National Aeronautics and Space Administration

2021 NASA SL
Student Launch

Handbook Supplement USLI Design Division








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Table of Contents

Design Division Project Milestones: Criteria and Expectations

Timeline for NASA Student Launch

(Dates are subject to change.)

January

04 Critical Design Review (CDR) report, presentation slides, and flysheet submitted to NASA project management team by 8:00 a.m. CST.

07-26 CDR video teleconferences

27 FRR Q&A

February

22 Design Division declaration deadline: teams must declare participation in the Design Division to NASA project management by 8:00 a.m. CST **in writing**.

22 Final Rocket Design RockSim (.rkt) file submitted to NASA project management team by 8:00 a.m. CST.

25 Mock-Demonstration Flight data distributed to teams.

March

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

11-29 FRR video teleconferences

29 Launch Week Q&A

April

06 Payload Modification Vehicle Redesign (PMVR) specifications distributed to teams.

08-12 Launch Week Activities

27 Payload Modification Vehicle Redesign (PMVR) report submitted to NASA project management by 8:00 a.m. CDT.

Acronym Dictionary

AGL = Above Ground Level

APCP = Ammonium Perchlorate Composite Propellant

ASC = Artemis Student Challenges

CDR = Critical Design Review

CG = Center of Gravity

CP = Center of Pressure

FAA = Federal Aviation Administration

FMEA = Failure Modes and Effects Analysis

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

NASA = National Aeronautics and Space Administration

PDF = Portable Document Format

PDR = Preliminary Design Review

PHA = Personnel Hazard Analysis

PLAR = Post Launch Assessment Review

PMVR = Payload Modification Vehicle Redesign

PPE = Personal Protective Equipment

RFP = Request for Proposal

RSO = Range Safety Officer

SLI = Student Launch Initiative

SLS = Space Launch System

SME = Subject Matter Expert

SOW = Statement of Work

STEM = Science, Technology, Engineering, and Mathematics

TRA = Tripoli Rocketry Association

UAS = Unmanned Aerial System

USLI = University Student Launch Initiative

VDF = Vehicle Demonstration Flight

WBS = Work Breakdown Structure

Design Division Project Milestones: Criteria and Expectations

Critical Design Review (CDR)

Traditionally, the CDR demonstrates that the maturity of the design is appropriate to support proceeding to full-scale fabrication, assembly, and integration; showing that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet overall performance requirements within the identified cost, schedule, and technical performance constraints. Progress against management plans, budget, and schedule, as well as risk assessment, are also presented. The CDR is a review of the final design of the launch vehicle and payload system.

For the Design Division, the intent of CDR remains the same, however certain adjustments must be made to accommodate the omission of a subscale launch and subsequent launch analysis. Although there will not be a discussion of subscale models, the CDR documents need to primarily discuss the final design of the intended full-scale launch vehicle and subsystems. All other analyses 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.

Be sure to read over the Report and Presentation requirements below to be certain your team is including all the necessary information. The panel will be expecting a professional and polished report that follows the order of sections as they appear below.

Critical Design Review Report

Page Limit: CDRs will only be scored using the first 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
- Document the number of hours spent working on the CDR milestone.

Launch Vehicle Summary

- Target altitude (ft.)
- Final motor choice
- Size and mass
- Recovery system
- Rail size

Payload Summary

- Payload title
- Summarize payload experiment

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

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

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

III) Vehicle Criteria

Design and Verification of Launch Vehicle

Flight Reliability and Confidence

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

Recovery Subsystem

- Identify which of the design alternatives from PDR were chosen as the final components for the recovery
- subsystem. Describe why those alternatives are the best choices.
- Describe the parachutes, 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 the operating frequency of the locating tracker(s).

Mission Performance Predictions (Using the most up to date model)

- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify that the vehicle design is robust enough to withstand the expected loads.
- Show stability margin and simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
- Calculate the expected descent time for the rocket and any section that descends untethered from the rest of the vehicle, including planetary landers.
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV) Payload Criteria

Design of Payload Equipment

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

V) Safety

Launch Concerns and Operation Procedures

- Submit a draft of final assembly and launch procedures/checklists including:
    - Recovery preparation
    - Payload preparation
    - Electronics preparation
    - Rocket preparation
    - Motor preparation
    - Setup on the launch pad
    - Igniter installation
    - Launch procedure
    - Troubleshooting
    - Post-flight inspection

- These procedures/checklists should include specially demarcated steps related to safety. Examples include:
    - Warnings of hazards that can result from missing a step
    - PPE required for a step in the procedure (identified BEFORE the step)
    - Required personnel to complete a step or to witness and sign off verification of a step

Safety and Environment (Vehicle and Payload)

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

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.

Requirements Compliance

- Create a verification plan for all requirements from sections 1-5 of the project requirements listed in the SL Handbook with the exception of requirements 2.17, 2.18, 2.19, 2.20, 3.2, 4.3.4.4 and 5.4. Identify if test, analysis, demonstration, or inspection are required to verify the requirement. After identification, describe the associated plan needed for verification.
- Update the ongoing list of team derived requirements in the following categories: Vehicle, Recovery, and Payload. These are a set of requirements for mission success that are beyond the minimum success requirements presented in this handbook. Create a verification plan for each team derived requirement identifying whether test, analysis, demonstration, or inspection is required with an associated plan.
-

Budgeting and Timeline

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

Critical Design Review Presentation

Please include the following information in your presentation:

- Final launch vehicle and payload dimensions
- Discuss key design features
- Visually show points of separation along with location of energetic materials
- Final motor choice
- Rocket flight stability in a 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
- Final payload design overview
- Payload integration plans
- Payload retention system
- Interfaces (internal within the launch vehicle and external to the ground)
- Status of requirements verification

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

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

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

Traditionally, the FRR examines tests, demonstrations, analyses, and audits that determine the overall system's (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 hardware, software, personnel, and procedures are operationally ready.

For the Design Division the intent of FRR remains the same, however certain adjustments must be made to accommodate the lack of subscale and full-scale flight data. Additionally, because no physical hardware for either the rocket or payload will be constructed, testing, demonstration, and construction/build details are either omitted from the milestone requirements or those requirements are modified to apply to the unique circumstances of Design Division. Be sure to read over the Report and Presentation requirements below to be certain your team is including all the necessary information. The panel will be expecting a professional and polished report that follows the order of sections as they appear below.

Finally, make special note of requirements found in Section V of the FRR as a submission of vehicle specifications and dimensions is required **before** the report deadline in order to provide teams with mock flight data to use in place of Full-Scale demonstration launch data.

Flight Readiness Review Report

Page Limit: FRRs 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 FRR report (1 page maximum)

Team Summary

- Team name and mailing address
- Name of mentor, NAR/TRA number and certification level, and contact information
- Document the number of hours spent working on the FRR milestone

Launch Vehicle Summary

- Size and mass
- Motor selected (as declared at CDR milestone)
- Target altitude (ft.) (as declared at PDR milestone)
- Recovery system
- Rail size (either 8' 1010 rail, or 12' 1515 rail)

Payload Summary

- Payload title
- Summarize payload experiment

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

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

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

III) Vehicle Criteria

Design and Construction of Vehicle

- Describe any changes in the launch vehicle design from CDR and explain why those changes are necessary.
- Discuss final locations of separation points along with locations of black powder and/or energetics.
- Describe features that will enable the vehicle to be launched and recovered safely.
    - Structural elements (such as airframe, fins, bulkheads, attachment hardware, etc.)
    - Electrical elements (wiring, switches, battery retention, retention of avionics boards, etc.)
- Discuss flight reliability confidence. Demonstrate that the design can meet mission success criteria.
- Provide extensive construction plans and procedures for the vehicle. Consider including any of the following:
    - Descriptions of material preparation, manufacturing, processing, cutting, molding, shaping, and finishing.
    - Assembly of subsystems, fins, motor mounting hardware, altimeter and avionics bays. Include how the subassemblies interface, are affixed to one another, and additional preparations or adjustments that may be required to ensure a smooth and effective assembly process.
    - Step-by-step procedures for the above bullet points, especially where order of operations is important.
    - Pictures or drawings detailing the steps of construction and how parts interface. For reference, consider the style and method used for construction instructions found in modular furniture systems, or the assembly drawings included with products like LEGO® playsets.
    - Note any safety precautions required during construction/assembly and appropriate PPE.
    - This section should not include final launch assembly procedures or any steps that are repeated during rocket preparation for launch.
- Include schematics of the FINAL rocket design. There is a chance dimensions have changed slightly due to final edits and the anticipated construction process.

Recovery Subsystem

- Describe and defend the robustness of the design.
    - Structural elements (such as bulkheads, harnesses, attachment hardware, etc.)
    - Electrical elements (such as altimeters/computers, switches, connectors)
    - Redundancy features
    - Parachute sizes and descent rates
    - Detailed drawings and schematics of the electrical and structural assemblies
    - Rocket-locating transmitters with a discussion of frequency, wattage, and range
- Discuss the sensitivity of the recovery system to onboard devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis section.

Mission Performance Predictions

- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and
- simulated motor thrust curve. Verify that the vehicle is robust enough to withstand the expected loads.
- Show stability margin and FINAL rocket design Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
- Calculate the expected descent time for the rocket and any section that descends untethered from the rest of the vehicle, including planetary landers.
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

IV) Payload Criteria

Payload Design and Testing

- Describe any changes in the payload design from CDR and explain why those changes are necessary.
- Describe unique features of the payload. Include the following:
    - Structural elements
    - Electrical elements
- Discuss flight reliability confidence. Demonstrate that the design can meet mission success criteria.
- Provide extensive construction plans and procedures for the payload. Consider including any of the following:
    - Descriptions of material preparation, manufacturing, processing, cutting, molding, shaping, and finishing.
    - Assembly of subsystems, electric motors, wiring, microcontrollers, mounting or attachment hardware. Include how the subassemblies interface, are affixed to one another, and additional preparations or adjustments that may be required to ensure a smooth and effective assembly process.
    - Step-by-step procedures for the above bullet points, especially where order of operations is important.
    - Pictures or drawings detailing the steps of construction and how parts interface. For reference, consider the style and method used for construction instructions found in modular furniture systems, or the assembly drawings included with products like LEGO® playsets.
    - Note any safety precautions required during construction/assembly and appropriate PPE.
    - This section should not include any steps that are performed during payload preparation for launch.
- Include schematics of the FINAL Payload design. There is a chance dimensions have changed slightly due to final edits and the anticipated construction process.

V) Mock-Demonstration Flight Assessment

Design Division teams shall submit final vehicle design to the NASA Student Launch review panel by 8:00 a.m. CST on 02/22/2021 in the form of a RockSim (.rkt) data file. This file will be used by the NASA panel to generate Mock-Demonstration Flight altimeter data that will then be provided to the team. The team shall use this data to perform analysis and make conclusions about the full-scale design as though it were “real” data gathered from a Vehicle Demonstration Flight. Please be aware that the more detailed your data file submission (including things like mass distribution, payload dummy masses, and estimated coefficient of drag) the more useful the results will be to the team when performing the post-flight analysis.

Evaluate the Mock-Demonstration Flight profile data supplied by NASA and provide the following:

- Launch conditions summary (conditions data supplied by NASA)
- Motor flown (brand and designation, as declared at CDR milestone)
- Ballast flown (lbs.)
- Official target altitude (ft.)
- Mock-Demonstration Flight apogee (ft.)
- Provide graphs of mock-altimeter flight profile and performance data (altitude vs. time, velocity vs. time, and acceleration vs. time)
- Perform an analysis of the Mock-Demonstration Flight data provided by the NASA review panel.
- Update your simulated flight model with launch day conditions data (as provided by NASA) and compare the predicted flight performance to the Mock-Demonstration Flight data. Discuss the results.
- Estimate the drag coefficient of the full-scale rocket utilizing the Mock-Demonstration Flight data.

VI) Safety and Procedures

Safety and Environment (Vehicle and Payload)

- Update the Personnel Hazard Analysis, the Failure Modes and Effects Analysis, and the Environmental Hazard Analysis to include:
    - Finalized hazard descriptions, causes, and effects for the rocket and payload the team would have built. **Note**: These sections can change from CDR to FRR if there are design related changes made as a result of refined modeling and analysis. These should specify the mechanisms for the hazards and uniquely identify them from other hazards. Ambiguity is not useful in safety work.
    - A completed list of mitigations addressing the hazards and/or their causes.
    - A completed list of verifications for the identified mitigations. This should include methods of verifying the mitigations and controls that are (or will be) in place, and how they will serve to ensure the mitigation.
- Be sure to discuss any concerns that remain as the project would move into the operational phase of the life cycle. Emphasize concerns related to your procedures as well as the environment.

Launch Operations Procedures

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

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

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

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

VII) Project Plan

Requirements Compliance

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

Budgeting and Funding Summary

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

Flight Readiness Review Presentation

Please include the following information in your presentation:

- Launch vehicle design and dimensions
- Visually show points of separation along with location of energetic materials
- Discuss key design features of the launch vehicle
- Motor description (motor was declared at CDR milestone)
- 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
- Mock-Demonstration Flight results. Present and discuss the Mock-Demonstration Flight test data.
- Compare and contrast NASA-provided Mock-Demonstration Flight data with Mission Performance Predictions.
- Summary of requirements verification (launch vehicle)
- Payload design and dimensions
- Key design features of the payload
- Payload integration into the vehicle
- Payload retention system design
- Summary of requirements verification (payload)
- Interfaces with ground systems (vehicle and payload)

The FRR will be presented to a panel that may be comprised of scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the designed launch vehicle and payload, showing that the launch vehicle and payload meet all requirements and mission objectives and that the design could be safely launched and recovered.

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 an overall professional 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.

Payload Modification Vehicle Redesign (PMVR)

The PMVR is a significant change to competition requirements and is specific to the Design Division of NASA's USLI competition. It is intended to represent a common occurrence in contract-based space vehicle design. Occasionally, due to a multitude of reasons, a previously awarded space vehicle design contract is modified to meet the changing (or updated) mission objectives of NASA. This is preferable to rebidding contracts, as it utilizes existing designs and hardware to continue the new mission, typically with minimal impact to cost and schedule. NASA USLI will be simulating a contract modification by altering the needs and requirements of the payload mission objective. Details specific to the modification will be released to Design Division teams on 04/06/2021.

Teams are NOT required to design a new payload. Instead, teams will be provided with an alternate payload description and shall redesign the launch vehicle and ancillary systems to accommodate the new specifications. Be aware, this redesign will likely include payload retention method, payload bay dimensions, and/or vehicle motor.

Teams are expected to perform this redesign maintaining as much of the original vehicle design as possible, while also minimizing effects to budget and schedule. This simulates NASA/Contractor obligations to provide design services at reasonable and efficient cost to the federal government.

Payload Modification Vehicle Redesign (PMVR) Report

This report does not require the finalized and polished design criteria of the FRR. Instead, NASA expects the redesign to be similar in scope and fidelity to that of the PDR submission. For each bullet point below, include discussion of changes to that aspect of the design (if changes were made). Otherwise, simply provide the information as it existed in the FRR.

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

Team Summary

- Team name and mailing address
- Document the number of hours spent working on the PMVR milestone.

II) Vehicle Criteria

Design and Rationale of Launch Vehicle

- Include a unique mission statement and new mission success criteria.
- Explain the design at both a system and subsystem level.
    - Describe each subsystem and the components within those subsystems. Emphasis should be placed on Payload Bay, Payload Retention, and subsystem interfaces as these are likely to require redesign.
    - Provide a dimensional drawing annotating dimensions modified as a result of the redesign.
    - Provide estimated masses for each subsystem.
    - Provide sufficient justification for design selections.
- Review motor alternatives and present data on each alternative.

Recovery Subsystem

- Review the design at a component level.
- Using the estimated mass of the launch vehicle and modified payload, perform an analysis on parachute sizing required for a safe descent.
- 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. Keep in mind, this redesign should intend to keep the altitude as close to the original as possible. Verify that the vehicle is robust enough to withstand the expected loads.
- Show stability margin and simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
- Calculate the expected descent time for the rocket and any section that descends untethered from the rest of the vehicle.
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.
- Present data from a different calculation method to verify that original results are accurate.
- Discuss any differences between the different calculations.
- Perform multiple simulations to verify that results are precise.

III) Safety

- Summarize Personnel Safety and Failure Mode and Effects Analysis changes as a result of redesign. Indicate if a hazard or failure mode is worse in likelihood, severity, or both and how this affects mitigation techniques.
- Define the risks to schedule, resources, and budget associated with the redesign.

IV) Project Plan

Budgeting and Timeline

- Provide a line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Provide a timeline beginning at the date of payload mission vehicle redesign that includes all activities and expected activity durations until a redesigned vehicle could be built for testing. GANTT or milestone charts are encouraged.

National Aeronautics and Space Administration

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

www.nasa.gov

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