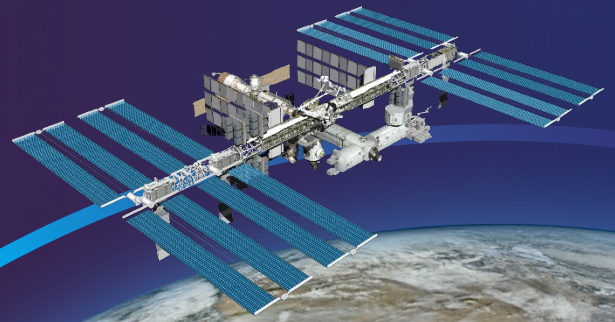
National Aeronautics and Space Administration

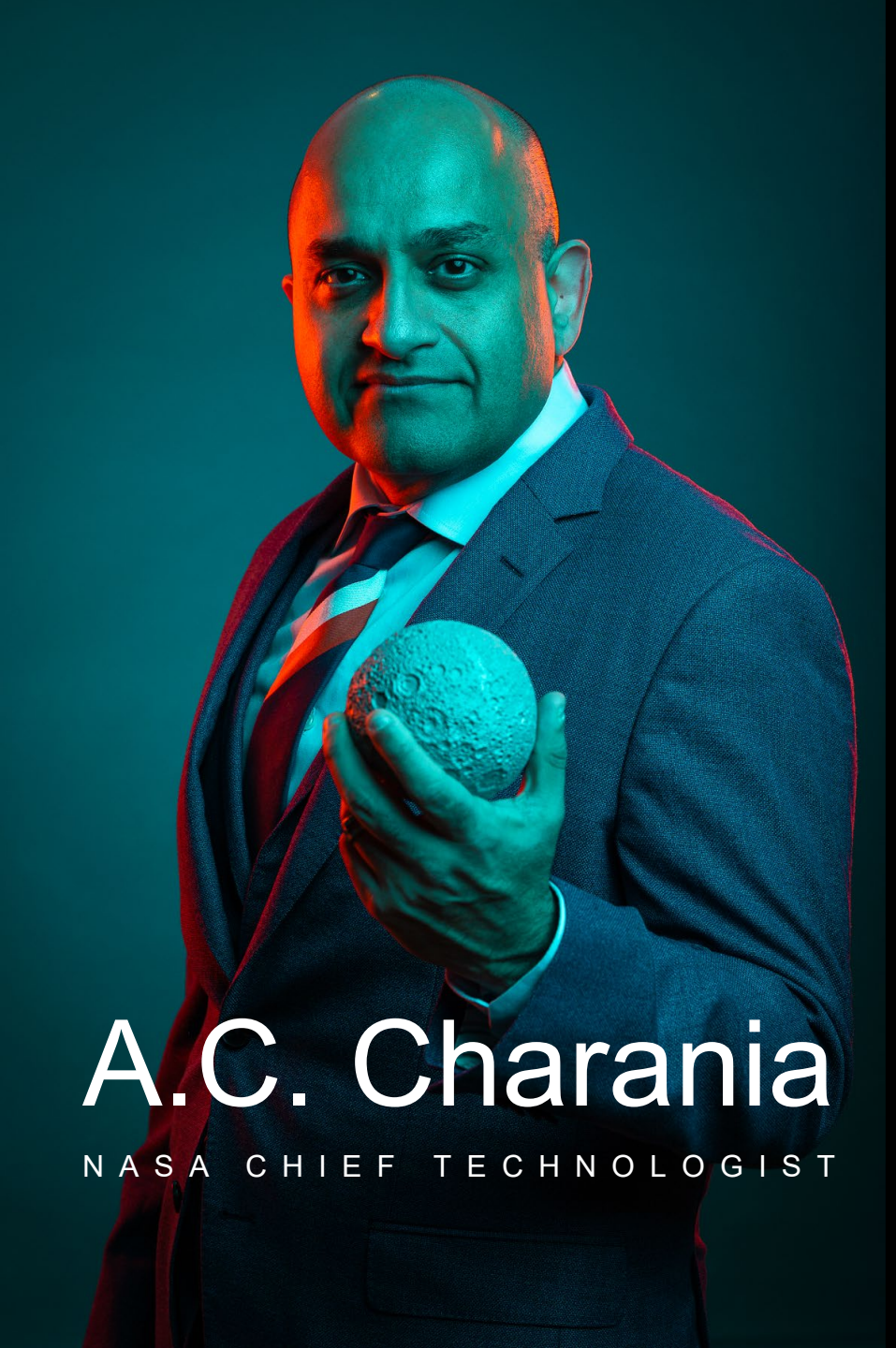


DRIVING INNOVATION

Artificial Intelligence (AI)

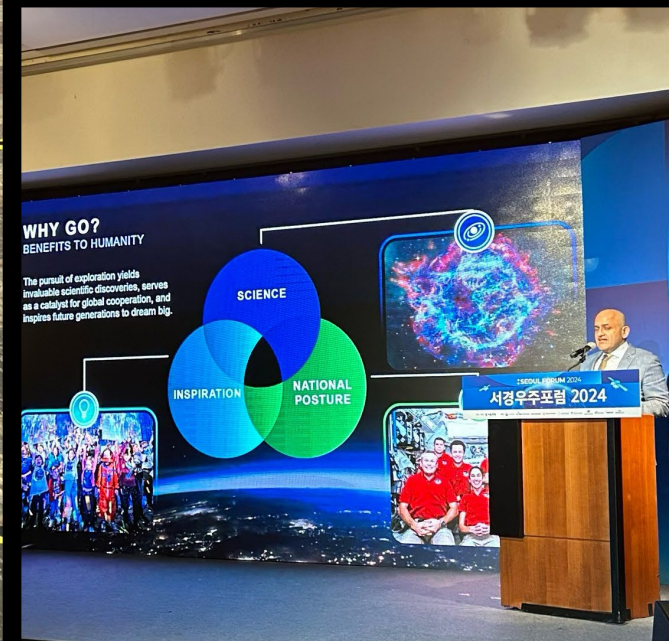
A.C. Charania | NASA Chief Technologist

September 24, 2024 | AWS Wind River Space Day

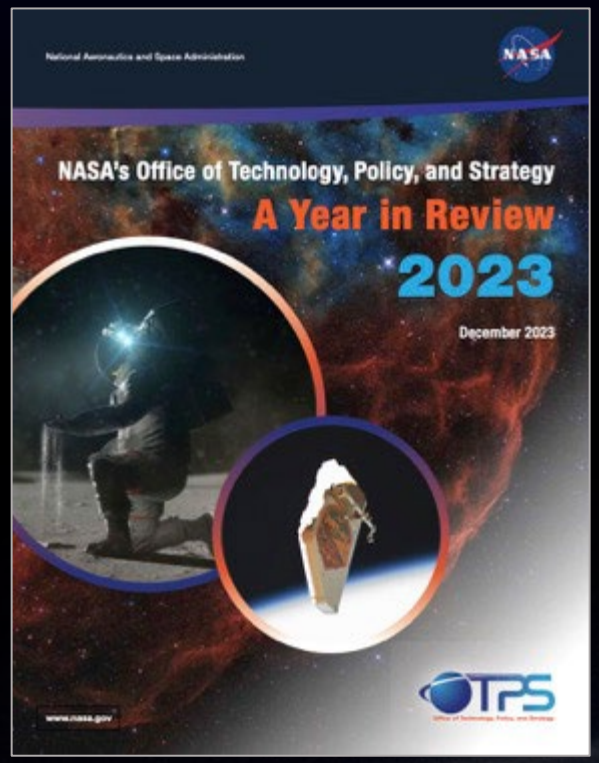


A.C. Charania

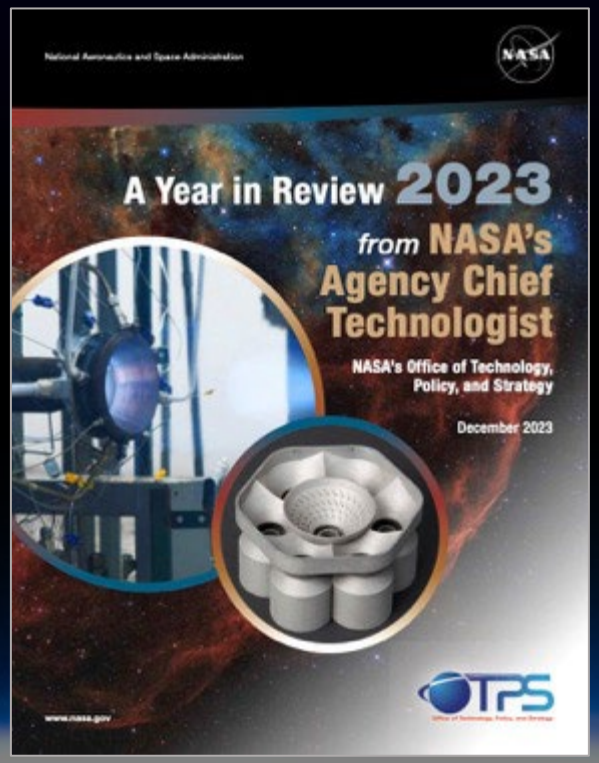
NASA CHIEF TECHNOLOGIST



OFFICE OF TECHNOLOGY, POLICY, AND STRATEGY (OTPS) AND AGENCY CHIEF TECHNOLOGIST (ACT) ANNUAL REPORTS



Scan to read the OTPS Year in Review 2023



Scan to read the Agency Chief Technologist Year in Review 2023

View All Public OTPS Reports

Vision

Exploring the secrets of the universe for the benefit of all.

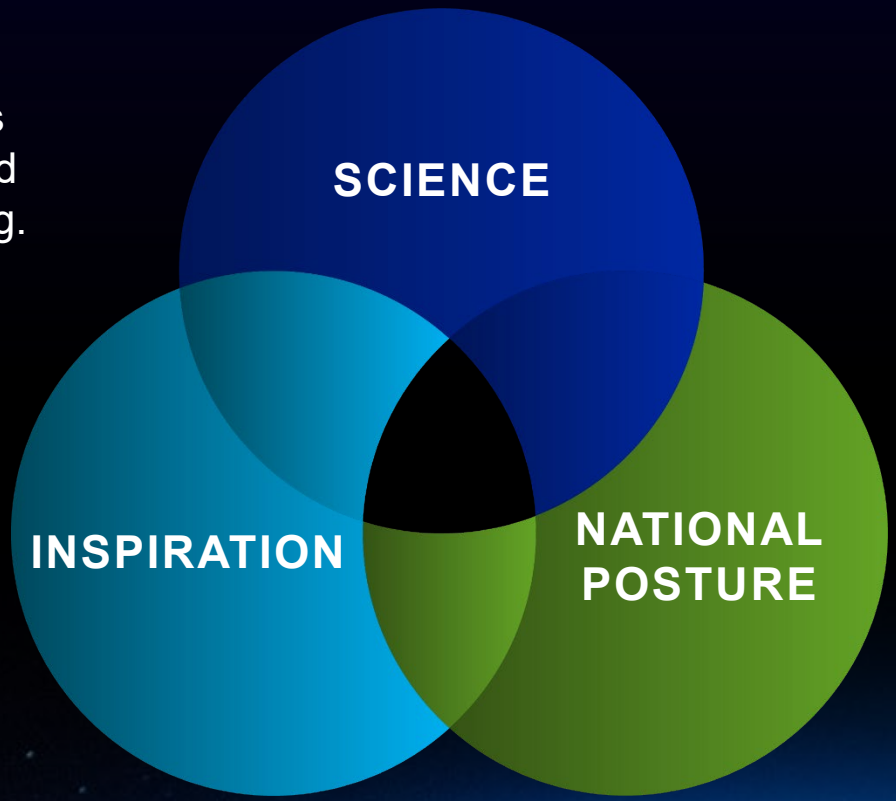
Mission

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

WHY GO?

BENEFITS TO HUMANITY

The pursuit of exploration yields invaluable scientific discoveries, serves as a catalyst for global cooperation, and inspires future generations to dream big.

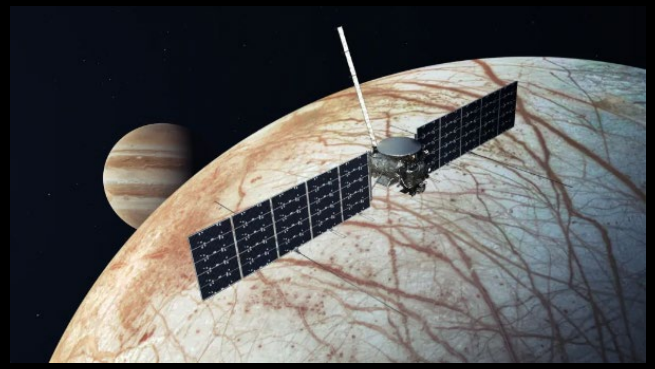


NASA Directorates

Aeronautics
Research Mission Directorate - ARMD

Space Technology
Mission Directorate - STMD

Science
Mission Directorate - SMD

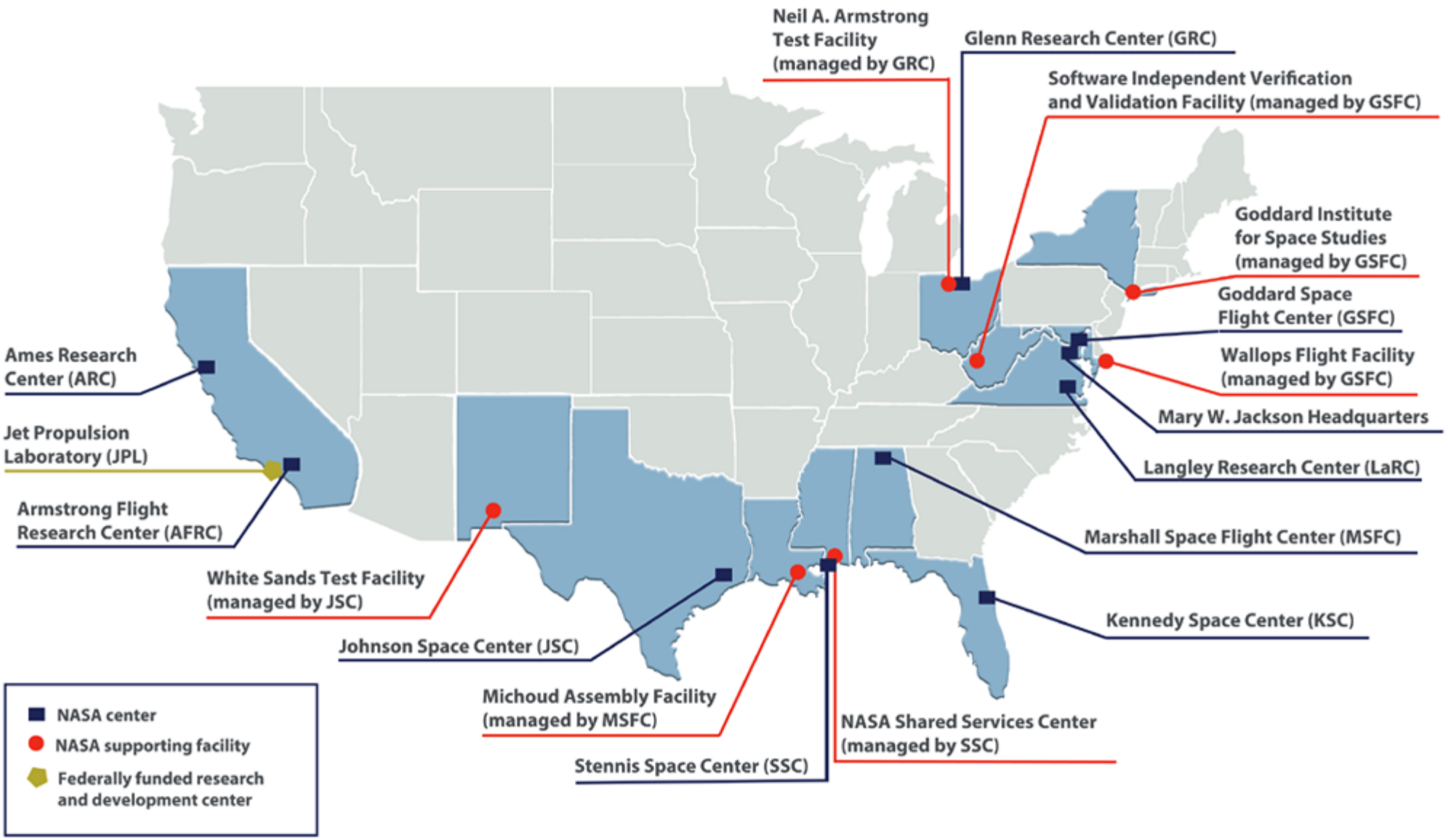


Exploration Systems Development
Mission Directorate - ESDMD

Space Operations
Mission Directorate - SOMD

Mission Support
Directorate – MSD

NASA Centers and Facilities



ARTEMIS I

First Mission
(Uncrewed Flight Test)

COMPLETE

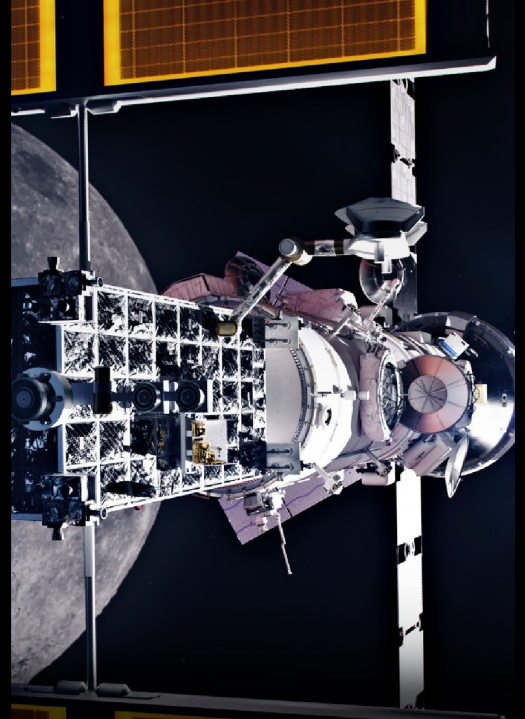
ARTEMIS II

First Crew

ARTEMIS III

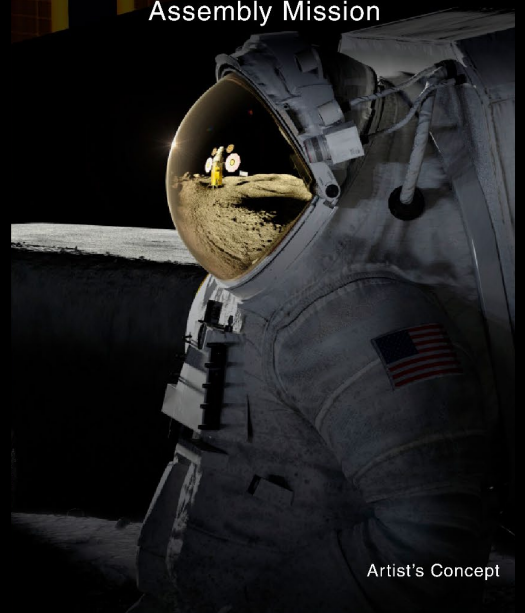
First Human Surface Landing

Artist's Concept



ARTEMIS IV

First Lunar Space Station
Assembly Mission



Artist's Concept

ARTEMIS V

Crewed Mobile Surface Exploration,
Gateway Expansion

Artist's Concept

ARTEMIS I

MISSION TYPE

Uncrewed lunar flight test

MISSION DURATION

25 days, 10 hours, 53 minutes

LAUNCH

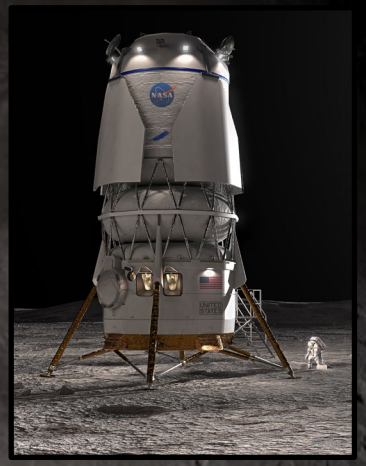
Nov. 16, 2022

SPLASHDOWN

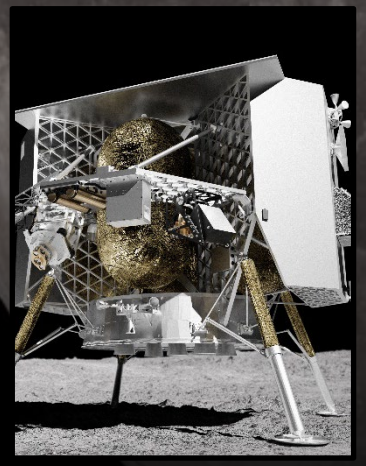
Dec. 11, 2022

LUNAR CAPABILITIES AND **TECHNOLOGY**

SPACEX

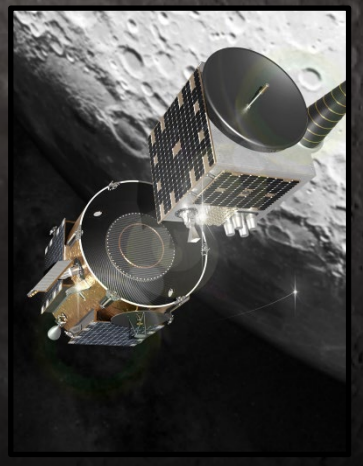


BLUE ORIGIN



ASTROBOTIC TECHNOLOGY

INTUITIVE MACHINES



FIREFLY AEROSPACE

DRAPER LABORATORY

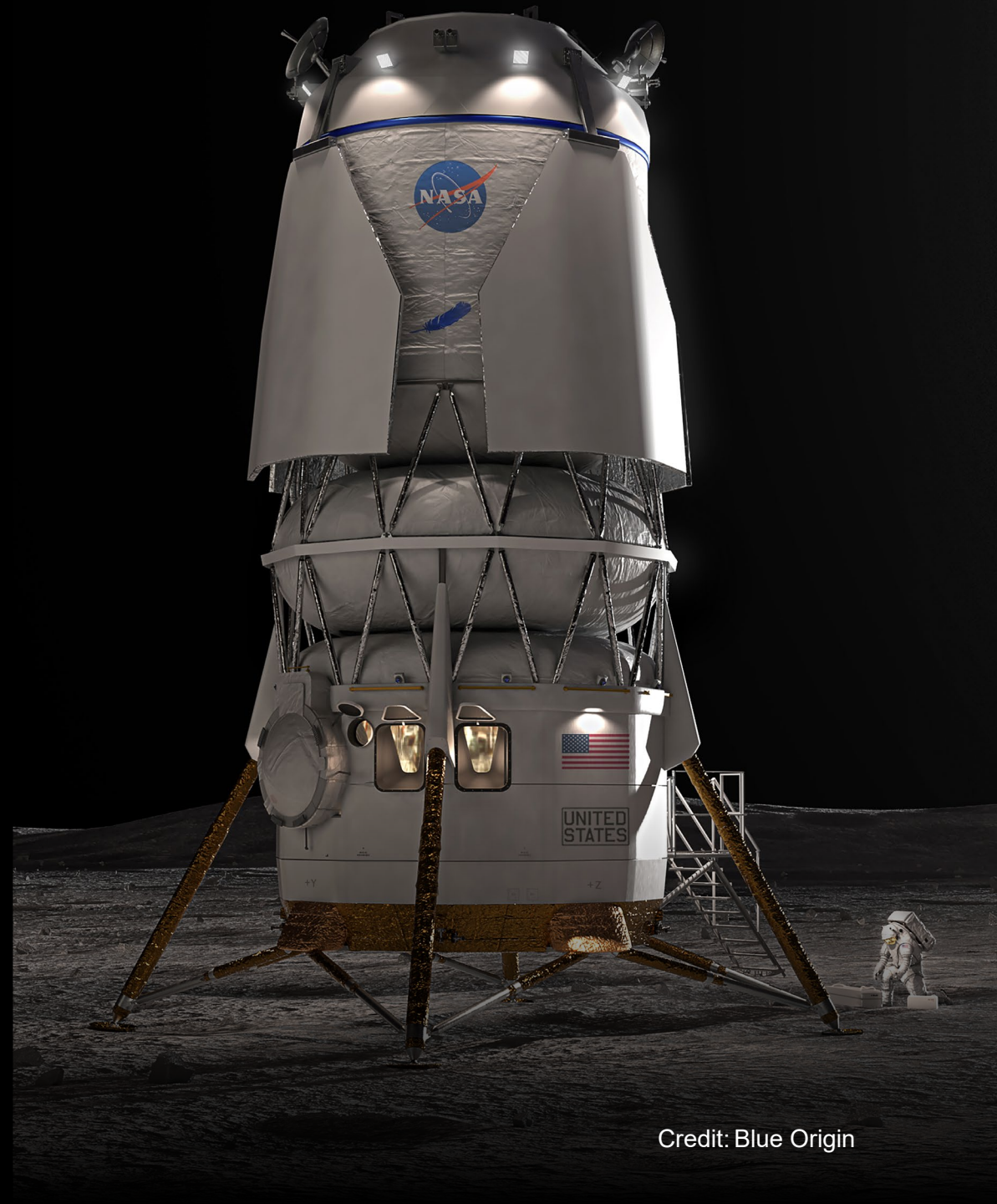
CLPS Landing: Intuitive Machines

IM-1 MISSION

Human Landing System

H L S

Credit: SpaceX

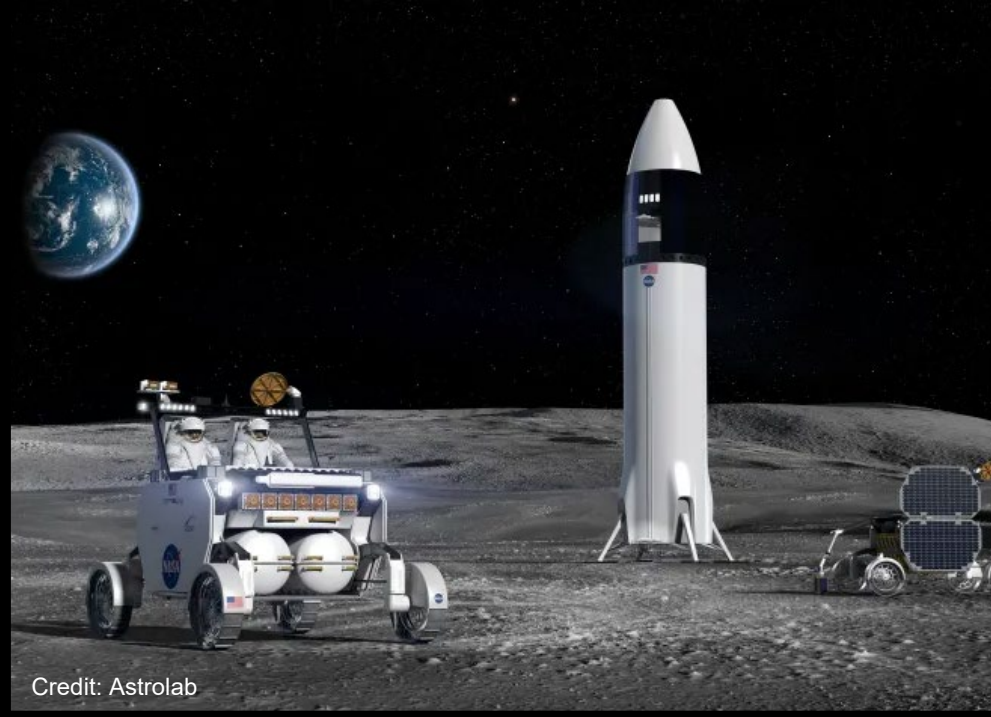


Credit: Blue Origin

Lunar Terrain Vehicle

L T V

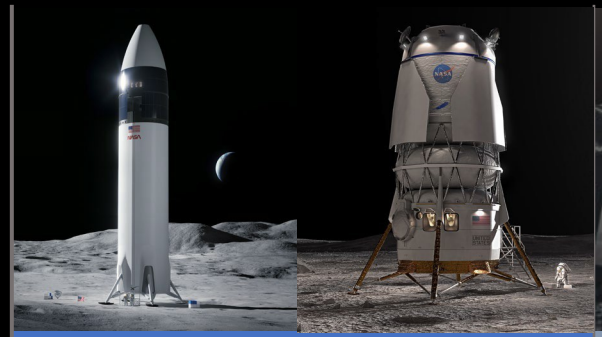
Credit: Intuitive Machines



Credit: Astrolab

Credit: Lunar Outpost

Moon to Mars Segments



Human Lunar Return

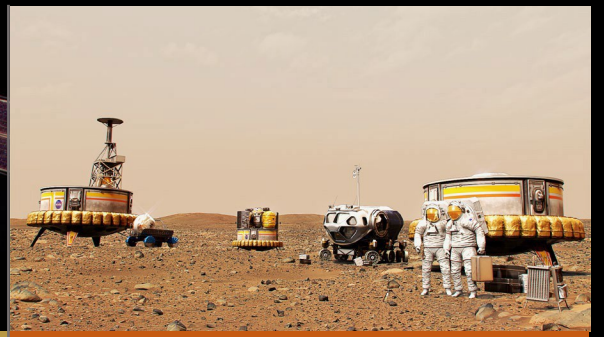
Initial capabilities, systems, and operations necessary to re-establish human presence and initial utilization (science, etc.) on and around the Moon.

Foundational Exploration

Expansion of lunar capabilities, systems, and operations supporting complex orbital and surface missions to conduct utilization (science, etc.) and Mars forward precursor missions.

Sustained Lunar Evolution

Enabling capabilities, systems, and operations to support regional and global utilization (science, etc.), economic opportunity, and a steady cadence of human presence on and around the Moon.



Humans to Mars

Initial capabilities, systems, and operations necessary to establish human presence and initial utilization (science, etc.) on Mars and continued exploration.

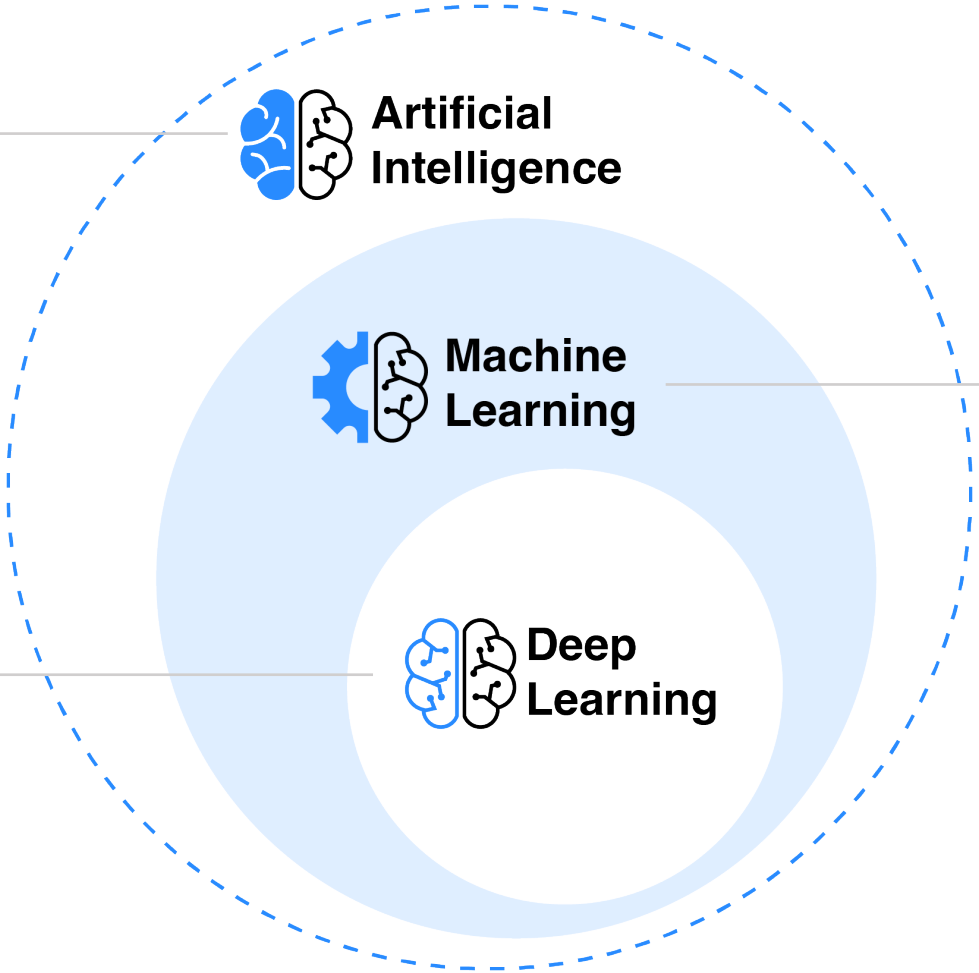
DEFINING ARTIFICIAL INTELLIGENCE

ARTIFICIAL INTELLIGENCE REFERS TO COMPUTER SYSTEMS THAT CAN PERFORM COMPLEX TASKS NORMALLY DONE BY HUMAN-REASONING, DECISION MAKING, CREATING, ETC.

ARTIFICIAL INTELLIGENCE

Computer systems that can perform tasks normally done by humans – reasoning, decision making, creating, etc.

For official purposes, NASA uses the definition from the 2019 National Defense Authorization Act, a de facto government standard



MACHINE LEARNING

Subset of AI that uses statistical methods to enable machines to improve with experience using datasets vs. programming

DEEP LEARNING

Subset of ML that uses neural networks (processing that imitates brain neurons)

AI DEFINITION FROM THE 2019 NATIONAL DEFENSE AUTHORIZATION ACT

AI includes the following:

1. Any artificial system that performs tasks under varying and unpredictable circumstances without significant human oversight, or that can learn from experience and improve performance when exposed to data sets.
2. An artificial system developed in computer software, physical hardware, or other context that solves tasks requiring human-like perception, cognition, planning, learning, communication, or physical action.
3. An artificial system designed to think or act like a human, including cognitive architectures and neural networks.
4. A set of techniques, including machine learning that is designed to approximate a cognitive task.
5. An artificial system designed to act rationally, including an intelligent software agent or embodied robot that achieves goals using perception, planning, reasoning, learning, communicating, decision-making, and acting.

TYPES OF AI AND DIFFERENCES

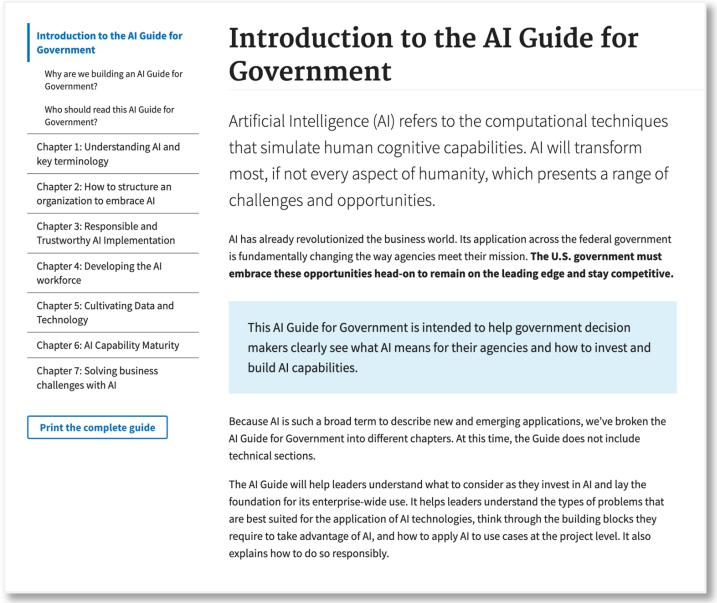
- **AI (Artificial Intelligence):** The broad field of creating machines or software that can perform tasks usually requiring human intelligence, such as learning, reasoning, and problem-solving.
- **ML (Machine Learning):** A subset of AI focused on building systems that can learn from data and improve their performance over time without being explicitly programmed.
- **LLM (Large Language Model):** An LLM is an advanced AI system trained on vast amounts of text data to understand and generate human-like text.
- **GPT (Generative Pre-trained Transformer)**: GPT is a type of LLM specifically designed to generate coherent and contextually relevant text based on pre-training on large datasets
- **ChatGPT:** An AI chatbot based on the GPT model that can engage in conversations, answer questions, and generate text based on prompts.
- **GenAI (Generative AI):** AI that creates new content, such as text, images, music, or videos, based on the data it has been trained on.
- **NLP (Natural Language Processing):** A field of AI that focuses on the interaction between computers and human language, enabling machines to understand, interpret, and generate human language.

AI AND THE FEDERAL GOVERNMENT

GSA: “The AI Guide for Government”

“A living and evolving guide to the application of Artificial Intelligence for the U.S. federal government, provided by the GSA IT Modernization Center of Excellence.”

https://coe.gsa.gov/coe/ai-guide-for-government/introduction/index.html



Introduction to the AI Guide for Government

Why are we building an AI Guide for Government?

Who should read this AI Guide for Government?

Chapter 1: Understanding AI and key terminology

Chapter 2: How to structure an organization to embrace AI

Chapter 3: Responsible and Trustworthy AI Implementation

Chapter 4: Developing the AI workforce

Chapter 5: Cultivating Data and Technology

Chapter 6: AI Capability Maturity

Chapter 7: Solving business challenges with AI

Print the complete guide

Introduction to the AI Guide for Government

Artificial Intelligence (AI) refers to the computational techniques that simulate human cognitive capabilities. AI will transform most, if not every aspect of humanity, which presents a range of challenges and opportunities.

AI has already revolutionized the business world. Its application across the federal government is fundamentally changing the way agencies meet their mission. **The U.S. government must embrace these opportunities head-on to remain on the leading edge and stay competitive.**

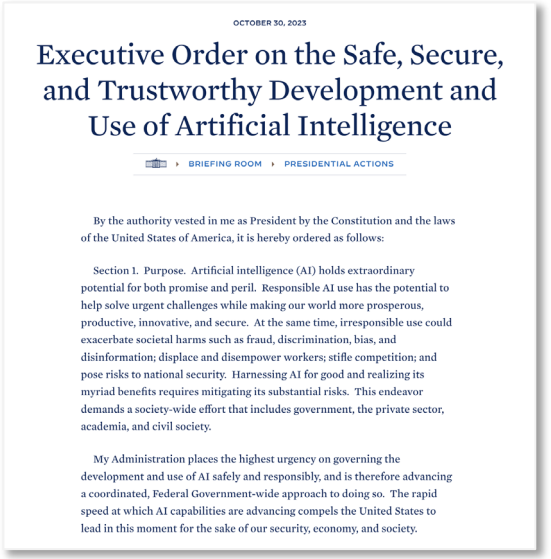
This AI Guide for Government is intended to help government decision makers clearly see what AI means for their agencies and how to invest and build AI capabilities.

Because AI is such a broad term to describe new and emerging applications, we've broken the AI Guide for Government into different chapters. At this time, the Guide does not include technical sections.

The AI Guide will help leaders understand what to consider as they invest in AI and lay the foundation for its enterprise-wide use. It helps leaders understand the types of problems that are best suited for the application of AI technologies, think through the building blocks they require to take advantage of AI, and how to apply AI to use cases at the project level. It also explains how to do so responsibly.

White House: “Executive Order 14110"

“Artificial intelligence (AI) holds extraordinary potential for both promise and peril. Responsible AI use can help solve urgent challenges and enhance prosperity, productivity, and security. [...] Irresponsible use could exacerbate societal harms, displace workers, stifle competition, and pose national security risks. Harnessing AI for good requires mitigating its substantial risks [...] through a society-wide effort involving government, the private sector, academia, and civil society.”



OCTOBER 30, 2023

Executive Order on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence

BRIEFING ROOM › PRESIDENTIAL ACTIONS

By the authority vested in me as President by the Constitution and the laws of the United States of America, it is hereby ordered as follows:

Section 1. Purpose. Artificial intelligence (AI) holds extraordinary potential for both promise and peril. Responsible AI use has the potential to help solve urgent challenges while making our world more prosperous, productive, innovative, and secure. At the same time, irresponsible use could exacerbate societal harms such as fraud, discrimination, bias, and disinformation; displace and disempower workers; stifle competition; and pose risks to national security. Harnessing AI for good and realizing its myriad benefits requires mitigating its substantial risks. This endeavor demands a society-wide effort that includes government, the private sector, academia, and civil society.

My Administration places the highest urgency on governing the development and use of AI safely and responsibly, and is therefore advancing a coordinated, Federal Government-wide approach to doing so. The rapid speed at which AI capabilities are advancing compels the United States to lead in this moment for the sake of our security, economy, and society.

NASA'S APPROACH TO AI GOING FORWARD

AI Readiness

"What does 'AI-Ready' mean?

It means taking steps to collect data around relevant systems, equipment, and procedures, and storing and curating that data in a way that makes it easily accessible to others for use in future AI applications.

An AI-Ready organization is one that is prepared to effectively implement and leverage AI technologies to drive mission outcomes."

Guiding Principles

- Maximize benefit, manage risk
- Amplify existing mission AI momentum
- Empower workers with AI
- Governance: coordination vs. control
- Share best practices, pool investments
- Learn & evolve

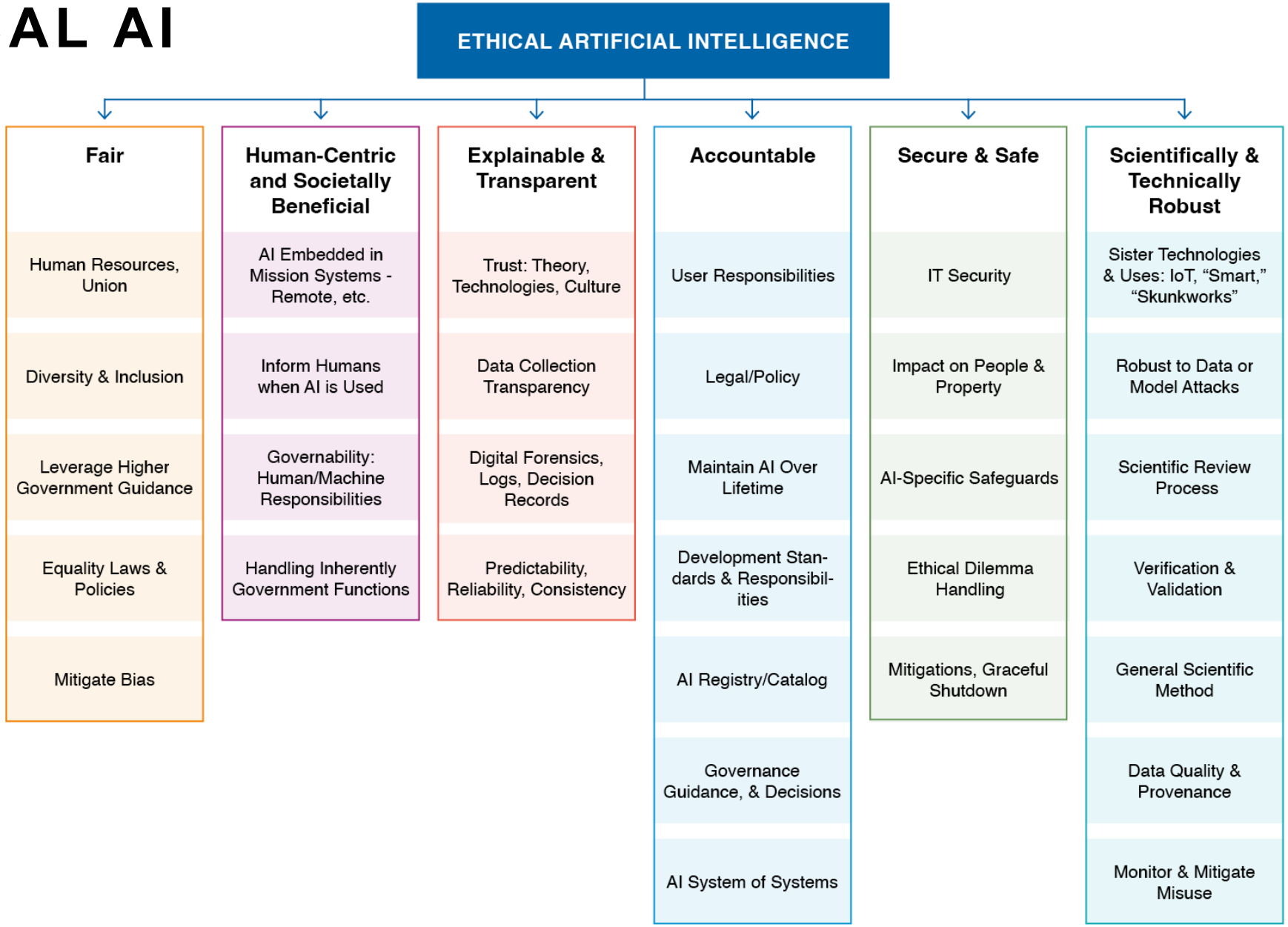
David Salvagnini
NASA Chief Data Officer
NASA Chief AI Officer

As NASA's Chief Data Officer and Chief Artificial Intelligence Officer, Salvagnini fosters synergy between these critical roles, especially in assuring data readiness for responsible and transparent use of artificial intelligence (AI).

Read interview with David Salvagnini at AIAA.org:
https://aerospaceamerica.aiaa.org/departments/nasas-ai-czar/

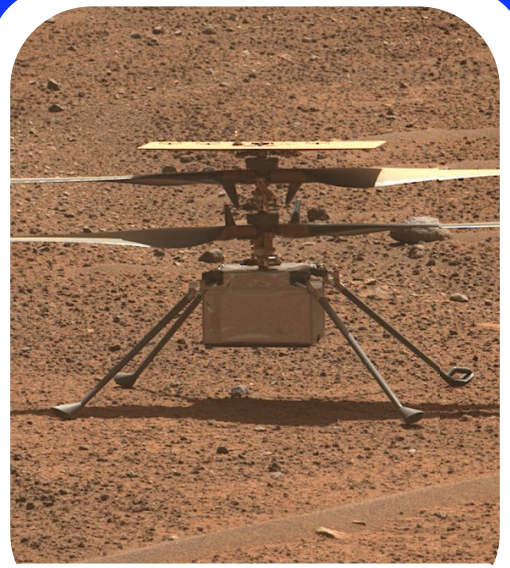
AI Town Hall
Hear NASA administrators speak on AI at NASA, May 2024 in a recorded, public Town Hall:
https://www.youtube.com/watch?v=n3LH7Hd0L5s

ETHICAL AI

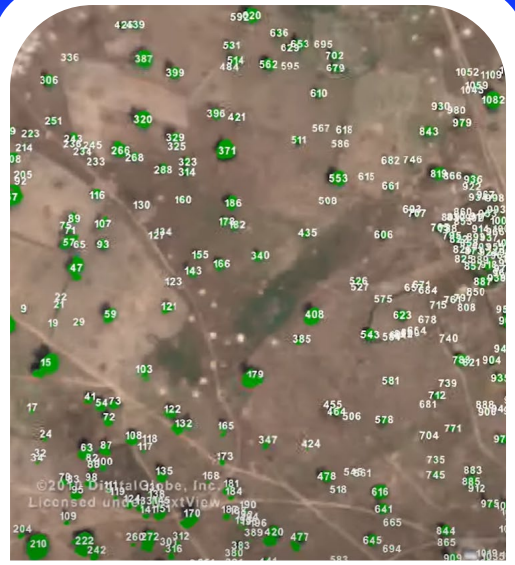

ETHICAL ARTIFICIAL INTELLIGENCE
Fair
Human Resources, Union
Diversity & Inclusion
Leverage Higher Government Guidance
Equality Laws & Policies
Mitigate Bias
Human-Centric and Societally Beneficial
AI Embedded in Mission Systems - Remote, etc.
Inform Humans when AI is Used
Governability: Human/Machine Responsibilities
Handling Inherently Government Functions
Explainable & Transparent
Trust: Theory, Technologies, Culture
Data Collection Transparency
Digital Forensics, Logs, Decision Records
Predictability, Reliability, Consistency
Accountable
User Responsibilities
Legal/Policy
Maintain AI Over Lifetime
Development Standards & Responsibilities
AI Registry/Catalog
Governance Guidance, & Decisions
AI System of Systems
Secure & Safe
IT Security
Impact on People & Property
AI-Specific Safeguards
Ethical Dilemma Handling
Mitigations, Graceful Shutdown
Scientifically & Technically Robust
Sister Technologies & Uses: IoT, "Smart," "Skunkworks"
Robust to Data or Model Attacks
Scientific Review Process
Verification & Validation
General Scientific Method
Data Quality & Provenance
Monitor & Mitigate Misuse

ADVANCING AI AND BENEFITING HUMANITY

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING AS AN ENABLING FORCE



Missions



Science

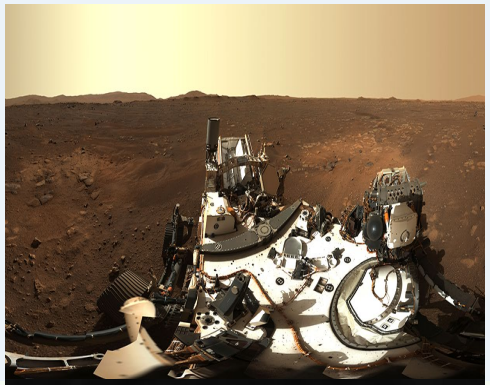
Working Digitally

MISSION VALUE FROM AI@NASA

Enable the Impossible

Mission-Embedded AI:

Rovers, Satellites, Spacecraft, Aircraft, UAS, Habitats, Coordination & Control…

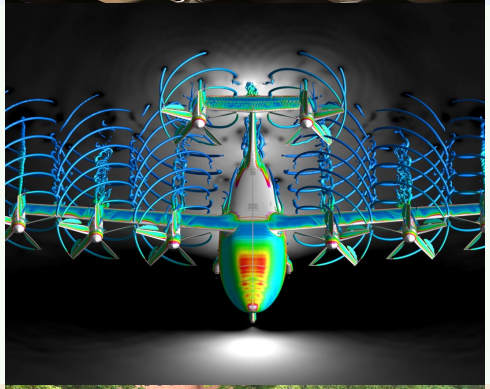


- AI Image Analysis for Space Inspection (e.g., Glove)
- Enable Scaled Air Traffic Control
- Detect and Recover from Emergencies
- Early Warning of Severe Storms
- Discover ExoPlanets and Multi-Star Systems

Improve Safety

Mission-Enabling AI:

Research, Engineering, Science; Labs, Experiments, Tests, Requirements, Plans, Analysis…



- AI-Assisted Vehicle Design / Engineering
- AI-Enabled Project Management
- AI-Augmented PSR Images for Lunar Plans
- AI-Augmented System Engineering
- Predictive Modeling – AI-Enhanced Digital Twin

Save Resources

AI in Mission Support:

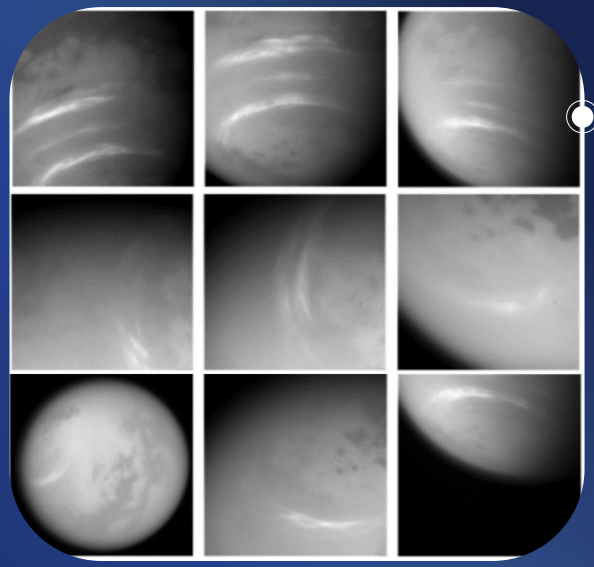
Finance, Procurement, Information Technology, Security, Facilities, Human Resources…

- Automate Repetitive Processes
- Condition Based Facilities Maintenance
- AI-Fueled IT Security
- HR – Resume Reviews; Performance
- AI-Enabled Financial Analysis & Fraud Det.

NASA FY2023 AI INVENTORY

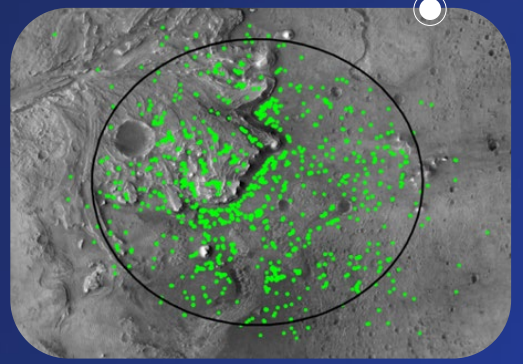
Bureau / Department	Summary of Use Case
Ames Research Center	Testing complex systems often requires computationally intensive Monte Carlo sampling approach
Marshall Space Flight Center	Deep learning-based airplane detection from high-resolution satellite imagery
Glenn Research Center	PeTaL (the Periodic Table of Life) is an open source artificial intelligence (AI) design tool that lever
Jet Propulsion Laboratory	Based on AI techniques, ASPEN is a modular, reconfigurable application framework which is capabl
Marshall Space Flight Center	Uses a U-Net based architecture with VGG-19 as an encoder block and custom decoder block to map
Jet Propulsion Laboratory	Due to the communication paradigm associated with operating an underwater submersible on an C
Langley Research Center	Using an existing security camera and YOLO Machine Learning model to detect and count number o
Ames Research Center	RNA sequencing data from spaceflown and control mouse liver samples, sourced from NASA Genel
Ames Research Center	This study uses fluorescence microscopy images from the Biological and Physical Sciences Open Sci
Jet Propulsion Laboratory	The Compressed Large-scale Activity Scheduling and Planning (CLASP) project is a long-range schec
Marshall Space Flight Center	Uses a U-Net based architecture to map surface water using the Sentinel-1 SAR Images
Marshall Space Flight Center	A web-based situational awareness tool that uses deep learning on satellite images to objectively
Goddard Space Flight Center	Machine Learning applied to Galileo space probe imagery to detect and classify ice blocks in the ch
Marshall Space Flight Center	Deep analyses on image datasets from different satellites. Machine learning will help to identify th
Marshall Space Flight Center	Natural Language Processing-based science keyword suggestion tool
Langley Research Center	Three capstone projects conducted 2021-2022 with Georgia Tech and University of Rochester to dev
Ames Research Center	Our project conducts high-performance scalable and explainable machine learning for flight-opera
Jet Propulsion Laboratory	Future space missions will enable unprecedented monitoring of the Earth's environment and will g
Marshall Space Flight Center	Web-based Collaborative Machine Learning Training Data Generation Tool
Glenn Research Center	Discovering new materials is typically a mix of art and science, with timelines to create and robustl
Langley Research Center	In near real-time, the Lessons Learned Bot, or LLB, brings lessons learned (LL) documents to users t
Marshall Space Flight Center	Uses a U-Net based architecture with MobileNetV2 based encoder with transfer learning from glob
Jet Propulsion Laboratory	MEXEC is a lightweight, multi-mission software for activity scheduling and execution developed to
Jet Propulsion Laboratory	The M2020 onboard scheduler incrementally constructs a feasible schedule by iterating through act
Langley Research Center	NASA Langley Research Center (LaRC) is actively experimenting with Unmanned Aerial Systems (UA
Marshall Space Flight Center	Uses a long short-term memory model to predict streamflow at USGS gauges sites with inputs from

NASA'S USE OF **AI/ML**

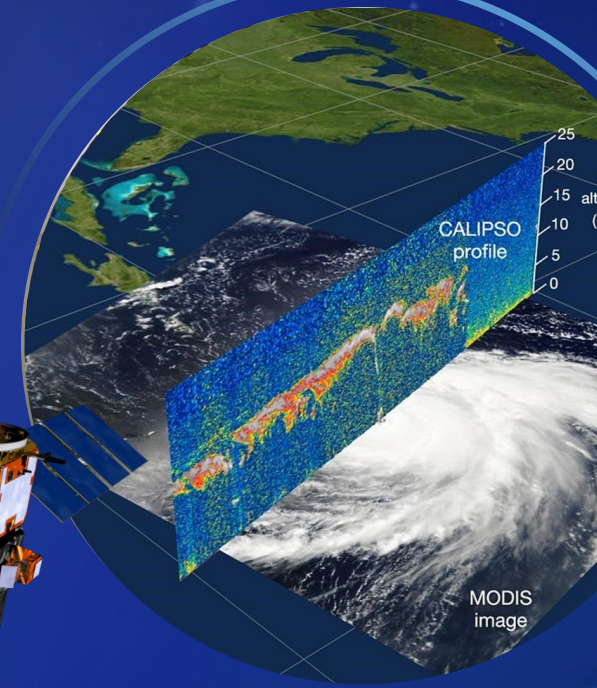


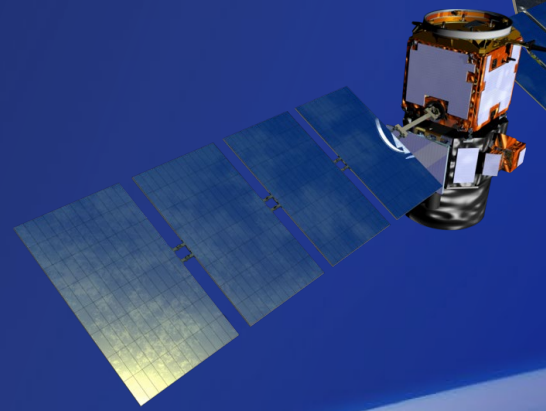
TITAN METHANE CLOUD DETECTION

TERRAIN RELATIVE NAVIGATION: AUTONOMOUS, VISION-BASED SYSTEM FOR LANDMARK RECOGNITION, SPACECRAFT POSITION ESTIMATION, AND SPACECRAFT RETARGETING

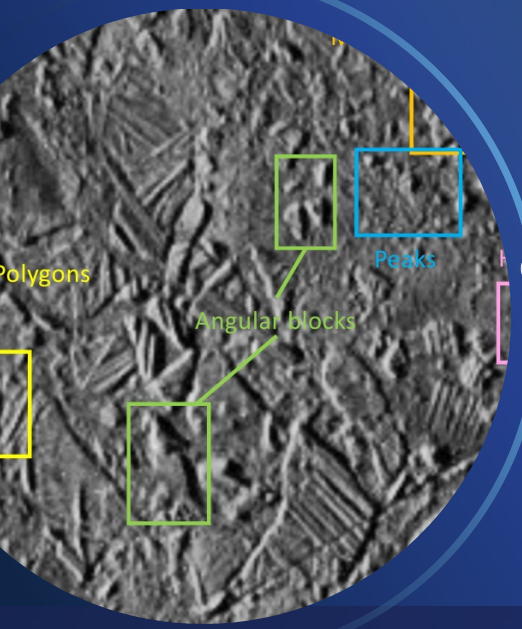


GEOPHYSICAL OBSERV S TOOLKIT FOR EVALUA CORAL HEALTH





PERIODIC TABLE OF LIFE (PETAL): TOOL AND OPEN-SOURCE FRAMEWORK THAT USES ARTIFICIAL INTELLIGENCE TO AID IN THE SYSTEMATIC INQUIRY OF BIOLOGY FOR ITS APPLICATION TO HUMAN SYSTEMS



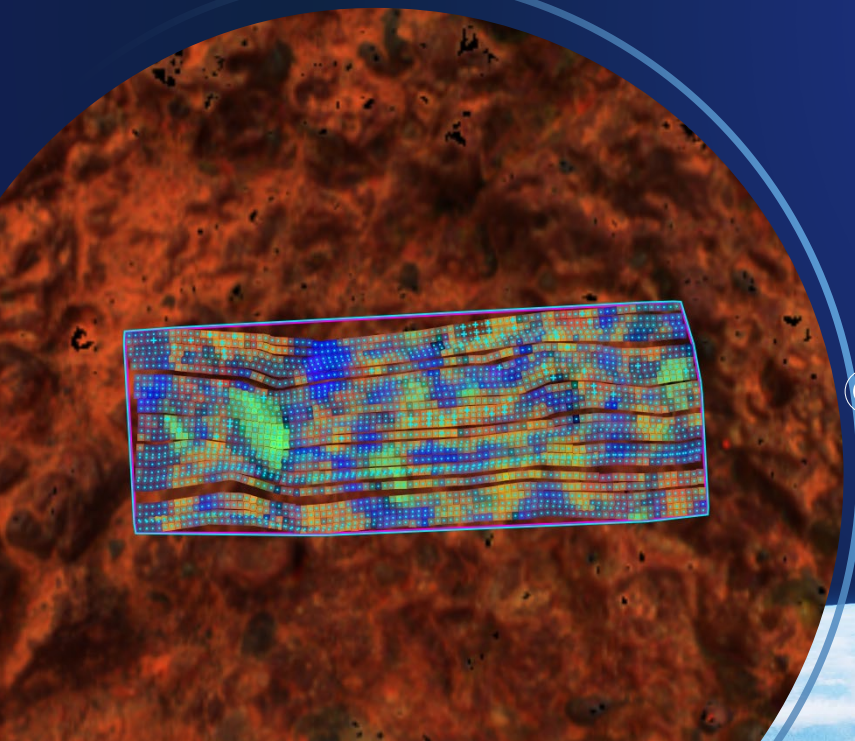
DETECTING ICE PLATES IN EUROPA'S CHAOS TERRAINS

> "ML will have large and increasing role to play in planetary exploration, including not just science applications but also in engineering and autonomous operations and decision making."
>
> *– IEEE Paper (Nixon, C., et. Al) October 2023*

ARTIFICIAL INTELLIGENCE (AI) / MACHINE LEARNING (ML) CASE STUDY

ARTIFICIAL INTELLIGENCE IS HELPING SCIENTISTS TO IDENTIFY MINERALS WITHIN ROCKS STUDIED BY THE PERSEVERANCE ROVER ON MARS

"ADAPTIVE SAMPLING," THE SOFTWARE AUTONOMOUSLY POSITIONS THE INSTRUMENT CLOSE TO A ROCK TARGET, THEN LOOKS AT SCANS OF THE TARGET TO FIND MINERALS WORTH EXAMINING MORE DEEPLY.



DETERMINES THE MINERAL COMPOSITION OF ROCKS BY ZAPPING THEM WITH X-RAYs (BLUE DOTS IN THE IMAGE)

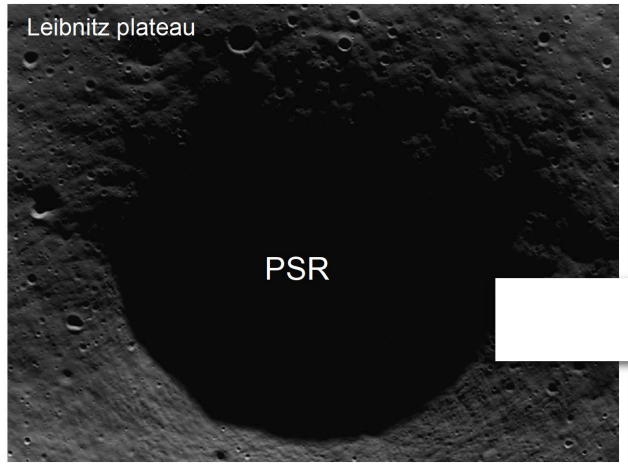
AI/ML CASE STUDY

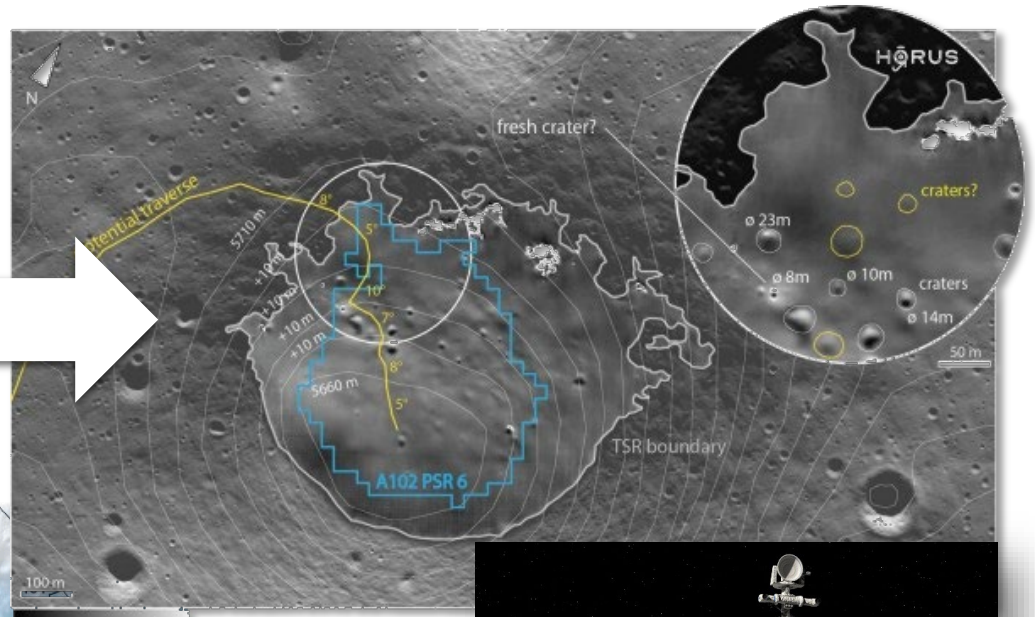
MISSION-EMBEDDED AI: LUNAR FEATURE DETECTION

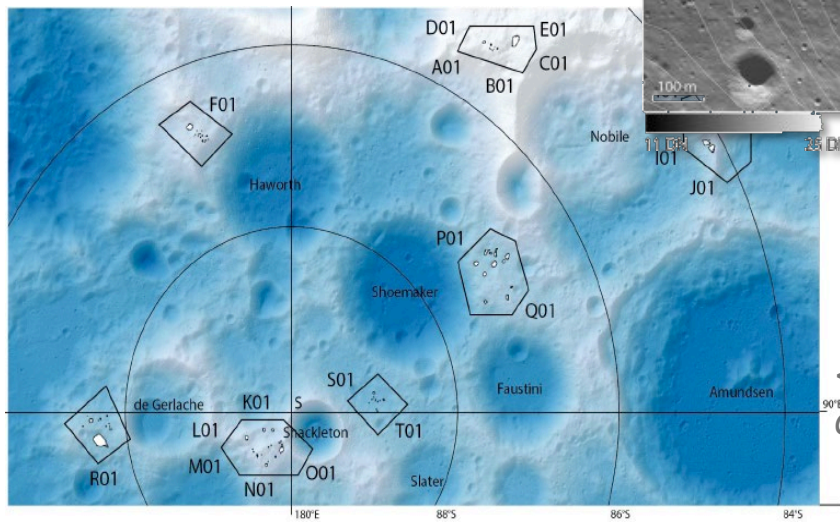
Leveraged ML for image processing of lunar dark-side data:

Produced >4,000 validated, high-resolution, low-noise images (22TB) with ~3 m feature resolution to **significantly reduce uncertainty** for landing site / traverse planning & science target selection for VIPER & other future missions

Ignacio Lopez-Francos
Ames Research Center



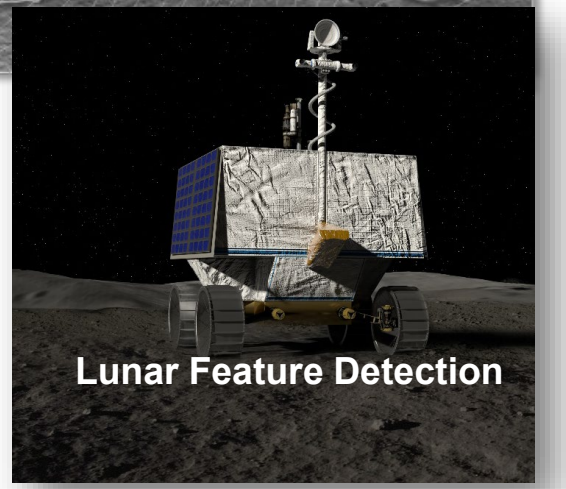




20 Landing Sites

<3m feature detection

22TB data



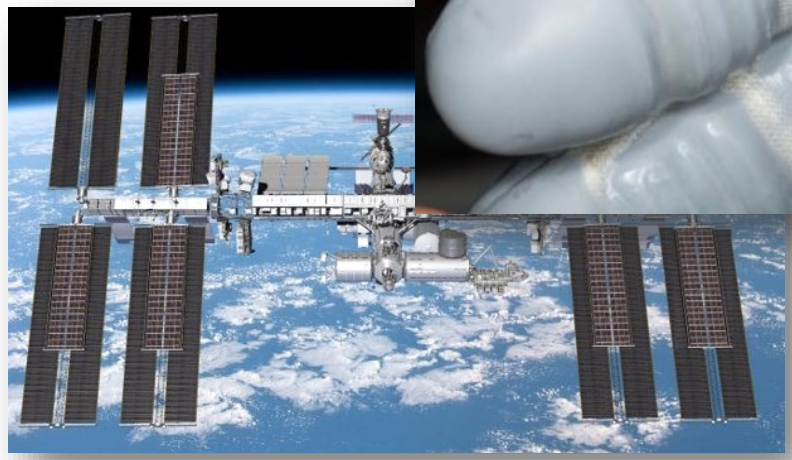
AI/ML CASE STUDY

MISSION-EMBEDDED AI: EVA GLOVE INSPECTION

December 2021:
First US AI/ML model on the International Space Station

AI/ML prototype performed diagnostics & generated a GO/NO-GO recommendation on the glove condition in **45 seconds**, a process that normally takes multiple days for a group of people.

Martin Garcia
Johnson Space Center



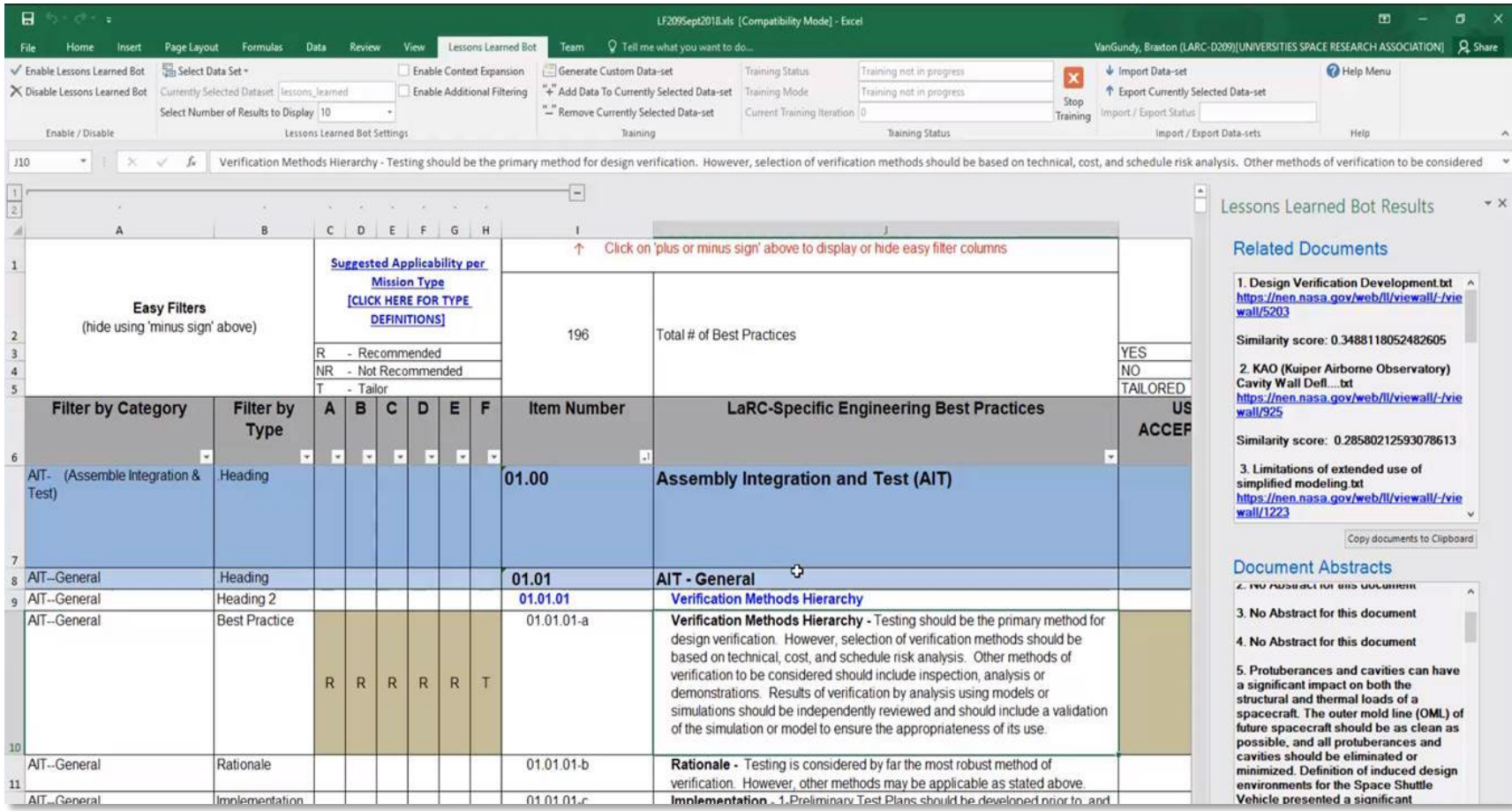
AI/ML CASE STUDY

MISSION-ENABLING AI: PROJECT MANAGER'S LESSONS LEARNED ASSISTANT

Centralized, contextualized, real-time intelligent (NLP/ML) document content search

provides **real-time alerts** to Project Managers on possible risks

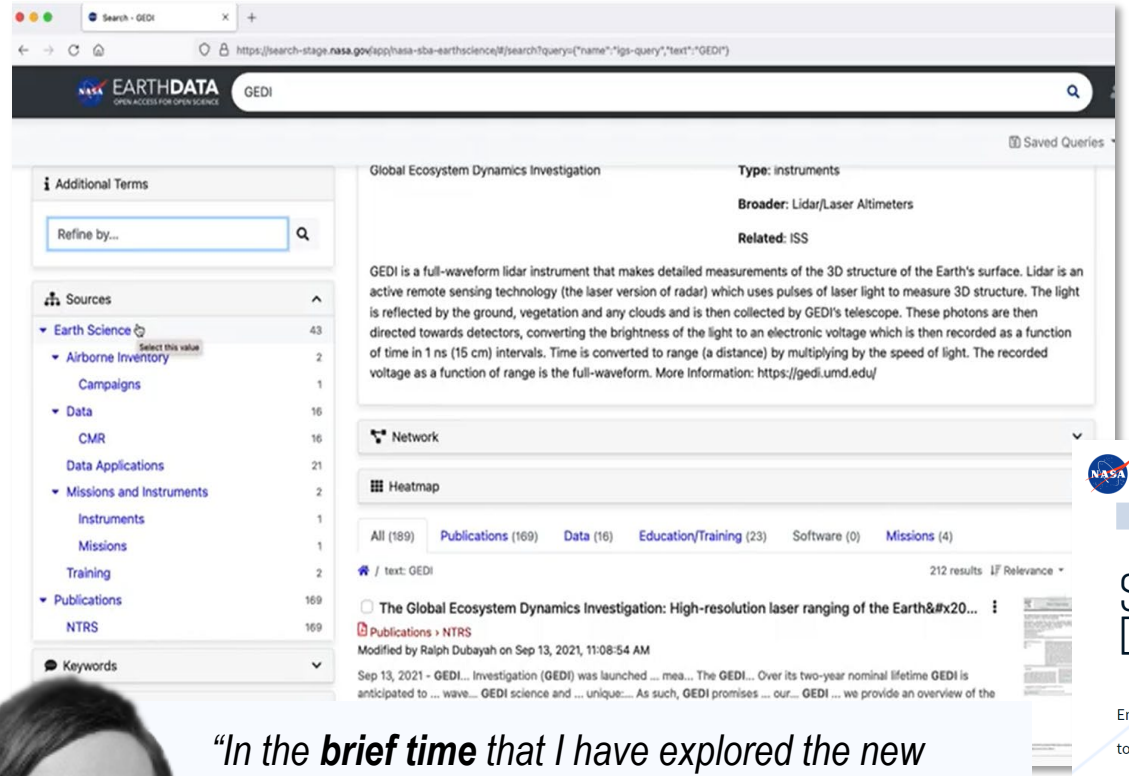
Nipa Phojanamongkolkij
Langley Research Center



Project Manager's Lessons Learned Assistant

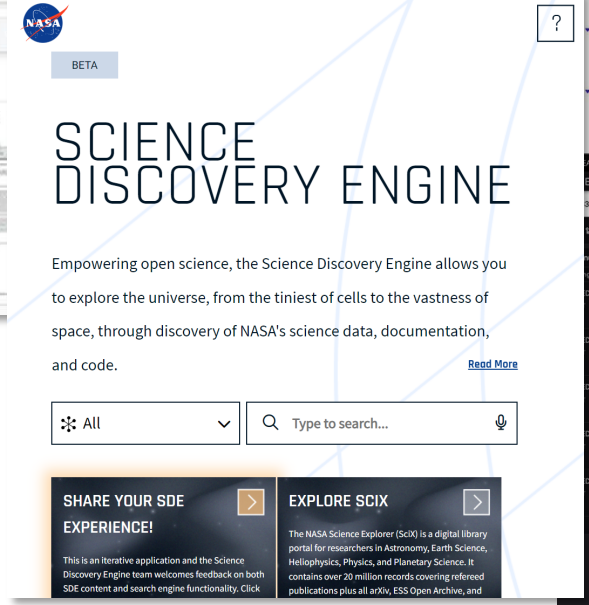
AI/ML CASE STUDY

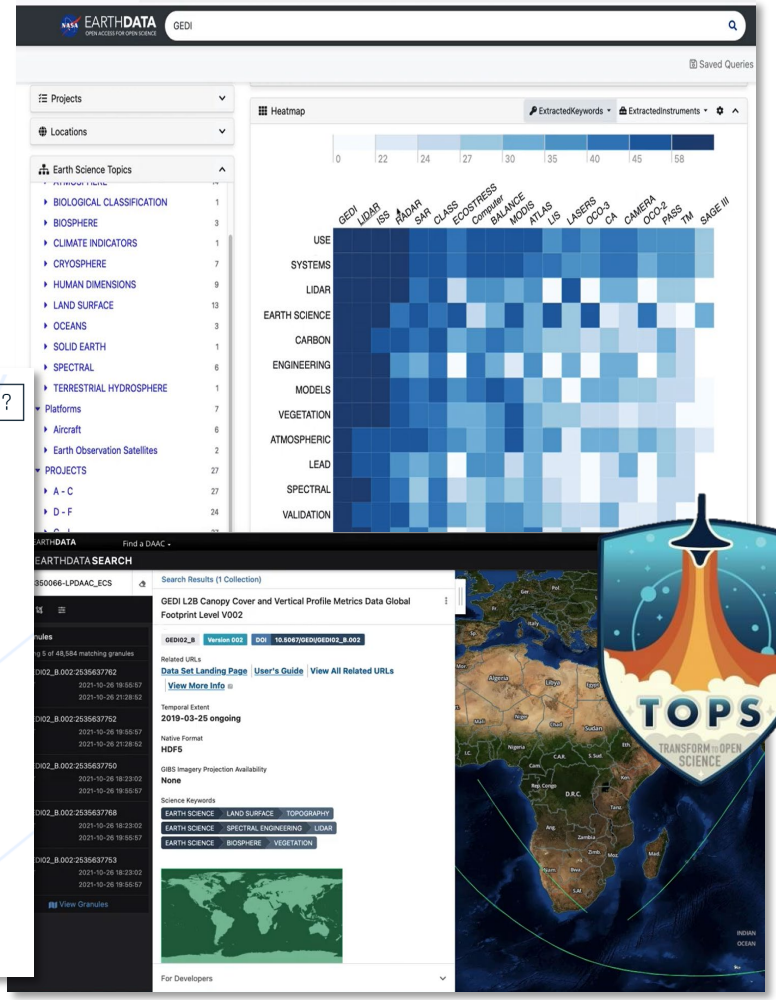
MISSION-ENABLING AI: SCIENCE DISCOVERY ENGINE



*"In the **brief time** that I have explored the new search interface, I was **able to learn a lot** about the GEDI mission, the data that are available, and the calibration & validation that have occurred."*

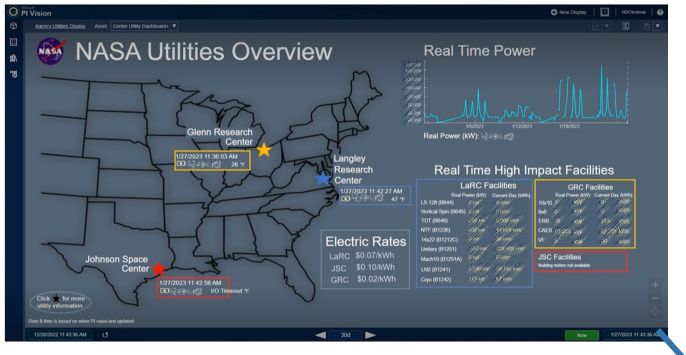
Kaylin Bugbee
Marshall Space Flight Center





AI/ML CASE STUDY

AI IN MISSION SUPPORT: PREDICTIVE MAINTENANCE



Analyzing real-time data & insights into facilities/systems to ***predict probable failures***

Smart Centers today…

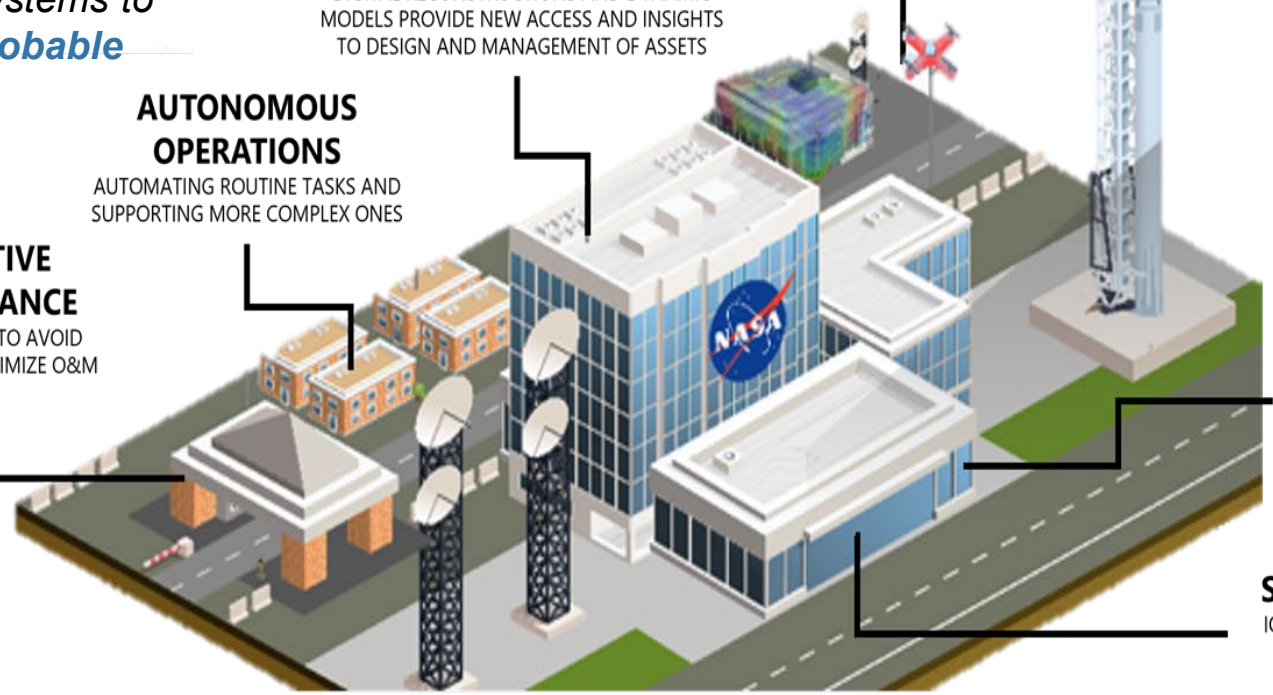
… enable **Smart Bases** tomorrow

sUAS INSPECTIONS
DRONES PROVIDE GREATER ACCESS AND NEW PERSPECTIVES FOR ASSESSING INFASTRUCTURE, FACILITIES AND ASSETS

DIGITAL TWINS
DIGITAL RECONSTRUCTIONS AND DYNAMIC MODELS PROVIDE NEW ACCESS AND INSIGHTS TO DESIGN AND MANAGEMENT OF ASSETS

AUTONOMOUS OPERATIONS
AUTOMATING ROUTINE TASKS AND SUPPORTING MORE COMPLEX ONES

PREDICTIVE MAINTENANCE
CBM AND AI/ML TO AVOID FAILURES AND OPTIMIZE O&M

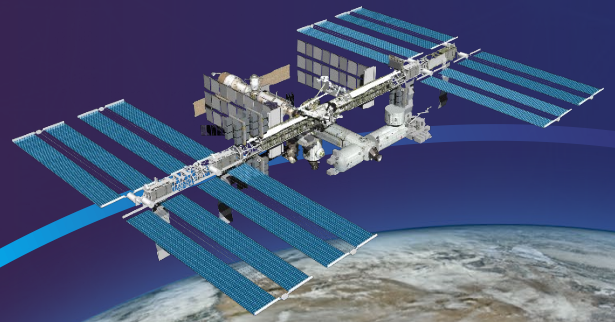


EXTENDED REALITY
AR/VR REMOTE PRESENCE FOR COLLABORATION AND SUPPORT

SPACE OPTIMIZATION
IOT SENSORS DRIVE OPTIMAL SPACE UTILIZATION AND WORKPLACE OF THE FUTURE

Benjamin Galke
Langley Research Center

National Aeronautics and Space Administration



DRIVING INNOVATION

Artificial Intelligence (AI)

A.C. Charania | NASA Chief Technologist

September 24, 2024 | AWS Wind River Space Day