Model Based Systems Engineering

and How it Aids DoD Acquisition & Systems Engineering

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Briefing Objectives

- Vision for Model-Based Systems Engineering (MBSE)
  - Primarily from INCOSE's perspective
- How MBSE enables better and faster system trade-offs and related DoD acquisition decisions
  - From my perspective

INCOSE Vision 2020 Model-Based Systems Engineering (MBSE)

Highlights from

MBSE Workshop

July 7, 2006

Definitions

- Model
  - A representation of one or more concepts that may be realized in the physical world. Models are represented in many forms including graphical, mathematical, and physical prototypes.
  - Typical systems engineering models may include behavioral, structural, geometric, performance, and other engineering analysis models.
- Model based systems engineering (MBSE)
  - Model based systems engineering is the formalized application of modeling to support system requirements, design, analysis, verification and validation beginning in the conceptual design phase, and continuing throughout development and later life cycle phases.

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MBSE Benefits

- ***MBSE enhances the ability to capture, analyze, share, and manage the information*** associated with the complete specification of a product, resulting in the following benefits:
  - ***Improved communications*** among the development stakeholders (e.g. the customer, program management, systems engineers, hardware and software developers, testers, and specialty engineering disciplines).
  - ***Increased ability to manage system complexity*** by enabling a system model to be viewed from multiple perspectives, and to analyze the impact of changes.
  - ***Improved product quality*** by providing an unambiguous and precise model of the system that can be evaluated for consistency, correctness, and completeness.
  - ***Enhanced knowledge capture*** and reuse of the information by capturing information in more standardized ways and leveraging built in abstraction mechanisms inherent in model driven approaches. This in-turn can result in reduced cycle time and lower maintenance costs to modify the design.
  - ***Improved ability to teach and learn systems engineering fundamentals*** by providing a clear and unambiguous representation of the concepts.

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MBSE Drivers

- Information technology explosion
  - Networking
  - Computing power
  - Storage capacity
- Evolving profile of the Systems Engineer
  - Chat generation adaptive to rapid change in technology and information

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MBSE State of Practice Factors

- MBSE applications
  - What are the applications/uses of MBSE?
- Model scope
  - What is the scope that the system model is intended to represent (e.g. system to component, ilities, life cycle, …) ?
- Model quality and robustness
  - How adequately does the model represent the real world concepts?
- Modeling standards
  - What industry standards support MBSE?
- MBSE process, methods, tools, and training
  - What is the process infrastructure for MBSE?

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MBSE State of Practice - 2006

- Practiced in pockets across industry
  - Functional modeling with some executable behavior
  - Performance simulation models
- MBSE not fully integrated into SE process
- SoS and System models not integrated with hardware, software, ilities
- Use of architecture frameworks gaining steam (e.g. DODAF, MODAF) for SoS/Enterprise modeling
- MBSE standards emerging (SysML, AP233, BPMN, UPDM, ..)

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MBSE State of Practice - 2010

- Commonly practiced across broad range of industry
- Standards based MBSE tools
- Modeling methods matured
- Integrated models from SoS down to hardware and software
- Enhanced integration between architecture models, behavior execution, simulation, and engineering analysis
- Some model reuse
- Modeling metrics defined to assess “model goodness”
- MBSE standards increasing in precision and leveraging model and data management standards
- MBSE certification underway

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MBSE State of Practice - 2020

- MBSE extends to domains beyond engineering to support complex predictive and affects-based modeling that includes integration of engineering models with scientific and phenomenology models, social, economic, and political models, and human behavioral models
- Use of domain specific languages and visualization that enable the systems engineer to focus on abstract modeling of the user domain
- Modeling standards based on a firm mathematical foundation that support high fidelity simulation and real world representations
- Extensive reuse of model libraries, taxonomies, and design patterns
- Standards that support integration and management across a distributed model repository
- Highly reliable and secure data exchange via published interfaces
- Systems engineering workflow supported by standard “SE services” to access model information (e.g. requirements trace)

Potential Challenges

- Evolution of standards to meet evolving needs
- Availability of model driven methods
- Availability of interoperable modeling tools
  - Tool interoperability and standards support
- Availability of model driven training
- Stakeholder/User acceptance of model driven approach

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Recommendations For Advancing MBSE

- Research
  - Mathematical foundation for modeling semantics
  - Application of data mining/search/pattern recognition methods to architecture engineering including use of semantic web
  - Metrics and value of MBSE
- Promote use of modeling tools
  - INCOSE tool fairs including model and data exchange demos
  - Increase emphasis on simulation and engineering analysis
- Promote and advance MBSE process and methods
  - Identify and capture MBSE best practices
  - Identify modeling metrics
  - Add human centric to systems engineering methods (human to machine, human to human)
  - Establish criteria/guidelines for selecting and organizing models
- Promote and advance standards for MBSE
  - OMG SysML
  - AP233
  - OMG model interchange and model management
  - Architecture frameworks (UML Profile for DODAF/MODAF)
  - Integration between SysML and simulation standards
- Education in MBSE
  - MBSE certification

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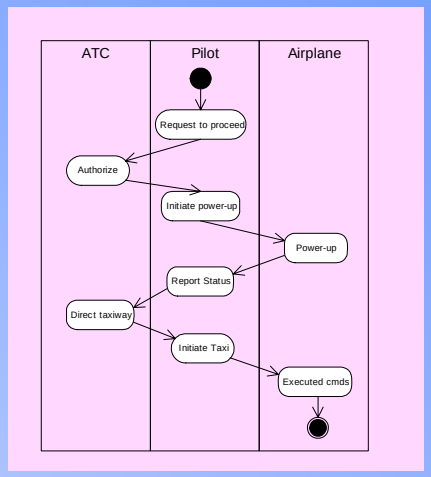
Transition to MBSE

Past

- **Specifications**
- **Interface requirements**
- **System design**
- **Analysis & Trade-off**
- **Test plans**

Future



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SE Practice Transitioning from Document centric to Model centric

Summary

- ***MBSE offers significant benefits*** to enhance communications, manage complexity, improve product quality, enhance knowledge capture, and improve the ability to teach SE
- ***Systems engineering is in the early state of transition from a document centric to a model centric approach***, and is expected to advance rapidly over the next 15 years.
- ***The current state of MBSE practice in 2006*** is immature and practiced in an ad-hoc manner. MBSE standards are emerging (OMG SysML, XMI, AP233, BPMN, Architecture Frameworks).
- ***The projected state of MBSE practice in 2010*** is that the MBSE methods and tools will be significantly more mature based on implementation of standards and lessons learned. Architecture modeling for enterprise and SOS applications will be common place. The integration of the system models with the hardware and software models and engineering analysis models will be substantially improved.
- ***The projected state of MBSE practice in 2020*** will extend MBSE to modeling domains beyond engineering models to support complex predictive and affects-based modeling. This will include integration of the engineering models with scientific and phenomenology models, social, economic, and political models, and human behavioral models, The key characteristics of MBSE in 2020 include:
  - Domain specific languages and visualization that enable the systems engineer to focus on abstract modeling of the user domain
  - Modeling standards based on a firm mathematical foundation that support high fidelity simulation and real world representations
  - Extensive reuse of model libraries, taxonomies, and design patterns
  - Standards that support integration and management across a distributed model repository
  - Highly reliable and secure data exchange via published interfaces
- ***INCOSE and the SE community should*** promote research, and advances in MBSE process and methods, tools, education, and standards to facilitate the transition to MBSE and achieve the desired benefits

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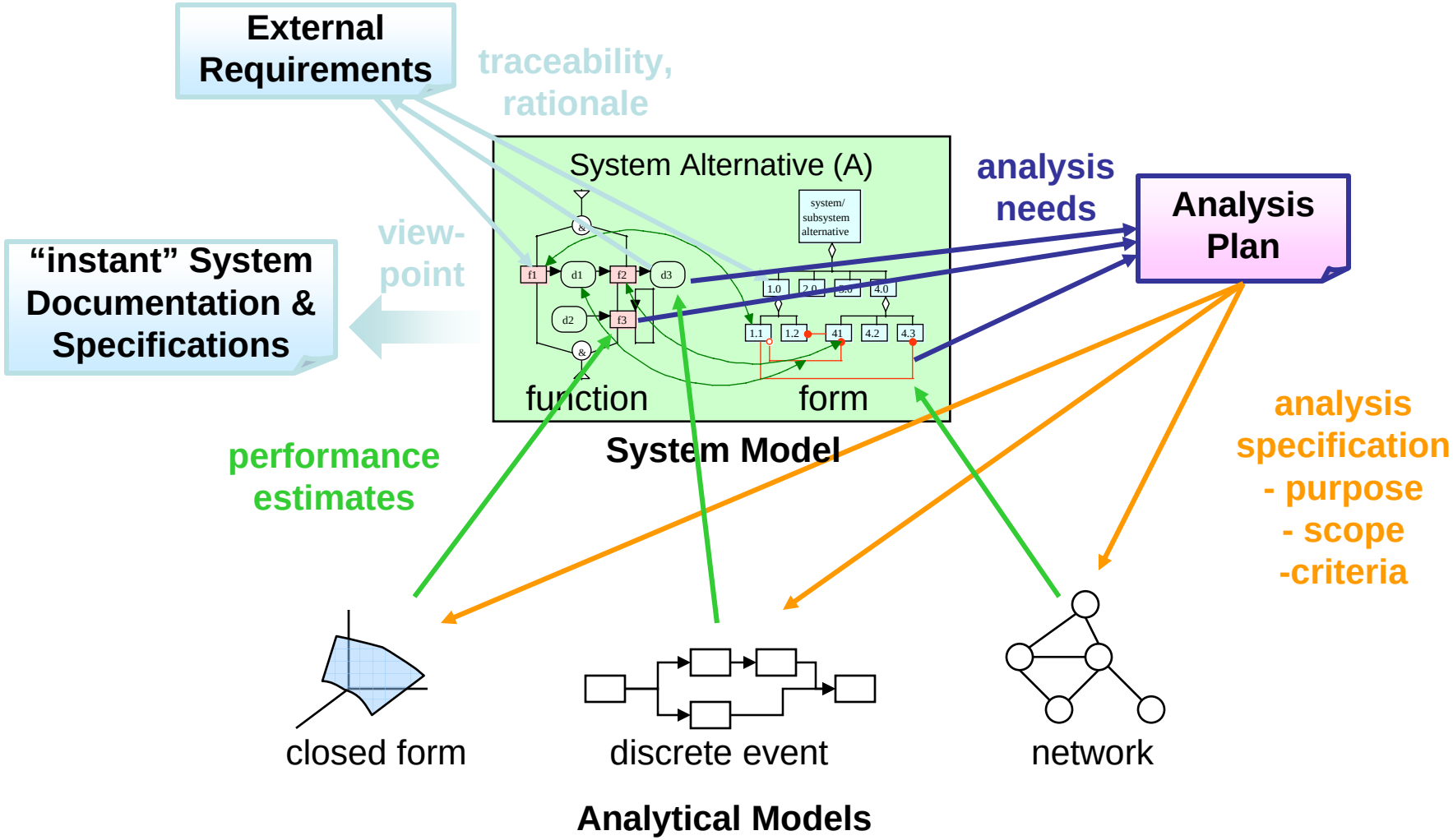
In MBSE, SE Processes Must Leverage M&S



The "Working Fluid" of SE becomes the system model, not the document

How MBSE Aids
DoD Acquisition & Systems Engineering

Transforming Acquisition

Reversing the Trend

"Now, when I was secretary of defense . . . a quarter of a century ago . . . the reality was that the acquisition period was about half of what it is today . . . technology is advancing about four times as fast as it used to. Now how in the world can we expect to live in a circumstance like that?"

31 Jan 2002
National Defense University

... we have taken important steps that will help us to produce improved capability on time and within budget by re-energizing our approach to systems engineering. This critical discipline has always contributed significantly to effective program management at every level and will receive sustained emphasis during my tenure.

Testimony of The Honorable Kenneth J. Krieg, USD(AT&L),
before US Committee on Armed Services,
September 27, 2005

… and Revitalization of Systems Engineering

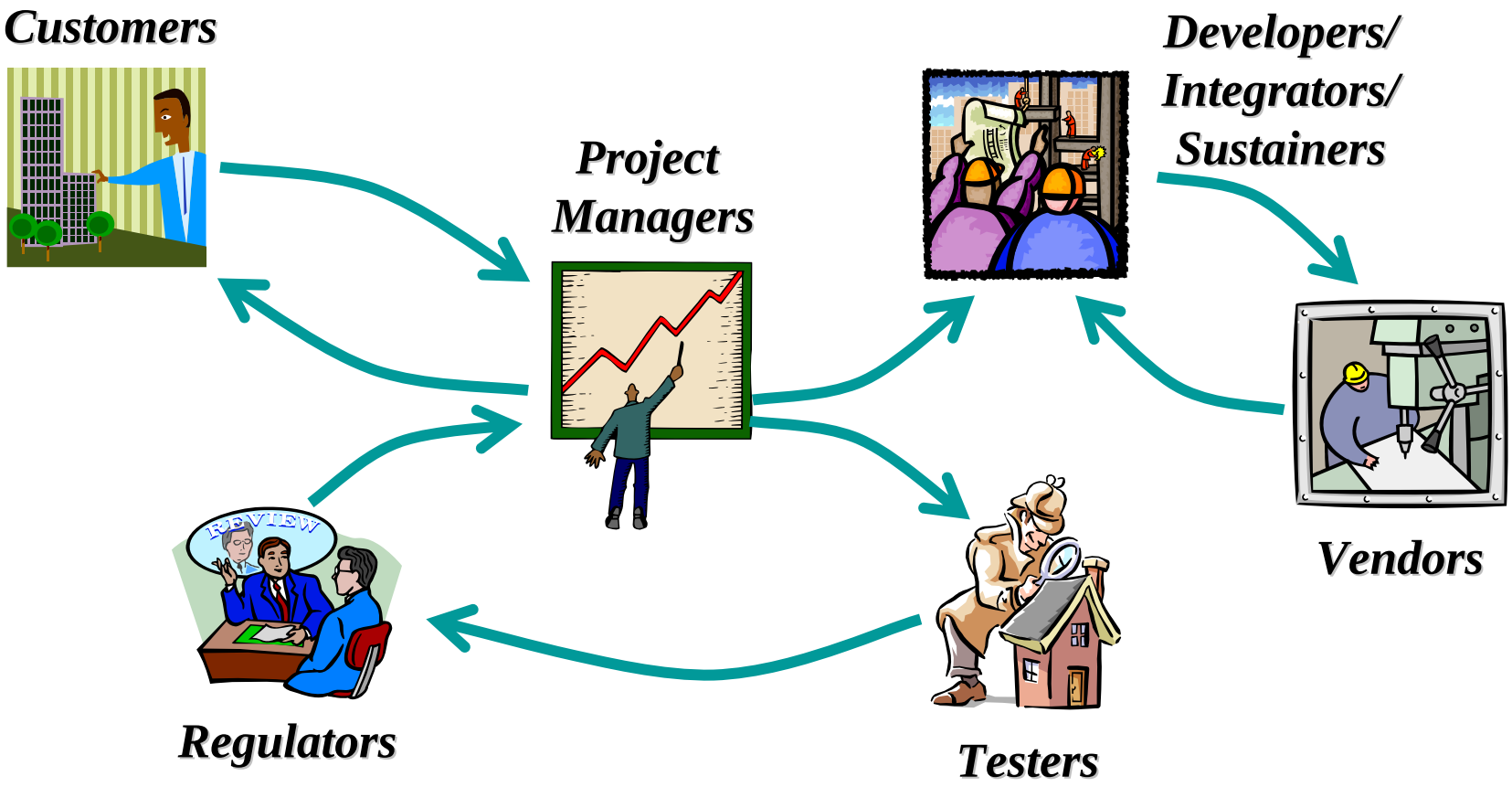
Top 10 Emerging Systemic Issues

1. Management	• IPT roles, responsibilities, authority, poor communication • Inexperienced staff, lack of technical expertise
2. Requirements	• Creep/stability • Tangible, measurable, testable
3. Systems Engineering	• Lack of a rigorous approach, technical expertise • Process compliance
4. Staffing	• Inadequate Government program office staff
5. Reliability	• Ambitious growth curves, unrealistic requirements • Inadequate "test time" for statistical calculations
6. Acquisition Strategy	• Competing budget priorities, schedule-driven • Contracting issues, poor technical assumptions
7. Schedule	• Realism, compression
8. Test Planning	• Breadth, depth, resources
9. Software	• Architecture, design/development discipline • Staffing/skill levels, organizational competency (process)
10. Maintainability/Logistics	• Sustainment costs not fully considered (short-sighted) • Supportability considerations traded

Areas where MBSE might help

SE Issue – Poor Communications

SE's Interface with many other system stakeholders over the life cycle



MBSE can facilitate Improved Communications through use of technical data that is more precise and semantically comparable with other taxonomies

SE Issue – Tangible, Measurable and Testable

Technical Performance Measurements (TPMs) and technical baselines must be precise and comparable

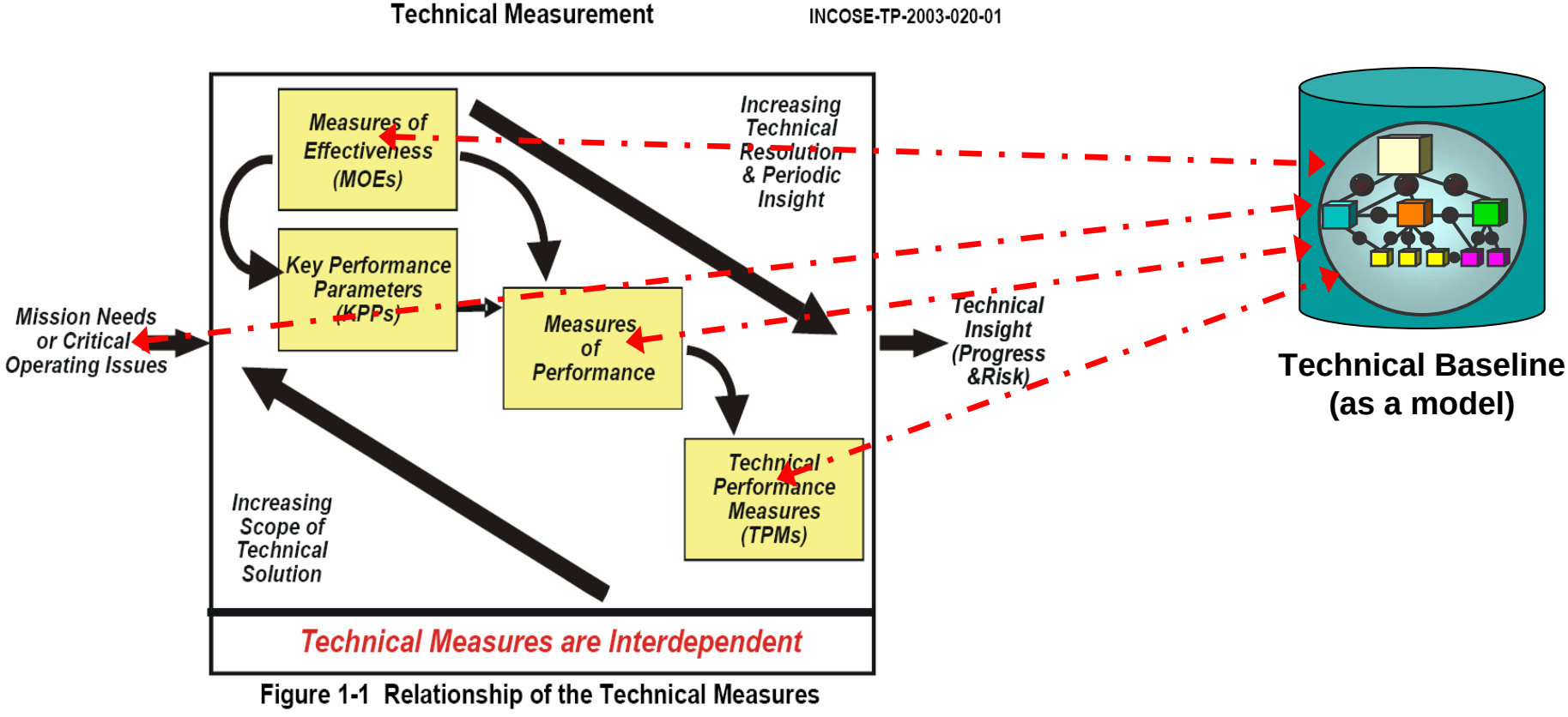
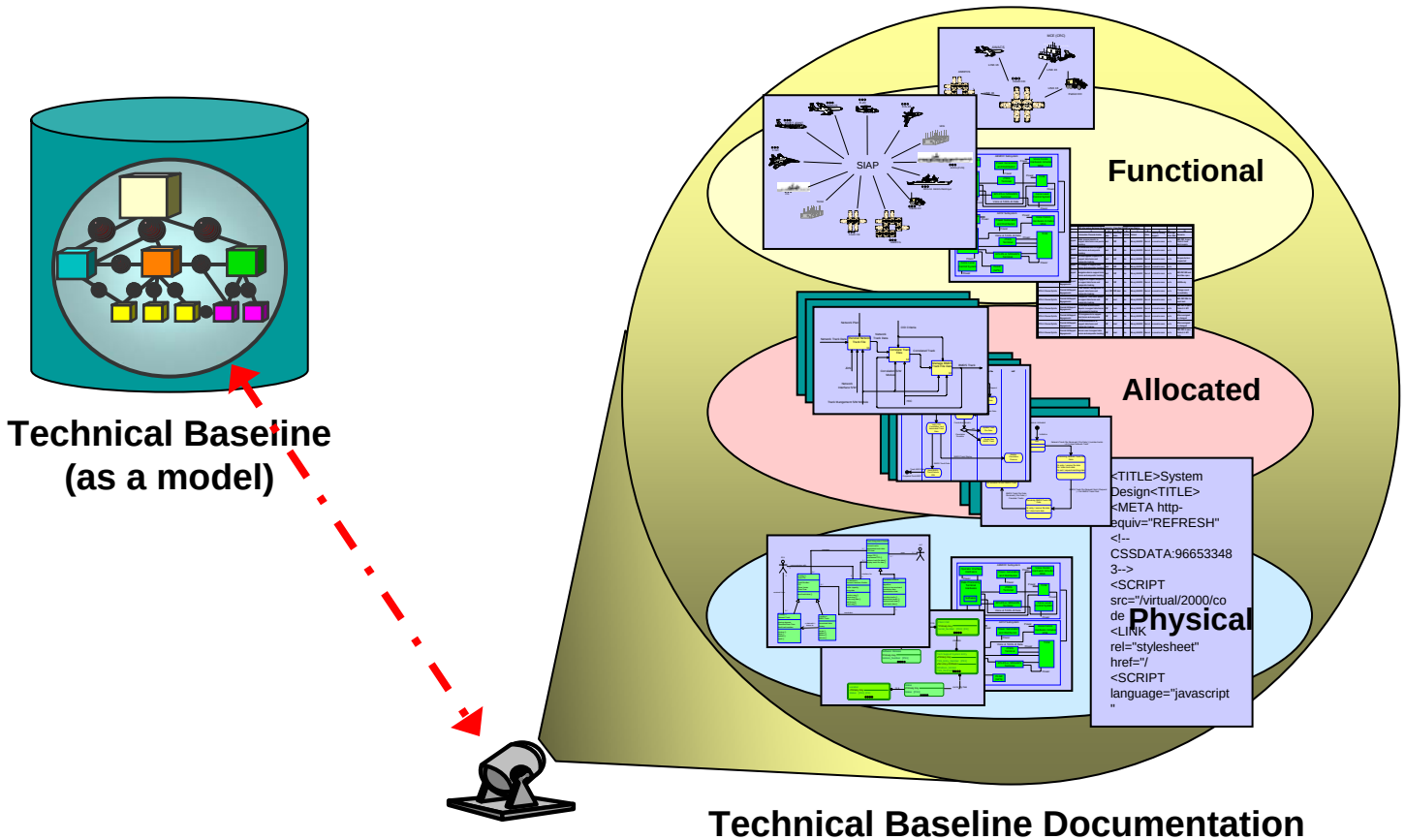


Figure 1-1 Relationship of the Technical Measures

MBSE should provide greater traceability of solutions to requirements and insight into technical risks

SE Issue – Poor Technical Assumptions

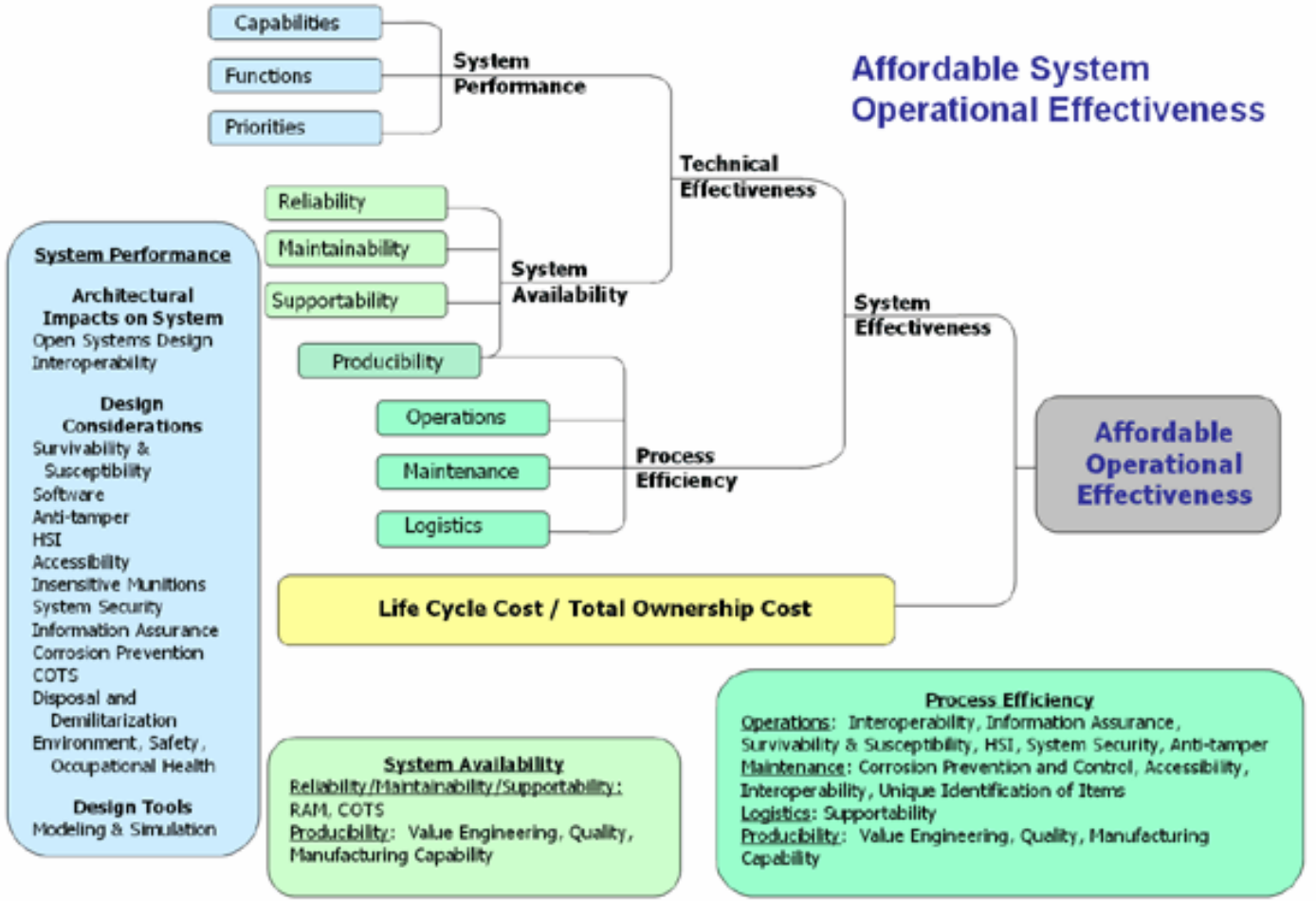
These are often caused by unclear or inconsistent data contained in the numerous program documents and technical databases that are maintained individually



MBSE should minimize unclear or inconsistent data by improved data management and data sharing

SE Issue – Sustainment not Fully Considered or Traded

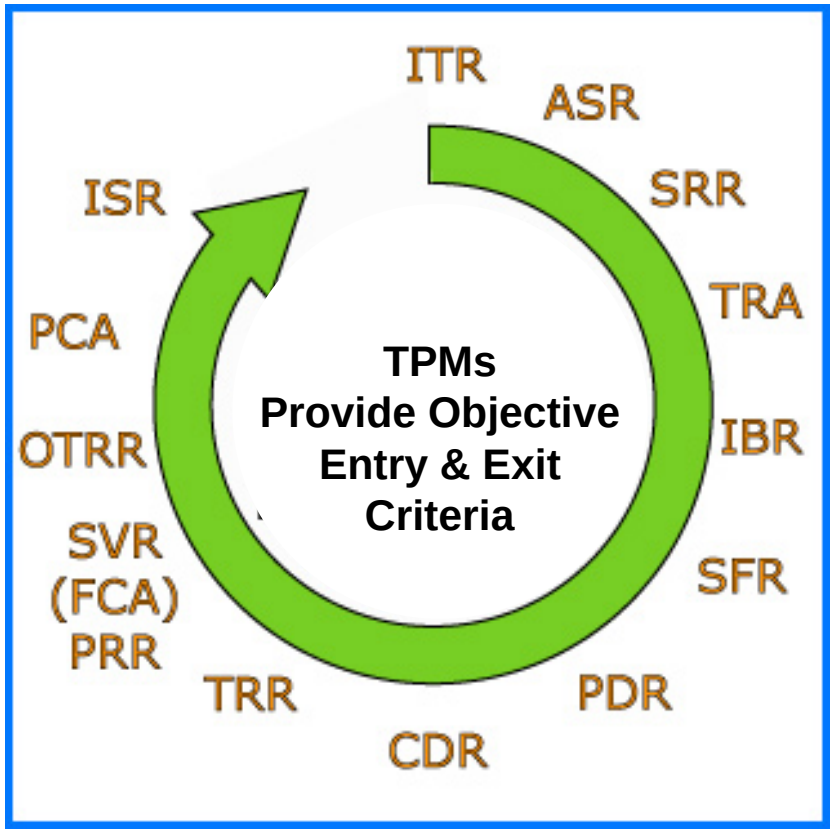
PMs are responsible for Total Life Cycle Systems Management



MBSE should facilitate earlier and better trade-offs between competing requirements and ALL design considerations

SE Issue – Rigorous and Disciplined Approach

DoD's SE approach is centered on measurable results and timely reviews

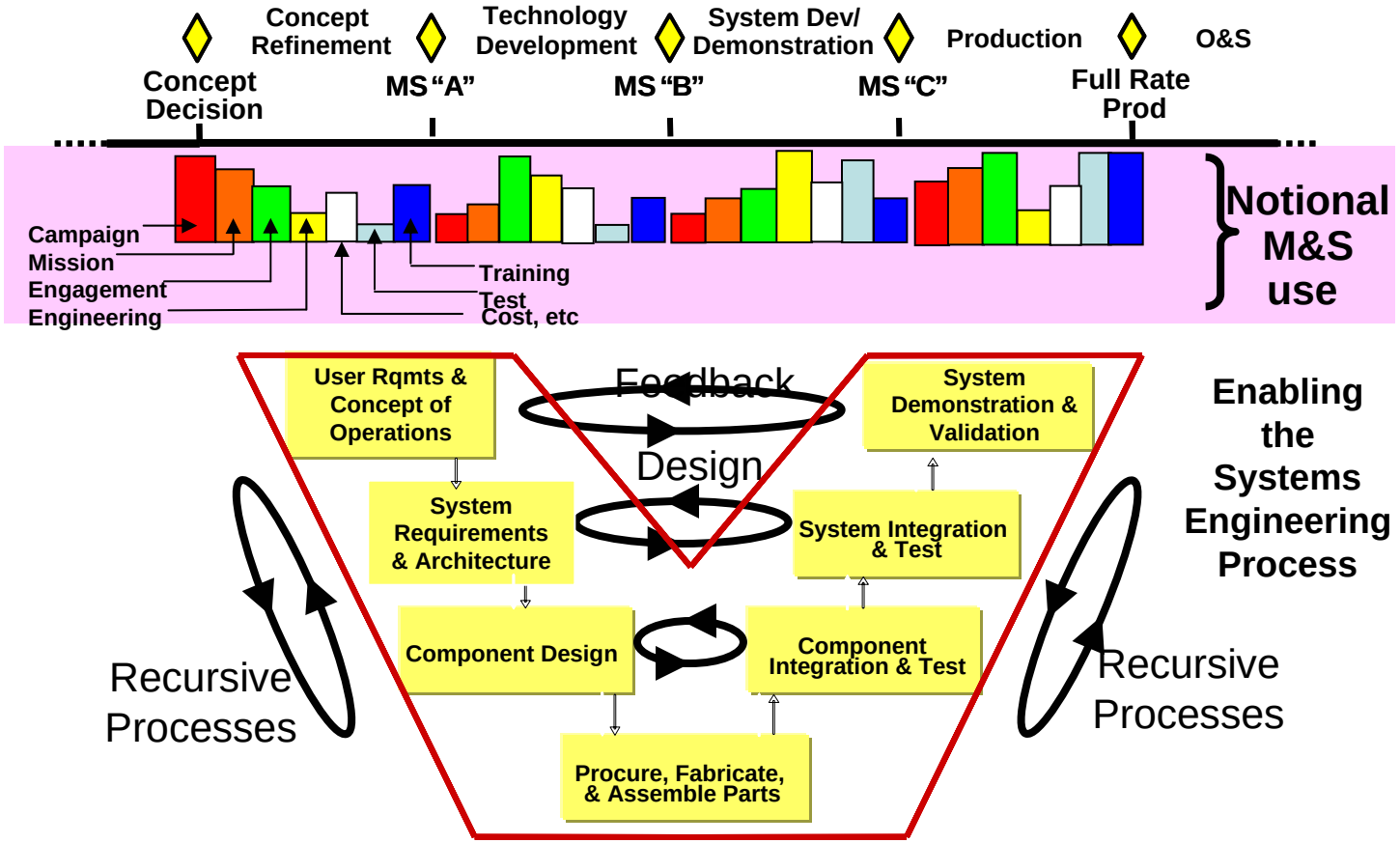


- Measure degree to which system requirements are met in terms of performance, cost, schedule, and progress in implementing risk handling
- Are critical to balancing cost & performance throughout the life cycle
- Basis for trade-off analysis
- Provide management insight
- Inform Reviews & Decisions

MBSE should provide a technical baseline that is measurable and permits more timely evaluation of key system characteristics because it continuously evolves

SE Issue – Inadequate "Test Time"

Ideally, M&S is used across the acquisition life cycle



Source: Initial Draft Acquisition M&S Business Plan - August 4, 2006

MBSE should enable greater use of M&S to permit earlier and continuous evaluation of solutions

Summary

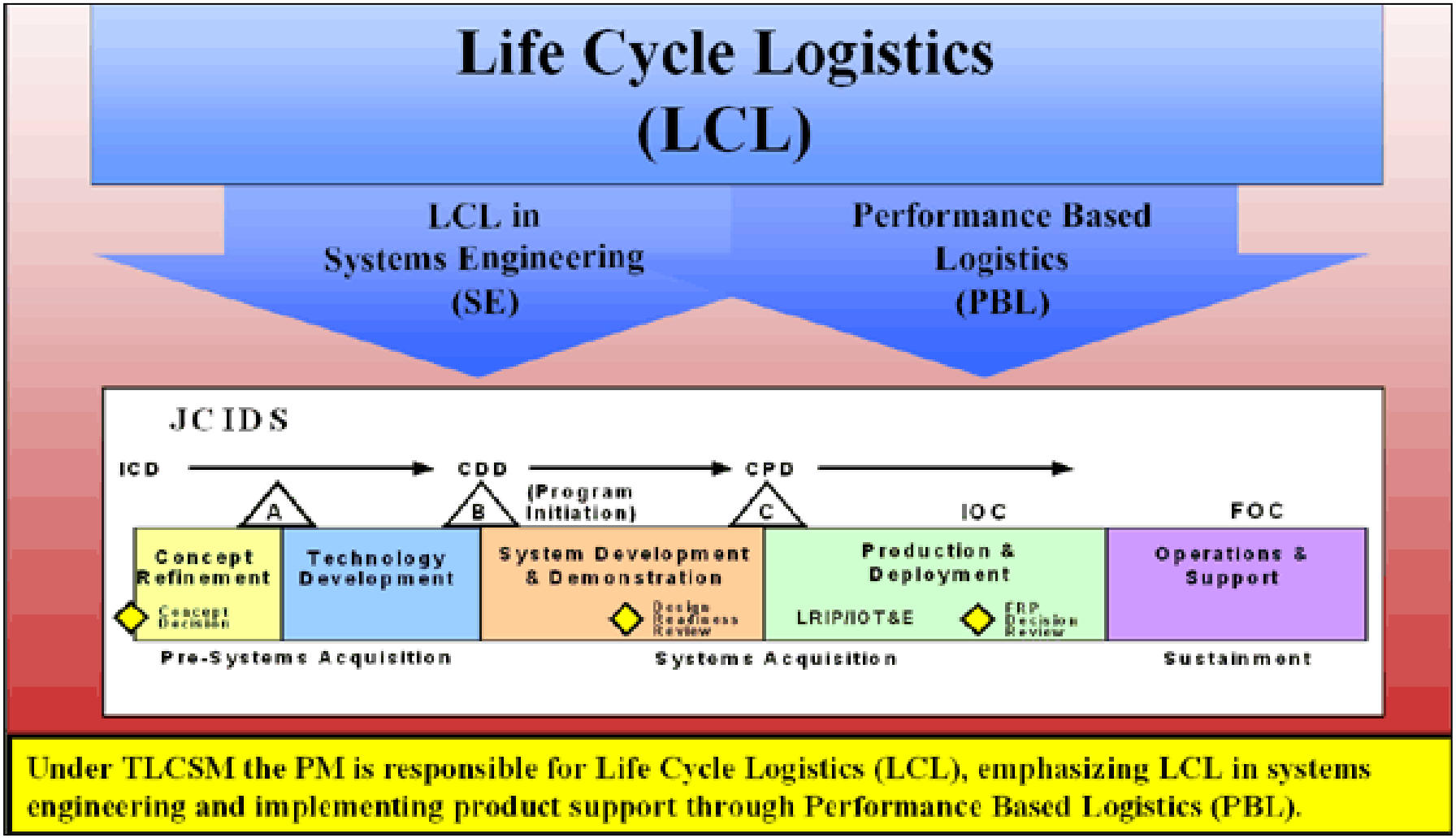
- MBSE is a focus area that is part of INCOSE Vision 2020 for SE
- MBSE benefits are directly applicable to improving the practice of SE in DoD
  - Improved communications
  - Integrating consideration of total system life cycle needs
  - Early and continuous evaluation
  - More rigorous & disciplined reviews
  - More timely trade-offs and decisions
- MBSE is not new, but most applications to-date have been limited in scope
- Broader application of MBSE requires some emerging enablers
  - Data & modeling standards
  - Alignment with SE 'process' standards
  - Interoperable tool support
  - Application experience
    - Real benefits and limitations
    - Refinement needed

Questions?

Key MBSE Enablers – Related Data & Modeling Standards Activities

- Open Standards
  - SysML - Object Management Group SE DSIG
    - Standard language and notation for modelling all types of systems
    - Model interchange with AP233
  - AP233 (ISO 10303-233)
    - Defines a neutral information model for complex systems engineering concerns to exchange systems engineering data with other data models
  - GEIA-927
    - Facilitates the exchange of complex systems data concepts between product data domains
  - UPDM (UML Profile for DoDAF & MODAF)
    - Define standardized architecture framework views & viewpoints
    - Data interchange with other architecture data sets, such as CADM, M3 & IDEAS schemas
- Standards-based Tool Interoperability Framework & Demos
  - Assists vendors to built interoperable SE tools using these standards
    - NIST-DoD sponsored plug-fest

Facilitating Improved Total Life Cycle Systems Management



Under TLCSM the PM is responsible for Life Cycle Logistics (LCL), emphasizing LCL in systems engineering and implementing product support through Performance Based Logistics (PBL).

MBSE shared data should enable balancing design and support decisions that affect the total life cycle