National Aeronautics and
Space Administration

2018 NASA SL Student Launch

College and University Handbook

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.

Table of Contents

Proposal/Statement of Work

Vehicle/Payload Criteria

Safety

Related Documents

Timeline for NASA Student Launch Projects

(Dates are subject to change.)

August 2017

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

September 2017

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

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

Fred Kepner: fred.kepner@nasa.gov

October 2017

06 Awarded proposals announced
12 Kickoff and PDR Q&A

November 2017

03 Team web presence established, and URL sent to project office.
03 Preliminary Design Review (PDR) reports, presentation slides, and flysheet posted on the team Web site by 8:00 a.m. CDT.
06-29 PDR video teleconferences

December 2017

06 CDR Q&A

January 2018

12 Critical Design Review (CDR) reports, presentation slides, and flysheet posted on the team Web site by 8:00 a.m. CST.
16-31 CDR video teleconferences

February 2018

07 FRR Q&A

March 2018

05 Flight Readiness Review (FRR) reports, presentation slides, and flysheet posted to team Web site by 8:00 a.m. CST.
06-22 FRR video teleconferences

April 2018

04 Teams travel to Huntsville, AL
04 Launch Readiness Reviews (LRR)
05 Official Launch Week Kickoff, LRRs. Launch Week Activities.
06 Launch Week Activities
07 Launch Day
07 Banquet
08 Backup launch day
27 Post-Launch Assessment Review (PLAR) posted on the team Web site by 8:00 a.m. CDT.

Acronym Dictionary

AGL = Above Ground Level

APCP = Ammonium Perchlorate Composite Propellant

CDR = Critical Design Review

CG = Center of Gravity

CP = Center of Pressure

EIT = Electronics and Information Technology

FAA = Federal Aviation Administration

FN = Foreign National

FRR = Flight Readiness Review

HEO = Human Exploration and Operations

LCO = Launch Control Officer

LRR = Launch Readiness Review

MSDS = Material Safety Data Sheet

MSFC = Marshall Space Flight Center

NAR = National Association of Rocketry

PDR = Preliminary Design Review

PLAR = Post Launch Assessment Review

PPE = Personal Protective Equipment

RFP = Request for Proposal

RSO = Range Safety Officer

SLI = Student Launch Initiative

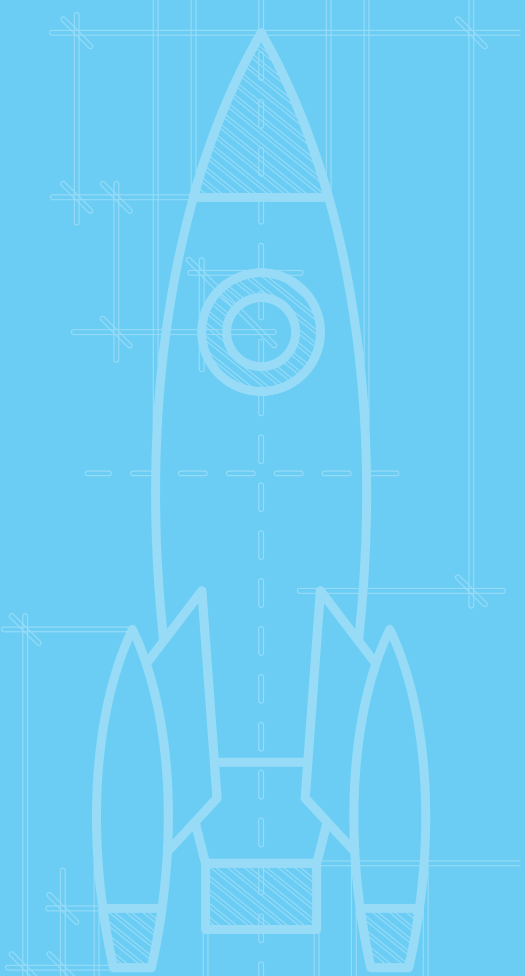
SME = Subject Matter Expert

SOW = Statement of Work

STEM = Science, Technology, Engineering, and Mathematics

TRA = Tripoli Rocketry Association

Proposal/ Statement of Work



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

1. **Project Name: NASA Student Launch Initiative for Colleges and Universities**

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

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

4. **Introduction**

The Academic Affairs Office at NASA Marshall Space Flight Center (MSFC) seeks proposals from colleges and universities to conduct the NASA University Student Launch Initiative (USLI) during the 2017-2018 academic year. The USLI is a research-based, competitive, and experiential learning project that provides relevant and cost-effective research and development. Additionally, NASA USLI connects learners, educators, and communities in NASA-unique opportunities that align with Science, Technology, Engineering, and Mathematics (STEM) Challenges. Supported by the Office of Education, Human Exploration and Operations (HEO) Mission Directorate, and commercial industry, USLI is a unique, NASA-specific opportunity to provide resources and experiences for university and college students.

The project involves reaching a broad audience of colleges and universities across the nation in an 8-month commitment to design, build, launch, and fly a payload(s) and vehicle components that support NASA research on high-power rockets to an altitude of 5,280 feet above ground level (AGL). The challenge is based on team selection of one of the following experiment options: 1) target identification, 2) deployable rover, or 3) landing coordinates via triangulation. College and university teams must successfully complete the requirements for one of the provided experiments in Section 4 and are eligible for awards through Student Launch. Any team who wishes to incorporate additional research through the use of a separate payload may do so. The team must provide documentation in all reports and reviews on components and systems outside of what is required for the project.

After a competitive proposal selection process, teams participate in a series of design reviews that are submitted to NASA via a team-developed Web site. These reviews mirror the NASA engineering design lifecycle, providing a NASA-unique experience that prepares individuals for the HEO workforce. Teams must successfully complete a Preliminary Design Review (PDR), Critical Design Review (CDR), Flight Readiness Review (FRR), Launch Readiness Review (LRR) that includes safety briefings, and an analysis of vehicle systems, ground support equipment, and flight data. Each team must pass a review in order to move to a subsequent review. Teams will present their PDR, CDR, and FRR to a review panel of scientists, engineers, technicians, and educators via video teleconference. Review panel members, the Range Safety Officer (RSO), and Subject Matter Experts (SME) provide feedback and ask questions in order to increase the fidelity between the SL and research needs, and will score each team according to a standard scoring rubric.

The requirements for NASA Student Launch are as follows:

1. **General Requirements**
    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).

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

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

    1.4. The team must identify all team members attending launch week activities by the Critical Design Review (CDR). Team members will include:
        1.4.1. Students actively engaged in the project throughout the entire year.
        1.4.2. One mentor (see requirement 1.14).
        1.4.3. No more than two adult educators.

    1.5. The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement Activity Report, by FRR. An educational engagement activity report will be completed and submitted within two weeks after completion of an event. A sample of the educational engagement activity report can be found on page 31 of the handbook. To satisfy this requirement, all events must occur between project acceptance and the FRR due date.

    1.6. The team will develop and host a Web site for project documentation.

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

    1.8. All deliverables must be in PDF format.

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

    1.10. In every report, the team will include the page number at the bottom of the page.

    1.11. The team will 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 broadband Internet connection. Cellular phones can be used for speakerphone capability only as a last resort.

    1.12. All teams will be required to use the launch pads provided by Student Launch's launch service provider. No custom pads will be permitted on the launch field. Launch services will have 8 ft. 1010 rails, and 8 and 12 ft. 1515 rails available for use.

1.13. Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194)

Subpart B-Technical Standards (http://www.section508.gov):

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

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

2. Vehicle Requirements

2.1. The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).

2.2. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the maximum number of altitude points (5,280) if the official scoring altimeter reads a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude.

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

2.4. Each altimeter will have a dedicated power supply.

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

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

2.7. The launch vehicle will 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.

2.8. The launch vehicle will be limited to a single stage.

2.9. The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.

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

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

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

2.13. The launch vehicle will 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).

2.13.1. Final motor choices must be made by the Critical Design Review (CDR).
2.13.2. Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.

2.14. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:
2.14.1. 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.
2.14.2. Each pressure vessel will include a pressure relief valve that sees the full pressure of the valve that is capable of withstanding the maximum pressure and flow rate of the tank.
2.14.3. Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.

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

2.16. The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.

2.17. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.

2.18. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets.
2.18.1. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model.
2.18.2. The subscale model will carry an altimeter capable of reporting the model's apogee altitude.

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

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

2.19.2.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.

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

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

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

2.19.5. The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.

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

2.19.7. Full scale flights must be completed by the start of FRRs (March 6th, 2018). If the Student Launch office determines that a re-flight is necessary, then an extension to March 28th, 2018 will be granted. This extension is only valid for re-flights; not first-time flights.

2.20. Any structural protuberance on the rocket will be located aft of the burnout center of gravity.

2.21. Vehicle Prohibitions

2.21.1. The launch vehicle will not utilize forward canards.
2.21.2. The launch vehicle will not utilize forward firing motors.
2.21.3. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)
2.21.4. The launch vehicle will not utilize hybrid motors.
2.21.5. The launch vehicle will not utilize a cluster of motors.
2.21.6. The launch vehicle will not utilize friction fitting for motors.
2.21.7. The launch vehicle will not exceed Mach 1 at any point during flight.
2.21.8. Vehicle ballast will not exceed 10% of the total weight of the rocket.

3. Recovery System Requirements

3.1. The launch vehicle will 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.

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

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

3.4. The recovery system electrical circuits will be completely independent of any payload electrical circuits.

3.5. All recovery electronics will be powered by commercially available batteries.

3.6. The recovery system will contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.

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

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

3.9. Recovery area will be limited to a 2500 ft. radius from the launch pads.

3.10. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.
  3.10.1. Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device.
  3.10.2. The electronic tracking device will be fully functional during the official flight on launch day.

3.11. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).
  3.11.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.
  3.11.2. The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.
  3.11.3. The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.
  3.11.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

4. Experiment Requirements

4.1. Each team will choose one design experiment option from the following list.
4.2. Additional experiments (limit of 1) are allowed, and may be flown, but they will not contribute to scoring.
4.3. If the team chooses to fly additional experiments, they will provide the appropriate documentation in all design reports, so experiments may be reviewed for flight safety.

Option 1	Target detection
Option 2	Deployable rover
Option 3	Landing coordinates via triangulation

4.4. Target detection

4.4.1. Teams will design an onboard camera system capable of identifying and differentiating between 3 randomly placed targets.

4.4.1.1. Each target will be represented by a different colored ground tarp located on the field.

4.4.1.2. Target samples and RGB values will be provided to teams upon acceptance and prior to PDR.

4.4.1.3. All targets will be approximately 40'X40' in size.

4.4.1.4. The three targets will be adjacent to each other, and that group will be within 600 ft. of the launch pads.

4.4.2. Data from the camera system will be analyzed in real time by a custom designed on-board software package that shall identify, and differentiate between the three targets.

4.4.3. Teams will not be required to land on any of the targets.

4.5. Deployable rover

4.5.1. Teams will design a custom rover that will deploy from the internal structure of the launch vehicle.

4.5.2. At landing, the team will remotely activate a trigger to deploy the rover from the rocket.

4.5.3. After deployment, the rover will autonomously move at least 5 ft. (in any direction) from the launch vehicle.

4.5.4. Once the rover has reached its final destination, it will deploy a set of foldable solar cell panels.

4.6. Landing coordinates via triangulation

4.6.1. Teams will design an optical range finding system to determine launch vehicle landing coordinates within a grid provided by the NASA SL office.

4.6.2. Teams will remotely locate three different colored objects placed on the field via an onboard camera, and determine the distance from each object using the rangefinder.

4.6.3. The RGB values for the objects will be provided upon acceptance, and prior to PDRs.

4.6.4. The grid coordinates for each object will be provided to teams during launch week, and the objects will sit high enough above ground level to be seen from anywhere on the field. Using the readings from the rangefinder, and a heading for each object, the payload will determine its landing location within the grid.

5. Safety Requirements

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

5.2. Each team must identify a student safety officer who will be responsible for all items in section 5.3.

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

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

5.3.1.1. Design of vehicle and payload

5.3.1.2. Construction of vehicle and payload

5.3.1.3. Assembly of vehicle and payload

5.3.1.4. Ground testing of vehicle and payload

5.3.1.5. Sub-scale launch test(s)

5.3.1.6. Full-scale launch test(s)

5.3.1.7. Launch day

5.3.1.8. Recovery activities

5.3.1.9. Educational Engagement Activities

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

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

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

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

5.5. Teams will abide by all rules set forth by the FAA.

Proposal Requirements

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

General Information

1. A cover page that includes the name of the college/university, mailing address, title of the project, and the date.

2. Name, title, and contact information (including phone number) for up to two adult educators.

3. Name and title of the individual who will take responsibility for implementation of the safety plan. (Safety Officer)

4. Name, title, and contact information for the student team leader.

5. Approximate number of student participants who will be committed to the project and their proposed duties. Include an outline of the project organization that identifies the key managers (students and/or educator administrators) and the key technical personnel. Only use first names for identifying team members; do not include surnames.

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

Facilities/Equipment

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

Safety

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

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

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

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

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

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

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

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

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

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

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

Technical Design

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

Educational Engagement

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

Project Plan

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

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

3. Provide a detailed funding plan.

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

Deliverables required for successful participation are listed below. More details are provided in the PDR and CDR requirement documents:

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

2. A scale model of the rocket design must be flown before CDR and a report of the flight data brought to CDR

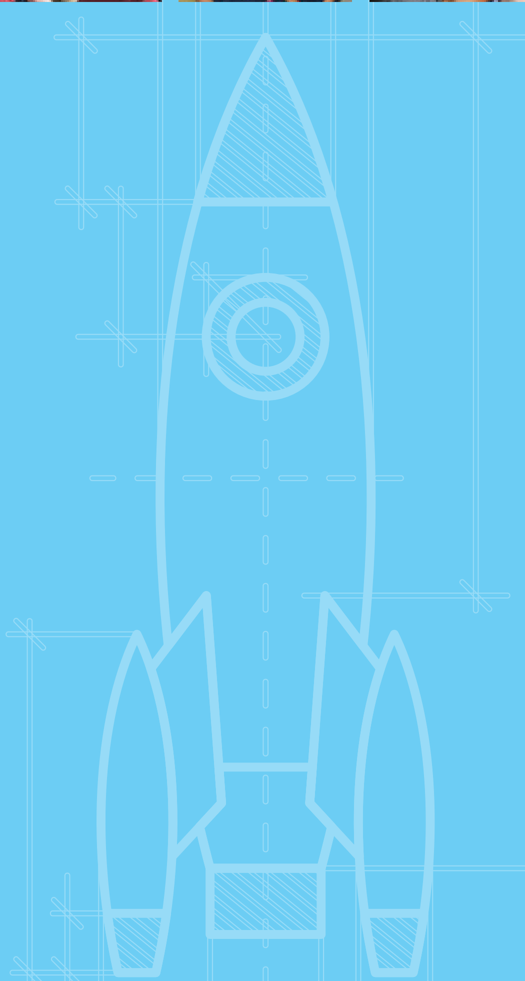
3. A team Web site that is maintained/updated throughout the period of performance

4. Reports, PDF slideshows, and Milestone Review Flysheets completed and posted to team Web site by due date.

5. Electronic copies of the Educational Engagement form(s) and any lessons learned submitted prior to FRR and within two weeks of the educational engagement event.

6. Participation in PDR, CDR, FRR, LRR, and PLAR

Vehicle/ Payload Criteria



Preliminary Design Review (PDR)
Vehicle and Payload Experiment Criteria

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

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

Preliminary Design Review Report

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

Page Limit: PDRs will only be scored using the first 250 pages of the report (not including title page). Any additional content will not be considered while scoring.

I) Summary of PDR report (1 page maximum)

Team Summary

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

Launch Vehicle Summary

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

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 systems' 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.
- 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 a dimensional drawing 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 what size is required for a safe descent.
- Choose leading components amongst the alternatives, present them, and explain why they are the current leaders.
- Prove that redundancy exists within the system.

Mission Performance Predictions

- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve, and verify that they are robust enough to withstand the expected loads.
- Show stability margin, simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that the rocket will be launch straight up (zero-degree launch angle).
- 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) 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 sub-scale 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, MSDS, etc.
- Provide a 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 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.

V) 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 systems' 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.
- 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 with estimated masses.
- Describe the justification used when making design selections.
- Describe the preliminary interfaces between the payload and launch vehicle.

VI) Project Plan

Requirements Verification

- Create a verification plan for every requirement from sections 1-5 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.
- Create a set of team derived requirements in the following categories: Vehicle, Payload, Recovery, Safety, and General. These are a set of minimal requirements for mission success that are ideally beyond the minimum success requirements presented in this handbook. Like before, create a verification plan identifying whether test, analysis, demonstration, or inspection is required with an associated plan. Demonstrate the requirements are not arbitrary, and are required for teams unique project.

Budgeting and Timeline

- Line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Funding plan describing sources of funding, allocation of funds, and material acquisition plan.
- Timeline includes all team activities, and activity duration. Schedule appears complete, and encompasses the full term of the project. Deliverables are defined with reasonable activity duration. GANTT charts are encouraged.

Preliminary Design Review Presentation

Please include the following in your presentation:

- Vehicle dimensions, materials, and justifications
- Static stability margin, and CP/CG locations
- Preliminary motor selection and justification
- Thrust-to-weight ratio and rail exit velocity
- Drawing/Discussion of each major component and subsystem, especially the recovery subsystem
- Preliminary payload design
- Requirement compliance plan

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

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

The presentation of the PDR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy-to-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)
Vehicle and Payload Experiment Criteria

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

The panel expects a professional and polished report. Report should to follow the order of sections as they appear below.

Critical Design Review Report

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

Page Limit: CDRs will only be scored using the first 250 pages of the report (not including title page). Any additional content will not be considered while scoring.

I) Summary of CDR report (1 page maximum)

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

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

Payload Summary
- Payload title
- Summarize experiment

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

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

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

III) Vehicle Criteria

Design and Verification of Launch Vehicle

Flight Reliability and Confidence

- Include unique mission statement, and mission success criteria
- Identify which of the design alternatives from PDR is chosen are chosen as the final components for the launch vehicle. Describe why that alternative is the best choice.
- Using the final designs, create dimensional and computer aided design (CAD) drawings to illustrate the final launch vehicle, its subsystems, and its components.
- Demonstrate that the design is complete, and is 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 launch vehicle, as well as its subsystems.
- Provide justification for material selection, dimensioning, component placement, and other unique design aspects.

Subscale Flight Results

- At least one data gathering device must be onboard the launch vehicle during the test launch. At a minimum, this device must record the apogee of the rocket. If the device can record more than apogee, please include the actual flight data.
- Describe the scaling factors used when scaling the rocket. What variables are kept constant and why? What variable 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 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 is chosen are chosen as the final components for the recovery subsystem. Describe why that alternative is the best choice.
- Describe the parachute, harnesses, bulkheads, and attachment hardware.
- Discuss the electrical components, and prove that redundancy exists within the system.
- Include drawings/sketches, block diagrams, and electrical schematics.
- Provide operating frequency(s) of the locating tracker(s).

Mission Performance Predictions (Using most up to date model)

- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve, and verify that they are robust enough to withstand the expected loads.
- Show stability margin, simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that the rocket will be launch straight up (zero-degree launch angle).
- 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) Safety

Launch concerns and operation procedures

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

V) Payload Criteria

Design of Payload Equipment

- Identify which of the design alternatives from PDR is chosen as the final components for the payload. Describe why that alternative is the best choice.
- 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.
- Demonstrate that the design is complete.
- Discuss the payload electronics with special attention given to safety switches and indicators.
    - Drawings and schematics
    - Block diagrams
    - Batteries/power
    - Switch and indicator wattage and location
- Provide justification for all unique aspects of your payload (like materials, dimensions, placement, etc.)

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 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.
- Create a set of team derived requirements in the following categories: Vehicle, Payload, Recovery, Safety, and General. These are a set of minimal requirements for mission success that are ideally beyond the minimum success requirements presented in this handbook. Like before, create a verification plan identifying whether test, analysis, demonstration, or inspection is required with an associated plan.

Budgeting and Timeline

- Line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Funding plan describing sources of funding, allocation of funds, and material acquisition plan.
- Timeline includes all team activities, and activity duration. Schedule appears complete, and encompasses the full term of the project. Deliverables are defined with reasonable activity duration. GANTT 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
- Final motor choice
- Rocket flight stability in static margin diagram
- Thrust-to-weight ratio and rail exit velocity
- Mass Statement and mass margin
- Parachute sizes, recovery harness type, size, length, and descent rates
- Kinetic energy at key phases of the mission, especially landing
- Predicted drift from the launch pad with 5-, 10-, 15-, and 20-mph wind
- Test plans and procedures
- Scale model flight test
- Tests of the staged recovery system
- Final payload design overview
- Payload integration
- Interfaces (internal within the launch vehicle and external to the ground)
- Status of requirements verification

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

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

The presentation of the CDR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy-to-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)
Vehicle and Payload Experiment Criteria

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

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

Flight Readiness Review Report

Page Limit: FRRs will only be scored using the first 300 pages of the report (not including title page). Any additional content will not be considered while scoring.

I) Summary of FRR report (1-page maximum)

Team Summary

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

Launch Vehicle Summary

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

Payload Summary

- Payload title
- Summarize experiment

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

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

- Changes made to vehicle criteria
- Changes made to 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 why those changes are necessary.
- 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.).
    - Drawings and schematics of the as built launch vehicle to describe the assembly.
- 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 will change slightly due to construction.
- 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 (such as bulkheads, harnesses, attachment hardware, etc.).
    - Electrical elements (such as altimeters/computers, switches, connectors).
    - Redundancy features.
    - As built parachute sizes and descent rates
    - Drawings 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 onboard devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis section.

Mission Performance Predictions

- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve, and verify that they are robust enough to withstand the expected loads.
- Show stability margin, 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 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 the rocket will be launch straight up (zero-degree launch angle).
- 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.

Full Scale Flight

- Describe launch day conditions, and perform a simulation using those conditions.
- Perform an analysis of the full-scale 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 full scale rocket with launch data. Use this value to run a post flight simulation.
    - Discuss the similarities and differences between the full scale and sub scale flight results.

IV) Payload Criteria

Payload Design

- Describe any changes in the payload design from CDR, and why those changes are necessary.
- Describe unique features of the payload.
    - Structural elements
    - Electrical elements
    - Drawings and schematics of the as built payload
- 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 will change slightly due to construction.
- Discuss how and why the constructed payload differs from earlier models.

V) Safety

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 the team has built.
        - Note: These sections can change from CDR to FRR if there are design related changes made as a result of Sub-scale and Full-scale test flights, and refined modeling and analysis.
        - These should identify specifically 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
- Note: Be sure to discuss any concerns (especially operational, and environmental) that remain as the project moves into the operational phase of the life cycle.

VI) Launch Operations Procedures

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

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

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

VII) Project Plan

Testing

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

Requirements Compliance

- Create a verification plan for every requirement from sections 1-5 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.
- Create a set of team derived requirements in the following categories: Vehicle, Payload, Recovery, Safety, and General. These are a set of minimal requirements for mission success that are ideally beyond the minimum success requirements presented in this handbook. Like before, create a verification plan identifying whether test, analysis, demonstration, or inspection is required with an associated plan.

Budgeting and Timeline

- Line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Funding plan describing sources of funding, allocation of funds, and material acquisition plan.

Flight Readiness Review Presentation

Please include the following information in your presentation:

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

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

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

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

Launch Readiness Review (LRR)
Vehicle and Payload Experiment Criteria

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

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

Each team will demonstrate these tasks with the RSO present who 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 should be corrected and verified by launch services/NASA prior to launch day. A flight card will be provided to teams, to be completed and provided at the RSO booth on launch day.

Post-Launch Assessment Review (PLAR)
Vehicle and Payload Experiment Criteria

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

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

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

Educational Engagement Activity Report

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

School/Organization name:

Date(s) of event:

Location of event:

Instructions for participant count

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

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

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

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

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

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

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

If yes, what group/organization?

Briefly describe your activities with this group:

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

Describe the comprehensive feedback received.

Safety

High Power Rocket Safety Code

Provided by the National Association of Rocketry

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

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

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

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

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

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

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

8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (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 (2,000 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	1000
10,240.01 – 20,480.00	N	125	1000	1500
20,480.01 – 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors
Revision of July 2008

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

Related Documents

College and University Division Awards

Award:	Award Description:	Determined by:	When awarded:
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.	USLI panel	Awards Ceremony
Experiment Design Award	Awarded to the team with the most creative and innovative payload design while maximizing safety and science value.	USLI panel	Awards Ceremony
Safety Award	Awarded to the team that demonstrates the highest level of safety according to the scoring rubric.	USLI panel	Awards Ceremony
Project Review (PDR/CDR/FRR) Award	Awarded to the team that is viewed to have the best combination of written reviews and formal presentations	USLI panel	Awards Ceremony
Educational 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. This team not only presented a high number of activities to a large number of people, but also delivered quality activities to a wide range of audiences.	USLI panel	Awards Ceremony
Web Design/Social Media Award	Awarded to the team that has the best, most efficient Web site with all documentation posted on time, and the most active and creative social media presence.	USLI panel	Awards Ceremony
Altitude Award	Awarded to the team that achieves the best altitude score according to the scoring rubric and requirement 1.2.	USLI panel	Launch Day
Best Looking Rocket	Awarded to the team that is judged by their peers to have the "Best Looking Rocket"	Peers	Awards Ceremony
Best Team Spirit Award	Awarded to the team that is judged by their peers to display the "Best Team Spirit" on launch day.	Peers	Awards Ceremony
Best Rocket Fair Display Award	Awarded to the team that is judged by their peers to display the "Best Display" at the Rocket Fair.	Peers	Awards Ceremony
Rookie Award	Awarded to the top overall rookie team using the same criteria as the Overall Winner Award. (Only given if the overall winner is not a rookie team).	USLI panel	TBD
Overall Winner	Awarded to the top overall team. Design reviews, outreach, Web site, safety, and a successful flight will all factor into the Overall Winner.	USLI panel	TBD

NASA Project Life Cycle

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

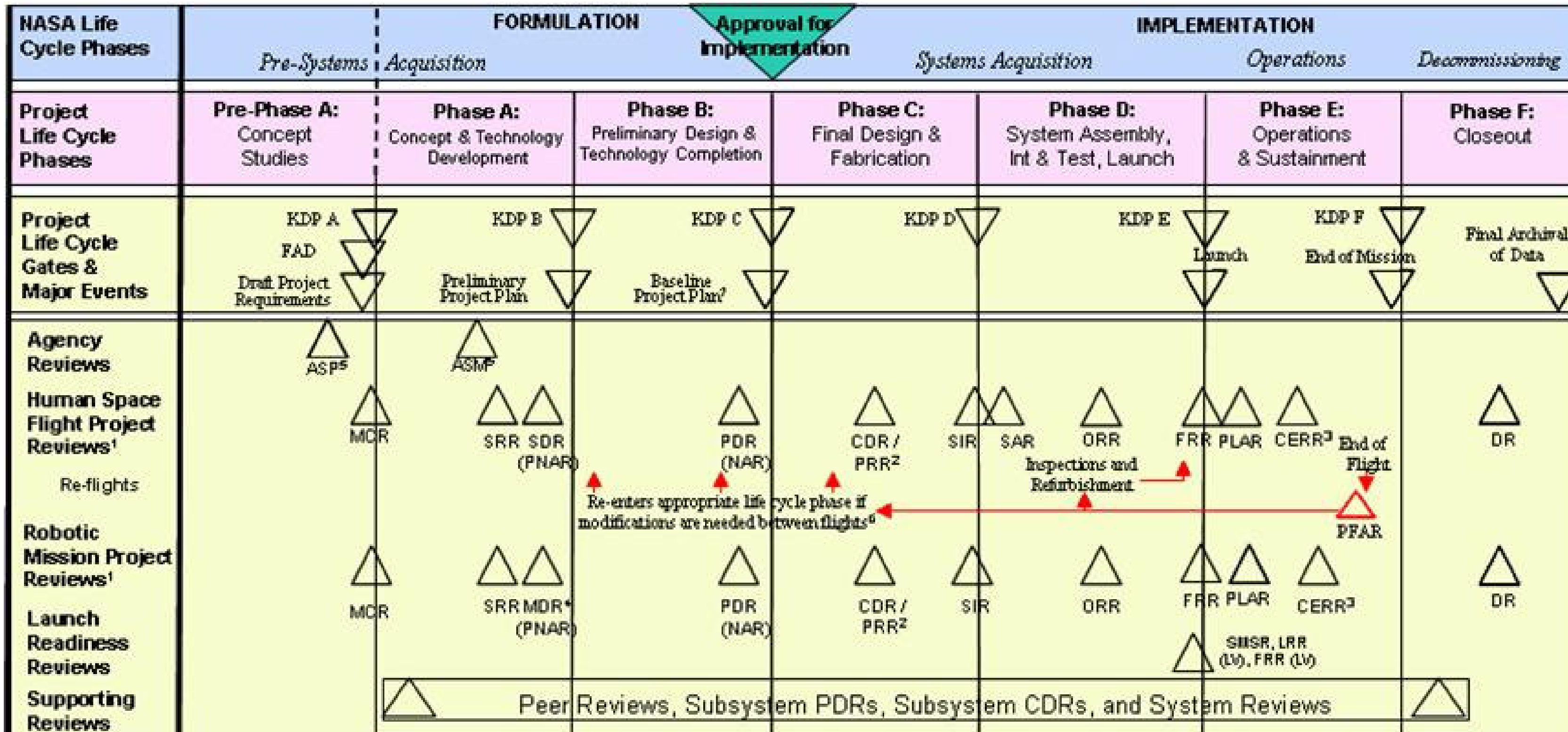
Topics

- Purpose / Objective
- Project Life Cycle
- ~~System Requirements Review~~ (N/A to NASA Student Launch)
- Preliminary Design
- Critical (Final) Design
- Flight Readiness

Purpose/Objectives of the NASA Project Life Cycle

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

Typical NASA Project Life Cycle



FOOTNOTES

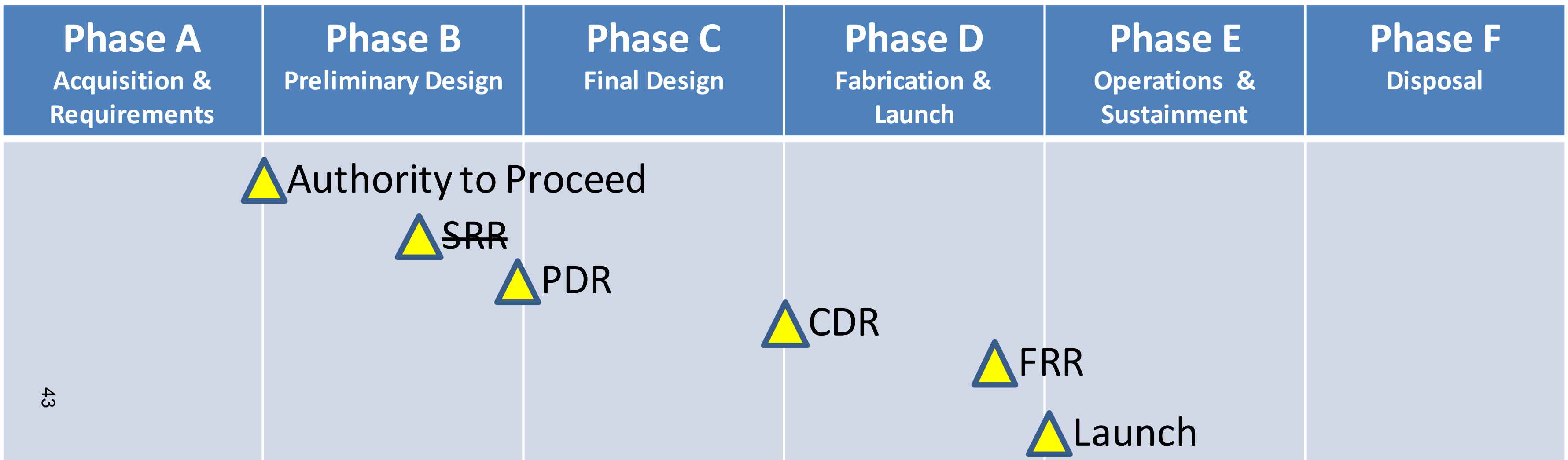
1. Flexibility is allowed in the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan. These reviews are conducted by the project for the independent SRB. See Section 2.5 and Table 2-6.
2. PRR needed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

ACRONYMS

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

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

Student Launch Projects Life Cycle



- ATP (Authority to Proceed) – Funding is applied to the contract/effort and work performance can begin
- SRR (System Requirements Review) – Top Level Requirements are converted into system requirements. System Requirements are reviewed and authority is given to proceed into Preliminary Design. The NASA Student Launch Project skips this step.
- PDR (Preliminary Design Review) – Preliminary Design is reviewed and authority is given to proceed into Final Design.
- CDR (Critical Design Review) – Final Design is reviewed and authority is given to proceed to build the system.
- FRR (Flight Readiness Review) – As-built design and test data are reviewed and authority is given for Launch.

Preliminary Design Review

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

Critical Design Review

- Objective
  - Complete the final design of the rocket/payload system
  - Receive authority to proceed into Fabrication and Verification phase
- Typical Products (Vehicle and Payload)
  - PDR Deliverables (matured to reflect the final design)
  - Report and discuss completed tests
  - Procedures and Checklists

Flight Readiness Review

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

Hazard Analysis

Introduction to Managing Risk

What is a Hazard?

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

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

Hazard Description

A hazard description is composed of 3 parts.

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

Example Hazard Description

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

Hazard

Cause

Effect

Risk

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

Risk is defined by 2 factors:

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

Risk Matrix Example

(excerpt from NASA MPR 8715.15)

TABLE CH1.1 RAC

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

Table CH1.2 RISK ACCEPTANCE AND MANAGEMENT APPROVAL LEVEL

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

Risk Continued

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

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

Mitigations/Controls

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

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

Types of Controls:

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

Verification

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

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

Example Hazard Analysis

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

Safety Assessment Report (Hazard Analysis)

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

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

RAC CLASSIFICATIONS

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

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

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

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

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

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

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
				3. Attendant will be posted outside chamber to monitor in-chamber activities, facilitate evacuation or rescue if required, and to restrict access to unauthorized personnel 4. Fire Dept. to be notified that confined space entries are being made	3. "Test Panel Install/Removal Procedure," page 1, requires the use of existing METTS confined space entry procedures, which includes requirement for an attendant when entering the 12 ft vacuum chamber reference Confined Space Permit 0298. 4. "Test Panel Install/Removal Procedure," page 1, requires the use of existing METTS confined space entry procedures, which includes requirement to notify the Fire Dept. prior to entering the 12 ft vacuum chamber. Reference Confined Space Permit 0298.	
Personnel exposure to lamp thermal energy	• Proximity to lamps while energized • Accidental contact with lamp or calibration plate while out	Personnel burns requiring medical treatment	3C	1. During test operation, lamp banks circuits will be energized only when no personnel are inside chamber. 2. Door to chamber will closed prior to energizing circuits 3. Designated personnel will wear leather gloves to handle calibration plate if required.	1. 304-TCP-016, Section 3.1.3 requires disabling heater electrical circuit before entering chamber 2. Per 304-TCP-016, tests will only be performed under personal direction of Test Engineer 3. 304-TCP-16, Section 1.4, Hazards and Controls, requires insulated gloves as required if hot items need to be handled.	3E

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Failure of pressure systems	Over-pressurization	• Personnel injury • Equipment damage	1C	1. TS300 facility pressure systems are certified. 2. Per ET10 test engineer, high purity air system will be used at < 150 psig operating pressure, therefore certification not required. 3. All non-certified test equipment is pneumatically pressure tested to 150% of Maximum Allowable Working Pressure (MAWP)	1. Per the MSFC Pressure Systems Reporting Tool (PSRT), facility systems have been recertified under TLWT-CERT-10-TS300-RR2002 until 3/3/2020. The certification includes Gaseous Helium, Gaseous Hydrogen, Gaseous Nitrogen, High Purity Air, Liquid Hydrogen and Liquid Nitrogen systems. 2. 304-TCP-016, Step 2.1.14, requires HOR-12-128, 2nd Stage HP Air HOR, to be Loaded to 75psig. 3. See Pressure Test Report PTR-001455 (Appendix A). All non-certified equipment has a minimum factor of safety of 4:1.	1E
Foam panel catches fire during testing	Test requires high heat with possibility of panel burning	Release of hazards materials into test chamber	1C	1. Byproducts of combustion have been evaluated by Industrial Hygiene personnel and a ventilation requirement of 10 minutes with the chamber 300 cfm ventilation fan has been established. This will provide enough air changes so very little or no residual gasses or vapors remain.	1. A minimum ventilation of the chamber should the foam panel burn during or after testing has been established by procedure 304-TCP-016 which requires the minimum 10 minute ventilation before personnel are allowed to enter. Additionally, if any abnormalities are observed the Industrial Health representative will be called to perform additional air sampling before personnel entry.	1E

Understanding MSDS's

By: Jeff Mitchell

MSFC Environmental Health

What is an MSDS?

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

What is an MSDS?

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

Required data for MSDS's

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

Required data for MSDS's (Cont.)

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

Important Agencies

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

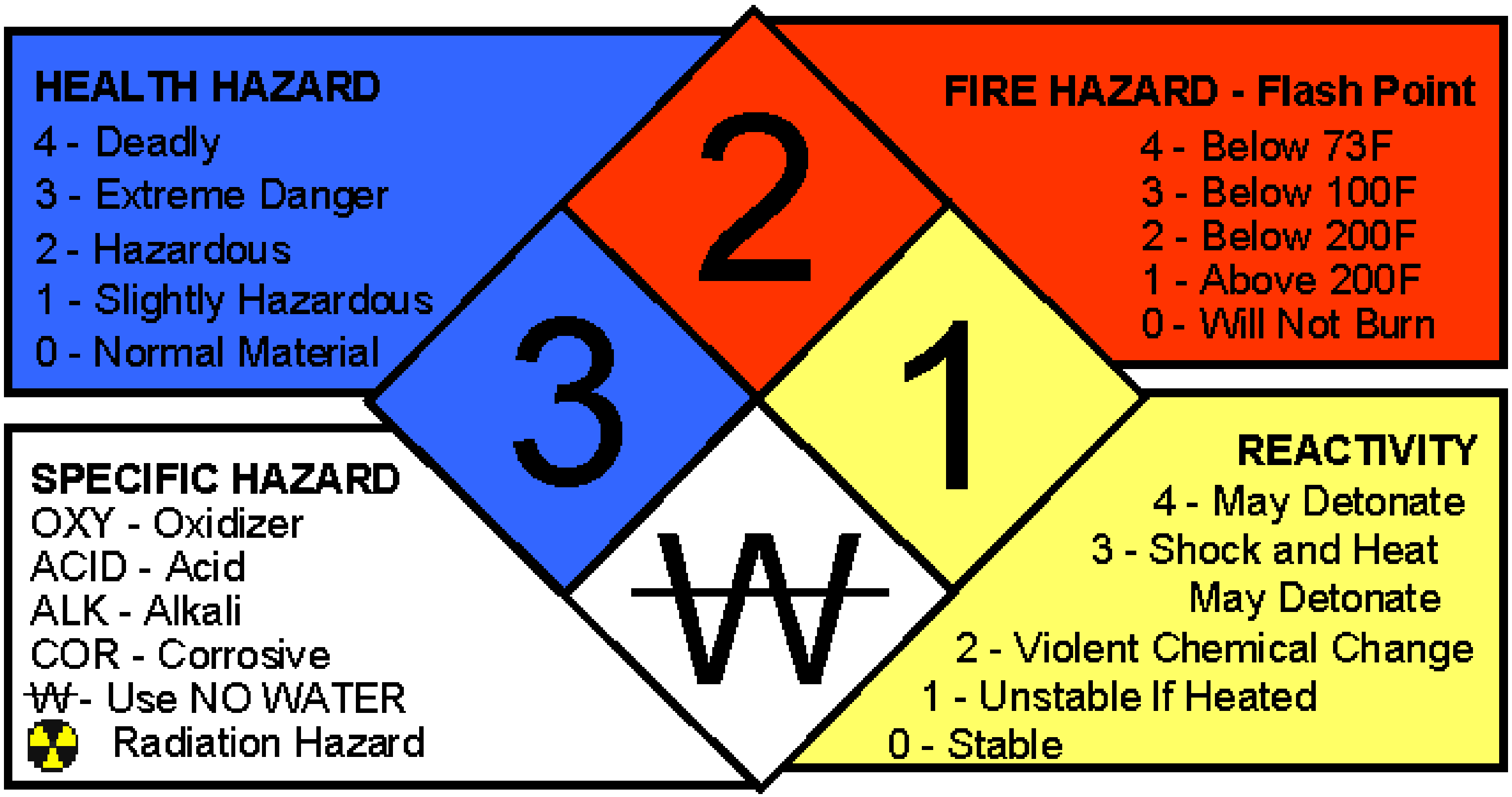
Important Agencies (Cont.)

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

Important Agencies (Cont.)

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

NFPA Diamond



Important Agencies (Cont.)

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

Important Agencies (Cont.)

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

Exposure Limits

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

Exposure Limits (Cont.)

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

Exposure Limits (Cont.)

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

Exposure Limits (Cont.)

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

Chemical and Physical Properties

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

Chemical and Physical Properties (Cont.)

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

Things you should learn from MSDS's

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

Take your time!

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

The following slides are an abbreviated version of a real MSDS

Study it and become more familiar with this chemical

MSDS: METHYL ETHYL KETONE

Abbreviated MSDS

SECTION 1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

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

Manufacturer name
and phone #

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

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

SUBSTANCE: METHYL ETHYL KETONE

Last revision

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

CHEMICAL FAMILY:
Ketones, aliphatic

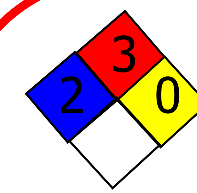
CREATION DATE: Sep 28 1984
REVISION DATE: Mar 30 1997

SECTION 2. COMPOSITION, INFORMATION ON INGREDIENTS

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

SECTION 3. HAZARDS IDENTIFICATION

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



Good info for labeling containers

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

POTENTIAL HEALTH EFFECTS:

What happens when exposed?

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

SKIN CONTACT:
SHORT TERM EXPOSURE: irritation
LONG TERM EXPOSURE: same as effects reported in short term exposure
EYE CONTACT…
INGESTION…

CARCINOGEN STATUS:
OSHA: N
NTP: N
IARC: N

Does it cause cancer?

SECTION 4. FIRST AID MEASURES

INHALATION…
SKIN CONTACT…
EYE CONTACT…
INGESTION…

What should you do if exposed?

SECTION 5. FIRE FIGHTING MEASURES

SECTION 6. ACCIDENTAL RELEASE MEASURES

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

SECTION 7. HANDLING AND STORAGE

Store and handle in accordance …

SECTION 8. EXPOSURE CONTROLS, PERSONAL PROTECTION

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

8 hr avg
15 min avg

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

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

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

MEK vapor is heavier than air

MEK liquid will float on stagnant water

Not very soluble in water

Will likely smell MEK before being overexposed

Goes to vapor easy

SECTION 10. STABILITY AND REACTIVITY

SECTION 11. TOXICOLOGICAL INFORMATION

SECTION 12. ECOLOGICAL INFORMATION

SECTION 13. DISPOSAL CONSIDERATIONS

SECTION 14. TRANSPORT INFORMATION

SECTION 15. REGULATORY INFORMATION

SECTION 16. OTHER INFORMATION

MSDS's have an abundance of information useful in many different aspects

National Aeronautics and Space Administration

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

www.nasa.gov

NP-2017-08-83-MSFC
G-322745b