INCOSE Healthcare Working Group

5th Annual Systems Engineering in Healthcare Conference

May 1-2, 2019
Minneapolis, MN

From
Digital Thread
to
Human Connection

prior title:
MBSE and LEAN in Health Care: Leveraging Integrated Tools for In Situ Device Development

Chris Meeker, MS, PE
Dassault Systèmes

chris.meeker@3ds.com

INCOSE Healthcare Working Group

5th Annual Systems Engineering in Healthcare Conference

May 1-2, 2019
Minneapolis, MN

From Digital Thread to Human Connection

A Case Study of
Model-Based Systems Engineering
in the
Hospital Environment

Enabling Design Context for Early Validation,
Robust Requirements and Rapid Prototyping

Presenter Background

Human-centered Systems Engineering

- Mechanical – Human Factors - Industrial
- Model-based systems engineering
- Process improvement (Lean / Six Sigma)
- Integrated facility design / 3P
- Equipment design & planning
- Production system flow

DASSAULT SYSTEMES

ELECTROIMPACT BOEING AIRBUS

JOHNS HOPKINS MEDICINE Stanford HEALTH CARE Sutter Health Virginia Mason

Takeaways

Context enables effective design decisions for operational performance

Model-Based Systems Engineering enables **Context**

- Aerospace
- Health care delivery

Case Study in **Context** through **MBSE** illustrates efficient:

- Problem identification and stakeholder needs
- Requirements development, elicitation, and revision
- Early validation for system model refinement
- Rapid prototyping and use testing

Context … is critical.

Image sourced from https://www.architecturendesign.net/poor-design-decisions-fails/

Context … is critical.

Image sourced from https://www.reddit.com/r/funny/comments/1jnklk/suspicious_water_fountain/

Model-Based Systems Engineering

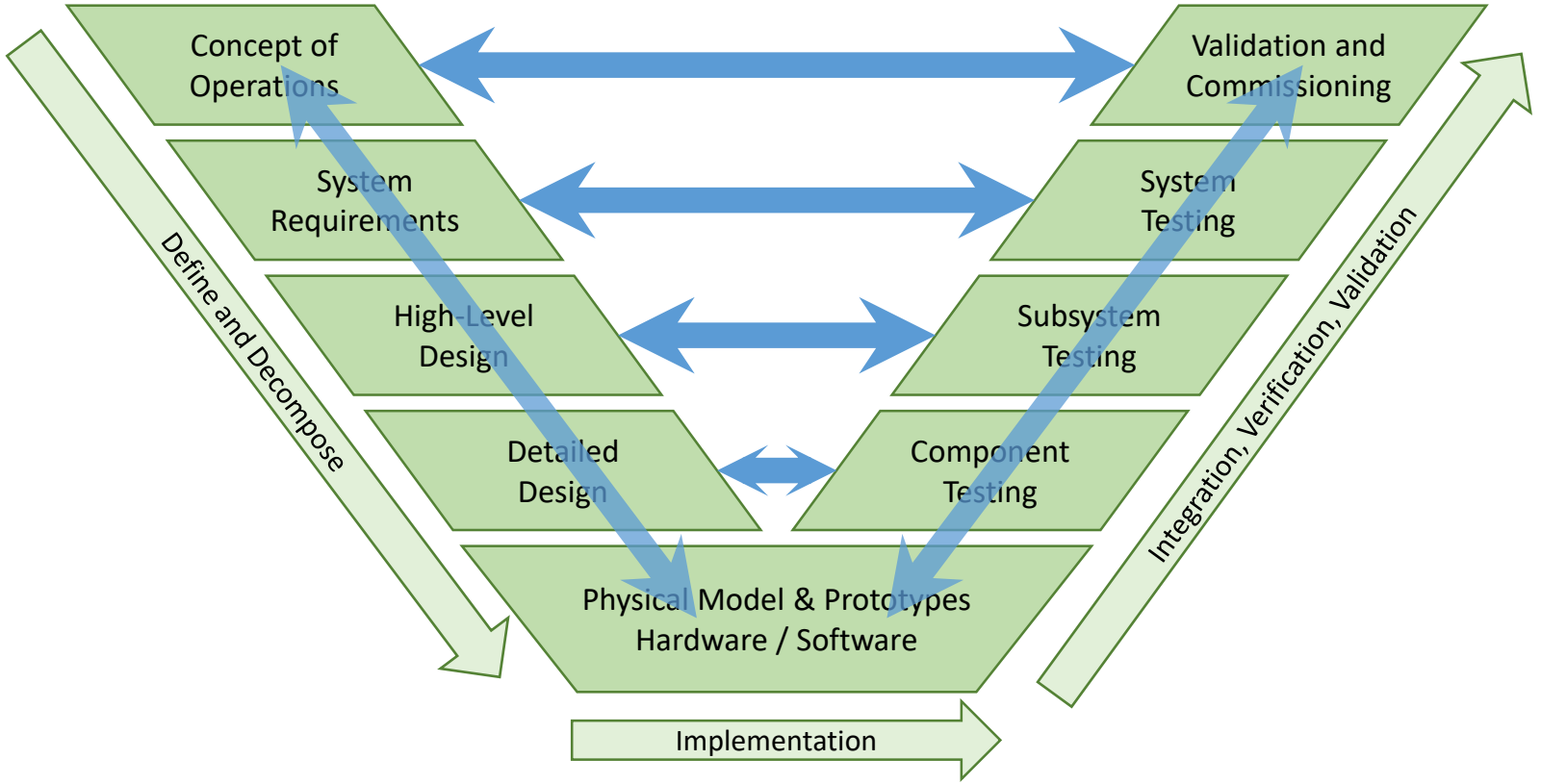
The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. (INCOSE 2007)

https://www.sebokwiki.org/wiki/Model-Based_Systems_Engineering_(MBSE)_(glossary)

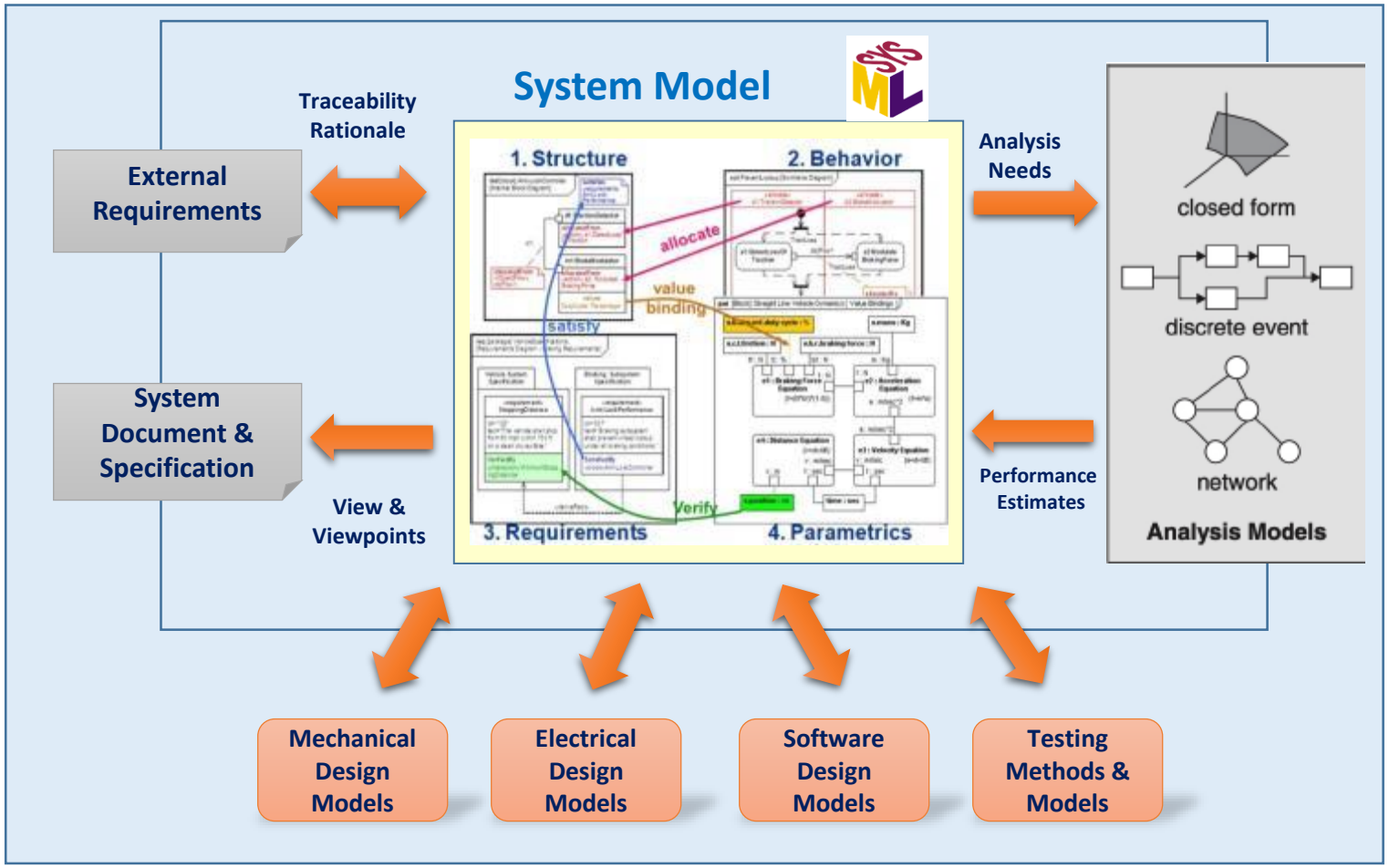
MBSE in Aerospace

Image © 2017 Airbus SAS; https://www.airbus.com/

MBSE enables context



System Model – As An Integration Framework

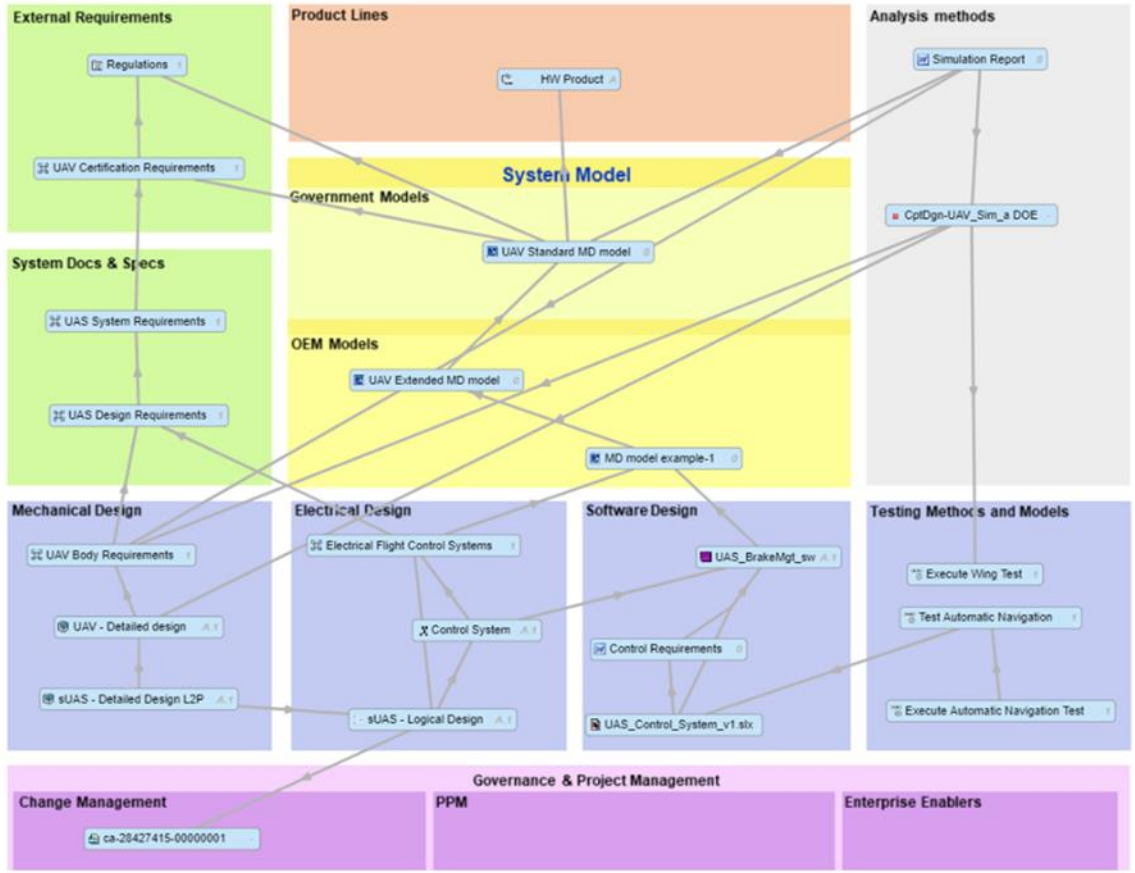


System Framework for Design (includes Discipline-Specific Models)

The system model is linked "upstream" to mission effectiveness models, and "downstream" to decomposed and allocated sub-system requirements and associated designs.

It is also linked to verification tools (FEM, CFD) which validate it's fidelity and utility for intended purpose.

System Model - Integration



SE / MBSE in care delivery?

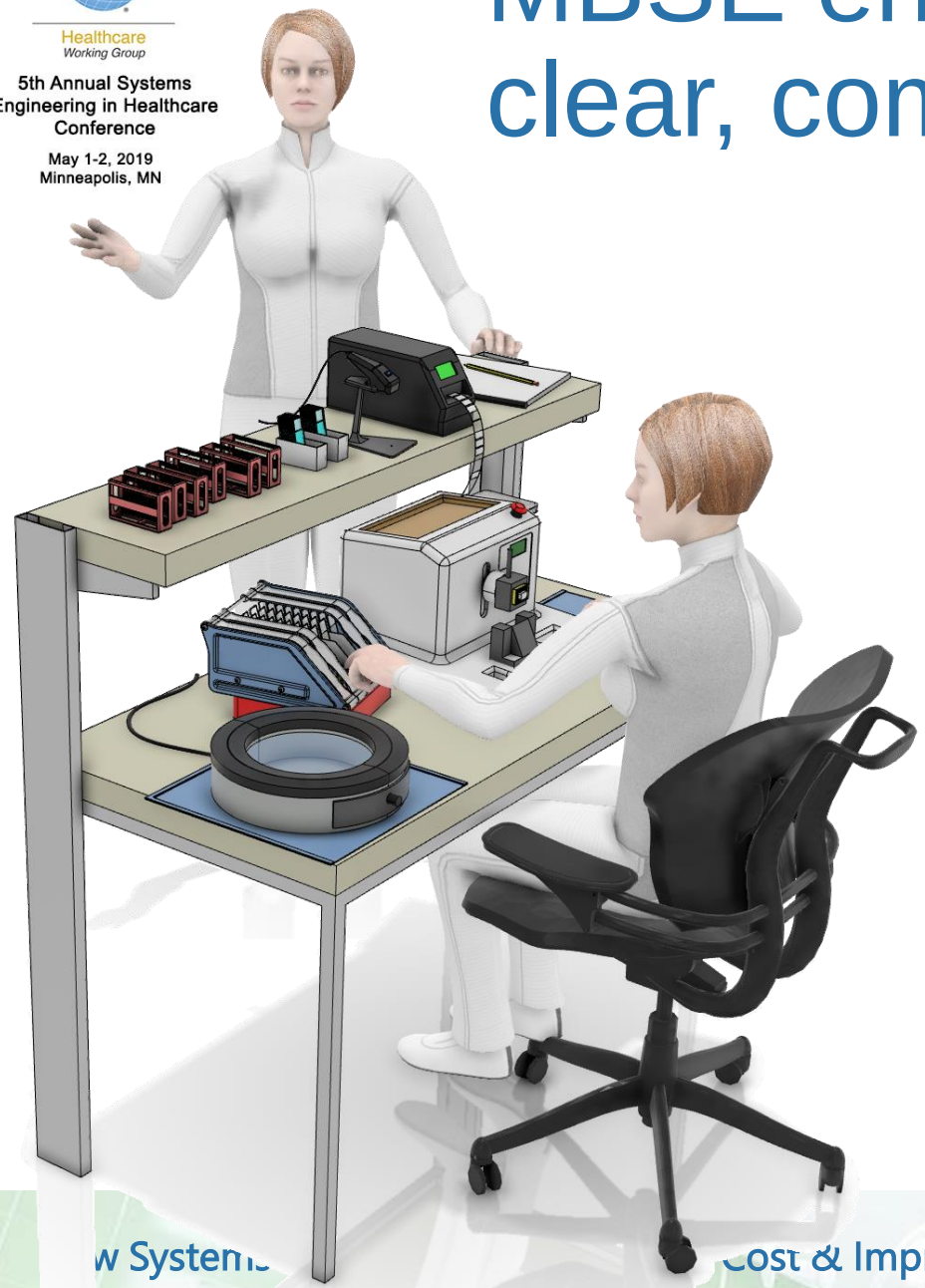
	Weapons	Healthcare delivery projects
Number of FT employees per project	Thousands -10,000s	2-3
Number of PT employees	Minimal	Several
Typical schedule	Tens of years	Weeks to months
Typical budget	$100 millions - billions	$ 10,000s to $100,000s
Typical number of top level requirements (lower levels x 10)	Hundreds to thousands	Tens
Complexity	Huge technical and political	Small (few unknown unknowns)
Execution	50 states	One clinic or hospital; then disseminated to others

INCOSE
Healthcare
Working Group

5th Annual Systems Engineering in Healthcare Conference

May 1-2, 2019
Minneapolis, MN

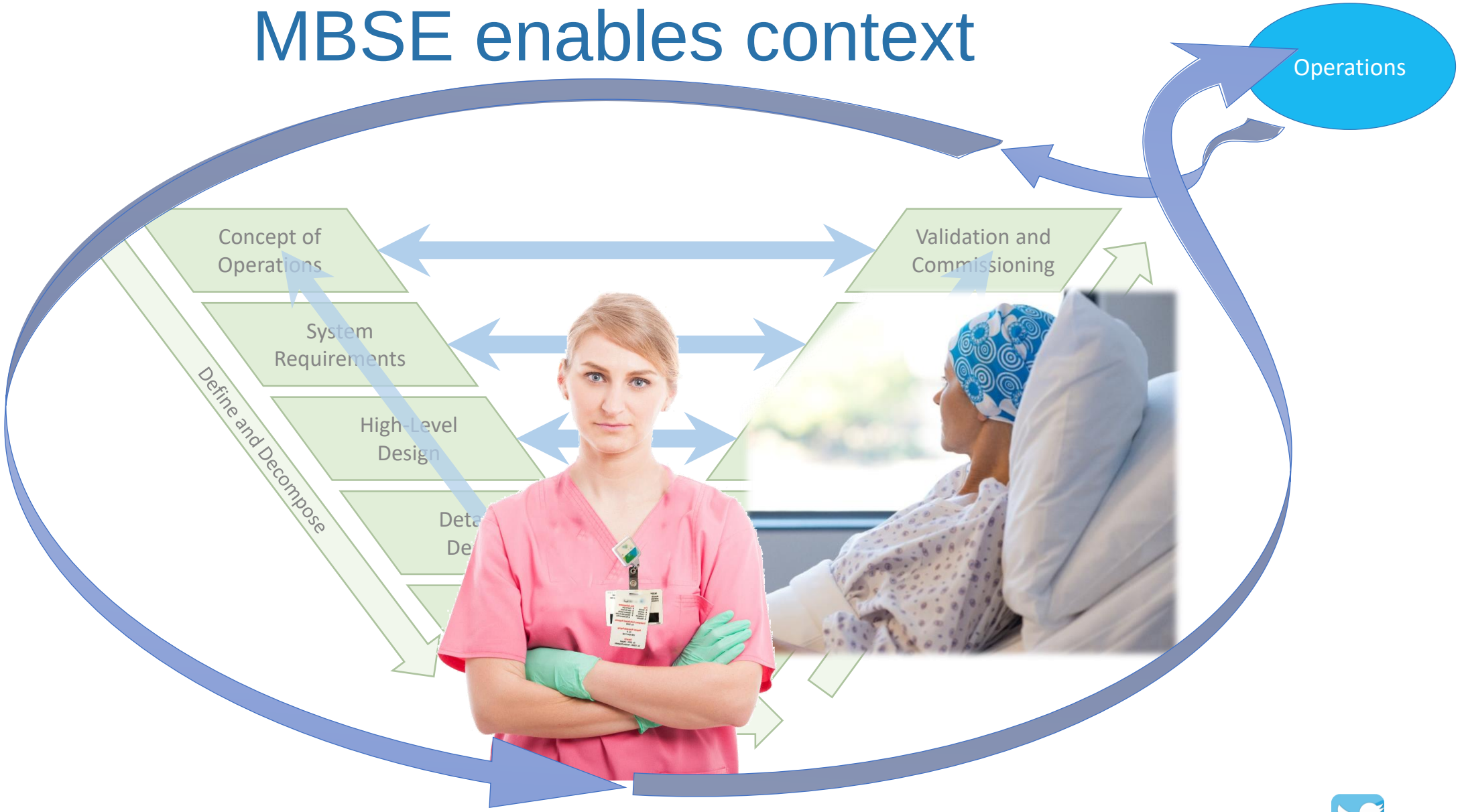
MBSE enables clear, common context



w Systems

Cost & Improve Quality

MBSE enables context



Case Study: The Problem

Stakeholder Needs

Define

Background:
The Puget Sound Medical Center performance on the Urinary Catheter Removal core measure was inconsistent across the health system during CY 11 and CY 12 with some entities performing below the target compliance rate of ≥ 96%.

Objective / Goal:
Achieve and sustain ≥ 96% compliance on Urinary Catheter Removal across all PSMC entities by CY 13.

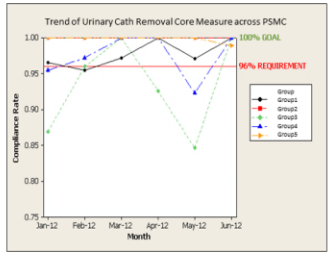
Team Members:
- PSMC Clinical & Quality Improvement KPO core team

Key Metrics:
- Monthly and Quarterly Urinary Catheter Removal core measure compliance data
- Detailed case data on failure modes (providing opportunities for data driven interventions)
- "Bright spots" (interventions that are driving high reliability)

Measure

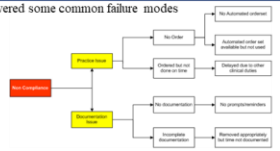
Sampling approaches
Discussion revealed variability in sampling methods

Current Year Data:



Analyze: Identifying & Prioritizing root causes of failures and "bright spots"

Initial meetings uncovered some common failure modes



Identified Challenges:
- Removed before midnight POD2 and not documented until after midnight POD2
- Not removed by midnight POD2 and no documented reason for maintaining the urinary catheter
- Patient transferred between units and communication unclear during handoff
- Not all providers using automated order sets (some continue on paper)
- Removing catheter not on ICU checklist when patient transferred from ICU to unit
- Small population size for some entities

Improve

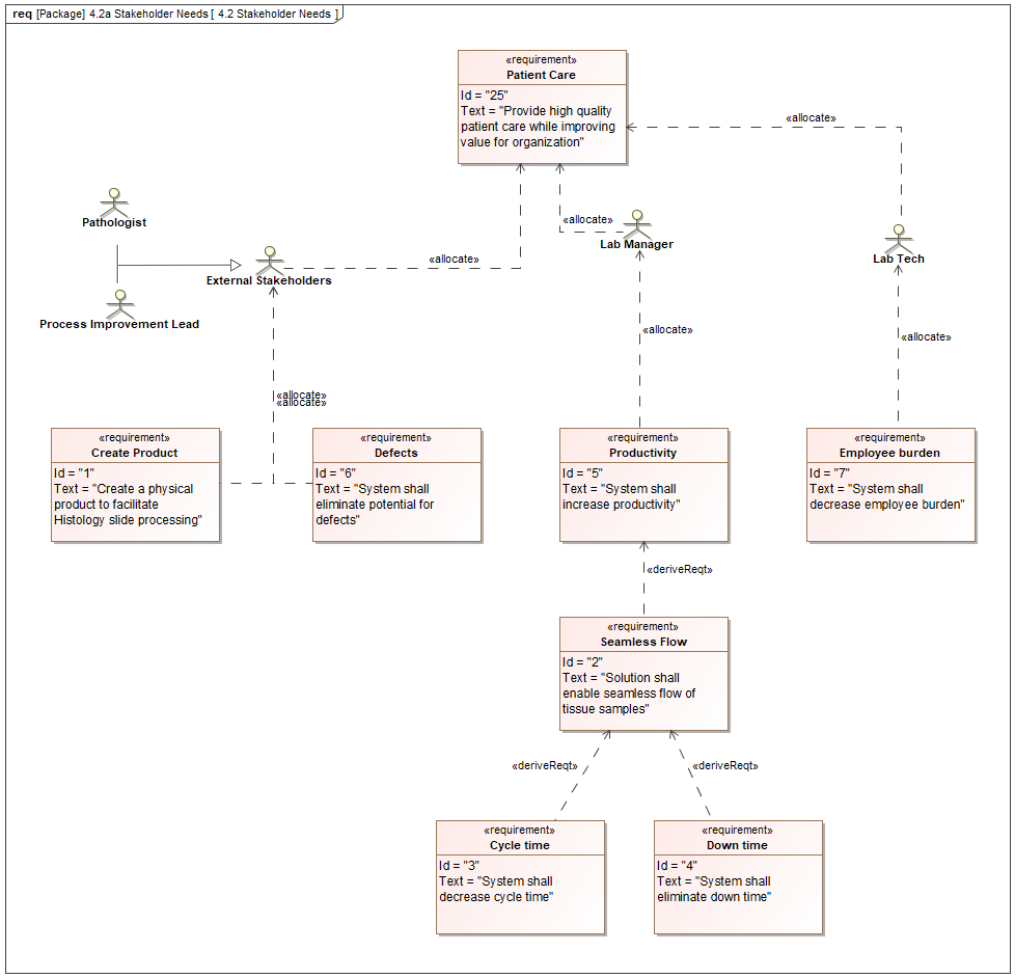
Optimize abstraction/sampling techniques for each entity.
Leverage when possible "bright spot" concepts performing well within the health system.

Order sets, Alerts and Feedback Loops:
- Nurse driven protocol with order sets – to remove w/i 24 hours
- Some data sets have drop down menus to select why catheter not removed
- Concurrent reviews
- Direct education for nurses when catheters not removed
- SBAR assessment of failures

Stakeholder Needs
- Create a physical product to facilitate Histology slide processing
- System shall enable seamless flow of tissue samples
- System shall decrease cycle time
- System shall eliminate down time
- System shall increase productivity
- System shall eliminate potential for defects
- System shall decrease employee burden

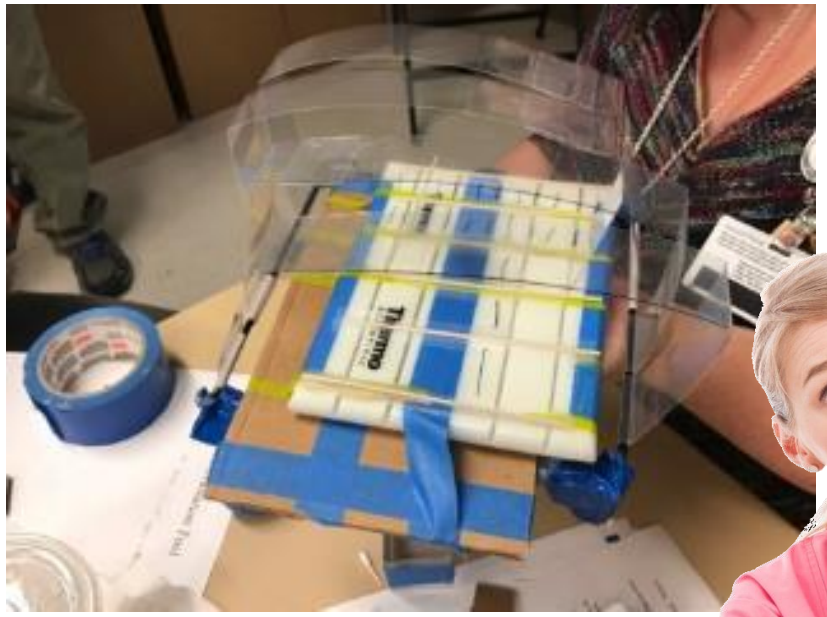
Control: Achieving High Reliability

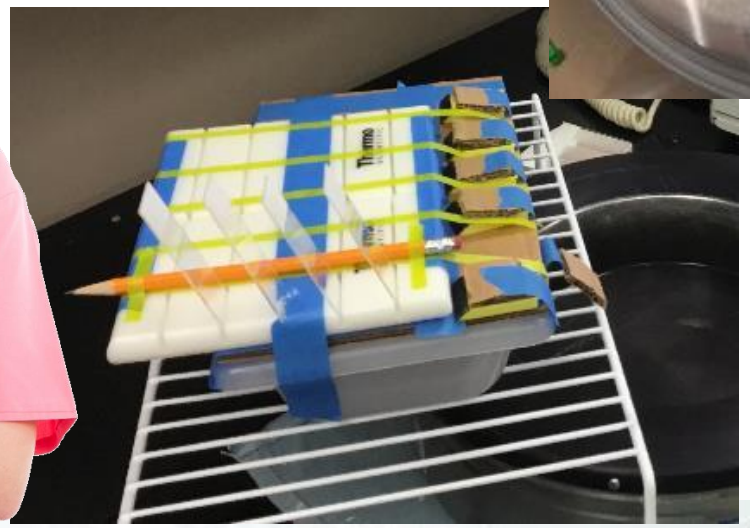
Improvement Verification & Future Stability:
TBD



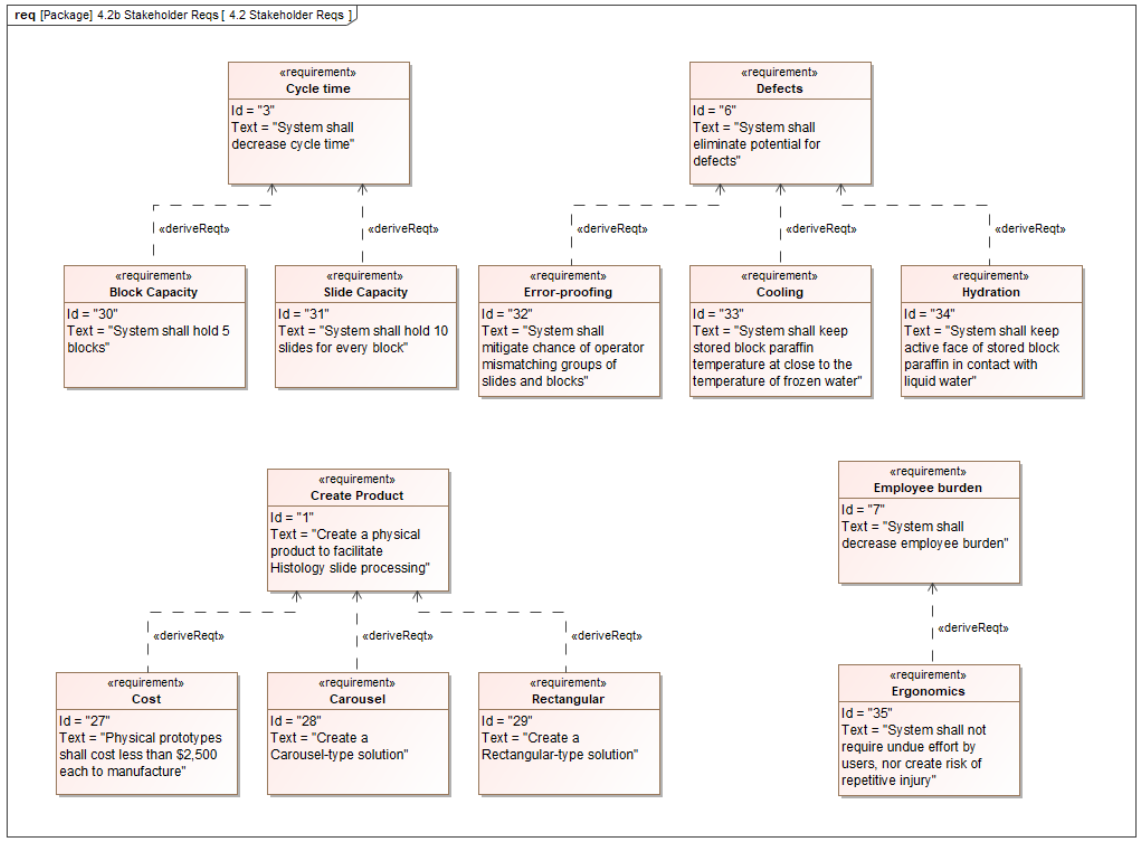
Note: for more rigorous use of SysML in care delivery, see Malins (2018).

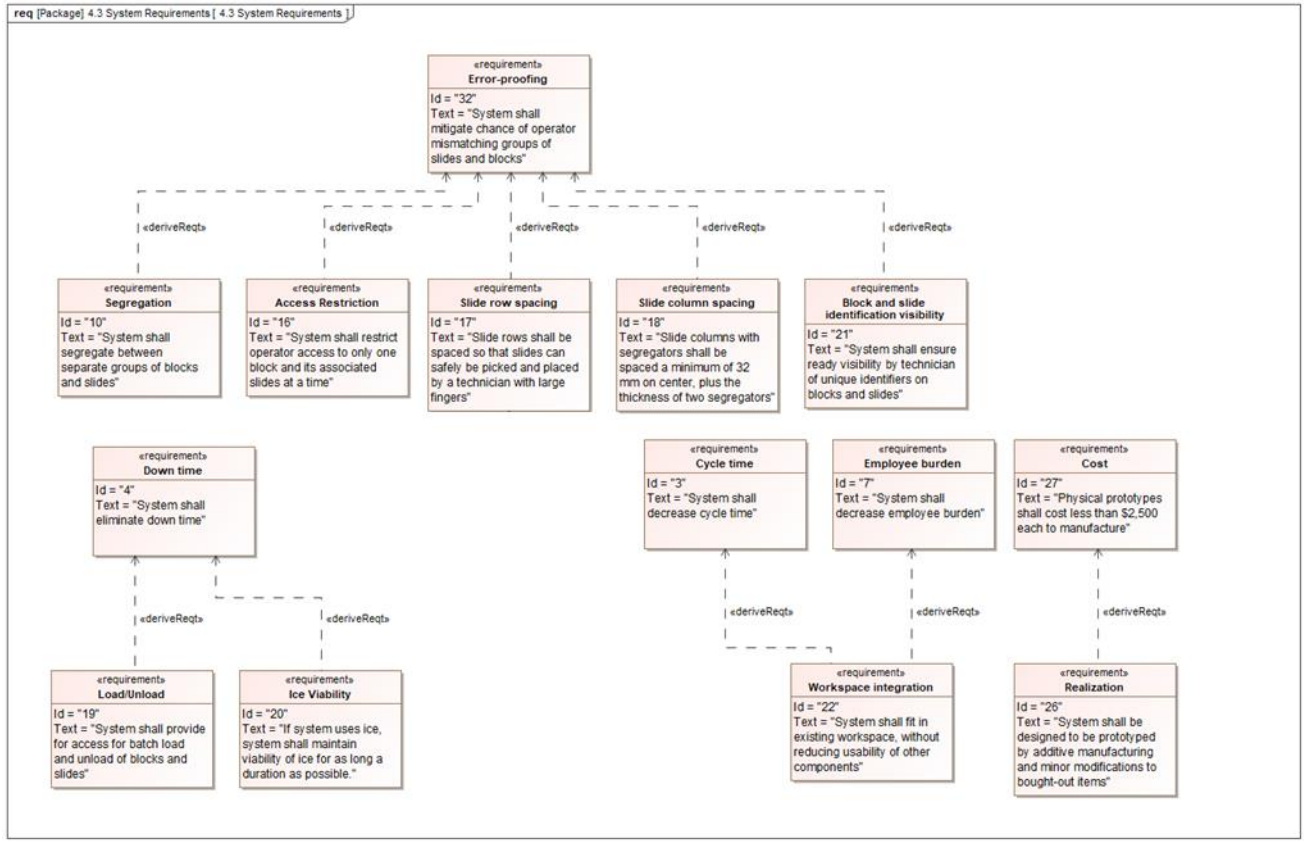
Innovation Day – Initial mockups



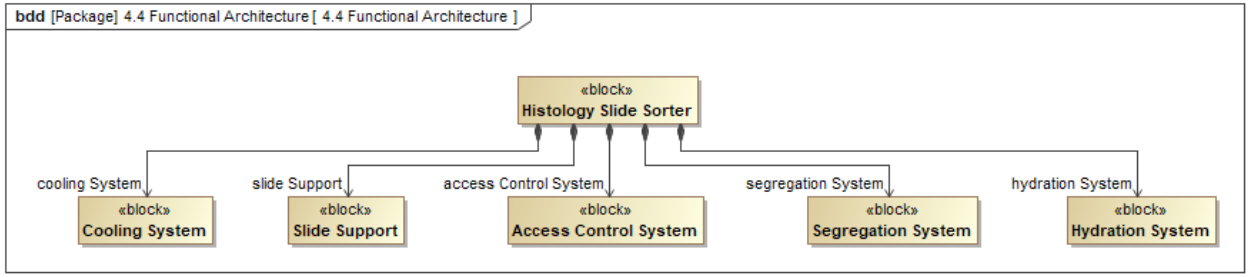


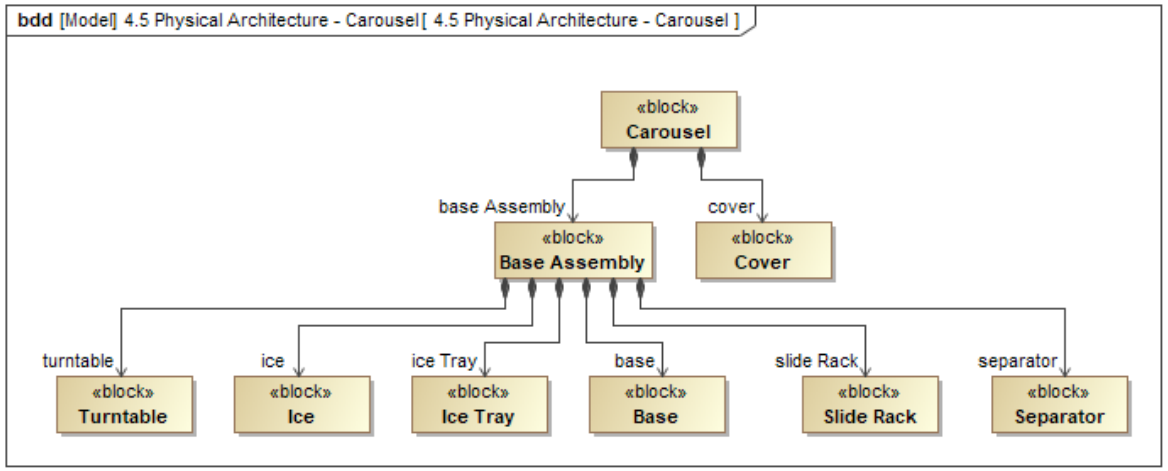
Stakeholder & System Requirements

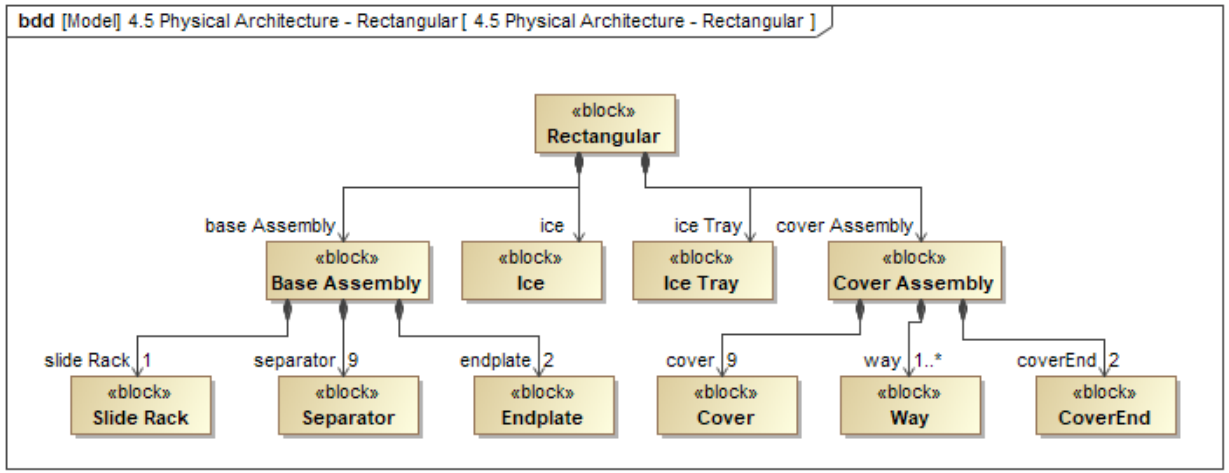




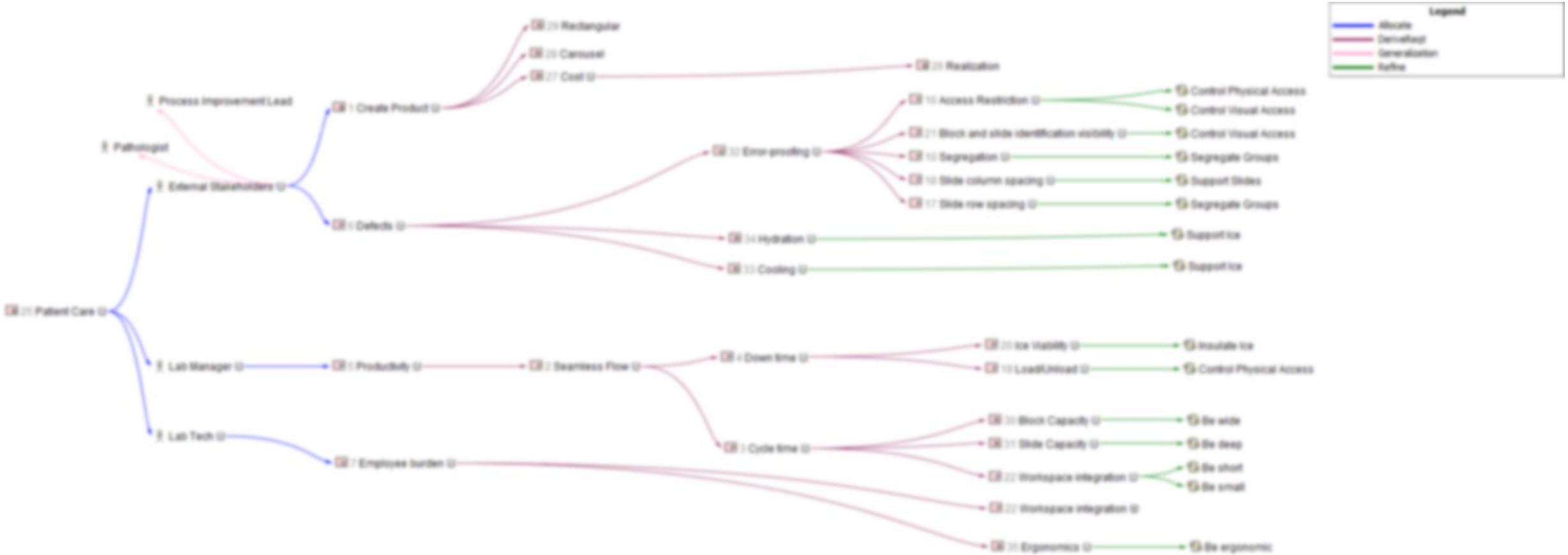
System Architecture







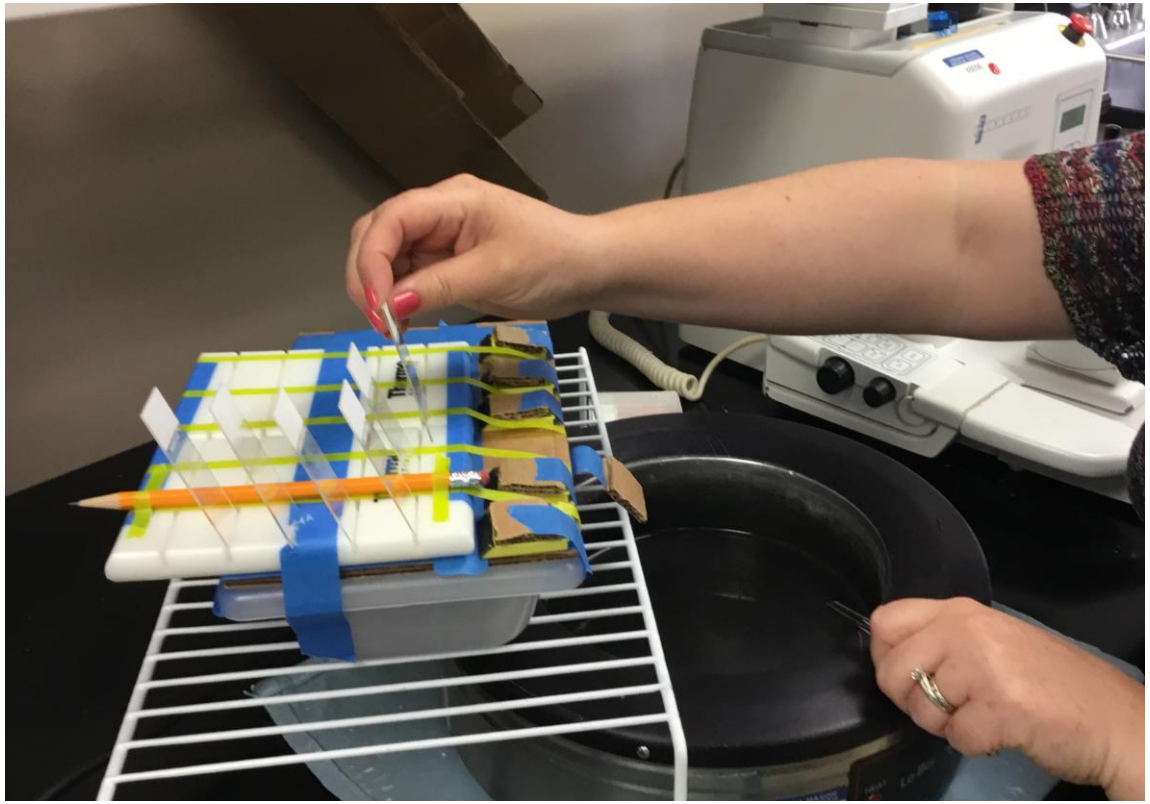
Requirements Flowdown



Requirement Elicitation

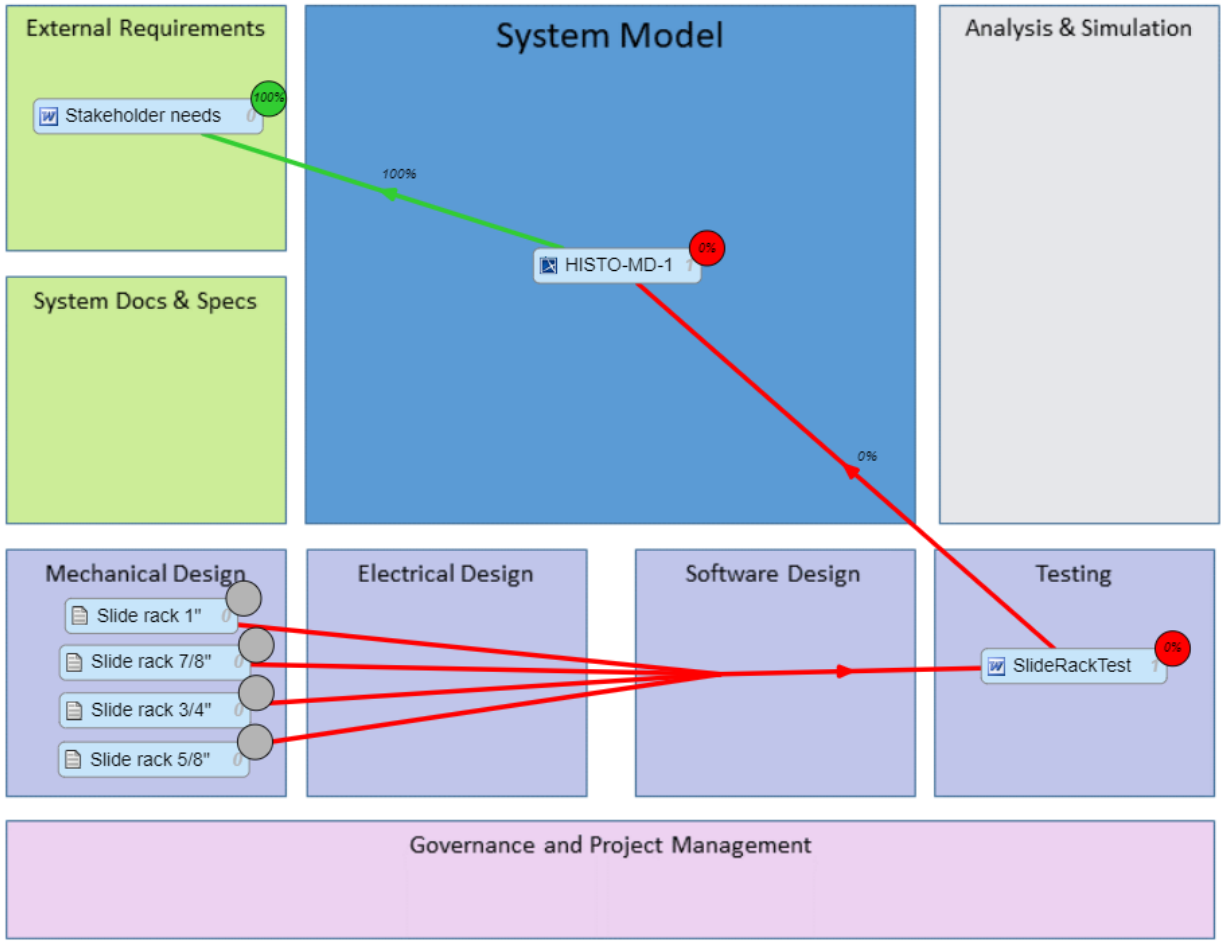
«requirement»
Slide row spacing

Id = "17"
Text = "Slide rows shall be spaced so that slides can safely be picked and placed by a technician with large fingers"

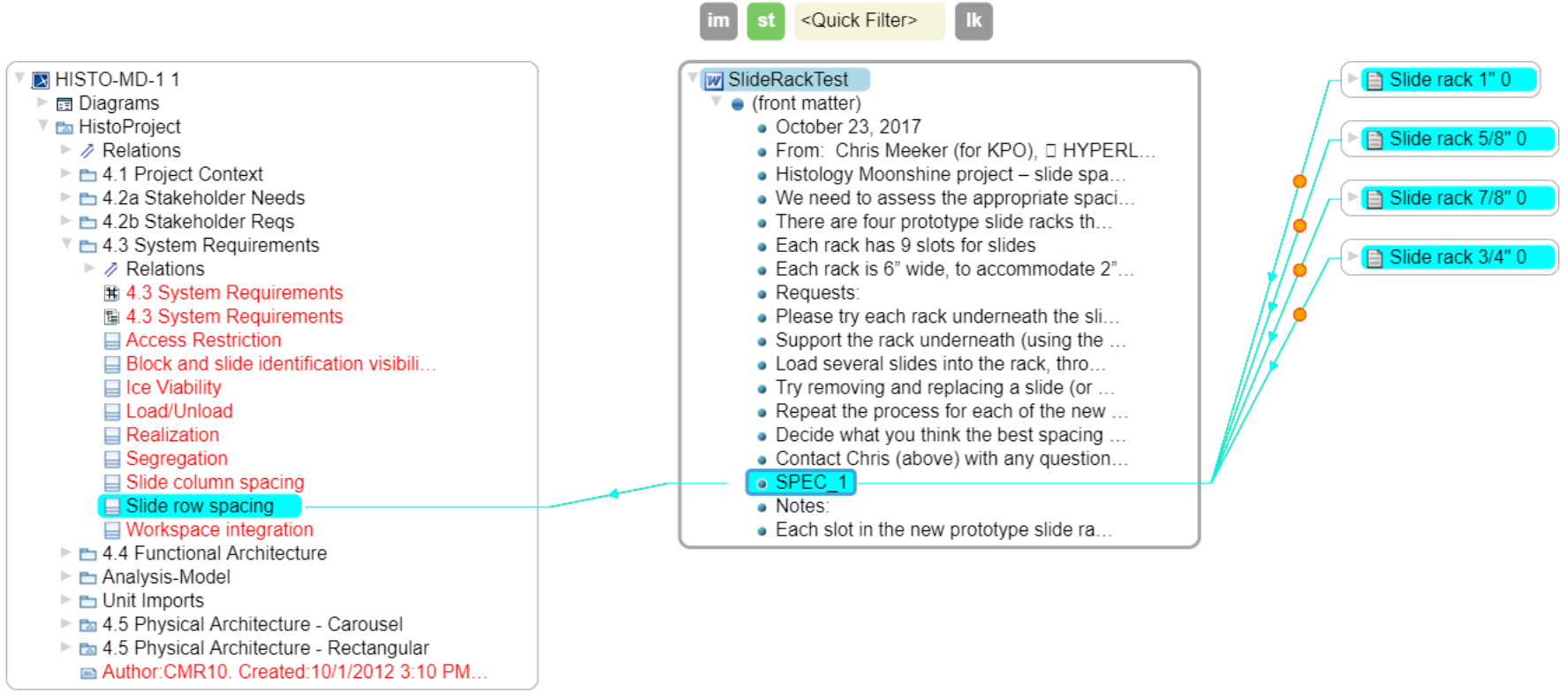


Requirement Elicitation

Coverage for Test



Traceability for Test

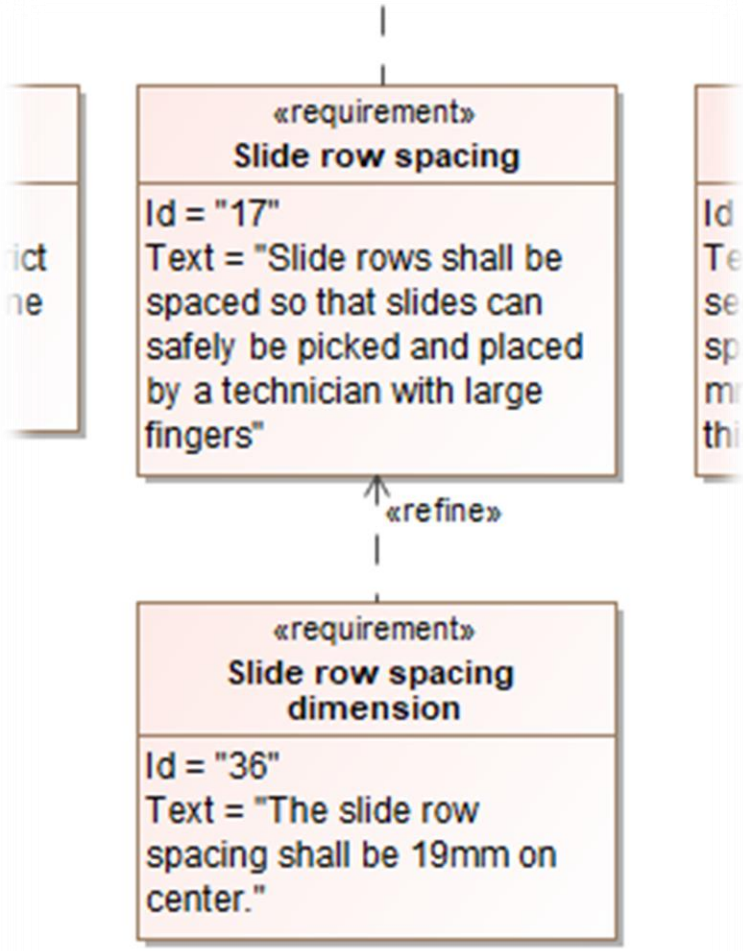


SPEC_1

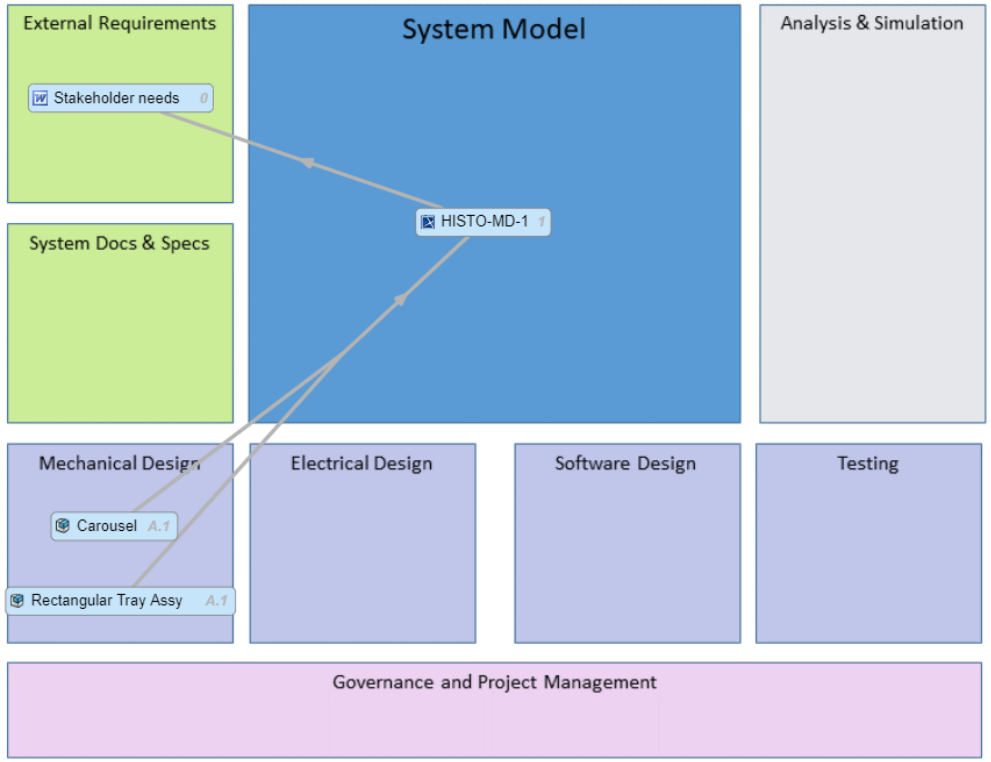
Description

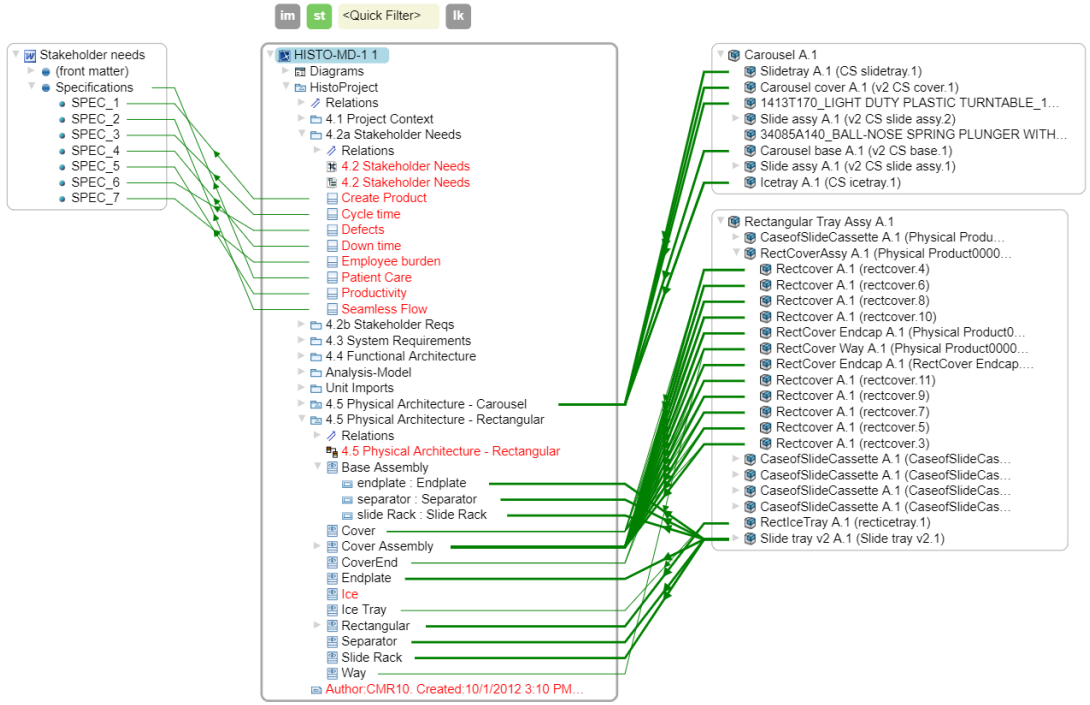
Decide which spacing is preferable by technicians with various hand size.

Requirement Refine

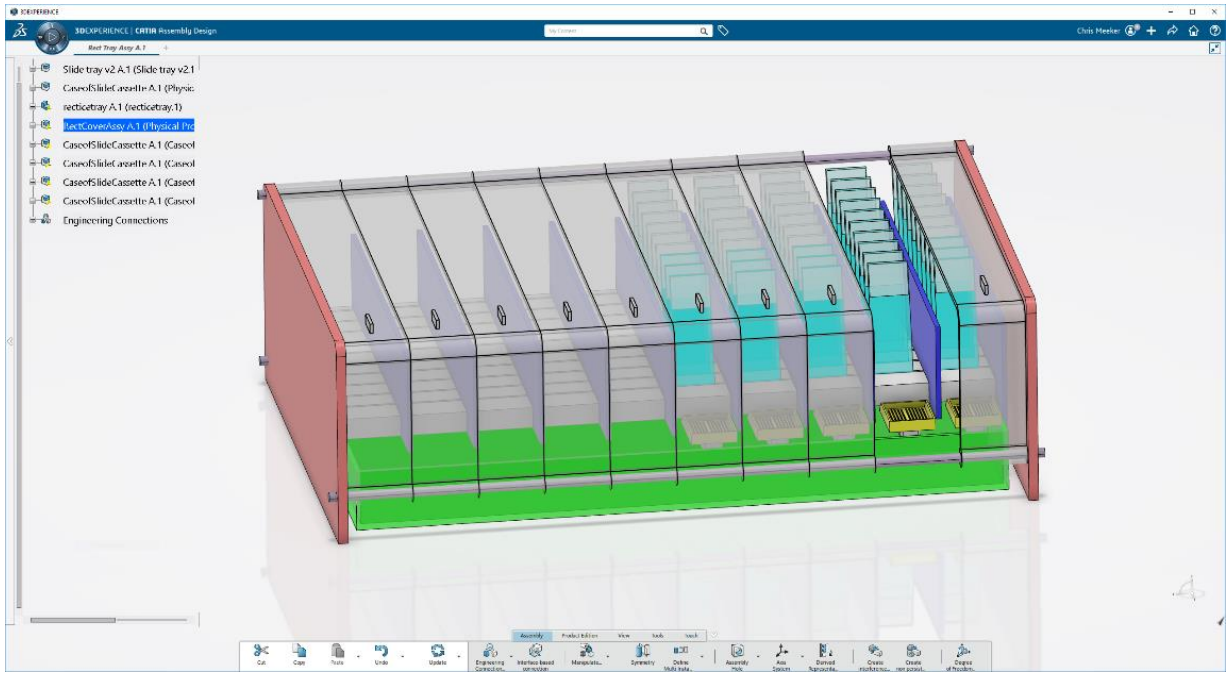


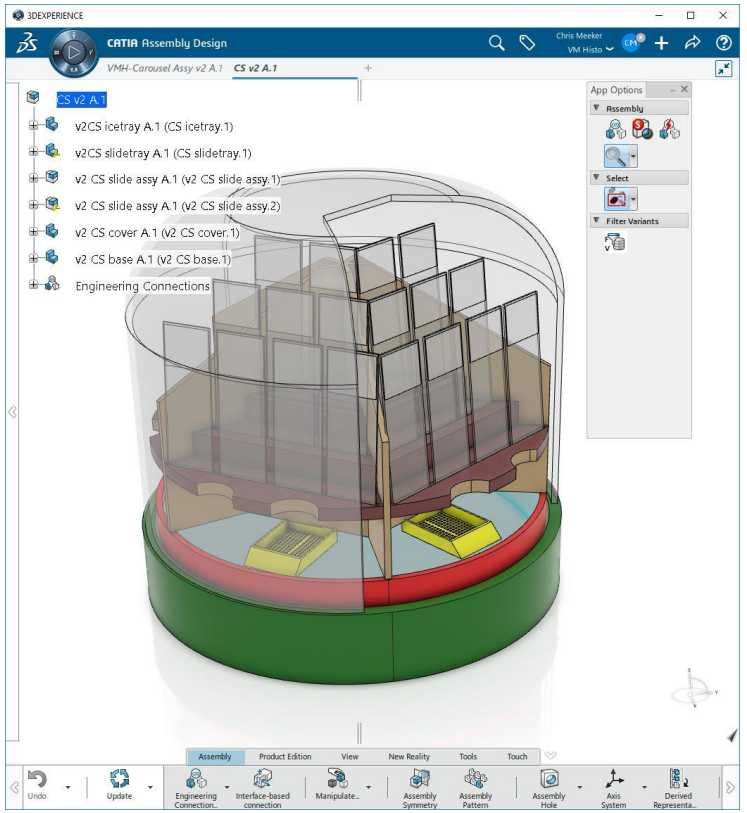
Linkage to 3D models





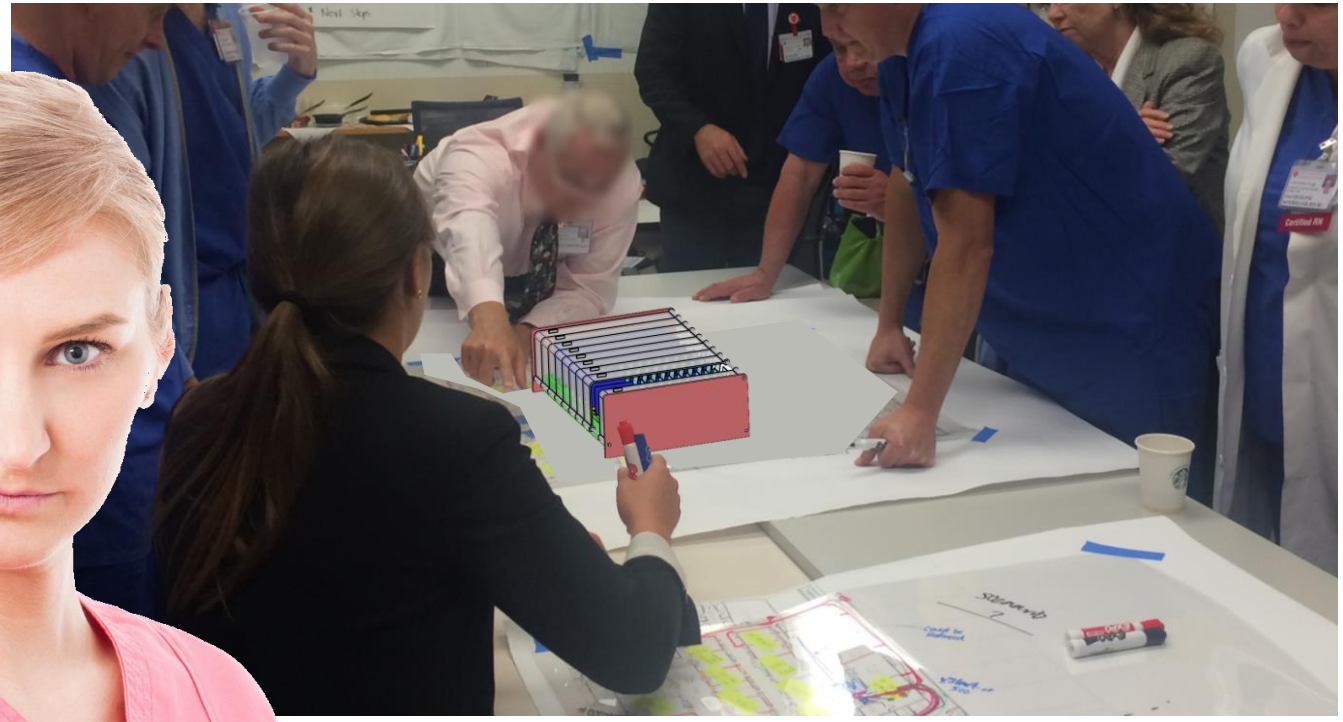
Conceptual Design – Version 1





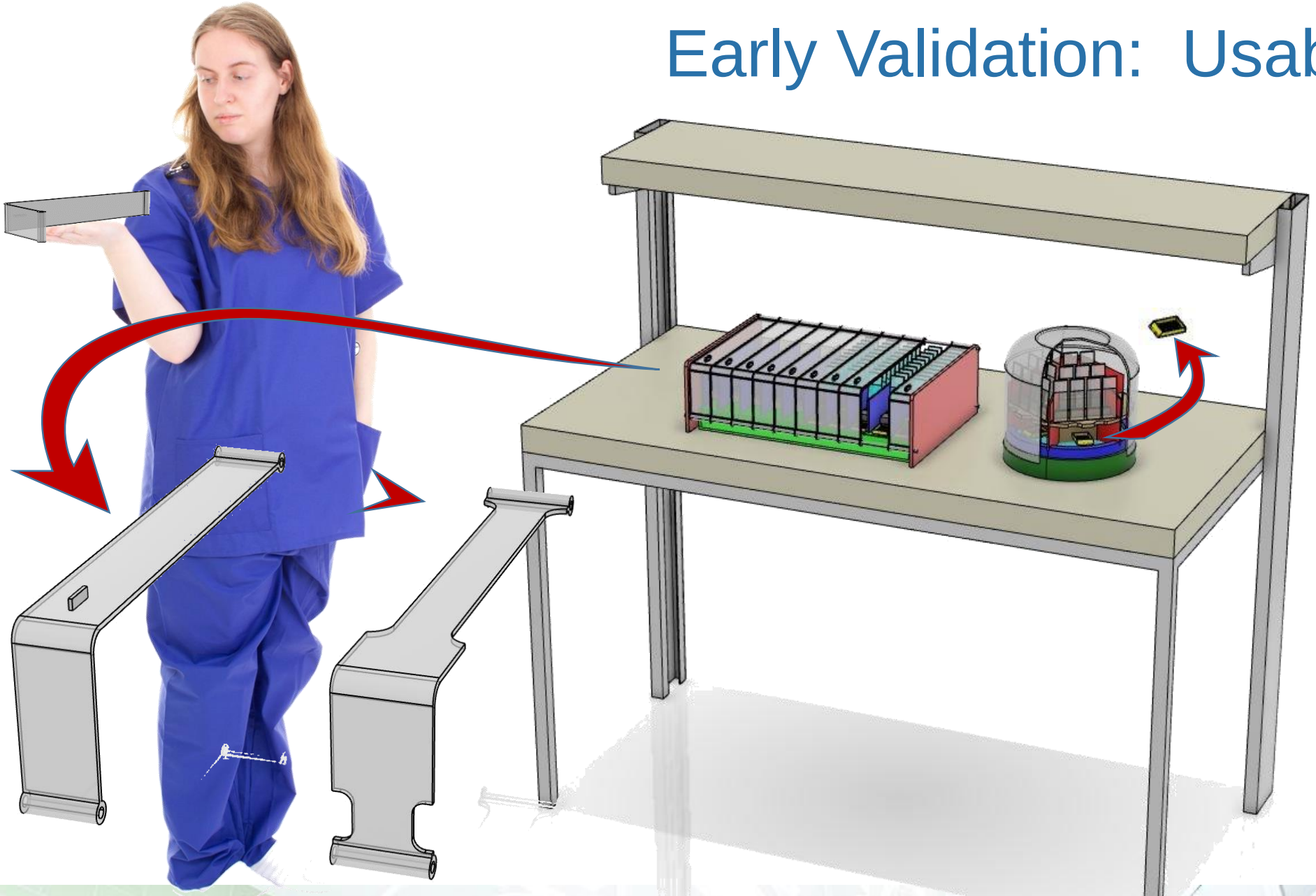
Early validation with end-users: Version1

Early validation with end-users: Augmented Reality

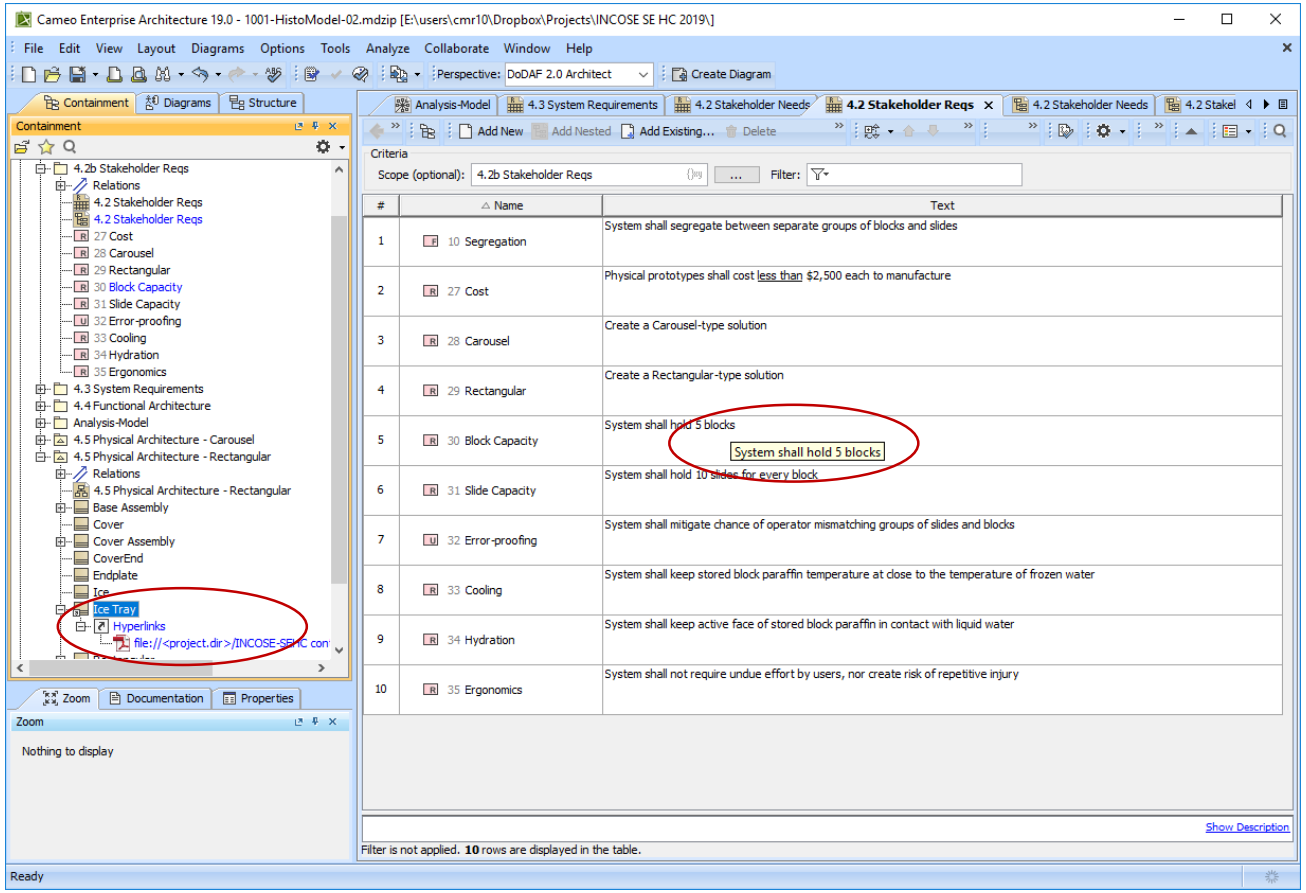


Early Validation: Conflicting requirements

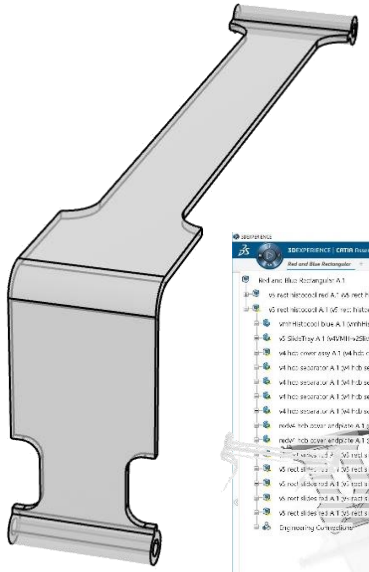
Early Validation: Usability

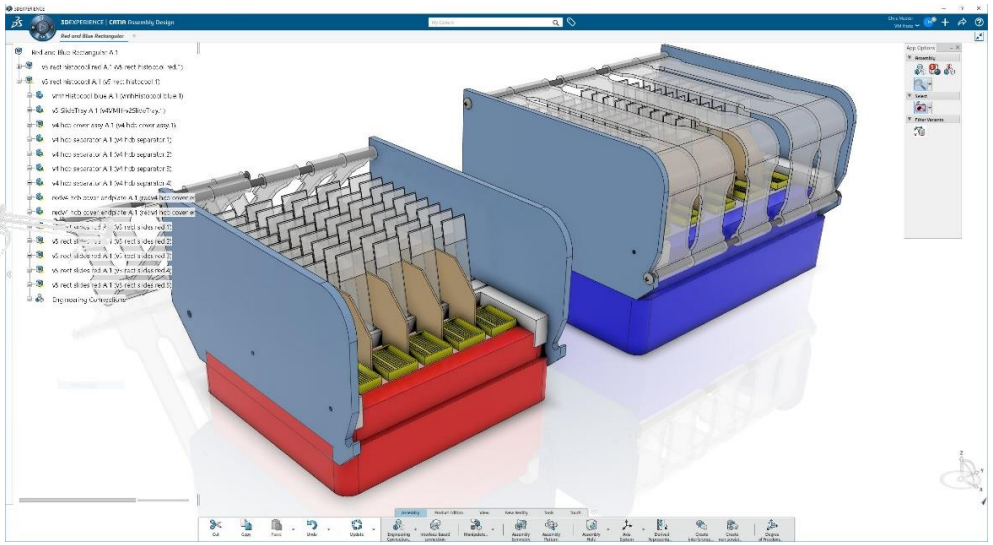


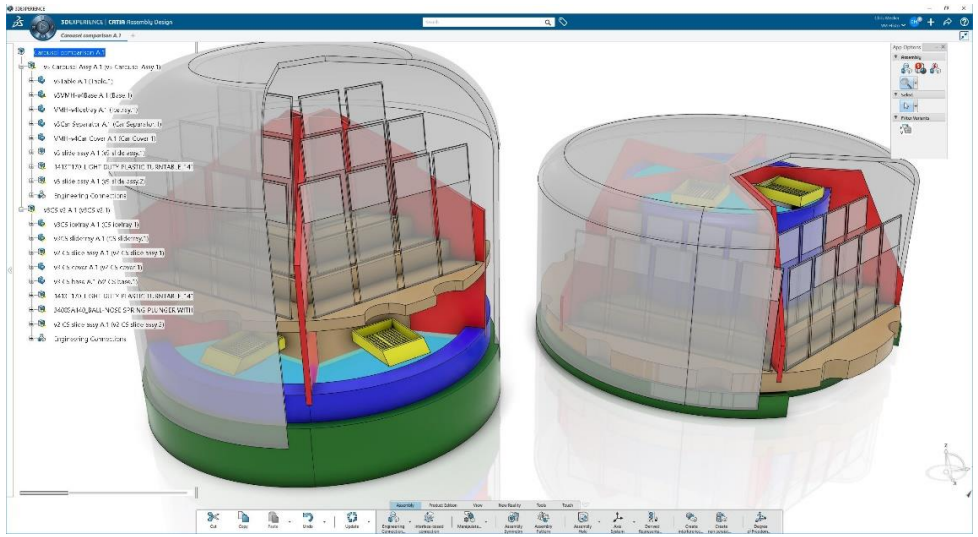
System Model – Version 2



Conceptual Design – Version 2

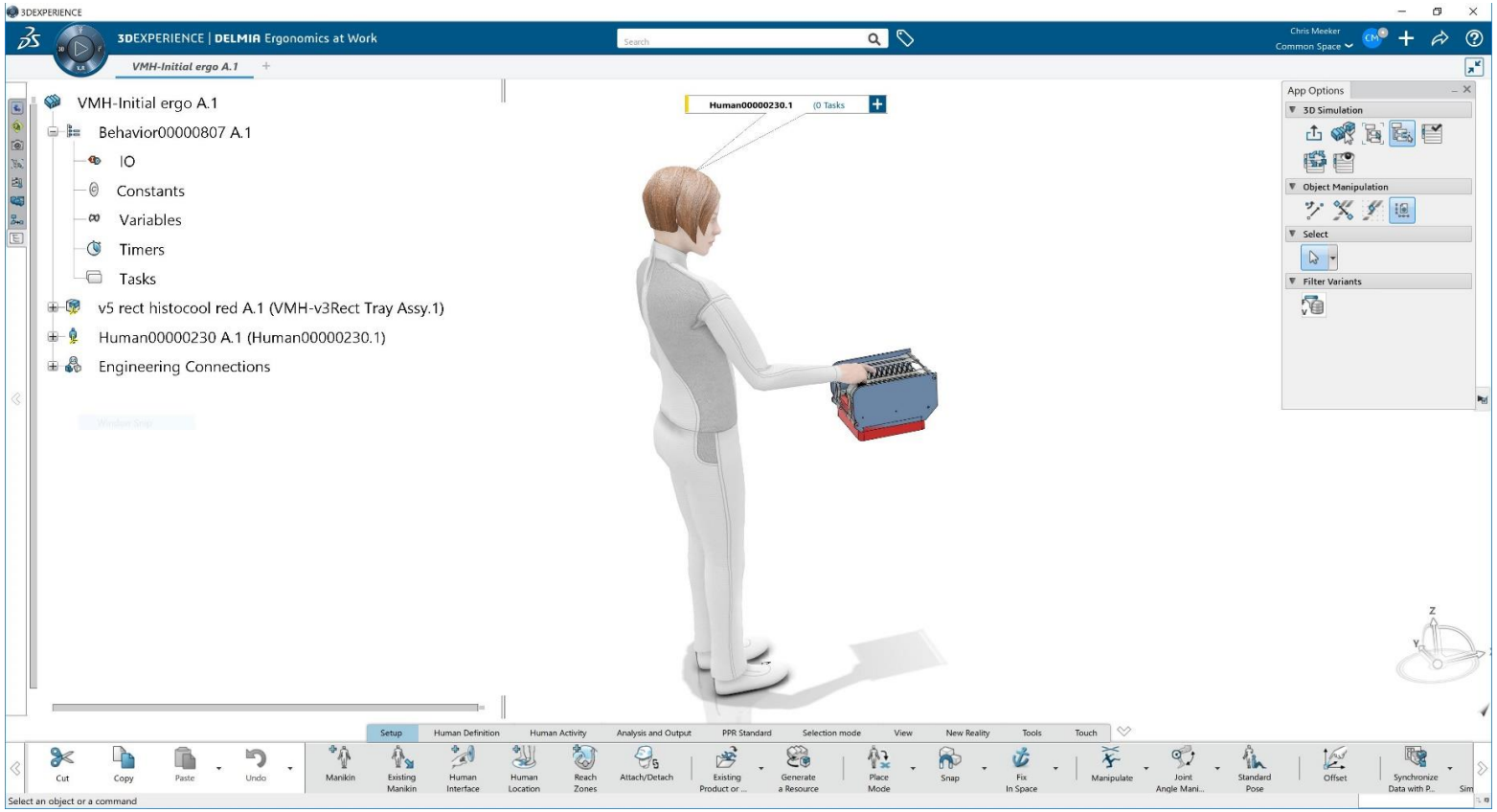


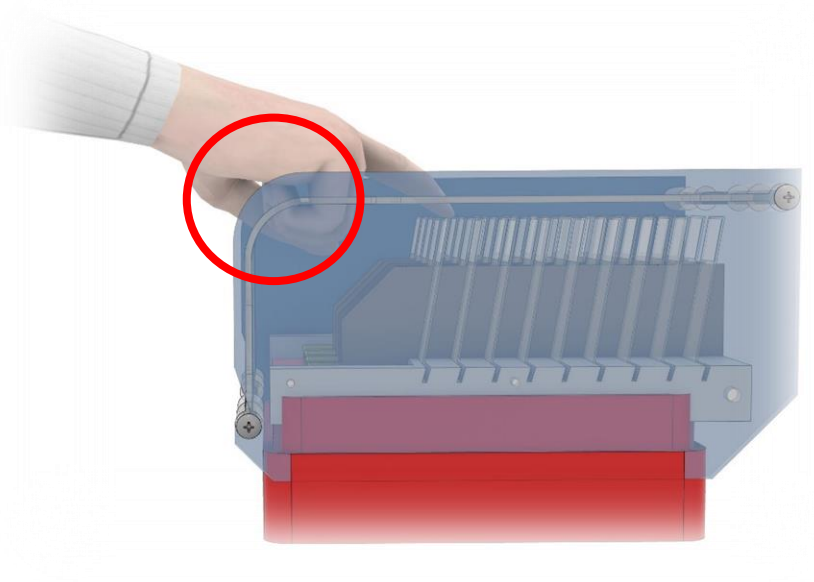




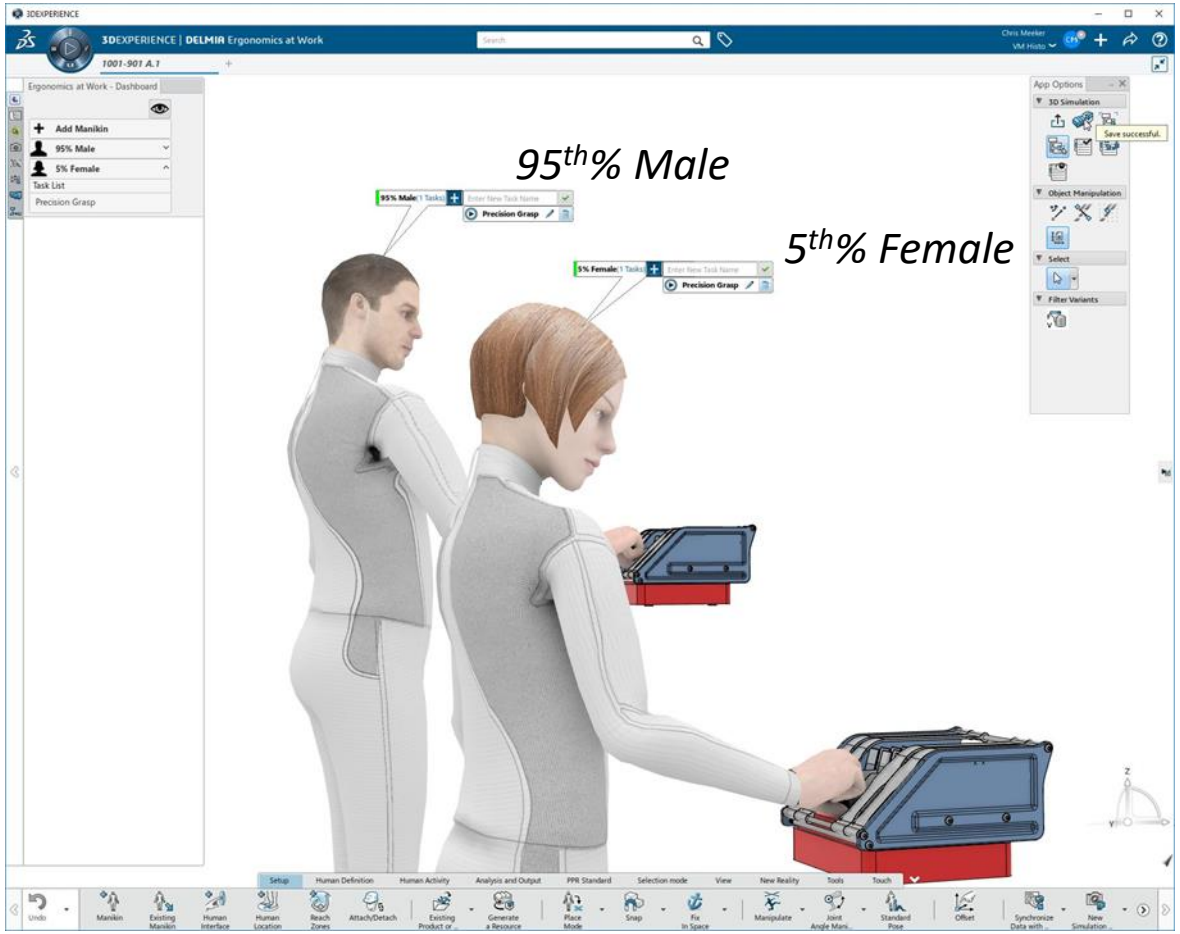
Early Validation: Version 2

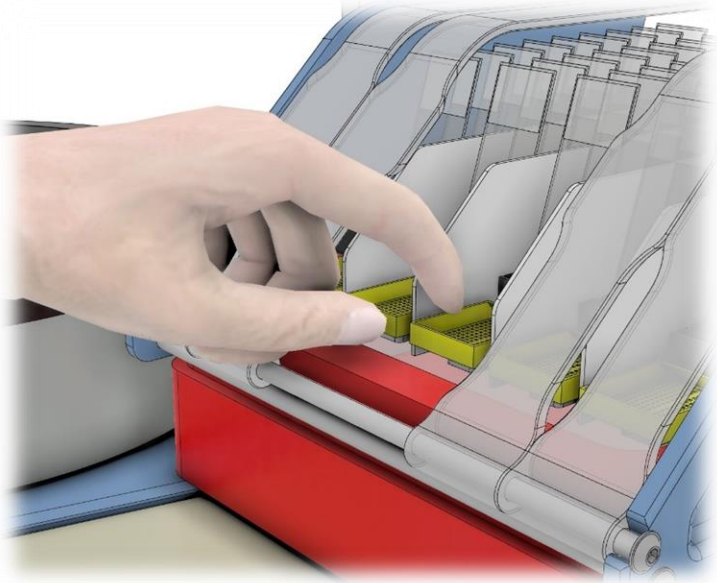
Early Validation: Virtual Human Factors



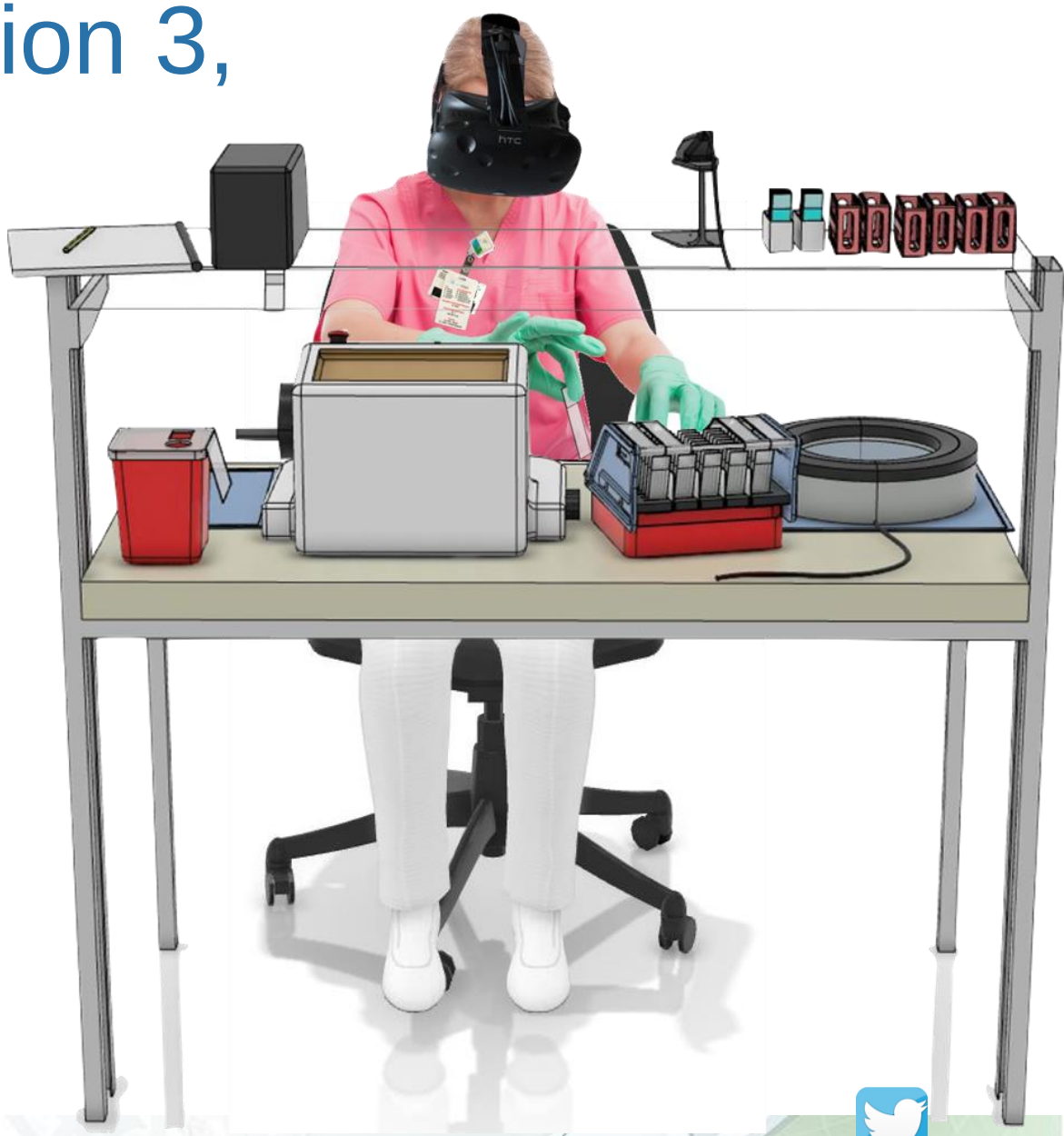


Virtual Human Factors

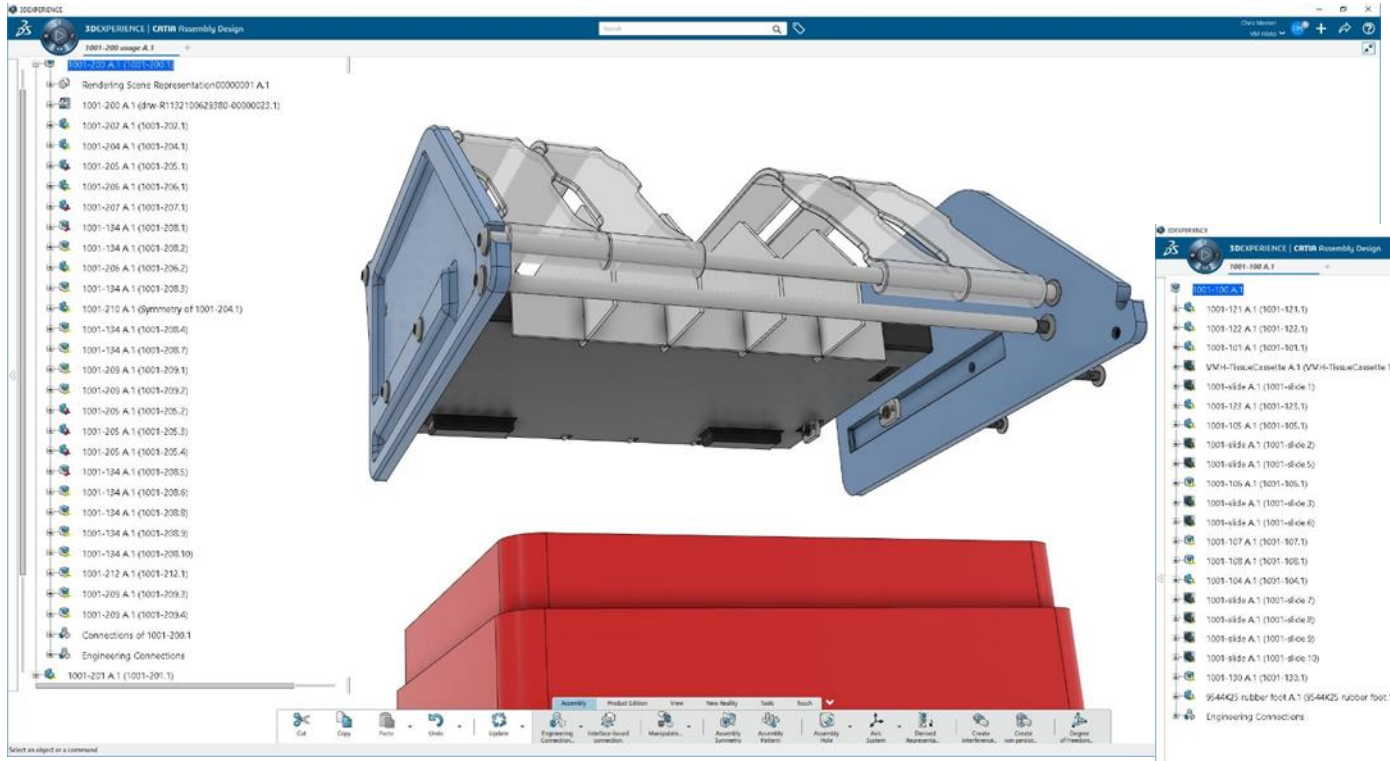


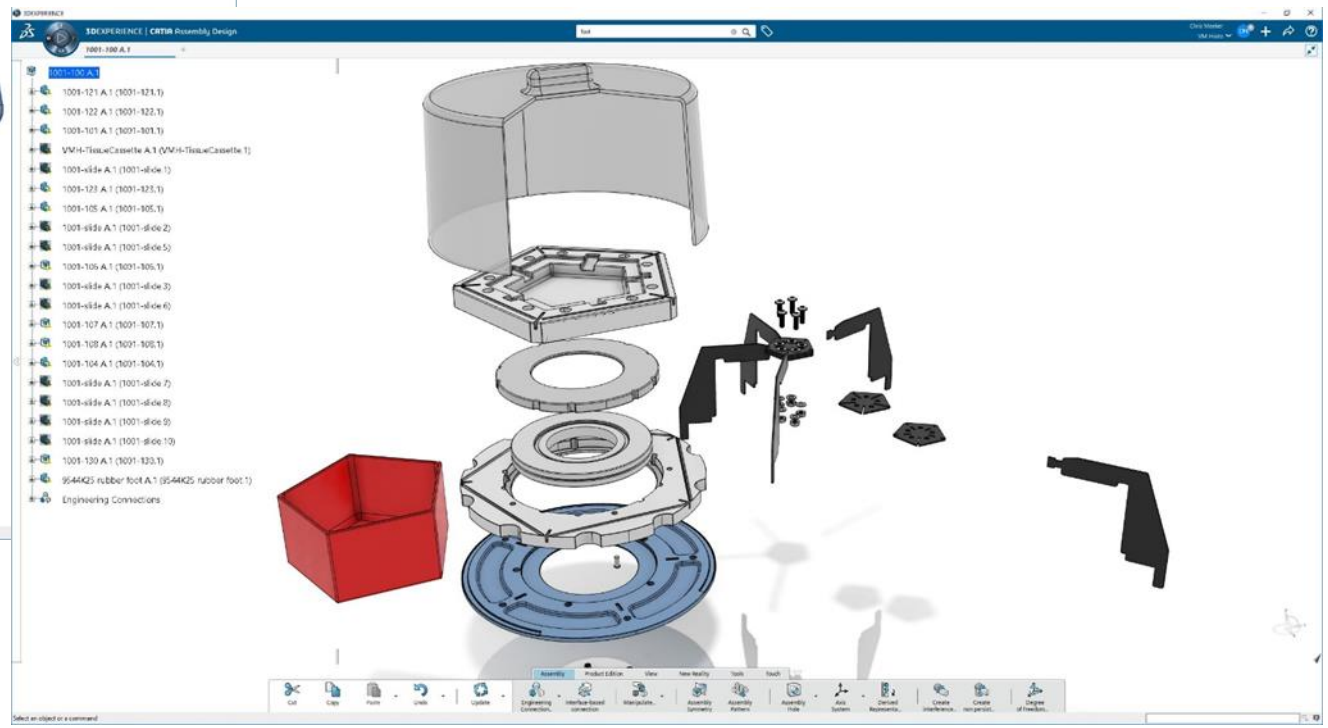


Early Validation: Version 3, Virtual workspace assessment

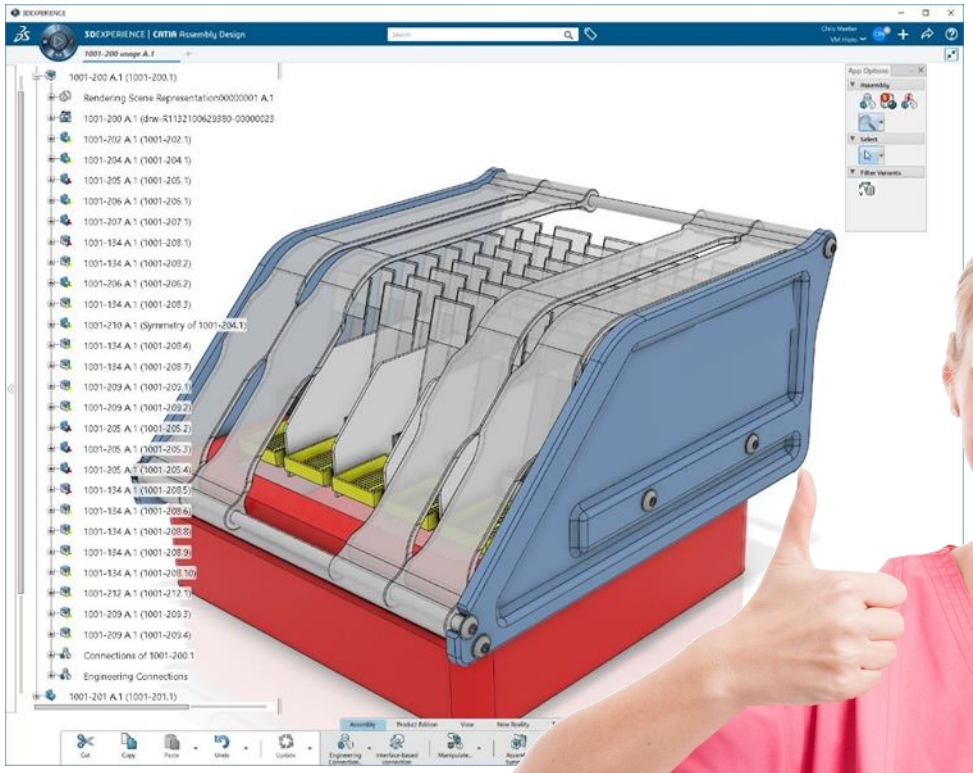


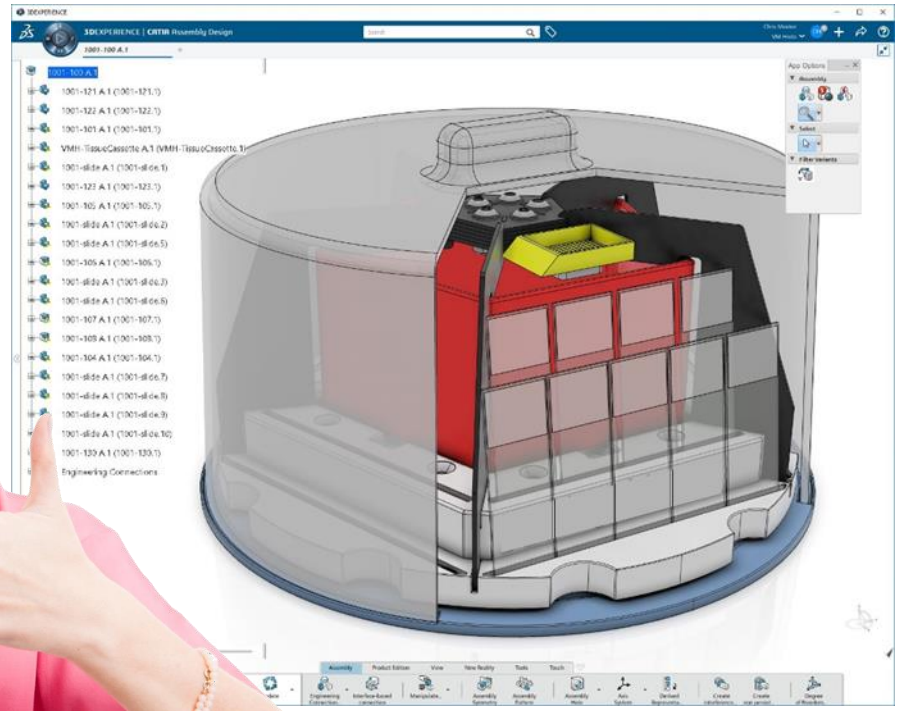
Detailed Design: Version 3





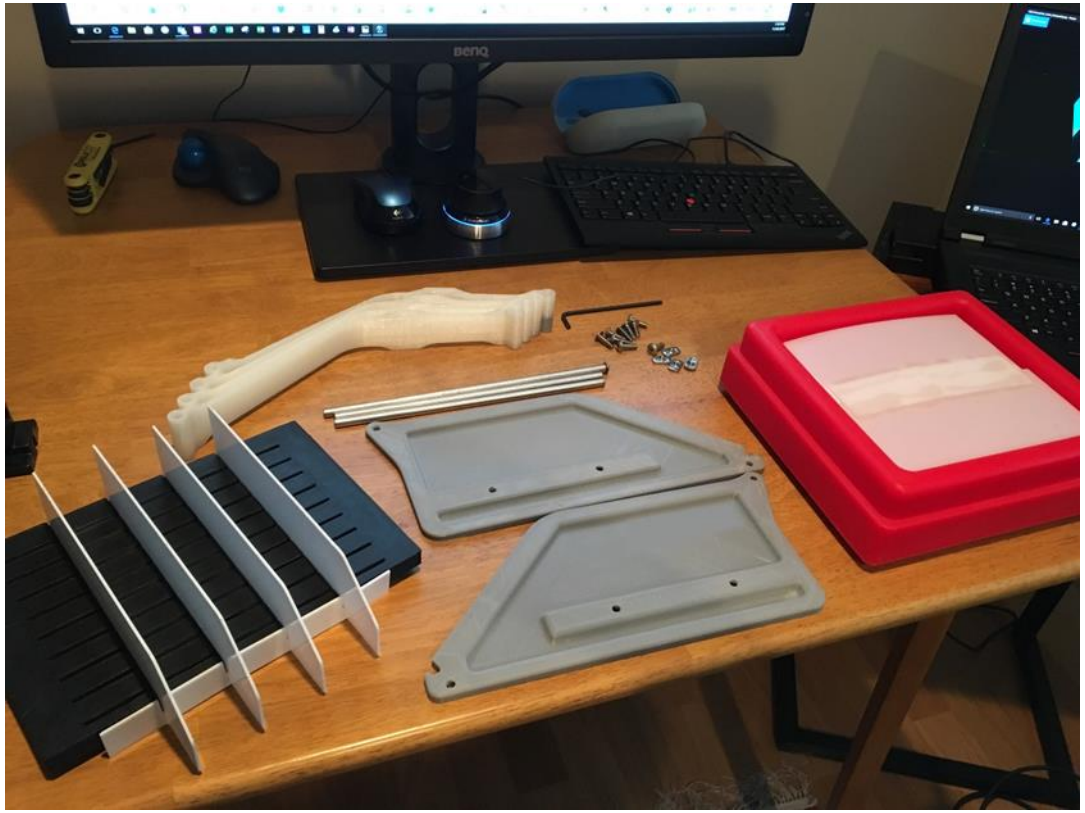
Stakeholder buy-in: Version 3

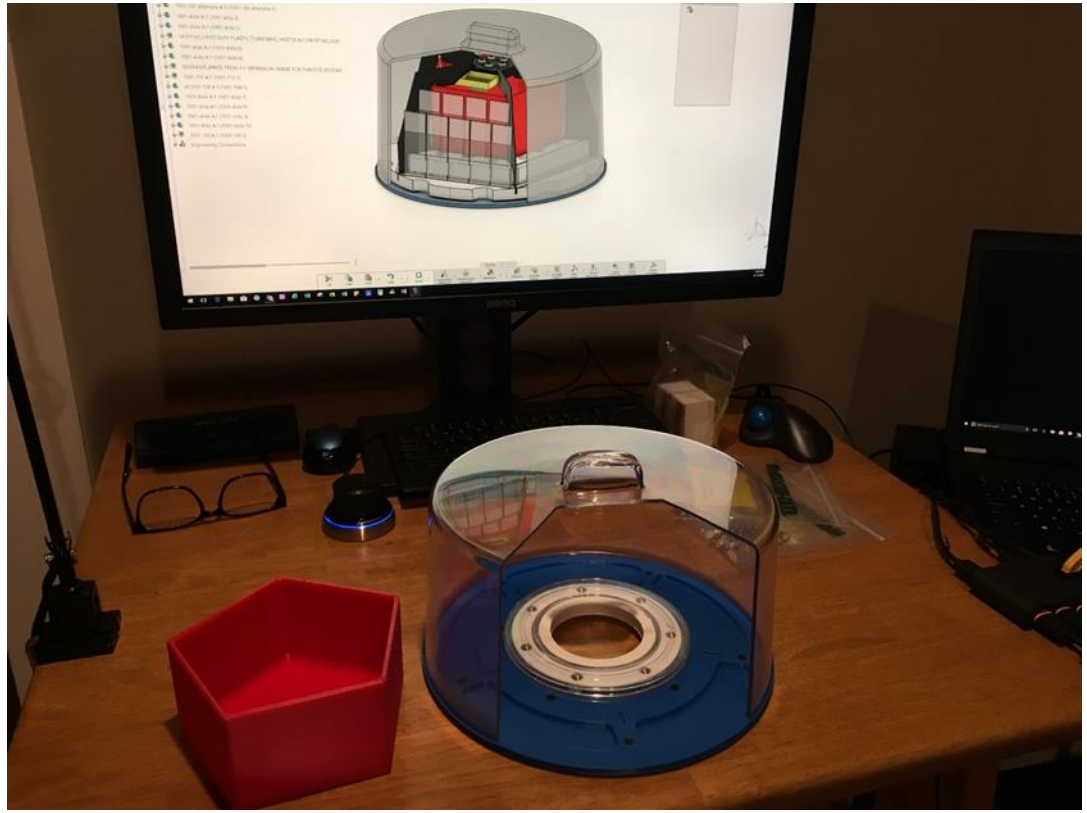




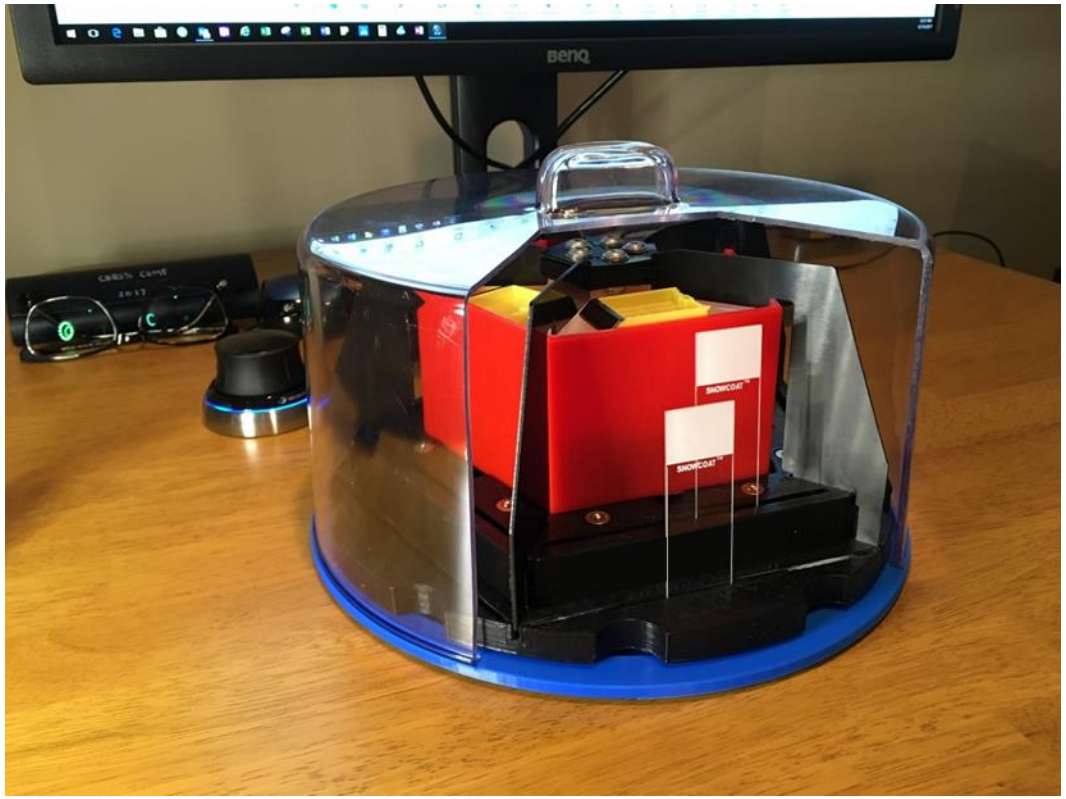
Parts ready for 3D printing

3D printed parts



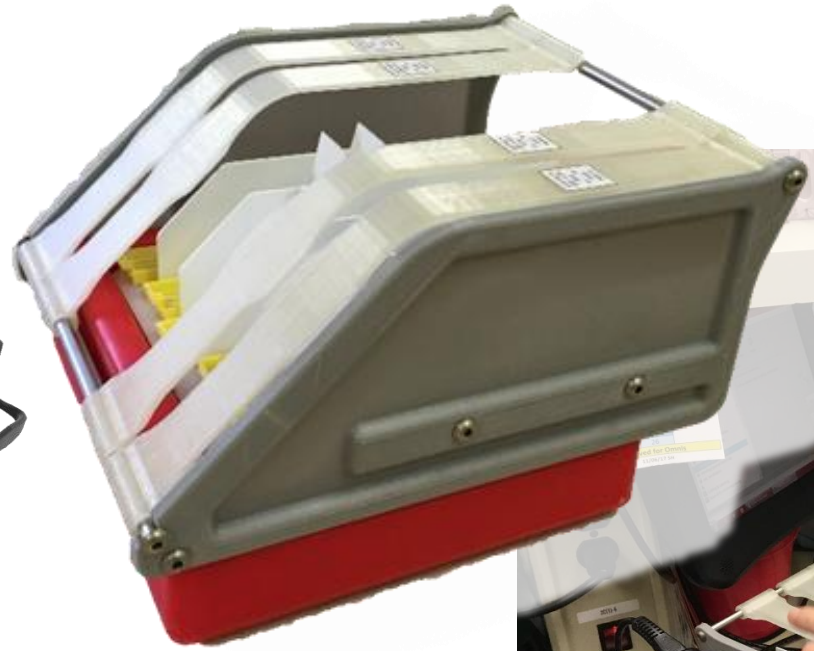


Rapid Prototyping / Assembly

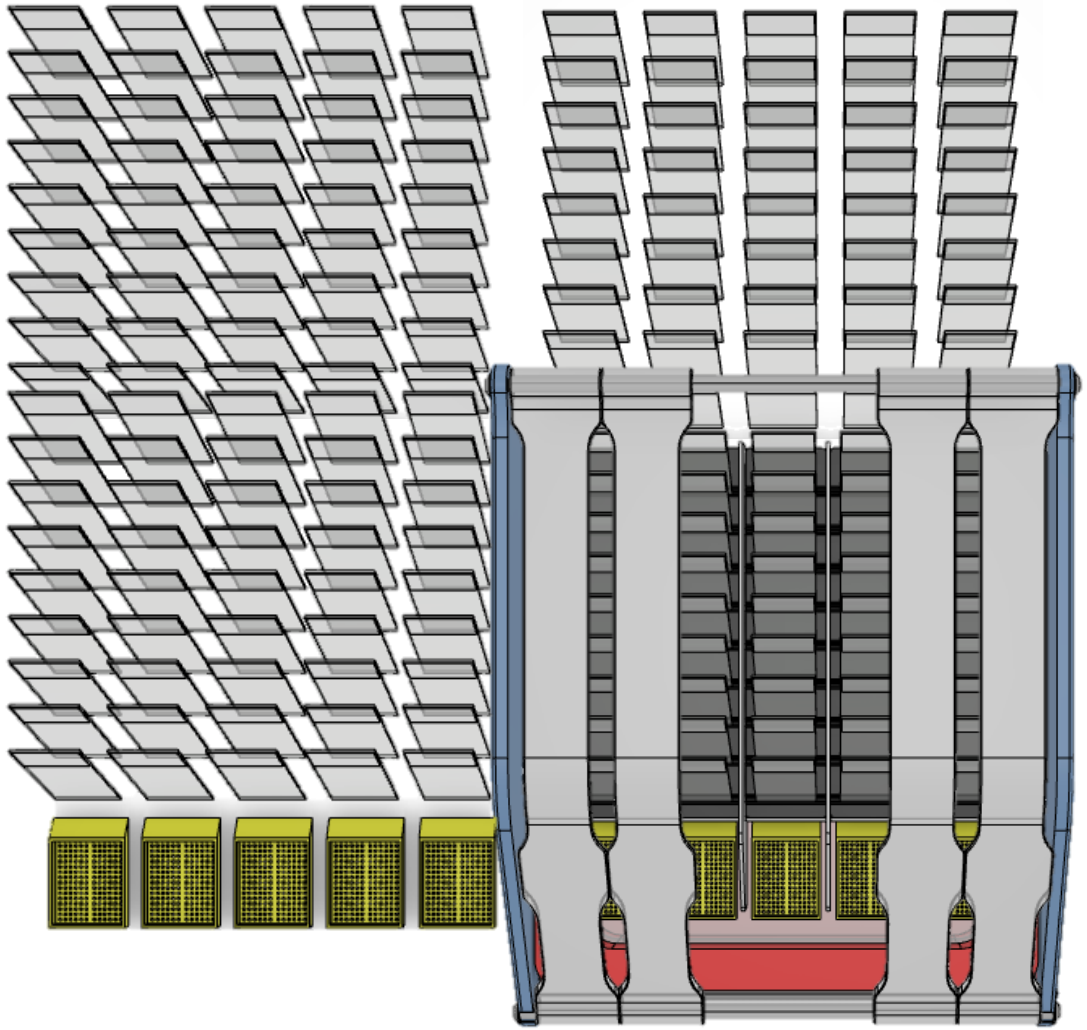


Use Testing

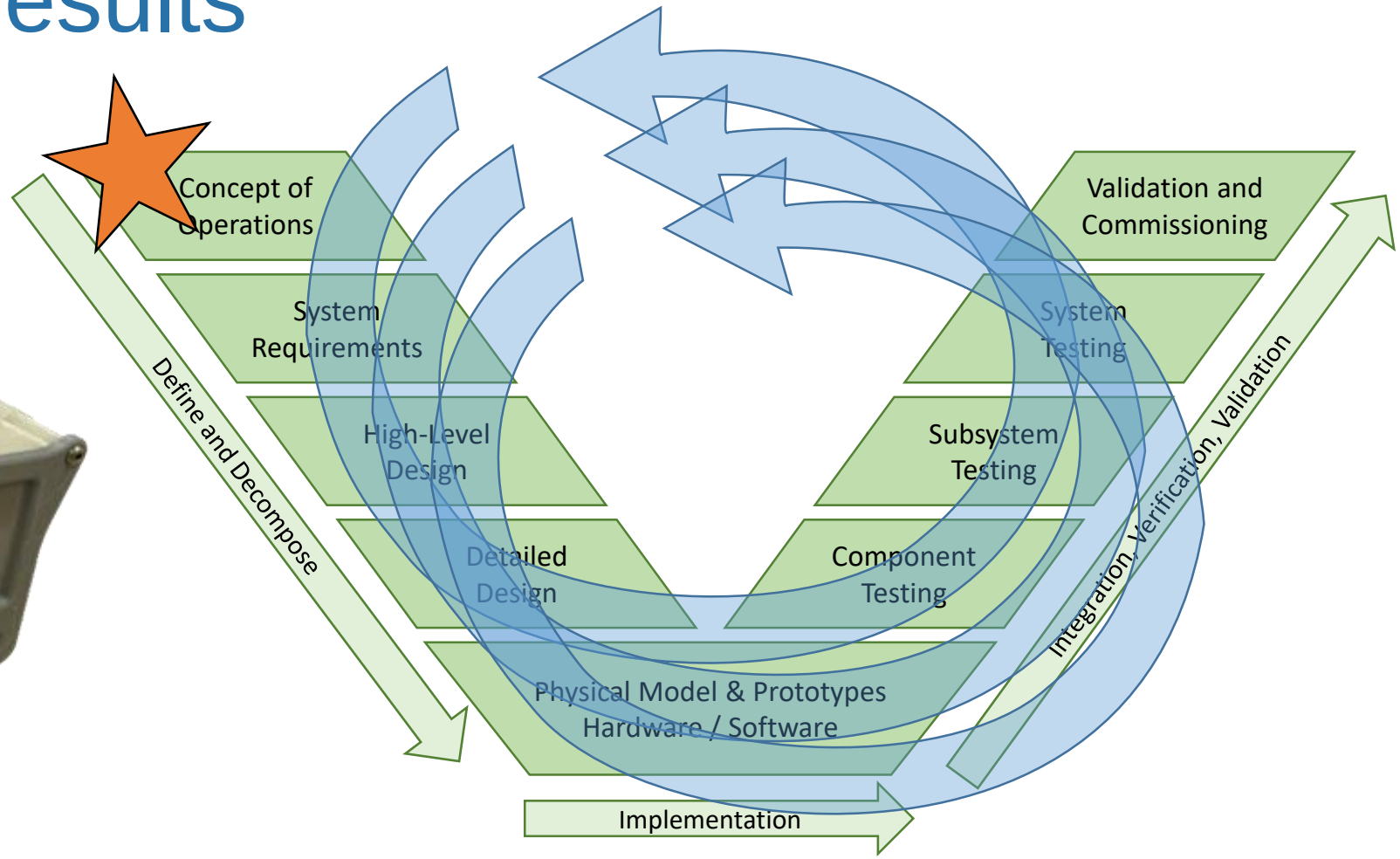
Results



Results



Results


Concept of Operations
System Requirements
High-Level Design
Detailed Design
Physical Model & Prototypes
Hardware / Software
Component Testing
Subsystem Testing
System Testing
Validation and Commissioning
Define and Decompose
Integration, Verification, Validation
Implementation

MBSE ➡ Context ➡ Value

- Minimal infrastructure; rapid deployment; ready accessibility through Cloud, iPad, AR, VR for ease of stakeholder engagement
- Rapid, iterative concept development
- Requirements definition, elicitation and conflict resolution
- Early validation, through efficient collaboration on models with end-users and other stakeholders
- Early and valuable human factors models
- Stakeholder engagement
  - “Seeing our ideas represented in the lifelike 3D models makes this process so much more real”

INCOSE
Healthcare
Working Group

5th Annual Systems Engineering in Healthcare Conference

May 1-2, 2019
Minneapolis, MN

Questions?

Thank you for attending!

Share your experiences at #HWGSEC

Chris Meeker, MS, PE
Dassault Systèmes
chris.meeker@3ds.com

Seattle, WA
www.3ds.com

References

- Oppenheim, B., 2018. *A Study of the Potential of Systems Engineering in Healthcare*. INCOSE I/S 2018.
- NAVAIR Public Release 2017-370. Accessed from *Capability Based Acquisition Overview*, http://www.paxpartnership.org/docs/SE%20Transformation%20Overview%20%28Industry%20Day%29%20V39%20David%20Cohen.pdf
- Malins, R., 2018. *Case Study: Application of DoD Architecture Framework to Characterizing a Hospital Emergency Department as the Intended Use Environment for Medical Devices.* INCOSE I/S 2018.