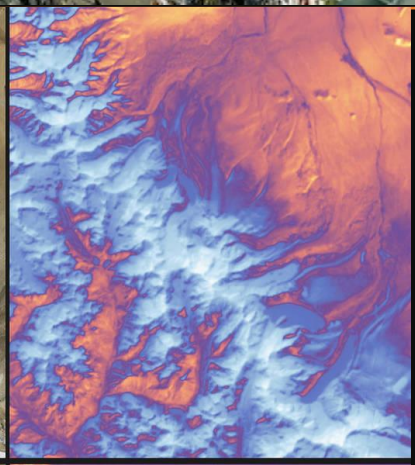
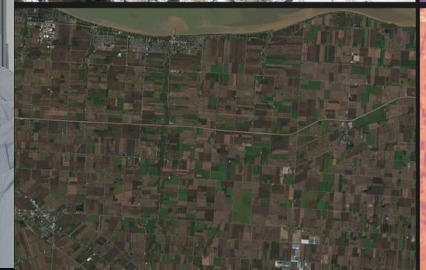
National Aeronautics and Space Administration

NASA GSFC ETD: Digital Engineering Overview





NASA Goddard Space Flight Center (GSFC)
Engineering and Technology Directorate (ETD)
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Digital Transformation at NASA

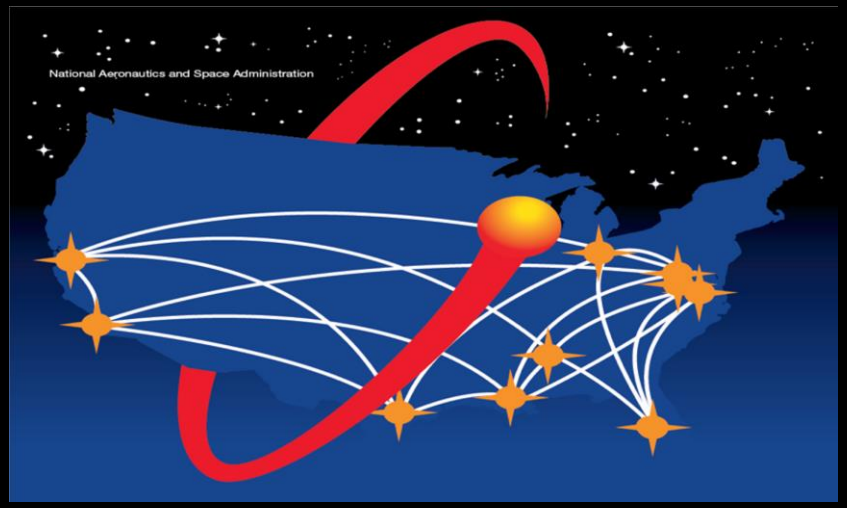
- Digital Transformation: *Employment of digital technologies to change a process, product, or capability so dramatically that it's unrecognizable compared to its traditional form*
- Brief History of NASA DT
  - FY18: NASA's Digital Transformation (DT) officially kicked off
    - Formulation effort identified increased industry focus on DT
    - Led to internal assessment of the current state of 'digital' at NASA centers and major projects
    - Found many examples already underway at various levels of maturity – termed '*Silos of Curiosity*'
  - FY20: Agency DT mandate, which focused effort in FY21 to define the DT vision and strategy
    - Included mobilization of early adopters – termed '*Coalitions of Willing*'
  - FY22+ (*we are here*): Development of an agency-level plan, in the form of DT Targets, Levers, and Foundations
- Agency DT vision involves fully leveraging evolving digital technologies to advance missions, enhance efficiency, and encourage a culture of innovation
  - Digital Transformation is now officially housed within OCIO (Office of the Chief Information Officer) with OCE (Office of the Chief Engineer) as a primary stakeholder

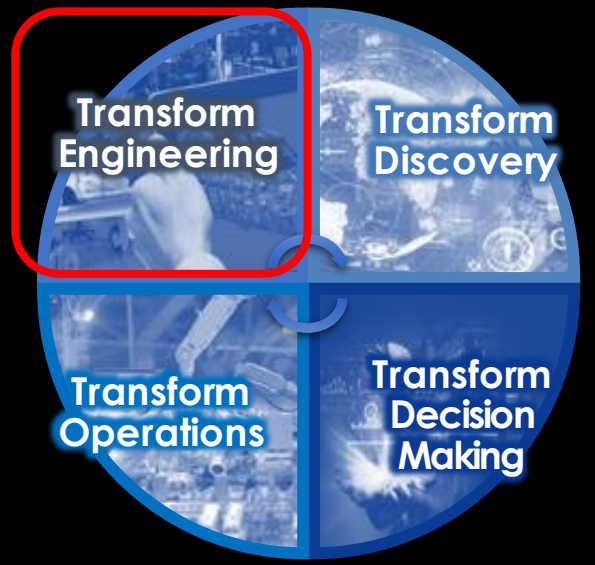
What is Digital Engineering?

- Transform Engineering "*enables agile multi-center/partner engineering teams to solve frontier problems*"

  Transform Engineering = Digital Engineering

- Digital Engineering efforts at various levels of maturity at the agency and center-level





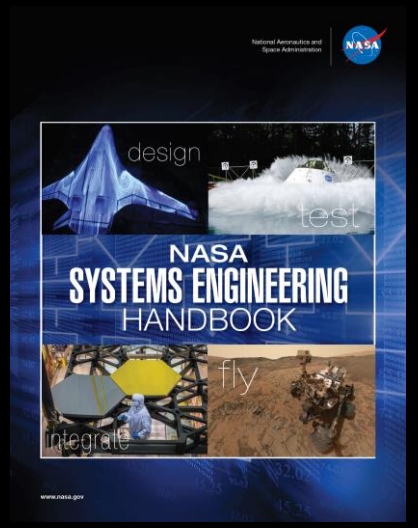
- GSFC definition of **Digital Engineering** is *an interdisciplinary field that leverages the use of digital tools and processes for the design, development, and production of engineering products and systems*
  - Involves use of digital technologies to improve efficiency and accuracy of the engineering process

Holistic Digital Engineering Strategy

1. Break down barriers through education to increase community understanding of Digital Engineering capability and value
   - Digital Engineering Workshop in October 2022 identified that **Cultural Inertia** was the biggest roadblock across all attending federal agencies
2. Develop scalable, sustainable DE framework aligned with Agency, OGA's, Industry, Academia, and foreign partners
   - Pilot data-first architecture to *demonstrate* discipline-specific functionality, with community engagement
3. Infuse DE into existing missions to develop workforce digital competency
   - Publicize enabling technologies that *demonstrate* immediate value (i.e., generative design), while advertising other technologies under development
4. Increase the efficiency and effectiveness of long-standing systems engineering practices via a multi-year phased program
   - Focus on process pain points (i.e., manual, error-prone inefficiencies)

Digital Engineering vs Systems Engineering

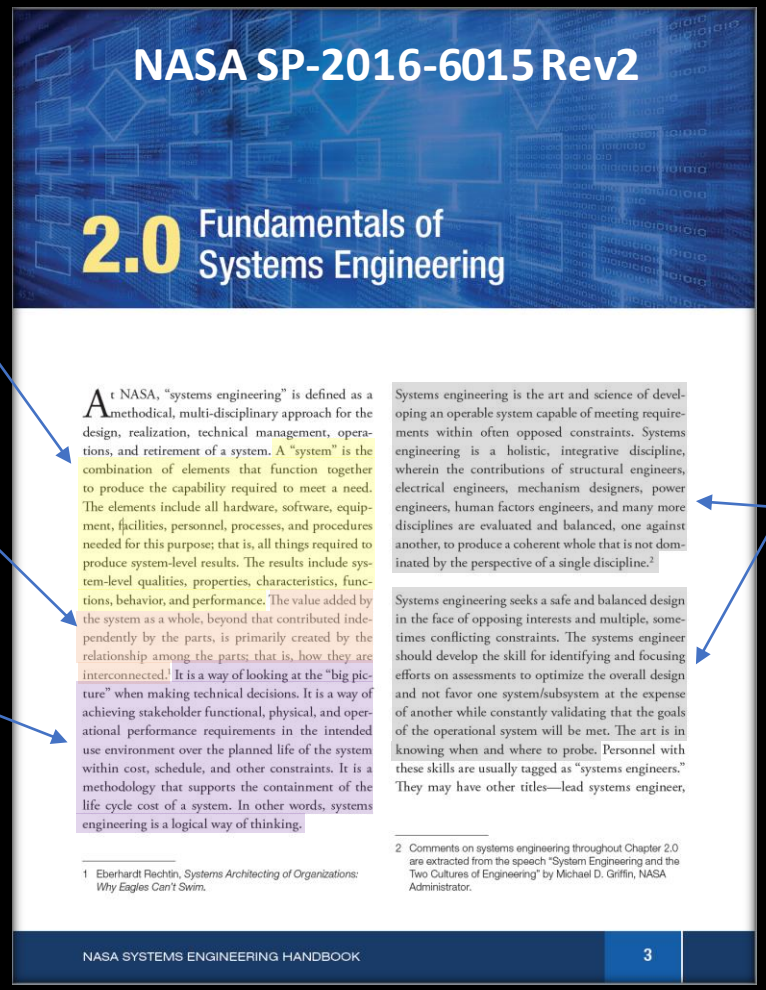
"Systems Engineering is defined as a methodical, multi-disciplinary approach for the design, realization, technical management, operations, and retirement of a system."



Systems Modeling
(i.e., Model-Based Systems Engineering)

Digital Thread
(i.e., model the relationships between information contained within models)

Digital Programmatics
(i.e., lifecycle modeling of cost, schedule, predictions, facilities, workforce, etc.)



NASA SP-2016-6015 Rev2

2.0 Fundamentals of Systems Engineering

At NASA, "systems engineering" is defined as a methodical, multi-disciplinary approach for the design, realization, technical management, operations, and retirement of a system. A "system" is the combination of elements that function together to produce the capability required to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose; that is, all things required to produce system-level results. The results include system-level qualities, properties, characteristics, functions, behavior, and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected.[1] It is a way of looking at the "big picture" when making technical decisions. It is a way of achieving stakeholder functional, physical, and operational performance requirements in the intended use environment over the planned life of the system within cost, schedule, and other constraints. It is a methodology that supports the containment of the life cycle cost of a system. In other words, systems engineering is a logical way of thinking.

Systems engineering is the art and science of developing an operable system capable of meeting requirements within often opposed constraints. Systems engineering is a holistic, integrative discipline, wherein the contributions of structural engineers, electrical engineers, mechanism designers, power engineers, human factors engineers, and many more disciplines are evaluated and balanced, one against another, to produce a coherent whole that is not dominated by the perspective of a single discipline.[2]

Systems engineering seeks a safe and balanced design in the face of opposing interests and multiple, sometimes conflicting constraints. The systems engineer should develop the skill for identifying and focusing efforts on assessments to optimize the overall design and not favor one system/subsystem at the expense of another while constantly validating that the goals of the operational system will be met. The art is in knowing when and where to probe. Personnel with these skills are usually tagged as "systems engineers." They may have other titles—lead systems engineer,

1 Eberhardt Rechtin, *Systems Architecting of Organizations: Why Eagles Can't Swim.*

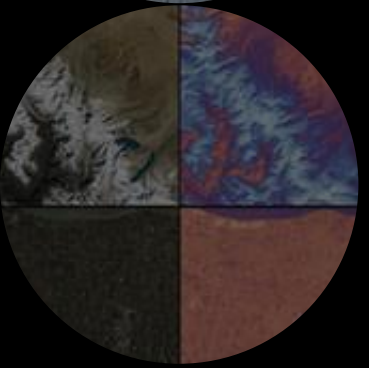
2 Comments on systems engineering throughout Chapter 2.0 are extracted from the speech "System Engineering and the Two Cultures of Engineering" by Michael D. Griffin, NASA Administrator.

NASA SYSTEMS ENGINEERING HANDBOOK 3

Multi-Disciplinary Analysis & Optimization
(i.e., system-level analysis and optimization exploration using discipline-level models and parameters as adjustable variables)

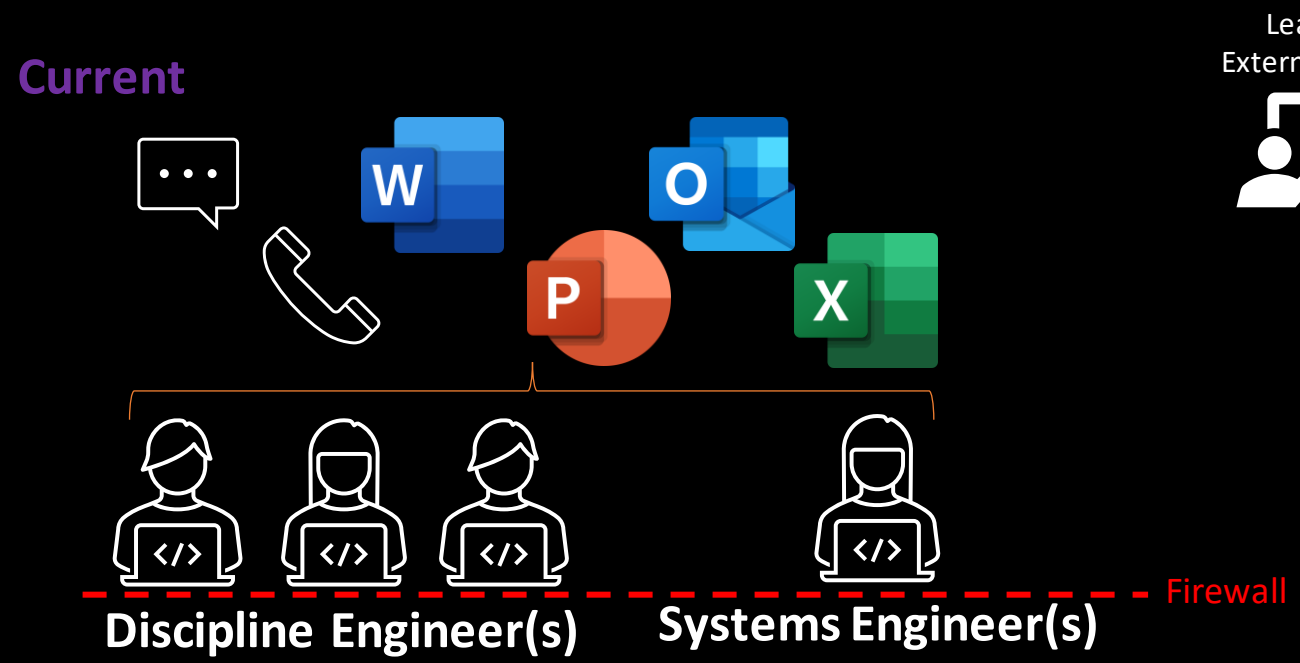
Digital Engineering enables *interactive* **Systems Engineering** at *machine speed*



What Does DE Look Like in Context?

- ETD projects are typically year(s)/decade(s) efforts and see dozen(s)/hundred(s) of engineers

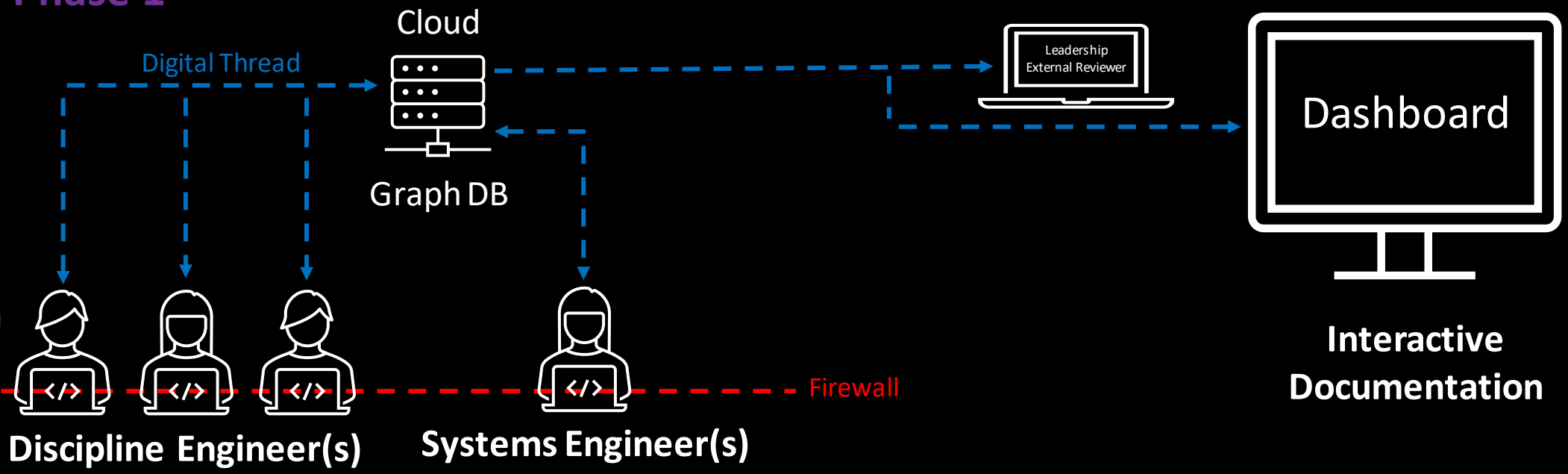


- DE strategy must
  - Reduce tedious tasks
  - Minimize onboarding/training disruption
  - Captures the full project lifecycle, from formulation through implementation

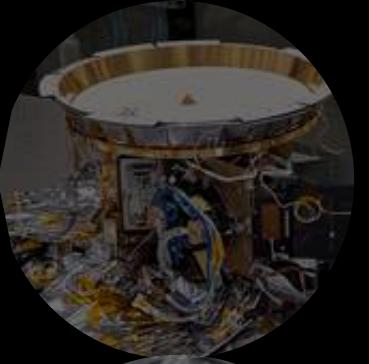
What Does DE Look Like in Context?

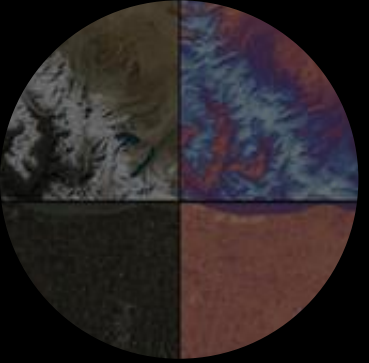
- Align siloed efforts of enabling capabilities into a common vision focused on science impact
- Reduce tedious tasks and maximize asynchronous collaboration across science and engineering
- Emphasize knowledge capture to minimize onboarding/training disruption for technical team

Phase 1



Digital Thread is the foundation for ***improved project coordination***, ***asynchronous collaboration***, and ***enables matrixed technical tasking***



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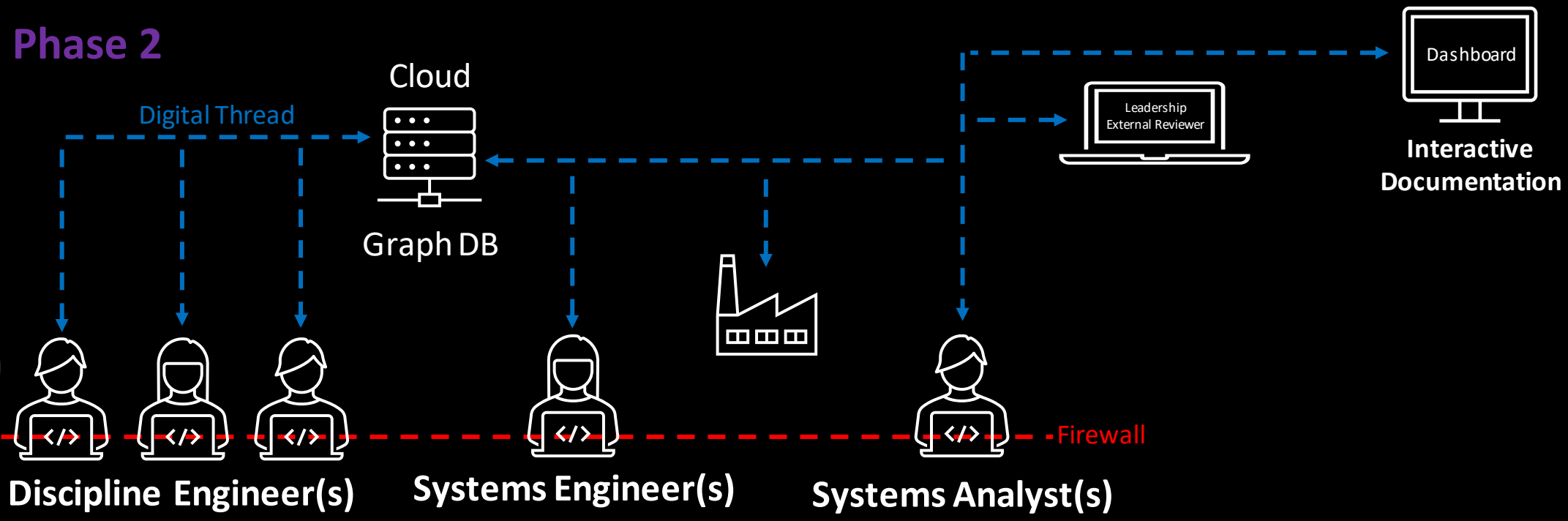
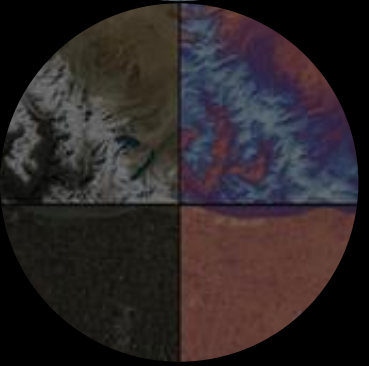


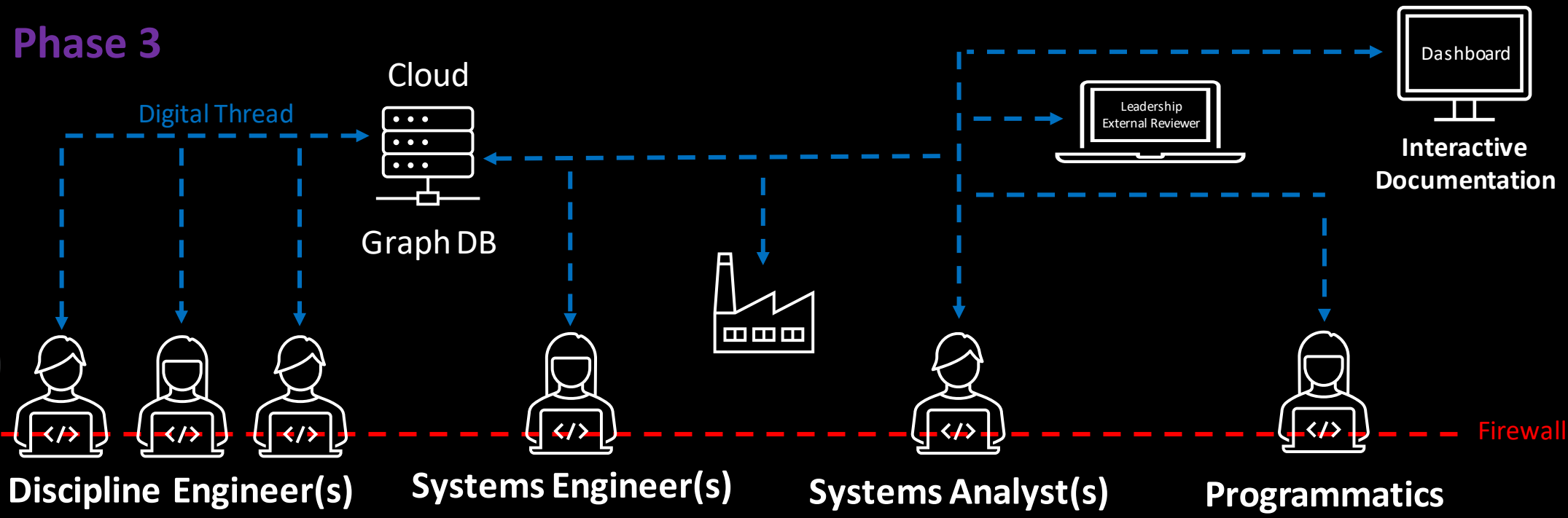
Cross-Disciplinary Analysis & Optimization (CDAO) provides **discipline-level trade study and optimization** capabilities for timely ***science-level impacts***



What Does DE Look Like in Context?

- Reduce tedious tasks and maximize asynchronous collaboration
- Captures the full project lifecycle, from formulation through implementation
- Dynamically couple science, engineering, and programmatics



Connecting programmatics enables timely **project-level decision-making** using **engineering developments** for relevant ***project-scale projection and traceability***

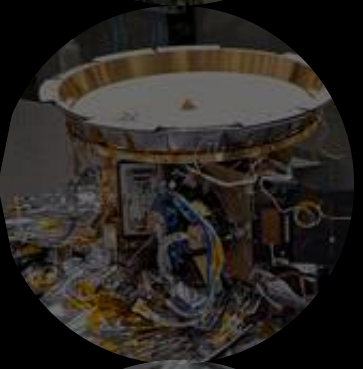
Digital Engineering Transformation is a Journey

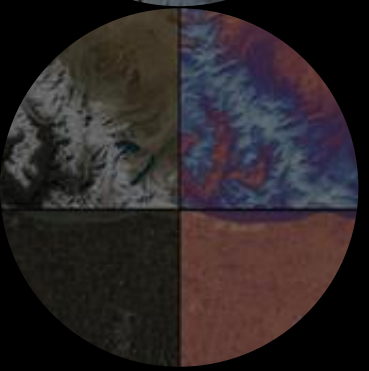
- Transforming Engineering is part technical and part cultural; cannot be accomplished without harmonious coupling of both
- Existing engineering processes work (ref. Apollo, HST, Shuttle, JWST, etc.); the point of transforming is NOT to reinvent the engineering wheel
- Transformation allows for a holistic approach to addressing pain points and potential synergies within existing processes

  Inform timely decision making across the enterprise
  NEED with an increasingly connected, decentralized workforce
  APPROACH using modern advancements, processes, and technology
  FUNCTION free-up workforce to focus on skill-driven tasking
  BENEFITS improving efficiency and workforce happiness

- To develop a truly connected (digital) ecosystem that allows skilled workforce to focus on skilled tasks and reduce tedium

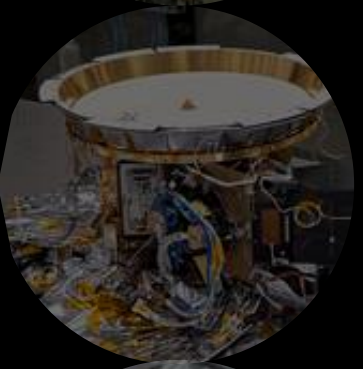
ETD's **most precious resource** is **skilled workforce *time***
Digital Engineering *reduces* day-to-day ***tedium,***
prioritizing renewed focus on ***innovation*** and ***technical challenges***

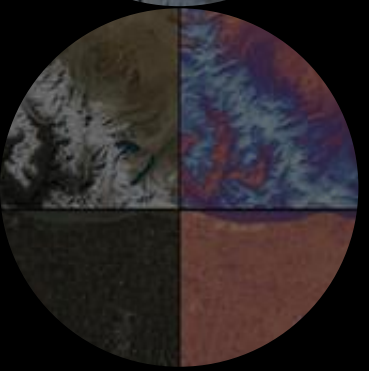





Backup

Includes several examples of engineering innovation at GSFC

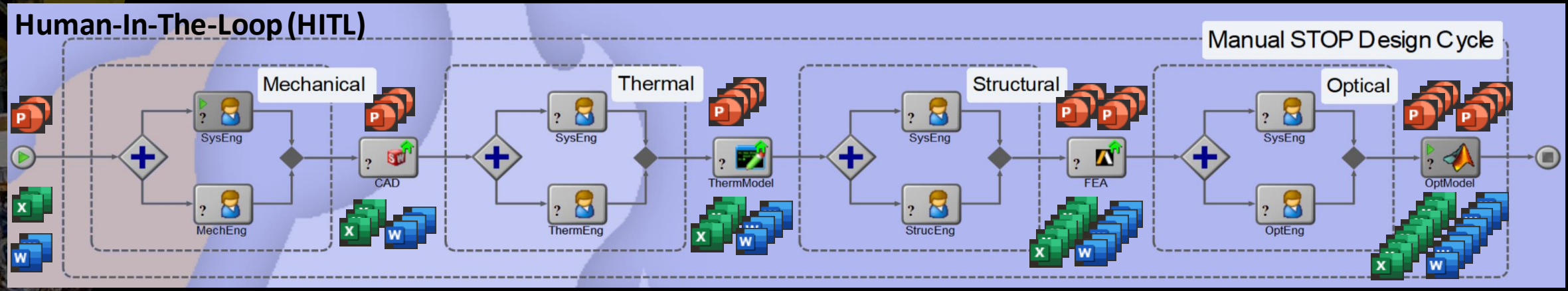


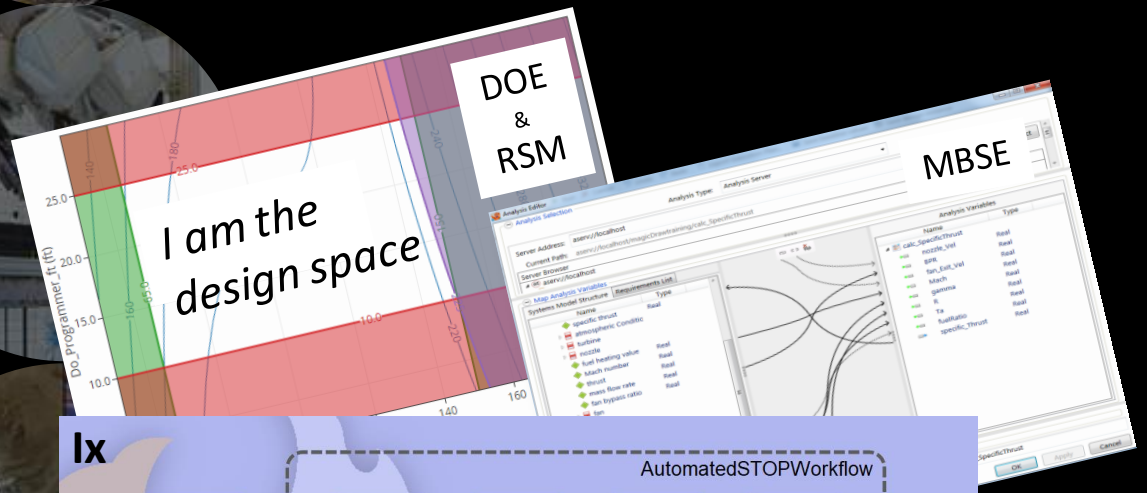
How Does Digital Engineering help?

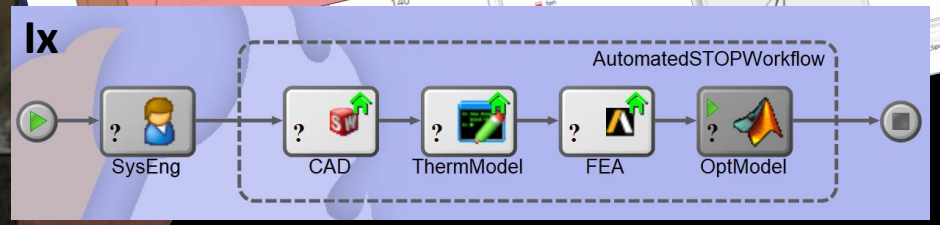
- Digital Engineering reduces system risk by enabling further interrelated analysis and optimization, with benefits including:
  - Faster design iterations
  - Reduced development costs
  - Improved product quality
  - Better collaboration among team members
- Consider a simple use case (i.e., increase diameter of an instrument mirror)
- Standard engineering processes can get complex quickly
  - More disciplines involved means more coordination required
  - Matrixed engineering support limits availability for project work
  - Email used for ALL communication can easily saturate and cause technical misses
    - ALL = organizational, coordination and technical updates across multiple projects, etc.

Integrated Everything (*Ix*)

POC: Aaron Comis







	HITL	Ix
Setup time	Month(s)	Month(s)
Cycles completed after setup	1	1
Documents generated	XXXX	X
Design Validation of Requirements	Manual	Automated
Time per iteration cycle*	W/M	H/D
Surrogate Modeling	N	Y
Engineers for surrogate exploration	All	1

Equivalent to the transition from hand drafting to CAD