National Aeronautics and Space Administration

# Model Based Systems Engineering (MBSE) At GSFC


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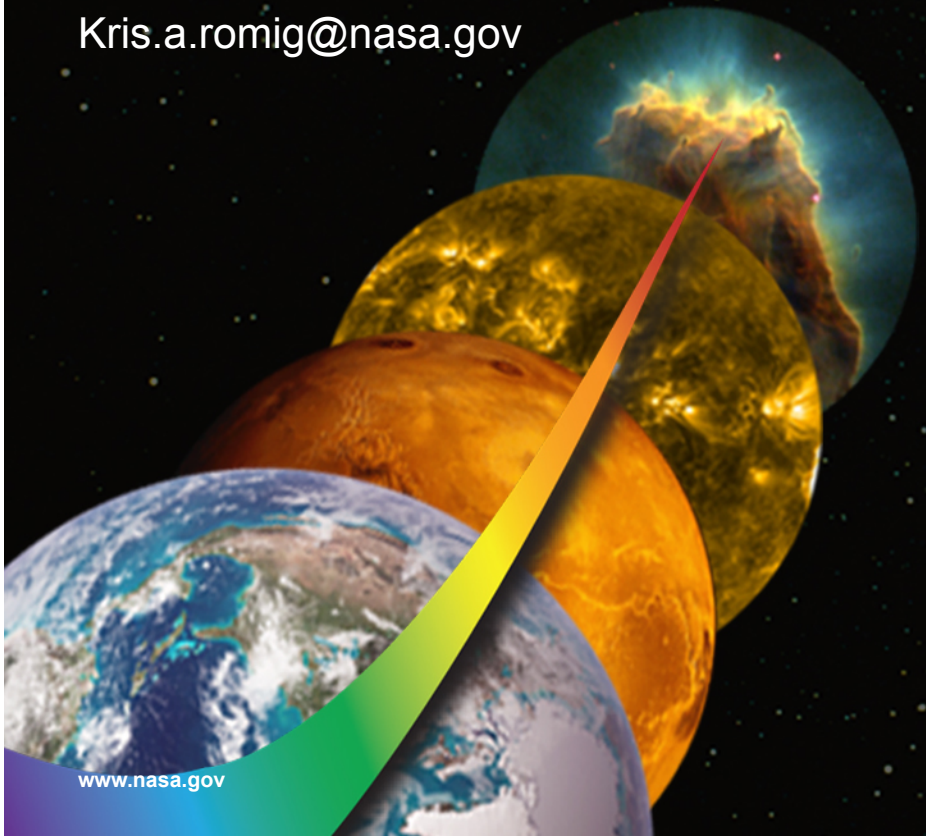

## Goddard Space Flight Center
## Instrument & Payload
## Systems Engineering Branch

MESA Code 590
MISSION ENGINEERING AND SYSTEMS ANALYSIS DIVISION

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# Agenda

- What is MBSE?
- So What?
- NASA Overview
- GSFC Goals/Objectives
- Where we're at
- Challenges
- What's next

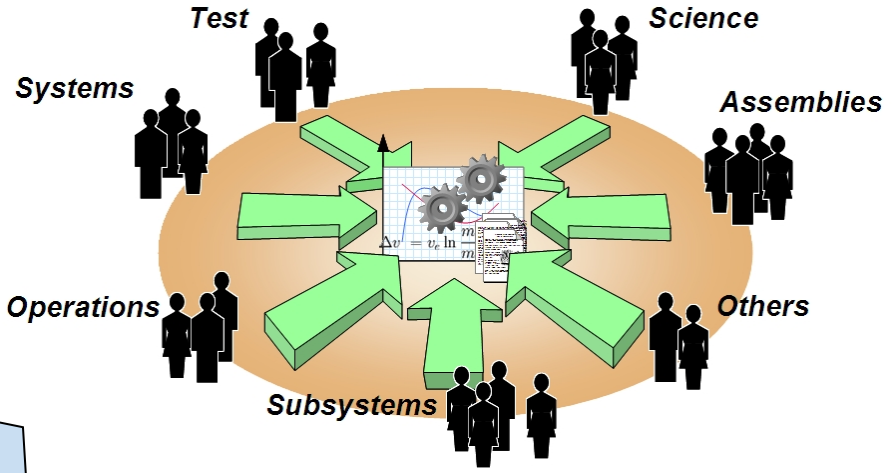
# What is MBSE?

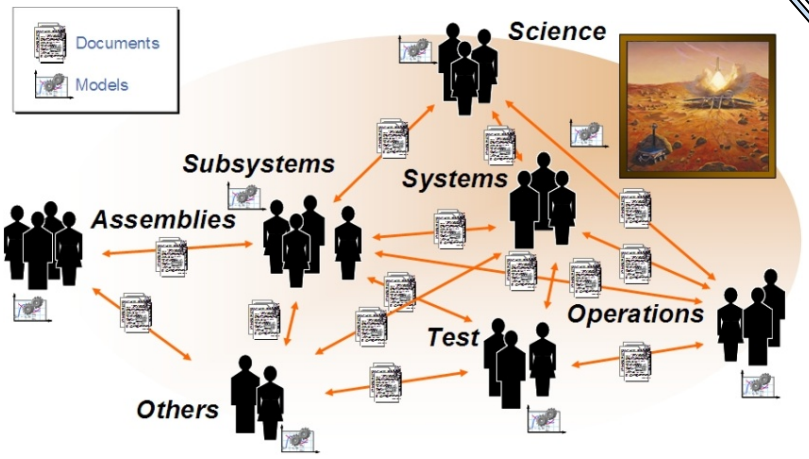
- **The INCOSE SE Vision 2020** defines MBSE as - The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. MBSE is part of a long-term trend toward model-centric approaches adopted by other engineering disciplines, including mechanical, electrical and software. In particular, MBSE is expected to replace the document-centric approach that has been practiced by systems engineers in the past and to influence the future practice of systems engineering by being fully integrated into the definition of systems engineering processes.

  http://www.omgwiki.org/MBSE/doku.php

- **Other Terms:** Digital Thread, Digital Tapestry, Single Source of Truth, Model Based Engineering, Model Based XYZ, Document Centric/Model Centric, etc

Advance from our current document-centric engineering practice to one in which model-based data representing the technical designs, as well as Program Management & Systems Engineering information, are integrated and evolve throughout the life-cycle




To do this we must:

- Enhance the ability to share and exchange information
- Improve workforce knowledge, skills and abilities
- Facilitate the exchange and adoption of model-based technical solutions and methodologies

# So What?

**Adoption of MBSE Tools/Methods is expected to:**

- Increase early life cycle design fidelity to better meet science requirements and improve proposal win rates;
- Reduce discrepancies between flight project documentation and reporting artifacts;
  - Reduce human data entry errors
- Enhance data exchange between programmatic and technical disciplines
- Improve decision makers' insight into project (technical, risk, cost/ schedule) trades and performance

- **Ultimate Goal:**
  - Enhance GSFC's ability to more effectively meet it's commitments through improved cost, schedule, and technical performance.

# Systems Engineering TDT
## Sampling of MBSE Across NASA

- **ARC**
  - ✓ Resource Prospector (RP) Mission
  - ✓ EuCROPIS Project
  - ✓ Intelligent Systems Division (Code TI)
- **GRC**
  - ✓ ARRM/SEP (in conjunction with JPL
  - ✓ Spacecraft Fire Safety Demonstration Project
  - ✓ SLS Mission and Fault Management
  - ✓ Space Communications and Navigation Program
  - ✓ AOSP SMART-NAS
  - ✓ AES Hab Comm Architecture (in conjunction with JSC)
- **GSFC**
  - ✓ JPSS
  - ✓ SCaN
  - ✓ ARRM
  - ✓ OSIRIS-Rex
  - ✓ SN – TDDF
  - ✓ SGSS
  - ✓ Sounding rockets
  - ✓ CATTENS
  - ✓ CubeSat Design Tool
  - ✓ S&MA MBE
- **JPL**
  - ✓ Europa Mission
  - ✓ Mars 2020
  - ✓ ARRM
  - ✓ Ni-SAR
  - ✓ SWOT
  - ✓ Mars Helicopter
  - ✓ RefBus, ELF
  - ✓ MSFC SLS and Europa Mission
- **JSC**
  - ✓ AES Hab Comm Architecture
- **LaRC**
  - ✓ Materials on ISS Experiment – X (MISSE-X)
  - ✓ On-orbit Autonomous Assembly of Nanosatellites (OAAN)
  - ✓ Engineering Design Studio (EDS)
  - ✓ Radiation Budget Instrument (RBI)
- **MSFC**

  **SLS**
  - ✓ Vehicle Integration
  - ✓ Payload Interface
  - ✓ Requirements Management
  - ✓ Advanced Concepts Trade Studies
  - ✓ Flight Software Development

# Systems Engineering TDT
## NASA MBSE Pathfinder

### 1. Architectures and Mission Campaigns

Demonstrate system modeling for mission architecture use and reuse for a campaign of missions. The campaign of Lunar Prospector, Lunar Sample Return, Human Lunar, Mars Sample Return, and Human Mars are being considered. The system modeling would be done at the mission and system levels. Show model re-use, requirement reuse, sensitivity analysis, consistency, change evaluation, technology evaluation, etc.

### 2. Additive Manufacturing and Re-Tooling Engineering

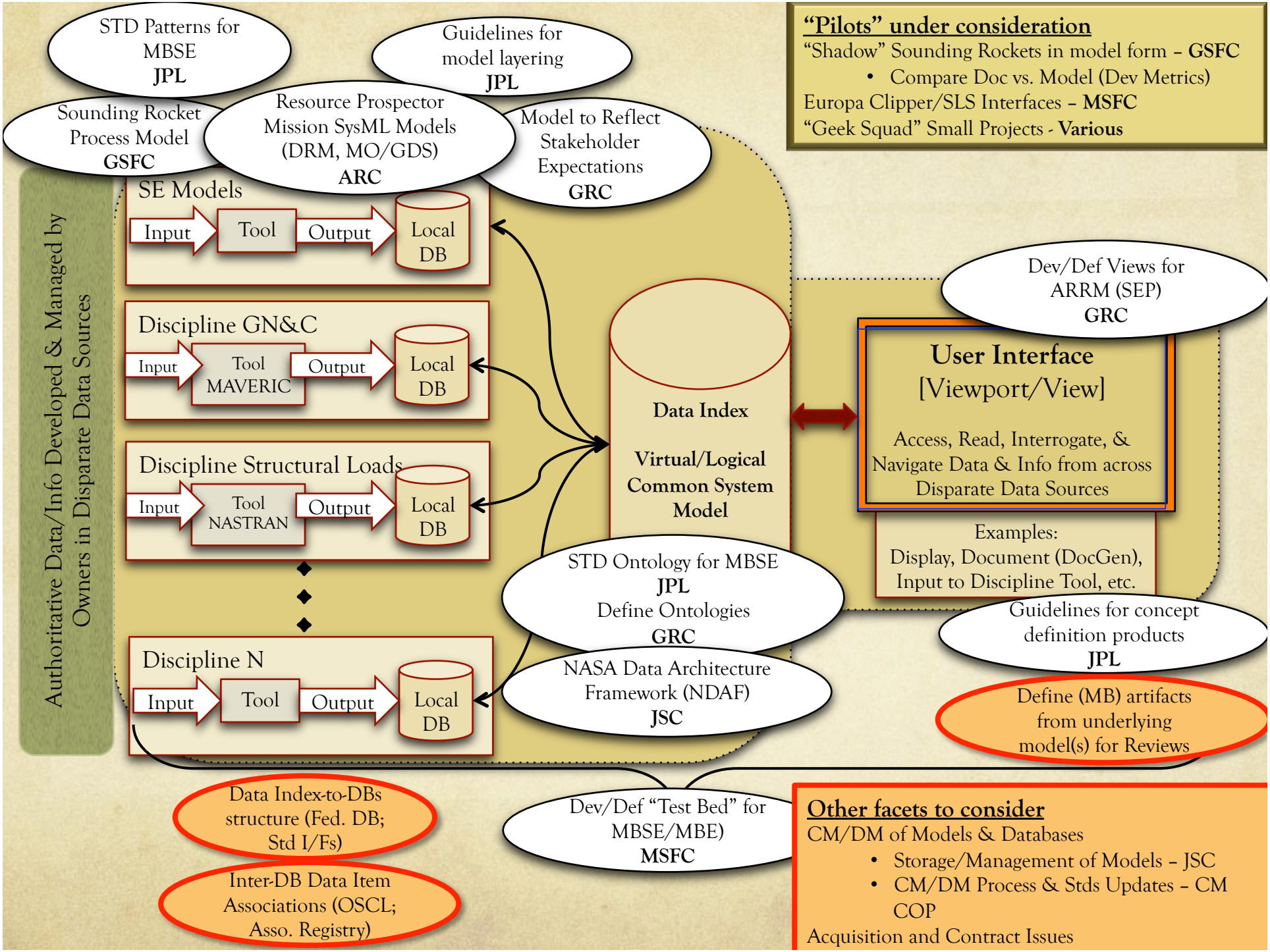
Demonstrate how the use of system models and additive manufacturing can lead to design and manufacturing improvements. Examine ways for schedule reductions on the design and reduced changes during manufacturing for a part or assembly. Manufacturing of an engine or light-weight structure are being considered.

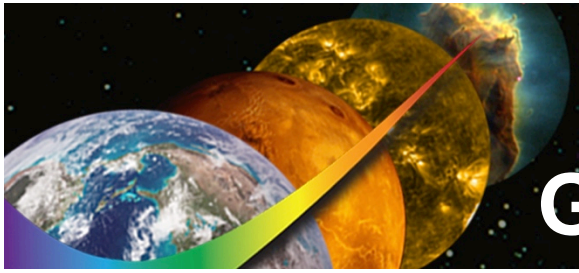
### 3. Hardware/Design Commonality

Demonstrate system modeling of a mission element, such as a lander or in-space stage, for interactions among the System Model and other engineering disciplines (CAD, physics-based models, etc.). Modeling would be done at a system and subsystem level. Look for areas that are common across all campaign elements. Demonstrate interactions between the System Model and CAD model, requirements, and physics-based models. Capture external interfaces between payload and launch vehicle.

### 4. Mission Flow Shadowing

Evaluate actual mission processing flow for sounding rockets via MBSE to understand how, and how much improvement can be made over multiple flight iterations. DoD is also a possible partner on this effort.


STD Patterns for MBSE
JPL
Guidelines for model layering
JPL
Sounding Rocket Process Model
GSFC
Resource Prospector Mission SysML Models (DRM, MO/GDS)
ARC
Model to Reflect Stakeholder Expectations
GRC
"Pilots" under consideration
"Shadow" Sounding Rockets in model form – GSFC
• Compare Doc vs. Model (Dev Metrics)
Europa Clipper/SLS Interfaces – MSFC
"Geek Squad" Small Projects - Various
Authoritative Data/Info Developed & Managed by Owners in Disparate Data Sources
SE Models
Input
Tool
Output
Local DB
Discipline GN&C
Input
Tool MAVERIC
Output
Local DB
Discipline Structural Loads
Input
Tool NASTRAN
Output
Local DB
Discipline N
Input
Tool
Output
Local DB
Data Index
Virtual/Logical Common System Model
Dev/Def Views for ARRM (SEP)
GRC
User Interface
[Viewport/View]
Access, Read, Interrogate, & Navigate Data & Info from across Disparate Data Sources
Examples:
Display, Document (DocGen), Input to Discipline Tool, etc.
STD Ontology for MBSE
JPL
Define Ontologies
GRC
NASA Data Architecture Framework (NDAF)
JSC
Guidelines for concept definition products
JPL
Define (MB) artifacts from underlying model(s) for Reviews
Data Index-to-DBs structure (Fed. DB; Std I/Fs)
Inter-DB Data Item Associations (OSCL; Asso. Registry)
Dev/Def "Test Bed" for MBSE/MBE)
MSFC
Other facets to consider
CM/DM of Models & Databases
• Storage/Management of Models – JSC
• CM/DM Process & Stds Updates – CM COP
Acquisition and Contract Issues



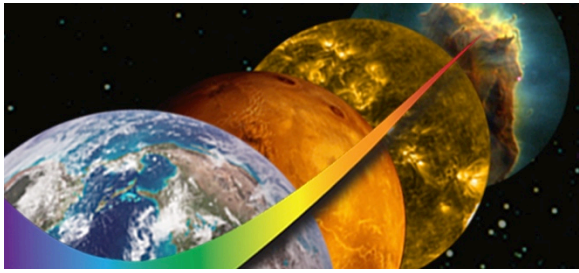


# GSFC's Goals for Implementation

- Investigate and assess the applicability and process for deploying model centric tools and methodologies to GSFC instrument and spacecraft development activities.
- Generate real world data within GSFC business model, via pilot projects, for answering tough but fair questions regarding the value of these methods
  - How does it help program/project technical performance and risk posture?
  - How will this impact program/project cost and schedule? Etc.
- Create informed process and guidelines for model centric approaches for future GSFC programs/projects.
- Establish and maintain a trained and capable workforce for implementation of model centric methods within SE discipline
- Regularly and consistently engage the wider community to share best practices, leverage unique experiences and form partnerships

# Challenges

- **Adoption and Implementation** of model centrism isn't anyone's full time job
  - Part time, grass roots, disconnected efforts
  - Leads to inconsistent engagement within GSFC and the wider community
- **Workforce**
  - Because GSFC SEs must function as technical managers and chief engineers only seasoned employees are targeted for open SE positions
  - Very few internships or hiring opportunities for junior individuals who have had exposure and training with emerging SE tools and methods
- **Training & Tools**
  - Access to training opportunities are frequently limited by insufficient resources, but is improving
  - Access to COTS tools has been an issue, but is improving
- **Process/Guidelines**
  - A process for deployment that is in alignment with Agency and GSFC level procedural requirements and standards has not yet been established





# Current GSFC Projects



- Space Geodesy Project (SGP)
- Space Network (SN) – Development, Test and Training Facility (DTTF)
- Space Network Ground Network Sustainment (SGSS)
- OSIRIS Rex Ground System
- JPSS Ground System
- ARRM (collaboration w/ JPL)
- 2016 IRADs – CATTENS, CubeSat Design Tool
- Model Based Sounding Rocket Pilot Project
  - Partnership between IV&V/WFF/Greenbelt/NESC/OSD

# Current Activities

- Raising general awareness through guest speakers, colloquia, and vendor workshops
- Working with GSFC training office to coordinate and fund training opportunities for employees in both tools and methods
- Procuring additional licenses for COTS tools as resources become available
- Some early adopters have begun to work “behind the scenes” to produce their SE deliverables
- Several high profile flight projects have adopted model centrism as part of their ground systems development efforts
- Developing implementation strategies that fits within the GSFC culture and business model
- Formation of MBE Community of Practice (CoP)
- Continue collaboration with the broader community (OGAs, Academia, Industry)

# Next Steps

- **Mature implementation strategy for MBSE at GSFC**
  - Technical implementation on projects
  - Training, communication methods, access to tools, etc
  - Identify and leverage the work of others
  - Create comm. plan for stakeholders and leadership
- **Develop standards and guidelines for implementation on new projects**
- **Workforce**
  - Grow a capable MBSE workforce for project support
    - Mentors
    - Practitioners
    - Advocates
  - Assignment to projects to perform duties using MBSE tools/methods,
  - Ensure flexibility to make mistakes (project stakeholders, supervisors)
- **Identify project(s) that are willing to deploy MBSE tools/methods**
- **Monthly GSFC MBE CoP meetings**
  - Keep the community active and engaged
  - Identify gaps, issues, address the needs of the community
  - Celebrate/communicate our wins/work to ourselves, stakeholders, and leadership

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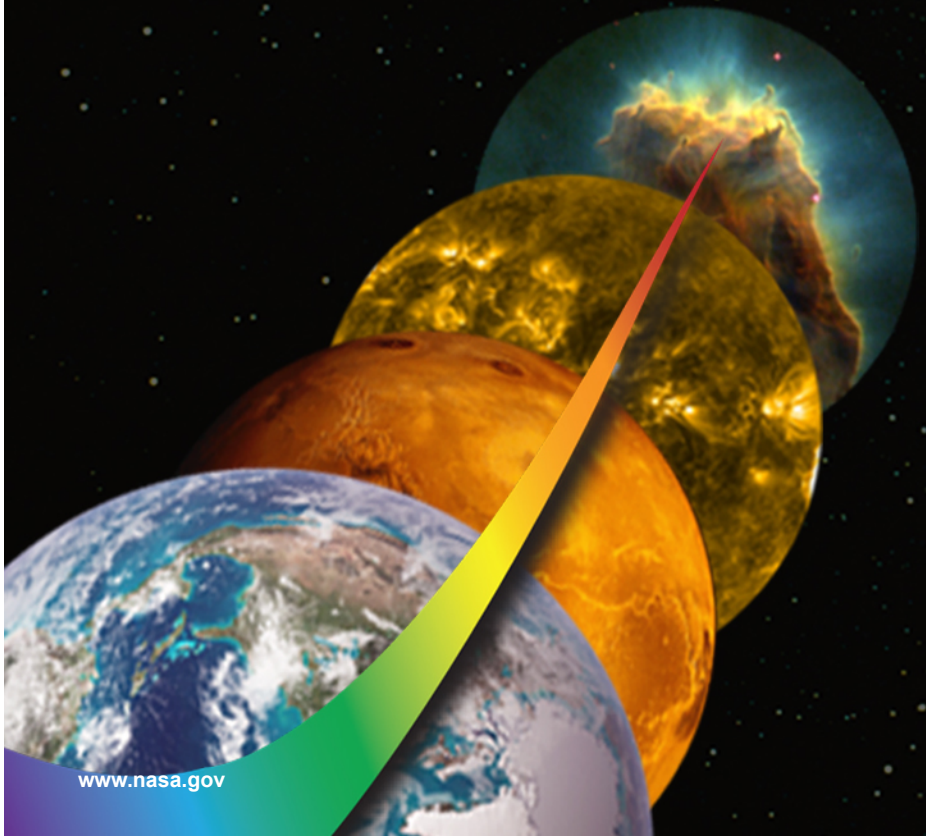
# Questions?



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