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OTRA Safety Mission Statement

For Oregon Tech Rocketry and Aerospace (OTRA) safety is built into every aspect of our work from design to flight. OTRA will strive to set the gold standard in safety of student lead projects here at OIT and nationally. OTRA will demonstrate this commitment by our track record and by developing internal safety procedures and directives as well as maintaining a database of outside safety rules and regulations.

Introduction

The approach to safety taken by OTRA can be broken into six categories—several of which may be appropriate at any given time. These categories are: safety by regulation, safety by imitation, safety by oversight, safety by design, safety by process, and safety by certification.

OTRA is fundamentally an engineering project. What we do will often be regulated by federal and state agencies: this is **safety by regulation**. These include the FAA CFR 101.21-29, the NFPA (section 1127), OSHA regulations regarding the storage and handling of our fuels, local fire codes, manufacturer MSDS, contest rules and regulations developed by ERSA/IREC, and safety regulations developed and maintained by Tripoli Rocketry (initial flight tests), Reaction Research Society (experimental flight tests), among others.

Safety by imitation recognizes that OTRA is a junior member in the field of rocketry and can learn by imitating the safety practices of other clubs and teams involved in the field. While there are inherent dangers, the contest for which OTRA is designing and the field of amateur rocketry in general is remarkably safe. ESRA/IREC has hosted the contest without incident since 2002, RRS has not had an accident since their founding in 1943, and according to Oregon Rocketry there has not been a single serious injury or fatality associated with Tripoli Rocketry clubs in its 50 years [1]. We are in contact with both Portland State University Aerospace Society and Michigan Aeronautical Science Association regarding their own safety procedures and will continue to develop our contacts with other clubs.

As OTRA designs, builds, and tests our rocket we will have a great deal of oversight. Following this and seeking it out is what we mean by **safety by oversight.** The first line of oversight is our club advisor Sean Sloan, then our senior project advisor Dongbin Lee, oversight during the manufacturing process will be provided by TAs and MMET faculty, oversight during the launches will be provided by certified Tripoli members, RRS members and at the Spaceport Cup America by a variety of aerospace professionals who make up the judging and operations staff. Safety by oversight includes periodic design reviews, proposals, and oral and written explanations that OTRA will have to submit in order to test and fly our rocket.

Safety by design is the student lead initiative to follow industry standard regulations regarding safety in design applications. These primarily relate to factors of safety in structural and pressurized components, in house design verification, selecting nonhazardous materials, simulating stresses on our components before testing, and a general mentality of focusing on safety and developing safety guidelines as we design the rocket. For instance in our selection of fuels, safety was a guiding factor. Butanol was selected not only because of its combustion

[1] Oregon Rocketry. “Who We Are.” Oregon Rocketry. http://www.oregonrocketry.com/?page_id=4 (7 Oct. 2017)

properties, but also because it can be made from biofuels reducing environmental hazards and has no listed injuries or deaths with OSHA. Similarly LOX was chosen due to safety concerns brought up in technical advice given by Blue Origin—a large player in private aerospace.

In all of engineering and industry in general, processes are a primary concern with safety—which is why there are lock out/tag outs and similar. To give a domestic example a gas heater poses substantial, innate risk to a home and its occupants. However, by following predetermined processes operation and maintenance of these is quite safe. A homeowner would be ill-advised to relight a pilot light on a gas heater that has been out for some time without first ventilating the area. Failure to do this could result in an explosion, but by doing this the innate risk of explosion posed by natural gas is mitigated. Similarly, by developing processes for the activities we do we can mitigate the innate danger of these activities. For instance, manufacture using composite materials poses specific dangers: inhalation of toxic fumes, skin and eye irritation, damage to vacuum equipment. Consequently, OTRA has created an instruction manual for composites manufacture which is based off industry experience by David Minar and Micah Hicks and experience in a MECH 407 Advanced Composites class taught by Prof. Joe Stuart. This is required reading for anyone manufacturing with composites in our club—this goes above the procedures of other clubs using the composites lab. Actions of this sort comprise **safety by process** and it is key to keeping the club members and property safe.

Both for professional and safety reasons, OTRA will pursue safety related certifications where relevant and feasible. Thus, we will ensure **safety by certification.** OTRA member Jason Peters is working with Kingsley Field and the 173rd fighter squadron to organize training for OTRA in LOX handling and their engine testing procedures. Other examples are the progressive flight certifications team members will be receiving through Tripoli and Oregon Rocketry that focus on design and launch safety and include written exams, rocket inspection, and safe launch and recover criteria. In some cases, certification will be the result of OTRA developed training.

Specific Material Concerns

Access: Access to all materials is contingent on approval from first Risk Management (if they deem it necessary), second Lab Managers and Campus Safety, third club advisors and OTRA officers. Access to most materials will be granted on a per user basis. For most materials this will require a lab pass and OTRA advisor and officer consent. LOX, N2, and butanol will require training. Access to N2 will be granted only on a per use basis.

Liquid Oxygen (LOX): serves as the oxidizer in our combustion cycle.

> **Dangers:** LOX is extremely cold (-297°F) and can cause burns as well as reduce the strength of many materials. If vented in an enclosed environment can potentially cause oxygen saturated atmosphere posing fire and inhalation hazards. Long term storage of LOX results in increasing pressure in tanks which if not properly fitted with relief valve can result in rupture of tank.
>
> **Prevention:** LOX will not be stored by OTRA. LOX will not be stored in enclosed environments for at any time. LOX will only be purchased in quantities needed for scheduled tests. LOX will be delivered as close to test date as possible (safety by process). Any excess LOX at a test location will be removed as soon as possible by professionals.

OSHA regulations regarding Personal Protective Equipment (PPE) and handling will be strictly followed (safety by regulation). PPE includes cryogenic-safe gloves, face shields & safety glasses, fire resistant coveralls. Further regulation can be found in SAF-TECH-0001. Handling training will be received from Air Force or other qualified institution. Handling of LOX will only be performed by certified individuals (safety by certification).

Contingency: In event of injury a first aid kit will be kept on hand with warm packs included. In the event of fire or explosion, fire extinguishers are kept on hand any time LOX is used and test stand has integrated fire suppression system (safety by design).

Storage: As LOX must be maintained at low temperatures, all LOX has a limited shelf life. Adequate ventilation is necessary for storage to enable the gas to be released as it warms and expands. To avoid these complications, OTRA will purchase LOX locally from Airgas for same day use and return. Unused LOX can be safely vented to atmosphere to empty the vessel or returned to Airgas.

Butanol: is our rocket fuel.

Dangers: OSHA lists no associated deaths or injuries with this substance. It is an organic biofuel and nontoxic. Dangers are primarily fire and explosion. It is a 1-3-1-0 substance and generally regarded as safer than gasoline (stored by FSAE and BajaSAE on campus) due to its much higher flashpoint and lower combustibility.

Prevention: OSHA handling regulations to be followed at all times (safety by regulation). In general, it is to be treated like gasoline. Sealed containers, kept away from areas in which flammable operations are being performed, etc.

Contingency: The fire department will be notified a week before and the day of any scheduled test (safety by process). No less than two members will stand at ready with fire extinguishers at each test and will be trained in their use (safety by process). Test stand will contain integrated fire suppression system (safety by design). OTRA has reached out to civil engineering professors and the Klamath County Fire Marshall for assistance on developing and implementing a fire prevention plan.

Storage: Unpressurized butanol can be safely stored and handled in the same manner as any alcohol solvent.

Composite fibers include glass and carbon fiber weaves, tape, and tow. These will be used in the manufacture of the body tube and support structure.

Dangers: Primarily dangers come from the manufacturing process rather than material itself. Fine carbon fiber and glass dusts are respiratory system, eye, and skin irritant.

Prevention: Best practice composite labs safety will be followed and team members will be instructed of dangers, PPE, and warning signs (safety by process). Basic lab safety procedures from OIT professors will be followed including ventilation and the buddy system (safety by process). OIT Faculty & Campus will be aware when OTRA members are using the composites lab. Any member using the composites lab will have received a lab pass from Campus Safety. OSHA has not developed any specific guidance on composites. The composites lab is in compliance with OSHA Oregon guidance.

Contingency: In the event of respiratory problems, members will be instructed to leave the lab immediately. Any student who demonstrates irritation, experiences dizziness, respiratory problems, or other negative reactions to composite fibers will be required to use PPE including respirator and goggles. If eye or skin irritation occurs, wash stations are readily available and members will be instructed to rinse for up to 15 minutes.

Storage: Storage of fibers and tows pose no dangers and already done on campus. Any purchased composite fibers will be labeled and stored with existing in the Composites Lab (CO 118).

Composite resins including epoxies, polymers, phenolics and similar will be used in manufacture of body tube, structural components, and similar.

Dangers: Most resins and curing agents are toxic if ingested and before fully cured will emit fumes that can be dangerous to health if not vented. Allergic reaction (skin contact/ingestion), poisoning (ingestion), liver damage (ingestion) are possible. Many resins are carcinogenic, and can cause bronchitis and pulmonary edema (prolonged inhalation). Curing process generates heat which can be danger if uncured resin stored next to combustibles.

Prevention: OSHA and lab safety standards will be followed (safety by regulation/process). These include proper use of PPE, inspection of lab equipment before use (ventilation and wash stations), buddy system, and in-house training (safety by certification). OSHA has not developed any specific guidance on composites. The composites lab is in compliance with OSHA Oregon guidance.

Contingency: Poison control center numbers are posted around lab in case of ingestion. Wash stations will be used in case of skin irritation and 911 called in case of allergic reaction. Inhalation concerns can only be addressed with PPE, proper lab procedure and engineering controls (ventilation).

Storage: Storage of these chemicals is routine and already done on campus. OTRA will consult with lab managers and Risk Management regarding storage. Requisite labels are present in the lab and all chemicals purchased by the club will be labeled and stored in designated part of Composites Lab (CO 118).

Nitrogen gas will be used to purge the plumbing systems of the engine between test fires and to leak test the system.

Dangers: N2 compressed gas is nontoxic, nonflammable, and is treated by OSHA as a general compressed gas. If vented in a confined space N2 may displace oxygen creating a suffocation hazard.

Prevention: The dangers of N2 are those common to all compressed gasses—primarily failure of the pressurized vessel. OTRA will follow OSHA regulations contained in 1910.101 (safety by regulation). If Risk Management stores N2 in a confined area, the storage area will be vented for 30 minutes before entry. Permit required confined space rules will be followed. An N2 detector will be purchased for this purpose.

Contingency: In the event of an OTRA member starting to experience lightheadedness, dizziness or other low oxygen symptoms, they will be escorted to an area with breathable air.

Storage: We will identify with Risk Management an appropriate venue for storage of the gas. If such cannot be found due to the Cornett re-model N2 will be purchased from Airgas locally for same day use and return.

Specific Process Concerns

Testing

Testing is where most catastrophic safety hazards are present. OTRA will engage in two very different kinds of testing: **flight testing** and **engine testing**.

Flight testing will be governed by Tripoli and Reaction Research Society (RRS) rules (safety by regulation) and design review by officials from those organizations (safety by oversight) in addition to the safety considerations that will have been addressed in design process (safety by design) and by advisors to the club (safety by oversight). Because the primary safety controls on flight tests cannot be quickly addressed, the reader is deferred to the List of Safety Documents below, particularly those by Tripoli regarding range safety and experimental rocket safety.

Engine testing is done in house by OTRA and this will be addressed in this subsection.

Dangers: Fire, projectiles, acoustic injury, LOX handling dangers, & high-pressure handling dangers.

Prevention: OTRA has after consultation with other clubs and Blue Origin begun developing a testing schedule that takes the dangers possible in a full test and spreads them into smaller controllable chunks (safety by process). Initial Cold-Flow testing will be done with pressurized water and nitrogen to test the pressure viability of the engine. This insures the systems integrity without chance of combustion. Initial hot fire testing will be performed with minimal fuel loaded and 1-second burns. This requires only ounces of fuel and so both fire and rupture hazards are minimal. The test stand is being designed with blast shields, fire suppression, and addition safety shut off features. Any approved test site will have a Fire Marshall approved fire prevention plan. OTRA members will be at a distance of 30m from the test stand behind a safety structure wearing PPE before countdown procedures starts. A lockout/tagout procedure will be used to insure all members are accounted for. Testing will end immediately if any member requests so for safety reasons.

Contingency: In the event of injury a first aid kit is on hand and members will be trained in First Aid Procedures. Due to the distance members will be from the engine during testing, any injuries will be minor and are extremely unlikely, but both Skylakes and the Fire department will be notified before testing.

Flight

Flight safety will be addressed primarily by the range safety officers of the organization sponsoring the launch—for the year 2017-2018 this is likely to only be Tripoli Rocketry Association. Tripoli has decades of experience without accident and works closely with the FAA, NFPA, and OSHA to ensure that each launch is successful and safe.

Materials Handling

Materials handling presents dangers both in the transportation of materials or the loading unloading of their containers. At present the only material which poses danger in its transportation to and from flight sites or testing is LOX. The dangers LOX presents to students is mitigated by the use of proper PPE (safety by regulation), the training OTRA members will be required to receive from Air Force or other organization before handling (safety by certification), and the same-day use policy OTRA maintains regarding its use and storage (safety by process).

Storage

OTRA will not store materials that are hazardous in passive storage. Materials that are hazardous to passively handle will be handled by certified individuals (safety by certification). When OTRA does intend to store materials or chemicals, an appropriate location will be identified in consultation with lab managers and Risk Management well in advance of purchase.

Manufacturing

Dangers due to manufacturing will be approached primarily through safety through certification, which in this case means classwork. Students who have not taken the appropriate classes—as an example MFG 103 for welding—will not be allowed to use the equipment that class teaches. Beyond this, the appropriate lab pass will be required and OIT's lab and safety policies followed. OTRA is not engaged in any exotic manufacture of parts and for many components will be contracting out the work.

Fire

Preventing fire is key to the safety of this project. As such we have reached out the Fire Marshall for help in developing a fire prevention plan (safety by oversite), are seeking training regarding handling of flammables and in the containment of small fires (safety by certification), are creating our test schedule with fire prevention as the key concern (safety by process), and are integrating a fire suppression system into the test stand (safety by design).

List of Key Safety Documents

Author Organization	**Document Title**	**Document Number**	**Doc Status**
OTRA	*Composite Lab Safety*	SAF-MAN-0001	Approved
OTRA	*LOX Safety*	SAF-SHEET-0001	Pending Rev.
Tripoli	*Range Safety*	SAF-REG-0001	Approved
Tripoli	*Metal in Rockets*	SAF-MAN-0002	Approved
Tripoli	*Range Safety Officer Req.*	SAF-REG-0002	Approved
Tripoli	*Research Safety Code*	SAF-REG-0003	Approved
Tripoli	*Safe Launch Practices*	SAF-REG-0004	Approved
NFPA	*Rocket Fire Reg. 1127*	SAF-REG-0005	Approved
Tripoli	*High Power Safety Code*	SAF-REG-0006	Approved
OTRA	*General Lab Safety*	SAF-MAN-0003	Developing
OTRA	*Test Schedule*	SAF-TECH-0002	Developing

Bureau Safety and Health Montana	*Handling Pressure Vessels*	SAF-TECH-0003	Approved
OTRA	*Test Safety Processes*	SAF-TECH-0004	Developing
OTRA	*Engine Test Fire Prevention Plan*	SAF-TECH-0005	Developing
OTRA	*Materials Handling and Storage*	SAF-TECH-0006	Developing
DOW	*SDS n-Butanol*	SAF-TECH-0007	Approved
OSHA	*Confined Space Entry*	SAF-REG-0007	Approved
OTRA	*Model Rocket Safety Code*	SAF-SHEET-0002	Approved
OTRA	*Pressurized Tank Safety*	SAF -SHEET-0003	Pending Rev.

Glossary

Confined Space: OSHA defines a confined space as any area that is not designed or suitable for continuous human habitation. Examples include: tanks, vessels, silos, storage bins, hoppers, vaults, pits, manholes, tunnels, equipment housings, ductwork, pipelines, etc.

Permit Required Confined Space: refers to any confined space that has one or more of the following characteristics: (1) Contains or has a potential to contain a hazardous atmosphere; (2) Contains a material that has the potential for engulfing an entrant; (3) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or (4) Contains any other recognized serious safety or health hazard.

Passive Storage: containers are tightly closed and may not be filled or emptied or opened for any reason while they are being stored.