6.8 NATURAL ATMOSPHERIC ENVIRONMENT MODEL DEVELOPMENT FOR THE NATIONAL AERONAUTICS AND SPACE ADMINSTRATION'S SECOND GENERATION REUSABLE LAUNCH VEHICLE

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1. INTRODUCTION

The National Aeronautics and Space Administration (NASA) recently began development of a new reusable launch vehicle. The program office is located at Marshall Space Flight Center (MSFC) and is called the Second Generation Reusable Launch Vehicle (2GRLV). The purpose of the program is to improve upon the safety and reliability of the first generation reusable launch vehicle, the Space Shuttle. Specifically, the goals are to reduce the risk of crew loss to less than 1-in-10,000 missions and decrease costs by a factor of 10 to approximately $1,000 per pound of payload launched to low Earth orbit.

The program is currently in the very early stages of development and many two-stage vehicle concepts will be evaluated. Risk reduction activities are also taking place. These activities include developing new technologies and advancing current technologies to be used by the vehicle.

The Environments Group at MSFC is tasked by the 2GRLV Program to develop and maintain an extensive series of analytical tools and environmental databases which enable it to provide detailed atmospheric studies in support of structural, guidance, navigation and control, and operation of the 2GRLV.

2. ROLE OF ATMOSPHERIC ENVIRONMENTS

Natural atmospheric environment phenomena play a significant role in the design and safe flight of reusable launch vehicles and in the integrity of the associated aerospace systems and structures. The natural atmospheric environment affects all elements of the vehicle including airframe, avionics, propulsion, flight mechanics, and operation. Therefore, natural atmospheric environments is a multifaceted discipline and plays a major role in the Systems Engineering and Integration effort at the very beginning. Natural environment assessment in the early stages of the vehicle program is critical for the development of a vehicle with a minimum operational sensitivity to the environment. For those areas of the environment that need to be monitored prior to and during tests and operations, early planning will permit development of the required measuring and communication systems for accurate and timely monitoring of the environment.

The vehicle's response to environmental parameters must be carefully evaluated to insure an acceptable design relative to operational requirements that include flight safety. The choice of criteria depends upon the specific launch location(s) and vehicle mission configuration. Vehicle design, operation, and flight procedures can be separated into specific categories for proper assessment of environmental influences and impacts upon the life cycle history of each vehicle and all associated systems. These include: 1) initial purpose and concept of the vehicle, 2) preliminary engineering design for flight, 3) structural design, 4) vehicle guidance and flight control design, 5) optimization of design limits regarding the various environmental factors, and 6) final assessment of environmental design criteria to ensure mission safety, launch availability, and cost. It is important to use good judgment and to apply sound engineering principles in preparing atmospheric criteria that are descriptive and concise.

3. MODEL DEVELOPMENT

During the early development phase of the 2GRLV it is important to evaluate the competing architectures against program goals. The Atmospheric Parametric Risk Analysis (APRA) tool is being developed by the Environments Group to evaluate risks associated with the natural atmospheric environment.

The APRA tool will examine a record of atmospheric observations and calculate the risk of flight delay using as input a set of flight constraints, which include range safety constraints and vehicle constraints. The constraints could be design values and/or flight rules that specify atmospheric constraints, such as no flight through thunderstorms/precipitation or a specified cloud ceiling.

The APRA program counts occurrences of each flight constraint violation and tabulates the percent exceedance for each constraint and combination of the constraints by hour for monthly reference periods. This

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procedure eliminates the problem of combining probabilities. APRA is to be a versatile tool for multiple databases and/or mission phases to provide a concise way to compare possible launch sites and means to determine the site most suitable for vehicle launches.

Using the technology tool and analysis, a safe, reliable vehicle with simple operations, high operational utility and turnaround time can be developed relative to natural atmospheric environments. Thus, optimum launch availability with maximum safety of flight is achievable to decrease the cost of delivering payloads to space.

As architectures are selected and developed, a high resolution Vector Wind Profile Model (VWPM) and the Global Reference Atmosphere Model (GRAM) are to be used with the APRA tool to refine vehicle design.

A VWPM was developed in the early 1990's by Adelfang, et al., 1994. The monthly vector wind profiles the model generates are used to establish realistic estimates of dispersions of critical vehicle design parameters related to wind profile dispersions. They are used primarily to evaluate vehicle launch control and trajectory variables required for the assessment of proposed vehicle architectures. To date VWPM's have been developed for Kennedy Space Center and Edwards Air Force Base. Additional VWPM's are to be developed for other sites as required during the 2GRLV program.

The GRAM is used to simulate atmospheric variability at any location in the world (Justus, et al., 1999). It provides complete global geographical variability of the thermodynamic variables and wind components. The model not only provides geographical, height and monthly variations of the mean atmospheric state, but also the ability to simulate spatial and temporal perturbations of these atmospheric parameters (e.g. fluctuations due to turbulence and other phenomena). Because of the many capabilities of GRAM, it will be used throughout all design phases of the 2GRLV. If the 2GRLV program needs any new capabilities not currently in GRAM, the Environments Group will add them as needed.

4. CONCLUSION

The design, testing, and flight of aerospace launch vehicles must include from the beginning stage of development the natural atmospheric environment element of systems engineering to prevent unnecessary operational constraints due to natural environment conditions, to increase flight safety, and to reduce cost associated with development and operations.

5. REFERENCES

Adelfang, S. I., O. E. Smith, G. W. Batts, 1994: Ascent Wind Model for Launch Vehicle Design, AIAA J. Spacecraft and Rockets, Vol. 31, No. 3, 502-508

Justus, C. G., D. L. Johnson, 1999 : The NASA/MSFC Global Reference Atmospheric Model-1999 Version (GRAM-99), NASA/TM-1999-209630