Sounding Rocket Working Group

National Aeronautics and Space Administration

Meeting of December 19-20, 2017

Findings

1. Remote Campaigns and Scheduling/Logistics for Australia 2019-2020

Summary

The SRWG applauds the efforts of the Sounding Rocket Program Office (SRPO) to find an alternative solution for southern hemisphere launch sites that provides land recovery. The pivot from the Woomera to the Equatorial Launch Australia (ELA) site will likely enable an Australian launch campaign to become a reality in 2020 and hopefully permit a regular cadence of such launches in the decades to come. The Sounding Rocket Working Group (SRWG) provides recommendations to help optimize operations from the experimenter perspective.

Background

NASA has announced an Australian launch opportunity every year since 2011, with advertised solicitations for relevant experiment proposals in 2014, 2016, and 2018. The political challenges of securing a civilian agency agreement with the Australia government for launches from the Woomera test range, which last supported a NASA rocket campaign in 1995, has proven to be a major obstacle. In 2015, a second potential launch site option was identified, known as the Equatorial Launch Australia (ELA) site in Arnhemland, Northern Territory, Australia. While this site remains relatively undeveloped, many of the logistic hurdles at Woomera do not exist at the ELA and this site could be ready to support NASA launches by September, 2019. From the scientific perspective, we note that the only real drawback of the ELA compared to Woomera is its relatively low southern latitude (12˚ S compared to Woomera's 31˚ S), such that the launch windows for higher latitude, scientifically important southern targets (e.g., the Magellanic Clouds), could be restrictive.

The astrophysics users community is excited about the possibilities that regular launches from the ELA may offer (see previous SRWG findings on southern hemisphere launch opportunities with land recovery), and the SRWG thanks the SRPO for the work they have invested in making this new range a possibility.

There are several challenges that we have identified for astrophysics telescope payloads that would be launched from the ELA site that we encourage the SRPO to bear in mind when developing the infrastructure to support launch campaigns. A partial list of typical requirements for telescope payloads includes: 1) fine-guidance ACS systems (1–10 arc-second pointing stability), necessitating command uplink facilities at the range; 2) many payloads operating in the X-ray and infrared bands require liquid nitrogen to cool detectors and optical assemblies, as well as UHP dry nitrogen for payload purging, and optical contamination control – local LN_2 and GN_2 sources will be required; 3) most payloads require relatively clean environments for integration and testing procedures – permanent infrastructure, including basic clean integration space, will reduce costs for future campaigns; and 4) payload recovery is paramount.

In addition to specific requirements of telescope payloads, there are a number of logistical challenges that a remote campaign at the ELA will face, particularly for the first time. The ELA is advantageous owing to the deep water port access that could reduce shipping costs (modulo the construction of the roads leading from the port to the launch site). However, recent remote campaign shipments to Kwajalein have shown that many stages of the shipping process can be subject to delays and endanger the timing of a campaign. To this end, we note that many UV payloads have environmental sensitivity that cannot tolerate multi-week transit times on surface ships.

The SRWG recommends that the relevant experimenters assist the SRPO and NSROC in their study of logistics challenges as part of campaign planning. This will allow flight and surface freight options to the ELA to be identified at the campaign kickoff. Export control regulations, ground safety requirements, I&T and shipping timelines, and similar items could also be documented and made available to the experiment teams at their MIC. As with other NASA remote campaigns, we anticipate the selection of a Campaign Scientist to take an organizational lead and be the point of contact with the experimenters participating in the campaign. We would welcome a presentation by the Campaign Scientist at a future SRWG meeting at some appropriate time.

2. Towards a Sustained Capability for Small, Mesospheric Rockets

Summary

The Sounding Rocket Working Group (SRWG) is extremely happy with the renewed efforts of the Sounding Rocket Program to develop a sustained capability to fly small, mesospheric payloads on a routine basis and that this initiative has reappeared on the Sounding Rocket Technology "Roadmap". We seek to engage the science community to help provide requirements and other guidance that might help optimize the scientific utility of this new aspect of the sounding rocket program.

Background

The SWRG appreciates the December 2017 response from Wallops to our Finding #2 on Mesospheric Rockets that was written as a result of the July, 2017 meeting. We are extremely happy that the development of a sustained capability to fly small, mesospheric payloads on a routine basis is back on the Sounding Rocket Technology "Roadmap".

The SRWG is in the process of organizing a workshop at the June 2018 CEDAR meeting in Santa Fe, which is an annual meeting sponsored by NSF that traditionally gathers a number of core researchers and students interested in mesospheric science. Members of the SRWG plan to solicit input from the science community on requirements and potential applications for small rockets with apogees of 90 to 120 km, as discussed at the last meeting. The review provided by NASA on the current status of the Mesquito avionics package and mesospheric motor options and capabilities was very helpful. We encourage Wallops to send a participant to attend this workshop to support with technical expertise and to help underline the renewed thrust of this endeavor within the program.

We also appreciate the presentation by Cathy Hesh of the SRPO on technology development of the Sub-TEC payload and the next planned test flight (Sub-TEC 8) in 2019 from Wallops. Such a swarm of sub-payloads based on the Mesquito dart package, with communication to the main payload and other new technology, is very exciting and is expected to increase community interest for future mesospheric and lower thermosphere investigations, for which spatially distributed measurements are of special interest.

3. Embracing the Talos-Oriole-Oriole Vehicle

Summary

The SRWG is very pleased with the anticipated performance of the Talos-Oriole-Oriole Vehicle. Although the predicted apogee, and hence "hang time" above 150 km, is not as high as originally anticipated, this new vehicle offers significant improvement compared to the Black Brant IX and we endorse efforts to make this new system available for future scientific missions.

Background

The SRWG is pleased with NSROC's continued efforts in finding a solution for longer duration flights. Recently, several configurations were considered, including a Talos-Oriole-Oriole (TOO), which appeared to have the potential of offering 700 seconds above 150 km for a 1000 pound payload. However, as we learned at the recent SRWG meeting, a re-analysis showed that the time above 150 km was more likely to be ~650 seconds.

Despite the fact that the predicted performance appears more limited compared to initial expectations, the SRWG strongly encourages this study to be continued and even broadened. Even though >700 seconds was not obtained, a motor capable of producing over 600 seconds is still a tremendous increase in capability given that current observation times for bulbous, 1000 pound payloads are ~300 seconds. In light of this new potential capability, a suite of other related issues should be studied. For example, we understand that Oriole motors are more expensive than Black Brants, but the costs may be comparable if the Orioles are bought in bulk. Also, since the payloads would travel to much higher apogees, they would thus have much higher reentry speeds, challenging recovery efforts. (This case would exist even with the more capable vehicle.) An appropriate recovery system should be developed, as we know the SRPO continues to investigate, particularly for water landings. Next, the concept of a fully integrated, bulbous payload was presented at the SRWG meeting. This was very compelling and offers exciting new possibilities, particularly for astrophysics and solar telescope payloads. The potential for implementing such a system should be pursued, at least from our vantage point, particularly if the bulbous nosecone might have a diameter of 1-meter or more. Enabling such routine, cost-effective flights with 1m diameter telescopes represents a substantial improvement compared to the current methodology.

To summarize, the significant increase in observation time promised by the T-O-O, combined with recent developments in recovery systems/water recovery payloads, and future studies such as those involving a larger, bulbous nosecone, have the potential for transformative change in suborbital science capability for astrophysics and solar missions, in particular.

4. Improving Confidence in Accuracy of "Coarse" Attitude Solutions

Summary

The SRWG is pleased that a dialogue has begun in earnest between the user community and NSROC regarding the accuracy of the coarse attitude solutions and ways to verify these solutions. We provide herein suggestions to improve the confidence in the accuracy of the "coarse" attitude solutions as well as verification procedures.

Background

Knowledge of the payload attitude in the Earth frame is essential to the success of many NASA sounding rocket missions. For example, in the geospace discipline, "coarse" attitude knowledge providing solutions with an accuracy of 1 degree (or better) in each orthogonal direction is routinely required and is usually met with a gyroscope or sun sensor provided by NSROC. On the other hand, astrophysics and solar telescope payloads typically utilize sub-arc second, fine-pointing star cameras to attain precise attitude information. Those devices which provide "fine" attitude knowledge (and which are expensive and are typically recovered), are not part of this discussion.

In addition to requiring attitude knowledge, geospace payloads frequently include attitude control systems (ACS) to orient the payload, for example, by placing the spin axis along the magnetic field direction or by keeping one surface of the payload maintained along the ram direction. The successful orientation of the payload attitude is not a substitute for the required attitude knowledge, which usually includes more precise angular requirements than those of the actual pointing -- typically at least one degree or better -- and also requires knowledge of the roll angle to this accuracy or better. For reference, for a typical spin rate of 1 spin/second, one degree of roll corresponds to a time of 2.78 msec.

There are a number of possible sources of error in the successful determination of the payload attitude knowledge post flight. We list some of these here and, in concert with the NSROC attitude engineers, seek to explore ways to minimize their effects. Attitude error sources include: (1) uncertainty of the mechanical alignment of the reference attitude fiducial with respect to the payload reference systems and that of the science instruments; (2) timing errors that may arise from a number of sources, including uncertainty of the time tags applied to the precise attitude information that is embedded in the asynchronous digital stream and different reference clocks between different data links; (3) errors in the gyroscope itself, such as drift of the offset during the flight, gyro calibration errors, and "stiction" that introduces errors for very small movements that are not successfully recorded by the gyro (these errors were more common with the older, Space Vector systems, but are mentioned for completeness); (4) errors that arise from procedural steps, such as uncertainty of the exact pointing directions when the gyro is uncaged or where zero degrees on the payload is with reference to the launch rail; and (5) documentation errors, such as the definition of reference axes used in the solutions provided by NSROC.

As of today, to our knowledge, there is not a standard verification procedure that NSROC routinely carries out before the attitude data are delivered to the experimenter, although most success criteria require "verified attitude data" as the required post flight "deliverable". The most straightforward means to verify the attitude data is to compare the measured magnetometer data with that predicted by the measured attitude data, using a standard magnetic field model (such as the IGRF) for the earth, which is generally valid to a degree or better below 1000 km altitude at all latitudes. Although there are errors in the magnetometer data (e.g., from uncertainty of its placement on the payload and with its calibration) that could account for 1-2 degrees of uncertainty, this is an excellent, proven way to catch most errors and verify that the solution is sensible and largely accurate. There are also independent means to verify the attitude data, particularly on daytime flights with sun sensors. Furthermore, there is the box test on the rail that can be used for verifying the attitude while on the rail, and other tests, such as tracking the detailed, dynamic payload orientation as it leaves the rail and begins its spin.

It should be emphasized that the most demanding performance verification of the attitude knowledge is the accurate determination of the roll angle information, since typically the yaw and pitch components are generally well determined, particularly on payloads whose principal axis is aligned by an ACS system. Accurate roll information, which can be verified by de-spinning the vector magnetic field data in the spin plane, is the most challenging to verify due to its sensitivity to timing error issues. Nevertheless, fitted solutions should be able to eliminate spin components of the magnetic field to the nT level, regardless of the absolute accuracy of the on-board magnetometer.

In a number of previous missions, particularly recently, attitude solutions provided to experimenters have contained large errors or required excessive back-and-forth communication to sort out errors and to verify/achieve the desired accuracy. The SRWG would gladly enlist a subcommittee of users (composed of community members who may or may not be members of the working group) to work with NASA/NSROC to discuss the attitude knowledge data and analysis procedures. Among the areas that we believe should be considered include: (1) improved documentation of the procedure so that best practices are followed in every applicable mission, including details on specifications of science or ACS mag data formats and inflight calibrations; (2) a means to document/verify the exact position of the reference fiducial (sometimes call the "top dead center") of the gyro within the ACS module; (3) characterization of the time tagging of the attitude data within the asynchronous bit stream and improved determination of possible errors between ACS timing, GPS timing (used for IGRF minimization to find inflight calibration matrix), and TM data; and (4) for at least one payload, conduct an experiment during I and T on a spinning platform (e.g., in the spin bay) to independently check for unexpected time delays and also to verify the successful de-spinning of the roll component with an independent external reference in addition to the magnetometer data. This test would also include a direct measurement on the spin platform of gyro alignment (ref M. Disbrow for specifics); and (5) assignment of a dedicated NSROC employee to be the point of contact to help work these requirements.

5. Improving Data Precision by Minimizing Uncertainties Due to Timing

Summary

At the last meeting, a spirited discussion took place concerning timing errors in rocket data streams, particularly in efforts to compare data from multiple telemetry downlinks. The SRWG wishes to continue this discussion with NSROC engineers and seeks ways to improve the precision of data acquired by various instruments on sounding rocket payloads by minimizing uncertainties due to timing.

Background

In conjunction with the discussion on attitude knowledge verification on rocket payloads, there arose a vigorous discussion of past and current issues with respect to the accurate time tagging of science and engineering data on sounding rocket payloads in general.

Both NSROC and members of the SRWG noted that accurate coordinated time tagging of data collected and telemetered using independent TM stacks was extremely challenging, particularly on the sub msec level. This issue appears to arise from two root causes:

First, the timing clocks of such independent TM stacks are not synchronized in flight, leading in some cases to significant uncertainties in the time tagging of data from different TM stacks. While the offset (i.e. fixed differences in starting times) and drift (i.e. differences in actual vs. nominal clock rate over flight) between the TM clocks can be small in an absolute sense, the impact of the unknown differences between the clocks and in-stream time-tags derived from them can have a significant relative impact, especially when working with high roll rates and high sample rate waveform data.

A persistent and long-standing example of this issue would be time series (i.e., waveform) science data gathered on typical geospace payloads (electric field, magnetic field, LP currents, etc.) that are acquired and telemetered on one link, while the attitude and position data (GPS position and velocity, gyro angles and rates, etc.) required to transform the data from the body-fixed frame and coordinates to geophysically relevant coordinates are acquired and telemetered on a different link. Without the ability to accurately time tag the data from each link relative to each other and to the absolute time (e.g. GPS time), errors in the magnitude and direction of the electric and magnetic fields, for example, in the Earth-fixed frame would occur and complicate the data analysis, in some cases significantly.

Second, that there are rarely shared periodic data "events" common between such links, which prevents direct post-flight "synchronization" of the TM links in the absence of on-board synchronization of the TM hardware. An example of this would be a case where one had multiple independent TM links as in the example above that one wanted to synchronize on the ground. One can often find events early in the flight – e.g. deployment of booms and other mechanisms, dynamics of booms associated with maneuvers, response of various science sensors to ACS pulses – where the science time series data (electric field or magnetic field, for example) and engineering data (ACS and accelerometer data, for example) can be compared and some estimate of the timing offsets between the two links made at that point in the flight. However, without some sort of periodic shared events between the two links (e.g., with a few seconds cadence), the end user cannot accurately determine how the time tagging drifts over the flight.

Two possible methods of synchronization are suggested, and the SRWG encourages the exploration of each, both in terms of feasibility, risk (e.g. single-point failure of entire TM system, rather than loss of single links), and cost (TM volume overhead to implement; increased integration time to assemble and test; etc.):

First, implementation of a shared TM clock amongst multiple TM links on the same payload. Naively speaking, this would keep all the TM systems "in-step", allowing for much simpler post-flight data reduction and analysis.

Second, implementation of a standard shared data product amongst all TM links on a single payload derived from the on-board GPS timing and position data if at all possible. This would allow for unambiguous estimation of accurate relative and absolute time tags amongst all the data available from the payload (science and engineering).

The SRWG looks forward to learning the comments of the NSROC engineering team, as well as their own suggestions, regarding such timing errors and the possibilities for such synchronization techniques at our next meeting.

6. Appreciation -- Philip J. Eberspeaker

The Sounding Rocket Working Group expresses its profound appreciation and deep gratitude to Mr. Phil Eberspeaker, Chief of the Sounding Rocket Program, who managed this core program so well for NASA over the past fifteen years and who retired earlier this year.

Beginning as a co-op student in 1982, Phil worked for over 35 years in the rocket program, including many years as a payload manager. Since becoming Chief of the Sounding Rocket Program in 2002, Phil has been the guiding force in keeping the program as the undisputed international leader in sounding rocket research and launch capability.

Coupled with his in-depth knowledge and experience with all aspects of sounding rockets, Phil's firm grasp on the management and execution of this program enabled him to work with consistent success on all fronts of NASA's Sounding Rocket Program. To this end, Phil consistently demonstrated a deep commitment to making NASA's sounding rocket program the best it could possibly become, including excellence in science, engineering, launch vehicles, remote campaigns, and education and public outreach. Importantly, through his leadership, he sought out, nurtured, and empowered, a dedicated cadre of personnel within the Sounding Rocket Program Office who he so expertly managed and led. His ability to ensure that the NASA Sounding Rocket Contract (NSROC), the major contract which the SR Program Office managed, maintained its expertise, personnel, and camaraderie, is a testament to how Phil excelled in all aspects of his position.

From the standpoint of the Principal Investigators, we were continuously impressed with how Phil kept "Achieving Scientific Excellence" as the foremost goal of the program and continuously suggested creative solutions to meet or exceed requirements -- whether it was enabling an auroral sounding rocket with numerous sub-payloads equipped with small motors, facilitating, for the first time, a "tailored" trajectory with a large horizontal velocity component, encouraging NASA's use of launch sites in Kwajalein and Australia, or championing high altitude rockets with water recovery for astrophysics and solar telescope payloads.

Philip Eberspeaker's outstanding leadership, his highly effective and responsible program management, and his visionary planning have enabled NASA's highly successful Sounding Rocket Program to continuously produce outstanding, internationally renowned scientific research, for which the scientific community, NASA, and the United States, can be proud.

7. Appreciation -- Tripp Ransone

The Sounding Rocket Working Group expresses its sincere appreciation and heartfelt thanks to Mr. Emmett (Tripp) D. Ransone, Assistant Chief of the Sounding Rocket Program, who retired last December. Tripp started at Wallops in 1985 in the Mechanical Systems Section and joined the Program Office as the Assistant Chief in June, 1998.

Tripp is the epitome of the "unsung hero", forever working behind the scenes to keep the program running smoothly and to make sure its goals were met. He was tremendous force for good for NASA's Sounding Rocket Program, consistently helping the SR Program Chiefs, first Mr. Bobby Flowers and then Mr. Phil Eberspeaker, manage and maintain the schedules, personnel, and budget needed to ensure a successful program. He also contributed significantly to the program in general, via his expert knowledge of sounding rocket vehicle systems, payloads, mobile and fixed launch sites, and the need to keep the success of the science investigation at the forefront.

We salute Tripp for his untiring dedication to the program for so many years, and the unselfish manner in which he kept the good ship "Sounding Rockets" on course.

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