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A Pilot Study to Determine MBSE Utility for Process Modeling of Complex Interfaces

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About the Authors

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Pilot Study Overview

Do the benefits of MBSE outweigh the modeling efforts (cost) required to sustain the use of MBSE for the Launch Services Program (LSP)?

- **Key Decision: Should LSP…**
  - Adopt MBSE?
  - Not adopt MBSE?
  - Wait to adopt MBSE until used more widely by its launch vehicle (LV) contractors and spacecraft (SC) customers?

A Summary of NASA LSP

"The Launch Services Program is responsible for NASA oversight of the launch service including launch vehicle engineering and manufacturing, launch operations and countdown management, and providing added quality and mission assurance in lieu of the requirement for the launch service provider to obtain a commercial launch license."

A Summary of NASA LSP

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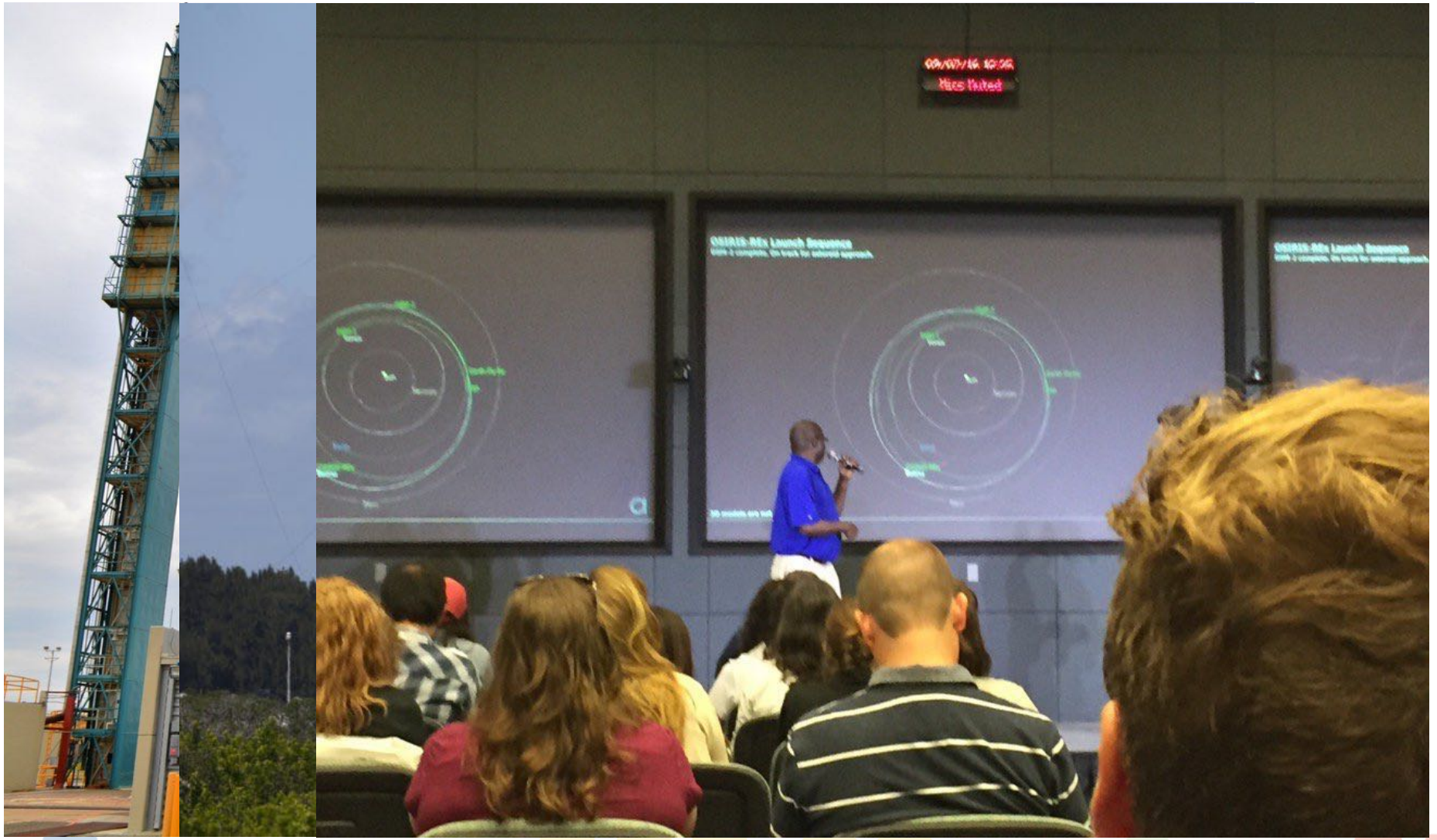

A Summary of NASA LSP

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A Summary of LSP Integration Engineering

More Specifically, the LSP Integration Engineer (IE), is the systems engineer responsible for defining, managing, integrating and verifying the spacecraft-to-launch vehicle interface

A Summary of LSP Integration Engineering

- Primary focus of the LSP IE is to manage the interface between the launch vehicle and the spacecraft
  - Ensures interface requirements are developed & verified
  - Process is started early in the mission planning and development stage of the spacecraft project

A Summary of LSP Integration Engineering

- Major LSP IE activities include (but are not limited to)…
  - Early spacecraft concept development & trade studies
  - Development of the spacecraft's interface requirements
  - Establishing spacecraft environmental test levels
  - Verification of integrated requirements
  - Major spacecraft and launch vehicle design reviews
  - Integrated operations
  - Launch

A Summary of LSP Integration Engineering

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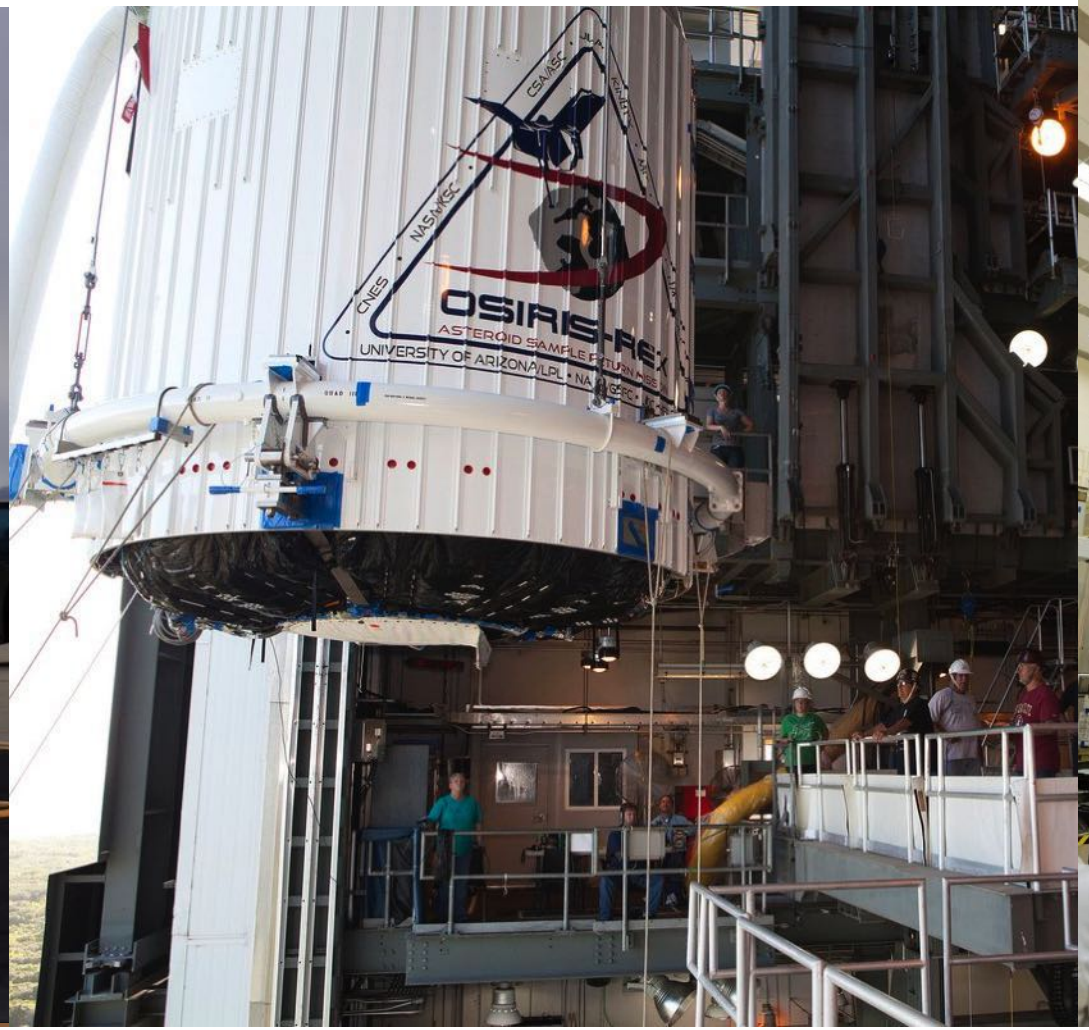
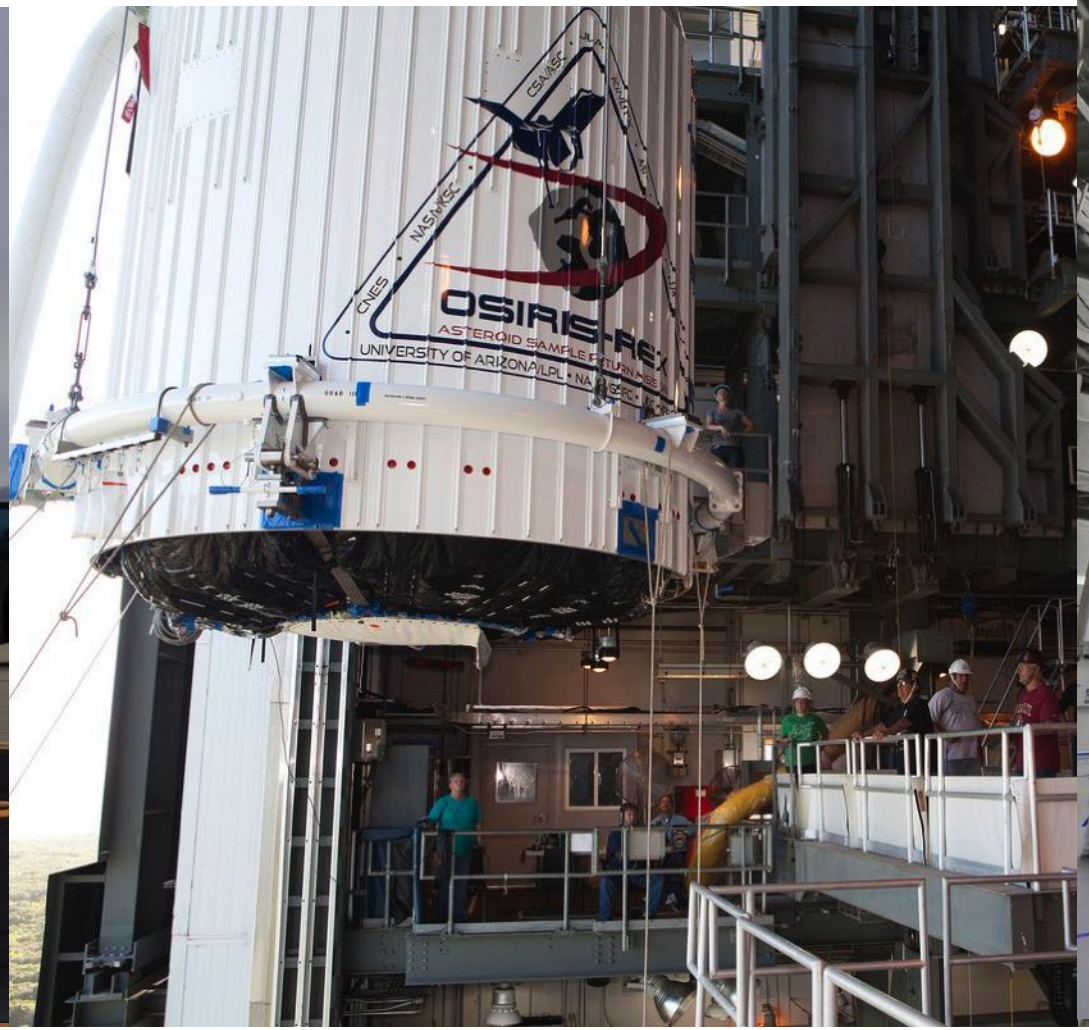


A Summary of LSP Integration Engineering



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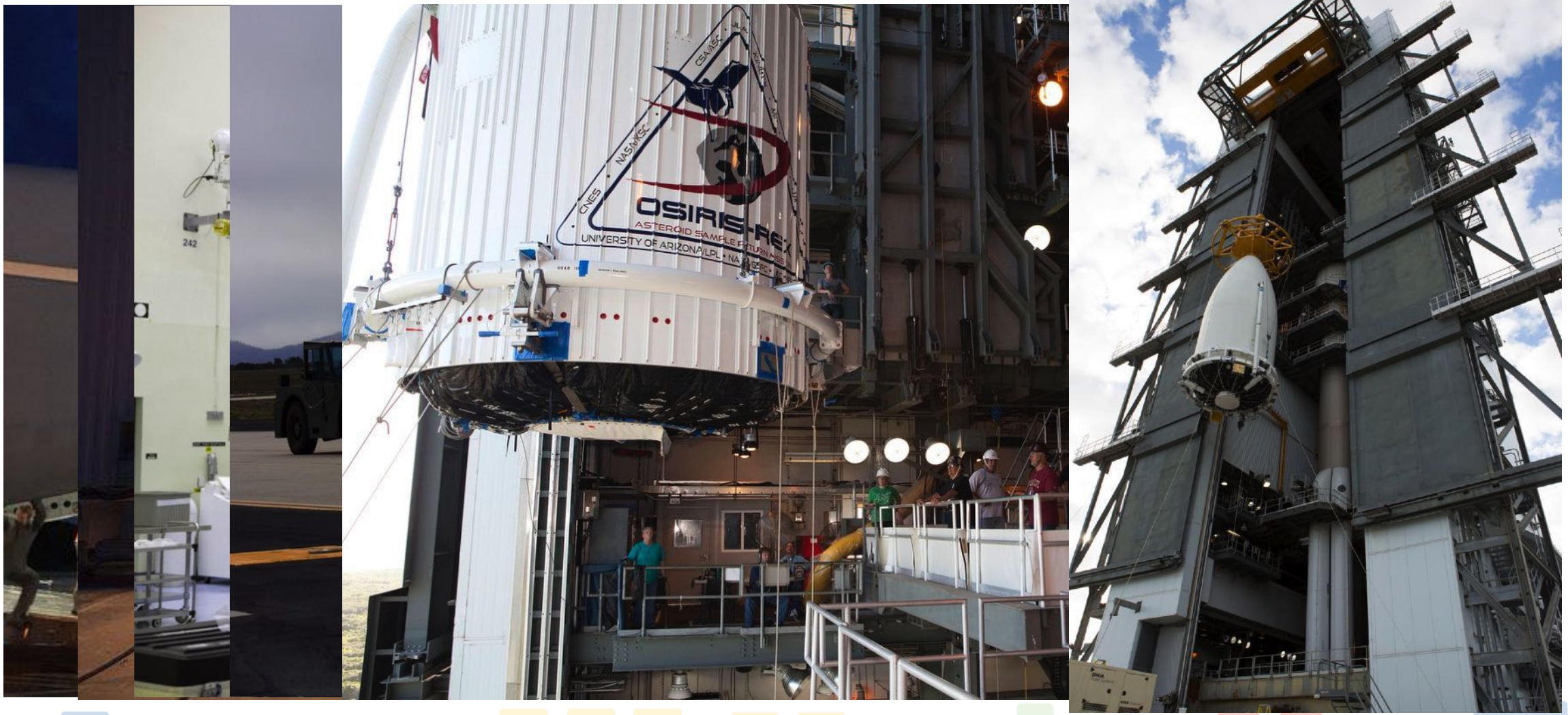


A Summary of LSP Integration Engineering

A Summary of LSP Integration Engineering

- LSP Integration Engineers (IEs) are responsible for working with our spacecraft customers on:
  - Development of the Spacecraft Interface Requirements Document (IRD) – pre Launch Vehicle Selection
  - Development of the Launch Vehicle (LV) to Spacecraft Interface Control Document (ICD) – post Launch Vehicle Selection
- The LV ICD then becomes the main focus for requirements, verifications and integrated activities for the mission
- LSP MBSE modeling efforts therefore heavily involve the ICD

MBSE Modeling for the Pilot

- Mars 2020 was chosen as the LSP mission to model for the pilot for the following reasons:
  - The Mars 2020 spacecraft components and interfaces are nearly identical to MSL (The Mars Curiosity Rover), which was an LSP mission launched back in 2011
  - Could leverage historical MSL engineering products in the early modeling efforts of Mars 2020
  - JPL is the lead NASA Center for Mars 2020 (and MSL), and they are heavily involved in MBSE activities

Tools & Resources

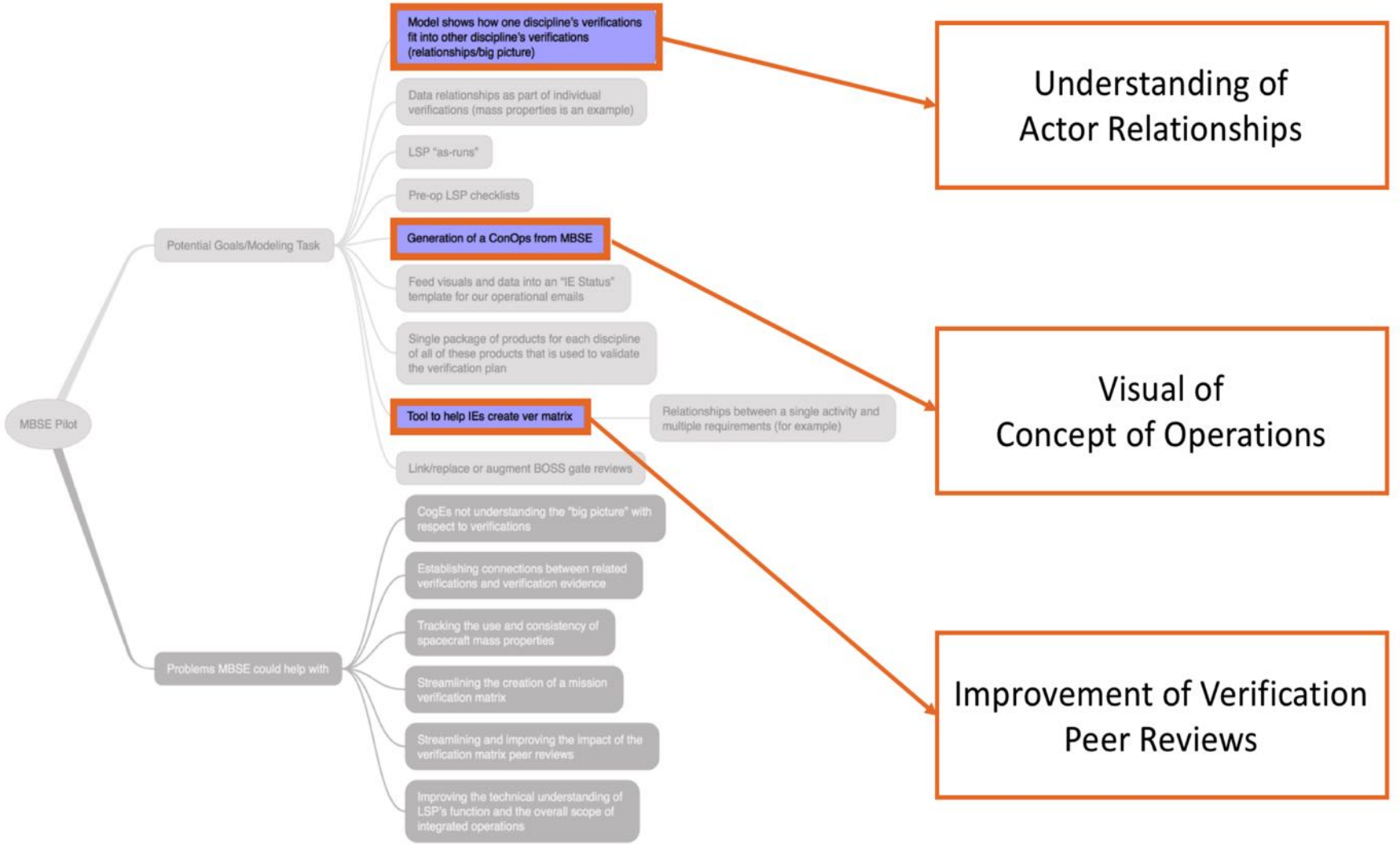
- Magic Draw was chosen as the MBSE tool due to its extensive use at JPL and its license availability at Kennedy Space Center
- Used the book ‘SysML Distilled’ by Lenny Delligatti as a starting point
- Procured consulting services from Lenny Delligatti to ensure our modeling efforts remained on an efficient path

Our MBSE Modeling Approach

Three Steps

1) Determine the needs of the LSP
2) Select example modeling cases and develop an understanding of the launch vehicle systems or operations chosen that would best test MBSE's ability to meet LSP's needs
3) Create a model to determine/evaluate that ability

Potential LSP Needs



MBSE Defined

"MBSE is the formalized application of **modeling to support systems requirements, design, analysis, verification, and validation activities** beginning in the conceptual design phase and continuing throughout development and later life cycle phases"

– INCOSE SE Vision 2020

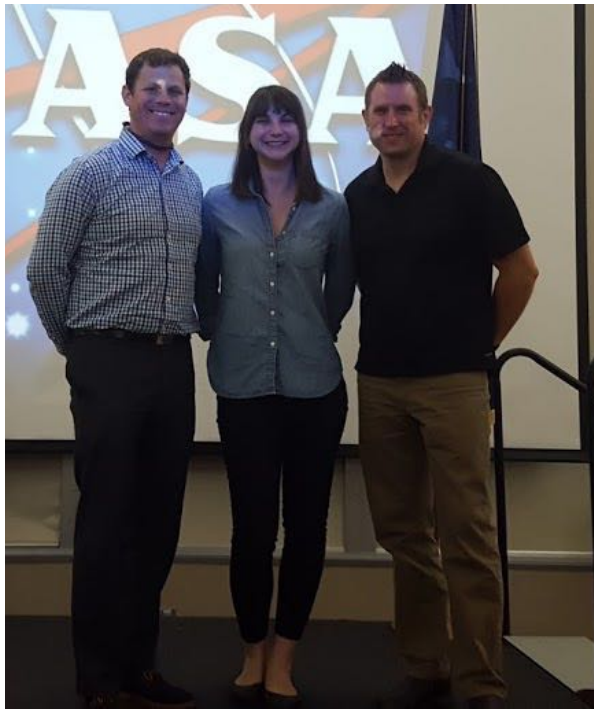
(INCOSE-TP-2004-004-02, Sept. 2007)

Identified Challenges

- Skeptical Engineers
- Time

Strategies to Address the Challenges

- Skeptical Engineers
  - **What can MBSE do tomorrow that our IEs can't do today?**
- Time
  - **Start small**
  - **Utilize the resources we had**



Scoping The Modeling Effort

- Pilot study “proof of concept” could be attained without having to model everything (all systems & all requirements)
- We didn’t have a team of MBSE experts, just a single MBSE modeler (summer intern)
- Started by just modeling the artifacts necessary to model the 3 needs/cases identified
- But how do you identify these required modeling artifacts?

Understanding the Chosen Cases

- With 3 needs/modeling cases chosen, our next step was to ensure a complete understanding of what we were modeling
- Our MBSE modeler (Alexandra Dukes) was a summer intern, only with LSP for 10-weeks and was brand new to our Program

“Pre-Coding” the Model

- “Pre-Coding” was found to be an essential activity to complete BEFORE starting to model within the MBSE environment
- “Pre-Coding” is defining the model elements and their relationships to other identified elements before modeling the system
- ”Pre-Coding” opens the possibility for a “non-system expert” to be your MBSE modeler

Research

- Information needed for pre-coding and modeling was spread across multiple sources:
  - NASA documentation
  - Contractor documentation
  - MSL design documentation and requirement verifications
- Search began with the completed verifications from MSL for the system being modeled & then expanded the search from there as needed

Questions Asked While Researching

- What system elements (i.e. actors, hardware, and requirements) should be modeled?
- What are the relationships between those elements?
- What are the verification activities involving those elements?

Microsoft Excel & MBSE?

- Microsoft Excel: a good tool for “Pre-Coding”
  - Used Excel to identify and document everything during the Pre-Coding activities
  - Excel Pre-Coding spreadsheet then used as a guide to build the model

Iterative Modeling Approach

- With only 10-weeks to conduct the pilot we wanted maximize our affective time modeling rather than find out it the wrong things were modeled (or ineffective)
- Modeled in small fits and starts
  - Started with one aspect of one operation or verification activity
  - Would jump from one modeling effort to another
  - Slowly added to the all aspects/pieces of the model
  - Weekly consulting telecons with Lenny Delligatti

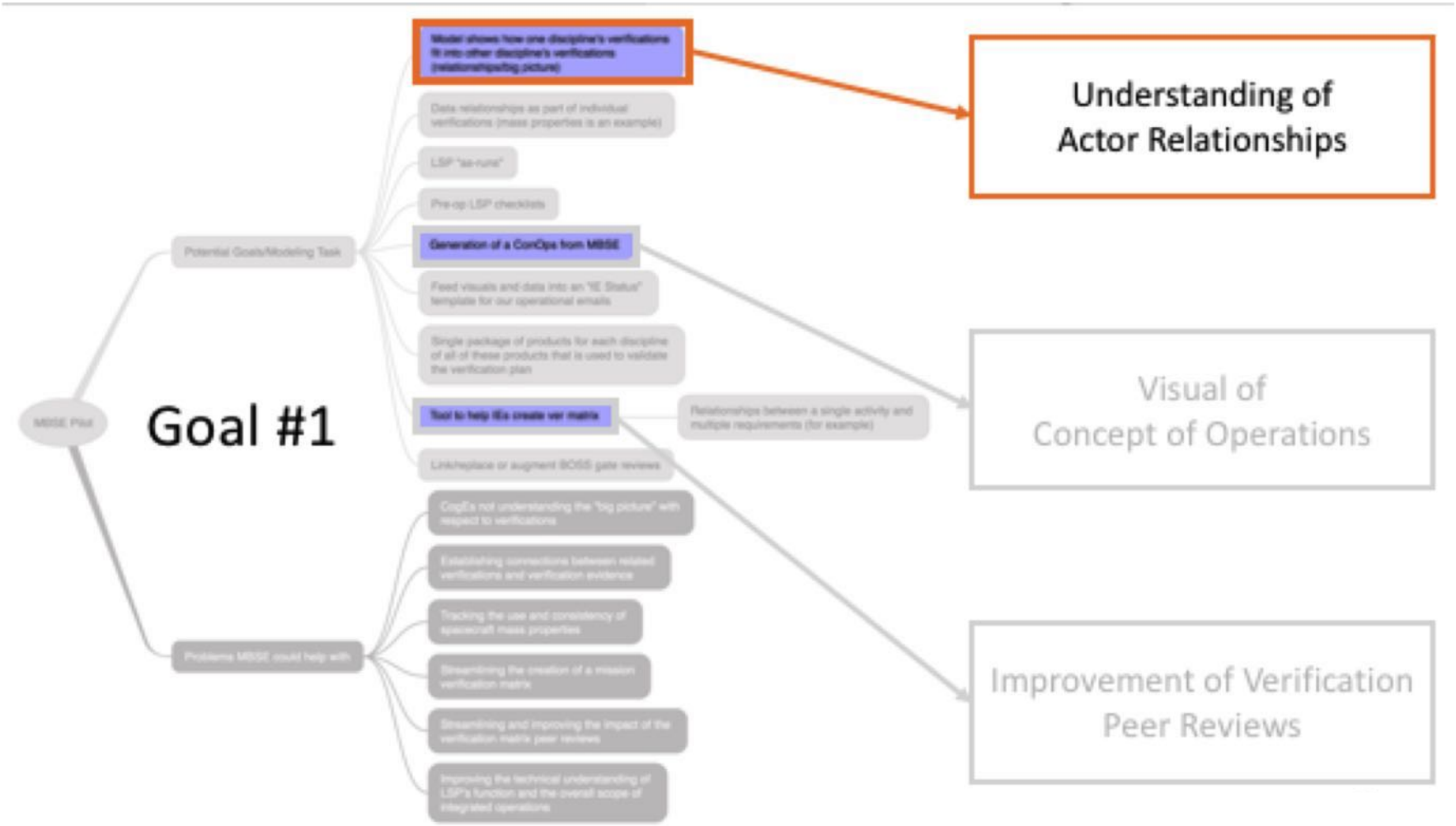
Iterative Modeling Approach

- As we gained experience modeling different aspects of the launch operations with various methods we were able to identify specific SysML diagrams that directly meet the 3 LSP needs we previously identified
  1) Understanding of Actor Relationships
  2) Visual of Concept of Operations
  3) Improvement of Verification Peer Reviews

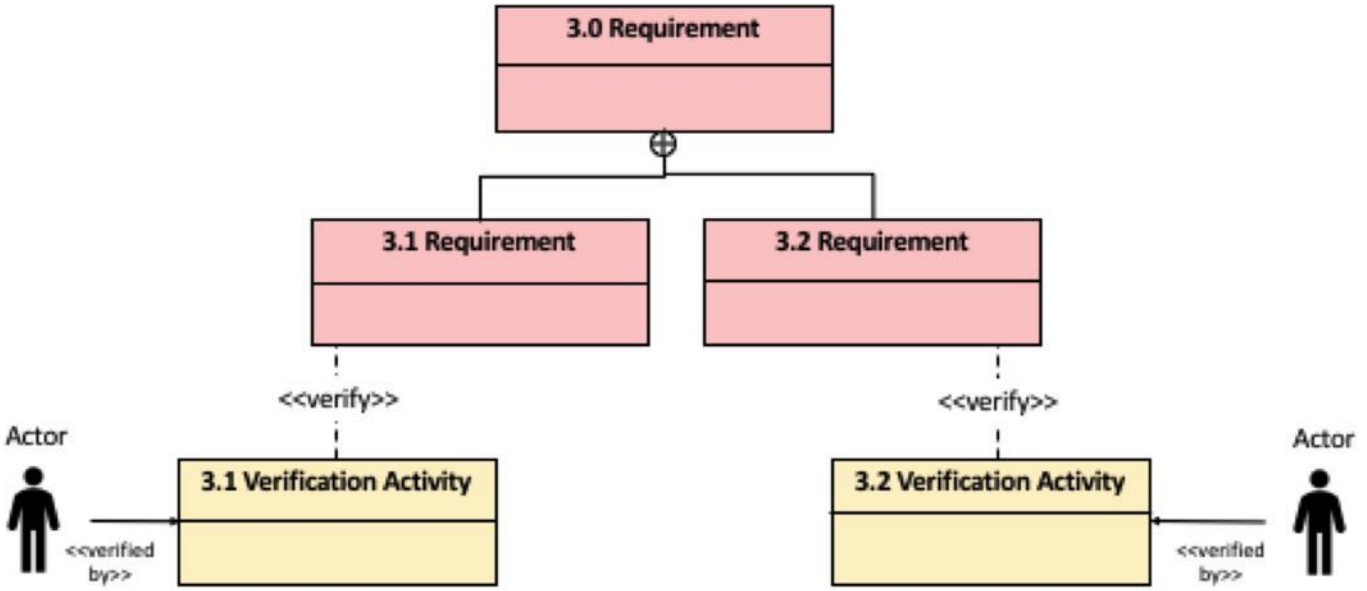
Matching Needs with Modeling

1) Understanding of Actor Relationships
   - Requirement Diagram
   - Verification Activity Diagram
2) Visual of Concept of Operations
   - Activity Diagram
   - Block Definition Diagram
   - Requirements Diagram
3) Improvement of Verification Peer Reviews
   - Requirements Diagram

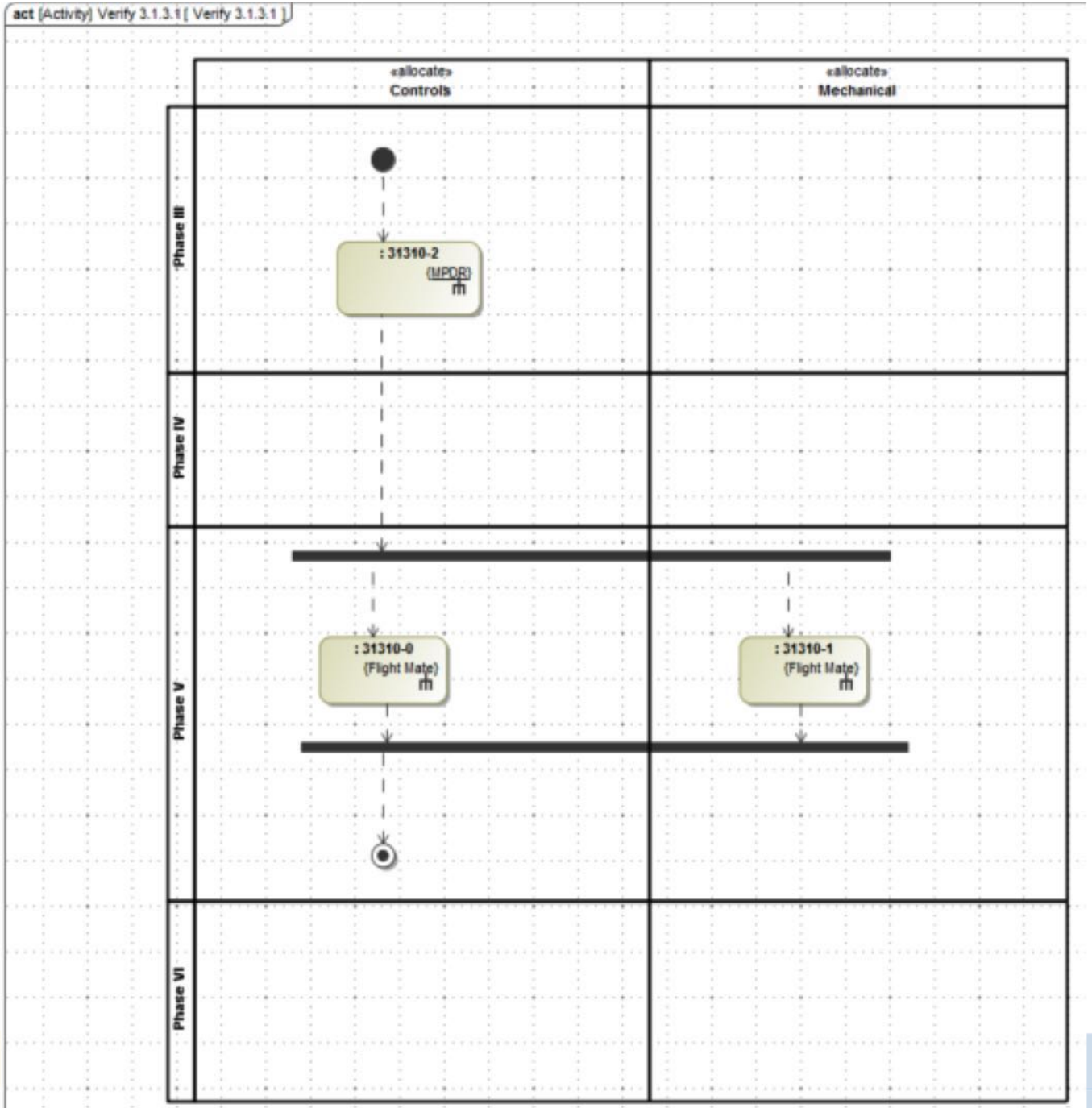
Pilot Study Results: Goal #1



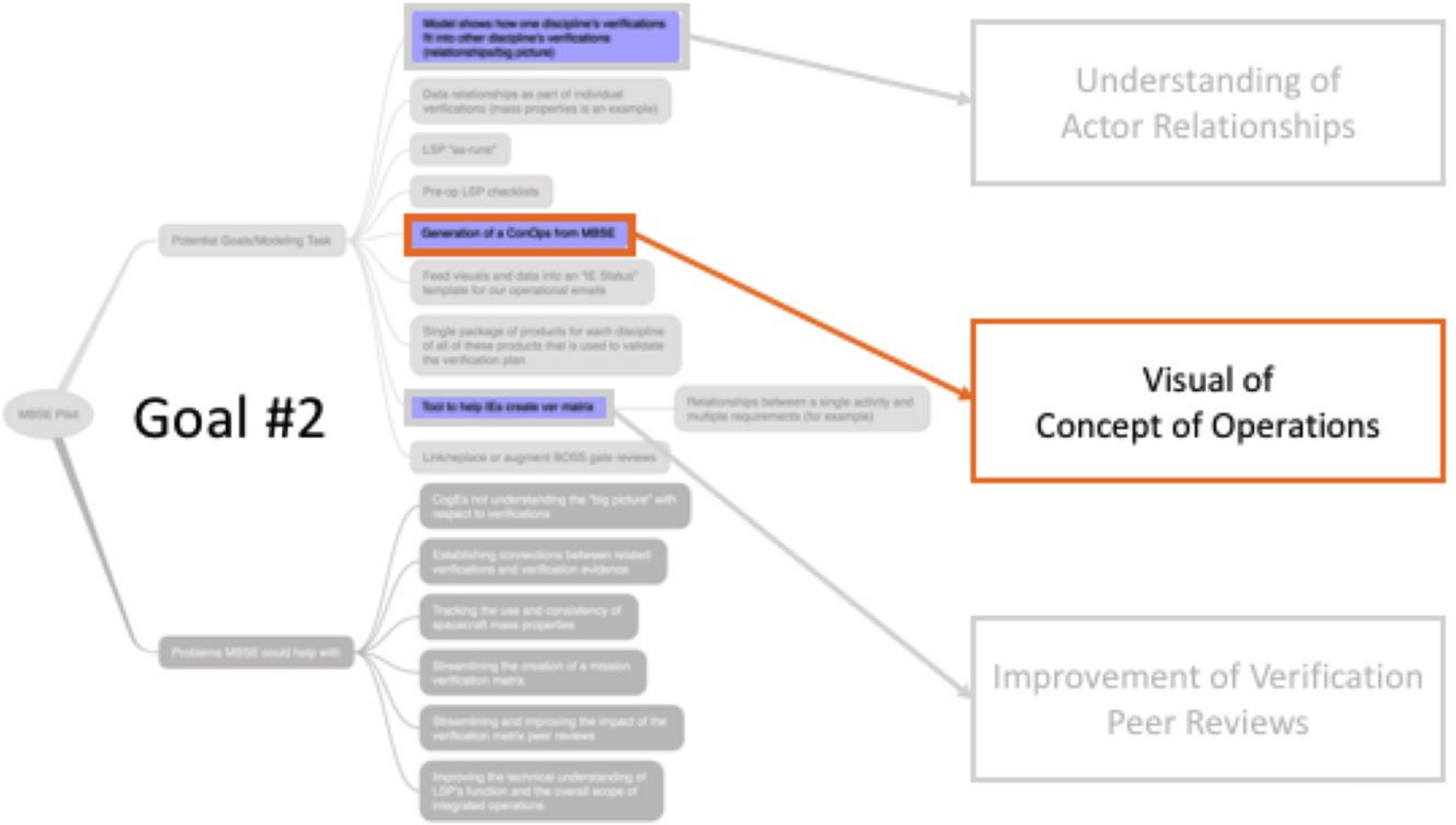
Requirement Diagram



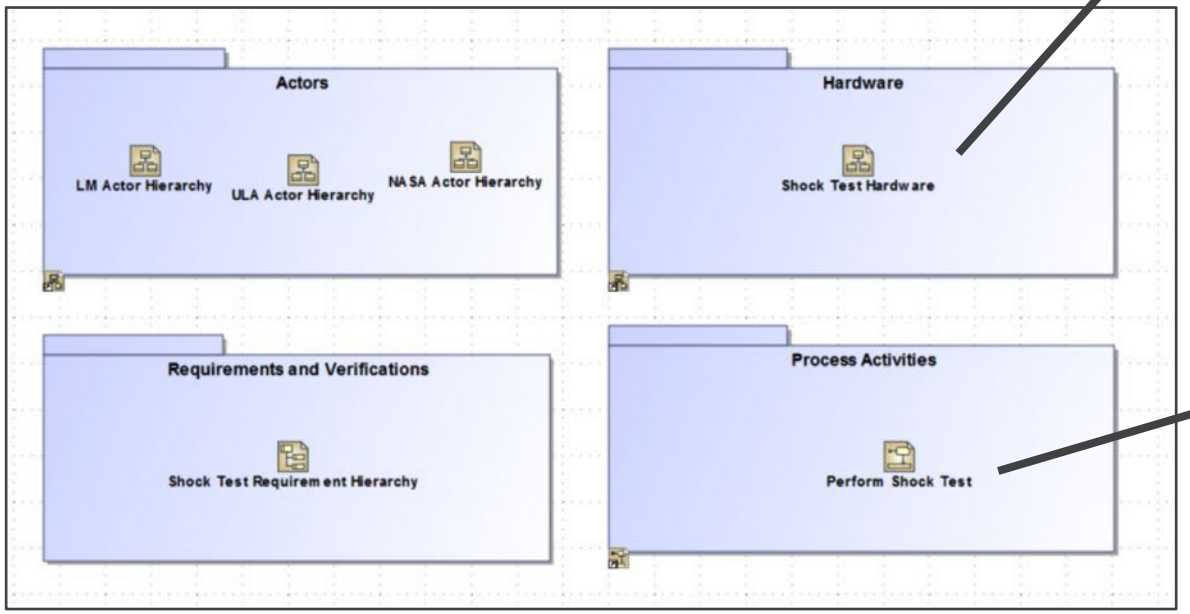
Verification Activity Diagram

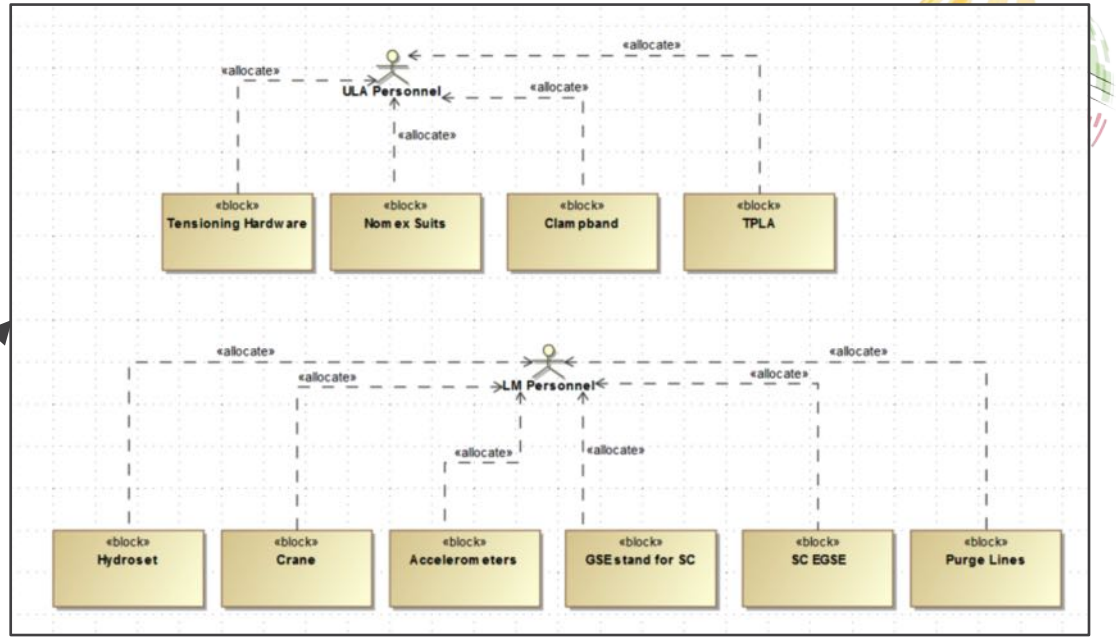


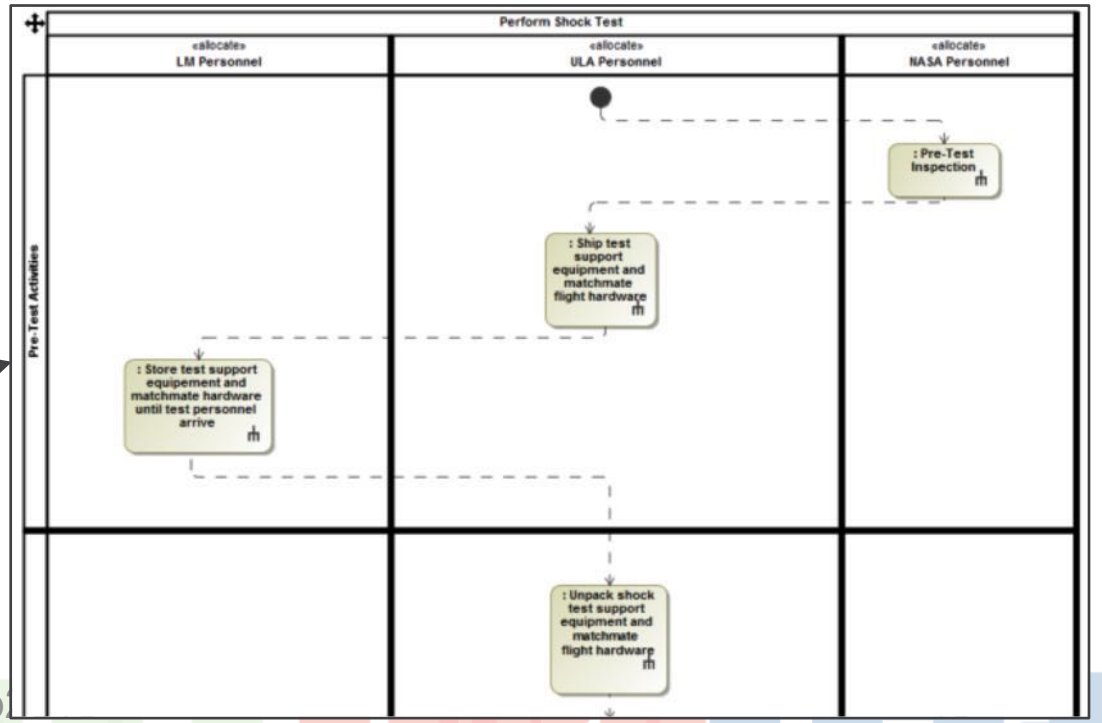
Pilot Study Results: Goal #2



Package, Block Definition & Activity Diagrams

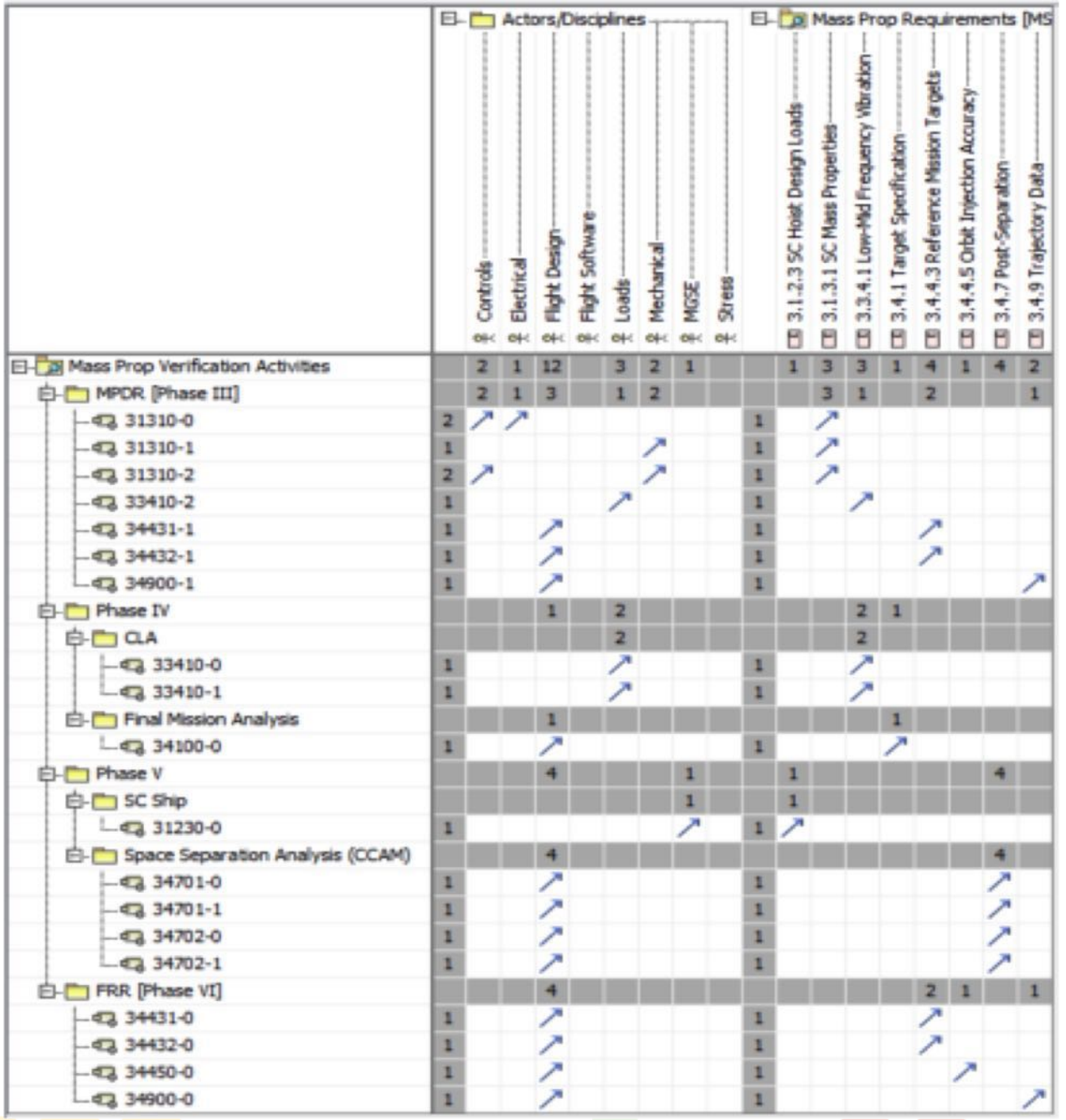






Pilot Study Results: Goal #3

Verification Matrix



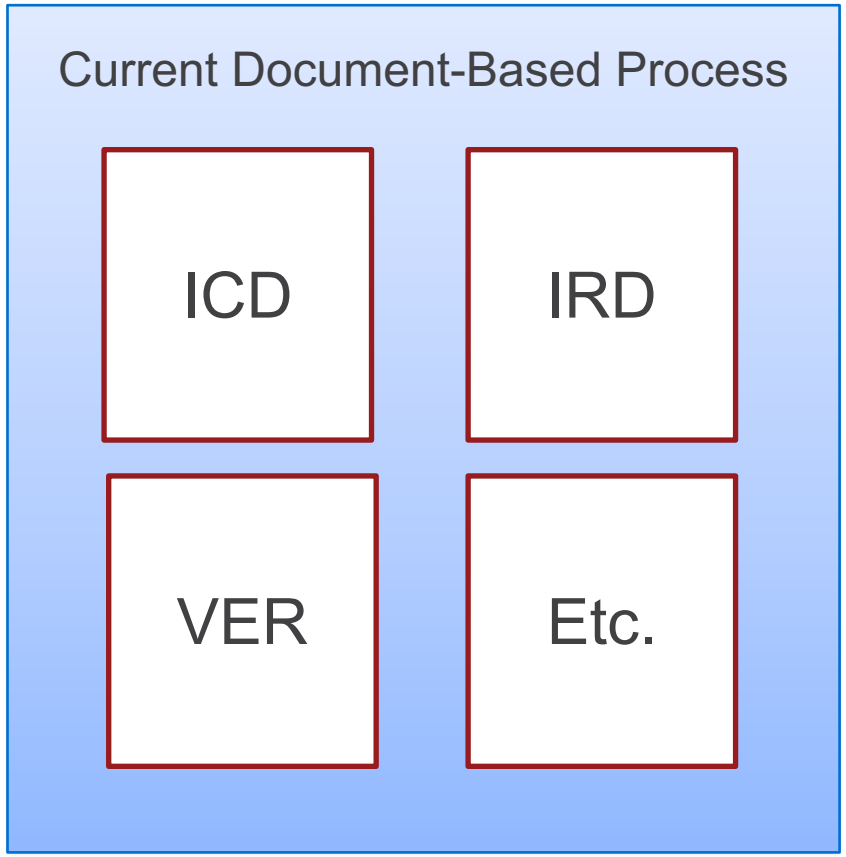
Pilot Study Summary

- Demonstrated potential for improvement in:
  - Communication
    - Understanding of Actor Relationships
  - Productivity
    - Visual of Concept of Operations
  - Quality
    - Improvement of Verification Peer Reviews

Process Modeling

- ”Process Modeling” was a term we used a lot during our model development
  - LSP relies on our processes to esnsure consistency in our management and risk mitigation from mission to mission
  - Rather than allow MBSE to dictate a way of doing things we used MBSE to **improve** our already successful processes

Non-Linear Modeling



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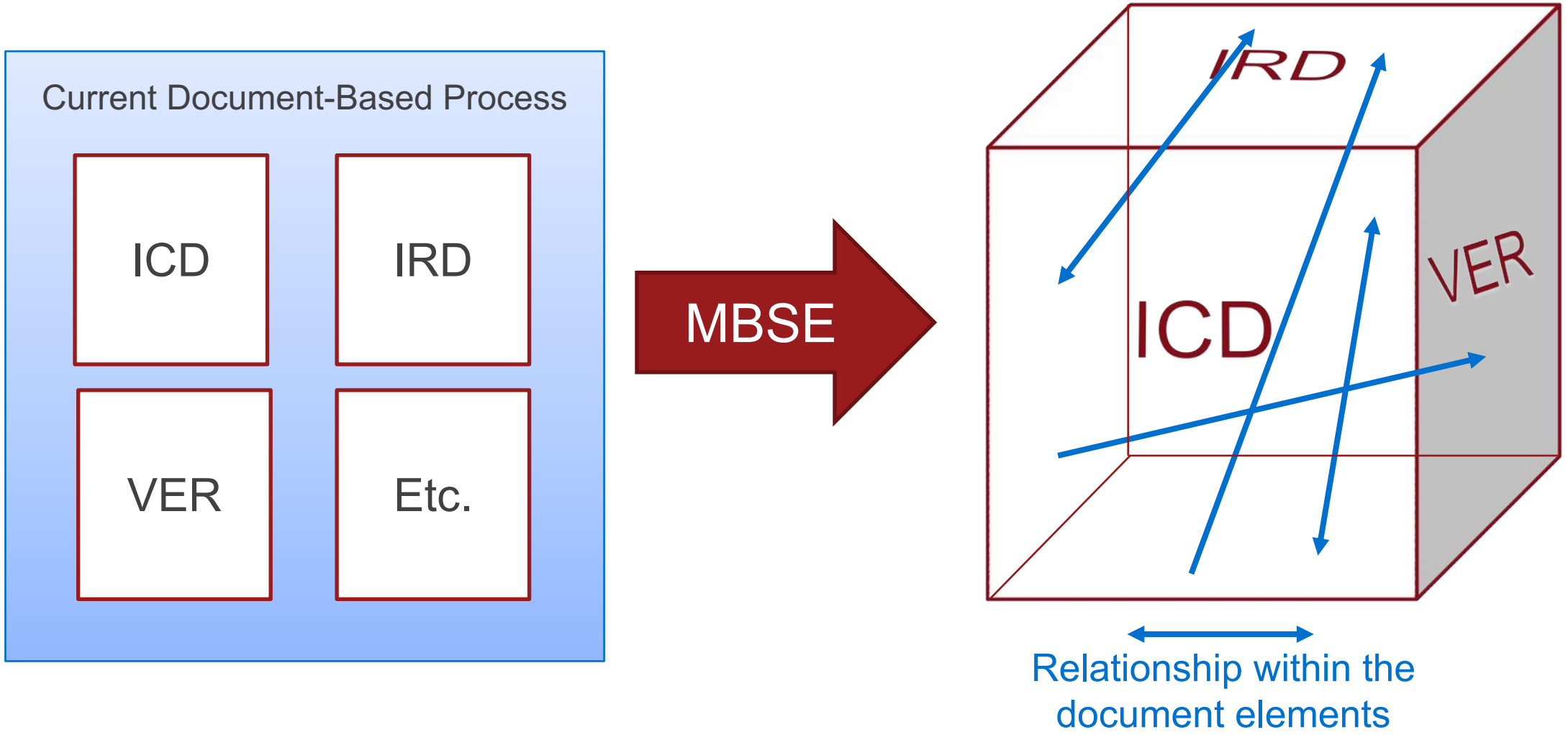
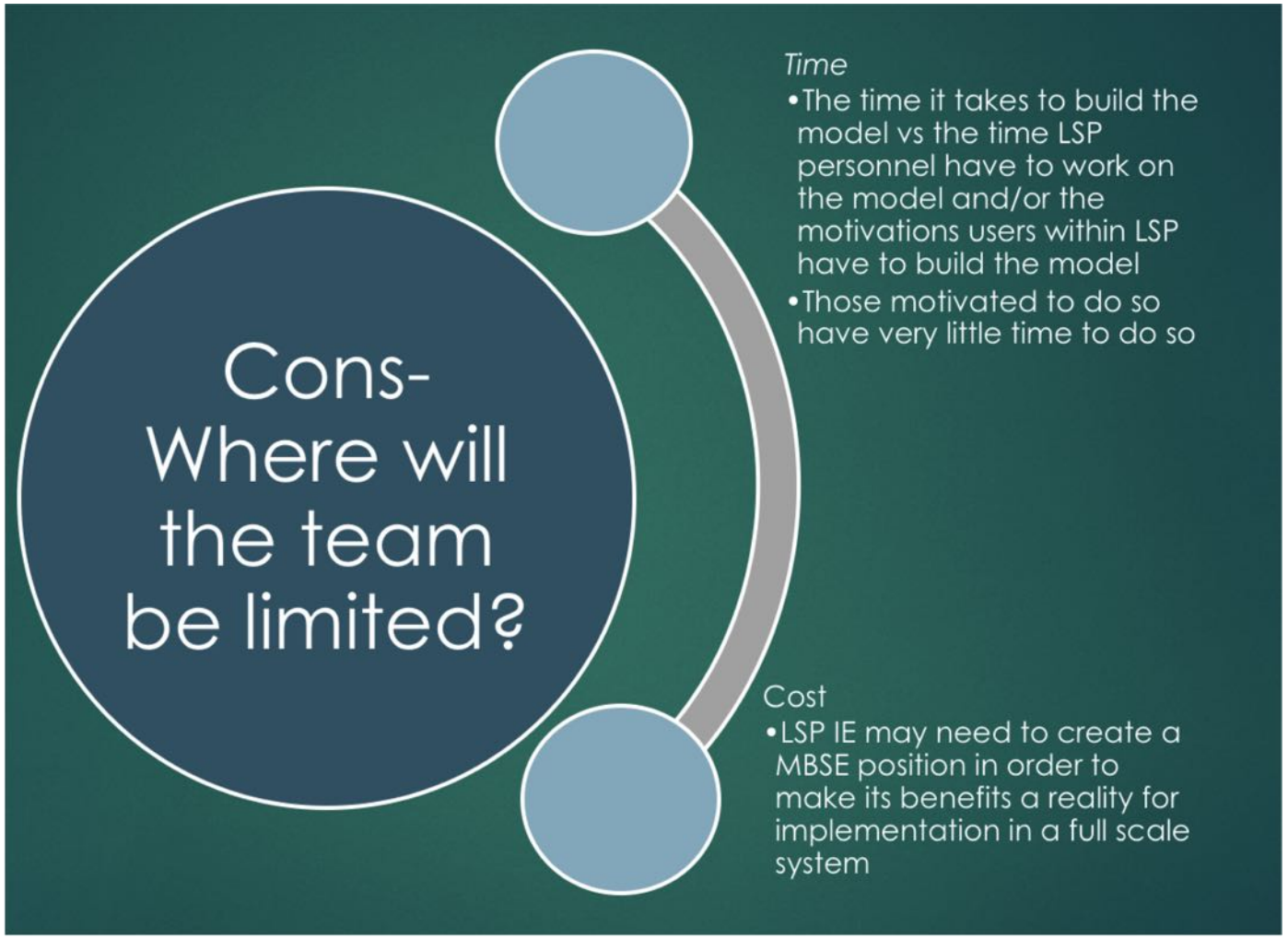
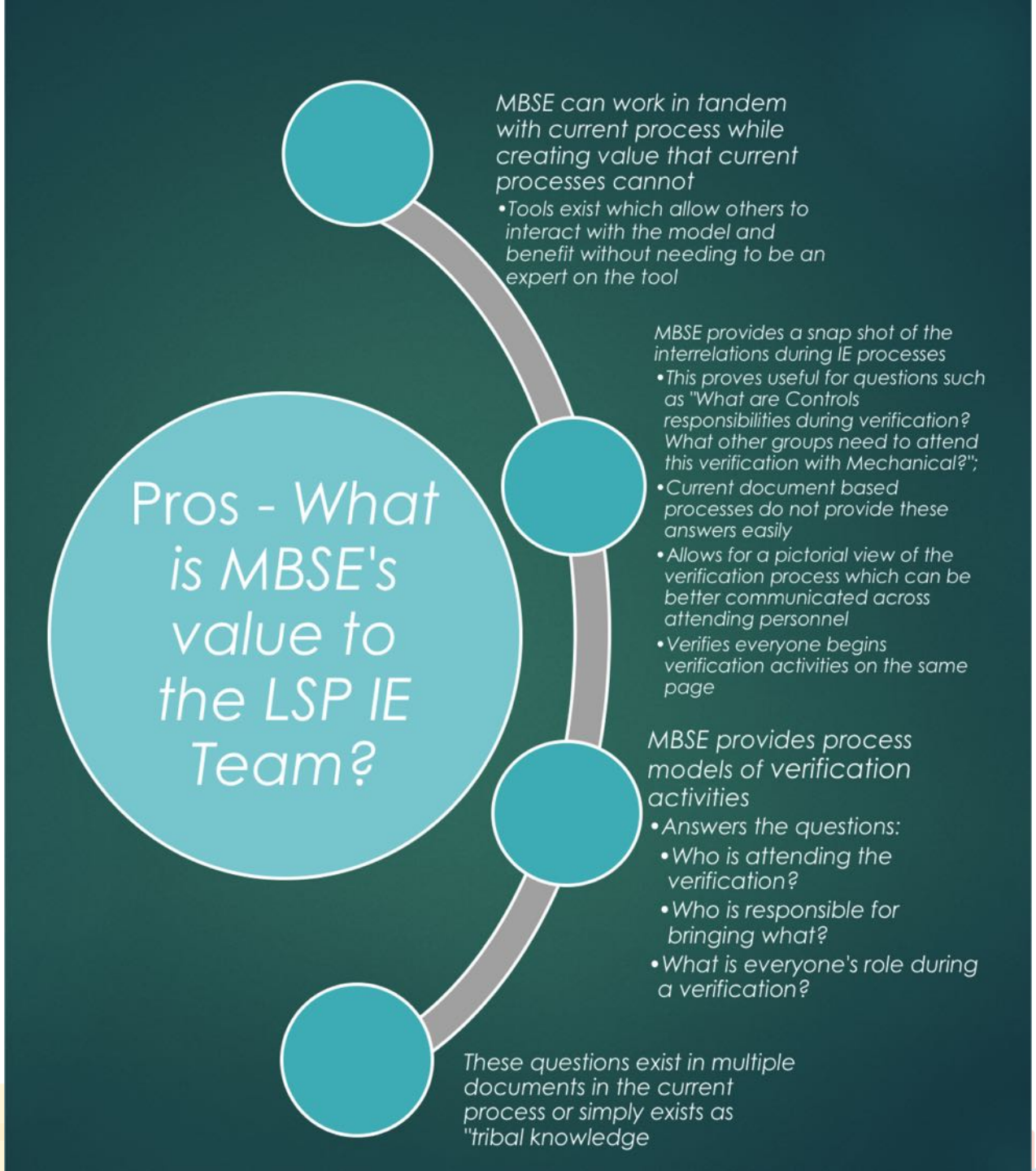


MBSE Cons


Cons-
Where will
the team
be limited?
Time
•The time it takes to build the model vs the time LSP personnel have to work on the model and/or the motivations users within LSP have to build the model
•Those motivated to do so have very little time to do so
Cost
•LSP IE may need to create a MBSE position in order to make its benefits a reality for implementation in a full scale system

MBSE Pros


Pros - What is MBSE's value to the LSP IE Team?
MBSE can work in tandem with current process while creating value that current processes cannot
•Tools exist which allow others to interact with the model and benefit without needing to be an expert on the tool
MBSE provides a snap shot of the interrelations during IE processes
•This proves useful for questions such as "What are Controls responsibilities during verification? What other groups need to attend this verification with Mechanical?";
•Current document based processes do not provide these answers easily
•Allows for a pictorial view of the verification process which can be better communicated across attending personnel
•Verifies everyone begins verification activities on the same page
MBSE provides process models of verification activities
•Answers the questions:
•Who is attending the verification?
•Who is responsible for bringing what?
•What is everyone's role during a verification?
These questions exist in multiple documents in the current process or simply exists as "tribal knowledge

Lessons Learned

1) **Pre-coding your engineering material before modeling within a MBSE environment, while time-consuming, was a very necessary and valuable step to ensure an accurate model**

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3) **A community of practice for interface management utilizing MBSE does not exist and in general a robust MBSE community can be hard to find due to the highly specialized nature of applying MBSE to a wide variety of systems and environments**

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3) A community of practice for interface management utilizing MBSE does not exist and in general a robust MBSE community can be hard to find due to the highly specialized nature of applying MBSE to a wide variety of systems and environments
4) **One organization’s lessons learned concerning MBSE may not be applicable to another organization using MBSE due to the differing environments and needs of the organizations**

MBSE Take-Aways

- Initial MBSE initiatives (a small pilot) can be done with limited time & resources
- You don’t need a standing army of MBSE experts to get started with MBSE
  - Having an expert consultant is a must
  - In the end you end up becoming the “MBSE expert” for your organization because you learn how to use it best for your application

Conclusion

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MBSE has enough potential to become a productive modeling application to LSP that it is worth further pursuing in larger scale pilot studies.