Breakthroughs in Applying Systems Engineering to Technology Development

NDIA 16th Annual Systems Engineering Conference

Mr. Jeffrey Craver

Defense Acquisition University

Ms. Melanie Klinner

US Army Space and Missile Defense Command/
Army Forces Strategic Command

Mr. Jim Heusmann

Defense Threat Reduction Agency

Mr. Mike Ellis

Intrepid

Overview

- ***Describe the problem space*** of managing the maturation of technology for transition from the perspective of the Program Manager, User, and the Technologist
- Provide an ***overview of the* Technology Program Management Model (*TPMM) solution set*** in terms of Processes, Systems Engineering, and Transition Management
- Describe the Systems Engineering Module (SEM) as ***a government-owned SharePoint@ application*** that provides online implementation
- Describe how the SEM exists within the S&T Enterprise and for the ***Management of Technology Programs/Portfolio's/Project's***
- Describe how the DTRA TPMM Project has ***applied the model to improve current processes and add-value*** to the enterprise,
- Provide the ***Way Forward*** and the extension of the TPMM process into the Technology Development Domain from Basic Research to Program Management.

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The Problem

<u>Fact:</u> There are diminishing resources and belt tightening ongoing in DoD

<u>Unfortunate Reality:</u> Warfighter Needs are increasing at a significant rate in an attempt to outpace an Asymmetric Threat

Faced With this Reality, What Needs to Be Done?

- If we can't get adequate funding,
  - **We need to *make smarter choices in what to fund.***
- If we can't build things faster,
  - **We need to *build them more efficiently with less re-work.***
- If we can't afford the full set of performance,
  - **We should *focus on the highest priority needs.***
- If we can't afford to fail,
  - **We must effectively *identify and manage the risk*.**

Culture Change: Adopt a Stage-Gate Process in the Development Phase and Incorporate a Systems Engineering-Based Criteria Set for Assessing Technology Maturity

Technology Development Challenges

Consistency in *Technology Development Planning*

- Requirements definition and plans for maturity advancement are not developed consistently or effectively.
- No common set of tools and standards to gauge technology maturity.

Improve the rate for *Transitioning of Technologies*

- Transition not always considered as a part of Technology Development
- Limited Customer/User identification/involvement

Establish "a management methodology that balances the portfolio by Incorporating Discipline and Rigor through the use of clear, well-defined and Measurable Metrics!"
J. Heusmann DTRA-J9 (7 May 09)

Perspectives

Hey Buddy - I OWN The Requirements!

Gotta be small, lightweight, and 99.99% reliable

I Want it All!
I Want it Cheap
I Want it Now!

I'm [illegible] by the JCIDS

Your next chance for funding is 5 years down the road – stud!

I NEED a REQUIRMENT (CDD)!

My prime can do that!!

I am governed by DoD[illegible]02

[illegible] about the "illities"!!!

If you "Push" long enough – they will come!

You don't understand - This project is different from everyone else

S&T does not [illegible] process – I have been doing it for years

Customer role is to integrate

Budget???

- Threat Driven
- Soldier-Proof
- Fieldable
- Meets Mission Needs
- DOTMLPF

USER

Value Added
- Capability
- Probability of Success
- Acquisition Strategy
- Budget (LLC/POM)
- Schedule - WBS
- The System " approach"

PM

- Technical "break-through"
- Performance Goals
- Risk
- Cost Estimate.
- Program Plan
- Build a prototype

S&T

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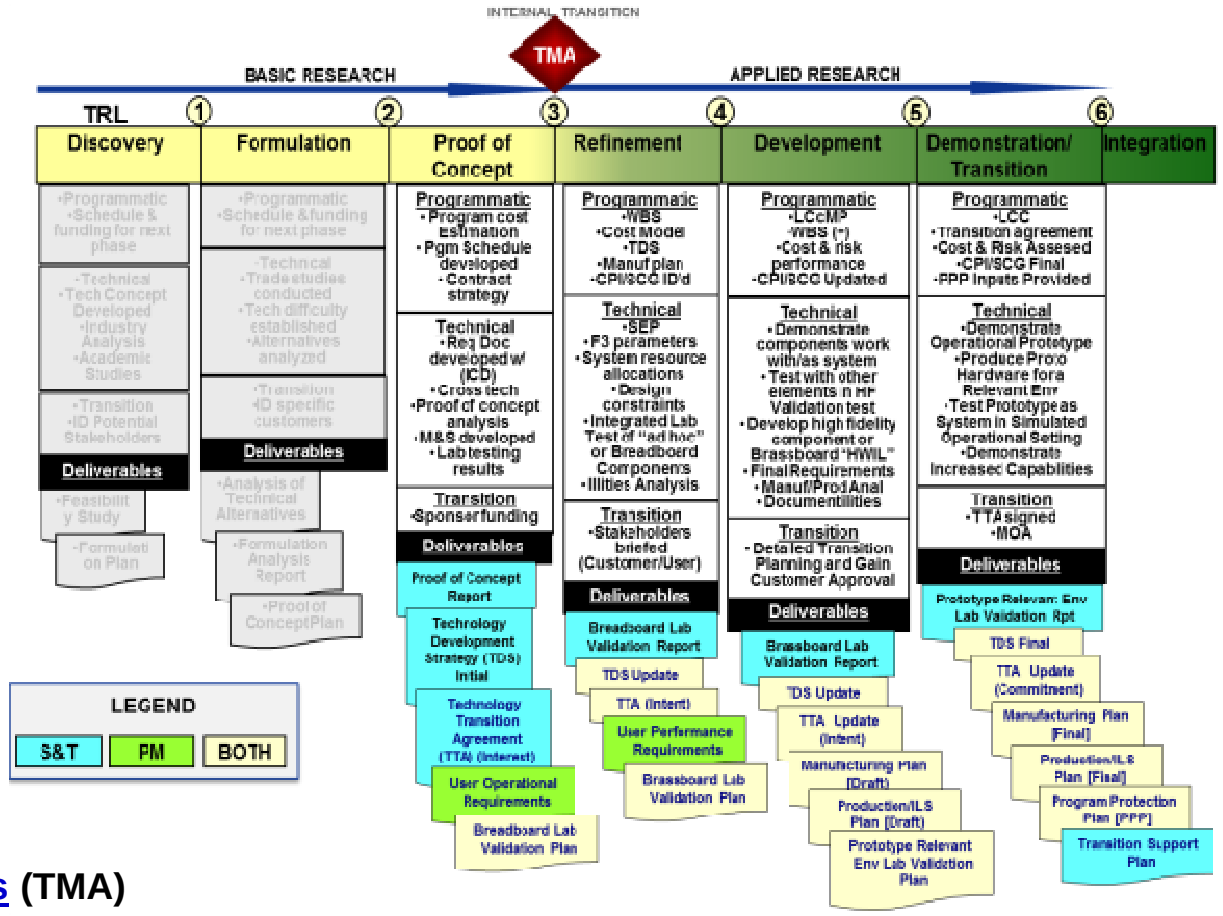
Functions Performed by TPMM

- **Program Definition**
  - Identify Activities to consider
  - Identify Deliverable Documents
  - Provide guidance for Tailoring
  - Employ "Best Practice" Tools
  - Identify and Mitigate Risk
- **Transition Management**
  - Technology Transition
  - Technology Transfer
  - Technology Marketing
- **Maturity Assessments**
  - Establishes Entry/Exit Criteria
  - Provides a Framework for

  Technology Maturity Assessments (TMA)



Legend:
TTA = Technology Transition Agreement TDS = Technology Development Strategy

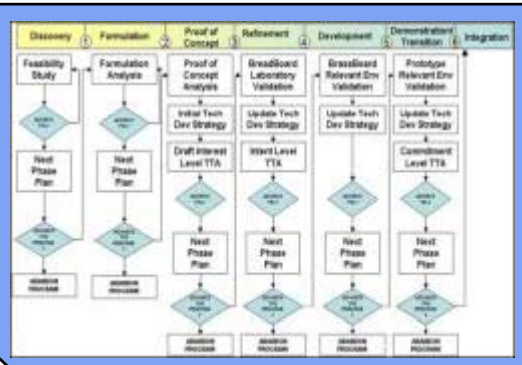
A TRL-Based, Stage Gate Model Designed for Technology Development and Transition

TPMM Collaboration

The TPMM Collaboration was formed to improve and expand the TPMM methodology and jointly develop a tool-based process intent on reducing the risk to technology development.

DTRA

DAU



USASMDC

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SMDC/DAU/DTRA Collaboration Project Breakthroughs

- A ***paradigm shift in Project and Portfolio Management has begun*** with the use of a *SharePoint* capability to :
  - ***Plan***
  - ***Execute***
  - ***Communicate progress***
  - ***Assess technical maturity***
  - ***Manage risk***

DAU has recommended TPMM as a Systems Engineering best practice since 2008.

- ***A significant advance*** **in the** consistent ***SE product set*** (SE artifacts, metrics, Exit Criteria, & online SEM reports).
- ***Revolutionary changes to cultural norms*** evident by Increasing interest from (Senior-DoD) early-adopters to a ***software tool that can overcome resistance from the S&T community to apply SE principles***.
- Enterprise Adoption facilitated by the ***pervasiveness of SharePoint*** throughout the DoD which allows for easy adoption and simplified IA requirement.

Validation

DTRA Process Improvement effort has been recognized by ***AT&L Value Engineering Achievement Award***.

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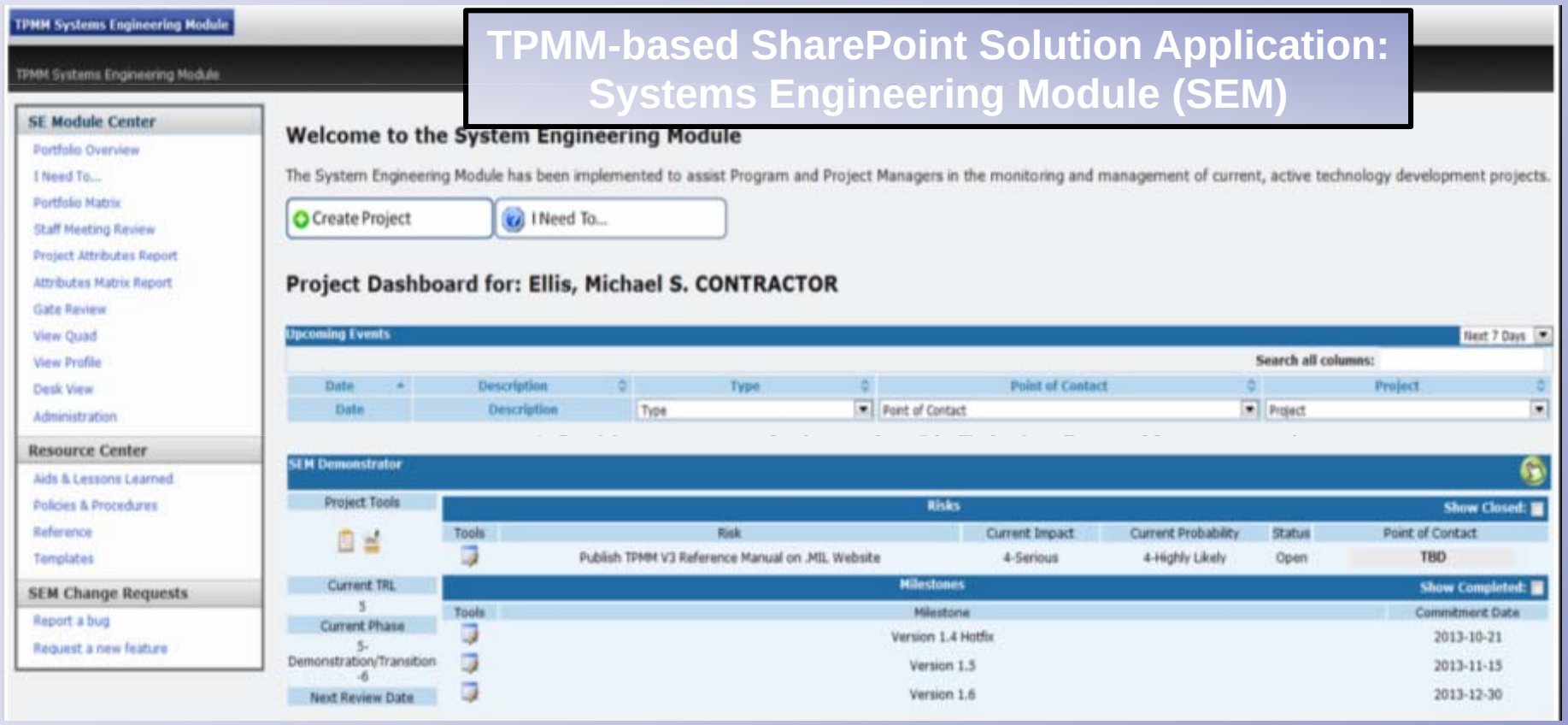
Recipient of a USD(AT&L) 2012 Value Engineering Achievement Award

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON

TPMM-based SharePoint Solution Application: Systems Engineering Module (SEM)



Frank Kendall

implementation of this best practice systems engineering method to develop and assess a technology's maturity.

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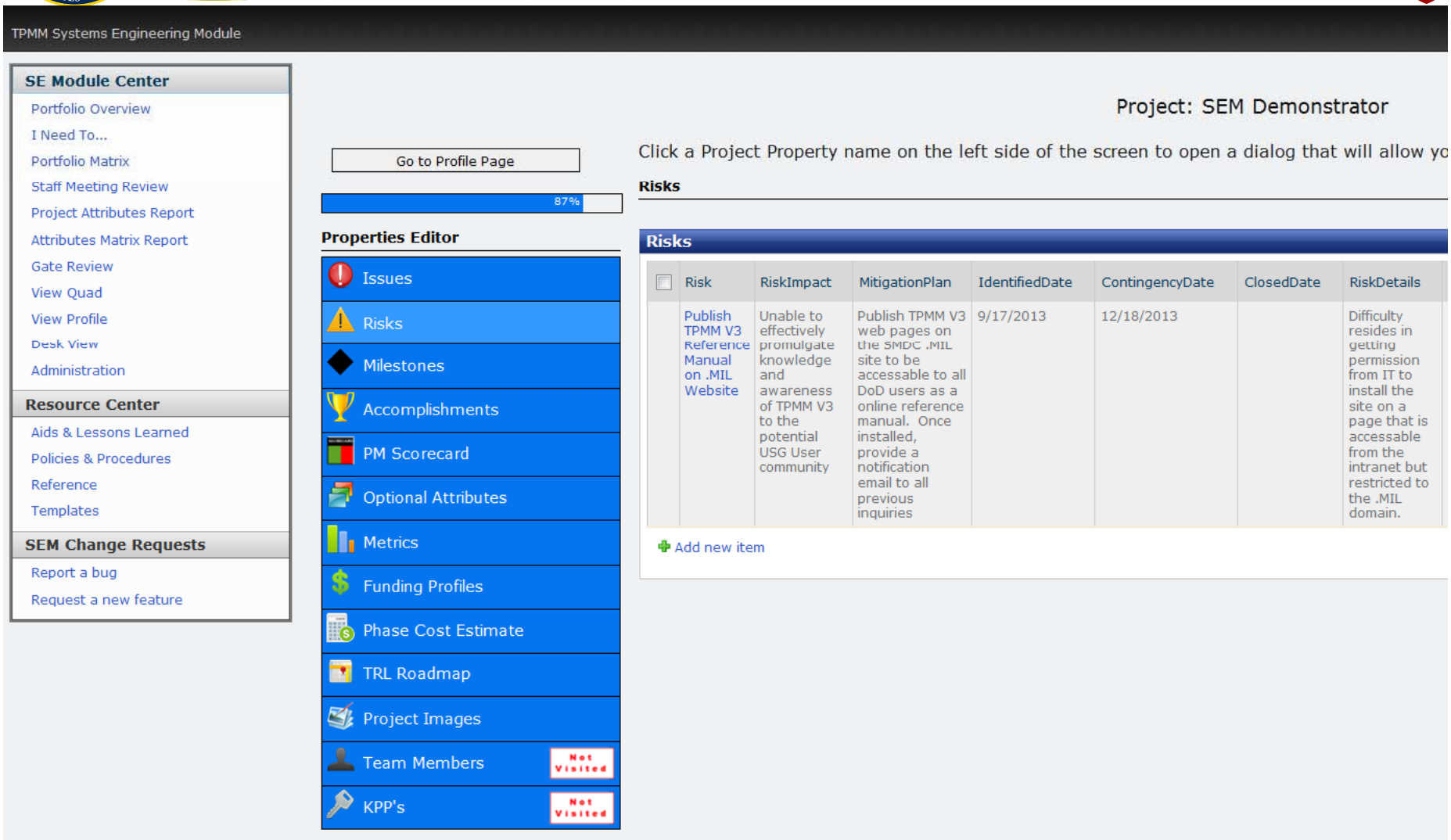
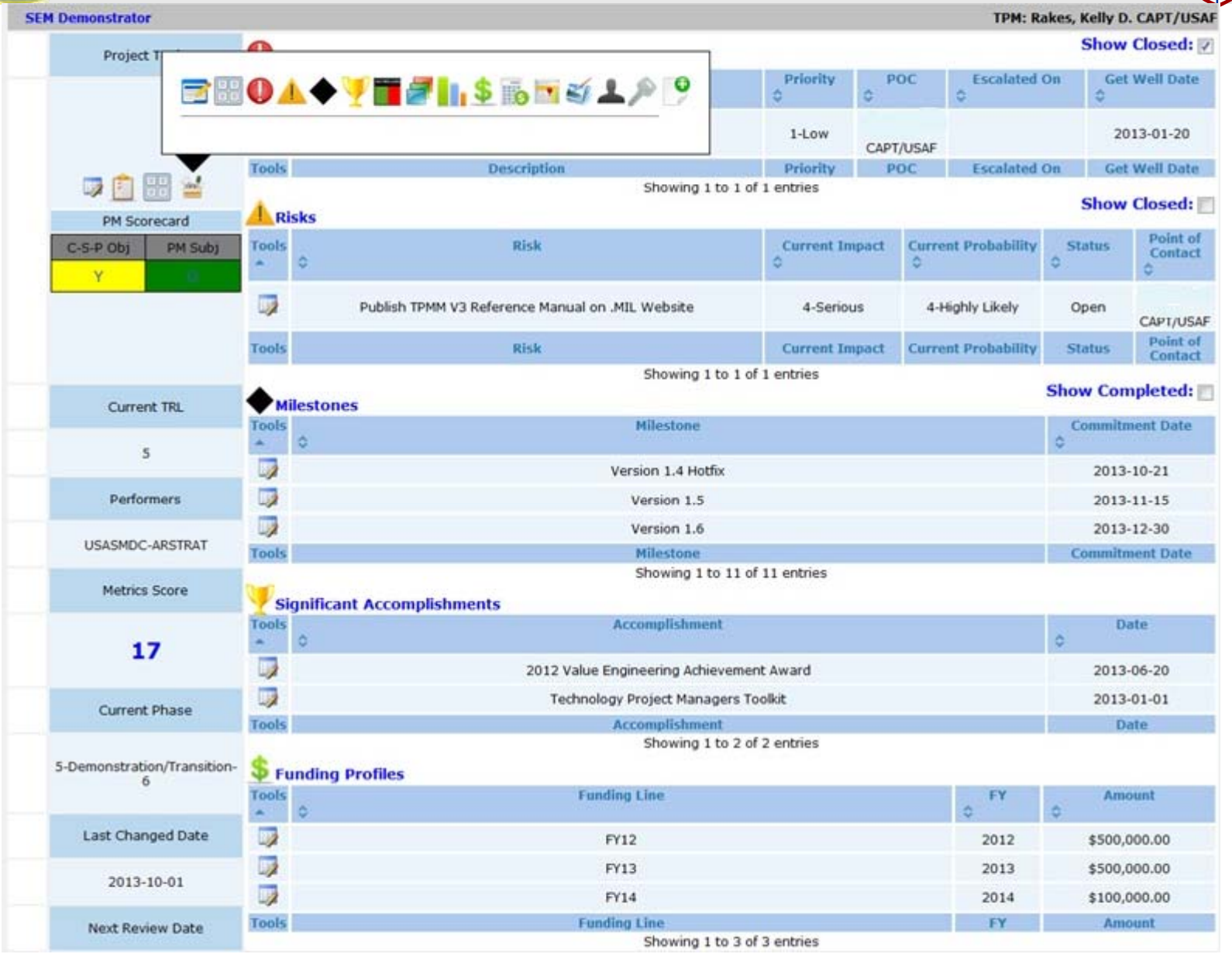
Systems Engineering Module (SEM)



Staff Meeting Review Graphic



TPMM Capabilities for Decision Support

Capability	Decision Support
Prepare and execute TRL Checklists	Consider viable interest, intent or commitment to Transition
Automatically Produce a Project Quad Chart	Provide consistent format for Program/Project Status Review
Report on Portfolio by Performer, Collaborator	Assist Synergy among Performers, Contract Vehicles
Plot Portfolio Matrix to Analyze Distribution	Support for Portfolio Balanacing, Clustering, and Gap Filling
Trace to Rqmts (% covered, uncovered, dups)	Program/Portfolio Balancing based on Capability Coverage
Provide a platform for Risk Management	Consistency in Risk Mgmt and Promotes use in Project Mgmt
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Project Gate Review Manager

Gate Review

% Completes

Go	No Go	Go with conditions	Incomplete
0%	0%	0%	100%

TMA Checklist — Enabled Only

	Exit Criteria	Reference	Comments	Omission Justification	Determination	Reviewer Comments
Program Management						
	Technology has been assessed at TRL 6.				Go No Go CONDITIONS	
	The technology program development strategy has been Finalized				Go No Go CONDITIONS	
	A realistic estimate of the costs for Transition and Technology Integration into Acquisition Program was provided				Go No Go CONDITIONS	
	Hardware, Software and Algorithm Development Cost projections for the Transition phase are updated in the TDS				Go No Go CONDITIONS	
	A realistic estimate total life-cycle costs have been documented				Go No Go CONDITIONS	
	A Risk Management Plan has been documented and reviewed for Programmatic Mitigation				Go No Go CONDITIONS	
	The Technology Advancement Degree of Difficulty has been revised based on the validation process.				Go No Go CONDITIONS	

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Project Planning For Execution

TAA Checklist

	Exit Criteria	Enabled	Omission Justification	Determination	Reviewer Comments
Program Management ✓✗					
Will the Technology Project conduct a formal assessment at TRL5? ✓✗					
	Technology has been assessed at TRL 5.	✓			
Will the Program development strategy be updated? ✓✗					
	The technology program development strategy has been updated	✓			
Will an estimate of the Demonstration Phase cost be developed? ✓✗					
	Provide an estimate of the Demonstration phase cost	✓			
Will the Technology Life Cycle Cost estimate be revised? ✓✗					
	A realistic estimate total life-cycle costs have been documented	✓			
Will the TPMM Metrics be updated and maintained? ✓✗					
	A Risk Management Plan has been documented and reviewed for Programmatic Mitigation	✓			
	The Technology Advancement Degree of Difficulty has been updated	✓			
Will a plan for Configuration Management of Project work products be maintained? ✓✗					
	Software is under Formal Configuration Control under a published CM Process	✓			
	Software defects and changes follow an established Corrective Action Process	✓			
Will an estimate of the Demonstration Phase cost be devloped? ✓✗					
	Hardware, Software and Algorithm Development Cost projections for the Transition phase are updated in the TDS	✓			
Technical Management ✓✗					
Will the Operational and Mission Requirements/Objectives be finalized? ✓✗					
	Refined Operational and Mission Requirements/Objectives were finalized	✓			
Will the TPMM Metrics be updated and maintained? ✓✗					
	Measures Of Effectiveness are adequate to allow qualitative assessment of the technology	✓			
Will the System Functional Requirements be finalized? ✓✗					
	System Functional Requirements were finalized	✓			
Will a Systems Engineering Review be conducted to support the effectiveness of the developed technology? ✓✗					
	The interfaces for the system and subsystems have been adequately identified for each technology spiral	✓			
	Finalize the Key Technology Component Architecture to be used during this				

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Prepare and Execute TRL Checklists

Program Management						Complete:0%
Technical Management						Complete:28%
	Activity	Completed	Reference	Comments	Reviewed	Reviewer Comments
[+]	Refined Operational and Mission Requirements/Objectives were finalized	✗				
[+]	System Functional Requirements were finalized	✓	Project Management Development Plan.DOC			
	Specific performance goals and exit criteria that must be met before exceeding number of prototypes were met	✗	DTRA Systems Engineering Toolbook Design.doc	Page 8		
	Planned Start Date: 2012-10-01 (yyyy-mm-dd) **% Complete**: 85 % **Planned Completion Date**: 2013-12-20 (yyyy-mm-dd) **Completed**: ☐ **Enabled**: ☑ **Example Template** :Proof of Concept Plan			**External Reference**: **Waiting on**: **Reference**: DTRA Systems Engineering Toolbook Design.doc DTRA Systems Engineering Toolbook Design.doc **Comments**: Page 8		
[+]	The Physical Requirements to be used during this spiral or increment of development are complete	✗				

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Automatically Produce Project Quad

Description:

SEM is a SharePoint-based application for assisting Program and Project Managers in the maturation, monitoring and management of current, active technology development projects and portfolios

Impact:

Portfolio Project Management will provide better information, in a standard way, so people can make better decisions about product investments. • Organizations will realize the full benefit of portfolio management when it is a fixed part of their day-to-day culture. • Provide the tools and practices that fuel sustainable portfolio management.

Executive Summary:

Develop an online system to achieve four high-level goals for strategic portfolio management: • Value Extension - The goal should always be to maximize the return on all projects in the portfolio • Balance - Every portfolio should reflect the unique organizational profile with a mix of projects • Strategic Direction - should demonstrate a link between projects and organizational strategy. • Portfolio Agility - should evaluate current portfolio against ability to shift with changing dynamics

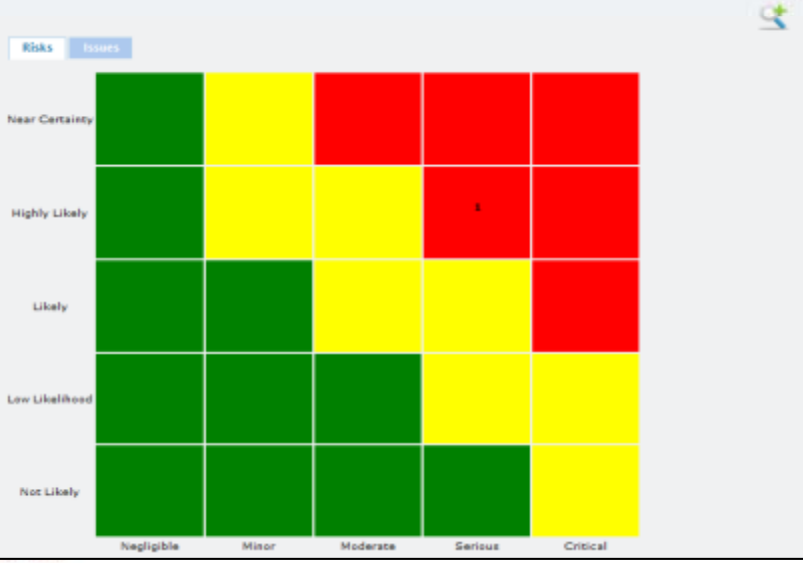
Current Phase: 5-Demonstration/Transition-6 **Last Completed TRL:** 5

Metrics Score: 17

Project Images:

Performers:

- USASMDC-ARSTRAT



Significant Accomplishments

View Items: View All

Level 1 Level 2 Level 3

Title	Date	Details
Technology Project Managers Toolkit	2013-01-01	Developed Technology Project Managers Toolkit Including: - Business Module (PR Tracker for NT – now SMART for Agency) - Systems Engineering Module (collaboratively funded with DIA)

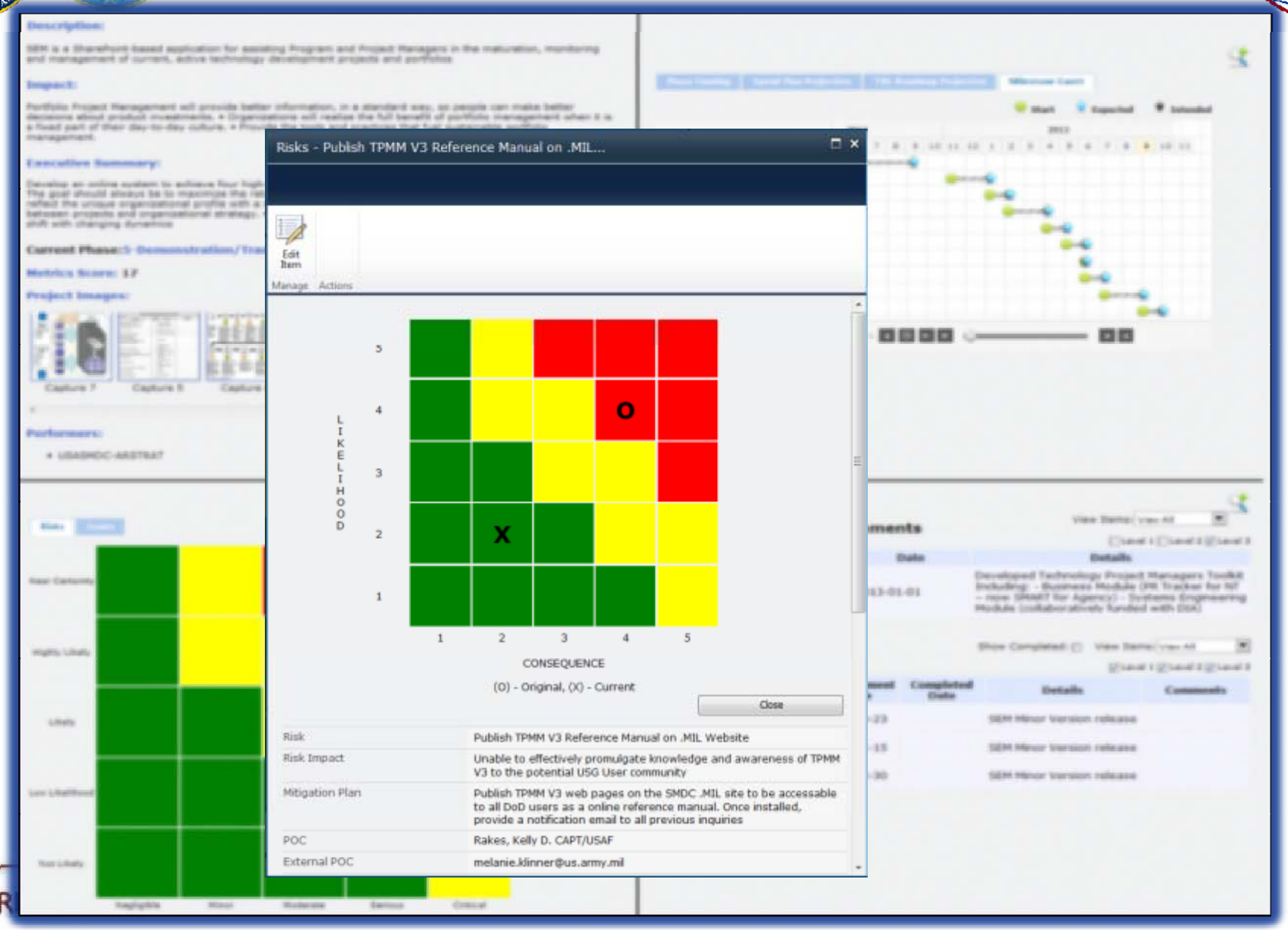
Milestones

Show Completed: View Items: View All

Level 1 Level 2 Level 3

Title	Closure	Commitment Date	Completed Date	Details	Comments
Version 1.4	In-Process	2013-09-23		SEM Minor Version release	
Version 1.5	In-Process	2013-11-15		SEM Minor Version release	
Version 1.6	In-Process	2013-12-30		SEM Minor Version release	

Risk Drill-Down from Project Quad



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Portfolio Reports/Views

Collaboration: Type

Attribute Type 1: Technology Area | Attribute Type 2: Collaboration Type | Go

Show/Hide Filters

☑ Highlight Project Gaps ☑ Highlight Collaboration Type Gaps ☐ Show Grid Lines ☐ Show Duplicates

		Interdependence	Shared_Responsibility	Information_Sharing	Awareness	
Training-Demo Portfolio	SEM Demonstrator	X				(1), 25%
	Training_B. c y		X			(1), 25%
	Training_I. is	X				(1), 25%
	Training_F	X				(1), 25%
		(3), 75%	(1), 25%	(0), 0%	(0), 0%	

Innovation: Type

Attribute Type 1: Technology Area | Attribute Type 2: Innovation | Go

Show/Hide Filters

☑ Highlight Project Gaps ☑ Highlight Innovation Gaps ☐ Show Grid Lines ☐ Show Duplicates

		Architectural	Disruptive	Incremental	
Training-Demo Portfolio	SEM Demonstrator		X		(1), 33%
	Training_B c y			X	(1), 33%
	Training_E s	X			(1), 33%
	Training_F n	X			(1), 33%
		(2), 50%	(1), 25%	(1), 25%	

Performer:

Attribute Type 1: Technology Area | Attribute Type 2: Performer | Go

Show/Hide Filters

☑ Highlight Project Gaps ☑ Highlight Performer Gaps ☐ Show Grid Lines ☐ Show Duplicates

		USASMDC-ARSTRAT	Nuclear Science and Engineering Research Center	Missile Defense Agency	Defense Intelligence Agency	Defense MicroElectronics Activity	
Training-Demo Portfolio	SEM Demonstrator	X					(1), 20%
	Training_B y	X					(1), 20%
	Training_E s	X					(1), 20%
	Training_Fi n	X					(1), 20%
		(4), 100%	(0), 0%	(0), 0%	(0), 0%	(0), 0%	

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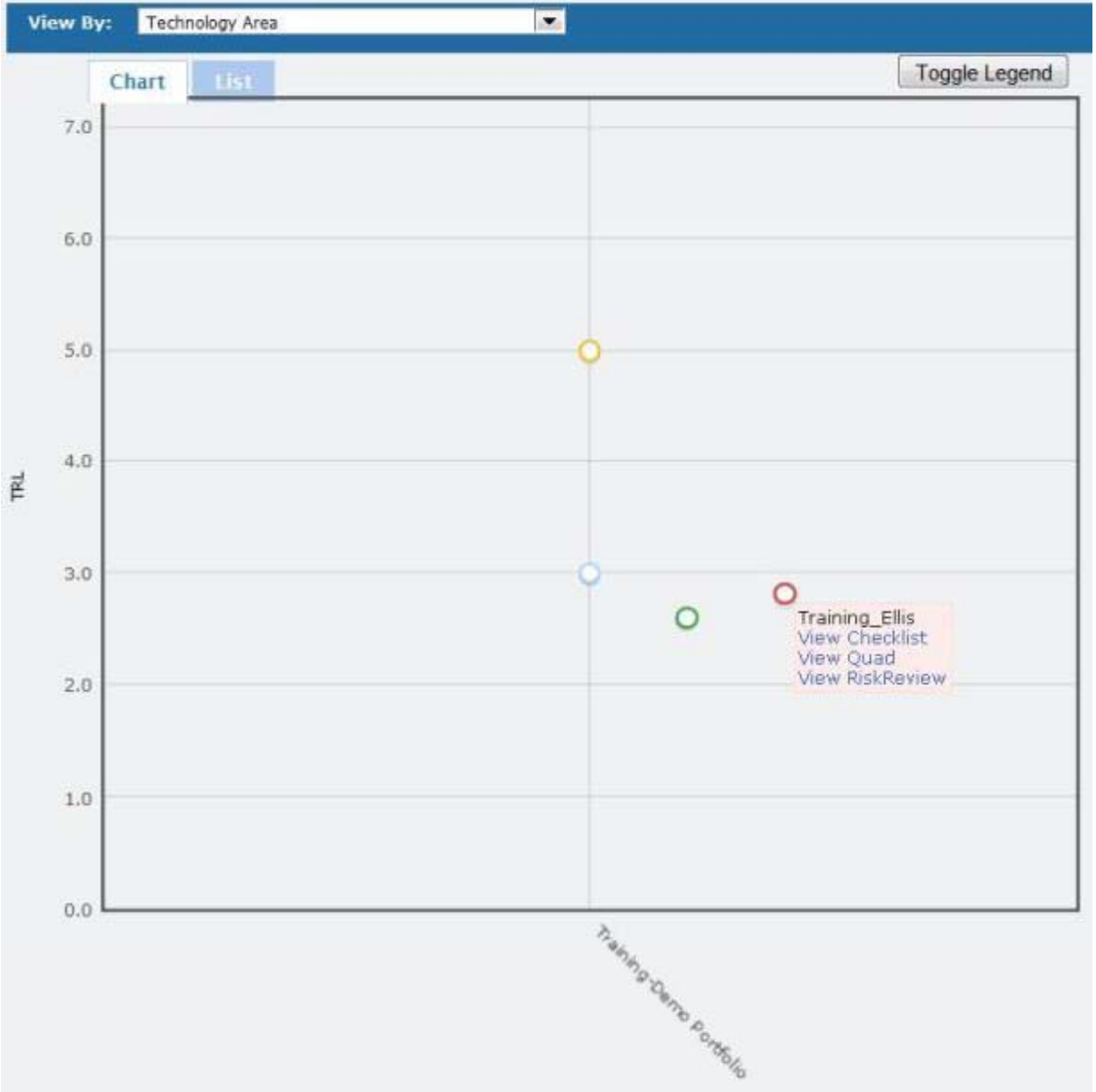
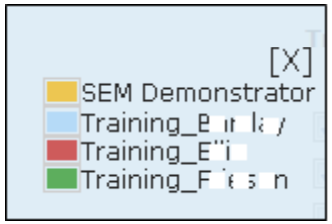
Portfolio Matrix Analysis





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Capability Needs Coverage Matrix

Attribute Type 1: Technology Area Attribute Type 2: Requirement Go

Show/Hide Filters

☑ Highlight Project Gaps ☑ Highlight Requirement Gaps ☑ Show Grid Lines ☐ Show Duplicates

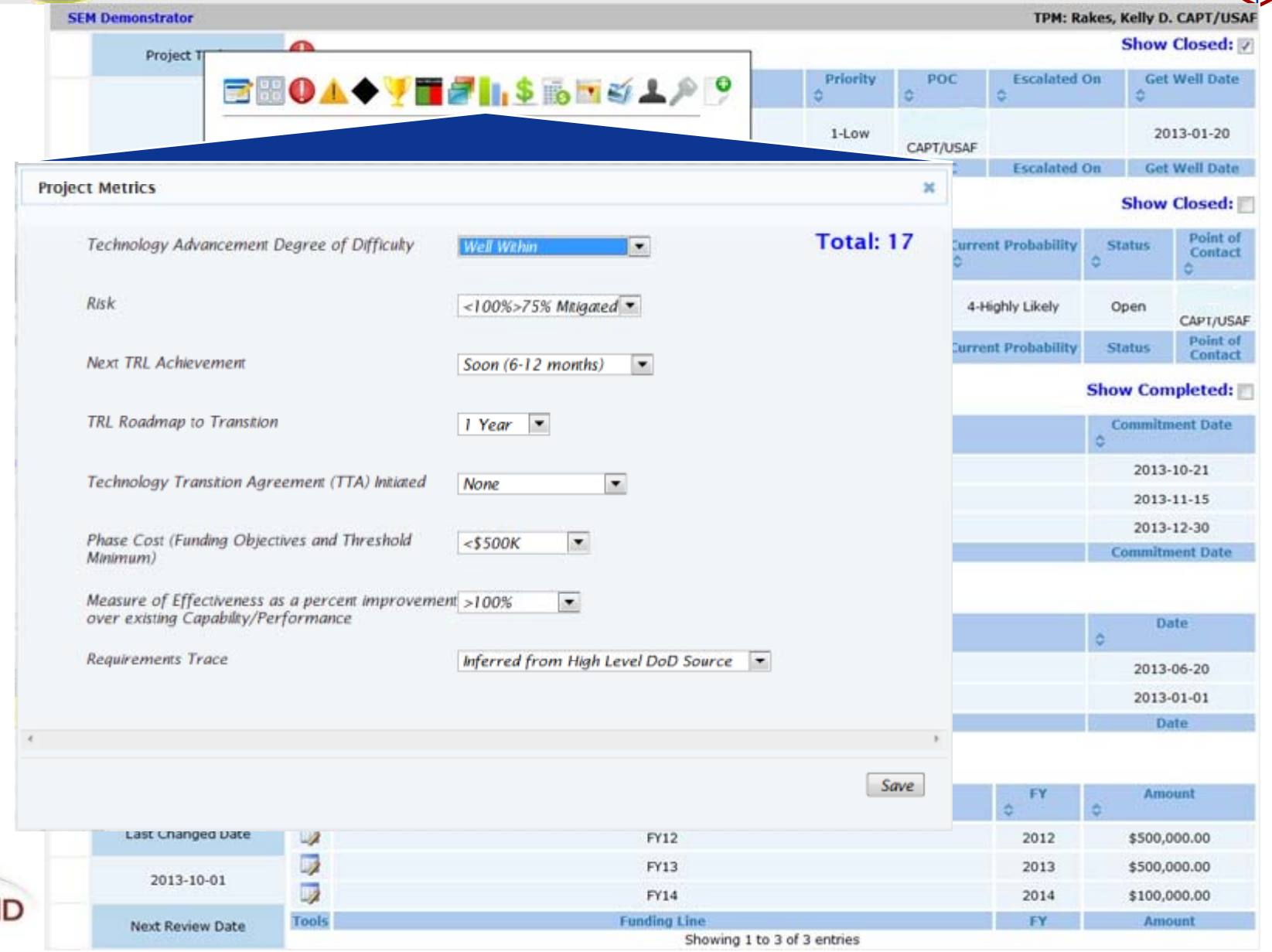
		CNT Capability Gap 5	CNT Capability Gap 10	CNT Capability Gap 2	CNT Capability Gap 1	CNT Capability Gap 15	CNT Capability Gap 19	
Training-Demo Portfolio	SEM Demonstrator				X	X		(2), 33%
	Training_E[illegible]y	X			X		X	(3), 50%
	Training_E[illegible]is	X			X			(2), 33%
	Training_Fi[illegible]n		X		X			(2), 33%
		(2), 50%	(1), 25%	(0), 0%	(4), 100%	(1), 25%	(1), 25%	

Gaps NOT Covered

Gaps Potentially Duplicated

Gaps Partially Covered

Staff Meeting Review Graphic



Way-Ahead

Using SE-Based process to change the culture promotes:

- Balanced Technology Portfolio's where ***Investment Priorities are aligned to Mission Strategy*** and ***customer needs are clearly understood*** by Technology Portfolio and Project Managers
- ***Improved Project Management Performance*** in the areas of requirements traceability, system engineering rigor, transition focus, maturity assessment, and in planning/execution/reporting
- Exchange "informational" ***calendar-driven Project Technical Reviews*** with ***"decisional" event-driven Reviews*** where technical progress is examined "as-needed" in accordance with a Project's Lifecycle Plan.
- Increase the ratio for ***Successful Transition of Technology Solutions to Acquisition Authorities*** in response to documented Requirements.
- Consistency in ***technical interpretation of TRL-based maturity levels*** throughout an S&T enterprise and with Program Managers

Contact/Consultation Information

Mr. Jeffrey Craver
Defense Acquisition University
South Region
Huntsville, AL
E-mail: Jeffrey.Craver@dau.mil

Mr. James Heusmann
DTRA-RD
Ft. Belvoir, VA
E-mail: James.Heusmann@dtra.mil

Ms. Melanie Klinner
USASMDC/ARSTRAT
Technical Center/Cyberspace Technology Division
Redstone Arsenal, Huntsville, AL
E-Mail: Melanie.G.Klinner.civ@mail.mil

Mr. Mike Ellis
DTRA-RD
(USASMDC/INTREPID)
Ft. Belvoir, VA
E-mail: Mike.Ellis@Intrepidinc.com

US Government Personnel can request a link to the TPMM Web Site at:
http://www.tpmm.info

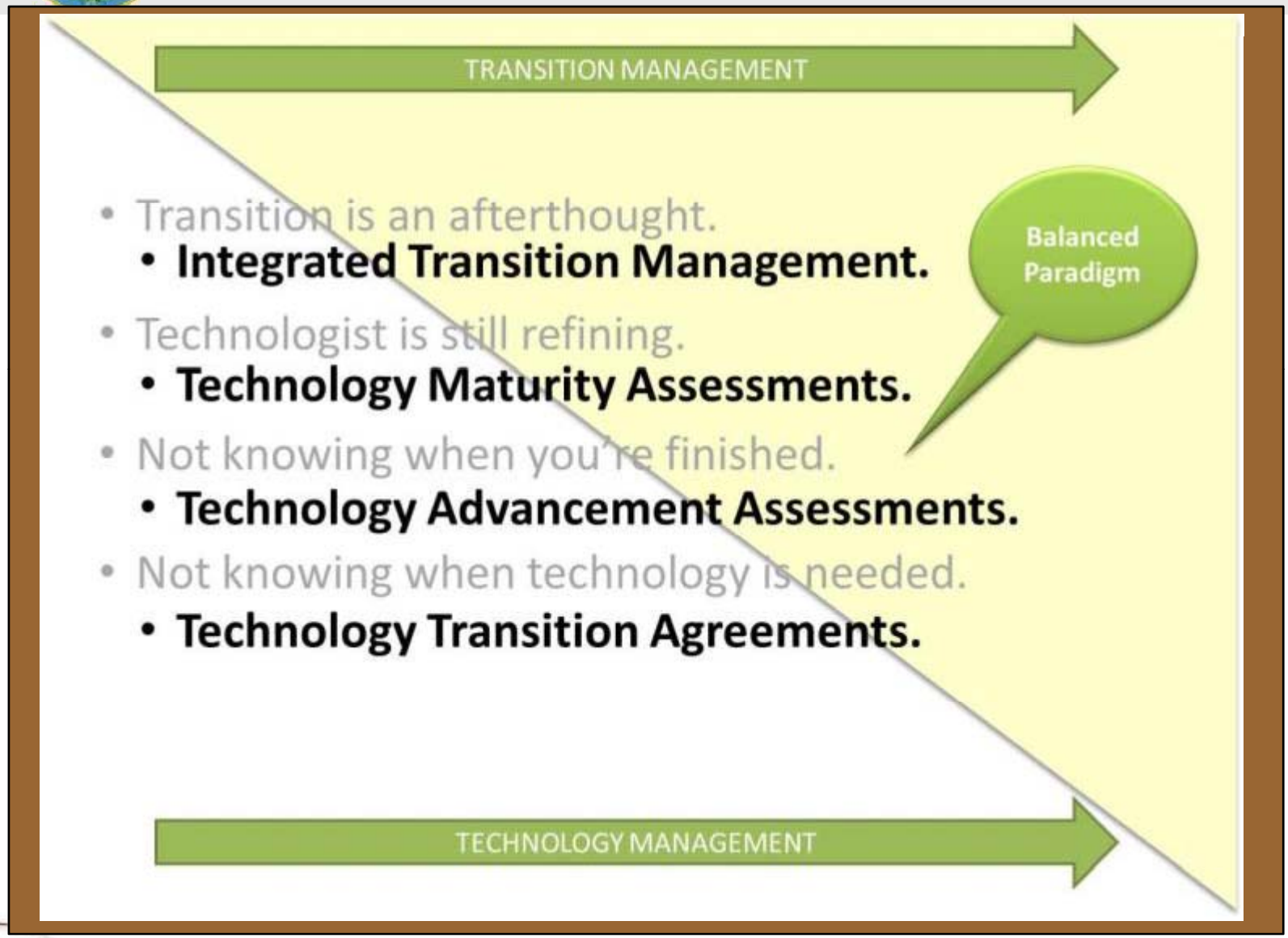
QUESTIONS?

BACKUP

Systems Engineering-Based Stage Gates

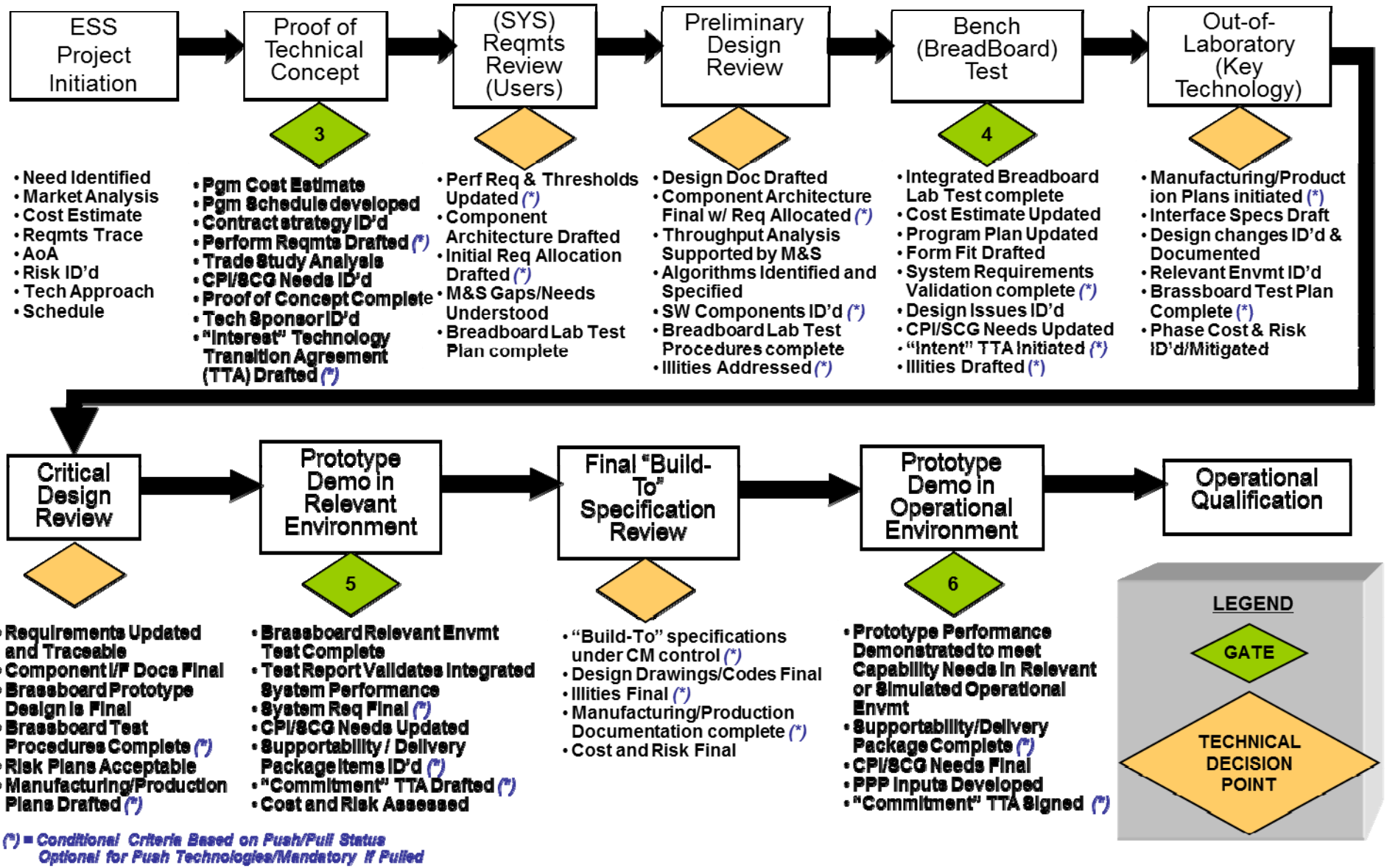
Capability	Value
Establish Consistent Criteria for Technology project management at all maturity levels	High quality project management tools available to ***a staff of technologists*** doing project management and positively affecting project success
Create a Commonly Accessible Repository for Project Information	Encourage transparency and enhance visibility – also reduce dependency on personnel who could be unavailable during critical data calls
Inject systems engineering rigor into technology project management	Ensures consideration of requirements traceability and transition focus
Provide criteria and structure for TRL-based Project Gate Reviews	Enables ***event-driven*** decisional Project Technical Progress Reviews
Develop Visualization Tools for portfolio level information	Highlights redundancies, investment opportunities, and how we are covering our requirements

Change the Culture - Set a New Paradigm

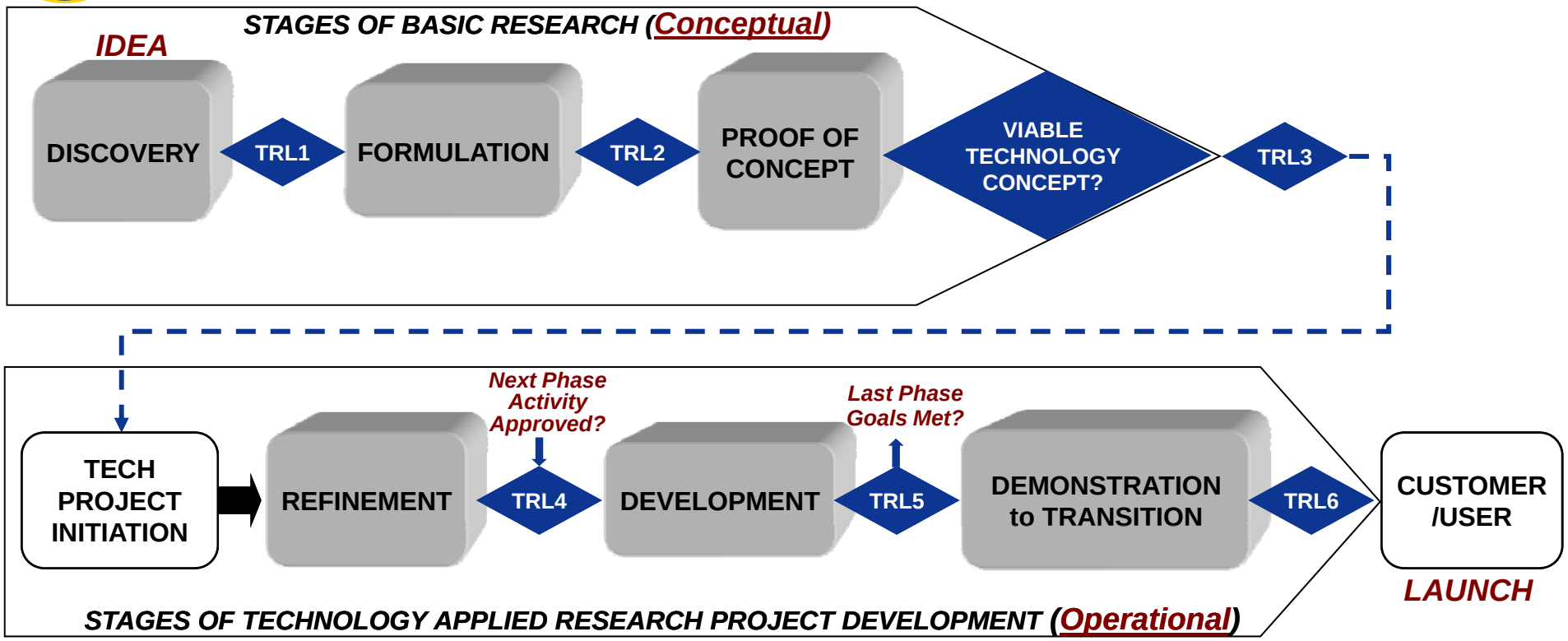


Tech Program Events Gates/TDP's

[With Sample Entry/Exit Criteria]



SE Rigor Using Stage-Gate



Process Represented by:

- Distinct Blocks for ***Conceptual*** and ***Operational*** development paths that when combined, traverse from ***Idea*** to ***Launch***.
- Managed process of ***Defined Stages*** composed of ***Activities/Tasks*** that are evaluated as input criteria for planning/approval to ***proceed to the next stage***.
- Stages culminate in ***Decision Gates*** of measurable Exit Criteria used to evaluate technical accomplishment and technology readiness/maturity.

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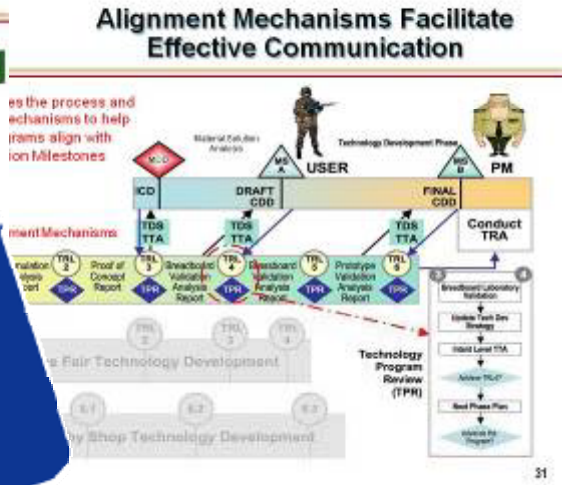
DAU Courseware includes Best Practice Methodologies and Tools

Technology Program Management Model

- U. S. Army Space and Missile Defense Technical Center
- Logical methodology to guide technology managers through the planning and development of their projects
- Seven phases with exit criteria and deliverables
- Technology process reviews after each phase
- Currently in use by Missile Defense Agency, Defense Threat Reduction Agency, Department of Homeland Security, Air Force Research Laboratory and Defense Threat Reduction Agency

TPMM



Technology Assessment and Tra… Management (TATM) Proces…

- Stable process agreed upon by AMRDEC and PEO Aviation
- User and sustainer are involved from start
- Technologies are judged on criticality and sustainability as well as technical maturity
- Identify where risk reduction efforts are needed
- Basis for Technology Transition Agreements

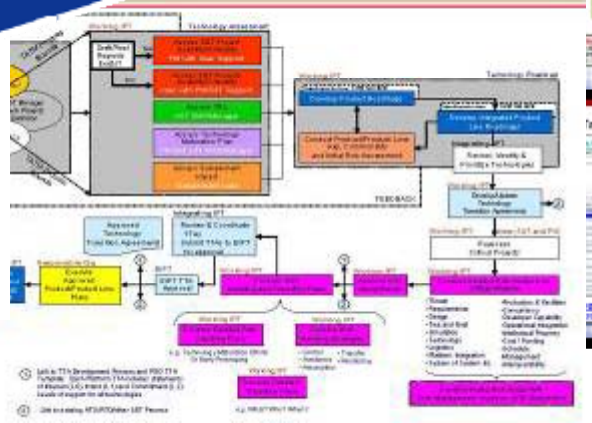
- DAU POC for TATM and TPMM: Mr. Jeff Craver,
  jeffrey.craver@dau.mil (256-895-3453)
  william.decker@dau.mil (256-895-3448)

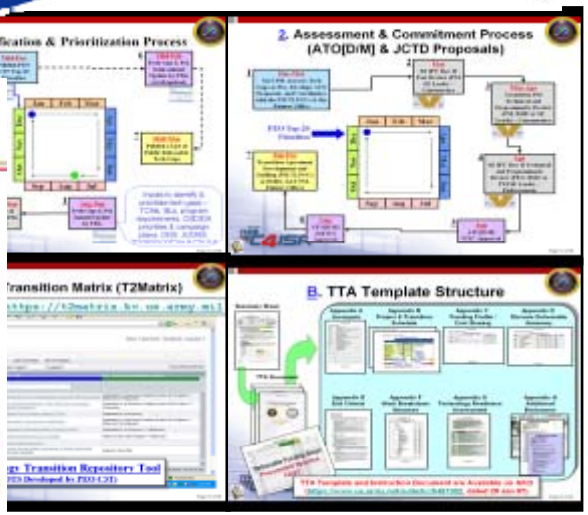
TATM

Science and Technology Management

STM 202

Example content





T2 MATRIX

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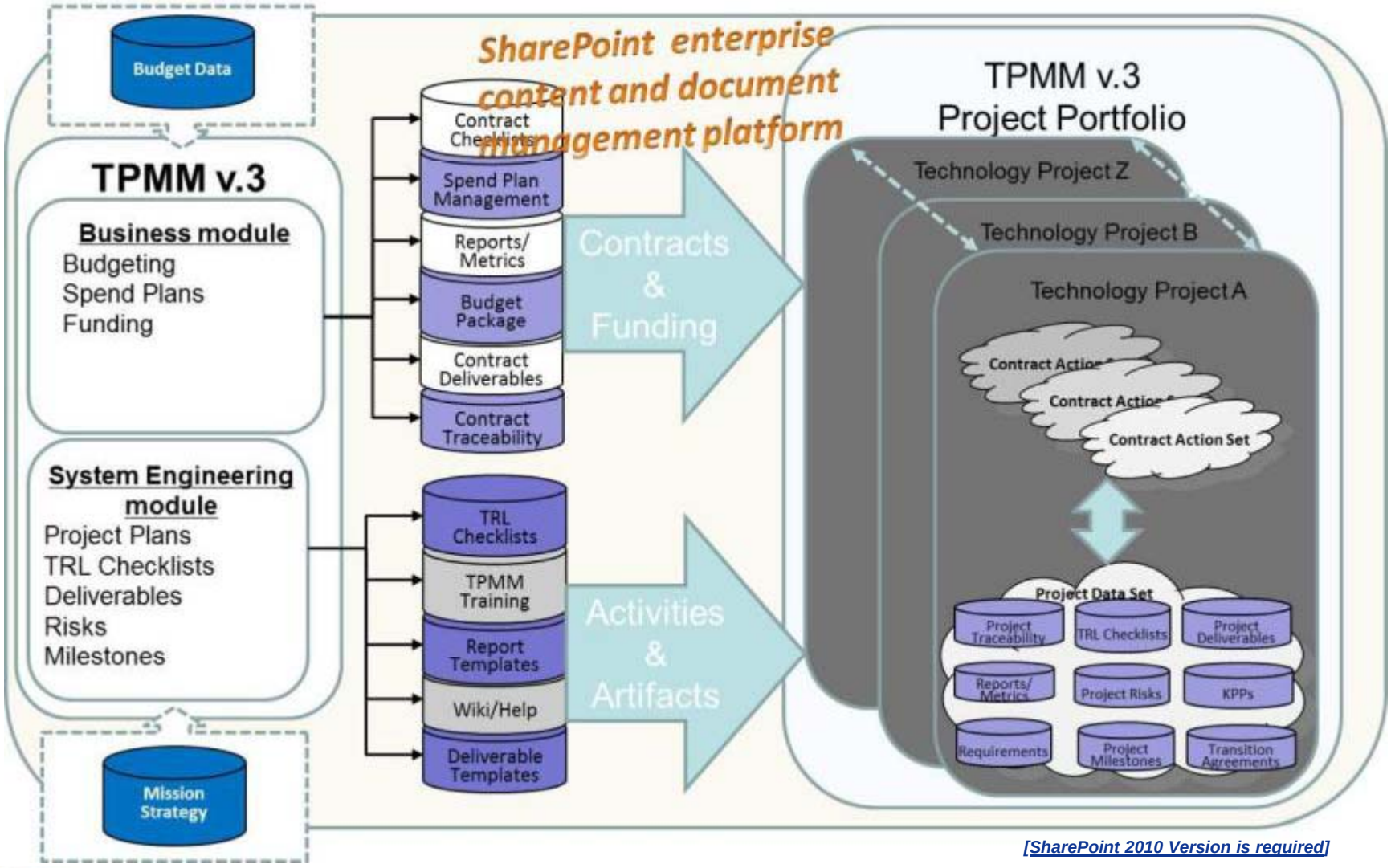
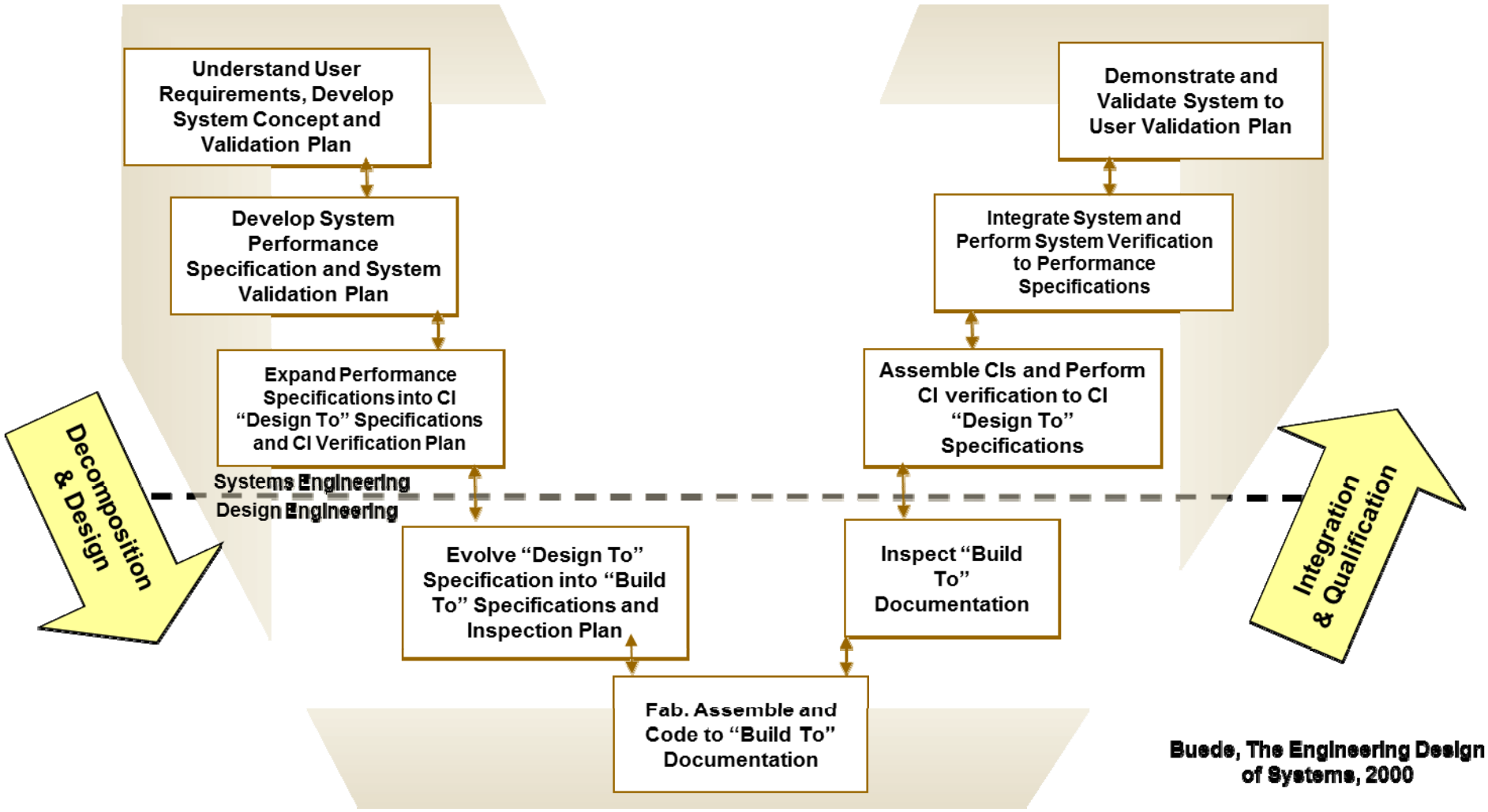
Technology Project Managers Toolkit



[SharePoint 2010 Version is required]

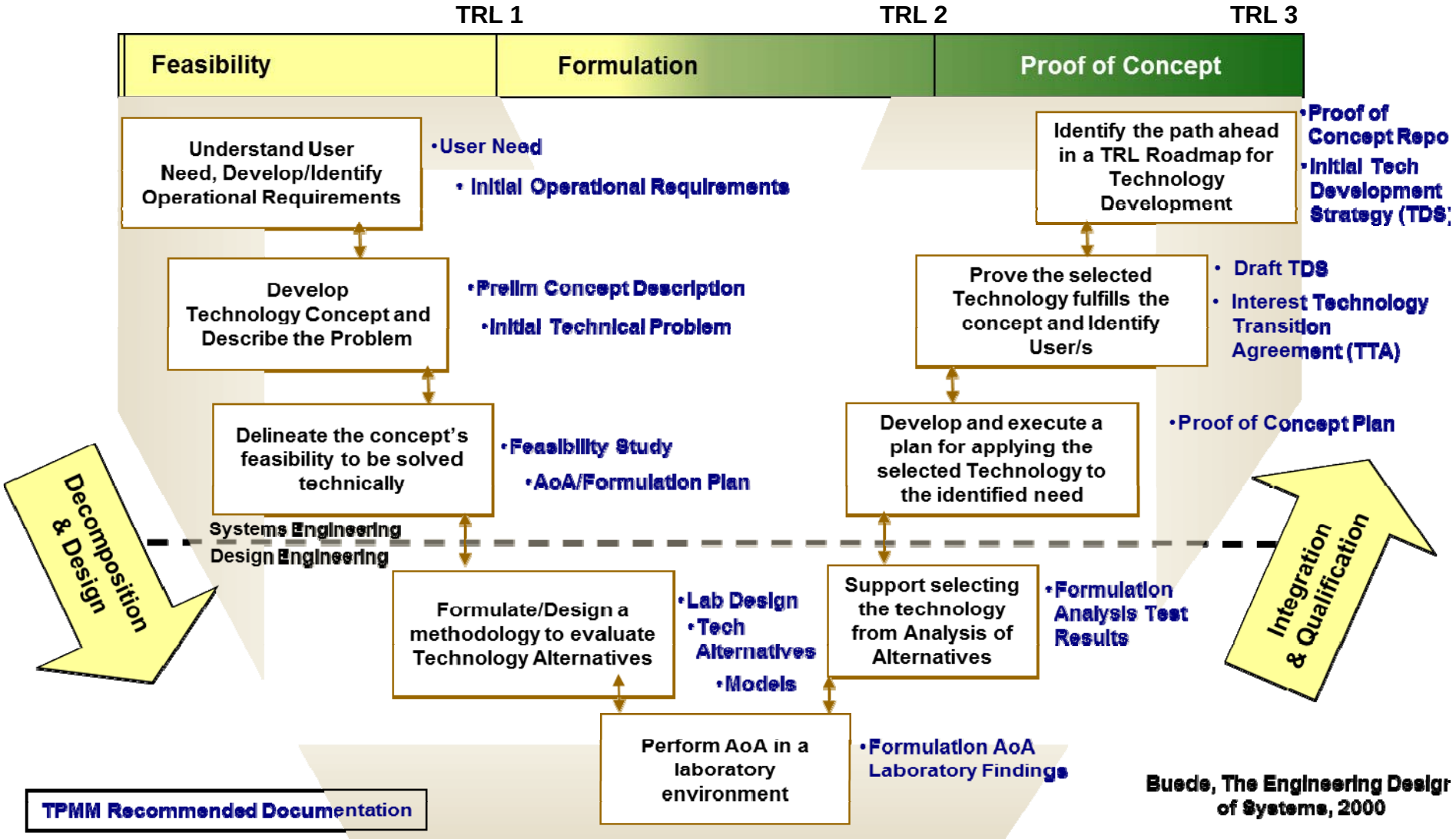
[TPMT Package Modules Can Work together or Separately]

TPMM Rooted in the Systems Engineering "V"

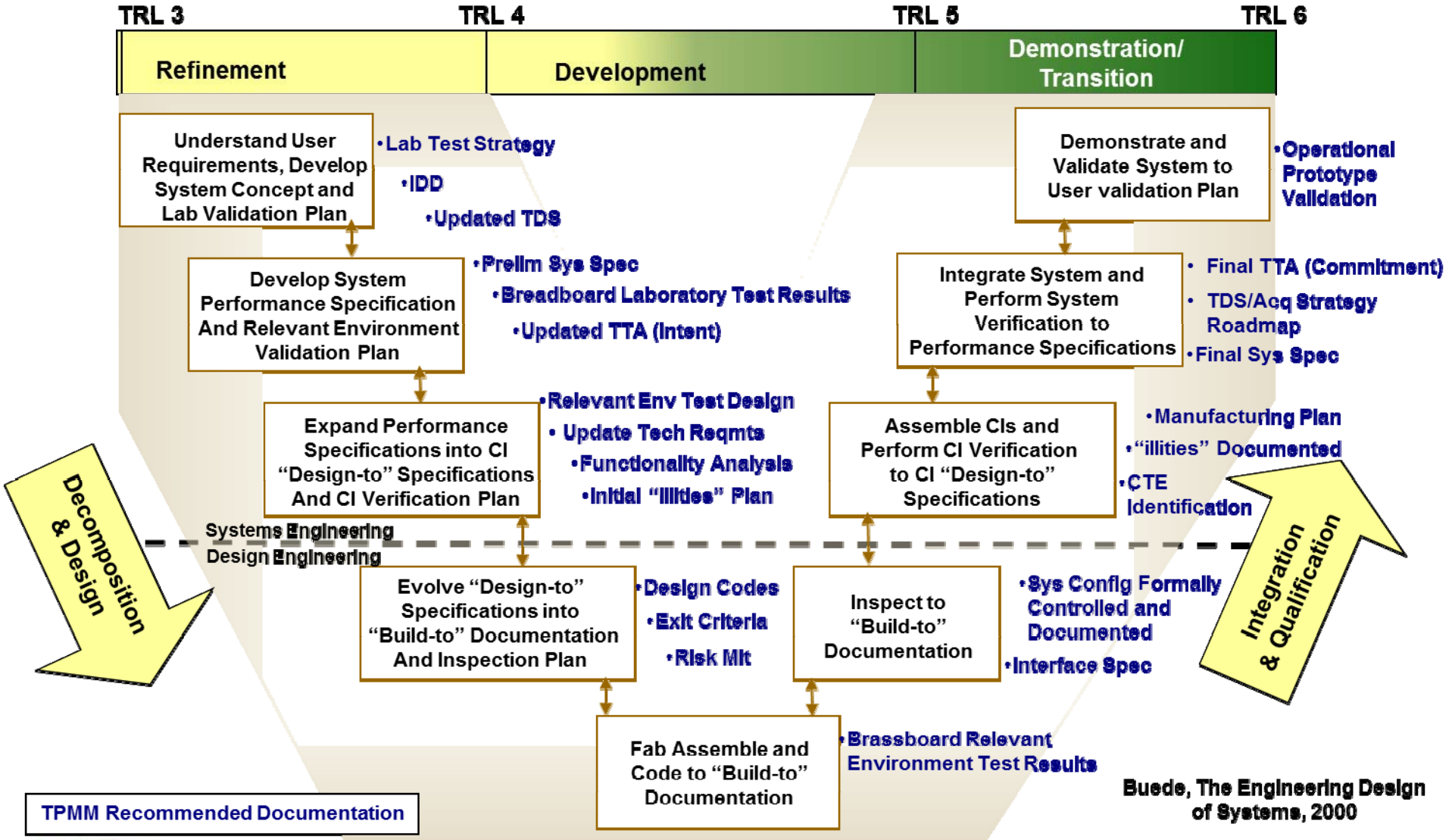


Buede, The Engineering Design of Systems, 2000

TPMM Rooted in the Systems Engineering "V"



TPMM Rooted in the Systems Engineering "V"



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TPMM ®

On Aug 30, 2011 a US Patent was Awarded for TPMM :

- To: US Army – SMDC
- For Inventors:
  - *Mr. Jeffrey Craver (DAU)*
  - *Mr. Michael Ellis (DMD)*

US008010584B1

(12) **United States Patent**
Craver et al.

(10) **Patent No.: US 8,010,584 B1**
(45) **Date of Patent: Aug. 30, 2011**

(54) **RELATIONAL DATABASE METHOD FOR TECHNOLOGY PROGRAM MANAGEMENT**

(75) Inventors: **Jeffrey T. Craver**, Meridianville, AL (US); **Michael S. Ellis**, Hunstville, AL (US)

(73) Assignee: **The United States of America, as represented by the Secretary of the Army**, Washington, DC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 457 days.

(21) Appl. No.: **12/235,128**

(22) Filed: **Sep. 22, 2008**

Related U.S. Application Data

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(51) **Int. Cl.**
G06F 7/00 (2006.01)
G06F 17/00 (2006.01)

(52) **U.S. Cl.** **707/812**; 707/804; 715/227; 715/255

(58) **Field of Classification Search** 707/812, 707/804; 715/227, 255
See application file for complete search history.

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(Continued)

Primary Examiner — Mohammad Ali
Assistant Examiner — Bao G Tran
(74) *Attorney, Agent, or Firm* — C. Joan Gilsdorf

(57) **ABSTRACT**

A Technology Program Management Model (TPMM) for management of technology development. The TPMM is an activities-based model that is subdivided along technology readiness level (TRL) boundaries into phases of technology development that logically progress from concept to operational capability and readiness for transition to the customer/end user. The TPMM provides a standardized approach to technology development that incorporates systems engineering and programmatic principles and practices with transition management in a stage-gated process for TRL-based maturity

"The TPMM Provides a Standardized Approach to Technology Development that Incorporates Systems Engineering and Programmatic Principles and Practices"

TPMM Metrics Support Decision Making

TPMM Output	Priority	1	2	3	4	5
Technology Advancement Degree of Difficulty (TAD^2)	1	Well Within	Within	Pushing the Science	Hard Push on Science	Breakthrough Required
Risk	1	100% Mitigated	< 100% > 75% Mitigated	< 75% > 50% Mitigated	< 50% > 25% Mitigated	< 25% Mitigated
Next TRL Achievement	1	Imminent (0-6 months)	Soon (6-12 months)	Ranged (12-18 months)	Far (18-24 months)	Horizon (>24 months)
TRL Roadmap to Transition	1	1 Year	2 Years	3 Years	4 Years	>4 Years
Technology Transition Agreement (TTA) Initiated	1	Commitment	Intent	Interest	Under Development	None
Phase Cost (Funding Objectives and Threshold Minimum)	1	< $500K	>$500K <$1M	>$1M <$2M	>$2M <$3M	>$3M
Measure of Effectiveness as a % improvement over existing capability/performance	1	>100%	< 100% > 75%	< 75% > 50%	< 50% > 25%	< 25%
Requirements Trace	1	Traceable to DTRA Mission	Traceable to RD-NT	Traceable to RD-NT-NTD	Level DoD Source	Not Traceable

- **A priority can be set for any given factor when one has more influence with the decision than another (i.e., where MoE is more important than cost but equal in relevance to TAD^2)**
- **TPMM outputs can be used to support investment decisions applied as follows*(*)*:**
  - **A Project that totals [≥ 33] is in need of review for continuation**
  - **A Project that ranks [≥ 21 but ≤ 32] needs Management Oversight**
  - **A Project that totals [≥ 11 but ≤ 20] has moderate risk**
  - **A Project that totals [≤10] should be considered as well targeted and relatively Low Risk**

[*Criteria Should be Tailored to the Technology Enterprise]

S&T Goals for Using TPMM

- Create an environment in which The S&T ***transitions Technology-based solutions to an Acquisition Authority*** in response to documented end user capability needs/requirements.
- Maintain a balanced ***Technology Portfolio*** where investment priorities are ***aligned to Mission Strategy*** and ***customer needs*** .
- ***Improve project management performance*** in the areas of requirements traceability, system engineering rigor, transition focus, and maturity assessment.
- Achieve ***consistency*** and ***quality*** in planning, execution, and reporting across the S&T portfolio
- Replace “informational” ***calendar-driven*** Project Technical Reviews with “decisional” ***event-driven*** Reviews IAW the Project Plan.

TPMM Investment Decision Guide

Project Initiation/Investment Decision Checklist					
Branch = AAAA				Project = Name	Date = YYYYMMDD
Description	Yes	No	N/A	Comments	Actions
Value to the Warfighter - why are we doing it? - Should answer the "So, what?" - What are the products to be delivered?	√			Identify the Impact to the Warfighter/Military Significance of pursuing this technology	Operational Prototypes are frequently builts and delivered for characterization and to cultivate User/POR interest
Who are we doing it for?		√		Which Portfolio is it in and how aligned to the Strategic Mission and/or ICD Capability Gaps	Interactive SEM Example
What are the technical challenges?			√	Describe the complexity involved (Breakthrough Req - to Well Within the Science)	Interactive SEM Example
How mature is the technology?	√			The technology maturity stated as TRL last achieved	Interactive SEM Example
What technology readiness level (TRL) is it?		√		The technology development phase that will begin the cycle	Execute TRL X Planning Checklist
What are the metrics?			√	Evaluate Metrics and calculate Risk Summary Score	[> 33] (High Risk) [> 21 but < 32] (Moderate Risk) [> 11 but < 20] (Low Risk) [<10] is considered "On Rails"
What have we accomplished - current and future?	√			Is the technology out of a Vendor IRAD or University R&D	Provide TRL Roadmap Example
When will it be delivered?		√		Identify year that a Capability Demonstration is estimated for	Provide TRL Roadmap Example
What is the transition plan?			√	Transition planning should start with the development of a TTA	Provide TRL Roadmap Example