National Aeronautics and Space Administration

Power Source Global Summit: Vision to Reality Interactive Demo

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Engineering and Technology Directorate (ETD)

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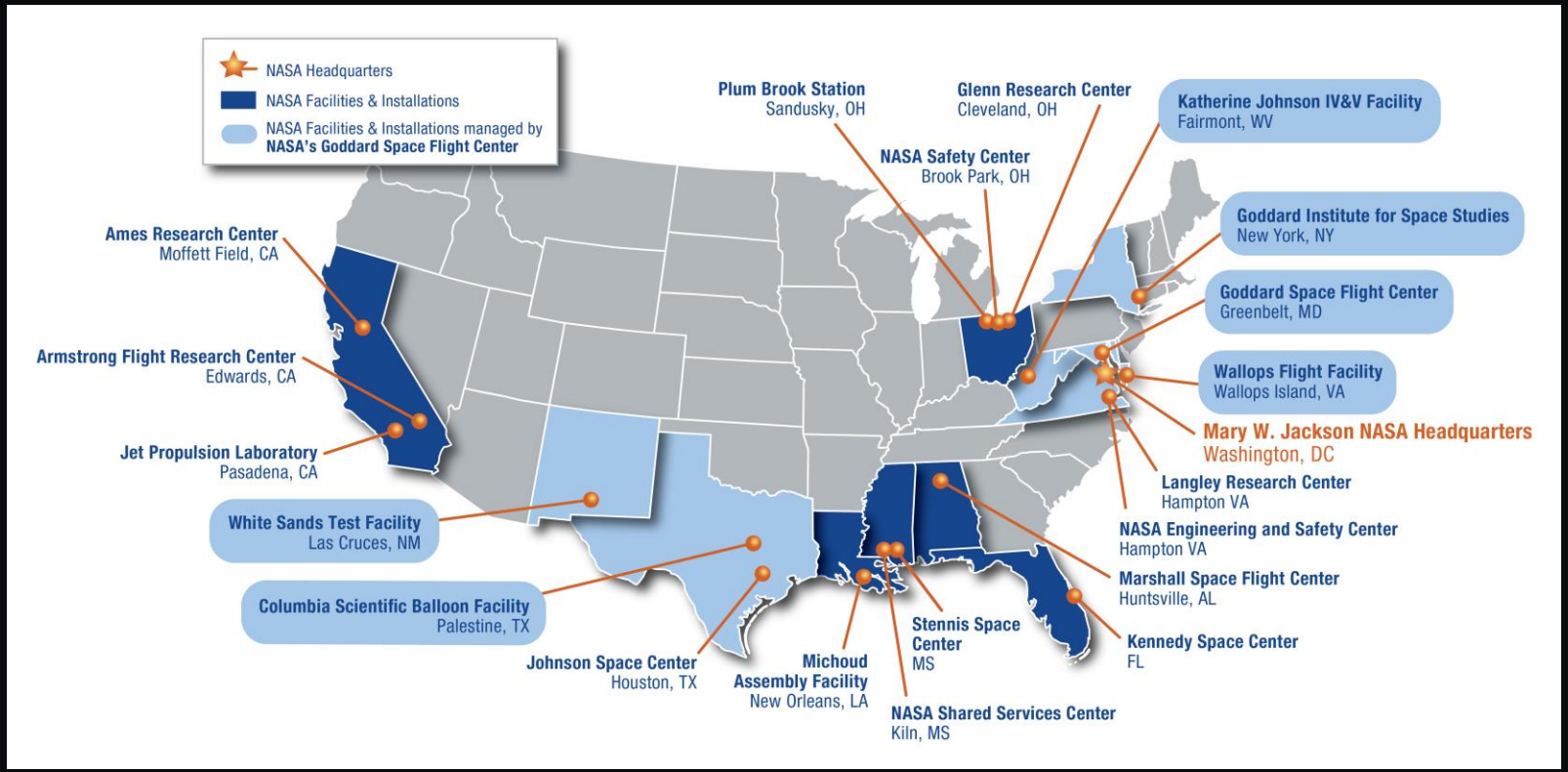
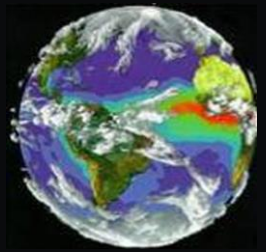
NASA Across America

- Goddard is the largest Science, Engineering & Technology Organization in the US



NASA Goddard Lines of Business

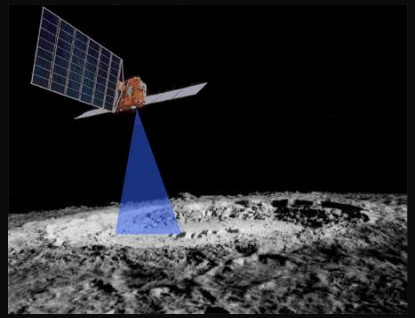
Astrophysics



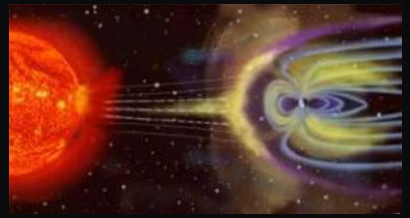
Earth Science

Planetary &
Lunar Science

Suborbital Platforms
& Range Services



Cross Cutting Technology
& Capabilities



Heliophysics

Communications &
Navigation

Enables & Transforms

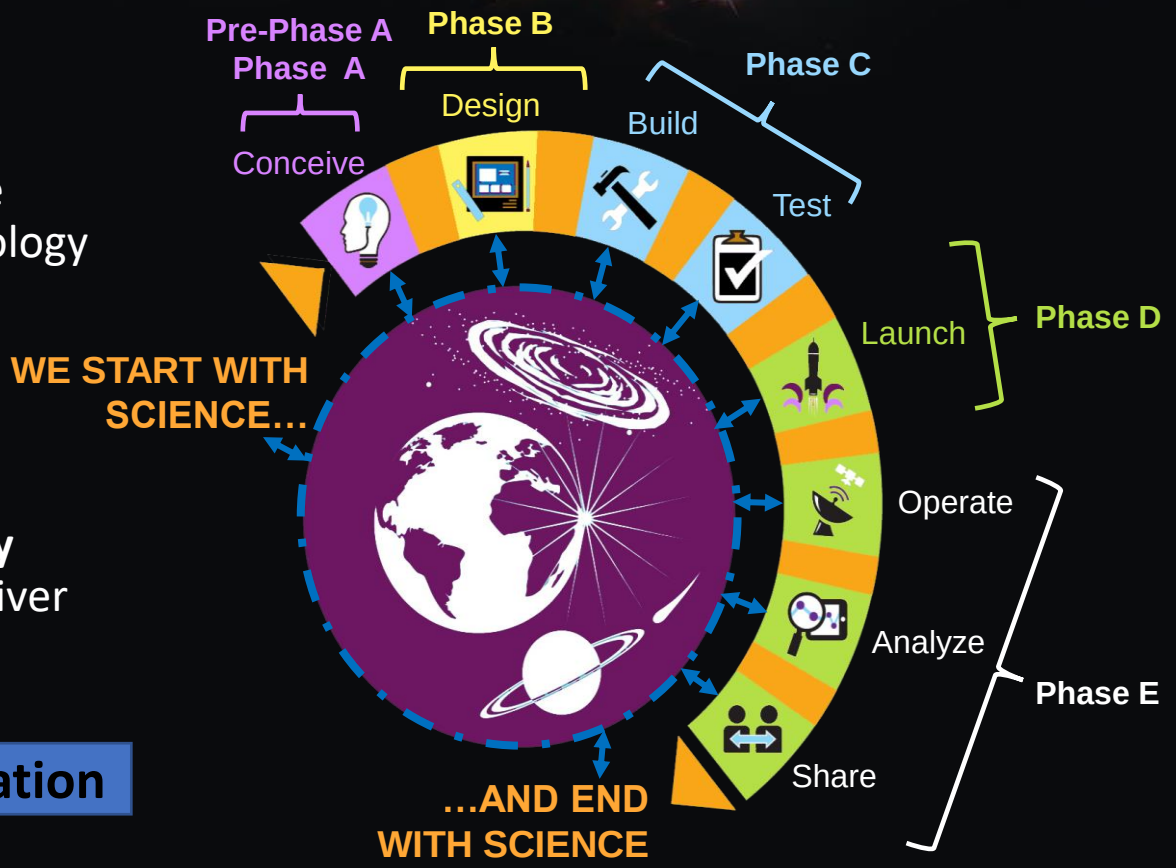
Engineering and Technology

NASA Project Lifecycle

- At Goddard, it all **begins and ends with science**. We derive and share information, solutions, and technology **for the benefit of all**—NASA, the nation, and the world.

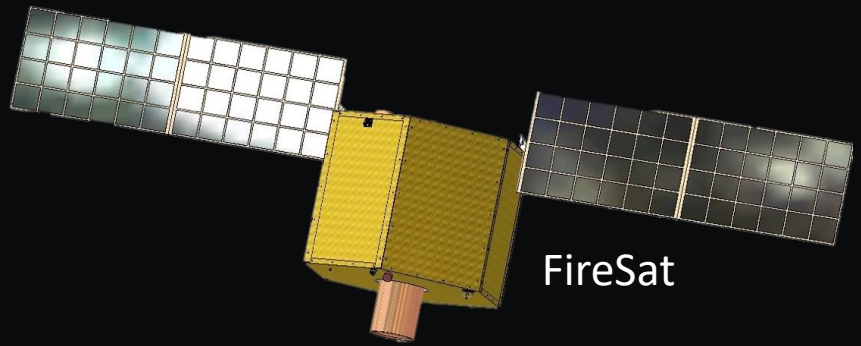
- ETD is the engine that powers Goddard with enabling **technology and engineering excellence** to deliver **transformational science**.

Focus on **connecting information**

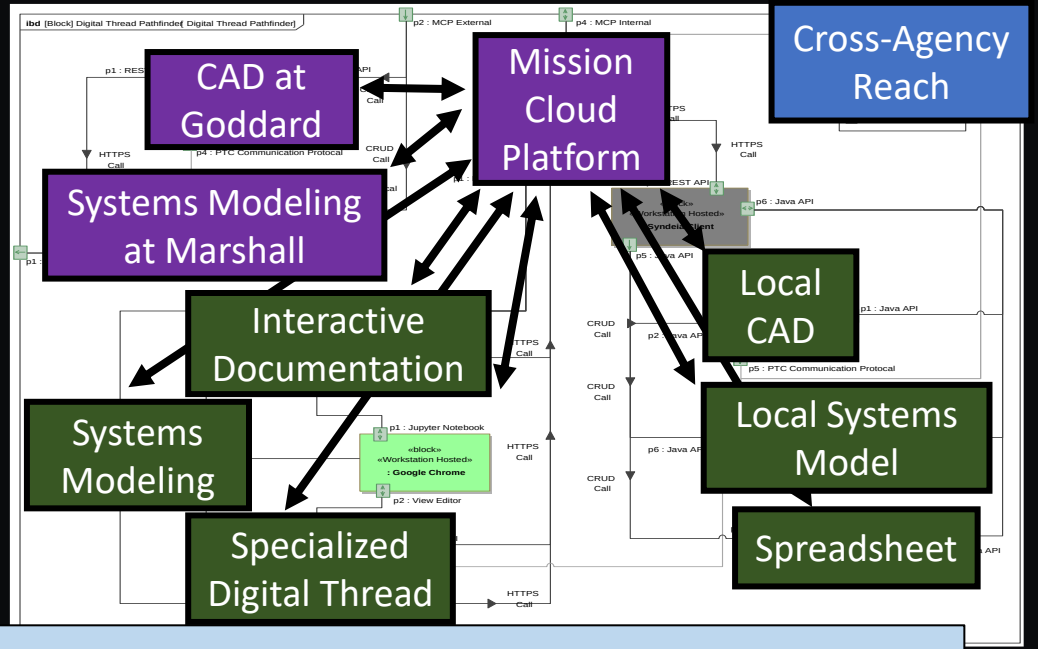


Digital Thread Pathfinder

- Digital Thread is foundational
  - Efficient project coordination
  - Asynchronous collaboration
  - Consistency management



FireSat



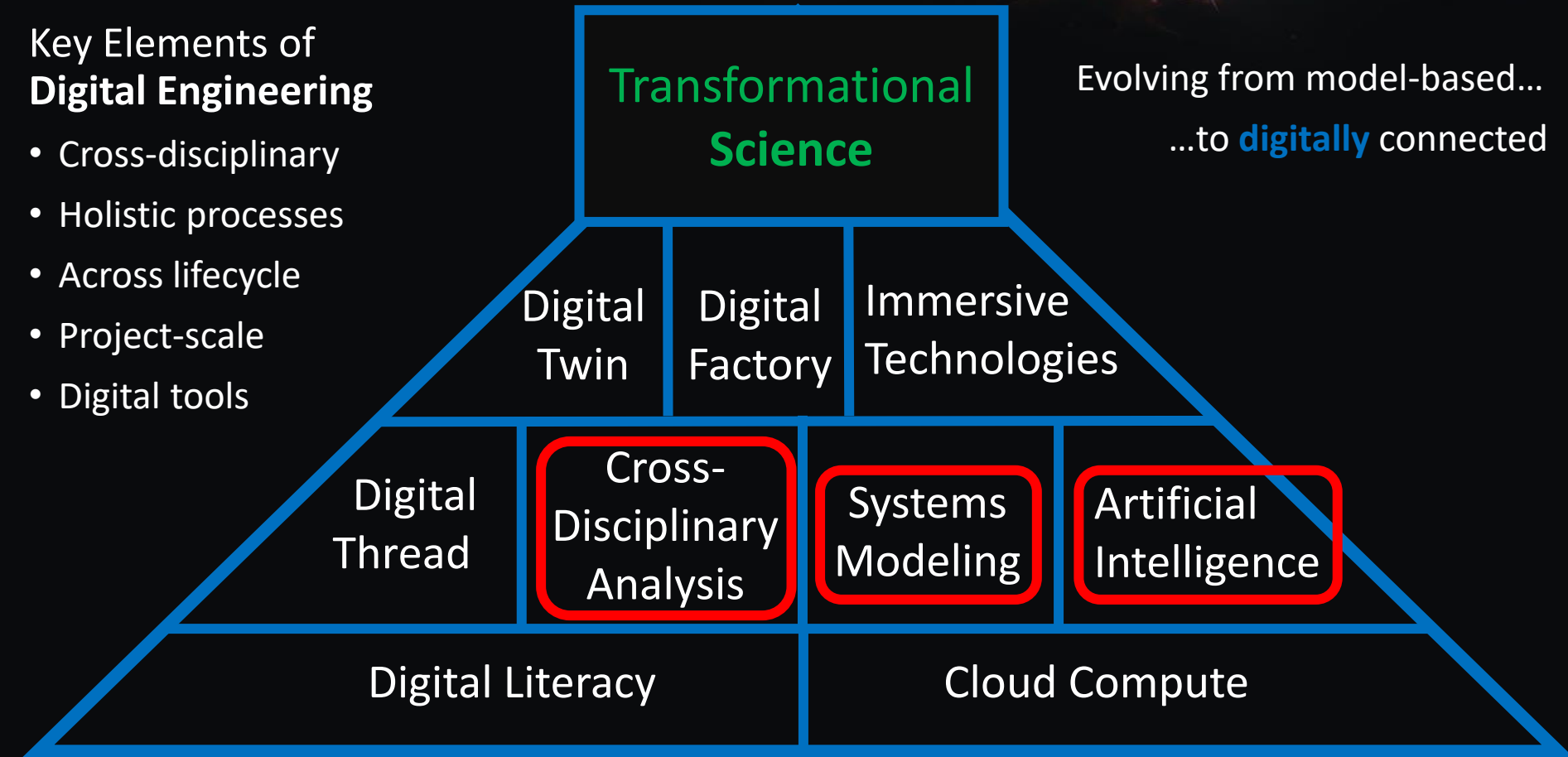
Game changer for large team, complex project **collaboration**

FireSat image credit: TSTI Dr. Jerry Sellers

*Evolving Process, by **Revolutionizing Collaboration***

Key Elements of
Digital Engineering

- Cross-disciplinary
- Holistic processes
- Across lifecycle
- Project-scale
- Digital tools

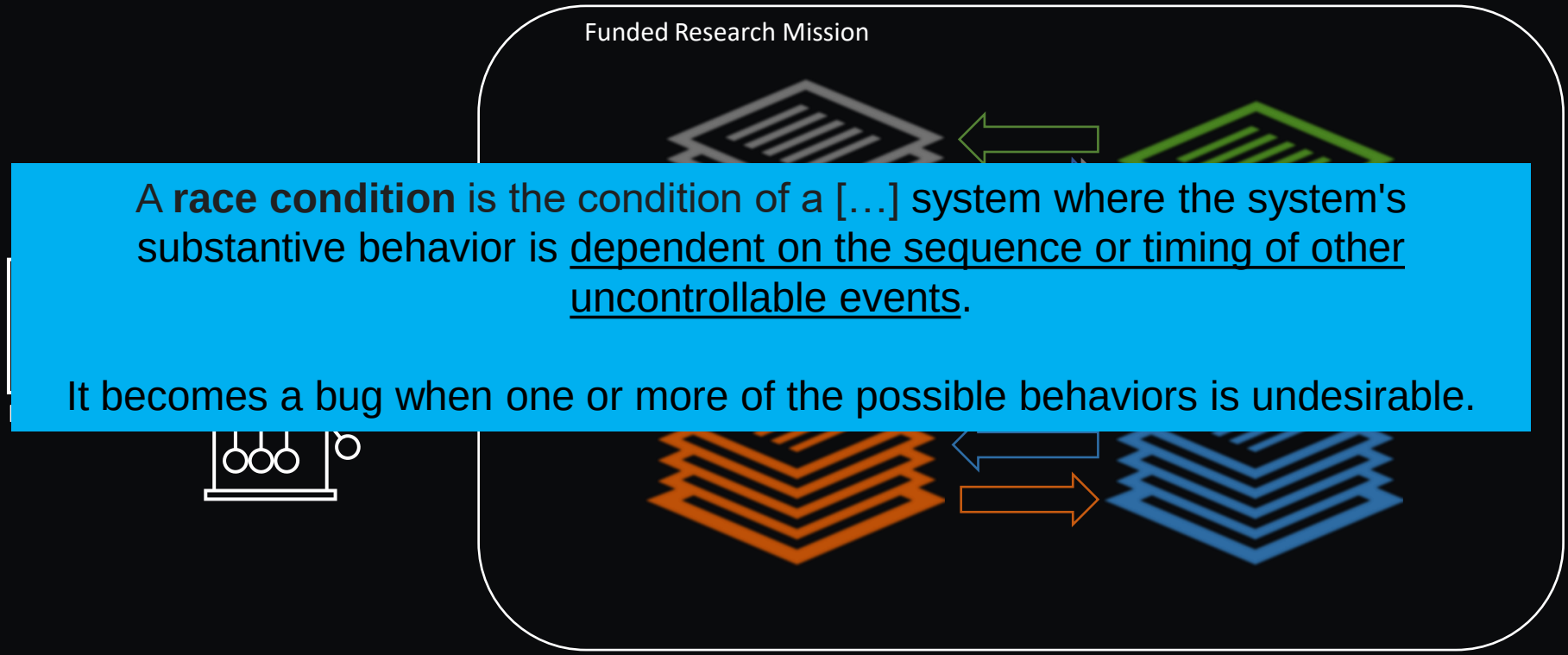


Evolving from model-based…

…to **digitally** connected

It all starts with requirements

- Let’s look at some existing issues with requirements development

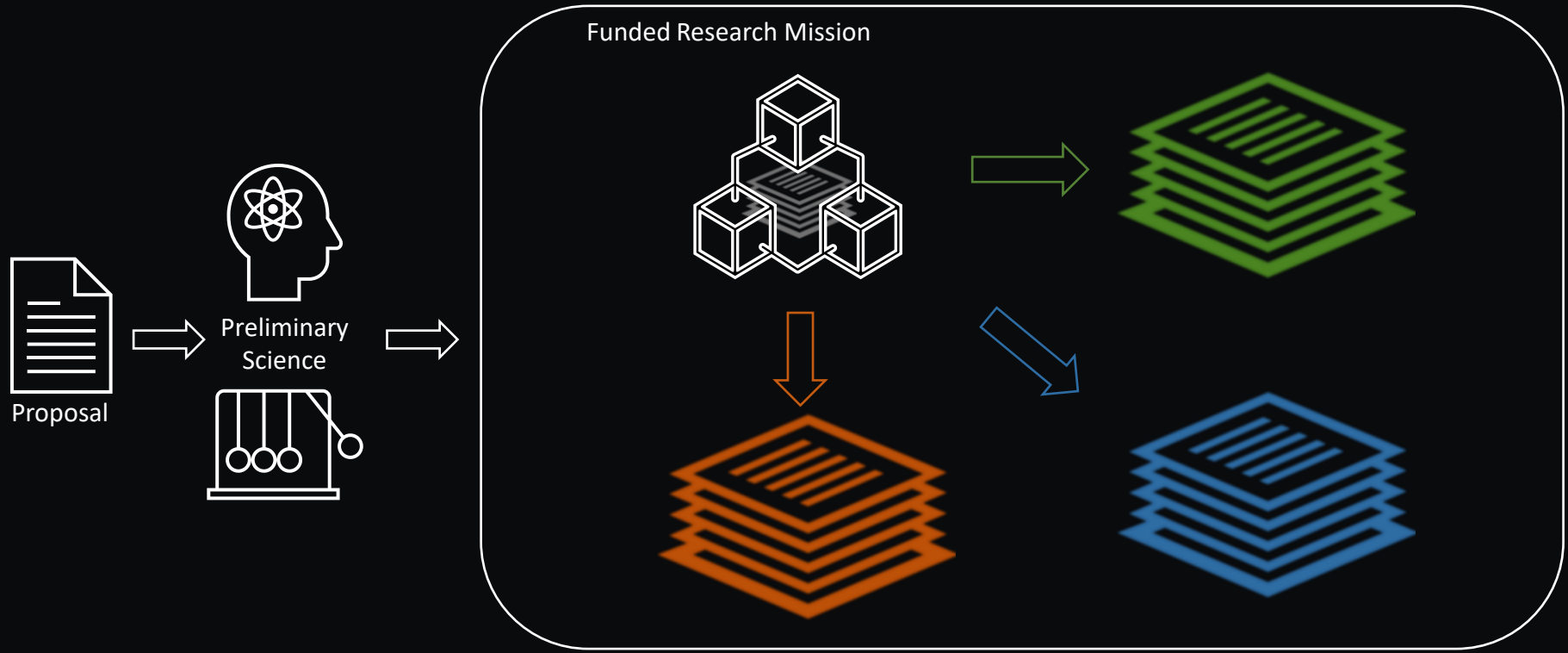


A **race condition** is the condition of a […] system where the system's substantive behavior is dependent on the sequence or timing of other uncontrollable events.

It becomes a bug when one or more of the possible behaviors is undesirable.

Upstream Ripples

- How can AI, Generative Design, and Model Based System Engineering change the paradigm for requirement development and maintenance?



Downstream Results of MBSE and AI

- Recapturing time and money
- Better communication and increased understanding across the team
- More easily determine appropriate testing and synthesize the results
- Can you do more?

Why Autonomy in Space?

Image source: https://militaryembedded.com/ai/big-data/autonomous-space-systems-to-be-developed-for-csa

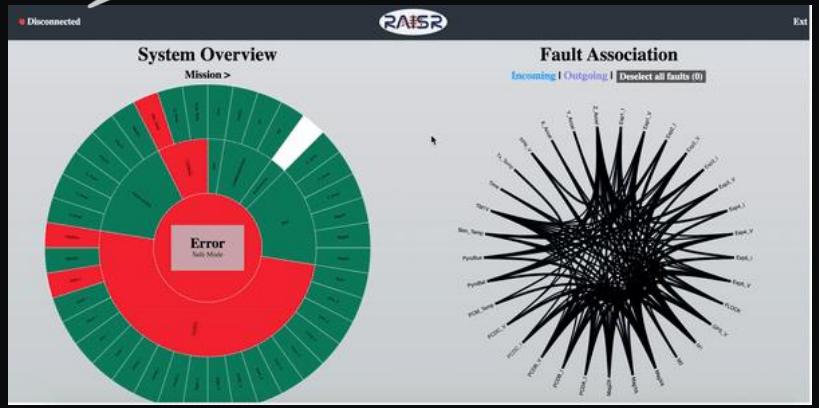
- Traditional spaceflight requires human-in-the-loop ground control intervention for operations. This paradigm is limiting due to:
  - Time delays
  - Data downlink bandwidth
  - Proximity restrictions
- We must consider autonomy to enable in-situ intelligent scientific observation and real-time mission operations to maximize scientific discovery
- At GSFC, we have focused our efforts on autonomy in areas such as:
  - Mission Resilience
  - Intelligent Instruments
  - Onboard Science Data Processing

Autonomous Fault Mitigation Architecture

- Project RAISR (Research in Artificial Intelligence for Spacecraft Resilience) addresses spaceflight limitations with an intelligent systems architecture, which uses AI for autonomous system-level fault diagnosis
  - Outperformed state-of-the-art AI approaches by > 55%
  - Currently being used in a notional mission design for Distributed Systems Missions (DSM)

Grecius, Tony, "Mars 2020 Perseverance Healthy and on Its Way." NASA Blogs. July 30, 2020.

- Goddard of the future will see a new wave of scientific discovery through intelligent systems architectures, as they will enable
  - Fully autonomous spaceflight
  - Next-gen spaceflight paradigms like DSM



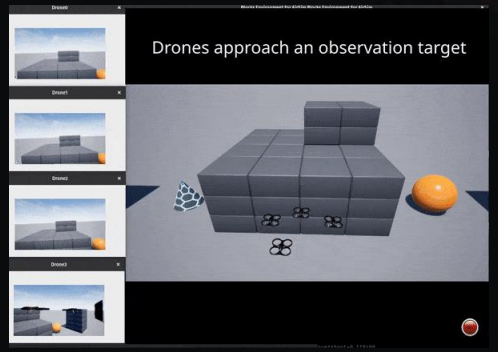
Distributed Systems Missions

- The Distributed Systems Mission (DSM) project focuses on building an autonomy-enabled *fleet of satellites* to increase scientific discovery in interplanetary environments

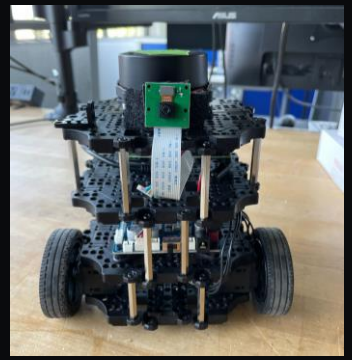
- The GSFC DSM project is comprised of a diverse team of researchers, currently designing and prototyping an intelligent satellite fleet mission using **accessible tools**:
  - Robots: Turtlebots, Raspberry Pi's, Drones
  - Open-sourced tools, including simulation environments, and our GSFC Onboard AI Research (OnAIR) platform

  OnAIR Available at https://github.com/nasa/OnAIR

- Goddard of the future will see a new class of complex missions through DSMs



DSM development is using various open-sourced simulation environments for rapid prototyping (AirSim shown above), and publicly available AI agents for representative prototyping (Turtlebot Berger3 shown below).



Inspiration

*"AI is one of the most important things humanity is working on. It is more profound than, I dunno, **electricity or fire**,"*
-Sundar Pichai (Google CEO)

Image source: https://expanse.fandom.com/wiki/Tycho_Station?file=Tycho-stn-3.png

Image source: https://www.artstation.com/artwork/Z5lYJm

Image source: https://en.wikipedia.org/wiki/Millennium_Falcon

- We aren't going to get there with current development methods
  - ~$250K per kg
- How can AI be applied to spaceflight structure development?

Image source: https://mobile.twitter.com/aebdigital/status/1079504882393116674

Generative Design

- AI that generates multiple design outputs based on constraints
  - Human designer collaborates to get ideal design
- Applications
  - Visual art
  - Text
  - Music
  - Architecture
  - Structural design
  - Complex systems ???

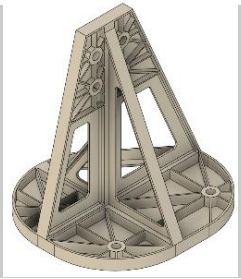
TEXT PROMPT: an armchair in the shape of an avocado. an armchair imitating an avocado.

AI-GENERATED IMAGES

Evolved Structures

AI and robots enable 10x faster/cheaper development of spaceflight structures

- Evolved Structures process
  - Design requirements are digitally encoded
  - Generative Design AI evolves optimal structures
    - Iterative design, analysis, and fabrication simulation
  - Digital Manufacturing robots fabricate parts from CAD
- Typical metallic structures – now automated
  - Requirements➞parts for fab in 1-2 days(!)
  - Parts ~3x stiffer/lighter/stronger than human designs
  - Demonstrated by test
- The Future
  - Make all structure development 10x faster/cheaper

Designer	Expert Humans (2X)	AI
Design		
Design time	2 days	1 hour
Design iterations	4	31
Mass (kg)	0.27	0.2
1st Mode (Hz)	65	177
Max Stress (MPa)	103	11.2
Manufacturing	CNC - Difficult to machine (no quotes)	3D Printed

Vision to Reality

- V2R team looking to design a demo, but we need some help…from you!

Scenario: You are an astronaut near the lunar south pole on a sample collection mission to gather *at least* 20g of rare lunar minerals

- You want to stay safe
  - No aliens this time of day
- You don't know what you may encounter
- What tool do you make?
  - Shovel? Hoverboard?
  - Handheld? Mounted?

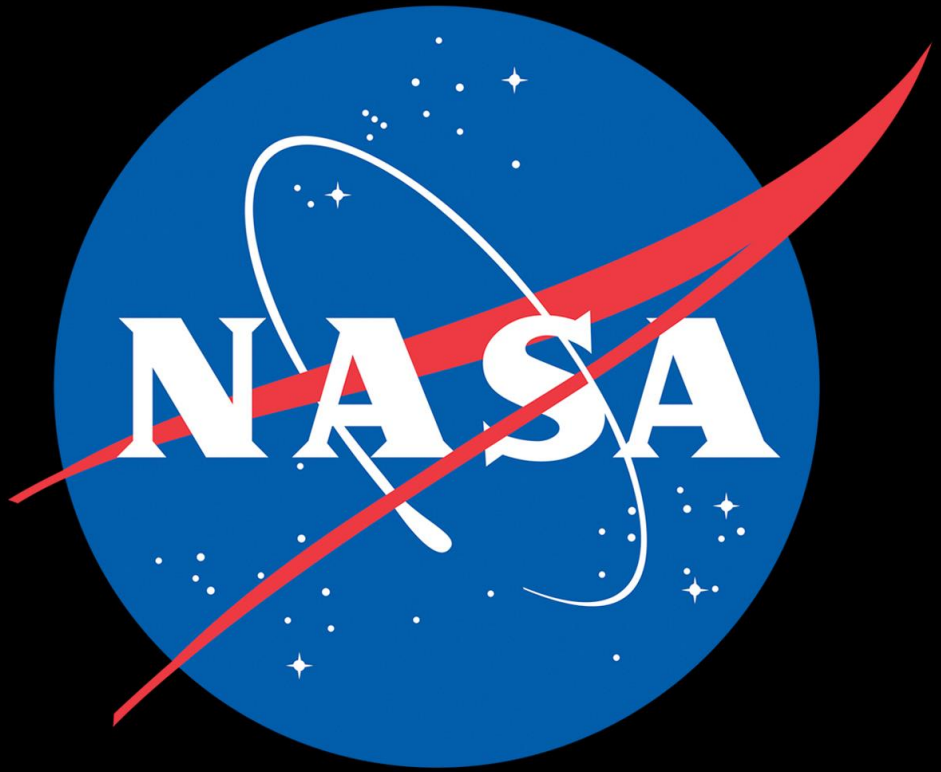
Design Constraints

- Some kind of mechanical structure (e.g. no electronics)
  - Forces/loads that can be estimated
  - Possible to be made as a single part
- Ideally ~shoe box sized
  - Larger structures possible, but will need to be scaled down due to fabrication constraints
- No weapons

- Decisions Needed
  - What tool do you make?

Timeline for Remainder of Conference

- Day 1 (10/12):
  - Stop by the NASA booth to learn about innovative design processes and help collaborate on ideas
  - Designs will be sent out that evening to external manufacturing company for rapid turnaround fabrication.
- Day 2 (10/13):
  - Explore 3D printing and learn about innovative design processes
- Day 3 (10/14):
  - Demo the parts during lunch



For more information, please visit our web site:
www.nasa.gov/goddard