Presented to:

SoSECIE

A Practitioner's Approach using MBSE in Systems of Systems

IAW DoD Directive 5230.24, Distribution A

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Topic Overview

- Background
- Enterprise Mission/Purpose
- M&S Enterprise Management
- M&S Enterprise Engineering
- New Enterprise Approaches
- Summary

Purpose: Provide an Overview of MDA M&S Enterprise efforts

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Increasing Complexity Requires a Paradigm Shift

"The trend toward networked capabilities will increasingly demand movement away from acquisition of platforms in isolation and toward a more sophisticated consideration of how the Army should integrate systems into existing and future formations."

- **More preparatory system engineering is needed for such a large, ambitious program.**
- **Systems of Systems Engineering should have been much stronger early in the program.**

"Lessons Learned from the Army's Future Combat Systems"
[RAND Corporation, 2012]

SoS Characteristics

A System is a "System of Systems" if it exhibits significant amounts of:

- Emergent behavior
  - SoS performs functions not achievable by the independent component systems
- Geographic distribution
  - Geographic extent forces the elements to exchange information in a remote way
- Evolutionary development
  - Functions and purposes are added, removed and modified in an ongoing way
- Operational independence
  - Component systems have purpose even if detached
- Managerial independence
  - Component systems are developed and managed for their own purposes

"Architecting Principles for SoS," Mark Maier, 1998, *Systems Engineering* (INCOSE)

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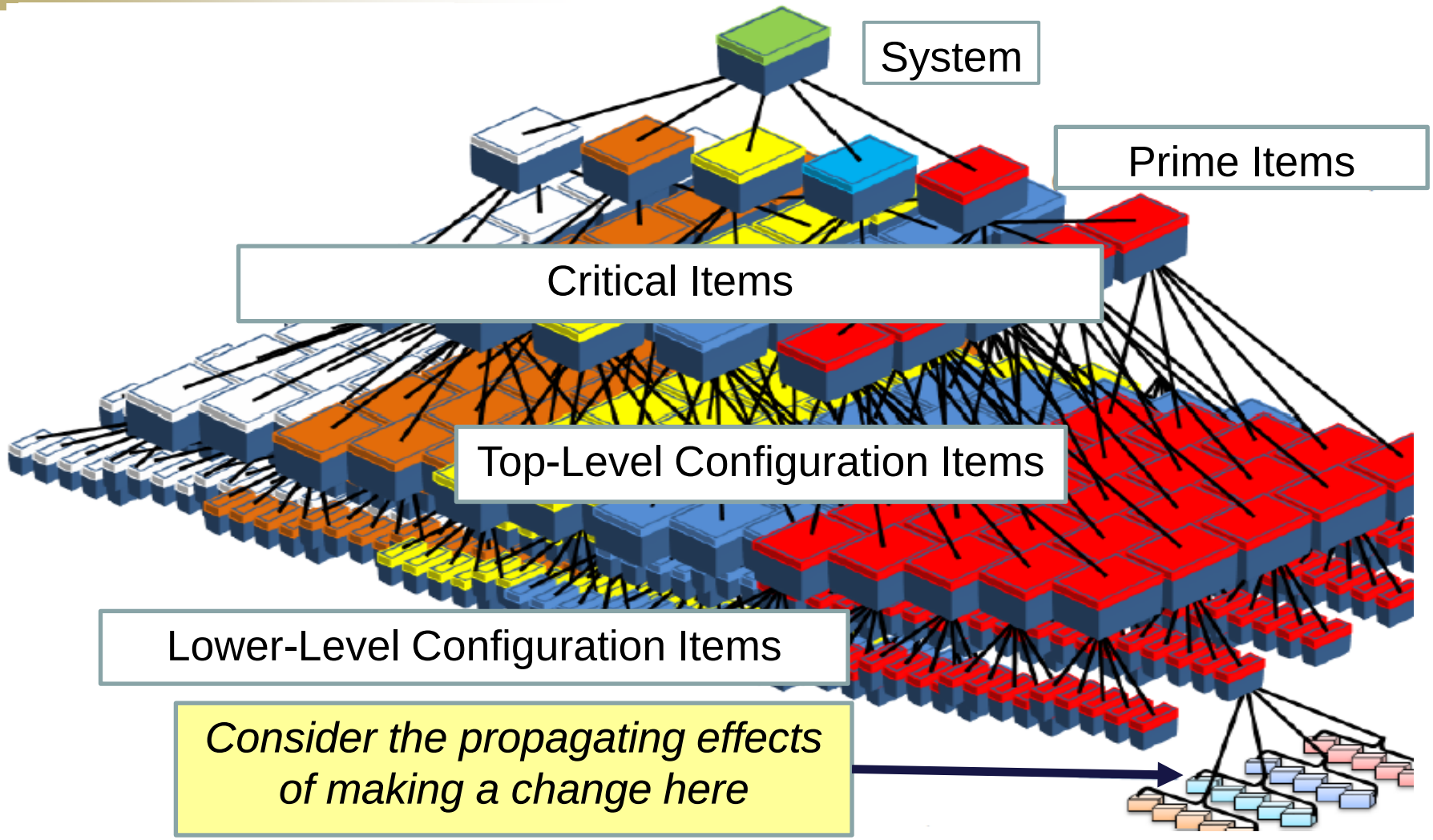
An SoS Model Representation



As Complexity Grows Traditional SE Can Become Intractable

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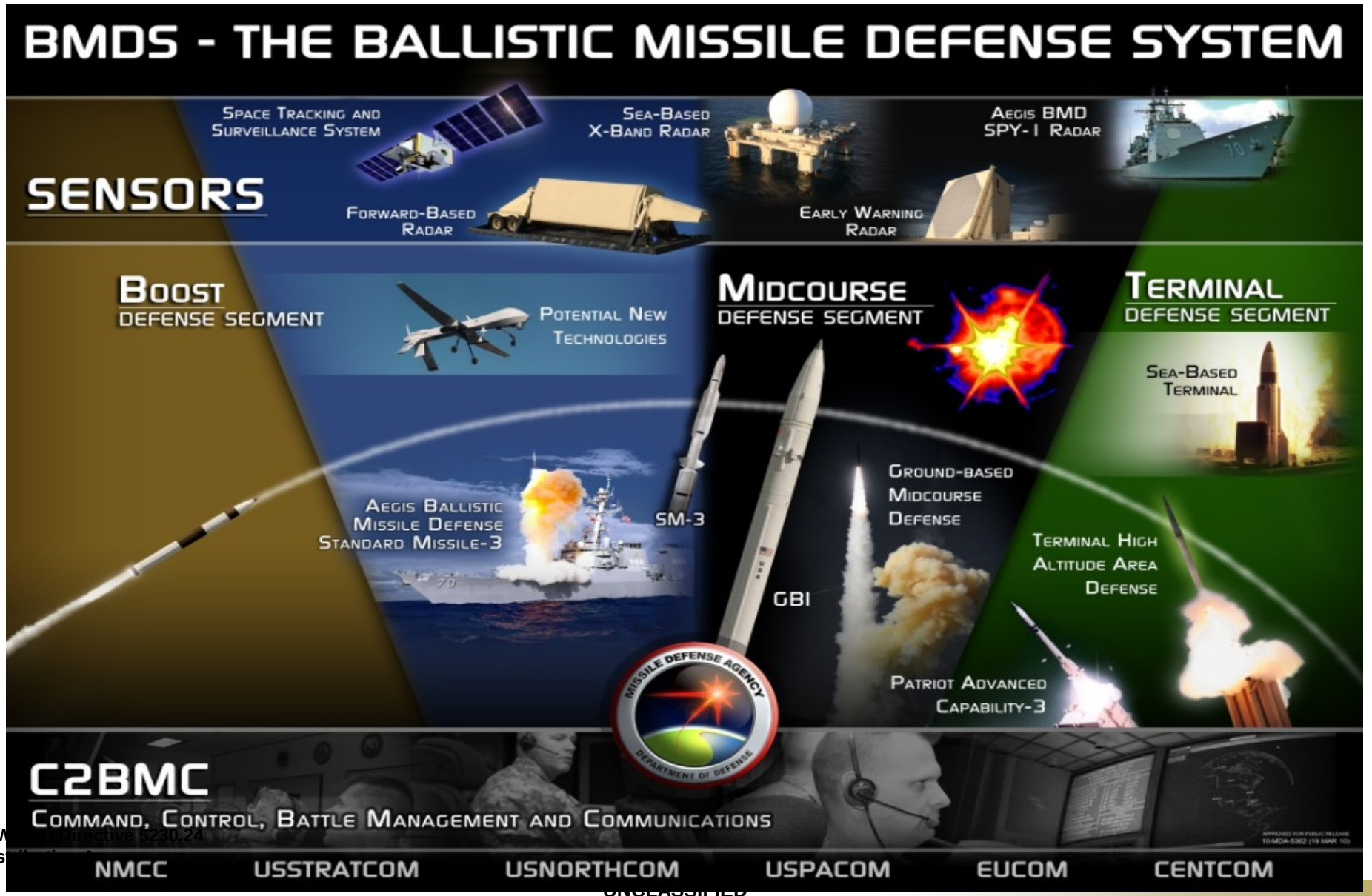
An SoS Tactical Representation



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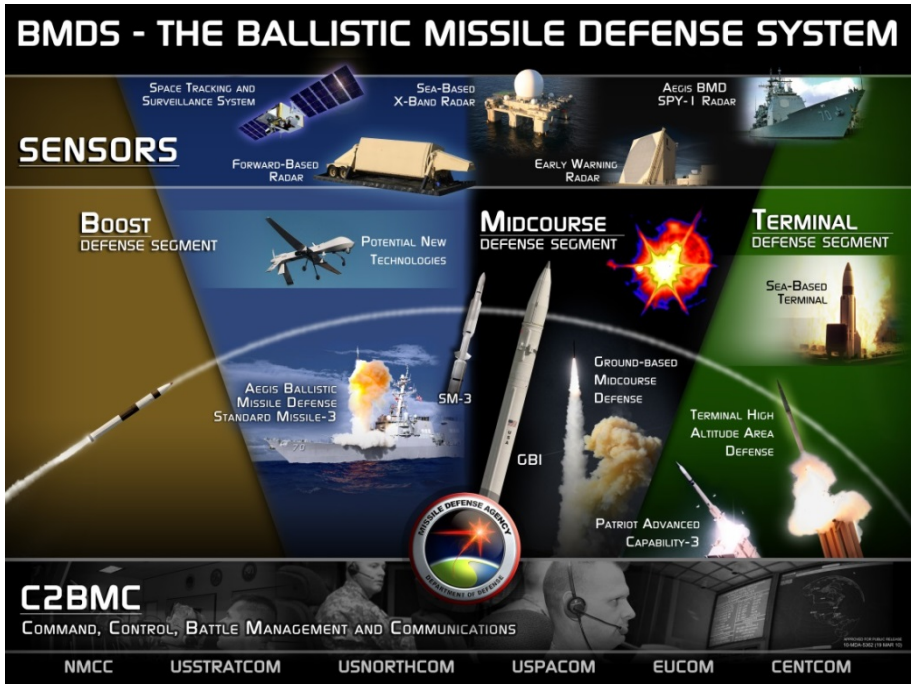
Systems of Systems Challenges Pain Points

- ***Lack of Systems of Systems Authorities & Funding***
- ***Leadership***
- ***Constituent Systems***
- ***Capabilities & Requirements***
- ***Autonomy, Interdependencies & Emergence***
- ***Testing, Validation & Learning***
- ***Systems of Systems Principles***

“SoS Pain Points & Implication to MBSE”, Dr. Judith Dahmann, 2013

BMDS M&S Enterprise Mission/Purpose

Establish and implement an enterprise-wide program management and engineering approach to ensure adequate resources and synchronized development and delivery of credible and timely BMDS M&S.



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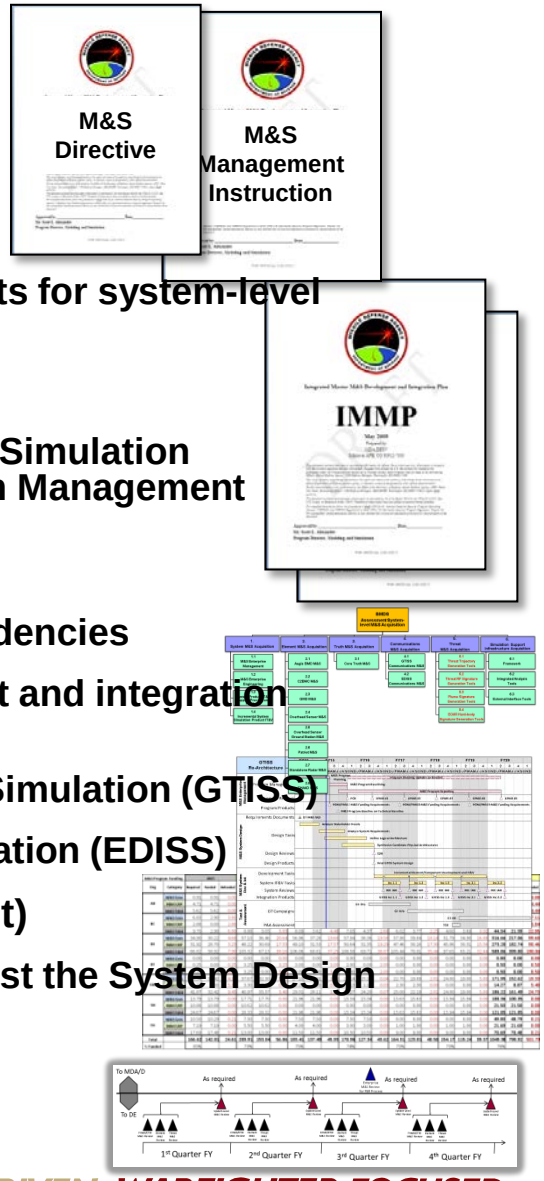
BMDS M&S Enterprise Vision & Goal

- **Design, develop and deliver credible and timely system-level and element/component-level M&S to support the BMDS Life Cycle**
  - **Decision quality data**
  - **Accredited for intended uses with acceptable limitations**
  - **Synchronized development, integration and delivery to better meet customer/user stakeholder needs**
  - **Efficient use of manpower, resources and facilities**
  - **Best value to the government to provide the most capability while minimizing cost and optimizing schedule**
  - **Complimentary suite of agency M&S products and capabilities to meet MDA Mission and BMDS Life Cycle Needs**

- **M&S Re-Architecture Goal**
  - **Address the long-standing M&S limitations**
    - **Initially identified in the Corrective Action Plan (CAP)**
    - **Incorporated as requirements in the M&S SRDs**
    - **Target system-level M&S that supports BMDS assessment**

BMDS M&S Enterprise Approach

- **M&S Governance Structure**
  - M&S Directive and M&S Management Instructions
- **M&S Systems Engineering Approach**
  - Independent M&S Requirements Document
  - Top Down Design based on independent M&S Requirements for system-level simulations
- **M&S Management Approach**
  - Leverages M&S Enterprise WBS, IMP/IMS for System-level Simulation Acquisition, M&S Program Baseline and Quarterly Program Management Reviews
- **Pre-planned, Synchronized Incremental M&S Capabilities**
  - Leverages system design to inform capabilities and dependencies
  - Leverages integrated planning to synchronize development and integration activities across the M&S Enterprise community
  - Product focused for Ground Test Integrated System-level Simulation (GTISS)
  - Product focused for End-to-end Digital System-level Simulation (EDISS)
- **System <u>Product</u> Integration, Test and Verification (pre-event)**
  - Verify implementation of the System-level simulation against the System Design and associated decomposed requirements



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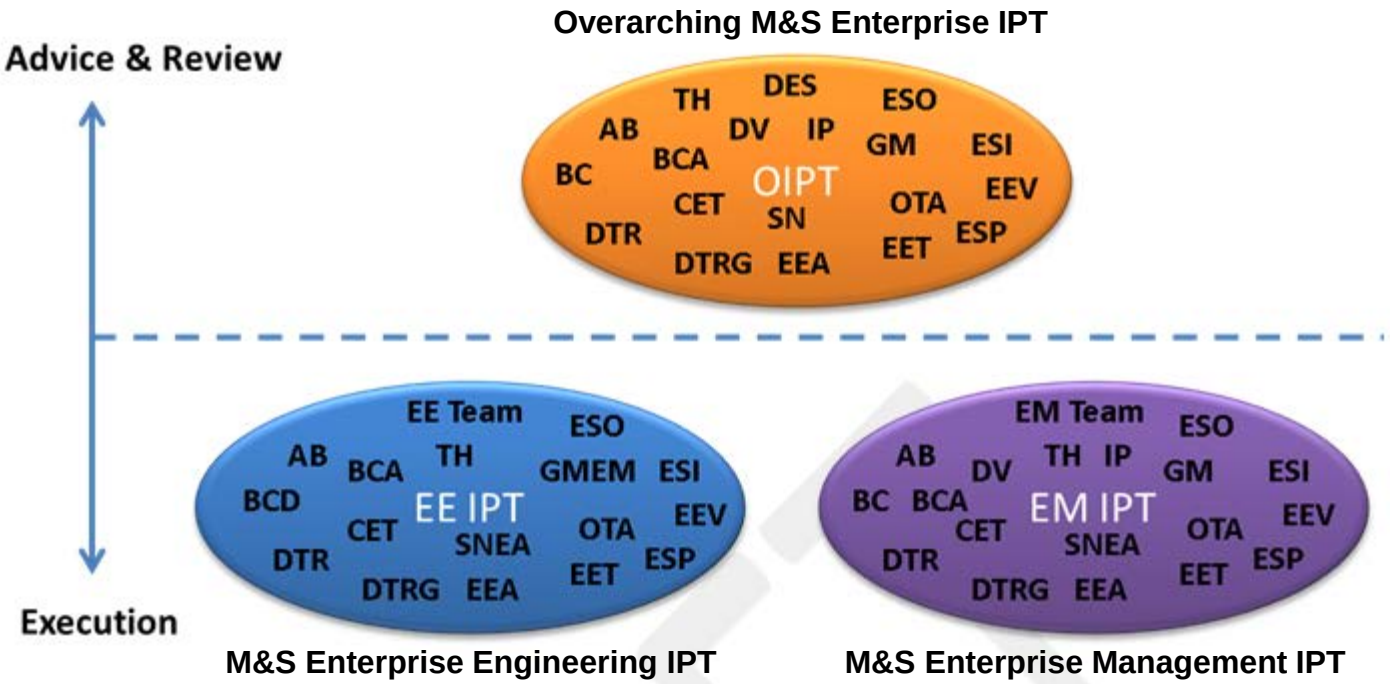
Enterprise Integrated Product Teams (IPTs)



M&S Enterprise Engineering IPT

M&S Enterprise Management IPT

To be effective we must…

1) Get full M&S community participation
2) Avoid overtaxing community
3) Bring together proper technical expertise

The right people to solve the right problems

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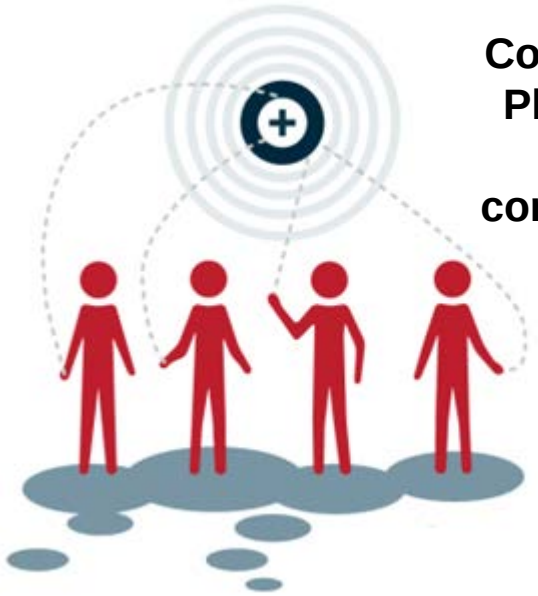
Enterprise Management Vision

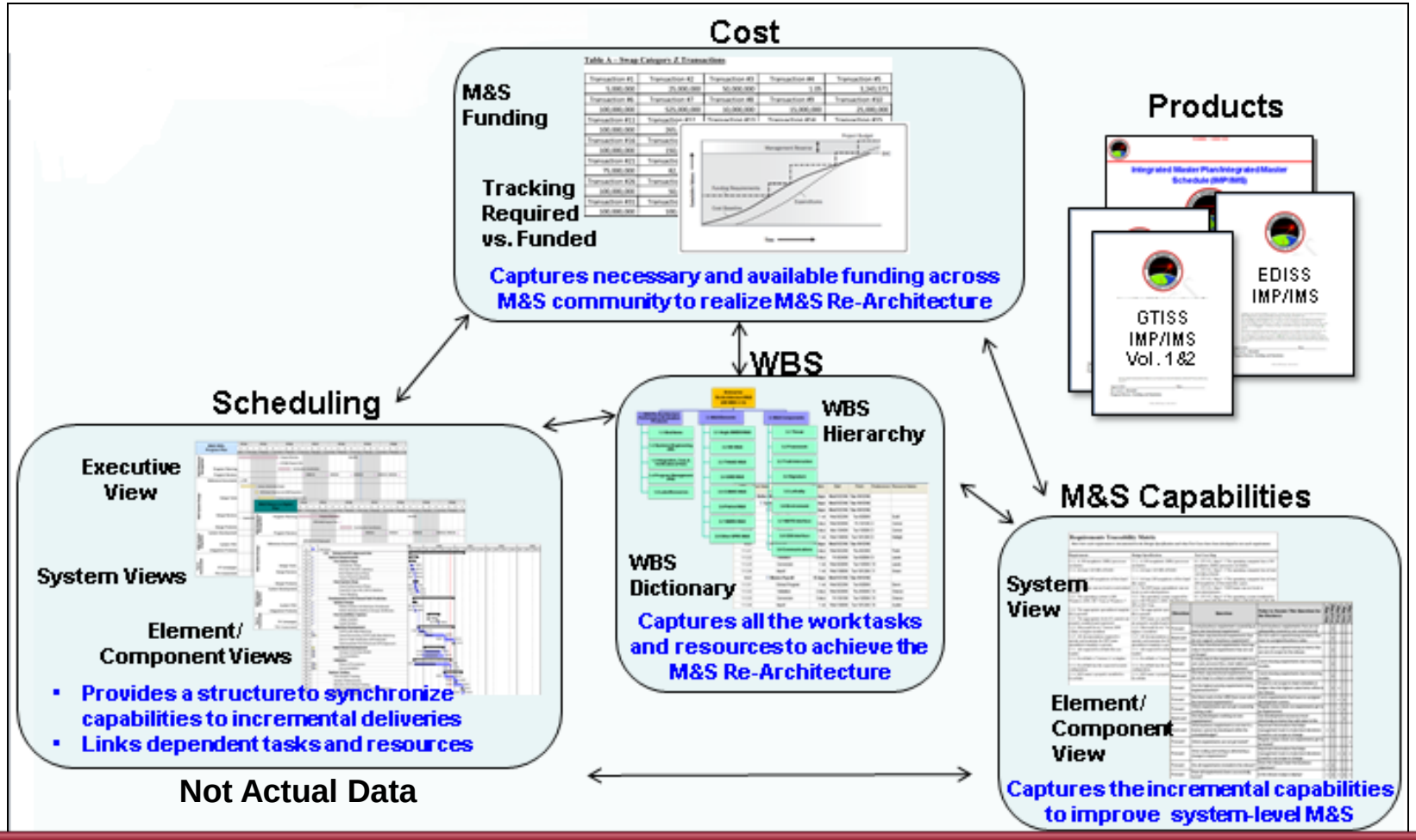
- *Centrally managed M&S SoS*
  - *Optimized/synchronized in quality, time, and resources*
  - *Strategically aligned*
  - *Cohesive Community*
  - *Credible system-level simulations*
- *Centralized monitoring/reporting of funding for all agency M&S*
  - *Includes System-level, Standalone Element and Other MDA M&S*



Collaborative Planning to reach common goal

Synchronized Execution to reach common goal

IMP/IMS Concept



Create a master planning document that contains the details for Captures the Cost, Schedule, Performance planning across the SoS system-level simulations and the supporting M&S development and system integration

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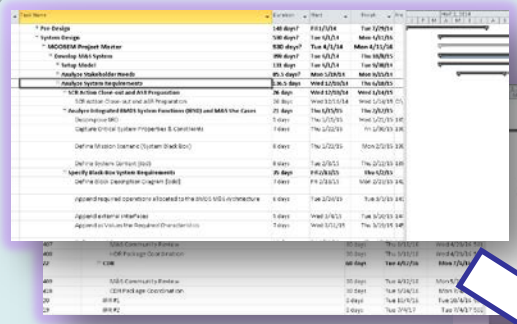
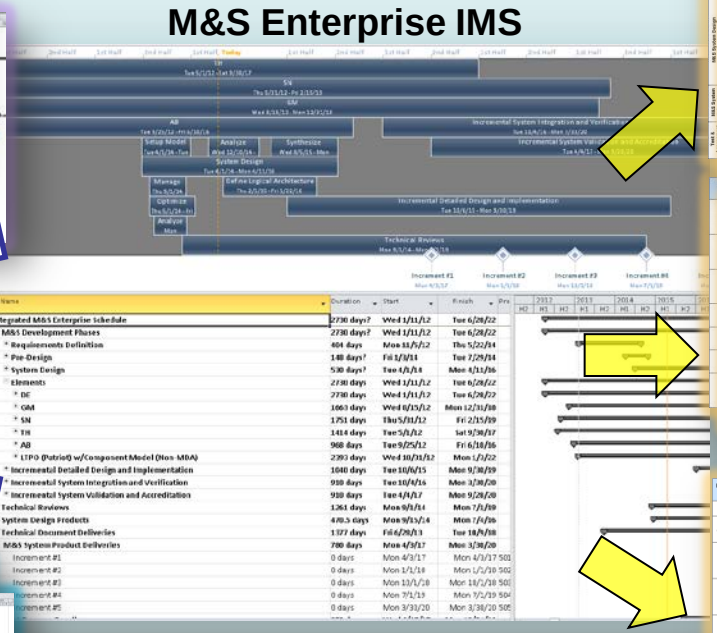
M&S IMS Concept

BMDS Project Server

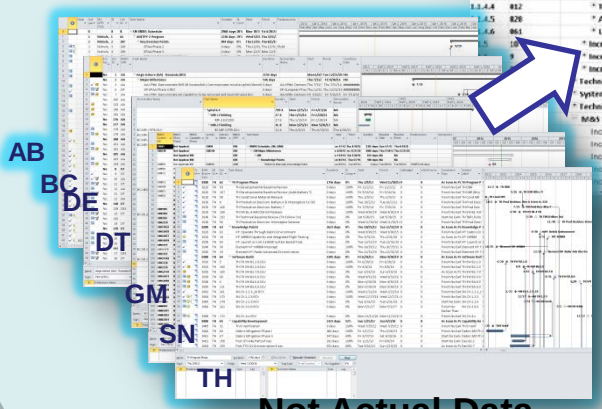
System IT&V Schedules



M&S Enterprise IMS



PO Managed M&S Element/Component Schedules



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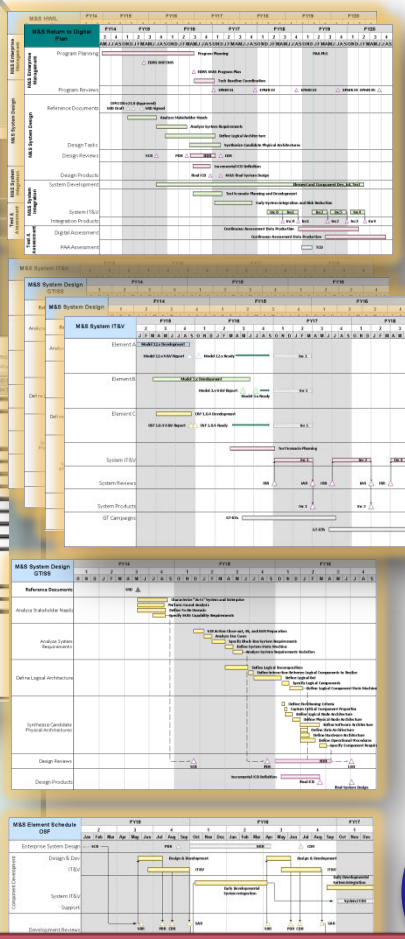
M&S Schedule Reports



Levels

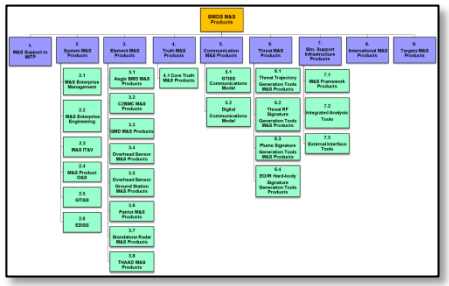
- Exec
- System Overview
- System Detail
- Element/ Component Overview

IMS provides a centralized environment to effectively manage the *horizontal* (breadth) and *vertical* (depth) schedule integration across the Enterprise. This reduces schedule *risk* and helps ensure early planning for timely deliveries.

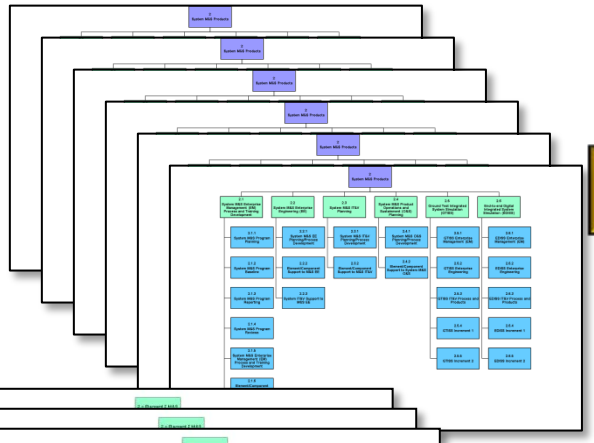
WBS Concept

WBS Hierarchy

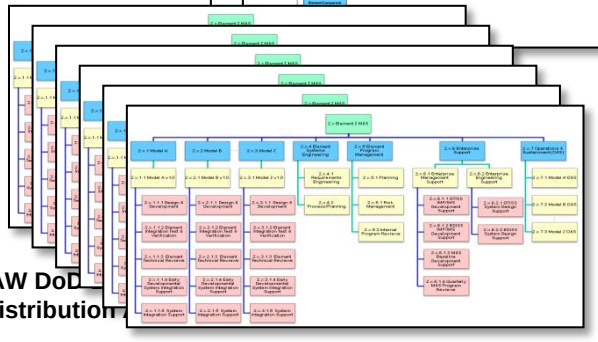
Hierarchical Decomposition of all work necessary to support the M&S Re-Architecture



M&S Re-Architecture (Levels 0, 1, and 2)



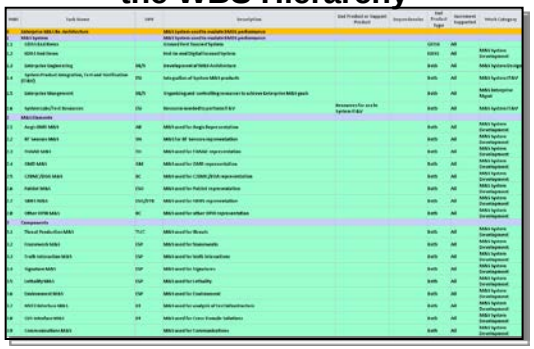
System View (Levels 1, 2 and 3)

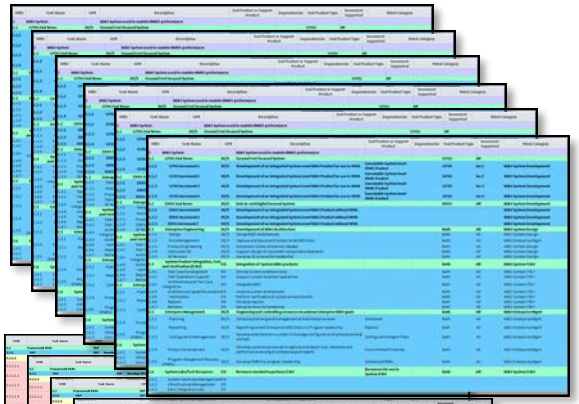


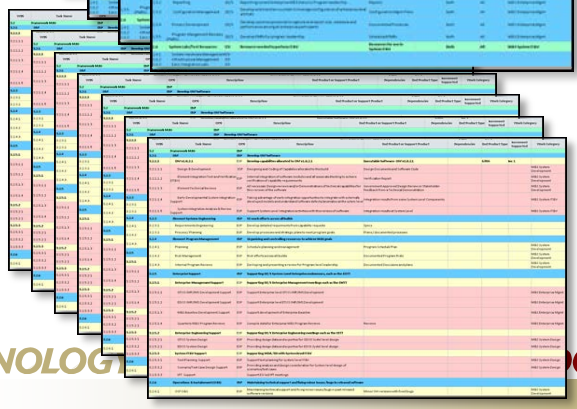
Element/Component Views (Levels 2, 3, 4 and 5)

WBS Dictionary

Supporting information for each item in the WBS Hierarchy







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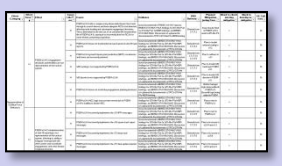
M&S System Capabilities Concept

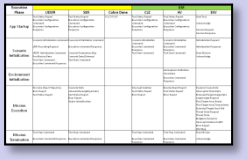
M&S SRDs

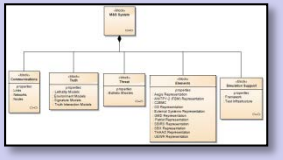
M&S System Design Analysis/Products



Causal Analysis

Enterprise Data Model (EDM)

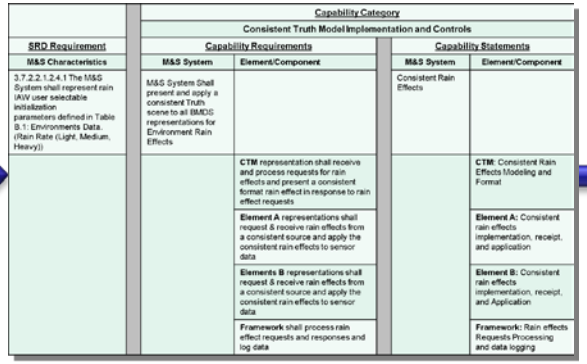




Engineering Analysis and System Modeling

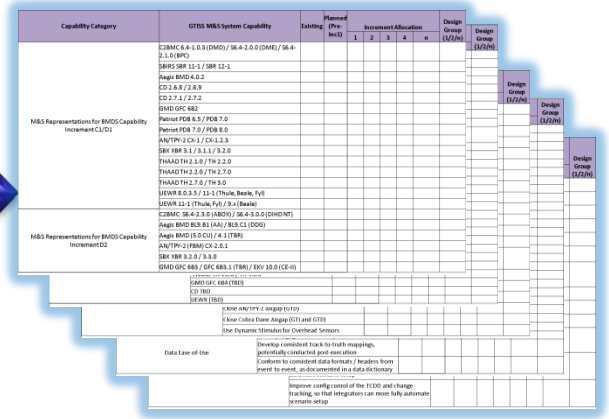
M&S Capability Categories & Requirements

(System and Element/Component level)



M&S Capability Categories & Statements

(System and Element/Component level)



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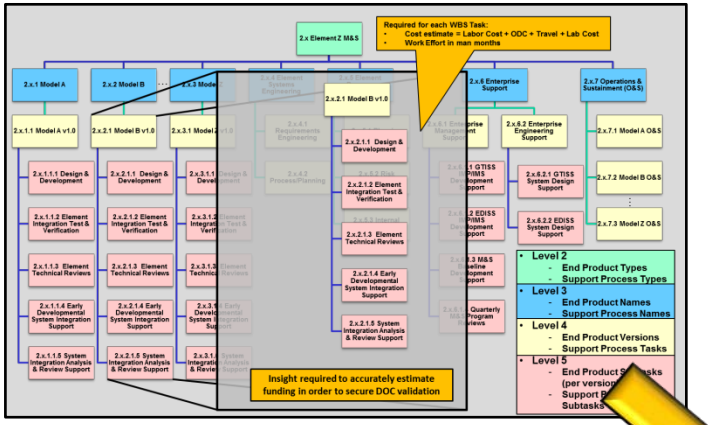
M&S Funding Requirements Concept

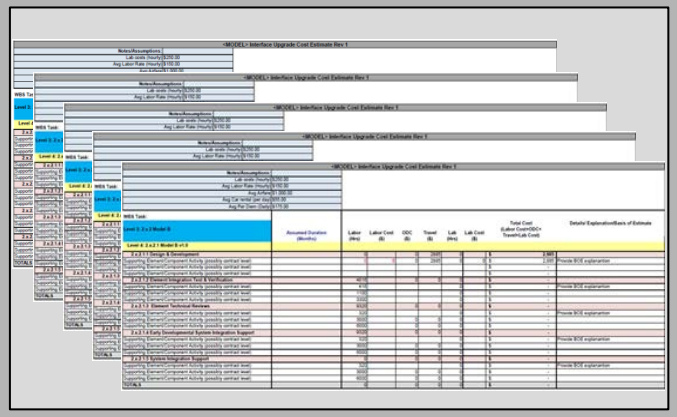
WBS



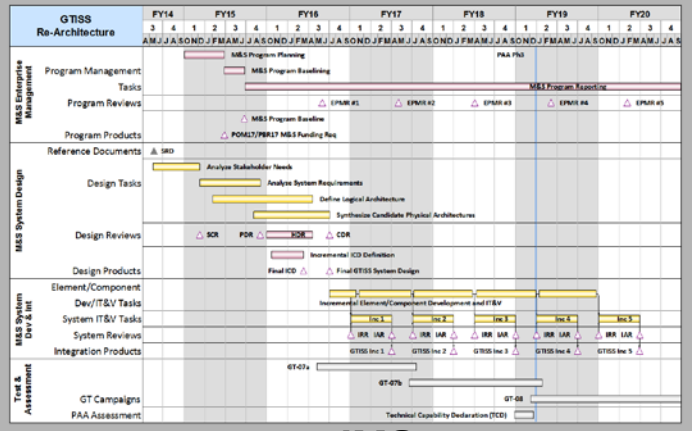
Required M&S Funding

M&S Program Funding		2015			2016			2017			2018			2019			2020			Totals		
Organization	Category	Required	Funded	Unfunded	Required	Funded	Unfunded	Required	Funded	Unfunded	Required	Funded	Unfunded	Required	Funded	Unfunded	Required	Funded	Unfunded	Required	Funded	Unfunded
AB	M&S Re-Arch	5.62	5.62	0.00	10.17	5.94	4.23	3.50	3.50	0.00	3.22	3.22	0.00	3.22	3.22	0.00	2.18	2.40	-0.22	27.91	23.91	4.44
BC	M&S Re-Arch	9.70	2.90	6.80	8.88	3.05	5.83	8.09	3.62	4.47	7.05	4.37	2.68	6.02	3.77	2.25	4.60	3.69	0.91	44.34	21.39	22.95
DE	M&S Re-Arch	66.82	58.92	7.90	105.32	67.15	38.17	106.06	68.81	37.25	108.58	69.71	38.87	105.44	70.01	35.44	97.65	65.21	32.44	589.86	399.80	190.06
DT	M&S Re-Arch	0.25	0.00	0.25	3.25	0.00	3.25	3.00	0.00	3.00	2.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	8.50	0.00	8.50
GM	M&S Re-Arch	41.87	32.42	9.45	40.97	35.57	5.40	29.31	28.11	1.20	24.27	24.20	0.07	25.00	22.19	2.81	24.80	19.00	5.80	186.22	161.49	24.73
SN	M&S Re-Arch	24.67	24.67	0.00	28.33	28.32	0.01	21.96	21.96	0.00	15.34	15.34	0.00	15.63	15.63	0.00	15.94	15.94	0.00	121.85	121.85	0.00
TH	M&S Re-Arch	17.69	17.48	0.21	13.00	13.00	0.00	11.50	11.50	0.00	10.50	10.50	0.00	9.00	9.00	0.00	9.00	9.00	0.00	70.69	70.48	0.21
Total		166.62	142.01	24.61	209.92		56.89	183.42	137.50	45.92	170.96	127.34	43.62	164.31	123.82	40.50	154.17	115.24	38.93	1049.37	798.92	250.89
% Funded		85%			73%			75%			74%			75%			75%			76%		

Not Actual Data



Cost Estimate by WBS Task



IMS

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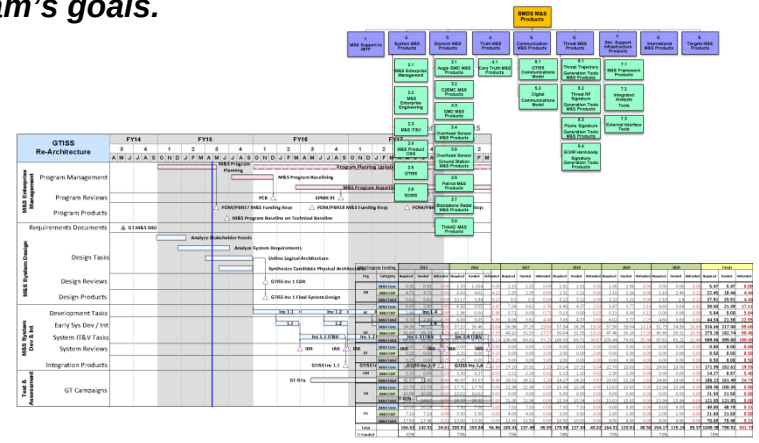
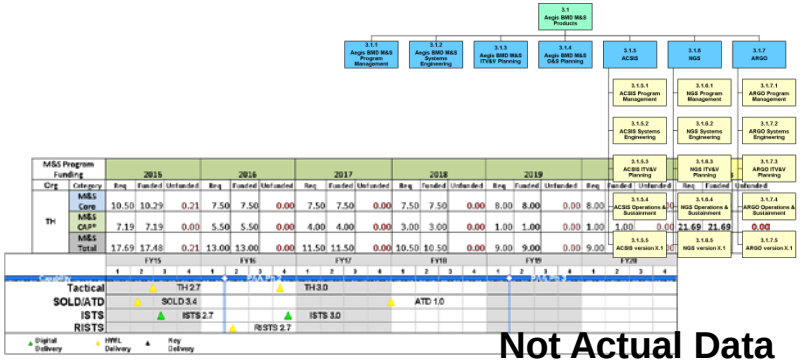
M&S Re-Architecture Program Baseline Concept

- **Program Baseline Definition:**
  - ***Formally documents the program's critical cost, schedule, and performance parameters, expressed in measurable, quantitative terms that must be met in order to accomplish the program's goals.***
  - ***Changes to Baseline Require Board approval***
- **Draft Program Baseline Document Outline**
  - **Program Overview**
    - **Mission Need**
    - **Program Objectives**
    - **Program Description**
    - **References**
  - **GTISS & EDISS System Program Baselines**
    - **Program Performance**
    - **Program Schedule**
    - **Program Cost**
  - **Element/Component Program Baselines**
    - **Program Performance**
    - **Program Schedule**
    - **Program Cost**

System



Element/Component



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PMR Concept

**Where are we? How are we doing? How do we know?
What do we need to do about it?**

Entrance Criteria

- Program control data
- Schedule status
- Funding status
- PM Assessment
- Risk/Issue/Problem data
- Management guidance

PMR

- Prepare for review
- Conduct review
- Record review
- Perform review wrap-up

Exit Criteria

- Action Item Forms
- Action Item Tracking List
- Meeting minutes
- Management approval to proceed

**Quarterly Element/Component & System-Level PMRs
Annual Executive PMRs**

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Enterprise Engineering

- **Purpose:**
  - **Provides the system architecting and design for the system-level simulations, traceable to the System Requirements Document (SRD) and M&S Re-Architecture Vision**
  - **Facilitates a collaborative Integrated Product Team (IPT) approach to system design by working with engineering Subject Matter Experts across the M&S Element, Component, Threat and Stakeholder/User Community**
- **Products:**
  - **System Design for Ground Test Integrated System-level Simulation (GTISS) for the GT07 Campaign M&S**
  - **System Design for End-to-end Digital Integrated System-level Simulation (EDISS) M&S**

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Model Based Systems Engineering Approach using SysML

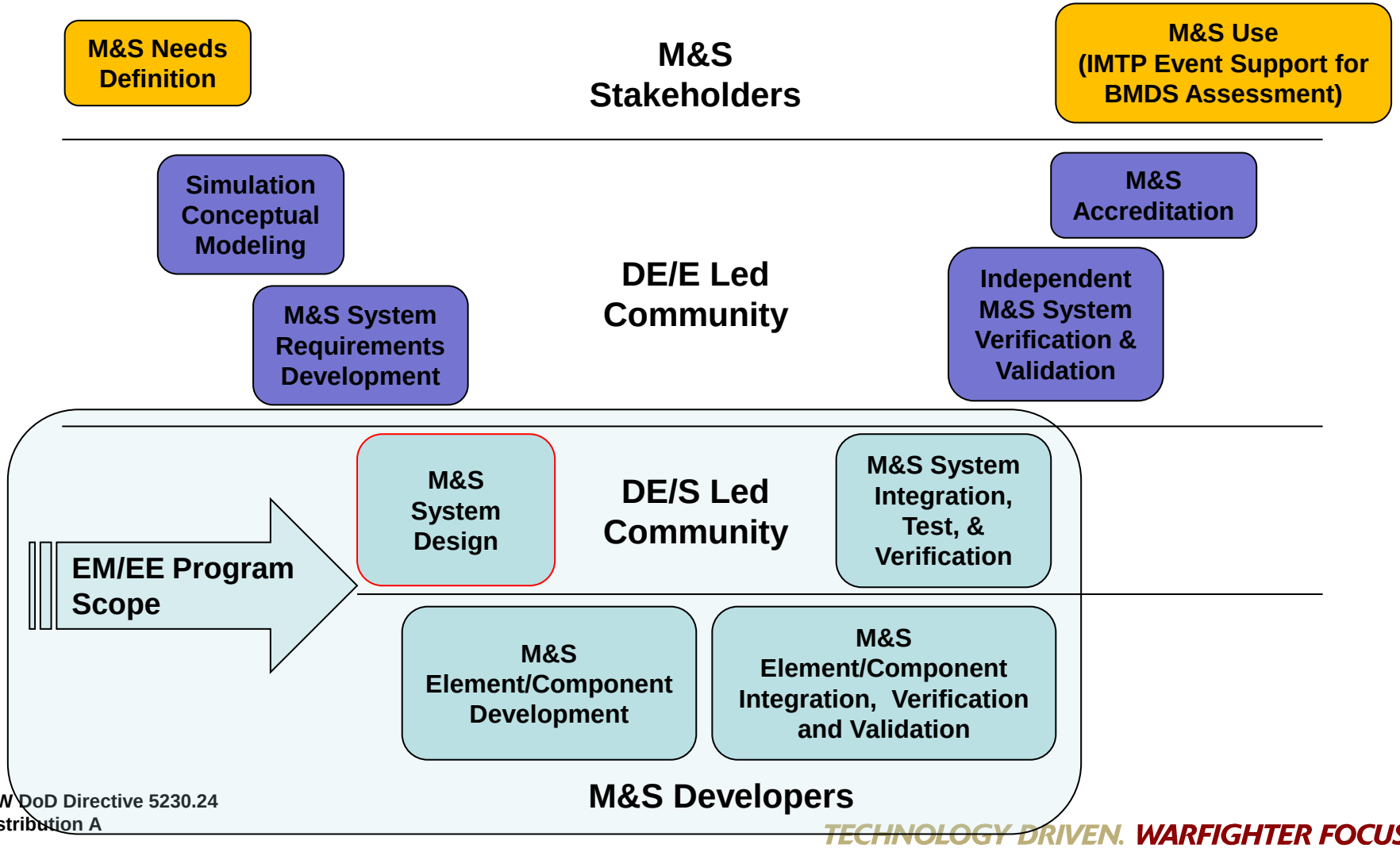
Model Based Systems Engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases." **[INCOSE, 2007]**

- **The goal of the MBSE process is the creation of a well-reasoned and consistent *system model.***
- **Focused on a shared system model with multiple views.**
- **Distinct from traditional systems engineering, which tends to be centered on a static, document-based approach in the form of design documents and text specifications.**

Implementation using SysML as the Graphical Modeling Language

Scope

M&S Enterprise Lifecycle for BMDS Assessment Simulations



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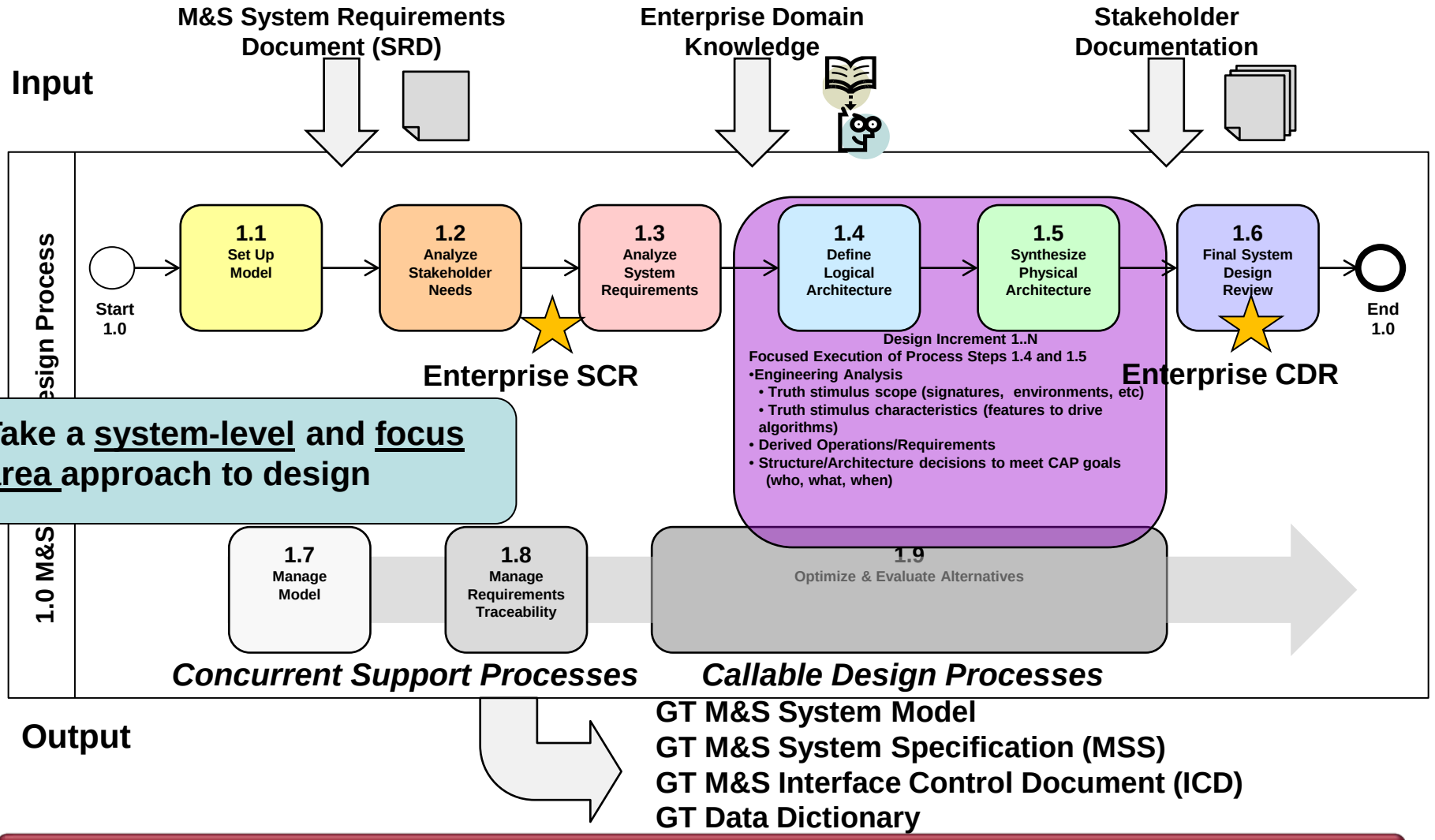
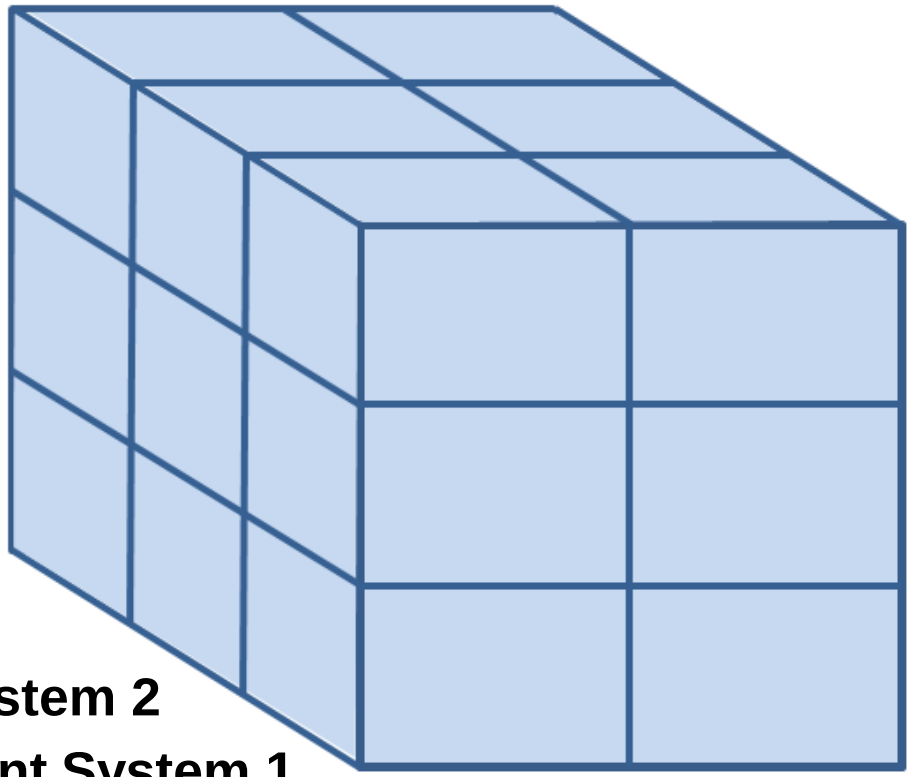
Hybrid Top Down Design Process Design Inc #1



Following tailored INCOSE OOSEM design methodology

SoS Tradeoffs and Evolution
Simultaneous, Multi-Dimensional Considerations

Systems of Systems Cube



Leadership Support and Constituent System Collaboration are Essential to Systems of Systems Engineering Success

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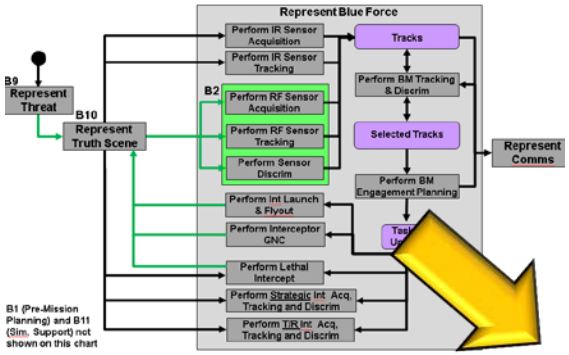
Incremental Design Scope



Allocation to Design Increments

Design Inc. 1

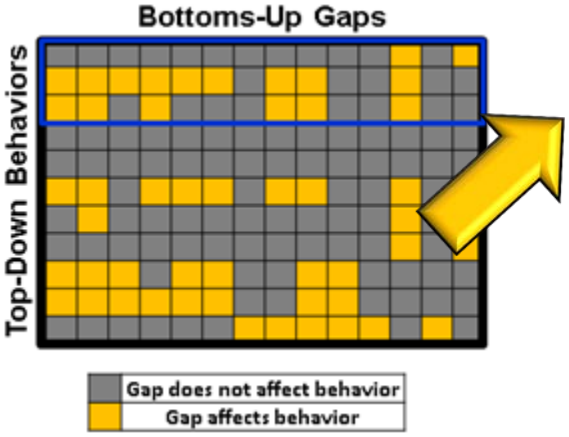
- Behavior 1
- Related Gaps
- Behavior 2
- Related Gaps

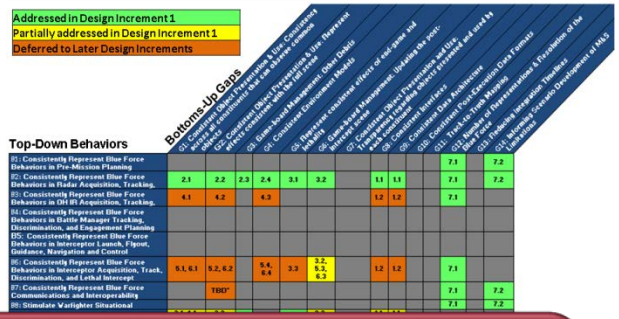
Early System Functions

Design Inc. 2

- ...
- Behavior N-1
- Related Gaps
- Behavior N
- Related Gaps

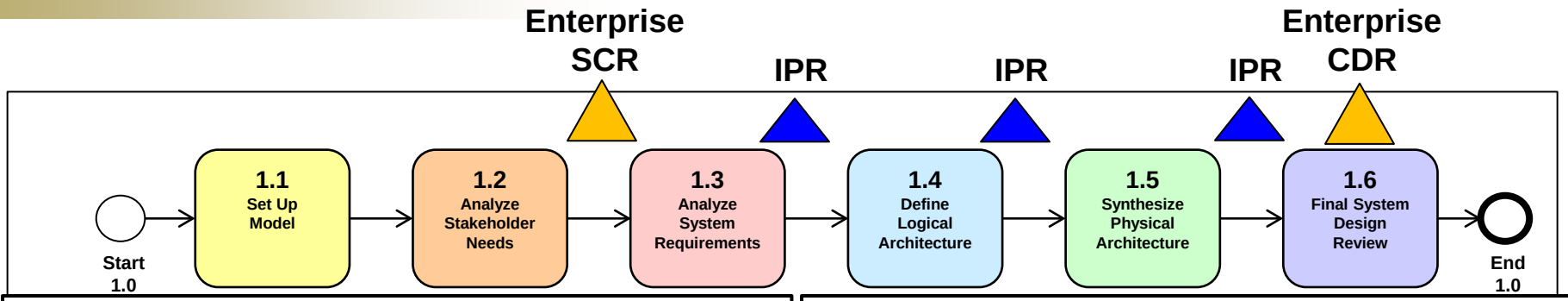
Later System Functions Providing Sim. Support





Incremental approach allows for the right balance of capability, schedule, and resources that provide increasing capability over time to stakeholders with the overall plan for the entire effort

Design Review Approach



System Concept Review (SCR)
- Used to understanding implications of System Requirements Document
- Design scoped (As Is versus To Be M&S System)
- Identify major design changes to existing system called for by M&S System Requirements Document

Critical Design Review (CDR)
- Conducted after "Synthesize Candidate Physical Architecture"
- Design details including allocation to physical components, and derived requirements are identified

In Progress Review (IPR)
- Topic-focused review series
- Design options/COAs, based on system inputs, outputs, constraints and behaviors identified
- Design characterizations including functionality and interoperability identified
- Establish allocated baseline

- **Implemented a content-driven sequence of design reviews corresponding to phases of the design process**
- **Used to evaluate the status, adequacy, and risk of the technical design**
- **Single system review methodology not easily supported in SoS context**

Following tailored design review methodology

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New Enterprise M&S IT&V

- **Pre-planned, Synchronized Incremental M&S Capabilities**
  - **Leverages system design to inform capabilities and dependencies**
  - **Leverages integrated planning to synchronize development and integration activities across the M&S Enterprise community**
- **System Product Integration, Test and Verification (pre-event)**
  - **Provide more opportunities to integrate early and often**
  - **Create informal and formal test and verification opportunities**
  - **Implement readiness and acceptance reviews**
  - **Verify implementation of the System-level simulation against the System Design and associated decomposed requirements**
    - **Focus on new incremental capabilities**
    - **Confirm verification/regression of cumulative existing capabilities**
  - **Continue to support event specific integration and certification activities**

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Summary

- **The trend toward more complex systems that are inter-dependent to achieve systems-of-systems missions is on the increase.**

- **A well formed system model with community collaboration as part of the design and development process can help avoid the painful, unintended consequences often not discovered until during integration and event execution.**

- **Model Based Systems Engineering and enterprise like techniques offer an approach to address systems-of-systems challenges.**

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