Latest Global Reference Atmospheric Model (GRAM) Suite Upgrades

National Aeronautics and Space Administration

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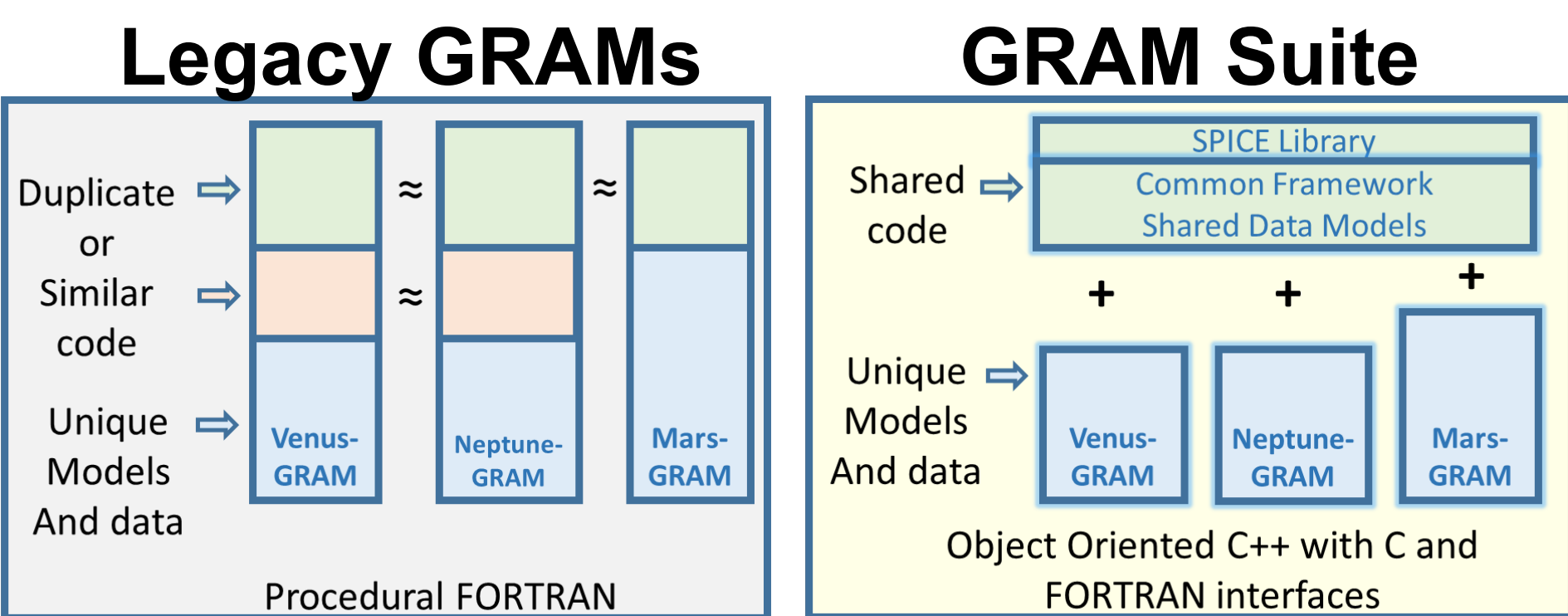
Introduction

The inability to test planetary spacecraft in the flight environment prior to a mission requires engineers to rely on ground-based testing and models of the vehicle and expected environments. One of the most widely used engineering reference models of planetary atmospheres are the Global Reference Atmospheric Models (GRAMs). The NASA Science Mission Directorate (SMD) has provided funding support to upgrade the GRAMs since Fiscal Year 2018. The GRAM upgrades are being developed by NASA Marshall Space Flight Center and NASA Langley Research Center. This poster provides details regarding recent GRAM Suite upgrades.

GRAM Overview

- Engineering-oriented atmospheric models that estimates mean values and statistical variations of atmospheric properties for numerous planetary destinations
- Currently available for Venus, Earth, Mars, Jupiter, Titan, Uranus, and Neptune
- Outputs include atmospheric density, temperature, pressure, chemical composition, radiative fluxes (for Mars-GRAM), and wind components along a user-defined path
- Includes seasonal, diurnal, geographic, and altitude variations
- Widely used by the engineering community because of ability to generate realistic atmospheric dispersions
- Can be integrated into high fidelity flight dynamic simulations of launch, entry, descent and landing (EDL), aerobraking and aerocapture
- Not a forecast model
- Distributed in the GRAM Suite[1]
- Available through the NASA Software Catalog https://software.nasa.gov/software/MFS-33888-1

GRAM Suite

- Common object-oriented C++ framework that simplifies model updates, integration, testing, and maintenance
  - Supports all solar system destination models
  - Provides a uniform user interface for all GRAMs
  - Includes C++ library with C and Fortran interfaces that can be incorporated in a trajectory or orbit propagation code
  - All future GRAM Upgrades will be released in the GRAM Suite

Legend: Legacy GRAMs (Procedural FORTRAN) — Duplicate or Similar code, Unique Models And data (Venus-GRAM, Neptune-GRAM, Mars-GRAM); GRAM Suite (Object Oriented C++ with C and FORTRAN interfaces) — Shared code (SPICE Library, Common Framework, Shared Data Models), Unique Models And data (Venus-GRAM, Neptune-GRAM, Mars-GRAM)

Initial GRAM Suite Upgrades

- Rearchitected the legacy GRAMs (Venus, Mars, Titan, and Neptune-GRAM), rearchitected and updated Earth-GRAM, and added new GRAMs (Jupiter[2] and Uranus-GRAM[3]) to the GRAM Suite
- GRAM ephemeris upgraded to NASA Navigation and Ancillary Information Facility (NAIF) Spacecraft Planet Instrument C-matrix Events (SPICE) toolkit (version N0067) for increased accuracy
- Improved calculation of the speed of sound
- Renamed input parameters to be more descriptive and reformatted output files
- Topography model based on Magellan data[4] added to Venus-GRAM
- 2019 Range Reference Atmosphere database added to Earth-GRAM
- Addition of Python Application Program Interface (API)
- Earth-GRAM Modern Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) Update[5]
- Added GRAM Programmer's Manual
- User Guides for all GRAMs have been published as NASA Technical Memos

Latest GRAM Suite Release

- GRAM Suite Version 2.1.0 (Released November 2024) included:
  - Addition of MATLAB API
  - Earth-GRAM Upgrades:
    - New Range Reference Atmosphere for Woomera, Australia
    - Option to input gridded forecast data from the Global Forecasting System weather model
  - Earth-GRAM Bug Fixes
  - Mars-GRAM Upgrades:
    - Mars Orbiter Laser Altimeter (MOLA) Topography model option to read in higher resolution data from the NASA Planetary Data System
  - Uranus-GRAM Upgrades:
    - Input model data is now from a Uranus Atmospheric Model developed by the NASA GRAM team that includes modern reanalyses of Voyager flyby measurements, recent observations, and zonal wind speeds with an estimated vertical shear[6]
  - Updated Earth-GRAM, Uranus-GRAM 2024 User Guide, and Mars-GRAM 2024 User Guides
  - Updated GRAM Programmer's Manual

Future GRAM Suite Upgrades

- Gravity data upgrades to all GRAMs
- Input model data upgrades for future GRAM Suite releases
  - Titan-GRAM – incorporating new model data based on modeling conducted for upcoming missions, including Dragonfly, and reconstruction of past data
  - Mars-GRAM – will incorporate new lower atmosphere data from Mars General Circulation Model and new thermosphere data from the Mars Global Ionosphere-Thermosphere Model
- Addition of Saturn-GRAM to the GRAM Suite
  - 1D atmospheric basis for the first Saturn-GRAM release is atmospheric profiles derived from occultation measurements of the planet by the Pioneer, Voyager, and Cassini spacecrafts

Conclusions

- The GRAMs are a frequently used toolset and vital in assessing effects of atmospheres on spacecraft during the program life cycle process
- The GRAM Suite that is available via the NASA Software Catalog https://software.nasa.gov/software/MFS-33888-1
- Upgrades of the GRAMs and GRAM Suite are continuing
- Updating the inherent data in the GRAM Suite to reflect current best estimates
- Ongoing discussions with:
  - Modeling groups within NASA and academia regarding status of their models
  - Planetary mission teams (VERITAS, DAVINCI, Dragonfly, MAV, MAVEN, etc.) to determine potential mission support by the GRAM team, utilization of collected atmospheric data, and needed GRAM upgrades
- Feedback regarding the GRAMs is encouraged and welcomed

Acknowledgements

References

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