Sugar Shot to Space

Program Scope

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Sugar Shot to Space Program

Introduction

The Sugar Shot to Space (SS2S or SStS) Program has as its core goal to reach into the beginnings of space and to meet this challenge with sound engineering, a little sugar and a whole lot of spice. The SS2S program is an agglomeration of ideas and know-how of skilled individuals across many disciplines as well as international borders. SS2S takes it cue from the annals of amateur rocketry -- SS2S will use a sugar-based propellant to drive a payload to the edge of space. This will be accomplished by use of a novel dual-burn experimental motor with the timing between each of the motor's burns tailored to maximize altitude in the vehicle's trajectory. A "build a little and test a little" philosophy will be applied to all aspects of SS2S vehicle development, from small scale to full scale static motor tests, to scaled down intermediary vehicle flights, to individual system and component testing. Thus, the team of volunteer SS2S participants can breech the learning curve and move forward toward space with confidence.

The Projects

The basic tenet of the SS2S program is to fly high while smoking some sugar. SS2S will reveal itself via a series of motor development projects and three primary rocket vehicle projects with the last being the vehicle by which SS2S reaches space. The proposed primary vehicles and motors are illustrated Figure 1 with an appropriate scale. In addition, two elective projects are included, as detailed later in this document

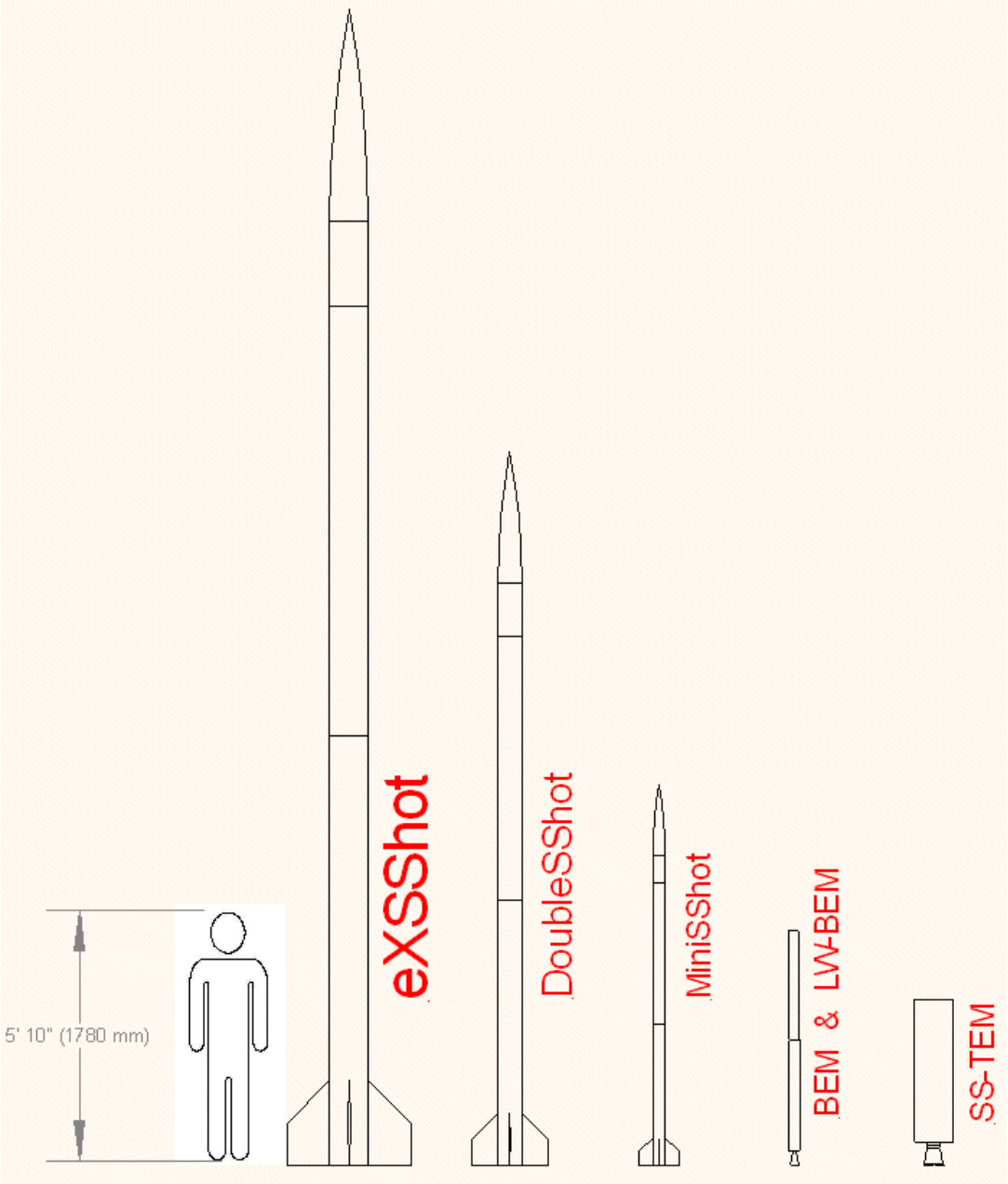

Figure 1 - The proposed Sugar Shot to Space program's primary flight vehicles and motors

Motor Development

Initial development will begin with a series of smaller motor projects where a range of parameters and design elements can be put to the test prior to committing to complete motor design. A primary element of SS2S is the testing of the dual-burn motor burn concept, which is key to obtaining high altitudes using amateur sugar-based propellants. The motor test series have received the following designations

- BEM

- LW-BEM
- SS-TEM

In addition to these “static test only” motors, the motor design for each of the three primary flight vehicles will be static test proven prior to committing to flight. The motor development stages are illustrated in Figure 1.

BEM: Ballistic Evaluation Motor

The first technological challenge facing the Sugar Shot program, the BEM is a ¼ scaled version of the proposed full-size motor slated for the eXSShot space flight attempt. The concept of the motor design is novel in the sense that the operation involves a “dual burn”. The motor consists of two distinct combustion chambers with separate propellant grain charges. The charges fire sequentially, separated in time by a delay period, thus the term “dual-burn”. The two chambers are separated by a “mid bulkhead” which incorporates a combustible “delay plug”, which is fully consumed during the delay period. The purpose of having two separate propellant charges with a delay between operation of each is to allow a rocket vehicle to coast between firings. This greatly increases the potential peak altitude in comparison to a conventional single-burn motor.

The BEM is intended solely as a static test motor, and as such, incorporates “boilerplate” design philosophy.

Motor Designation

The BEM series will use the following naming convention:

BEM XX

The XX is Roman numeral series designation. For example, if the motor being fired is the third in the series that motor will have the designation BEM III

Objectives:

- To design, fabricate and fire the BEM within 4 months from project start.
- To prove the “dual-burn” concept using a largely similar, but scaled-down, design corresponding to that of the proposed flight motor
- To obtain actual performance data for comparison to predicted, and thus aid in the design of the flight vehicle motor and subsequent test motors.
- To obtain motor-specific operating characteristics of the KNSB propellant
- Confirm delay-plug concept is feasible
- Test and validate elements of the dual-ignition system

Success Criteria

- The BEM is fabricated and test fired within 4 months or less from project start date.
- Criteria for design and testing meets that outlined in the Technical Specification document.
- Operation of both motor burns is achieved without significant structural or operational anomalies.
- Delay between motor burns is within limits specified in Technical Specification document
- Motor thrust, pressure and thermal data is gathered.
- Performance is within acceptable limits.

Deliverables

- Technical Specification document
- Drawings for motor detail parts and assembly (CAD, etc)
- Ballistic Evaluation Motor complete with propellant grains.
- Motor static test stand
- Dual-ignition system suitable for dual-burn with delay between firings.
- Data acquisition system(s) as specified.
- Motor assembly and test equipment integration; operation checklists
- Test firing report including design modification recommendations

Assumptions

- Necessary resources (money, personnel, materials, etc) are available
- All design considerations were evaluated, and the design finalized, prior to BEM design phase
- Multiple firing dates are available to implement design modifications, as required
- Data acquisition equipment development and testing is complete on time

LW-BEM: *Light Weight Ballistic Evaluation Motor*

A lightweight in all regards, this test motor is a direct descendant of the ¼ scale Ballistic Evaluation Motor (BEM). The BEM is a proof-of-concept motor and consequently is largely “boilerplate” design. The BEM is to be reworked in order to reflect design changes relevant to the LW-BEM. These design changes are to include, but not be limited to, significant mass reduction, resolution of heat transfer issues, reduction of parts count and new manufacturing and assembly procedures. The LW-BEM design is to be verified through at least one static firing. Design modifications that are directly applicable to the design of the MiniSShot flight motor. These modifications could find their way into future motors and vehicles.

Motor Designation

The LW-BEM series will use the following naming convention:

LW-BEM XX

The XX is Roman numeral series designation. For example, if the motor being fired is the third in the series that motor will have the designation LW-BEM III

Objectives:

- To design, fabricate and fire the LW-BEM within three months from project start.
- To verify design modifications of the various LW-BEM components and materials
- To obtain actual performance data for comparison to predicted, and thus aid in the design of the flight vehicle motor and subsequent test motors.
- To obtain motor-specific operating characteristics of the KNSB propellant geometry and layout modifications
- Confirm improved delay-plug design
- Test and further validate elements of the dual-ignition system
- Obtain data resolutions higher than in previous motor tests

Success Criteria

- The LW-BEM is fabricated and test fired within 3 months or less from project start date.
- Criteria for design and testing meets that outlined in the LW-BEM Technical Specification document.
- Delay between motor burns is within limits specified in LW-BEM Technical Specification document
- Thrust, pressure and thermal data is gathered.
- Performance is within acceptable limits and meets minimally established requirements for operation.

Deliverables

- Technical Specification document
- 3D models and production drawing package for motor parts and assemblies
- Light Weight Ballistic Evaluation Motor complete with propellant grains.
- Protoflight version of the dual-ignition system suitable for “dual-burn” with delay between firings.
- Data acquisition system(s) as specified.
- Motor assembly and test equipment integration; operation checklists
- Test firing report including design modification recommendations for MiniSShot tests

Assumptions

- Necessary resources (money, personnel, materials, etc) are available
- All design considerations were evaluated, and the design finalized, prior to LW-BEM design and fabrication phase
- Multiple firing dates are available to implement design modifications, as required
- Data acquisition equipment development and testing is complete on time

SS-TEM : Short Stack Technical Evaluation Motor

Another major technological challenge facing the Sugar Shot program, the SS-TEM is a full-diameter version of the proposed full-size motor slated for the eXSShot space flight attempt. A major difference from the full-scale version is that the SS-TEM is a much shortened version. Whereas each chamber of the full-scale motor is slated to contain 6 grain segments, the "Short Stack" will be limited to 2 grain segments, and will not be dual-burn. The motor will have an integral delay plug with the aim of confirming its operation in a full diameter configuration.

The SS-TEM is intended solely as a static test motor However, unlike the BEM, the SS-TEM is designed with a minimum weight philosophy in mind, an exercise that should prove beneficial for the future eXSShot motor development.

Motor Designation

The SS-TEM series will use the following naming convention:

SS-TEM XX

The XX is Roman numeral series designation. For example, if the motor being fired is the second in the series that motor will have the designation SS-TEM II

Objectives:

- To design, fabricate and fire the SS-TEM within 12 months from project start.
- To test manufacturing techniques for large-scale components similar to that full-size flight motor
- To test the structural and thermal capability of the various motor materials and design techniques that are directly applicable to the full-size motor.
- To obtain actual performance data for comparison to predicted, and thus aid in the design of the flight vehicle motors and subsequent static test motors.
- To develop an efficient and safe large-scale propellant production method
- To obtain motor-specific operating characteristics of the KNSB propellant in a full-diameter configuration
- Confirm delay-plug concept is feasible on a full-size scale

Success Criteria

- The SS-TEM is fabricated and test fired within 12 months or less from project start date.
- Criteria for design and testing meets that outlined in the Technical Specification document.
- Operation of the motor burn is achieved without significant structural, thermal or operational anomalies.
- Delay plug structural integrity is maintained throughout the entire burn, and the time delay before burnthrough is within limits specified in Technical Specification document
- Motor thrust, pressure and thermal data is gathered.
- Performance is within acceptable limits.

Deliverables

- Technical Specification document
- Drawings for motor detail parts and assembly (CAD, etc)
- Hydrostatic test article
- Materials testing results for proposed composite casing and closure design
- Complete Short Stack Technical Evaluation Motor
- Enhanced scale propellant manufacturing system
- Propellant grains required for (each) static test
- Motor static test stand
- Suitable ignition system .
- Data acquisition system(s) as specified.
- Motor assembly and test equipment integration; operation checklists
- Test firing report including design modification recommendations

Assumptions

- Necessary resources (money, personnel, materials, etc) are available
- All design considerations were evaluated, and the design finalized, prior to SS-TEM design phase
- Multiple firing dates are available to implement design modifications, as required
- Upscaled propellant manufacturing technique is developed
- Manufacturing of full-size components proves feasible
- Data acquisition equipment development and testing is complete on time

Vehicle Development

Three flight vehicles are in the critical path of the goal of reaching space using sugar-based propellant. In honor of the Sugar Shot to Space mantra these vehicles have received the following designations

- MiniSShot
- DoubleSShot
- eXSShot ("extreme shot")

Each successive vehicle is to build upon the successes and failures of the vehicles that precede it.

MiniSShot: *Miniature Sugar Shot*

Small with a lot of punch, MiniSShot is a 30 % (approximate) scale version of the eXSShot vehicle. The MiniSShot vehicle will be used to further the SS2S Team's experience in sugar-based propellant, dual-burn motor design, avionics testing and all phases of launch operations. The MiniSShot vehicle serves three primary purposes. The first is to validate vehicle sub-system integration and avionics operation. This will give the SS2S Team a real measure of the integrated design. The second is to test dual-burn sugar-based motor design under actual flight conditions to include, but not limited to, mass reduction using lightweight composites, resolution of heat transfer issues, enhanced nozzle design, and new manufacturing and assembly procedures. Finally, the Team must put to the test launch, safety, transportation, and vehicle recovery and on-site propellant manufacturing procedures and capabilities. In addition, initial data is to be obtained in the scaling of sugar-based propellant motors. Thus, to ensure proper motor operation and optimized burn separation timing, and to gain experience with the additional design refinements over the LW-BEM motor, at least one static test firing of the MiniSShot motor prior to giving the motor a flight ready designation will be required. MiniSShot will be the first high-altitude capable vehicle with an integrated payload and is meant to be recovered and potentially reused. Postflight analysis is expected to aid in revealing any challenges that may need to be addressed in the DoubleSShot and eXSShot vehicles.

Vehicle Designation

The MiniSShot vehicle series will use the following naming convention:

MiniSShot XX

The XX is Roman numeral vehicle series designation. For example, if the vehicle being launched is the third vehicle in the series that vehicle will have the designation MiniSShot III.

Objectives

Primary

- To design, fabricate and launch the MiniSShot vehicle in less than 8 months from project start date
- Attain an altitude of at least 15 km
- Verify motor operation and performance in a flight mission
- Perform in-flight tailoring of the vehicle flight profile by tailoring the delay between motor burns via on-board computer control
- Integration of external sensors to the avionics systems
- Integration of the payload with RF systems
- Incorporate aerodynamic improvements to vehicle
- Ensure security of all participants and general public and minimize environmental impact during all phases of the project

Secondary

- Obtain in-flight, real-time data on vehicle stresses and fin aerodynamics
- Successfully recover the MiniSShot vehicle after flight testing
- Establish vehicle launch and in-flight operational procedures
- Verify payload and vehicle recovery operations

Tertiary

- Take measure of refurbishment and reflight readiness procedure by a turnaround time of less than 14 days

Success Criterion

These mission criteria are the minimums to be met by the MiniSShot vehicle

- The MiniSShot vehicle fabricated and launched in 8 months or less from project start date
- A verifiable altitude of no less than 15 km is attained
- In-flight, real-time data on motor and vehicle performance is obtained
- The tailoring of the vehicle flight profile by optimizing the delay between motor burns is verified
- Successfully recover the MiniSShot vehicle and payload after flight testing
- Obtain attitude and position data via vehicle-to-ground communications link through apogee

Deliverables

- Requirements and Technical Specification documentation
- Static test & flight version of the MiniSShot motor
- Integrated avionics payload with RF communications
- Construction and fabrication of the MiniSShot vehicle

- Data, summary, and detailed results in report format for each flight
- Design data and fabrication information for each vehicle (CAD, how to, etc)
- Vehicle assembly, integration, testing and operation checklists

Assumptions

- Static testing of MiniSShot Motor is successfully completed within allowed scheduled time period
- Avionics electronics development and testing is complete before flight
- Necessary resources (money, personnel, materials, etc) are available
- Multiple flight dates are available
- Preliminary ProtoSShot and LW-BEM flight testing and validation is complete
- All design considerations were evaluated, and the design finalized, prior to MiniSShot vehicle implementation
- Schedule to implement vehicle is met
- Ground support equipment and materials for propellant manufacture, launch, communications, and mission control are available

DoubleSShot: *Double Sugar Shot*

Need a double shot of sugar? The DoubleSShot vehicle is a 60 % (approximate) scale version of the eXSShot vehicle and approximately twice the size of the MiniSShot vehicle. DoubleSShot will be another stepping stone in the quest to get to the edge of space for the Sugar Shot to Space Team. It is expected that after the launch of the MiniSShot (series) and the subsequent data reduction expected, further refinements to launch operations and the vehicle itself will be implemented and tested. DoubleSShot is expected to reach one-third of the Team's ultimate altitude -- nearly 33 km. Static testing of the DoubleSShot motor is imperative before declaring the motor ready for flight. A fourteen-day turn-around and reflight of the launch vehicle and payload will be examined. DoubleSShot will also serve to test the ground support equipment that is to be used for launch, safety, transportation, and vehicle recovery procedures and for on-site propellant manufacturing capabilities for the larger eXSShot vehicle. As with MiniSShot, this vehicle is meant to be recovered intact for potential reuse.

Vehicle Designation

The DoubleSShot vehicle series will use the following naming convention:

DoubleSShot XX

The XX is Roman numeral vehicle series designation. For example, if the vehicle being launched is the third vehicle in the series that vehicle will have the designation DoubleSShot III.

Objectives

Primary

- To design, fabricate and launch the DoubleSShot vehicle in less than 8 months from project start date
- Attain an altitude greater than 30 km
- Obtain in-flight, real-time data on vehicle performance
- Perform in-flight tailoring of the vehicle flight profile by adjusting the delay between motor burns via on-board computer control
- To test the ground support services and equipment required to support the eXSShot flight.
- Verification of transport and all on-site assembly, testing and integration of vehicle and payload.
- Verification of launch and recovery operations for eXSShot vehicle
- Ensure security of all participants and general public and minimize environmental impact during all phases of the project

Secondary

- Successfully recover the DoubleSShot vehicle after flight testing
- Obtain end user data via vehicle-to-ground communications link
- Test and verify end user payload in-flight operations

Tertiary

- Take measure of refurbishment and reflight readiness procedure by a turnaround time of less than 14 days

Success Criterion

These mission criteria are the minimums to be met by the DoubleSShot vehicle

- The DoubleSShot vehicle fabricated and launched in 8 months or less from project start date
- A verifiable altitude of no less than 30 km is attained
- In-flight, real-time data on motor and vehicle performance is obtained
- The tailoring of the vehicle flight profile by adjusting the delay between motor burns is verified
- Successfully recover the DoubleSShot vehicle and payload after flight testing
- Obtain attitude and position data via vehicle-to-ground communications link through apogee

Deliverables

- Requirements and Technical Specification documentation
- DoubleSShot Motor
- Integrated avionics payload
- Construction and fabrication of the DoubleSShot vehicle

- Data, summary, and detailed results in report format for each flight
- Design data and fabrication information for each vehicle (CAD, how to, etc)
- Vehicle assembly, integration, testing and operation checklists

Assumptions

- Static testing of DoubleSShot Motor is successfully completed within allowed scheduled time period
- Necessary resources (money, personnel, materials, etc) are available
- Multiple flight dates are available
- MiniSShot flight testing and validation is complete
- All design considerations were evaluated, and the design finalized, prior were performed prior to DoubleSShot vehicle implementation
- Schedule to implement vehicle is met
- Ground support equipment and materials for propellant manufacture, launch, communications, and mission control are available

eXSShot: eXtreme Sugar Shot

X marks the spot. This is the full-scale vehicle, designed and manufactured to reach the 100 km target. This vehicle will be the culmination of all of the prior vehicle developments and separate efforts, such as the Short Stack (SS-TEM) and subsequent full-scale eXSShot static motor testing, in order to achieve the goal of reaching space. The eXSShot vehicle should carry an end user payload to the edge of space and safely recover the eXSShot vehicle and the payload. A key endeavor is to take measure of the reflight readiness procedures established with the DoubleSShot series in an attempt to make the launch vehicle and a different payload flight ready in less than fourteen days. This vehicle is meant to be recovered and potentially reused.

Vehicle Designation

The eXSShot vehicle series will use the following naming convention:

eXSShot XX

The XX is Roman numeral vehicle series designation. For example, if the vehicle being launched is the second vehicle in the series that vehicle will have the designation eXSShot II.

Objectives

Primary

- To design, fabricate and launch the eXSShot vehicle in less than 12 months from project start date

- Attain an altitude of at least 100 km (the official boundary of space)
- Obtain in-flight, real-time data on vehicle performance
- Optimize the vehicle flight profile by tailoring the delay between motor burns
- Obtain end user data via vehicle-to-ground communications link
- Successfully recover the eXSShot vehicle and end user payload after the flight
- Ensure security of all participants and general public and minimize environmental impact during all phases of the project

Secondary

- Refurbishment and reflight readiness with a turnaround time of less than fourteen days

Success Criterion

These mission criteria are the minimums to be met by the eXSShot vehicle

- The eXSShot vehicle fabricated, tested and launched in 16 months or less from project start date
- A verifiable altitude of no less than 100 km is attained
- In-flight, real-time data on motor and vehicle performance is obtained
- Successfully recover the eXSShot vehicle and end user payload after flight
- Downlink end user data and deliver to end user

Deliverables

- Requirements and Technical Specification documentation
- Complete integrated full eXSShot motor
- End user payload(s)
- Integrated avionics payload
- Construction and fabrication of the eXSShot vehicle
- Data, summary, and detailed results in report format for each flight
- Design data and fabrication information for each vehicle (CAD, how to, etc)
- Vehicle assembly, integration, testing and operation checklists

Assumptions

- Prior successful static testing of the SS-TEM (Short stack test evaluation motor)
- Static testing of dual-burn eXSShot motor is successfully completed within allowed scheduled time period
- Necessary resources (money, personnel, materials, etc) are available
- Multiple flight dates are available
- Preliminary ProtoSShot and MiniSShot flight testing and validation is complete
- At least one flight in each of the MiniSShot and DoubleSShot vehicle series is successful completed

- All design considerations were evaluated, and the design finalized, prior to eXSShot vehicle implementation
- Schedule to implement vehicle is met
- Ground support equipment and materials for propellant manufacture, launch, communications, and mission control are available

Elective Projects

Two elective projects outlined here are to be implemented only as needed and are not entirely dependent upon previous work. One such project is to serve as a development platform while the other is a back up for the MiniSShot project.

ProtoSShot: Prototype Sugar Shot

This series of small rocket vehicles are designed to be operationally simple, robust and cost effective tools to test and validate a number of other vehicle and ground systems separately from the main vehicle. The ProtoSShot vehicles are to be built and flown by the corresponding team or individual in charge of a system. ProtoSShot is to be an on-going series that will fly on an as-needed basis and serve as a component development platform to subject design elements to a launch environment. This will provide qualitative and quantitative data regarding various mechanical, electrical and thermal components and interfaces. A series of test flights of these vehicles should be flown to further yield data on the reliability of the chosen system design and to identify area where individual systems can be improved. These vehicles are meant to be recovered and reused. Depending on the specific goal, the ProtoSShot vehicle may be a commercially produced model rocket, hi-power rocket, or scratch-built rocket.

Vehicle Designation

The ProtoSShot series will use the following naming convention:

ProtoSShot XXXX

The XXXX is a one to four-letter abbreviation used to identify the system the vehicle is testing. For example, if the vehicle is testing the whole recovery system the vehicle could have the designation ProtoSShot R. Subsequent vehicle iterations shall have a designation of MARK X [X = Roman numeral].

Goals

The following are general, broad goals of the ProtoSShot vehicles. These vehicles will assign specific objectives and loose requirements based upon the needs of the SS2S project.

- To design, fabricate and launch the ProtoSShot vehicle series in less than one month from initiation
- Obtain in-flight, real-time data on vehicle performance
- Test and validate design of the recovery system and its components
- Test and validate the elements of the avionics system
- Test and validate elements of launch support and ground system
- Successfully recover the ProtoSShot vehicle after flight testing
- Verify aerodynamic performance and trajectory simulations

Success Criterion

The success criterion will depend upon the specific objectives of each ProtoSShot vehicle.

Deliverables

The minimum deliverables for all ProtoSShot vehicles shall include:

- Construction and fabrication of the ProtoSShot vehicle
- Data, summary, and detailed results in report for each flight
- Design data and fabrication information for each vehicle (CAD, how to, etc)
- Design Data and fabrication information for each SS2S element tested
- Final summary and results report for each specific ProtoSShot vehicle

Assumptions

To implement the ProtoSShot vehicle series, the following is assumed:

- Necessary resources (money, personnel, materials, etc) are available
- Multiple flights are performed to validate vehicle systems
- Multiple flight dates are available
- SS2S designs and/or elements are available and ready to be tested
- Criteria are supplied as quantitative objectives to be reached
- Trades were performed prior to ProtoSShot vehicle implementation
- Schedule to implement vehicle is met

LiteSShot: Lite Sugar Shot

The LW-BEM test motor will also serve as a backup motor to the MiniSShot vehicle in case of unexpected schedule slip or technical glitches in the initial MiniSShot motor and/or vehicle development so that a vehicle may fly by the close of 2007. If this scenario comes to pass the vehicle designation would then be LiteSShot. Thus the vehicle would be reworked so as to meet most of the MiniSShot requirements with an adjusted set of objectives listed below. It is stressed that the LiteSShot vehicle is to be a combination of

the LW-BEM motor and MiniSShot payload components. LiteSShot is not a separate project in the critical path of eXSShot development.

Vehicle Designation

The LiteSShot vehicle series will use the following naming convention:

LiteSShot XX

The XX is Roman numeral vehicle series designation. For example, if the vehicle being launched is the third vehicle in the series that vehicle will have the designation LiteSShot III.

Objectives

Primary

- To repurpose the LW-BEM into LiteSShot flight vehicle
- Launch prior to the end of 2007
- Attain an altitude greater than 7 km
- Obtain in-flight data on vehicle performance
- Tailor the vehicle flight profile by adjusting the delay between burns

Secondary

- Successfully recover the LiteSShot vehicle after flight testing
- Validate vehicle assembly procedures
- Validate recovery operational procedures

Success Criterion

These mission criteria are the minimums to be met by the LiteSShot vehicle

- The LiteSShot vehicle fabricated and launched before the end of 2007
- A verifiable altitude of no less than 7 km is attained
- In-flight, real-time data on motor and vehicle performance is obtained
- Tailor the vehicle flight profile by adjusting the delay between burns is verified
- Successfully recover the LiteSShot vehicle after flight testing
- Obtain attitude and position data via vehicle-to-ground communications link through apogee

Deliverables

- Redesigned flight version of the LW-BEM
- Integrated avionics payload to record altitude and to ignite second motor burn
- Construction and fabrication of the LiteSShot vehicle
- Data, summary, and detailed results in report format for each flight

- Design data and fabrication information for each vehicle (CAD, how to, etc)
- Vehicle assembly, integration, testing and operation checklists

Assumptions

- Static testing of LW-BEM is successfully completed within allowed scheduled time period
- Necessary resources (money, personnel, materials, etc) are available
- Multiple flight dates are available
- Avionics electronics development and testing is complete before flight
- Applicable ProtoSShot flight testing and validation is complete
- All design considerations were evaluated, and the design finalized, prior to LiteSShot vehicle implementation
- Schedule to implement vehicle is met
- Ground support equipment for propellant manufacture, launch, communications, and mission control are available

Project Schedule

As defined previously, six primary projects tackling ever more complexity within the mission envelope will guide us and serve as key steps within the SS2S program. An additional element that can serve the SS2S program is to place all of the projects, events and tasks of SS2S into a temporal context – via a timeline.

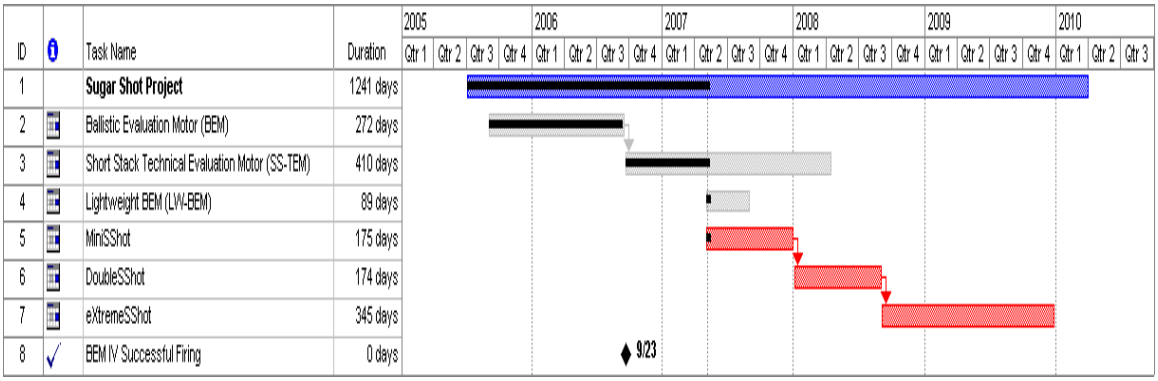

Figure 2 - An overall timeline of the SS2S program placing the defined projects in a basic sequence.

As is shown in Figure 2, the SS2S program began in mid-2005. The Ballistic Evaluation Motor was soon developed and various elements were tested and evaluated. In the fall of 2006 the BEM project concluded with the successful firing of BEM IV with most of the objectives having been met. This then brought about the beginning of a new motor development project at the end of 2006 on a single-burn motor with the diameter matching that of the proposed eXSShot vehicle. Spring of 2007 saw rework of the BEM into the LW-BEM via mass reductions and certain component design improvements. In parallel, MiniSShot, SS2S's first flight vehicle, will begin development and is expected

to conclude with a successful test at the end of 2007. After flight analysis is complete on the MiniSShot flight(s), work will begin in earnest on the next step in the SS2S program's drive to the 100 km goal with DoubleSShot, in spring 2008. DoubleSShot is expected to be tested, validated, and launched by winter of the same year. Upon a successful flight of the DoubleSShot vehicle, the eXSShot vehicle would begin development with an anticipated launch date planned for late 2009. The SS2S project is expected to conclude at the end of the first quarter of 2010, with completion of eXSShot flight analysis and reports.