Multidisciplinary Senior Design SRAD High Powered Rocket Engine Project

Project Title: Test Stand

Project Leader: Bailey Reid, RIT Launch Initiative Propulsion Officer

Team Advisor:

Faculty Champion: Gerald Fly, Lecturer - Mechanical Engineering gwfeme@rit.edu.

Project Number: N/A

Customer: RIT Launch Initiative

RIT Launch Initiative is a team of passionate students that design, manufacture, and launch high powered rockets. Launch's goal is to raise awareness for aerospace and become an acknowledged and well-respected institution in this field by attending the Intercollegiate Rocket Engineering Competition (IREC). In 2020, RIT will enter the 'advanced' category which requires that the team deliver a rocket and corresponding payload to exactly 30,000 feet.

This endeavor will be accomplished by developing and integrating a custom rocket engine. Building a custom engine will put RIT on the map, allow students to compete at the highest level with IVY League schools, and open up opportunities for future aerospace and propulsion projects for decades to come. In addition to its implications for IREC, this engine will create the possibility of collaborating with SPEX to deliver actual scientific payloads to our upper atmosphere. Ultimately, this project will provide a customizable, safe, and high-performing rocket engine to RIT Launch Initiative.

This will be phase two of this endeavor where the next set of students will work together to implement and continue the work done by the previous team. A hybrid rocket engine was chosen as the chemical engine to use for the endeavor. The main reasons is that a hybrid engine provides simplicity and it is safer than its solid and liquid counterparts. The team will perform further testing and design optimizations to make this endeavor come to fruition by the 2020 IREC competition. For phase two of the project, the project will be divided into two sub-teams, the test team and engine team. The reason for is to include more individuals in the project in order to meet time constraints and have the project be successful. Overall the 2018-2019 team will develop a test engine based on desired design, quantify its performance, and optimize it if needed to meet mission requirements. The test engine will then be integrated into a flight engine and vehicle the following year to compete in IREC 2020.

The responsibilities of the test team for fall of 2018 will be to design, develop, and manufacture a robust test stand for the hybrid rocket engine. The test stand is a structure that secures the engine during testing and measures different desired parameters. The test stand must be completed by the fall semester in order to begin testing of the test engine as soon as possible, and be able to quantify its performance. The test stand must be designed to constraint the engine during hot fire and allow for measuring of different desired parameters. The following semester, in the spring the test team will become the test engineers and integrate with the engine team to test the engine. Customer requirements are laid out below:

Customer Requirements

- **Space:** The test stand must be designed to be mounted to the bunker located on campus and allow for enough space for at least two individuals to work safely within the bunker.
- **Configuration:** Current test stand configuration is horizontal but design may change as needed. The stand must be able to securely mount the thrust chamber horizontally, feed system, oxidizer tank vertically, and pressurant tank vertically for testing.
- **Safety:** All materials used must be safe to handle, and mechanical safety mechanism must be implemented in the bunker in case of electronic failure or power loss. The team will be located 100 feet during hot fire testing. Safety mechanisms and guidelines must be implemented for testing and to ensure the safety of the team during testing in case of failures or emergencies.
- **Durability and Robustness:** The engine will output at least a maximum thrust of 1300 pounds. The stand must be designed to withstand the forces induced by the engine during operation. The test stand must be robust to safely constraint and contain the engine while also accurately measure the engine thrust. Although the thrust vector will be along the axial axis of the engine, the test stand must be design to also safely secure the engine in all other directions, and contain or secure as much of the engine as possible in case of an explosion event. Design engine failure is possible. The minimum factor of safety for the test stand design should be 5. The stand should sustain at minimum the following:
    - Engine induced vibrations up to 2000 Hz. For hybrid engines vibrations may typically oscillate up to 60 % of nominal operating chamber pressure.
    - Transient behaviors such as thrust vectoring, water hammer, and ignition.
    - Engine output thrust of 1300 lbs
    - Engine heat output specially from the plume during hot fire testing.
    - Testing events for up to 7 to 10 seconds.
- **Measurements:** The stand must allow for the measurement of at the least the following:
    - Oxidizer and pressurant tank pressures
    - Oxidizer and pressurant tank temperatures
    - Oxidizer and pressurant tank mass over time
    - Combustion chamber mass over time
    - Combustion chamber pressure
    - Combustion chamber external temperatures
    - Injector manifold temperature
    - Injector manifold pressure
    - Engine output thrust
    - Engine induced vibrations
    - Test time

  The test stand must be able to secure the desired sensors in the proper locations for the measurements mentioned above. Mitigation of systematic and random errors must be considered for mounting and use of sensors.
- **Testing:** The test stand must be designed for the following test:
    - System proof pressure test
    - System leak test (external and internal)
    - Cold flow test
    - Hot fire test
- **Reusability:** The stand must be usable for multiple engine test events.
- **Manufacturing:** Test stand must be designed and manufactured in fall of 2018. The stand must be designed considering manufacturing capabilities on campus, and for ease of manufacturing.

- **Simplicity and feasibility:** The stand must be designed to easily mount and dismount the engine, as well as the sensors that will be used. Design for simplicity and ease of use.
- **Assembly and Preparation:** The test stand team is responsible for the bunker, construction of the test stand, and preparing the bunker and test stand for testing of the engine.
- **Implementation:** The test stand must be implemented without damaging engine hardware, and must protect property, equipment, and team.

Constraints

1. Budget
2. IREC, ERSA, NMSA, and FAA regulations, rules, and requirements
3. FAA regulation of max total impulse of 40,960 N-sec for IREC SA Cup
4. Sensors (quality and robustness) - Can they withstand extreme conditions?
5. Manufacturing and storage feasibilities
6. Resources, chemicals, materials accessibility and feasibility
7. Special permits, licenses, or training that may be required
8. Location/setting
9. Time
10. Knowledge/experience
11. Additional:

(http://www.soundingrocket.org/uploads/9/0/6/4/9064598/sa_cup_irec_rules___requirements_document_20170217__baseline_.pdf)
(http://www.soundingrocket.org/uploads/9/0/6/4/9064598/sa_cup_irec-design_test___evaluation_guide_20170217__baseline_.pdf)

Test Stand Estimated Budget: ~$3000-$5000 (May change)

Intellectual Property: We will be planning to keep the IP on the project, unless a sponsor arises that requires otherwise. We are open to all considerations. The project is currently not expected to be confidential in anyway.

Required Resources: Bunker, Machine Shop, The Construct, electrical labs, storage space

Faculty Support:

1. Dr. Mark Olles, Assistant Professor, Mechanical and Manufacturing Engineering Technology, mwomet@rit.edu
2. Michael Buffalin, Launch Advisor and Construct Director, mjbovpr@g.rit.edu
3. Gerald Fly, Lecturer - Mechanical Engineering gwfeme@rit.edu , 585-475-5269 (work)

Team:

1. **Julian Caputo - ME**
2. **Josiah Klossner - ME**
3. **Nevin Mathew - ME**
4. **Avinash Ananth - ISE**
5. **Stelios Moisidis - EE**