Mars Global Reference Atmospheric Model (Mars-GRAM) Upgrades

H. L. Justh[1], A. M. Dwyer Cianciolo[2], K. L. Burns[3], J. Hoffman[4], and R. W. Powell[5]

[1]NASA, Marshall Space Flight Center, Mail Code EV44, Marshall Space Flight Center, AL, 35812, hilary.l.justh@nasa.gov, [2]NASA, Langley Research Center, Mail Stop 489, Hampton, VA 23681, alicia.m.dwyercianciolo@nasa.gov, [3]Jacobs Space Exploration Group, 1500 Perimeter Pkwy., Suite 400, Huntsville, AL 35806, kerry.l.burns@nasa.gov, [4]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, james.hoffman-1@nasa.gov, and [5]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, richard.w.powell@nasa.gov

Background

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 models of the Martian atmosphere is the Mars Global Reference Atmospheric Model (Mars-GRAM) developed and maintained by the NASA Marshall Space Flight Center (MSFC). The NASA Science Mission Directorate (SMD) has provided funding support to upgrade the planetary GRAMs in Fiscal Year 2018 and 2019. This poster summarizes the upgrades that have been made to Mars-GRAM, the release status of Mars-GRAM, the new GRAMs that are under development, and future Mars-GRAM upgrade plans.

Mars-GRAM Overview

- Mars-GRAM is an engineering-level atmospheric model applicable for engineering design analyses, mission planning, and operational decision making
  - Provides mean values and variability for any point in an atmosphere
  - Includes seasonal, geographic, and altitude variations
  - Outputs include winds, thermodynamics, chemical composition, and radiative fluxes
  - Rapidly integrates numerous data sets into a seamless composite climatology
  - Used by engineering community because of the need to simulate realistic dispersions; can be integrated into high fidelity flight dynamic simulations of launch, entry, descent, and landing (EDL), aerobraking, and aerocapture
  - Mars-GRAMs is not a forecast models
- GRAM models are also available for: Earth, Venus, Neptune, and Titan-GRAM
- GRAMs are available through the NASA Software Catalog https://software.nasa.gov/

Objectives

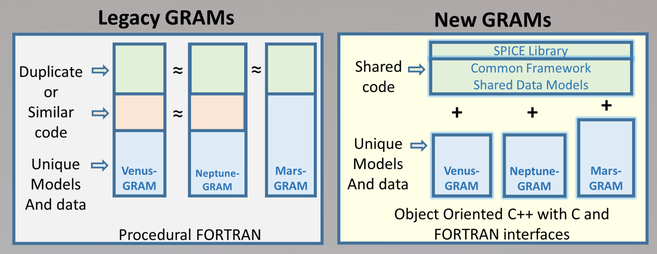
- The funding for the GRAM Upgrades aims to achieve three primary objectives:
  - Modernize the code
    - Develop a new framework that transitions the original Fortran code to C++
    - Take advantage of the object-oriented capabilities of C++
  - Upgrade atmosphere models
    - Update the atmosphere models in the existing GRAMs
    - Establish a foundation for developing GRAMs for additional destinations (Saturn, Uranus, and Jupiter)
  - Socialize plans and status to improve communication between users, modelers, and developers

Model Upgrades

- Focus of the model upgrade task is to improve the atmosphere models in the existing GRAMs and to establish a foundation for developing GRAMs for additional destinations
- Meeting with planetary modelers, mission data providers, and experts to determine new data sets and models that are currently available to upgrade Mars-GRAM
  - Subsequent Mars-GRAM release will include updated data from the Mars Global Ionosphere-Thermosphere Model (M-GITM) and Mars Global Circulation Model (MGCM)
- Identifying and obtaining planetary mission atmospheric data and analysis, that is available and appropriate, to use as the basis for verification and validation of the Mars-GRAM
  - MSL EDL Instrument (MEDLI) data from Mars Science Laboratory (MSL) and Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) Dust Storm Models, Mars Atmosphere and Volatile EvolutioN (MAVEN) data, and Mars Climate Sounder (MCS) data
- Plan to upgrade Mars-GRAM topography to the highest resolution available/reasonable

Code Modernization

- Developed a common C++ framework that simplifies model updates, integration, testing, and maintenance
  - Common framework that supports all solar system destination models
  - Provides a uniform user interface for all planetary GRAMs
  - Includes C++ library with C and Fortran interfaces which can be incorporated in a trajectory (or orbit propagation) code



- First C++ releases of the existing planetary GRAMs will be a straight conversion from the latest Fortran version
- GRAM ephemeris has been upgraded to the NASA Navigation and Ancillary Information Facility (NAIF) Spacecraft Planet Instrument C-matrix Events (SPICE) toolkit

Upcoming GRAM Releases

- Neptune-GRAM will be the first upgraded planetary GRAM released
  - Includes the new common C++ framework and SPICE
  - Beta test version now available
  - User's and Programmer's Guide will be included in the release
  - Releases of other upgraded planetary GRAMs (Mars, Venus, and Titan-GRAM) will follow the release of Neptune-GRAM
- Uranus-GRAM has been developed as a new planetary GRAM
  - Based on data generated by the Ames Research Center Uranus model
  - Beta test version now available
- New planetary GRAMs (Saturn and Jupiter-GRAM) are currently being developed

Conclusions

- Mars-GRAM and entire suite of GRAMs are critical tool sets that influence mission selection and decisions
- NASA SMD funding has been essential to addressing current limitations and accomplishing GRAM developmental goals
- Updates to Mars-GRAM and the existing planetary GRAMs and development of new planetary GRAMs are ongoing with initial release dates in 2019

Acknowledgements

- Author gratefully acknowledges support from the NASA SMD

Project Manager: Alicia Dwyer Cianciolo

Code Architect: James Hoffman
Analytical Mechanics Associates

Implementation Expert: Richard Powell
Analytical Mechanics Associates

NASA Langley Research Center

Atmosphere Modeling Lead: Hilary Justh

Mars-GRAM Developer: Lee Burns
Jacobs Space Exploration Group

NASA Marshall Space Flight Center