VENUS GLOBAL REFERENCE ATMOSPHERIC MODEL (VENUS-GRAM) UPGRADES. H. L. Justh[1], A. M. Dwyer Cianciolo[2], J. T. Aguirre[3], A. Diekmann[4], J. Hoffman[5], and R. W. Powell[6]. [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]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, john.t.aguirre@nasa.gov, [4]Jacobs Space Exploration Group, 1500 Perimeter Pkwy., Suite 400, Huntsville, AL 35806, anne.m.diekmann@nasa.gov, [5]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, james.hoffman-1@nasa.gov, and [6]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, richard.w.powell@nasa.gov.

Introduction: The Venus Global Reference Atmospheric Model (Venus-GRAM) is one of the most widely used engineering models of Venus' atmosphere. The Venus-GRAM upgrades are being developed by NASA Marshall Space Flight Center (MSFC) and NASA Langley Research Center (LaRC). This presentation will provide details regarding the upgrades that have been made to Venus-GRAM and the ongoing objectives, tasks, and milestones related to the GRAM upgrades funded by the NASA Science Mission Directorate (SMD).

Venus-GRAM: Venus-GRAM is an engineering-oriented atmospheric model that estimates mean values and statistical variations of the atmospheric properties of Venus. Venus-GRAM provides mean values and variability for any point in the atmosphere as well as seasonal, geographic, and altitude variations. Venus-GRAM outputs include atmospheric density, temperature, pressure, winds, and chemical composition along a user-defined path. It is extensively used by the engineering community because of its ability to create realistic dispersions. GRAMs have been integrated into high fidelity flight dynamic simulations of launch, entry, descent and landing (EDL), aerobraking and aerocapture. GRAMs are currently available for Earth, Mars, Venus, Neptune, Titan, and Uranus.

The lower atmosphere model in Venus-GRAM (up to 250 km) is based on the Venus International Reference Atmosphere (VIRA) [1]. The Venus-GRAM thermosphere (250 to 1000 km) is based on a MSFC-developed model [2] which assumes an isothermal temperature profile initialized using VIRA conditions at 250 km [3]. The VIRA version included in Venus-GRAM includes Pioneer Venus Orbiter and Probe data as well as Venera probe data, but it does not include a solid planet model or a high-resolution gravity model [4].

Venus-GRAM Upgrade Status:

Code Modernization. Venus-GRAM has been rearchitected from Fortran to a common object-oriented C++ framework called the GRAM Suite. This new architecture creates a common GRAM library of data models and utilities. The first C++ release of the rearchitected Venus-GRAM is a straight conversion from the latest Fortran version.

Model Upgrades. The 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. The GRAM ephemeris has been upgraded to the NASA Navigation and Ancillary Information Facility (NAIF) SPICE toolkit (version N0066). The calculation of the speed of sound has also been improved in the GRAMs.

In FY20, the GRAM project established contracts to improve the model data within Venus-GRAM. Hampton University is developing an empirical global model for Venus. The University of Wisconsin is reanalyzing the Venus Express radio occultation observations and analyzing the Akatsuki thermal imaging data.

Upgraded Venus-GRAM Release. GRAM Suite Version 1.3 will be released in September 2021 and will contain the rearchitected Venus-GRAM, including the common GRAM framework and planet–specific code. A User Guide and Programmer's Manual are released with all GRAMs.

Conclusions: GRAMs are frequently used toolsets and vital in assessing effects of atmospheres on interplanetary spacecraft during the program life cycle process. Releases of the GRAM Suite, upgrades of the existing planetary GRAMs, and development of new planetary GRAMs are ongoing. Venus-GRAM atmosphere model upgrades will be included in the next phase of GRAM tasks.

References: [1] Kliore, A. J. et al. (1985) *ASR*, 5, 11, 1-304. [2] Justh, H. L. et al. (2006) *AIAA/AAS Astrodynamics Specialist Conference & Exhibit*, Abstract AIAA-2006-6394. [3] *Guide to Reference and Standard Atmosphere Models*, BSR/AIAA G-003-2010. [4] Limaye, S. S. (2012), *LPSC VEXAG Townhall Meeting*.

Acknowledgments: The authors gratefully acknowledge support from the NASA SMD.