DoubleSShot

Technical Requirements

Rev. 2011/02/05

(Changes to previous revisions indicated by a vertical bar in left margin)

Introduction

This document serves to specify the technical requirements for the *DoubleSShot* (DSS) rocket vehicle and mission support infrastructure. The purpose of these requirements is to define the desired configuration and functionality required to best achieve the DSS Mission Statement and Objectives (Ref.1) within the scope of the Sugar Shot to Space program. This document is not intended to provide technical solutions to these requirements.

The DSS requirements cover the following:

- General
- Vehicle
- Recovery
- Propellant
- Propulsion
- Avionics/Payload*
- Ground Support

* Provided in a stand-alone document, Reference 2.

Definitions

SHALL -	This word means that the definition is an absolute requirement of the specification.
SHALL NOT -	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD -	The word "SHOULD", or the adjective “DESIRABLE”, means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications must be understood and carefully weighed before choosing a different course.
MAY -	The word "MAY" or the adjective “OPTIONAL”, means that this item is one of an allowed set of alternatives.

References

1. *DoubleSShot* Mission Goals, rev. 2010/09/15
2. *DoubleSShot* Avionics Requirements, rev. 2010/11/26
3. Nose Cone Drag Study for the *SStS* Rocket, rev. 2005/10/7
4. *DoubleSShot* Mass Targets, rev. 2010/11/26
5. *DoubleSShot* Standard Atmosphere Properties, rev. 2010/9/30

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1. General Requirements

1.1. Vehicle shall be designed to attain a minimum apogee of 33 km (108k ft).

1.2. Attaining minimum mass of the vehicle should be prime driving factor in all facets of vehicle design and selection of off-the-shelf components (see 1.3).

1.3. Vehicle shall be designed and built to attain a propellant mass-fraction of 72% or better (ratio of propellant mass to total vehicle mass at liftoff). A weight planning, control and tracking system shall be implemented to support this requirement.

1.4. All components of the vehicle should meet their mass targets provided in Ref.4.

1.5. Systems and components critical to mission success shall contain redundancies, to the extent practicable, to minimize risk. Where redundancy is not practical, a high degree of reliability shall be the driving factor, accomplished through:

1.5.1. simplicity of design to the extent practical to achieve required functionality

1.5.2. use of proven concepts

1.5.3. minimization of critical failure modes

1.5.4. sufficient testing to establish reliability

1.6. Vehicle shall not incorporate any novel features that could pose a significant risk to approval of launch clearance.

1.7. An abort system shall be incorporated which would inhibit ignition of the second burn if the trajectory, at time of planned 2nd burn ignition, deviates from true vertical by more than 15 degrees.

1.8. Safety to all participants and general public shall be considered as paramount in all aspects of the project.

1.9. Project should have negligible detrimental environmental impact.

1.10. All applicable laws and regulations shall be followed.

2. Vehicle Requirements

2.1. Vehicle shall be of approximately 2/3 scaled-down version of the proposed full-sized *ExSShot* (ESS) vehicle (Figure 1).

2.2. Vehicle shall consist of two distinct and separable units, namely Booster and Payload Capsule, consisting of the following basic components (Figure 1):
<u>Booster</u>- Propulsion unit, Aft Payload Bay and Fins
<u>Payload Capsule</u> – Nosecone (housing the Forward Payload Bay) and Recovery Bay.

2.3. Stability and minimization of trajectory dispersion shall be achieved passively by a combination of fins and natural vehicle roll during ascent.

2.4. Aerodynamic drag losses should be minimized by good design, fabrication and finishing technique, and by minimizing protrusions into the airstream.

2.5. The primary choice for payload location should be within the nosecone (Forward Payload Bay); secondary choice for payload location should be within the Aft Payload Bay.

2.6. The Aft Payload Bay may be integral to the propulsion unit or may be a discrete compartment.

2.7. Vehicle should be painted predominantly white colour using epoxy-based or polyurethane-based paint for durability. Another colour may be chosen if deemed more suitable for high-visibility on the ground. Darker shades should be avoided in order to minimize solar heating. Logos or stickers may be used as long as their thickness is within the air flow boundary layer.

2.8. The vehicle shall not contain any features that would result in items of significant mass (>10 grams) being released to free-fall, at any time during the flight from launch to recovery, that may pose a safety hazard to persons or property on the ground. Such items may be allowed to be separated from the vehicle and descend separately, but shall incorporate a descent velocity limiting feature such as parachute or streamer.

2.9. Assembled vehicle shall be designed to an ultimate load requirement of 200 lbs (90 kg) applied at the nosecone (just aft of the tip) in a direction perpendicular to the longitudinal axis.

2.10. Assembled vehicle shall be proof load tested to verify structural integrity, as specified in Appendix A.

2.11. Nosecone

2.11.1. Nosecone shape should be 0.75 power with 5.5 fineness ratio as described in Reference 3.

2.11.2. Nosecone shall consist of a thin-walled structural shell suited to housing the avionics bay.

2.11.3. The nosecone tip shall be made of lightweight heat-resistant material of sufficient robustness to withstand abuse proof-load as detailed in Appendix B.

2.11.4. Nosecone shell material shall be RF transparent. Tip material should also be RF transparent.

2.11.5. Nosecone shall be designed to be readily removable and re-installable to allow unhindered access to the payload while vehicle is in the launch tower or otherwise being prepped for launch.

2.11.6. Joint that secures nosecone to Recovery Bay shall be hermetically sealed to prevent air seepage during flight.

2.11.7. Avionics support structure shall not be attached directly to the nosecone and shall have sufficient clearance to avoid fouling during nosecone installation or removal.

2.11.8. Nosecone and nosecone joint shall be designed to withstand worst-case structural aerodynamic loading at an angle of attack ranging from zero to 10 degrees, with a safety factor of 1.5 applied.

2.11.9. Nosecone and nosecone joint shall be proof load tested with compression applied longitudinally, and with loading perpendicular to the longitudinal axis, applied at a point immediately aft of the nosecone tip, as described in Appendix B

2.11.10. Nosecone shall be designed to withstand thermal heating, as detailed in Appendix C, without loss of functionality (capability as an aerodynamic fairing and ability to protect payload).

2.12. **Fins**

2.12.1. Four fins shall be fitted to the Booster for stability.

2.12.2. Fins should have a clipped-delta planform and shall be sized to provide a static stability margin of no less than 2 calibres under most adverse combination of c.g. & c.p. locations over the entire expected flight regime.

2.12.3. Fins shall be designed to be flutter-resistant which may be achieved by a combination of high stiffness and low mass.

2.12.4. Fins should be structurally bonded to the motor casing, each fin equipped with a suitably-sized, integral “foot”. Or fins may be mounted by use of a “fin can” arrangement. Penetrations (e.g. by fasteners) into the motor casing shall not be allowed.

2.12.5. For robustness, fins shall be designed to an ultimate load requirement of 200 lbs (90 kg) applied perpendicular to the plane of the fin at the tip, as installed on the vehicle.

2.12.6. Installed fins shall be proof-loaded to verify stiffness and structural integrity of fins and joints, as described in Appendix D.

2.12.7. Fins shall be designed to withstand thermal heating, as detailed in Appendix C, without loss of functionality or structural integrity.

2.13. **De-spin**

2.13.1. Vehicle shall be equipped with a de-spin system that is designed to damp out vehicle roll (spin).

2.13.2. The de-spin system should be activated just prior to drogue deployment, upon receiving activation signal from Flight Computer.

2.13.3. Maximum roll following activation of the de-spin system shall be 1 rotation per second (RPS).

2.13.4. The complete de-spin system shall fit within the volume of the aftmost section of the Forward Payload Bay as specified in Appendix E

3. Recovery System Requirements

3.1. All key portions of the vehicle shall be recovered fully-intact (i.e. in flightworthy condition following nominal refurbishment).

3.2. Booster and Payload Capsule shall be configured to descend separately with no physical interconnection between the two sections.

3.3. Booster shall be equipped with a single parachute deployed at time of vehicle separation.

3.4. Payload Capsule shall be configured for dual-deployment. A drogue parachute shall be deployed at vehicle separation. Main parachute should be deployed at a nominal altitude of 2000 feet (600 metres).

3.5. Booster target touchdown velocity shall be 80 feet per second (24 metres/sec).

3.6. Payload Capsule target touchdown velocity shall be 30 feet per second (9.1 metres/sec).

3.7. Payload Capsule drogue descent rate should be chosen to allow for simultaneous touchdown (with respect to time) with Booster in order to minimize dispersion between the Capsule and the Booster.

3.8. All parachutes shall be housed solely within the Recovery Bay.

3.9. The complete recovery system shall fit within the volume of the Recovery Bay as specified in Appendix F.

3.10. Recovery Bay shall be hermetically sealed with sole openings to ambient air to be 6 static ports of 1 mm (0.040”) diameter, located equally spaced around the perimeter of the airframe, located at the aft-most practical location of the Recovery Bay.

3.11. Booster parachute, Payload drogue chute, attachment tethers and airframe anchors shall be capable of withstanding a dynamic pressure resulting from opening at a velocity of 500 ft/sec (150 m/sec) at an altitude of 115k ft (35 km) (consult Ref. 5).

3.12. Chute deployment system shall be capable of operation under conditions equivalent to an altitude of 115k ft (35 km) (consult Ref.5).

3.13. Chute deployment system shall incorporate redundant electrical initiators.

3.14. Verification testing of complete recovery system shall consist of both ground and flight testing, simulating as close a practicable the configuration to be flown during the *DoubleSShot* mission.

4. Propellant Manufacturing/Casting/Storage Requirements

4.1. Propellant shall be potassium nitrate/sugar based. A small percentage of additives may be incorporated, as deemed necessary, although the requirement of suitable characterization shall be imposed.

4.2. Potassium nitrate oxidizer shall have a nearly neutral or slightly acidic pH. Sample testing of each purchased lot shall be implemented by dissolving a 10 gram sample of oxidizer in 50 ml distilled water and pH measured at 20ºC. The resulting pH shall be in the range 5.5-7.0.

4.3. Propellant manufacture method shall be capable of operation at a remote site with minimal of infrastructure (see 6.7).

4.4. Safety of personnel involved in propellant preparation and casting shall be of paramount consideration in selecting manufacturing and casting method.

4.5. Method of propellant manufacture should be capable of producing 200 lbs (90 kg) of propellant per motor firing, considering a minimum of 3 firings.

4.6. Principle of propellant manufacture should be scalable to *ExSShot*, which will require approximately 1000 lbs (450 kg) per firing (a minimum of 2 firings are anticipated).

4.7. Casting method shall incorporate suitable feature(s) to minimize inclusion of air bubbles or porosity into propellant (e.g. vacuum or vibration may be used).

4.8. Casting method shall be capable of producing consistent propellant grains with no less than 97% theoretical mass density.

4.9. Manufacture and storage of cast propellant shall accommodate the shelf-life limit of the propellant.

4.10. Quality control procedures shall be in place to minimize likelihood of disbonding of inhibitor and a quality control check shall be used to verify positive bonding (e.g. tap test).

4.11. Quality control procedure shall be in place to measure and record grain density and all grain masses and pertinent dimensions.

5. Propulsion Requirements

5.1. Motor shall deliver total impulse to achieve project apogee goal. Effort should be made to achieve the goal with the least quantity of propellant that can be practically utilized to achieve all project objectives.

5.2. Motor should have dual-phase operation with a delay period of no more than 20 seconds between first-phase burn out and second phase initiation. Total impulse delivered per phase need not be equal.

5.3. Grain configuration shall provide for an approximately neutral kn (klemmung).

5.4. Pyrogen-motor ignition shall be used for both motor chambers.

5.5. Both motor casings shall incorporate a minimum safety factor of 1.5 x MEOP relative to failure pressure.

5.6. A minimum of two successful static firings shall be conducted. One may be with a "boilerplate" motor of the approximate dimensions of the flight motor. The second shall be of identical (to the extent practicable) to the flight motor. Both tests shall verify dual-phase operation. Both static firings shall incorporate a water dousing system to cool down motor interior immediately following firing, in order to preserve post-firing condition of motor components.

5.7. Second-phase chamber shall be hermetically sealed with a suitable burst diaphragm at the aft end. Diaphragm to be designed to withstand a pressure differential of 200 psi (1.38 MPa), and shall be fabricated from a frangible material that will not pose a threat of nozzle blockage.

5.8. A removable, electrical safety shunt shall be fitted in parallel with the 2nd phase motor initiator for the flight motor.

5.9. Both forward and aft motor casings shall be hydro-static proof tested to 125% MEOP with no indication of permanent detrimental damage and no detectable pressure leakage. Optional for boiler plate motor.

5.10. Motor design should place emphasis on re-use of as many components as possible following static firing, with nominal refurbishment.

5.11. Motor design shall consider relative ease of field assembly.

6. Ground Support Requirements

6.1. A tower or rail launch platform shall be used to support the vehicle and to guide the vehicle following liftoff.

6.2. The guide length shall provide for a minimum guided velocity of 70 ft/sec (21 m/sec).

6.3. Launch angle shall be 5º ±1 º from true vertical.

6.4. Orientation (compass direction) of launch elevation shall be chosen, based on rational analysis, to minimize downrange touchdown distance, taking into account drift due to winds-aloft.

6.5. A shunt-ejection device (see 5.8) shall be used to safely remove the 2nd phase initiator shunt prior to launch. The device may be remotely actuated or may utilize a timer to activate after a pre-set delay period.

6.6. FRS radios should be used for launch and recovery teams primary communication.

6.7. A portable power supply capable of delivering of a minimum of 2 kilowatt power at 120VAC @ 60 hz. shall be available.

6.8. Suitable safety equipment and supplies shall be present for all ground operations.

7. Avionics/Payload Requirements

The avionics and payload requirements are specified in Reference 2**.**

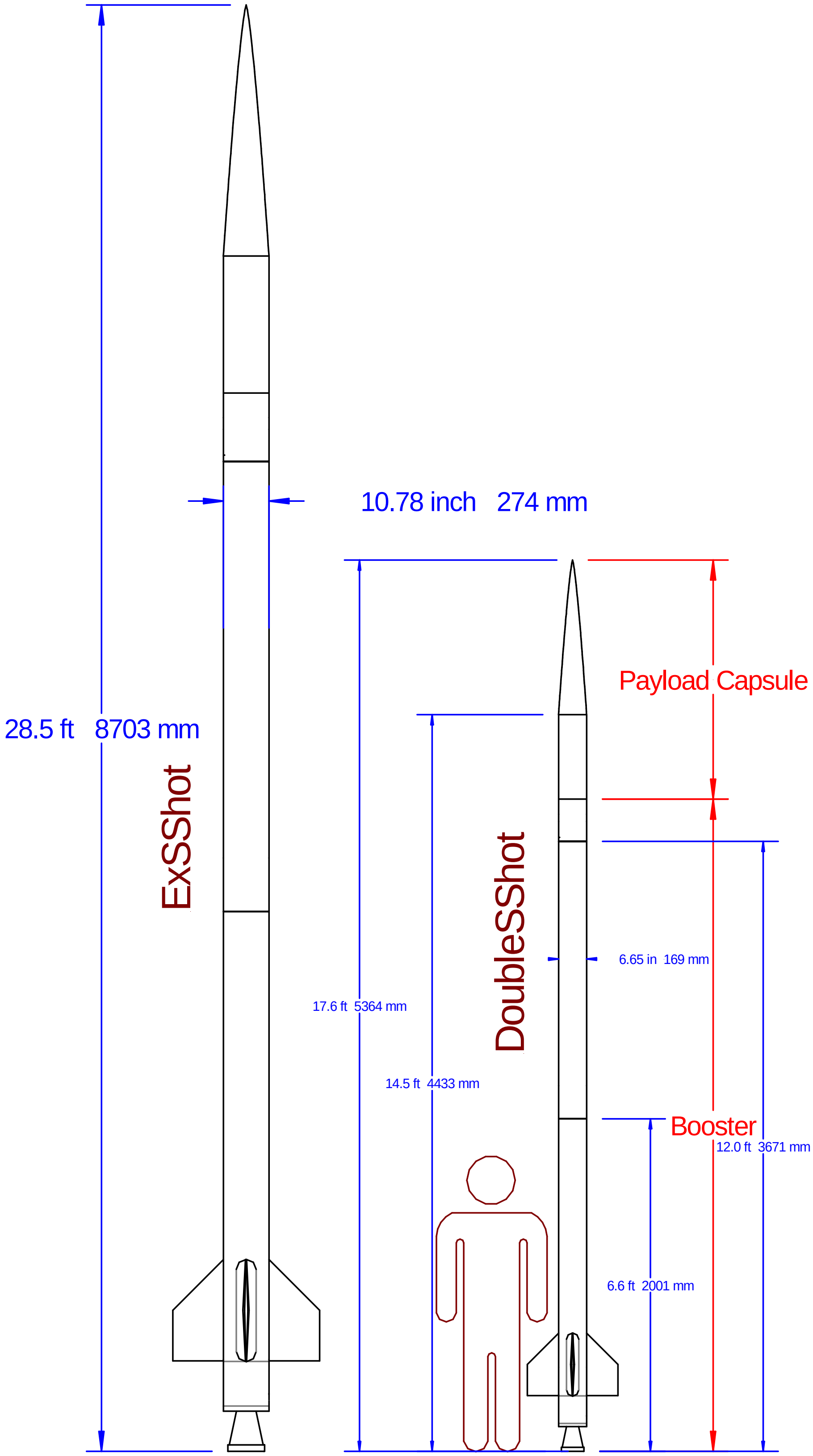
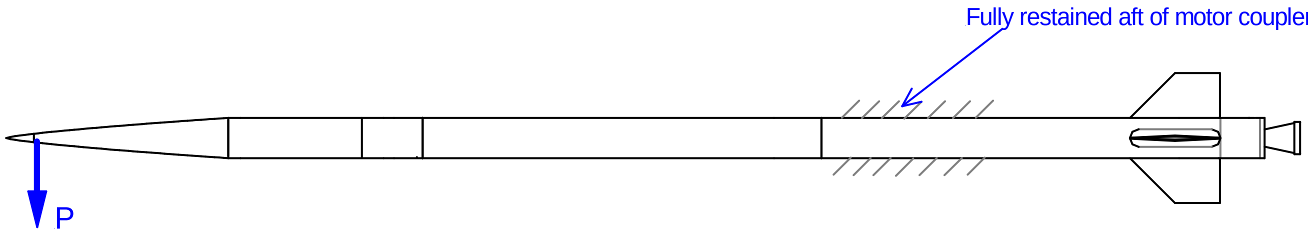


Figure 1 – DSS and ESS vehicles

Appendix A – Complete vehicle structural proof loading requirement

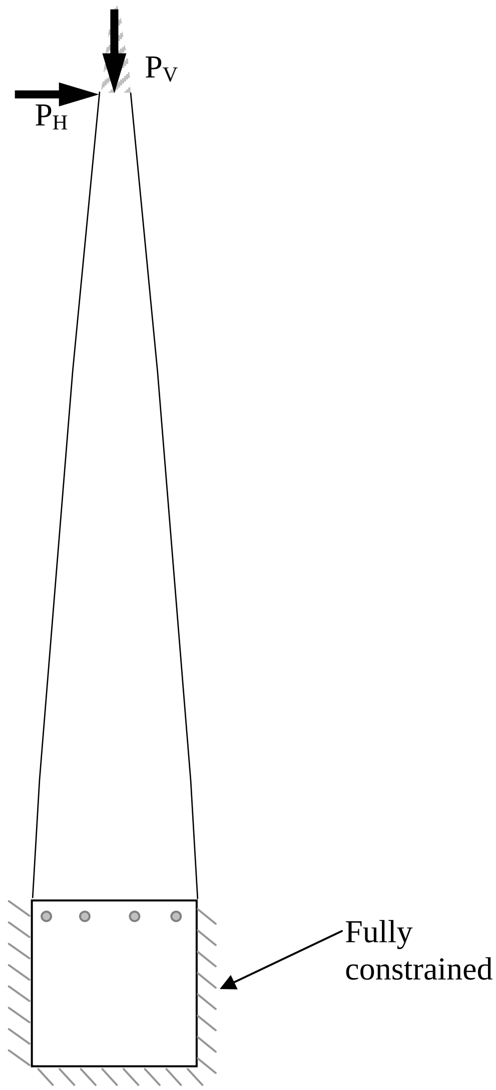
(Paragraph 2.10)



P = 25% ultimate load = 0.25 x 200 = 50 lb (23 kg)

Appendix B – Nosecone structural proof loading requirement

(Paragraph 2.11.9)



Nosecone Shell - Proof loading

Nosecone to be joined to an airframe section representative of the Recovery Bay, and fully restrained as shown to react applied loads P_V and P_H. Loads to be applied separately.

Vertical, P_V = 25% ultimate load

Lateral, P_H = 25% ultimate load × sin 10º

This proof load test is intended for nosecone shell only and as such tip need not be installed.

Note: Lateral proof loading may be performed in conjunction with complete vehicle proof loading (ref. 2.10)

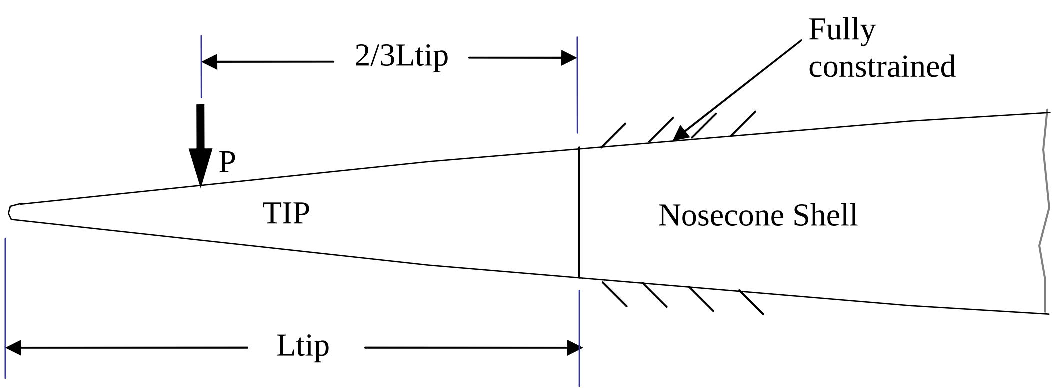
Appendix B – (continued)

Nosecone Tip - Proof loading

(Paragraph 2.11.3)

Nosecone tip to be joined to nosecone shell. Nosecone to be fully restrained as shown to react applied loads

P = abuse (handling) load of 15 lbs (6.8 kg) applied as shown.



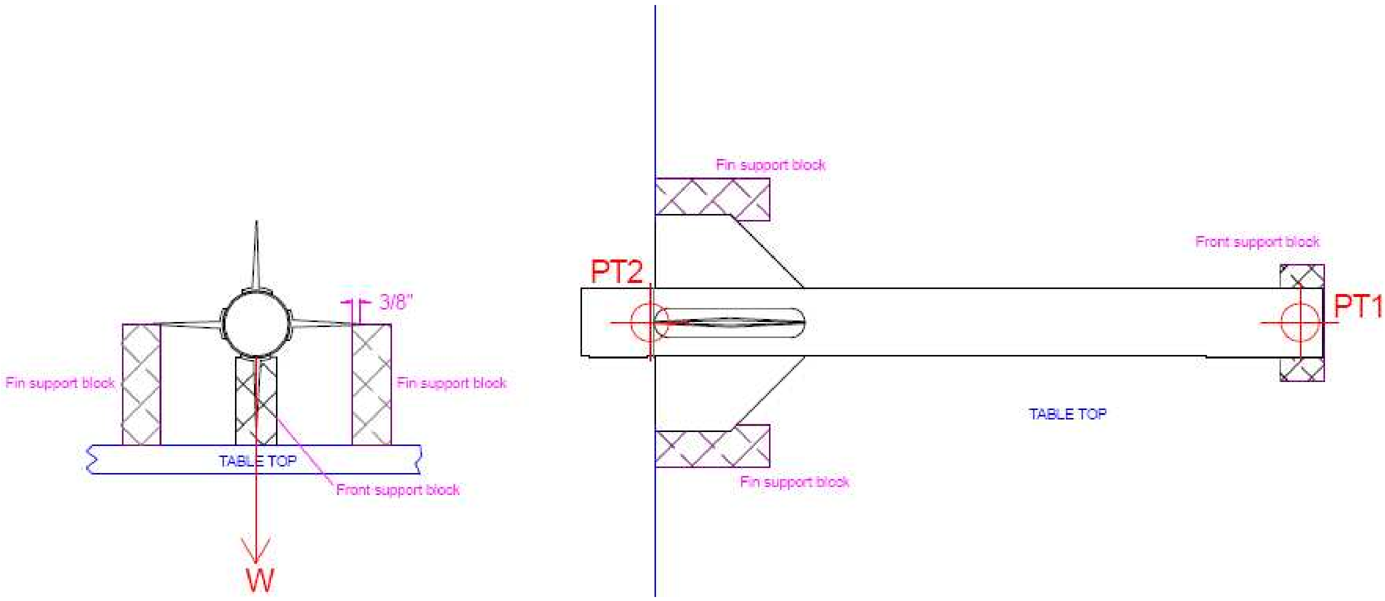
Appendix C – Nosecone/Fins thermal loading requirement

(Paragraph 2.11.10, 2.12.7)

TBD

Appendix D - Fin proof loading requirement

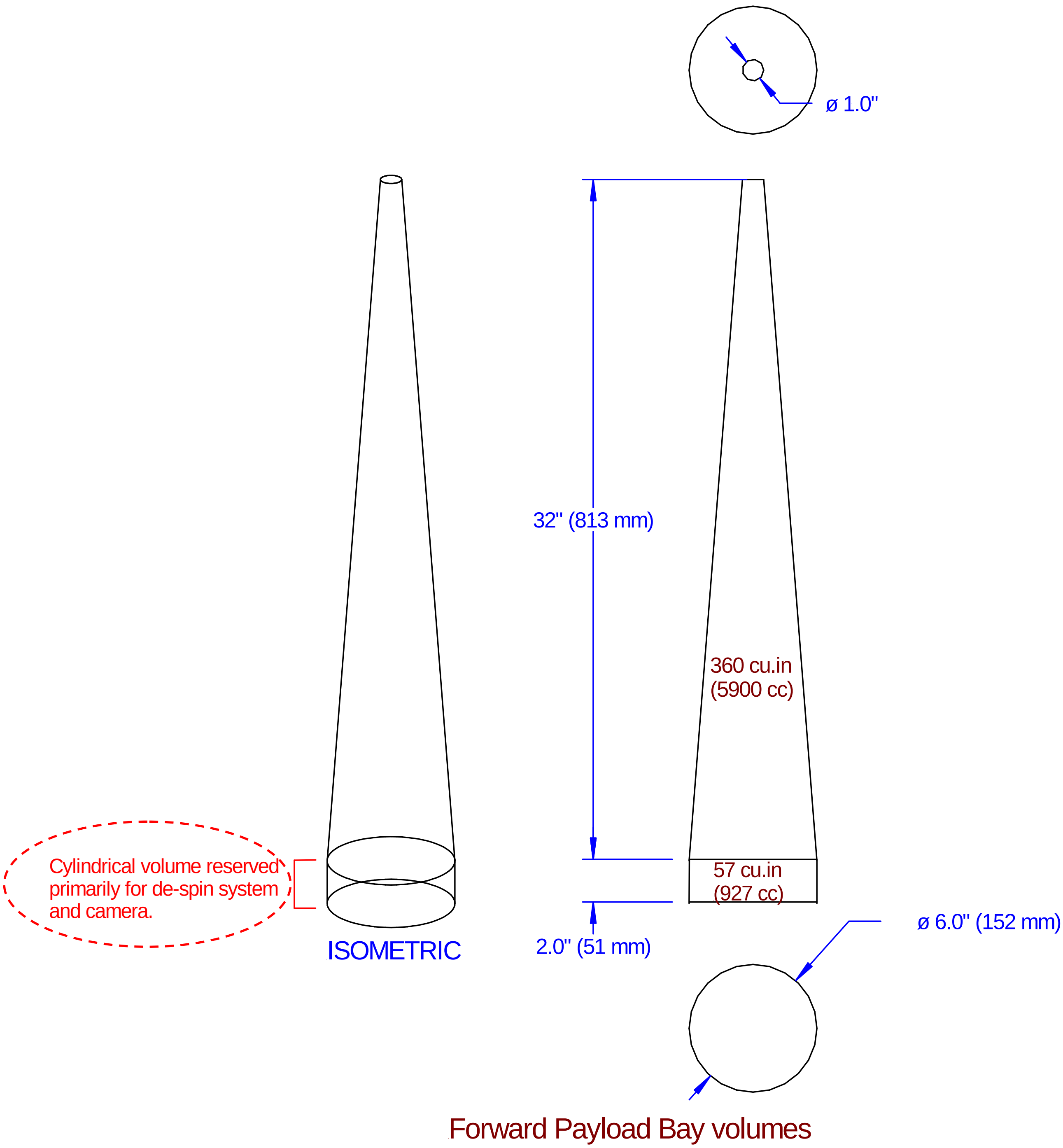
(Paragraph 2.12.6)



W = 100 lbf (45 kg) acting over 2 fins = 25% ultimate fin design load

Appendix E – Available volume for complete de-spin system

(Paragraph 2.13.4)



Note: Above figure excerpted from Ref. 2.

Appendix F– Available volume for complete Recovery System

(Paragraph 3.9)