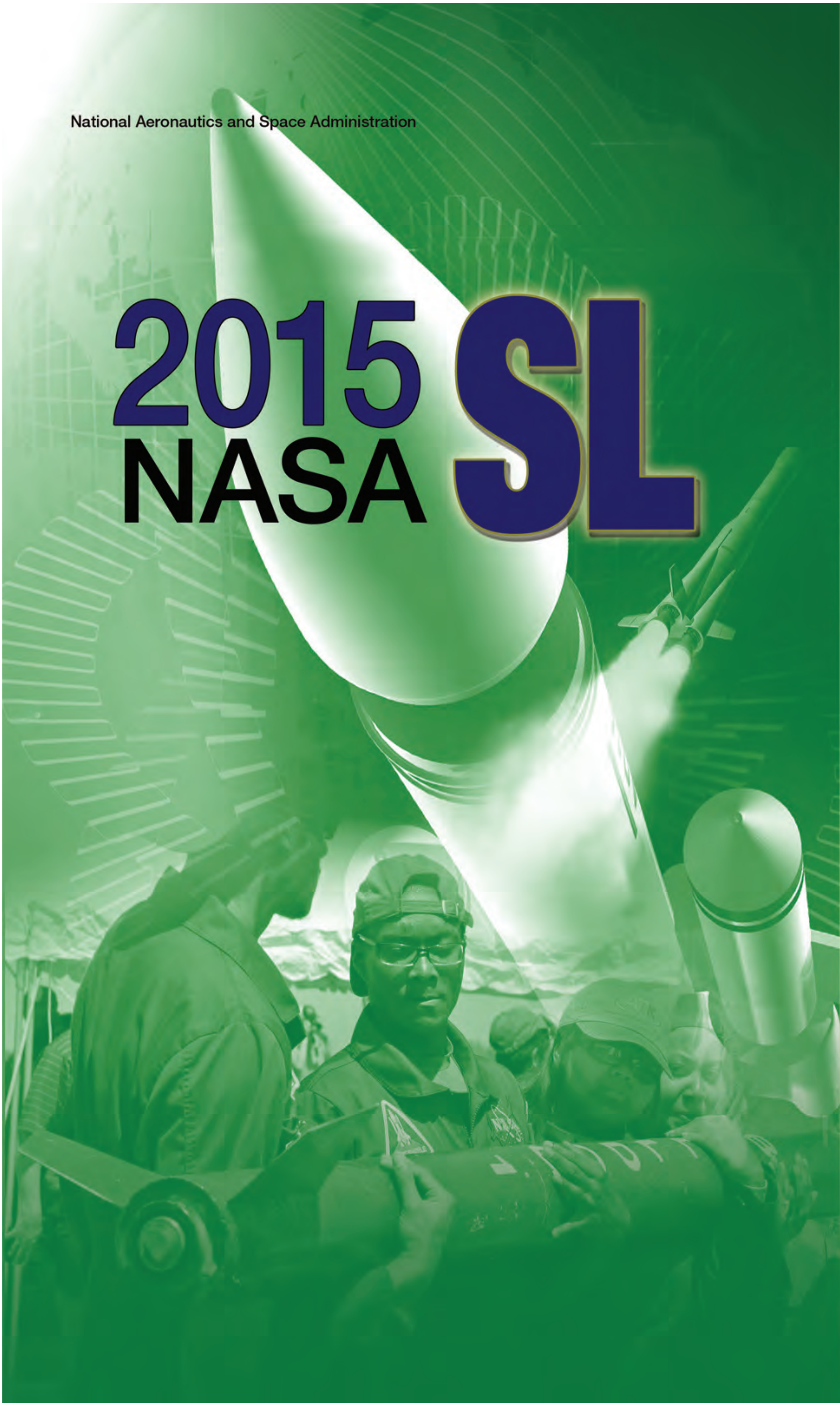
National Aeronautics and Space Administration

2015 NASA SL



Student Launch

Note: For your convenience, this document identifies Web links when available. These links are correct as of this publishing; however, since Web links can be moved or disconnected at any time, we have also provided source information as available to assist you in locating the information.

Contents

Proposal/Statement of Work for Colleges/Universities/Non-Academic Teams

Proposal/Statement of Work for Middle/High Schools

Vehicle/Payload Criteria

Safety

Related Documents

Timeline for NASA Student Launch

(Dates are subject to change.)

September 2014

11 Request for Proposal (RFP) goes out to all teams.

October 2014

6 Electronic copy of completed proposal due to project office by 5 p.m. CDT to

Ian Bryant (Jacobs ESSSA Group) ian.l.bryant@nasa.gov

Katie Wallace: katie.v.wallace@nasa.gov

Julie Clift: julie.d.clift@nasa.gov

17 Awarded proposals announced
31 Team web presence established

November 2014

5 Preliminary Design Review (PDR) reports, presentation slides, and flysheet posted on the team Website by 8:00 a.m. Central Time.
7-21 PDR video teleconferences

January 2015:

16 Critical Design Review (CDR) reports, presentation slides, and flysheet posted on the team Website by 8:00 a.m. Central Time.
21-31 CDR video teleconferences

February 2015

1-4 CDR video teleconferences

March 2015:

16 Flight Readiness Review (FRR) reports, presentation slides, and flysheet posted to team Website by 8:00 a.m. Central Time.
18-27 FRR video teleconferences

April 2015:

7 Teams travel to Huntsville, AL
7 Launch Readiness Reviews (LRR)
8 LRR's and safety briefing
9 Rocket Fair and Tours of MSFC
10 Mini/Maxi MAV Launch day, Banquet
11 Middle/High School Launch Day
12 Backup launch day
29 Post-Launch Assessment Review (PLAR) posted on the team Website by 8:00 a.m. Central Time.

May 2015:

11 Winning team announced

Acronym Dictionary

AGL=Above Ground Level

AGSE=Autonomous Ground Support Equipment

APCP=Ammonium Perchlorate Composite Propellant

CDR=Critical Design Review

CG=Center of Gravity

CP=Center of Pressure

EIT=Electronics and Information Technology

FAA=Federal Aviation Administration

FN=Foreign National

FRR=Flight Readiness Review

HEO=Human Exploration and Operations

LCO=Launch Control Officer

LRR=Launch Readiness Review

MAV=Mars Ascent Vehicle

MSDS=Material Safety Data Sheet

MSFC=Marshall Space Flight Center

NAR=National Association of Rocketry

PDR=Preliminary Design Review

PLAR=Post Launch Assessment Review

PPE=Personal Protective Equipment

RFP=Request for Proposal

RSO=Range Safety Officer

SL=Student Launch

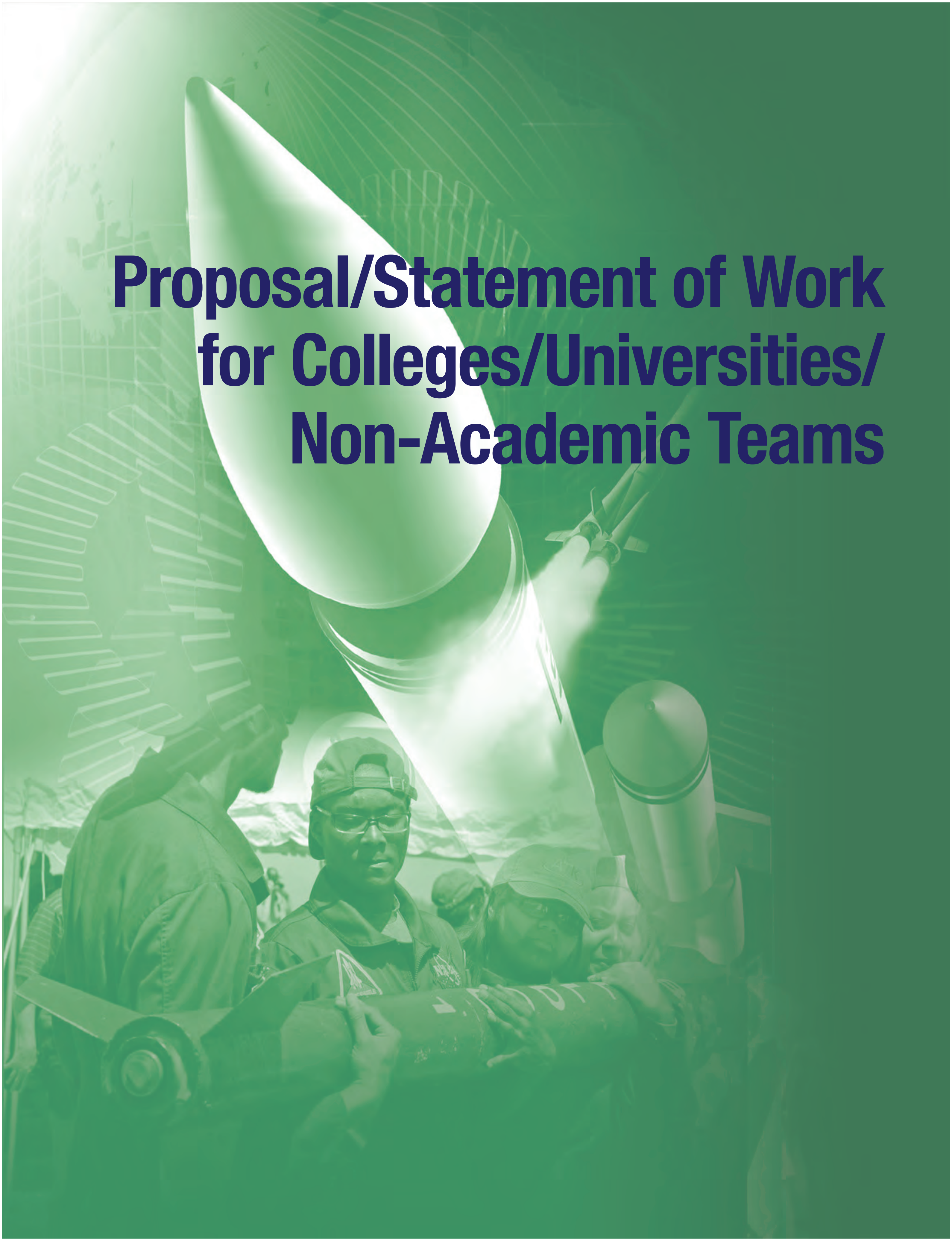
SME=Subject Matter Expert

SOW=Statement of Work

STEM=Science, Technology, Engineering, and Mathematics

TRA=Tripoli Rocketry Association

Proposal/Statement of Work for Colleges/Universities/ Non-Academic Teams



Design, Development, and Launch of a Reusable Rocket and Autonomous Ground Support Equipment Statement of Work (SOW)

1. **Project Name: NASA Student Launch Mini Mars Ascent Vehicle (MAV) (for colleges and universities) and Maxi MAV (for colleges, universities, and non-academic teams)**

2. **Governing Office: NASA Marshall Space Flight Center Academic Affairs Office**

3. **Period of Performance: Eight (8) calendar months**

4. **Introduction**

The NASA Student Launch (SL) is a research-based, competitive, and experiential exploration project that provides relevant and cost effective research and development. Additionally, NASA Student Launch connects learners, educators, and communities in NASA-unique opportunities that align with STEM Challenges under the NASA Education Science, Technology, Engineering, and Mathematics (STEM) Engagement line of business. NASA's missions, discoveries, and assets provide opportunities for individuals that do not exist elsewhere. The project involves reaching a broach audience of colleges, universities, and non-academic teams across the nation in an 8-month commitment to design, build, launch, and fly a "Mars Sample" and vehicle components that support the MAV on high-power rockets to an altitude of 3,000 feet above ground level (AGL). The challenge centers on highly reliable and autonomous sample insertion, preparation, launch, and deployment. Supported by the Human Exploration and Operations (HEO) Mission Directorate, Centennial Challenges Office, and commercial industry, SL is a unique, NASA-specific opportunity to provide resources and experiences that is built around a mission, not textbook knowledge.

The Centennial Challenges Program, part of NASA's Science and Technology Mission Directorate, awards incentive prizes to generate revolutionary solutions to problems of interest to NASA and the nation. The program seeks innovations from diverse and non-traditional sources and the challenges are open to private companies, student teams and independent inventors. The competitors are not supported by government funding and awards are only made to successful teams when the challenges are met. More than $6 million in prize money has been awarded in over 20 competitions

After a competitive proposal selection process, teams participate in a series of design reviews that are submitted to NASA via a team-developed website. These reviews mirror the NASA engineering design lifecycle, providing a NASA-unique experience that prepares individuals for the HEO workforce. Teams must successfully complete a Preliminary Design Review (PDR), Critical Design Review (CDR), Flight Readiness Review (FRR), Launch Readiness Review (LRR) that includes safety briefings, and an analysis of vehicle systems, ground support equipment, and flight data. Each team must pass a review in order to move to a subsequent review. Teams will present their PDR, CDR, and FRR to a review panel of scientists, engineers, technicians, and educators via video teleconference. Review panel members, the Range Safety Officer (RSO), and Subject Matter Experts (SME) provide feedback and ask questions in order to increase the fidelity between the SL and research needs, and will score each team according to a standard scoring rubric. The partnership of teams and NASA is win-win, which not only benefits from the research conducted by the teams, but also prepares a potential future workforce familiar with the NASA Engineering Design Lifecycle.

College and university teams must at a minimum successfully complete the Mini-MAV requirements and are eligible for awards through Student Launch. Non-academic teams are not eligible to participate in the Mini-MAV. Any team who wishes to incorporate additional research through the use of a separate payload may do so. The team must provide documentation in all reports and reviews on components and systems outside of what is required for the project. The Centennial Challenges Office will award prizes to college, university and non-academic teams for successful demonstration of the Maxi-MAV. The first place award for the Maxi-

MAV is $25,000, the second place team receives $15,000, and the third place team receives $10,000. Maxi-MAV teams will only be eligible for prize money after the successful completion of all parts of the Maxi-MAV competition. The awards listed on pages 50-51 will only be given to Mini/Maxi teams from an academic institution.

The performance targets for the reusable launch vehicle, AGSE, and payload are

1. Vehicle Requirements

1.1. The vehicle shall deliver the payload to, but not exceeding, an apogee altitude of 3,000 feet above ground level (AGL).

1.2. The vehicle shall carry one commercially available, barometric altimeter for recording the official altitude used in the competition scoring. The altitude score will account for 10% of the team's overall competition score. Teams will receive the maximum number of altitude points (3,000) by fully reaching the 3,000 feet AGL mark. For every foot of deviation above or below the target altitude, the team will lose 1 altitude point. The team's altitude points will be divided by 3,000 to determine the altitude score for the competition.

1.2.1. The official scoring altimeter shall report the official competition altitude via a series of beeps to be checked after the competition flight.

1.2.2. Teams may have additional altimeters to control vehicle electronics and payload experiment(s).

1.2.2.1. At the Launch Readiness Review, a NASA official will mark the altimeter that will be used for the official scoring.

1.2.2.2. At the launch field, a NASA official will obtain the altitude by listening to the audible beeps reported by the official competition, marked altimeter.

1.2.2.3. At the launch field, to aid in determination of the vehicle's apogee, all audible electronics, except for the official altitude-determining altimeter shall be capable of being turned off.

1.2.3. The following circumstances will warrant a score of zero for the altitude portion of the competition:

1.2.3.1. The official, marked altimeter is damaged and/or does not report an altitude via a series of beeps after the team's competition flight.

1.2.3.2. The team does not report to the NASA official designated to record the altitude with their official, marked altimeter on the day of the launch.

1.2.3.3. The altimeter reports an apogee altitude over 5,000 feet AGL.

1.2.3.4. The rocket is not flown at the competition launch site.

1.3. The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.

1.4. The launch vehicle shall have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.

1.5. The launch vehicle shall be limited to a single stage.

1.6. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.

1.7. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board component.

1.8. The launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider.

1.9. The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).

1.9.1. Final motor choices must be made by the Critical Design Review (CDR).

1.9.2. Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.

1.10. The total impulse provided by a launch vehicle shall not exceed 5,120 Newton-seconds (L-class).

1.11. Any team participating in Maxi-MAV will be required to provide an inert or replicated version of their motor matching in both size and weight to their launch day motor. This motor will be used during the LRR to ensure the igniter installer will work with the competition motor on launch day.

1.12. Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria:

1.12.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) shall be 4:1 with supporting design documentation included in all milestone reviews.

1.12.2. The low-cycle fatigue life shall be a minimum of 4:1.

1.12.3. Each pressure vessel shall include a solenoid pressure relief valve that sees the full pressure of the tank.

1.12.4. Full pedigree of the tank shall be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.

1.13. All teams shall successfully launch and recover a subscale model of their full-scale rocket prior to CDR. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale shall not be used as the subscale model.

1.14. All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full scale demonstration flight:

1.14.1. The vehicle and recovery system shall have functioned as designed.

1.14.2. The payload does not have to be flown during the full-scale test flight. The following requirements still apply:

1.14.2.1. If the payload is not flown, mass simulators shall be used to simulate the payload mass.

1.14.2.2. The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.

1.14.2.3. If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems shall be active during the full-scale demonstration flight.

1.14.3. The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulate, as closely as possible, the predicted maximum velocity and maximum acceleration of the competition flight.

1.14.4. The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the competition flight.

1.14.5. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer (RSO).

1.15. Each team will have a maximum budget they may spend on the rocket and the Autonomous Ground Support Equipment (AGSE). Teams who are participating in the Maxi-MAV competition are limited to a $10,000 budget while teams participating in Mini-MAV are limited to $5,000. The cost is for the competition rocket and AGSE as it sits on the pad, including all purchased components. The fair market value of all donated items or materials shall be included in the cost analysis. The following items may be omitted from the total cost of the vehicle:

- Shipping costs
- Team labor costs

1.16. Vehicle Prohibitions

1.16.1. The launch vehicle shall not utilize forward canards.

1.16.2. The launch vehicle shall not utilize forward firing motors.

1.16.3. The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).

1.16.4. The launch vehicle shall not utilize hybrid motors.

1.16.5. The launch vehicle shall not utilize a cluster of motors.

2. Recovery System Requirements

2.1. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery or streamer recovery from apogee to main parachute deployment is also permissible, provided the kinetic energy during drogue-stage descent is reasonable, as deemed by the Range Safety Officer.

2.2. Teams must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full scale launches.

2.3. At landing, each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.

2.4. The recovery system electrical circuits shall be completely independent of any payload electrical circuits.

2.5. The recovery system shall contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers. One of these altimeters may be chosen as the competition altimeter.

2.6. A dedicated arming switch shall arm each altimeter, which is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.

2.7. Each altimeter shall have a dedicated power supply.

2.8. Each arming switch shall be capable of being locked in the ON position for launch.

2.9. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.

2.10. An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.

2.10.1. Any rocket section, or payload component, which lands untethered to the launch vehicle shall also carry an active electronic tracking device.

2.10.2. The electronic tracking device shall be fully functional during the official flight at the competition launch site.

2.11. The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).

2.11.1. The recovery system altimeters shall be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.

2.11.2. The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.

2.11.3. The recovery system electronics shall be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.

2.11.4. The recovery system electronics shall be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

3. Competition and Autonomous Ground Support Equipment (AGSE) Requirements

There are two challenges in which teams may compete, Mini-MAV or Maxi-MAV. At a minimum, each college or university team shall participate in the Mini-MAV challenge with the option to participate in the Maxi-MAV/Centennial Challenge. Non-academic teams are not permitted to compete in the Mini-MAV challenge. The structure and requirements for each MAV challenge are detailed as follows.

3.1. Mini-MAV.

3.1.1. The Mini-MAV will introduce the team participants to autonomous systems with partial human intervention. Teams will be required to capture and contain a payload, launch it, and eject it during the launch vehicle's descent. On launch day, each launch will follow this general procedure.

3.1.1.1. Teams will position their launch vehicle horizontally or vertically on the launch pad.

3.1.1.2. A master switch will be activated to power on all autonomous procedures and subroutines.

3.1.1.3. After the master switch is turned on and all systems are booted, a pause switch will be activated, temporarily halting all AGSE procedure and subroutines. This will allow the other teams at the pads to set up, and do the same.

3.1.1.4. After setup, one judge, one launch services official, and the team will remain at the pad. During autonomous procedures, the team is not permitted to interact with their AGSE.

3.1.1.5. After all nonessential personnel have evacuated, the pause switch will be deactivated.

3.1.1.6. Once the pause switch is deactivated, the AGSE will capture and contain the payload within the launch vehicle. If the launch vehicle is in a horizontal position, the launch platform will then be manually erected by the team to an angle of 5 degrees off vertical, pointed away from the spectators. The launch services official may re-enable the pause switch at any time at his/her discretion for safety concerns.

3.1.1.7. After the erection of the launch vehicle, a team member will arm recovery electronics.

3.1.1.8. The igniter is manually installed and the area is evacuated.

3.1.1.9. Once the launch services official has inspected the launch vehicle and declares that the system is eligible for launch, he/she will activate a master arming switch to enable ignition procedures.

3.1.1.10. The Launch Control Officer (LCO) will activate a hard switch, and then provide a 5-second countdown.

3.1.1.11. At the end of the countdown, the LCO will push the final launch button, initiating launch.

3.1.1.12. The rocket will launch as designed and jettison the payload at 1,000 feet AGL during descent.

3.1.2. The Autonomous Ground Support Equipment (AGSE)

3.1.2.1. For the purpose of this challenge, ASGE is defined as all mechanical and electrical components not part of the launch vehicle, and is provided by the teams. Components may include the payload containment device, computers, batteries, etc.

3.1.2.2. The payload containment system shall be fully autonomous with no human intervention.

3.1.2.3. Any pressure vessel used in the AGSE will follow all regulations set by requirement 1.12 in the Vehicle Requirements section.

3.1.3. Prohibited Technology for AGSE

3.1.3.1. As one of the goals of this competition is to develop equipment, processes, and technologies that could be implemented in a Martian environment, the AGSE and any related technology cannot employ processes that would not work in such environments. Therefore, prohibited technologies include:

3.1.3.1.1. Sensors that rely on Earth's magnetic field

3.1.3.1.2. Ultrasonic or other sound-based sensors

3.1.3.1.3. Earth-based or Earth orbit-based radio aids (e.g. GPS, VOR, cell phone).

3.1.3.1.4. Open circuit pneumatics

3.1.3.1.5. Air breathing systems

3.1.4. Payload

3.1.4.1. Each launch vehicle must have the space to contain a cylindrical payload approximately 3/4 inch in diameter and 4.75 inches in length. The payload will be made of ¾ x 3 inch PVC tubing filled with sand and weighing approximately 4 oz., and capped with domed PVC end caps. Each launch vehicle must be able to seal the payload containment area autonomously prior to launch.

3.1.4.2. Teams may construct their own payload according to the above specifications, however, each team will be required to use a regulation payload provided to them on launch day.

3.1.4.3. The payload will not contain any hooks or other means to grab it. A diagram of the payload and a sample payload will be provided to each team at time of acceptance into the competition.

3.1.4.4. The payload may be placed anywhere in the launch area for insertion, as long as it is outside the mold line of the launch vehicle when placed in the horizontal or vertical position on the AGSE.

3.1.4.5. The payload container must utilize a parachute for recovery and contain a GPS or radio locator.

3.1.5. Safety and AGSE Control

3.1.5.1. Each team must provide the following switches and indicators for their AGSE to be used by the LCO/RSO.

3.1.5.1.1. A master switch to power all parts of the AGSE. The switch must be easily accessible and hardwired to the AGSE.

3.1.5.1.2. A pause switch to temporarily terminate all actions performed by AGSE. The switch must be easily accessible and hardwired to the AGSE.

3.1.5.1.3. A safety light that indicates that the AGSE power is turned on. The light must be amber/orange in color. It will flash at a frequency of 1 Hz when the AGSE is powered on, and will be solid in color when the AGSE is paused while power is still supplied.

3.2. Maxi-MAV.

3.2.1. The Maxi-MAV will provide each team with the opportunity to develop a unique method to capture, contain, launch, and eject a payload with limited human intervention. In addition, teams will develop a launch system that erects a rocket from a horizontal to vertical position, and has its igniter autonomously installed. On launch day, each launch will follow this general procedure.

3.2.1.1. Teams will position their launch vehicle horizontally on the AGSE.

3.2.1.2. A master switch will be activated to power on all autonomous procedures and subroutines.

3.2.1.3. After the master switch is turned on, a pause switch will be activated, temporarily halting all AGSE procedure and subroutines. This will allow the other teams at the pads to set up, and do the same.

3.2.1.4. After setup, one judge, one launch services official, and one member of the team will remain at the pad. The rest of the team must evacuate the area. The one team member is only there to answer questions the launch services official may have, and is not permitted to interact with the AGSE in any way.

3.2.1.5. After all nonessential personnel have evacuated, the pause switch will be deactivated.

3.2.1.6. Once the pause switch is deactivated, the AGSE will progress through all subroutines starting with the capture and containment of the payload, then erection of the launch platform, and lastly the insertion of the motor igniter. The launch platform must be erected to an angle of 5 degrees off vertical pointed away from the spectators. The launch services official may re-enable the pause switch at any time at his/her discretion. If the pause switch is re-enabled all systems and actions shall cease immediately. The launch services official will only do this if there is an obvious safety hazard. The judge, launch services official, and team leader will meet to discuss and decide if the team will be allowed to do a reset and rerun of their attempt. No modifications to the hardware will be allowed prior to a rerun.

3.2.1.7. The one team member will arm all recovery electronics.

3.2.1.8. Once the launch services official has inspected the launch vehicle and declares that the system is eligible for launch, he/she will activate a master arming switch to enable ignition procedures.

3.2.1.9. All personnel at the launch pad will evacuate the area.

3.2.1.10. The Launch Control Officer (LCO) will activate a hard switch, and then provide a 5-second countdown.

3.2.1.11. At the end of the countdown, the LCO will push the final launch button to initiate launch.

3.2.1.12. The rocket will launch as designed and jettison the payload at 1,000 feet AGL during descent.

3.2.2.The Autonomous Ground Support Equipment (AGSE)

3.2.2.1. For the purpose of this challenge, ASGE is defined as all mechanical and electrical components not part of the launch vehicle, and is provided by the teams. This includes, but is not limited to, the payload containment and igniter installation devices, computers, electric motors, batteries, etc.

3.2.2.2. All AGSE systems shall be fully autonomous. The only human interaction will be when the launch services official pauses or arms any equipment, when the team arms the recovery electronics, and when the LCO initiates launch.

3.2.2.3. Any pressure vessel used in the AGSE will follow all regulations set by requirement 1.12 in the Vehicle Requirements section.

3.2.3.Prohibited Technology for AGSE

3.2.3.1. As one of the goals of this competition is to develop equipment, processes, and technologies that could be implemented in a Martian environment, the AGSE and any related technology cannot employ processes that would not work in such environments. Therefore, prohibited technologies include:

3.2.3.1.1. Sensors that rely on Earth's magnetic field

3.2.3.1.2. Ultrasonic or other sound-based sensors

3.2.3.1.3. Earth-based or Earth orbit-based radio aids (e.g. GPS, VOR, cell phone).

3.2.3.1.4. Open circuit pneumatics

3.2.3.1.5. Air breathing systems

3.2.4.Payload

3.2.4.1. Each launch vehicle must have the space to contain a cylindrical payload approximately 3/4 inch in diameter and 4.75 inches in length. The payload will be made of ¾ x 3 inch PVC tubing filled with sand and weighing approximately 4 oz., and capped with domed PVC end caps. Each launch vehicle must be able to seal the payload containment area autonomously prior to launch.

3.2.4.2. Teams may construct their own payload according to the above specifications, however, each team will be required to use a regulation payload provided to them on launch day.

3.2.4.3. The payload will not contain any hooks or other means to grab it. A diagram of the payload and a sample payload will be provided to each team at time of acceptance into the competition.

3.2.4.4. The payload may be placed anywhere in the launch area for insertion, as long as it is outside the mold line of the launch vehicle when placed in the horizontal position on the AGSE.

3.2.4.5. The payload container must utilize a parachute for recovery and contain a GPS or radio locator.

3.2.4.6. Each team will be given 10 minutes to autonomously capture, place, and seal the payload within their rocket, and erect the rocket to a vertical launch position five degrees off vertical. Insertion of igniter and activation for launch are also included in this time. Going over time will result in the team's disqualification from the Maxi-MAV competition.

3.2.5. Safety and AGSE Control

3.2.5.1. Each team must provide the following switches and indicators for their AGSE to be used by the LCO/RSO.

3.2.5.1.1. A master switch to power all parts of the AGSE. The switch must be easily accessible and hardwired to the AGSE.

3.2.5.1.2. A pause switch to temporarily terminate all actions performed by AGSE. The switch must be easily accessible and hardwired to the AGSE.

3.2.5.1.3. A safety light that indicates that the AGSE power is turned on. The light must be amber/orange in color. It will flash at a frequency of 1 Hz when the AGSE is powered on, and will be solid in color when the AGSE is paused while power is still supplied.

3.2.5.1.4. An all systems go light to verify all systems have passed safety verifications and the rocket system is ready to launch.

3.2.6. Failure of the Maxi-MAV

3.2.6.1. Any team who fails to complete any of the procedures in requirement 3.2 will be ineligible of obtaining Centennial Challenges prizes.

4. Safety Requirements

4.1. Each team shall use a launch and safety checklist. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and launch day operations.

4.2. For all academic institution teams, a student safety officer shall be identified, and shall be responsible for all items in section 4.3. For competing, non-academic teams, one participant who is not serving in the team mentor role shall serve as the designated safety officer.

4.3. The role and responsibilities of each safety officer shall include but not limited to:

4.3.1. Monitor team activities with an emphasis on Safety during:

4.3.1.1. Design of vehicle and launcher

4.3.1.2. Construction of vehicle and launcher

4.3.1.3. Assembly of vehicle and launcher

4.3.1.4. Ground testing of vehicle and launcher

4.3.1.5. Sub-scale launch test(s)

4.3.1.6. Full-scale launch test(s)

4.3.1.7. Competition launch

4.3.1.8. Recovery activities

4.3.1.9. Educational Engagement activities

4.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities.

4.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.

4.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.

4.4. Each team shall identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor shall be certified by the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to the launch at the competition launch site. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend launch week in April.

4.5. During test flights, teams shall abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch and/or Centennial Challenges competition launch does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.

4.6. Teams shall abide by all rules and regulations set forth by the FAA.

5. General Requirements

5.1. Team members (students if the team is from an academic institution) shall do 100% of the project, including design, construction, written reports, presentations, and flight preparation. The one exception deals with the handling of black powder, ejection charges, and installing electric matches. These tasks shall be performed by the team's mentor, regardless if the team is from an academic institution or not.

5.2. The team shall provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assigned, educational engagement events, and risks and mitigations.

5.3. Each team shall successfully complete and pass a review in order to move onto the next phase of the competition.

5.4. Foreign National (FN) team members shall be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during these activities. If participating in the Maxi-MAV, less than 50% of the team make-up may be foreign nationals.

5.5. The team shall identify all team members attending launch week activities by the Critical Design Review (CDR). Team members shall include:

5.5.1. For academic institutions, students actively engaged in the project throughout the entirety of the project lifespan and currently enrolled in the proposing institution.

5.5.2. For non-academic teams, participants actively engaged in the project who will remain affiliated with the team for the entirety of the project lifespan. The Team Lead, Team Mentor, and team Safety Officer shall be noted on the team roster. Team members may hold multiple positions.

5.5.3. One mentor (see requirement 4.4).

5.5.4. No more than two adult educators per academic team.

5.6. The team shall engage a minimum of 200 participants (at least 100 of those shall be middle school students or educators) in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement form, by FRR. An educational engagement form shall be completed and submitted within two weeks after completion of each event. A sample of the educational engagement form can be found on page 45 of the handbook.

5.7. The team shall develop and host a Website for project documentation.

5.8. Teams shall post, and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline.

5.9. All deliverables must be in PDF format.

5.10. In every report, teams shall provide a table of contents including major sections and their respective sub-sections.

5.11. In every report, the team shall include the page number at the bottom of the page.

5.12. The team shall provide any computer equipment necessary to perform a video teleconference with the review board. This includes, but not limited to, computer system, video camera, speaker telephone, and a broadband Internet connection. If possible, the team shall refrain from use of cellular phones as a means of speakerphone capability.

5.13. Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194) Subpart B-Technical Standards (http://www.section508.gov):

- 1194.21 Software applications and operating systems.
- 1194.22 Web-based intranet and Internet information and applications.

Proposal Requirements

At a minimum, the proposing team shall identify the following in a written proposal due to NASA MSFC by the dates specified in the project timeline.

General Information

1. A cover page that includes the name of the college/university or non-academic organization, mailing address, title of the project, the date, and whether the team is participating in the Mini-MAV or Maxi-MAV portion of the competition.
2. Name, title, and contact information for up to two adult educators (for academic teams).
3. Name and title of the individual who will take responsibility for implementation of the safety plan. (Safety Officer)
4. Name, title, and contact information for the team leader.
5. Approximate number of participants who will be committed to the project and their proposed duties. Include an outline of the project organization that identifies the key managers (participants and/or educator administrators) and the key technical personnel. Only use first names for identifying team members; do not include surnames. (See requirement 5.3 and 5.4 for definition of team members).
6. Name of the NAR/TRA section(s) the team is planning to work with for purposes of mentoring, review of designs and documentation, and/or launch assistance.

Facilities/Equipment

1. Description of facilities and hours of accessibility, necessary personnel, equipment, and supplies that are required to design and build a rocket and the AGSE.

Safety

The Federal Aviation Administration (FAA) [www.faa.gov] has specific laws governing the use of airspace. A demonstration of the understanding and intent to abide by the applicable federal laws (especially as related to the use of airspace at the launch sites and the use of combustible/ flammable material), safety codes, guidelines, and procedures for building, testing, and flying large model rockets is crucial. The procedures and safety regulations of the NAR [http://www.nar.org/safety.html] shall be used for flight design and operations. The NAR/TRA mentor and Safety Officer shall oversee launch operations and motor handling.

1. Provide a written safety plan addressing the safety of the materials used, facilities involved, and team member responsible, i.e., Safety Officer, for ensuring that the plan is followed. A risk assessment should be done for all aspects in addition to proposed mitigations. Identification of risks to the successful completion of the project should be included.

   1.1. Provide a description of the procedures for NAR/TRA personnel to perform. Ensure the following:
      - Compliance with NAR high power safety code requirements [http://nar.org/NARhpsc.html].
      - Performance of all hazardous materials handling and hazardous operations.

   1.2. Describe the plan for briefing team members on hazard recognition and accident avoidance, and conducting pre-launch briefings.

   1.3. Describe methods to include necessary caution statements in plans, procedures and other working documents, including the use of proper Personal Protective Equipment (PPE).

   1.4. Provide a plan for complying with federal, state, and local laws regarding unmanned rocket launches and motor handling. Specifically, regarding the use of airspace, Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Amateur Rockets, Code of Federal Regulation 27 Part 55: Commerce in Explosives; and fire prevention, NFPA 1127 "Code for High Power Rocket Motors."

   1.5. Provide a plan for NRA/TRA mentor purchase, storage, transport, and use of rocket motors and energetic devices.

   1.6. Provide a written statement that all team members understand and will abide by the following safety regulations:

      1.6.1. Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.

      1.6.2. The RSO has the final say on all rocket safety issues. Therefore, the RSO has the right to deny the launch of any rocket for safety reasons.

      1.6.3. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

Technical Design

1. A proposed and detailed approach to rocket and payload design.
   a. Include general vehicle dimensions, material selection and justification, and construction methods.
   b. Include projected altitude and describe how it was calculated.
   c. Include projected parachute system design.
   d. Include projected motor brand and designation.
   e. Include description of the team's projected AGSE.
   f. Address the requirements for the vehicle, recovery system, and AGSE.
   g. Address major technical challenges and solutions.

Educational Engagement

1. Include plans and evaluation criteria for required educational engagement activities. (See requirement 5.5).

Project Plan

1. Provide a detailed development schedule/timeline covering all aspects necessary to successfully complete the project.

2. Provide a detailed budget to cover all aspects necessary to successfully complete the project including team travel to launch week.

3. Provide a detailed funding plan.

4. Provide a written plan for soliciting additional "community support," which could include, but is not limited to, expertise needed, additional equipment/supplies, sponsorship, services (such as free shipping for launch vehicle components, if required, advertisement of the event, etc.), or partnering with industry or other public or private schools.

5. Develop a clear plan for sustainability of the rocket project in the local area. This plan should include how to provide and maintain established partnerships and regularly engage successive teams in rocketry. It should also include partners (industry/community), recruitment of team members, funding sustainability, and educational engagement.

Prior to award, all proposing entities may be required to brief NASA representatives. The time and the place for the briefings will be determined by the NASA MSFC Academic Affairs Office.

Deliverables shall include:

1. A reusable rocket and required AGSE ready for the official launch.

2. A scale model of the rocket design with an AGSE prototype. This model should be flown prior to the CDR. A report of the data from the flight and the model should be brought to the CDR.

3. Reports, PDF slideshows, and Milestone Review Flysheets due according to the provided timeline, and shall be posted on the team Web site by the due date. (Dates are tentative at this point. Final dates will be announced at the time of award.)

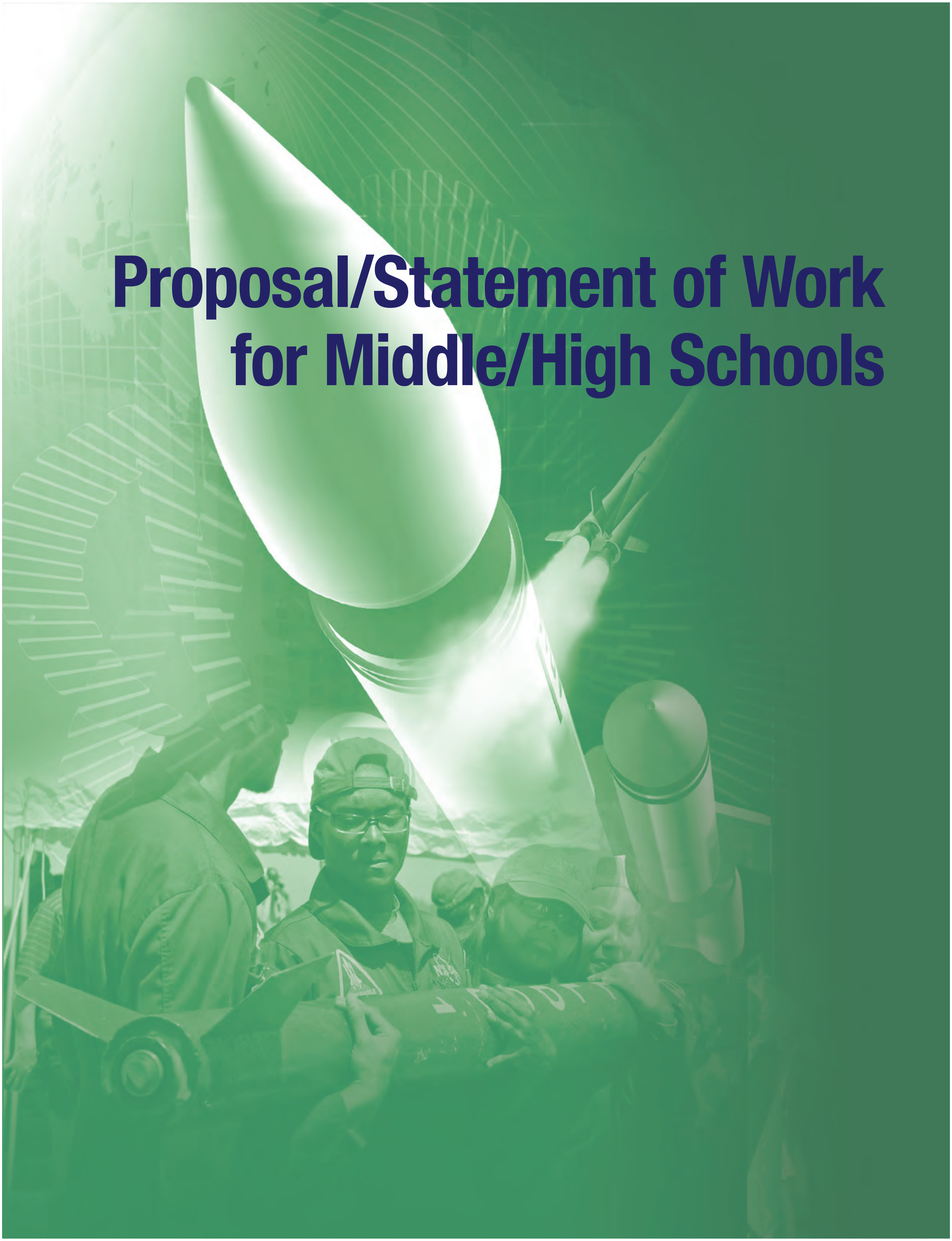
4. The team(s) shall have a Web presence no later than the date specified. The Web site shall be maintained/updated throughout the period of performance.

5. Electronic copies of the Educational Engagement form(s) and lessons learned pertaining to the implemented educational engagement activities shall be submitted prior to the FRR and no later than two weeks after the educational engagement event.

The team shall participate in a PDR, CDR, FRR, LRR, and PLAR. (Dates are tentative and subject to change.)

The PDR, CDR, FRR, and LRR will be presented to NASA at a time and/or location to be determined by NASA MSFC Academic Affairs Office.

Proposal/Statement of Work for Middle/High Schools



Design, Development, and Launch of a Reusable Rocket and Payload Statement of Work (SOW)

1. **Project Name: NASA Student Launch for Middle and High School**

2. **Governing Office: NASA Marshall Space Flight Center Academic Affairs Office**

3. **Period of Performance: Eight (8) calendar months.**

4. **Introduction**
   The Academic Affairs Office at the NASA Marshall space Flight Center (MSFC) will partner with middle school, high school, and informal organizations to sponsor the NASA Student Launch (SL) rocket and payload teams during the 2014-2015 academic year. This year's NASA SL is designed to engage teams who have previously qualified and successfully completed SL as a first year team in 2012-2013 or teams who have qualified at the Team America Rocketry Challenge or Rockets For Schools competition in 2014 and have participated in the NASA Advanced Rocketry Workshop. A maximum of 2 teams from the same institution may be accepted. NASA SL provides a learning opportunity that involves design, construction, test, and launch of a reusable launch vehicle and science-related fields. Teaming with engineers from government, business, and academia, students get a hands-on, inside look at the science and engineering professions.

   SL requires an 8-month commitment to design, construct, test, launch, and successfully recover a reusable rocket and payload to an altitude of 5,280 feet above ground level (AGL). The initiative is more than designing and building a rocket from a commercial kit. It involves diverse aspects, such as the following: scheduling, purchasing, performing calculations, financing the project, coordinating logistics, educational engagement, Web site development, and documenting impact made on education through reports and design reviews. Each team must complete a Preliminary Design Review (PDR), Critical Design Review (CDR), Flight Readiness Review (FRR), Launch Readiness Review (LRR) that includes a safety briefing, and a Post Launch Analysis Review (PLAR) which contains an analysis of vehicle systems and flight data from the final flight.

The performance targets for the reusable launch vehicle and payload are

1. **Vehicle Requirements**
   1.1. The vehicle shall deliver the science or engineering payload to, but not exceeding, an apogee altitude of 5,280 feet above ground level (AGL).

   1.2. The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.

   1.3. The launch vehicle shall have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.

   1.4. The launch vehicle shall be limited to a single stage.

   1.5. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.

1.6. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board component.

1.7. The launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider.

1.8. The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services).

1.9. The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).

1.9.1. Final motor choices must be made by the Critical Design Review (CDR).

1.9.2. Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.

1.10. Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria:

1.10.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) shall be 4:1 with supporting design documentation included in all milestone reviews.

1.10.2. The low-cycle fatigue life shall be a minimum of 4:1.

1.10.3. Each pressure vessel shall include a solenoid pressure relief valve that sees the full pressure of the tank.

1.10.4. Full pedigree of the tank shall be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.

1.11. The total impulse provided by a Middle and/or High School launch vehicle shall not exceed 2,560 Newton-seconds (K-class).

1.12. All teams shall successfully launch and recover a subscale model of their rocket prior to CDR. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale shall not be used as the subscale model.

1.13. All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full scale demonstration flight:

1.13.1. The vehicle and recovery system shall have functioned as designed.

1.13.2. The payload does not have to be flown during the full-scale test flight. The following requirements still apply:

1.13.2.1. If the payload is not flown, mass simulators shall be used to simulate the payload mass.

1.13.2.1.1. The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.

1.13.2.2. If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems shall be active during the full-scale demonstration flight.

1.13.3. The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulate, as closely as possible, the predicted maximum velocity and maximum acceleration of the launch day flight.

1.13.4. The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight.

1.13.5. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer (RSO).

1.14. Vehicle Prohibitions

1.14.1. The launch vehicle shall not utilize forward canards.

1.14.2. The launch vehicle shall not utilize forward firing motors.

1.14.3. The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)

1.14.4. The launch vehicle shall not utilize hybrid motors.

1.14.5. The launch vehicle shall not utilize a cluster of motors.

2. Recovery System Requirements

2.1. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the Range Safety Officer.

2.2. Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full scale launches.

2.3. At landing, each independent sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.

2.4. The recovery system electrical circuits shall be completely independent of any payload electrical circuits.

2.5. The recovery system shall contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.

2.6. Each altimeter shall be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.

2.7. Each altimeter shall have a dedicated power supply.

2.8. Each arming switch shall be capable of being locked in the ON position for launch.

2.9. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.

2.10. An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.

- 2.10.1. Any rocket section, or payload component, which lands untethered to the launch vehicle, shall also carry an active electronic tracking device.
- 2.10.2. The electronic tracking device shall be fully functional during the official flight on launch day.

2.11. The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).

- 2.11.1. The recovery system altimeters shall be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.
- 2.11.2. The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.
- 2.11.3. The recovery system electronics shall be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.
- 2.11.4. The recovery system electronics shall be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

3. Payload Requirements

3.1. The launch vehicle shall carry a science or engineering payload. The payload may be of the team's discretion, but shall be approved by NASA. NASA reserves the authority to require a team to modify or change a payload, as deemed necessary by the Review Panel, even after a proposal has been awarded.

3.2. Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.

3.3. Unmanned aerial vehicle (UAV) payloads of any type shall be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given the authority to release the UAV.

3.4. Any payload element that is jettisoned during the recovery phase, or after the launch vehicle lands, shall receive real-time RSO permission prior to initiating the jettison event.

3.5. The payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.

4. Safety Requirements

4.1. Each team shall use a launch and safety checklist. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and launch day operations.

4.2. Each team must identify a student safety officer who shall be responsible for all items in section 4.3.

4.3. The role and responsibilities of each safety officer shall include, but not limited to:

- 4.3.1. Monitor team activities with an emphasis on Safety during:
  - 4.3.1.1. Design of vehicle and launcher
  - 4.3.1.2. Construction of vehicle and launcher
  - 4.3.1.3. Assembly of vehicle and launcher
  - 4.3.1.4. Ground testing of vehicle and launcher
  - 4.3.1.5. Sub-scale launch test(s)
  - 4.3.1.6. Full-scale launch test(s)
  - 4.3.1.7. Launch day
  - 4.3.1.8. Recovery activities
  - 4.3.1.9. Educational Engagement Activities
- 4.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities
- 4.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data
- 4.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.

4.4. Each team shall identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor shall be certified by the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attends launch week in April.

4.5. During test flights, teams shall abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.

4.6. Teams shall abide by all rules set forth by the FAA.

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5.2. The team shall provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assigned, educational engagement events, and risks and mitigations.

5.3. Foreign National (FN) team members shall be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during these activities.

5.4. The team shall identify all team members attending launch week activities by the Critical Design Review (CDR). Team members shall include:

- 5.4.1. Students actively engaged in the project throughout the entire year and currently enrolled in the proposing institution.
- 5.4.2. One mentor (see requirement 4.4).
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5.5. The team shall engage a minimum of 200 participants (at least 100 of those shall be middle school students or educators) in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement form, by FRR. An educational engagement form shall be completed and submitted within two weeks after completion of an event. A sample of the educational engagement form can be found on page 45 of the handbook.

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Proposal Requirements

At a minimum, the proposing team shall identify the following in a written proposal due to NASA MSFC by the dates specified in the project timeline.

General Information

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2. Name, title, and contact information for up to two adult educators.
3. Name and title of the individual who will take responsibility for implementation of the safety plan. (Safety Officer)
4. Name, title, and contact information for the student team leader.
5. Approximate number of student participants who will be committed to the project and their proposed duties. Include an outline of the project organization that identifies the key managers (students and/or educator administrators) and the key technical personnel. Only use first names for identifying team members; do not include surnames. (See requirement 5.3 and 5.4 for definition of team members)
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1. Description of facilities and hours of accessibility, necessary personnel, equipment, and supplies that are required to design and build a rocket and payload.

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1. Provide a written safety plan addressing the safety of the materials used, facilities involved, and student responsible, i.e., Safety Officer, for ensuring that the plan is followed. A risk assessment should be done for all these aspects in addition to proposed mitigations. Identification of risks to the successful completion of the project should be included.

    1.1. Provide a description of the procedures for NAR/TRA personnel to perform. Ensure the following:
    - Compliance with NAR high power safety code requirements [http://nar.org/NARhpsc.html].
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1. Include plans and evaluation criteria for required educational engagement activities. (See requirement 5.5).

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5. Develop a clear plan for sustainability of the rocket project in the local area. This plan should include how to provide and maintain established partnerships and regularly engage successive classes of students in rocketry. It should also include partners (industry/community), recruitment of team members, funding sustainability, and educational engagement.

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1. A reusable rocket and required payload system ready for the official launch.

2. A scale model of the rocket design with a payload prototype. This model should be flown prior to the CDR. A report of the data from the flight and the model should be brought to the CDR.

3. Reports, PDF slideshows, and Milestone Review Flysheets due according to the provided timeline, and shall be posted on the team Web site by the due date. (Dates are tentative at this point. Final dates will be announced at the time of award.)

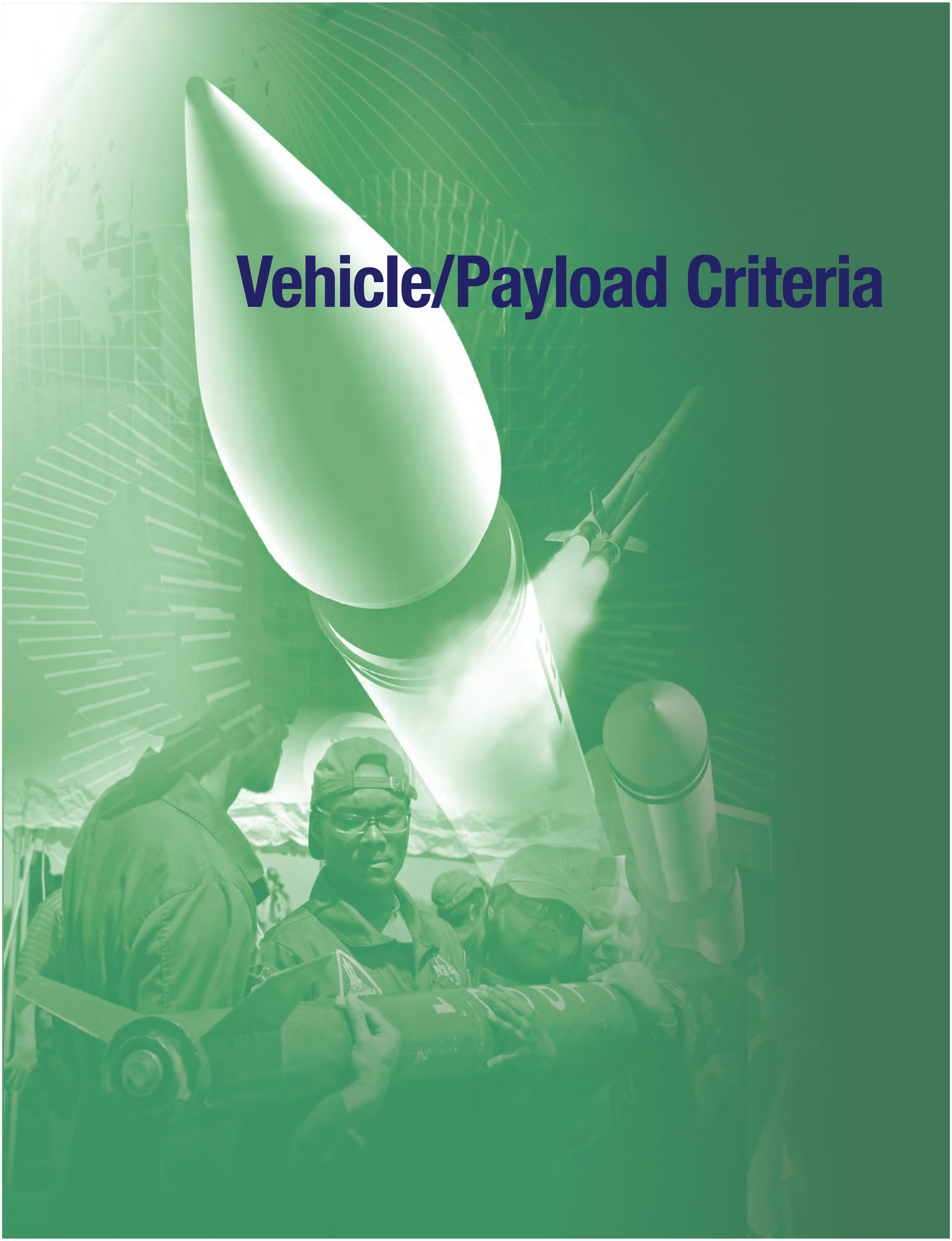
4. The team(s) shall have a Web presence no later than the date specified. The Web site shall be maintained/ updated throughout the period of performance.

5. Electronic copies of the Educational Engagement form(s) and lessons learned pertaining to the implemented educational engagement activities shall be submitted prior to the FRR and no later than two weeks after the educational engagement event.

The team shall participate in a PDR, CDR, FRR, LRR, and PLAR. (Dates are tentative and subject to change.)

The PDR, CDR, FRR, and LRR will be presented to NASA at a time and/or location to be determined by NASA MSFC Academic Affairs Office.

Vehicle/Payload Criteria



Preliminary Design Review (PDR)

Vehicle and Payload Experiment Criteria

The PDR demonstrates that the overall preliminary design meets all requirements with acceptable risk, and within the cost and schedule constraints, and establishes the basis for proceeding with detailed design. It shows that the correct design options have been selected, interfaces have been identified, and verification methods have been described. Full baseline cost and schedules, as well as all risk assessment, management systems, and metrics, are presented.

The panel will be expecting a professional and polished report. It is advised to follow the order of sections as they appear below.

Preliminary Design Review Report

All information contained in the general information section of the project proposal shall also be included in the PDR Report.

I) Summary of PDR report (1 page maximum)

Team Summary

- Team name and mailing address
- Name of mentor, NAR/TRA number and certification level

Launch Vehicle Summary

- Size and mass
- Motor choice
- Recovery system
- Milestone Review Flysheet

AGSE (As Necessary)/Payload Summary

- AGSE/Payload title
- Summarize method for autonomous procedures and the AGSE
- Summarize payload experiment (Middle/High School)

II) Changes made since Proposal (1-2 pages maximum)

Highlight all changes made since the proposal and the reason for those changes.

- Changes made to vehicle criteria
- Changes made to AGSE or payload criteria
- Changes made to project plan

III) Vehicle Criteria

Selection, Design, and Verification of Launch Vehicle

- Include a mission statement, requirements, and mission success criteria.
- Review the design at a system level, going through each system's functional requirements (includes sketches of options, selection rationale, selected concept, and characteristics).
- Describe the subsystems that are required to accomplish the overall mission.
- Describe the performance characteristics for the system and subsystems and determine the evaluation and verification metrics.
- Describe the verification plan and its status. At a minimum, a table should be included that lists each requirement (in SOW), and for each requirement briefly describe the design feature that will satisfy that requirement and how that requirement will ultimately be verified (such as by inspection, analysis, and/or test).
- Define the risks (time, resource, budget, scope/functionality, etc.) associated with the project. Assign a likelihood and impact value to each risk. Keep this part simple i.e. low, medium, high likelihood, and low, medium, high impact. Develop mitigation techniques for each risk. Start with the risks with higher likelihood and impact, and work down from there. If possible, quantify the mitigation and impact. For example; including extra hardware to increase safety will have a quantifiable impact on budget. Including this information in a table is highly encouraged.
- Demonstrate an understanding of all components needed to complete the project and how risks/delays impact the project.
- Demonstrate planning of manufacturing, verification, integration, and operations (include component testing, functional testing, or static testing).
- Describe the confidence and maturity of design.
- Include a dimensional drawing of entire assembly. The drawing set should include drawings of the entire launch vehicle, compartments within the launch vehicle (such as parachute bays, payload bays, and electronics bays), and significant structural design features of the launch vehicle (such as fins and bulkheads).
- Include electrical schematics for the recovery system.
- Include a Mass Statement. Discuss the estimated mass of the launch vehicle, its subsystems, and components. What is the basis of the mass estimate and how accurate is it? Discuss how much margin there is before the vehicle becomes too heavy to launch with the identified propulsion system. Are you holding any mass in reserve (i.e., are you planning for any mass growth as the design matures)? If so, how much? As a point of reference, a reasonable rule of thumb is that the mass of a new product will grow between 25 and 33% between PDR and the delivery of the final product.

Recovery Subsystem

- Demonstrate that analysis has begun to determine expected mass of launch vehicle and parachute size, attachment scheme, deployment process, and test results/plans with ejection charges and electronics.
- Discuss the major components of the recovery system (such as the parachutes, parachute harnesses, attachment hardware, and bulkheads), and verify that they will be robust enough to withstand the expected loads.

Mission Performance Predictions

- State mission performance criteria.
- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve, and verify that they are robust enough to withstand the expected loads.

- Show stability margin, simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind.

Interfaces and Integration

- Describe payload integration plan with an understanding that the payload must be co-developed with the vehicle, be compatible with stresses placed on the vehicle, and integrate easily and simply.
- Describe the interfaces that are internal to the launch vehicle, such as between compartments and subsystems of the launch vehicle.
- Describe the interfaces between the launch vehicle and the ground (mechanical, electrical, and/or wireless/transmitting).
- Describe the interfaces between the launch vehicle and the ground launch system.

Safety

- Develop a preliminary checklist of final assembly and launch procedures.
- Identify a safety officer for your team.
- Provide a preliminary Hazard analysis, including hazards to personnel. Also, include the failure modes of the proposed design of the rocket, payload integration, and launch operations. Include proposed mitigations to all hazards (and verifications if any are implemented yet). Rank the risk of each Hazard for both likelihood and severity.
    - Include data indicating that the hazards have been researched (especially personnel). Examples: NAR regulations, operator's manuals, MSDS, etc.
- Discuss any environmental concerns.
    - This should include how the vehicle affects the environment, and how the environment can affect the vehicle.

IV) AGSE (As Necessary)/Payload Criteria

Selection, Design, and Verification of AGSE

- Review the design at a system level, going through each system's functional requirements (includes sketches of options, selection rationale, selected concept, and characteristics).
- Describe the AGSE/payload subsystems that are required to accomplish the mission objectives.
- Describe the performance characteristics for the system and subsystems and determine the evaluation and verification metrics.
- Describe the verification plan and its status. At a minimum, a table should be included that lists each AGSE or payload requirement and for each requirement briefly describe the design feature that will satisfy that requirement and how that requirement will ultimately be verified (such as by inspection, analysis, and/or test).
- Describe preliminary integration plan.
- Determine the precision of instrumentation, repeatability of measurement, and recovery system.
- Include drawings and electrical schematics for the key elements of the AGSE/payload.
- Discuss the key components of the AGSE/payload and how they will work together to achieve the desired mission objectives

AGSE/Payload Concept Features and Definition

- Creativity and originality
- Uniqueness or significance
- Suitable level of challenge

Science Value

- Describe AGSE objectives.
- State the AGSE success criteria.
- Describe the experimental logic, approach, and method of investigation.
- Describe test and measurement, variables, and controls.
- Show relevance of expected data and accuracy/error analysis.
- Describe the preliminary experiment process procedures.

V) Project Plan

Show status of activities and schedule

- Budget plan (in as much detail as possible)
- Funding plan
- Timeline (in as much detail as possible). GANTT charts are encouraged with a discussion of the critical path.
- Educational engagement plan and status

VI) Conclusion

Preliminary Design Review Presentation

Please include the following in your presentation:

- Vehicle dimensions, materials, and justifications
- Static stability margin
- Plan for vehicle safety verification and testing
- Baseline motor selection and justification
- Thrust-to-weight ratio and rail exit velocity
- Launch vehicle verification and test plan overview
- Drawing/Discussion of each major component and subsystem, especially the recovery subsystem
- Baseline AGSE/Payload design
- AGSE/Payload verification and test plan overview

The PDR will be presented to a panel that may be comprised of any combination of scientists, engineers, safety experts, education specialists, and industry partners. This review should be viewed as the opportunity to convince the NASA Review Panel that the preliminary design will meet all requirements, has a high probability of meeting the mission objectives, and can be safely constructed, tested, launched, and recovered. Upon successful completion of the PDR, the team is given the authority to proceed into the final design phase of the life cycle that will culminate in the Critical Design Review.

It is expected that the **team participants** deliver the report and answer all questions. The mentor shall not participate in the presentation.

The presentation of the PDR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy-to-see slides; appropriate placement of pictures, graphs, and videos; professional appearance of the presenters; speaking clearly and loudly; looking into the camera; referring to the slides, not reading them; and communicating to the panel in an appropriate and professional manner. The slides should use dark text on a light background.

Critical Design Review (CDR)
Vehicle and Payload Experiment Criteria

The CDR demonstrates that the maturity of the design is appropriate to support proceeding to full-scale fabrication, assembly, integration, and test that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet overall performance requirements within the identified cost schedule constraints. Progress against management plans, budget, and schedule, as well as risk assessment, are presented. The CDR is a review of the final design of the launch vehicle and payload system. All analyses should be complete and some critical testing should be complete. The CDR Report and Presentation should be independent of the PDR Report and Presentation. However, the CDR Report and Presentation may have the same basic content and structure as the PDR documents, but with final design information that may or may not have changed since PDR. Although there should be discussion of subscale models, the CDR documents are to primarily discuss the final design of the full scale launch vehicle and subsystems.

The panel will be expecting a professional and polished report. It is advised to follow the order of sections as they appear below.

Critical Design Review Report

All information included in the general information sections of the project proposal and PDR shall be included.

I) Summary of CDR report (1 page maximum)

Team Summary

- Team name and mailing address
- Name of mentor, NAR/TRA number and certification level

Launch Vehicle Summary

- Size and mass
- Motor choice
- Recovery system
- Rail size
- Milestone Review Flysheet

AGSE (As Necessary)/Payload Summary

- AGSE/Payload title
- Summarize method for autonomous procedures ant the AGSE
- Summarize experiment

II) Changes made since PDR (1-2 pages maximum)

Highlight all changes made since PDR and the reason for those changes.

- Changes made to vehicle criteria
- Changes made to AGSE/Payload criteria
- Changes made to project plan

III) Vehicle Criteria

Design and Verification of Launch Vehicle

Flight Reliability and Confidence

- Include mission statement, requirements, and mission success criteria
- Include major milestone schedule (project initiation, design, manufacturing, verification, operations, and major reviews)
- Review the design at a system level
  - Final drawings and specifications
  - Final analysis and model results, anchored to test data
  - Test description and results
  - Final motor selection
- Demonstrate that the design can meet all system level functional requirements. For each requirement, state the design feature that satisfies that requirement and how that requirement has been, or will be, verified.
- Specify approach to workmanship as it relates to mission success.
- Discuss planned additional component, functional, or static testing.
- Status and plans of remaining manufacturing and assembly.
- Discuss the integrity of design.
  - Suitability of shape and fin style for mission
  - Proper use of materials in fins, bulkheads, and structural elements
  - Proper assembly procedures, proper attachment and alignment of elements, solid connection points, and load paths
  - Sufficient motor mounting and retention
  - Status of verification
  - Drawings of the launch vehicle, subsystems, and major components
  - Include a Mass Statement. Discuss the estimated mass of the final design and its subsystems and components. Discuss the basis and accuracy of the mass estimate, the expected mass growth between CDR and the delivery of the final product, and the sensitivity of the launch vehicle to mass growth (e.g. How much mass margin there is before the vehicle becomes too heavy to launch on the selected propulsion system?).
- Discuss the safety and failure analysis.

Subscale Flight Results

- Include actual flight data from onboard computers, if available.
- Compare the predicted flight model to the actual flight data. Discuss the results.
- Discuss how the subscale flight data has impacted the design of the full-scale launch vehicle.

Recovery Subsystem

- Describe the parachute, harnesses, bulkheads, and attachment hardware.
- Discuss the electrical components and how they will work together to safely recover the launch vehicle.
- Include drawings/sketches, block diagrams, and electrical schematics.
- Discuss the kinetic energy at significant phases of the mission, especially at landing.
- Discuss test results.
- Discuss safety and failure analysis.

Mission Performance Predictions

- State the mission performance criteria.
- Show flight profile simulations, altitude predictions with final vehicle design, weights, and actual motor thrust curve.
- Show thoroughness and validity of analysis, drag assessment, and scale modeling results.
- Show stability margin and the actual CP and CG relationship and locations.

AGSE/Payload Integration

Ease of integration

- Describe integration plan.
- Compatibility of elements.
- Simplicity of integration procedure.
- Discuss any changes in the AGSE or payload resulting from the subscale test.

Launch concerns and operation procedures

- Submit a draft of final assembly and launch procedures including:
  - Recovery preparation.
  - Motor preparation.
  - Setup on launcher.
  - Igniter installation.
  - Troubleshooting.
  - Post-flight inspection.

Safety and Environment (Vehicle and AGSE/Payload)

- Update the preliminary analysis of the failure modes of the proposed design of the rocket and payload integration and launch operations, including proposed, and completed mitigations.
- Update the listing of personnel hazards and data demonstrating that safety hazards have been researched, such as material safety data sheets, operator's manuals, and NAR regulations, and that hazard mitigations have been addressed and enacted.
- Discuss any environmental concerns.
  - This should include how the vehicle affects the environment, and how the environment can affect the vehicle.

IV) AGSE (As Necessary)/Payload Criteria

Testing and Design of AGSE/Payload Equipment

- Review the design at a system level.
  - Drawings and specifications
  - Analysis results
  - Test results
  - Integrity of design
- Demonstrate that the design can meet all system-level functional requirements.
- Specify approach to workmanship as it relates to mission success.
- Discuss planned component testing, functional testing, or static testing.
- Status and plans of remaining manufacturing and assembly.
- Describe integration plan.
- Discuss the precision of instrumentation and repeatability of measurement.

- Discuss the AGSE/payload electronics with special attention given to safety switches and indicators.
    - Drawings and schematics
    - Block diagrams
    - Batteries/power
    - Switch and indicator wattage and location
    - Test plans
- Provide a safety and failure analysis.

AGSE/Payload Concept Features and Definition

- Creativity and originality
- Uniqueness or significance
- Suitable level of challenge

Science Value

- Describe AGSE/payload objectives.
- State the AGSE/payload success criteria.
- Describe the experimental logic, approach, and method of investigation.
- Describe test and measurement, variables, and controls.
- Show relevance of expected data and accuracy/error analysis.
- Describe the experiment process procedures.

V) Project Plan

Show status of activities and schedule

- Budget plan (in as much detail as possible)
- Funding plan
- Timeline (in as much detail as possible). GANTT charts are encouraged with a discussion of the critical path.
- Educational engagement plan and status

VI) Conclusion

Critical Design Review Presentation

Please include the following information in your presentation:

- Final launch vehicle and AGSE dimensions
- Discuss key design features
- Final motor choice
- Rocket flight stability in static margin diagram
- Thrust-to-weight ratio and rail exit velocity
- Mass Statement and mass margin
- Parachute sizes, recovery harness type, size, length, and descent rates
- Kinetic energy at key phases of the mission, especially landing
- Predicted drift from the launch pad with 5-, 10-, 15-, and 20-mph wind
- Test plans and procedures
- Scale model flight test
- Tests of the staged recovery system
- Final AGSE/payload design overview
- AGSE/Payload integration
- Interfaces (internal within the launch vehicle and external to the ground)
- Status of requirements verification

The CDR will be presented to a panel that may be comprised of any combination of scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the final design of the launch vehicle (including the AGSE/payload), showing that design meets the mission objectives and requirements and that the design can be safety, constructed, tested, launched, and recovered. Upon successful completion of the CDR, the team is given the authority to proceed into the construction and verification phase of the life cycle which will culminate in a Flight Readiness Review.

It is expected that the **team participants** deliver the report and answer all questions. The mentor shall not participate in the presentation.

The presentation of the CDR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy-to-see slides; appropriate placement of pictures, graphs, and videos; professional appearance of the presenters; speaking clearly and loudly; looking into the camera; referring to the slides, not reading them; and communicating to the panel in an appropriate and professional manner. The slides should be made with dark text on a light background.

Flight Readiness Review (FRR)
Vehicle and Payload Experiment Criteria

The FRR examines tests, demonstrations, analyses, and audits that determine the overall system (all projects working together) readiness for a safe and successful flight/launch and for subsequent flight operations of the as-built rocket and payload system. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.

The panel will be expecting a professional and polished report. It is advised to follow the order of sections as they appear below.

Flight Readiness Review Report

I) Summary of FRR report (1 page maximum)

Team Summary
- Team name and mailing address
- Name of mentor, NAR/TRA number and certification level

Launch Vehicle Summary
- Size and mass
- Final motor choice
- Recovery system
- Rail size
- Milestone Review Flysheet

AGSE (As Necessary)/Payload Summary
- AGSE/Payload title
- Summarize the AGSE
- Summarize experiment

II) Changes made since CDR (1-2 pages maximum)

Highlight all changes made since CDR and the reason for those changes.
- Changes made to vehicle criteria
- Changes made to AGSE/Payload criteria
- Changes made to project plan

III) Vehicle Criteria

Design and Construction of Vehicle
- Describe the design and construction of the launch vehicle, with special attention to the features that will enable the vehicle to be launched and recovered safely.
    - Structural elements (such as airframe, fins, bulkheads, attachment hardware, etc.).
    - Electrical elements (wiring, switches, battery retention, retention of avionics boards, etc.).
    - Drawings and schematics to describe the assembly of the vehicle.

- Discuss flight reliability confidence. Demonstrate that the design can meet mission success criteria. Discuss analysis, and component, functional, or static testing.
- Present test data and discuss analysis, and component, functional, or static testing of components and subsystems.
- Describe the workmanship that will enable mission success.
- Provide a safety and failure analysis, including a table with failure modes, causes, effects, and risk mitigations.
- Discuss full-scale launch test results. Present and discuss actual flight data. Compare and contrast flight data to the predictions from analysis and simulations.
- Provide a Mass Report and the basis for the reported masses.

Recovery Subsystem

- Describe and defend the robustness of as-built and as-tested recovery system.
    - Structural elements (such as bulkheads, harnesses, attachment hardware, etc.).
    - Electrical elements (such as altimeters/computers, switches, connectors).
    - Redundancy features.
    - Parachute sizes and descent rates
    - Drawings and schematics of the electrical and structural assemblies.
    - Rocket-locating transmitters with a discussion of frequency, wattage, and range.
    - Discuss the sensitivity of the recovery system to onboard devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis section.
- Suitable parachute size for mass, attachment scheme, deployment process, test results with ejection charge and electronics
- Safety and failure analysis. Include table with failure modes, causes, effects, and risk mitigations.

Mission Performance Predictions

- State mission performance criteria.
- Provide flight profile simulations, altitude predictions with real vehicle data, component weights, and actual motor thrust curve. Include real values with optimized design for altitude. Include sensitivities.
- Thoroughness and validity of analysis, drag assessment, and scale modeling results. Compare analyses and simulations to measured values from ground and/or flight tests. Discuss how the predictive analyses and simulation have been made more accurate by test and flight data.
- Provide stability margin, with actual CP and CG relationship and locations. Include dimensional moment diagram or derivation of values with points indicated on vehicle. Include sensitivities.
- Discuss the management of kinetic energy through the various phases of the mission, with special attention to landing.
- Discuss the altitude of the launch vehicle and the drift of each independent section of the launch vehicle for winds of 0-, 5-, 10-, 15-, and 20-mph.

Verification (Vehicle)

- For each requirement (in SOW), describe how that requirement has been satisfied and by what method the requirement was verified. Note: Requirements are often satisfied by design features of a product, and requirements are usually verified by one or more of the following methods: analysis, inspection, and test.
- The verification statement for each requirement should include results of the analysis, inspection, and/or test which prove that the requirement has been properly verified.

Safety and Environment (Vehicle)

- Provide a safety and mission assurance analysis. Provide a Failure Modes and Effects Analysis (which can be as simple as a table of failure modes, causes, effects, and mitigations/controls put in place to minimize the occurrence or effect of the hazard or failure). Discuss likelihood and potential consequences for the top 5 to 10 failures (most likely to occur and/or worst consequences).
- As the program is moving into the operational phase of the Life Cycle, update the listing of personnel hazards, including data demonstrating that safety hazards that will still exist after FRR. Include a table which discusses the remaining hazards and the controls that have been put in place to minimize those safety hazards to the greatest extent possible.
- Discuss any environmental concerns that remain as the project moves into the operational phase of the life cycle.

AGSE Integration

- Describe the integration of the AGSE into the launch vehicle.
- Demonstrate compatibility of elements and show fit at interface dimensions.
- Describe and justify payload-housing integrity.
- Demonstrate integration: show a diagram of components and assembly with documented process.

IV) AGSE (As Necessary)/Payload Criteria

Experiment Concept

This concerns the quality of science. Give clear, concise, and descriptive explanations.

- Creativity and originality
- Uniqueness or significance

Science Value

- Describe AGSE/payload objectives in a concise and distinct manner.
- State the mission success criteria.
- Describe the experimental logic, scientific approach, and method of investigation.
- Explain how it is a meaningful test and measurement, and explain variables and controls.
- Discuss the relevance of expected data, along with an accuracy/error analysis, including tables and plots
- Provide detailed experiment process procedures.

AGSE/Payload Design

- Describe the design and construction of the AGSE/payload and demonstrate that the design meets all mission requirements.
  - Structural elements (such as airframe, bulkheads, attachment hardware, etc.).
  - Electrical elements (wiring, switches, battery retention, retention of avionics boards, etc.).
  - Drawings and schematics to describe the design and assembly of the AGSE/payload.
- Provide information regarding the precision of instrumentation and repeatability of measurement (include calibration with uncertainty).
- Provide flight performance predictions (flight values integrated with detailed experiment operations).
- Specify approach to workmanship as it relates to mission success.
- Discuss the test and verification program.

Verification

- For each AGSE/payload requirement, describe how that requirement has been satisfied, and by what method the requirement was verified. Note: Requirements are often satisfied by design features, and requirements are usually verified by one or more of the following methods: analysis, inspection, and test.
- The verification statement for each AGSE/payload requirement should include results of the analysis, inspection, and/or test which prove that the requirement has been properly verified.

Safety and Environment (AGSE/payload)

This will describe all concerns, research, and solutions to safety issues related to the AGSE/payload.

- Provide a safety and mission assurance analysis. Provide a Failure Modes and Effects Analysis (which can be as simple as a table of failure modes, causes, effects, and mitigations/controls put in place to minimize the occurrence or effect of the hazard or failure). Discuss likelihood and potential consequences for the top 5 to 10 failures (most likely to occur and/or worst consequences).
- As the program is moving into the operational phase of the Life Cycle, update the listing of personnel hazards, including data demonstrating that safety hazards that will still exist after FRR. Include a table which discusses the remaining hazards and the controls that have been put in place to minimize those safety hazards to the greatest extent possible.
- Discuss any environmental concerns that still exist.

V) Launch Operations Procedures

Checklist

Provide detailed procedure and check lists for the following (as a minimum).

- Recovery preparation
- Motor preparation
- Setup on launcher
- Igniter installation
- Launch procedure
- Troubleshooting
- Post-flight inspection

Safety and Quality Assurance

Provide detailed safety procedures for each of the categories in the Launch Operations Procedures checklist. Include the following:

- Provide data demonstrating that risks are at acceptable levels.
- Provide risk assessment for the launch operations, including proposed and completed mitigations.
- Discuss environmental concerns.
- Identify the individual that is responsible for maintaining safety, quality and procedures checklists.

VI) Project Plan

Show status of activities and schedule

- Budget plan (in as much detail as possible)
- Funding plan
- Timeline (in as much detail as possible). GANTT charts are encouraged with a discussion of the critical path.
- Educational Engagement plan and status

VII) Conclusion

Flight Readiness Review Presentation

Please include the following information in your presentation:

- Launch Vehicle and AGSE design and dimensions
- Discuss key design features of the launch vehicle
- Motor description
- Rocket flight stability in static margin diagram
- Launch thrust-to-weight ratio and rail exit velocity
- Mass statement
- Parachute sizes and descent rates
- Kinetic energy at key phases of the mission, especially at landing
- Predicted altitude of the launch vehicle with a 5-, 10-, 15-, and 20-mph wind
- Predicted drift from the launch pad with a 5-, 10-, 15-, and 20-mph wind
- Test plans and procedures
- Full-scale flight test. Present and discuss the actual flight test data.
- Recovery system tests
- Summary of Requirements Verification (launch vehicle)
- AGSE/payload design and dimensions
- Key design features of the launch vehicle
- AGSE/Payload integration
- Interfaces with ground systems
- Summary of requirements verification (AGSE/payload)

The FRR will be presented to a panel that may be comprised of any combination of scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the as-built launch vehicle (including the payload), showing that the launch vehicle meets all requirements and mission objectives and that the design can be safely launched and recovered. Upon successful completion of the FRR, the team is given the authority to proceed into the Launch and Operational phases of the life cycle.

It is expected that the **team participants** deliver the report and answer all questions. The mentor shall not participate in the presentation.

The presentation of the FRR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy to see slides; appropriate placement of pictures, graphs, and videos; professional appearance of the presenters; speaking clearly and loudly; looking into the camera; referring to the slides, not reading them; and communicating to the panel in an appropriate and professional manner. The slides should be made with dark text on a light background.

Launch Readiness Review (LRR)

Vehicle and Payload Experiment Criteria

The Launch Readiness Review (LRR) will be held by NASA and the National Association of Rocketry (NAR), our launch services provider. These inspections are only open to team members and mentors. These names were submitted as part of your team list. All rockets/AGSE will undergo a detailed, deconstructive, hands-on inspection. Your team should bring all components of the rocket and AGSE/payload except for the motor, black powder, and e-matches. Be able to present: anchored flight predictions, anchored drift predictions (15 mph crosswind), procedures and checklists, and CP and CG with loaded motor marked on the airframe. The rockets will be assessed for structural, electrical integrity, and safety features. At a minimum, all teams should have:

- An airframe prepared for flight with the exception of energetic materials.
- Data from the previous flight.
- A list of any flight anomalies that occurred on the previous full scale flight and the mitigation actions.
- A list of any changes to the airframe since the last flight.
- Flight simulations.
- Pre-flight check list and Fly Sheet.

Any team participating in the Mini/Maxi MAV portion of the completion must also participate in an AGSE inspection consisting of the following demonstrations.

- Demonstrate proper capture and containment of the payload.
- Demonstrate that the launch pad can autonomously erect itself with the model/inert motor installed.
- Demonstrate that the AGSE can properly install the igniter into the model/inert motor.
- For each of the above stages, the team must demonstrate that all safety switches and indicators function properly and at the correct times.

Each team will demonstrate these tasks with the RSO present who will have final word on whether the AGSE may be used on Launch Day.

A "punch list" will be generated for each team. Items identified on the punch list should be corrected and verified by launch services/NASA prior to launch day. A flight card will be provided to teams, to be completed and provided at the RSO booth on launch day.

Post-Launch Assessment Review (PLAR)

Vehicle and Payload Experiment Criteria

The PLAR is an assessment of system in-flight performance.

The PLAR should include the following items at a minimum and be about 4-15 pages in length.

- Team name
- Motor used
- Brief payload description
- Vehicle Dimensions
- Altitude reached (Feet)
- Vehicle Summary
- Data analysis & results of vehicle
- Payload summary
- Data analysis & results of AGSE/payload
- Scientific value
- Visual data observed
- Lessons learned
- Summary of overall experience (what you attempted to do versus the results and how you felt your results were; how valuable you felt the experience was)
- Educational Engagement summary
- Budget Summary

Educational Engagement Form

Please complete and submit this form each time you host an educational engagement event.
(Return within 2 weeks of the event end date)

School/Organization name:

Date(s) of event:

Location of event:

Instructions for participant count

Education/Direct Interactions: A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity. This includes instructor- led facilitation around an activity regardless of media (e.g. DLN, face-to-face, downlink.etc.). Example: Students learn about Newton's Laws through building and flying a rocket. ***This type of interaction will count towards your requirement for the project.***

Education/Indirect Interactions: A count of participants engaged in learning a STEM topic through instructor-led facilitation or presentation. Example: Students learn about Newton's Laws through a PowerPoint presentation.

Outreach/Direct Interaction: A count of participants who do not necessarily learn a STEM topic, but are able to get a hands-on look at STEM hardware. For example, team does a presentation to students about their Student Launch project, brings their rocket and components to the event, and flies a rocket at the end of the presentation.

Outreach/Indirect Interaction: A count of participants that interact with the team. For example: The team sets up a display at the local museum during Science Night. Students come by and talk to the team about their project.

Grade level and number of participants: *(If you are able to break down the participants into grade levels: PreK-4, 5-9, 10-12, and 12+, this will be helpful.)*

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4				
5-9				
10-12				
12+				
Educators (5-9)				
Educators (other)				

Are the participants with a special group/organization (i.e. Girl Scouts, 4-H, school)? Y N

If yes, what group/organization?

Briefly describe your activities with this group:

Did you conduct an evaluation? If so, what were the results?

Describe the comprehensive feedback received.

Safety

High Power Rocket Safety Code

Provided by the National Association of Rocketry

1. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.

2. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.

3. **Motors.** I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.

4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.

5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.

7. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor’s exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.

8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

9. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).

11. **Launcher Location.** My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

12. **Recovery System.** I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

Minimum Distance Table

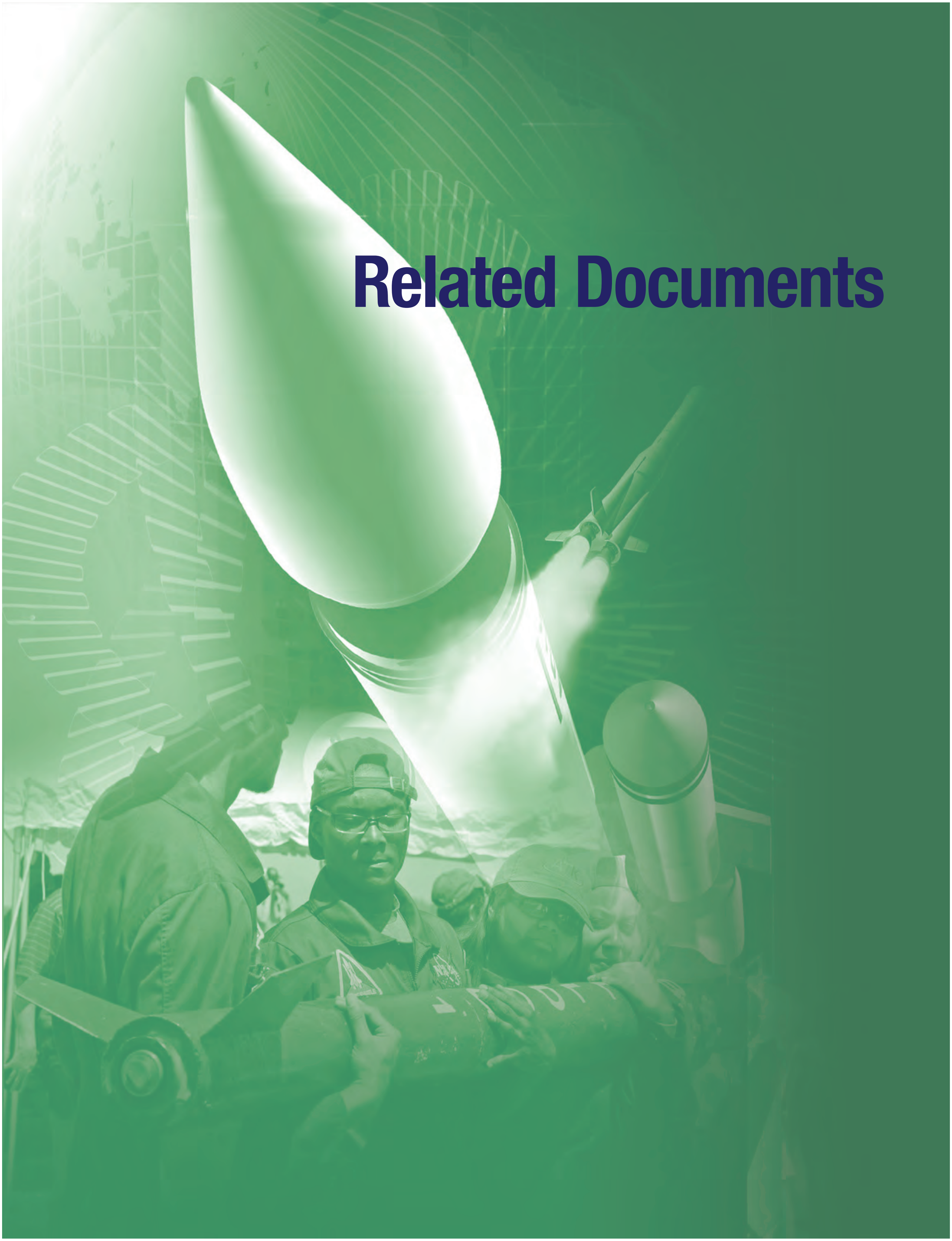
Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 – 320.00	H or smaller	50	100	200
320.01 – 640.00	I	50	100	200
640.01 – 1,280.00	J	50	100	200
1,280.01 – 2,560.00	K	75	200	300
2,560.01 – 5,120.00	L	100	300	500
5,120.01 – 10,240.00	M	125	500	1000
10,240.01 – 20,480.00	N	125	1000	1500
20,480.01 – 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Revision of July 2008

Provided by the National Association of Rocketry (www.nar.org)

Related Documents



NASA Project Life Cycle

Charles Pierce
Chief, Spacecraft Propulsion Systems Branch,
NASA - Marshall Space Flight Center

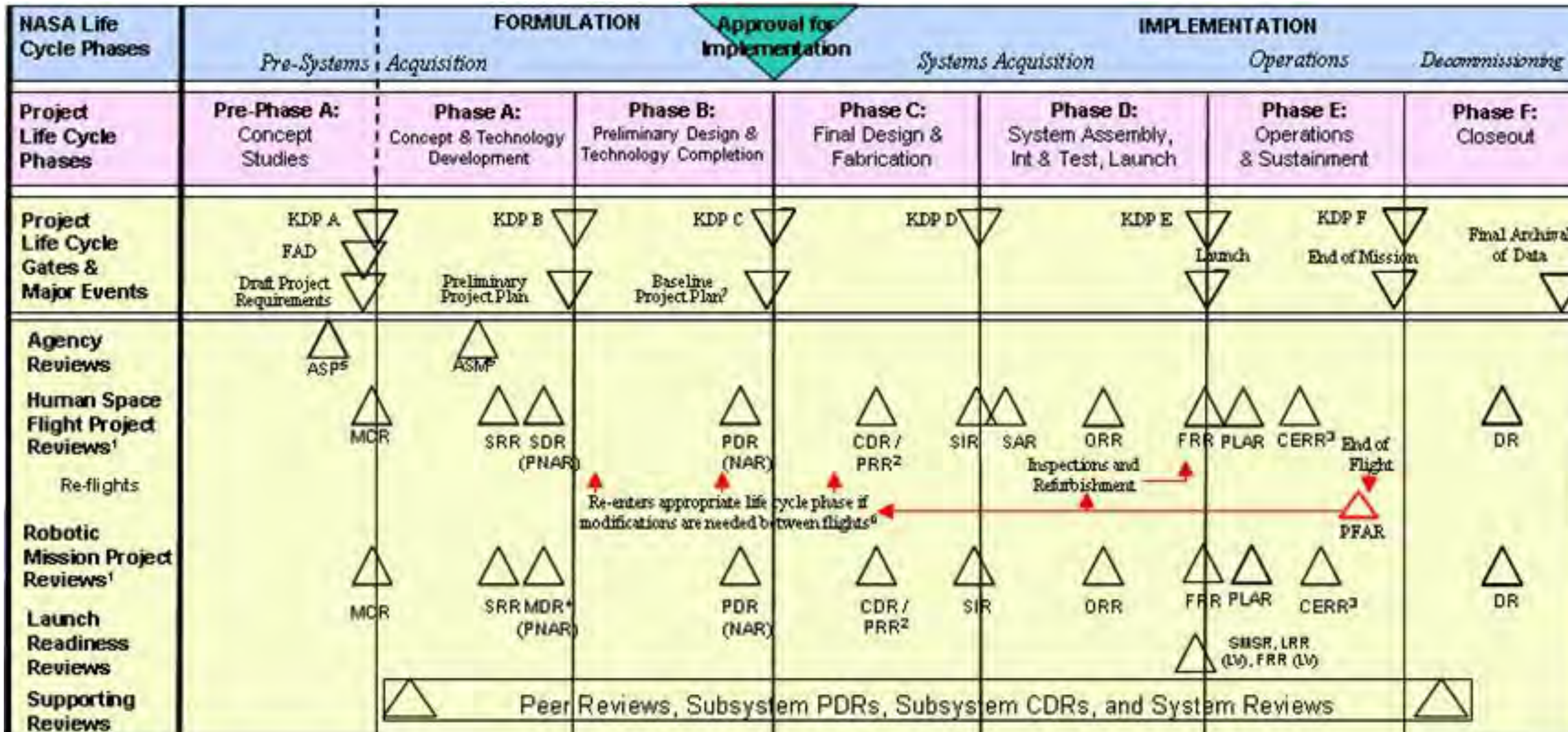
Topics

- Purpose / Objective
- NASA Project Life Cycle (Typical)
- Preliminary Design Review
- Critical (Final) Design Review
- Flight Readiness Review
- Post Flight

Purpose/Objectives of the NASA Project Life Cycle

- Plan for the design, build, verification, flight operations, and disposal of the desired system
- Maintain consistency between projects
- Set expectations for Project Managers, Scientists, & Engineers
  - Plans and Deliverables
  - Fidelity
  - Timing

Typical NASA Project Life Cycle



FOOTNOTES

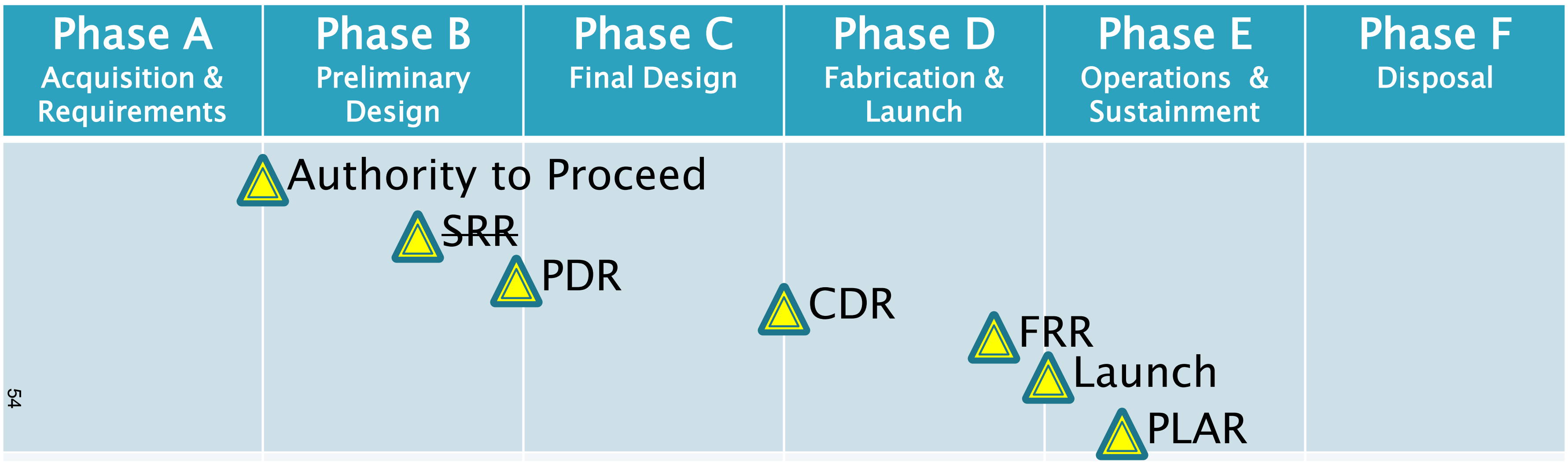
1. Flexibility is allowed in the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan. These reviews are conducted by the project for the independent SRB. See Section 2.5 and Table 2-6.
2. PRR needed for multiple (≥4) system copies. Timing is notional.
3. CERRs are established at the discretion of Program Offices.
4. For robotic missions, the SRR and the MDR may be combined.
5. The ASP and ASM are Agency reviews, not life-cycle reviews.
6. Includes recertification, as required.
7. Project Plans are baselined at KDP C and are reviewed and updated as required, to ensure project content, cost, and budget remain consistent.

ACRONYMS

ASP—Acquisition Strategy Planning Meeting
ASM—Acquisition Strategy Meeting
CDR—Critical Design Review
CERR—Critical Events Readiness Review
DR—Decommissioning Review
FAD—Formulation Authorization Document
FRR—Flight Readiness Review
KDP—Key Decision Point
LRR—Launch Readiness Review
MCR—Mission Concept Review
MDR—Mission Definition Review
NAR—Non-Advocate Review
ORR—Operational Readiness Review
PDR—Preliminary Design Review
PFAR—Post-Flight Assessment Review
PLAR—Post-Launch Assessment Review
PNAR—Preliminary Non-Advocate Review
PRR—Production Readiness Review
SAR—System Acceptance Review
SDR—System Definition Review
SIR—System Integration Review
SMSR—Safety and Mission Success Review
SRR—System Requirements Review

Reference: NPR 7120.5D, Figure 2-4: “The NASA Project Life Cycle”

NASA Student Launch Life Cycle



- ATP (Authority to Proceed) – Funding is applied to the contract/effort and work performance can begin
- SRR (System Requirements Review) – Top Level Requirements are converted into system requirements. System Requirements are reviewed and authority is given to proceed into Preliminary Design. The NASA Student Launch skips this step. Note: This review is skipped, due to time constraints.
- PDR (Preliminary Design Review) – Preliminary Design is reviewed and authority is given to proceed into Final Design.
- CDR (Critical Design Review) – Final Design is reviewed and authority is given to proceed to build the system.
- FRR (Flight Readiness Review) – As-built design and test data are reviewed and authority is given for Launch.
- PLAR (Post Launch Assessment Report) - Summarize project (cradle to grave), discuss mission results and compare to expected results, document lessons learned.

Preliminary Design Review (PDR)

- Objective
  - Prove the feasibility to build and launch the rocket/payload design.
  - Prove that all system requirements will be met.
  - Receive authority to proceed to the Final Design Phase
- Typical Products (Vehicle and Payload)
  - Preliminary Design Discussion
    - Drawings, sketches
    - Identification and discussion of components
    - Analyses (such as Vehicle Trajectory Predictions) and Simulation Results
    - Risks
    - Mass Statement and Mass Margin
  - Schedule from PDR to Launch (including design, build, test)
  - Cost/Budget Statement
  - Mission Profile (Concept of Operations)
  - Interfaces (within the system and external to the system)
  - Test and Verification Plan (for satisfying requirements)
  - Ground Support Equipment Designs/Identification
  - Safety Features

Critical Design Review (CDR)

- Objective
  - Complete the final design of the rocket/payload system
  - Receive authority to proceed into Fabrication and Verification phase
    - In a perfect world, fabrication/procurement of the final system wouldn't begin until a successful completion of CDR.
    - Due to schedule constraints, however, it is often necessary to start procurements and fabrication prior to CDR.
    - Procurements and Fabrication that start prior to CDR add an extra risk to the Project because design issues may be discovered at CDR that impact procurements or fabrication.
- Typical Products (Vehicle and Payload)
  - PDR Deliverables (matured to reflect the final design)
  - Report and discuss completed tests
  - Procedures and Checklists

Flight Readiness Review (FRR)

- Objective
  - Prove that the Rocket/Payload System has been fully built, tested, and verified to meet the system requirements
  - Prove that all system requirements have been, or will be, met
  - Receive authority to proceed to Launch
- Typical Products (Vehicle and Payload)
  - Schedule
  - Cost Statement
  - Design Overview
    - Key components
    - Key drawings and layouts
    - Trajectory and other key analyses
    - Key Safety Features
    - Mass Statement
    - Remaining Risks
  - Mission Profile
  - Presentation and analysis and models (use real test data)
  - System Requirements Verification
  - Ground Support Equipment
  - Procedures and Check Lists

Hardware Inspections (Hands on)

- Objective
  - To perform a hands-on final inspection of the rocket system, prior to launch
  - Performed by the operators of the Launch Range
- Process
  - Rockets deconstructed
    - Mechanical components pulled and twisted
    - Electronics and Wiring inspected (as much as possible)
    - Recovery System fully inspected
  - Questions asked
    - Arming, Activation, Execution Sequences
    - Rocket and Payload Functions
  - Launch Day Procedures reviewed
  - Questions Answered (anything about Launch Day or Range Operations)
  - Actions given to repair unsafe elements in the rocket system (if any are found)

- Note: This inspection is a Pre Range Safety Officer (RSO) inspection.
  - It occurs one day before launch and it purpose is to give the Student Teams an opportunity to correct hardware issues that could otherwise result in the denial of launch of their rocket.
  - A final RSO inspection will occur at the launch site (just like a normal NAR/TRA RSO Inspection at the launch site).

Post Launch Assessment Report

- Summary of the Project
- Summary of the Vehicle and Payload
  - Especially note anything that changed after FRR
- Presentation of Vehicle and Payload Results
  - Comparison to predicted results
  - Discussion of anomalies
- Lessons Learned

www.nasa.gov

Hazard Analysis

Introduction to Managing Risk

What is a Hazard?

Put simply, it’s an outcome that will have an adverse affect on you, your project, or the environment. A classic example of a Hazard is a Fire or Explosion.

- A hazard has many parts, all of which play into how we categorize it, and how we respond.
- Not all hazards are life threatening or have catastrophic outcomes. They can be more benign, like cuts and bruises, funding issues, or schedule setbacks.

Hazard Description

A hazard description is composed of 3 parts.

1. Hazard – Sometimes called the Hazardous event, or initiating event
2. Cause – How the Hazard occurs. Sometimes called the mechanism
3. Effect – The outcome. This is what you are worried about happening if the Hazard manifests.

Example Hazard Description

Chemical burns due to mishandling or spilling Hydrochloric Acid results in serious injury to personnel.

Hazard

Cause

Effect

Risk

Risk is a measure of how much emphasis a hazard warrants.

Risk is defined by 2 factors:

- Likelihood – The chance that the hazard will occur. This is usually measured qualitatively but can be quantified if data exists.
- Severity – If the hazard occurs, how bad will it be?

Risk Matrix Example

(excerpt from NASA MPR 8715.15)

TABLE CH1.1 RAC

Probability	Severity			
	1 Catastrophic	**2 Critical**	**3 Marginal**	**4 Negligible**
A – Frequent	1A	2A	3A	4A
B – Probable	1B	2B	3B	4B
C – Occasional	1C	2C	3C	4C
D – Remote	1D	2D	3D	4D
E - Improbable	1E	2E	3E	4E

Table CH1.2 RISK ACCEPTANCE AND MANAGEMENT APPROVAL LEVEL

Severity-Probability	**Acceptance Level/Approving Authority**
High Risk	Unacceptable. Documented approval from the MSFC EMC or an equivalent level independent management committee.
Medium Risk	Undesirable. Documented approval from the facility/operation owner's Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee.
Low Risk	Acceptable. Documented approval from the supervisor directly responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the supervisor directly responsible for operation the facility or performing the operation is highly recommended. Use of a generic JHA posted on the SHE Web page is recommended, if a generic JHA has been developed.

Risk Continued

Defining the risk on a matrix helps manage what hazards need additional work, and which are at an acceptable level.

Risk should be assessed before any controls or mitigating factors are considered AND after. Update risk as you implement your safety controls.

Mitigations/Controls

Identifying risk isn’t useful if you don’t do things to fix it!

Controls/mitigations are the safety plans and modifications you make to reduce your risk.

Types of Controls:

- Design/Analysis/Test
- Procedures/Safety Plans
- PPE (Personal Protective Equipment)

Verification

As you progress through the design review process, you will identify many ways to control your hazards. Eventually you will be required to “prove” that the controls you identify are valid. This can be analysis or calculations required to show you have structural integrity, procedures to launch your rocket, or tests to validate your models.

Verifications should be included in your reports as they become available. By FRR all verifications shall be identified.

Example Hazard Analysis

In addition to this handbook, you will receive an example Hazard Analysis. The example uses a matrix format for displaying the Hazards analyzed. This is not required, but it typically makes organizing and updating your analysis easier.

Safety Assessment Report (Hazard Analysis)

Hazard Analysis for the 12 ft Chamber IR Lamp Array - Foam Panel Ablation Testing

Prepared by:
Industrial Safety
Bastion Technologies, Inc.
for:
Safety & Mission Assurance Directorate
QD12 – Industrial Safety Branch
George C. Marshall Space Flight Center

RAC CLASSIFICATIONS

The following tables and charts explain the Risk Assessment Codes (RACs) used to evaluate the hazards indentified in this report. RACs are established for both the initial hazard, that is; before controls have been applied, and the residual/remaining risk that remains after the implementation of controls. Additionally, table 2 provides approval/acceptance levels for differing levels of remaining risk. In all cases individual workers should be advised of the risk for each undertaking.

Table 1 RAC				
Probability	Severity			
	1 Catastrophic	2 Critical	3 Marginal	4 Negligible
A – Frequent	1A	2A	3A	4A
B – Probable	1B	2B	3B	4B
C – Occasional	1C	2C	3C	4C
D – Remote	1D	2D	3D	4D
E – Improbable	1E	2E	3E	4E

TABLE 2 Level of Risk and Level of Management Approval	
Level of Risk	Level of Management Approval/Approving Authority
High Risk	Highly Undesirable. Documented approval from the MSFC EMC or an equivalent level independent management committee.
Moderate Risk	Undesirable. Documented approval from the facility/operation owner's Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee.
Low Risk	Acceptable. Documented approval from the supervisor directly responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the supervisor directly responsible for operating the facility or performing the operation is highly recommended. Use of a generic JHA posted on the SHE Web page is recommended, if a generic JHA has been developed.

TABLE 3 Severity Definitions - A condition that can cause:			
Description	**Personnel Safety and Health**	**Facility/Equipment**	**Environmental**
1-Catastrophic	Loss of life or a permanent-disabling injury	Loss of facility, systems or associated hardware.	Irreversible severe environmental damage that violates law and regulation.
2-Critical	Severe injury or occupational-related illness.	Major damage to facilities, systems, or equipment.	Reversible environmental damage causing a violoation of law or regulation.
3-Marginal	Minor injury or occupational-related illness.	Minor damage to facilities, systems, or equipment.	Mitigatible environmental damage without violation of law or regulation where restoration activities can be accomplished.
4-Negligible	First aid injury or occupational-related illness	Minimal damage to facility, systems, or equipment	Minimal environmental damage not violating law or regulation.

TABLE 4 Probability Definitions		
Description	**Qualitative Definition**	**Quantitative Defintion**
A-Frequen	High likelihood to occur immediately or expected to be continuously experienced.	Probability is > 0.1
B-Probable	Likely to occur or expected to occur frequently within time.	0.1 ≥ probability > 0.01
C-Occasional	Expected to occure several times or occasionally within time.	0.01 ≥ probability > 0.001
D-Remote	Unlikely to occur, but can be reasonably expected to occure at some point within time.	0.001 ≥ probability > 0.000001
E-Improbable	Very unlikely to occur and an occurrence is not expected to be experienced withim time.	0.000001 ≥ probability

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Personnel exposure to high voltage	Contact with energized lamp bank circuits	Death or severe personnel injury	1C	1. During test operation, lamp banks circuits will be energized only when no personnel are inside chamber. 2. Door to chamber will be closed prior to energizing circuits 3. TS300 access controls are in place for the test	1. 304-TCP-016, Section 3.1.3 requires disabling heater electrical circuit before entering chamber 2. Per 304-TCP-016, tests will only be performed under personal direction of Test Engineer 3. Access controls for this test are included in 304-TCP-016. These include: ○ Lower East Test Area Gate #6 and Turn C6 Light to RED ○ Lower East Test Area Gate #7 and Turn C7 Light to RED ○ Lower East Test Area Gate #8 and Turn C8 Light to RED ○ Verify all Government sponsored vehicles are clear of the area. ○ Verify all non-Government sponsored vehicles are clear of the area. ○ Make the following announcement: "Attention all personnel, test operations are about to begin at TS300. The area is cleared for the Designated Crew Only and will remain until further notice." (REPEAT)	1E
Personnel exposure to an oxygen deficient environment	Entry into 12 ft chamber with unknown atmosphere	Death or severe personnel injury	1C	1. Oxygen monitors are stationed inside chamber and chamber entryway 2. Chamber air ventilator operated after each panel test to vent chamber 3. Attendant will be posted outside	1. 304-TCP-016 requires installation of the Test Article using "Test Panel Install/Removal Procedure." This procedure requires use of a portable O2 monitor in the section entitled "Post Test Activities and Test Panel Removal," Step 1. 2. 304-TCP-016, Section 3.1.22 requires Chamber Vent System to run for 3+ Minutes prior to entering the chamber to remove the panel. 3. "Test Panel Install/Removal	1E

				chamber to monitor in-chamber activities, facilitate evacuation or rescue if required, and to restrict access to unauthorized personnel 4. Fire Dept. to be notified that confined space entries are being made	Procedure," page 1, requires the use of existing METTS confined space entry procedures, which includes requirement for an attendant when entering the 12 ft vacuum chamber reference Confined Space Permit 0298. 4. "Test Panel Install/Removal Procedure," page 1, requires the use of existing METTS confined space entry procedures, which includes requirement to notify the Fire Dept. prior to entering the 12 ft vacuum chamber. Reference Confined Space Permit 0298.	
Personnel exposure to lamp thermal energy	• Proximity to lamps while energized • Accidental contact with lamp or calibration plate while out	Personnel burns requiring medical treatment	3C	1. During test operation, lamp banks circuits will be energized only when no personnel are inside chamber. 2. Door to chamber will closed prior to energizing circuits 3. Designated personnel will wear leather gloves to handle calibration plate if required.	1. 304-TCP-016, Section 3.1.3 requires disabling heater electrical circuit before entering chamber 2. Per 304-TCP-016, tests will only be performed under personal direction of Test Engineer 3. 304-TCP-16, Section 1.4, Hazards and Controls, requires insulated gloves as required if hot items need to be handled.	3E
Failure of pressure systems	Over-pressurization	• Personnel injury • Equipment damage	1C	1. TS300 facility pressure systems are certified. 2. Per ET10 test engineer, high purity air system will be used at < 150 psig operating pressure, therefore certification not required. 3. All non-certified test equipment is pneumatically pressure tested to 150% of Maximum Allowable Working Pressure (MAWP)	1. Per the MSFC Pressure Systems Reporting Tool (PSRT), facility systems have been recertified under TLWT-CERT-10-TS300-RR2002 until 3/3/2020. The certification includes Gaseous Helium, Gaseous Hydrogen, Gaseous Nitrogen, High Purity Air, Liquid Hydrogen and Liquid Nitrogen systems. 2. 304-TCP-016, Step 2.1.14, requires HOR-12-128, 2nd Stage HP Air HOR, to be Loaded to 75psig. 3. See Pressure Test Report PTR-001455 (Appendix A). All non-certified equipment has a minimum factor of safety of 4:1.	1E
Foam panel catches fire	Test requires high heat with	Release of hazards materials into test	1C	1. Byproducts of combustion have been evaluated by Industrial Hygiene	1. A minimum ventilation of the chamber should the foam panel burn during or after	1E

during testing	possibility of panel burning	chamber		personnel and a ventilation requirement of 10 minutes with the chamber 300 cfm ventilation fan has been established. This will provide enough air changes so very little or no residual gasses or vapors remain.	testing has been established by procedure 304-TCP-016 which requires the minimum 10 minute ventilation before personnel are allowed to enter. Additionally, if any abnormalities are observed the Industrial Health representative will be called to perform additional air sampling before personnel entry.	

Understanding MSDS’s

By: Jeff Mitchell
MSFC Environmental Health

What is an MSDS?

- A Material Safety Data Sheet (MSDS) is a document produced by a manufacturer of a particular chemical and is intended to give a comprehensive overview of how to safely work with or handle this chemical

What is an MSDS?

- MSDS’s do not have a standard format, but they are all required to have certain information per OSHA 29 CFR 1910.1200
- Manufacturers of chemicals fulfill the requirements of this OSHA standard in different ways

Required data for MSDS's

- Identity of hazardous chemical
- Chemical and common names
- Physical and chemical characteristics
- Physical hazards
- Health hazards
- Routes of entry
- Exposure limits

Required data for MSDS's (Cont.)

- Carcinogenicity
- Procedures for safe handling and use
- Control measures
- Emergency and First-aid procedures
- Date of last MSDS update
- Manufacturer's name, address, and phone number

Important Agencies

- ACGIH
  - The American Conference of Governmental Industrial Hygienist develop and publish occupational exposure limits for many chemicals, these limits are called TLV’s (Threshold Limit Values)

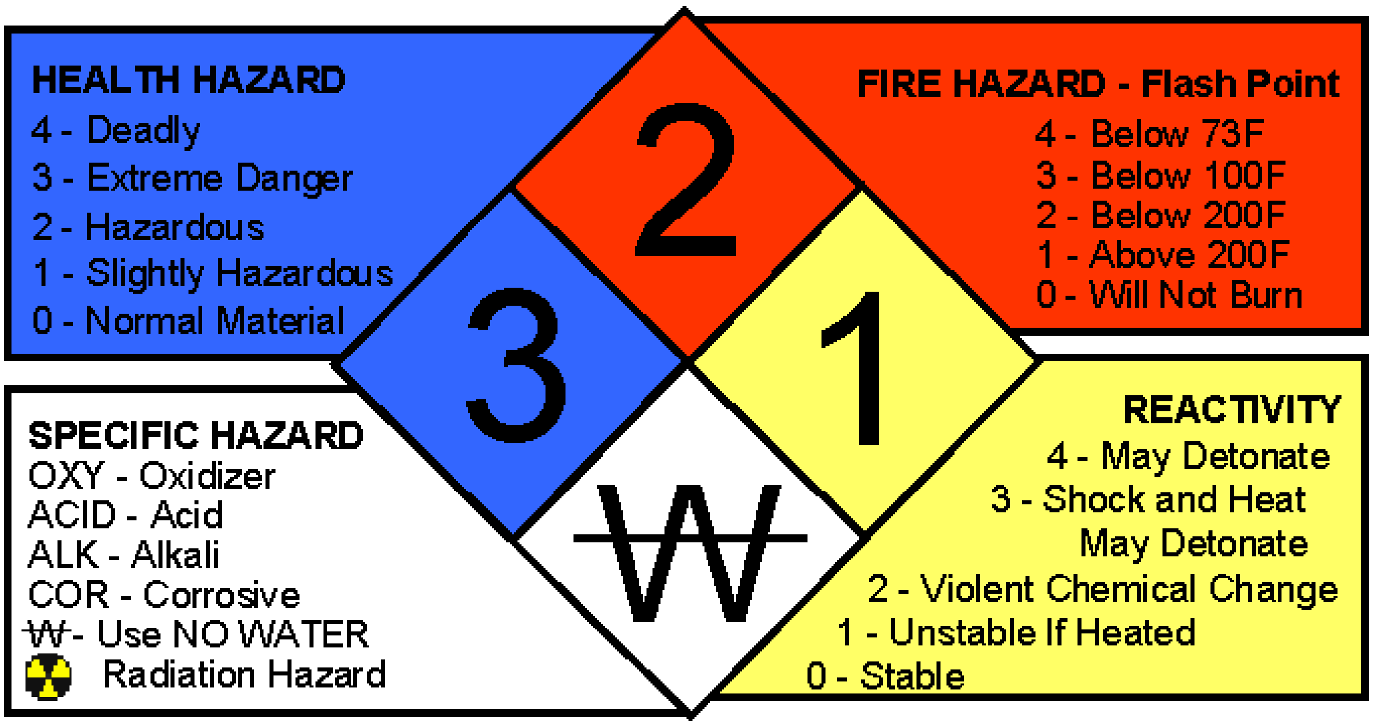
Important Agencies (Cont.)

- ANSI
  - The American National Standards Institute is a private organization that identifies industrial and public national consensus standards that relate to safe design and performance of equipment and practices

Important Agencies (Cont.)

- NFPA
  - The National Fire Protection Association, among other things, established a rating system used on many labels of hazardous chemicals called the NFPA Diamond
  - The NFPA Diamond gives concise information on the Health hazard, Flammability hazard, Reactivity hazard, and Special precautions
  - An example of the NFPA Diamond is on the next slide

NFPA Diamond



Important Agencies (Cont.)

- NIOSH
  - The National Institute of Occupational Safety and Health is an agency of the Public Health Service that tests and certifies respiratory and air sampling devices. It also investigates incidents and researches occupational safety

Important Agencies (Cont.)

- OSHA
  - The Occupational Safety and Health Administration is a Federal Agency with the mission to make sure that the safety and health concerns of all American workers are being met

Exposure Limits

- Occupational exposure limits are set by different agencies
- Occupational exposure limits are designed to reflect a safe level of exposure
- Personnel exposure above the exposure limits is not considered safe

Exposure Limits (Cont.)

- OSHA calls their exposure limits, PEL’s, which stands for Permissible Exposure Limit
  - OSHA PEL’s rarely change
- ACGIH, establishes TLV’s, which stands for Threshold Limit Values
  - ACGIH TLV’s are updated annually

Exposure Limits (Cont.)

- A Ceiling limit (noted by C) is a concentration that shall never be exceeded at any time
- An IDLH atmosphere is one where the concentration of a chemical is high enough that it may be Immediately Dangerous to Life and Health

Exposure Limits (Cont.)

- A STEL, is a Short Term Exposure Limit and is used to reflect a 15 minute exposure time
- A TWA, is a Time Weighted Average and is used to reflect an 8 hour exposure time

Chemical and Physical Properties

- Boiling Point
  - The temperature at which the chemical changes from liquid phase to vapor phase
- Melting Point
  - The temperature at which the chemical changes from solid phase to liquid phase
- Vapor Pressure
  - The pressure of a vapor in equilibrium with its non-vapor phases. Most often the term is used to describe a liquid’s tendency to evaporate
- Vapor Density
  - This is used to help determine if the vapor will rise or fall in air
- Viscosity
  - It is commonly perceived as "thickness", or resistance to pouring. A higher viscosity equals a thicker liquid

Chemical and Physical Properties (Cont.)

- Specific Gravity
  - This is used to help determine if the liquid will float or sink in water
- Solubility
  - This is the amount of a solute that will dissolve in a specific solvent under given conditions
- Odor threshold
  - The lowest concentration at which most people may smell the chemical
- Flash point
  - The lowest temperature at which the chemical can form an ignitable mixture with air
- Upper (UEL) and lower explosive limits (LEL)
  - At concentrations in air below the LEL there is not enough fuel to continue an explosion; at concentrations above the UEL the fuel has displaced so much air that there is not enough oxygen to begin a reaction

Things you should learn from MSDS's

- Is this chemical hazardous?
  - Read the Health Hazard section
- What will happen if I am exposed?
  - There is usually a section called Symptoms of Exposure under Health Hazard
- What should I do if I am overexposed?
  - Read Emergency and First-aid procedures
- How can I protect myself from exposure?
  - Read Routes of Entry, Procedures for safe handling and use, and Control measures

Take your time!

- Since MSDS’s don’t have a standard format, what you are seeking may not be in the first place you look
- Study your MSDS’s before there is a problem so you aren’t rushed
- Read the entire MSDS, because information in one location may compliment information in another

The following slides are an abbreviated version of a real MSDS

Study it and become more familiar with this chemical

MSDS: METHYL ETHYL KETONE

Abbreviated MSDS

SECTION 1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MDL INFORMATION SYSTEMS, INC.
14600 CATALINA STREET
1-800-635-0064 OR
1-510-895-1313

Manufacturer name and phone #

FOR EMERGENCY SOURCE INFORMATION CONTACT: 1-615-366-2000 USA

CAS NUMBER: 78-93-3
RTECS NUMBER: EL6475000
EU NUMBER (EINECS):
201-159-0
EU INDEX NUMBER:
606-002-00-3

SUBSTANCE: METHYL ETHYL KETONE

Last revision

TRADE NAMES/SYNONYMS:
BUTANONE; 2-BUTANONE; ETHYL METHYL KETONE; METHYL ACETONE; 3-BUTANONE; MEK; SCOTCH-GRIP ® BRAND SOLVENT #3 (3M); STOP, SHIELD, PEEL REDUCER (PYRAMID PLASTICS, INC.); STABOND C-THINNER (STABOND CORP.); OATEY CLEANER (OATEY COMPANY); RCRA U159; UN1193; STCC 4909243; C_4H_8O; OHS14460

CHEMICAL FAMILY:
Ketones, aliphatic

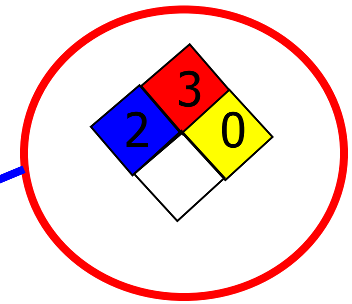
CREATION DATE: Sep 28 1984
REVISION DATE: Mar 30 1997

SECTION 2. COMPOSITION, INFORMATION ON INGREDIENTS

COMPONENT: METHYL ETHYL KETONE
CAS NUMBER: 78-93-3
PERCENTAGE: 100

SECTION 3. HAZARDS IDENTIFICATION

NFPA RATINGS (SCALE 0-4): Health=2 Fire=3 Reactivity=0



Good info for labeling containers

EMERGENCY OVERVIEW:
COLOR: colorless
PHYSICAL FORM: liquid
ODOR: minty, sweet odor
MAJOR HEALTH HAZARDS: respiratory tract irritation, skin irritation, eye irritation, central nervous system depression
PHYSICAL HAZARDS: Flammable liquid and vapor. Vapor may cause flash fire

POTENTIAL HEALTH EFFECTS:

What happens when exposed?

INHALATION:
SHORT TERM EXPOSURE: irritation, nausea, vomiting, difficulty breathing,

SKIN CONTACT:

SHORT TERM EXPOSURE: irritation

LONG TERM EXPOSURE: same as effects reported in short term exposure

EYE CONTACT…

INGESTION…

CARCINOGEN STATUS:

OSHA: N

NTP: N

IARC: N

Does it cause cancer?

SECTION 4. FIRST AID MEASURES

INHALATION…

SKIN CONTACT…

EYE CONTACT…

INGESTION…

What should you do if exposed?

SECTION 5. FIRE FIGHTING MEASURES

SECTION 6. ACCIDENTAL RELEASE MEASURES

AIR RELEASE:
Reduce vapors with water spray
SOIL RELEASE:
Dig holding area such as lagoon, pond or pit for containment. Absorb with…

SECTION 7. HANDLING AND STORAGE

Store and handle in accordance …

SECTION 8. EXPOSURE CONTROLS, PERSONAL PROTECTION

EXPOSURE LIMITS:
METHYL ETHYL KETONE:
METHYL ETHYL KETONE:
200 ppm (590 mg/m3) OSHA TWA
300 ppm (885 mg/m3) OSHA STEL
200 ppm (590 mg/m3) ACGIH TWA
300 ppm (885 mg/m3) ACGIH STEL

8 hr avg (OSHA TWA, ACGIH TWA)
15 min avg (OSHA STEL, ACGIH STEL)

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

COLOR: colorless
PHYSICAL FORM: liquid
ODOR: minty, sweet odor
MOLECULAR WEIGHT: 72.12
MOLECULAR FORMULA: C-H3-C-H2-C-O-C-H3
BOILING POINT: 176 F (80 C)
FREEZING POINT: -123 F (-86 C)
VAPOR PRESSURE: 100 mmHg @ 25 C
VAPOR DENSITY (air = 1): 2.5
SPECIFIC GRAVITY (water = 1): 0.8054
WATER SOLUBILITY: 27.5%
PH: No data available
VOLATILITY: No data available
ODOR THRESHOLD: 0.25-10 ppm
EVAPORATION RATE: 2.7 (ether = 1)
VISCOSITY: 0.40 cP @25 C
SOLVENT SOLUBILITY: alcohol, ether, benzene, acetone, oils, solvents

MYTH: if it smells bad it is harmful, if it smells good it is safe

MEK vapor is heavier than air

MEK liquid will float on stagnant water

Not very soluble in water

Will likely smell MEK before being overexposed

Goes to vapor easy

SECTION 10. STABILITY AND REACTIVITY

SECTION 11. TOXICOLOGICAL INFORMATION

SECTION 12. ECOLOGICAL INFORMATION

SECTION 13. DISPOSAL CONSIDERATIONS

SECTION 14. TRANSPORT INFORMATION

SECTION 15. REGULATORY INFORMATION

SECTION 16. OTHER INFORMATION

MSDS's have an abundance of information useful in many different aspects www.nasa.gov

National Aeronautics and Space Administration

George C. Marshall Space Flight Center
Huntsville, AL 35812
www.nasa.gov/marshall

www.nasa.gov

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