National Aeronautics and
Space Administration

STUDENT LAUNCH

2026 HANDBOOK & REQUEST FOR PROPOSAL

www.nasa.gov

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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.

Acronym Dictionary

AGL	Above Ground Level
APCP	Ammonium Perchlorate Composite Propellant
ASC	Artemis Student Challenges
CDR	Critical Design Review
CG	Center of Gravity
CP	Center of Pressure
FAA	Federal Aviation Administration
FMEA	Failure Modes and Effects Analysis
FRR	Flight Readiness Review
GPS	Global Positioning System
HAUS	Habitat for Agricultural Utilization Study
LCO	Launch Control Officer
LRR	Launch Readiness Review
MSFC	Marshall Space Flight Center
NAR	National Association of Rocketry
NASA	National Aeronautics and Space Administration
PDF	Payload Demonstration Flight
PDF	Portable Document Format
PDR	Preliminary Design Review
PHA	Personnel Hazard Analysis
PLAR	Post Launch Assessment Review
PPE	Personal Protective Equipment
RFP	Request for Proposal
RSO	Range Safety Officer
SDS	Safety Data Sheet
SLI	Student Launch Initiative
SLS	Space Launch System
SME	Subject Matter Expert
SOMD	Space Operations Mission Directorate
SOW	Statement of Work
STEM	Science, Technology, Engineering, and Mathematics
TRA	Tripoli Rocketry Association
UAS	Unmanned Aerial System
USLI	University Student Launch Initiative
VDF	Vehicle Demonstration Flight
WBS	Work Breakdown Structure

STATEMENT OF WORK

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

Activity Name: NASA's Student Launch

Governing Office: NASA's Marshall Space Flight Center Office of STEM Engagement

Period of Performance: Nine (9) calendar months

Introduction

The Office of STEM Engagement at NASA's Marshall Space Flight Center (MSFC) seeks proposals from colleges and universities to conduct NASA's University Student Launch Initiative (USLI) and qualified high schools, middle schools, and informal education groups to conduct NASA's Student Launch Initiative (SLI) during the 2025 – 2026 academic year. NASA's Student Launch (SL) is a Student Design Challenge designed to develop the aerospace workforce of tomorrow. As we collaborate with commercial and international partners to establish humanity's first long-term lunar presence, we're cultivating the skilled professionals who will drive this mission forward. NASA's SL equips the next generation with the knowledge, techniques, and technologies needed to sustain lunar operations and take the next giant leap: sending astronauts to Mars. For more information regarding Student Challenges, please visit stem.nasa.gov/artemis. NASA's SL connects learners, educators, and communities with NASA-unique opportunities that align with Science, Technology, Engineering, and Mathematics (STEM) Challenges. The activity is supported by the Space Operations Mission Directorate (SOMD) and commercial industry.

Student Launch reaches a broad audience of colleges, universities, and secondary institutions across the nation in a 9-month commitment to design, build, launch, and fly a payload(s) and vehicle components that support NASA research on high-power rockets. The College/University Division teams are challenged with designing, building, and flying a STEMnaut Habitat for Agricultural Utilization Study (HAUS) that safely houses four STEMnauts during extended missions. The habitat must include equipment capable of both collecting and testing soil samples to support agricultural research operations. STEMnauts are physical representations of the crew on-board the rocket. Teams may incorporate additional research with a separate payload if desired. Secondary experiments shall be approved by NASA. In addition, the team shall provide documentation on additional components and systems in all reports and reviews. High School/Middle School Division teams may elect to tackle the College/University Division challenge, or they may design their own science or engineering experiment. Awards are presented to teams in both divisions. More information about awards can be found on pages 44–46 and 86–87.

Proposals to participate in NASA's Student Launch College/University Division may be submitted from any U.S. college or university. Proposals to participate in the High School/Middle School Division may only be submitted from teams who have qualified at the American Rocketry Challenge (Top 25) or Rockets For Schools (Top 5) in 2025 and have completed the Advanced Rocketry Workshop (ARW). Student Launch proposals and participation are limited to one team per school.

After the competitive proposal selection process, teams will complete a series of design reviews that mirror the NASA engineering design lifecycle. Teams shall successfully complete a Preliminary Design Review (PDR), Critical Design Review (CDR), and Flight Readiness Review (FRR), which include safety briefings, analysis of vehicle and payload systems, and flight test data. Teams coming to Huntsville will undergo a Launch Readiness Review (LRR). Each team shall 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 team's work and research objectives. Each College/University Division team is scored according to a standard scoring rubric. High School/Middle School Division teams complete the same milestones but are not in competition and are not scored.

COLLEGE/UNIVERSITY
USLI DIVISION HANDBOOK

Timeline for NASA's USLI Division (Dates are subject to change.)

August 2025

8 .... Request for Proposal (RFP) released.

September 2025

22 .... Please visit https://www.nasa.gov/stem/studentlaunch/handbook/index.html for instructions on submitting your proposal. Proposals are due 8:00 a.m. CT.

October 2025

07 .... Awarded proposals announced.

09 .... Kickoff and PDR Q&A.

27 .... Preliminary Design Review (PDR) report, presentation slides, and flysheet submitted to NASA project management team by 8:00 a.m. CT.

November 2025

03 – 25 .... PDR video teleconferences.

28 .... Gateway Registration Deadline.

December 2025

03 .... CDR Q&A.

15 .... Huntsville rosters due for teams traveling to Huntsville for in person event.

January 2026

07 .... Subscale Flight deadline.

07 .... Critical Design Review (CDR) report, presentation slides, flysheet, and transmitter data sheet submitted to NASA project management team by 8:00 a.m. CT.

14 – Feb. 5 .... CDR video teleconferences.

February 2026

9 .... Team photos due.

11 .... FRR Q&A.

March 2026

9 .... Vehicle Demonstration Flight deadline.

9 .... Flight Readiness Review (FRR) report, presentation slides, and flysheet submitted to NASA project management team by 8:00 a.m. CT.

16 – Apr. 03...... FRR video teleconferences.

April 2026

03 .... Launch window opens for teams not traveling to Launch Week. PLAR must be submitted within 14 days of Launch. Teams launching at home must have successful VDF and PDF prior to final competition launch.

06 .... Payload Demonstration Flight and Vehicle Demonstration Re-flight deadlines.

06 .... FRR Addendum submitted to NASA project management team by 8:00 a.m. CT (teams completing additional Payload Demonstration Flights and Vehicle Demonstration Re-flights only).

15 .... Launch Week Q&A.

22 .... Teams arrive in Huntsville, AL.

23– 24 .... All-day Launch Week Events.

25 .... Launch Day.

26 .... Backup Launch Day.

May 2026

04 .... Launch window closes for teams not traveling to Huntsville for Launch Week. PLAR must be submitted within 14 days of launch.

11 .... Teams traveling to Launch Week: Post-Launch Assessment Review (PLAR) submitted to NASA project management team by 8:00 a.m. CT.

COLLEGE/UNIVERSITY RULES & REQUIREMENTS

Student Launch Rules

1. General Rules

1.1. Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor). Student team members shall only be a part of one team in any capacity. Teams will submit new work. Excessive use of past work will merit penalties.

1.2. Team members who will travel to the Huntsville Launch shall have fully completed registration in NASA's Gateway system before the roster deadline. Team members shall include:

1.2.1. Students actively engaged in the project throughout the entire year

1.2.2. One mentor (see Requirement 1.13)

1.2.3. No more than two adult educators

1.3. Teams shall upload via Box all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. Late submissions of PDR, CDR, or FRR milestone documents will NOT be accepted. Teams that fail to submit the PDR, CDR, or FRR milestone documents will be eliminated from the project.

1.4. Teams who do not satisfactorily complete each milestone review (PDR, CDR, FRR) will be provided action items to be completed following their review and will be required to address action items in a delta review session. After the delta session, the NASA management panel will meet to determine the teams' status in the program, and the teams will be notified shortly thereafter.

1.5. All deliverables shall be in PDF format.

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

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

1.8. The team shall provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to: a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.

1.9. All teams attending Launch Week shall be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted at the NASA launch complex. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails will be canted 5 – 10 degrees away from the crowd on Launch Day. The exact cant will depend on Launch Day wind conditions.

2. Vehicle Rules

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

2.2. The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).

2.3. Final primary and secondary motor choice shall be declared by the Preliminary Design Review (PDR) milestone.

2.4. Any motor change after PDR shall be approved by the NASA management team or NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment shall not be approved. A scoring adjustment against the team's overall score shall be incurred when a motor change is made after the PDR milestone. The only exception is teams switching to their secondary motor choice provided the primary motor choice is unavailable due to a motor shortage.

2.5. All teams shall successfully launch and recover a subscale model of their rocket. Success of the subscale is at the sole discretion of the NASA review panel. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline.

2.5.1. 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.

2.5.2. The subscale model shall carry an altimeter capable of recording the model's apogee altitude.

2.5.3. The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.

2.5.4. Proof of a successful flight shall be supplied in the CDR report and presentation.

2.5.4.1. Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) will not be accepted.

2.5.4.2. Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the CDR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.

2.6. Vehicle Demonstration Flight – All teams shall successfully launch and recover their full-scale launch vehicle prior to FRR in its final flight configuration. The rocket flown shall be the same rocket to be flown for their competition launch.

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

2.6.2. The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.

2.6.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:

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

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

2.6.4. If the payload changes the external surfaces of the rocket (such as camera housings or external probes) or changes the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.

2.6.5. Teams shall fly the competition launch motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the competition launch motor or in other extenuating circumstances.

2.6.6. The vehicle will be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the competition launch flight. Additional ballast shall not be added without a re-flight of the full-scale launch vehicle.

2.6.7. After successfully completing the full-scale demonstration flight, neither the launch vehicle nor any of its components shall be modified without the concurrence of the NASA management team or Range Safety Officer (RSO).

2.6.8. Proof of a successful flight shall be supplied in the FRR report.

2.6.8.1. Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.

2.6.8.2. Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the FRR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.

2.6.8.3. Raw altimeter data shall be submitted in .csv or .xlsx format.

2.6.9. Vehicle Demonstration flights shall be completed by the FRR submission deadline. No exceptions will be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST TIME FLIGHTS. Teams completing a required re-flight shall submit an FRR Addendum by the FRR Addendum deadline.

2.7. Payload Demonstration Flight — All teams shall successfully launch and recover their full-scale rocket containing the final active payload prior to the Payload Demonstration Flight deadline. The rocket flown shall be the same rocket to be flown as their competition launch. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed (if applicable) as designed. The following criteria shall be met during the Payload Demonstration Flight:

2.7.1. The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.

2.7.2. The payload flown shall be the final, active version.

2.7.3. If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.

2.7.4. Payload Demonstration Flights shall be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.

2.8. An FRR Addendum shall be required for any team completing a Payload Demonstration Flight or NASA- required Vehicle Demonstration Re-flight after the submission of the FRR Report.

2.8.1. Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly a final competition launch.

2.8.2. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload during launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.

2.9. The team's name and Launch Day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.

2.10. Transmitters shall not create excessive interference. Teams shall utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.

2.11. Excessive and/or dense metal shall not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.

3. Recovery System Rules

3.1. Each team shall perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full-scale vehicles.

4. Payload Rules

4.1. Any payload experiment element that is jettisoned during the recovery phase shall receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement by the RSO or NASA.

4.2. Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, shall be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAS.

4.3. Teams flying UASs shall abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112–95 Section 336; see https://www.faa.gov/uas/faqs).

5. Safety Rules

5.1. Each team shall use a launch and safety checklist.

5.2. The role and responsibilities of the safety officer shall include, but are not limited to:

5.2.1. Monitor team activities with an emphasis on safety during:

5.2.1.1. Design of vehicle and payload

5.2.1.2. Construction of vehicle and payload components

5.2.1.3. Assembly of vehicle and payload

5.2.1.4. Ground testing of vehicle and payload

5.2.1.5. Subscale launch test(s)

5.2.1.6. Full-scale launch test(s)

5.2.1.7. Competition Launch

5.2.1.8. Recovery activities

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

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

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

5.3. 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 NASA's Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams shall communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.

6. Final Flight Rules

Teams shall conduct the final flight in Huntsville during Launch Week (NASA's Launch Complex) or at a local launch field (Commercial Spaceport Launch Site) by the applicable deadlines as outlined in the Timeline for NASA's Student Launch.

6.1. NASA's Launch Complex

6.1.1. Teams are not permitted to show up at NASA's Launch Complex outside of launch day without permission from the NASA management team.

6.1.2. Teams shall complete and pass the Launch Readiness Review conducted during Launch Week.

6.1.3. The team mentor shall be present for Launch Readiness Reviews and oversee all rocket preparation and launch activities.

6.1.4. The scoring altimeter shall be presented to the NASA scoring official upon recovery. The scoring altimeter shall be one of the altimeters used for recovery events.

6.1.5. Teams may launch only once. Any launch attempt resulting in the rocket exiting the launch pad, regardless of the success of the flight, will be considered a launch. Additional flights beyond the initial launch, will not be scored and will not be considered for awards.

6.1.6. Teams who are planning on launching at NASA's Launch Complex in Huntsville but choose not to launch due to delays such as weather or the rain date being utilized will not be permitted to launch a final competition launch at a later date to complete the program.

6.2. Commercial Spaceport Launch Site

6.2.1. The launch shall occur at a NAR or TRA sanctioned and insured club launch. Exceptions may be approved for launch clubs who are not affiliated with NAR or TRA but provide their own insurance, such as the Friends of Amateur Rocketry. Approval for such exceptions shall be granted by NASA prior to the launch.

6.2.2. Teams shall submit their rocket and payload to the launch site Range Safety Officer (RSO) prior to flying the rocket. The RSO shall inspect the rocket and payload for flight worthiness and determine if the project is approved for flight. The local RSO shall have final authority on whether the team's rocket and payload may be flown.

6.2.3. The team mentor shall be present and oversee rocket preparation and launch activities.

6.2.4. BOTH the team mentor and the Launch Control Officer shall observe the flight and report any off-nominal events during ascent or recovery on the Launch Certification and Observations Report.

6.2.5. The scoring altimeter shall be presented to BOTH the team's mentor and the Range Safety Officer. The scoring altimeter shall be one of the altimeters used for recovery events.

6.2.6. The mentor, the Range Safety Officer, and the Launch Control Officer must be three separate individuals who must ALL complete the applicable sections of the Launch Certification and Observations Report. The Launch Certification and Observations Report document will be provided by NASA upon completion of the FRR milestone and shall be returned to NASA by the team mentor upon completion of the launch.

6.2.7. The Range Safety Officer and Launch Control Officer certifying the team's flight shall be impartial observers and shall not be affiliated with the team, individual team members, or the team's academic institution.

6.2.8. Teams may launch only once. Any launch attempt resulting in the rocket exiting the launch pad, regardless of the success of the flight, will be considered a launch. Additional flights beyond the initial launch will not be scored and will not be considered for awards.

NASA will maintain a Frequently Asked Questions (FAQ) list on the Student Launch website (www.nasa.gov/studentlaunch). This list will include important changes and/or clarifications to project requirements. Changes and clarifications appearing in the FAQ supersede what is written in this handbook. It is the team's responsibility to check the FAQ and be aware of any changes to the challenge

Student Launch Requirements

1. General Requirements

1.1. Teams shall engage with their communities in STEM industry or STEM education. To satisfy this requirement teams shall complete either a STEM Industry Engagement Plan and Summary OR a Community STEM Engagement Plan and Summary. Requirements for each can be found in the Engagement section pages 38–40.

1.2. The team shall establish and maintain a social media presence to inform the public about team activities.

1.3. Each team shall identify a "mentor." A mentor is defined as an adult who is included as a team member, supports the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The team mentor must adhere to the following requirements:

1.3.1. The mentor shall maintain a current certification and be in good standing with the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse class the team intends to use.

1.3.2. The mentor shall have flown and successfully recovered (using electronic, staged recovery) a minimum of two flights in the motor impulse class (or higher) the team intends to use, prior to PDR.

1.3.3. The mentor must attend all team launches throughout the project year, including launch week, as the mentor is designated the individual owner of the rocket for insurance and liability purposes.

2. Vehicle Requirements

2.1. The vehicle shall deliver the payload to an apogee altitude between 4,000 and 6,000 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,500 feet on their competition launch will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.

2.2. The launch vehicle and payload shall be capable of remaining in launch-ready configuration on the pad for a minimum of 3 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.

2.3. Teams shall declare their target altitude goal at the CDR milestone. The declared target altitude shall be used to determine the team's altitude score.

2.4. 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.

2.5. 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.

2.5.1. Coupler/airframe shoulders which are located at in-flight separation points shall be at least two airframe diameters in length. (one body diameter of surface contact with each airframe section).

2.5.2. Coupler/airframe shoulders which are located at non-in-flight separation points shall be at least 1.5 airframe diameters in length. (0.75 body diameter of surface contact with each airframe section.)

2.5.3. Nosecone shoulders shall be at least ½ body diameter in length.

2.6. The launch vehicle shall be capable of being launched by a standard 12-volt direct current firing system. The firing system shall be provided by the NASA-designated launch services provider.

2.6.1. Each team shall use commercially available ematches or igniters. Hand-dipped igniters shall not be permitted.

2.7. 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).

2.8. The launch vehicle shall be limited to a single motor propulsion system.

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

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

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

   2.10.2. Each pressure vessel shall include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.

   2.10.3. The full pedigree of the tank shall be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.

2.11. The launch vehicle shall have a minimum static stability margin of 2.0 while sitting on the pad.

2.12. The launch vehicle shall have a minimum thrust to weight ratio of 5.0:1.0.

2.13. Any structural protuberance on the rocket shall be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.

2.14. The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.

2.15. Subscale rockets are required to use a minimum motor impulse class of E (mid-power motor).

2.16. The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4" diameter, 100" length rocket, your subscale shall not exceed 3" diameter and 75" in length.

2.17. All teams shall complete demonstration flights as outlined below.

2.18. Vehicle Demonstration Flight—The purpose of the Vehicle Demonstration Flight is to validate 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 (drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.).

2.19. All Lithium Polymer batteries shall be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.

2.20. Vehicle Prohibitions:

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

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

   2.20.3. The launch vehicle shall not utilize hybrid motors.

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

   2.20.5. The launch vehicle shall not utilize friction fitting for motors.

   2.20.6. The launch vehicle shall not exceed Mach 1 at any point during flight.

   2.20.7. Vehicle ballast shall not exceed 10% of the total un-ballasted weight of the rocket, as it would sit on the pad (i.e., a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).

2.20.7.1. Ballast is defined as any non-essential mass that serves no structural or safety purpose for your launch vehicle or payload. This includes but is not limited to: increasing infill percentages beyond structurally necessary levels, deliberately oversizing hardware components, adding functionally unnecessary components.

2.20.7.2. Ballast must be mechanically retained. Friction fit is not a permissible form of retention.

2.20.7.3. Ballast shall be removable.

2.20.7.4. All requirements found in sections 1 through 5 of this handbook shall be met in both the minimum and maximum design ballast configurations. Where applicable, teams are expected to present calculations and performance metrics for both minimum and maximum design ballast configurations.

2.20.8. Transmissions from on-board transmitters, which are active at any point prior to landing, shall not exceed 250 mW of power (per transmitter).

3. Recovery System Requirements

3.1. The full-scale 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 lower altitude. Tumble 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 RSO.

3.1.1. The main parachute shall be deployed no lower than 500 feet.

3.1.2. The apogee event shall contain a delay of no more than 2 seconds.

3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.

3.2. Each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf at landing. Teams whose heaviest section of their launch vehicle, as verified by vehicle demonstration flight data, stays under 65 ft-lbf will be awarded bonus points.

3.2.1. Teams are only bonus point eligible if the flight was nominal and report all metrics as requested under Demonstration Flights.

3.3. The recovery system shall contain redundant, commercially available barometric altimeters that are specifically designed for initiation of rocketry recovery events. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.

3.4. Each altimeter shall have a dedicated power supply, and all recovery electronics shall be powered by commercially available batteries.

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

3.6. Each arming switch shall be capable of being locked in the ON position for launch (i.e., cannot be disarmed due to flight forces).

3.7. The recovery system, GPS and altimeters, and electrical circuits shall be completely independent of any payload electrical circuits.

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

3.9. Bent eyebolts shall not be permitted in the recovery subsystem.

3.10. The recovery area shall be limited to a 2,500 ft. radius from the launch pads.

3.11. Descent time of the launch vehicle shall be limited to 90 seconds (apogee to touch down). Teams whose launch vehicle descent, as verified by vehicle demonstration flight data, stays under 80 seconds will be awarded bonus points.

3.11.1. Teams are only bonus point eligible if the flight was nominal and report all metrics as requested under Demonstration Flights.

3.12. Electronic GPS Tracking device(s) shall be installed in the launch vehicle and will transmit the position of the tethered vehicle and any independent section(s) to a ground receiver.

3.13. To prevent system malfunctions the recovery system shall meet the following requirements:

3.13.1. 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.

3.13.2. The recovery system electronics shall be shielded from all on-board transmitting devices to avoid inadvertent excitation of the recovery system electronics.

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

3.13.4. The recovery system electronics shall be shielded from any other on-board devices which may adversely affect the proper operation of the recovery system electronics.

4. Payload Experiment Requirements

Light from the sun appears a rusty dark red as it filters through silt stirred into the air by a large churning auger. Grinding sounds of the auger are muffled inside the STEMnaut HAUS. The Habitat for Agricultural Utilization Study (HAUS) has been testing sites labeled "promising" by the reconnaissance rover for the last week, and so far, only one contained the minimum nitrogen and mineral content required to merit farming efforts. The Science Officer listens to the hum of the auger from the crew quarters of the HAUS and notes how similar it feels to his service time aboard a nuclear submarine. "And the coffee is just as bad too," he chuckles to himself as the dehydrated crystals of instant coffee mix in a metal cup with water from the potable tank. Scanning the storage cabinets, he notes there are enough supplies for at least another eight days. The excursion is only scheduled for two more, so there will be plenty to spare. As the auger retracts and stops its digging, the sound of grinding is replaced by servo valve clicks and the gurgle of water from the test reservoir. Soon the crew will get a data set to review and log as the autonomous testing system analyzes the freshly dug soil. The Science Officer walks to the test display console and sets a second cup of coffee down on the counter beside the crew Captain. She nods and points at the screen. A smile creeps over the Science Officer's face as the test results display highlighted in green. "Hah, a good one!" he rejoices and gives a little fist pump. "I vote we grow coffee beans first," he jokes as he sits to begin reviewing the data.

USLI Payload Mission objective: College/University Division—Teams are tasked with designing, building, and flying a STEMnaut Habitat for Agricultural Utilization Study (HAUS). The HAUS must have the capability of safely housing four STEMnauts in an extended excursion living quarters, and have equipment for collecting and testing soil samples. The method(s)/design(s) utilized to complete the payload mission shall be at the team's discretion and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. NASA reserves the right to require modifications to a proposed payload.

HAUS Mission Requirements:

4.1. After landing, teams shall autonomously collect and retain a soil sample of at least 50 milliliters.

4.1.1. All soil collection and analysis must be completed within 15 minutes of landing.

4.2. Teams shall autonomously test the collected sample for at least one of the following:

- Nitrate-Nitrogen content
- pH level
- electrical conductivity

4.2.1. Analysis results shall include time stamps for verification.

4.2.2. The results of these tests shall be included in the PLAR. Preliminary results shall be made available for confirmation by the NASA Student Launch management team at the competition launch.

4.3. The autonomous functions described above may be initiated by remote command.

4.4. The HAUS's structure shall include an atmosphere isolated compartment to serve as living quarters for 4 STEMnauts. The compartment shall be enclosed and separated from the external atmosphere; No additional requirements for "living conditions" are included, but teams are encouraged to consider appropriate accommodations the STEMnauts may need for an extended excursion on a lunar or planetary body.

- STEMnauts are assumed to have all qualities typical of astronauts. It is up to teams to be creative in how to depict their four STEMnauts in the HAUS design.
- "Atmosphere isolated compartment" means the living quarters must be enclosed and separated from the external atmosphere. Pressure equalization holes are exempt from this isolation requirement.

4.4.1. The HAUS enclosure shall not incorporate or rely on the structural airframe (including couplers) of the launch vehicle to meet requirement 4.4.

4.5. The STEMnauts shall be safely retained within the HAUS during flight (no alternative launch seating or location is permitted).

4.6. The payload shall not have any protrusions from the vehicle prior to apogee that extend beyond a quarter inch exterior to the airframe.

An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety.

4.7. General Payload Requirements:

4.7.1. Black powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics will not be permitted for any surface operations.

4.7.2. Any UAS weighing more than .55 lbs. shall be registered with the FAA and the registration number marked on the vehicle.

5. Safety Requirements

5.1. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.

5.2. Each team shall identify a student safety officer. See rule 5.2 for all guidelines pertaining to the student safety officer.

COLLEGE/UNIVERSITY

PROJECT MILESTONES: CRITERIA & EXPECTATIONS

Proposal Requirements

At a minimum, the proposing team shall identify the following in a written proposal due to NASA's MSFC by the date specified in the project timeline. Proposals are subject to a maximum of 75 pages.

1. **General Information**

    a. Please visit the Student Launch Website for instructions on submitting your proposal.

    b. A cover page that includes the name of the college/university or secondary education institution, mailing address, title of the project, and the date. The mailing address provided will be used if we need to mail anything throughout the project year to the team.

    c. Name, title, and contact information (including email address and phone number) for up to two adult educators (minimum of one required).

    d. Name, title, and contact information (including email address and phone number) for the team mentor. Team mentor NAR or TRA flyer number shall be included along with the level of certification they currently hold (see requirement 1.13).

    e. Name and email address for the student team leader.

    f. Name and email address for the student team member who will take responsibility for implementation of the safety plan (Safety Officer).

    g. 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 and technical personnel.

    h. Name of the NAR/TRA section(s) the team is planning to work with for purposes of mentoring, review of designs and documentation, and launch assistance.

2. **Facilities/Equipment**

    a. Description of facilities and hours of accessibility, necessary personnel, equipment, and supplies that are required to design and build the rocket and payload(s). Specify what is on hand and what will need to be acquired.

3. **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 shall be used for flight design and operations. The NAR/TRA mentor and Safety Officer shall oversee launch operations and motor handling.

The Federal Communications Commission (FCC) [www.fcc.gov] is a government agency that has specific rules and regulations regarding communications via radio, television, wire, satellite, and cable across the United States. Teams transmitting must ensure they are following all applicable local, state, and federal laws, including appropriate licensing for broadcasting via radio.

    a. Provide a safety plan that does the following:

        i. Detail how your team will perform hazards analysis, including identification of hazards, ranking and categorizing of risk, and mitigation of those hazards.

        ii. Detail how your team will manage safety in the various locations that will be utilized for the activities of your program, including: design, fabrication, storage, and launching.

        iii. Provide a preliminary list of Safety Data Sheets (SDS) for materials and chemicals your team anticipates will be used. The entire SDS need not be copied into the proposal. A series of hyperlinks, documents on a cloud storage, or sample screenshots is sufficient.

iv. Detail how and where your team will purchase, store, transport, and use rocket motors and other energetic devices.

1. The team's NAR/TAR mentor is required to be the owner of your rocket and should always be present for activities involving rocket motors and other energetic devices.

b. Provide an example preliminary Hazards Analysis. This analysis does not need to be complete. It is meant only to demonstrate the concept described in the Safety Plan.

c. Describe Student Briefings that the team has planned. These should include subject, timeframe, and any necessary personnel.

d. Identify any federal, state, and/or local laws regarding unmanned rocket launches and motor handling and indicate how the team intends to abide by those laws. Include any specific actions the team will need to take to obey these laws.

i. Examples of this could include the following: 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 Rocketry."

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

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

ii. 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.

iii. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. A team shall not fly a rocket until the mentor has reviewed the design, examined the build, and is satisfied the rocket meets established amateur rocketry design and safety guidelines.

iv. Compliance with NAR [High Power Rocket Safety Code].

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

4. Technical Design

a. Demonstrate an understanding of rocket, recovery, and payload design to include the following:

i. General vehicle dimensions, preliminary material selection and justification, and construction methods.

ii. Projected altitude and describe how it was calculated.

iii. Planned recovery system design.

iv. Projected motor brand and designation.

v. Detailed description of the team's projected payload.

vi. Identify major technical challenges and solutions.

5. Project Plan

a. Provide a detailed development schedule/timeline or work breakdown structure (WBS) covering all aspects necessary to complete the project successfully, including specific dates for meetings, activities, report writing, builds, travel, and milestones.

b. Provide a detailed budget to cover all aspects necessary to complete the project successfully, including team travel to the launch, organized fair market values, vendors, and travel costs.

c. Provide a detailed funding plan, including expected funding amounts, sources of funding, and addressing cost overruns and funding shortfalls.

d. Include a STEM Industry OR Community STEM Engagement Plan (1 page maximum) (see pages 38–40).

Project Deliverables

a. A reusable rocket with required payload system ready for official launch.

b. A scale model of the rocket design shall be flown during the PDR or CDR milestones and the altimeter flight profile data or a quality video encompassing the entire liftoff and flight, as well as quality pictures of the landed configuration of the launch vehicle shall be reported in the CDR.

c. A full-scale Vehicle Demonstration Flight and Payload Demonstration Flight shall be flown, and a raw altimeter flight data file in csv or xlsx along with the flight profile graph, as well as quality pictures of the landed configuration of the launch vehicle shall be reported in the FRR and/or FRR Addendum.

d. A team social media presence established and maintained/updated throughout the project year.

e. Reports, PDF slideshows, and Milestone Review Flysheets completed and submitted to the Student Launch Projects management team by due dates.

f. Successful completion of PDR, CDR, FRR, FRR addendum (if applicable), LRR, and PLAR.

Preliminary Design Review (PDR)

The PDR demonstrates the overall preliminary design meets all requirements with acceptable risk, within the cost, schedule, and technical performance constraints, and establishes the basis for proceeding with detailed design. It shows the correct design options have been selected, and interfaces have been identified. 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 that follows the order of sections as they appear below.

Preliminary Design Review Report

Page Limit: PDRs will only be scored using the first 200 pages of the report (not including title page).

Any additional content will not be considered while scoring. Font size shall be at a minimum of 12 point.

I. Summary of PDR report (1 page maximum)

Team Summary—Include the following in a table:

- Team name and mailing address.
- Name of mentor, NAR/TRA number and certification level, and contact information.
- Indication of plans to launch in Huntsville during launch week or at home during the launch window of April 5th – May 4th.
- Team social media presence established. Include a table listing all social media handles.

Launch Vehicle Summary—Include the following in a table:

- Final primary and secondary motor choice.
- Size and mass of individual sections:
  — Include the total length along with the lengths of each individual section of your vehicle. Include the total dry mass, total wet mass, fully ballasted mass (if applicable), and burnout mass. Finally, include the landing mass of each section of your launch vehicle.
- Recovery system:
  — Include drogue and main parachute brand, model, size, and projected descent rate. Include altimeter brand, model, and deployment settings. Include energetic material, quantity for main and backup, and any deployment altitudes.

Payload Summary

- Payload title
- Summarize payload experiment

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 payload criteria
- Changes made to project plan

III. Vehicle Criteria

Selection, Design, and Rationale of Launch Vehicle

- Include unique mission statement and mission success criteria.
- Review the design at a system level, going through each system's alternative designs, and evaluating the pros and cons of each alternative.
- For each alternative, present research on why that alternative should or should not be chosen.
- For each alternative, conduct a feasibility study.
- For each alternative, locate points of separation on each design and show location(s) of energetic materials
- After evaluating all alternatives, present a vehicle design with the current leading alternatives, and explain why they are the leading choices.
  - Describe each subsystem and the components within those subsystems.
  - Provide detailed dimensional drawings using the leading design.
  - Provide estimated masses for each subsystem.
  - Provide sufficient justification for design selections.
- Review different motor alternatives and present data on each alternative.

Recovery Subsystem

- Review the design at a component level, going through each components' alternative designs, and evaluating the pros and cons of each alternative.
- For each alternative, present research on why that alternative should or should not be chosen.
- Using the estimated mass of the launch vehicle, perform a preliminary analysis on parachute sizing, and determine what size is required for a safe descent.
- Include drawings/sketches, wiring diagrams, and electrical schematics.
- Choose leading components amongst the alternatives, present them, and explain why they are the current leaders. Teams shall discuss at a minimum: shock cord length, diameter, material, anchor point hardware and location, and strength ratings for all components.
- Prove that redundancy exists within the system.

Mission Performance Predictions

- Show flight profile simulations. This includes altitude, velocity, and acceleration versus time predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify the vehicle is robust enough to withstand the expected loads.
- Show stability margin and 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 expected descent time for the rocket and any section that descends untethered from the rest of the 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. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV. Payload Criteria

Selection, Design, and Rationale of Payload

- Describe what the objective of the payload is and what experiment it will perform. What results will qualify as a successful experiment?
- Review the design at a system level, going through each system's alternative designs, and evaluating the pros and cons of each alternative.
- For each alternative, present research on why that alternative should or should not be chosen.
- For each alternative, conduct a feasibility study.
- After evaluating all alternatives, present a payload design with the current leading alternatives and explain why they are the leading choices.
- Include drawings and electrical schematics for all elements of the preliminary payload. List estimated masses for components.
- Describe the justification used when making design selections.
- Describe the preliminary interfaces between the payload and launch vehicle.
- Describe the preliminary design of the payload retention system.

V. Safety

- Demonstrate an understanding of all components needed to complete the project and how risks/delays impact the project.
- Provide a preliminary Personnel Hazard Analysis. The focus of the Hazard Analysis at PDR is identification of hazards, their causes, and the resulting effects. Preliminary mitigations and controls can be identified, but do not need to be implemented at this point unless they are specific to the construction and launching of the subscale rocket, or are hazards to the success of the SL program (i.e., cost, schedule, personnel availability). 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, SDS, etc.
- Provide preliminary Failure Modes and Effects Analysis (FMEA) of the proposed design of the rocket, payload, payload integration, launch support equipment, and launch operations. Again, the focus for PDR is identification of hazards, causes, effects, and proposed mitigations. Rank the risk of each hazard for both likelihood and severity.
- Discuss any environmental concerns using the same format as the Personnel Hazard Analysis and FMEA.
  - This should include how the vehicle affects the environment and how the environment can affect the vehicle.
- 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 a 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.

VI. Project Plan

Requirements Verification

- Create team derived requirements in the following categories: Vehicle, Recovery, and Payload. These are requirements for mission success that are beyond the minimum success requirements presented in this handbook. Demonstrate that the requirements are not arbitrary and are required for the team's unique project.

Budgeting and Timeline

- Provide a line item budget for all aspects of the project with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Provide a funding plan describing sources of funding, allocation of funds, and material acquisition plan.
- Provide a timeline including all team activities and expected activity durations. The schedule should be complete and encompass the full term of the project. Deliverables should be defined with reasonable activity duration. GANTT or milestones charts are encouraged.

Preliminary Design Review Presentation

Please include the following in your presentation:

- Vehicle dimensions and justification
- Vehicle materials and justification
- Static stability margin and CP/CG locations
- Visually show points of separation along with location of energetic materials and all recovery components clearly labeled
- Final motor selections and justification
- Thrust-to-weight ratio and rail exit velocity
- Discussion of alternative designs and why each should or should not be chosen
- Drawing/discussion of each major component and subsystem, especially the recovery subsystem
- Discussion of current Mission Performance Predictions
- Preliminary payload design
- Preliminary payload retention system design
- Requirements compliance plan

The PDR will be presented to a panel that may be comprised of scientists, engineers, safety experts, education specialists, and industry partners. The purpose of this review is to convince the NASA Review Panel 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, which will culminate with the Critical Design Review.

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

The presentation of the PDR shall be well prepared with an overall professional appearance. This includes, but is not limited to: easy-to-read 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 rather than 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)

The CDR establishes the maturity of the design is appropriate to support proceeding to full-scale fabrication, assembly, and integration. It demonstrates 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, and technical performance 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 expects a professional and polished report that follows the order of sections as they appear below.

Critical Design Review Report

Page Limit: CDRs will only be scored using the first 200 pages of the report (not including title page).

Any additional content will not be considered while scoring. Font size shall be at a minimum of 12 point.

I. Summary of CDR report (1 page maximum)

Team Summary—Include the following in a table:

- Team name and mailing address.
- Name of mentor, NAR/TRA number and certification level, and contact information.
- If planning to conduct the final competition launch at home, teams shall provide anticipated primary and backup launch locations and dates.

Launch Vehicle Summary—Include the following in a table:

- Official target altitude (ft.).
- Primary and secondary motor choice.
- Size and mass of individual sections:
  - Include the total length along with the lengths of each individual section of your vehicle. Include the total dry mass, total wet mass, fully ballasted mass (if applicable), and burnout mass. Finally, include the landing mass of each section of your launch vehicle.
- Recovery system:
  - Include drogue and main parachute brand, model, size, and projected descent rates. Include altimeter brand, model, and deployment settings. Include energetic material, quantity for main and backup, and any deployment altitudes.
- Rail size

Payload Summary

- Payload title
- Summarize payload 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 payload criteria
- Changes made to project plan

III. Vehicle Criteria

Design and Verification of Launch Vehicle

- Include unique mission statement and mission success criteria.
- Identify which of the design alternatives from PDR were chosen as the final components for the launch vehicle. Describe why those alternatives are the best choices.
- Using the final designs, create dimensional and computer-aided design (CAD) drawings to illustrate the final launch vehicle, its subsystems, and its components.
- Using the final designs, create dimensional cross-sectional views of each airframe and coupler component.
- Using the final designs, locate points of separation and show location(s) of energetic materials.
- Demonstrate that the designs are complete and ready to manufacture.
- Discuss the integrity of design.
  - Suitability of shape and fin style for mission
  - Proper use of materials in fins, bulkheads, and structural elements
  - Sufficient motor mounting and retention
  - Estimate the final mass of the launch vehicle, as well as the individual subsystems
- Provide justification for material selection, dimensioning, component placement, and other unique design aspects.

Subscale Flight Results

- At least one data gathering device shall be onboard the launch vehicle during the test launch. At a minimum, this device shall record the apogee of the rocket. If the device can record more than apogee, please include the actual flight data in the report.
- Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) will not be accepted.
- Quality pictures of the as landed configuration of all sections of the launch vehicle. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Describe the scaling factors used when scaling the rocket. What variables were kept constant and why? What variables do not need to be constant and why?
- Describe launch day conditions and perform a simulation using those conditions.
- Perform an analysis of the subscale flight.
  - Compare the predicted flight model to the actual flight data. Discuss the results.
  - Discuss any error between actual and predicted flight data.
  - Estimate the drag coefficient of the full-scale rocket with subscale data.
- Discuss how the subscale flight data has impacted the design of the full-scale launch vehicle.

Recovery Subsystem

- Identify which of the design alternatives from PDR were chosen as the final components for the recovery subsystem. Describe why those alternatives are the best choices.
- Include a Concept of Operations (CONOPS) of your recovery system.
- Describe in detail the parachute sizes, locations, and method of protection. Teams shall discuss at a minimum: shock cord length, diameter, material, anchor point hardware and location, and strength ratings for all components.
- Discuss the electrical components and prove that redundancy exists within the system.
- Include drawings/sketches, wiring diagrams, and electrical schematics.
- Provide the operating frequency of the locating tracker(s).

Mission Performance Predictions (using the most up-to-date model)

- Show flight profile simulations. This includes altitude, velocity, and acceleration versus time predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify that the vehicle is robust enough to withstand the expected loads
- Show stability margin and 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 expected descent time for the rocket and any section that descends untethered from the rest of the 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. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that the original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV. Payload Criteria

Design of Payload Experiment

- Identify which of the design alternatives from PDR was chosen for the payload. Describe why that alternative and its components were chosen.
- Include a Concept of Operations (CONOPS) of your payload system.
- Review the design at a system level.
  - Include drawings and specifications for each component of the payload, as well as the entire payload assembly.
  - Describe how the payload components interact with each other.
  - Describe how the payload integrates within the launch vehicle.
  - Describe the payload retention system.
- Demonstrate that the design is complete.
- Discuss the payload electronics with special attention given to safety switches and indicators. Include the following:
  - Drawings and schematics
  - Block diagrams
  - Batteries/power
  - Switch and indicator wattages and locations
- Provide justification for all unique aspects of your payload (materials, dimensions, placement, etc.)

V. Safety

Launch concerns and operation procedures

Submit a draft of final assembly and launch procedures/checklists including:

- Recovery preparation
- Payload preparation
- Electronics preparation
- Rocket preparation
- Motor preparation
- Setup on the launch pad
- Igniter installation
- Launch procedure

- Troubleshooting
- Post-flight inspection

These procedures/checklists should include specially demarcated steps related to safety. Examples include:

- Warnings of hazards that can result from missing a step
- PPE required for a step in the procedure (identified BEFORE the step)
- Required personnel to complete a step or to witness and sign off verification of a step.

Safety and Environment (Vehicle and Payload)

- Update the Personnel Hazard Analysis, the Failure Modes and Effects Analysis, and the Environmental Hazard Analysis to include:
  - Finalized hazard descriptions, causes, and effects. These should specifically identify the mechanisms for the hazards, and uniquely identify them from other hazards. Ambiguity is not useful in safety work.
  - A near-complete list of mitigations, addressing the hazards and/or their causes
  - A preliminary list of verifications for the identified mitigations. These should include methods of verifying the mitigations and controls are (or will be) in place, and how they will serve to ensure the mitigation. These do not need to be finalized at this time, but they will be required for FRR. Example verifications include: test data, written procedures and checklists, design analysis, as-built configuration drawings, and Personal Protective Equipment.

VI. Project Plan

Testing

- Identify all tests required to prove the integrity of the design.
- For each test, present the test objective and success criteria, as well as testing variable and methodology.
- Justify why each test is necessary to validate the design of the launch vehicle and payload.
- Discuss how the results of a test can cause any necessary changes to the launch vehicle and payload.
- Present results of any completed tests.
  - Describe the test plan and whether or not the test was a success.
  - How do the results drive the design of the launch vehicle and/or payload?

Requirements Compliance

- Create a verification plan for every requirement from Sections 1 – 5 of the project requirements listed in this handbook. Identify if test, analysis, demonstration, or inspection are required to verify the requirement. After identification, describe the associated plan needed for verification.
- Update the ongoing list of team derived requirements in the following categories: Vehicle, Recovery, and Payload. These are a set of requirements for mission success that are beyond the minimum success requirements presented in this handbook. Create a verification plan for each team derived requirement identifying whether test, analysis, demonstration, or inspection is required with an associated plan.

Budgeting and Timeline

- Provide an updated line item budget for all aspects of the project with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Provide an updated funding plan describing sources of funding, allocation of funds, and material acquisition plan.
- Provide an updated timeline, including all team activities and expected activity durations. The schedule should be complete and encompass the full term of the project. Deliverables should be defined with reasonable activity duration. GANTT or milestone charts are encouraged.

Critical Design Review Presentation

Please include the following information in your presentation:

- Final launch vehicle and payload dimensions
- Discuss key design features
- Visually show points of separation along with location of energetic materials and all recovery components clearly labeled
- Final motor choices
- Official target altitude (ft.)
- 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
- Recovery System CONOPS
- 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 data
- Tests of the staged recovery system
- Final payload design overview
- Payload integration plans
- Payload retention system
- 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 scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the final design of the launch vehicle and payload, proving the design meets the mission objectives and requirements and can be safely 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 that will culminate in a Flight Readiness Review.

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

The presentation of the CDR shall be well prepared with an overall professional appearance. This includes, but is not limited to: easy-to-read 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 rather than 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)

The FRR examines tests, demonstrations, analyses, and audits that determine the overall system (all subsystems 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 hardware, software, personnel, and procedures are operationally ready.

The panel will be expecting a professional and polished report that follows the order of sections as they appear below.

Flight Readiness Review Report

Page Limit: FRRs will only be scored using the first 200 pages of the report (not including title page).

Any additional content will not be considered while scoring. Font size shall be at a minimum of 12 point.

I. Summary of FRR report (1 page maximum)

Team Summary—Include the following in a table:

- Team name and mailing address.
- Declared final launch location. If flying at a local launch, identify the launch club, national affiliation, name and contact information of a club officer who will attend the launch, and anticipated date of launch. Provide this information for both the primary and back up launch plans.
- Name of mentor, NAR/TRA number and certification level, and contact information.

Launch Vehicle Summary—Include the following in a table:

- Size and mass of individual sections:
  - Include the total length along with the lengths of each individual section of your vehicle. Include the total dry mass, total wet mass, fully ballasted mass (if applicable), and burnout mass. Finally, include the landing mass of each section of your launch vehicle.
- Competition Launch Motor.
- Target altitude (ft.).
- Recovery system:
  - Include drogue and main parachute brand, model, size, and projected descent rates. Include altimeter brand, model, and deployment settings. Include energetic material, quantity for main and backup, and any deployment altitudes.
- Rail size

Payload Summary

- Payload title
- Summarize payload 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 payload criteria
- Changes made to project plan

III. Vehicle Criteria

Design and Construction of Vehicle

- Describe any changes in the launch vehicle design from CDR and explain why those changes are necessary.
- Discuss final locations of separation along with where black powder or energetics will be located.

- Describe features that will enable the vehicle to be launched and recovered safely.
  - Structural elements (airframe, fins, bulkheads, attachment hardware, etc.)
  - Electrical elements (wiring, switches, battery retention, retention of avionics boards, etc.)
- Discuss flight reliability confidence. Demonstrate that the design can meet mission success criteria.
- Prove that the vehicle is fully constructed and fully document the construction process.
- Include schematics of the AS-BUILT rocket. There is a good chance dimensions have changed slightly due to the construction process.
- Discuss how and why the constructed rocket differs from earlier models.

Recovery Subsystem

- Describe and defend the robustness of the as-built and as-tested recovery system.
  - Structural elements (bulkheads, shock cords, attachment hardware, anchor points, etc.)
  - Electrical elements (altimeters/computers, switches, connectors)
  - Redundancy features
  - As-built parachute sizes and descent rates with justification, include all necessary calculations
  - Drawings, diagrams, and schematics of the as-built electrical and structural assemblies
  - Rocket-locating transmitters with a discussion of frequency, wattage, and range
- Discuss the sensitivity of the recovery system to on-board devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis section.

Mission Performance Predictions

- All of the following calculations, simulations, and models shall be done using the as-built launch vehicle and payload.
- Show flight profile simulations. This includes altitude, velocity, and acceleration versus time predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify that the vehicle is robust enough to withstand the expected loads.
- Show stability margin and as-built 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 expected descent time for the rocket and any section that descends untethered from the rest of the 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. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV. Payload Criteria

Payload Design and Testing

- Describe any changes in the payload design from CDR and explain why those changes are necessary.
- Describe unique features of the payload. Include the following:
  - Structural elements
  - Electrical elements
- Discuss flight reliability confidence. Demonstrate that the design can meet mission success criteria.
- Prove that the payload is fully constructed and fully document the construction process.
- Include schematics of the AS-BUILT payload. There is a good chance dimensions have changed slightly due to the construction process.

- Discuss how and why the constructed payload differs from earlier models.
- Discuss the planned or completed Payload Demonstration Flight. Include the following:
  - Date of flight or planned future flight
  - Success criteria
  - Results of flight
  - Analysis of payload retention system to the launch vehicle prior to jettison.

V. Demonstration Flights

Provide for all flights:

- Identify whether the flight was conducted to fulfill the requirements for the Vehicle Demonstration Flight, Payload Demonstration Flight, or both.
- Date of flight
- Location of flight
- Launch conditions
- Motor flown (brand and designation)
- Ballast flown (lbs.)
- Final payload flown (Y/N)
- Air brake system status during test flight (if design incorporates airbrakes)
- Official target altitude (ft.)
- Predicted altitude from simulations (ft.)
- Measured altitude (ft.)
- Altimeter flight profile data output with accompanying altitude and velocity versus time plots. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.
- Raw altimeter data in .csv or .xlsx format (subscale flight is exempt from this requirement).
- Quality pictures of the as landed configuration of all sections of the launch vehicle. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Identify all vehicle and recovery systems that functioned as intended.
- Identify and discuss any vehicle or recovery hardware or software that failed to function as intended.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
  - Include a table of kinetic energy calculations that provides, at a minimum: descent rate under both drogue and main parachutes, gross lift-off mass, landing mass of each individual rocket section, final kinetic energy number
  - When calculating landing masses, subtract the mass of expended propellant, deployed recovery parachutes, and shock cord as these are external to the launch vehicle. Clearly document the subtracted values. The sum of the propellant mass, recovery components, and individual section landing masses shall equal the gross lift-off mass.
- If the payload was not present, describe how the payload was simulated during the flight.
- Perform an analysis of the Vehicle Demonstration Flight. Update your simulated flight model with launch day condition data and compare the predicted flight performance to the actual flight data. Discuss the results.
- Estimate the drag coefficient of the full-scale rocket utilizing launch data. Use this value to run a post-flight simulation.
- Discuss any error between actual and predicted flight data.
- Discuss the similarities and differences between the full-scale and subscale flight results.
- Identify any hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss lessons learned from the flight.
- Identify any off-nominal events during mission execution.

If the final, active payload was flown (i.e., the flight qualified as a Payload Demonstration Flight), also provide:

- Identify all retention systems that functioned as intended.
- Identify and discuss any retention hardware or software that failed to function as intended.
- Identify any retention hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss retention system lessons learned from the flight.
- Summarize the designed payload mission sequence, from activation or deployment through mission completion.
- Identify all payload systems that functioned as intended.
- Identify and discuss any payload hardware or software that failed to function as intended.
- Identify any payload hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss payload lessons learned from the flight.

Provide a list of any planned future demonstration flights. Include a summary of the team's objectives for each launch.

VI. Safety and Procedures

Safety and Environment (Vehicle and Payload)

- Update the Personnel Hazard Analysis, the Failure Modes and Effects Analysis, and the Environmental Hazard Analysis to include:
  - Finalized hazard descriptions, causes, and effects for the rocket and payload the team has built.

    Note: These sections can change from CDR to FRR if there are design related changes made as a result of subscale and full-scale test flights, and refined modeling and analysis. These should specify the mechanisms for the hazards and uniquely identify them from other hazards. Ambiguity is not useful in safety work.
  - A completed list of mitigations addressing the hazards and/or their causes.
  - A completed list of verifications for the identified mitigations. This should include methods of verifying the mitigations and controls are (or will be) in place, and how they will serve to ensure the mitigation.
- Be sure to discuss any concerns that remain as the project moves into the operational phase of the lifecycle. Emphasize concerns related to your procedures as well as the environment.

Launch Operations Procedures

Provide detailed procedures and checklists for each of the following (at a minimum):

- Recovery preparation
- Payload preparation
- Electronics preparation
- Rocket preparation
- Motor preparation
- Setup on launch pad
- Igniter installation
- Launch procedure
- Troubleshooting
- Post-flight inspection

These procedures and checklists should include specially demarcated steps related to safety. Examples include:

- Warnings of hazards that can result from missing a step
- PPE required for a step in the procedure (identified BEFORE the step)
- Required personnel to complete a step or to witness and sign off verification of a step

VII. Project Plan

Testing

- Prove that all testing is complete and provide test methodology and discussion of results.
- Discuss whether each test was successful or not.
- Discuss lessons learned from the tests conducted.
- Discuss any differences between predicted and actual results of the tests conducted.

Requirements Compliance

- Review and update the verification plan. Describe how each handbook requirement was verified using testing, analysis, demonstration, or inspection.
- Review and update the team derived requirements for the vehicle, recovery system, and payload. Describe how each team derived requirement was verified using testing, analysis, demonstration, or inspection.

Budgeting and Funding Summary

- Provide an updated line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Provide an updated funding plan describing sources of funding, allocation of funds, and a material acquisition plan for any items that have not yet been obtained.

Flight Readiness Review Presentation

Please include the following information in your presentation:

- Launch vehicle design and dimensions
- Visually show points of separation along with location of energetic materials and all recovery components clearly labeled
- 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
- Vehicle Demonstration Flight results. Present and discuss the actual flight test data, as well as any issues or failures encountered.
- Recovery system tests
- Summary of requirements verification (launch vehicle)
- Payload design and dimensions
- Key design features of the payload
- Payload integration into the vehicle
- Payload retention system design
- Payload Demonstration Flight plans. If complete, discuss the actual flight test results, as well as any issues or failures encountered.
- Summary of requirements verification (payload)
- Interfaces with ground systems (vehicle and payload)

The FRR will be presented to a panel that may be comprised of scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the as-built launch vehicle and payload, showing that the launch vehicle and payload meet 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 or faculty advisor shall not participate in the presentation.

The presentation of the FRR shall be well prepared with an overall professional appearance. This includes, but is not limited to: easy-to-read 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 Addendum

The FRR Addendum is a required submission for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report. It is expected to be a brief but informative document highlighting the successes and failures of the new flight(s) and any updates or changes to the vehicle or payload design. The information reported in the FRR Addendum will be reviewed by NASA to determine eligibility of each team to perform their competition launch.

Flight Readiness Review Addendum Document Outline

Page Limit: The FRR Addendum is not scored and does not have a specific minimum or maximum page count, but each requested item listed below shall be sufficiently addressed.

I. Summary of FRR Addendum

Team Summary

- Team name, mailing address, and contact information

Purpose of Flight(s)

- Identify whether the flight(s) conducted were conducted to fulfill the requirements for the Payload Demonstration Flight, Vehicle Demonstration Re-flight, or both.

Flight Summary Information (for each flight)

- Date of flight
- Location of flight
- Launch conditions
- Motor flown (brand and designation)
- Ballast flown (lbs.)
- Final payload flown (Y/N)
- Air brake system status during test flight (list N/A if your vehicle does not contain an air brake system)
- Official target altitude (ft.)
- Predicted altitude from simulations (ft.)
- Measured altitude (ft.)
- Identify any off-nominal events during mission execution

Changes made since FRR

- Describe changes made to the vehicle design and explain why those changes are necessary.
- Describe changes made to the payload design and explain why those changes are necessary.

II. Payload Demonstration Flight Results (if applicable)

Summarize the retention system and mission of the payload, along with discussing its successes and failures.

- Summarize the designed payload mission sequence, from activation or deployment through mission completion
- Summarize the design of the payload retention system
- Provide altimeter flight profile data
- Identify all systems that functioned as intended
- Identify and discuss any hardware or software that failed to function as intended
- Identify any hardware that was damaged and required repair or replacement and discuss the plan of action
- Discuss payload lessons learned from the flight

III) Vehicle Demonstration Re-flight (if applicable)

Summarize the flight of the rocket and discuss its successes and failures.

- Identify all systems that functioned as intended.
- Identify and discuss any hardware or software that failed to function as intended.
- If the payload was not present, describe how the payload was simulated during the flight.
- Altimeter flight profile data output with accompanying altitude and velocity versus time plots. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.
- Include quality pictures of the as landed configuration of all sections of the launch vehicle. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
  - Include a table of kinetic energy calculations that provides, at a minimum: descent rate under both drogue and main parachutes, gross lift-off mass, landing mass of each individual rocket section, final kinetic energy number
  - When calculating landing masses, subtract the mass of expended propellant, deployed recovery parachutes, and shock cord as these are external to the launch vehicle. Clearly document the subtracted values. The sum of the propellant mass, recovery components, and individual section landing masses shall equal the gross lift-off mass.
- Perform an analysis of the Vehicle Demonstration Re-flight. Update your simulated flight model with launch day condition data and compare the predicted flight performance to the actual flight data. Discuss the results.
- Estimate the drag coefficient of the full-scale rocket utilizing launch data. Use this value to run a post-flight simulation.
- Identify any hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss lessons learned from the flight.

Launch Readiness Review (LRR)

The Launch Readiness Review (LRR) will be conducted by NASA and the National Association of Rocketry (NAR), our launch services provider. These inspections are mandatory for team members and mentors. These names were submitted as part of your team list. All rockets/payloads will undergo a detailed, deconstructive, hands-on inspection.

Your team should bring all components of the rocket and payload except for the motor, black powder, and electric 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 and electrical integrity, as well as safety concerns. At a minimum, all teams shall have:

- An airframe prepared for flight with the exception of energetic materials
- Data from the previous flight(s)
- A list of any flight anomalies that occurred on the previous full-scale flight(s) and the mitigation actions
- A list of any changes to the airframe since the last flight
- Flight simulations
- Pre-flight launch procedures and checklist(s)
- Fly Sheet
- Team name and contact info in or on the airframe and any untethered section of the vehicle

Each team will demonstrate these tasks to the NAR Review Team. The RSO has final word on whether the rocket and/or payload may be flown on Launch Day.

A "punch list" will be generated for each team. Items identified on the punch list must be corrected and verified by NAR/NASA prior to Launch Day. A flight card will be provided to teams and is to be completed and submitted at the LCO booth on Launch Day.

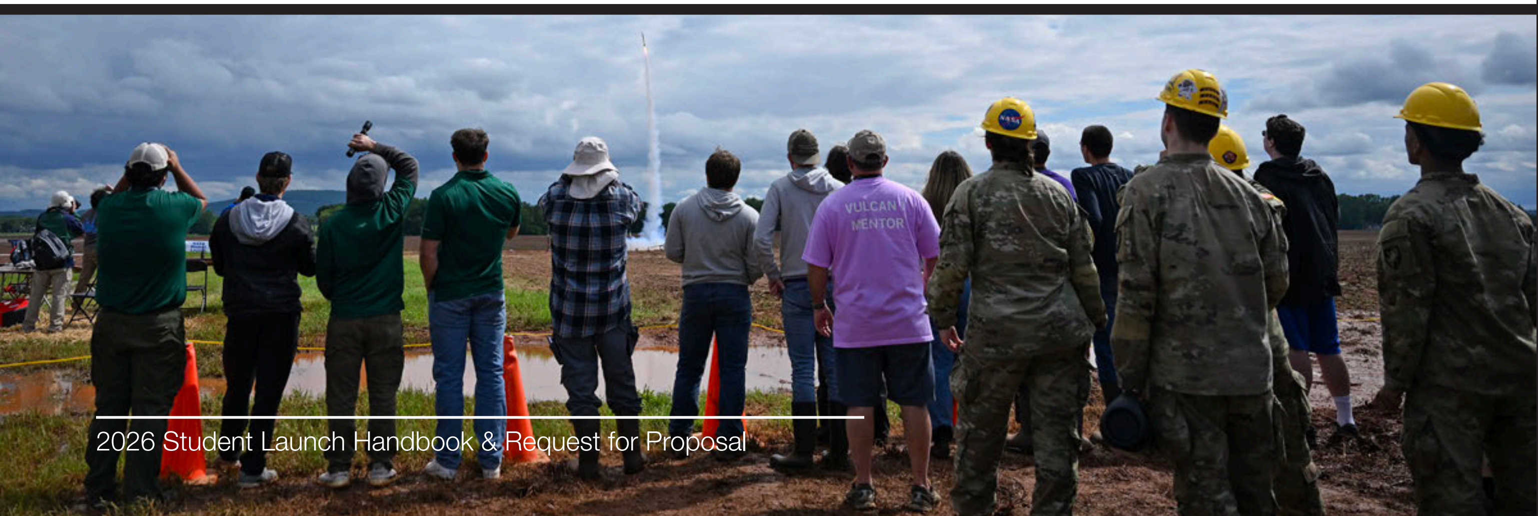
Post-Launch Assessment Review (PLAR)

The PLAR is an assessment of system in-flight and payload mission performance from your final competition launch. All scientific and engineering results and findings shall be reported along with a cumulative summary of your teams' experience on the project as a whole.

Page Limit: PLARs will only be scored using the first 25 pages of the report (not including title page).

Any additional content will not be considered while scoring. Font size shall be at a minimum of 12 point.

- Team name
- Motor used
- Vehicle dimensions
- Altitude reached (ft.)
- Official target altitude (ft.)
- Competition Launch altimeter flight profile data
- Quality photo of fully assembled and painted final competition rocket as flown.
  Photo shall only include the rocket and not any team members.
- Vehicle summary
- Payload summary
- Data analysis and results of the vehicle and payload
- Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) will not be accepted.
- Raw altimeter data in .csv or .xlsx format.
- Quality pictures of the as landed configuration of all sections of the launch vehicle.
  This includes, but is not limited to: nosecone, recovery system, airframe, and booster.
  Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Describe separation events and state altitude of events
- Ascent and descent analysis and metrics of the launch vehicle
- Scientific value achieved
- Visual data observed
- Lessons learned for vehicle, payload, and overall project
- Discussion of successes and failures of individual subsystems
- Summary of overall experience (what you attempted to do versus the results; how valuable you felt the experience was). Include feedback on program elements you found effective, areas that need improvement, and specific recommendations for changes you'd like to see.
- Include STEM Industry Engagement OR Community STEM Engagement Summary (1-page maximum) (see pages 38–40)
- Final Budget summary



COLLEGE/UNIVERSITY ENGAGEMENT

Engagement Requirement Option 1—STEM Industry Engagement:

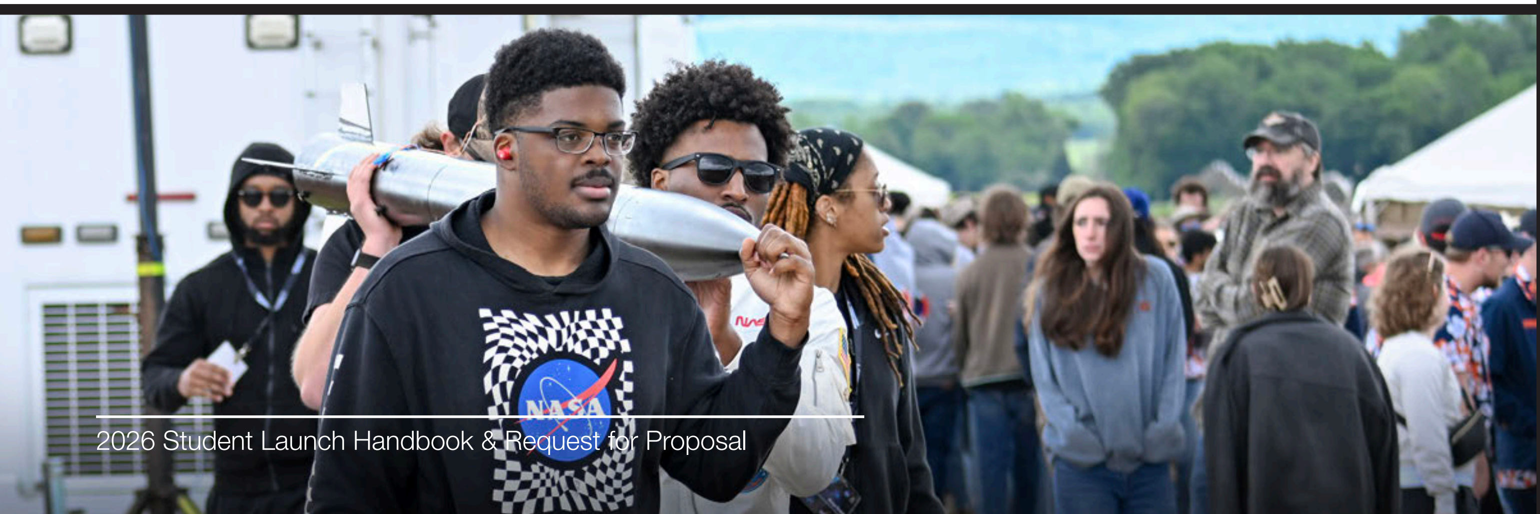
Provide a plan for how your team will engage with industry professionals and community leaders to enhance your project's impact and educational value while developing meaningful connections that could lead to future workforce opportunities for your team members. Your plan should be no more than 1 page maximum.

Proposal Requirement—STEM Industry Engagement Plan:

- Audit local community and create a list of potential partners and alignment with project goals. Consider technical expertise, mentorship, skills development, certifications or resources sought to advance project goals.
- Your plan should assess the team's **Professional Development Strategy** (choose at least one from this category).
  - Summarize mentorship arrangements your team plans to target with industry experts/partners.
  - Identify skills development and certification opportunities your team members plan to seek with industry partners (e.g. welding, safety training, electrical, software).
  - Explain how your team's industry connections would support team members' career goals.
  - Identify potential internship, fellowship, apprenticeship, or career opportunities your team members plan to seek.
- Your plan should assess the team's **Community Leadership Outreach** (choose at least one from this category).
  - Describe how your team engage with local civic and community leaders.
  - Summarize the method your team will use to raise awareness about your NASA challenge participation.
  - Identify and outline connections your team has and/or will seek with community leaders and industry partners.

PLAR Requirement—STEM Industry Engagement Summary

- Provide a list of partners you engaged with this activity year. Identify the area in which you engaged with them: technical expertise, mentorship, skills development, certifications or resources sought to advance project goals.
- Your summary should assess the team's Professional Development Strategy (choose at least one from this category).
  - Summarize any mentorship arrangements your team developed with industry experts/partners.
  - Identify skills development and certification opportunities your team members received through industry partners (e.g. welding, safety training, electrical, software).
  - Explain how your team's industry connections supported team members' career goals.
  - Identify internship, fellowship, apprenticeship, or career opportunities your team members have received or will receive.
- Your summary should assess the team's Community Leadership Outreach (choose at least one from this category).
  - Describe how your team engaged with local civic and community leaders.
  - Summarize the method your team used to raise awareness about your NASA challenge participation.
  - Identify and outline connections your team has or developed with community leaders and industry partners.



Engagement Requirement Option 2—Community STEM Engagement

Provide a plan for how your team will engage with local schools, educational institutions, and your community to enhance your project's impact and educational value while developing meaningful connections to inspire the next generation of space explorers. Your plan should be no more than 1 page maximum.

Proposal Requirement—Community STEM Engagement Plan

- Audit local schools, and community educational institutions, and create a list of potential opportunities for your team to host or implement STEM Engagement events.
- Your plan should assess the team's STEM Engagement and Outreach Strategy (include all three from this category)
  - Identify a goal for your team to reach with your STEM Engagement and Outreach Strategy.
  - Summarize activities, or events, the team plans to host or implement in for STEM Engagement.
  - Provide potential dates or schedule for your plan.

PLAR Requirement—Community STEM Engagement Summary

- Provide a list of local schools, and/or community educational institutions your team partnered with for STEM Engagement activities and events.
- Your summary should assess the team's **STEM Engagement and Outreach Strategy** (include all three from this category)
  - Summarize how your team reached your goal with your STEM Engagement and Outreach Strategy.
  - Summarize each activity, or event your team implemented.
  - Provide activity and event dates along with number of participants engaged with for each.

COLLEGE/UNIVERSITY
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 on-board 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 on-board 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 (9,208 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 1,500 feet, whichever is greater, or 1,000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1,500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. **Launcher Location**. My launcher will be 1,500 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	1,000
10,240.01 – 20,480.00	N	125	1,000	1,500
20,480.01 – 40,960.00	O	125	1,500	2,000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors Revision as of August 2012.

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

COLLEGE/UNIVERSITY AWARDS

College and University Division Awards

Award	Award Description	Determined By
Vehicle Design Award	Awarded to the team with the most creative and innovative overall vehicle design for their intended payload while still maximizing safety and efficiency.	NASA Panel
Experiment Design Award	Awarded to the team with the most creative and innovative payload design while maximizing safety and science value.	NASA Panel
Safety Award	Awarded to the team that demonstrates the highest level of safety according to the scoring rubric.	NASA Panel
Project Review Award	Awarded to the team that is viewed to have the best combination of written reviews and formal presentations.	NASA Panel
Community STEM Engagement Award	Awarded to the team that is determined to have best inspired the study of rocketry and other science, technology, engineering, and math (STEM) related topics in their community.	NASA Panel
Social Media Award	Awarded to the team that has the most active and creative social media presence throughout the project year.	NASA Panel
Altitude Award	Awarded to the team that comes closest to their declared target altitude on their competition launch.	NASA Panel
Best Looking Rocket Award*	Awarded to the team that is judged by their peers to have the "Best Looking Rocket."	Peers
Rookie Award	Awarded to the top overall rookie team using the same criteria as the Overall Winner Award. If a rookie team is the Overall Winner, this award will go to the 2nd place Rookie Team.	NASA Panel
Overall Winner	Awarded to the top overall team. Design reviews, outreach, safety, and a successful flight will all factor into the Overall Winner.	NASA Panel
2nd Place Winner	Awarded to the second overall team. Design reviews, outreach, safety, and a successful flight will all factor into the Runner Up Award winner.	NASA Panel
3D Printed Award	Awarded to the team with the best consideration, design, and implementation in regards to 3D printing of launch vehicle and payload.	NASA Panel

* Only teams traveling to NASA's Launch Complex event are eligible.

Student Design Challenge Awards

The Student Design Challenges provide foundational learning opportunities for students from middle school through graduate level, preparing them for the future workforce through engagement in Artemis-focused challenges that align with mission needs. Teams from across all challenges will be selected to receive prestigious awards in the three categories below.

Pay It Forward Award
This award is given to teams that best conduct impactful educational engagement events in their community or beyond. Educational engagement includes instructional, hands-on activities where participants engage in learning a STEM-related concept by actively participating in an activity.

Innovation Award
This award is given to teams that best create new, innovative ideas and/or solutions within the scope of their respective challenge. Ingenuity, creativity, and inventiveness in either technology or non-technology focused ideas are awarded for their original ideas, creating efficiency, effective results, and/or solving a problem.

Artemis Educator Award
This award is given to educators/faculty/mentors in each challenge as nominated by student team members. Student team members will recognize their faculty/mentor(s) who inspire learners and motivate them to work hard, achieving more than the team members thought possible. The award acknowledges the time and dedication educators/faculty/mentors take to be exceptional teachers. Educators/faculty/mentors are noted for their commitment to learning and their valuable efforts for motivating and inspiring others. The NASA management team shall share the nomination process after the FRR milestone.

MIDDLE/HIGH SCHOOL
SLI DIVISION HANDBOOK

Timeline for NASA's SLI Division (Dates are subject to change.)

August 2025

8 .... Request for Proposal (RFP) released.

September 2025

22 .... Please visit https://www.nasa.gov/stem/studentlaunch/handbook/index.html for instructions on submitting your proposal. Proposals are due 8:00 a.m. CT.

October 2025

07 .... Awarded proposals announced.

09 .... Kickoff and PDR Q&A.

27 .... Preliminary Design Review (PDR) report, presentation slides, and flysheet submitted to NASA project management team by 8:00 a.m. CT.

November 2025

03 – 25 .... PDR video teleconferences.

28 .... Gateway Registration Deadline.

December 2025

03 .... CDR Q&A.

15 .... Huntsville rosters due for teams traveling to Huntsville for in person event.

January 2026

07 .... Subscale Flight deadline.

07 .... Critical Design Review (CDR) report, presentation slides, flysheet, and transmitter data sheet submitted to NASA project management team by 8:00 a.m. CT.

14 – Feb. 5 .... CDR video teleconferences.

February 2026

9 .... Team photos due.

11 .... FRR Q&A.

March 2026

9 .... Vehicle Demonstration Flight deadline.

9 .... Flight Readiness Review (FRR) report, presentation slides, and flysheet submitted to NASA project management team by 8:00 a.m. CT.

16 – Apr. 03...... FRR video teleconferences.

April 2026

03 .... Launch window opens for teams not traveling to Launch Week. PLAR must be submitted within 14 days of Launch. Teams launching at home must have successful VDF and PDF prior to final competition launch.

06 .... Payload Demonstration Flight and Vehicle Demonstration Re-flight deadlines.

06 .... FRR Addendum submitted to NASA project management team by 8:00 a.m. CT (teams completing additional Payload Demonstration Flights and Vehicle Demonstration Re-flights only)

15 .... Launch Week Q&A.

22 .... Teams arrive in Huntsville, AL.

23– 24 .... All-day Launch Week Events.

25 .... Launch Day.

26 .... Backup Launch Day.

May 2026

04 .... Launch window closes for teams not traveling to Huntsville for Launch Week. PLAR must be submitted within 14 days of launch.

11 .... Teams traveling to Launch Week: Post-Launch Assessment Review (PLAR) submitted to NASA project management team by 8:00 a.m. CT.

MIDDLE/HIGH SCHOOL

RULES & REQUIREMENTS

Student Launch Rules

1. General Rules

1.1. Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor). Student team members shall only be a part of one team in any capacity. Teams will submit new work. Excessive use of past work will merit penalties.

1.2. Team members who will travel to the Huntsville Launch shall have fully completed registration in NASA's Gateway system before the roster deadline. Team members shall include:

1.2.1. Students actively engaged in the project throughout the entire year;

1.2.2. One mentor (see Requirement 1.13);

1.2.3. No more than two adult educators.

1.3. Teams shall upload via Box all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. Late submissions of PDR, CDR, or FRR milestone documents will NOT be accepted. Teams that fail to submit the PDR, CDR, or FRR milestone documents will be eliminated from the project.

1.4. Teams who do not satisfactorily complete each milestone review (PDR, CDR, FRR) will be provided action items to be completed following their review and will be required to address action items in a delta review session. After the delta session, the NASA management panel will meet to determine the teams' status in the program, and the teams will be notified shortly thereafter.

1.5. All deliverables shall be in PDF format.

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

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

1.8. The team shall provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to: a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.

1.9. All teams attending Launch Week shall be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted at NASA's launch complex. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails will be canted 5–10 degrees away from the crowd on Launch Day. The exact cant will depend on Launch Day wind conditions.

2. Vehicle Rules

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

2.2. The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).

2.3. Final primary and secondary motor choice shall be declared by the Preliminary Design Review (PDR) milestone.

2.4. Any motor change after PDR shall be approved by the NASA management team or NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment shall not be approved. The only exception is teams switching to their secondary motor choice provided the primary motor choice is unavailable due to a motor shortage.

2.5. All teams shall successfully launch and recover a subscale model of their rocket. Success of the subscale is at the sole discretion of the NASA review panel. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline.

2.5.1. 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.

2.5.2. The subscale model shall carry an altimeter capable of recording the model's apogee altitude.

2.5.3. The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.

2.5.4. Proof of a successful flight shall be supplied in the CDR report and presentation.

2.5.4.1. Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) will not be accepted.

2.5.4.2. Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the CDR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.

2.6. Vehicle Demonstration Flight – All teams shall successfully launch and recover their full-scale launch vehicle prior to FRR in its final flight configuration. The rocket flown shall be the same rocket to be flown for their competition launch.

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

2.6.2. The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.

2.6.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:

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

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

2.6.4. If the payload changes the external surfaces of the rocket (such as camera housings or external probes) or changes the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.

2.6.5. Teams shall fly the competition launch motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the competition launch motor or in other extenuating circumstances.

2.6.6. The vehicle will be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the competition launch flight. Additional ballast shall not be added without a re-flight of the full-scale launch vehicle.

2.6.7. After successfully completing the full-scale demonstration flight, neither the launch vehicle nor any of its components shall be modified without the concurrence of the NASA management team or Range Safety Officer (RSO).

2.6.8. Proof of a successful flight shall be supplied in the FRR report.

2.6.8.1. Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.

2.6.8.2. Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the FRR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.

2.6.8.3. Raw altimeter data shall be submitted in .csv or .xlsx format.

2.6.9. Vehicle Demonstration flights shall be completed by the FRR submission deadline. No exceptions will be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST TIME FLIGHTS. Teams completing a required re-flight shall submit an FRR Addendum by the FRR Addendum deadline.

2.7. Payload Demonstration Flight — All teams shall successfully launch and recover their full-scale rocket containing the final active payload prior to the Payload Demonstration Flight deadline. The rocket flown shall be the same rocket to be flown as their competition launch. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed (if applicable) as designed. The following criteria shall be met during the Payload Demonstration Flight:

2.7.1. The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.

2.7.2. The payload flown shall be the final, active version.

2.7.3. If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.

2.7.4. Payload Demonstration Flights shall be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.

2.8. An FRR Addendum shall be required for any team completing a Payload Demonstration Flight or NASA- required Vehicle Demonstration Re-flight after the submission of the FRR Report.

2.8.1. Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly a final competition launch.

2.8.2. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload during launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.

2.9. The team's name and Launch Day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.

2.10. Transmitters shall not create excessive interference. Teams shall utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.

2.11. Excessive and/or dense metal shall not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.

3. Recovery System Rules

3.1. Each team shall perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full-scale vehicles.

4. Payload Rules

4.1. Any payload experiment element that is jettisoned during the recovery phase shall receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement by the RSO or NASA.

4.2. Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, shall be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAS.

4.3. Teams flying UASs shall abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112–95 Section 336; see https://www.faa.gov/uas/faqs).

5. Safety Rules

5.1. Each team shall use a launch and safety checklist.

5.2. The role and responsibilities of the safety officer shall include, but are not limited to:

5.2.1. Monitor team activities with an emphasis on safety during:

5.2.1.1. Design of vehicle and payload

5.2.1.2. Construction of vehicle and payload components

5.2.1.3. Assembly of vehicle and payload

5.2.1.4. Ground testing of vehicle and payload

5.2.1.5. Subscale launch test(s)

5.2.1.6. Full-scale launch test(s)

5.2.1.7. Competition Launch

5.2.1.8. Recovery activities

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

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

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

5.3. 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 NASA's Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams shall communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.

6. Final Flight Rules

Teams shall conduct the final flight in Huntsville during Launch Week (NASA's Launch Complex) or at a local launch field (Commercial Spaceport Launch Site) by the applicable deadlines as outlined in the Timeline for NASA's Student Launch.

6.1. NASA's Launch Complex

6.1.1. Teams are not permitted to show up at NASA's Launch Complex outside of launch day without permission from the NASA management team.

6.1.2. Teams shall complete and pass the Launch Readiness Review conducted during Launch Week.

6.1.3. The team mentor shall be present for Launch Readiness Reviews and oversee all rocket preparation and launch activities.

6.1.4. The scoring altimeter shall be presented to the NASA scoring official upon recovery. The scoring altimeter shall be one of the altimeters used for recovery events.

6.1.5. Teams may launch only once. Any launch attempt resulting in the rocket exiting the launch pad, regardless of the success of the flight, will be considered a launch. Additional flights beyond the initial launch will not be considered for awards.

6.1.6. Teams who are planning on launching at NASA's Launch Complex in Huntsville but choose not to launch due to delays such as weather or the rain date being utilized will not be permitted to launch a final competition launch at a later date to complete the program.

6.2. Commercial Spaceport Launch Site

6.2.1. The launch shall occur at a NAR or TRA sanctioned and insured club launch. Exceptions may be approved for launch clubs who are not affiliated with NAR or TRA but provide their own insurance, such as the Friends of Amateur Rocketry. Approval for such exceptions shall be granted by NASA prior to the launch.

6.2.2. Teams shall submit their rocket and payload to the launch site Range Safety Officer (RSO) prior to flying the rocket. The RSO shall inspect the rocket and payload for flight worthiness and determine if the project is approved for flight. The local RSO shall have final authority on whether the team's rocket and payload may be flown.

6.2.3. The team mentor shall be present and oversee rocket preparation and launch activities.

6.2.4. BOTH the team mentor and the Launch Control Officer shall observe the flight and report any off-nominal events during ascent or recovery on the Launch Certification and Observations Report.

6.2.5. The scoring altimeter shall be presented to BOTH the team's mentor and the Range Safety Officer. The scoring altimeter shall be one of the altimeters used for recovery events.

6.2.6. The mentor, the Range Safety Officer, and the Launch Control Officer must be three separate individuals who must ALL complete the applicable sections of the Launch Certification and Observations Report. The Launch Certification and Observations Report document will be provided by NASA upon completion of the FRR milestone and shall be returned to NASA by the team mentor upon completion of the launch.

6.2.7. The Range Safety Officer and Launch Control Officer certifying the team's flight shall be impartial observers and shall not be affiliated with the team, individual team members, or the team's academic institution.

6.2.8. Teams may launch only once. Any launch attempt resulting in the rocket exiting the launch pad, regardless of the success of the flight, will be considered a launch. Additional flights beyond the initial launch will not be considered for awards.

NASA will maintain a Frequently Asked Questions (FAQ) list on the Student Launch website (www.nasa.gov/studentlaunch). This list will include important changes and/or clarifications to project requirements.
Changes and clarifications appearing in the FAQ supersede what is written in this handbook.
It is the team's responsibility to check the FAQ and be aware of any changes to the challenge

Student Launch Requirements

1. General Requirements

1.1. Teams shall engage with their communities in STEM industry or STEM education. To satisfy this requirement teams shall complete either a STEM Industry Engagement Plan and Summary OR a Community STEM Engagement Plan and Summary. Requirements for each can be found in the Engagement section pages 80–82.

1.2. The team shall establish and maintain a social media presence to inform the public about team activities.

1.3. Each team shall identify a “mentor.” A mentor is defined as an adult who is included as a team member, supports the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The team mentor must adhere to the following requirements:

1.3.1. The mentor shall maintain a current certification and be in good standing with the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse class the team intends to use.

1.3.2. The mentor shall have flown and successfully recovered (using electronic, staged recovery) a minimum of two flights in the motor impulse class (or higher) the team intends to use, prior to PDR.

1.3.3. The mentor must attend all team launches throughout the project year, including launch week, as the mentor is designated the individual owner of the rocket for insurance and liability purposes.

2. Vehicle Requirements

2.1. The vehicle shall deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL). Teams flying below 3,000 feet or above 6,000 feet on their competition launch will not be eligible for the Altitude Award.

2.2. The launch vehicle and payload shall be capable of remaining in launch-ready configuration on the pad for a minimum of 3 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.

2.3. Teams shall declare their target altitude goal at the CDR milestone. The declared target altitude shall be used to determine the team’s altitude score.

2.4. 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.

2.5. 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.

2.5.1. Coupler/airframe shoulders which are located at in-flight separation points shall be at least two airframe diameters in length. (one body diameter of surface contact with each airframe section).

2.5.2. Coupler/airframe shoulders which are located at non-in-flight separation points shall be at least 1.5 airframe diameters in length. (0.75 body diameter of surface contact with each airframe section.)

2.5.3. Nosecone shoulders shall be at least ½ body diameter in length.

2.6. The launch vehicle shall be capable of being launched by a standard 12-volt direct current firing system. The firing system shall be provided by the NASA-designated launch services provider.

2.6.1. Each team shall use commercially available ematches or igniters. Hand-dipped igniters shall not be permitted

2.7. 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).

2.8. The launch vehicle shall be limited to a single motor propulsion system.

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

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

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

2.10.2. Each pressure vessel shall include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.

2.10.3. The full pedigree of the tank shall be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.

2.11. The launch vehicle shall have a minimum static stability margin of 2.0 while sitting on the pad.

2.12. The launch vehicle shall have a minimum thrust to weight ratio of 5.0:1.0.

2.13. Any structural protuberance on the rocket shall be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.

2.14. The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.

2.15. Subscale rockets are required to use a minimum motor impulse class of E (mid-power motor).

2.16. The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4" diameter, 100" length rocket, your subscale shall not exceed 3" diameter and 75" in length.

2.17. All teams shall complete demonstration flights as outlined below.

2.18. Vehicle Demonstration Flight—The purpose of the Vehicle Demonstration Flight is to validate 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 (drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.).

2.19. All Lithium Polymer batteries shall be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.

2.20. Vehicle Prohibitions:

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

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

2.20.3. The launch vehicle shall not utilize hybrid motors.

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

2.20.5. The launch vehicle shall not utilize friction fitting for motors.

2.20.6. The launch vehicle shall not exceed Mach 1 at any point during flight.

2.20.7. Vehicle ballast shall not exceed 10% of the total un-ballasted weight of the rocket, as it would sit on the pad (i.e., a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).

2.20.7.1. Ballast is defined as any non-essential mass that serves no structural or safety purpose for your launch vehicle or payload. This includes but is not limited to: increasing infill percentages beyond structurally necessary levels, deliberately oversizing hardware components, adding functionally unnecessary components.

2.20.7.2. Ballast must be mechanically retained. Friction fit is not a permissible form of retention.

2.20.7.3. Ballast shall be removable.

2.20.7.4. All requirements found in sections 1 through 5 of this handbook shall be met in both the minimum and maximum design ballast configurations. Where applicable, teams are expected to present calculations and performance metrics for both minimum and maximum design ballast configurations.

2.20.8. Transmissions from on-board transmitters, which are active at any point prior to landing, shall not exceed 250 mW of power (per transmitter).

3. Recovery System Requirements

3.1. The full-scale 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 lower altitude. Tumble 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 RSO.

3.1.1. The main parachute shall be deployed no lower than 500 feet.

3.1.2. The apogee event shall contain a delay of no more than 2 seconds.

3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.

3.2. Each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf at landing.

3.3. The recovery system shall contain redundant, commercially available barometric altimeters that are specifically designed for initiation of rocketry recovery events. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.

3.4. Each altimeter shall have a dedicated power supply, and all recovery electronics shall be powered by commercially available batteries.

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

3.6. Each arming switch shall be capable of being locked in the ON position for launch (i.e., cannot be disarmed due to flight forces).

3.7. The recovery system, GPS and altimeters, and electrical circuits shall be completely independent of any payload electrical circuits.

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

3.9. Bent eyebolts shall not be permitted in the recovery subsystem.

3.10. The recovery area shall be limited to a 2,500 ft. radius from the launch pads.

3.11. Descent time of the launch vehicle shall be limited to 90 seconds (apogee to touch down).

3.12. Electronic GPS Tracking device(s) shall be installed in the launch vehicle and will transmit the position of the tethered vehicle and any independent section(s) to a ground receiver.

3.13. To prevent system malfunctions the recovery system shall meet the following requirements:

3.13.1. 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.

3.13.2. The recovery system electronics shall be shielded from all on-board transmitting devices to avoid inadvertent excitation of the recovery system electronics.

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

3.13.4. The recovery system electronics shall be shielded from any other on-board devices which may adversely affect the proper operation of the recovery system electronics.

4. Payload Experiment Requirements

4.1. All payload designs 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.

4.2. USLI Payload Mission objective: College/University Division—Teams are tasked with designing, building, and flying a STEMnaut Habitat for Agricultural Utilization Study (HAUS). The HAUS must have the capability of safely housing four STEMnauts in an extended excursion living quarters, and have equipment for collecting and testing soil samples. The method(s)/design(s) utilized to complete the payload mission shall be at the team's discretion and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. NASA reserves the right to require modifications to a proposed payload.

HAUS Mission Requirements:

4.3. After landing, teams shall autonomously collect and retain a soil sample of at least 50 milliliters.

4.3.1. All soil collection and analysis must be completed within 15 minutes of landing.

4.4. Teams shall autonomously test the collected sample for at least one of the following:

- Nitrate-Nitrogen content
- pH level
- electrical conductivity

4.4.1. Analysis results shall include time stamps for verification.

4.4.2. The results of these tests shall be included in the PLAR. Preliminary results shall be made available for confirmation by the NASA Student Launch management team at the competition launch.

4.5. The autonomous functions described above may be initiated by remote command.

4.6. The HAUS's structure shall include an atmosphere isolated compartment to serve as living quarters for 4 STEMnauts. The compartment shall be enclosed and separated from the external atmosphere; No additional requirements for "living conditions" are included, but teams are encouraged to consider appropriate accommodations the STEMnauts may need for an extended excursion on a lunar or planetary body.

- STEMnauts are assumed to have all qualities typical of astronauts.
  It is up to teams to be creative in how to depict their four STEMnauts in the HAUS design.
- "Atmosphere isolated compartment" means the living quarters must be enclosed and separated from the external atmosphere. Pressure equalization holes are exempt from this isolation requirement.

4.6.1. The HAUS enclosure shall not incorporate or rely on the structural airframe (including couplers) of the launch vehicle to meet requirement 4.4.

4.7. The STEMnauts shall be safely retained within the HAUS during flight (no alternative launch seating or location is permitted).

4.8. The payload shall not have any protrusions from the vehicle prior to apogee that extend beyond a quarter inch exterior to the airframe.

4.9. STEMnauts are assumed to have all qualities typical of astronauts. It is up to teams to be creative in how to depict their four STEMnauts in the HAUS design.

4.10. "Atmosphere isolated compartment" means the living quarters must be enclosed and separated from the external atmosphere. Pressure equalization holes are exempt from this isolation requirement.

4.11. Soil sample collection shall commence within one minute upon landing. All soil analysis must be completed within 15 minutes of landing. Test results shall include time stamps for verification.

An additional experiment (limit of 1) is allowed, and may be flown. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety.

4.12. General Payload Requirements:

4.12.1. Black powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics will not be permitted for any surface operations.

4.12.2. Any UAS weighing more than .55 lbs. shall be registered with the FAA and the registration number marked on the vehicle.

5. Safety Requirements

5.1. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.

5.2. Each team shall identify a student safety officer. See rule 5.2 for all guidelines pertaining to the student safety officer.

MIDDLE/HIGH SCHOOL

PROJECT MILESTONES: CRITERIA & EXPECTATIONS

Proposal Requirements

At a minimum, the proposing team shall identify the following in a written proposal due to NASA's MSFC by the date specified in the project timeline. Proposals are subject to a maximum of 75 pages.

1. **General Information**
    a. Please visit the Student Launch website for instructions on submitting your proposal.
    b. A cover page that includes the name of the college/university or secondary education institution, mailing address, title of the project, and the date. The mailing address provided will be used if we need to mail anything throughout the project year to the team.
    c. Name, title, and contact information (including email address and phone number) for up to two adult educators (minimum of one required).
    d. Name, title, and contact information (including email address and phone number) for the team mentor. Team mentor NAR or TRA flyer number shall be included along with the level of certification they currently hold (see requirement 1.13).
    e. Name and email address for the student team leader.
    f. Name and email address for the student team member who will take responsibility for implementation of the safety plan (Safety Officer).
    g. 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 and technical personnel.
    h. Name of the NAR/TRA section(s) the team is planning to work with for purposes of mentoring, review of designs and documentation, and launch assistance.
2. **Facilities/Equipment**
    a. Description of facilities and hours of accessibility, necessary personnel, equipment, and supplies that are required to design and build the rocket and payload(s). Specify what is on hand and what will need to be acquired.
3. **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 shall be used for flight design and operations. The NAR/TRA mentor and Safety Officer shall oversee launch operations and motor handling.

The Federal Communications Commission (FCC) [www.fcc.gov] is a government agency that has specific rules and regulations regarding communications via radio, television, wire, satellite, and cable across the United States. Teams transmitting must ensure they are following all applicable local, state, and federal laws, including appropriate licensing for broadcasting via radio.

a. Provide a safety plan that does the following
    i. Detail how your team will perform hazards analysis, including identification of hazards, ranking and categorizing of risk, and mitigation of those hazards.
    ii. Detail how your team will manage safety in the various locations that will be utilized for the activities of your program, including: design, fabrication, storage, and launching.
    iii. Provide a preliminary list of Safety Data Sheets (SDS) for materials and chemicals your team anticipates will be used. The entire SDS need not be copied into the proposal. A series of hyperlinks, documents on a cloud storage, or sample screenshots is sufficient.

iv. Detail how and where your team will purchase, store, transport, and use rocket motors and other energetic devices.

    I. The team's NAR/TAR mentor is required to be the owner of your rocket and should always be present for activities involving rocket motors and other energetic devices.

b. Provide an example preliminary Hazards Analysis. This analysis does not need to be complete. It is meant only to demonstrate the concept described in the Safety Plan.

c. Describe Student Briefings that the team has planned. These should include subject, timeframe, and any necessary personnel.

d. Identify any federal, state, and/or local laws regarding unmanned rocket launches and motor handling and indicate how the team intends to abide by those laws. Include any specific actions the team will need to take to obey these laws.

   i. Examples of this could include the following: 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 Rocketry."

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

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

   ii. 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.

   iii. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. A team shall not fly a rocket until the mentor has reviewed the design, examined the build, and is satisfied the rocket meets established amateur rocketry design and safety guidelines.

   iv. Compliance with NAR High Power Rocket Safety Code.

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

4. **Technical Design**

   a. Demonstrate an understanding of rocket, recovery, and payload design to include the following:

      i. General vehicle dimensions, preliminary material selection and justification, and construction methods.

      ii. Projected altitude and describe how it was calculated.

      iii. Planned recovery system design.

      iv. Projected motor brand and designation.

      v. Detailed description of the team's projected payload.

      vi. Identify major technical challenges and solutions.

5. **Project Plan**

   a. Provide a detailed development schedule/timeline or work breakdown structure (WBS) covering all aspects necessary to complete the project successfully, including specific dates for meetings, activities, report writing, builds, travel, and milestones.

   b. Provide a detailed budget to cover all aspects necessary to complete the project successfully, including team travel to the launch, organized fair market values, vendors, and travel costs.

   c. Provide a detailed funding plan, including expected funding amounts, sources of funding, and addressing cost overruns and funding shortfalls.

   d. Include a STEM Industry OR Community STEM Engagement Plan (1 page maximum) (see pages 80–82).

Project Deliverables

a. A reusable rocket with required payload system ready for official launch.

b. A scale model of the rocket design shall be flown during the PDR or CDR milestones and the altimeter flight profile data or a quality video encompassing the entire liftoff and flight, as well as quality pictures of the landed configuration of the launch vehicle shall be reported in the CDR.

c. A full-scale Vehicle Demonstration Flight and Payload Demonstration Flight shall be flown, and a raw altimeter flight data file in csv or xlsx along with the flight profile graph, as well as quality pictures of the landed configuration of the launch vehicle shall be reported in the FRR and/or FRR Addendum.

d. A team social media presence established and maintained/updated throughout the project year.

e. Reports, PDF slideshows, and Milestone Review Flysheets completed and submitted to the Student Launch Projects management team by due dates.

f. Successful completion of PDR, CDR, FRR, FRR addendum (if applicable), LRR, and PLAR.

Preliminary Design Review (PDR)

The PDR demonstrates the overall preliminary design meets all requirements with acceptable risk, within the cost, schedule, and technical performance constraints, and establishes the basis for proceeding with detailed design. It shows the correct design options have been selected, and interfaces have been identified. 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 that follows the order of sections as they appear below.

Preliminary Design Review Report

Page Limit: PDR reports are to be no longer than 100 pages in length (not including title page).

Any additional content will not be considered while reviewing. Font size shall be at a minimum of 12 point.

I. Summary of PDR report (1 page maximum)

Team Summary—Include the following in a table:

- Team name and mailing address.
- Name of mentor, NAR/TRA number and certification level, and contact information.
- Indication of plans to launch in Huntsville during launch week or at home during the launch window of April 5th–May 4th.
- Team social media presence established. Include a table listing all social media handles.

Launch Vehicle Summary—Include the following in a table:

- Final primary and secondary motor choice
- Size and mass of individual sections:
  - Include the total length along with the lengths of each individual section of your vehicle. Include the total dry mass, total wet mass, fully ballasted mass (if applicable), and burnout mass. Finally, include the landing mass of each section of your launch vehicle.
- Recovery system:
  - Include drogue and main parachute brand, model, size, and projected descent rate. Include altimeter brand, model, and deployment settings. Include energetic material, quantity for main and backup, and any deployment altitudes.

Payload Summary

- Payload title
- Summarize payload experiment

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 payload criteria
- Changes made to project plan

III. Vehicle Criteria

Selection, Design, and Rationale of Launch Vehicle

- Include unique mission statement and mission success criteria.
- Review the design at a system level, going through each system's alternative designs, and evaluating the pros and cons of each alternative.
- For each alternative, present research on why that alternative should or should not be chosen.
- For each alternative, conduct a feasibility study.
- For each alternative, locate points of separation on each design and show location(s) of energetic materials
- After evaluating all alternatives, present a vehicle design with the current leading alternatives, and explain why they are the leading choices.
  - Describe each subsystem and the components within those subsystems.
  - Provide detailed dimensional drawings using the leading design.
  - Provide estimated masses for each subsystem.
  - Provide sufficient justification for design selections.
- Review different motor alternatives and present data on each alternative.

Recovery Subsystem

- Review the design at a component level, going through each components' alternative designs, and evaluating the pros and cons of each alternative.
- For each alternative, present research on why that alternative should or should not be chosen.
- Using the estimated mass of the launch vehicle, perform a preliminary analysis on parachute sizing, and determine what size is required for a safe descent.
- Include drawings/sketches, wiring diagrams, and electrical schematics.
- Choose leading components amongst the alternatives, present them, and explain why they are the current leaders. Teams shall discuss at a minimum: shock cord length, diameter, material, anchor point hardware and location, and strength ratings for all components.
- Prove that redundancy exists within the system.

Mission Performance Predictions

- Declare the team's official competition launch target altitude (ft.).
- Show flight profile simulations. This includes altitude, velocity, and acceleration versus time predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify the vehicle is robust enough to withstand the expected loads.
- Show stability margin and 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 expected descent time for the rocket and any section that descends untethered from the rest of the 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. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that original results are accurate.

- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV. Payload Criteria

Selection, Design, and Rationale of Payload

- Describe what the objective of the payload is and what experiment it will perform. What results will qualify as a successful experiment?
- Review the design at a system level, going through each system's alternative designs, and evaluating the pros and cons of each alternative.
- For each alternative, present research on why that alternative should or should not be chosen.
- For each alternative, conduct a feasibility study.
- After evaluating all alternatives, present a payload design with the current leading alternatives and explain why they are the leading choices.
- Include drawings and electrical schematics for all elements of the preliminary payload. List estimated masses for components.
- Describe the justification used when making design selections.
- Describe the preliminary interfaces between the payload and launch vehicle.
- Describe the preliminary design of the payload retention system.

V. Safety

- Demonstrate an understanding of all components needed to complete the project and how risks/delays impact the project.
- Provide a preliminary Personnel Hazard Analysis. The focus of the Hazard Analysis at PDR is identification of hazards, their causes, and the resulting effects. Preliminary mitigations and controls can be identified, but do not need to be implemented at this point unless they are specific to the construction and launching of the subscale rocket, or are hazards to the success of the SL program (i.e., cost, schedule, personnel availability). Rank the risk of each hazard for both likelihood and severity.
- Include data indicating the hazards have been researched (especially personnel). Examples: NAR regulations, operator's manuals, SDS, etc.
- Provide preliminary Failure Modes and Effects Analysis (FMEA) of the proposed design of the rocket, payload, payload integration, launch support equipment, and launch operations. Again, the focus for PDR is identification of hazards, causes, effects, and proposed mitigations. Rank the risk of each hazard for both likelihood and severity.
- Discuss any environmental concerns using the same format as the Personnel Hazard Analysis and FMEA.
  - This should include how the vehicle affects the environment and how the environment can affect the vehicle.
- 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 a 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. ncluding this information in a table is highly encouraged.

VI. Project Plan

Requirements Verification

- Create team derived requirements in the following categories: Vehicle, Recovery, and Payload. These are requirements for mission success that are beyond the minimum success requirements presented in this handbook. Demonstrate the requirements are not arbitrary and are required for the team's unique project.

Budgeting and Timeline

- Provide a line item budget for all aspects of the project with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.

- Provide a funding plan describing sources of funding, allocation of funds, and material acquisition plan.
- Provide a timeline including all team activities and expected activity durations. The schedule should be complete and encompass the full term of the project. Deliverables should be defined with reasonable activity duration. GANTT or milestones charts are encouraged.

Preliminary Design Review Presentation

Please include the following in your presentation:

- Vehicle dimensions and justification
- Vehicle materials and justification
- Static stability margin and CP/CG locations
- Visually show points of separation along with location of energetic materials and all recovery components clearly labeled.
- Final motor selections and justification
- Thrust-to-weight ratio and rail exit velocity
- Discussion of alternative designs and why each should or should not be chosen
- Drawing/discussion of each major component and subsystem, especially the recovery subsystem
- Discussion of current Mission Performance Predictions
- Preliminary payload design
- Preliminary payload retention system design
- Requirements compliance plan

The PDR will be presented to a panel that may be comprised of scientists, engineers, safety experts, education specialists, and industry partners. The purpose of this review is to convince the NASA Review Panel 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, which will culminate with the Critical Design Review.

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

The presentation of the PDR shall be well prepared with an overall professional appearance. This includes, but is not limited to: easy-to-read 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 rather than 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)

The CDR establishes the maturity of the design is appropriate to support proceeding to full-scale fabrication, assembly, and integration. It demonstrates 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, and technical performance 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 expects a professional and polished report that follows the order of sections as they appear below.

Critical Design Review Report

Page Limit: CDR reports are to be no longer than 100 pages in length (not including title page).

Any additional content will not be considered while reviewing. Font size shall be at a minimum of 12 point.

I. Summary of CDR report (1 page maximum)

Team Summary—Include the following in a table:

- Team name and mailing address.
- Name of mentor, NAR/TRA number and certification level, and contact information.
- If planning to conduct the final competition launch at home, teams shall provide anticipated primary and backup launch locations and dates.

Launch Vehicle Summary—Include the following in a table:

- Official target altitude (ft.).
- Primary and secondary motor choice.
- Size and mass of individual sections:
  - Include the total length along with the lengths of each individual section of your vehicle. Include the total dry mass, total wet mass, fully ballasted mass (if applicable), and burnout mass. Finally, include the landing mass of each section of your launch vehicle.
- Recovery system:
  - Include drogue and main parachute brand, model, size, and projected descent rate. Include altimeter brand, model, and deployment settings. Include energetic material, quantity for main and backup, and any deployment altitudes.
- Rail size

Payload Summary

- Payload title
- Summarize payload 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 payload criteria
- Changes made to project plan

III. Vehicle Criteria

Design and Verification of Launch Vehicle

- Include unique mission statement and mission success criteria.
- Identify which of the design alternatives from PDR were chosen as the final components for the launch vehicle. Describe why those alternatives are the best choices.
- Using the final designs, create dimensional and computer-aided design (CAD) drawings to illustrate the final launch vehicle, its subsystems, and its components.
- Using the final designs, create dimensional cross-sectional views of each airframe and coupler component.
- Using the final designs, locate points of separation and show location(s) of energetic materials.
- Demonstrate the designs are complete and ready to manufacture.
- Discuss the integrity of design.
  - Suitability of shape and fin style for mission
  - Proper use of materials in fins, bulkheads, and structural elements

- Sufficient motor mounting and retention
- Estimate the final mass of the launch vehicle as well as the individual subsystems

- Provide justification for material selection, dimensioning, component placement, and other unique design aspects.

Subscale Flight Results

- At least one data gathering device shall be on-board the launch vehicle during the test launch. At a minimum, this device shall record the apogee of the rocket. If the device can record more than apogee, please include the actual flight data in the report.
- Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) will not be accepted.
- Quality pictures of the as landed configuration of all sections of the launch vehicle. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Describe the scaling factors used when scaling the rocket. What variables were kept constant and why? What variables do not need to be constant and why?
- Describe launch day conditions and perform a simulation using those conditions.
- Perform an analysis of the subscale flight.
  - Compare the predicted flight model to the actual flight data. Discuss the results.
  - Discuss any error between actual and predicted flight data.
  - Estimate the drag coefficient of the full-scale rocket with subscale data.
- Discuss how the subscale flight data has impacted the design of the full-scale launch vehicle.

Recovery Subsystem

- Identify which of the design alternatives from PDR were chosen as the final components for the recovery subsystem. Describe why those alternatives are the best choices.
- Include a Concept of Operations (CONOPS) of your recovery system.
- Describe in detail the parachute sizes, locations, and method of protection. Teams shall discuss at a minimum: shock cord length, diameter, material, anchor point hardware and location, and strength ratings for all components.
- Discuss the electrical components and prove that redundancy exists within the system.
- Include drawings/sketches, wiring diagrams, and electrical schematics.
- Provide the operating frequency of the locating tracker(s).

Mission Performance Predictions (using the most up-to-date model)

- Show flight profile simulations. This includes altitude, velocity, and acceleration versus time predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify the vehicle is robust enough to withstand the expected loads.
- Show stability margin and 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 expected descent time for the rocket and any section that descends untethered from the rest of the 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. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify the original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV. Payload Criteria

Design of Payload Experiment

- Identify which of the design alternatives from PDR was chosen for the payload. Describe why that alternative and its components were chosen.
- Include a Concept of Operations (CONOPS) of your payload system.
- Review the design at a system level.
  - Include drawings and specifications for each component of the payload, as well as the entire payload assembly.
  - Describe how the payload components interact with each other.
  - Describe how the payload integrates within the launch vehicle.
  - Describe the payload retention system.
- Demonstrate the design is complete.
- Discuss the payload electronics with special attention given to safety switches and indicators. Include the following:
  - Drawings and schematics
  - Block diagrams
  - Batteries/power
  - Switch and indicator wattages and locations
- Provide justification for all unique aspects of your payload (materials, dimensions, placement, etc.)

V. Safety

Launch concerns and operation procedures

Submit a draft of final assembly and launch procedures/checklists including:

- Recovery preparation
- Payload preparation
- Electronics preparation
- Rocket preparation
- Motor preparation
- Setup on the launch pad
- Igniter installation
- Launch procedure
- Troubleshooting
- Post-flight inspection

These procedures/checklists should include specially demarcated steps related to safety. Examples include:

- Warnings of hazards that can result from missing a step
- PPE required for a step in the procedure (identified BEFORE the step)
- Required personnel to complete a step or to witness and sign off verification of a step

Safety and Environment (Vehicle and Payload)

- Update the Personnel Hazard Analysis, the Failure Modes and Effects Analysis, and the Environmental Hazard Analysis to include:
  - Finalized hazard descriptions, causes, and effects. These should specifically identify the mechanisms for the hazards, and uniquely identify them from other hazards. Ambiguity is not useful in safety work.
  - A near-complete list of mitigations, addressing the hazards and/or their causes
  - A preliminary list of verifications for the identified mitigations. These should include methods of verifying the mitigations and controls are (or will be) in place, and how they will serve to ensure the mitigation.

These do not need to be finalized at this time, but they will be required for FRR. Example verifications include: test data, written procedures and checklists, design analysis, as-built configuration drawings, and Personal Protective Equipment.

VI. Project Plan

Testing

- Identify all tests required to prove the integrity of the design.
- For each test, present the test objective and success criteria, as well as testing variable and methodology.
- Justify why each test is necessary to validate the design of the launch vehicle and payload.
- Discuss how the results of a test can cause any necessary changes to the launch vehicle and payload.
- Present results of any completed tests.
  - Describe the test plan and whether or not the test was a success.
  - How do the results drive the design of the launch vehicle and/or payload?

Requirements Compliance

- Create a verification plan for every requirement from Sections 1–5 of the project requirements listed in this handbook. Identify if test, analysis, demonstration, or inspection are required to verify the requirement. After identification, describe the associated plan needed for verification.
- Update the ongoing list of team derived requirements in the following categories: Vehicle, Recovery, and Payload. These are a set of requirements for mission success that are beyond the minimum success requirements presented in this handbook. Create a verification plan for each team derived requirement identifying whether test, analysis, demonstration, or inspection is required with an associated plan.

Budgeting and Timeline

- Provide an updated line item budget for all aspects of the project with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Provide an updated funding plan describing sources of funding, allocation of funds, and material acquisition plan.
- Provide an updated timeline, including all team activities and expected activity durations. The schedule should be complete and encompass the full term of the project. Deliverables should be defined with reasonable activity duration. GANTT or milestone charts are encouraged.

Critical Design Review Presentation

Please include the following information in your presentation:

- Final launch vehicle and payload dimensions
- Discuss key design features
- Visually show points of separation along with location of energetic materials and all recovery components clearly labeled
- Final motor choices
- Official target altitude (ft.)
- 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
- Recovery system CONOPS
- 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 data

- Tests of the staged recovery system
- Final payload design overview
- Payload integration plans
- Payload retention system
- 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 scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the final design of the launch vehicle and payload, proving the design meets the mission objectives and requirements and can be safely 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 that will culminate in a Flight Readiness Review.

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

The presentation of the CDR shall be well prepared with an overall professional appearance. This includes, but is not limited to: easy-to-read 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 rather than 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)

The FRR examines tests, demonstrations, analyses, and audits that determine the overall system (all subsystems 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 hardware, software, personnel, and procedures are operationally ready.

The panel will be expecting a professional and polished report that follows the order of sections as they appear below.

Flight Readiness Review Report

Page Limit: FRR reports are to be no longer than 100 pages in length (not including title page).

Any additional content will not be considered while reviewing. Font size shall be at a minimum of 12 point.

I. Summary of FRR report (1 page maximum)

Team Summary—Include the following in a table:

- Team name and mailing address.
- Declared final launch location. If flying at a local launch, identify the launch club, national affiliation name and contact information of a club officer who will attend the launch, and anticipated date of launch. Provide this information for both the primary and back up launch plans.
- Name of mentor, NAR/TRA number and certification level, and contact information.

Launch Vehicle Summary—Include the following in a table:

- Size and mass of individual sections:
  - Include the total length along with the lengths of each individual section of your vehicle. Include the total dry mass, total wet mass, fully ballasted mass (if applicable), and burnout mass. Finally, include the landing mass of each section of your launch vehicle.
- Competition Launch Motor.
- Target altitude (ft.).

- Recovery system:
  - Include drogue and main parachute brand, model, size, and projected descent rate. Include altimeter brand, model, and deployment settings. Include energetic material, quantity for main and backup, and any deployment altitudes.
- Rail size

Payload Summary

- Payload title
- Summarize payload 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 payload criteria
- Changes made to project plan

III. Vehicle Criteria

Design and Construction of Vehicle

- Describe any changes in the launch vehicle design from CDR and explain why those changes are necessary.
- Discuss final locations of separation along with where black powder or energetics will be located.
- Describe 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.)
- Discuss flight reliability confidence. Demonstrate the design can meet mission success criteria.
- Prove the vehicle is fully constructed and fully document the construction process.
- Include schematics of the AS-BUILT rocket. There is a good chance dimensions have changed slightly due to the construction process.
- Discuss how and why the constructed rocket differs from earlier models.

Recovery Subsystem

- Describe and defend the robustness of the as-built and as-tested recovery system.
  - Structural elements (bulkheads, shock cords, attachment hardware, anchor points, etc.)
  - Electrical elements (altimeters/computers, switches, connectors)
  - Redundancy features
  - As-built parachute sizes and descent rates with justification, include all necessary calculations
  - Drawings, diagrams, and schematics of the as-built electrical and structural assemblies
  - Rocket-locating transmitters with a discussion of frequency, wattage, and range
- Discuss the sensitivity of the recovery system to on-board devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis section.

Mission Performance Predictions

- All of the following calculations, simulations, and models shall be done using the as-built launch vehicle and payload.
- Show flight profile simulations. This includes altitude, velocity, and acceleration versus time predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify the vehicle is robust enough to withstand the expected loads.
- Show stability margin and as-built 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 expected descent time for the rocket and any section that descends untethered from the rest of the 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. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV. Payload Criteria

Payload Design and Testing

- Describe any changes in the payload design from CDR and explain why those changes are necessary.
- Describe unique features of the payload. Include the following:
  - Structural elements
  - Electrical elements
- Discuss flight reliability confidence. Demonstrate the design can meet mission success criteria.
- Prove the payload is fully constructed and fully document the construction process.
- Include schematics of the AS-BUILT payload. There is a good chance dimensions have changed slightly due to the construction process.
- Discuss how and why the constructed payload differs from earlier models.
- Discuss the planned or completed Payload Demonstration Flight. Include the following:
  - Date of flight or planned future flight
  - Success criteria
  - Results of flight
  - Analysis of payload retention system performance (if applicable)

V. Demonstration Flights

Provide for all flights:

- Identify whether the flight was conducted to fulfill the requirements for the Vehicle Demonstration Flight, Payload Demonstration Flight, or both.
- Date of flight
- Location of flight
- Launch conditions
- Motor flown (brand and designation)
- Ballast flown (lbs.)
- Final payload flown (Y/N)
- Air brake system status during test flight (if design incorporates air brakes)
- Official target altitude (ft.)
- Predicted altitude from simulations (ft.)
- Measured altitude (ft.)
- Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.
- Raw altimeter data in .csv or .xlsx format (subscale flight is exempt from this requirement).

- Quality pictures of the as landed configuration of all sections of the launch vehicle. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Identify all vehicle and recovery systems that functioned as intended.
- Identify and discuss any vehicle or recovery hardware or software that failed to function as intended.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
  - Include a table of kinetic energy calculations that provides, at a minimum: descent rate under both drogue and main parachutes, gross lift-off mass, landing mass of each individual rocket section, final kinetic energy number.
  - When calculating landing masses, subtract the mass of expended propellant, deployed recovery parachutes, and shock cord as these are external to the launch vehicle. Clearly document the subtracted values. The sum of the propellant mass, recovery components, and individual section landing masses shall equal the gross lift-off mass.
- If the payload was not present, describe how the payload was simulated during the flight.
- Perform an analysis of the Vehicle Demonstration Flight. Update your simulated flight model with launch day condition data and compare the predicted flight performance to the actual flight data. Discuss the results.
- Estimate the drag coefficient of the full-scale rocket utilizing launch data. Use this value to run a post-flight simulation.
- Discuss any error between actual and predicted flight data.
- Discuss the similarities and differences between the full-scale and subscale flight results.
- Identify any hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss lessons learned from the flight.
- Identify any off-nominal events during mission execution.

If the final, active payload was flown (i.e., the flight qualified as a Payload Demonstration Flight), also provide:

- Identify all retention systems that functioned as intended.
- Identify and discuss any retention hardware or software that failed to function as intended.
- Identify any retention hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss retention system lessons learned from the flight.
- Summarize the designed payload mission sequence, from activation or deployment through mission completion.
- Identify all payload systems that functioned as intended.
- Identify and discuss any payload hardware or software that failed to function as intended.
- Identify any payload hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss payload lessons learned from the flight.

Provide a list of any planned future demonstration flights. Include a summary of the team's objectives for each launch.

VI. Safety and Procedures

Safety and Environment (Vehicle and Payload)

- Update the Personnel Hazard Analysis, the Failure Modes and Effects Analysis, and the Environmental Hazard Analysis to include:
  - Finalized hazard descriptions, causes, and effects for the rocket and payload the team has built.

    Note: These sections can change from CDR to FRR if there are design related changes made as a result of subscale and full-scale test flights, and refined modeling and analysis.

These should specify the mechanisms for the hazards and uniquely identify them from other hazards. Ambiguity is not useful in safety work.

  – A completed list of mitigations addressing the hazards and/or their causes.
  – A completed list of verifications for the identified mitigations. This should include methods of verifying the mitigations and controls are (or will be) in place, and how they will serve to ensure the mitigation.

- Be sure to discuss any concerns that remain as the project moves into the operational phase of the lifecycle. Emphasize concerns related to your procedures as well as the environment.

Launch Operations Procedures

Provide detailed procedures and checklists for each of the following (at a minimum):

- Recovery preparation
- Payload preparation
- Electronics preparation
- Rocket preparation
- Motor preparation
- Setup on launch pad
- Igniter installation
- Launch procedure
- Troubleshooting
- Post-flight inspection

These procedures and checklists should include specially demarcated steps related to safety. Examples include:

- Warnings of hazards that can result from missing a step
- PPE required for a step in the procedure (identified BEFORE the step)
- Required personnel to complete a step or to witness and sign off verification of a step

VII. Project Plan

Testing

- Prove that all testing is complete and provide test methodology and discussion of results.
- Discuss whether each test was successful or not.
- Discuss lessons learned from the tests conducted.
- Discuss any differences between predicted and actual results of the tests conducted.

Requirements Compliance

- Review and update the verification plan. Describe how each handbook requirement was verified using testing, analysis, demonstration, or inspection.
- Review and update the team derived requirements for the vehicle, recovery system, and payload. Describe how each team derived requirement was verified using testing, analysis, demonstration, or inspection.

Budgeting and Funding Summary

- Provide an updated line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Provide an updated funding plan describing sources of funding, allocation of funds, and a material acquisition plan for any items that have not yet been obtained.

Flight Readiness Review Presentation

Please include the following information in your presentation:

- Launch vehicle design and dimensions
- Visually show points of separation along with location of energetic materials and all recovery components clearly labeled
- 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
- Vehicle Demonstration Flight results. Present and discuss the actual flight test data, as well as any issues or failures encountered.
- Recovery system tests
- Summary of requirements verification (launch vehicle)
- Payload design and dimensions
- Key design features of the payload
- Payload integration into the vehicle
- Payload retention system design
- Payload Demonstration Flight plans. If complete, discuss the actual flight test results, as well as any issues or failures encountered.
- Summary of requirements verification (payload)
- Interfaces with ground systems (vehicle and payload)

The FRR will be presented to a panel that may be comprised of scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the as-built launch vehicle and payload, showing the launch vehicle and payload meet all requirements and mission objectives and 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 the team participants deliver the report and answer all questions. The mentor or faculty advisor shall not participate in the presentation.

The presentation of the FRR shall be well prepared with an overall professional appearance. This includes, but is not limited to: easy-to-read 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 Addendum

The FRR Addendum is a required submission for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report. It is expected to be a brief but informative document highlighting the successes and failures of the new flight(s) and any updates or changes to the vehicle or payload design. The information reported in the FRR Addendum will be reviewed by NASA to determine eligibility of each team to perform their competition launch.

Flight Readiness Review Addendum Document Outline

Page Limit: The FRR Addendum does not have a specific minimum or maximum page count, but each requested item listed below shall be sufficiently addressed.

I. Summary of FRR Addendum

Team Summary

- Team name, mailing address, and contact information

Purpose of Flight(s)

- Identify whether the flight(s) conducted were conducted to fulfill the requirements for the Payload Demonstration Flight, Vehicle Demonstration Re-flight, or both.

Flight Summary Information (for each flight)

- Date of flight
- Location of flight
- Launch conditions
- Motor flown (brand and designation)
- Ballast flown (lbs.)
- Final payload flown (Y/N)
- Air brake system status during test flight (list N/A if your vehicle does not contain an air brake system)
- Official target altitude (ft.)
- Predicted altitude from simulations (ft.)
- Measured altitude (ft.)
- Identify any off-nominal events during mission execution

Changes made since FRR

- Describe changes made to the vehicle design and explain why those changes are necessary.
- Describe changes made to the payload design and explain why those changes are necessary.

II. Payload Demonstration Flight Results (if applicable)

Summarize the retention system and mission of the payload, along with discussing its successes and failures.

- Summarize the designed payload mission sequence, from activation or deployment through mission completion
- Summarize the design of the payload retention system
- Provide altimeter flight profile data
- Identify all systems that functioned as intended
- Identify and discuss any hardware or software that failed to function as intended
- Identify any hardware that was damaged and required repair or replacement and discuss the plan of action
- Discuss payload lessons learned from the flight

III. Vehicle Demonstration Re-flight (if applicable)

Summarize the flight of the rocket and discuss its successes and failures.

- Identify all systems that functioned as intended.
- Identify and discuss any hardware or software that failed to function as intended.
- If the payload was not present, describe how the payload was simulated during the flight.
- Altimeter flight profile data output with accompanying altitude and velocity versus time plots. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.
- Include quality pictures of the as landed configuration of all sections of the launch vehicle. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
  - Include a table of kinetic energy calculations that provides, at a minimum: descent rate under both drogue and main parachutes, gross lift-off mass, landing mass of each individual rocket section, final kinetic energy number
  - When calculating landing masses, subtract the mass of expended propellant, deployed recovery parachutes, and shock cord as these are external to the launch vehicle. Clearly document the subtracted values. The sum of the propellant mass, recovery components, and individual section landing masses shall equal the gross lift-off mass.
- Perform an analysis of the Vehicle Demonstration Re-flight. Update your simulated flight model with launch day condition data and compare the predicted flight performance to the actual flight data. Discuss the results.
- Estimate the drag coefficient of the full-scale rocket utilizing launch data. Use this value to run a post-flight simulation.
- Identify any hardware that was damaged and required repair or replacement and discuss the plan of action.
- Discuss lessons learned from the flight.

Launch Readiness Review (LRR)

The Launch Readiness Review (LRR) will be conducted by NASA and the National Association of Rocketry (NAR), our launch services provider. These inspections are mandatory for team members and mentors. These names were submitted as part of your team list. All rockets/payloads will undergo a detailed, deconstructive, hands-on inspection.

Your team should bring all components of the rocket and payload except for the motor, black powder, and electric 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 and electrical integrity, as well as safety concerns. At a minimum, all teams shall have:

- An airframe prepared for flight with the exception of energetic materials
- Data from the previous flight(s)
- A list of any flight anomalies that occurred on the previous full-scale flight(s) and the mitigation actions
- A list of any changes to the airframe since the last flight
- Flight simulations
- Pre-flight launch procedures and checklist(s)
- Fly Sheet
- Team name and contact info in or on the airframe and any untethered section of the vehicle

Each team will demonstrate these tasks to the NAR Review Team. The RSO has final word on whether the rocket and/or payload may be flown on Launch Day.

A "punch list" will be generated for each team. Items identified on the punch list must be corrected and verified by NAR/NASA prior to Launch Day. A flight card will be provided to teams and is to be completed and submitted at the LCO booth on Launch Day.

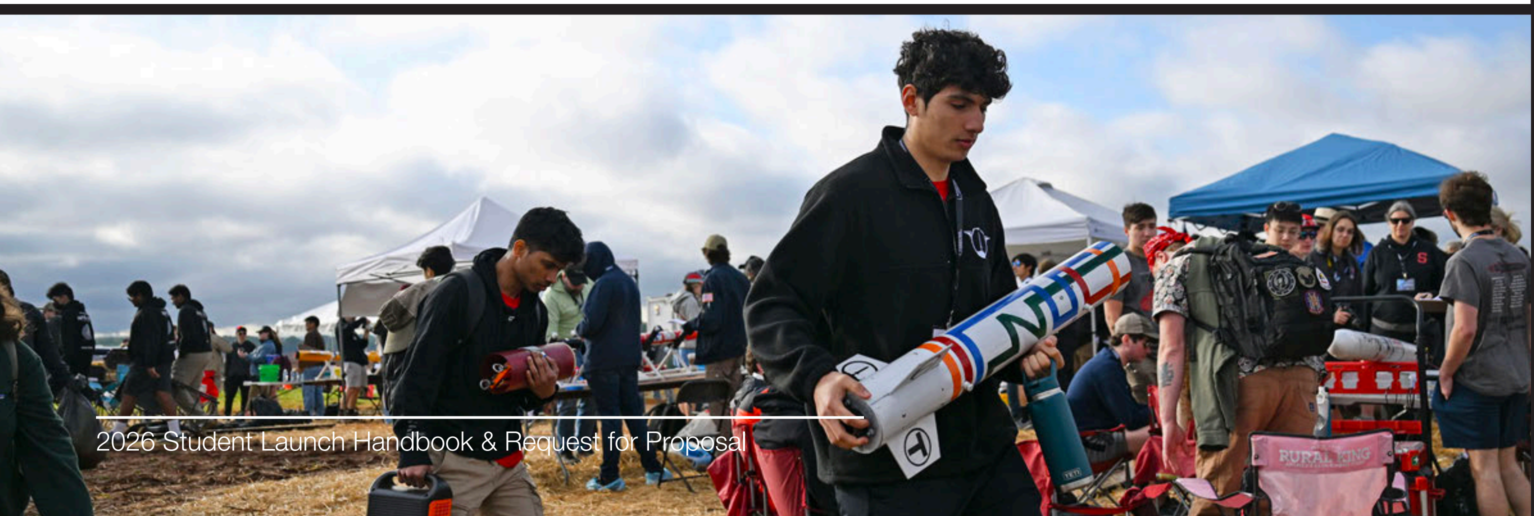
Post-Launch Assessment Review (PLAR)

The PLAR is an assessment of system in-flight and payload mission performance from your final competition launch. All scientific and engineering results and findings shall be reported along with a cumulative summary of your teams' experience on the project as a whole.

Page Limit: PLAR reports are to be no longer than 25 pages in length (not including title page).

Any additional content will not be considered while reviewing.

- Team name
- Motor used
- Vehicle dimensions
- Altitude reached (ft.)
- Official target altitude (ft.)
- Competition Launch altimeter flight profile data
- Vehicle summary
- Quality photo of fully assembled and painted final competition rocket as flown. Photo shall only include the rocket and not any team members.
- Payload summary
- Data analysis and results of the vehicle and payload
- Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) will not be accepted
- Raw altimeter data in .csv or .xlsx format
- Quality pictures of the as landed configuration of all sections of the launch vehicle. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. Close-up, high-quality photos of individual rocket sections are more effective than a single wide shot.
- Describe separation events and state altitude of events
- Ascent and descent analysis and metrics of the launch vehicle
- Scientific value achieved
- Visual data observed
- Lessons learned for vehicle, payload, and overall project
- Discussion of successes and failures of individual subsystems
- Summary of overall experience (what you attempted to do versus the results; how valuable you felt the experience was). Include feedback on program elements you found effective, areas that need improvement, and specific recommendations for changes you'd like to see.
- Include STEM Industry Engagement OR Community STEM Engagement Summary (1-page maximum) (see pages 80–82)
- Final Budget summary



MIDDLE/HIGH SCHOOL
ENGAGEMENT

Engagement Requirement Option 1—STEM Industry Engagement:

Provide a plan for how your team will engage with industry professionals and community leaders to enhance your project's impact and educational value while developing meaningful connections that could lead to future workforce opportunities for your team members. Your plan should be no more than 1 page maximum.

Proposal Requirement—STEM Industry Engagement Plan:

- Audit local community and create a list of potential partners and alignment with project goals. Consider technical expertise, mentorship, skills development, certifications or resources sought to advance project goals.
- Your plan should assess the team's **Professional Development Strategy** (choose at least one from this category).
  - Summarize mentorship arrangements your team plans to target with industry experts/partners.
  - Identify skills development and certification opportunities your team members plan to seek with industry partners (e.g. welding, safety training, electrical, software).
  - Explain how your team's industry connections would support team members' career goals.
  - Identify potential internship, fellowship, apprenticeship, or career opportunities your team members plan to seek.
- Your plan should assess the team's **Community Leadership Outreach** (choose at least one from this category).
  - Describe how your team engage with local civic and community leaders.
  - Summarize the method your team will use to raise awareness about your NASA challenge participation.
  - Identify and outline connections your team has and/or will seek with community leaders and industry partners.

PLAR Requirement—STEM Industry Engagement Summary

- Provide a list of partners you engaged with this activity year. Identify the area in which you engaged with them: technical expertise, mentorship, skills development, certifications or resources sought to advance project goals.
- Your summary should assess the team's Professional Development Strategy (choose at least one from this category).
  - Summarize any mentorship arrangements your team developed with industry experts/partners.
  - Identify skills development and certification opportunities your team members received through industry partners (e.g. welding, safety training, electrical, software).
  - Explain how your team's industry connections supported team members' career goals.
  - Identify internship, fellowship, apprenticeship, or career opportunities your team members have received or will receive.
- Your summary should assess the team's Community Leadership Outreach (choose at least one from this category).
  - Describe how your team engaged with local civic and community leaders.
  - Summarize the method your team used to raise awareness about your NASA challenge participation.
  - Identify and outline connections your team has or developed with community leaders and industry partners.

Engagement Requirement Option 2—Community STEM Engagement

Provide a plan for how your team will engage with local schools, educational institutions, and your community to enhance your project's impact and educational value while developing meaningful connections to inspire the next generation of space explorers. Your plan should be no more than 1 page maximum.

Proposal Requirement—Community STEM Engagement Plan

- Audit local schools, and community educational institutions, and create a list of potential opportunities for your team to host or implement STEM Engagement events.
- Your plan should assess the team's STEM Engagement and Outreach Strategy (include all three from this category)
  - Identify a goal for your team to reach with your STEM Engagement and Outreach Strategy.
  - Summarize activities, or events, the team plans to host or implement in for STEM Engagement.
  - Provide potential dates or schedule for your plan.

PLAR Requirement—Community STEM Engagement Summary

- Provide a list of local schools, and/or community educational institutions your team partnered with for STEM Engagement activities and events.
- Your summary should assess the team's **STEM Engagement and Outreach Strategy** (include all three from this category)
  - Summarize how your team reached your goal with your STEM Engagement and Outreach Strategy.
  - Summarize each activity, or event your team implemented.
  - Provide activity and event dates along with number of participants engaged with for each.

MIDDLE/HIGH SCHOOL
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 (9,208 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 1,500 feet, whichever is greater, or 1,000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1,500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. **Launcher Location**. My launcher will be 1,500 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	1,000
10,240.01 – 20,480.00	N	125	1,000	1,500
20,480.01 – 40,960.00	O	125	1,500	2,000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors Revision as of August 2012.

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

MIDDLE/HIGH SCHOOL AWARDS

Middle and High School Division Awards

Award	Award Description	Determined By
Community STEM Engagement Award	Awarded to the team that is determined to have best inspired the study of rocketry and other science, technology, engineering, and math (STEM) related topics in their community.	NASA Panel
Social Media Award	Awarded to the team that has the most active and creative social media presence throughout the project year.	NASA Panel
Altitude Award	Awarded to the team that comes closest to their declared target altitude on their competition launch.	NASA Panel
Best Looking Rocket Award*	Awarded to the team that is judged by their peers to have the "Best Looking Rocket."	Peers
Vehicle Design Award	Awarded to the team with the most creative and innovative overall vehicle design for their intended payload while still maximizing safety and efficiency.	NASA Panel
Experiment Design Award	Awarded to the team with the most creative and innovative payload design while maximizing safety and science value.	NASA Panel
Judges' Choice Award	Selected during Launch Week by a panel of guest judges and awarded for the best combination of payload innovation, vehicle design and construction, and public engagement.	VIP Panel
3D Printed Award	Awarded to the team with the best consideration, design, and implementation in regards to 3D printing of launch vehicle and payload.	NASA Panel

* Only teams traveling to the NASA's Launch Complex event are eligible.

Student Design Challenge Awards

The Student Design Challenges provide foundational learning opportunities for students from middle school through graduate level, preparing them for the future workforce through engagement in Artemis-focused challenges that align with mission needs. Teams from across all challenges will be selected to receive prestigious awards in the three categories below.

Pay It Forward Award
This award is given to teams that best conduct impactful educational engagement events in their community or beyond. Educational engagement includes instructional, hands-on activities where participants engage in learning a STEM-related concept by actively participating in an activity.

Innovation Award
This award is given to teams that best create new, innovative ideas and/or solutions within the scope of their respective challenge. Ingenuity, creativity, and inventiveness in either technology or nontechnology focused ideas are awarded for their original ideas, creating efficiency, effective results, and/or solving a problem.

Artemis Educator Award
This award is given to educators/faculty/mentors in each challenge as nominated by student team members. Student team members will recognize their faculty/mentor(s) who inspire learners and motivate them to work hard, achieving more than the team members thought possible. The award acknowledges the time and dedication educators/faculty/mentors take to be exceptional teachers. Educators/faculty/mentors are noted for their commitment to learning and their valuable efforts for motivating and inspiring others. The NASA management team shall share the nomination process after the FRR milestone.

National Aeronautics and Space Administration

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www.nasa.gov/marshall

www.nasa.gov

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