ME 491 | Fall 2018 Product Design Specifications Report

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Fligh**t Ready Electric Feed System**

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**Sponsored by Portland State** Aerospace Society (PSAS)

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**INTRODUCTION**

Portland State Aerospace Society (PSAS) requires the production of a flight ready device that can be used to increase fluid pressure in both the Liquid Fuel Engine Test Stand (LFETS) and PSAS liquid fuel rocket. The Flight Ready Electric Feed System (EFS) is an electronically controlled pump system to be designed for the Launch Vehicle 4 (LV4). This project has been proposed by PSAS in order to make the use of lightweight, low-pressure, composite propellent flight tanks possible. As opposed to utilizing a more traditional high pressure "blow down” system, an EFS will be used to provide the necessary pressure to pump

the propellants into the engine. Design and manufacturing of the EFS will be a part of a

senior capstone project involving six Mechanical Engineering students. This approachable

and affordable alternative to a pressurized tank is a challenging and innovative task for an

amateur rocket design.

**MISSION STATEMENT**

“To create affordable, lightweight rocket propulsion technology that will increase the

capabilities of amateur rocketry and student education.”

**PROJECT PLAN (Top-Level)**

ESSIN

The pump design will utilize electric drive shafts to introduce mechanical work into the system, producing an increase in pressure. Each housing will be optimized for the required pressure of two independent fluids. The pump design will be designed for flight capability, utilizing a compact lightweight casing to enclose individual chambers which separately in crease the pressure of isopropyl alcohol and liquid oxygen. The pump will be powered by an onboard lithium ion battery pack, providing DC current to an electric inverter. AC converted

current will power the brushless motors to provide shaft power in order to rotate both of the specially engineered pumps within the system as shown in *Figure 1.* As the system provides rotational energy, the pressure of the incoming propellants will increase from 45 PSI to 500 PSI as the impellers increase the propellant potential energy.

er

**a**

**Battery**

Fuel pump Oxidizer pump

**erter**

Electric **motor**

The manufacturing process will begin with 3D rendering in SolidWorks to create the shape and layout of the housing and motors. A machinable prototype needs to fit within specified dimensions of the airframe module which will house the onboard EFS. A func tional design will be followed by ANSYS vi brational and thermal analysis to show ev idence of structural integrity. Once the de sign has been analytically verified, it will be approved and passed on to the CNC ma chine shop for physical fabrication. Initial machine prototypes will be machined out of inexpensive plastics for trial mock-ups be fore any machining out of metal will begin.

**Combus lon chamber**

**Heat exchanger**

**Nozzle**

**e**

Figure 1: Overview of an EFS

The corrosive properties of liquid oxygen will

**mmon**

limit the material options available for pump components that will come into contact with it. 304 stainless steel is the most common metal alloy used for liquid oxygen components and its availability makes it a logical candidate for material selection. In addition, research will be performed on the feasibility of using alternative materials that may be more cost effective and easier to machine, such as aluminum alloys*. Table 6: Electric Feed System*

*Project Budget* summarizes our expected component costs and plan to stay within the given customer budget (see attachments).

Tolerance testing will begin upon completion of machined parts in either plastic or metal. All dimensions will be compared against the CAD model for machining accuracy and precision. Once a metal casing has been created leak testing will check for fitment of the final assembly. The pump will be assembled and filled with water (up to 1000 psi) to identify any potential leakage points in the system. In addition, we will analyze the resilience of the system from vibration effects, as well as the effects of gravitational force, as the pump will be subjected to a harsh launch environment. It is imperative that the system is not compromised so the rocket can achieve consistent thrust during flight.

**manc**

Upon completion, the desired deliverable is a tested electronically controlled pump that provides reliable performance during flight. Crucially, the pump and associated system components must be compatible with both propellants and ensure absolute fluid separation at all points within the system. Cross-contamination of fluids will be considered a design failure and impose a major safety risk. The minimum lifespan without significant overhaul is

ten full-length engine test fires. Surpassing ten fires is preferred if possible. The pump and its related systems should be embedded with sensors as this testing data is also a required deliverable. The milestone timeline for the project can be found in *Table 4: EFS Completion*

*Timeline* (see attachments).

**2TSOTS**

**CUSTOMER IDENTIFICATION**

**en**

**Sum**

**ma**

**ler 1**

**DIT**

Portland State Aerospace Society will be sponsoring this capstone project and is responsible for all of the given engineering requirements. *Table 1: Product Design Specification*s sum marizes the customer needs and their ranking of priority upon final completion. Further, *Table 2: Customer Requirement*s, and *Table 3: Engineering Requirements,* cover targets and metrics as well as the verification process for achieving these goals. In addition, the Oregon NASA Space Grant Consortium (OSGC) will also be sponsoring the Flight Ready EFS cap

stone, as the project proposal has won an Undergraduate Team Experience Award Program (UTEAP) grant. Upon acceptance of the grant, OSGC has required the project team to raise a non-negotiable amount of 1.5 times the donation through fundraising or further faculty donation of advisory time. Dr. Mark Weislogel has agreed to work as the faculty advisor to meet this requirement. His cost share portion donation can also be found in Table 6. This additional sponsor will require a project presentation to the OSGC board to serve as publish ing project documentation. The basic level requirements from both customers are outlined in *Table 5: Customer Requirements For P*SAS *and Oregon Space Grant Consortium.*

**CUSTOMER FEEDBACK**

The Flight Ready EFS Capstone group will provide a weekly update to PSAS through a short presentation at the general meetings. This will ensure all progress is shared with the customer and all designs are to be to reviewed as they progress. Use of funds will involve direct communication with OSGC on a per part basis. All purchase requests will be reviewed by the teams Principal Investigator and then sent off to OSGC for reimbursement. All declined part requests will undergo a secondary review in order to reselect a similar part

which can be purchased.

**PRODUCT DESIGN SPECIFICATION (PDS)**

The PDS tables below will serve as a resource to structure the EFS design agenda over the next coming months. Numerical target values and item priority will make for simplified task assignment amongst team members, as well as, communication reference when reporting progress and results to PSAS and OSGC.

*Table 1: Product Design Specification*

**Product Design Specification (PDS)**

**Custom er Need**

**Primary Customer**

**Priority**

**Time**

Must be compatible with liquid oxygen

(LOX) and isopropyl alcohol

PSAS

Must safely keep the propellants separated until injection into the engine

even in the event of a pump failure

PSAS

**tttt**

Must be able to be used on the PSAS

engine test stand

**tttt**

PSAS

Must be able to operate without overhaul for multiple rocket engine test

fires > 10 firings)

\*

\*\*

PSAS

Must handle launch environment, including vibration and an acceleration

of 10 g for 20 seconds.

PSAS

Should have embedded sensors for data acquisition, feedback, and control

PSAS

Should be plumbed efficiently to

minimize pressure loss

PSAS

Must deliver propellants at 300-500

PSI from a tank at 45-70 PSI.

PSAS

*Table 2: Customer Requirements*

**Customer Requirements**

**Requirements**

**Primary Customer**

**Metrics & Targets**

**Metric**

**Target**

**Target Basis**

**Verification**

LOX Compatibity

PSAS

| Must be able to safely pump

liquid oxygen

NIA

No damage

Customer Defined

Cold flow testing

Performance

Fluid Separation

PSAS

Must restict fluid mixing even in

the event of failure

N/A

No fluid mixing

Customer Defined

Prototyping

Manpower to test

PSAS

Manpower

# People

I

4 People

Customer Defined

Cold flow testing

Installation

Time to replace

spare parts

PSAS

Time

Mins

2 Hours

Team Defined

Timed after prototype built

LOX Safety

PSAS

Design with all chemical safety requirements via B11 Training

N*/*A

No LOX hazards

Customer Defined

Cold flow testing

Safety

Electrical Safety

PSAS

N/*A*

No electrical

hazards

Customer Defined

Prototyping

Ensure all controls systems

are safe from fluids, etc. No overhaul to be required

between tests

Minimal upkeep between test fires

PSAS

Hours of Work Ror'd

<4 hours

Group Defined

Testing

Cost Maintenance

Replaceable Parts

PSAS

Readily Available Parts for replacement bearings, rings etc.

N/A

Off the Shelf

Parts

Group Decision

Budget

Minimal production cost

PSAS

Cost

Dollars

< $9,500.00

Customer Defined

Budget

*Table 3: Engineering Requirements*

**Engineering Requirements**

**Requirements**

**Primary Customer**

**Metrics & Targets**

**Metric**

**Target Basis**

**Verification**

EFS size

PSAS

Must be able to fit within LV4

rocket module

inches

11.3"

Customer Defined | Airframe simulation

Repeatability

PSAS

Reusable for 10 test fires

# Fires

10

Customer Defined

Failure testing

Performance

Launch Environment

PSAS

10

Customer Defined

Failure testing

Pressure Gain

PSAS

300-400psi

Customer Defined

Cold flow testing

PSAS

Must be able to withstand

launch conditions Must achieve target pressure

differential Maintain operation during

launch conditions Components must be designed to avoid harmonic frequency of

rocket structure

10g

Customer Defined

Testing

Environment

Withstand Launch

Environment Withstand vibration of

Airframe

PSAS

TBD

Customer Defined

Simulation

**CONCLUSIONS**

**Con**

The Flight Ready Electric Feed System, upon completion, will be a major accomplishment for the amateur aerospace community. This project will further develop research performed by previous and concurrent PSU Capstone teams associated with the liquid propulsion team within PSAS. Over the next few months, we anticipate developing a cryogenic, electronically controlled, propellant delivery system for Launch Vehicle 4 as specified by our Capstone Sponsor, PSAS. By the end of the school year, we will be presenting our findings, prototype, and will publish all documentation related to the project.

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**ATTACHMENTS**

*Table 4: Electric Feed System Milestone Timeline*

**Week Milestone Description**

1-3

Research and locate budget line items to optimize spending. Discus pump design process to dictate the purchase sequence.

4-6

Finalize design for preliminary prototyping with 3D printing and mock testing

7-10

Integrate Control system with proven test design

Coordinate Electric Feed System design with Engine Test Stand and Airframe

**15**

16 - 20

Begin manufacturing process for steel housing, plumbing, and airframe fixture

21.

Testing cryogenic compatibility, fluid leak, and durability to cycle usage

22

23 - **25**

Department testing with Test Stand and Airframe

Finalize Electric Feed System Design

26 - *27*

28 - 30

Organize project material for finalized report and presentation

*Table 5: Customer Requirements For PS*AS *and Oregon Space Grant Consortium*

**Week**

**Milestone Description**

1-3

Research and locate budget line items to optimize spending. Discus pump design process to dictate the purchase sequence.

4-6

Finalize design for preliminary prototyping with 3D printing and mock testing

7 - 10

Integrate Control system with proven test design

Coordinate Electric Feed System design with Engine Test Stand and Airframe

11 - 15

16 - 20

Begin manufacturing process for steel housing, plumbing, and airframe fixture

21 -

Testing cryogenic compatibility, fluid leak, and durability to cycle usage

22

23 - 25

Department testing with Test Stand and Airframe

26 - *27*

Finalize Electric Feed System Design

| 28 - 30

Organize project material for finalized report and presentation

10

*Table 6: Electric Feed System Project Budget*

**Item**

**Description**

**Vendor**

**Award *A*mount**

**1.5:1 Cost**

**Share**

**Cost Share**

In-Kind AY **effort**

$6,556

Dr. Mark Weislogel donating his time Portland State working as PI on Project

University

**Award Budget** The raw material used to machine pump

McMaster-Car **housing**

304 SS Steel

$800

Tooling

Pump House machine tooling

Western **Precision** Products Inc

$1,400

6061 Aluminum

Raw Material to create EFS Airframe

Structure

McMaster-Cart

$200

304 SS Steel

44" x 24" TGP Precision Shaft

Metals Depot

$10

Impeller

Rotational Impellers for propellants

Shapeways

$200

ISO Plumbing

Various plumbing fittings for alcohol

Home Depot

$100

Various LOX compatible fittings

AcmeCryo

$300

LOX Plumbing

**Aluminium** Piping Seals

\* Aluminum piping for plumbing

Metals Depot

$100

Metal C-Ring Internal Pressure Face Seals Parker

$30

Liquid Oxygen

40 Gallons of LOX for testing

**Airgas**

$200

Liquid Nitrogen 40 Gallons of LN for cryo testing

Airgas

$200

Electric Motor

Brushless Motor for shaft drive

Hobbyking

Heat Sink

Heat Sink for Brushless motor

**Amazon**

$150 $25

$50

Arduino

**Amazon**

Arduino to Controlling pump Pressure Transducers and flow meters for fluid **monitoring**

Omega

$500

Sensing Equipment **Total Direct Costs**

$4,265

$6,556

**Total Indirect Costs**

48.50%|

$2,069

$3,180

**Total Project Costs**

**$6,334**

$9,736

**Cost Share Ratio**

1.591

1.53*7*