Propellant Electric Feed System

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ME-491 Capstone Project Proposal

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Team Members

1. **Jorden Roland, Team Facilitator:** jroland@pdx.edu
PSAS member since 2013 including team lead on multiple projects, aerospace nerd, published AIAA member, Licensed HAM radio operator (Technician class), Working on this particular project since Sept. of 2016.

2. **Johnny Froehlich, Lead: Design/Analysis:** froeh@pdx.edu
PSAS member, aerospace nerd. Propulsion engineering intern at NASA Goddard, 2015. Research assistant in Dryden Drop Tower lab at PSU, 2014-current. Statistics and R programming, scientific computing with Python, rapid prototyping, Arduino, design analysis and testing, CFD, strong believer in reproducible research.

3. **John Talik, Lead: Design/Modeling:** JTalik@pdx.edu
Psas member and aerospace nerd. Relevant work experience includes Nike Design Engineering Intern, Undergraduate Research program in WET lab, Viking Motorsports Composite Team 2015/14. Heavy solid modelling/surfacing experience, preparing drawings for manufacturing, machine design and automation, 3D printing/rapid prototyping, Composite design and manufacturing.

4. **Rawand Rasheed, Lead: Turbomachinery:** Rawand@pdx.edu
PSAS member and Aerospace nerd, President and Co-Founder of the Kurdish Youth Organization, Officer and Co-Founder of ASME: Engineers for Global Development at PSU, Undergraduate Researcher: WET Lab, Design Engineering Intern at Sulzer Pumps, Mechatronics Intern: Powertrain Systems at Daimler Trucks, Mechanical Engineering Intern at Intel: STTD R&D Pathfinding Lab, Tutor for MME Department at PSU. Proficient in Solidworks, NX, Autodesk: Inventor, R, Arduino, Swift, MATLAB, and LaTeX.

5. **Mimi Shang, Lead: Mechatronics/power:** mshang@pdx.edu
PSAS member since September 2016, president and member of Society of Women Engineers since 2015, Mechatronics Intern: Powertrain Systems at Daimler Trucks, Mechatronics Intern: HVAC and Lighting Control at Daimler Trucks, Undergraduate Research: Ecoroof monitoring. Proficient in MATLAB, Simulink, Solidworks, Arduino and R.

6. **James Luce, Lead: Thermal/Structures:** jaluce@pdx.edu
NASA internship at Marshall Space Flight Center, 2016: Finite element analysis for thermal and launch loads in rocket motors. Undergraduate research at PSU DDT lab, 2015: Microgravity capillary fluidics experiments and data analysis for ISS experiments. Product/Project management at Trulia et al, 2004-2013. Research, feature prioritization, logistics & project planning.

Customer requirements: (As of 11/14/2016)

1. Design, build, and ground test an electric bi-propellant pump system that delivers a reasonable NPSH with a (~ 0.04 ft^3/s) delivery of isopropanol and a (~ 0.03 ft^3/s) delivery of LOX. Must be constructed from commercial-off-the-shelf parts (COTS) or manufactured in house.
2. Initial prototype is to be designed for the existing liquid fueled engine (LFE) with a targeted chamber pressure of (~375 psi)
3. Develop a design tool for choosing a candidate pump based on specific parameter inputs. The Design tool must be adaptable and well documented.
4. Perform a comparison study between a classic blowdown pressurization system and an electric feed system for the purpose of identifying possible advantages and disadvantages. Example output would be a ratio between the feed system mass and the total propellant mass for the analyzed systems in function of the combustion chamber pressure, propellant mass, and burn time.
5. Determine required power delivery system.
    a. Evaluate current battery technologies (Li-Ion, Li-Po, Li-S, etc,.) for use in EFS
    b. Evaluate candidate DC-Brushless motors
        i. Must be COTS or manufactured in house
        ii. Must be reasonably priced
    c. Evaluate candidate inverters
6. Work in parallel with the CPFT team (Carbon Fiber Propellant Tank) to optimize the pressure requirements for both groups. Pump successfully suppresses cavitation at whatever pressure the CFPT team is able to deliver.
7. LOX handling procedures and SOP documents.
8. Proposed materials for feed system manufacturing.
9. Reproducibility and technical documentation.

<u>Additional Requirements</u>

1. Design a test apparatus that is compatible with the existing Liquid engine test stand (LETS). This would contain sensors and safety/emergency shutdown provisions.
2. Prototype testing to be performed if there is time
    a. Cold flow test w/ water -> Cold flow test w/ LN2.
    b. Possible Hot fire test.

Project Objective Statement

Design, build, and test an electric feed system using COTS parts and in-house manufacturing for Portland State Aerospace Society's liquid fueled rocket engine by June 6, 2017.

Design Techniques:

- Information Gathering Methods:
    - Large cache of professional papers gathered on the subject.
    - Access to professional mentoring:
        - Army Air National Guard (for LOX handling procedures)
        - Industry expert contacts at SpaceX, Spaceflight Ind, NASA, Orbital ATK, Blue Origin.
- Currently Existing/Relevant Work and Studies:
    - Nadir Bagaveyev
        - Founder of Bagaveyev Corparation, currently developing LOX Turbomachinery technology and 3D printed nozzles for rocket propulsion.
    - Rutherford Engine
        - Rutherford is a liquid propellant rocket engine, designed in New Zealand by Rocket Labs. It uses LOX and kerosene as propellants and is the first flight-ready engine to use the electric pump feed cycle. This is the State of the Art product developed by Rocket Lab.
    - Analytical studies from University of Rio
        - Relevant studies from the University of Rio on electric feed systems for rocket engines. Contains reports on the comparison of propellent feed system, propellent selection, and sizing and design of liquid propellent rocket engines. These studies will provide a basis for comparison and development of the feasibility of an electric feed system for use by PSAS.
- Analysis and Simulation Tools:
    - Github will be used for team version control on documents, models, and programs. This will also be used for final uploading of the required customer documents. This will include the LOX handling and SOP procedures, Reproducibility and technical documentation, the design tool, and comparison studies.
    - iPython notebooks for design tool development. This will be the main tool for iterative design development, which will be uploaded to Github for PSAS use as one of the main customer requirement deliverable.
    - Statistical analysis using R.
    - SolidWorks for CAD design.
    - Various software for simulation (Abaqus, Star-CCM, Matlab,.)

Resources:

- Access to most prototyping labs at PSU.
- Access to donated metal, professional machining labor, and DMLS 3D printing.
- Storage and workspace in PSAS Rocket Room
- Liquid Fuelled Engine Test Stand (LFETS) completed by 2014 capstone.
- Testing site outside The Dalles, OR

Key Milestones and Deliverables:

	Deliverables:	Objectives	Date
1	Pump Sizing Requirements (Design Outputs)	Determine number of stages, pump rotational speed, pump impeller tip speeds, impeller entrance and exit diameters, pump efficiency, shaft power required to drive pump.	15-Jan-17
2	Initial COTS components selection	Individual team members finalize and present 5-10 candidate OTS tech (Bearings, Motor, inverter,).	22-Jan-17
3	Feasibility Study of COTS Parts	Burn times that optimize battery mass	29-Jan-17
4	Submit Purchasing Request For COTS		1-Feb-17
5	Non-Functional prototype	Determine feasibility of form, flow loop, and test bench size and orientation.	26-Feb-17
6	Subsystem testing	Assembly and validation of subsystems and COTS components	2-Apr-17
7	functional prototype	Assembly of subsystems	23-Apr-17
8	Initial testing	Static checks, dynamic checks (cold test), validation runs.	25-Apr-17
9	Post processing, comparison to alternative methods.	Validation for final prototype go-ahead	7-May-17
10	Final prototype		21-May-17
11	Final Prototype cold testing	Static checks, dynamic checks (cold test), validation runs.	28-May-17
12	Final Prototype hot testing	Cryo testing	7-Jun-17

Organization:

Team Meetings: Mondays @ 4:30pm in Rocket room
General PSAS meeting: Tuesday @ 7:00pm in FAB 86-01
Version control and shared file storage: Github
Document sharing/research bank: Google Docs
Task assignment: Trello
Team communication: Slack