<u>HIGH POWER ROCKET RULES FOR COLLEGES AND UNIVERSITIES</u>
BALLS LAUNCHED ON THE BLACK ROCK DRY LAKEBED

<u>PURPOSE</u>

The purpose of this document is to provide rules for colleges and universities that wish to launch **<u>ANY</u>** high power rocket project at BALLS. All questions, concerns, or other matters should be directed to the Prefect or the Launch Director.

<u>NOTICE TO ALL INDIVIDUALS INVOLVED IN THE PURSUIT OF FLYING A TEAM ROCKET</u>

By being a member of a college high power rocketry project team, all team members are assuming liability in the event something goes wrong. Neither the team's mentor nor TRA are specifically liable, especially if operating outside of the TRA safety code. Rocketry can be a dangerous especially if not operating in a safe manner. Have a full plan, be safe and ask for help if ever unsure before taking the next step of the process.

<u>RULES</u>

The following applies to **<u>ALL</u>** college and university team projects, whether single, multi-stage, or hybrids; **<u>NO EXCEPTIONS.</u>**

1. MENTORS AND MENTORING

   A. All teams must have a TRA mentor, with a Level 3 certification and appropriate experience to supervise the project. No non-Tripoli mentors will be allowed, except with TRA board approval. A list of approved mentors can be provided in writing if so desired.

   B. The mentor must be wholly engaged with the project from beginning to end, attending to the details as described below:

      I. Specific design and construction areas must be reviewed and approved by the mentor. These shall include airframe, electronics, motors, recovery systems, payloads, and validated flight profiles. When the design is approved, it must be built that way and not divert from the design plan. If in the construction phase, design changes are necessary, such revisions must be reviewed and approved by the mentor. All approved changes must be documented. Much/all of this can be accomplished remotely, by the team submitting written documentation with digitized images of the design/construction. Personal on-site interaction from time to time is of course preferable.

      II. When the project arrives at the launch venue, the mentor will inspect the project comprehensively to ensure it conforms to the design/construction as portrayed by the team to the mentor, and/or if it can fly safely as configured. Any deficiencies must be corrected prior to approval for flight. No flight attempts may be made without written authorization by the mentor.

      III. The mentor must accompany the team through all phases of the project's actual flight attempt. If the mentor is the official flyer, they must act in that capacity. In all cases, the mentor must ensure a reasonably qualified flyer of the cert level of the project understands the project, is personally present, and acts as the official flyer.

      IV. In the event that the mentor of record is unavailable to follow the project through the launch, a substitute mentor may assume the role of mentor. The substitute must be on the approved mentor list and approved by the Launch Director or designated person.

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2. PROJECT DESIGN BASICS

A. An application to launch any university project must be submitted to the Launch Director 45 days ahead of the scheduled launch date as established by the Launch Director. All applications will be acknowledged in writing by the Launch Director or a designated person.
B. Any project with an installed impulse greater than 40960 Newton-seconds must be submitted to the Tripoli Class 3 Research Committee [C3RC]. Once approved they will submit it to the FAA. A copy of the Certificate of Authorization [COA] received from the FAA must be forwarded to the Launch Director.
C. Any project that will attain an altitude of 50,000 feet AGL or greater must be submitted to the C3RC and a copy of the approved C3RC paper work received by the team and must be forwarded to the Launch Director.
D. Application must include the following and the Launch Director may ask for additional information as required for the specific project/team:

   I. Design drawings
   II. Calculations or Finite Element Analysis [FEA] models for structure, electronics mounts, etc. including materials being used
   III. Electrical schematic for recovery systems and flight computers
   IV. A description of any additional instrumentation onboard
   V. A checklist to include complete arming and disarming procedures for every propulsion or energetic system
   VI. A Safety Concerns document, documenting possible safety concerns and assigned roles to team members for each.

E. For non-commercial motors, it is strongly recommended that the mentor work with the team to develop the motor design. Resources outside of the normal team members may be used if the necessary experience is not contained on the team. For any project utilizing non-commercial motors, the project team must submit:

   I. At least (1) static test firing for each motor type in the project
   II. Propellant formulation
   III. Propellant characterization data
   IV. Burn Sim output

F. All projects must be approved in writing by the Launch Director or a designated person; projects that do not have prior approval will not be allowed to launch.
G. Projects must have a signed letter from the appropriate university or college department head(s) stating that they agree that the students are ready and sufficiently prepared to launch their project. Under no circumstances will any team be allowed onto the launch site without this letter. This letter must be received no later than 14 days prior to the Friday of the launch. No exceptions.
H. All changes must be approved by the Launch Director.
I. Only commercially manufactured electronics may be used for recovery electronics.
J. Home assembled, and/or home manufactured electronics are not permitted for use as primary or secondary recovery devices. They may be used at the tertiary level as long as commercially produced electronics are used as the primary and secondary systems.

3. PROCEDURES AND OPERATIONS

A. Checklists must be provided that cover ground preparation in regard to airframe checkout/assembly, avionics preparation, and ground testing, recovery systems, and devices preparation.

B. A pad setup and loading checklist must be provided for all projects being loaded on the pad and erection of the launcher, including any preflight payload checks.
C. A final preparation procedure or checklist, including igniter installation, avionics power up and any payload power up is required.

3. PROCEDURES AND OPERATIONS (continued)

D. A Safety Procedure Document will also be required to ensure the rocket electronics can be disarmed and made safe to allow lowering and removal from the launch pad.
E. Projects must plan for an on-pad hold time of between 30 minutes to one hour, with this not applying to hybrids.
F. A dedicated Safety Person must be assigned for each team. The Safety Person and the Flyer of Record are responsible for overall project safety, including monitoring safety during preparation, transport to the away cell, and loading the project onto the pad. This responsibility does not stop until the rocket has lift-off and is recovered. These participants must have a written plan in place with assigned roles and separate procedures to address any and all potential safety concerns, including but not limited to:

    I. Pad fire
    II. Motor CATO on the pad
    III. Motor CATO in flight
    IV. Primary and/or secondary electronics failure on the pad or in flight
    V. Injury
    VI. Any damage to the rocket, or motor(s)

G. No more than three team members and the mentor shall be at the pad once the rocket is loaded onto the pad and raised into a vertical orientation.
H. Strict attention must be paid to the proper sequence of operation on any project:

    I. Test igniters for continuity away from any energetic materials before transporting the project to the away cell.
    II. Load rocket onto the pad
    III. Raise rocket to the vertical orientation and lock the pad mechanism to secure the rocket
    IV. Relocate all but three team members and the mentor back to the range head or other gathering point
    V. Arm recovery electronics **RECOVERY IS MANDATORY; LAUNCHING IS NOT!**
    VI. Arm any additional flight avionics
    VII. Insert the igniter into the motor
    VIII. Before attaching the initiator clips to the initiator, touch the igniter clips together, looking for a spark. If there is a spark, the system has power. Stop all operations and contact the Away Cell manager immediately. **UNDER NO CIRCUMSTANCES CONNECT THE CLIPS TO THE MOTOR INITIATOR!**
    IX. If no spark is present, connect the clips of the initiator leads to the igniter.
    X. Check continuity. If continuity is good, relocate to the area assigned by the Away Cell Manager. If no continuity, contact the Away Cell Manager immediately.

4. HAZARD IDENTIFICATION AND ANALYSIS (Base on MIL-STD-882)

A. A mishap that leads to the unintended, unplanned, or premature ignition of a rocket motor is considered a high hazard and is categorized as a Catastrophic Hazard. Systems related to rocket motor ignition are always considered Category A (hazardous).
B. A mishap that leads to the unintended, unplanned, or premature operation of a conventionally designed ejection system or recovery system may be categorized as a Critical, Marginal or Negligible Hazard depending on the amount of stored energy involved and how it could be released.

4. HAZARD IDENTIFICATION AND ANALYSIS (continued)

   C. Each Class 3 project must include a hazard assessment to determine the appropriate design requirements for the individual systems. Other potentially hazardous systems that probably would not lead to ignition of a rocket motor but could lead to injury (e.g. pressurized gas systems, etc.) should be evaluated and addressed as well. A Fault Mitigation Effects and Criticality Analysis [FMECA] is appropriate for any hazardous systems. The methods of Military Standard 882 [MIL-STD-882], (available on-line) should be tailored to the particular project. Please refer to MIL-STD-882 for further information regarding risk assessment.
   D. Assess and document risk: The severity category and probability level of the potential mishap(s) for each hazard across all system modes are assessed using the definitions in Tables I and II.

To determine the appropriate severity category as defined in Table I for a given hazard at a given point in time, identify the potential for death or injury, environmental impact, or monetary loss. A given hazard may have the potential to affect one or all of these three areas.

TABLE I – Severity Categories

SEVERITY CAREGORIES		
DESCRIPTION	**SEVERITY CATEGORY**	**MISHAP RESULT CRITERIA**
Catastrophic	1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: permanent partial disability, injuries, or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	4	Could result in one or more of the following: injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100K.

When available, the use of appropriate and representative quantitative data that defines frequency or rate of occurrence for the hazard, is generally preferable to qualitative analysis. The Improbable level is generally considered to be less than one in a million.

TABLE II – Probability Levels

PROBABILITY LEVELS			
DESCRIPTION	**LEVEL**	**SPECIFIC INDIVIDUAL ITEM**	**FLEET OR INVENTORY**
Frequent	A	Likely to occur often in the life of an item.	Continuously experienced
Probable	B	Will occur several times in the life of an item	Will occur frequently
Occasional	C	Likely to occur sometime in the life of an item.	Will occur several times
Remote	D	Unlikely, but possible to occur in the life of an item	Unlikely, but can reasonably be expected to occur
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced in the life of an item.	Unlikely to occur, but possible
Eliminated	F	Incapable of occurrence. This level is used when potential hazards are identified and later eliminated	Incapable of occurrence. This level is used when potential hazards are identified and later eliminated.

4. HAZARD IDENTIFICATION AND ANALYSIS (continued)

TABLE III – Risk Assessment Matrix

SEVERITY / PROBABILITY	CATASTROPHIC (1)	CRITICAL (2)	MARGINAL (3)	NEGLIGABLE (4)
FREQUENT (A)	HIGH	HIGH	SERIOUS	MEDIUM
PROBABLE (B)	HIGH	HIGH	SERIOUS	MEDIUM
OCCASIONAL (C)	HIGH	SERIOUS	MEDIUM	LOW
REMOTE (D)	SERIOUS	MEDIUM	MEDIUM	LOW
IMPROBABLE (E)	MEDIUM	MEDIUM	MEDIUM	LOW
ELIMINATED (F)	ELIMINATED			

The definitions in Tables I and II, and the RACs in Table III shall be used, unless tailored alternative definitions and/or a tailored matrix are formally approved by the TRA Board of Directors. Alternates shall be derived from Tables I through III.

E. Identify and document risk mitigation measures. Potential risk mitigation(s) shall be identified, and the expected risk reduction(s) of the alternative(s) shall be estimated and documented in the Hazard Tracking System [HTS]. The goal should always be to eliminate the hazard if possible. When a hazard cannot be eliminated, the associated risk should be reduced to the lowest acceptable level within the constraints of cost, schedule, and performance by applying the system safety design order of precedence. The system safety design order of precedence identifies alternative mitigation approaches and lists them in order of decreasing effectiveness.

i. Eliminate hazards through design selection. Ideally, the hazard should be eliminated by selecting a design or material alternative that removes the hazard altogether.
ii. Reduce risk through design alteration. If adopting an alternative design change or material to eliminate the hazard is not feasible, consider design changes that reduce the severity, and/or the probability of the mishap potential caused by the hazard(s).
iii. Incorporate engineered features or devices. If mitigation of the risk through design alteration is not feasible, reduce the severity or the probability of the mishap potential caused by the hazard(s) using engineered features or devices. In general, engineered features actively interrupt the mishap sequence and devices reduce the risk of a mishap.
iv. Provide warning devices. If engineered features and devices are not feasible or do not adequately lower the severity or probability of the mishap potential caused by the hazard, include detection and warning systems to alert personnel to the presence of a hazardous condition or occurrence of a hazardous event.
v. Incorporate signage, procedures, training, and Personal Protection Equipment [PPE]. Where design alternatives, design changes, and engineered features and devices are not feasible and warning

devices cannot adequately mitigate the severity or probability of the mishap potential caused by the hazard, incorporate signage, procedures, training, and PPE. Signage includes placards, labels, signs and other visual graphics. Procedures and training should include appropriate warnings and cautions. Procedures may prescribe the use of PPE. For hazards assigned Catastrophic or Critical mishap severity categories, the use of signage, procedures, training, and PPE as the only risk reduction method should be avoided.

4. HAZARD IDENTIFICATION AND ANALYSIS (continued)

F. Reduce risk. Mitigation measures are selected and implemented to achieve an acceptable risk level. Consider and evaluate the cost, feasibility, and effectiveness of candidate mitigation methods as part of the project team. Present the current hazards, their associated severity and probability assessments, and status of risk reduction efforts at technical reviews.

G. Verify, validate, and document risk reduction. Verify the implementation and validate the effectiveness of all selected risk mitigation measures through appropriate analysis, testing, demonstration, or inspection.

H. Accept risk and document. Before exposing people, equipment, or the environment to known system-related hazards, the risks shall be accepted by the mentor and the Launch Director. The definitions in Tables I and II, the RACs in Table III shall be used to define the risks at the time of the acceptance decision, unless tailored alternative definitions and/or a tailored matrix are formally approved by the mentor. The flyer of record shall be part of this process throughout the life-cycle of the project and shall provide formal concurrence of all Serious and High risk acceptance decisions. After fielding, data from mishap reports, user feedback, and experience with similar systems or other sources may reveal new hazards or demonstrate that the risk for a known hazard is higher or lower than previously recognized.

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MULTI-STAGE PROJECTS

In addition to the previous items outlined, the following are specifically directed to all multi-stage projects launched at any Tripoli venue. Submission deadlines are identical as noted above.

1. PROJECT DESIGN BASICS FOR MULTI-STAGE PROJECTS

   A. An application to launch any multi-stage project must be filled out, submitted to the Launch Director 45 days ahead of the scheduled launch date. All applications will be acknowledged in writing by the Launch Director or a designated BALLS committee member.
   B. Application must include the following and the Launch Director may ask for additional information as required for the specific project/team:

      I. Design drawings
      II. Electrical schematic for staging, and recovery
      III. A description of any additional instrumentation onboard
      IV. Staging plan/program including a simulation
      V. Sustainer and/or secondary booster ignition sequence(s)
      VI. Sustainer and/or secondary booster ignition velocities, altitudes, and/or times
      VII. Motor ignition delay(s),
      VIII. Off-axis ignition tolerances
      IX. Sustainer and/or secondary booster ignition lock-out for arming on the pad
      X. A checklist to include complete arming and disarming procedures for every propulsion or energetic system.
      XI. A Safety Concerns document, documenting possible safety concerns and assigning roles to team members for each.
      XII. Any additional documentation requested by the Launch Director

2. MINIMUM REQUIREMENTS

   A. All projects must have electronics on board capable of preventing sustainer and/or secondary booster ignition during arming. Circuit designs can be provided by the mentor.
   B. “Tilt Sensing Electronics” must be capable of providing lock-outs that utilize altitude, angle of attack, and booster motor burn-out. Simple timers are prohibited except when used with altitude/axis lock-outs. Common currently available devices that are highly recommended are:

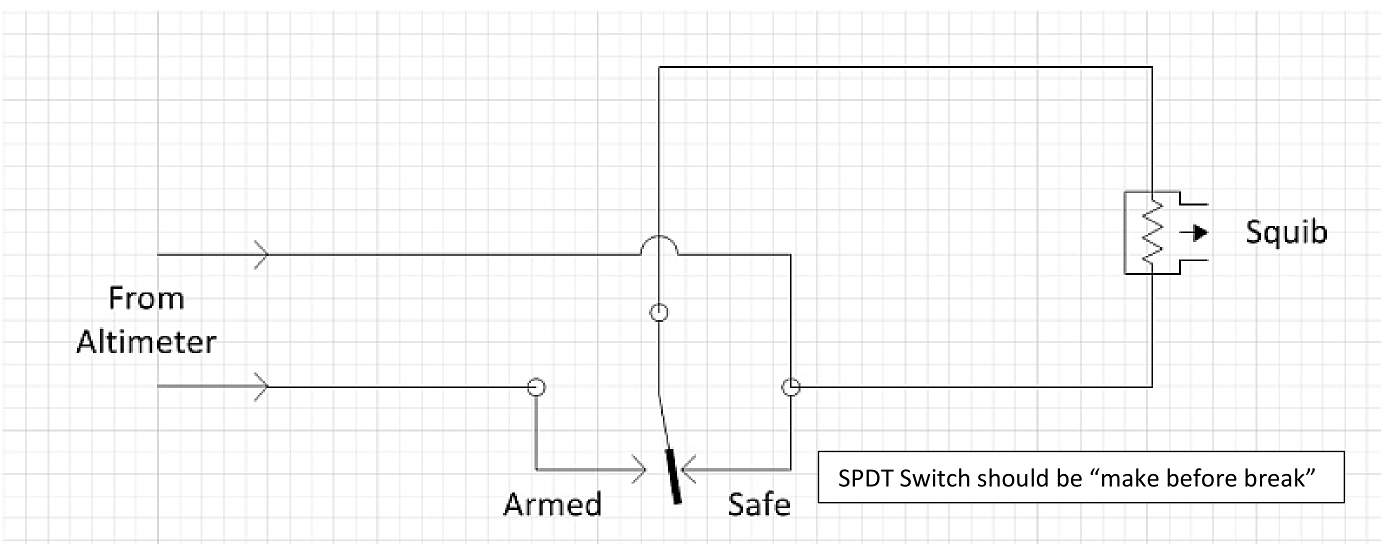
      I. Featherweight “Raven”
      II. Altus Metrum “TeleMega” and “EasyMega”
      III. Projects may use the “Tilt-O-Meter” although this unit has been out of production for several years.
      IV. MARSA Systems Tilt Module & interface with either the MARSA 54 or MARSA 33 flight computers
      V. Home assembled, and/or home manufactured devices are not permitted as staging electronics to light sustainer motor(s).

C. Provision to isolate the sustainer(s) initiator from the battery during electronics power-up is mandatory. Shunts may also be used but are not a substitute for mandatory isolation of the initiator. If used, shunt circuitry and calculations must be approved by the mentor.
D. Multiple switches in the initiator circuit are recommended. **RECOVERY IS MANDATORY; STAGING IS NOT!**

2. MINIMUM REQUIREMENTS (continued)

E. Remote wireless switches are recommended for sustainer electronics arming to prevent “climbing the ladder/tower” to arm electronics.
F. All circuitry diagrams must be approved in writing by the mentor.
G. An absolute minimum thrust-to-weight ratio of 5:1 on the total stack and any minimum boosters is required.
H. An absolute minimum thrust-to-weight ratio of 3:1 is required on the sustainer by itself.

3. SAMPLE SCHEMATIC FOR SAFING SUSTAINER ELECTRONICS



Schematic courtesy of Fred Azinger

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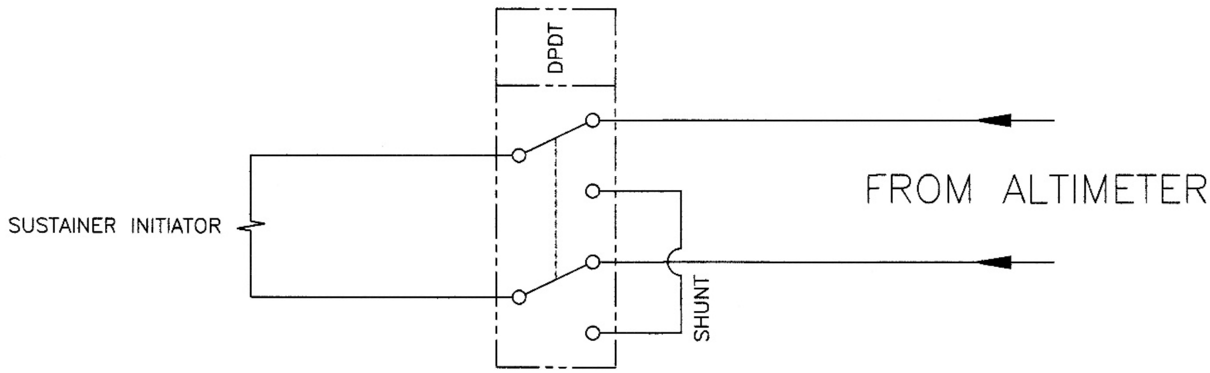
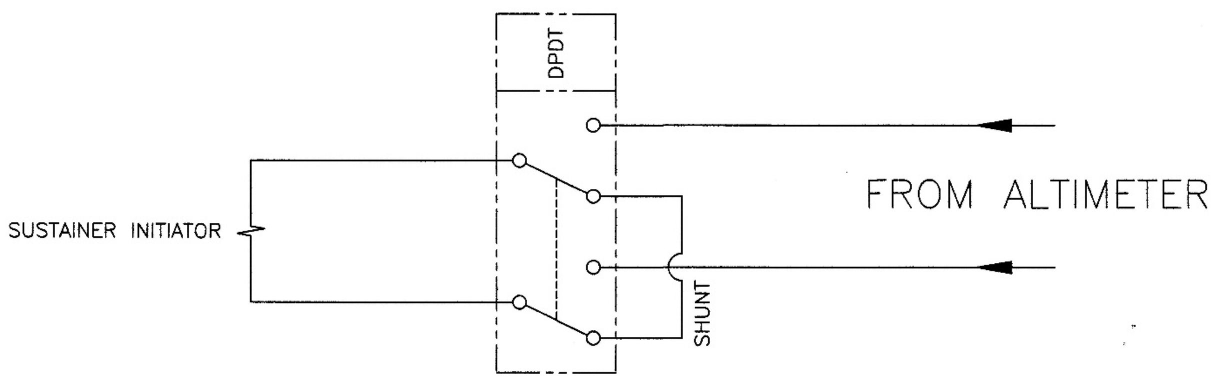
2. <u>SAMPLE SCHEMATIC FOR SAFING SUSTAINER ELECTRONICS</u> (continued



SUSTAINER INITIATOR ARMED



SUSTAINER INITIATOR SAFE

<u>Schematic Courtesy of Steve Shannon</u>