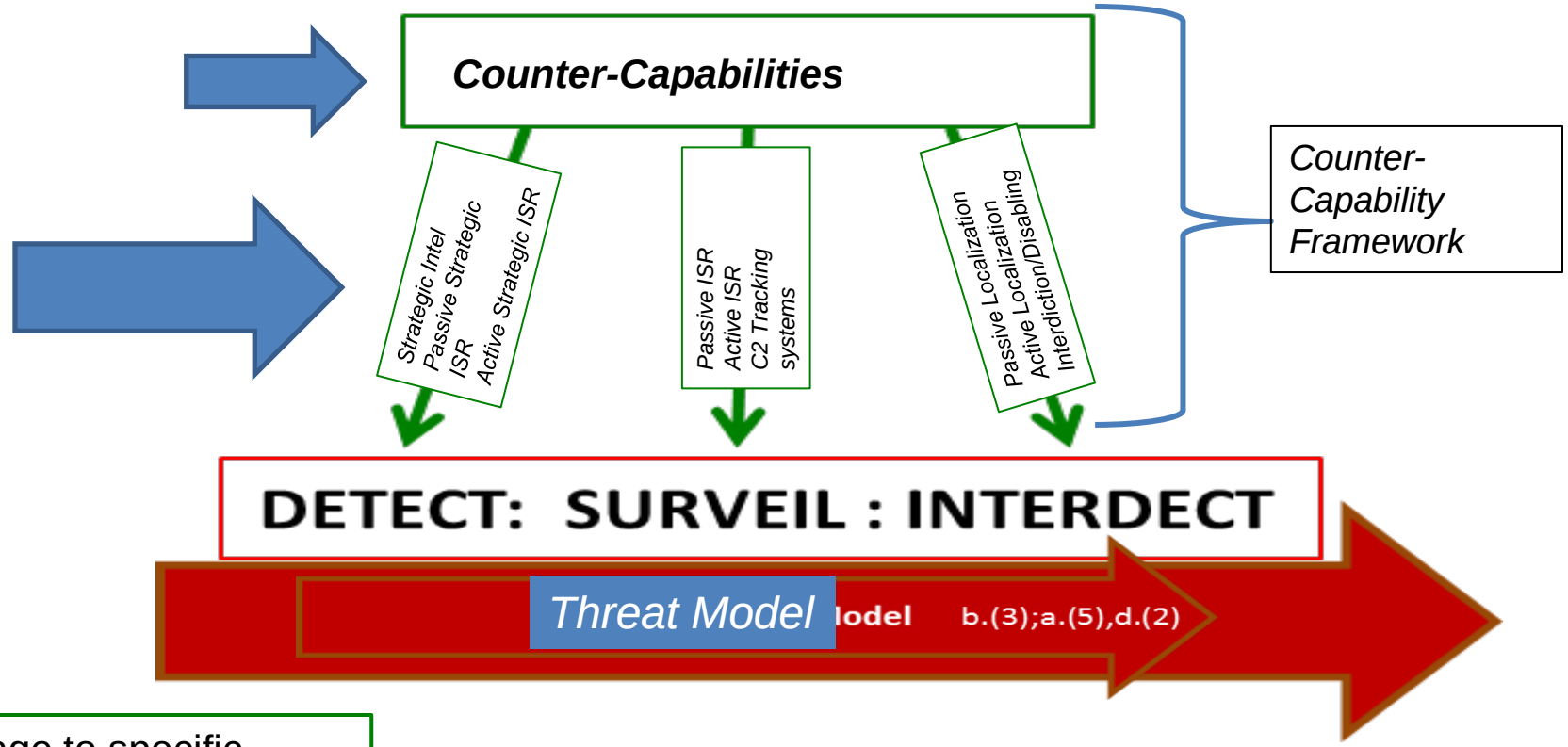
# *Threat Capability Framework*

*Linkage to Capabilities*

Specific Counter-Threat Capabilities **(Systems)**

Counter-Threat Capability areas **(Systems of Systems)**

That link to Threat b,.(3);a(5).d.(2)




Composable model allows linkage to specific Counter- Capabilities specific to that Threat:

- Identify gaps and overlaps
- Validate requirements for Counter System Capabilities

# Threat Modeling Results

- A process modeling methodology can be used to define a generic threat process and lifecycle, and define a wide set of attributes
- The threat model can be used to represent all scenarios associated with the threat
- A threat model allows for decomposition of complex scenarios to objective elements, which can then be linked to a counter-capability framework(model) that includes:
  - Counter-threat capability areas (systems of systems)
  - Specific capabilities/systems in those counter-threat capability areas
- We used an event-driven process chain type conceptual methodology

Consistent, traceable, objective conceptual modeling of threats is required to reduce subjectivity in the **capabilities** to counter them

# Threat Modeling and Counter- Capability Framework

- Provides an *objective method of comparing* scenarios, vignettes, and operational plans and lessons learned, and *linking* those to counter-threat capabilities.
- Reduces complex threat scenarios into well defined components
- Common frame of reference for analysis between disparate scenarios, studies, strategies, plans and operations.
- Lends itself to looking at countering threats as a *systems of systems* problem.
- Can be coded into applications: SysML/UML, Architecture tools; modeling environments.

# Threat Model and  Counter-Capability Framework Usage

- This methodology/model can be used for:
  - Characterizing the threat among Concepts, Strategies, Doctrine, and counter-capability requirements.
  - Determining  counter-capability gaps and overlaps
  - Comparative analysis between scenarios for many purposes
  - Performance assessment when linked with performance models; of capabilities against various combinations of  threats - could enable optimization of counter-capabilities against “classes” of threats
  - Requirements assessment and validation among capability programs that support the counter-threat mission

# Wrap Up

- Model-based systems engineering is key to oversight and development both of DoD capabilities and understanding mission performance in a system of systems/complex systems environment.
  - Need to move beyond “one factor at a time” modeling and analysis
  - Parallel and simultaneous process are the real world mission environment
- Threats/CONOPS/Mission Threads etc.  can be modeled and analyzed using systems engineering techniques, our insight is to use systems engineering tools and methodologies to model and link these key scenarios that drive us  to DoD and adversary capabilities.
- We need a **conceptual** MBSE framework/methodology that will accommodate various tools.
  - A merging of “Architectures” and MBSE
  - A concept for MBSE beyond a tool and the limitations built into it
  - Maybe “standards”.. How about ISO?  9000 anyone?  Quality Development??

# End