The rocket balloon (Rocketball): applications to science, technology, and education

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Originally envisioned to study upper atmospheric phenomena, the Rocket Balloon system (or Rocketball for short) has utility in a range of applications, including sprite detection and in-situ measurements, near-space measurements and calibration correlation with orbital assets, hurricane observation and characterization, technology testing and validation, ground observation, and education. A salient feature includes the need to reach space and near-space within a critical time-frame and in adverse local meteorological conditions. It can also provide for the execution of technology validation and operational demonstrations at a fraction of the cost of a space flight. In particular, planetary entry probe proof-of-concepts can be examined. A typical Rocketball operational scenario consists of a sounding rocket launch and subsequent deployment of a balloon above a desired location. An obvious advantage of this combination is the additional mission "hang-time" rendered by the balloon once the sounding rocket flight is completed. The system leverages current and emergent technologies at the NASA Goddard Space Flight Center and other organizations.

1.0 APPLICATIONS

Rocketball is useful for technology validation and in applications that require fast, on-site measurement of scientific phenomena. Two particular applications are outlined.

1.1 Sprite Observation and Measurement

Sprites are upper atmospheric phenomena that involve the release of large amounts of electricity into the stratosphere and mesosphere. They have been observed in association with thunderstorms at altitudes reaching 40 to 70 km, but are poorly understood. In addition, they remain difficult to observe, having been seen a few times from space, and seldom from cameras overlooking thunderstorms on the horizon. Sprites also exhibit low luminance levels, and require sensitive cameras for detection. An ideal platform to detect and study these phenomena would be located directly in the vicinity of an event, such as a high-flying balloon. The problem of course is in how to position the asset over a thunderstorm. The solution can be found in the Rocketball approach. The concept would require the careful planning and observation of approaching thunderstorms near the (fixed or mobile) launch site. Rocketball would be launched over the horizon, at an angle that ensures vehicle deployment directly over the area in question.

1.2 Planetary Entry Mission Design

The speeds involved in planetary entry are greater than those possible with a modest sounding rocket launch. However, deployment schemes, material selection, subsystem technologies, and operational proof-of-concepts can be effectively exercised and validated. A preliminary analysis of the speeds, thermal, and operational environments encountered in a Terrier Improved-Orion will be used to scale a system for entry into the atmosphere of Saturn's moon, Titan. The Huygens probe entered Titan's atmosphere at a speed of about 6 km/sec, with a stagnation heat load peak of about 600 kW/m^2, and deceleration around 12g [1]. The Terrier Orion vehicle is expected to re-enter at about 1.7 to 3.4 km/sec. Earth re-entry heat loads and deceleration will be estimated based on the final payload configuration and ballistic coefficient. Nonetheless, launch from a sounding rocket will still expose the space vehicle prototype through larger-than-expected radial and axial loads than those on planetary entry, and overall provides a reasonable scaled validation of the system.

2.0 SYSTEM DESCRIPTION

The sounding rocket of choice is the Terrier-Orion vehicle. This vehicle is capable of lifting a 91 kg payload to an altitude of 200 km. The actual downrange distance and altitude would depend on the chosen launch elevation (Figure 1). Payload sizes supported by this vehicle include a bulbous 44 cm diameter, and a total length (including support, adapter, and recovery systems) of about 434 cm.

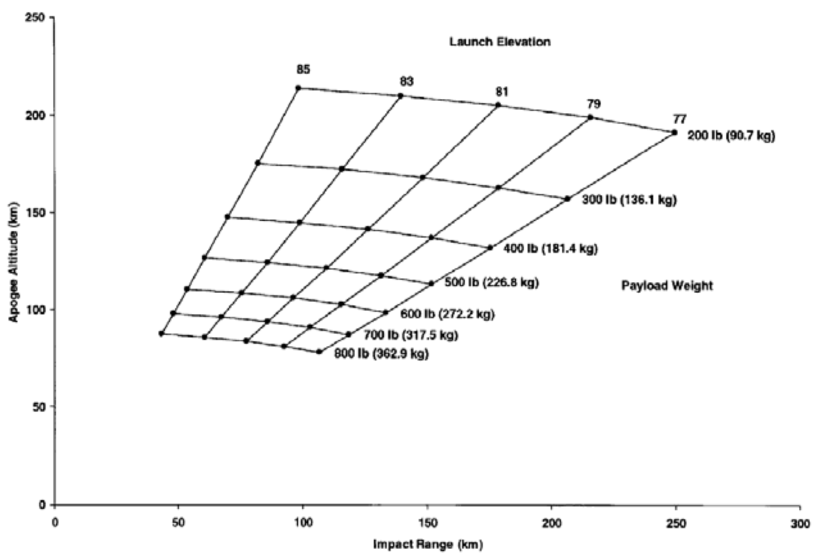

Figure 1: Flight profile varies depending on the initial launch elevation

Figure 2 shows the Terrier-Orion configuration and overall dimensions. The Terrier-Orion rocket system is a two stage spin stabilized vehicle which utilizes a Terrier MK 12 Mod 1 for the first stage and an Improved Orion motor for the second stage. Mechanical loads and vibration qualification requirements for sounding rockets can be significantly higher than some orbital ELV, and depend on payload mass. The Terrier motor has a longitudinal acceleration during boost phase that may reach up to 26g's, for a 91kg payload. Second stage longitudinal acceleration may be in the order of 20g's. Axial acceleration is affected by vehicle spin rate among other factors, and this rate is typically about 4 to 5 cycles per second at burn-out. Supersonic speeds are reached a few seconds after liftoff, and maximum dynamic pressure occurs around first-stage burnout (~6 sec). Entry velocities range between 5 and 10 Mach at about 90 km altitude. Payload skin temperatures during the ascent vary depending on material and configuration used, but can vary between 90 to 230 degrees C. Vibration and acoustic conditions will not be discussed here.

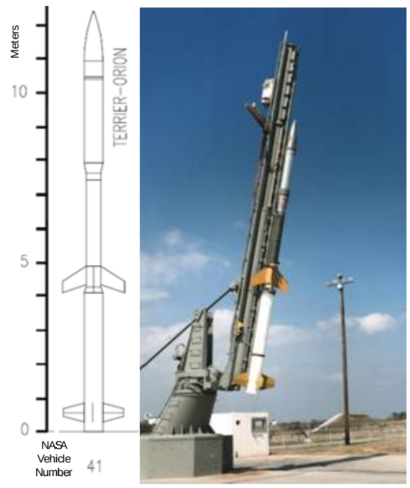

Figure 2: Terrier-Improved Orion Sounding Rocket

The space and near-space vehicle is composed of four major elements: the parachute and container, the balloon with its container and helium inflation tank, the spacecraft and instruments, and the reentry aeroshell. The complete system is shown in Figure 3a. At this moment only the spacecraft features will be presented in some detail.

The spacecraft/science bus is based on a scaled-down version of the MR^2/MARS-compatible vehicle developed at GSFC in 2003 [2]. Although plug-and-play modularity and scalability was determined to be best suited for vehicles in the Pegasus to Delta II class, the current version applicable to Rocketball would normally apply to secondary payloads, and can leverage similar architectural principles. Figure 3b shows the concept layout for this vehicle, with major components identified. The basic structure is composed of a scalable “spider” frame that may be stacked-up depending on mission needs. Only a single spider structure is required in this concept. The central thrust tube enables the routing of connectors and fuel pipes through different bays as needed. The electronics and instruments are radially configured, and may have several shapes to fit a specific application. The avionics feature interface standards, and leverage considerable work at GSFC in the development of plug-and-play devices. The core is based on the current “space cube”, a Xilinx/PPC-450 computer system demonstrated in the Hubble Space Telescope (HST) Servicing Mission 4. The spacecraft’s attitude will be controlled along the roll axis via cold gas thrusters developed for the Space Technology 5 mission, a constellation of three GSFC “birthday cake” sized spacecraft successfully launched in 2006. The power system will be fed by body-mounted solar arrays, also of ST5 heritage. The instrument payload consists of a choice of two visible/IR side and bottom-viewing cameras for full stereo ground and nearly 360-degree horizon coverage, or a visible/IR camera and particles and fields package combination. The upgradable UHF RF package features a bottom-mounted patch antenna. This instrument suite is only used for scale validation purposes, and does not necessarily represent a final payload configuration.

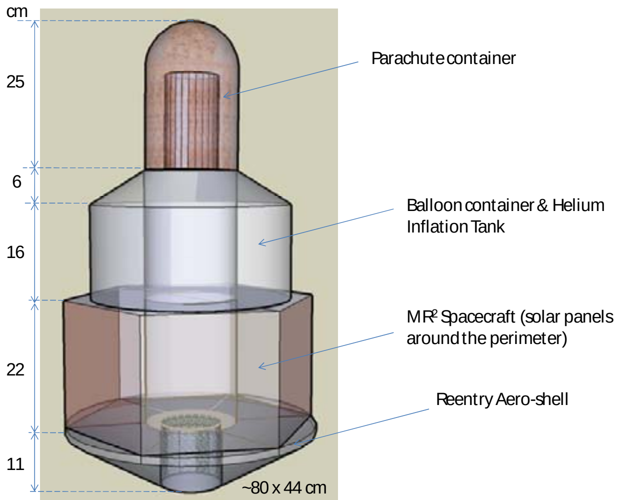

Figure 3a: Rocketball System

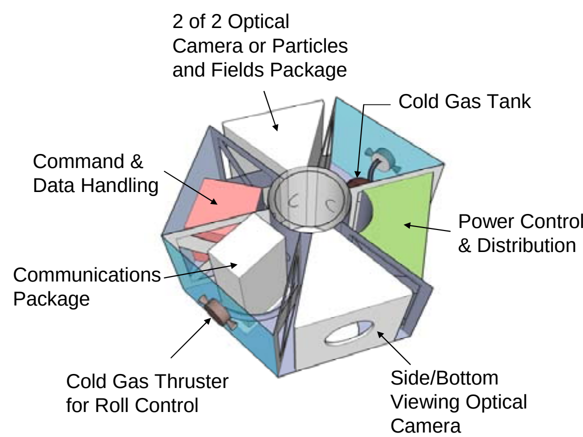

Figure 3b: The MR^2 Bus Prototype

3.0 CONCLUSION

Rocketball provides an effective way to deliver scientific payloads downrange to near space, that otherwise would be impossible due to local meteorological conditions. It also provides a means to validate systems and technologies that may be used for a broad range of applications, from planetary entry (at higher speeds), to other scientific and earth observation implementations. Given its reasonable cost compared to orbital flights, it also provides an excellent alternative for testing out student-developed systems.

4.0 REFERENCES

[1] A. Ball, J. Garry, R. Lorenz and V. Kerzhanovich, *Planetary Landers and Entry Probes*, Cambridge University Press, New York (2007).

[2] J. Esper, "Modular, Adaptive, Reconfigurable Systems: Technology for Sustainable, Reliable, Effective, and Affordable Space Exploration". *Proceedings of the Space Technology and Applications International Forum,* American Institute of Physics (2005).