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## Improving Requirements Development Efficiency and Quality with Decision Aids

PEO STRI

MITRE

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For the past two years, the U.S. Army Program Executive Office for Simulation, Training and Instrumentation (PEO STRI) has researched, developed, and is currently implementing an approach for managing project requirements. PEO STRI began by establishing the Requirements Management Working Group (RMWG), an experienced oversight team of requirements engineering subject matter experts (SMEs) and enterprise architects. The RMWG is chartered to facilitate and promote strategic reuse of requirements management assets across the enterprise.

In 2020, the RMWG is developing a requirements decision aid, the Requirements Management Process

Model (RMPM). The RMPM will assist projects with adopting and adapting enterprise assets – processes, tools, templates, and training materials. Our I/ITSEC paper and this presentation describe the RMWG’s process for creating the RMPM and how it will be used to identify PEO STRI enterprise assets appropriate to a given project. It defines the relationship between RMPM processes and project management approaches, and presents the planned path forward for prototyping this aid with PEO STRI program managers.

Our Background: The PEO STRI mission is to develop, acquire, provide, and sustain modeling and simulation solutions in support of training and testing in order to optimize warfighter readiness. The MITRE Corporation supports the PEO STRI, located in Orlando, Florida. For over 25 years, PEO STRI and MITRE have partnered to develop simulation, training, testing and modeling solutions for the Army. Together our partnership is helping to shape the direction of future Army training systems and priorities.

Introduce the PEO STRI and MITRE authors.

## Topics

- Requirements Management (RM) Challenges
- Army Context
- Key to "Right Sizing" RM
- Requirements Management Process Model (RMPM)
- RMPM Web Application
- RMPM and System Development Approach
- RMPM Web Application User Assessments
- Summary



This presentation is organized similar to its companion 2020 IITSEC paper, "Improving Requirements Development Efficiency and Quality with Decision Aids."

We first provide this subject's context by discussing the most significant requirements management challenges that organizations face today.

We then present the problems facing the U.S. Army PEO STRI military domain experts and systems engineering professionals responsible for delivering modeling and simulation solutions for training and who manage the complexities of systems engineering. We illustrate the challenges they face in writing, tracing, and managing requirements sets of

all sizes.

We present and discuss the questions that engineering project and product teams must answer to optimize their requirement engineering processes and execution.

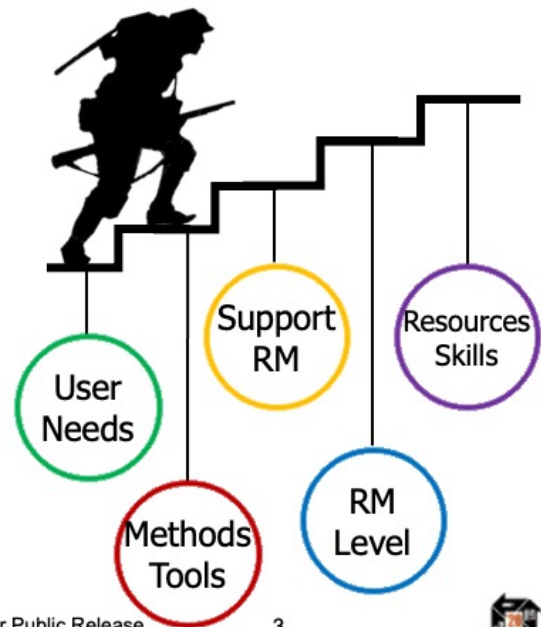
In seeking to understand and provide a guide to organizations challenged by these questions, we explain the RMWG-developed decision aid that guides requirements engineers to identify and apply the right processes, templates, best practices, and training.

Later in our presentation, we introduce a solution for managing these artifacts, which is an extension to an application the RMWG developed and presented in our 2019 I/ITSEC research paper topic, 'Requirements Engineering Innovations for Agile-Based Programs'.

We conclude with an illustration of how the standard decision aid / solution supports both traditional and agile systems engineering methodologies, and our plan for validating this solution through user assessments in FY21.

## Requirements Management Challenges

- Focusing on user needs and value delivery
- Understanding which requirements methods and tools are available to requirements engineers (RE)
- Understand and support RM at the business and technical management levels
- Understanding the RM level appropriate for each program
- Enabling organizations to recognize and acknowledge when they have inadequate engineering resources and skills to gain efficiencies in managing enterprise–product–process requirements.



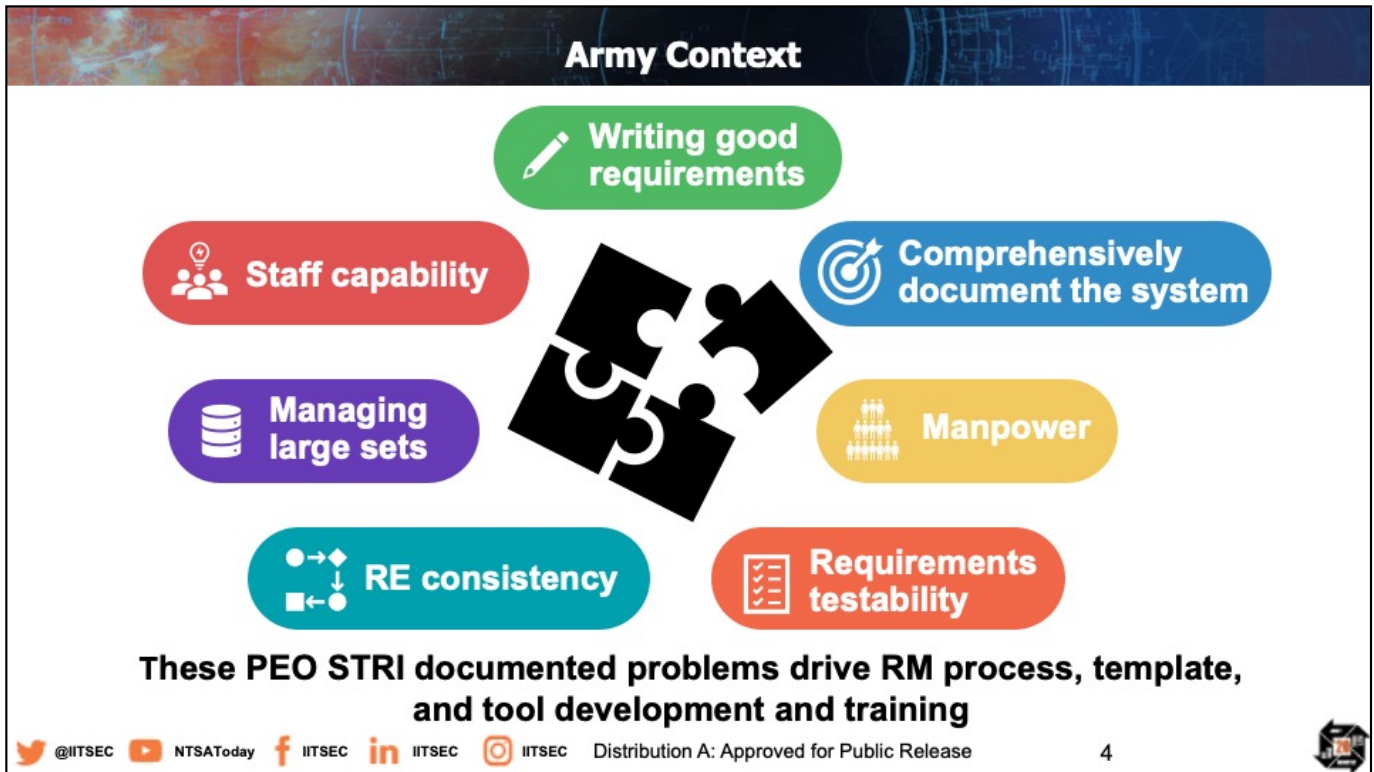
Requirements management (RM) is the process of eliciting, collecting, documenting, analyzing, refining, tracing, prioritizing, and testing requirements while performing change management and communicating changes to end-users and other stakeholders. It is a continuous process that does not end with a product release, since user needs and stakeholder understanding of the system continually evolve, perpetuating a requirements life cycle that comprises definition, validation, documentation, and management.

Based on the RMWG research, the five most significant challenges of RM are (as noted on this slide):

- Focusing on user needs and value delivery
- Understanding which requirements methods and tools are available to requirements engineers
- Understand and support RM at the business and technical management levels
- Understanding the RM level appropriate for each program
- Enabling organizations to recognize and acknowledge when they have inadequate engineering resources and skills to fundamentally manage (and gain efficiencies in) enterprise–product–process requirements

The authors examined the first three of these challenges in our 2019 research. We presented strategies for collaborating with users throughout the product life cycle to understand their needs, and traditional and agile processes and tools that harness change focused on the end-user. We also recommended practices for overcoming cultural barriers to requirements engineering at the business and technical management levels.

In our 2020 paper and this presentation our objectives are the last two challenges. We do this by presenting the PEO STRI strategy for assisting projects in adopting requirements processes, tools, templates and training materials – assets that PEO STRI continually enhances and maintains for its Program Managers (PMs).



This slide presents the problem statement and context from the perspective of the U.S. Army PEO STRI.

Organizations must recognize and acknowledge when they have inadequate resources and skillsets available to manage requirements. This may require a culture change (reference, the RMWG 2019 I/ITSEC research paper).

Capability gaps in engineering resources take many forms, as shown in this figure and described in these colored bubbles.

- Developing, retaining, and leveraging the

knowledge of experienced engineers with the individual skillsets to elicit, document, and trace requirements and execute the RM processes described in the introduction (“writing good requirements” and “manpower”)

- Developing and maintaining staff knowledge necessary to consistently manage many engineering demands, including architecture requirements, business/training requirements, user/stakeholder requirements, functional requirements, quality of service or non-functional requirements (“comprehensively document the system”, “managing large data sets”, and “requirements engineering consistency”)
- Training engineering staff to be capable of decomposing user requirements into technical performance requirements in a testable form (“staff capability” and “requirements testability”)

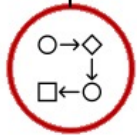
These problem areas drive RM process, template, and tool development and training - failure to recognize and address these gaps significantly weakens an organization’s RM abilities, resulting in incomplete and untestable requirements that do not meet the end-user’s needs.

## The Key to "Right Sizing" Requirements

It is essential that projects answer these questions in order to develop / adopt the right RM processes, tools, and training



What RM training is required and when should it occur?



What RM processes must be developed and executed?



What RM experience and skills are needed?



What RM tools are needed, and when should they be used in the systems engineering life cycle?



What RM templates exist for structuring requirements documentation and requirements databases?



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Organizations such as PEO STRI continually face RM challenges, but also must balance technical needs against budgets, resources, and schedules. Project and product teams must make difficult choices regarding how to optimally leverage engineering staff and RM processes, tools, and training materials. Naturally, they want to achieve the highest level of RM maturity possible, but understand that attaining higher levels require more time, effort, and money.

They must therefore know what resources and assets exist to help them determine where on the scale of RM they belong, in order to "right-size" their requirements.

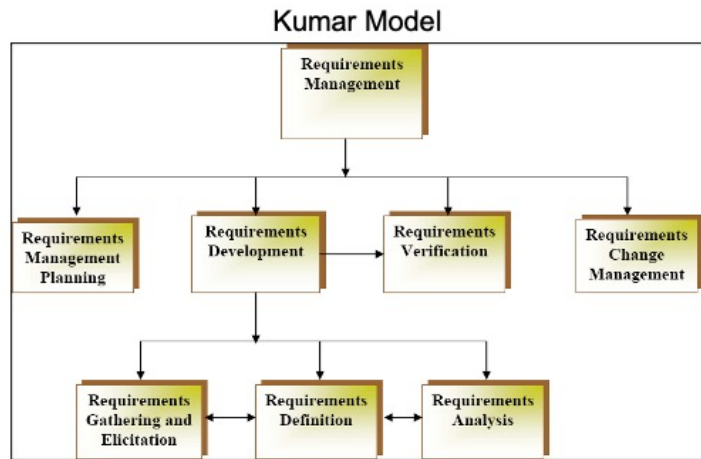
Specifically, they must determine the answer to the following questions:

- What RM experience and skills do they need?
- What RM processes must they develop and execute?
- What RM tools do they need, and when should they be used in the systems engineering life cycle?
- What RM templates exist for structuring requirements documentation and requirements databases?
- What RM training do they require and when should it occur?

These questions led the RMWG to investigate ways to improve requirements development efficiency and quality. This investigation, discussed in the following slides, resulted in the development of a standard decision aid that guides REs in PEO STRI organizations on how to identify and use processes, training materials, templates, and best practices while leveraging existing assets from an enterprise database.

## Requirements Management Process Model (RMPM)

- The RMPM allows REs to identify a standardized set of processes, templates, tools, and training materials to help achieve their objectives
- The Requirements Management Working Group (RMWG) developed and expanded the RMPM using primarily two sources:
  - Kumar Model Structure
  - Object-Oriented Systems Engineering Model



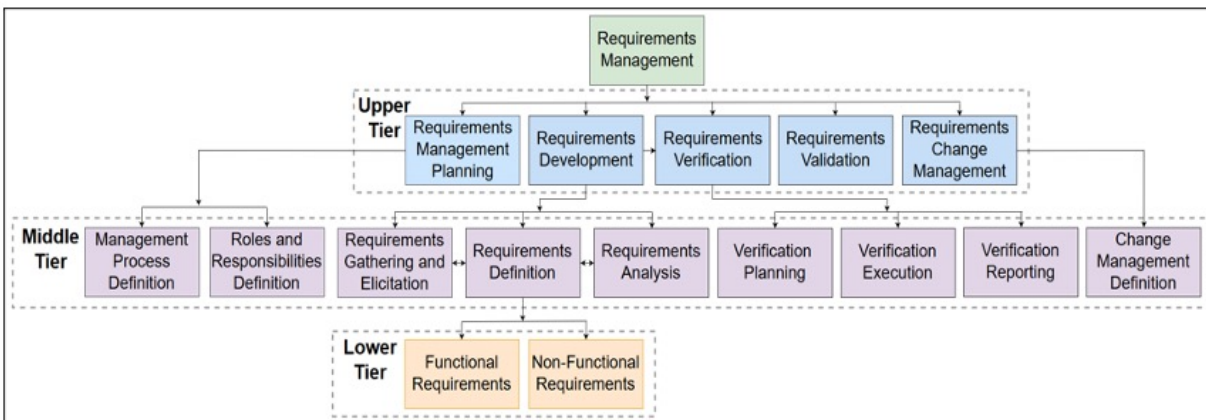
In 2019, RMWG recognized the need for a standardized set of processes, templates, tools, and training. In 2020, the RMWG designed the RMPM to address this need. The RMWG developed the RMPM using primarily two sources and then extended the process using a standards-based system design model.

It adapted the first three tiers from the Kumar model. The RMWG identified and evaluated various requirements methodologies from The Object Management Group, International Council on Systems Engineering, Institute of Electrical and Electronics Engineers, and Organization for the Advancement of Structured Information Standards to validate its approach.

In the following slides, we will discuss the process the RMWG followed to extend the RMPM.

## RMPM Model Structure

- Upper tier – Common RM Processes
- Middle tier – Detailed processes that decompose the upper tier
- Lower tier – Components (specific procedures or products)



The Kumar model was broadened and extended in the second and third tiers.

The “upper tier” consists of common RM processes: planning, development, verification, validation, and change management. The “middle tier” consists of detailed processes that are further decomposed from the upper tier. The “lower tier” of the hierarchy would consist of components (either procedures or products) that a RE would implement to complete the detailed process.

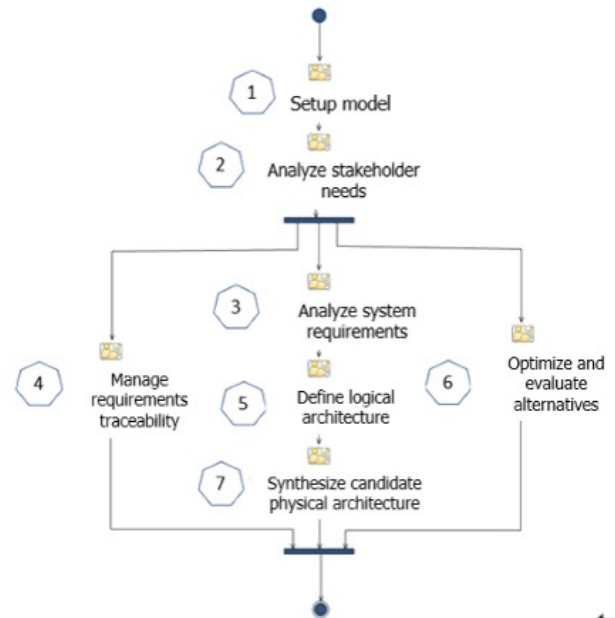
As REs traverse the hierarchy during implementation, they would use the middle tier processes to obtain a list of recommended tools to meet a given need. In this case, the tools (e.g., DOORS, Visure, Jira, etc.)

are identified at the middle tier Requirements Definition stage.

The components of the lower tier identify the assets (processes, training materials, templates, and best practices) that PMs use to adopt standardized approaches. In this example, Functional and Non-Functional Requirements are potential products to be created by this process.

## Object-Oriented Systems Engineering Model

- INCOSE Object-Oriented Systems Engineering Model (OOSEM)
  - Capture and analyze requirements and design information to specify complex systems
  - Integration with object-oriented software, hardware, and other engineering methods
  - Support for system-level reuse and design evolution
- The RMWG validated the RMPM by mapping the middle tier processes to the OOSEM activities



OOSEM integrates a top-down, model-based approach that uses OMG SysML™ to support the specification, analysis, design, and verification of systems. The objectives of OOSEM, listed below, are aligned with the chartered objectives of the RMWG:

- Capture and analysis of requirements and design information to specify complex systems
- Integration with object-oriented software, hardware, and other engineering methods
- Support for system-level reuse and design evolution

OOSEM specifies seven major activities as depicted in the figure.

OMG SysML is an enabler of a Model-Based Systems Engineering approach to improve

productivity, quality, and reduce risk for complex systems development.

The RMWG examined each OOSEM activity to determine RM applicability. To ensure RMPM completeness, the RMWG validated the RMPM by mapping the middle tier processes to the OOSEM activities.

## RMPM Model Validation

Kumar and OOSEM Validation Results		
OOSEM Activity	RMPM Middle Tier Processes	Validation Outcome
1. Setup model	<ul style="list-style-type: none"> <li>• Management Process Definition</li> <li>• Roles and Responsibilities Definition</li> </ul>	Validated
2. Analyze stakeholder needs	<ul style="list-style-type: none"> <li>• Requirements Gathering and Elicitation</li> <li>• Requirements Definition</li> <li>• Requirements Analysis</li> </ul>	Validated
3. Analyze system requirements	<ul style="list-style-type: none"> <li>• Requirements Gathering and Elicitation</li> <li>• Requirements Definition</li> <li>• Requirements Analysis</li> </ul>	Validated
4. Manage requirements traceability	<ul style="list-style-type: none"> <li>• Must be added under Requirements Development</li> </ul>	Gap
5. Define logical architecture	<ul style="list-style-type: none"> <li>• OOSEM activity is not related to RM</li> </ul>	N/A
6. Optimize and evaluate alternatives	<ul style="list-style-type: none"> <li>• OOSEM activity is not related to RM</li> </ul>	N/A
7. Synthesize candidate physical architecture	<ul style="list-style-type: none"> <li>• OOSEM activity is not related to RM</li> </ul>	N/A



The RMWG analyzed each OOSEM activity to ensure the objective and scope of that activity was addressed by a middle-tier process in the RMPM.

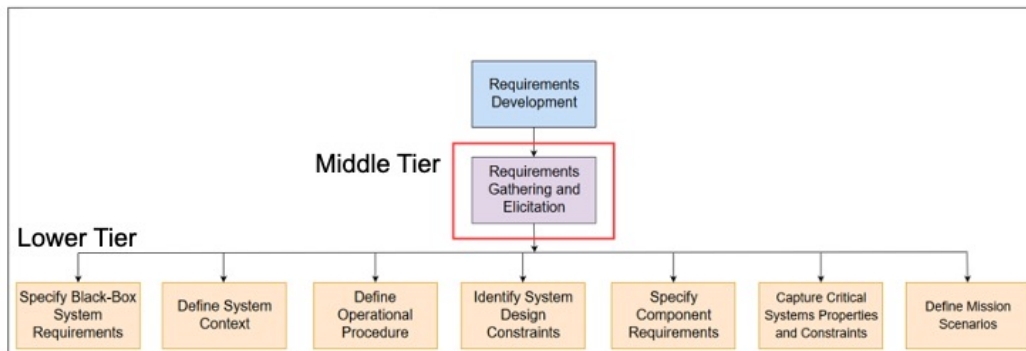
As shown in the table, the first three OOSEM activities mapped to at least one RMPM process.

The last three OOSEM activities were not related to requirements management and were not added to the RMPM.

One OOSEM RM activity, Manage requirements traceability, was not defined in the RMPM and thus identified as a gap. The RMWG updated the RMPM by adding this activity to the middle tier.

## Updated RMPM Model

- RMWG used the OOSEM to identify additional lower tier tasks for the RMPM middle tier processes

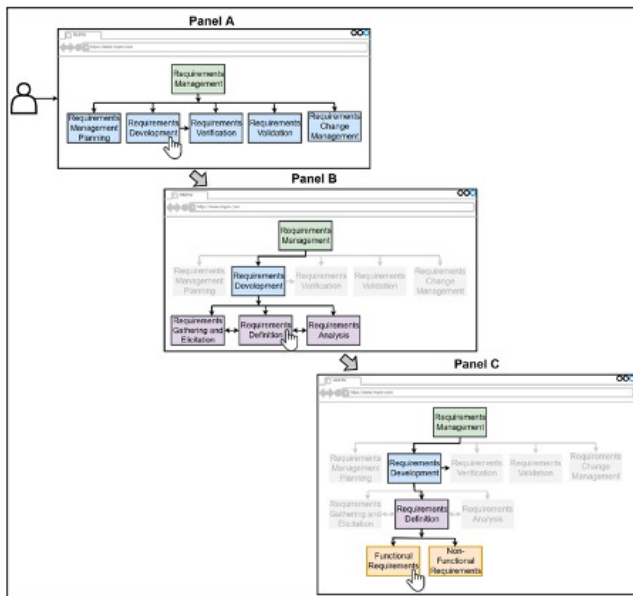


- For the Requirements Gathering and Elicitation process, the RMWG identified seven additional tasks



In addition to using the OOSEM activities to validate the RMPM middle tier, the RMWG used OOSEM to define additional components at the lower tier. The RMWG evaluated OOSEM tasks against the RMPM middle tier to determine if they represented a decomposition of a middle tier process; if so, the task was added to the RMPM as a lower tier component. An example of this decomposition is shown in the displayed figure where seven OOSEM tasks were added as components beneath 'Requirements Gathering and Elicitation'.

## RMPM Web Application



The web application, through a graphical user interface, will guide REs through the process of selecting the appropriate requirements assets for their project.

### Functional Requirements

Functional requirements describe capabilities that directly support the users' accomplishment of their mission/tasks (features, components, etc.) (The MITRE Corporation, 2014, p.306). Functional requirements describe how a system or software should behave.



Processes



Training



Templates



Best Practices

#### Processes

- Document Functional Requirements
- Document requirements' types and attributes

#### Outcomes

- Documented Functional Requirements follow proper INCOSE standards.
- If applicable, Functional Requirements are documented in the Statement of Work and Capability Development Document.

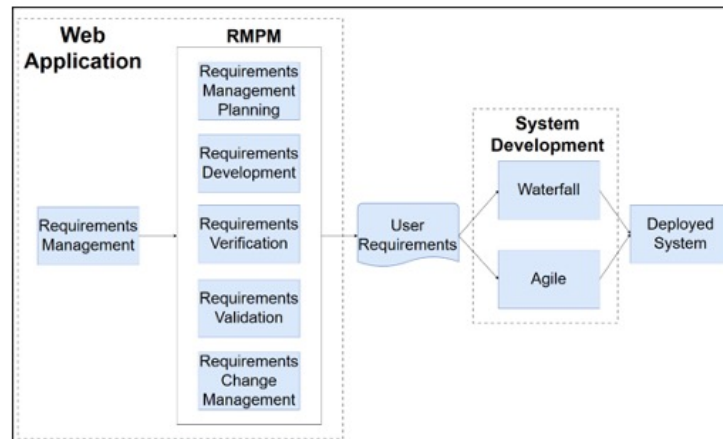


Leveraging past RMWG experience in developing and deploying the Help and Instruction Guide (HInGe), the RMPM will become a part of the HInGe application. By hosting the RMPM and all its' assets on a single platform, it will allow PEO STRI engineers to easily and quickly access information.

The web application will first display the upper tier of the RMPM. Once a user has selected a process, the middle tier of the RMPM will be displayed accordingly and the same process will occur when the user has selected a middle tier box. After selecting a lower tier box, the user will be presented with all the related assets (Processes, Training, Templates, and Best Practices).

## RMPM and System Development Approach

- RMPM is not specific to one systems development approach
- Determine a specific systems engineering methodology and carefully consider the risks of a hybrid approach



By leveraging the RMPM, a project will develop user requirements and then select a system development approach. The RMPM is not specific to one systems development approach; it can be used in both the traditional waterfall approach and in agile development. An agile project approach involves similar types of work as a traditional project; for example, create requirements and designs, develop the product, document, integrate the product with other products (if necessary), test the product, and deploy it for the user. However, instead of completing these steps for all product features at once, as in a waterfall project, the project is broken down into iterations, often called sprints.

The chosen system development determines what

technical documentation is developed; however, user capabilities/requirements are always developed.

## RMPM Web Application User Assessments

Identify users with a diverse set of experience and skills

Identify the objectives and outcomes

Ensure the appropriate materials are available

Define performance metrics and success criteria

Prepare a list of tasks for the assessment

Prepare a survey to evaluate the web application

Conduct an after-action review / hotwash session

Evaluate the survey results and feedback



User assessments will be conducted on the RMPM web application. The web application's intent is to build a foundational knowledge base of requirements management. The primary objective of the assessment is to determine if the application can serve as a standalone tool for requirements engineers with various levels of experience and skillsets.

The outlined plan, shown on this slide, leverages RMWG's experience in conducting user assessments on the HInGe application.

## Summary

- RMWG has identified ways and is developing aids to improve RM efficiency and quality by addressing PEO STRI's most significant challenges
- The RMPM provides PEO STRI a sound, validated, expandable requirements management process that can be applied to waterfall and agile acquisition approaches
- RMWG will prototype the RMPM as part of a web application. User assessments will be conducted to assess the value and usability of the RMPM.
- In FY21, PEO STRI engineers plan to use the RMPM to guide and execute their RM processes, achieving efficiencies in this critical enterprise area and delivering value to end users



The imperative to “right-size” RM arises from the need to deliver solutions that satisfy the needs of project REs (ultimately end users) while following a requirements process that is repeatable, measurable, and affordable, and carries an acceptable level of risk. Organizations have long struggled to determine ways to improve requirements development efficiency and quality, while staying within their technical and management budgets. To assist PEO STRI in meeting this challenge, the RMWG is developing aids to assist projects with discovering and using requirements processes, tools, templates, and training materials for the PEO STRI enterprise.

The RMWG developed the RMPM as the basis for performing requirements management across the

PEO STRI portfolio of programs. To ensure the RMPM was a sound approach the RMWG validated it against the Object-Oriented Systems Engineering Model. The RMPM will continue to evolve as additional tools and detailed activities are identified.

Based on RMWG's experience, a web implementation of the RMPM will enable rapid access to information in a user-friendly interface. The RMWG will conduct user assessments where engineers will employ the RMPM, through the web application, to select enterprise assets and implement them. The user assessments will provide valuable user feedback and will be integrated to enhance the RM processes for PEO STRI.

In FY21, PEO STRI plan to use the RMPM to guide project and product teams in their RM processes, through strategic reuse of a common technical approach and shared assets, enabling teams to improve efficiency and effectiveness in their requirements engineering, delivering value to our end users.

## Points of Contact

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*The opinions and assertions contained herein are the private opinions of the authors and are not to be construed as official or reflecting the views of the Department of Defense.*



To learn more about this topic, refer to the I/ITSEC 2020 Proceedings entry: 'Improving Requirements Development Efficiency and Quality with Decision Aids'.

To learn more about PEO STRI, the Requirements Management Working Group (RMWG), and the requirements engineering practices supported by Army training programs, please contact the PEO STRI Chief Technology Officer (CTO), Mr. Harry Sotomayor, or CTO staff member, Dr. Barbara Pemberton.