Sounding Rocket Working Group

National Aeronautics and Space Administration

Meeting of June 10-11, 2010

Findings

1. Black Brant Instability Issue

Summary:

The Sounding Rocket Working Group (SRWG) supports the Sounding Rocket Program Office's (SRPO's) considered approach to the current issues regarding what appears to be instabilities in the Black Brant Mk1 motors. The SRWG believes that accepting loss in vehicle performance (i.e., returning to the previous Black Brant performance levels) is certainly acceptable if this is necessary to ensure motor reliability and hence substantially decrease risk. The SRWG looks forward to results from the continued analysis and simulations by the Wallops team as it seeks to understand the performance of the existing motors, including suggested modifications. We request updates from the SRPO so that the experimenter community might stay abreast of developments with the Black Brant vehicle and the outlook for future launches.

Background:

Two Black Brant missions in recent months have experienced unstable and excessive launch loads that have endangered the experiments and affected the overall performance of the vehicle. It is hypothesized that these instabilities result from a combination of effects, but may primarily be due to the relatively recent reduction in the nozzle diameter. It has been suggested that the nozzle diameters of existing motors be increased by an amount that is expected to remove the instabilities at the expense of some vehicle performance. The increased nozzle diameter, as well as other changes to the fuel composition, would then be incorporated into future motor purchases.

This development comes at a time when Black Brant motors are in limited supply and the launch queue is already pressured by the even more limited availability of thrust termination systems. The SRWG shares the SRPO's very serious concern surrounding this issue.

The anticipated performance of the Black Brant, after the modifications to the nozzle diameter, will be reduced, and is anticipated to be at or near the levels of the standard (previous) Black Brant vehicle. We strongly believe that this reduced level of performance is an acceptable trade for the benefit of increased reliability of the motor.

The SRWG requests regular updates from the SRPO regarding this issue until it is deemed solved, insofar as practical. These updates would ideally include any results learned from simulations or other studies, as well as results from any upcoming launches, including test flights.

2. Revisiting the Mesquito Project

Summary

The SRWG appreciates the technical difficulties encountered with development of the Mesquito vehicle and the uncertainty regarding the required time and resources that will be needed to bring this concept to fruition. At the request of the SRPO, the SRWG, drawing from our representatives familiar with this science area, provides some general comments (below) regarding the scientific motivation of developing this vehicle. We are prepared to carry out a more extensive review of the science motivation for developing this vehicle, in conjunction with more extended community input as well as with the NASA HQ discipline scientist.

-- The original performance characteristics of the Mesquito vehicle rest on solid scientific motivation and hence remain a valid science priority, provided it can be developed with viable resources and launched as a low-resource vehicle.

-- The 70-100 km region is vital to mesospheric science and thus a nominal “target” apogee of 100 km for reasonable science payloads remains a crucial requirement.

-- The multiple-flight capability is currently not available in present capability for mesospheric investigations, and it is our understanding that this can only be achieved with smaller, less complex vehicles.

-- We recommend that the SRPO consider simpler, non-instrumented versions (Level 0, such as passive falling sphere, or Level 1, for example fixed nosecone with fixed Langmuir probe, basic TM, no GPS), as detailed in our previous recommendations regarding this vehicle.

-- We urge NASA to preserve and investigate other small payload developments, such as the MET-P, based on the Super-Loki Dart, which could serve as interim solutions for less complex payloads (Level 1) and has multi-launch capability. We also are also concerned about, and request information about, the future of the Falling Sphere (Viper-Dart) capability as standard measurement technique in the mesosphere.

-- We note with enthusiasm that the development to date of the Mesquito avionics package (as part of a Level 3b payload), could be used for a variety of sub-payload applications for larger vehicle missions in addition to its intended use in the Mesquito.

-- The SRWG is very concerned about the cost of the Mesquito, both for development of the platform and the estimated costs of these rockets after the development work is completed, and request that these estimates be provided to us at a future SRWG meeting.

Background:

The Mesquito, also known as the MLRS (Multiple Launch Rocket System) development effort is driven by: (a) the scientific need for a low-cost, mesospheric sounding rocket that can be used in multiple launches in a single set of launches over a short interval, and (b) the availability of small surplus motors in this class.

The background for this vehicle has been documented in the SRWG Report: “New Mesospheric Payload -- Science-Driven Design Considerations” on the SRWG web site: (http://rscience.gsfc.nasa.gov/keydocs/New_Mesospheric_Payload.pdf).

The target region is the upper mesosphere and mesopause region (70-110 km), with interesting scientific objectives: meteor ablation, sporadic layers, meteoric dust; noctilucent cloud particles; wave breaking and highly variable turbulent regions; chemically active species and reaction products, such as O, O2*, OH*, NO; ionization layers due to photon and particle ionization; water cluster ion chemistry, most of which can studied only by in situ measurements.

The Mesquito has been envisioned as somewhat larger and more capable than traditional meteorological rockets (Viper, Super Loki) equipped with instrumentation and telemetry, but smaller and less disturbing to the plasma environment than payloads launched on single-stage Orions. The development and first test flights of the Mesquito system, including miniaturized avionics system tailored for a 4-inch diameter "Dart" payload, have revealed new difficulties towards realizing a working vehicle and payload. Accordingly, the SRPO has asked the SWRG to reiterate and/or reevaluate the science requirements in order to guide future resource allocations.

The SRWG maintains that certain characteristics need to be met to make this platform useful and cost-effective for mesospheric applications. A target apogee of 100 km should be maintained. The predicted payload volume (3.9" x 5'') and mass (5-7 lb) is acceptable and can accommodate basic instrumentation such as originally developed for meteorological rockets with dart payloads (MET-P). It is noted that the form factor is similar to a CubeSat, and some new instrumentation development paths for small nanosatellites could potentially be adapted for or tested on the Mesquito.

The SRWG is concerned about the complexity of the new vehicle (e.g., active motor separation issues) limiting the number of multiple launches (only 2-3 per 3 hours or requiring several launchers). This brings the Mesquito expectations closer to the Orion capabilities, which is a proven vehicle with much larger capacity.

The SRWG recommends that the SRPO consider simpler, non-instrumented versions (Level 0, such as passive falling sphere, or Level 1, such as fixed nosecone with a Langmuir probe, basic TM, no GPS), as detailed in previous recommendations regarding this vehicle. Furthermore, we urge NASA to preserve and investigate other small payloads, such as the MET-P, based on the Super-Loki Dart, which could serve as interim solutions for less complex payloads (Level 1) and has multi-launch capability. We are concerned about, and request information about, the future of the Falling Sphere (Viper-Dart) capability as a standard measurement technique in the mesosphere.

The SRWG is concerned about the preliminary cost estimates of a Mesquito mission (45% of a single-stage Orion mission). We request further information on how much integrated research effort has been used since 2006 to develop this platform as well as the estimate cost to complete the vehicle development.

Despite these concerns about the viability of the vehicle itself, the SRWG is excited about the parallel development of the avionics package, which in addition to the Mesquito, could be used for a variety of subpayload applications for packages deployed from larger vehicles. Multipoint sub-payload arrays are one of the strengths of the WFF/NSROC program and these miniaturized avionics can advance this effort. The 2Mbs PCM stack, while small in bandwidth, can be an attractive small component for small subpayloads. The 4" wraparound GPS/S band antenna provides a convenient small TM system and the GPS positioning is important for array science.

We look forward to continue dialogue with the SRPO regarding the development of miniaturized payloads for both the Mesquito and small payloads in general.

3. Woomera Test Facility -- Towards Developing a New Standard Range for NASA Rocket Launches particularly for Telescope Payloads that Require Land Recovery

NOTE: This finding is nearly identical to Finding #2 of the Feb. 2010 meeting except the emphasis is now on the use of the range for STANDARD operations.

Summary:

The SRWG applauds the Sounding Rocket Program Office (SRPO) for its recent inquiries into returning NASA launch operations to the Woomera Test Facility (WTF) in Australia. We wish to underscore our interest in this range and urge that a full feasibility study and implementation plan be developed as soon as possible with a view of using the range for *standard launch operations* with permanent or quasi-permanent infrastructure. This location is particularly appealing for land recovery of payloads that include telescopes, such as those which are primarily launched from White Sands Missile Range (WSMR). The Woomera range is unique for its view of the southern sky, and the potential for less constrained launch operations compared to WSMR. Furthermore, the Woomera range would also facilitate multiple launches, "triggered" launch windows on geophysical or solar events, less constrained access to radio spectrum, and higher apogees, compared to WSMR.

Background:

The Woomera Test Facility (WTF) in Australia has been used by the NASA sounding rocket program since 1961 for both astrophysics and geospace missions. From the standpoint of astrophysical payloads, the WTF provides an astronomical view of the southern sky, which includes the Large Magellanic Cloud (LMC), the closest galaxy to our own, the center of our own galaxy, and the southern galactic bulge, to name a few important astrophysical targets not available for observation from the White Sands Missile Range (WSMR) in New Mexico. In addition, the Woomera range appears to offer less restrictive range operations than WSMR. The less restrictive range operations may allow for high bandwidth telemetry, multiple launch windows, and geophysical and solar "event triggered" launches, as well as higher payload apogees.

Unfortunately, the Woomera range has only been utilized by NASA in campaign mode, where large parts of the launch infrastructure are deployed at the range for each campaign and then removed at the completion of the campaign. The last such campaign was over 20 years ago to observe the SN1987a supernova in the LMC in 1989. There have been no campaigns since that time, given the large financial barrier to mounting such an endeavor. Now that the SRPO is returning to long term financial stability, developing the capability for land recovered (generally astrophysical and solar) payloads in the southern hemisphere should be among the program's priorities.

4. Science Benefits from High Altitude Rockets to Increase Astrophysics and Solar Observing Time (HARIASOT)

Summary:

The SRWG summarizes the general, improved science capabilities for Astrophysics and Solar telescope payloads gained by increasing by extending the time spent above 150-250 km. These advantages open discovery space and generally represent a linear growth in science benefits with increased observing time. It is shown that most of these advantages do not scale as simply increases of the "signal-to-noise" ratio.

Background:

As an outcome of the February 4, 2010 SRWG meeting, the SRWG released a finding on the benefits of High Altitude Rockets to Increase Astrophysics and Solar Observing Time (HARIASOT) with the goal of extending the science achieved by the Sounding Rocket Program (SRP) by significantly increasing the available observing time above 250 km. This increased time was to be achieved through the use of existing rocket program launch vehicles, such as the Black Brant XI and XII (BBXI and BBXII), with payload recovery. A question was raised at the subsequent SRWG meeting concerning what tangible benefits might result from such increased observing time, since signal/noise ratios are improved only by the square root of the observing time.

The SRWG believes that significant improvements in the science capabilities of astrophysics and solar payloads would result from increases in the observing time above 150-250 km. These are summarized below:

(1) permitting observations that are otherwise background limited (faint sources);
(2) permitting observations with previously limited instruments (e.g. higher resolution spectroscopy, novel technologies) and hence previously unachievable;
(3) providing increased time to observe an increased number of targets (pointings) on a single flight;
(4) increasing the field of view (area) on nearby extended targets, such as the Sun. (Note that some Solar missions scan a slit across the sun to build a spatial-spectral picture. Increasing the observing time by a factor of two increases the FOV by a factor of two. Because the atmosphere of the Sun evolves on timescales of minutes, the scientifically useful FOV cannot be increased by combining two flights with adjacent FOVs.)
(5) increasing the signal-to-noise on observable targets to enable the detection of spatial or spectral structures, in particular, of structures previously background limited.

Only for the last motivational argument (5), do science benefits scale as signal-to-noise which scales as square root of the observing time. For all of the other science motivators, the figure of merit grows much more rapidly: opportunities 1 and 2 open discovery space whereas capabilities 3 and 4 represent a linear growth in science benefits with increased observing time.

We estimate that for launches of a 1000 pound payload from WFF at an elevation angle of 85 degrees, the gains in time above 250 km compared to the BB IX vehicle are 164 and 114 percent for the BB XII and XI, respectively. The percentage gains in time over 150 km are 85 and 62 percent, respectively.

Additional technical information regarding this finding is appended in the report entitled: “General Science Benefits of Increased Observing Time for Astrophysical and Solar Sounding Rockets’’ provided by the SRWG Sub-Committee on High Altitude Rockets to Increase Astrophysics and Solar Observing Time.

If the gains in observing time promised by the BBXI and BB XII vehicles are to be realized, then a high altitude recovery system must be implemented, together with either: (1) a larger land range, (2) a means to stay within the WSMR range limits, or (3) sea recovery. SRPO has identified the use of the larger land range at the Woomera Test Facility (WTF) as the most attractive option to initially pursue at this time.

The SRWG fully supports the prioritization of these options as presented by SRPO and requests that a summary of the technical feasibility and cost-benefit analysis of the WTF be presented with consideration given to the increase in observing time, additional sky coverage achievable, rocket dispersion, payload recovery costs, and infrastructure costs.

5. Flight Termination Systems

Summary:

The SRWG was pleased to see the development plan for moving to a long-term, viable, qualified, flight termination system (FTS) for launch operations at WSMR. However, the SRWG remains concerned that the project stay on schedule, particularly with respect to the full deployment of the interim "Hybrid II" system in January, 2011. If the Hybrid II system is delayed, launch operations at WSMR could be suspended, delaying a significant number of payloads. Even if the Hybrid II system is on-time, this risk recurs if the stock of 18 Hybrid II systems is depleted before the "final design" FTS system is deployed in 2012. The SRWG would welcome additional information on the detailed development and qualification schedule leading to both the "Hybrid II" and "Final design" flight termination systems, including schedule risks, "tall poles", workarounds, and backup plans.

Background:

Flight termination systems are required for BBIX operations at White Sands Missile Range (WSMR) as well as other launch operations depending on the vehicle and range. The legacy system used until 2009 is no longer available, and furthermore, no longer allowed by WSMR range safety. Our understanding is that a recovery plan was agreed to between the SRPO, NSROC, and WSMR starting with a limited quantity of "Hybrid I" systems deployed in 2009. The stock of Hybrid I systems, however, was not large enough to meet the need for flights manifested in 2010, and the agreement did not allow additional "Hybrid I" systems to be manufactured. The current plan is to deploy the next development unit ("Hybrid II") in January 2011 with 21 units to be procured, 3 of which will be used for qualification testing. The remaining 18 units will be used for flights, bridging the gap until the "final" design is ready sometime in 2012. The "final" design is to be fully compatible with WSMR range safety rules and should provide a viable, long term solution for WSMR flight operations. However, the manifest for WSMR will, effectively, be suspended when the final 4 Hybrid I units are deployed, currently by September 2010. No flights will then occur until the Hybrid II systems are ready. Delays to the Hybrid II schedule will continue to slip WSMR flights until it is qualified and accepted by WSMR range safety. This situation will recur if the 18 Hybrid II systems are depleted before the "final" FTS systems become available. Clearly, the user community is very concerned about the availability of useable FTS systems to facilitate launches from White Sands Missile Ranges.

The SRWG would welcome detailed insight into the development activities including schedule, qualification plans, negotiations with WSMR, risks, and any contingency planning. This would allow the SRWG to fully understand the path-forward to returning launch operations to WSMR.

6. PFISR Interference and Communications at the Poker Flat Research Range

Summary.

The SRWG reiterates the urgent need to develop a routine means to solve the problem of RF interference between the rockets and the Poker Flat Incoherent Scatter Radar (PFISR) and to develop workable procedures so that PFISR might operate routinely before, during, and after the sounding rocket launches.

The SRWG finds that the ability to listen to the Poker Flat countdown on a suitable website is invaluable for field operations and urges that this capability be maintained.

Background

As detailed in the SRWG Finding #4 of its July, 2008 meeting, the SRWG recognizes that the National Science Foundation (NSF) Poker Flat Incoherent Scatter Radar (PFISR) is a critical instrument that brings much needed context to auroral rockets launched from Poker Flat. Turning this radar off to avoid interference with the sounding rocket launches is both disruptive to routine PFISR operations and may significantly degrade the scientific return of the rocket/radar experiment.

The SRWG continues to be concerned that workable solutions are not in place to enable the Poker Flat Incoherent Scatter Radar (PFISR) to operate continuously and routinely during countdowns and sounding rocket launches. The Wallops telemetry groups and the PFISR operators have learned a great deal in recent years about the possible interferences between our systems and PFISR. Although we understand that mitigation techniques have been developed so PFISR may continue to operate, P.I. teams learn in the field that PFISR must be turned off during launch operations.

SRWG requests that the PFISR interference problem be clarified and that the necessary design and development procedures be followed so that all Poker missions (whether they are using PFISR observations or not) include avoidance of PFISR S-band interference frequencies (if at all possible) such that PFISR can operate continuously during all launch operations. Such actions should be verified at the Design Review and Mission Readiness Review of all Poker Flat launches.

On a separate note, the SRWG finds that the ability to listen to the audible countdown on the Poker Flat web site is extremely valuable for field operations and believes that this capability should be maintained as part of the Poker Flat operations.

NASA Sounding Rocket Working Group

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APPENDIX

June 2010

Report of the SRWG Sub-Committee on High Altitude Rockets to Increase Astrophysics and Solar Observing Time

As an outcome of the February 4, 2010 SRWG meeting, the SRWG released a finding on the use of High Altitude Rockets to Increase Astrophysics and Solar Observing Time (HARIASOT) with the goal of extending the science achieved by the Sounding Rocket Program (SRP) by significantly increasing the available observing time above 250 km through the use of existing rocket program launch vehicles, the Black Brant XI and XII (BBXI and BBXII), with payload recovery.

Science capabilities would be increased by extending the time above 150-250 km by

(1) permitting execution of programs that would otherwise be background limited (faint sources);
(2) permitting the execution of previously instrument limited programs (e.g. higher resolution spectroscopy, novel technologies) and hence previously unachievable programs;
(3) providing time to observe an increased number of targets (pointings) on a single flight;
(4) increasing the field of view (area) on nearby extended targets, such as the Sun. Some solar missions scan a slit across the Sun to build a spatial-spectral picture. Increasing the observing time by a factor of two increases the FOV by a factor of two. Because the atmosphere of the Sun evolves on timescales of minutes, the scientifically useful FOV cannot be increased by combining two flights with adjacent FOVs.
(5) increasing the signal-to-noise on observable targets to enable the detection of spatial or spectral structures in the target, in particular, structures previously background limited.

Note that only for the last motivational argument (5), do science benefits scale as signal-to-noise, which scales as square root of the observing time. For all other science motivators, the figure of merit grows much more rapidly: opportunities 1 and 2 open discovery space, capabilities 3 and 4 represent a linear growth in science benefits with increased observing time.

From carpet plots generated by WFF (Mr. Brent Edwards), it was estimated that for launches of a 1000 pound payload from WFF (i.e. near sea-level) at an elevation angle of 85 degrees the **gains** in time above 250 km relative to the BB IX are 164 and 114 percent for the BB XII and XI. The percentage **gains** in time over 150 km are 85 and 62 percent respectively. Typical elevation angles from WSMR are higher and, as is the altitude of the site relative to WFF, each of these effects would yield a higher apogee.

If the gains in observing time promised by the BBXI and BB XII vehicles are to be realized, then a high altitude recovery system must be implemented, together with either: (1) a larger land range, (2) a means to stay within the WSMR range limits, or (3) sea recovery. SRPO has been investigating many of these options over the years, and the SRWG requested that a summary of the technical feasibility and cost-benefit analysis of these alternatives be presented with consideration given to the increase in observing time, additional sky coverage achievable, rocket dispersion, payload recovery costs, and infrastructure costs. The SRWG does not have the independent means to assess the full costs associated with options 1-3.

Costs: Excepting the option for an alternate or modification to the Nihka stage, it should be emphasized that **no new vehicle development is needed.** The use of refurbished military motors has been successful in holding down the costs of the BB XI and XII vehicles.

The SRWG concluded previously that use of the BBX was not cost effective due to the cost of the Nihka motor in combination with the modest apogee gain for this launch vehicle.

Use of existing, on-site, technical infrastructure and operations, such as the SRPO uses U.S. Army facilities for tracking, range control and recovery at WSMR, would significantly reduce the cost of an ongoing NASA sounding rocket program at Woomera Test Facility (WTF) in Australia**.**

Time gains: The increase in observing time that can be expected from use of the BB XI and XII are summarized in Table 1. Times above two fiducial altitudes are provided: an altitude of 150 km, which satisfies many astrophysical observations, and 250 km, a figure of merit for astrophysical observations at infrared wavelengths. The figure of merit for many solar EUV observations is time above 200 km. The greatest gains can be achieved for payloads (e.g. near-infrared) where OH and other high-altitude contaminants are a concern. Using Table 2, we estimate that for launches from WFF (i.e. near sea-level) the **gains** in time above 250 km relative to the BB IX are 164 and 114 percent for the BB XII and XI. The **percentage gains** in time over 150 km are 85 and 62 percent, respectively.

Table 1. The apogee altitude, impact range and times above 150 and 250 km for a 1000 lb payload launched by the BB IX, XI and XII from WFF, and by the BB IX launched from WSMR : Q.E. = 85°

Range	**Vehicle**	**Apogee km**	**Range km**	**Time above 150 km sec**	**Time above 250 km sec**
WFF	BB IX	294	169	321	194
WSMR	BB IX	312	122	379	232
WFF	BB XI	438	272	521	416
WFF	BB XII	528	433	595	513

Table 2. Approximate 1-sigma impact dispersions for the BB IX, XI and XII. Incorporation of a radex joint fitting to the Nihka motor is in progress and is hoped to reduce the dispersion of the BB XII configuration.

Vehicle	**Launch Site**	**Launch Elevation Angle [degree]**	**Apogee km**	**Range km**	**EW 1-sigma Dispersion**	**NS 1-sigma Dispersion**
BB IX	WSMR	85	312	122	8	8
BB IX	WFF	85	294	169		
BB XI	WFF	85	438	272	40	60
BB XII	WFF	85	528	433	120	130

Alternate ranges: SRPO has experience in launching sounding rockets from two southern ranges, Roi Namur in the Marshall Islands (Reagan Test Site (RTS): US Army) and the Woomera Test Facility (WTF) in Australia. The WTF is an attractive candidate site for launch of the BB IX, XI and XII vehicles. *The WTF can accommodate the impact range and dispersion of these vehicles, satisfy the requirement for low particle background at sounding rocket altitudes, allow payload recovery, and provide access to the region around the South Celestial Pole which is inaccessible from WSMR, a factor important to astrophysicists*. Providing the capability to use WTF as a routine launch site for the BB IX will enable the use of the BBXI and BBXII launch vehicles with no additional development costs known to the SRWG.

Table 3 Physical size of potential launch ranges for the BB IX, XI and XII vehicles.

Range	EW Size [km]	NS Size [km]	Recovery
WFF			water
WSMR	60	160	land
WSMR + North Extension	60	215	land
Roi Namur (RTS)			water
Woomera (WTF)	600	220	land

The WTF operates a launch range of about 127,000 sq. km, measuring ~ 600 × 220 km (Table 3). Comparison of the 1-sigma impact dispersions (Table 2) with range dimensions indicates that launches of the BB XI and the BB XII and payload recovery should be feasible. The growing technical infrastructure available at the range, the international scope of WTF operations, and the invitation to extend and negotiate the use of range facilities for new users are described in the documents ``Woomera Test Facility Capability Brief'' and ``Trial Activities at the Woomera Test Facility'' (available on request).

This report is an updated abbreviation of the October 17, 2009 report of the SRWG sub-committee on High Altitude Rockets to increase Astrophysics and Solar Observing Time located at http://rscience.gsfc.nasa.gov/keydocs.html.