Space Challenge

System Requirements

13 October 2018

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1. Introduction

1.1. Purpose

This document establishes the minimum system requirements for a liquid-fuel rocket eligible to compete in the Base 11 Space Challenge. These initial requirements, also known as *stakeholder requirements*, apply to a fully integrated *flight system* (rocket) and fully integrated *ground system*. A high-level view of these systems, along with some notional lower-level architectural elements is shown in Figure 1.

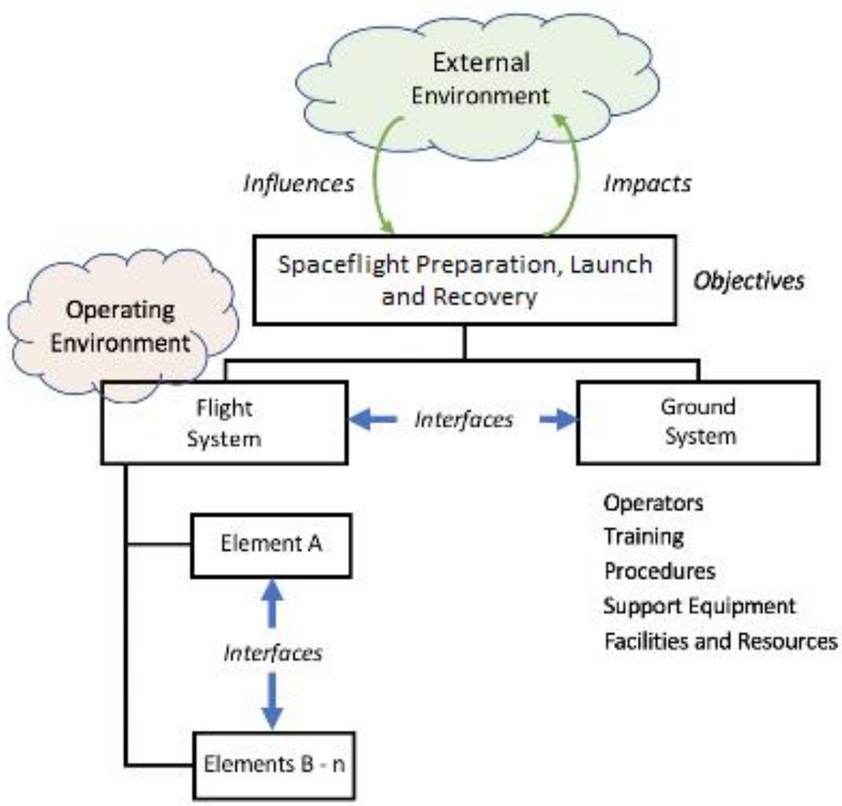

Figure 1 -Launch & Recovery Mission Systems and Environments

The stakeholder requirements contained herein, with very few necessary exceptions, intentionally do not prescribe a particular architectural solution or design approach. Rather, the stakeholder requirements provide a baseline upon which to synthesize a real system that is affordable, producible, and that will be available in time for launch.

You will need to create your own *system requirements* that apply uniquely to *your* system. These expanded and improved system requirements need to satisfy the stakeholder requirements but will also need to include your *derived requirements*. Your system requirements are the outcome of early concept trade studies and analyses, safety requirements derived from your *preliminary hazard analysis*, and those that evolve as you reach your design solution.

Each requirement that is to be part the system requirements must be traceable to one or more of the stakeholder requirements. And each stakeholder requirement must be satisfied by a combination of one or more of your system requirements. Also, each system requirement must be accompanied by your plan to verify or validate it. Your system requirements must contain every system-level requirement needed to conduct the mission and a complete system verification and validation.

Once you have defined your system requirements, it is essential that they be reviewed by everyone on your project team, and as many stakeholders, interested parties, and experts who are willing to participate. In industry this is referred to as the *System Requirements Review* (SRR) and is one of the most important gate reviews in the entire project lifecycle.

And once any necessary changes are incorporated, your system requirements are baselined and placed under configuration control.

The baselined system requirements become the foundation upon which your system architectural design starts, upon which every subsequent step in your systems engineering lifecycle depends.

1.2. Document Organization

The requirements are grouped, albeit imperfectly, into three sections each from a different view point:

<u>3.1 Functional Requirements:</u> how the ground and flight systems must function (what they must do).

<u>3.2 Performance Requirements:</u> how critical things within the system must perform to enable the system to function safely and reliably.

<u>3.3 Safety Requirements</u> what project personnel must do to protect the health and safety of themselves, the public, property, and the environment.

Key definitions and acronyms are in Section 4; some general guidelines can be found in Section 5.

1.3. Contest Requirements and Guidelines

This document is a supplement to the *Base 11 Space Challenge Guidelines*, which provides guidance and establishes expectations and requirements for teams desiring to participate in the launch contest. These requirements are complete in themselves and are not repeated in this document.

2. References

2.1. Applicable Documents

Number	Rev	Date	Title
No Number	---	---	Base 11 Space Challenge Guidelines
14 CFR	---	---	Code of Federal Regulations - Aeronautics and Space Federal Aviation Administration (FAA) [1]

2.2. Guidance Documents

Number	Rev	Date	Title
No Number	---	---	Supplemental Application Guidance for Unguided Suborbital Launch Vehicles (FAA)
RSM2002C	---	15 Mar 2013	NASA - Range Safety Manual for Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF)
Guide: 437.53	---	28 Feb 2011	Calculation of Safety Clear Zones for Experimental Permits under 14 CFR § 437.33(a) (FAA)
NFPA 1127	---	19 Jul 2002	Code for High Power Rocketry - National Fire Protection Association [2]
36 CFR	---	--	36 CFR 1194, Appendix D - Electronic and Information Technology Accessibility Standards
ISO/IEC 15288	---	1 Feb 2008	Systems and Software Engineering - System Life Cycle Processes [2]
ISO/IEC 12207	---	1 Feb 2008	Systems and Software Engineering - Software Life Cycle Processes [2]
NASA/SP-2016-6105-SUPPL	---	Mar 2016	Expanded Guidance for NASA Systems Engineering Volume 1: Systems Engineering Practices (NASA)
MIL-STD-1522A	---	28 May 1984	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems
NASA-STD-5012B	---	16 Jun 2016	Strength and Life Assessment Requirements for Liquid-Fueled Space Propulsion System Engines

3. Requirements

3.1. Functional Requirements

3.1.1. The Chief Safety Officer, or a designated member of the safety team, shall have oversight and insight for these technical requirements and will be responsible for ensuring these requirements are met.

3.1.2. All mission ground operations shall be governed by approved operating procedures, and all persons performing these operations shall be suitably trained for the procedures. The training will be documented in the safety log. Any deviation from procedures must be approved by the relevant team lead(s), and by the Range Safety Officer.

3.1.3. The rocket shall be operated within the operating limitations for Class 3 - Advanced High-Power Rockets specified in 14 CFR §101.23 and §101.25.

3.1.4. The rocket shall be operated within any additional operating limitations imposed by the FAA on the operator's approved Certificate of Waiver.

3.1.5. The rocket shall be designed to achieve an apogee of not less than 100 km, but not more than 150 km per Requirement 3.1.16.1

3.1.6. Prelaunch Preparation

3.1.6.1. If required for smooth ignition transients, the rocket and ground equipment shall perform functions necessary to precondition (chill) the propulsion system plumbing and components prior to ignition.

3.1.7. SAFE and ARM - Pyrotechnic and High Pressure Devices

3.1.7.1. Any and each pyrotechnic or high pressure device in the rocket shall remain in its approved SAFED configuration until the launch commander authorizes the launch crew to set it to its ARMED configuration.

3.1.7.2. Safing of pyrotechnic devices shall involve shorting and grounding the initiator. Keylocks at both the pad and mission control shall be employed to prevent unintentional firing of a pyrotechnic device while personnel are near the rocket.

3.1.7.3. The propellant feed system shall remain in its approved SAFED configuration until the launch commander authorizes it to be set it to its ARMED configuration.

3.1.7.4. The flight recovery system shall remain in the SAFE configuration until after the powered flight phase.

3.1.7.5. No high explosive devices shall be used. Low explosives such as black powder are permitted.

3.1.8. SAFE and ARM - Fire Control System

3.1.8.1. The fire control system (circuits or transmitters and receivers between the launch control room and the propulsion system ignitor) shall remain in the approved SAFED configuration until the launch safety officer, with the concurrence of the range safety officer, authorize the launch commander to send the ARM signal from the control room.

3.1.8.2. The fire control system shall remain ARMED until the launch safety officer, with the concurrence of the range safety officer, authorize the launch commander send the START signal from the control room.

3.1.9. Start and Liftoff

3.1.9.1. The rocket and ground equipment shall perform all functions needed to safely start the propulsion system and release the rocket for liftoff.

3.1.10. Powered Flight

3.1.10.1. The rocket shall perform any propulsion system monitoring and control functions needed to achieve and maintain the thrust necessary to reach mission apogee.

3.1.11. Optional Propulsion System Shutdown

3.1.11.1. If a controlled engine shutdown is desired, or necessary to guarantee compliance with 3.1.3, the rocket shall include all necessary provisions for implementing it in compliance with requirements 3.1.11.1 - 3.1.11.5. Otherwise, the propulsion system may run until propellant exhaustion.

3.1.11.2. The shutdown sequence shall shutoff propellant feed systems in a manner that prevents propulsion system instability, propellant fire, or explosion.

3.1.11.3. The rocket shall initiate a nominal propellant and pressurant offload sequence.

3.1.11.4. The offload sequence shall control opening and closing feed system valves to expel remaining oxidants, fuel and pressurants to the atmosphere in a manner that prevents propellant fire or explosion.
Simultaneous venting of fuel and oxidizer through the engine that could allow mixing of propellants and formation of an explosive mixture is not considered acceptable.

3.1.11.5. At the completion of offload, feed system valves shall be closed or set to known positions needed for safe ground recovery operations.

3.1.12. Coast to Apogee

3.1.12.1. The recovery system shall be ARMED and functionally verified prior to launch.

3.1.12.2. If onboard altitude measurement is employed, the rocket shall record the altitude at apogee with an accuracy of $\frac{+0}{-10}$ km: in other words, it may not over-report the apogee, but is permitted to under-report it.

3.1.12.3. For official apogee determination, the Competition will provide radar as an independent means of vehicle tracking. Rockets will need to have sufficient radar cross section to be tracked by radar. Composite rockets will be required to incorporate an omni-directional radar reflector at least 5-inches in diameter to facilitate tracking.

3.1.13. Recovery Phase

3.1.13.1. The recovery system shall deploy its drogue parachute following apogee but before the atmospheric density and descent rate would make its deployment unsafe.

3.1.13.2. The drogue parachute shall stabilize the descent of tethered components and provide sufficient drag to permit safe deployment of the main parachute.

3.1.13.3. The recovery system shall deploy the main parachute late enough in the descent to minimize the effects of wind drift.

3.1.13.4. The main parachute shall reduce the force of impact sufficiently to allow continued operation of the telemetry system and preservation of recorded flight telemetry data, continued operation of the ground recovery transponder, and continued operation of systems needed to support the ground recovery operation

3.1.13.5. The ground recovery transponder shall transmit locator signals to, and respond to command signals from, the ground recovery team.

3.1.14. Emergency Launch Abort

3.1.14.1. A launch abort sequence shall be initiated if the launch commander transmits a LAUNCH ABORT signal prior to liftoff.

3.1.14.2. The launch abort sequence shall autonomously perform functions needed to shut down the oxidant and fuel feed systems in a manner that prevents propellant fire or explosion.

3.1.14.3. The rocket shall incorporate features to allow all tanks to be depressurized remotely.

3.1.14.4. Following a launch abort sequence, certified ground personnel shall perform approved operational procedures to safely offload propellants and pressurization gases and return the launch vehicle to a SAFE configuration.

3.1.14.5. The rocket shall incorporate features to address contingency liquid propellant offloading operations. For example, making the system fill-and-drain valve readily accessible on the launch pad.

3.1.14.6. The rocket shall incorporate features allowing the propellants to be drained by gravity alone.

3.1.15. System Monitoring and Reporting

3.1.15.1. If an active stability control system is employed (see 3.1.16.4), critical propulsion system performance parameters shall be measured and recorded throughout launch and powered flight that pertain to flight safety conditions, system and predicted impact point.

3.1.15.2. If stability control is not employed, onboard monitoring of propulsion and vehicle performance parameters is optional.

3.1.16. Functional Constraints

3.1.16.1. The rocket shall not reach an apogee of greater than 150 km above ground level (AGL).

3.1.16.2. The total impulse shall not exceed 889,600 Newton-seconds (200,000 pounds-seconds) in accordance with the FAA upper limit for a class 3 amateur rocket.

3.1.16.3. Active flight control systems that have the capability to guide the rocket or any of its components to a spatial target are prohibited.

3.1.16.4. Active stability control systems that allow the rocket to maintain its orientation, but do not allow it to be guided to a specific location, are permitted.

3.1.16.5. If active stability control is employed, a flight termination system must be incorporated capable of terminating engine thrust in the event of a trajectory deviation that would carry the rocket beyond the approved exclusion zone. This may be either:
a) An autonomous system, if that system is shown to have acceptable reliability as determined by the New Mexico Spaceport Authority, or
b) A system employing ground-based radar to track the vehicle (provided through the New Mexico Spaceport Authority)

3.2. Performance Requirements

3.2.1. Each flight and ground element or component shall be tested for functionality and shall be designed to have sufficient reliability to function nominally throughout the full duration and all expected environments of operation.

3.2.2. Flight Performance

During flight, the integrated mission system (rocket, ground equipment, and operations) shall meet the following ground safety requirements:

3.2.2.1. The casualty expectation shall not exceed an estimated casualty (*Ec*) of 30 x 10 -6 per launch. *This calculation is described in the FAA's "**Supplemental Application Guidance for Unguided Suborbital Launch Vehicles**," and detailed in Attachment 3 of that guide. The New Mexico Spaceport Authority will support this analysis.*

3.2.2.2. No overflight or impact (*impact hazard area*) shall occur outside of pre-determined exclusion zones. Exclusion zones will be determined in collaboration with the New Mexico Spaceport Authority. (see Figure 2).

3.2.2.3. The rocket shall achieve a rigid body stability of at least 2.0 calibers upon departing the launch rail and throughout powered flight.

Departing the launch rail is defined as the first instant in which the rocket becomes free to move about the pitch, yaw, or roll axis. This generally occurs at the instant the last rail guide forward of the vehicle's center of gravity (Cg) separates from the launch rail.

This means the center of pressure (Cp) shall be located behind the center of gravity (Cg), and the distance between the Cp and the Cg divided by the largest frontal diameter of the rocket is least 2.0.

3.2.3. Structures

3.2.3.1. The rocket structure shall support and protect its systems, elements, components, assemblies, harnesses, ducting, etc., and allow the system to perform and function as specified during exposure to the worst-case thermal and mechanical loads (including acoustic, vibration, shock, acceleration, and ground impact) of the launch and recovery mission.

3.2.3.2. Airframe shall be adequately vented where necessary to prevent excessive internal pressures developed during flight.

3.2.4. Propulsion System

3.2.4.1. The propulsion system shall be bi-propellant liquid-fueled. (Solid and/or hybrid propulsion systems are not permitted.)

3.2.4.2. Propellants shall be liquid. The use of hypergolics, hydrazine, and nitrogen tetroxide are not permitted. Proper handling procedures and appropriate personal protective equipment shall be used at all times when working with propellants.

3.2.4.3. The propulsion system shall include a thermal management system or method to protect the thrust chamber and nozzle from destructive overheating, such as ablative, regenerative, and/or film cooling.

3.2.4.4. Electrical circuits that operate liquid propellant flow control devices shall be designed to ensure that propellant valves cannot open until positive indication of igniter firing is received.

3.2.4.5. The engine igniter shall be both physically and electrically isolated from the power source by a minimum of two independent inhibits.

3.2.4.6. The engine igniter shall be electrically isolated by switches in both the power and return legs

3.2.4.7. The igniter shall be locked out to prevent any sort of ignition event when personnel are in the vicinity, and this lockout shall short and ground the igniter.

3.2.4.8. If pyrotechnic or otherwise EMI-sensitive igniters are employed, the igniter wiring shall be in a separate cable, which is twisted, shielded, double insulated, and independent of all other systems.

3.2.4.9. Protection of igniter wiring by use of physical barriers or by physical location of components shall be employed such that short circuits to other power systems are impossible, even assuming loose or broken wires.

3.2.4.10. Pressure relief devices shall be incorporated on all systems having a pressure source which can exceed the maximum allowable pressure of the system, or where the malfunction / failure of any component can cause the maximum allowable pressure to be exceeded. Relief devices are required downstream of all regulating valves and orifice restrictors unless the downstream system is designed to accept full source pressure.

3.2.4.11. Relief devices shall be selected to ensure the pressure does not exceed 110% of the maximum expected operating pressure of the system, or does not exceed a value that would cause general yielding of the pressure vessel or system.

3.2.4.12. All pressure relief devices shall be sized to provide relief at full flow capacity at the pressure specified in 3.2.4.11, or lower.

3.2.4.13. The size of pressure relief devices shall be specified to withstand maximum pressure and flow capacities of the pressure source, to prevent pressure from exceeding the value specified in 3.2.4.11.

3.2.4.14. Any pressure vessel with a burst pressure less than 4.0 times the maximum expected operating pressure (i.e. Factor of Safety of 4.0) shall only be pressurized and de-pressurized remotely and shall never be approached by personnel while pressurized.

3.2.4.15. Vehicle propellant tanks shall not have a burst pressure of less than 1.5 times the maximum expected operating pressure, and other pressure vessels shall not have a burst pressure of less than 2.0 times the maximum expected operating pressure.

3.2.4.16. If a propellant tank is designed with a burst pressure of less than 2.0 times the maximum expected operating pressure, or if the tank is composite, hydrostatic burst testing must be performed to demonstrate that the design and manufacturing process actually achieved or exceeded the design burst pressure.

3.2.4.17. If a tank incorporates welds, the weld and vicinity shall be designed for a factor of safety at least 20% greater than that of the tank on the whole, to account for inconsistency and imperfections in the welding process.

3.2.4.18. Prior to use, pressure vessels intended for static testing or flight shall be proof tested. Proof pressure shall be selected such that the gross stress level in the tank during the proof test does not exceed 95% of the yield strength of the material, and does not exceed 75% of the ultimate strength of the material.

3.2.4.19. The tank shall be designed such that Requirement 3.2.4.18 can be met with a proof pressure not less than 1.1 times the maximum expected operating pressure.

3.2.4.20. If composite pressure vessels or fluid components are to be used with an oxidizer such as liquid oxygen, material testing shall be undertaken in accordance with ASTM D2512 - 17: Standard Test Method for Compatibility of Materials with Liquid Oxygen, or an equivalent approved standard, to demonstrate that the risk of ignition in a high pressure oxidizer environment is acceptably low.

3.2.4.21. Volumes within the fuel feed system where cryogenic propellant could become trapped shall have a relief valve or other overpressure protection.

3.2.4.22. A quality control program shall verify that all system fittings and seals are properly installed and have leak integrity. This could include, for example, provisions for lower-pressure leak testing of the assembled system(s) at ~100 psig, and a process for inspection and supervision of the installation of fittings and seals.

3.2.4.23. Propulsion system welds shall be made only by certified welders.

3.2.4.24. All seal materials shall be compatible with the fluids and temperatures to which they will be exposed.

3.2.5. Electrical Systems

3.2.5.1. Transmitters and receivers used onboard the rocket and those used for ground operations shall have the necessary characteristics and protections to perform required communication functions during all phases and operating environments of the mission.

3.2.5.2. Electrical assemblies and devices shall be compatible with the external and self-induced electromagnetic environments that will exist during flight or testing.

3.2.5.3. All onboard electrical systems, including avionics, GPS and telemetry, shall be tested as an integrated system to insure that no components cause any apparent interference with any others.

3.2.5.4. Onboard avionics and control systems shall be electrically isolated from any pyrotechnic or electro-explosive devices such that a short of a pyrotechnic device cannot disable the control system.

3.2.5.5. Electrical systems shall be designed to limit or prevent a short in one system from disabling other flight- or safety-critical systems.

3.2.5.6. An optional payload may be included on the rocket (with optional instrumentation or experiments.

3.2.5.7. If a payload is included, it shall not compromise the safety or performance of other systems.

3.3. Safety

3.3.1. Analysis

3.3.1.1. Hazard Analysis

3.3.1.1.1. The assigned safety officer, working with all team leads, shall conduct and maintain a hazard analysis to:

- Identify and describe hazards, including but not limited to each of those that result from component, subsystem, or system failures or faults; software errors; environmental conditions; human errors; design inadequacies; or procedural deficiencies.
- Prepare a qualitative "risk cube", where the approximate relative likelihood of occurrence and severity of each risk are plotted, to aid in the identification and mitigation of unacceptable risks.
- Identify and select risk mitigation measures that ensure that (a) any hazardous condition that could cause death or serious injury to the public will be remote, and (b) any hazardous condition that could cause major property damage to the public, major safety-critical system damage or reduced capability, a significant reduction in safety margins, or a significant increase in crew workload will be remote. Risk mitigation measures should be selected in the following order of preference: (a) safety design features, (b) incorporate safety devices, (c) provide warning devices, or (d) implement procedures and training.
- Ensure that risk approved mitigation systems or procedures are implemented.
- Ensure the continued accuracy and validity of its hazard analysis throughout the project lifecycle.
- The assigned safety officer shall ensure that safety requirements derived from the hazard analysis are captured early in the system requirements development phase whenever possible.

3.3.1.2. Ground Safety Analysis

3.3.1.2.1. The system analyst shall calculate safety clear zones for hazardous preflight and post-flight operations (including recovery operations) in accordance with **FAA Guide 437.53-1, *Calculation of Safety Clear Zones for Experimental Permits under 14 CFR §***

437.53(a) or an equivalent method. This analysis will be supported and vetted by the New Mexico Spaceport Authority.

3.3.1.2.2. The system analyst shall define flight criteria and calculate a *maximum impact range* and flight *impact hazard area* in accordance with FAA publication ***Supplemental Application Guidance for Unguided Suborbital Launch Vehicles,*** **Attachments 1 - 4**, or an equivalent method (see Figure 2).

3.3.2. Planning

3.3.2.1. The safety officer shall develop a *ground operations plan* that identifies each operation to be performed and establishes the sequence and timing for their execution.

3.3.2.2. The safety officer shall prepare and document step-by-step procedures and/or checklists for every ground operation.

These may be contained within an overall safety plan but should be separable as needed during actual operation and training.

3.3.2.3. Operating procedures shall ensure that any critical cleanliness requirements (e.g. for oxidizer plumbing) are maintained and no unacceptable contamination can occur.

3.3.2.4. Any necessary procedures for transportation, storage and handling of propellants, pyrotechnics and other hazardous materials shall be prepared, and approvals obtained from regulating authorities prior to performing these operations.

3.3.2.5. Hazardous operations shall be planned such that, should an incident occur, they will cause the least possible injury to personnel or damage to facilities or surrounding property.

3.3.2.6. Hazardous operations shall be planned such that the minimum number of people will be exposed to the hazard.

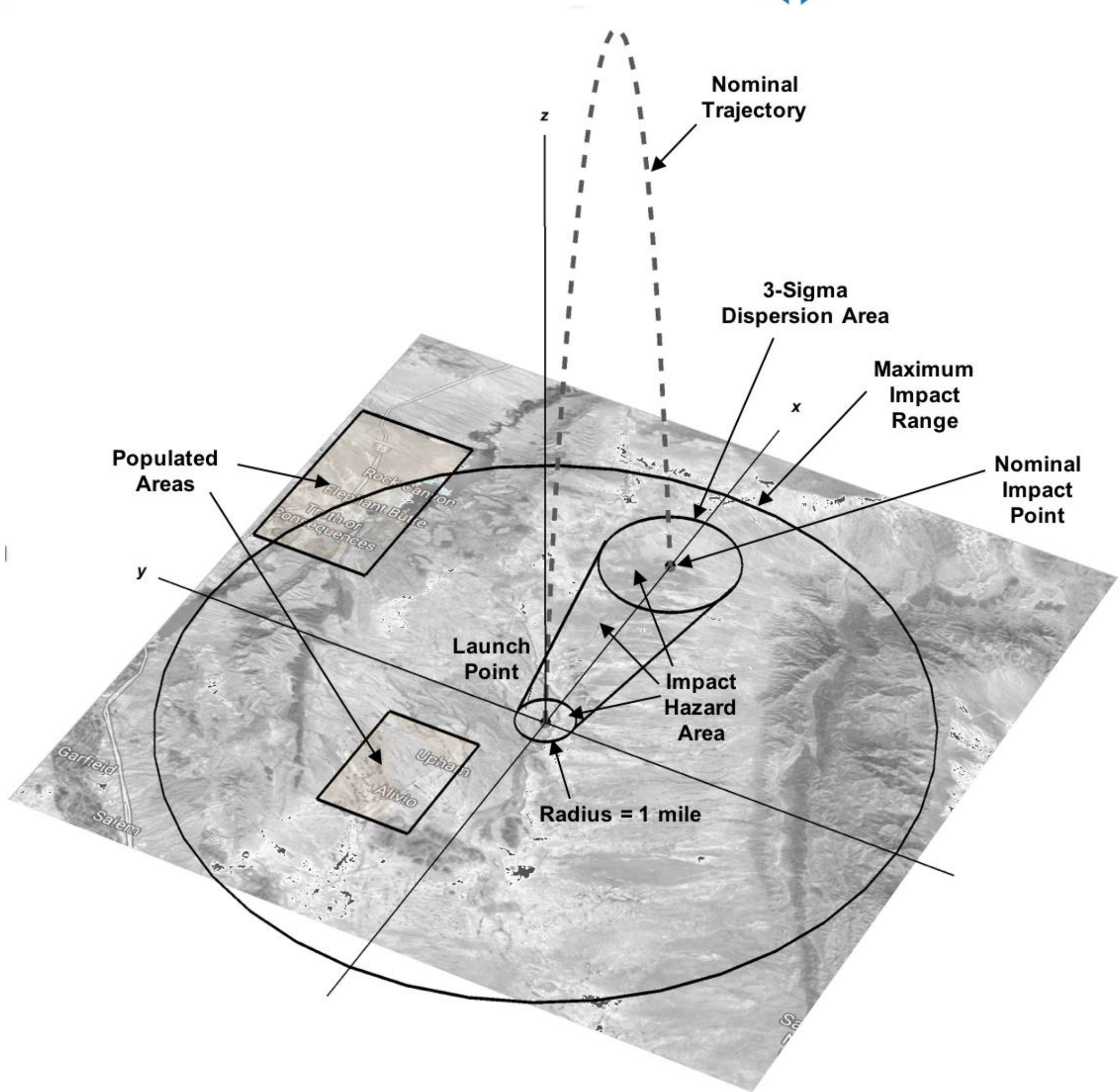

Figure 2 - Maximum Impact Range and Impact Hazard Area

3.3.2 Planning (continued)

3.3.2.7. The safety officer shall identify hazardous operations that will require operators to use personal protective clothing and/or equipment (PPE).

3.3.2.8. The safety officer shall make arrangements for necessary PPE to be acquired and available in time for and use in operation and for any necessary training.

3.3.2.9. The safety officer shall develop training and certification plans, procedures, and training materials that cover each planned ground operation.

3.3.2.10. The safety officer shall schedule and perform training and certification for persons performing each planned ground operation.

3.3.2.11. The safety officer shall maintain up-to-date training and certification records.

3.3.2.12. The safety officer shall coordinate with Spaceport America to agree on and prepare the *launch commit criteria* and ensure that they are adhered to.

3.3.2.13. The safety officer shall ensure that all safety documents, data, and analysis are prepared and maintained.

3.3.2.14. <u>Operations Requiring Personal Protective Equipment (PPE)</u>

3.3.2.14.1. If electronic or other devices are employed that are sensitive to electrostatic discharge (ESD), suitable static dissipating equipment such as a wrist strap shall be worn when handling them.

3.3.2.14.2. Personnel conducting operations where an ocular hazard may exist shall wear safety glasses or face shields.

3.3.2.14.3. Personnel conducting operations under potentially dangerous overhead objects (such as crane and lifting operations) shall wear hardhats with a chin strap.

3.3.2.14.4. Personnel conducting hazardous chemical operations shall use PPE (identified on a case-by-case basis) to provide adequate protection

3.3.2.14.5. Personnel performing operations involving propellants shall have completed the necessary training to do so, and shall employ the appropriate PPE and practices for the specific propellant.

3.3.2.15. <u>Launcher Setting Procedures</u>

3.3.2.15.1. For flight missions performed without a flight safety system, the maximum effective launcher elevation shall be 85 degrees, or as per the FAA waiver.

3.3.2.15.2. If the mission-configured rocket, including any component, is unguided and has sufficient energy to reach any populated area in any direction from the launch point (see *maximum impact range* in the ground safety analysis section), a *wind weighting safety system* shall be used to correct for the effects of wind conditions at the time of flight to provide a safe impact location.
The New Mexico Spaceport Authority will provide the necessary wind data on the day of the launch, and the team will be required to use this data to determine the necessary launch rail angle.
Wind weighting calculation is described in ***Attachment 4*** *of the FAA's* ***Supplemental Application Guidance for Unguided Suborbital Launch Vehicles****.*

3.3.2.15.3. For flight missions performed with a wind weighting safety system, the maximum wind-corrected launcher elevation shall be 85 degrees, or as per the FAA waiver.

3.3.2.15.4. The nominal launcher azimuth shall be limited such that the calculated *impact hazard area* does not fall outside the pre-approved exclusion zone (see maximum impact area in the ground safety analysis section).

3.3.2.16. <u>Ground Recovery Procedures</u>

3.3.2.16.1. Any mechanical hazards shall have a means of restraining all stored energy that remains prior to ground recovery. In other words, the system must be safed.

Methods of reducing this hazard include applying approved mechanical restraints and/or venting high pressure sources, while limiting access to recovery area).

3.3.2.16.2. If risk reduction cannot be accomplished (reducing the energy of hazardous systems to their lowest energy states or consuming the hazardous materials), then a suitably trained 2-person ground recovery team shall perform any necessary safing tasks after a strategy has been agreed upon with the Range Safety Officer.

3.3.2.16.3. A procedure shall be put in place for recovering a crashed rocket that ensures all pieces are bagged and removed from the site.

3.3.2.17. <u>Agreements and Notifications</u>

3.3.2.17.1. A designated person shall be responsible for preparing the application and coordinate with the FAA to obtain a Certificate of Waiver to authorize the launch. The New Mexico Spaceport Authority will support the application with any needed data.

3.3.2.17.2. An assigned official from the school (for example the general counsel) shall obtain an agreement in writing with the launch site operator, or any other party that provides access to or use of property and services required to support the launch and recovery operation.

3.3.2.17.3. An assigned official working with the Spaceport shall obtain an agreement with responsible Air Traffic Control authority having jurisdiction over the airspace through which the flight is to take place and establish the measures necessary to ensure the safety of aircraft.

3.3.3. <u>Training and Certification</u>

3.3.3.1. All persons who will be assigned perform any launch or recovery operation shall be trained and proficient to perform that operation.

3.3.3.2. All persons who will be assigned to perform a hazardous operation shall be trained and certified to perform that operation.
"Certified" in this context refers to internal training to ensure that only personnel who are cognizant of the procedure and associated hazards and safety aspects shall perform a given operation. In any cases where the operation is governed by other regulatory bodies (for example ATF in the case of explosives), "Certified" shall be as per the relevant regulations.

3.3.3.3. Trained and/or certified personnel shall perform operation rehearsals to ensure proficiency shortly before operations are to take place.

3.3.3.4. Persons who will be required to use PPE shall be trained on the proper use and care.

3.3.4. <u>Restricted Areas during Mission Operations</u>

3.3.4.1. Only authorized launch support personnel are permitted to be in launch preparation areas.

3.3.4.2. The safety clear zone shall be put in place and clear of the public and non-essential support personnel before and during hazardous operations.

3.3.4.3. Only designated *launch essential personnel* are permitted to be within the safety clear zone prior to launch.

3.3.4.4. All personnel shall be cleared from the safety clear zone prior to arming the fire control system.

3.3.4.5. Only authorized ground recovery personnel are permitted to be within the safety clear zone established at the recovery site.

4. Definitions and Acronyms

AGL: Above ground level

CFR: Code of Federal Regulations

CG: Center of Gravity

CP: Center of Pressure

EC: Estimated Casualty

EMI: Electromagnetic Interference

ESD: Electrostatic Discharge

FAA: Federal Aviation Administration

GPS: Global Positioning System

GSFC: Goddard Space Flight Center

MEOP: Maximum Expected Operating Pressure

NFPA: National Fire Protection Association

PPE: Personal Protective Equipment

RSM: Range Safety Manual

RSO: Range Safety Officer

SRR: System Requirements Review

WFF: Wallops Flight Facility

5. Guidelines

5.1. Project Lifecycle Processes

Project and systems engineering management should always adopt and follow a usable development life cycle and integrated and set of applicable processes. This is particularly important for complex projects (like this one), which need to effectively deal with lots of tasks being performed by lots of different people. Prior to integrated modelling systems, like the Dassault Systèmes 3D Experience® platform (being provided to teams participating in the Base 11 Space Challenge), managers and engineers had to try to keep track of everything manually, on paper, through emails, or by hearing second hand about decisions made at meetings. I recommend you don't even try to go down that path.

For inspiration you should read section 8.2 out of NASA/SP-2016-6105-SUPPL, *Expanded Guidance for NASA Systems Engineering Volume 1: Systems Engineering Practices* titled Model-Based Systems Engineering. It's short and enlightening.

The Dassault platform may have most of the management and engineering process tools built right in and it should be adaptable to your institution's management processes.

If you are not presently using some form of standard processes, or if the ones you are trying to use are burdensome, I recommend you try something like those in ISO/IEC 15288 *Systems and Software Engineering - System Life Cycle Processes*. They are clear, instructive, and easily simplified (tailorable) to meet your needs - so check them out.

5.2. A Model Development Plan

While your own plan will be unique to you, an example of a simplified internal master schedule is shown in Figure 3.

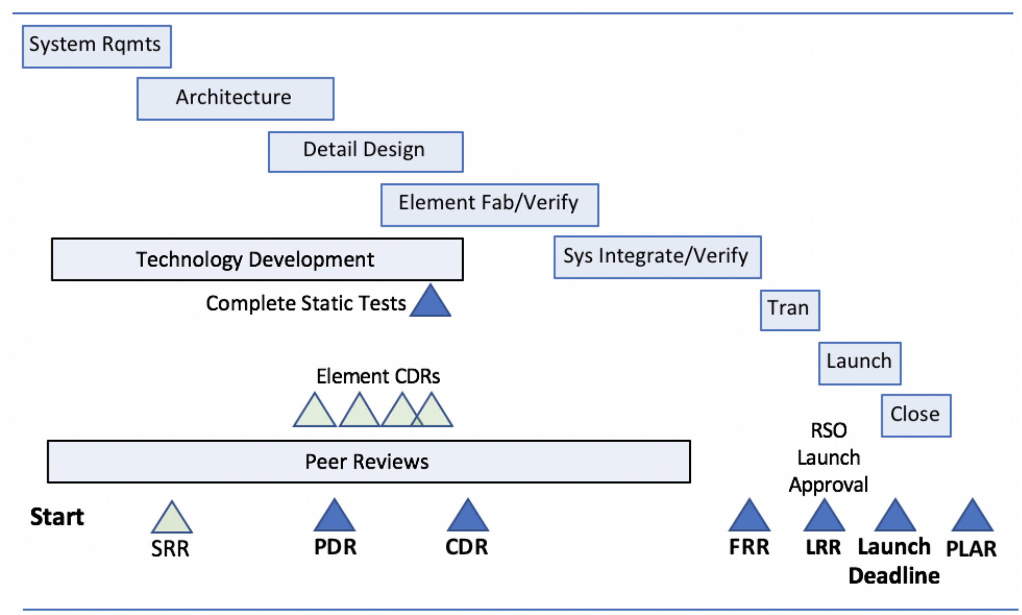

Figure 3 - Sample Internal Schedule

In the introduction to this document, I spent some time explaining what *your* system requirements are and the importance of getting them out of the way ASAP.

So now let's look at "the whole plan" and some important things you may wish to consider.

Just like your system requirements are not going to be exactly the same as those of your stakeholder, *your* internal plan will not, and should not, be the same as the stakeholder's either. You still need to get through the gate reviews on time and provide all the required documents and other services, but internally you need to do a lot more than that. And that is why you need a realistic project plan for getting it all done. Once you get your plan set up, you shouldn't need to spend much tending to it. You'll just need to feed it a little information from time to time, and it will go off by itself and do a bunch of number crunching and by the time you get back from lunch, it will have just the information you needed along with some useful insights you didn't realize you *really* needed.

Your integrated modelling system is rapidly gathering more and more information: your requirements, analyses, designs, trade studies, simulations, everything! Well, maybe not everything, but most of the stuff. Because all the technical and project data are all in one place, everybody can find whatever they need and even know what they're supposed do next. If you don't think that's just awesome, then you don't realize much manual labor, stacks of shuffled paper, late nights, and cold coffee, us old-timers had to deal with just to try to get a vague feeling of what was really going on. Learn how to use the system, and put it to work.

Realistically, an integrated system can't design and build a rocket for you, but it can relieve you of enough non-productive busy work that you can do what really needs to be done - like communicating concepts and ideas with your colleagues, conducting peer reviews with well-informed participants, and doing your detailed technical work while understanding the big picture. So, get with the program, and best of luck!