NASA/TM-20205002911/SUPPL

Strategic Perspectives on the Future of Systems Engineering at NASA

Supplemental Information: Appendixes A to K

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July 2020

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July 2020

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Level of Review: This material has been technically reviewed by technical management.

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Summary

NASA's Model-Based Systems Engineering (MBSE) Infusion and Modernization Initiative (MIAMI) chartered a strategy group comprising early to middle career NASA subject matter experts with diverse experiences to look into the future of systems engineering (SE) at NASA. The purpose of the group was to provide a vision for the future state of SE practices and to develop a strategic plan to enable the evolution of the art up to 20 years in the future. The strategy group used a design-thinking approach to gather ideas. The group obtained insight into current engineering processes and domain outlook by interviewing engineers of varying expertise and experiences who had worked on teams of different sizes for missions large and small. The group built a roadmap to highlight future needs, projected capabilities, and technology and competency gaps and developed a strategic plan to ensure the expedient introduction of these capabilities. The resulting strategic plan recommends capability development and workforce strategies and provides guidance for Agency-wide SE policy. Artifacts, details, and raw data from the strategy team's work are contained in this supplement to NASA/TM-20205002911.

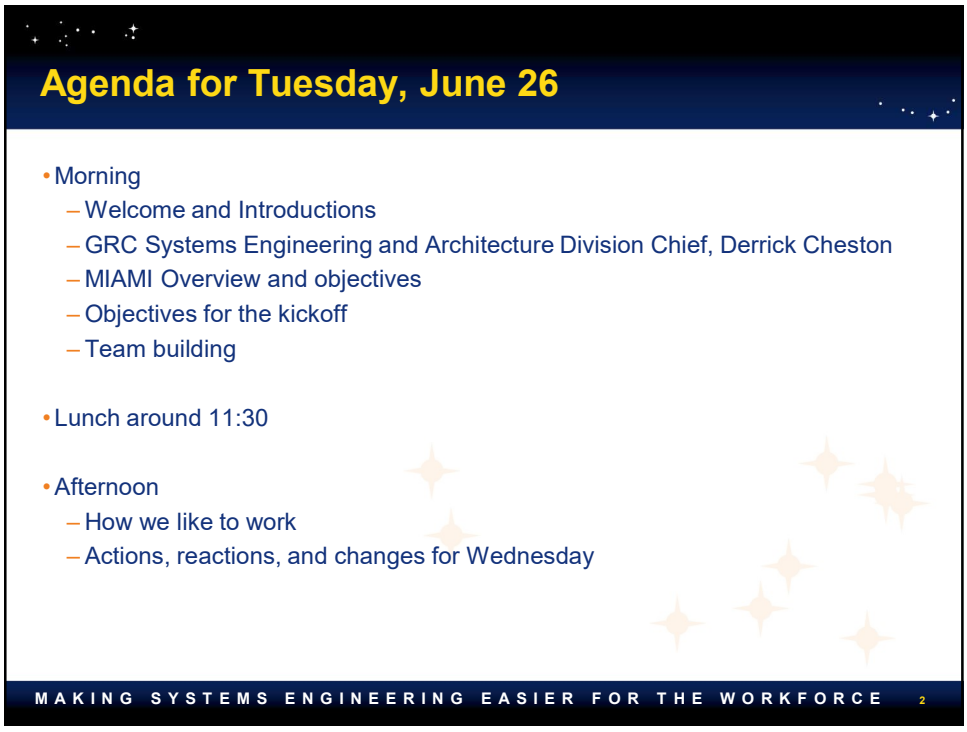
Appendix A.—MIAMI Strategy Group Kickoff Meeting, June 26 and 27, 2018

A.1 Challenge Questions

The MIAMI lead challenged the strategy group to consider the following questions:

- What are our missions of the future and what do systems engineers need to do to support the missions?
- What would provide the most value to our stakeholders and why should they be excited about it?
- What types of projects and phases of the systems life cycle will NASA systems engineers, prime contractors, academia, and other organizations perform?
- What new functions and capabilities do we need?
- What are the different types of tools we need in the systems engineer's toolbox and what is the supporting infrastructure?
- What are the megatrends (big data, collaboration tools, communication devices, computing devices, and advanced manufacturing) that we need to be aware of and how will they affect SE in the future?
- Where are we now, and what are the waypoints along the way to the full capability?
- What are the (rough) estimates of resources to get us to the waypoints on the roadmap?
- Who can we collaborate with to share the load?

A.2 Strategy Group Kickoff Meeting—Selected Presentation Slides



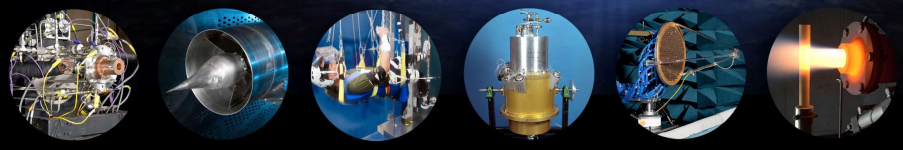
Glenn Research Center
Welcome to MBSE Strategy Group
June 25, 2018

NASA Glenn Research Center

R&E

RESEARCH AND ENGINEERING DIRECTORATE

Derrick J. Cheston – Systems Engineering and Architecture Division



LS Organization Challenges

- Balancing current and future demand and attrition
  - Fully subscribed in all areas SE, S/W, GNC, Mission Design
  - Dynamic environment with great potential for new work
- Investing and Integrating State of the Art Methods and Tools
- Developing the future Engineers of Systems
  - Growing complexity of systems and projects
  - Maintaining relevant technical domain knowledge
  - SE Acquisition/Hiring Approach = Pipeline + Hire to Grow
  - Training and Development Approach
  - Requires Strategic Succession Planning
    - Hiring cycle time scale vs. Development Timeline vs. Pipeline
- Right Sizing SE and Clarifying the SE Role
  - Being agile to project changes and needs

State of NASA SE Discipline, FY18

(based on FY16 deep dive and FY17/FY18 state of the discipline follow-on activities)

Description	Health Assessment	Future Trend
Systems Engineering, FY18		

Green - Discipline adequately positioned to meet mission requirements. No serious risks or issues to execution of Mission. No near-term action required.

Yellow - Discipline has marginal ability to meet mission requirements. Some risks to execution of Mission. Near-term corrective actions required.

Red - Discipline is inadequately positioned to meet mission requirements. Serious ri and/or issues to execution of Mission. Immediate action required.

Current health of discipline is yellow, stakeholders indicated issues with pipeline of good System Engineers.

State of discipline opportunities for improvement and observations:

- **We are improving the system engineering discipline with the TDT activities**
- **We need to continue to develop and utilize system engineering tools (example use of MBSE)**
- **We need to continue workforce development (system engineering workshops, OJT, training)**

EMB support to improve system engineering:

- **Emphasizing risk-based tailoring needs to be coupled with experience on diverse projects (different life cycle phases, different types) so people have the experience to inform proper tailoring.**
- **Supporting a culture of innovation (innovation being another word for continuously improving how we do things and being open to new ideas and techniques)**
- **Focus on improving system engineering technical leadership by enforcing compliance and checks, ensure that we are doing good system engineering on our projects**
- **Improve accountability and efficiency within the system engineering discipline, accountable for performance to programmatic requirements**
- **Emphasize and reward proper systems focus and risk tolerance**

SE Capability Strategic Vector: Outcomes, Benefits, Implementation

	Near-Term (1-5yrs)	Longer-Term (5-20 yrs)
Outcomes	• Value added partner for complex systems integration • Transform ways of thinking and doing; systems thinking, risk based decision making, strong technical leaders • Increased Technical understanding of our systems • Improve requirements generation process and definition • Improved integration between systems and software engineering	• More intense Systems based perspective/understanding throughout the agency • A more integrated, progressive, efficient, and capable agency • Adapting to emerging capabilities and technology • Reusable requirements and test procedures • System modeling tools that integrate with manufacturing and software development

Benefits	• Integration of the needs of the other disciplines, taking advantage of their advancements
	• Improved ability to work and collaborate inter-agency and with industry partners
	• Improve project life-cycle efficiency through consistent risk based tailoring
	• Better understanding of system definition and fault modes
		• Improved integration across complex projects involving multiple centers and partners.
		  • Complex system of systems modeling and increased integration between hardware and software
		  • Ability to support the integration of complex program information and data architectures to support seamless integration and production of integrated engineering artifacts
		  • Consistency across NASAs SE workforce
		• Reduce development time and cost
		• More effective design solutions and risk awareness
		• Take advantage of statistical engineering, advanced modeling and physics based capabilities

NASA Implementation	• Strengthen priority on SE technical understanding and integration via more rapid experience cycles (insight, hands-on, etc.) and more intentional focused technical integration training.
	• Active engagement across disciplines to understand and support the infusion of advanced techniques at the system level and across systems domains
	• Coordinated implementation and demonstration of model based methods across the majority of our NASA portfolio. Include framework to support expanded analytical systems evaluation capabilities.
		• Fully integrated systems data architecture – MBE
		  • Design Baselines (T, t, $) maintained across product life-cycle
		  • Design Baseline to Systems Simulation
		  • More robust SE analysis capability
		  • Richer more graphical evaluation capability
		  • Digital twins of operational hardware
		  • Design baseline to Advanced Manufacturing capability

7

Objectives for Strategy Group Kickoff

- Individuals get to know each other and begin forming a team
- Exchange initial ideas
- Discuss and reach consensus on how to work together as a group
- Decide on immediate next steps

MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE 8

A Lesson From History…

- Winds of Change - 2006
  - https://www.youtube.com/watch?v=JYW49bsiP4k
- What Happened? - 2018
  - https://www.youtube.com/watch?v=eVrmFgvEnAA
- Scott Anthony, Harvard Business Review, "Kodak's Downfall Wasn't About Technology," July 15, 2016

  "The right lessons from Kodak are subtle. Companies often see the disruptive forces affecting their industry. They frequently divert sufficient resources to participate in emerging markets. Their **failure is usually an inability to truly embrace the new business models the disruptive change opens up**. Kodak created a digital camera, invested in the technology, and even understood that photos would be shared online. Where they failed was in realizing that online photo sharing *was* the new business, not just a way to expand the printing business."

Lesson Learned from Kodak – Questions to Ask

- **What business are we in today?** Don't answer the question with technologies, offerings, or categories. Instead, *define the problem you are solving for customers*, or, in our parlance "the job you are doing for them." For Kodak, that's the difference between framing itself as a chemical film company vs. an imaging company vs. a moment-sharing company.
- **What new opportunities does the disruption open up?** Our colleague Clark Gilbert described more than a decade ago a great irony of disruption. Perceived as a threat, *disruption is actually a great growth opportunity*. Disruption always grows markets, but it also always transforms business models. Gilbert's research showed how executives who perceive threats are rigid in response; those who see opportunities are expansive.
- **What capabilities do we need to realize these opportunities?** Another great irony is that *incumbents are best positioned to seize disruptive opportunities*. After all, they have many capabilities that entrants are racing to replicate, such as access to markets, technologies, and healthy balance sheets. Of course, these capabilities impose constraints as well, and are almost always insufficient to compete in new markets in new ways. Approach new growth with appropriate humility.

Why Are We Right Here, Right Now?

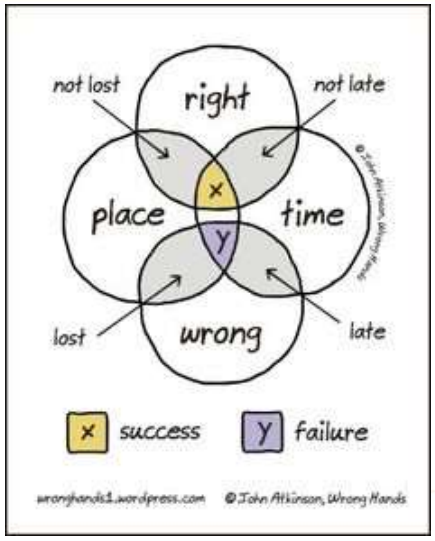


Illustration © John Atkinson, Wrong Hands. Used with permission.

Extended Introductions

- Lightning Rounds
  - Quick notes
  - Collect the notes at the end
  - Use for later reference
- Name
- Center
- Past and present organizations
  - Engineering, projects, research, etc.

Virtual Teams and Working Across Boundaries

- Experiences with Virtual Teams
  - Membership or leading a team
- Experiences working across organizational and cultural boundaries
  - Membership or leading a team

Work and Personal Experiences

- Your most productive work or personal experience, ever
- Your most satisfying work or personal experience, ever!!

Prior NASA MBSE Work

- **NASA Integrated Model-Centric Architecture (2011-15)**
  - Focused on Modeling & Simulation, Model-Based Systems Engineering, Computer Aided Design, Product Data and Lifecycle Management
  - Industry benchmarking
  - Recommended pilots as next step
- **Workshops and Training**
  - NASA/JPL in 2012, '15, '17
  - GSFC in 2016
  - 30+ SysML classes (**>600 people**)

- **MBSE Pathfinder Parts 1 and 2 (2016-17)**
  - Participants from 8 NASA Centers and JPL
  - Piloted Cloud ecosystem (S/W licenses and model)
  - Demonstrated MBSE to complex NASA projects

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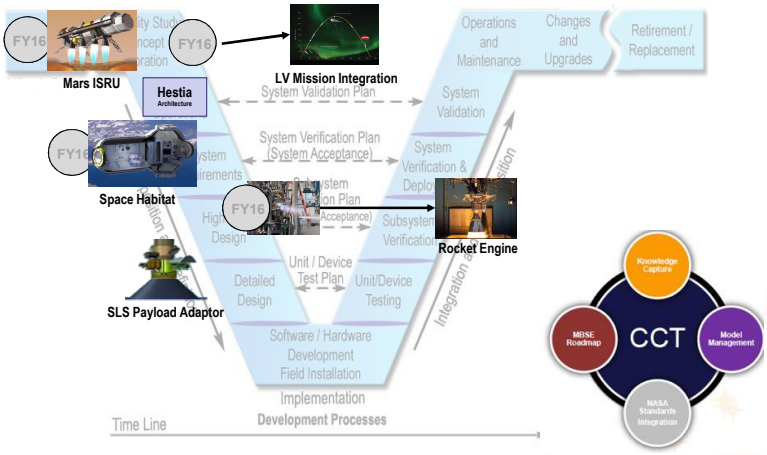
MBSE Pathfinder Part 1, 2 - Across the Lifecycle



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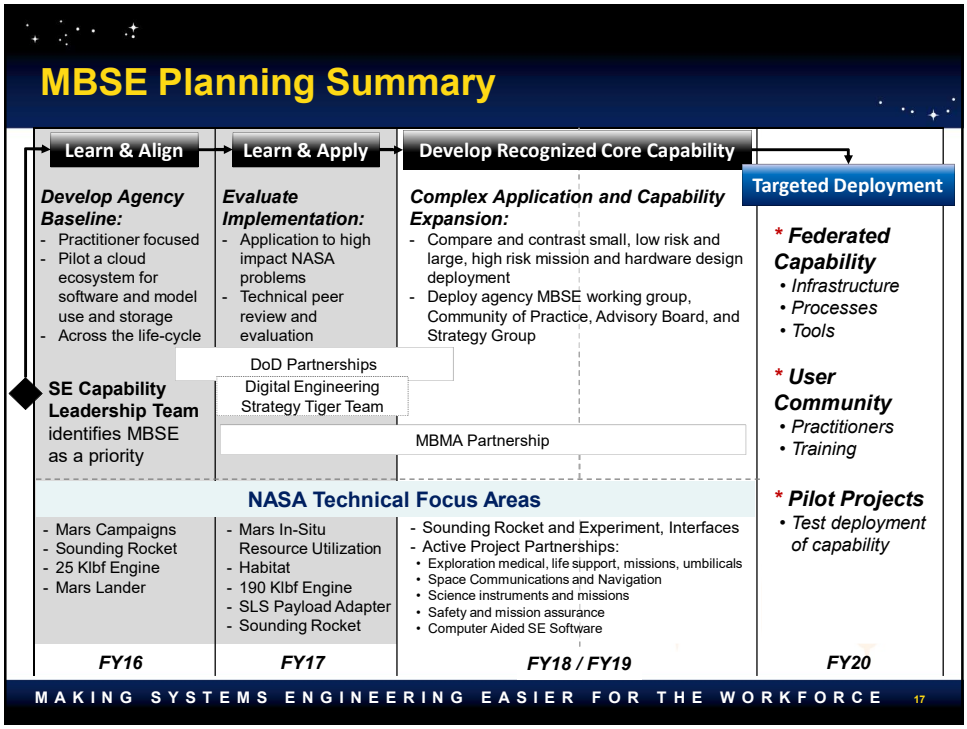
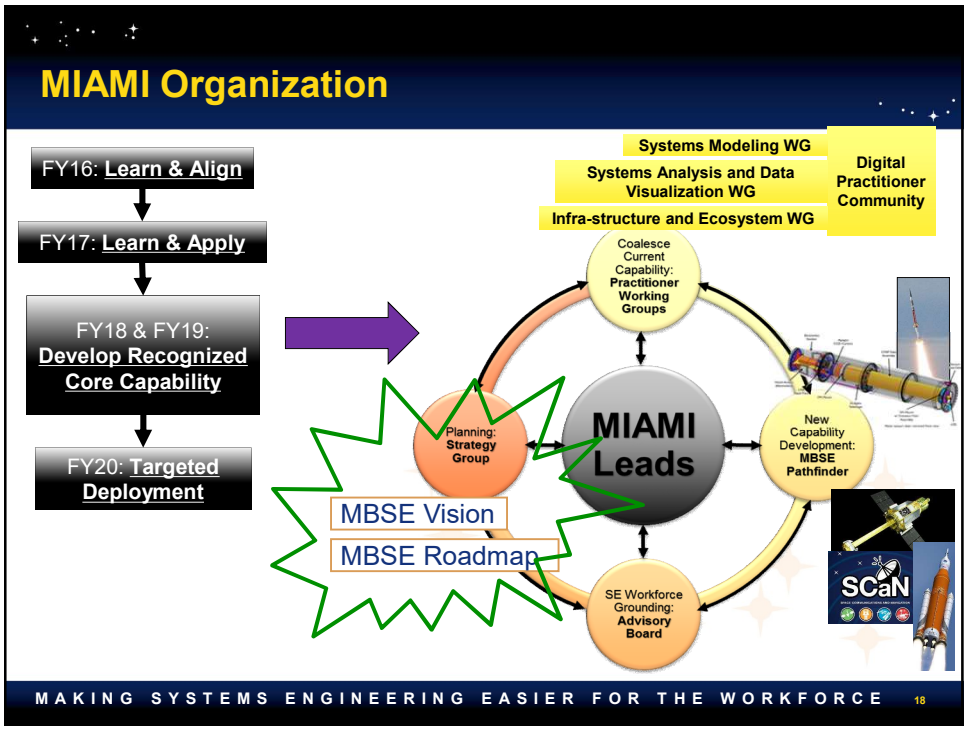

MBSE Planning Summary
Learn & Align
Learn & Apply
Develop Recognized Core Capability
Targeted Deployment
Develop Agency Baseline:
- Practitioner focused
- Pilot a cloud ecosystem for software and model use and storage
- Across the life-cycle
Evaluate Implementation:
- Application to high impact NASA problems
- Technical peer review and evaluation
Complex Application and Capability Expansion:
- Compare and contrast small, low risk and large, high risk mission and hardware design deployment
- Deploy agency MBSE working group, Community of Practice, Advisory Board, and Strategy Group
* Federated Capability
• Infrastructure
• Processes
• Tools
* User Community
• Practitioners
• Training
* Pilot Projects
• Test deployment of capability
DoD Partnerships
Digital Engineering Strategy Tiger Team
MBMA Partnership
SE Capability Leadership Team identifies MBSE as a priority
NASA Technical Focus Areas
- Mars Campaigns
- Sounding Rocket
- 25 Klbf Engine
- Mars Lander
- Mars In-Situ Resource Utilization
- Habitat
- 190 Klbf Engine
- SLS Payload Adapter
- Sounding Rocket
- Sounding Rocket and Experiment, Interfaces
- Active Project Partnerships:
• Exploration medical, life support, missions, umbilicals
• Space Communications and Navigation
• Science instruments and missions
• Safety and mission assurance
• Computer Aided SE Software
FY16
FY17
FY18 / FY19
FY20
MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE 17


MIAMI Organization
FY16: Learn & Align
FY17: Learn & Apply
FY18 & FY19: Develop Recognized Core Capability
FY20: Targeted Deployment
Systems Modeling WG
Systems Analysis and Data Visualization WG
Infra-structure and Ecosystem WG
Digital Practitioner Community
Coalesce Current Capability: Practitioner Working Groups
Planning: Strategy Group
MIAMI Leads
New Capability Development: MBSE Pathfinder
SE Workforce Grounding: Advisory Board
MBSE Vision
MBSE Roadmap
SCaN
MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE 18

MIAMI Goals

- For Modernizing the SE Workforce through MBSE
  - Informed decision making through increased transparency and greater insight
  - Enhanced communication
  - Increased understanding for greater flexibility/adaptability in design
  - Increased confidence that the capability will perform as expected
  - Increased efficiency and reduced errors
  - Close chasm between systems analysis and systems engineering
- For MIAMI
  - Make systems engineering easier
  - Realize potential benefits of digitization
  - Establish MBSE capability
  - Link our work with Systems Engineering Technical Discipline Team, SE Capability Leadership Team, and NESC Assessments work
  - Communicate MIAMI efforts

MBSE Strategy Group Overview

- MBSE Strategy Group
  - Small, cross agency group of big picture thinkers responsible for defining and planning a digital future, from now to 20+ years in the future
  - Aware of trends in political, technological, educational, organizational, and engineering environments

MBSE Vision	MBSE Roadmap
– Top-level, succinct statement that captures goals and objectives (the “why”) – Use to evaluate proposed investments in workforce and capability development	– Defines broad categories of workforce development and capabilities – Depiction of desired end points and waypoints over time for each category

- MBSE Strategic Plan
  - Details the investment approach

How We Will Work Together

- Keeping in touch with other team members
- Meeting management
- Working together to produce or review deliverables
- Use of Technology
- Decision making and problem solving
- Conflict management

- We will discuss these today, and finalize our agreement on Wednesday afternoon

Buy-in from Stakeholders

- In team-oriented organizations, support for teams and their work can rarely be mandated
- To get buy-in:

- Determine whom you need to get buy-in from

- Determine what you need to get buy-in on

- Plan how to get buy-in, and implement the plan

- Take steps to maintain buy-in

Who Are Our Stakeholders?

- Identify people whose buy-in is important to the Strategy Group's success
- Core team – members of the Strategy Group
- Middle circle – names of stakeholders with whom the Strategy Group will frequently interact
  - Individuals, teams, or groups
- Outer circle – names of stakeholders who are important to the success of the Strategy Group, but with whom the Strategy Group has limited contact
- Underline three or four key stakeholder whose buy-in is critical to you
- Let's compare our stakeholders!

External Communication Plan

- Which stakeholders, partners, champions, and others will get what information and when?
- Which team members will coordinate with those individuals and answer questions?

I Need Your Clothes, Your Boots and Your Motorcycle

- Terminator 2
- Clip shows augmented reality, sensor processing, data analytics, pattern matching
- Movie came out in 1991

- https://www.youtube.com/watch?v=IYOoWCv_PYE

Hiro Upgrades Baymax

- Big Hero 6
- Clip shows the design process to do upgrades of a robot
- Movie came out in 2014

- https://www.youtube.com/watch?v=wILITsjnYYw

Meeting Management

- Time zone considerations
- Length of meetings
- Structured meetings, free-for-all discussions, parking lots
- Side meetings (a few people without the entire Strategy Group)
- Who will schedule, develop the agenda, take and distribute minutes, facilitate?

Working Together to Produce or Review Documents or Deliverables

- What are the major activities of the Strategy Group?
- What are the different ways the Strategy Group could work together?
- Which ways are suited to the major activities?
- How often does the team want to meet together? When?

Use of Technology

- Agreement on major type of work (parallel, sequential, or pooled sequential)
  - Parallel – individuals work separately, then integrate into a final product
  - Sequential – individuals work and then pass it on, like an assembly line
  - Pooled sequential – individuals check out document, make changes, check in
- Technology needed given the type of work
- How to exchange information and documents
- Hardware and software needs of team members (e-mail, fax, telephone, video, and so on)
- How information and documents will be stored (team Web site, shared files, or other)

Use of Technology

- When to mark e-mail messages and other documents "urgent," "important," or the like
- Acquisition of new technology (for example, groupware, electronic meeting systems)
- Training and orientation for team members in technology
- Review of compatibility issues (MAC or PC, word-processing applications, Internet providers)

Decision Making and Problem Solving Approaches

- What are possible approaches to decision making?
- Which ones have you used and liked?
  - If it didn't go well, could it be improved?
- Which ones have you not used but want to try?
- What does the Strategy Group want to use?
- Repeat for problem solving…

Conflict Management

- What is your organization's code of conduct to resolve differences in ways of doing business?
- Does your organization has an established conflict-management process?
- What does the Strategy Group want to use?

Agenda for Wednesday, June 27

- Morning
  - Welcome and Introductions
  - NASA Systems Engineering Technical Fellow, Jon Holladay
  - Idea sharing, capturing areas of opportunity, Rebecca Kwiat
- Lunch around 11:30
- Afternoon
  - HQ Office of Chief Engineer, Rob Moreland
  - GVIS tour, Herb Schilling
  - Deliverables
  - Decide on team norms and objectives
  - Agree on schedule and next steps
  - Final take-aways

Summarize

- Summarize what we learned
  - About our ideas
  - About our knowledge base
  - About who we could contact
- Identify possible next steps
- Facilitator – Rebecca Kwiat, GRC Creativity & Innovation Ideation Lead

Strategy Group Deliverables

- Charter and Work Plan
- MBSE Vision – top-level statement of goals and objectives
- MBSE Roadmap – top-level depiction of capabilities over time, with supporting information
- MBSE Strategic Plan – approach to accomplish the vision and roadmap

Examples of Vision/Roadmap for MBSE strategy

Examples from Program Planning and Control (PP&C) Agency Working Group

June 27, 2018

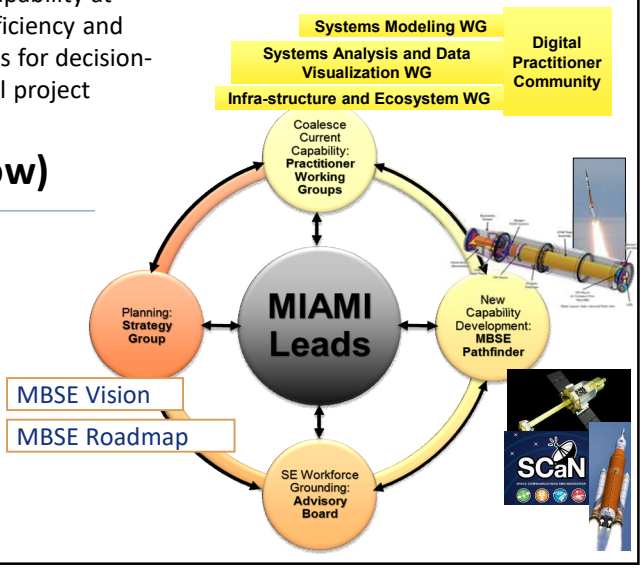
Rob Moreland
NASA Headquarters
Office of Chief Engineer

Vision Statement (the what – future focus)

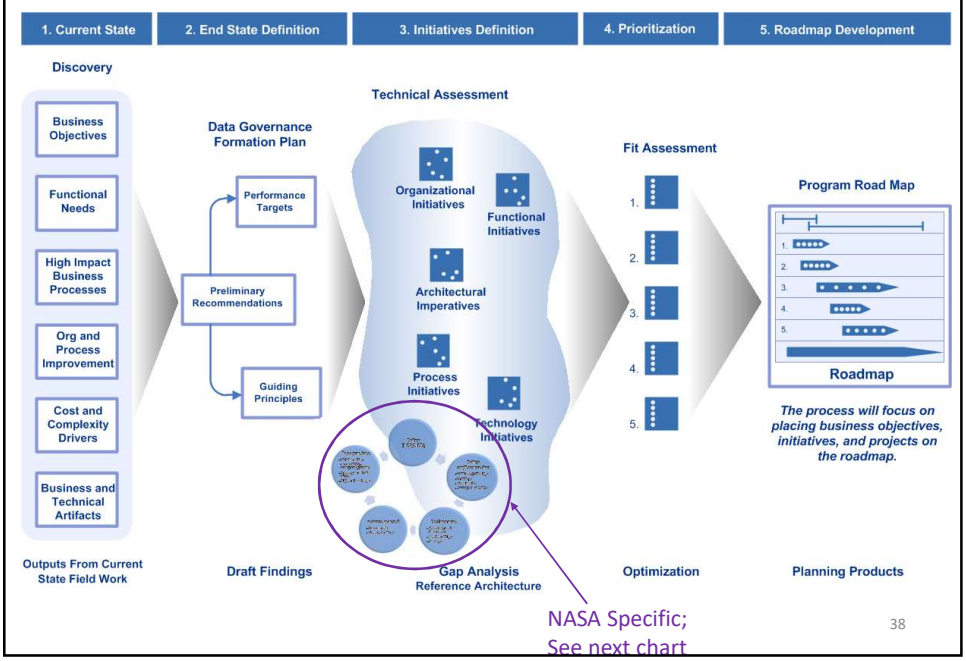
To embed an MBSE capability at NASA that enables efficiency and efficacy improvements for decision-making and successful project execution

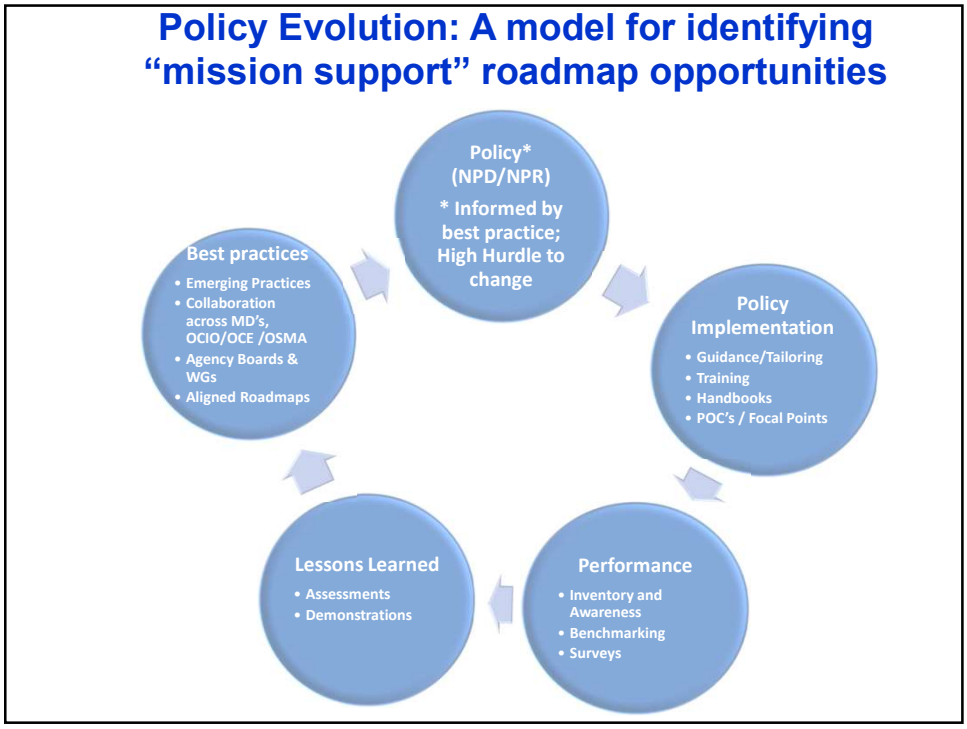
Mission (How)

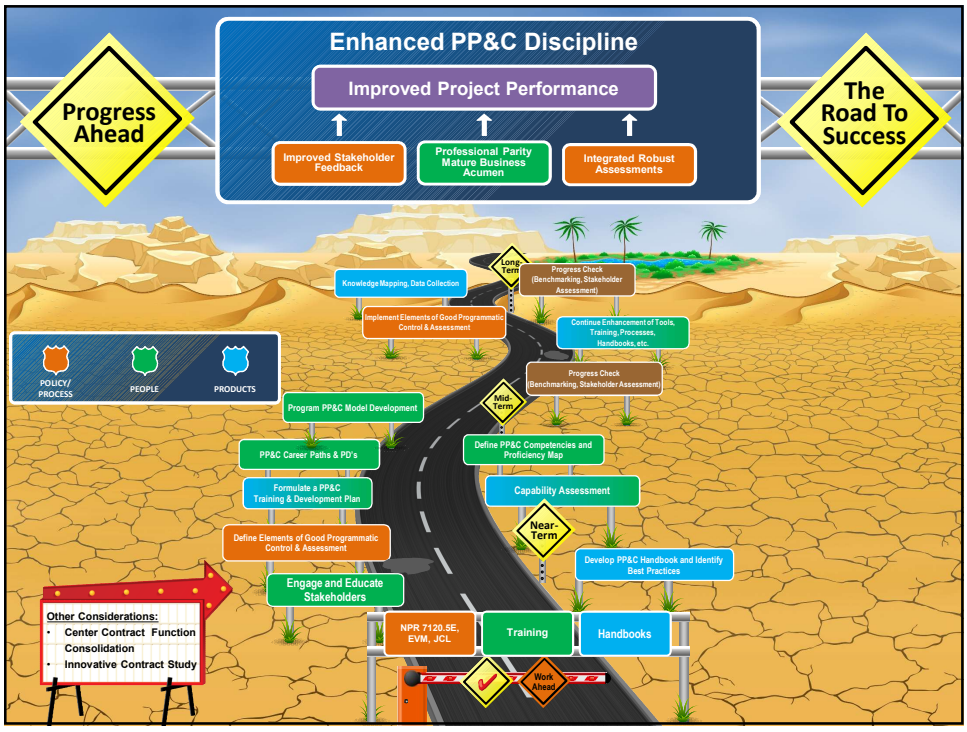
Provide a set of inter-related, aligned, and logically linked activities to improve the capabilities, products and policies leading to systemic MBSE adoption



Generic Strategic View

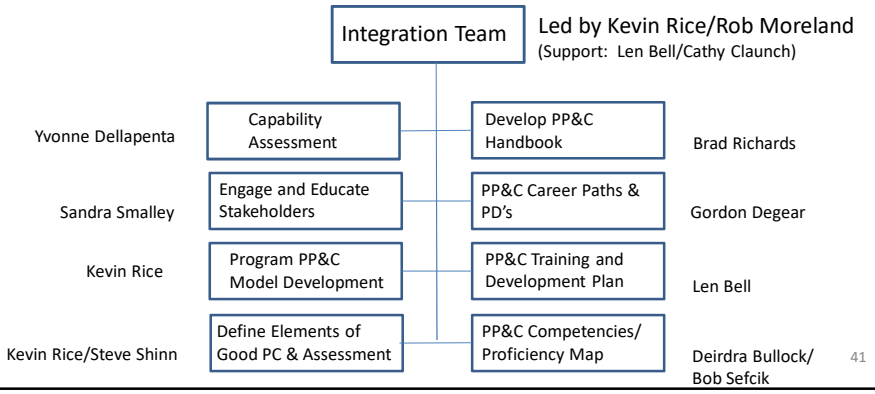



Policy Evolution: A model for identifying "mission support" roadmap opportunities
Policy* (NPD/NPR)
* Informed by best practice; High Hurdle to change
Policy Implementation
• Guidance/Tailoring
• Training
• Handbooks
• POC's / Focal Points
Performance
• Inventory and Awareness
• Benchmarking
• Surveys
Lessons Learned
• Assessments
• Demonstrations
Best practices
• Emerging Practices
• Collaboration across MD's, OCIO/OCE /OSMA
• Agency Boards & WGs
• Aligned Roadmaps


Enhanced PP&C Discipline
Improved Project Performance
Improved Stakeholder Feedback
Professional Parity Mature Business Acumen
Integrated Robust Assessments
Progress Ahead
The Road To Success
POLICY/ PROCESS
PEOPLE
PRODUCTS
Long-Term
Knowledge Mapping, Data Collection
Progress Check (Benchmarking, Stakeholder Assessment)
Implement Elements of Good Programmatic Control & Assessment
Continue Enhancement of Tools, Training, Processes, Handbooks, etc.
Progress Check (Benchmarking, Stakeholder Assessment)
Mid-Term
Program PP&C Model Development
Define PP&C Competencies and Proficiency Map
PP&C Career Paths & PD's
Capability Assessment
Formulate a PP&C Training & Development Plan
Near-Term
Define Elements of Good Programmatic Control & Assessment
Develop PP&C Handbook and Identify Best Practices
Engage and Educate Stakeholders
Other Considerations:
• Center Contract Function Consolidation
• Innovative Contract Study
NPR 7120.5E, EVM, JCL
Training
Handbooks
Work Ahead

Detail the Approach to Working Milestones

- Determine broad objectives for near- and mid-term milestones
- Identify responsible lead for each near-term milestone
- Follow progress and ensure "connectivity" through Integration Team



41

Herb Schilling
GRC Office of Chief Information Officer
GRC Creativity and Innovation Lead

GVIS TOUR

MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE 42

MBSE Vision

- Vision
  - Big-picture view
  - Captures how (systems) engineers will work in the future at NASA
- Purpose of a vision
  - Inform and inspire people
  - Succinctly present the future in a way that everyone involved can understand
- Uses
  - Communicate with key stakeholders for awareness and when asking for their support
  - Jumping off point for a MBSE Roadmap
  - Helps to evaluate whether to pursue or fund (or not) an activity, by how well it supports the MBSE vision

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MBSE Roadmap

- Depicts where you want to go and the stops along the way
- Contains broad categories, and gives the desired status of each category as a function of time
- Can be multi-level
  - Top-level depiction
  - Additional details on each category
- Map vs. directions
  - Map shows roads, towns, features of interest, way-points
  - Directions tell you go 3 miles, turn right, go 2 miles, turn left, arrive in 500 feet

MBSE Strategic Plan

- Approach to accomplish the Vision and Roadmap
- Approach will have multiple aspects due to these factors
  - Stakeholders
  - Resources
  - Timing and phasing
  - Ability to buy, borrow, watch, partner, defer
- Strategy and tactics may change without affecting the Vision or Roadmap

Groups Doing Related Work at NASA and Beyond

- Groups doing related work at NASA and beyond:
  - Those on which you work
  - Those that you know somebody is working
  - Those you have heard about
- For those that are located beyond NASA
  - Organization
  - Point of Contact if you know of one
- Example: NASA Information Architecture Working Group, co-chartered by OCIO and SE (Jon Holladay), PoCs are Rebecca Deschamp and Paul Schwindt

Upcoming Events

- MIAMI Annual Review
  - Week of August 20, 2018
  - NASA GSFC
  - Review of plans and progress to-date by Advisory Board
  - Training in design thinking and lean start-up (tentative)
- Quarterly Q1FY19
  - December 2018
  - TBD location, at a NASA Center
  - TBD people will have travel supported by NESC

Top-level Schedule – Discuss and Agree

- Charter – final by Annual Review, August 20
- Work Plan – final by Annual Review, August 20

- Vision – draft by August 20, for Advisory Board feedback, update after Annual Review, final draft by mid-September
- Roadmap – draft by end of September
- Roadmap supporting details – draft by mid-December
- Strategic Plan – draft by mid-December

- Strategic Investment Recommendations – mid-February 2019

References

- Scott Anthony, "Kodak's Downfall Wasn't About Technology"
  - https://hbr.org/2016/07/kodaks-downfall-wasnt-about-technology

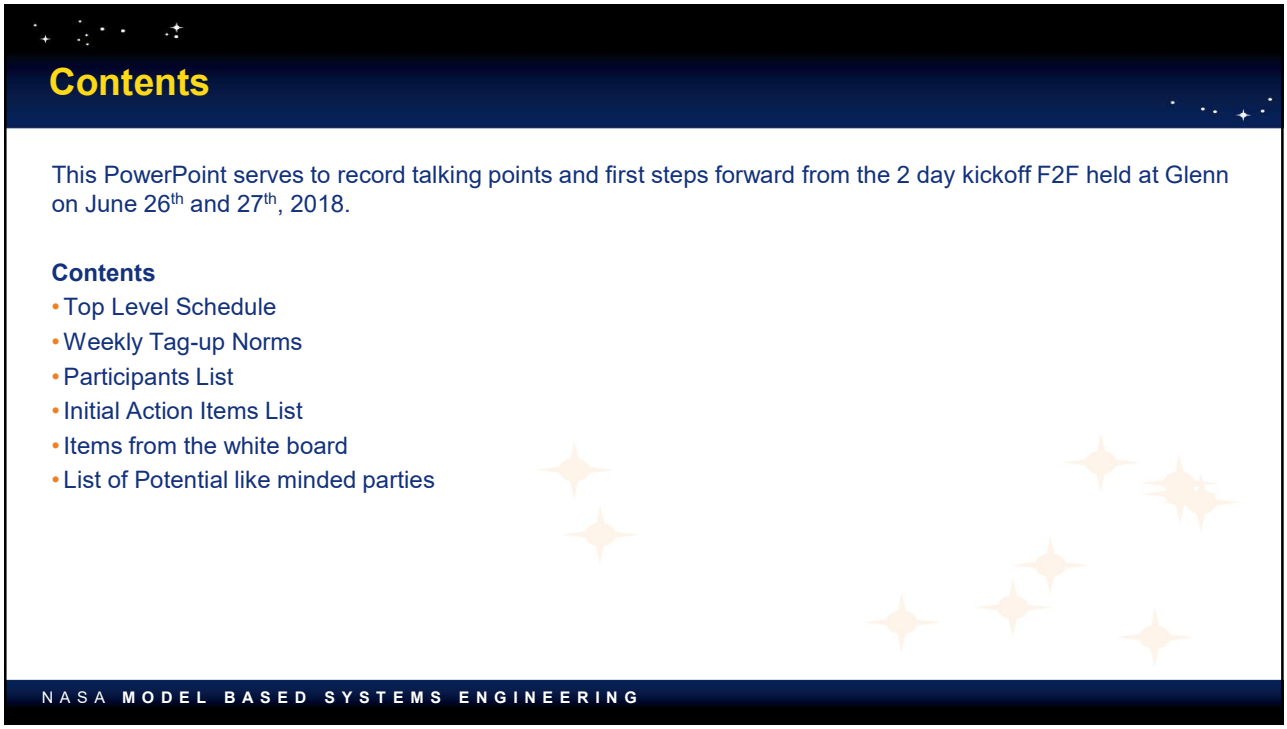
- Clark Gilbert and Joseph L. Bowers, "Disruptive Change: When Trying Harder Is Part of the Problem"
  - https://hbr.org/2002/05/disruptive-change-when-trying-harder-is-part-of-the-problem

A.3 Concept Fan

Generate ideas on ways to disrupt the current state of NASA engineering to become more agile in our response to the changing needs of the Agency or the public

Approach: TRAINING		Approach: COMMUNICATION		Approach: ORGANIZATION			Approach: ???
Concept - Ways to: Ways to engage kids/students	Concept - Ways to: Workforce education/training	Concept - Ways to: Ways to collaborate with industry	Concept - Ways to: Ways to communicate what NASA is doing	Concept - Ways to: Ways to provide strategy input to NASA	Concept - Ways to: Ways to increase budget flexibility	Concept - Ways to: Ways to increase workforce productivity	Concept - Ways to: Ways to encourage adoption of MBSE
Idea!! Let university research drive all engineering	Idea!! Agile training	Idea!! Virtual collaboration	Idea!! Agency-wide platform to capture Q&A	Idea!! Enable NASA Administrator to direct Agency programs	Idea!! Create program office to add funds to projects trying innovative approaches	Idea!! Have less chains of management	Idea!! Mandate MBSE implementation on flight projects to force an understanding/ learning process
Idea!! Gamification app to create requirements, level up, use models in game. Teach kids SE.	Idea!! Add software development skills to all positions, even nontech positions, i.e., contracting	Idea!! NASA increase collaboration with industry, i.e., be their R&D departments	Idea!! NASA ambassador/ cheerleader. Informs public and Agency on happenings at NASA	Idea!! Convey upcoming changes in public/Agency to feed into NASA	Idea!! Allow Agency budget to be authorized more than 1 year	Idea!! Increase workforce	Idea!! Legal sensitive but unclassified (SBU) issues
Idea!!	Idea!!	Idea!! Hire celebrities to leadership positions	Idea!! Improve knowledge capture, management, and sharing	Idea!! Designate more term positions intended to rotate personnel into and out of organizations	Idea!!	Idea!!	Idea!!
Idea!!	Idea!!	Idea!! Require all CSs to work/get a detail commercially	Idea!! Hire celebrities to leadership position	Idea!! Reorganize the Agency/organization/ group structure to accommodate agility	Idea!!	Idea!!	Idea!! Focus only on using models. No written documents
Idea!!	Idea!!	Idea!!	Idea!! Gaming app to create requirements, use models in game. Players level up from intern to Director. Teach SE to future workforce	Idea!! Gamification app to create requirements, level up, use models in game. Teach kids SE.	Idea!!	Idea!!	Idea!!
Idea!!	Idea!!	Idea!!	Idea!!	Idea!! Create organizationally isolated teams	Idea!!	Idea!!	Idea!!
Idea!!	Idea!!	Idea!!	Idea!!	Idea!! Conduct continuous surveys of stakeholders	Idea!!	Idea!!	Idea!!
Idea!!	Idea!!	Idea!!	Idea!!	Idea!! Create seedling funds for organizational improvement	Idea!!	Idea!!	Idea!!
Idea!!	Idea!!	Idea!!	Idea!!	Idea!! Mandate MBSE on flight projects to force an understanding/ learning process	Idea!!	Idea!!	Idea!!
Idea!!	Idea!!	Idea!!	Idea!!	Idea!! Let university research drive all engineering	Idea!!	Idea!!	Idea!!

A.4 Talking Points and First Steps Forward—Presentation Slides



Major Activities

- Generate Deliverables
- Research Esoteric Tech
- Conduct Interview
- Research Curves Decision-Making
- Charter, Work Plan, Vision, Roadmap, Strategic Plan
  - All decisions will be voted upon by the entire group unless someone is unavailable for an extended time. Efforts will be made to include all
- Activity Leads
  - Poll people, get consensus, address issues if possible, decide, move out
- Prototype Ideas
- Reporting/Outbriefing
- Cost-benefit analysis
- Define metrics
- Generating
- Writing lists

Decision Making

- Charter, Work Plan, Vision, Roadmap, Strategic Plan
  - All decisions will be voted upon by the entire group unless someone is unavailable for an extended time. Efforts will be made to include all
- Activity Leads
  - Poll people, get consensus, address issues if possible, decide, move out

Success Definition

- Described end dream state of engineering
  - Prototype?
  - Provide rationale
- Begin implementing plan to achieve dream
- Template for implementation
- High level conops – "Day in the life"
- Leverage multiplier effect?

Parking Lot Items

- Paper -> artifact -> global SE community
- Tie in w/INCOSE Natural Systems Working Group (NSWG) and Virtual Interchange for Nature-Inspired Exploration (VINE) Grand Challenge

Working Together To Produce/Review Documents and Deliverables

Questions:

- What are the major activities of the Strategy Group?
- What are the different ways the Strategy Group could work together?
- Which ways are suited to the major activities?
- How often does the team want to meet together? When?

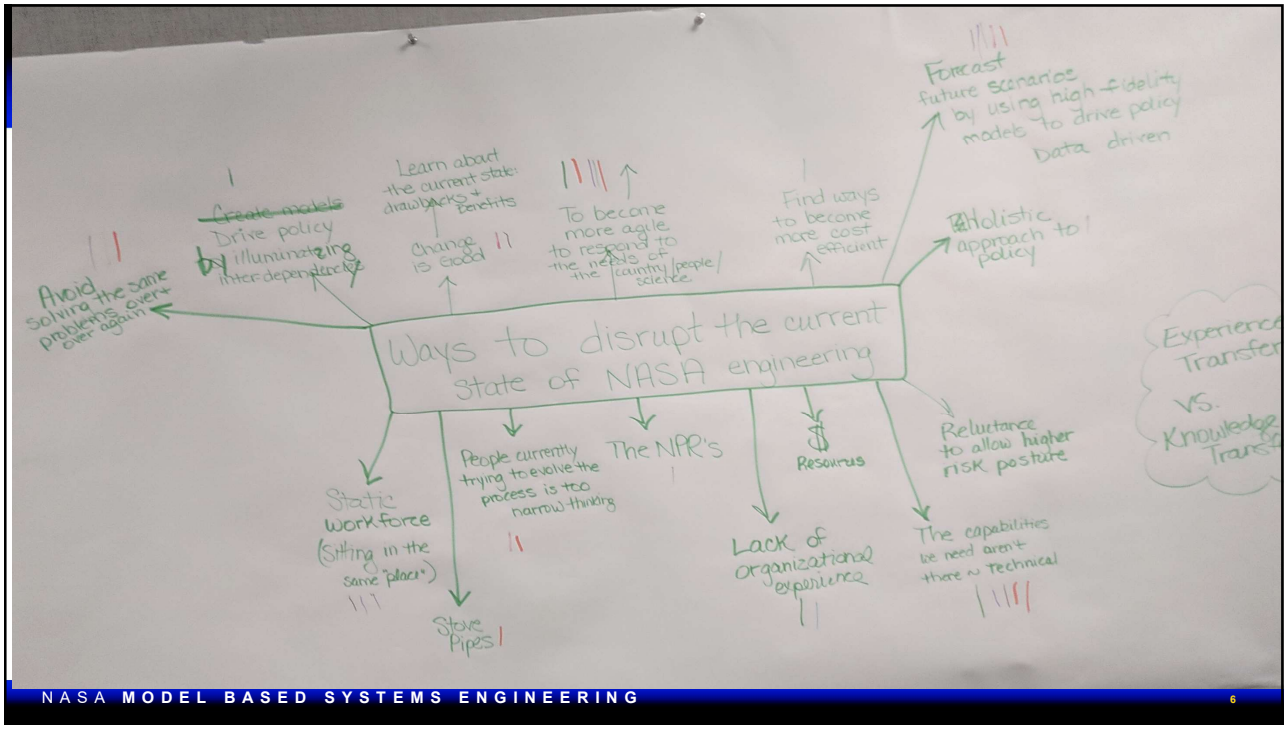
Brainstorming

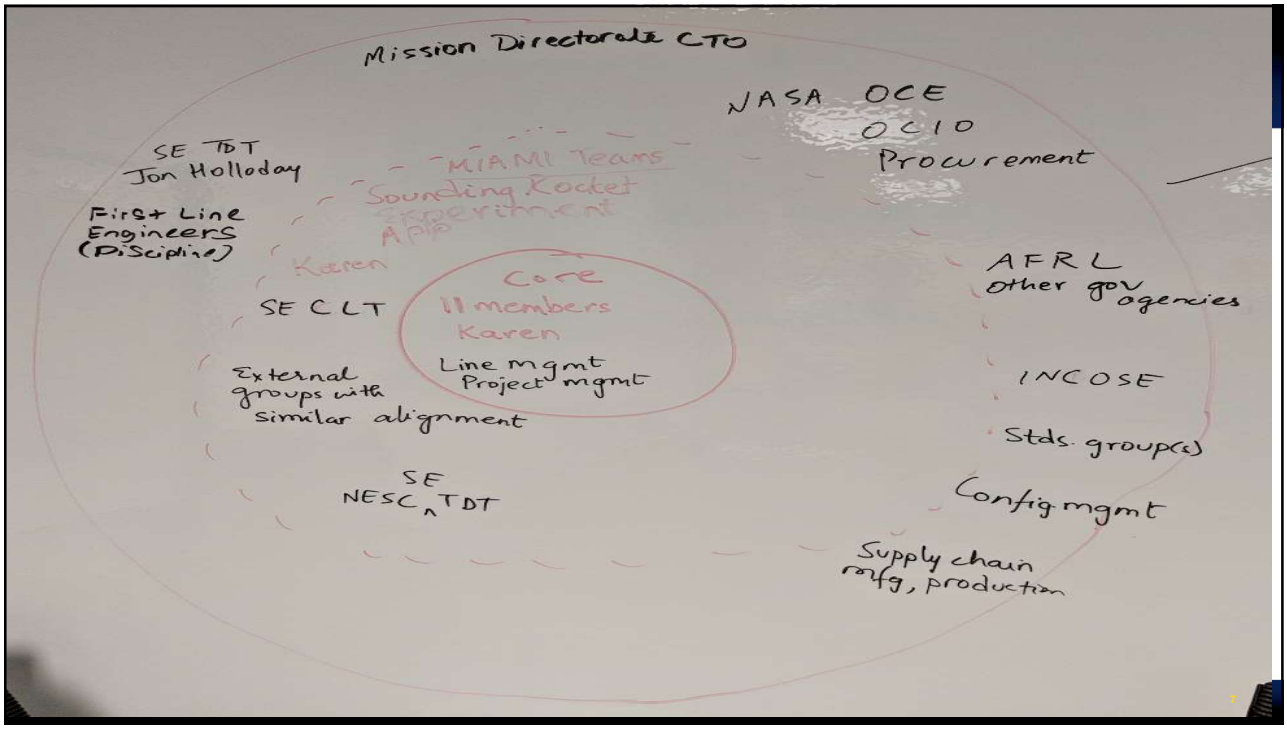
- Upload to SharePoint so entire team can see
- Break out into subsections by domain of interest/responsibility
- Comment on changes for uploads
- Maybe GSuite?
- 1-on-1 communication to address suggestions
- Flag sensitivity if needed
- WATCH OUT FOR SPIES!
- Go through Karen and Jessica for document releases to client
- Provide Updates to meeting leader prior to telecon (15-minute) if you can't make it
- Distinguish between taking minutes/directing meeting

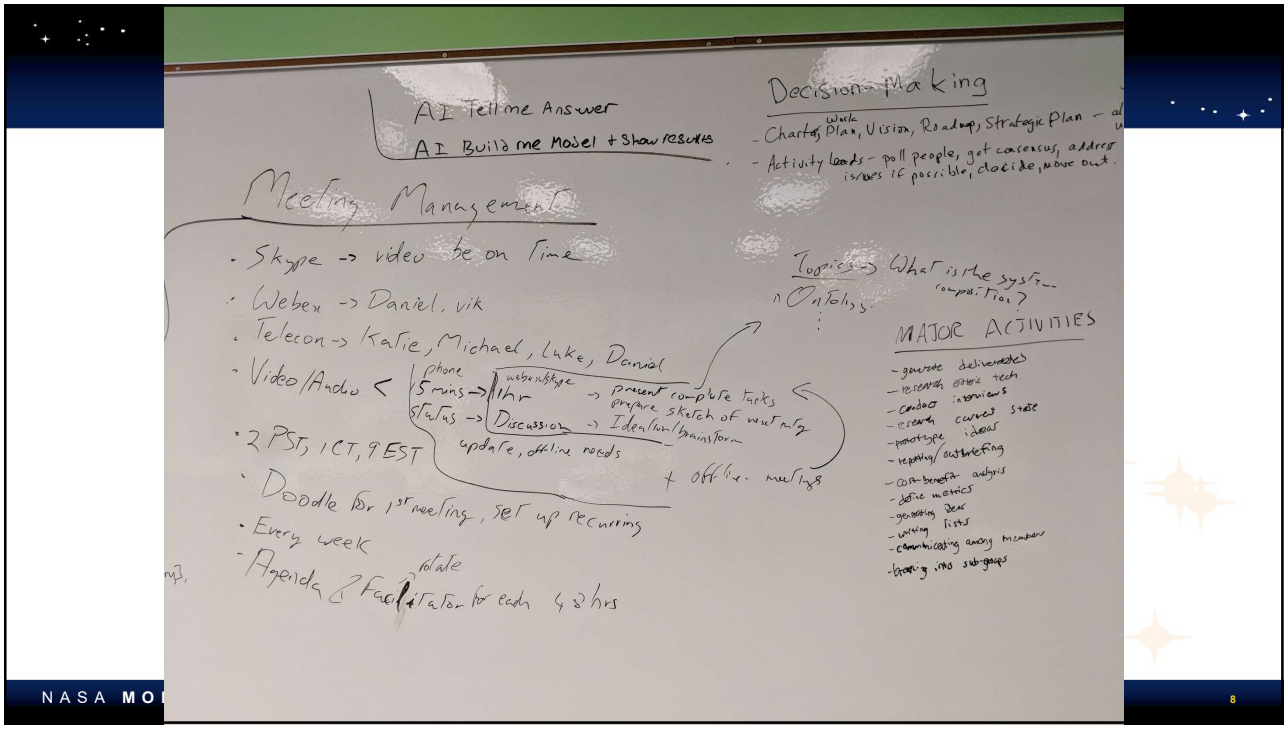
Other NASA and NASA Potential Contacts for Collaboration

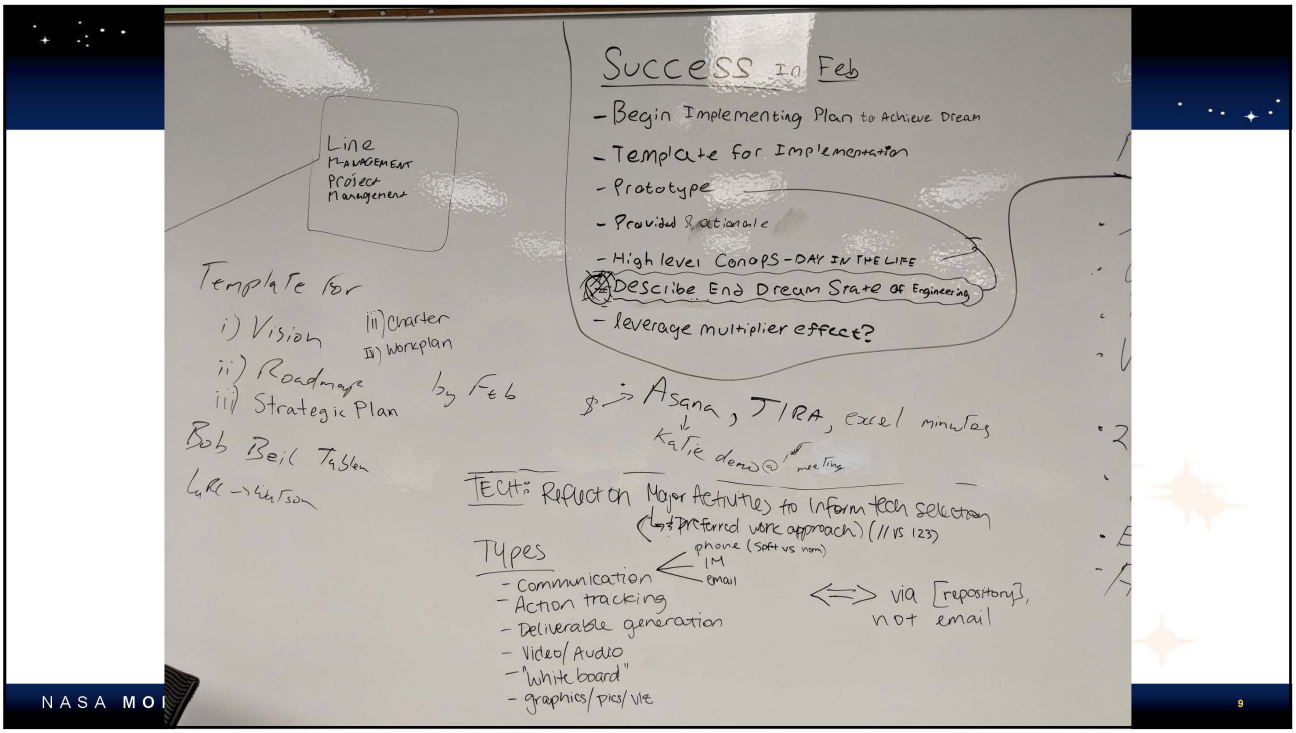
#	POC/Group	Strategy Group POC
1	RockSatC	Vikram
2	MIAMI Working Groups	Katie
3	INCOSE Natural Systems	Vikram
4	Tech Area Roadmaps - OCT	Anupa
5	NASA Information Architecture WG	Katie
6	Air Force Model Acquisition	Luke
7	Big Data	Karen
8	Center MBSE WGs - LaRC	Luke
9	Center MBSE WGs - ARC	Anupa
10	Center MBSE WGs - GRC	Katie
11	Digital Transformation	Karen
12	Autonomous Systems CLT	Anupa
13	ESD DI-ITT	Katie
14	Cost and schedule modeling	Karen
15	Configuration Management	Katie
16	IMCE, CAE, Foundry @ JPL	Nick
17	GVIZ	Katie
18	Scientific Visualization Studio	James

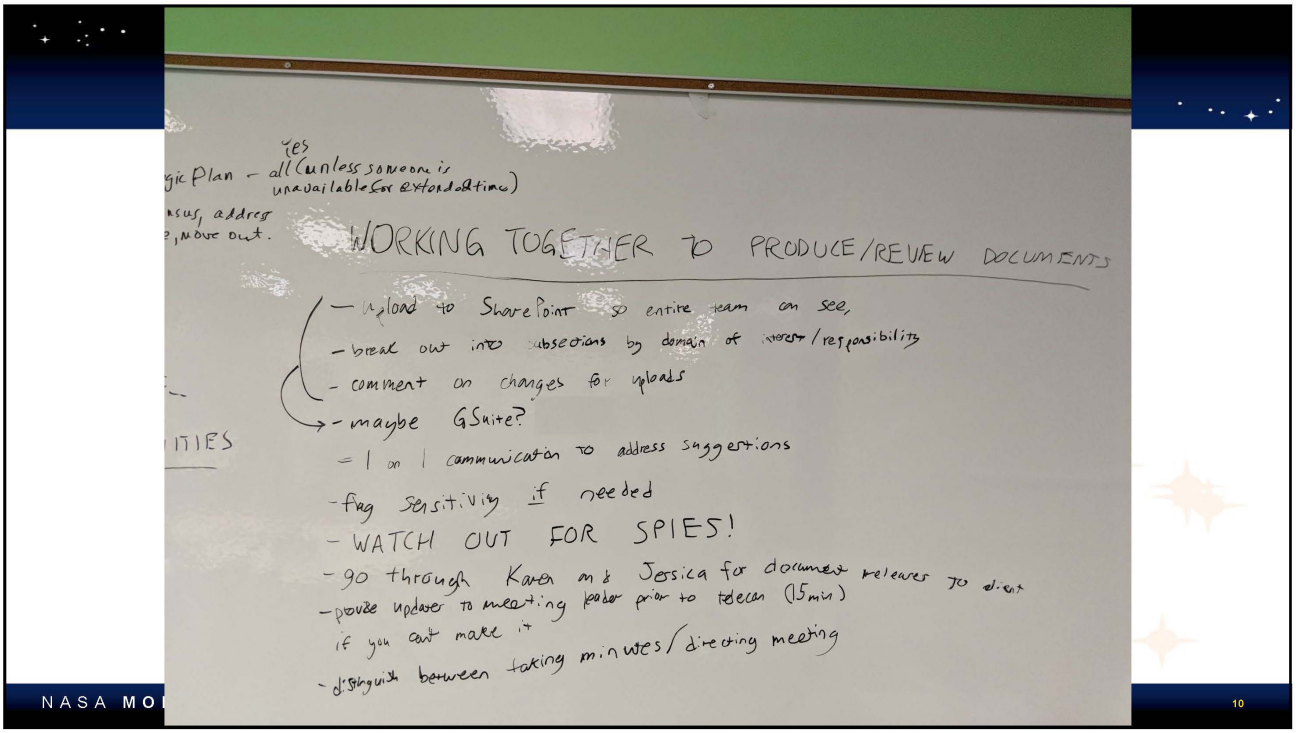
#	POC/Group	Strategy Group POC
19	Conservation Groups	Vikram
20	Additive Manufacturing	Vikram
21	Academia: Georgia Tech	
22	Academia: Carnegie Mellon	
23	Academia: Stevens Institute of Technology/SERC	Karen
24	Academia: MIT	
25	MITRE	Karen
26	Center Mission Concept Teams: COMPASS	Katie
27	Center Mission Concept Teams: TeamX	Nick
28	Center Mission Concept Teams: EDS	
29	GRC Institutional Vision Report	Vikram
30	LaRC Nexus Group	Luke
31	Innovation Research Interchange	Vikram
32	Human Factors	Daniel
33	Ames Campus of the Future/Green Team	Anupa
34	Employee Resource Groups	Esther
35	Rocket University - GRC	Katie
36	Cube Sat Teams (AFRL, Universities, Ames)	Luke




Mission Directorate CTO
NASA OCE
OCIO
Procurement
SE TDT
Jon Holloday
First Line Engineers (Discipline)
MIAMI Teams
Sounding Rocket Experiment Appl
Karen
SE CLT
Core
11 members
Karen
Line mgmt
Project mgmt
External groups with similar alignment
AFRL
other gov agencies
INCOSE
Stds. group(s)
Config mgmt
Supply chain mfg, production
SE
NESC
TDT


AI Tell me Answer
AI Build me Model + Show results
Decision-Making
- Charter, Work Plan, Vision, Roadmap, Strategic Plan
- Activity leads - poll people, get consensus, address issues if possible, decide, move out.
Meeting Management
- Skype -> video be on time
- Webex -> Daniel, vik
- Telecon -> Karie, Michael, Luke, Daniel
- Video/Audio < phone 5 mins -> 1hr webex/skype -> present complete tasks, prepare sketch of white/brainstorm
status -> Discussion -> Ideation/brainstorm
update, offline needs
+ offline meetings
- 2 PST, 1 CT, 9 EST
- Doodle for 1st meeting, set up recurring
- Every week
- Agenda, facilitator for each 4 hrs, rotate
Topics -> What is the system composition?
Ontology
MAJOR ACTIVITIES
- generate deliverables
- research other tech
- conduct interviews
- research current state
- prototype ideas
- reporting/outbriefing
- cost-benefit analysis
- define metrics
- generating gear
- writing lists
- communicating among members
- breaking into subgroups


Success in Feb
- Begin Implementing Plan to Achieve Dream
- Template for Implementation
- Prototype
- Provided Rationale
- High level ConOps - DAY IN THE LIFE
- Describe End Dream State of Engineering
- leverage multiplier effect?
Line
MANAGEMENT
Project
Management
Template for
i) Vision
ii) Roadmap
iii) Strategic Plan
iii) Charter
iv) Workplan
by Feb
Bob Beil Tasks
Asana, JIRA, Excel minutes
Katie demo @ meeting
TECH: Reflect on Major Activities to inform tech selection
(preferred work approach) (// vs 123)
Types
- Communication
- Action tracking
- Deliverable generation
- Video/Audio
- "White board"
- graphics/pics/vis
phone (Soft vs non)
IM
email
<=> via [repository], not email
NASA MO
9


yes
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WORKING TOGETHER TO PRODUCE/REVIEW DOCUMENTS
- upload to SharePoint so entire team can see,
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- maybe GSuite?
= 1 on 1 communication to address suggestions
- flag sensitivity if needed
- WATCH OUT FOR SPIES!
- go through Karen and Jessica for documents releases to client
- provide updates to meeting leader prior to telecon (15min)
if you can't make it
- distinguish between taking minutes/directing meeting
NASA MO
10

A.5 Creativity and Innovation Ideation—Systems Engineering—Strategic Ideation Session, June 27, 2018

What are the possible returns on investment for adopting model-based systems engineering (MBSE) Agency wide?

Yellow Hat Thoughts

1. Less time spent on rework; less rework
2. Easier to assess previous projects and generate evidence-based lessons learned
3. Earlier identification of constraints
4. Clarity of expectation across life cycle
5. Better understanding of emergent behaviors
6. More time spent doing engineering (vs documenting or tracking)
7. Less time rehashing/remembering how we “got here”
8. Greater opportunity for metrics
9. Reduced “dumb” errors
10. Increased precision
11. More time exploring the design space
12. Better traceability of data/views
13. Automation reduces labor cost eventually
14. Reducing the labyrinth of system knowledge process mistakes/mission failure/risk in the future
15. Getting everyone on board creates institutional standard, which bolsters communication between codes (efficiency)
16. Agility, lower cost, reduced time to delivery to enhance chances of mission success and ultimately agency survival in a competitive environment with increasing privatization and political pressure
17. Provide reference framework/model to solve similar problems
18. Better communication of data/thoughts across groups/centers
19. Reduce potential “information lost” because information already exist in the model
20. Elimination of duplicative document generation and rework
21. Better long-term information retention
22. Near elimination of interface conflicts
23. Reuse of models developed that were successful
24. Work on distributed teams efficient
25. Easy to transfer work with trained team
26. Integrate systems at required before any design is done
27. Flexibility for change
28. Once teams are trained they can use common onthology
29. MBSE enables formalization of ideas
30. Flexibility
31. Culture agnostic
32. Increased productivity
33. Once a team is trained in MBSE, their next project is worked more efficiently
34. MBSE provides a single, authoritative source of truth
35. MBSE enhances communication between groups of the current state of the system
36. MBSE allows redesign of system before actual hardware is procured

What challenges do we face when integrating MBSE into the mainstream of NASA programs/projects?

Black Hat Thoughts

1. Limited resources: devoting time to learn new tools (by systems engineers)
2. Limited resources: developing model methodologies
3. Tackling too much at once
4. Limited resources: developing custom tools/capabilities
5. Limited budget: initial investment required to realize benefits
6. MBSE not required by NPRs
7. MBSE benefits not understood, but communication efforts are growing
8. Education, familiarity, understanding, and adoption of MBSE tools
9. Learning curve to this “common” language
10. Push back from folks who are used to the way things are/were
11. Not enough resources for using MBSE: available seats; learning courses
12. Agreeing on which tools are by consensus the best investment for the money
13. Collecting problems/experiences/tool knowledge and sharing effectively
14. Showing progress by applicability/utility to projects right away versus laying the foundation fully
15. Text versus swipe. Hard to change mindset
16. Limited ability or difficult to integrate older legacy tools
17. Initial effectiveness is lower
18. It is not readily embraced by discipline engineers
19. MBSE terminology sounds foreign to project team
20. SE meaning control systems; engineer of systems
21. Return on investment takes time to show for SE tools
22. SE is too similar to project management when viewed by other engineers
23. Blocks are not as cool as hardware
24. We call the old thing something new. IDEF – MBSE
25. Model-based engineering has head start on SE
26. SE at times is too fluffy

Appendix B.—MIAMI Strategy Group Charter

NASA Model Based System Engineering (MBSE) Strategy Group (SG) Charter

1.0 PURPOSE

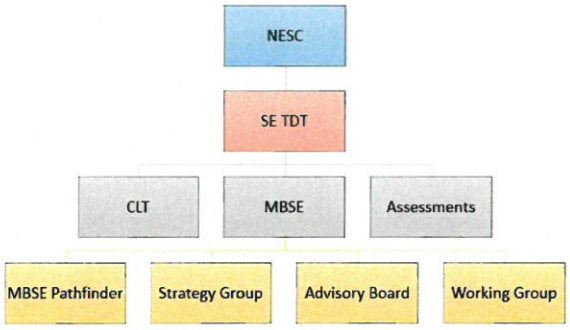
The purpose of this charter is to establish the NASA Model Based Systems Engineering (MBSE) Strategy Group (SG) (hereinafter called the MBSE SG) and sets forth its responsibilities, membership and internal procedures.

The purpose of the NASA MBSE SG is to provide a vision of the state of the art of Systems engineering practices at NASA and develop a strategic plan to enable the state of the art up to 20 years in the future:

A. Insight into current engineering processes and approaches and domain outlook
B. Researching emerging technologies that benefit the Systems Engineering and discipline engineering communities
C. Catalog current trends at other government agencies, internal NASA organizations, and interviewing stakeholders regarding their future outlook and current challenges.

2.0 AUTHORITY

The MBSE SG is chartered under the authority of the NASA Engineering and Safety Center Systems Engineering Technical Discipline Team NESC SE TDT MBSE Group.



3.0 DELIVERABLES

The MBSE SG is tasked with providing the following deliverables. The scope and fidelity of the items listed in this section is tailored to align with the direction of the MBSE Group.

1. *MBSE Vision:*
   a. Draft by August 20th 2018
   b. The Vision statement is a top-level, succinct statement that captures the goals and objectives of the engineering capability in 20 years, and provides a basis from which proposed investments to the workforce and capabilities can be evaluated.
2. *MBSE Roadmap*:
   a. Draft by end of September 2018
   b. Roadmap supporting details draft by mid-December 2018

c. The Roadmap defines broad categories of workforce development and engineering capabilities, and depicts desired waypoints over time to achieve these developments. Endpoints are also described.

3. *MBSE Strategic Plan:*
   a. Draft by mid-December 2018
   b. Strategic investment recommendations due mid-February 2019
   c. The Strategic Plan provides specific investment recommendations in order to achieve the waypoints and endpoints described in the Roadmap.

4.0 REPORTING

1. Weekly, the MBSE SG will record minutes in a shared OneNote notebook, visible to the members, after each meeting. Link: https://cop.ksc.nasa.gov/NESC/1612NESCMB/Shared%20Documents/2018%20MIAMI/Strategy%20Group/SE%20Strategy%20Group%20Meeting%20Notes
2. Monthly, the MBSE SG will provide status reports on the Strategy Group's progress to the MBSE Group leads.
3. Quarterly, the MBSE SG will provide a report on the SG's progress/accomplishments to NESC SE TDT personnel.

5.0 MEMBERSHIP, ROLES AND RESPONSIBILITIES

The MBSE Strategy Group consist of members across the agency to research the future direction of MBSE across NASA. The SG Members are selected by the MBSE Group Lead. The nominee must have approval from their management to accept the position. The term lasts for half a year till February 2019.

5.2 Membership

1. The MBSE SG consists of only one type of member with equal responsibility. Each SG Member is responsible for identifying, prioritizing and executing the tasks generated by or assigned to the SG as a whole.
   a. For purposes of reporting out from the strategy group to the MBSE Group leads, one of the SG Leads will be designated as a POC for the group, reporting status and collecting actions to bring back to the SG; the designated POC will be rotated.

2. SG Members:

Name	Center		Name	Center
Amanda Stein	MSFC		Ken Toro	LaRC
Anupa Bajwa	ARC		Luke Murchison	LaRC
Daniel Hoffpauir	LaRC		Mike Pepen	GRC
Esther Lee	LaRC		Nick Waldram	JPL
James Mackinnon	GSFC		Vikram Shyam	GRC
Katie Trase	GRC		Karen Weiland	GRC

6.0 MEETINGS AND ATTENDANCE

1. The MBSE SG will meet weekly, with updates on individual tasks.
   a. Attendance: All MBSE SG Members
2. Additional meetings will be scheduled as appropriate to discuss specific topics
   a. Attendance: SG Members assigned to tasks
3. The MBSE SG designated POC will attend monthly meetings with the MBSE Group to provide status and issues.
4. The MBSE SG membership will attend the MBSE Group Annual Review

7.0 OPERATING PRINCIPLES

1. Objectives of the MBSE SG will be implemented through the actions of its membership.
2. Decisions of the MBSE SG will be made by consensus.
3. The MBSE SG meeting facilitator will send out the agenda and any presentation materials to the MBSE SG members prior to the meeting.
4. The MBSE SG meeting facilitator or designee will track actions and record all of the dispositions from the MBSE SG.

8.0 CHARTER CHANGES

Changes to this charter will be reviewed by the MBSE SG and formally submitted to the MBSE Group for approval.

9.0 RECORDS

1. All MBSE SG material (presentations, minutes, actions, reference material, etc.) will be maintained in the MBSE SharePoint (address), or other online repository, as applicable.
2. MBSE SG members will have read access to the repositories hosting the materials produced by the membership.

10.0 ASSESSMENT

The effectiveness of the MBSE SG is based on the completion and acceptance of the SG deliverables by the MBSE Group by the dates specified in Section 3.

11.0 PERIOD OF PERFORMANCE

The charter for the MBSE SG will re-evaluated at the end of February, 2019, at which point its functions may be validated, revised or the SG disbanded, at the discretion of NESC SE TDT management.

Approved By

Karen J. Weiland

Karen Weiland

Sept. 13, 2018

Date

Appendix C.—MIAMI Strategy Group Work Plan

C.1 Strategy Group Communication Plan, August 16, 2018—Presentation Slide

Strategy Group Communication Plan

- Maintain regular communication amongst all SG members
  - Brainstorm ideas and questions during weekly tag-ups
  - Track tasks for SG members (Asana)
  - Collaborate on knowledge-sharing (SharePoint)
- Maintain a two-way dialogue with stakeholders
  - MIAMI Leads and NESC Executives
  - NASA's Capability Leadership Teams (CLT) and Communities of Practice (CoP) such as Systems Engineering, Modeling and Simulation, Autonomous Systems
  - Offices of the Chief Engineers and Chief Technologists at NASA Centers and HQ
- Learn and share Systems Engineering best practices with
  - Universities, Companies, Industry Groups (such as INCOSE)

C.2 Interview Rubric

How many people do you interact with on a daily basis (on average) to do your job?

- Small (1-5)
- Mid (6-15)
- Large (more than 15)

Personality

- Introvert
- Extrovert

Experience

- Early
- Mid
- Late

Expertise (Field)

- Procurement
- Manufacturing/Production
- Contracts
- Systems Engineering/Architect
- Systems Analysis/Mission Design
- Project Management
- Principal Investigator
- Configuration/Data Management
- Test and Verification
- Quality Assurance
- S&MA
- Program Planning and Control
- Flight Operations
- Engineering Disciplines
- Executives (Chief Technologist, Scientist, and Engineer)

Phase of Life Cycle

- Pre-formulation/proposal
- Mission concept development/pre-Critical Design Review (CDR))
- Product realization/hardware or software build/post-CDR/verification and validation/manufacturing
- Mission operations
- (Pervasive throughout life cycle, like configuration management, project management, risk management, etc.)

C.3 Interviews Overview

MIAMI Strategy Group Interviews and Survey

Interview goals:

1. Learn about key roles in the NASA enterprise that get missions designed, built, tested, implemented, and flown – *especially those areas that are outside the expertise of the strategy group.*
2. Get insight into the nature of the work these key roles perform to understand whether anticipated future technologies (such as model/data-driven, big data, machine learning, natural language processing, artificial intelligence, augmented reality/virtual reality, etc.) might be relevant to that domain.
    a. In particular, appreciating what sorts of decisions these roles make, and how they are made/where they get their supporting data or evidence, helps evaluate potential technologies for application.
3. Learn about key technology adoptions already underway in these key roles.
4. Learn about aspects of their jobs these folks do/don't like, so we take care not to "design out" the good stuff, or perpetuate the bad stuff in our strategy.
5. Get a cross-section of demographics, as much as reasonably achievable, to ensure balanced input. "Extremes" identified:
    a. Stage in career
    b. Project size
    c. Life cycle emphasis
    d. Support or skeptical of MBSE
6. Encourage/promote grassroots buy-in and inclusion in development of roadmap/strategic plan/vision

The goal of the interview is ***not*** to get their input on systems engineering, MBSE, etc. Time permitting, we could ask.

Survey Goals (to be refined):

1. Audience:
2. Quantity goal:
3. Collect (additional) data on opinions/readiness/openness to upcoming technologies that may impact engineering/mission development and execution
4. Verify assumptions of problems we identify/assume should be resolved/mitigated by the vision
5. Recruit follow-on interview subjects, or draft deliverable reviewers ("focus group" members)

Interview approach summary:

1. Set up meeting, provide a bit of background of the conversation and its goals
    a. Face-to-face is best (for interviewer, at a minimum; note taker is optional?)
    b. Not planning to provide questions in advance, to encourage more "emotion-based" responses (email request should summarize goals/topics of interview)
    c. Make sure another strategy group member or helper is available to take notes while you interview
2. Kickoff interview
    a. Introduce yourself and note taker, remind them of the interview purpose/goals, MIAMI strategy group, etc.
    b. Ask questions in the order listed
    c. Ask follow-on or probing questions: these aren't yes/no answers! Get at the root of their issues, challenges, concerns, etc.

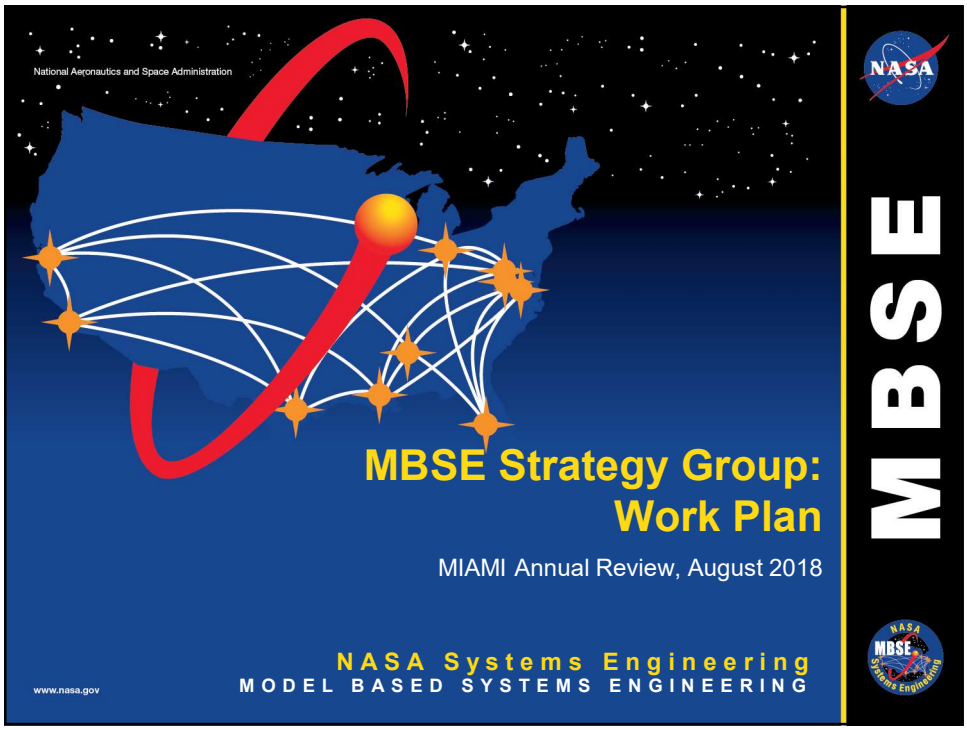
3. Share (draft) vision statement and ask for feedback
    a. What do they like/dislike about it?
    b. What would they change?
    c. How might this vision/approach change the way they work, if it were to be realized?
    d. Do they foresee any unexpected challenges in implementing/realizing the vision?
4. Wrap up – thanks for their time; will incorporate your comments into our roadmap/strategic plan
    a. Do they want to review our draft deliverables?

"Cold email" text:
Hello [person],
I'm part of an Agency-level strategic planning team tasked with envisioning how the Agency will develop and implement its projects and missions 20 years from now. From this vision, we'll be developing a roadmap of capabilities we think the Agency should cultivate, and a strategic plan to guide investment in tools and the workforce. We are interviewing a cross section of roles at the agency to ensure a well-rounded vision.
I'd like to conduct an hour-long interview to learn about your role at the Agency and get your thoughts on how your role might evolve in the future, given existing "transformative" activities or various technological advancements. The team would like to know what you'd like to change, or keep the same, about your future envisioned role, as well.
Would you be available at any of the following times, for a conversation with myself and [co-interviewer/note taker]?

- [list some candidate times]

Thanks for your consideration,
[signature]

C.4 MBSE Strategy Group: Final Work Plan, MIAMI Annual Review, August 2018—Presentation Slides



MBSE Strategy Group: Outline of Work Plan

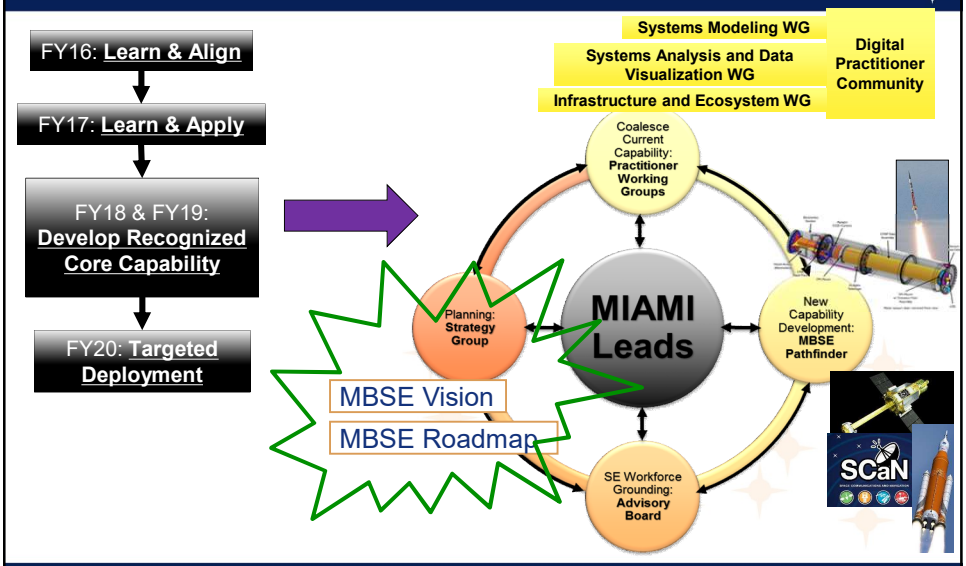
Content	Notes
Team Members	Lead, members, associates, advisors, students, other; include name, Center or institution, MBSE involvement
Goals and Objectives	Trace to the MIAMI goals and objectives in the MIAMI Plan
Team Charter Overview	Short summary (two pages maximum). The specifics for our work.
Resource Requests	What we need from MIAMI to meet our objectives. E.g., access/ funding for software tools/licenses, travel to team meetings, advising, student intern, or other.
Metrics	Metrics/characteristics being captured at start, during, and end of the work
Deliverables	List of items and due dates
Milestones	List of top-level milestones, including any decision points
Team Work Approach	Rules of engagement for working as a group, team work processes, use of collaboration site by the team, communication within the team
Outreach Communication Plan	Reporting to MIAMI; communications back to the Centers about what we are doing – who communicates, to whom, how often; conferences, etc.

NASA MODEL BASED SYSTEMS ENGINEERING 2

MBSE Strategy Group Members

Name	Center	Previous Role(s) for MBSE
Amanda Stein	MSFC	MBSE Pathfinder 2 (Engine Team)
Anupa Bajwa	ARC	MBSE Pathfinder 3 (Experiment Team); ARC SE CoP
Daniel Hoffpauir	LaRC	New to group
Esther Lee	LaRC	MBSE Pathfinder 2 (ISRU Team)
James MacKinnon	GSFC	New to group and MBSE in general
Katie Trase	GRC	Former GRC MBSE WG Chair and ARRM MBSE Usability Lead; current MIAMI Systems Analysis and Data Visualization WG Co-Lead
Ken Toro	LaRC	MBSE Pathfinder 2 (Engine Team)
Luke Murchison	LaRC	MBSE Pathfinder 2 (Engine Team), SAGE IV
Mike Pepen	GRC	New to MBSE team at NASA; several years' experience implementing MBSE in commercial industry
Nick Waldram	JPL	MBSE Pathfinder 2 (HESTIA Team), Pathfinder 3 (Sounding Rocket)
Vikram Shyam	GRC	New to group
Karen Weiland	GRC	Advisor to the Strategy Team; MIAMI Co-Lead

MBSE Strategy Group is a part of the MIAMI Organization



MBSE Strategy Group Overview

To project Agency needs and capabilities over the next 20 years

- A multi-Center group of big-picture thinkers responsible for defining and planning our digital future
  - Aware of trends in politics, technology, education, engineering, and organizations
- Group works to formulate, refine, and deliver
  - The MBSE Vision
  - A MBSE Roadmap
  - A Strategic Plan
- Group defines its own collaboration style and pace
  - Reports quarterly to the NESC TDT Lead

MIAMI Goals and Objectives Addressed by SG

Strategy Group Objective	MIAMI Plan Objective
Investigate methods of data management to achieving a single source of truth	Define what we want from integrated tool and data sets.
Develop a Strategic Plan to guide investment needed to design and implement increasingly autonomous and complex systems	Increased understanding for greater flexibility and adaptability in design. Increased confidence that the capability will perform as expected. Increase efficiency and reduce errors.
Ensure that the Roadmap and Strategic Plan resonate with the MIAMI stakeholders	Communicate MIAMI message to stakeholders. Multiple views to bridge differences in language and communication style.
Inspire and Guide Agency-wide engineering policy and investments with Roadmap and Strategic Plan	Define the high priority needed capabilities. Look at 15-20 year plans for new technologies – how can we start to incorporate this?

MBSE Strategy Group Metrics

- The effectiveness of the MBSE SG is based on the completion and acceptance of the SG deliverables by the MBSE Group by the dates specified in the charter

MBSE Strategy Group Deliverables

MBSE VISION
- Draft by August 20, 2018
- Top-level, succinct statement to capture goals and objectives
- Helps evaluate proposed investments to develop capability and workforce

MBSE ROADMAP
- Draft by end of September 2018
- Top-level depiction of desired capabilities over time
- Based on an assessment of future engineering needs, existing/projected capabilities, technology and competency gaps, proposed investments
- Depict desired endpoints, and waypoints over time, for each capability

STRATEGIC PLAN
- Draft by mid-December 2018
- Propose approach to accomplish the Vision
  - Stakeholders
  - Resources
  - Timing and phasing
  - Ability to buy, borrow, watch, partner, defer
- Recommendation for Strategic Investment and continuation of Strategy Group

MBSE Strategy Group Milestones

- May 2018 – Invitations to selected personnel to form the Group
- June 26-27, 2018 – Participate in a Face-to-Face Kickoff Meeting at GRC
- August 20, 2018 – Deliver Strategy Group Charter and Work Plan
- August 20, 2018 – Deliver a draft of the MBSE Vision
- September 28, 2018 – Deliver a draft of an MBSE Roadmap
- December 14, 2018 – Deliver a draft of MBSE Roadmap's Supporting Details, and a draft of A Strategic Plan
- February 20, 2019 – Deliver recommendations for Strategic Investments; Deliver Vision, Roadmap, and Strategic Plan

MBSE Strategy Group Teamwork Approach

- Working together
  - Keeping in touch with other team members using phone, emails, weekly tag-ups, and Asana
  - Rotating facilitator and note taker for weekly tag-ups, and monthly meetings
  - Working together to produce or review deliverables via meetings and document sharing on SharePoint site
- Decision making by consensus
  - All decisions will be voted upon by the entire group unless someone is unavailable for an extended time. Efforts will be made to include all group members.

MBSE Strategy Group Outreach/Communication Plan

- Maintain regular communication amongst all SG members
  - Brainstorm ideas and questions during weekly tag-ups
  - Track tasks for SG members (Asana)
  - Collaborate on knowledge-sharing (Sharepoint)
- Maintain a two-way dialogue with stakeholders
  - Monthly status reports to MIAMI/MBSE Group leads
  - Quarterly report to NESC SE TDT personnel and MIAMI community
  - Systems Engineering Communities of Practice (CoP)
  - (stretch goal) NASA's Capability Leadership Teams (CLT) and, Modeling and Simulation, Autonomous Systems
  - (stretch goal) Offices of the Chief Engineers and Chief Technologists at NASA Centers and HQ
- (Stretch goal) Learn and share Systems Engineering best practices with
  - Universities, Companies, Industry Groups (such as INCOSE)

Appendix D.—Reviews and Lessons Learned

D.1 Annual Review, August 21, 2018—Presentation Slides

MBSE Strategy Group (SG)

- Part of the MIAMI Organization
- A multi-Center group of big-picture thinkers responsible for defining and planning our digital future
  - Aware of trends in politics, technology, education, engineering, and organizations

MBSE Strategy Group Charter

The purpose of the NASA MBSE SG is to provide a vision of the state of the art of Systems Engineering practices at NASA and develop a strategic plan to enable the state of the art up to 20 years in the future:

- Insight into current engineering processes and approaches and domain outlook
- Researching emerging technologies that benefit the Systems Engineering and discipline engineering communities
- Catalog current trends at other government agencies, internal NASA organizations, and interviewing stakeholders regarding their future outlook and current challenges.

Membership, Roles and Responsibilities

- The MBSE SG consists of only one type of member with equal responsibility. Each SG member is responsible for identifying, prioritizing, and executing the tasks generated by or assigned to the SG as a whole.

Name	Center	Previous Role(s) for MBSE
Amanda Stein	MSFC	MBSE Pathfinder 2 (Engine Team)
Anupa Bajwa	ARC	MBSE Pathfinder 3 (Experiment Team); ARC SE CoP
Daniel Hoffpauir	LaRC	New to group
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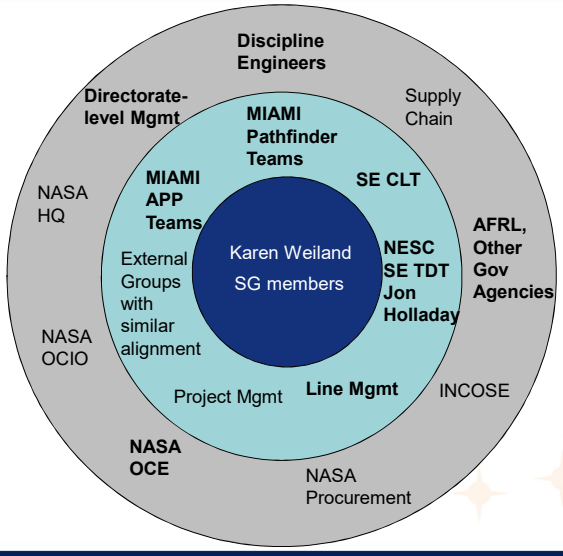
Core Team and Stakeholders



Stakeholders' Problems and Challenges

- Inconsistency in terms used to describe a system or components
- Failure to find/retain relevant and current data
- Retaining data and models to be shared across projects life cycles, domains, and across centers, protect from data discrepancies
- Traceability between levels of abstraction, domain viewpoints across time
- Lack of training and opportunities to develop and nurture current and future technical leaders in SE
- Lack of motivation to invest in advanced SE techniques that could be integrated into projects

Goals and Objectives

Strategy Group Objective	MIAMI Plan Objective	Stakeholders' Problems and Challenges
Investigate methods of data management to achieving a single source of truth	Define what we want from integrated tool and data sets.	Retaining data and models to be shared across projects' life cycles, domains, and across centers, protect from data discrepancies
Understand and verify requirements for increasingly autonomous and complex systems	Increased understanding for greater flexibility and adaptability in design. Increased confidence that the capability will perform as expected. Increase efficiency and reduce errors.	Lack of motivation to invest in advanced SE techniques that could be integrated into projects
Ensure that the Roadmap and Strategic Plan resonate with the MIAMI stakeholders	Communicate MIAMI message to stakeholders. Multiple views to bridge differences in language and communication style.	Traceability between levels of abstraction, domain viewpoints across time
Inspire and guide Agency-wide engineering policy and investments with Roadmap and Strategic Plan	Define the high-priority needed capabilities. Look at 15- to 20-year plans for new technologies—how can we start to incorporate this?	Lack of training and opportunities to develop and nurture current and future technical leaders in SE

Description of Work

- Project Agency needs and capabilities over the next 20 years based on current states and trends of SE
- Create a Vision of Systems Engineering/Engineering in 20 years at NASA centers
- Formulate a Roadmap to identify major milestones in achieving the Vision
- Establish a Strategic Plan to suggest prioritization of resources and capabilities in order to provide an agile response to Agency and society's needs

Metrics and Deliverables

Metrics

- The effectiveness of the MBSE SG is based on the completion and acceptance of the SG deliverables by the MBSE Group by the dates specified in the charter

Deliverables (Final due February 20, 2018)

- MBSE VISION (Draft by August 20th 2018)
  - Top-level, succinct statement to capture goals and objectives
  - Helps evaluate proposed investments to develop capability and workforce
- MBSE ROADMAP (Draft by end of September 2018)
  - Top-level depiction of desired capabilities over time
  - Based on an assessment of future engineering needs, existing/projected capabilities, technology and competency gaps, proposed investments
  - Depict desired end points, and waypoints over time, for each capability
- STRATEGIC PLAN (Draft by mid-December 2018)
  - Propose approach to accomplish the Vision
    - Stakeholders
    - Resources
    - Timing and phasing
    - Ability to buy, borrow, watch, partner, defer

Milestones

- May, 2018 – Invitations to selected personnel to form the Group
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Outreach Communication Plan

- Maintain regular communication amongst all SG members
  - Brainstorm ideas and questions during weekly tag-ups
  - Track tasks for SG members (Asana)
  - Collaborate on knowledge-sharing (SharePoint)
- Maintain a two-way dialogue with stakeholders
  - MIAMI Leads and NESC Executives
  - Systems Engineering Communities of Practice (CoP)

  - NASA's Capability Leadership Teams (CLT) and, Modeling and Simulation, Autonomous Systems
  - Offices of the Chief Engineers and Chief Technologists at NASA Centers and HQ
- Learn and share Systems Engineering best practices with
  - Universities, Companies, Industry Groups (such as INCOSE)

Vision (20 Years+): Imaginable, Desirable, Feasible, Focused, Flexible, Easy to Communicate

- **To provide informed, reliable, real-time decision-making capability to entire hierarchy of stakeholders throughout the life cycle of projects**.
  - Instantiate trade priorities, parameters, scope, hard constraints, and building-blocks
  - Curate and understand intelligent systems
    - Feeding models with source data, “experiences,” and proper training
    - Hierarchical models with reusable analysis modules
    - Automated knowledge capture to provide source data and generate data lake
  - Prune design decision trees
    - Data-driven holistic view reveals hidden problems by extracting meaning from data lakes (legacy mission information, documents, lessons learned)

Obstacles Overcame and Obstacles Remaining

- Utilized weekly tag-ups and online task/document sharing to communicate current progress/status
- Accommodating everyone’s schedules
- What obstacles should we prepare for?

D.2 Advisory Board Annual Review Comments, August 22, 2018

From the Advisory Board:

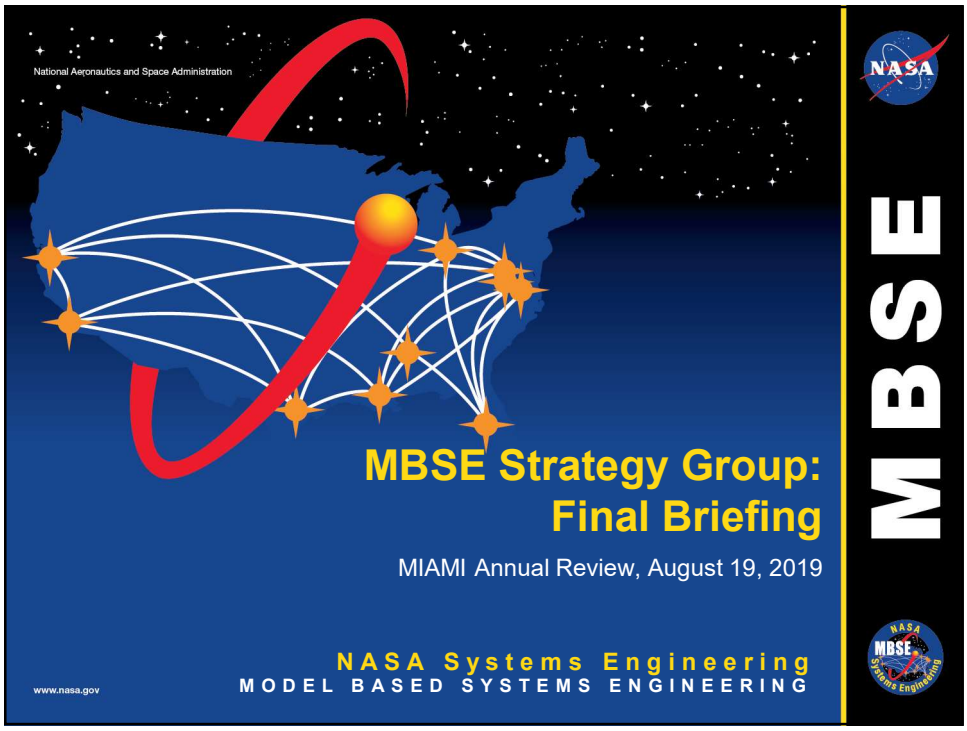
Strategy Working Group:

Looking ahead we need data standards. Address how data is stored. If data's stored in open format can use multiple tools. Look at innovative companies to see what they're doing…SpaceX, Automotive industry, ESA/JAXA, Boeing commercial, commercial satellite builders, etc.

Review Discipline CLT strategic vectors to at least be informed of what disciplines are forecasting as they're engineering needs.

Would like for team to interview as many as possible. Lots of people who have strong opinions and lots that don't. Not just systems engineers, but those who interact with systems engineers.

D.3 MBSE Strategy Group: Final Briefing—MIAMI Annual Review, August 19, 2019—Presentation Slides



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Vikram Shyam	GRC	New to group
Karen Weiland	GRC	Advisor to the Strategy Team; MIAMI Co-Lead

MBSE Strategy Group Accomplishments

- Defined the Charter
  - Established the SG and set forth its responsibilities, memberships and internal procedures
- Developed a Vision
  - As a top-level, succinct statement to capture goals and objectives
- Depicted the Vision with a set of Graphics
  - Emphasized machine-led, data-driven technical development with the humans in-the-loop in seamless, distributed work environments
- Developed a Roadmap
  - As a top-level depiction of desired capabilities over time
  - Based on an assessment of future engineering needs, existing/projected capabilities, technology and competency gaps
- Delivered a Strategic Plan
  - Proposed an approach to accomplish the Vision

Utilized Design Thinking to develop Vision and Roadmap

- Interviewees: Variety of Roles, Team Size, Personality, Experience, Field of Expertise, Phase of Mission
- Ideas we wanted to draw from the interviewees:
  - Future processes, methodologies and approaches within their work and the agency in general
  - Aspects of their work that “works”
  - Pitfalls that should be mitigated and solved
  - Technology help that could improve their work

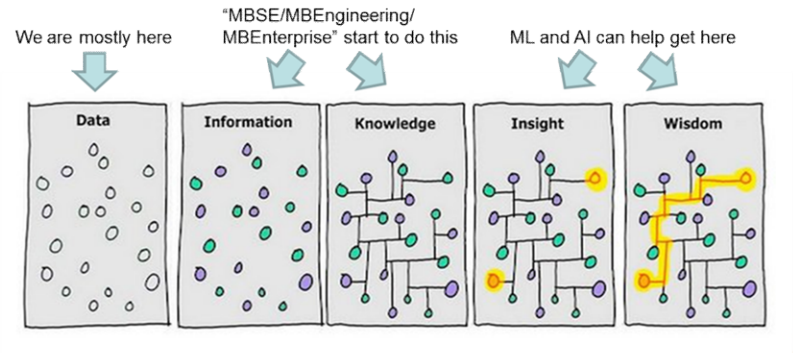
Interview Questions

- What do you think NASA will be working on in 20 years?
- How do you think NASA will be working in 20 years? (processes, methodologies, approaches) Would the way we work need to change to enable those future missions?
- What do you like about your work today/currently? Dislike? Why?
- Do you see any big changes to your job in the next decade or so?
- What's the "hot topic" in your domain right now? Are there any 'transformative' activities underway? What are your thoughts on that "hot topic?" (Is it buzz or something real? why?)
- What kinds of decisions do you make in your role? (Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc...)(Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B, who gets funding, etc.)
- Do you have all the information you need to do your job?
- What are the major problems in your workflow? The best aspects of your workflow (what's working)?
- What might some sort of "computer helper" do for you, to enable you to do your job better/faster/easier/etc.?
- Do you feel you have an opportunity to be innovative in your role? (If yes... What innovative change would you propose?) (If no… what's preventing/prohibiting you from being innovative?)

The Vision Statement

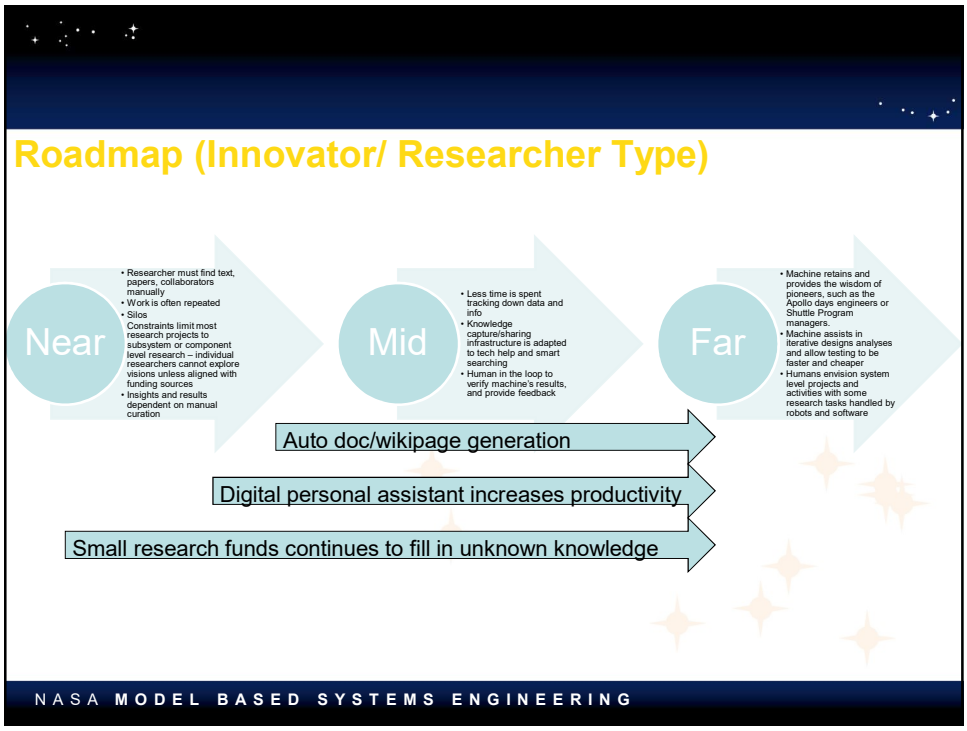
"NASA engineers enable extraordinary, unprecedented missions by adopting system-focused, human-centered, influential technologies for the benefit of all."

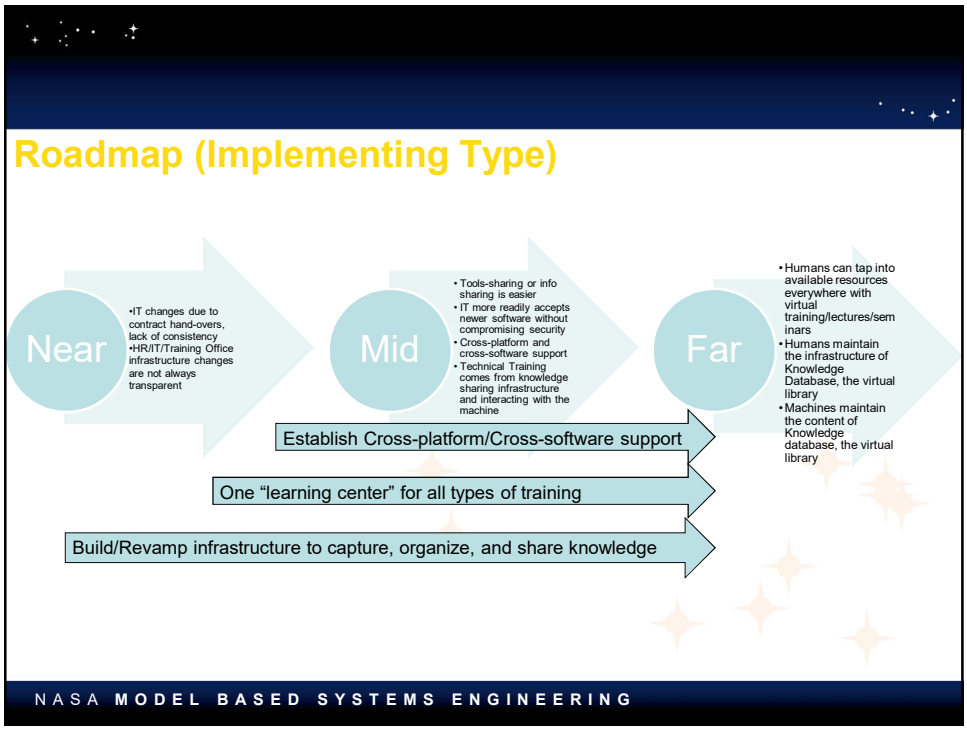
Developing the Roadmap: Initial Ideas



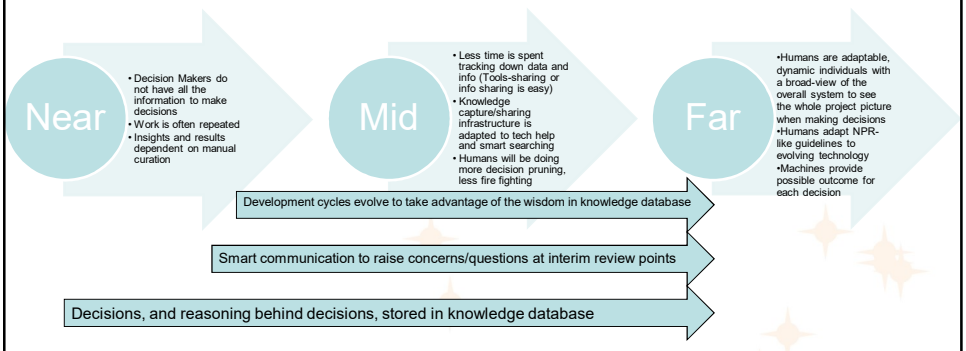
Cartoon by David Somerville, based on a two-pane version by Hugh MacLeod. Used with permission.

Pragmatic:	Today	8 years	12 years	15 years	20 years
Wishful:	Today	5 years	8 years	10 years	15 years


Roadmap (Innovator/ Researcher Type)
Near
• Researcher must find text, papers, collaborators manually
• Work is often repeated
• Silos
Constraints limit most research projects to subsystem or component level research – individual researchers cannot explore visions unless aligned with funding sources
• Insights and results dependent on manual curation
Mid
• Less time is spent tracking down data and info
• Knowledge capture/sharing infrastructure is adapted to tech help and smart searching
• Human in the loop to verify machine's results, and provide feedback
Far
• Machine retains and provides the wisdom of pioneers, such as the Apollo days engineers or Shuttle Program managers.
• Machine assists in iterative designs analyses and allow testing to be faster and cheaper
• Humans envision system level projects and activities with some research tasks handled by robots and software
Auto doc/wikipage generation
Digital personal assistant increases productivity
Small research funds continues to fill in unknown knowledge
NASA MODEL BASED SYSTEMS ENGINEERING


Roadmap (Implementing Type)
Near
•IT changes due to contract hand-overs, lack of consistency
•HR/IT/Training Office infrastructure changes are not always transparent
Mid
• Tools-sharing or info sharing is easier
• IT more readily accepts newer software without compromising security
• Cross-platform and cross-software support
• Technical Training comes from knowledge sharing infrastructure and interacting with the machine
Far
• Humans can tap into available resources everywhere with virtual training/lectures/seminars
• Humans maintain the infrastructure of Knowledge Database, the virtual library
• Machines maintain the content of Knowledge database, the virtual library
Establish Cross-platform/Cross-software support
One "learning center" for all types of training
Build/Revamp infrastructure to capture, organize, and share knowledge
NASA MODEL BASED SYSTEMS ENGINEERING

Roadmap (Decision Maker Type)

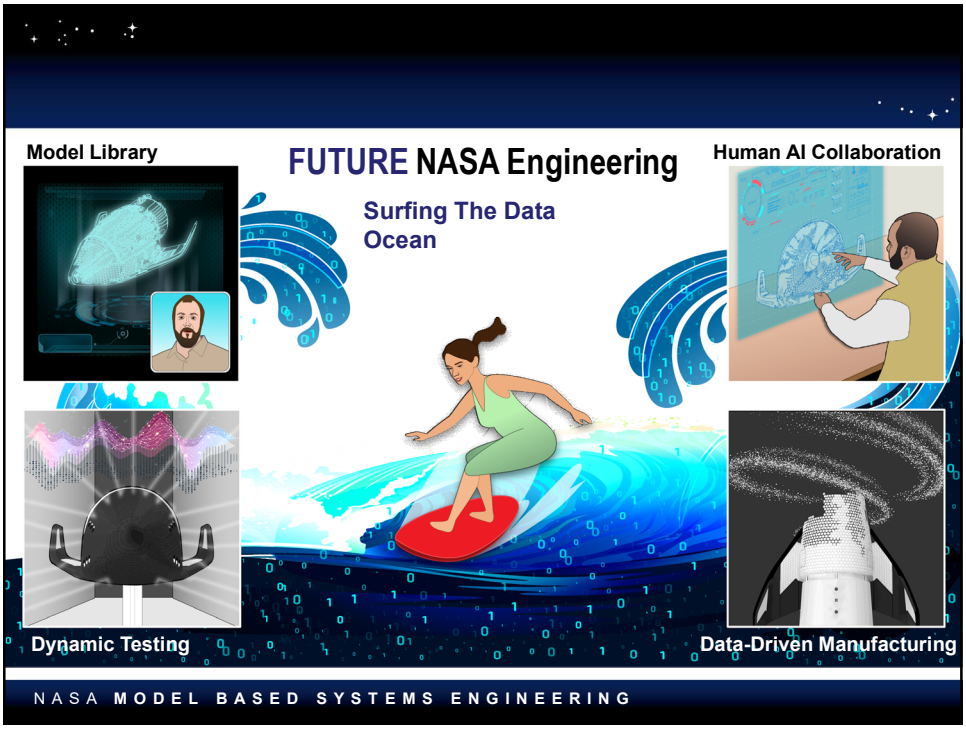


MBSE Strategy Group Roadmap

Evolving Aspect				
Mission Risk-tolerance	Mostly low-risk, some high-risk	High risk, high reward	Radical innovation, giant leaps	Bold missions, huge breakthroughs
Mission Design and Operations	Scripted Mission Operations with Human Monitoring	Autonomous, Remote, Reactive Science	Human-guided, Machine-generated Mission Design	Machine-driven Operational Decisions
Software Architecture	Monolithic: hard to scale to large, distributed systems	Micro-services architecture: scalable, efficient	Flexible, independently-deployable	Adaptive, learning architecture
Software and Services Marketplace	Purchase from established, large companies	License from emerging, small companies, continuous digital transformation	Automated V&V of software, radical digital transformation	Software-generated software, rapid adoption of emerging technology
Artificial Intelligence Tools	Clustering, classification, Natural Language Processing	Human-assisted design decisions, and change approvals	Autonomous decisions, continuous learning	Automated model design, creation, test, and refinement
Use of Data	Stewardship of fragmented data, tagged for future use	Distributed data warehouse provides information when queried	Automated data queries provide knowledge when asked	Machine-generated, data-driven designs provide insight
Analytics	Descriptive: What happened?	Diagnostic: Why did it happen?	Predictive: What will happen?	Prescriptive: How should we react to what will happen?
Timeframe →	Now	Mid-term	Far-term	Data Zen

Developing the Vision Graphics

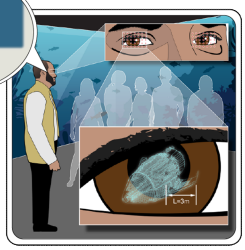
- We saw a need for a set of graphics/story board to explain what it would be like to perform the role of an engineer in the year 2038 at NASA
- We compiled a list of visions from movie clips, to images, and other media that gathered ideas to visualize “a day in the life of a 2038 NASA Engineer”
  - What does your office look like?
  - What data are you interacting with?
- The goal is to capture the flow of technical development with the human in the loop as the conductor of the oceans of data



DEEP Collaboration Environment

Design Engineering Experience Platform

Digital Assistant BUZZ!



Virtual collaborative environment

Immersive environment simulates system of interest in operation

Personal, mixed-reality work environment

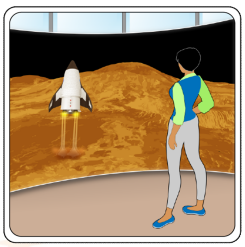
NASA MODEL BASED SYSTEMS ENGINEERING

DEEP Collaboration Environment

Design Engineering Experience Platform

Digital Assistant BUZZ!

Virtual collaborative environment



Immersive environment simulates system of interest in operation

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NASA MODEL BASED SYSTEMS ENGINEERING

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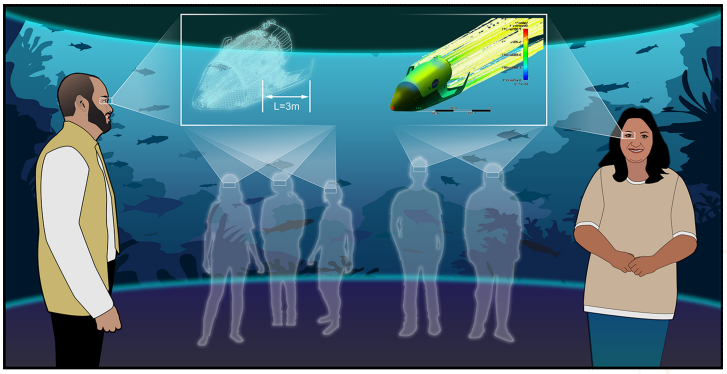
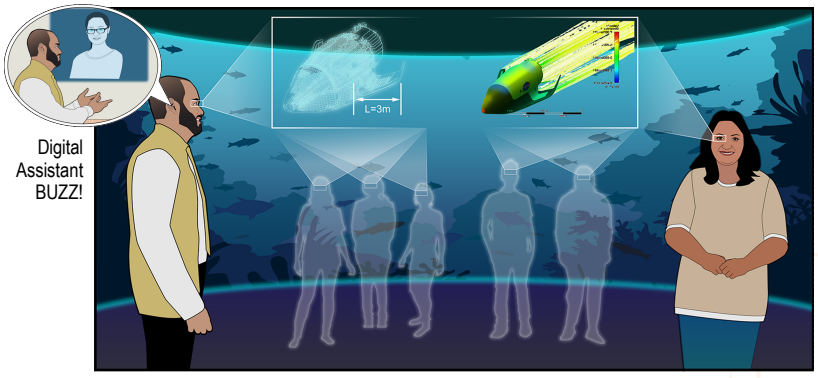


Real-time collaboration with virtual team members.

NASA MODEL BASED SYSTEMS ENGINEERING

DEEP Collaboration Environment

Design Engineering Experience Platform



Real-time collaboration with virtual team members.

NASA MODEL BASED SYSTEMS ENGINEERING

Strategic Plan: Proposed Investment Landscape

- Technologies:
  - Hardware: Processors, Servers, Smartboards
  - Software: Operating Systems, Applications, Visualization Software, Collaboration Tools
  - Services: Data Warehousing, Cloud Services
- Tools for Modeling and Analysis: IDEF or SysML SE tools from various vendors, new modeling tools
- Equipment: Virtual Reality or Augmented Reality headsets, Smart Sensors,
- Methods: Automated Drawing Generation, Rapid V&V,
- Infrastructure: Cloud Networks, Cyber-security, Resilient Networks
- Process: e.g. Automated Design Iteration
- Facilities: Innovation Hubs, Labs, Test Sites, Test Airspace,
- Organization: hierarchies that facilitate communication and enable engineering innovation
- Partnerships: inter-agency sharing of best practices, collaboration with industry and academia
- Workforce: refreshed and replenished for the right skill-mix

D.4 Advisory Board Annual Review Comments, August 19, 2019

Advisory Board Feedback on Strategy Group
August 19, 2019

Advisory Board attendees: 5 board members attended.
MIAMI Leadership attendees: 3 co-leads of the MIAMI leadership team attended.
Strategy Group attendees: 3 members of the Strategy Group attended.
Other attendees: 10 people from ARC, GRC, GSFC, HQ, JSC, and WFF attended.
Advisory Board [AB] comments and questions during open session

AB #1

This makes sense and looks achievable. Did you benchmark with any companies?

> Response: We did look at what is out there, such as virtual reality and the Cloud, and in the commercial world. We did not do a cost comparison. When I went to GRC and used the VR headsets, that was a Wow moment. It changed how I would look at mission design.

AB #2

Maybe this would be a place to figure out a strategy on where we could do a big collaboration. This is not beyond MBSE; it is how do you get from where MBSE can tackle small projects to where MBSE can be broader.

> Response: This is a place where collaboration can start, such as a small digital transformation team. MIAMI leadership is working to see how to do it in the next phase. My hope is for a framework where tools talk, for a full end-to-end life cycle. It is a huge gap in where we are today in MBSE.

AB #3

On my ESA work, I saw Airbus using virtual reality to do their hardware integration work. It showed hardware clearance, and the tools and the people in tight spots to show they could built it. I saw them use it successfully. I recommend using this in a targeted area and show the benefits, in a targeted use case.

> Response: Virtual reality headsets are cheap now. I used it on a Small Orbital Dynamics analysis demonstration for a constellation of a swarm of satellites. The virtual reality headset let me visualize it, instead of on a flat screen.

AB #4

I have been thinking that this looks like this is bigger than systems engineering. Look at limiting the scope and try to get it to the systems engineer. The graphics showed digital manufacturing was big, and moving to a digital NASA. Show less of the future of NASA engineering and more of the NASA systems engineer.

> Response: Sometimes looking wide and then focusing down can help us.
> Follow-up from **AB #2**: Focus it even more narrowly on MBSE. What do we need to do to get from today to the future vision of MBSE?
> Follow-up from **AB #4**: The Air Force has a parallel effort. People have grabbed onto, what does a technical review look like?
> Response: On Apollo, it was blueprints and people around a table. We want to get beyond PowerPoint and Excel. We want to do it on live models in the future. To enable it, we need to integrate model and data, and train people. We need model libraries that the Community of Practice can curate.

Other attendees [OA] during open session

OA #1

Is there a tie in with the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis? Which gaps are critical? Where are we? I didn't understand which weaknesses to address immediately and which to anticipate for the future.

Response: The SWOT is in the full Strategic Plan, along with the Day in the Life and the stakeholders. There is a mix of gaps that are not well pointed out. We did not do a deep dive into the gap analysis. There is future work planned for the fall of 2019. We left it open-ended. We were asked to be creative and to push beyond the near term. We had a diverse group, from lots of Centers and we had lots of ideas.

OA #2

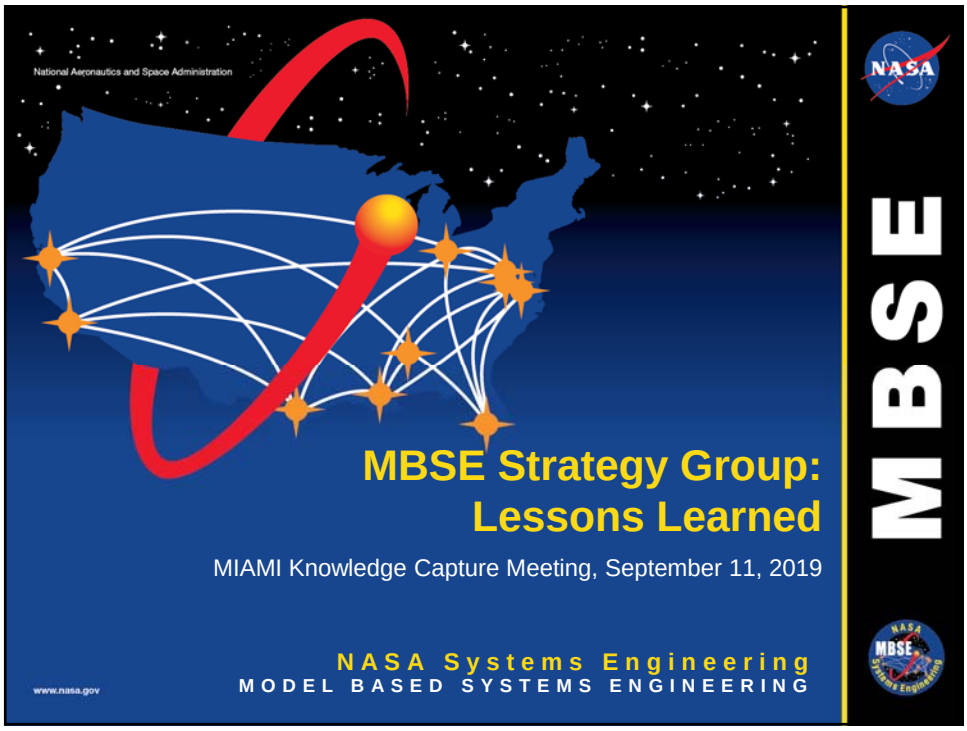
The idea is to move to digital data-centric for real-time discrepancy identification. From the Project Manager's perspective on what MBSE can offer, I didn't see it. We use people to integrate across people. Look to codify SME interests and concerns. Currently requires point assessments. An opportunity to push SE down into the disciplines. Like a seal change may need a change in cleaning fluid. Avoid the problems in discipline engineering, early design phases and other disciplines. SE does not have a qual. test article. Exercise the model. Each discipline will want to engage with you, to manage their requirements and verification matrix, to show interfaces comply with limits. Trying to show how a far-out vision is important. Compliment for looking out twenty years.

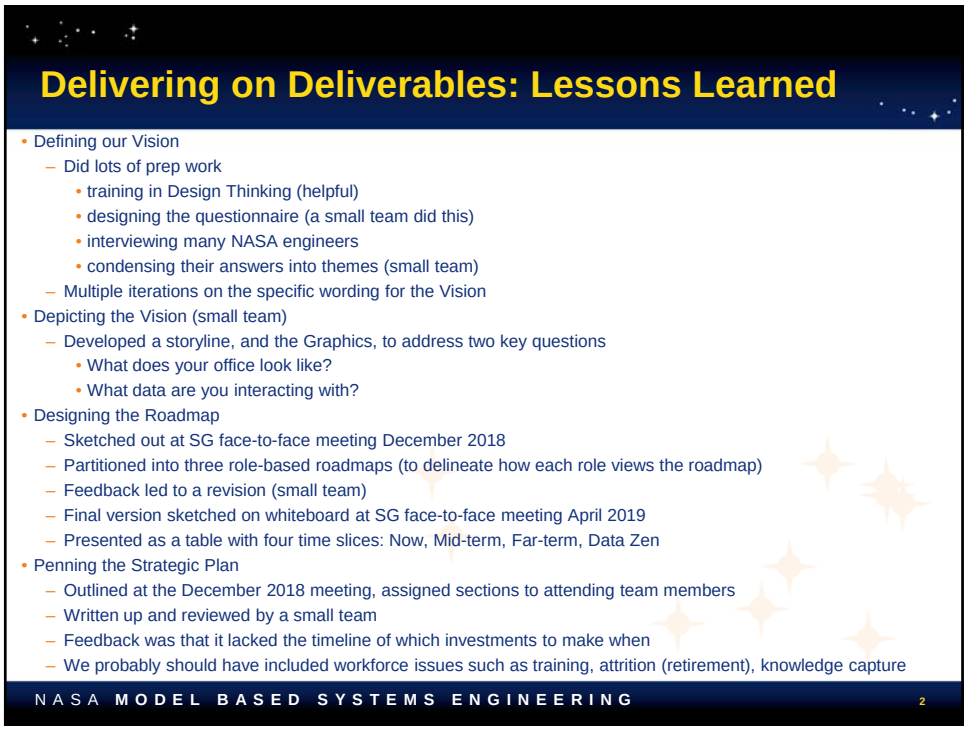
Response: We can add that to a follow-on. We received tremendous support from the MIAMI executives. We were asked to think of the future in a wide-open way.

Follow-up from **AB #1**: The questions in in the "how." Is this something that will go forward to the October Agency Program Management Council? Who is the audience? This looks good. You did a great job.

Response from **MIAMI co-lead**: This work was done for Jon Holladay. The OCE representative to the Digital Transformation Team has the Strategic Plan.

D.5 MBSE Strategy Group: Lessons Learned, MIAMI Knowledge Capture Meeting, September 11, 2019—Presentation Slides





Team Formation and Evolution: Lessons Learned

- A newly setup group of people with varying backgrounds from different Centers
- Given the freedom and the responsibility to think big and long-term
- Encouraged to not limit ourselves

- Lost one member to industry
- A few members got pulled, fulltime, into their primary projects
- About half the group stayed active in online discussions and attended the last two face-to-face meetings

- Used Asana as a productivity tool
  - Worked well for the larger group
  - Smaller team did not need it to coordinate tasks
- Sharepoint was adequate
- Occasionally used Slack for quick communications.

- Enthusiastic about writing a conference paper, submitted the abstract. That has been withdrawn.

Appendix E.—Engineer Interviews

E.1 Subject 1

Interviewee Background

Interacts with 1 to 5 people on a daily basis (on average) to do his or her job
Personality: Introvert who wants to be an extrovert
Experience: Mid career
Expertise (field): S&MA Lead
Phase of life cycle: Pervasive throughout life cycle

What's your role?

13 years doing thermal analysis, some design. Currently in S&MA. For SCaN, have been doing risk for the team, but should be helping identify work and adding risk. Tracking watch items, but soon having another risk facilitator come in. Keep risks in a repository.

Other disciplines, figure out what makes sense to bring on board in which phases of life cycle. Systems Safety, QA, vs. reliability (NextGen). Other offices, doing similar. Issues in tech development - see where S&MA can contribute: hazard, FMEAs, fault trees. In beginning, trying to come up to speed, understand what can be done.

One S&MA role or multiple on a project?

Ambiguity between CSO and S&MA lead, or discipline leads (safety lead, risk facilitator, etc.) - depends on the project and support it needs. CSO might be involved, but S&MA lead may help lead specific activities. Depends on scope of work. S&MA lead may not do discipline work, still go to reliability or software assurance. S&MA lead identify what needs done, when. CSO looking at broader portfolio.

If project is large enough, S&MA lead may not be sufficient - may need another CSO.

Interactions with leads?

Yes, mostly with project managers, sometimes with tech area leads. Especially for risk tracking. Lot of projects in SCaN, not much interaction currently = work is in the lab, not much S&MA. Not much interacting with people doing the work - feel left in the dark a lot.

Role asks you to interact, or do you get fed information?

Currently feels like she has to be fed info, rely on people. If she can't get it, have to track down the info. Stigma with S&MA. Don't give S&MA time it deserves. Others don't feel like responding to requests for info is a priority.

Normal interaction for future phases?

More interaction later in life cycle if they didn't interact early in the life cycle. S&MA can be boring/mundane. Document what you know, keep track of things to do later on. Not many products early in life cycle. But need awareness - bring them on too late, lose insight/foresight into what might be needed. People like to guess what S&MA might be needed, tailor docs, reviews.... but involving S&MA can help protect against go-backs/gotchas. Often S&MA isn't involved early in those discussions.

Interview Questions

1. What do you think NASA will be working on in 20 years?

Think still working to go to Mars in 20 years.

Wishes we were already there by that time, had crews there. Be on track to determine how sustainable cycling crews can be. Go there once, with lots of effort? Or successful ways to sustainably travel back and forth. Demonstrate it can do

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

Haven't thought much. Assume it's similar to now. Little evolutions happen. Try to make things less cumbersome, but becomes more cumbersome. Lessons learned, so we add process. And have one more thing to tailor if it doesn't apply… and understand how to properly tailor. More things to consider... lot of go-backs. Process can be cumbersome. Don't know if we get over that... want to think we will... think we want to streamline... concept behind MBSE.

Streamline? Maybe different risk posture. NASA is govt... worried about human lives. But because we have done things in space, such value on life, still had tragedies. Risk averse. Understand risk posture better, give in the right areas, take certain technical risks... there are people who appreciate we are doing something that hasn't been done before. Try to design risk out, you'll never get there.

3. What do you like about your work today/currently? Dislike? Why?

Like: Trying to be integrated in process. Think about safety, how to assure you will meet requirements properly. Second set of eyes on project. Checks and balances is good role.

Dislike: Stigma of how it's perceived (or can be real) - cumbersome to work together to final point. Should be a way for S&MA to do its job without being so invasive/time consuming on other people. Resistance from people to not want to care about S&MA. Stigma comes from... if nothing to recognize as hazard/goes wrong... then maybe you did your job - put in measures to avoid mishaps, nonconformances. But people lose sight of that, don't hear about S&MA until something goes wrong... then ask where were they?

4. Do you see any big changes to your job in the next decade or so?

Like to do: Have opportunity to be a CSO on another project, another project office/program. Want to do more of the same thing.

S&MA change? Went to the MBSE SMA talk with [names redacted]. Still thinking... How would MBMA connect to MBSE. Great if one way to wrap everything up together, be go-to place for repository of info. Information mecca... talked to a [different Center] person visiting, S&MA director maybe... asked his thoughts on MBMA... he had no idea… never heard of it before. Can see MBSE benefiting engineering disciplines... interesting to think of how S&MA could benefit.

5. What's the "hot topic" in your domain right now? Are there any "transformative" activities underway? What are your thoughts on that "hot topic?" (Is it buzz or something real? Why?)

Probably the MBMA. Another perspective, programs are the Buzz programs (PPE). NextGen Earth relay… but S&MA is skeptical whether it will go anywhere… Where HQ thinks we need to focus our efforts, can [this Center] manage something like that?

In her area, don't see much beyond MBMA.

STEP program - levels of certification. Lot of interest. Make sure broader audience knows about it, not just for S&MA. Through NSC.

NPR for risk management recently rewritten... lots of folks don't think it's written well. Where it was vs. where it is... taken a step back. Not effective, people don't know how to translate it to something they can use at their centers.

Use of SpaceDoc on projects: how can affect collecting the data you get. Used by MSI at [Center name redacted]. Base contract, any project that is under contract with SpaceDoc will meet these requirements and DRDs. But write delivery order for any project delivered. Within that delivery order, can disqualify, or add additional stuff... add/subtract things. Once that's delivered, SpaceDoc gives response, PM signs off, COR signs off. But, if they miss something requested in DO, or wasn't requested... and someone signs off, w/o input from engineering, LSE/CE, or S&MA... to say we can't do our oversight... it's a contract with a prime contractor... can't do due diligence to assess whether they meet the contract without some of those data products. Supposed to be PM, SMA, Eng concurrence... but no requirement under contract surveillance plan that says it has to be done... just an expectation. W/o requirement, how to make sure it's implemented.

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.) (Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)
Gate decisions: Milestones, KDPs… go/no-go… Did we meet success criteria. She gathers data from others so that she can make informed decisions?

SCENIC, have user interface, incremental software release. Each release, add certain new capabilities to UI, for communications analysis for SCaN networks. At gate reviews, review the product delivered by contractor, assess whether they satisfied their requirements, have supporting documentation, did they consider risks, how did they get from previous milestone to today, assess implementation. Then say yes, ready for release or go back.

Go back - usually a few things that have to be addressed. Some more major than others, but usually not ready at that moment to go forward.

7. Do you have all the information you need to do your job?

Doesn't always have it. Hands are tied. Contract mechanism, SpaceDoc. Projects use it. Made with idea to use for ISS payloads. Want to implement using that on the Communications side, was used for SCaN testbed pretty successfully. But was used for SCENIC, it was a mess. How contract was written. S&MA stuff needed to be provided, but right people weren't kept in the loop. Rotating managers, snowball effect. The overlooking of stuff that shouldn't have been overlooked.

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Favorite parts: When she does get insight into what people are doing, can confirm it looks good, or point out where there could be a hole (or is that OK?). Require insight from people. Otherwise, won't know what to ask for. Get see what people are working on, read their design, test plans, figure out where there are holes.

Stigma... think it's cost savings... don't think anything in deliverables is helpful. Have to go to meetings to know what to ask for sometimes.

Day-to-day... people don't realize how much the risk process is already part of their work. Balance is getting people to balance how they are already taking risk into account- tool to show management that they are doing the right things. Cumbersome, why put it in words, update it, go over every month. Like when process is successful - supposed to be something already integrated... if not part of the plan, help the team to get the right work in their plans. Don't see that happen enough.

9. What might some sort of "computer helper" do for you, to enable you to do your job better/faster/easier/etc.?

Risk facilitator manages updating risk stuff. Good to have one person doing it for centralization. But see them emailing people, going to their offices all the time. Wish people could put things into a system. It was already as same interface level as risk repository... facilitator could grab the inputs, use what makes sense. Or same time each month, people provide their inputs. Get that more ingrained in people. Less work for that person do to. Risk facilitator - most cumbersome part of their job is tracking people down to get responses.

Her decisions are project-specific. Currently, lot of process-based. Each gate is same, (should be)... criteria changing a lot. Gate decisions are similar going into a software release, e.g., rely on inputs from presenter or contractor to give to them. Gate criteria... changing because the project changes them. Ideally, criteria done, tailoring is easy based on consensus. Lack of consensus - NASA personal preference... their ability to incorporate feedback. Turnover of project managers.

That churn makes her feel terrible. Input has been given, but not taken into account. Get to next gate... should we be here, we haven't met these... we have to, schedule pressure from HQ. That needs to be a risk! Could raise an issue or dissenting opinion... can't oversee the work that is being done because S&MA stuff isn't on the contract... so can just offer opinions.

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

Struggling with it. Previously, felt more innovative as a thermal analyst. Figure out ways to interact with those people she had to depend on, interfaces, get inputs or extract data. Felt she could create those relationships more organically. Now, don't feel sense of being able to be innovative. But haven't thought about it at all. It's a process-based thing, do what she can with what she has, but hands are tied by the way the contract was written, what processes are, what marching orders are from HQ. You can push back, but it may not go anywhere... can't see a way to be innovative.

On other projects? Would want to be. Not sure what it would look like. Struggle to see that now. Do like that it's very methodical. Process-based. But like the tailoring, considering what we can't do, but maybe could do if we did something else. Good to articulate the rationale for why something doesn't apply.

First time working on Communications projects.

Additional Feedback

Root cause investigations, use those to generate fault trees, look at interface issues. Interfaces of people could feed risk.

Suggestion: Value in going to discipline area leads - reliability, safety, etc. They are at crux of doing the work, using the tools. CSO/S&MA lead may not have right insight. In her case, she isn't doing that work in her current role. Lead names on SMA website.

E.2 Subject 2

Interviewee Background

Interacts with 1 to 5 people on a daily basis (on average) to do his or her job
Personality: Introvert
Experience: Mid career
Expertise (Field): Engineering disciplines
Phase of life cycle: Pre-formulation/proposal

Interview Questions

1. What do you think NASA will be working on in 20 years?

It changes with every administration, science mission, more planetary bodies. Titan Europa, Working getting to Mars, people back on the Moon. Done with low Earth orbit science work. Lunar based exploration. More robotic mission than manned, less expensive, less dangerous.

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

It will not change much. "I am afraid that it will steer to less personal interaction." Less face to face communication, people will use more email or social sites. 250 emails in 2 weeks. Take email breaks to keep up with communication. Every message should be thought out and complete. People will interact less in the future. NASA will give up LEO and commercial will take over. Expensive problems without profit. motivation to improve documentation and reduce bureaucracy. Mission control at SpaceX compared to Apollo age with all the paper. Bogged down with procedural confusion since Challenger and Columbia. NPR, CLPR confusing numbering schemes. Cannot understand why requirements are disaggregated. "Stakeholder requirements, and device requirements are separate." Cluttered organization of work. Each website on the company is completely different from the others which gives the appearance of incohesive working teams even at the same center. Duplicative research may be changes.

3. What do you like about your work today/currently? Dislike? Why?

Like: Get to use my degree. Get to do rewarding work, less turning the crank. Not driven by profit and agency provides the landscape that other engineering companies would not bother doing.

Dislike: Misuse of PowerPoint. Large organization, it is really hard to get anything done, too many reviews to even do a proposal. Too many boards that delay moving towards getting funding. A lot of overhead for unlikely results.

4. Do you see any big changes to your job in the next decade or so?

Yes, the goal of moving up the ranks of engineering. The field will soon get a mission to space. Energy conversion research or NASA improvement in the available technology options for powering spacecraft of human mission power. Improvement from technology from the 60s.

5. What's the “hot topic” in your domain right now? Are there any “transformative” activities underway? What are your thoughts on that “hot topic?” (Is it buzz or something real? Why?)

The Kilopower, it has a lot of attention because it has not been attempted since the 60s. It will enable a complete new classification of exploration missions. Open opportunities to missions that allow you to stay, conversion plus reactor, with solar power will enable Mars bases. On the science side, the technology will improve the efficiency of the use of plutonium, which is expensive to produce. The fuel will go from 6% to 40% efficiency benefit.

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.) (Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)

In charge of a WBS funding and technical division for tech development. Project decisions, project management on EMB. Laboratory work, how to execute experiments and analysis of results. Typically learn everything from review of research of the engineer who came before, textbooks, technical papers, or derive the answer.

7. Do you have all the information you need to do your job?

YES, except for when people retire and don't organize their file. Spend a lot of time to centralize information so that others can keep. NTRS to gather information. A database of papers from NASA and other sources. From a lot of different sources. In general rarely can't find what he needs. Electronic textbooks.

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Hard to get people to attend meetings, travel and other meetings, hard to call impromptu meetings. An electronic way to review documents at the same time and get signatures at the same time like Google docs. Ambiguous definitions of who has final call on process or document or release.

9. What might some sort of “computer helper” do for you, to enable you to do your job better/faster/easier/etc.?

Travel planning, give AI data and have it write the report. Schedule planning for when “find me a time when everyone is available in the next 7 days.”

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

For people who are not tied to a mission. Innovation is stifled for people who are not on proposal tracks that will allow you to innovate. Research is limited if you are not part of major project. A system is needed to encourage ideas to be developed outside of missions. Solve problems that contractors are facing. Not much encouragement of new physics support.

E.3 Subject 3

Interviewee Background

Interacts with 1 to 5 people on a daily basis (on average) to do his or her job

Personality: Introvert

Experience: Early career

Expertise (Field): Systems Engineering/Architect

Phase of life cycle: Pre-formulation/proposal

Interview Questions

1. What do you think NASA will be working on in 20 years?

Hope NASA is on the Moon and developing the techniques to travel to Mars. Expanding Gateway and maintaining sustained life on the Moon. This would serve as a place where we practice before we travel to Mars. If these goals are not in place not sure what NASA would be working on!

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

In the SE role, interact with <5 people usually. These interfaces are on flow or direction not full attention or formal meetings.

NASA will have increased management and oversight similar to the work being done on PPE. Oversight/Insight: Moving towards pushing the edge of technology. At [Center name redacted] Aero is leading the way in technology. The full NASA agency will be moving towards more commercial processes and use of fully commercially developed products.

Any upcoming technology/Ideas: Not in the role to think up research-focused ideas

3. What do you like about your work today/currently? Dislike? Why?

Currently dislike that due to the development of new process on PPE the team may be lost when a contractor is selected.

4. Do you see any big changes to your job in the next decade or so?

SE: the major changes will be the processes of relaxing NPR directives and utilizing more commercial standards. With this new focus NASA desires that commercial partners perform their own standard processes and best practices. Example: PPE is a FFP contract where NASA developed a set of unique requirements and capability needs which only reference to interoperability and don't dictate the final design.

The challenge with this new approach is that the SE will not know when a component is deficient in its design because the processes are commercially developed. Or even when NASA needs to perform a trade or evaluate the potential issues of a design change.

5. What's the "hot topic" in your domain right now? Are there any "transformative" activities underway? What are your thoughts on that "hot topic?" (Is it buzz or something real? Why?)

SE is at the transitionary stage, MBSE (Magic Draw) allows engineers to interact with the system in a different way.

The next development can be a world of documents/drawings interconnected via a model that captures small changes and propagates these changes through the architecture. These tools will drive trade analysis and report of the holistic effect of these changes.

Systems models will be data focused with the use of technology to provide automated relationship determination (i.e., big data type) in a repository where all the data is accessible. The tools will be able to tell the user what data/trade is missing and reduce the management burden to the SE.

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.) (Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)

Typically for SE decisions are made by management using inputs from SE. For example, how should requirements be managed? SE suggested Excel, management decided to go with Word.

7. Do you have all the information you need to do your job?

No, for this role there is no defined expectations on what comes next.

No definition on what activities the role is required to perform and how to interact with the project. There is no expectations on what the vendors will do with the requirements provided.

Test bed for solar electric propulsion had much more defined requirements than PPE**.**

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Need more experience on this new role

9. What might some sort of "computer helper" do for you, to enable you to do your job better/faster/easier/etc.?

A computer software that would allow read only versions of a document that everyone can evaluate on their own to review requirements. This process would occur prior to CM/Verification. This would allow each member to evaluate updates that have been made. Need a tool better than E-room that everyone can see but only SE can change. This will also allow the team to review and approve documents.

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

In the SE role being innovative is not currently required.

E.4 Subject 4

Interviewee Background

Interacts with 6 to 15 people on a daily basis (on average) to do his or her job

Personality: Extrovert

Experience: Late career

Expertise (field): Manufacturing/Production

Phase of life cycle: Mission concept development/pre-CDR

Interview Questions

1. What do you think NASA will be working on in 20 years?

NASA is performing in house work for building/integrating/designing.

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

Developing workflow, documents and processes electronically. Electronic version of document will reduce errors, improve data retention, and simplify data management. Example: At one point some Items were completed and signed off out of order this lead to disciplinary action.

Interact with <15 people on process and plan. Interacting with projects before PDR would ensure that costly constraints are not introduced. Example: tolerance that would create difficult manufacturing processes. Typically team is busy determining what things need inspection during MRB of Qualification reviews.

3. What do you like about your work today/currently? Dislike? Why?

Enjoy the phases after PDR because it gives and opportunity to work with a lot of different people.

Things that can be improved in the requirements validation develop processes that are focused on ensuring critical changes are not lost and communicated properly.

Career wise wish first SE project was with a smaller group because with the larger group of PPE it is difficult to feel important. Or work closely with a relatable team.

4. Do you see any big changes to your job in the next decade or so?

[Center name redacted] manufacturing will no longer be here in 20 years and replaced with commercial services. This will be the trend across the agency where most manufacturing will go commercial and the research centers will be the last to adopt this model. USA manufacturing will grow as a result of this change by government agencies.

Other changes will be the introduction of more electronic record keeping and drawings. This change will be lead the current generational culture change that will occur when the current workforce retires. The new generation is starting to ask question on how can we do things differently.

5. What's the “hot topic” in your domain right now? Are there any “transformative” activities underway? What are your thoughts on that “hot topic?” (Is it buzz or something real? Why?)

[no answer recorded]

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.) (Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)

The typical decisions include what how much work can the team handle?

This decision is made by polling the team and evaluating the launch schedule. Participating in FAB message board to discuss the balance of work across the agency and using other centers to complete the work and balance workload.

Example: during manufacturing process a coating was delaminated from a substrate. Using existing knowledge and conversation with SMEs a vendor was identified to repair the coating and complete the build.

7. Do you have all the information you need to do your job?

Because of the COOP experience the job was clear on what steps to perform and how to get answers to questions.

The process flow on how to build components was clear. The locations of drawings and what step in the manufacturing the part was in was well identified. The need date for manufacturing were not always driven by integration need or launch dates.

There were opportunities on how things will get done could provide insight on how the flow can be improved.

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Lack of electronic document system

9. What might some sort of “computer helper” do for you, to enable you to do your job better/faster/easier/etc.?

AI could help with tracking of parts. A manual process was developed with a big board to show where parts were and what step will get done next. This could be automated.

The AI could provide notification of what percent of the manufacturing has been completed and when things are ready for integration.

AI could also schedule meetings for the team to resolve a problem.

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

Able to solve problems that often occur in this role. The process could be improved by finding a system that could be used to find and track errors.

E.5 Subject 5

Interviewee Background

Role: High-level programs manager: connects people to the right work

20+ year vision of what NASA will be working on

- LV for manned space vehicles in service
- Gateway in service
- ISRU on lunar or Mars or wherever surface
- UAVs (policy vs. technology)
- Low boom come to fruition
- Space tourism?!

Workflow change

- Already changing:
  - Virtual teams for expertise needed to solve problem
  - But need to build trust before virtually working together (caution: older person view)
- Future change: automation of hardware and better analysis

20 years ago

- Ex. CFD will drive WTs away; current effect of that vision – less folks who can run the tunnel
- Project timeline hasn't really changed
- Prototypical data/prelim results of small project (easier to get funding, later scale to larger project)
  - Less of this today, aka research seed corn

Blunders

- Issue-tracking: should be less stringent in prototype/smaller projects, and more on the larger projects
- Systems view is important!
- Lack the "go quick & move quick"
- Efficient meetings are a must/need
- Saving reports in complete detail
- Lack of "hands-on," practical experience nowadays
  - Fewer projects available for this kind of experience
- How to do risk assessment and reduction
  - Older folks use their experiences
- Technology as tools and human as decision maker vs. technology as decision maker
  - Technology development is economy driven and political driven
  - Tech as decision maker requires lots of the same design to iterate over and over again
- Advocates: communication and politics
- "Out of sight; out of mind" for people working out of office (whether it's detail or telecommuting)

E.6 Subject 6

Interviewee Background

Interacts with 9 people per day (on average) out of a 15- to 20-person team, would like to talk to all if possible

Personality: Extrovert role, even though he's an introvert

Experience: Late career

Expertise (field): Engineering (optimization/programming)

Phase of life cycle: Has supported all phases, and flown 4 different missions (ACTS (x2), GOES, and Cassini). Worked with [center name redacted] on console.

What's your role?

Started right out of school at NASA; background in mission design and trajectory analyses. Soon expanded scope to system design. Has undertaken several examples of integrating tools to do higher level analyses, recognizes the challenges in helping people understand the idiosyncrasies/subtleties associated with integrated tool chains, and which tool to use in which circumstances. He thinks there will always need to be a person "in the loop" of the analysis chain; can't just push a button and solve. Currently, he's a "spacecraft mission architect" - looking at the technologies needed to get to the Moon/Mars, and emphasizing what types of propulsion systems are useful where.

Interview Questions

1. What do you think NASA will be working on in 20 years?

Probably still working to get to Mars, but hopes we are there. Think budget will the key limiting factor. Hopes that by then, we will be working on long-term habitation somewhere like the Moon or Mars. Sees planning for mission operations early enough in the life cycle to be a big challenge. Due to Gateway, there will be competition for funding.

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

He doubts there will be much advancement in systems integration. Think the overall approach for interfacing with disciplines and vendors will probably be similar, and more about managing risk posture. He assumes there will be "typical" advancements in the disciplines. Think there will still be a role of "putting pieces together and verifying them" that will be basically similar to what is done today.

(How does he hope NASA will be working?) He WISHES that people would get more used to MBSE-type things. Wants us to think about how to make people not fear losing their jobs. Think JPL is the furthest along, and that the rest of the agency isn't really there, or MBSE is only being done in small pockets. Think MBSE will enable projects to better recognize earlier when the project needs to suboptimize some areas in order to improve overall system. We need to be able to do more with fewer people.

3. What do you like about your work today/currently? Dislike? Why?

He likes that he needs to get to know his colleagues to be effective, a team that gels can do great things.

He dislikes the tendency for people to work within their center or discipline within their own areas, and don't often seek to collaborate or share across groups. He thinks tools and processes we currently use don't enable creativity.

4. Do you see any big changes to your job in the next decade or so?

Without a paradigm shift (e.g., to more MBSE-like things), he thinks there won't be much different. He doesn't think that paradigm shift can come from NASA management, though - things like this can't be done "by direction" - and also think it can't come from the disciplines - they are too stovepiped. Think it will be the people in the middle, project LSEs, CEs, leads, etc., that make the change happen.

5. What's the "hot topic" in your domain right now? Are there any "transformative" activities underway? What are your thoughts on that "hot topic?" (Is it buzz or something real? Why?)

Lunar surface missions on the long term, within budget constraints. Recent studies of lunar initiatives have shown more discussion about the practicality/feasibility within cost and budget profiles than studies done years ago, which tended to focus only on the technically best solution (disregarding cost). The methods they use to do the studies haven't changed much. At [Center redacted], they've tried doing vehicle analyses, to combine models and systems, but haven't re-integrated them in a way with disciplines to be able to generate response surfaces, e.g. He once heard of an effort to use genetic algorithms to "mutate" pieces of the system, and bring in new "evolved" branches, but didn't see it going anywhere. The algorithm had a hard time coming up with things totally new - didn't think technology was there yet. Architecture has not changed in a decade.

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.)
(Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)

On Power and Propulsion Element (PPE), he decides things like the impacts of the size of solar arrays on the electric propulsion system, or what does that size enable the mission to do. Or if we have less EP performance, how are the missions limited?

7. Do you have all the information you need to do your job?

No - but part of the process is to figure out what you don't know, then conduct studies to learn about that and close the gap.

But - he does feel that there is confidence in the team ability to go figure out what they need.

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Getting data from everyone, and synthesizing it together. Also an issue that EP systems have not been human rated before - how could we do that?

9. What might some sort of “computer helper” do for you, to enable you to do your job better/faster/easier/etc.?

Go to meetings for him - he attends long meetings but only needs to be tuned in and actively engaged for a small period. Otherwise he's there to answer questions if they come up. Wishes for a better way to graphically represent the tradespace - show shape curves coming from all manners of inputs. Figure out how best to generate the right number of response surfaces, and understand the off-nominal cases: how real are those off-nominal cases, how could we protect against them? Assess the risk at the integrated system level.

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

Time is his main inhibitor, but otherwise, feels he can be innovative. He has the information at his fingertips: if he changes this parameter, what are the impacts? However, he's very challenged to be anything other than application-specific. Hard to make one model that can effectively be re-used in future analysis, when interfaces and details change. Think if we better understand impacts of changes, we can have more focused investigations, and prioritize more intelligently. Would be great to have a tool to pull together information (with people in the loop) akin to a “Watson.” Once participated in a 2nd generation reusable Launch Vehicle tool, integrating the airframe, LV engine, and trajectory. It was good for point cases, but if you wanted to change the propellant system, for example (rocket -based to turbine -based), you basically needed a new tool - parameters in play, and solution space were totally different.

Additional Feedback

Caution: Need to keep people in the loop.

E.7 Subject 7

Interviewee Background

Interacts with roughly 15 people on a daily basis (on average) to do his or her job

Personality: Extrovert

Experience: Mid career

Expertise (field): Engineering

Phase of life cycle: Works in a, b, c phases [pre-formulation/proposal; mission concept development/pre-CDR; product realization/hardware or software build/post-CDR/verification and validation/manufacturing) and some of e [pervasive throughout life cycle, like configuration management, project management, risk management, etc.], in particular CM. All on Class D and lower missions.

What's your role?

Embedded processing group lead, provide technical oversight of various projects

Interview Questions

1. What do you think NASA will be working on in 20 years?

Interstellar Travel! More realistically, completely autonomous space operations (no human in the loop). Eventually humans will explore other worlds, but autonomous systems will be doing everything, almost everything, for them. This would be facilitated by robust deep space gateways. Edge Processing (onboard processing) will dominate science collection landscape.

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

Much more contractor oversight (privatization of space), civil servants mostly relegated to management roles. Business driving space exploration, like SpaceX, Virgin Galactic, Blue Origin**.**

3. What do you like about your work today/currently? Dislike? Why?

The Good: Likes the challenges of creating new things, especially new things that haven't been done before. Things that NASA pioneers tend to make it to consumer devices eventually. Always something new with everything spacecraft.

The Bad: IT infrastructure is terrible, lack of trust of engineers, full cost accounting stifles innovation, more center discretionary funds necessary, larger IRAD program necessary. NASA needs long-term vision: 20 years (or even 100 years!).

4. Do you see any big changes to your job in the next decade or so?

Yeah, compute capability is always growing, in particular radiation hardened technology in space, AI, neuromorphic. Development life cycle will change, there has to be balance between rigorous process and lower cost electronics to balance budgets. Not enough money.

5. What's the “hot topic” in your domain right now? Are there any “transformative” activities underway? What are your thoughts on that “hot topic?” (Is it buzz or something real? Why?)

Blockchains are very buzz wordy right now, but don't see the use case. AI is also buzzy and has the real possibility of overpromising, it has failed in the past (think perceptrons), although spaceflight is constrained enough it might work okay (unlike something like self driving cars). Due to the ending of Moore's law, there is a lot of buzz in new, specialized computer architectures that could be useful for space. Cross link communication between satellites could be a game changer. As far as non technological trends: Agile gets bad rap, most people do it wrong, but it can be very hard to dedicate a team to it with full cost accounting. Very hard to apply, management needs to change. Also, MBSE might be overpromising.

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.)
(Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)

Do a lot staffing decisions, participate in trades, help reduce technical risk and make good plans going forward. Internal education, gear staffing to make sure things new people are always learning new things. Long term decisions for technological development, e.g., writing and assisting in writing proposals.

7. Do you have all the information you need to do your job?

Not really, spend a lot of tracking down information. The existence of better tools to organize info would be great. Hates when people hold information and do not share it readily. Having to go out of way to get information is a big part of day.

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Tracking down and disseminating information. How can you tell easily if information is stale or up to date? Not enough time to do testing (but there's never enough time to do testing). Lack of “good” tools and “bad” tools pushed on us like Spaces, and Microsoft Teams.

9. What might some sort of “computer helper” do for you, to enable you to do your job better/faster/easier/etc.?

A systems engineering “Alexa” would be a huge help. Searching email for mission critical information is a drag, we need a digital personal assistant that is easy to use, and actually works.

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

Huge limiting factor is funding. I know people make decisions up top but so many innovative problems are snuffed out because of full cost accounting. Need more discretionary funds. Staffing issues make it hard to commit people as well. He does feel like he can be innovative at work but there is much left on the table.

E.8 Subject 8

Interviewee Background

Interacts with more than 15 people on a daily basis (on average) to do his or her job

Personality: Extrovert

Experience: Late career

Expertise (field): Systems Engineering/Architect

Phase of life cycle: Pre-formulation/proposal

Interview Questions

1. What do you think NASA will be working on in 20 years?

Small sats that are doing the jobs of what we do now with large spacecraft, as well as in situ, probe kind of things. The manned side of things is more up in the air, improper funding. We should have a facility on the surface of the Moon for manned spaceflight. Should have astronauts go to an asteroid. Will not be on Mars.

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

A lot more automated, more sophisticated software programs to help us do more, faster. More sophisticated trade spaces. We will do more remote work, ways for virtual teams to work remotely, for all aspects of missions. We can make changes to enable more progress if we're able to shift the culture away from its extreme anti-risk inclination, but it won't change nearly as much as it needs to. One thing that would help is integrating more FFRDCs into the structure. Also, need much greater efficiency at risk of pushing out some of the innovation/creativity.

3. What do you like about your work today/currently? Dislike? Why?

Like - creative, working around people who are changing textbooks/encyclopedias on a regular basis, smart people.

Dislike - more and more rules that make it harder to be an out-of-the-box organization. Too much obsession with too many things which are ancillary to “getting the job done.” Everybody thinks they know a lot more than they do about cost.

4. Do you see any big changes to your job in the next decade or so?

Record keeping will need to improve a lot. Plan and manage fully quantitatively in a data-driven way, using metrics, with all the information needed at our fingertips. Not using Gantt charts where they aren't appropriate (they aren't metrics, they're a visual aid to see a project), need BOE, need numbers.

5. What's the “hot topic” in your domain right now? Are there any “transformative” activities underway? What are your thoughts on that “hot topic?” (Is it buzz or something real? Why?)

Model-based engineering. Two flavors - SysML, MBSE, behavioral modeling side of things, and then getting all of our tools integrated and data captured in a digital form that we can transfer easily. Need data properly stored in a database. Need more integrated tools. Need to be more adaptive and flexible. I'm more knowledgeable of the tool integration/systems side than MBSE. There will be red herrings, but it's

important not to shy away from discovering them. Keep coming up with great ideas, overcome reluctance to do ugly, dirty work instead of just having fun aspects when modeling. Leadership loses focus on these efforts, and squashes the original intent. Systems engineering (and MBE) also needs to be more rigorous and more mathematical.

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.)
(Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)

One side (group supervisor side) - care and feed people, where do you want to be and what will it take to get you there? And strategic placement to get work done? Cost-estimation decisions. Make lots of decisions arching over a span of projects, rather than just in the weeds of data applicable to a given project.

7. Do you have all the information you need to do your job?

On one hand, no - shouldn't have to spend a work year cleaning up mucky data, in an ideal world this would already be done. Have most of the data necessary to do group supervisor aspects of job, but it's hard to know the ways that job could improve or be made easier with more data available.

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Major problems - shoddy tools, HR always changing the rules, constantly reinventing workarounds for these things. HR creates more problems than they solve (people management problem). No remedy for this in [location redacted]!

Best aspects - is not workflow necessarily, my work is spontaneous so it's hard to pin down.

9. What might some sort of “computer helper” do for you, to enable you to do your job better/faster/easier/etc.?

Rapid access to data needed to make decisions. For planning for this year, needed to know how much time people in this group spend staffing Team-X, concurrent engineering teams, and it very difficult to get that information. End up spending a lot of time digging around and making assumptions. Better system for updating Work Authorization Memos.

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

Yes. Already king for the day! Innovating at the level I want to be. It's a small role, but I have what I need to be doing what I want. If I ran [Center name redacted], I would make it more academic, allow for greater what-if analysis, and have less HR in my life. We allow creativity in areas that are a waste. We have a standard WBS, but we don't properly enforce it. We have ways to allocate and track charge numbers but we don't enforce it. For mundane things, things should be more top-down, rather than re-inventing WBS. In many ways, [Center name redacted] is a great place to work. I would make sure everyone is properly trained on how to run meetings, because that is another area of inefficiency.

E.9 Subject 9

Interviewee Background

Interacts with 1 to 5 people on a daily basis (on average) to do job

Personality: Introvert

Experience: Late career

Expertise (field): Systems Engineering Architect

Phase of life cycle: Pervasive throughout life cycle

Interview Questions

1. What do you think NASA will be working on in 20 years?

Moving more towards AI, meaning robots and other forms of smart intelligence - being able to make decisions without human intervention.

2. How do you think NASA will be working in 20 years (processes, methodologies, approaches)? Would the way we work need to change to enable those future missions?

There's always going to be a need for NASA in terms of studying the Earth, doing weather forecasts, investigating global warming, etc. For deep space and advanced mission concepts, we'll need more intelligence in more compact and smarter implementations to get a return on our investment. Can see vast improvements in automation in next 10 years.

3. What do you like about your work today/currently? Dislike? Why?

Like: Cutting-edge development

Dislike: Challenge of being able to sell this to individuals to support this effort, and getting the funding necessary. Resistance to change has always been a challenge, I remember this when I first started and we transitioned from FORTRAN to C++. I understand where it's coming from, because it can eliminate old jobs. Part of the resistance is institutional, partly people are dependent on the tools they're used to. As part of this process, though, we need to understand the output of AI, and not trust the results blindly. There needs to be good knowledge transfer.

4. Do you see any big changes to your job in the next decade or so?

A lot has changed in the past (e.g., WebEx, working remotely), so I'm inclined to think it will in the future, especially technologically. I think that virtual reality is something that will become more integrated into the norms of the job. From a testing standpoint, things have changed a lot. Before, I did testing myself, but now it's primarily automated via computer software scenarios.

5. What's the “hot topic” in your domain right now? Are there any “transformative” activities underway? What are your thoughts on that “hot topic?” (Is it buzz or something real? Why?)

Virtual reality is the hot topic that I see up and coming, which concerns AI, automation, etc.

6. What kinds of decisions do you make in your role?

(Technical/data-driven vs. strategic vs. consensus-building vs. process/approach, etc.)
(Also... Literally, what decisions? Buy A vs. B; truss A vs. B; contract mechanism A vs. B; who gets funding; etc.)

I'm only one year into MBSE, so I'm more reacting than being on the leading edge. From my standpoint, I'm drinking from the firehose, trying to understand how everything works. People are now creating tools which would eliminate a lot of the effort that has been done.

7. Do you have all the information you need to do your job?

Need more information. A lot of projects are not making MBSE a big line item, there's a resistance from those that control the budget. "It works, why do I need to change?" Because of this attitude, I could use a lot more useful training which would help me understand and advance MBSE to a greater degree.

8. What are the major problems in your workflow? The best aspects of your workflow (what's working)?

Problems: Funding for MBSE is sparse, it would be good to get a long-term sponsor for these efforts. More funding/sponsor would lead to better training and understanding among the MBSE community.

Best aspects: Community of Practice, knowledge-base, working group's efforts. Learning that some of the things I'm trying to do have already been done is critical. Networking has also been positive in terms of knowledge transfer to further my MBSE education. The CAE Office Hour sessions have also been useful, along with the MBSE workshops.

9. What might some sort of “computer helper” do for you, to enable you to do your job better/faster/easier/etc.?

There's a lot of tools out there, all are good, it's a matter of finding the right fit to accomplish what you want. Continuing to publicize the pros and cons of these tools towards systems engineering will help with decision making.

10. Do you feel you have the opportunity to be innovative in your role? (If yes, what innovative change would you propose? If no, what is preventing/prohibiting you from being innovative?)

Yes. If I were to have it my way, every system engineer should take a course in MBSE so that it is understood by system engineers in general as well as MBSE tool smiths in particular. With this training, it would greatly advance the effort of MBSE implementation.

E.10 Subject 10

Interviewee Background

Position: Assistant Branch Head

Works on projects with TRL levels of 0-3, and 9-10

Works daily with 12-20 people, and usually contacts with upwards of 32

Has worked outside of NASA for a number of years in many different work environments

Interview Questions

Where is NASA in 20 years? (Q1)

Digital transformation, will be a shift to systems that [name redacted] talks about, Alexa in the lab. Would ask for complex mathematics and can process engineering data.

IRAD projects already funded that help connect laboratories. Stockpile information that is gathered in experiments automatically, make available for the rest of the work force. Help make reviews quicker and easier, since data is more accessible.

Data fusion.

Mission side: Would be shifting to more a commercial environment to refocus on more science and exploration oriented.

Problems that are going to come?

Early career employees are more adapted for digital transformations to come, which is opposite of the older employees. Having issues aliening certain employees with technologies, since they are not accustomed to new tech, even an issue with early career.

Retaining new early career employees due to lack of progress or disappointment in the technology standpoint here at NASA.

OCIO specific future issues

NASA employees are unaware of resources that are already available to them that are offered by OCIO and other IT groups at NASA.

Need better regulations on software to allow for more flexibility for researchers, to reduce obstructions to their workflow.

Need to not appear as a hindrance or enemy of researchers or employees. Current IT security posture alienates researchers from OCIO due to the appearance of a policing force.

Future outlooks of the past and their outcomes

Machine learning (ML) was talked of greatly in the 90s, in terms of that it will solve many problems and automate repetitive tasks. This is still the talk of today.

Smart phones were a paradigm shift that was not fully expected, which has greatly impacted everyone's lifestyle and work. Increased in connectivity between everyone, enabling faster decisions and information flow.

E.11 Subject 11

Interviewee Background

Role: Is a system engineer with a background in a discipline, where the term system engineer is involved with optimization of multiple disciplines. Where the projects are part of a pre-A phase, trade studies.

Number of people who typically work on a project: The answer was broken down into the two projects that he works with on a daily basis; one being around 2 people, and 3 for the other. The first project is part of a larger team where the teams are split up between analysis tasks. The second is just a small team that exists in a larger research group, but is different enough that it is not seen as a larger team.

Interview Questions

Where do you think NASA will be in 20 years? (Q1)

Specific to his field: Hypersonics/propulsion will be conducting more flight tests of practical vehicles, where they use more useful fuel systems. Get away from air launched vehicles.

Workflow change (Q2)

Due to the majority of the work being secret, he is unsure how much can change due to the slow and harder process of data management.

What do you like about your current work? (Q3)

Working close to the folks in his branch, being able to walk down the hall and discuss with others on project issues. Whiteboards have proven to be very helpful to convey ideas and work through problems.

What do you not like about your current work? (Q3)

- Hard to find past reports and data that are relevant to the current task. Lost institutional knowledge through retirements, since there is no repository.
- Documentation regarding internal software tends to not be entirely useful.
- Sometimes feels like he is slowing down others when asking for help using internal analysis software.

Current position in 10 years (Q4)

- Increase reliance of custom codes that are developed by others to do trade space studies
- OpenMDAO, multidisciplinary optimization code

Are there any hot topics in the field? (Q5)

- Uncertainty quantification is becoming part of a lot of topics and is becoming a major research field.
- There is interest in UQ beyond NASA and might have real impact.

What kind of decisions do you make currently? (Q6)

Make decisions on which variables in an optimization routine should be considered to be varied in trade studies.

- Down sampling from hundreds of variables to a few important ones

Do you feel that you have the opportunity to be creative? (Q10)

"I think so…" There is a lot of freedom in how to accomplish a task, and greatly appreciates that freedom.

External hot topics (quantum computing and machine learning)

- Quantum computing can be a game changer if it provides orders of magnitude in speed up in CFD analysis. And if it does provide this, it should become more routine to use.
- Machine learning, on the other hand, does not seem too applicable, since it is difficult to understand why a given ML gives a certain answer.
    - People already have a good understanding of problems in the field of study.

What do you think of NASA engineering and SE?

There are two types of SE at NASA:

- SE - Hardware integration:
    - Testing hardware
    - Integration of hardware into a product
    - Development of requirement
- SA - system analysis:
    - Low fidelity studies
    - MDO

He has more experience as a SA and not SE.

Are there time speed ups that you can come up with? (Q8)

- Searching for relevant information is a major problem.
- Finding the right people to talk to or ask about issues.
- Capture of knowledge prior to personnel leaving NASA due to retirement.
- Project cycle of hypersonics impedes knowledge capture due to constant changing of work.
- Waves of projects, during the down turn, folks leave the project and knowledge is lost.

Closing thoughts

- Better contextual analysis of papers stored in report database; missing possible reports due to not matching text in titles.
- There used to be a lot more flight test of hypersonics, and now we are too risk averse to make progress in this field. Need to take on risk to get more flight data that is required for current research.

E.12 Subject 12

Interviewee Background

Interacts with 1 to 10 people on a daily basis (on average) to do job

Experience: Early/mid career

Expertise: Engineering; technical monitor

Phase of life cycle: Pre-[phase] A world

Interview Questions

20+ years into the future (Q1)

- NASA will be in a more supportive role in the commercial space contract, much like the aero-side
- Pre-A phase would still exist for conceptual work
- High-fidelity codes would be easier to run, we would be more reliant on the high-fidelity tools and getting more use out of them, but low-fidelity tools will still be around for that quick check

Hurdles to overcome for the future (Q2)

- File standards
- I/O file formats consistency
- Standard tools for communication, file transfer. Hopefully in 20 years:
  - Consistent communication option that is easy to use
  - Telecommuting to be more like working in a virtual space instead of being "out of office"
  - Portable work phone
- Consistent training for tools:
  - Communications (ex. how to setup a meeting on Skype) or file servers, etc.
- Limited access to new tools and training, especially tools that adhere to NASA policies

Enough info to do your job? (Q7)

No, but in the conceptual world, you are working on unknowns - that's the nature of the work

Hot topics (Q5)

AI, ML. Not enough understanding of how they would work and be integrated into his work

MBSE concept

MBSE concept is nice, but there will be engineer(s) in the loop, not good to hook up random tools (esp. those with built-in assumptions - will need a knowledgeable person to operate)

- Universal UI is not available across tools
- Tools with built-in assumptions may not apply across projects

Computer helper to help with job (Q9)

- Smart assistant for scheduling meetings, filling out forms, finding forms, converting file formats
- Computer help with image processing to hunt for info, digging through databases or internal documents (smart searching: search context not words)
    - Not easy to know where to find certain docs, especially ITAR ones

Decisions made on the job (Q6)

- Which software
- Design concept selection
- Which data to use

Ability to be creative and innovative at work? (Q10)

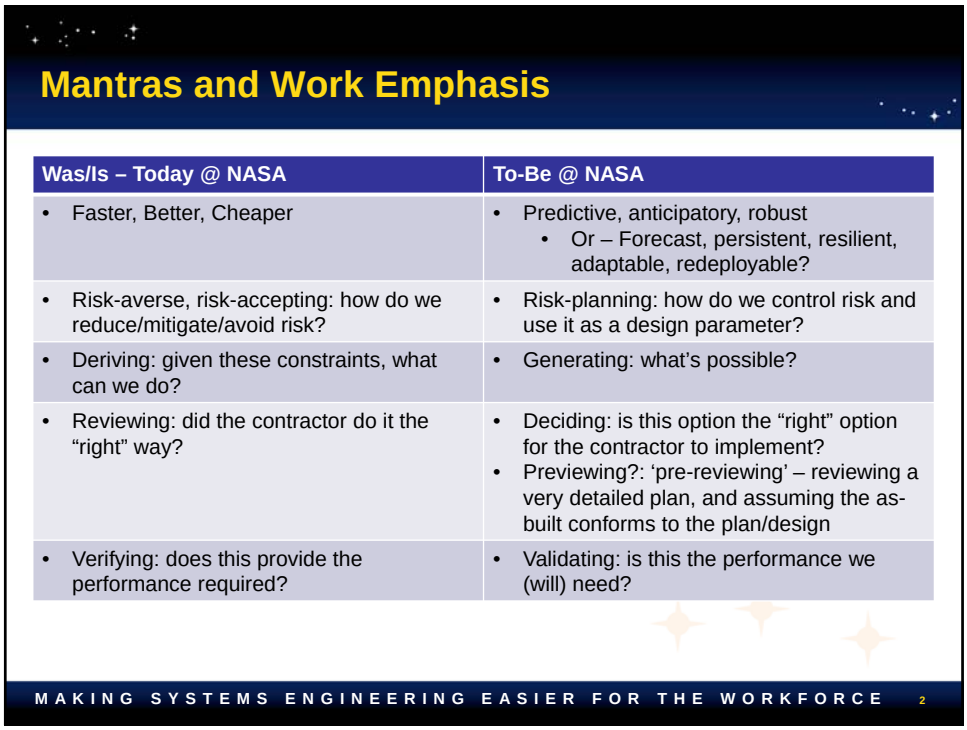
Yes

E.13 Themes From Interviews

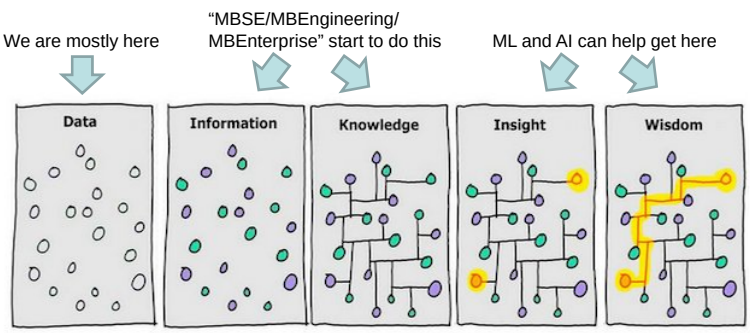
Themes	Description of the theme
Agency's risk-averse posture needs to change.	- Need to manage risk
Knowledge is not captured, and/or organized, and/or shared	- Knowledge from senior folks are not captured and appropriated stored to be shared somewhere - Not a consistent shared platform for lessons learned or nuggets of knowledge; not everyone knows about where to find these past lessons learned either
Spends a lot of time tracking down data or information	- Version controlling the data (is it up to date?) - People don't want to share information or data!
Small groups research/IRAD/research seed/academic-like is needed	- Small amount of resources needed to do small-scaled projects (more prototyping, testing, exploring trade-space or design space) - More opportunities to get hands-on experiences, esp. the young folks to gain that "engineer's intuition" - More center discretionary funding
Development life cycles, work procedures, guidelines/rules needs to be changed	- Not using Gantt charts - NPR needs to change to accommodate technology advances
Lack of training	- Training current people to be up-to-date with technology/approaches/practices - Training people to run meetings properly and efficiently - Training people to understand MBSE (or future evolved version of MBSE)
Budget constraints, fixed processes, and specific tools restricts creativity and innovation	- Different center using their internal codes - Processes are laid out step-by-step, no room for creativity - Full cost-accounting stifles innovation
Lack of trust in engineers	----------
Digital personal assistant that actually works	- Consolidating meeting information - Searching for nuggets of information within the email box or server or data - Attending meetings on our behalf - Planning travel itinerary and finding meeting times for us
Working remotely or virtually needs to feel "normal," as if in the office.	- Trust needs to be built prior to working virtually - Personal interactions and F2F communications need to be "normal"
Infrastructure needs to change	- IT infrastructure is terrible - Disconnect between what the engineers need and what higher-level is pushing - HR rules that are constantly changing
Human in the loop is necessary until we trust the machine can create reasonable results	- Human needs to check the results - Can't trust machine outputs blindly
Future engineers need to understand impact of changes	- Changes to parameter - Changes to interfaces
Needs more efficient meetings	----------

Appendix F.—Vision

F.1 Vision, Roadmap, Strategic Plan: Thoughts—Katie Trase, October 2018—Presentation Slides



Top-Level Roadmap



Cartoon by David Somerville, based on a two-pane version by Hugh MacLeod. Used with permission.

Timeline could be different for different sectors of agency; I guessed at "most of agency"

Pragmatic Katie:	Today	8 years	12 years	15 years	20 years
Wishful Katie:	Today	5 years	8 years	10 years	15 years

Roadmap Characteristics

Era	Characteristics of the Era
Data	• Unstructured; unqueryable
Information	• Structured; basic statistics; categorization • Processes are basically the same, but with better data integration/reuse
Knowledge	• 'relational queries?'; provenance; traceability; multiple viewpoints; system-level optimization • Processes begin to be revised
Insight	• "this thing looks like this other thing: are they the same?" • "I thought you'd be interested in reviewing these changes since yesterday (daily design (update) briefing!)" • "I noticed this parameter changed yesterday: do you also want to update it's usage, here?"
Wisdom	• "if you start here, and do these things, you can get to this other place" • "This waiver and this other deviation suggest 'this thing' might happen with [%] confidence" • "because this project historically did this, this other thing happened" • "I noticed this parameter A changed yesterday: if you were to make this additional change, we can increase performance of X by Y, but note parameter B will also change"

Strategic Plan

Era	Invest in these to realize the era:
Data	(We are here)
Information	Databases; NLP; interoperability standards/interfaces; schemas/ontologies
Knowledge	NLP; access permissions and data security; operations research/optimization methods; collaboration tools; advanced query methods
Insight	NLP; AI, ML, DL
Wisdom	AI, ML, DL

Vision Statement (20 Years+)

- 20 years from now, integrated databases, legacy tools, and domain-specific tools will enable the NASA workforce to respond with greater agility and resiliency to changing agency needs.
- Data from historical projects and current trends will co-mingle in an integrated, queryable ‘data lake,’ which facilitates agency policy compliance, workforce training/education, and project development.
- Improved capability to manage our workforce, budgets, and contracting partners will result in greater insight into resource constraints and likely project outcomes, resulting in greater budget, cost, and schedule estimates.
- Increased project agility, a ‘data lake,’ and refined resource management capabilities will ultimately allow the agency to more accurately forecast both technological improvements and systemic effects/impacts.
- With greater forecasting abilities, the agency will be suited to influence policy and decision making, and facilitate communication across diverse stakeholders, resulting in the benefit of all mankind.

F.2 Strategy Group Vision Notes

A Vision for Systems Engineering

NASA engineers architect missions, adapt to changes, and make decisions in real time. Engineering of systems is a highly collaborative effort, focused around communication. Our future centralizes communication and analysis into a dynamic model to give decision makers what they need, when they need it.

Intuitive

Interacting with this centralized model is so **intuitive** it feels like a game. The work environment of the future makes it is easy to contribute, extract, and manipulate information.

Availability

The user will be delighted to have everything they need at their fingertips. Information is fully searchable and **available** on any device, anywhere, any time, whether that information be design parameters, relationships, or methods describing how values are arrived at.

Confidence

Having all information in a centralized model will enable stakeholder **confidence** the information they have is correct. This confidence is built on knowing the data mining, machine language, etc., used in analysis and decision making are appropriate and technically correct.

Action:
Write a term, write a description of what the stakeholder will feel, what is awesome, and how this might be implemented.

Good vision statements have common components:

- It is written in the present, not future tense. They describe what we will feel, hear, think, say and do as if we had reached our vision now.
- It describes an outcome, the best outcome we can achieve. It does not confuse vision with the business goal and objectives for a particular period of time. A vision statement, therefore, does not provide numeric measures of success.
- It uses unequivocal language. It does not use business speak or words like maximise or minimise.
- It evokes emotion. It is obviously and unashamedly passionate. However, it separates the hard aspect of vision in what we see, hear and do from the soft aspect of vision in what we think and feel.
- It helps build a picture, the same picture, in people's minds.

  Reproduced from The Components of a Good Vision Statement, ChangeFactory, *https://www.changefactory.com.au/our-thinking/articles/the-components-of-a-good-vision-statement/*.

In the future we envision a centralized model to which everyone contributes. This model is viewable by engineers and stakeholders through customizable portals, delivering the exact information they need to perform their roles, communicate with colleagues, and modify the model. When information is changed the model can be automatically rerun, allowing changes to propagate through the system in near real time, giving stakeholders the most current information for decision making.

As persons contribute to the model the useable knowledge base for all projects using such a system grows, allowing for quicker and cheaper assessment of new systems.
The systems that enable the workplace described above are also envisioned.

In today's world, much of the systems engineer's time is consumed by tedious tasks. Drafting text documents, requirements, etc., to describe a system. Reviewing completed work to ensure the approach is proper and the content error free. Keeping documents up to date. Waiting for so-and-so to update an analysis or report. Connecting models through the exchange of data files and reports. This is a manual process. At every step, every interchange there is the opportunity to inject human error into the product.

Screen capture from 10/9/2018 Skype conversation:

[10/9/2018 12:42 PM] Shyam, Vikram (GRC-LTE0):
NASA engineers architect missions, adapt to changes and make decisions in real-time
[10/9/2018 12:43 PM] Hoffpauir, Daniel L. (LARC-C101)[LAMPS 2]:
Empower NASA engineers to tame complexity through automation of design
[10/9/2018 12:46 PM] Shyam, Vikram (GRC-LTE0):
NASA Engineers and AI automate mission architecting.... and make decisions in real-time
[10/9/2018 12:47 PM] Lee, Esther (LARC-E401):
Wouldn't AI be a bit too specific?
[10/9/2018 12:47 PM] Shyam, Vikram (GRC-LTE0):
we would add AI as people ;)
[10/9/2018 12:48 PM] Hoffpauir, Daniel L. (LARC-C101)[LAMPS 2]:
Empower NASA engineers to make real-time mission architecting decisions through automation of design

F.3 Vision: Combined Charts—Presentation Slides

F.3.1 Vision: 2–11–2019

New Ideas

- Develop cartoon animation similar to PHD comics or Dilbert or other to show a day in the life of the 2040 NASA engineer
- The panels together tell the story depicted in the text. It could be a series of panels which could be reduced in the future.

Day in the Life of 2040 NASA Engineer

- I wake up in my *ergo-fit pod* at 8 p.m. on a Wednesday evening. The pod contours to provide maximum sleep and sitting comfort. It is powered wirelessly by the smart grid and builds on NASA's multifunctional materials research. I'm just in time for a conference with collaborators in Australia and China. I have no papers or cabinets in my *office*. Just *an open space* under the night sky. As far as I'm concerned it's just me and a wide open field. I tell my mobile GreenScape to connect to the Rendezvous. Instantly, displays materialize around me and I am transported to a beautiful underwater conference room aboard Captain Nemo's Nautilus. This is all virtual of course and I am still sitting in my GreenScape at the *NASA Biomimicry Institute,* located in the Metroparks.
- The walls are multi-optical and can transform from transparent to opaque on command. They are solar powered and can act as a CAVE. Slowly more participants enter our mutually agreed upon submarine meeting place. Next time we are meeting on Mars. Motion sensitive projection dots (M-SPots) track our eyes and provide us with a 3D environment. We share information through the NASA Quantum Cloud – NASA's own secure server system. Building on decades-old technology such as the Oculus and Microsoft's Hololens, several options are now available to seamlessly share 3D and 4D (texture and feel) information.
- A colleague passes a new model of a biomorphing planet jumper to the circle and runs a simulation sequence. I want to see how it will do in a wind tunnel so I send the model to a nanoprinter at NASA's Facility for Autonomous Test and Experimentation (FATE). The model assembles inside the test section. Holographic controls display in front of me and I set the parameters for the test. We all watch as streamlines and vortices fill the test section. The Big Data Analysis and Display Service (BigDADyS) filters important flow features in real time. I morph my virtual model to see the effect and the test article obliges by losing some scales on its undercarriage. Satisfied, we conclude the meeting and return to our "real" worlds. 65 Vikram Shyam, 2015
- I step outside my GreenScape into the rec room – equipped with games, beverages and food grown on-site. I don't partake as I am heading home for the night. I'll spend the rest of the week at home working from my telestudio.

Roadmap (3 waypoints) to get to 2040 vision

NOW

- Trainings available to combat lack of trust in engineers' capabilities and build their soft skills
- IRAD/small research groups to fill in the data gaps and set examples of how to share information and knowledge
- Infrastructure to capture, organize, and share knowledge is created or revamped
- IT and HR infrastructure changes are thoughtful and productive (IT more readily accepts newer software)
- NPR is updated to accommodate technology advances

Mid-point

- Agency's risk posture is to manage risk
- Tools sharing or info sharing is easy
- Less to no time is spent hunting down data and info
- Knowledge capturing/sharing infrastructure is adapted to tech help and smart searching
- Remote or virtual working feels as if in the office
- Development cycles adapted to technology help
- Small research funds continue to fill in unknown knowledge/provide insights
- Human in the loop to verify machine's results and provide feedback
- NPRs are periodically reviewed

20 years

- Digital personal assistant helps us manage our work life (schedule meetings, distill information, triage work priority, smart communications)
- Automated knowledge capture network/database (AI/NLP)
- Engineers make sound decisions because they fully understand impact of changes to parameters, interfaces, etc., when machine presents results
- Technical training comes from knowledge sharing infrastructure and interacting with the machine
- Machine retains and provides the wisdom of pioneers, such as the Apollo days engineers, Shuttle Program managers, etc.
- Development cycles evolve to take advantage of the wisdom
- Machine knows NPR guidelines when presenting results
- Human creates more NPR guidelines as appropriate

3

I'm just in time for a conference with collaborators in Australia and China. I have no papers or cabinets in my *office*. Just *an open space* under the night sky. As far as I'm concerned it's just me and a wide open field. I tell my mobile GreenScape to connect to the Rendezvous.

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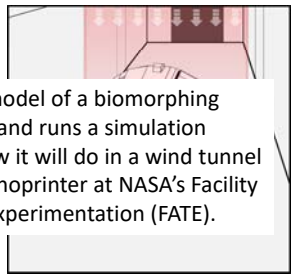
F.3.2 Vision: 2–25–2019

The walls are multi-optical and can transform from transparent to opaque on command. They are solar powered and can act as a CAVE. Slowly more participants enter our mutually agreed upon submarine meeting place. Next time we are meeting on Mars.

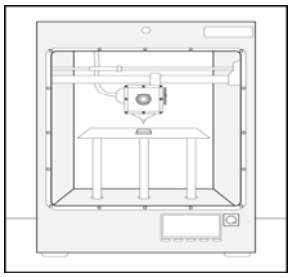
Motion sensitive projection dots (M-SPots) track our eyes and provide us with a 3D environment (Laser type lines monitoring your eye). We share information through the NASA Quantum Cloud – NASA's own secure server system. Building on decades-old technology such as the Oculus and Microsoft's Hololens (these exist in 2019), several options are now available to seamlessly share 3D and 4D (texture and feel) information.

A colleague passes a new model of a biomorphing planet jumper to the circle and runs a simulation sequence. I want to see how it will do in a wind tunnel so I send the model to a nanoprinter at NASA's Facility for Autonomous Test and Experimentation (FATE).



Biomorphing planet jumper model assembled and sent to wind tunnel test. BigDADyS filters important flow features in real time.

Test parameters set by holographic controls (less IPAD more like a table where things float from)



Part revisions made and printed in real time.

The model assembles inside the test section. Holographic controls display in front of me and I set the parameters for the test. We all watch as streamlines and vortices fill the test section (https://www.youtube.com/watch?v=1kWApU3o6ko). The Big Data Analysis and Display Service (BigDADyS - these are software tools https://vimeo.com/102998774) filters important flow features in real time. I morph my virtual model to see the effect and the test article obliges by losing some scales on its undercarriage (hologram duplicate of the real hardware in the wind tunnel). Satisfied, we conclude the meeting and return to our "real" worlds. 65 Vikram Shyam, 2015

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I step outside my GreenScape into the rec room – equipped with games, beverages and food grown on-site. I don't partake as I am heading home for the night. I'll spend the rest of the week at home working from my telestudio.

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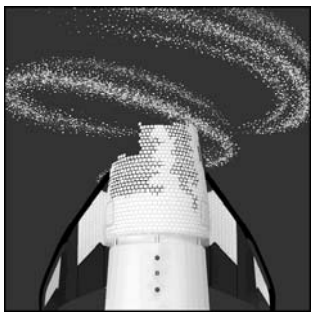

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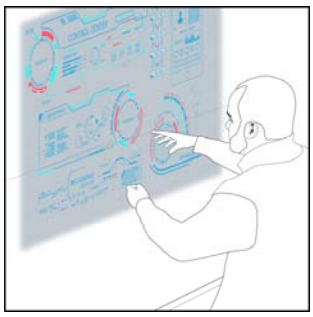
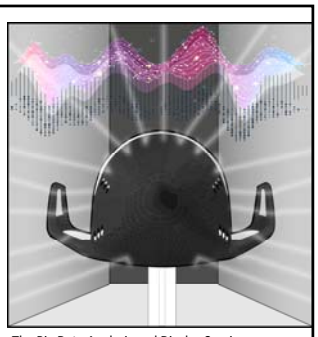
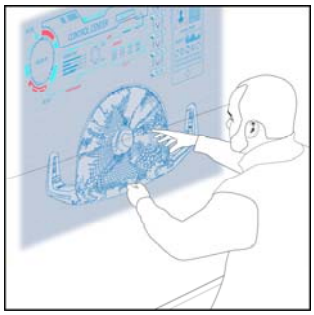


Holographic controls display in front of me and I set the parameters for the test.

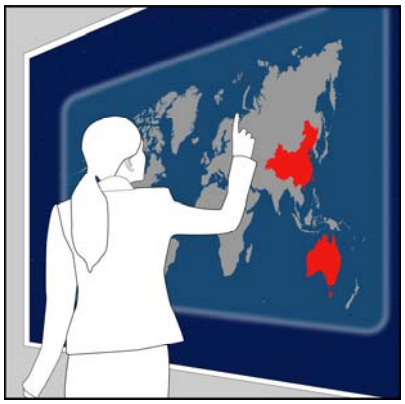


The Big Data Analysis and Display Service BigDADyS - filters important flow features in real time.



I morph my virtual model to see the effect and the test article obliges by losing some scales on its undercarriage (hologram duplicate of the real hardware in the wind tunnel).

F.3.3 Vision: 2–26–2019



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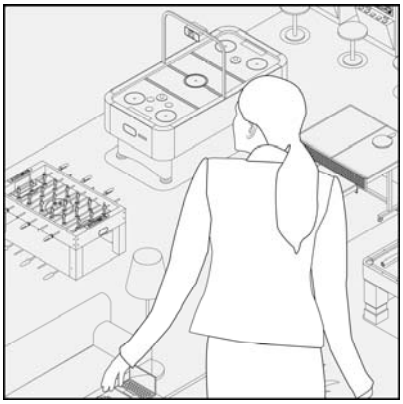

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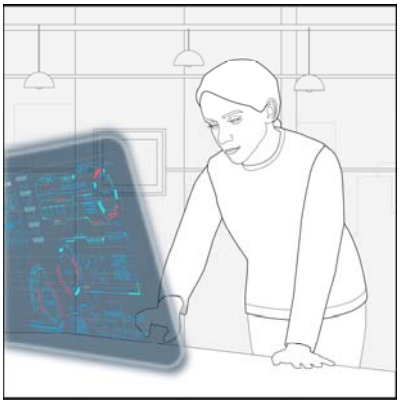
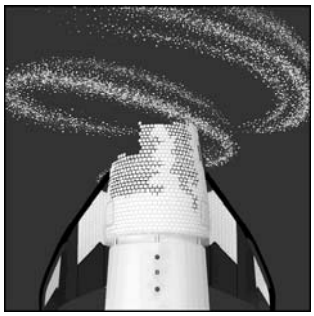


I'll spend the rest of the week at home working from my telestudio.

F.3.4 Vision: 2–27–2019

A colleague passes a new model of a biomorphing planet jumper to the circle and runs a simulation sequence.



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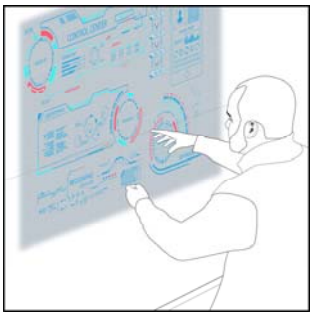

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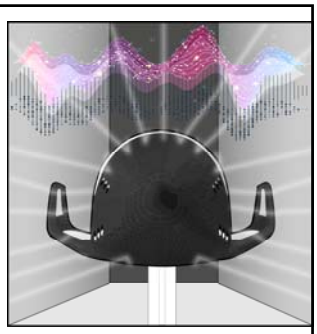
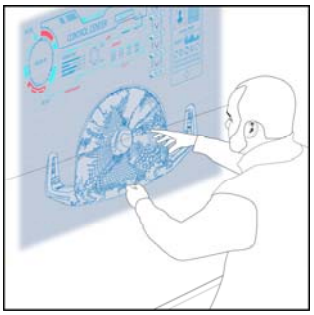


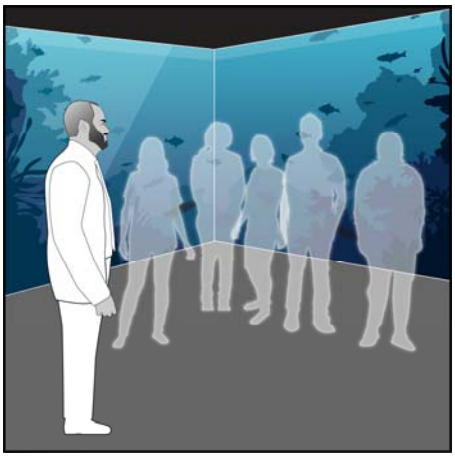
The Big Data Analysis and Display Service BigDADyS - filters important flow features in real time.

Computer/machine/ tech suggests alternative solutions or designs or other variables.



The engineer provides decision-pruning actions to "train the machines further."

F.3.5 Vision: 3–4–2019



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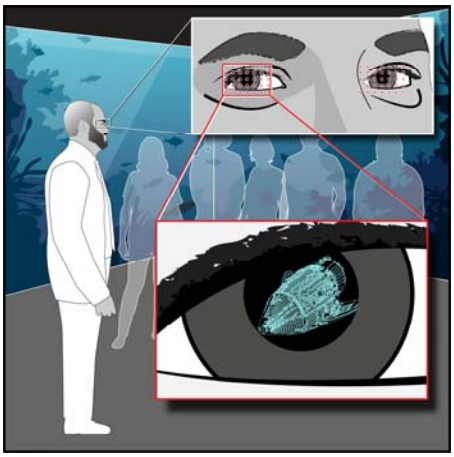

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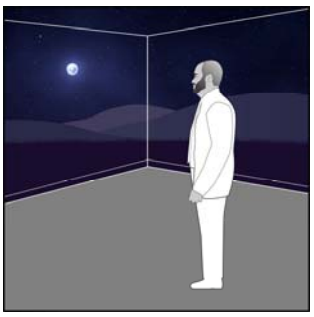
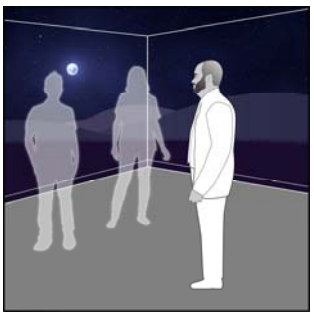
F.3.6 Vision 3–7–2019





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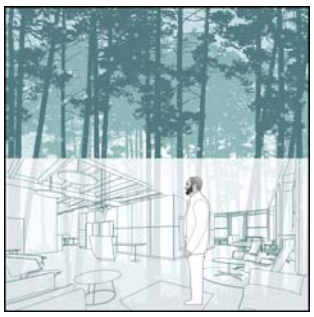

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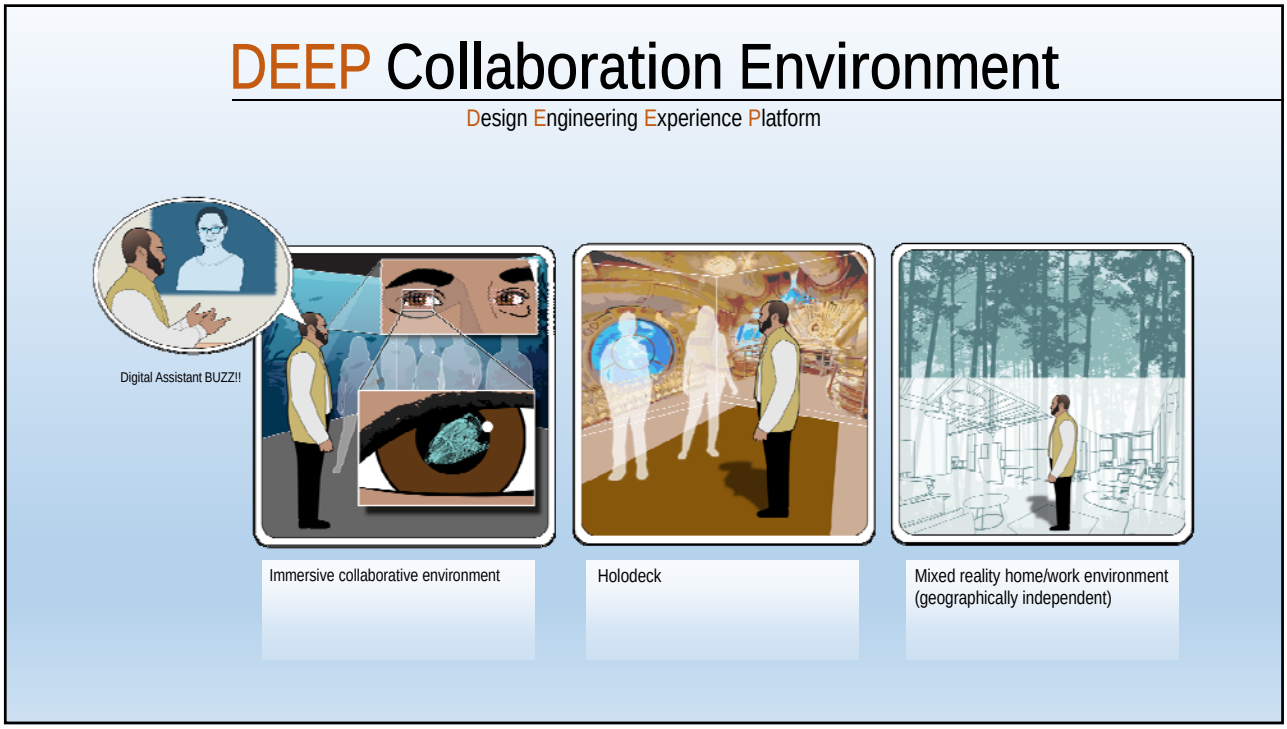
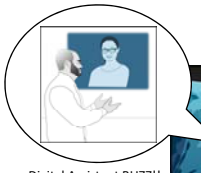
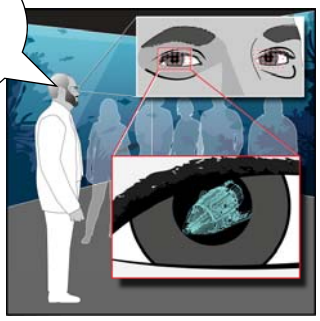
F.3.7 Vision: 4–26–2019



DEEP Collaboration Environment

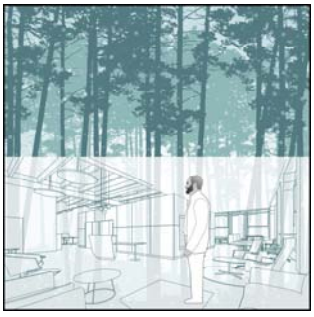
Design Engineering Experience Platform



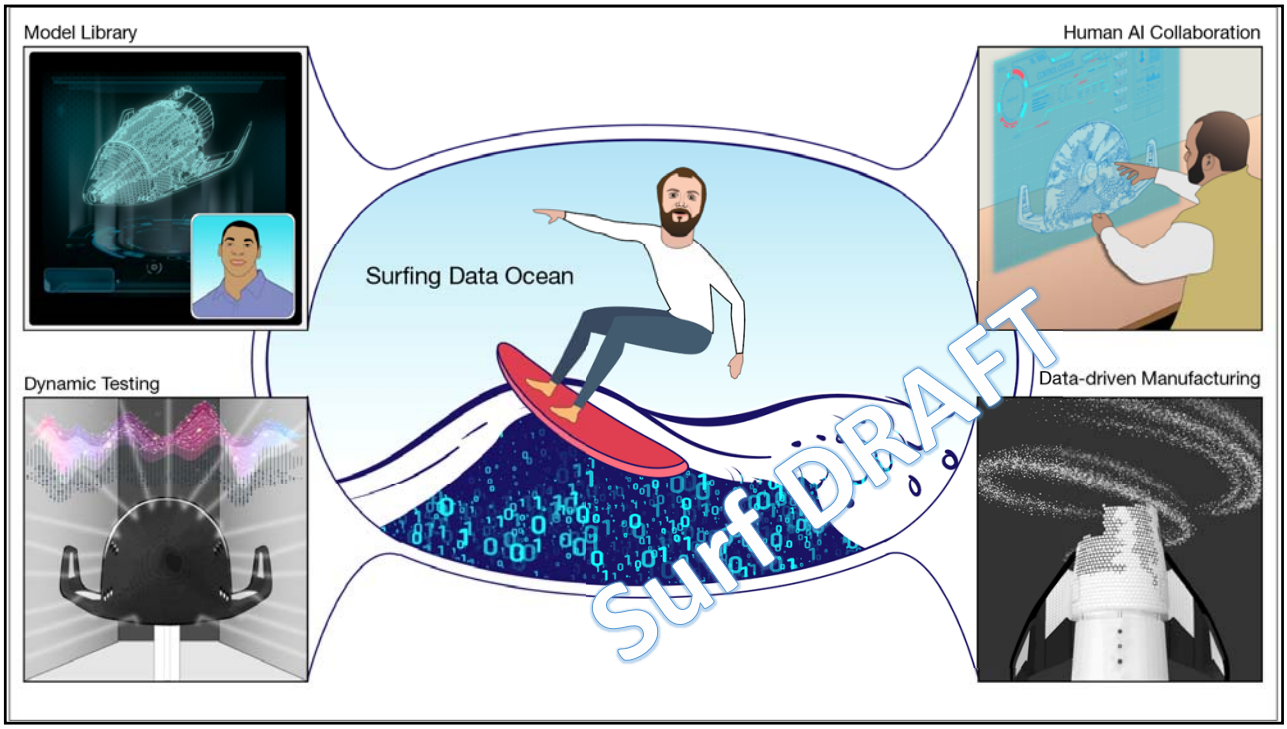


Immersive collaborative environment

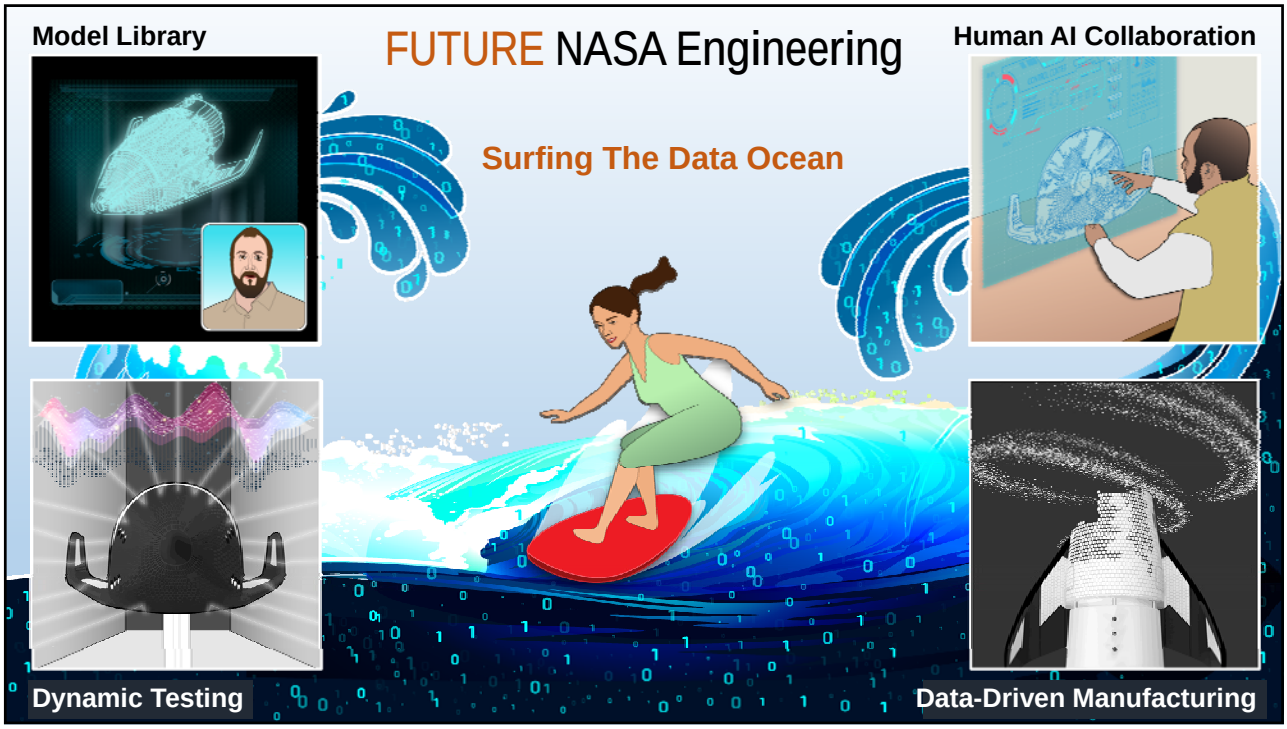
Holodeck



Mixed reality home/work environment (geographically independent)



F.3.8 Vision: 6–5–2019



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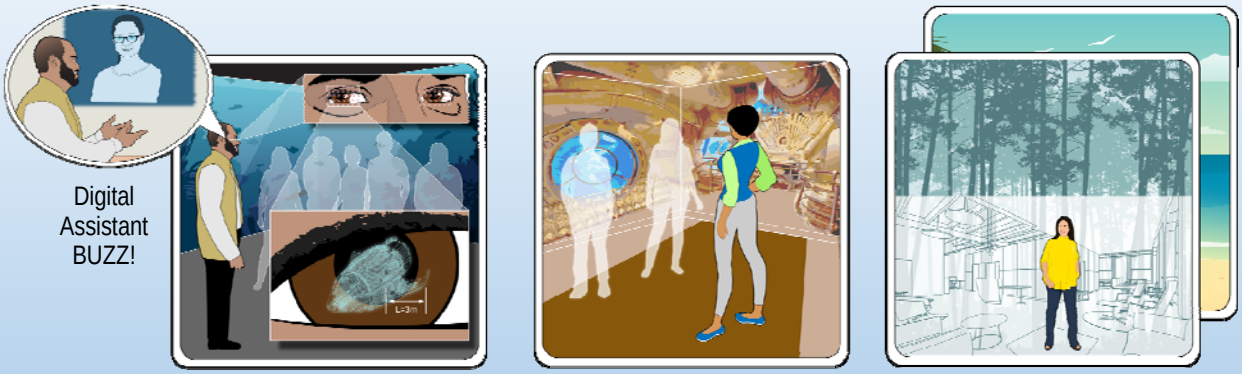


Digital Assistant BUZZ!

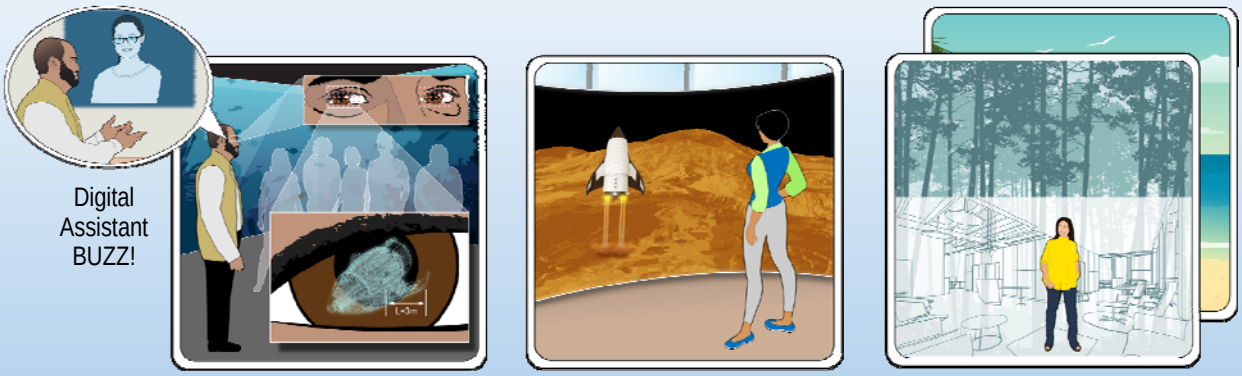
Virtual collaborative environment

Immersive environment simulates system of interest in operation

Personal, mixed-reality work environment

DEEP Collaboration Environment

Design Engineering Experience Platform



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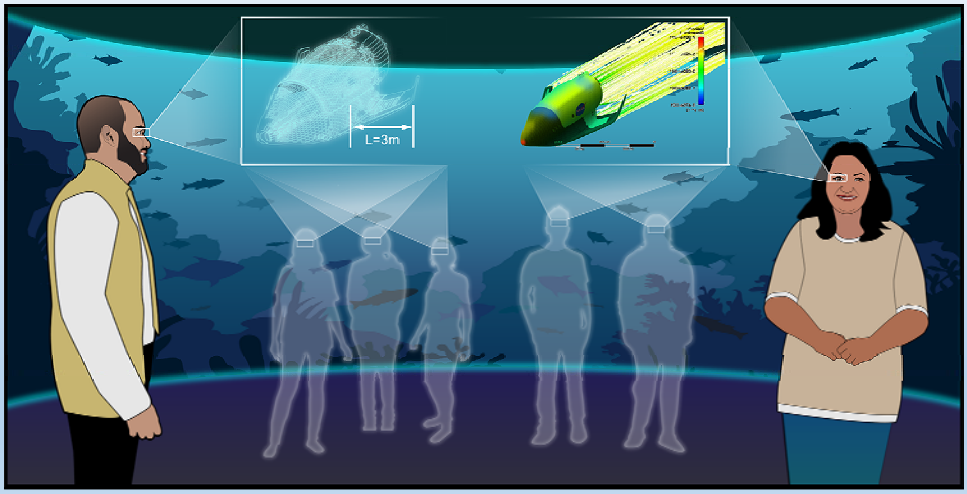
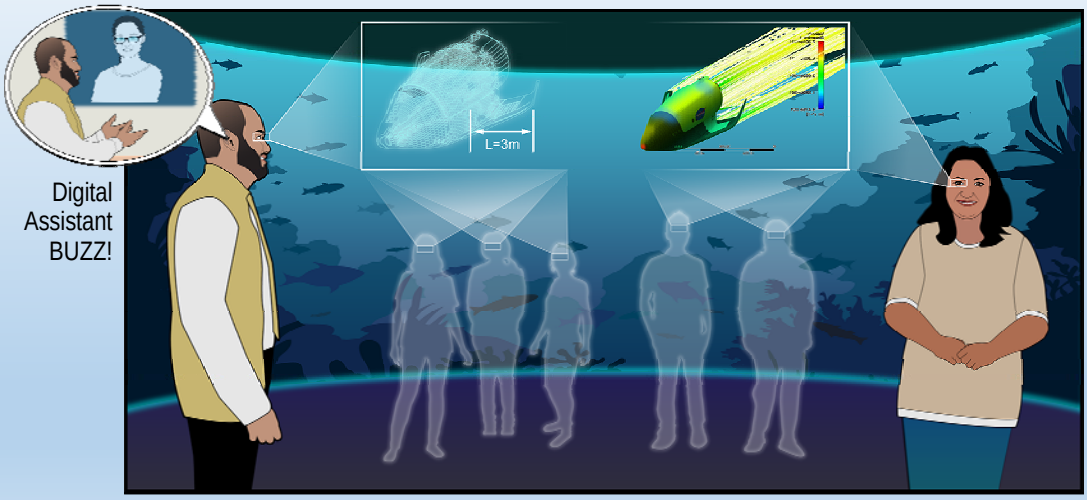


Real-time collaboration with virtual team members.

DEEP Collaboration Environment

Design Engineering Experience Platform

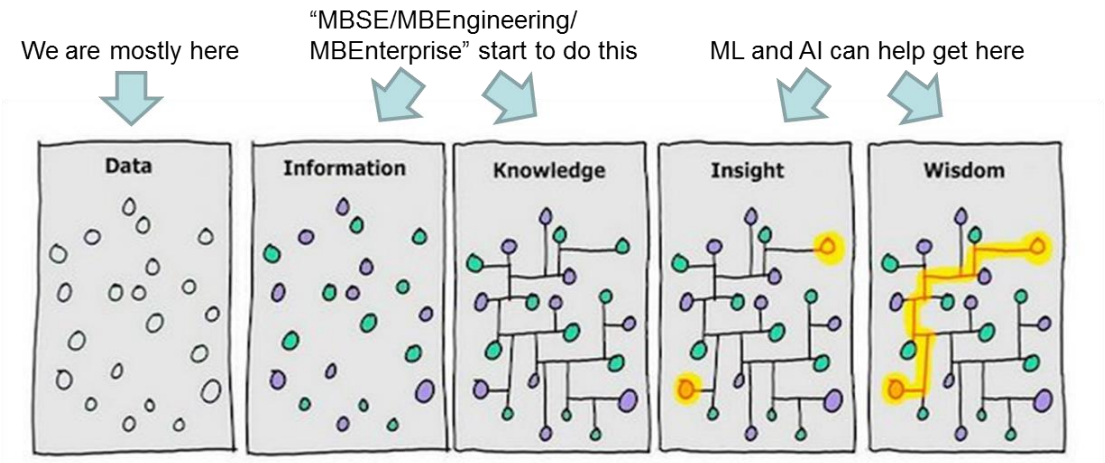


Real-time collaboration with virtual team members.

Appendix G.—Roadmap

G.1 Ideas That Informed the Development of the Roadmap

Ideas that informed the development of the Roadmap:



Cartoon by David Somerville, based on a two-pane version by Hugh MacLeod. Used with permission.

Pragmatic:	Today	8 years	12 years	15 years	20 years
Wishful:	Today	5 years	8 years	10 years	15 years

G.2 Roadmap Draft Version 4—Presentation Slides

- Build trust in human
- Build Infrastructure to share data and work efficiently

- Build trust in machine AND human decision maker
- Maintain infrastructure to grow knowledge and retain wisdom

NOW

- Trainings available to combat lack of trust in engineers' capabilities and build their soft skills
- IRAD/small research groups to fill in the data gaps and set examples of how to share information and knowledge
- Infrastructure to capture, organize, and share knowledge is created or revamped

5 years

- Less time is spent tracking down data and info (Tools-sharing or info sharing is easy)
- Efficient meetings!
- IT and HR infrastructure changes are thoughtful and productive (IT more readily accepts newer software)
- NPR is updated to accommodate tech advances

10 years

- Agency's risk posture is to manage risk
- No more hunting down data and info!
- NPRs are periodically reviewed
- Remote or virtual working feels as if in the office
- Knowledge capture/sharing infrastructure is adapted to tech help and smart searching

15 years

- Development cycles adapted to technology help
- Human in the loop to verify machine's results, and provide feedback
- Automated knowledge capture (AI/NLP)
- Small research funds continues to fill in unknown knowledge/provide insights

20 years

LE(3 LE(5 LE(2 LE(1

- Decision-pruning: Engineers make sound decisions because they fully understand impact of changes to parameters, interfaces, etc., when machine presents results
- Digital personal assistant helps us schedule meetings, etc.
- Machine knows NPR guidelines when presenting results; human creates more NPR guidelines as appropriate
- Machine retains and provides the wisdom of pioneers, such as the Apollo days engineers, Shuttle Program managers, etc.
- Development cycles evolve to take advantage of the wisdom
- Technical training comes from knowledge sharing infrastructure and interacting with the machine
- Faster, cheaper hands-on experiments to fill in unknown knowledge/provide insights/anchor machine data

MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE

Slide 1

LE(1	Separate Machine vs Human tasks Lee, Esther (LARC-E401), 12/3/2018
LE(2	Day in the Life needs to match up with this state Lee, Esther (LARC-E401), 12/3/2018
LE(3	Missing: Researcher/Innovator, Implementing type (SE, HR, Service Provider), Decision Maker Lee, Esther (LARC-E401), 12/5/2018
LE(5	What about the folks who like to do the hands-on work? Lee, Esther (LARC-E401), 12/11/2018

Roadmap (3-waypoints)

NOW

- Trainings available to combat lack of trust in engineers' capabilities and build their soft skills
- IRAD/small research groups to fill in the data gaps and set examples of how to share information and knowledge
- Infrastructure to capture, organize, and share knowledge is created or revamped
- IT and HR infrastructure changes are thoughtful and productive (IT more readily accepts newer software)
- NPR is updated to accommodate technology advances

Mid-point

- Agency's risk posture is to manage risk
- Tools sharing or info sharing is easy
- Less to no time is spent hunting down data and info
- Knowledge capturing/sharing infrastructure is adapted to tech help and smart searching
- Remote or virtual working feels as if in the office
- Development cycles adapted to technology help
- Small research funds continue to fill in unknown knowledge/provide insights
- Human in the loop to verify machine's results, and provide feedback
- NPRs are periodically reviewed

20 years

- Digital personal assistant helps us manage our work life (schedule meetings, distill information, triage work priority, smart communications)
  - Automated knowledge capture network/database in communications and meetings, etc. (AI/NLP)
- Engineers make sound decisions because they fully understand impact of changes to parameters, interfaces, etc., when machine presents results
- Faster, cheaper hands-on experiments to fill in unknown knowledge/provide insights/anchor machine data
- Technical training comes from knowledge sharing infrastructure and interacting with the machine
- Machine retains and provides the wisdom of pioneers, such as the Apollo days engineers, Shuttle Program managers, etc.
- Development cycles evolve to take advantage of the wisdom
- Machine knows NPR guidelines when presenting results
- Human creates more NPR guidelines as appropriate

Slide 2

LE(6	Engineers will be thinking, exploring, and coming up with ideas and testing them. 1) testing more, faster and cheaper with the aid of machines 2) doing iterative design analyses with computer aid and also testing 3) communicate effectively with different groups and disciplines for better collaboration Lee, Esther (LARC-E401), 12/11/2018
LE(8	Technical training falls into 1 and 2 Lee, Esther (LARC-E401), 12/11/2018
LE(7	Tech will help make the actual job easier; including 1) mundane scheduling meetings, taking notes 2) assist in iterative designs analysis 3) make testing more, faster and cheaper 4) improve collaboration between groups and disciplines (more efficient data sharing; better communications; remote working collaboration) Lee, Esther (LARC-E401), 12/11/2018
LE(9	Decision Makers Lee, Esther (LARC-E401), 12/11/2018
LE(13	1) sees the whole project picture when making decisions (Machine provide possible outcome for each decision) Lee, Esther (LARC-E401), 12/14/2018
LE(14	2) smart communication to raise concerns/questions at interim review points Lee, Esther (LARC-E401), 12/14/2018
LE(10	Implementors (HR, IT, workforce training) Lee, Esther (LARC-E401), 12/11/2018
LE(11	1) tap into available resources everywhere with virtual training/lectures/seminars (establish education network from technical to softskills, all in one learning center) Lee, Esther (LARC-E401), 12/11/2018
LE(12	2) Adapt NPR-like guidelines to evolving technology Lee, Esther (LARC-E401), 12/11/2018
LE(15	3) Maintain Knowledge database, the virtual library Lee, Esther (LARC-E401), 12/14/2018

- Build trust in human
- Build Infrastructure to share data and work efficiently

- Build trust in machine AND human decision maker
- Maintain infrastructure to grow knowledge and retain wisdom

LE(2

NOW

- Trainings available to combat lack of trust in engineers' capabilities and build their soft skills
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LE(1

20 years

- Digital personal assistant helps us schedule meetings, etc.
- Decision-pruning: Engineers make sound decisions because they fully understand impact of changes to parameters, interfaces, etc., when machine presents results
  - Machine knows NPR guidelines when presenting results; human creates more NPR guidelines as appropriate
- Machine retains and provides the wisdom of pioneers, such as the Apollo days engineers, Shuttle Program managers, etc.
- Development cycles evolve to take advantage of the wisdom
- Technical training comes from knowledge sharing infrastructure and interacting with the machine

Legend:
- Red = knowledge capture
- Black = researchers/analysts/engineers
- Blue = decision makers

MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE

Slide 3

LE(1 Separate Machine vs Human tasks
Lee, Esther (LARC-E401), 12/3/2018

LE(2 Day in the Life needs to match up with this state
Lee, Esther (LARC-E401), 12/3/2018

Roadmap (Knowledge Sharing Infrastructure)

NOW

- IRAD/small research groups to fill in the data gaps and set examples of how to share information and knowledge
- Infrastructure to capture, organize, and share knowledge is created or revamped
- IT and HR infrastructure changes are thoughtful and productive (IT more readily accepts newer software)

Mid-point

- Less to no time is spent hunting down data and info!
- Tools sharing or info sharing is easy
- Knowledge capture/sharing infrastructure is adapted to tech help and smart searching
- Small research funds continue to fill in unknown knowledge/provide insights
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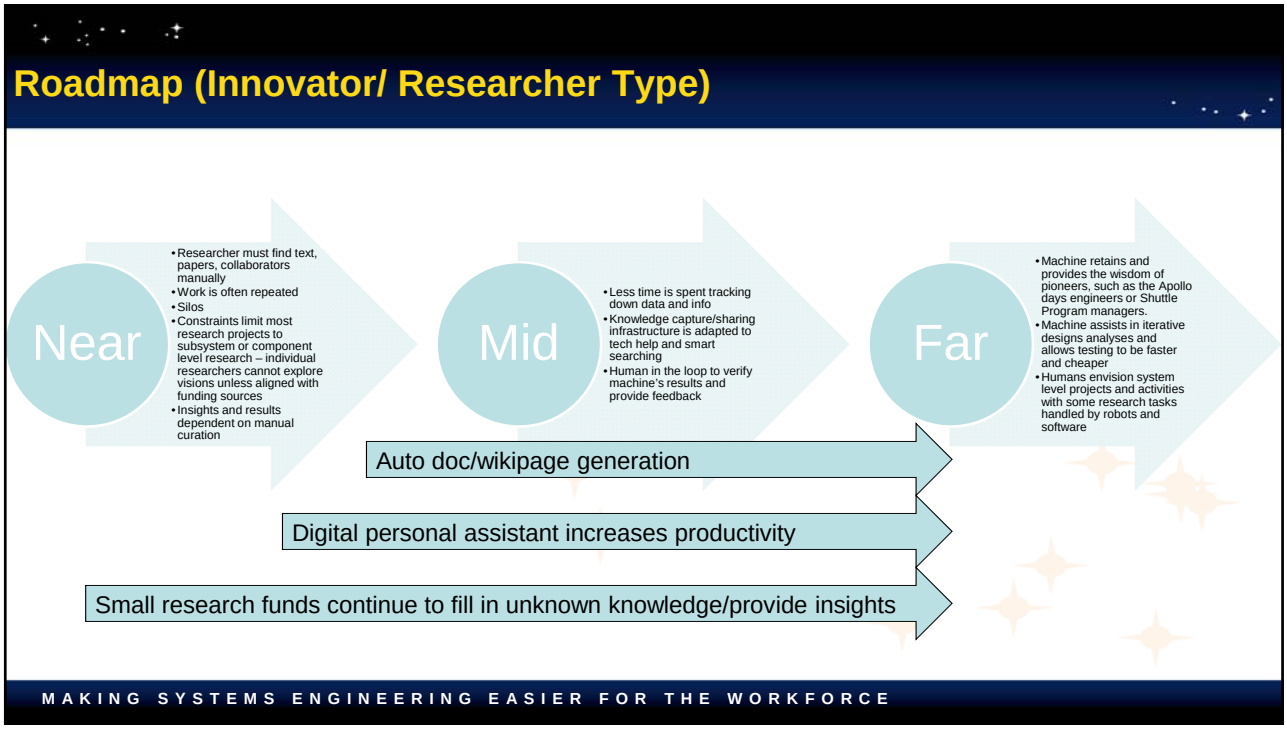
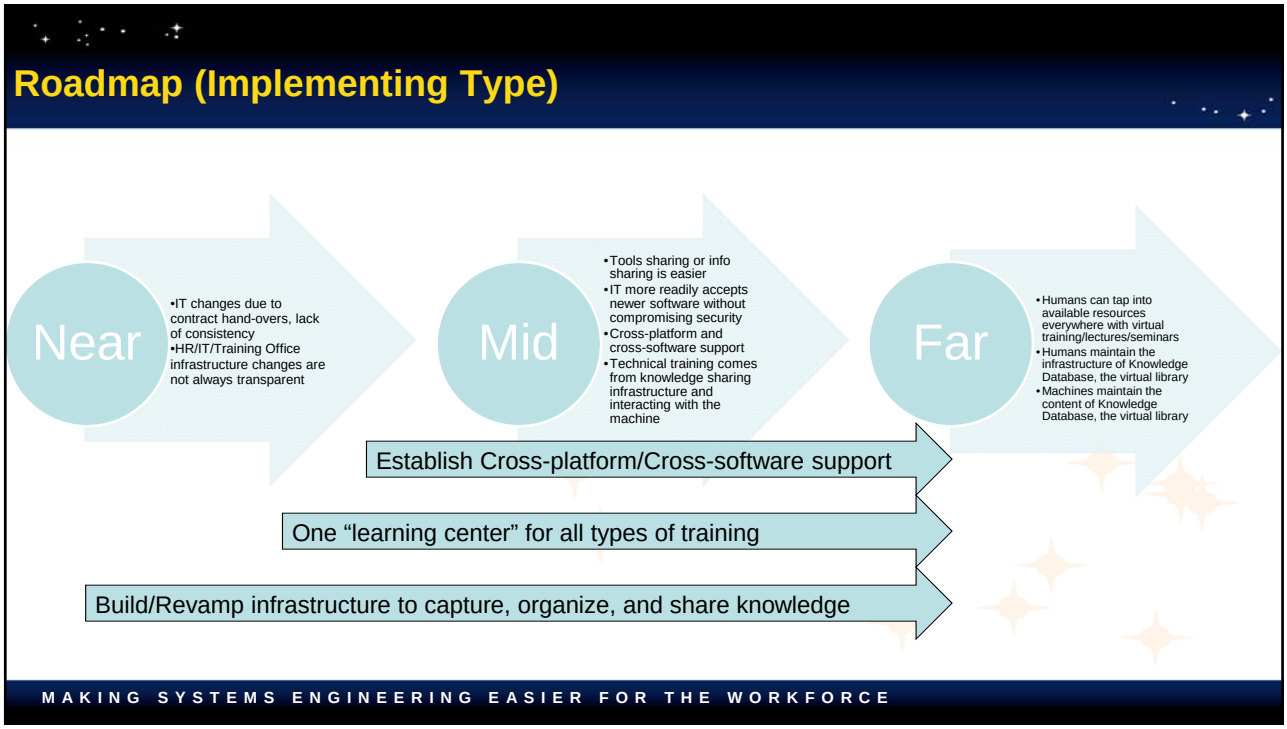
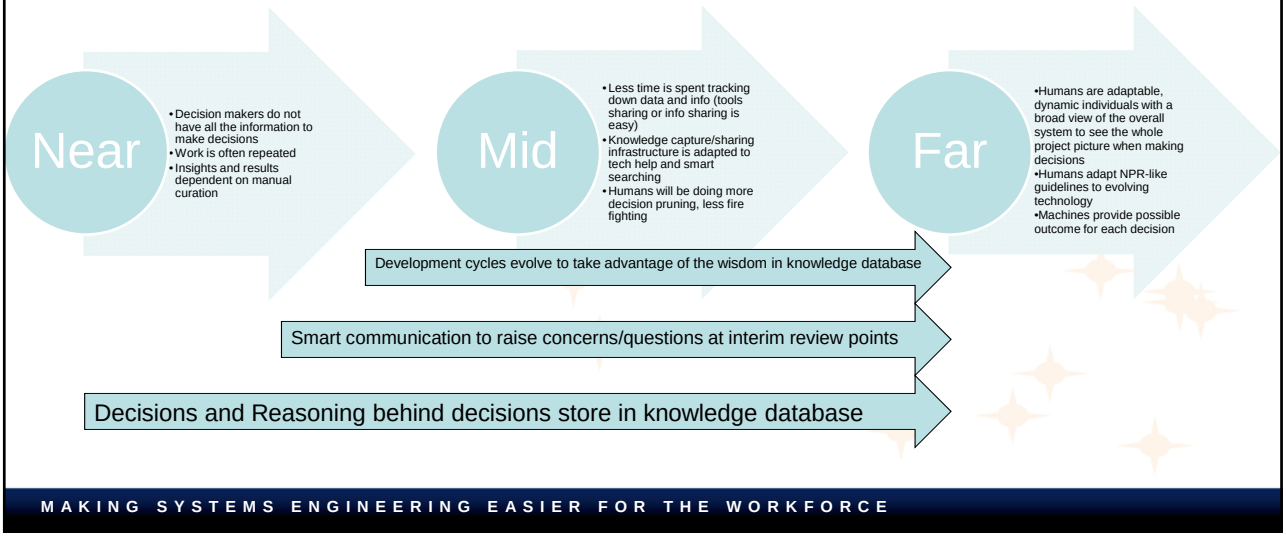
- Development cycles evolve to take advantage of the wisdom
- Machine knows NPR guidelines when presenting results; human creates more NPR guidelines as appropriate

G.3 Roadmap Draft, Version 5—Presentation Slides



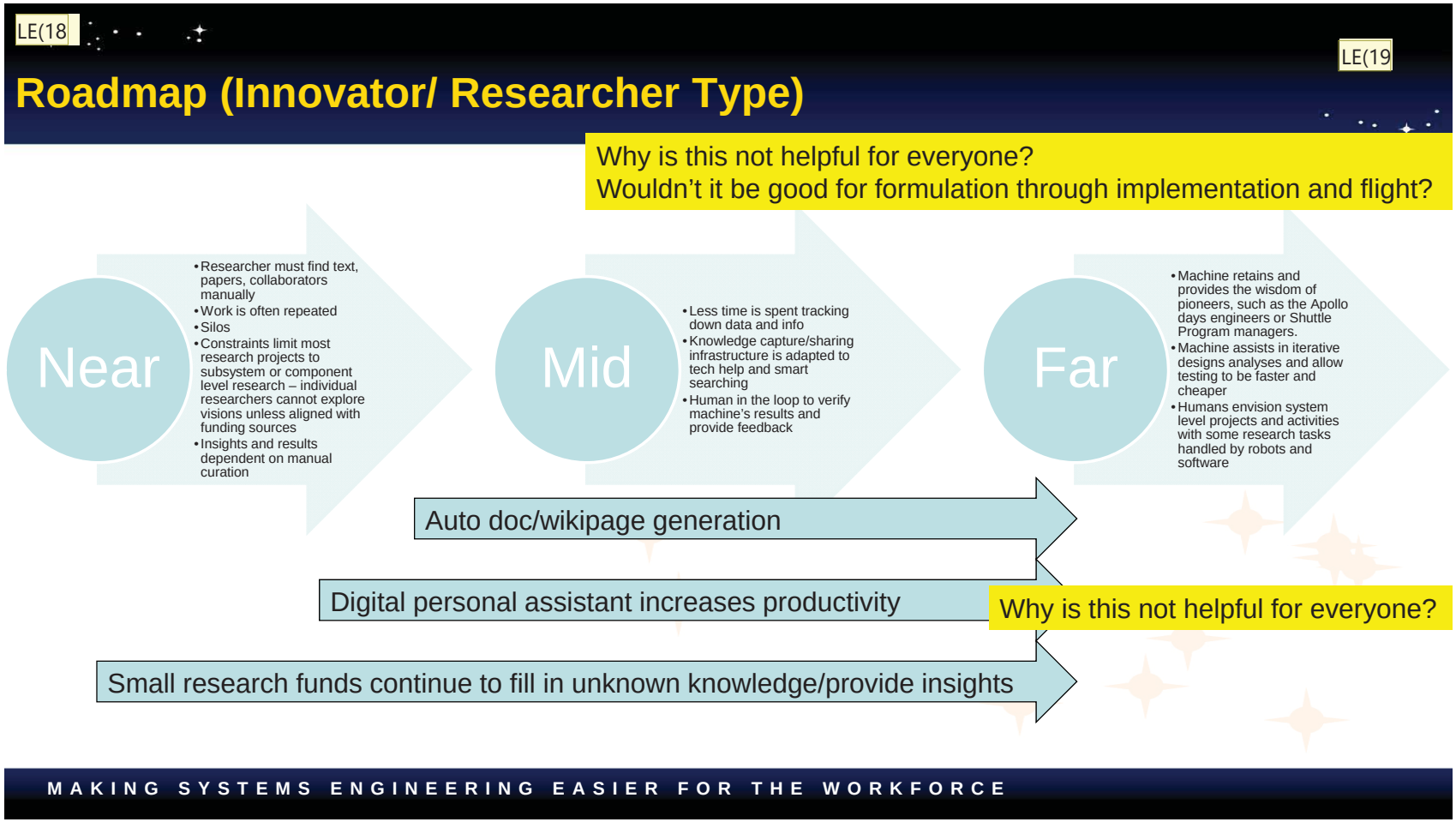


Roadmap (Decision Maker Type)



MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE

G.4 Roadmap Draft, Version 5 With Comments—Presentation Slides



Slide 1

LE(18 GOALS from strategic plan
Lee, Esther (LARC-E401), 4/2/2019

LE(19 - how quickly adopting technology
Lee, Esther (LARC-E401), 4/2/2019

LE(16

LE(17

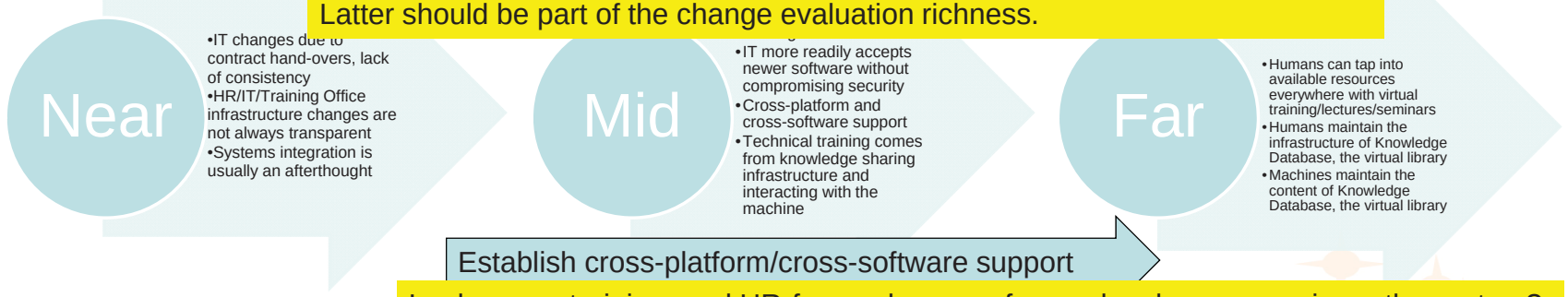
Roadmap (Implementing Type)

Implementing implies Phase BCD of our life cycles.

Where do we get to enhanced analysis and understanding of our systems?

How about real-time change integration, evaluation, and baseline updates?

Seamless integration with other disciplines, including safety and programmatics. Latter should be part of the change evaluation richness.



Establish cross-platform/cross-software support

Looks more training- and HR-focused, versus focused on how we engineer the system?

One “learning center” for all types of training

Build/revamp infrastructure to capture, organize, and share knowledge

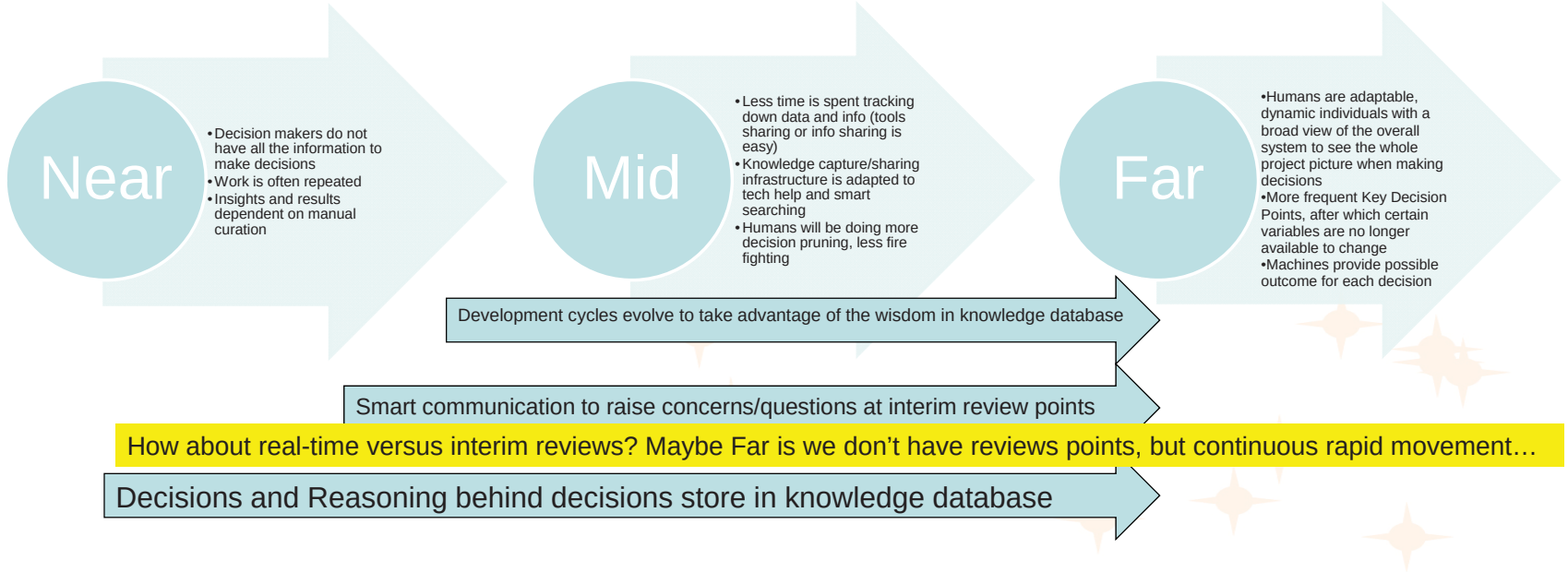
Share knowledge is good, but how does that help? We have knowledge sharing now, but problem is people don’t use it effectively.

MAKING SYSTEMS ENGINEERING EASIER FOR THE WORKFORCE

LE(16 User roles instead of roadmap
Lee, Esther (LARC-E401), 4/2/2019

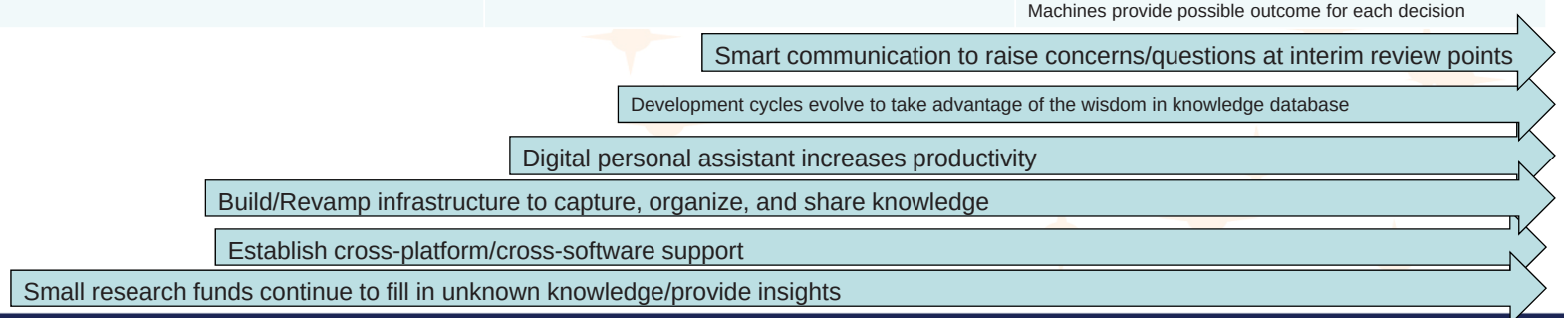
LE(17 Consider smushing these into one, but put the products that applies separate.
Lee, Esther (LARC-E401), 4/2/2019

Roadmap (Decision Maker Type)

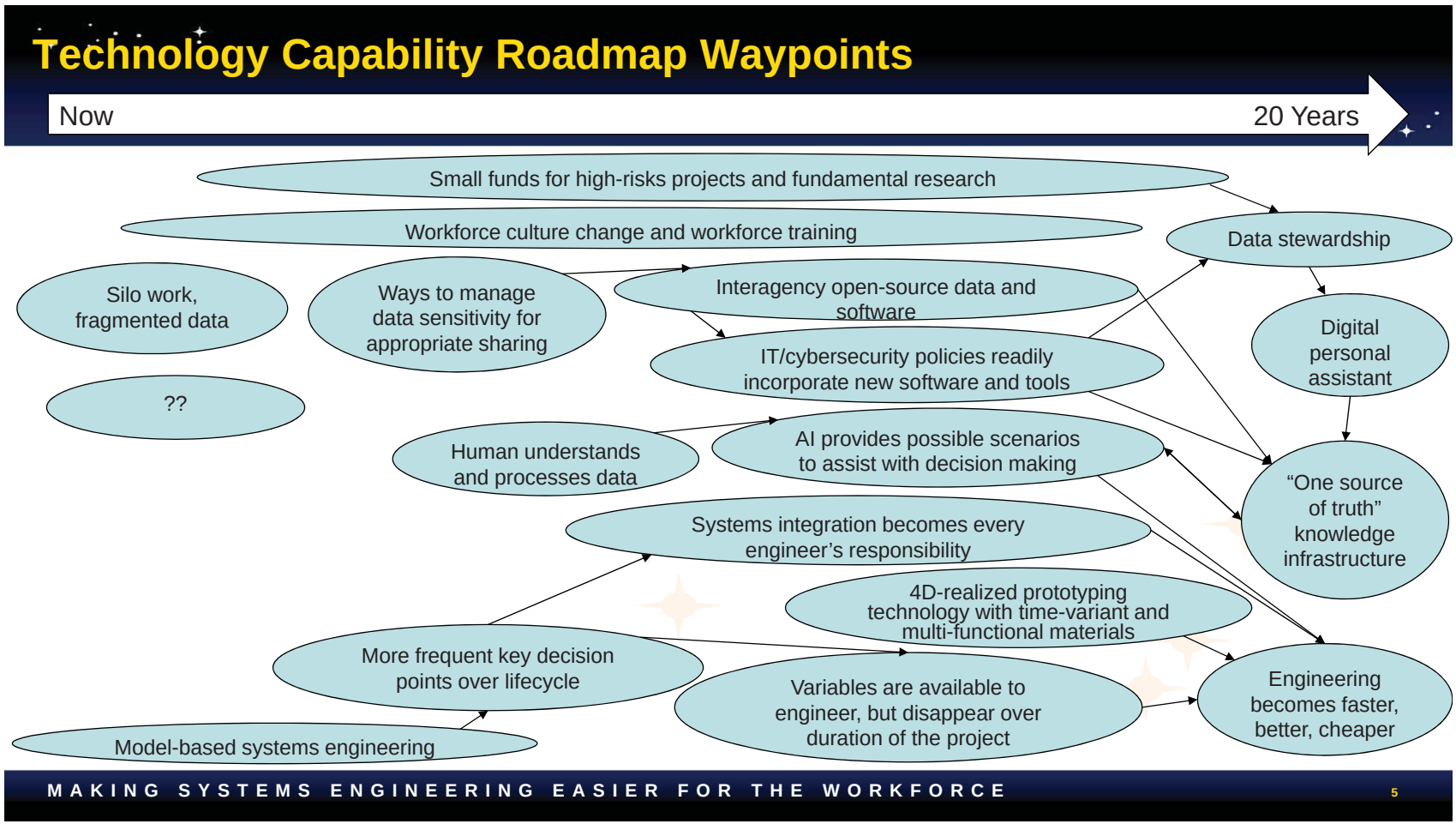


Roadmap

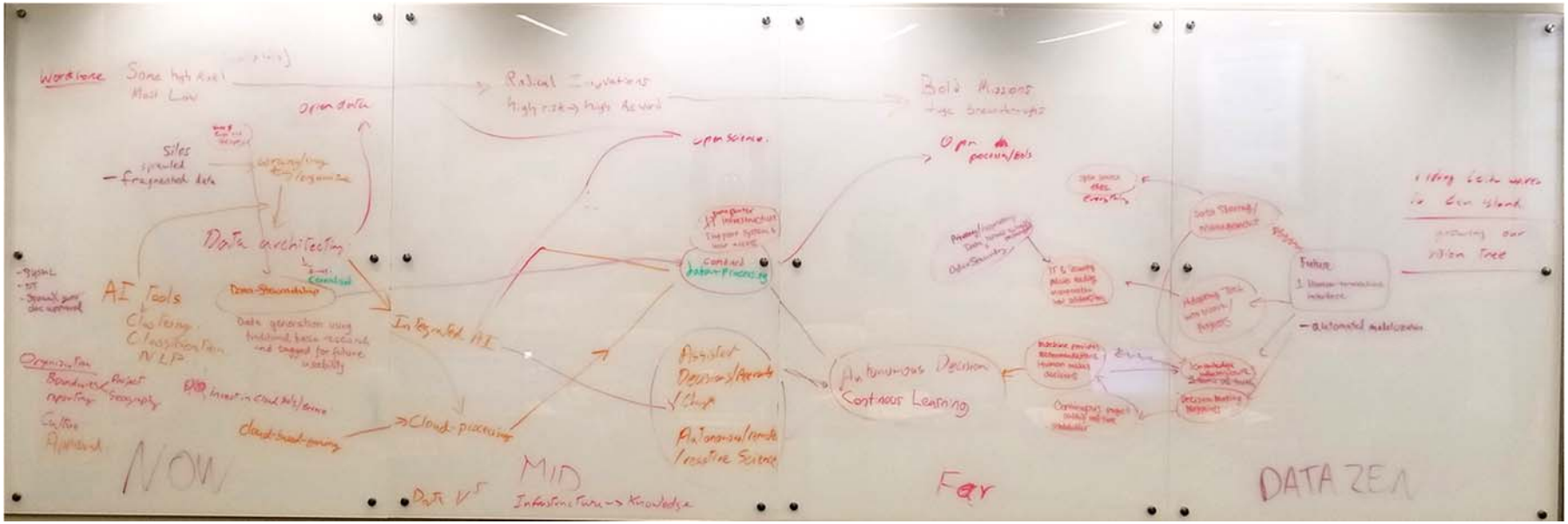
	Now	Mid	Far
Researcher	Researcher must find text, papers, collaborators manually Work is often repeated or siloed Constraints limit most research projects to subsystem or component level research – individual researchers cannot explore visions unless aligned with funding sources Insights and results dependent on manual curation	Less time is spent tracking down data and info Knowledge capture/sharing infrastructure is adapted to tech help and smart searching Human in the loop to verify machine's results and provide feedback	Machine retains and provides the wisdom of pioneers, such as the Apollo days engineers or Shuttle Program managers. Machine assists in iterative designs analyses and allows testing to be faster and cheaper Humans envision system-level projects and activities with some research tasks handled by robots and software
Implementer	IT changes due to contract handovers, lack of consistency HR/IT/Training Office infrastructure changes are not always transparent Systems integration is usually an afterthought	Tools sharing or info sharing is easier IT more readily accepts newer software without compromising security Cross-platform and cross-software support Technical training comes from knowledge sharing infrastructure and interacting with the machine	Humans can tap into available resources everywhere with virtual training/lectures/seminars Humans maintain the infrastructure of Knowledge Database, the virtual library Machines maintain the content of Knowledge Database, the virtual library
Decision makers	Decision makers do not have all the information to make decisions Work is often repeated Insights and results dependent on manual curation	Less time is spent tracking down data and info (tools sharing or info sharing is easy) Knowledge capture/sharing infrastructure is adapted to tech help and smart searching Humans will be doing more decision pruning, less fire fighting	Humans are adaptable, dynamic individuals with a broad view of the overall system to see the whole project picture when making decisions More frequent Key Decision Points, after which certain variables are no longer available to change Machines provide possible outcome for each decision

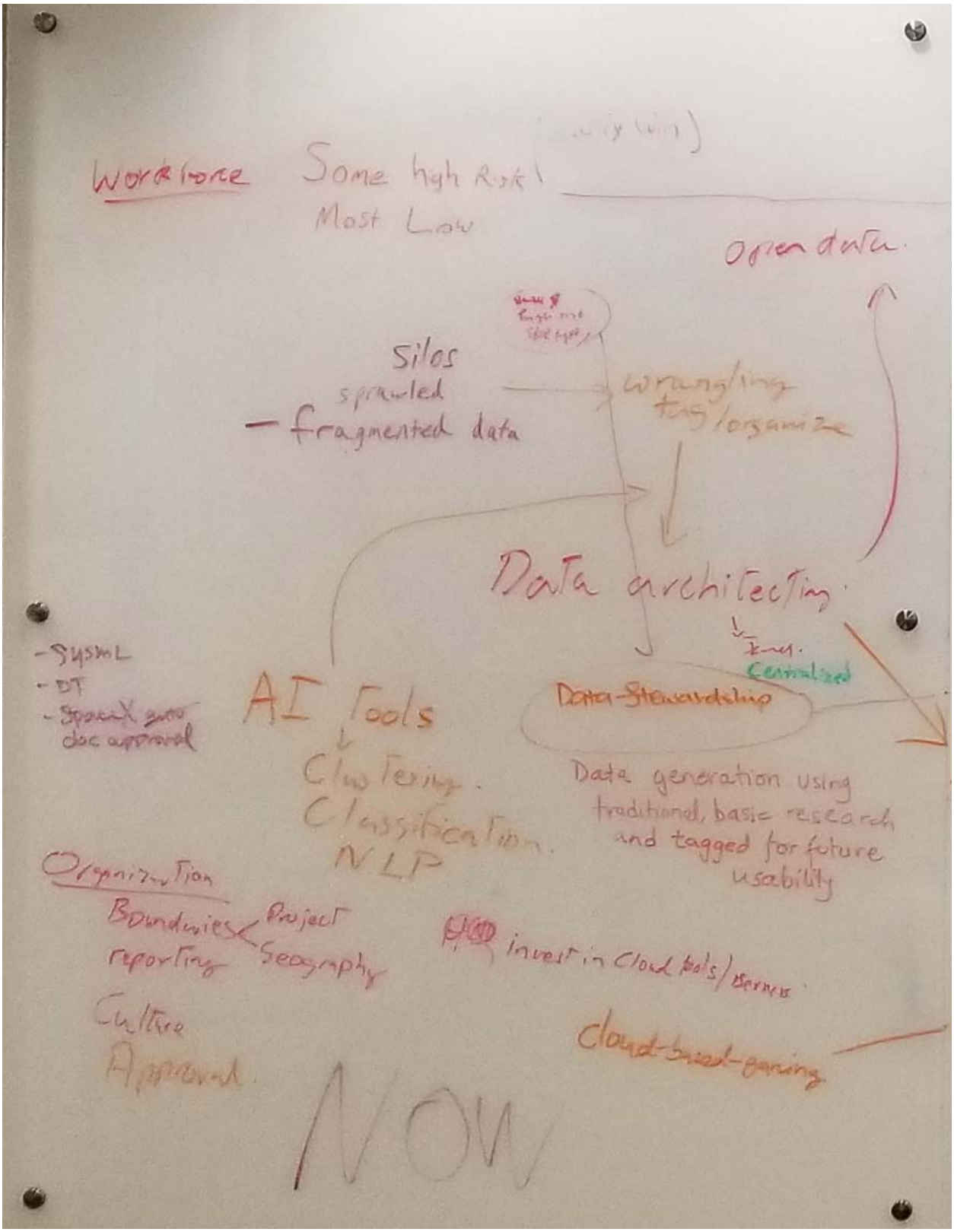


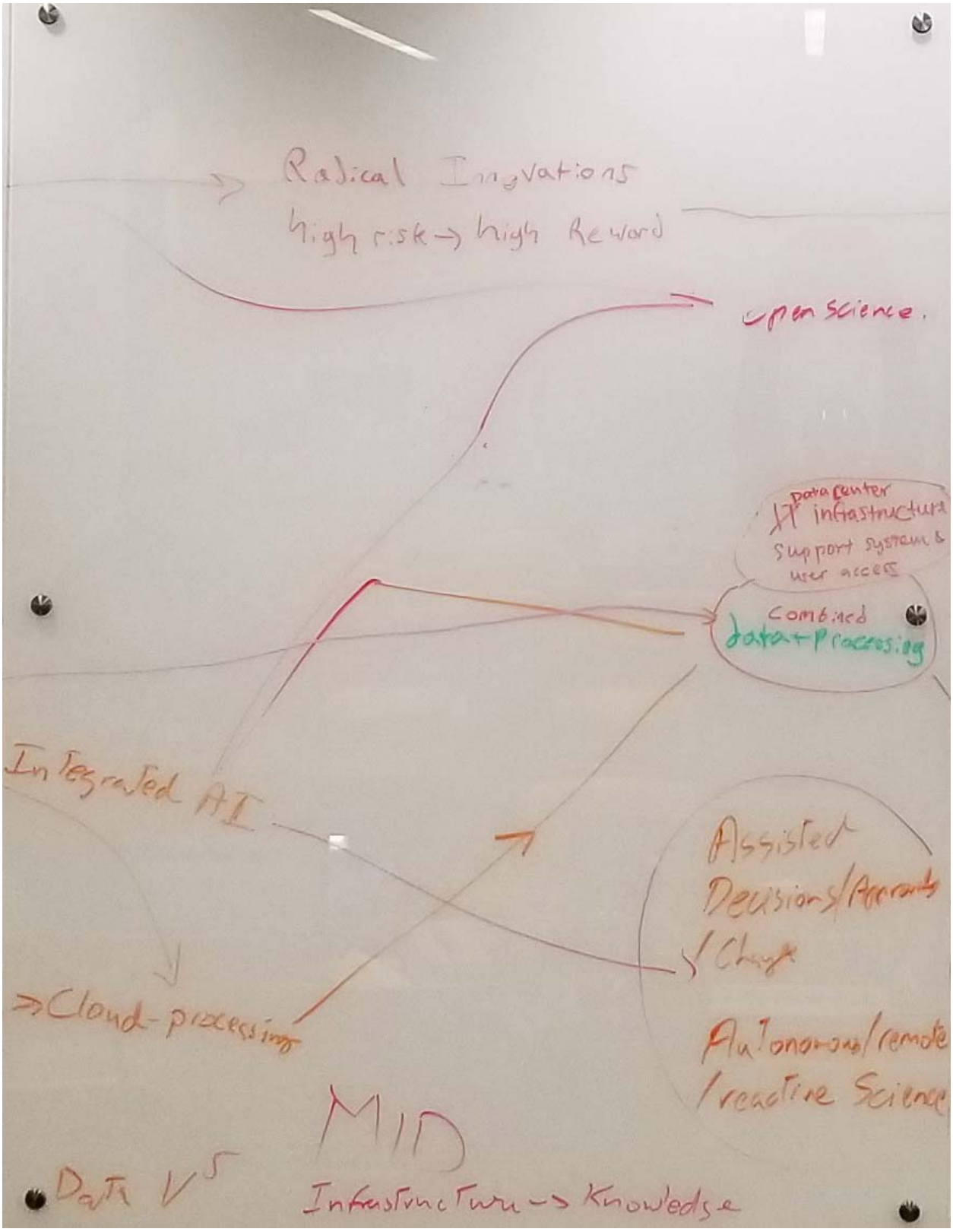
Technology Capability Roadmap Waypoints

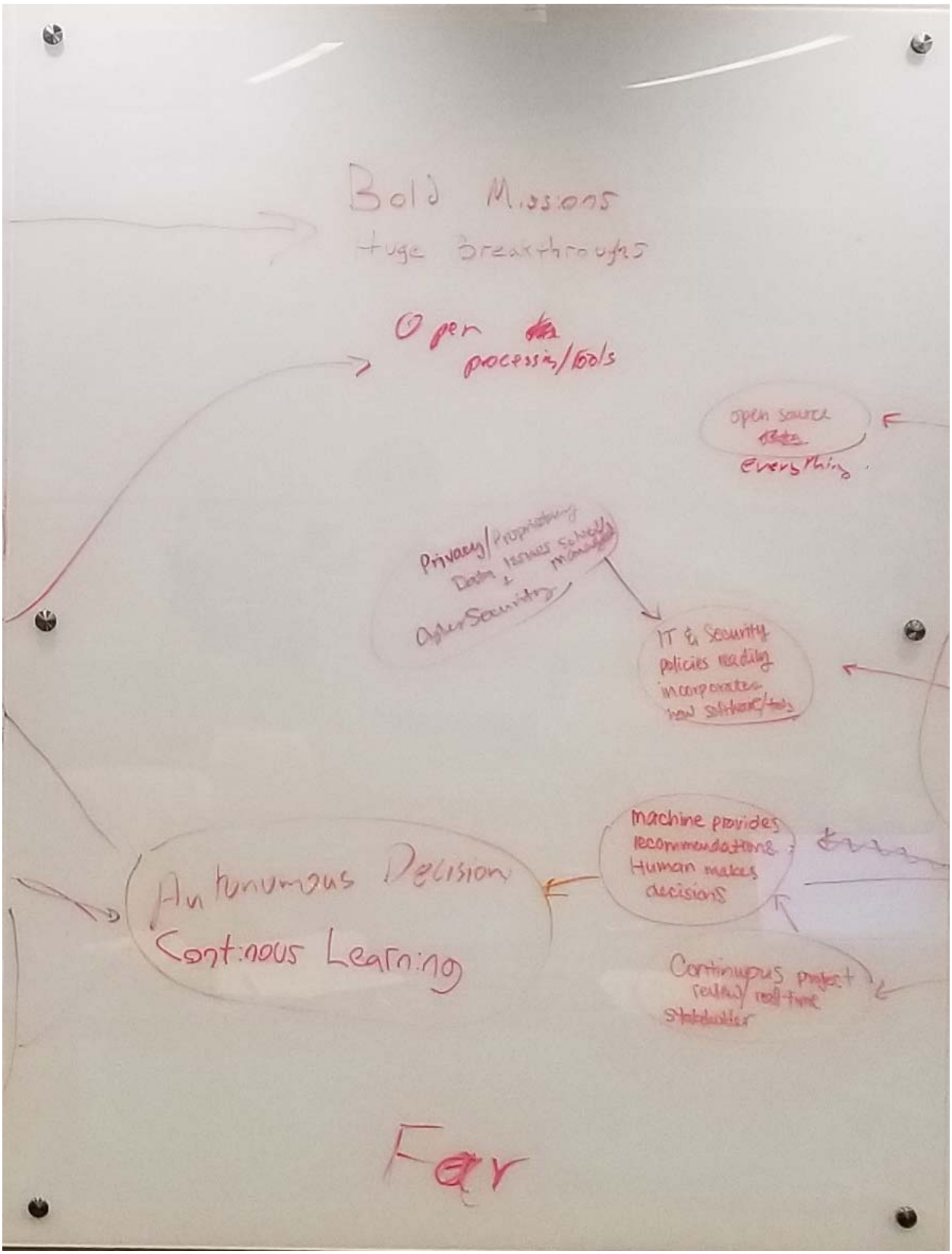


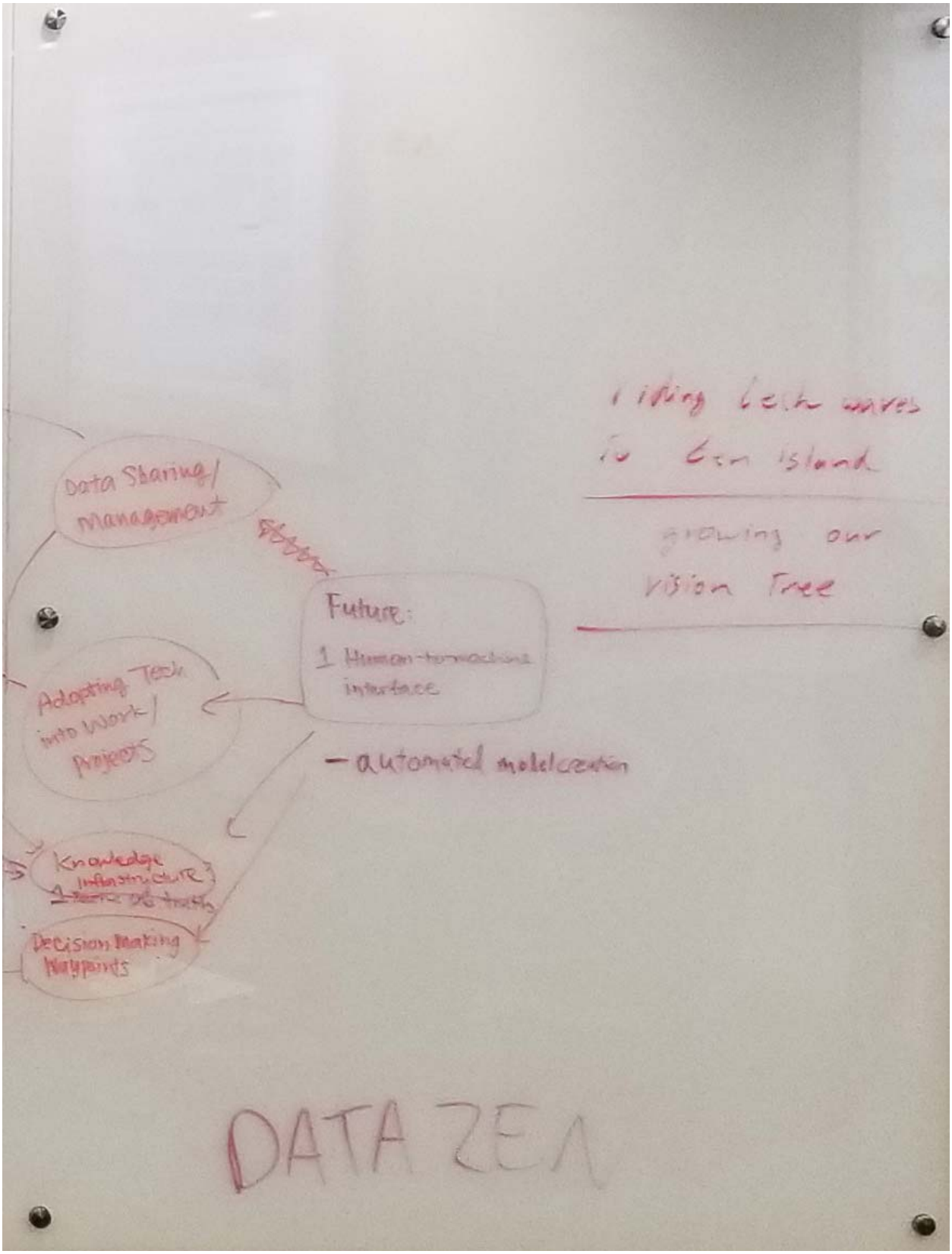
G.5 Roadmap Whiteboard




Workforce
Some high Risk
Most Low
open data.
Silos
sprawled
fragmented data
wrangling
tag/organize
Data architecting.
Centralized
-SysML
-DT
-Spaces and doc approval
AI Tools
Clustering.
Classification.
NLP
Data-Stewardship
Data generation using traditional, basic research and tagged for future usability
Organization
Boundaries
Project
Geography
reporting
Culture
Approval.
invest in Cloud tools/Servers
cloud-based-gaming
NOW

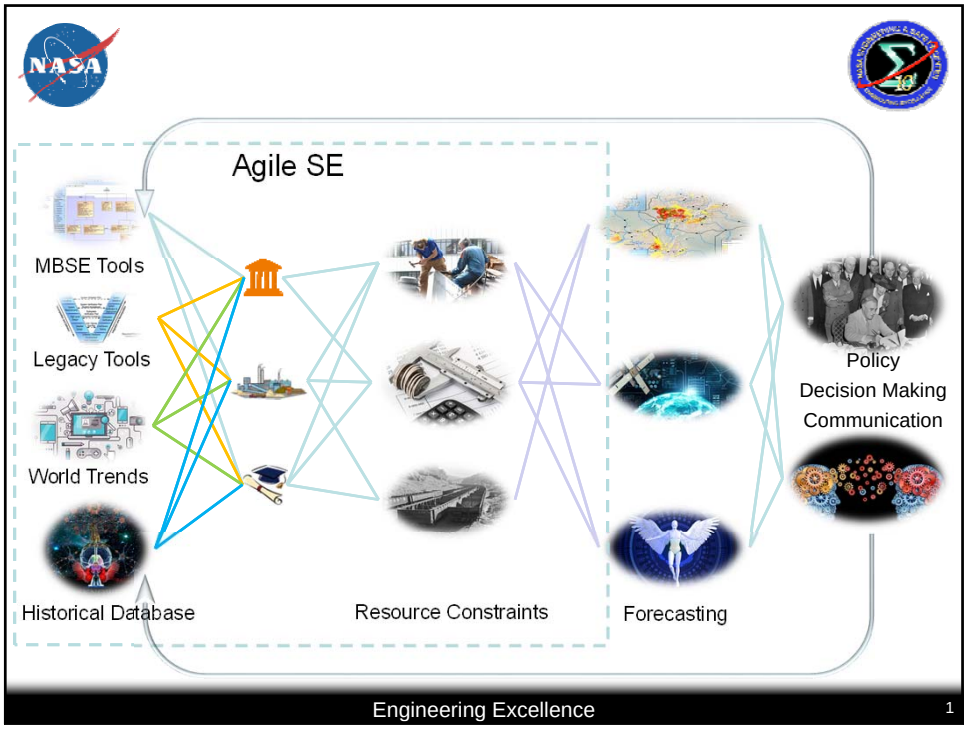

Radical Innovations
High risk → high Reward
open science.
data center
IT infrastructure
support systems &
user access
Combined
data + Processing
Integrated AI
Assisted
Decisions/Approvals
Autonomous/remote
/reactive Science
→ Cloud-processing
MID
Data V5
Infrastructure → Knowledge

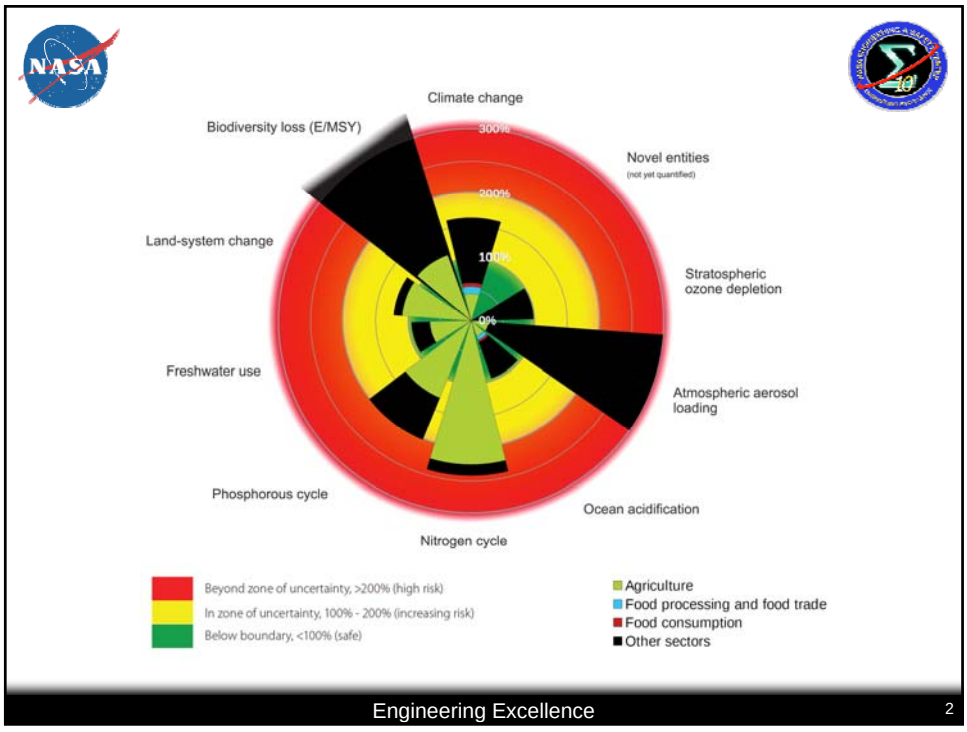

Bold Missions
huge breakthroughs
Open
processes/tools
open source
everything
Privacy/Proprietary
Data issues solved/
managed
&
Cyber Security
IT & Security
policies readily
incorporated
new software/tools
machine provides
recommendations
Human makes
decisions
Autonomous Decision
Continous Learning
Continuous project
real-time/ real-time
stakeholder
Fear


riding tech waves
to Zen island
growing our
vision Tree
Data Sharing/
management
Future:
1 Human-interaction
interface
Adapting Tech
into Work/
Projects
- automated model creation
Knowledge
Infrastructure
Decision Making
Waypoints
DATA ZEN

Appendix H.—Strategic Plan

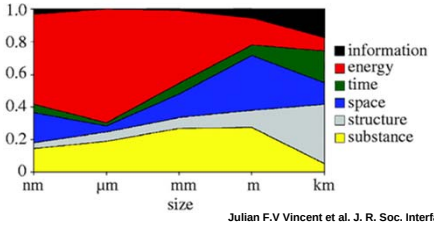
H.1 Strategic Plan Ideas, July 3, 2018, Version 1—Presentation Slides



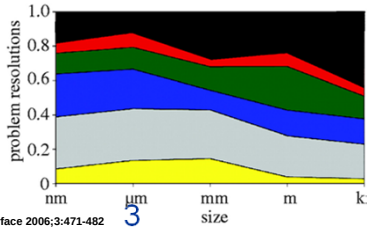


The information age meets design by information

Human solutions create problems



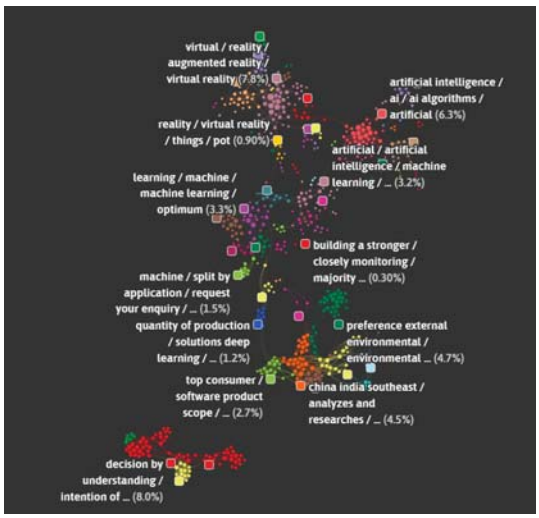
Nature uses information to solve them



Julian F.V Vincent et al. J. R. Soc. Interface 2006;3:471-482

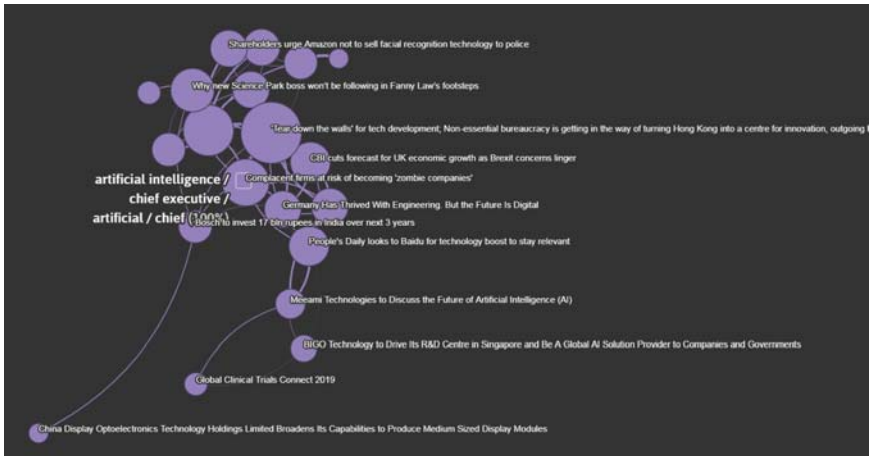
3

Data mining trends example



Analysis by Dr. Vikram Shyam, 2018, Powered by Quid

AI stories



Analysis by Dr. Vikram Shyam, 2018, Powered by Quid

More AI

Analysis by Dr. Vikram Shyam, 2018, Powered by Quid

Examples

- http://blog.tmcnet.com/blog/rich-tehrani/ai/how-to-prepare-for-the-future-of-work.html
- https://www.tmcnet.com/usubmit/-artificial-intelligence-ai-military-global-industry-analysis-forecast-/2018/06/06/8767792.htm
- https://www.design-reuse.com/news/44366/daimler-ag-xilinx-artificial-intelligence-based-automotive-applications.html?utm_medium=rss&utm_source=designreuse&utm_content=1&utm_campaign=44366
- http://news.morningstar.com/all/business-wire/BWIPREM20180628005816/global-61-bn-artificial-intelligence-robotics-for-defense-market-technology-forecast-to-2027-researchandmarketscom.aspx

H.2 Strategy Group's Vision, Roadmap, and Strategic Plan Draft: For Advisory Board Review, April 24, 2019—Presentation Slides

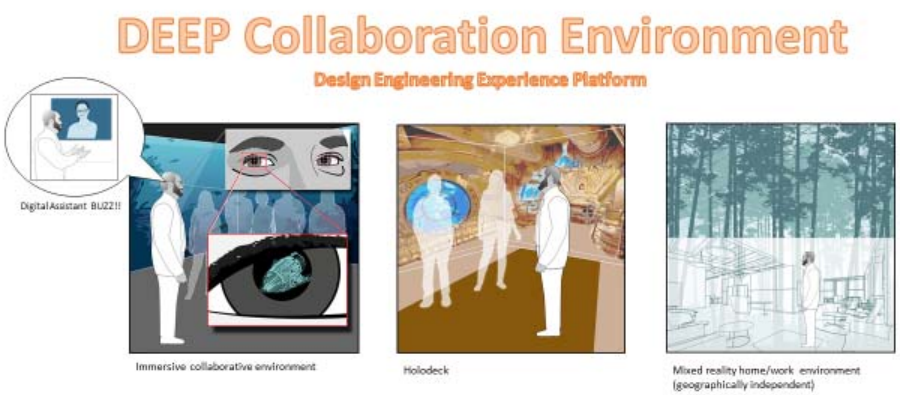
Strategy Group's Vision, Roadmap and Strategic Plan Draft: For Advisory Board Review

Wednesday, April 24, 2019

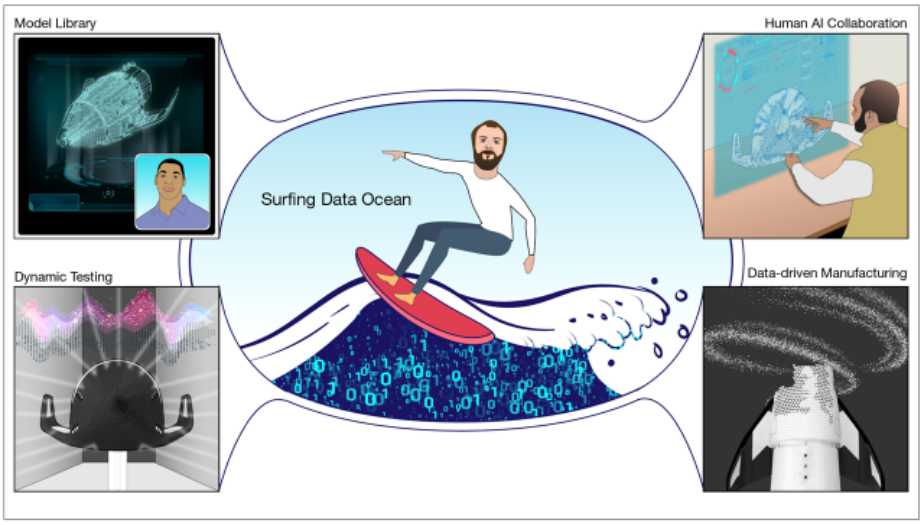
Strategy Group's Vision

NASA engineers enable extraordinary, unprecedented missions by adopting system-focused, human-centered, influential technologies for the benefit of all.

Depicting the Vision



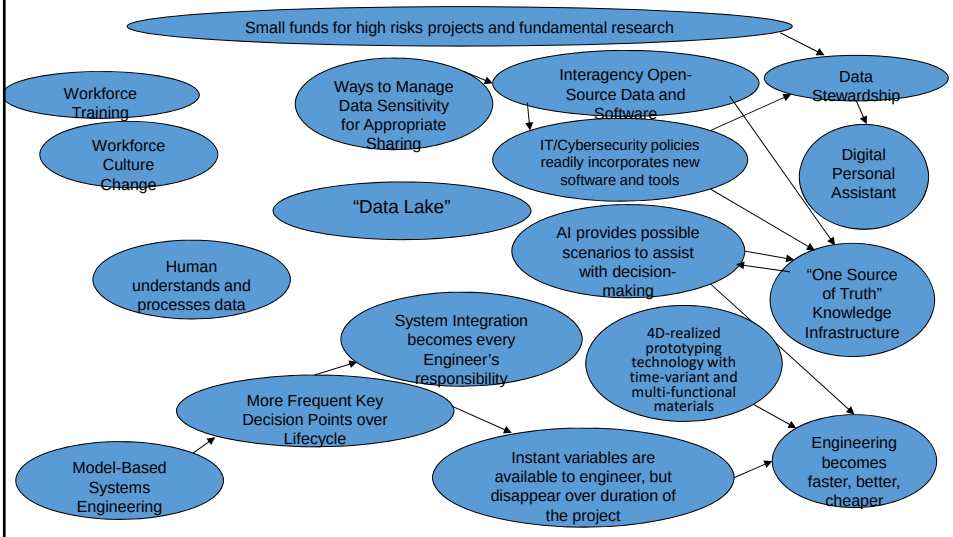
Depicting the Vision (contd.)



How Engineers Will Work

- Digital Personal Assistant helps increase productivity
- Engineers makes sound decisions by fully understanding impact of changes to parameters and/or interfaces when machine presents alternatives
- Technical Training comes from knowledge sharing infrastructure and interacting with the machine
- Machine retains and provides the wisdom of pioneers, such as the Apollo days engineers, Shuttle Program managers
- Development cycles evolve to take advantage of the wisdom
- Machine knows NASA Guidelines and accounts for them in the design; human tailors Guidelines as appropriate

Technology Capability Roadmap Waypoints



Objectives for creating a Strategic Plan

- Communicate the value proposition of early investments in Engineering capabilities with key stakeholders
  - Cultivate and maintain rapport with opinion leaders and influencers
  - Facilitate engagement with, and interaction between, agencies, academia, and companies
- Understand and leverage Engineering technology at NASA
  - Articulate the capabilities, innovations, challenges, and benefits of Engineering technology
    - Enable innovative applications
    - Improve trust of Cyber-Physical Systems
  - Mobilize a subset of the NASA workforce to serve as ambassadors
- Increase awareness and visibility of Engineering technology
  - Capture missions, savings, outreach, and communication activities as proof points for return on investment
    - Maintain high visibility at Launches, Test Flights, and Milestone Events
    - Make Engineering membership a "big deal"

Strategic Plan Outline

- Section 1 Executive Summary: We will complete this last.
- Section 2 Elevator Pitch: A brief description of our Engineering Strategy.
- Section 3 Mission Statement: What we wish to achieve.
- Section 4 SWOT: Analysis of our Agency's Strengths, Weaknesses, Opportunities and Threats
- Section 5 Goals: Setting and tracking goals is a critical element of our Strategic Plan.
- Section 6 Target Customers: Identify the wants and needs of each of our target customer groups.
- Section 7 Industry Analysis: Identify new opportunities for growth.
- Section 8 Timeline Options for Technology Investment.

Section 1 Executive Summary: We will complete this last.

- Why this document is being created. How we went about it. Summary of outcomes.
- Vision text and graphics
- Top level takeaways of Roadmap and Strategic Plan

Section 2 Elevator Pitch: A brief description of our Engineering Strategy.

- 1 paragraph (30-second pitch)

- Why
- What
- How

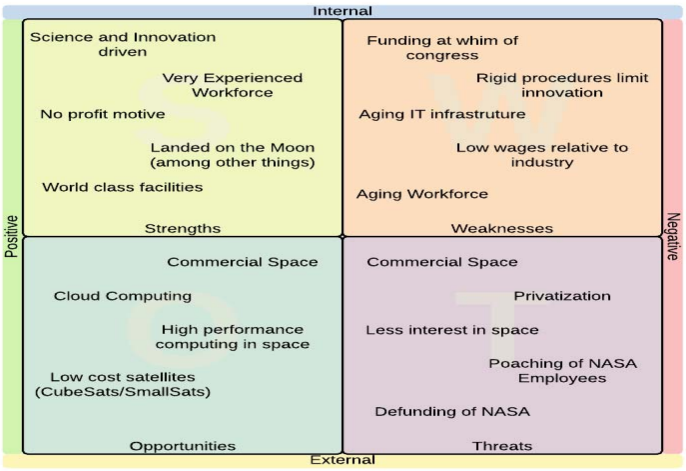
- "We want to do this because… and this is what we will do… and this is how it will play out…"

Section 3 Mission Statement: What we wish to achieve.

- Enhance NASA Engineers' repertoire to enable future missions
  - IT/knowledge capture Infrastructure
  - Efficient means of communications
  - Leverage technology to assist in decision making/doing work more efficiently
  - Predict impact of tech changes on engineering/SE

- Summary of roadmap (delineate human vs machine tasks)
  - Decision-makers
    - Tech provides big project big pictures/effective ways to communicate
    - People makes decisions with the big pic in mind
  - Researchers/innovators
    - Tech provides more streamline way of design, build, test, and effective ways to communicate
    - People does the actual thinking of design, build and test
  - Implementers (HR, IT, workforce training)
    - Tech provides
      - infrastructure to capture data and knowledge, and serve as virtual smart library
      - Network of virtual classrooms
    - People maintain infrastructure and its usability

Section 4 SWOT: Analysis of our Agency's Strengths, Weaknesses, Opportunities and Threats.



Section 5 Goals: Setting and tracking goals is a critical element of our Strategic Plan.

- To chart Engineering's possible path(s) from now to the future
  - What we have now
    - Inputs from Interviews with NASA Engineers, External Partners
    - Inputs from Project Reports
  - Our anticipated needs in the future
    - Crewed and un-crewed exploration of the Moon, Mars, rest of the Solar System
    - Earth Science, Heliophysics, Astrophysics, Astrobiology
  - How to meet those needs
    - Technology enablers for previously-improbable missions
- To align technology and people with NASA's missions of the future

Section 6 Target Customers: Identify the wants and needs of each of our target customer groups.

- Leadership: Executives, Policy Makers, Program Managers, Project Managers
- Workforce: Engineers, Scientists, Technicians, IT specialists
- SG, MIAMI, groups involved in similar initiatives,
- …

Section 7 Industry Analysis: Identify new opportunities for growth.

- Inputs from the MIAMI team
- Inputs from Center SMEs
- Technologies:
  - Hardware: VR/AR, smartboard
  - Software: GDrive, AWS, Azure, …
- Tools: SysML tools at various companies
- Equipment: e.g., Hololens at Microsoft
- Methods: e.g., automated drawing generation
- Infrastructure: cloud networks, cyber-security,
- Process: e.g., automated design iteration
- Facilities: Innovation Hubs, Labs, Test Sites
- Organization: hierarchies that enable engineering innovation
- Workforce: the right skill-mix

Section 8: Timeline Options for Technology Investment

- Invest now
  - Technology is maturing and issues have been worked out
  - Commercial platforms exist, can be tailored
  - Other organizations are beginning to invest
- Watch
  - Technology is too early, untried in the field
  - Heavy investment in time and/or people needed to develop
- Unclear
  - Technology is all hype with limited potential
  - Technology is incompatible with SE/Aerospace
  - Too early or too many unknowns

H.3 Blockchain: Market Analysis—Presentation Slides

[blockchain](blockchain OR cryptocurrency)

April 15, 2019

analysis by vikram.shyam-1@nasa.gov

Powered by Quid

B. Blockchain Connections Network

Company network with 156 companies. Colored by sub-clusters. Sized by degree. Labeled by s

Source: Quid©

Sub-clusters	
iot / internet of things / agriculture / iot devices	17%
vehicle / transportation / drone / automotive	16%
internet of things / transportation / automotive / vehicle	16%
travel / accommodation / connecting travelers / blockchain based travel	12%
innovation / blockchain technology partners / financial services industries / distributed technologies	7.7%
synchronization / wireless networking / small cell / vicw control	5.1%
supply chain management / data access / sensors / lpwan	3.8%
cyber security / iot networks / unauthorized / iot devices	3.2%
merchant / online and offline / mobile phone number / sms communication	3.2%
cutting edge / edge blockchain technology / provide the financial / edge	2.6%
kubernetes installation / compute / docker / containerum platform	2.6%
architects / universal registration / develops a distributed / leveraging advanced	1.9%
fair / unparalleled customer service / exchange and cryptocurrency / cryptography and security	1.9%
travel experiences / hospitality / typical / guests	1.9%
cars / improve the experience / clients worldwide / enables to deploy	1.3%
financial services innovation / network users / edge technology platform / technology real	1.3%

C. Blockchain Connections Heatmap

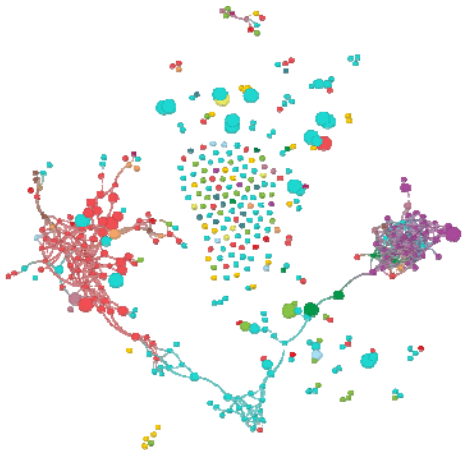
Tags	Num. Companies	Founding Year Median	Inv. Rcvd. Count Total	Inv. Rcvd. Amt.		Inv. CAGR (2015 - 2018)
				Total	Median	
Cloud	161	2015	253	$3.0B	$1.6M	273.8%
IoT	95	2016	140	$550.7M	$1.5M	70.3%
Democratized	38	2017	52	$162.4M	$1.1M	310.5%
Virtual/Augmented Reality	34	2016	55	$86.0M	$1.5M	118.8%
Machine Learning	30	2017	35	$106.8M	$2.5M	N/A
Quantum	10	2017	17	$56.3M	$2.3M	N/A
Robotics	10	2016	13	$72.7M	$999.2K	252.1%
Aerospace	9	2017	14	$202.9M	$1.1M	N/A
Wearables	8	2015	16	$239.6M	$1.8M	-41%
Natural Language	7	2017	9	$5.3M	$640.0K	N/A
Autonomous vehicles	6	2017	7	$100.0K	$100.0K	N/A
Location Based Services	6	2017	10	$5.5M	$1.0M	N/A
Ethics	5	2015	6	$9.3M	$220.1K	N/A

Source: Quid®

Value
Low High

D. Blockchain Future Tech Network Maturity

Company network with 413 companies. Colored by tags. Sized by inter-cluster connectivity. Labeled by tags.

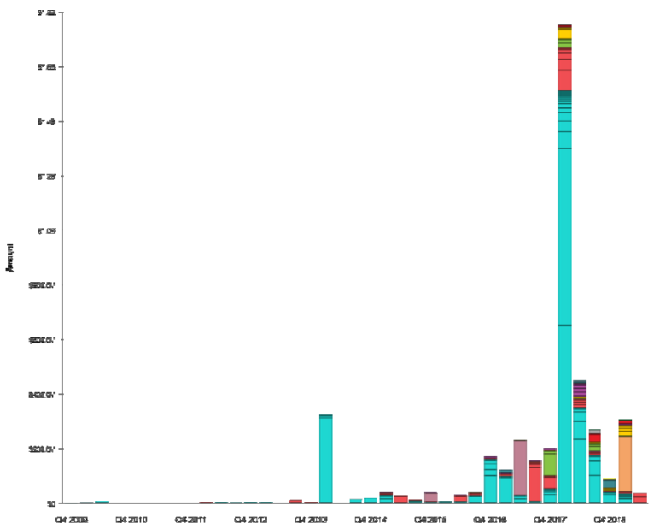


Source: Quid®

Tags	
Cloud	38%
IoT	23%
Democratized	9.0%
Virtual/Augmented Reality	8.2%
Machine Learning	6.1%
Quantum	2.4%
Aerospace	2.2%
Robotics	2.2%
Wearables	1.9%
Natural Language	1.7%
Location Based Services	1.5%
Autonomous vehicles	1.2%
Ethics	1.2%
Machine Learning; Cloud	0.73%
Machine Learning; Autonomous vehicles; Robotics	0.24%
Machine Learning; Democratized	0.24%

E. Blockchain Future Tech Investments by Year

Company timeline aggregated into 376 events. Colored by tags.

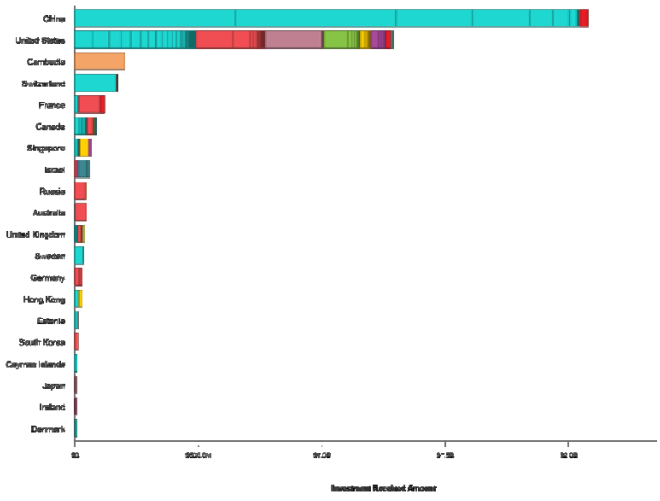


Source: Quid®

Tags	
Cloud	39%
IoT	22%
Virtual/Augmented Reality	9.0%
Democratized	8.3%
Machine Learning	4.7%
Wearables	2.6%
Quantum	2.5%
Aerospace	2.3%
Location Based Services	1.6%
Natural Language	1.5%
Robotics	1.5%
Autonomous vehicles	0.98%
Ethics	0.90%
Machine Learning; Cloud	0.65%
Machine Learning; Autonomous vehicles; Robotics	0.16%
Machine Learning; Democratized	0.16%
N/A	0.33%

G. Blockchain Investments by Country

Company bar chart with 231 companies. Colored by tags.

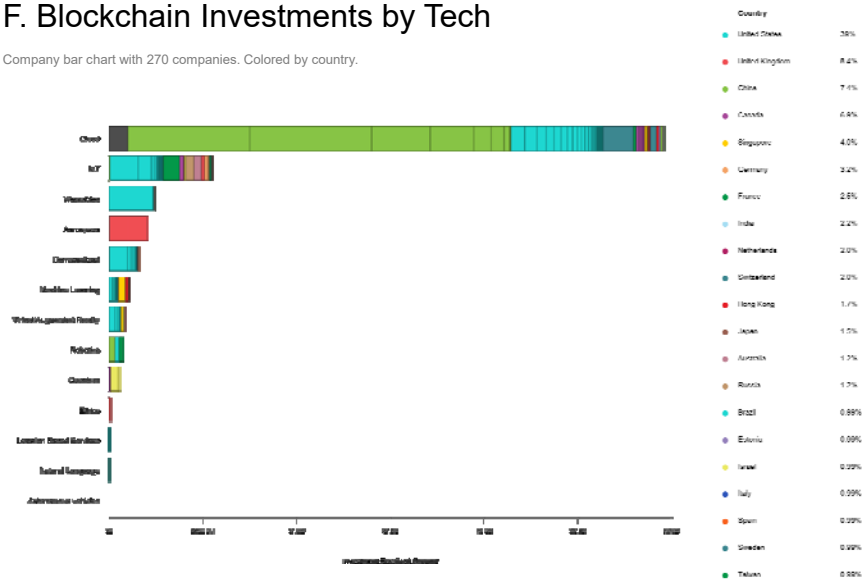


Source: Quid®

Tags	
Cloud	38%
IoT	23%
Democratized	9.0%
Virtual/Augmented Reality	8.2%
Machine Learning	6.1%
Quantum	2.4%
Aerospace	2.2%
Robotics	2.2%
Wearables	1.9%
Natural Language	1.7%
Location Based Services	1.5%
Autonomous vehicles	1.2%
Ethics	1.2%
Machine Learning; Cloud	0.73%
Machine Learning; Autonomous vehicles; Robotics	0.24%
Machine Learning; Democratized	0.24%

F. Blockchain Investments by Tech

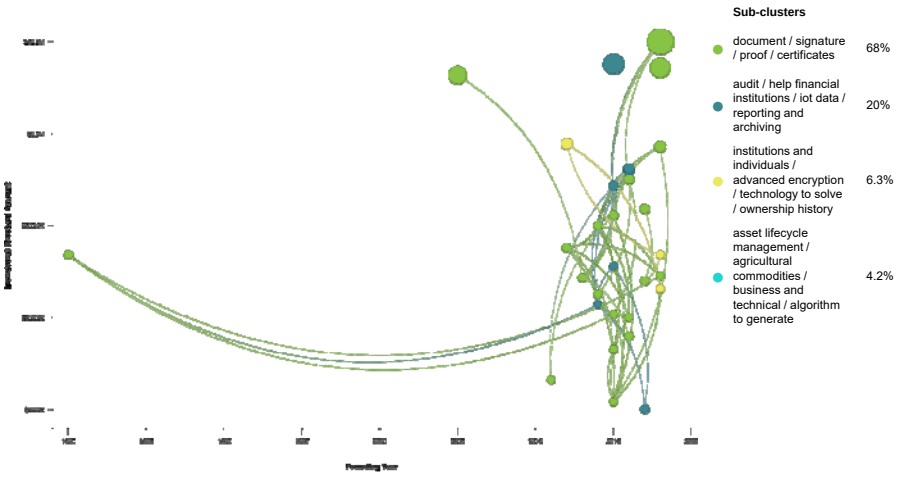
Company bar chart with 270 companies. Colored by country.



Source: Quid®

A. Blockchain Document management companies Investment Received

Company scatter plot with 30 companies. Colored by sub-clusters.



Source: Quid®

H.4 Cloud Delivery: Market Analysis—Presentation Slides

["cloud"]("cloud" OR "cloud computing" OR cloud-based OR "hybrid cloud") OR "cloud services" OR "cloud delivery" OR "cloud delivered application environments"

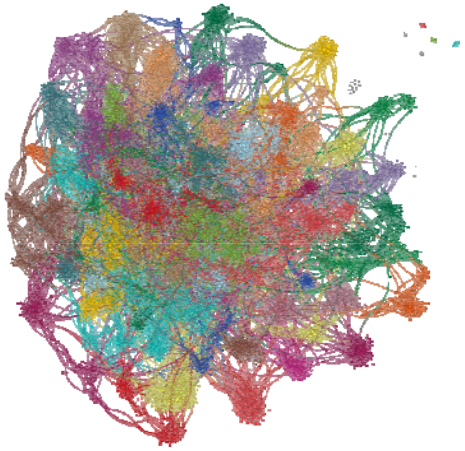
April 15, 2019

analysis by vikram.shyam-1@nasa.gov

Powered by Quid

A. Cloud Network

Company network with 7000 companies. Colored by clusters. Sized by degree. Labeled by clusters.

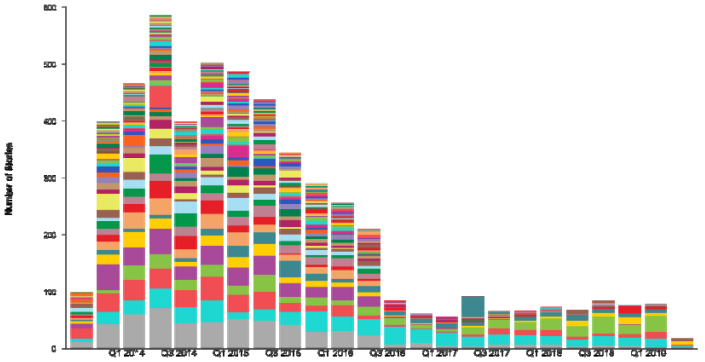


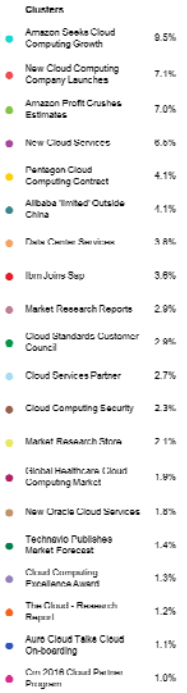
Source: Quid®

Timeline

News article timeline with 5299 stories. Colored by clusters.

Hype peak in 2014

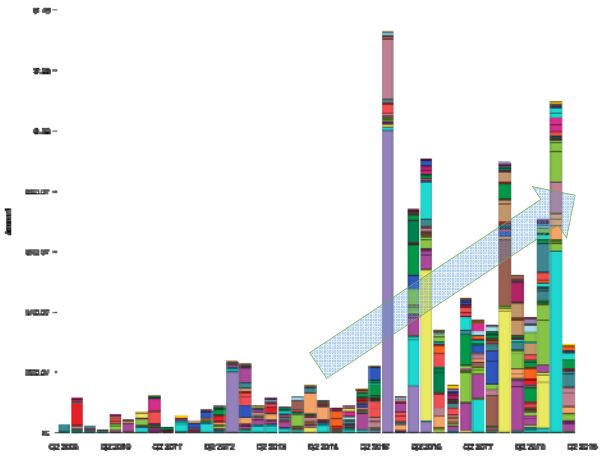




Source: Quid®

H. Cloud Total Investment by Year by Cluster

Company timeline aggregated into 1519 events. Colored by clusters.



Alibaba seems to have received most of the investment here

Source: Quid®

Cloud Blogs and News

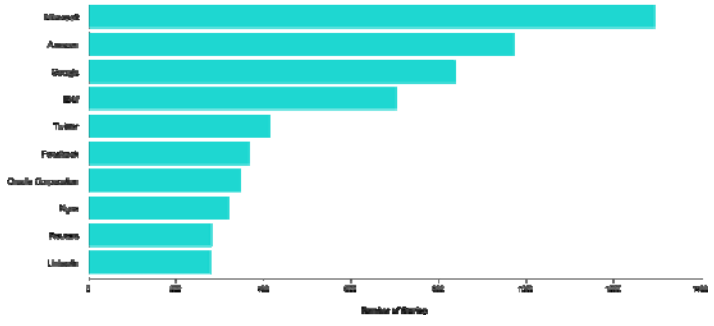
April 16, 2019

analysis by vikram.shyam-1@nasa.gov

Powered by Quid

Companies (Any Mention)

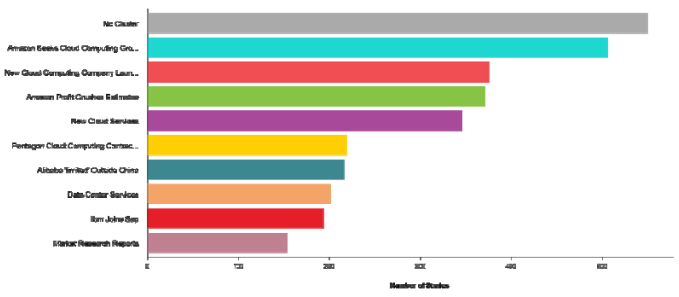
News article bar chart with 2827 stories. Colored by uniform.



Source: Quid®

Top Clusters

News article bar chart with 3128 stories. Colored by clusters.



Source: Quid®

B. Cloud Connections Network

Company network with 503 companies. Colored by clusters. Sized by degree. Labeled by clusters.

Source: Quid®

C. Cloud future tech heat map

Company heatmap showing 11 rows

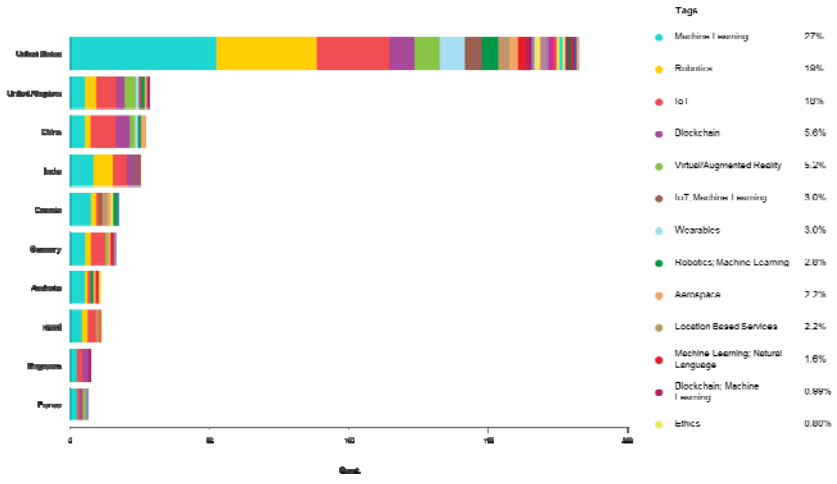
	Tags	Num. Companies	Founding Year Median	Inv. Rcvd. Count (sum)	Inv. Rcvd. Amt. (sum)	Inv. Rcvd. Amt. (median)	Inv. CAGR (2015 - 2018)
	Machine Learning	192	2015	100	$233.6M	$1.1M	340.6%
	IoT	123	2014	57	$91.5M	$1.3M	6.5%
	Robotics	121	2013	15	$11.8M	$160.0K	N/A
	Blockchain	36	2017	22	$103.7M	$378.4K	46%
	Virtual/Augmented Reality	33	2014	18	$1.3B	$5.0M	-71.5%
	Wearables	21	2014	10	$37.7M	$2.9M	N/A
	Location Based Services	16	2013	4	$82.3K	$41.2K	-100%
	Aerospace	15	2013	5	$2.1M	$1.0M	N/A
	Natural Language	13	2014	12	$21.8M	$462.5K	364.2%
	Ethics	4	2010	0	$0	N/A	N/A
	Autonomous	3	2015	1	$0	N/A	N/A

Source: Quid®

Value
Low High

Cloud Investment by Country

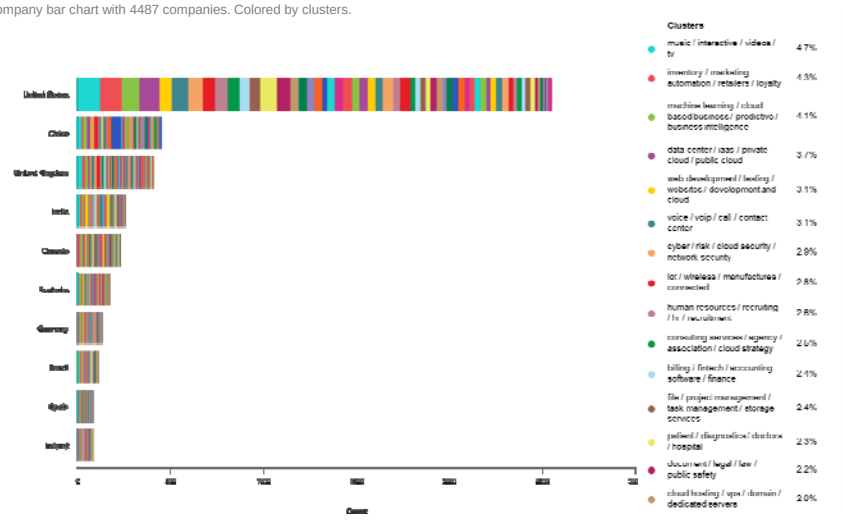
Company bar chart with 330 companies. Colored by tags.



Source: Quid®

Cloud Investment by Country all sectorrs

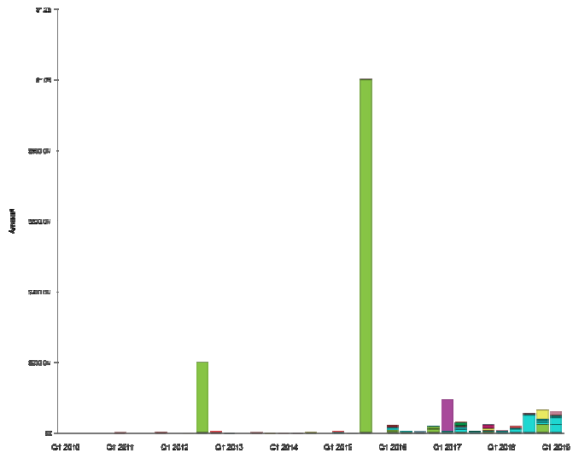
Company bar chart with 4487 companies. Colored by clusters.

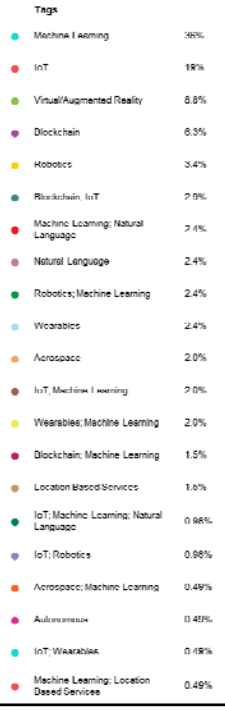


Source: Quid®

Cloud Investment by Year

Company timeline aggregated into 139 events. Colored by tags.

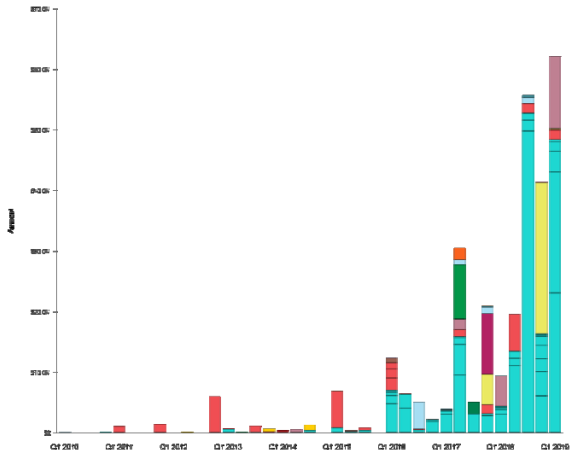




Source: Quid®

D. Cloud investment by year without Alibaba and Blockchain

Company timeline aggregated into 120 events. Colored by tags.

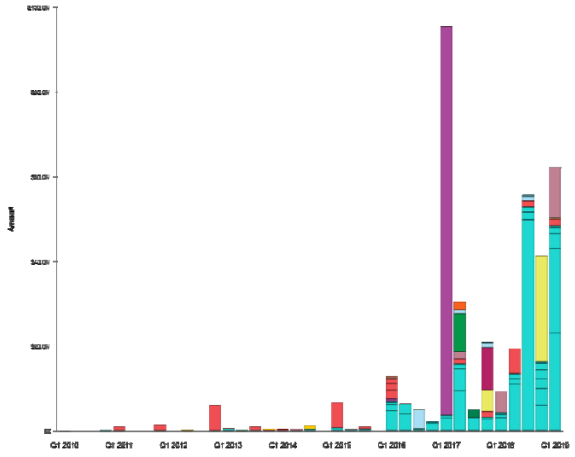


Tags	
Machine Learning	43%
IoT	22%
Robotics	4.0%
Blockchain; IoT	3.4%
Machine Learning; Natural Language	2.9%
Natural Language	2.9%
Robotics; Machine Learning	2.9%
Wearables	2.9%
Aerospace	2.3%
IoT; Machine Learning	2.3%
Wearables; Machine Learning	2.3%
Blockchain; Machine Learning	1.7%
Location Based Services	1.7%
IoT; Machine Learning; Natural Language	1.1%
IoT; Robotics	1.1%
Aerospace; Machine Learning	0.57%
Autonomous	0.57%
IoT; Wearables	0.57%
Machine Learning; Location Based Services	0.57%

Source: Quid®

E. Cloud Investment by Year without Alibaba

Company timeline aggregated into 125 events. Colored by tags.



Tags	
Machine Learning	40%
IoT	21%
Blockchain	7.0%
Robotics	3.7%
Blockchain; IoT	3.2%
Machine Learning; Natural Language	2.7%
Natural Language	2.7%
Robotics; Machine Learning	2.7%
Wearables	2.7%
Aerospace	2.1%
IoT; Machine Learning	2.1%
Wearables; Machine Learning	2.1%
Blockchain; Machine Learning	1.6%
Location Based Services	1.0%
IoT; Machine Learning; Natural Language	1.1%
IoT; Robotics	1.1%
Aerospace; Machine Learning	0.53%
Autonomous	0.53%
IoT; Wearables	0.53%
Machine Learning; Location Based Services	0.53%

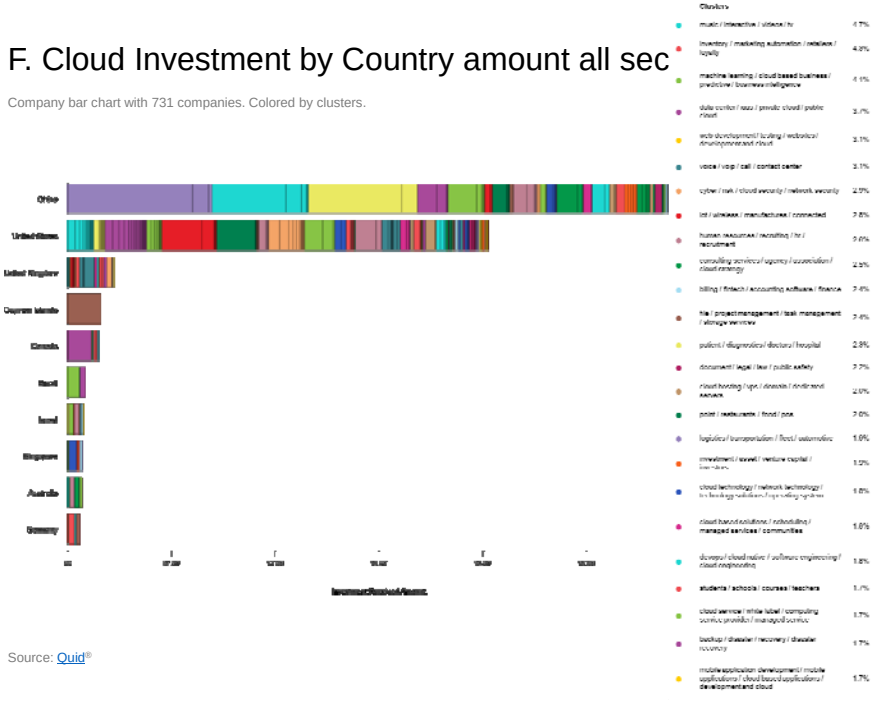
Source: Quid®

China scaled up for comparison

Investment Pattern appears to be similar in many areas with some large differences in a few

F. Cloud Investment by Country amount all sec

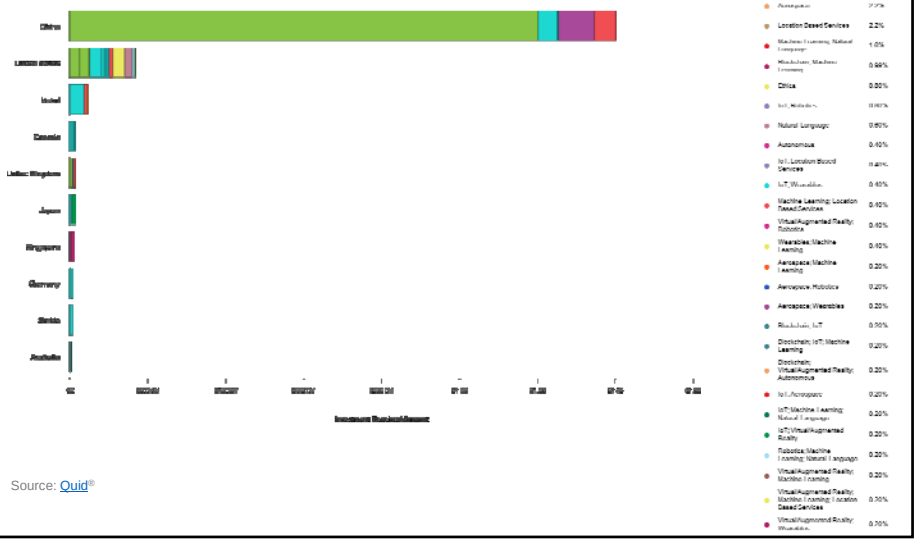
Company bar chart with 731 companies. Colored by clusters.



Source: Quid®

G. Cloud Investment by Country Amount for Future te

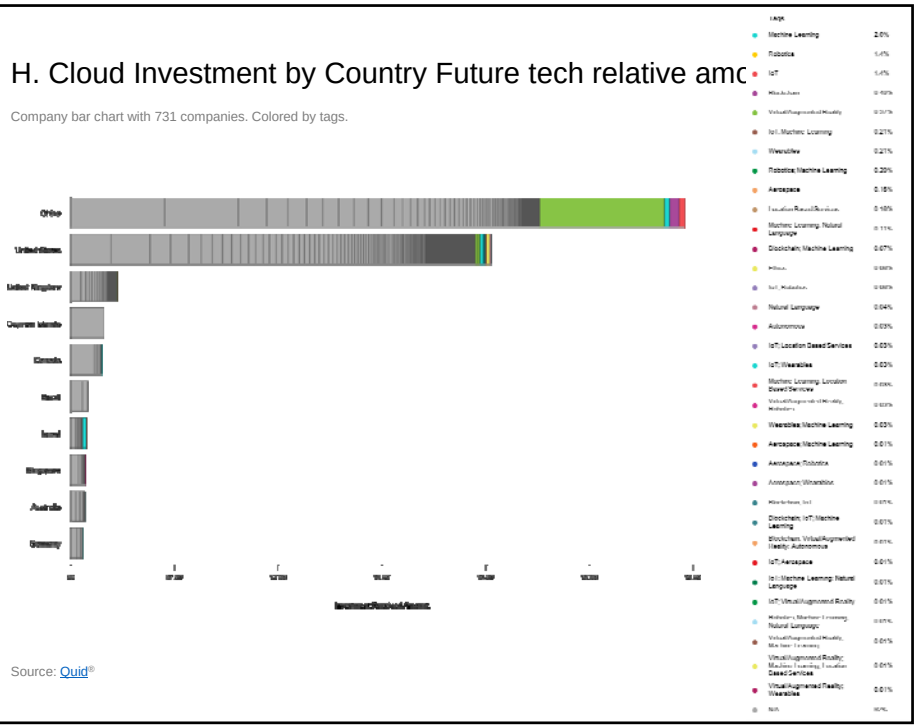
Company bar chart with 66 companies. Colored by tags.



Source: Quid®

H. Cloud Investment by Country Future tech relative amc

Company bar chart with 731 companies. Colored by tags.



Source: Quid®

H.5 Machine Learning: Market Analysis—Presentation Slides

["machine learning"]("machine learning" OR "artificial intelligence" OR "neural networks" OR "pattern recognition" OR "big data") OR "computer vision" OR "natural language processing"

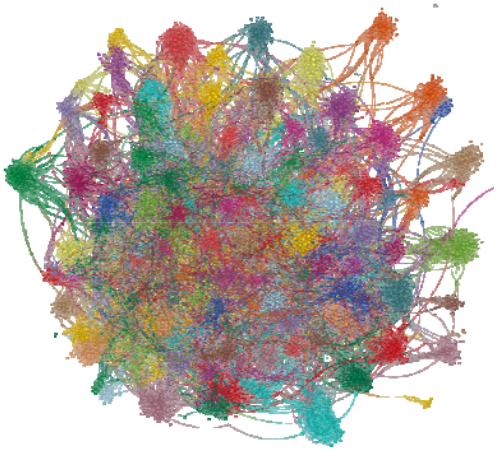
April 15, 2019

analysis by vikram.shyam-1@nasa.gov

Powered by Quid

A. AI/Machine Learning Network by Cluster

Company network with 7000 companies. Colored by sub-clusters. Sized by degree. Labeled by s

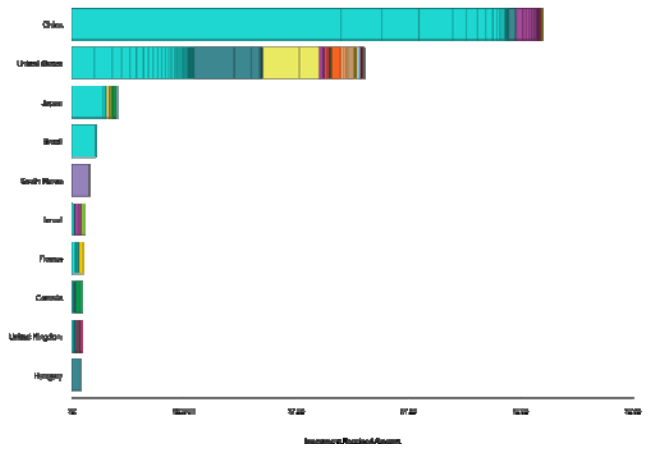


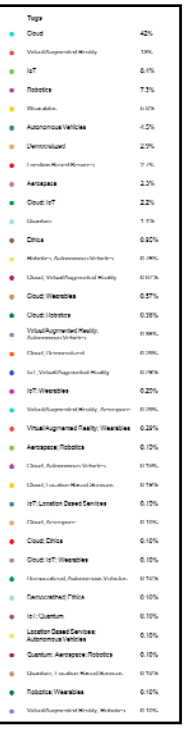
Sub-clusters

recruiting / human resources / recruitment / talent	1.7%
news / articles / topics / fake news	1.7%
cyber / network security / threat / cyber security	1.6%
artificial intelligence software / intelligence software products / developers sdk/sdk / designs and develops	1.3%
students / edtech / children / educational	1.3%
biotechnology / pharmaceutical / drug / life science	1.2%
campaigns / brands / ad / content marketing	1.2%
artificial intelligence technology / data and artificial / surgeon / intelligence technology solutions	1.2%
crm / email / relationship management / customer relationship	1.2%
big data solutions / implementation / offers big data / organizations	1.2%
face / facial / camera / object	1.1%
artificial intelligence solutions / business intelligence solutions / solutions provider / intelligence solutions provider	1.1%
energy / energy efficiency / energy management / renewable energy	1.1%
big data analysis / analysis services / analysis solutions / data analysis platform	1.1%
legal / law / legal tech / attorneys	1.1%
pattern / pattern recognition / signal processing / signal	1.1%
learning platform / automated machine learning / cloud based machine / ai machine	1.0%
real estate / commercial real estate / real estate investment / real estate industry	1.0%
patient / providers / clinical / records	0.96%
agriculture / farming / agtech / crops	0.94%
robotic / ai and robotics / personal robot / books	0.94%
assistant / personal assistant / virtual assistant / powered personal	0.93%

AI/ML Investments by Country

Company bar chart with 223 companies. Colored by tags.

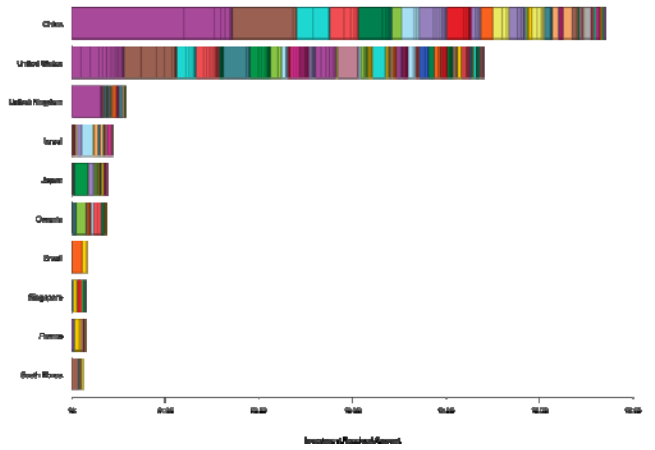




Source: Quid®

AI/ML Investments by Country For all sectors

Company bar chart with 1089 companies. Colored by clusters.



Source: Quid®

B. AI/Machine Learning connections Heatmap

Company heatmap showing 11 rows

Tags	Num. Companies	Founding Year Median	Inv. Rcvd. Count (sum)	Inv. Rcvd. Amt. (sum)	Inv. Rcvd. Amt. (median)	Inv. CAGR (2015 - 2018)
Cloud	499	2014	356	$3.0B	$2.9M	-27.2%
Virtual/Augmented Reality	164	2016	73	$145.1M	$606.2K	90.2%
IoT	121	2016	69	$102.1M	$1.0M	74.7%
Robotics	94	2016	69	$424.5M	$2.9M	525%
Wearables	67	2015	47	$63.3M	$180.0K	189.6%
Autonomous Vehicles	63	2016	58	$720.8M	$5.0M	199.9%
Democratized	35	2016	20	$73.6M	$2.0M	2.2%
Location Based Services	34	2015	21	$13.6M	$675.0K	48.5%
Aerospace	31	2015	9	$1.2M	$56.5K	-100%
Quantum	18	2017	23	$31.3M	$3.6M	138.8%
Ethics	12	2018	0	$0	N/A	N/A

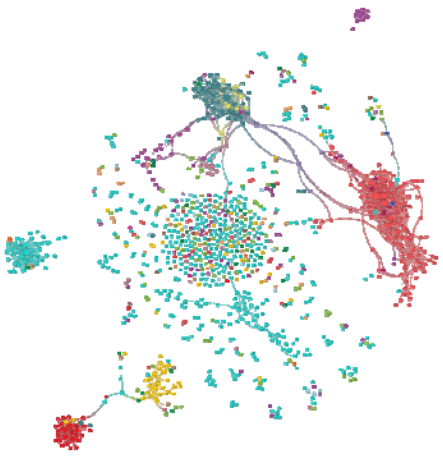
Source: Quid®

Value

Low High

C. AI/Machine Learning Connections Maturity

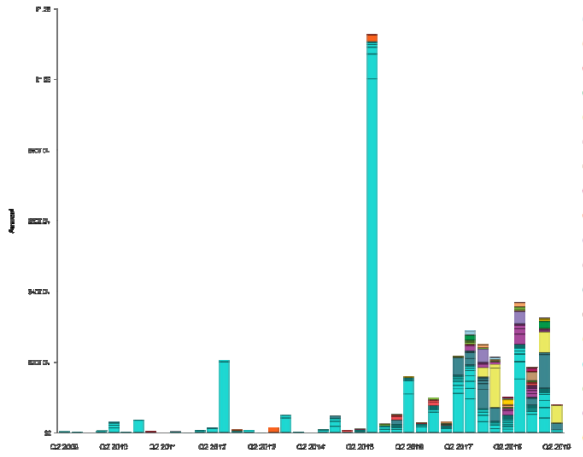
Company network with 1050 companies. Colored by tags. Sized by degree. Labeled by tags.



Source: Quid®

D. AI/ML Investments by Year by Tech

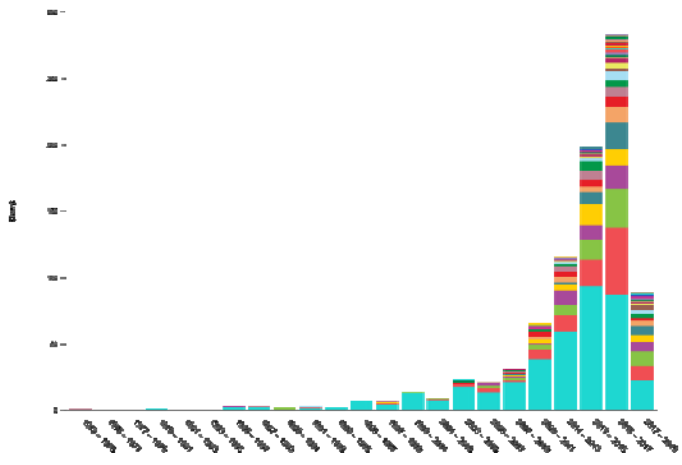
Company timeline aggregated into 441 events. Colored by tags.



Source: Quid®

E. AI/ML Companies per year

Company histogram with 878 companies. Colored by tags.



Source: Quid®

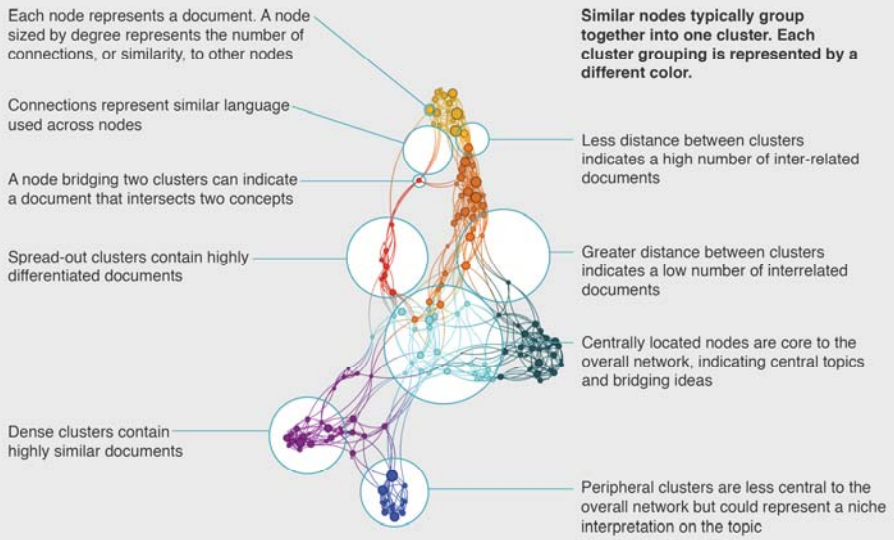
Appendix

Powered by Quid

How to Read a Network

Quid

Quid creates a visual map to represent the landscape. Example network: sized by degree, colored by cluster.



H.6 Systems Engineering: Market Analysis—Presentation Slides

"systems engineering"

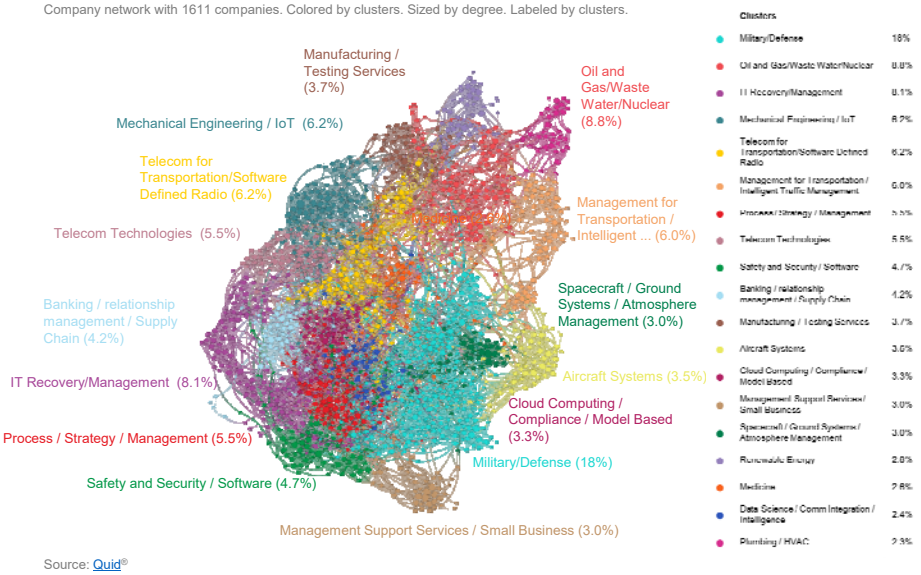
April 15, 2019

analysis by vikram.shyam-1@nasa.gov

Powered by Quid

A. Systems Engineering Network by Cluster

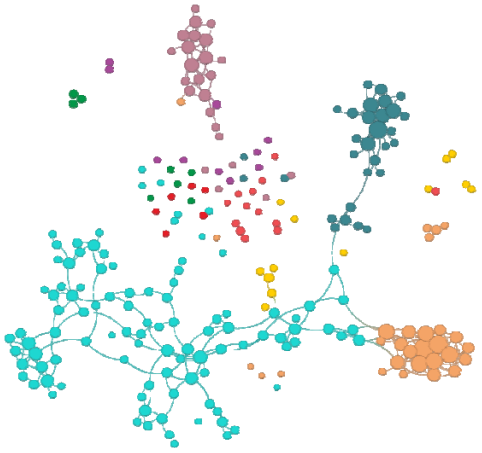
Company network with 1611 companies. Colored by clusters. Sized by degree. Labeled by clusters.



Source: Quid©

B. Systems Engineering in Aerospace

Company network with 234 companies. Colored by clusters. Sized by degree. Labeled by clusters.



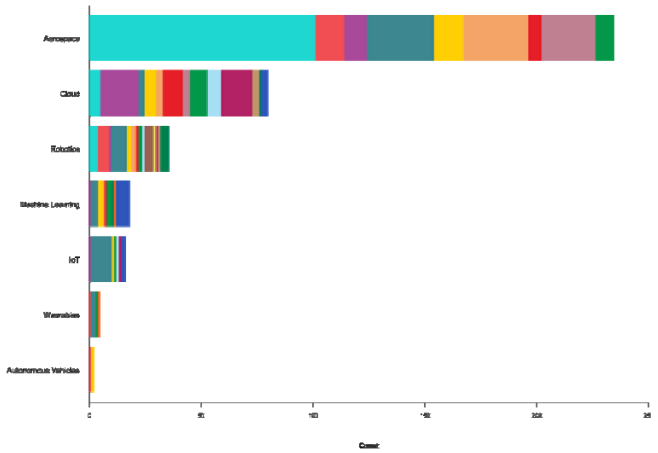
Clusters

Military/Defense	43%
Mechanical Engineering / IoT	12%
Management for Transportation / Intelligent Traffic Management	12%
Telecom Technologies	10%
Oil and Gas/Waste Water/Nuclear	5.6%
Telecom for Transportation/Software Defined Radio	5.6%
IT Recovery/Management	4.3%
Safety and Security / Software	3.4%
Process / Strategy / Management	2.6%

Source: Quid®

C. SE in Tech by Cluster

Company bar chart with 360 companies. Colored by clusters.



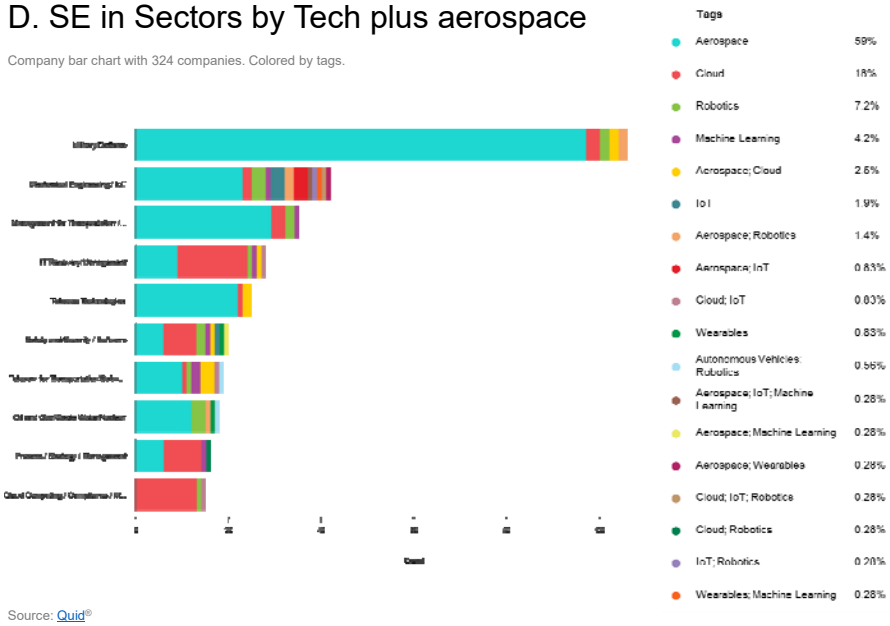
Clusters

Military/Defense	18%
Oil and Gas/Waste Water/Nuclear	8.0%
IT Recovery/Management	8.1%
Mechanical Engineering / IoT	6.2%
Telecom for Transportation/Software Defined Radio	6.2%
Management for Transportation / Intelligent Traffic Management	6.0%
Process / Strategy / Management	5.5%
Telecom Technologies	5.0%
Safety and Security / Software	4.7%
Banking / relationship management / Supply Chain	4.2%
Manufacturing / Testing Services	3.7%
Aircraft Systems	3.5%
Cloud Computing / Compliance / Model Based	3.3%
Management Support Services / Small Business	3.0%
Spacecraft / Ground Systems / Atmosphere Management	3.0%
Renewable Energy	2.0%
Medicine	2.6%
Data Science / Comm Integration / Intelligence	7.4%
Plumbing / HVAC	2.3%

Source: Quid®

D. SE in Sectors by Tech plus aerospace

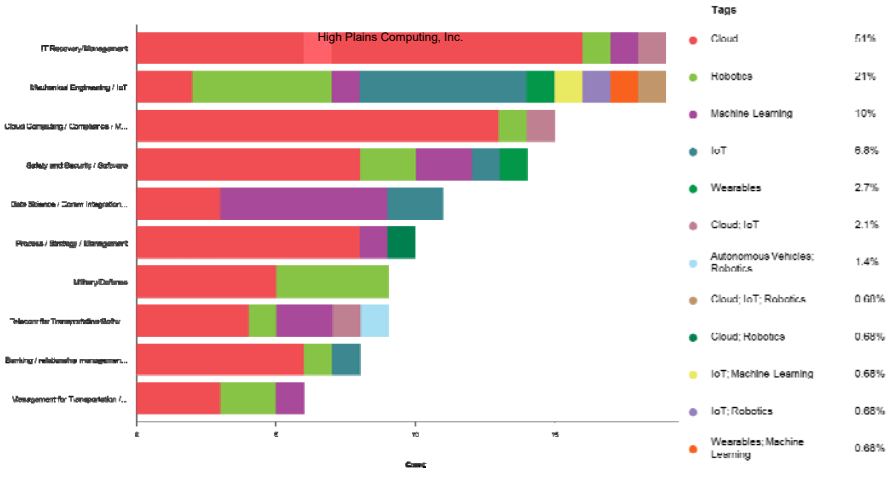
Company bar chart with 324 companies. Colored by tags.



Source: Quid®

E. Intersection of Systems Engineering and Tech

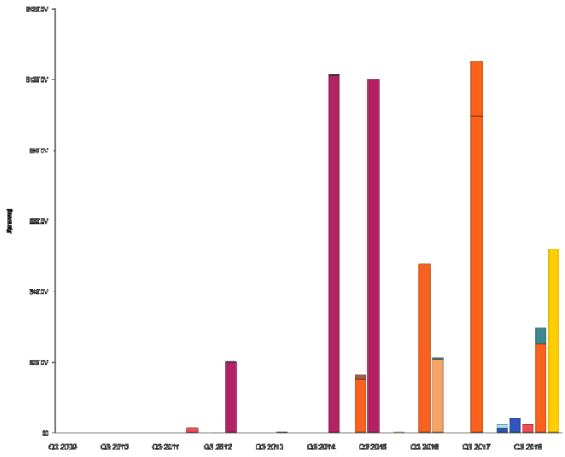
Company bar chart with 120 companies. Colored by tags. Labeled by company name.



Source: Quid®

F. Investments by Year

Company timeline aggregated into 25 events. Colored by clusters.



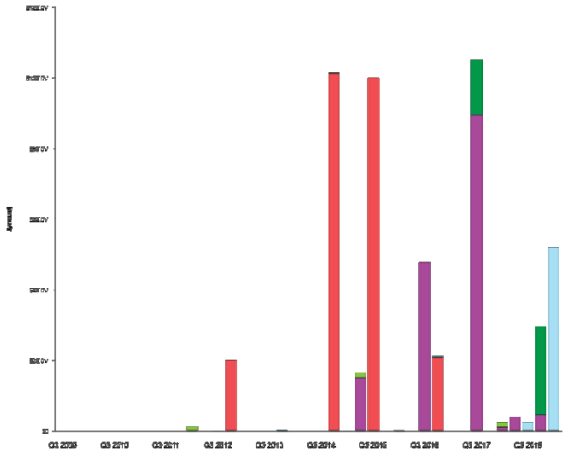
Clusters

Mechanical Engineering / IoT	30%
Medicine	15%
Cloud Computing / Compliance / Model Based	10%
Data Science / Comm Integration / Intelligence	7.5%
Telecom for Transportation/Software Defined Radio	7.5%
Banking / relationship management / Supply Chain	5.0%
IT Recovery/Management	5.0%
Manufacturing / Testing Services	5.0%
Oil and Gas/Waste Water/Nuclear	5.0%
Management for Transportation / Intelligent Traffic Management	2.5%

Source: Quid®

G. Investments by Year by Tech

Company timeline aggregated into 25 events. Colored by tags.



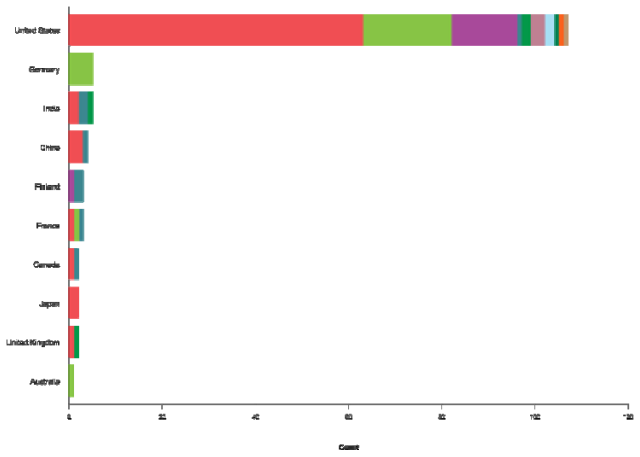
Tags

Cloud	27%
IoT	25%
Machine Learning	17%
Robotics	12%
Wearables	10%
Autonomous Vehicles; Robotics	5.0%
Cloud; IoT	2.5%

Source: Quid®

H. Companies by Country by Tech

Company bar chart with 134 companies. Colored by tags.

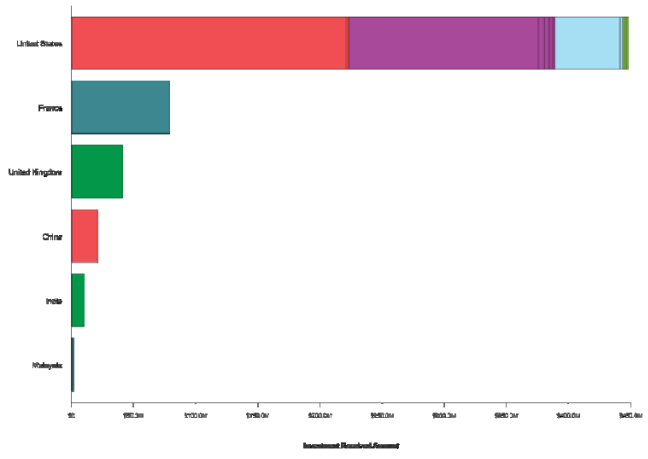


Tags	
Cloud	51%
Robotics	21%
Machine Learning	10%
IoT	6.8%
Wearables	2.7%
Cloud; IoT	2.1%
Autonomous Vehicles; Robotics	1.4%
Cloud; IoT; Robotics	0.68%
Cloud; Robotics	0.68%
IoT; Machine Learning	0.68%
IoT; Robotics	0.68%
Wearables; Machine Learning	0.68%

Source: Quid®

I. Investments by Country by Tech

Company bar chart with 22 companies. Colored by tags.



Tags	
Cloud	51%
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Wearables	2.7%
Cloud; IoT	2.1%
Autonomous Vehicles; Robotics	1.4%
Cloud; IoT; Robotics	0.68%
Cloud; Robotics	0.68%
IoT; Machine Learning	0.68%
IoT; Robotics	0.68%
Wearables; Machine Learning	0.68%

Source: Quid®

H.7 Future Trend Analysis—Presentation Slides

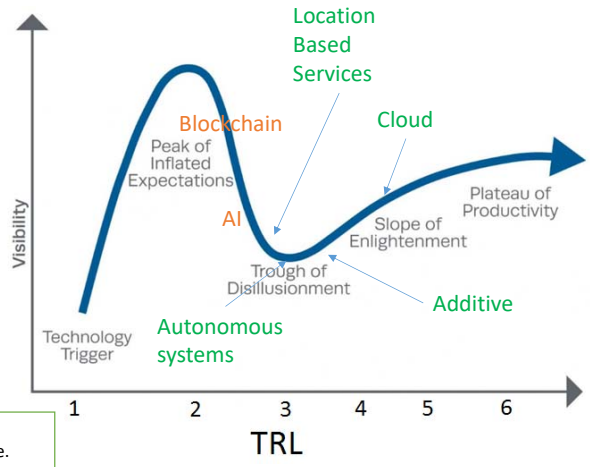
Future Trend Analysis

Vikram Shyam, NASA GRC

Method

- QUID was used to survey the market for emerging and future trends/technology.
- Each tech segment was analyzed for dependencies individually to
  - Uncover potentially new trends/tech
  - Chart growth over last decade by looking at number of companies and investments by year
  - Identify connectedness of the network
  - Discover time to maturity if applicable (through peaks in investment or number of companies levelling off)
- All identified technologies analyzed together to
  - Identify interdependencies
  - Identify cross-technology platforms
  - Analyze relative maturity and growth
  - Analyze investments by country

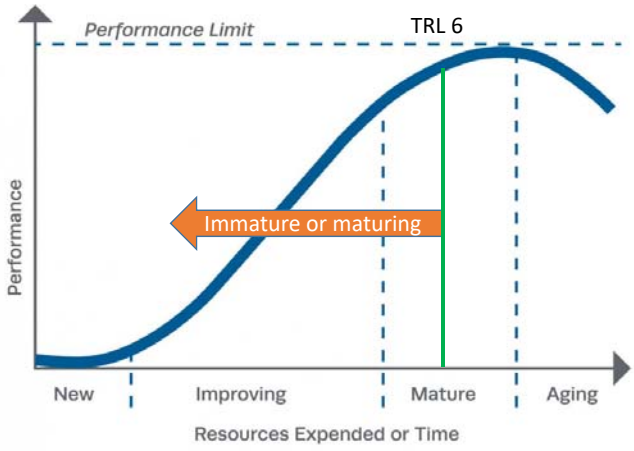
Analyzing technology



The TRL location is a mean of all underlying dependencies with application to aerospace. Cloud for example is considered close to mature or mature by some but application within SE and aerospace is not.

Gartner, Inc., Gartner Hype Cycles, accessed April 16, 2019

TRL and maturity



Investment rationale

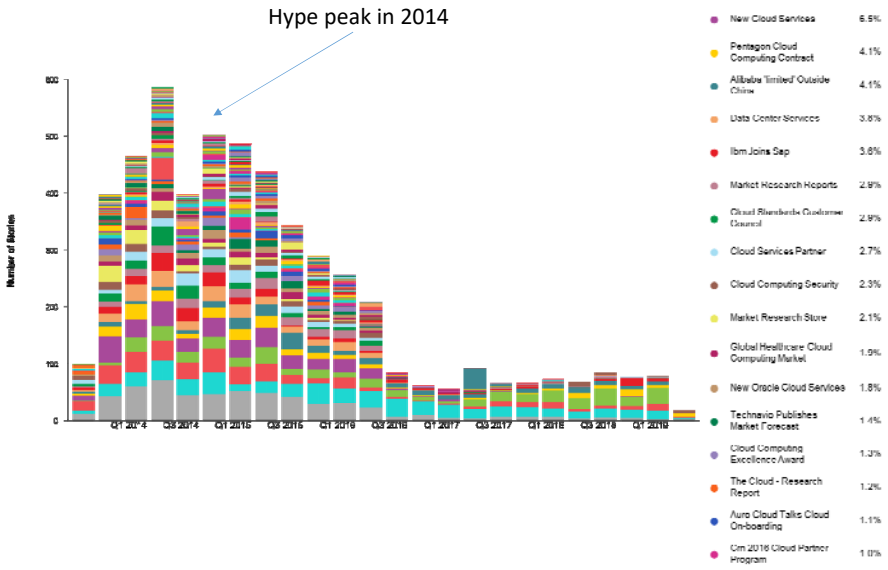
- Adopt
  - Technology is maturing and bugs have been worked out
  - Commercial platforms exist that can be tailored
  - Other sectors are beginning to invest including dependencies
- Invest in niche applications
  - Technology is early (can take leadership)
  - Heavy investment in time/people needed to develop (ID partners)
- Identify potential
  - Tech is mostly hype at the moment
  - Too early or too many unknowns (conduct feasibility studies)

Cloud – Adopt

An example of a maturing technology

Cloud Hype Timeline – mentions in news and blogs

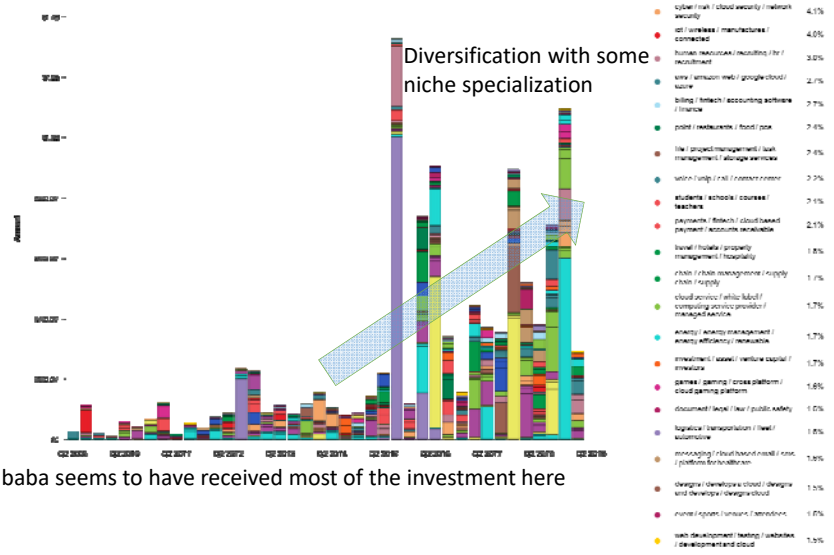
News article timeline with 5299 stories. Colored by clusters.



Source: Quid®

H. Cloud Total Investment by Year by Cluster

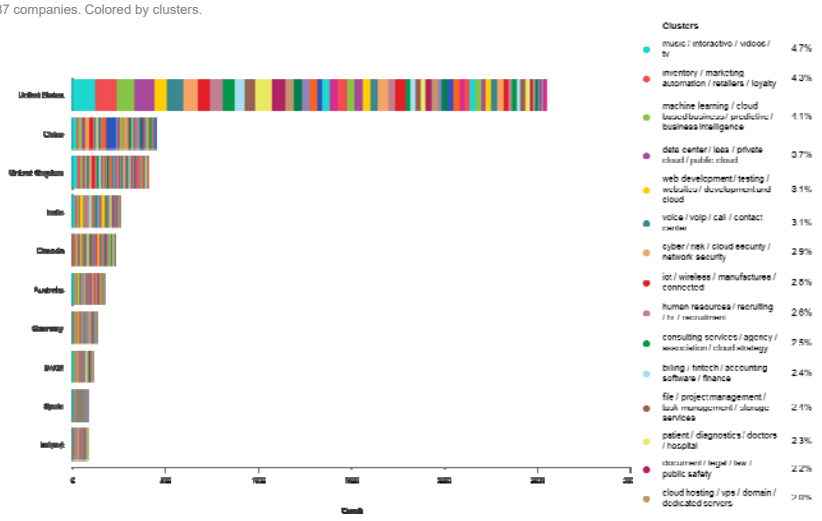
Company timeline aggregated into 1519 events. Colored by clusters.



Source: Quid®

Cloud Investment by Country all sectorrs

Company bar chart with 4487 companies. Colored by clusters.



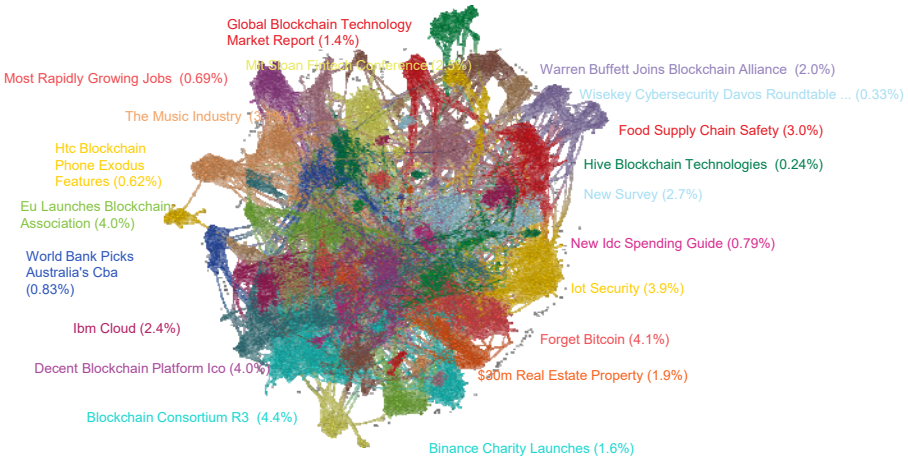
Source: Quid®

Blockchain – Identify niche

We are just getting over the hype – need to identify strategic niches and make small investments to grow infrastructure – proprietary data handling, supply chain

Blog, News Network Map

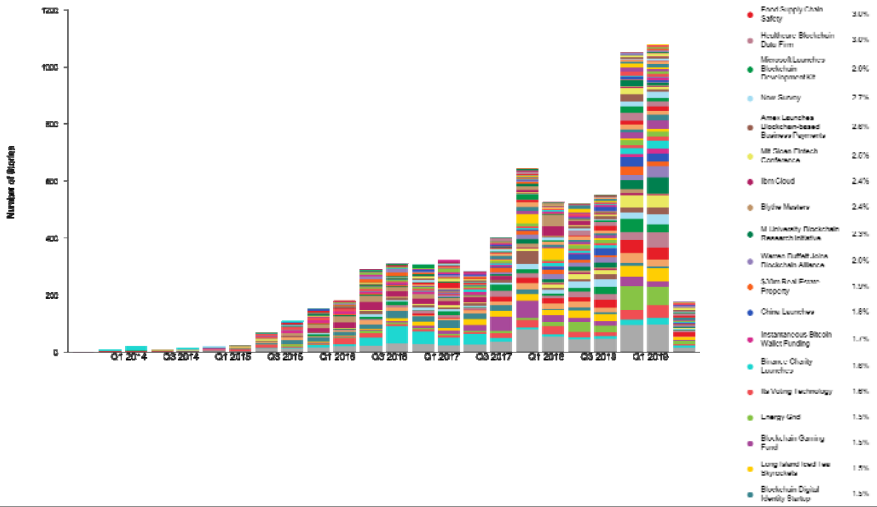
News article network with 7074 stories. Colored by clusters. Sized by degree. Labeled by clusters.



Source: Quid®

Blockchain Hype Timeline – mentions in news and blogs

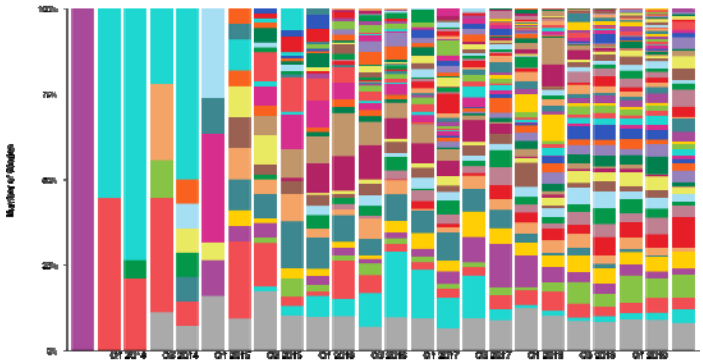
News article timeline with 7074 stories. Colored by clusters.

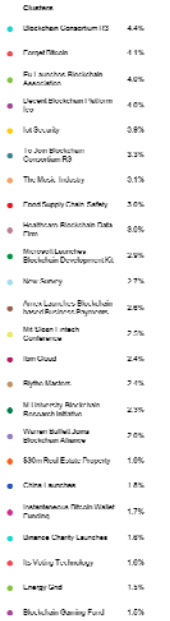


Source: Quid®

Diversification of hype – signs of acceptance

News article timeline with 7074 stories. Colored by clusters.

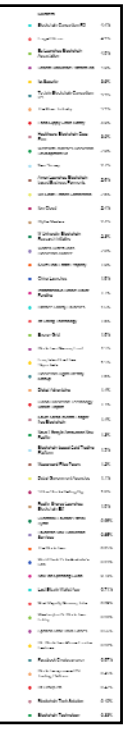




Source: Quid®

Aerospace related headlines

News article timeline with 44 out of 7074 stories selected. Colored by clusters. Labeled by story title.



Source: Quid®

AI – Invest and take leadership in niche markets

In niche applications – recommendation systems, HR, testing. Limited by data. Invest in data generation and management. NASA becomes data curator and keeper of *THE* model using privacy preserving networks, blockchain and cloud.

Blog, News Network Map

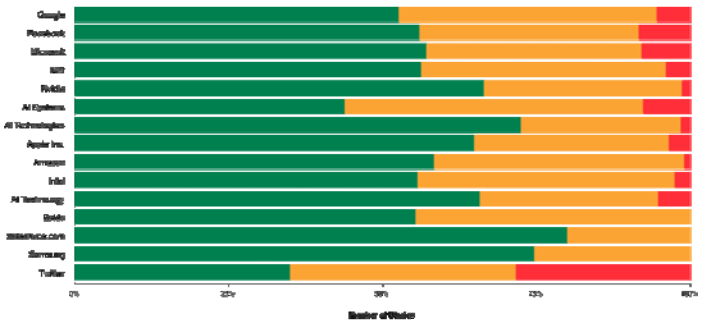
News article network with 6531 stories. Colored by clusters. Sized by degree. Labeled by clusters.

Clusters	
A New Ai Chip	6.2%
Enterprise Ai	5.4%
Google Neural Networks	5.0%
Ai Powered Marketing	4.3%
Elon Musk	3.9%
Google Assistant	3.9%
Filling Ai Jobs	3.8%
Customer Service	3.6%
Conversational Ai Platform Bonobo Ai	3.5%
Ai Ethics	3.2%

Source: Quid®

Sentiment by Company Comparison

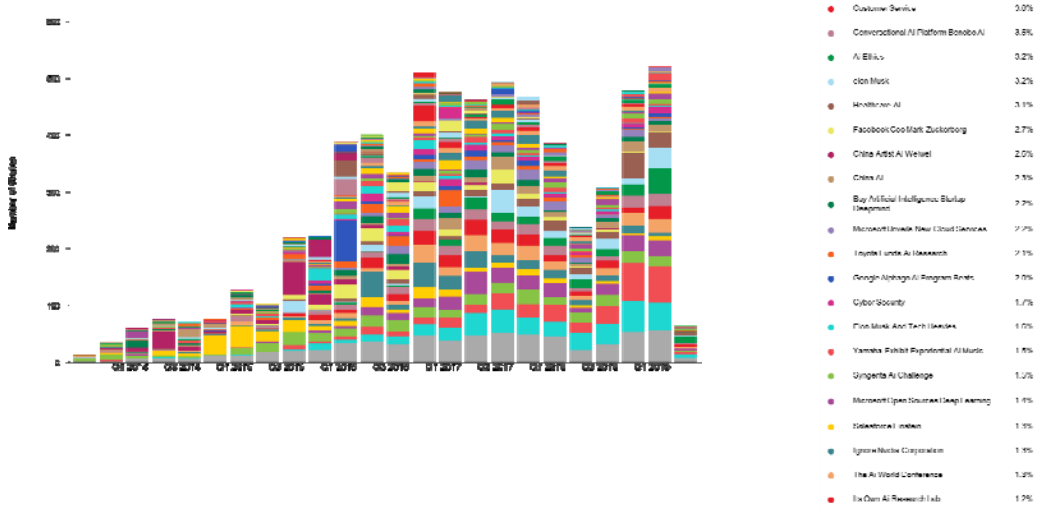
News article bar chart with 2455 stories. Colored by sentiment summary.



Source: Quid®

Timeline of blogs, news

News article timeline with 6531 stories. Colored by clusters.



Source: Quid®

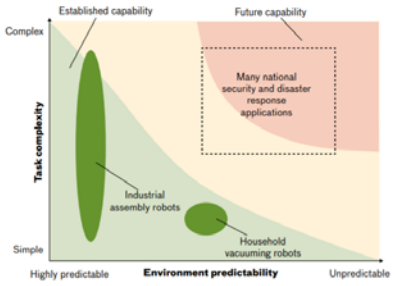


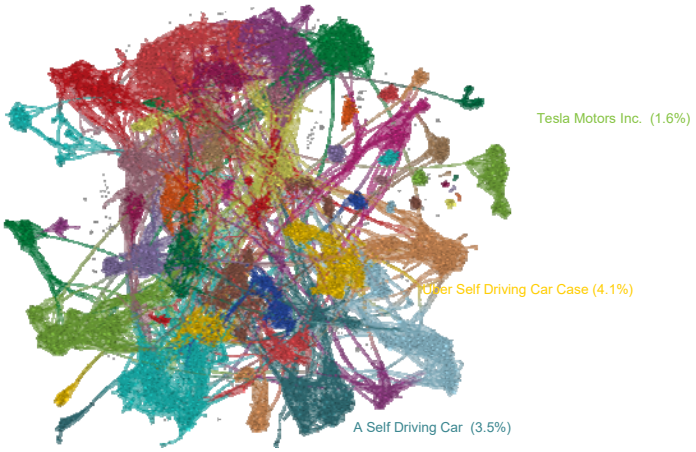
FIGURE 3. Today's operational autonomous systems can perform simple tasks in semi-unknown environments or complex tasks in well-known environments. Many anticipated national security and disaster response applications for autonomous systems demand complex task execution in largely unknown environments. Task complexity and environment predictability are just two dimensions describing the capability of autonomous systems. Other dimensions include frequency of human input, i.e., teleoperation to long-term independence, and task uncertainty.

Autonomous systems – Adopt and Invest

Navy, automobiles, manufacturing, household, NASA missions. Use COTS and develop in-house capability to monitor testing, manufacture, perform quality control and for health monitoring and failure prediction. Missions – sUAS, postal service, emergency response, in-space comm, smart rover swarms and gamification

Network Map

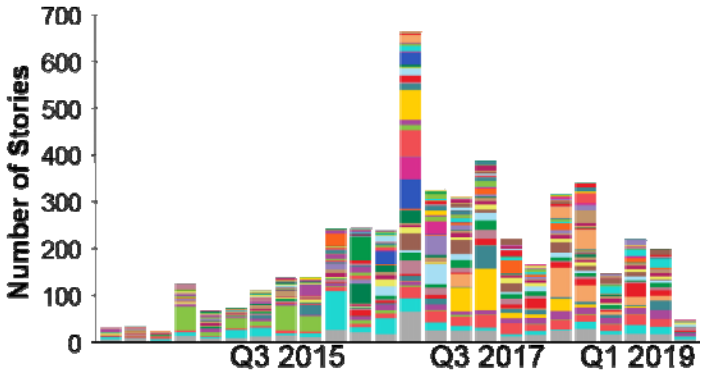
News article network with 4804 stories. Colored by clusters. Sized by degree. Labeled by clusters.



Source: Quid®

Timeline – blogs and news

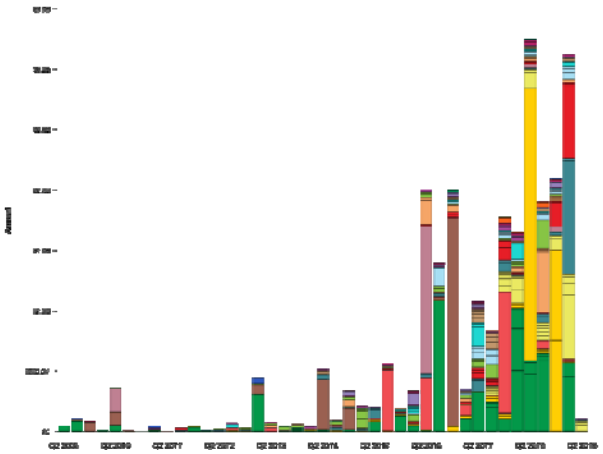
News article timeline with 4804 stories. Colored by clusters.



Source: Quid®

A. Autonomous systems Timeline - Companies

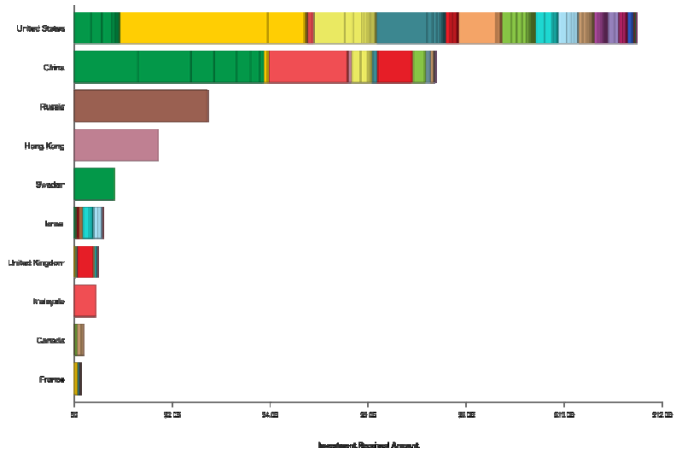
Company timeline aggregated into 896 events. Colored by clusters.



Source: Quid®

B. Autonomous Systems Investment by Country - all sectors

Company bar chart with 413 companies. Colored by clusters.



Source: Quid®

NASA/TM-20205002911/SUPPL 183

Appendix I.—Meeting Notes—Excerpts

2018-07-10 Weekly

Q&A

Direction?

- Charter and work plan finalized August 20
- Vision drafted by August 20
- Charter, vision, and roadmap. First revision of them is due August 20

Charter

To project Agency needs and capabilities over the next 20 years

- A multi-Center group of big-picture thinkers responsible for defining and planning our digital future
  - Aware of trends in politics, technology, education, engineering, and organizations
- Group works harmoniously to formulate, refine, and deliver
  - The Model-Based Systems Engineering (MBSE) Vision
  - An MBSE Roadmap
  - A Strategic Plan
- Group defines its own collaboration style and pace
  - Reports quarterly to the NASA Engineering and Safety Center (NESC) Technical Discipline Team Lead

Metrics related to what the strategy group (SG) is doing, e.g., number of times we talk to outside groups

2018-08-21 Annual Review Presentation Feedback

Feedback from Advisory Board and MBSE Infusion and Modernization Initiative (MIAMI) leadership team:

- Who will our stakeholders be in 20 years? Systems engineering (SE) future workforce?
- Challenges listed are for SE. Is the SG for SE or MBSE or something else?
- Metrics chart narrows it down too much to MBSE. Make it really broad NASA Engineering Vision (V). Or keep is focused on MBSE? Or SE? Team is free to go look at any area of interest. But for the charts use the "SE." We have the carte blanche to be creative, start with a clean sheet.
- We have to understand where information technology is going. We will not constrain ourselves to the SE "V"
- Understand where technology that are coming up are going, no longer living in the "V"
- This all boils down to more efficient way of doing SE
- Data integration, one source of truth, common ways of doing engineering, etc.
- Capture data and knowledge from operations phase
- Moving away from individual engineers turning the crank on the analysis
- Full flight qualification via analysis, no test needed (e.g., Aerosciences cannot do a full-scale test on the ground)
- The biggest obstacle in all of this is data. Storing, reuse, transferring, etc. Data standards are essential and we have to impose those on software vendors. OR it may go the other way with translation tools (but not seen evidence of that yet. Sharing data is getting harder and harder)
- Be prepared for cynic hat: old engineers "saw" this 20 years ago; be able to listen well to cynics as well and how to address/approach their issues

- Stakeholders: think about the group you want to interview. Pretty diverse, tough crowd. Ask the disgruntled employees. Also ask the happy people, what specifically they are happy about and why?
- Important to get buy in from people who need to support you through this evolution—the training officers, the contracts folks, environmental infrastructure, training support, policies, etc.
- Other Vision plans: CFD 2050, Aerosciences, etc. Aero test group
- How detailed will our roadmap be? Focus on milestone capabilities, make these waypoints really solid
- To interview center reps you could go through the NESC center chief engineers
- How will people interact with systems? How will engineers interact with SE?
- "How do we better engineer our systems?"
- "Where do you get the data you need to do your thing? Who do you give data to?"
- How do you transfer data? How do you like your job?
- Talk to people who interact with SE and discuss their collaboration, frustrations
- No simple answer for our questions. Answers will vary by person, by day, etc.

2018-08-23 Annual Review Notes
Design Thinking (Day 1 Training):
http://innovation.umd.edu/about/design-thinking/

- Appeal to the emotions of your stakeholders
- Brainstorming techniques and exercise

Lean Startup (Day 2 Training):
http://innovation.umd.edu/about/lean-startup/

- Breaking our assumptions: What did we do?

General assumption: Asteroid will not strike Earth in next 20 years

Project	Vision is needed more than culture change	That people will care	That people listen	There is one vision	
Goals	Change will only happen if we succeed/exist	We can influence the outcome			
Stakeholders	All centers want to work together as one Agency	NASA still exists in 20 years			
Approach	Are interviews the best way to get information	Is our approach "to brainstorm, interview, etc., to create our Roadmap" the correct way to do it	We are the appropriate people	We know the future of tech, people, universe	We have good intentions
Deliverables	Deliverables are valuable				
Decision makers	There will be multiple decision makers with different personalities				
Impact	Magnitude of (positive) impact is big				

Lean Startup:
Identify the user, decision maker, payer, and influencer of our strategy group's work and deliverables

	Customer Segment			Value Proposition			
User	Us: Engineers, scientists	Project managers	Financial/procurement staff; S&MA	Less time wasted – rework – data maintenance – waiting	Doing science faster, more in-depth	Less time searching for information about project (more time to analyze)	Know where expectations have not been met
Decision Maker	CE / CLT			Decision confidence, less delay; Complete, thorough impact analysis	Maintain world-class staff	Start faster – reuse; Understand decisions that are easy to "undo" vs those that aren't	Enhance risk-based decision making
Payer	Projects; Agency /Center CFO; MD; Engineers	Mission Directorate	Project members	Make decisions faster with more certainty	Perform on cost and schedule; Better status tracking of schedule/ cost	Do more missions and science; Tracking schedule/ cost	Faster to onboard new team members; Support communication (and understanding) of my vision
Influencer	Experienced staff	Academia		Still have my opinions heard in new tool environment	Bake in their legacy; Communicate and guard future colleagues from experienced trauma	Doing job more efficiently, effectively, fewer headaches	Breaking myths

- Creative Design Thinking:
  - Appeal to the emotions of your stakeholders
- Lean Startup:
  - Define your users, payers, stakeholders, and decision makers
- Consider performing a test round of interview questions
- Possible useful things for the group:
  - Value stream mapping: review process flow steps and information from origin to delivery, used to find and eliminate waste/optimize process
  - SCAMPER: creative thinking method
    - Substitute
    - Combine
    - Adjust
    - Modify

- Put to other uses
- Eliminate
- Reverse/Rearrange

- Scorecard balance: strategic planning and management system—could be used to help us move through the process of mission, vision, and strategy
  - Ref: http://www.balancedscorecard.org/BSC-Basics/About-the-Balanced-Scorecard

General Assumption: All highly interested

Project	Impact	Goals	Stakeholders	Approach	Deliverables	Decision makers
Final versions due February?	Plan better hit cost/deadlines	We have similar personal participation goals	Want to improve "things"	Intended to improve all engineering domains	Vision (V), RoadMap (RM), Strategic Plan (SP)	MIAMI can influence Agency $$
Net savings in cost	Greater data integration means more control	We can't dream too big	They are (even roughly) all on the same page	Interviews	Order of V, RM, SP delivery coincides with logical sequence	There will be a lot of indifference
We think at the right scale	Reduce development cost/time	We don't have enough resources	Know how their work affects/is impacted by SE	Someone else will execute our SP	Report format	If we demonstrate value "they" will buy in
All like dreaming		Digitization	They feel they have enough on their mind	We will correctly apply new technologies	Really actually happens	
We have enough "resources" to meet our deliverables		Enhance current capability		People will like "sharing" their data	Someone will read the deliverables	

Customer Segment				Value Proposition			
User	Future engineers	Project managers (PMs); Principal investigators (PIs)	Mission operators; Test engineers	Data traceability and provenance; Do better work with better ways	More science; Perfect workflow; Zero time lag; Ease of use	Get to live a "normal" life and fly spacecraft	Avoid repeat status charts (same chart for difference audience); Higher win rate: Know target metrics and opportunities
Decision maker	Center directors	PMs		Why now? Delivers great products on time, under budget achieve goals	Incremental change/avoid "shocks"; Minimize failures; Minimize impact on existing infrastructure	Avoid revisiting decisions (without new information /cause) – Remember why decision /what it was	Reduce time on overhead process; Work-life balance
Payer	Center directors	Headquarters	PI; Mission directorate (solicitation)	Minimize wasted resources time/money	Mitigate risks; Assess aggregate risk of multiple risks		
Influencer	Training office; Branch heads; Greybeards that resist or are skeptical; Key peers	Strategy group; Politicians; International competition; Industry trends	Academia; What programs available to recruit; Tech leads that PM trusts	Keeping the workforce up to date; Time lost on learning things that will go away	Use best and most modern tools to achieve NASA goals; Stay competitive with industry to retain talent and recruit	Keep constituents and taxpayers happy; Keep jobs in district	Win projects for the Center; Research funding, future jobs

2018-08-30

- Advisory board reviews may come in 2 weeks (mid-September)
- Next steps for leads:
  - Finishing plans and budget for FY19
  - Implementing advisory comments
- Updates for strategy group:
  - Roadmap interview meeting next week to:
    - Decide if we are doing empathetic or prototype interviews (Do we present a roadmap or collect information that feeds to our roadmap?)
    - What are we trying to get out of the interview questions?
    - Finalize the questions and give comments on the SurveyMonkey-like questionnaire
    - Rubric draft created
    - Opinion on the questionnaires
- No need to have TOO many (i.e., 200)
- Really dig into the story
- Get to the bean counters' emotions

- The questionnaires may only give you the generality; which we may already know
- What are we trying to get out of the interview questions?
  - Forward path for Vision:
    - Consider using a sketch approach to capture "day in the life" of a NASA systems engineer.

      https://www.youtube.com/watch?v=u6XAPnuFjJc

      Look at the type of graphics (sketches) as a possibility. The topic in the video is interesting, too. (Side assignment for you if you agree with the author's findings, is NASA an organization where people are motivated by autonomy, mastery, and purpose?)

      When GRC did their reorganization about 4 years ago, there was a sketch artist at the World Café who listened to the participants and sketched in real time what she heard on a large white posterboard. Both words and graphics. It was really cool. So I know this capability exists around NASA.

2018-09-04 Roadmap Planning

- What exactly are we trying to get out of the interview questions?
  - Review who we have tapped for interviews to cover broad variety of interviewees.
  - What are the goals and purposes of the interview and the survey?
  - Quantity is a good thing to strive for to ensure sufficient representation from a cross section of people.
  - Questions should be more open ended and be able to accommodate more personalized responses.
  - Ask about technologies they use, and about various issues they face in using the technology.
  - Should there be subquestions where we rank how bad it is and how often does it happen?
  - Will this information validate some of the pain points we think they have?
- Approximately 2 to 3 weeks (TBD) to perform interviews

Appendix J.—Bibliography

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Appendix K.—Acronyms

4D	four dimensional
AATT	Advanced Air Transport Technology
ACTS	Advanced Communications Technology Satellite
ADAS	advanced driver-assistance system
AFRL	Air Force Research Laboratory
AI	artificial intelligence
APP	Active Project Partnership
AR	augmented reality
ARC	Ames Research Center
ARMD	Aeronautics Research Mission Directorate
ARRM	Asteroid Robotic Redirect Mission
AS	autonomous systems
BOE	basis of estimate
BWB	blended wing body
CAE	computer-aided engineering
CAGR	compound annual growth rate
CCT	crosscutting themes
CDR	critical design review
CE	chief engineer
CFD	computational fluid dynamics
CLPR	center-level procedural requirements
CLT	Capability Leadership Team
CM	configuration management
COOP	continuity of operations plan
COP	community of practice
COR	contracting officer representative
CRM	continuous risk management
CSO	Chief Safety Officer
CTO	Chief Technology Officer
DEEP	Design Engineering Experience Platform
DI	data integration
DOD	Department of Defense
DOE	Department of Energy
DRD	Data Requirements Description
EDS	Engineering Design Studio
EMB	Engineering Management Board
EP	electric power
ERP	enterprise resource planning
ESA	European Space Agency
ESD	Exploration Systems Division
ETF	exchange-traded funds
F2F	face to face
FFP	firm fixed price
FFRDC	federally funded research and development centers

FMEA	failure mode and effects analysis
FTE	full-time equivalent
FY	fiscal year
GOES	Geostationary Operational Environmental Satellite
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
GVIS	Graphics and Visualization Lab
HEOMD	Human Exploration and Operations Mission Directorate
HR	human resources
IaaS	infrastructure as a service
ICO	initial coin offering
IDEF	Integrated Definition Methods
IMCE	integrated model-centric engineering
IMU	inertial measurement unit
INCOSE	International Council on Systems Engineering
IoT	internet of things
IRAD	Internal Research and Development
ISRU	in situ resource utilization
ISS	International Space Station
IT	information technology
ITAR	International Traffic in Arms Regulations
ITT	integration task team
IVHM	integrated vehicle health management
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KDP	key decision point
KSC	Kennedy Space Center
LADEE	Lunar Atmosphere and Dust Environment Explorer
LaRC	Langley Research Center
LASP	Laboratory for Atmospheric and Space Physics
LIDAR	light detection and ranging
LSE	lead systems engineer
LV	launch vehicle
MBE	model-based engineering
MBMA	model-based mission assurance
MBSE	model-based systems engineering
MDO	multi-disciplinary design optimization
MIAMI	Model-Based Systems Engineering (MBSE) Infusion and Modernization Initiative
MIT LL	Massachusetts of Technology Lincoln Laboratory
ML	machine learning
MRB	Material Review Board
MSFC	Marshall Space Flight Center
MoSSEC	Modeling and Simulation information in a collaborative Systems Engineering Context
NACA	National Advisory Committee for Aeronautics
NESC	NASA Engineering and Safety Center
NLP	natural language processing

NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NSC	NASA Safety Center
NTRS	NASA Technical Report Server
OCE	Office of the Chief Engineer
OCIO	Office of the Chief Information Officer
OCT	Office of the Chief Technologist
OJT	on-the-job training
OSMA	Office of Safety and Mission Assurance
PC	personal computer
PD	position description
PDR	preliminary design review
PI	principal investigator
PITEX	Propulsion IVHM Technology Experiment
PM	project manager or project management
POC	point of contact
PP&C	program or project planning and control
PPE	power and propulsion element
QA	quality assurance
RD	Research Directorate
R&T	research and technology
S&MA	Safety and Mission Assurance (also SMA)
SA	system analysis
SACD	Systems Analysis and Concepts Directorate
SAGE	Stratospheric Aerosol and Gas Experiment
SBKF	Shell Buckling Knockdown Factor
SCaN	space communications and navigation
SCENIC	Strategic Center for Networking, Integration, and Communications
SE	systems engineering
SEO	search engine optimization
SERC	Systems Engineering Research Center
SFW	subsonic fixed wing
SG	strategy group
SLS	Space Launch System
SMA	Safety and Mission Assurance (also S&MA)
SMD	Science Mission Directorate
SME	subject matter expert
SoA	state of the art
SSC	Stennis Space Center
STEP	SMA Technical Excellence Program
STMD	Space Technology Mission Directorate
SWOT	strengths, weaknesses, opportunities, and threats
SysML	Systems Modeling Language
TDT	technical discipline team
TRL	technology readiness level
UAV	unmanned aerial vehicle

UI	user interface
UQ	uncertainty quantification
V&V	verification and validation
VOIP	voice over internet protocol
VPS	virtual private server
VR	virtual reality
WBS	work breakdown structure
WFF	Wallops Flight Facility
WG	working group
WT	wind tunnel
WYE	work-year equivalent