NASA's Digital Transformation (DT) Initiative

Bryan Biegel, Co-Lead for NASA DT Initiative

J.-F. Barthelemy, Lead for NASA DT Initiative

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DT Essential for NASA Mission Leadership

Observations

- NASA is already doing DT, mostly at the grass roots (non-integrated)
- New digital capabilities can revolutionize how we achieve our mission
- Our partners are pursuing DT; NASA must continue to collaborate

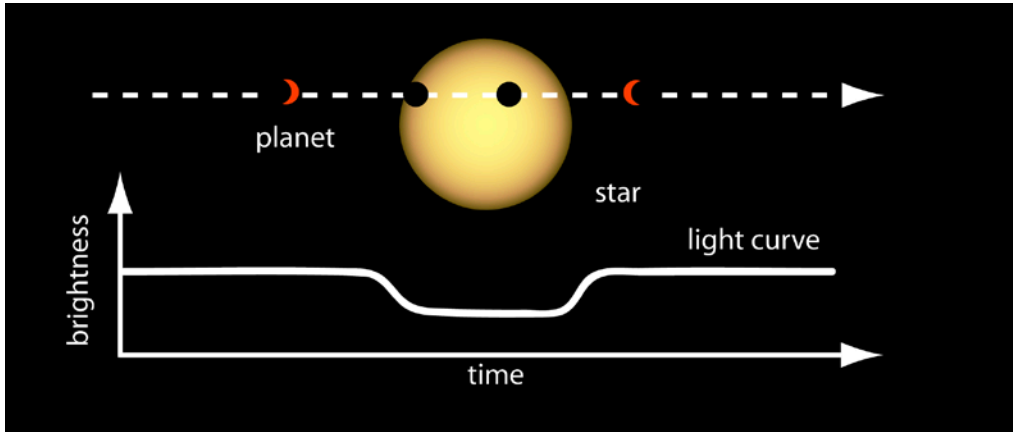
External DT Drivers for NASA

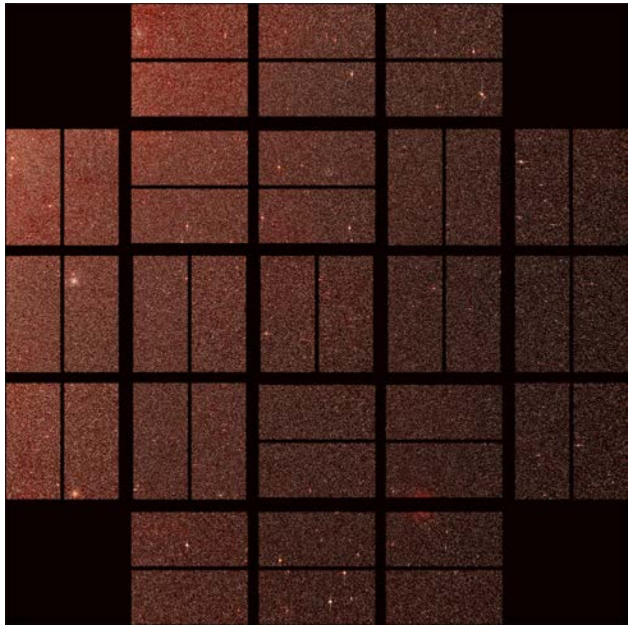
- **Digital convergence** opportunities
- Competition for **mission leadership**
- Increasing **mission complexity**
- Increasing **research complexity**
- Pervasive collaboration required
- **Big data challenges**
- **Resource constraints**
- **Workforce competition**
- **Cybersecurity threats**

NASA needs a comprehensive approach for evolving effectively and efficiently into a digitally-enabled world

Kepler Planet Search and Robovetter

Kepler spent 4 years monitoring approximately 200,000 stars for periodic changes in brightness – threshold crossing events or TCEs – and determining which were due to transiting exoplanets.





Technical Challenges (why DT was needed):

- Searching for all possible transits in the full Kepler dataset requires examining 1 trillion possible combinations -- not feasible with standard computer clusters.
- Traditional human-in-the-loop approach too laborious, did not yield uniform catalog suitable for statistical studies.

Approach (how DT was employed):

- Kepler pipeline ported to supercomputers at NASA ARC and optimized.
- Robovetter intelligent system developed to analyze TCEs.

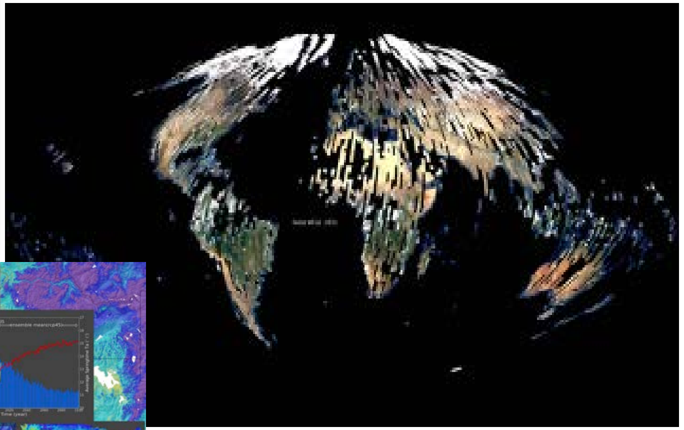
Benefits:

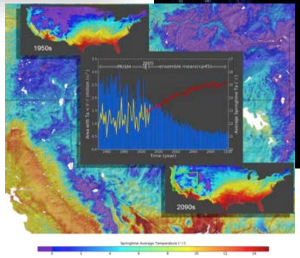
- Full dataset analysis accelerated from months to hours.
- Kepler pipeline identified over 30,000 TCEs.
- Robovetter created uniformly vetted catalog with over 4,000 planet candidates.
- Kepler transformed understanding of planetary systems

Lessons Learned:

- Deep understanding of data essential in developing suite of algorithms necessary to accurately analyze data.

NASA Earth Exchange (NEX)





NEX is virtual collaborative that brings scientists together in a knowledge-based social network and provides the necessary tools, computing power, and access to massive data to accelerate research, innovation and provide transparency.

Technical Challenges (why DT was needed):

* Earth science at NASA is community effort, 100s of investigators spend a majority of their time accessing and pre-processing data for further analysis.
* Redundant storage and processing facilities result in larger overall computing budgets
* Moving data sets that are getting larger each year is expensive & time-consuming
* Sharing KNOWLEDGE, ie. codes, algorithms, workflows, intermediate results) is difficult

Approach (how DT was employed):

* NASA ARC scientists/engineers built NEX through co-locating superomputing with cache copies of widely used Earth science data from multiple missions and large fast-access storage to access, manage and process the data

Benefits:

* Enables research at continental/global scales sharing codes/results with collaborators
* Immediate use of research results in applications
* Co-located, georeferenced datasets facilitate public access by reducing preprocessing labor, cost and knowledge barriers.

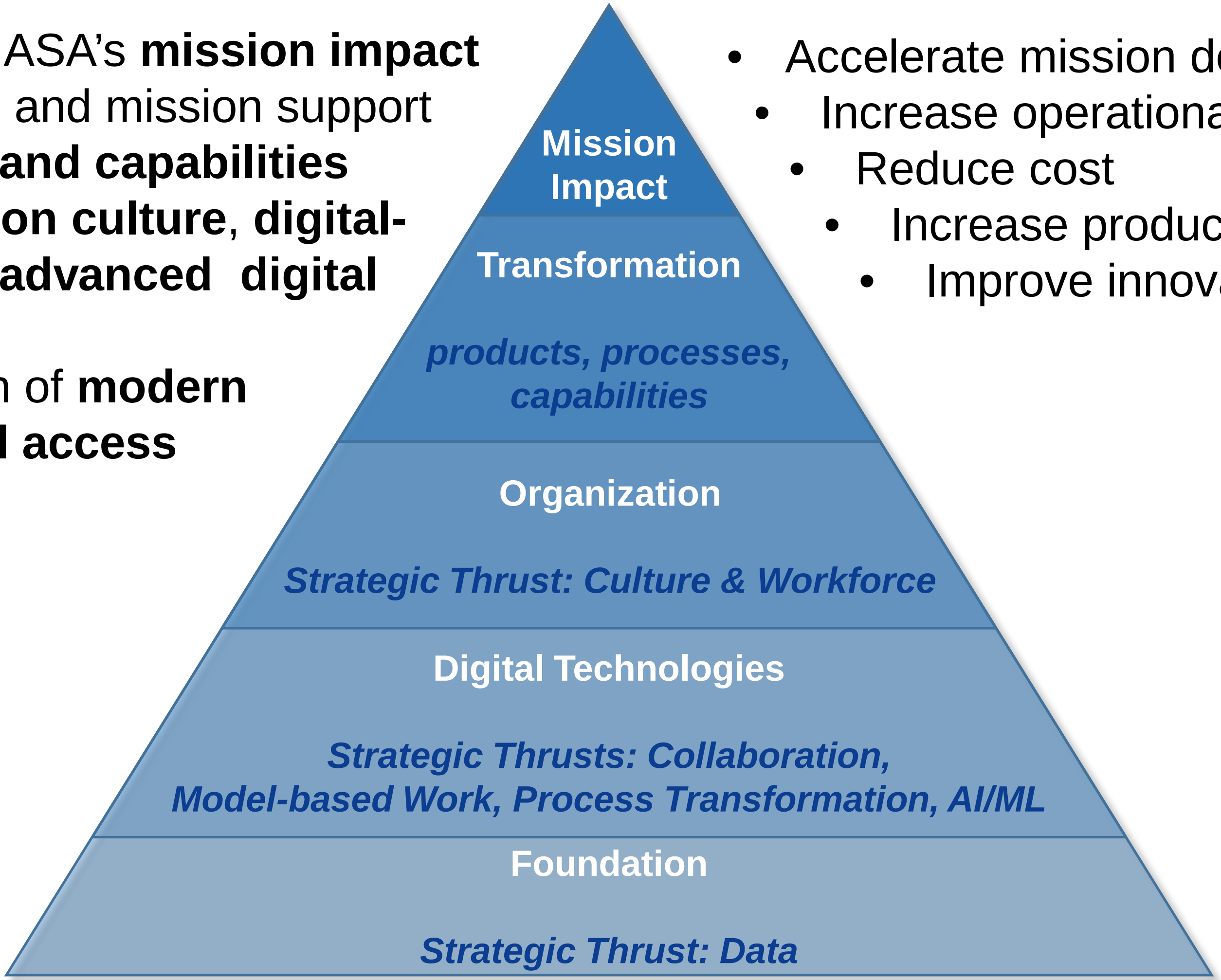
Lessons learned, best practices:

* Security, a challenge to provide wider access to the community
* NEX is well suited for
  - supporting mission teams
  - generating products for the community

NASA DT Initiative - Overview

Vision: DT will…

- dramatically enhance NASA's **mission impact**
- by **reinventing** mission and mission support **processes, products, and capabilities**
- enabled by an **innovation culture**, **digital-savvy workforce**, and **advanced digital technologies**,
- building on a foundation of **modern data management and access**



Mission Impact: Dramatically…

- Accelerate mission development
- Increase operational efficiency
- Reduce cost
- Increase productivity
- Improve innovation

How NASA’s DT Initiative is Antidisciplinary

- DT requires pervasive and fluid partnering across disciplines
  - Real challenges are always multi-disciplinary
  - Best opportunities for transformation happen when we merge discipline insights
  - If we just toss discipline-specific contributions over the wall, solutions will not be optimal.
  - Example: Boots on the Moon by 2024 requires contributions from many disciplines… DT will involve technologies, and encourage a culture, that support work across and outside of disciplines (e.g., innovative solution ideation).
- DT is already making us budding experts at everything
  - Google search, Wikipedia, YouTube, and other resources at our fingertips enable us to answer almost any question and undertake almost any task as if we had significant training.
- Envision a future where digital technologies (VR/AR collaboration systems, automation, AI assistants, etc.) enable us to perform like experts across many fields
  - Fluid collaboration and partnering
  - Needed training and data available to quickly expand knowledge
  - W bring our intellect, creativity, and viewpoint to each new challenge, which are always multi-disciplinary.

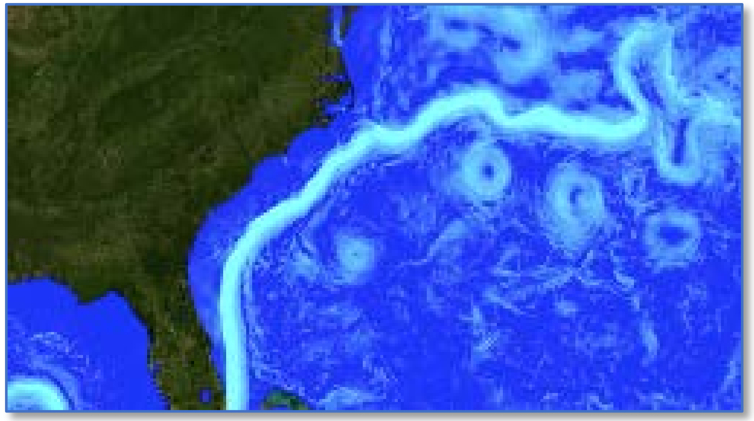
More on NASA’s DT Initiative

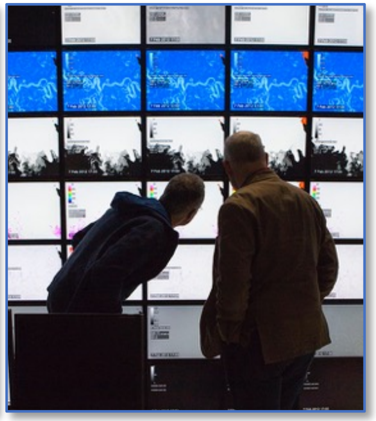
- https://www.nasa.gov/offices/oct/what-is-digital-transformation-and-why-is-nasa-doing-it.html

More DT Success Stories at NASA

Interactive Exploration of Multi-Petabyte Earth Science Data

The NASA Advanced Supercomputing (NAS) facility's visualization team at NASA ARC developed a new tool that enables ocean scientists to interactively explore their 5-petabyte dataset—the result of the highest-resolution simulation ever produced using the MIT General Circulation Model (MITgcm).





Technical Challenges (why DT was needed):

- Manage, organize, and analyze 5 petabytes of complex, vector/scalar field output of a global ocean circulation simulation of unprecedented resolution.
- Process extensive output of solution primitives to derive quantitative properties.

Approach (how DT was employed):

- Leveraged NAS high-end data access and processing capabilities (fast SSD filesystems, high-bandwidth InfiniBand network, hyperwall).
- Purpose-built software allowed interactive exploration of multi-PB data with user-controlled runtime rendering.

Benefits:

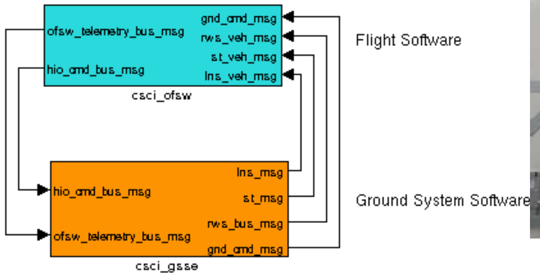
- Researchers can interactively explore massive datasets at full resolution on selected time scales, pursuing hunches, with custom-tuned multivariate views of any part of time series.
- Working as a group during a session at the 128-screen hyperwall, the researchers discovered new features in their data and found ways to improve their simulation.

Lessons learned, best practices:

- The group dynamic enabled by the large hyperwall is very useful for researchers to work efficiently with their data.
- With today's NAS resources, successfully completing an extensive simulation is just the beginning of science; the resulting rich dataset requires specialized tools to exploit the data.

Lunar Atmosphere & Dust Environment Explorer (LADEE)

LADEE



The Lunar Atmosphere and Dust Environment Explorer (LADEE) was a highly successful mission that launched in 2013 and orbited the moon for several months, collecting valuable information about the tenuous lunar atmosphere. The spacecraft and hence the onboard flight software was developed at NASA ARC. The ARC flight software team utilized Model Based Software Development techniques to generate the onboard software.

Technical Challenges (why DT was needed):

- LADEE was cost-constrained Class D mission, needed to reduce cost of developing onboard flight software.
- Traditional approaches for flight software development required separate phases of modeling and analysis, followed by coding and verification.

Approach (how DT was employed):

- Models of the Spacecraft Systems were developed in Mathworks Matlab/Simulink.
- Simulink Interface Layer (SIL) used to automatically generate Core Flight Systems (CFS) compatible software from the models.
- Resulting software verified using Processor and Hardware in-the-Loop simulators, also generated from the models.

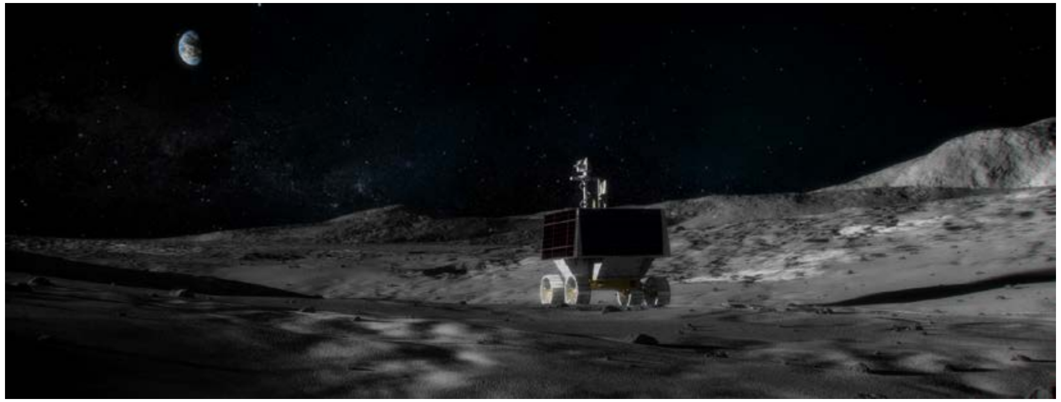
Benefits to date:

- Accelerated and lower cost development of the onboard software by automating the code generation.
- Reduced test costs by automating the generation of Processor and Hardware in-the-Loop simulators.
- Improved Mission Operations procedure development and training through the use of Simulators with necessarily identical features to the onboard software.

Lessons learned, best practices:

- Model based software development through automatic code generation is highly effective for onboard flight software development.
- SIL layer coupled with CFS architecture were key to “push-button” code generation and testing.

Resource Prospector (RP)



Resource Prospector (RP) showed how America could return to lunar surface to prospect for volatiles, including water ice, to determine resource potential for future exploration architectures. Systems engineering team led adoption of Model-Based Systems Engineering (MBSE) methods throughout multi-Center project team. RP rapid design was completed, and laid groundwork for VIPER (Volatiles Investigating Polar Exploration Rover), planned for launch in 2022.

Technical Challenges (why DT was needed):

- Project team at ARC, KSC, and JSC needed to maintain consistency of requirements, ConOps, and system architecture
- Difficult to manage complexity with traditional document-based systems engineering methods

Approach (how DT was employed):

- Created RP system model in SysML
- Integrated requirements management database (DOORS) with system model (MagicDraw) to perform functional analysis
- Used Agency Cloud to publish model to web interface (Cameo Collaborator) so non-modelers could access and review/comment on models

Benefits to date:

- Improved communication between systems engineers and software developers
- Accelerated development of Rover ground software architecture and integration with Ground Data System (GDS) software
- Mapping ops team functions to GDS architecture
- Ensuring consistent ConOps development and delineation of responsibility

Lessons learned, best practices:

- Lead adoption of new methods as an exemplar
- MBSE training essential for the team, even non-modelers
- Continued access to MBSE consultants to get through roadblocks
- Make the models accessible and navigable to non-modelers