

Future Global Reference Atmospheric Model (GRAM) Suite Upgrades



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GRAM Suite Development Cycle

Identify peer-reviewed models and data from remote sensing, in-situ, and other sources of updated atmospheric characteristics (NASA in-house or contracted)

Software development to reflect the model (Task by a software engineer)



Develop analytical and numerical models to capture latest atmospheric data (Task by planetary scientist)

Test of integrated software, develop documentation and test cases (Task by planetary scientist and aerospace engineer)



GRAM Suite Upgrade Process



- Model developer will bring the proposed model changes
- Show results with sample data but not necessarily with GRAM Suite
- If approved move to GRAM Suite implementation

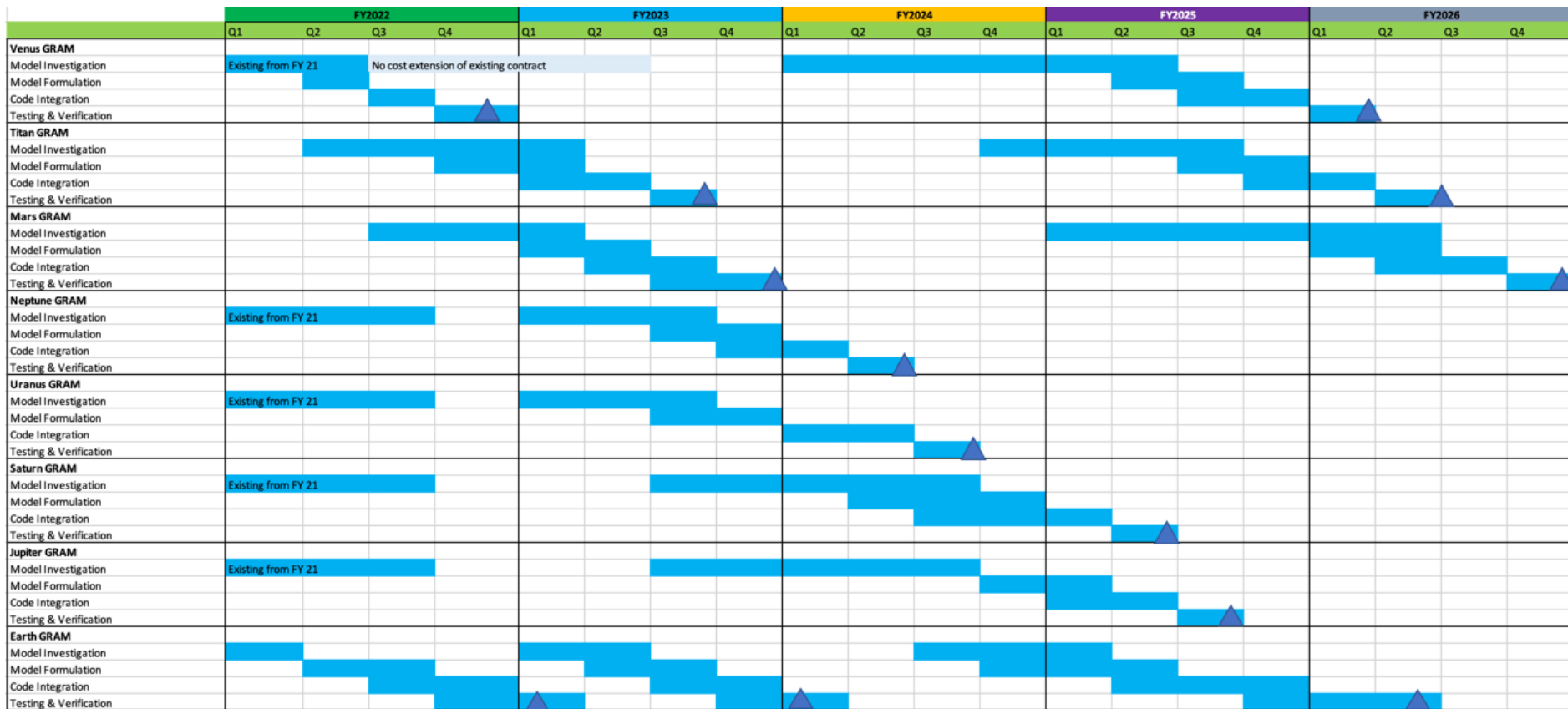
- GRAM Suite source code will be reviewed to demonstrate proposed model integration
- Test results and updated documentation will be reviewed
- Demonstrate improved modeling of current or past missions
- If approved, upgraded GRAM Suite would move towards release

Potential reviewers include mission personnel, planetary scientists, and EDL/atmospheric flight engineers

Goal: To establish a sustainable way to ensure GRAM Suite atmospheres reflect most recent observations and models



GRAM Development Cycle Schedule



GRAM Upgrades: Existing Grants/Contracts



- **Hampton University**
 - **Issue Addressed:** Global model data are not included in Jupiter, Uranus, Neptune, and Titan-GRAM; Global model data needs to be updated in Venus-GRAM
 - **Solution:** Contracted modeling experts at Hampton University, Kunio Sayanagi, and students, Justin Garland and Ryan McCabe, to develop models
 - **Hampton University FY21/22 Products:**
 - Venus: Three-Dimensional Arrays of temperature, pressure, density, and wind that are physically consistent
 - Titan: Temperature, pressure, density, and wind as function of altitude and longitude
 - Giant Planets: Temperature, pressure, density, and wind as function of altitude and longitude
 - Predicted range of variability for each of the variables
 - **Schedule:** Period of Performance ending in August 2022
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GRAM Upgrades: Existing Grants/Contracts



- **University of Wisconsin**
 - **Issue Addressed:**
 - Venus International Reference Atmosphere (VIRA) data in Venus-GRAM was published in 1985
 - Data from Venus Express radio occultations and Akatsuki thermal imaging is currently available, but needs to be processed to obtain atmosphere quantities prior to being used in Venus atmosphere model updates
 - **Solution:** Contracted data processing experts at University of Wisconsin, Sanjay Limaye, Patrick Fry, and one student
 - **University of Wisconsin FY21/22 Products:**
 - Report: Independent reprocessing of Venus Express Radio Occultation Data
 - Data files containing reprocessed atmosphere data
 - **Schedule:** Period of Performance ending in April 2022. No-cost extension of deadlines through April 2023.
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GRAM Upgrades: Existing Grants/Contracts



- **Applied Physics Laboratory**

- **Issue Addressed:** Titan-GRAM does not have bounding profiles that match Huygens/Cassini observations
 - **Solution:** Contracted APL and Ralph Lorenz, a scientist in the Huygens project and the upcoming Dragonfly project, to document models used by flight projects to describe Titan's atmosphere and to develop Dragonfly atmospheric profile for use in Titan-GRAM upgrade
 - **APL FY22/23 Products:**
 - Titan: Temperature, pressure, density, and wind as function of altitude and seasonal variability
 - Documentation of results in form of conference or journal paper
 - **Schedule:** Period of Performance is February 2022 - December 2022
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Future GRAM Suite Upgrade Plans

- Identify academic and industry partners for data assimilation and model development using an RFP-based procurement approach; potentially 2-3 selections/year
- Align GRAM Suite with planetary mission needs and priorities identified by the Planetary Science and Astrobiology Decadal Survey 2023-2032
 - Update Uranus and Neptune-GRAM to support potential probe and other atmospheric missions
 - Development of a new Saturn-GRAM
 - Update Venus, Mars, and Titan-GRAM to reflect current modeling knowledge
 - Address gaps in GRAM modeling for other planetary bodies
- Continue improvement of Earth-GRAM to support Exploration Systems Development Mission Directorate (ESDMD) and Space Operations Mission Directorate (SOMD) priorities – Commercial Crew and Artemis missions
- Increase accessibility of GRAM Suite: Move towards open-source, GRAM GUI, and digital notebooks

Potential Contracts for Planetary GRAM Development



- Incorporation of flight and remote sensing data for Mars, Venus, etc.
- Updates of GRAM Suite atmospheric data based on GCMs, potential application for Mars, Titan, Outer Planets, etc.
- Upper atmosphere (thermosphere) modeling updates for Outer Planets, Titan, etc.
- Incorporation of Cassini mission and model data into GRAM Suite as part of Saturn-GRAM development
- Incorporation of James Webb Space Telescope (JWST) dataset?



Issues for Discussion

- Comment on the prioritization of GRAM for science and mission development needs
- Is there an interest in an open-source version of GRAM?
- Are GUI and digital notebooks necessary?
- User Community Needs
- User issues/bugs