NASA

Discovering Digital Engineering Needs Through Human-Centered Approaches

Anna-Maria Rivas McGowan, Ph.D.

Agency ST for Complex Systems Design

Timothy W. Simpson, Ph.D.

Langley Senior Advisor for Advanced Manufacturing and Digital Engineering

January 11, 2025 AIAA Sci-Tech Conference

Outline

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- Concluding Remarks

National Aeronautics and
Space Administration

LANGLEY ENGINEERING

Langley Engineering Serves NASA and the Nation by delivering solutions for:

- Entry, Descent and Landing (EDL)
- Space Flight Instruments
- Aerospace Structures
- Atmospheric Flight Vehicles

We do it by:

- Developing, demonstrating, and delivering innovative concepts and technologies,
- Using multi-disciplinary engineering, testing, and manufacturing

Digital SAMARAI (Symbiosis of AM, AR, & AI)

Improving Team and Customer Engagement, Integrating Digital Workflows, Improving the DDT&E cycle

1 year IRAD with 1.7 FTE, ~300K

NASA Langley Engineering
Digital SAMARAI Team

Anna McGowan – PI, System Integration and Innovation
Justin Templeton – PM, Testing
Tim Simpson – AM, AR, AI SME
Greg Phillips – Manufacturing
Nancy Holloway – Manufacturing
Nick Kemp - Manufacturing
Miko Coleman – Testing
Chris Meek – Design
Salma Hassanain – Design
Adam Horn – SE
Caleb Thompson – Design
Trifeena James – Qualitative Analysis
Chris Wright – Data Management
Kurt Woodham – SE (Retired)

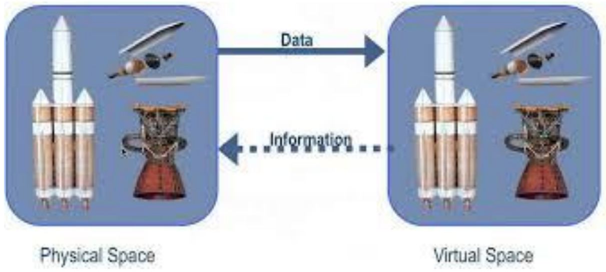
Collaborations with:

- **NASA GSFC (Ryan McClelland)**
- **NASA 2040 (Gugu Rutherford)**

Design ←→ Manufacturing ← → Testing

Artificial Intelligence

Digital Twins



XR

Additive Manufacturing

This Paper: How Human-Centered Approaches Were Used to Discover the DE Needs

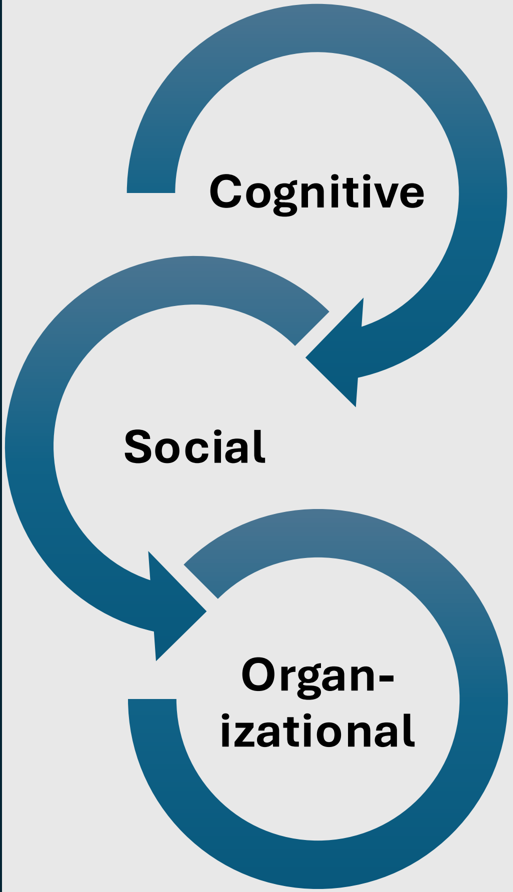
Human-Centered Approach to Discovering Digital Engineering Needs

WHY?

- Primary users of digital engineering are still people (at least for now…)
- Prioritize the development of digital solutions
- Improve the value of the solutions to the stakeholders
- Address pragmatic needs of engineering teams
- Increase technology adoption
- Minimizes new technology and methods being underutilized or implementation delayed

Cross-Disciplinary Interactions in Engineering Teams

→ *Driven by Human and Organizational Factors*[1]



Organizational and Social Aspects were Significantly More Important than Engineering Aspects

1:McGowan, A.-M. R., "Interdisciplinary Interactions During R&D and Early Design of Large Engineered Systems," 2014

Example Human-Centered Analysis Conducted

Mental models and understandings, knowledge gaps

Interactions between Design, Manufacturing, and Testing

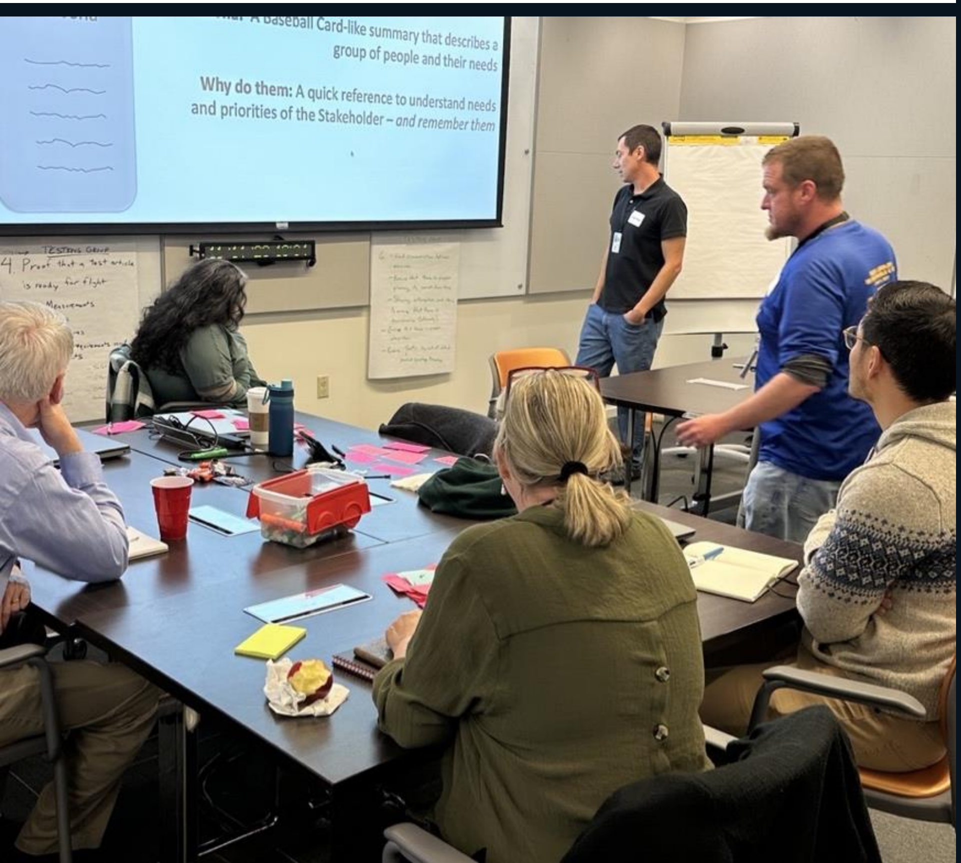
Organizational structures, policies, etc.

Example Findings from Human-Centered Analysis

- ❑ ***Iteration on requirements will likely always be required:** Important details necessary to realize a "real-world" system are often missing, incorrect, or incomplete, requiring iterative communication*
- ❑ ***Siloed and serial processes** can create inefficiencies and a lack of awareness of the impacts of upstream decisions on downstream development steps such as manufacturing and testing*
- ❑ ***"It wasn't that we were doing things wrong**. We were using processes that we were taught to use, but the process didn't really capture what we wanted."*

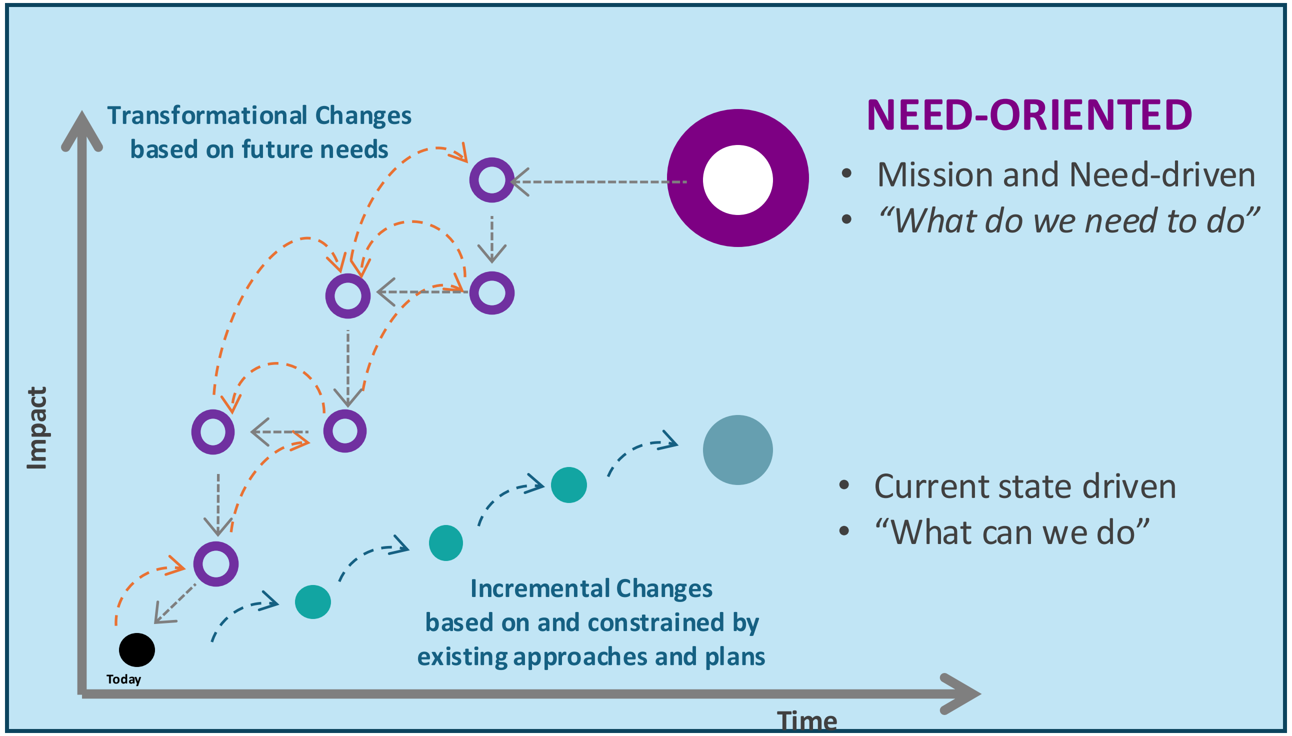
Human-Centered Approach to Discovering Digital Engineering Needs

HOW?



- Ethnography
- Interviews
- Process analyses
- Participatory design workshops
- Rapid prototyping with user feedback
- Qualitative and quantitative methods with internal validity
- ~50 participants, 7 organizations

Back-Casting Model: Need Driven



User-need pull vs purely tech push

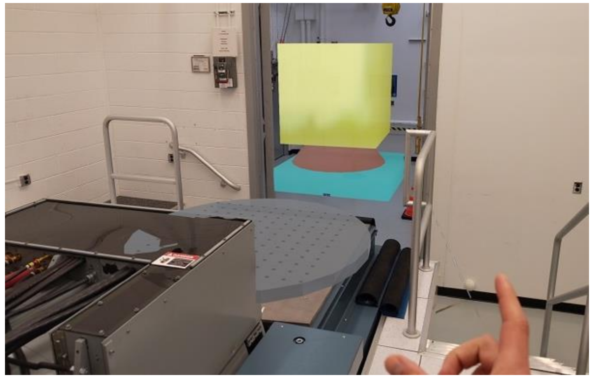
Conducted stakeholder analysis

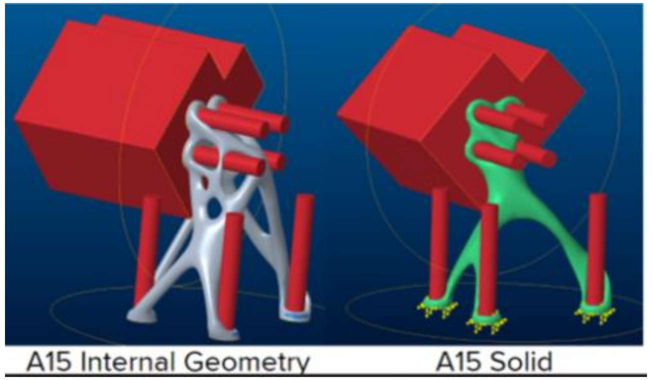
Problem discovery and problem formulation to identify key needs

Developed prototype solutions to identified needs

Experimented with prototypes with stakeholders in bench tests

Conducted stakeholder feedback and training sessions to improve products and infusion





Overarching Findings

A. Analyzing existing processes *with stakeholders* was crucial

B. Digitizing existing processes was not the real need

C. Primary needs were technology and software agnostic

D. Improved and interactive information exchange (beyond purely transactional exchanges) earlier in the system development cycle was widely emphasized by every stakeholder group

E. Traditional informal networking for knowledge sharing will likely reach limits with technology updates occurring more rapidly

F. Process inefficiencies need more in-depth analysis → innumerable and necessary iterations and modifications to processes are normal for one-off systems

G. Siloed and serial processes are cleaner and easier to track yet they can impede the more interactive information flow desired and create inefficiencies

Findings by Topic Area

National Aeronautics and Space Administration

Requirements

- Text requirements are often insufficient
- Iteration will likely always be required
- Over constraining requirements is costly

Design for Manufacturing:

- Upstream communication and stakeholder involvement
- Awareness of manufacturing capabilities
- 3D visualization for testing
- Avoid custom tooling

Materials

- Upstream iteration and research on material choices
- Improve material inventory system
- Improved visualizations

Design for Testing

- Upstream consideration of testing
- Benefits of proactive strategies
- Improved visualizations

Synthesis of All Analysis:

Design Guidelines or "Compass Statements"

***Short* Statements About What Successful Solutions Should Do/Have/Enable**

Focused on Needs	A vision of the idealized future state
Explanatory	Generative to encourage exploring divergent ideas and solutions
Key high-level desires and constraints	Guidelines for solutions

≠ Traditional Requirements

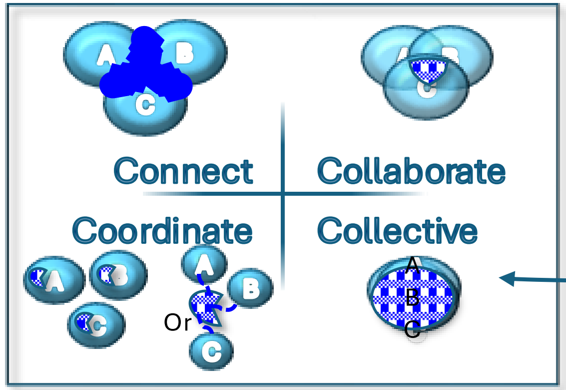
Abbreviated Compass Statements for Digital SAMARAI

- ❑ ***Increasing interdisciplinary communication with SMEs early on and throughout the system development effort including technicians***
- ❑ ***All requirements are not created equal. Distinguish "firm" requirements from those that could be modified to enable improvements and/or savings***
- ❑ ***Keeping up to date with project iterations:***
  - ❑ ***Integration of all natively stored info related to a project in an easy to access digital location - including all communication modes***
  - ❑ ***Assurance of digital version control for all info***
- ❑ ***User-centered communication approaches with more and enhanced visualizations***
- ❑ ***"Non-boring" training that is interactive and engaging on all new digital and non-digital capabilities and related processes.***

Discussion

Opportunity 1: Moving Downstream Efforts Upstream

- Earlier information to downstream SMEs (Manufacturing and Testing)
- Engagement of downstream SMEs upstream in the DDT&E to explore of potential improvements
  - To meet or exceed original expectations
  - Savings: Cost, time, rework, errors, risks
- Requires deeper level of team interaction
  - Beyond transactional exchanges
  - Co-construct and explore options
  - A ***Collective*** Approach to working with the broader DDT&E team[2]
    - Exploratory design discussions
    - "Interrelating Their Know-How"
    - Most innovative & most challenging style



Combining System Elements (CSE) Framework[2]

2: McGowan, A.-M. R., Papalambros, P., and Baker, W., (2015), "A Framework of Working Across Disciplines in Early Design and R&D of Large Complex Engineered Systems," (ICED 15), Design Society, Italy

Examples

- ❑ Re-considering tooling, finishing, etc.
- ❑ Consider minor design modifications that would allow existing test fixtures to be reused

Example data from prototyping:

- ❑ Upstream gatherings of diverse SMEs yielded emergent ideas and new possibilities
- ❑ With the support of AI and VR to explore ideas, several ideas could be quickly evaluated and subsequently implemented
- ❑ One prototype workflow:
  - ❑ Satellite bracket quickly re-designed with AI support
  - ❑ Final bracket design ≈ 1/2 mass; increased stiffness; completed 75% faster compared to expert manual design
  - ❑ *During the design phase: early* fit check for testing completed with support of VR saving 75% time and confirming that an existing shaker plate could be used
  - ❑ Performance of the bracket - verified with a vibration test

Vision:

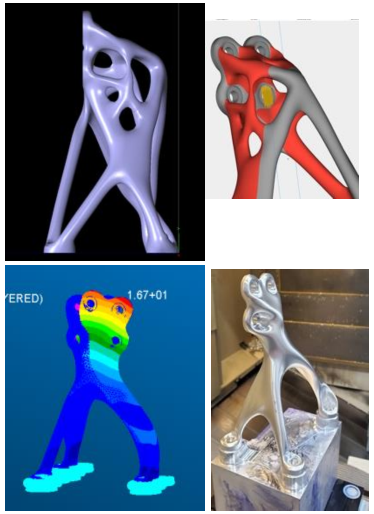
Next Generation Design for Manufacturing and Design for Testing with Digital Support and Collective Engagement

Discussion

Opportunity 2: Enabling Efficient Rapid Iterations

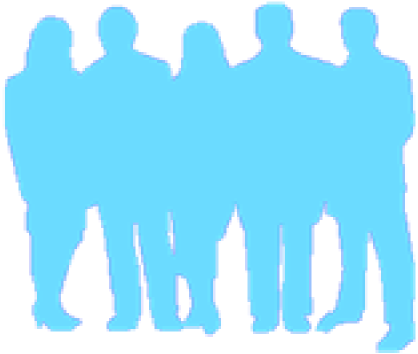
- Iterations are not going away – they are likely going to increase → Lean In to make them more efficient & effective

- Formalizing "Firm vs. Accommodating Requirements"
  - Systems engineers work with cross-disciplinary SMEs to understand where iteration is possible to improve mission outcomes and without negative impacts
  - Leveraging AI - explore options rapidly, enabling quick feedback on impacts of potential changes
  - Generative AI was prototyped as a design aid - enabled designers to work more closely with manufacturers and test leads to do very rapid re-designs
  - Learned some "firm" requirements could also be made "accommodating" without negative impacts



- Need IT – Information Therapy
  - TMI
  - IDCATI – I Don't Care About That Info
  - IPNGTRAOYE – I'm Probably Not Going to Read All Of Your Email
  - BINTFMI-*N!* – But I Need To Find My Info – Now!
  - PSSMMI – Please Stop Sending Me More Info
  - ISCFWILF – I Still Can't Find What I'm Looking For
  - #$%&!!

Summary



- Digital SAMARAI – Small 1 year IRAD effort on Digital Engineering
- Used Human-Centered approaches to discover the Digital Engineering needs of users
  - Prioritizes application areas, increases adoption, etc.
  - Used a blend of methods including interviewing and process analyses
  - User-need pull over purely tech push
- Considerable findings → Compass Statements → Prototypes → Further Insights and Improvements
- Conclusions:
  - Downstream system development steps to be considered further upstream in the project lifecycle to reduce the time, cost, and risks, and consider potential solutions that improve system performance
  - Developing methods and technologies to support efficient iterations
  - Digitally supported, upstream collective engagements open the door to greatly enhanced Design for Manufacturing and Design for Testing strategies
- Several results in use in current projects!

Acknowledgements to the SAMARAI Team & LTI:
Justin Templeton – PM, Testing
Tim Simpson – AM, AR, AI SME
Greg Phillips – Manufacturing
Nancy Holloway – Manufacturing
Nick Kemp - Manufacturing
Miko Coleman – Testing
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Trifeena James – Qualitative Analysis
Chris Wright – Data Management
Kurt Woodham – SE (Retired)
Langley Transformation Initiative (LTI) for Funding

Anna-Maria.R.McGowan@NASA.gov Or on LinkedIn

NASA Langley at a Glance*

Workforce

- 1,800 civil servants
- 1,700 on-site contractors