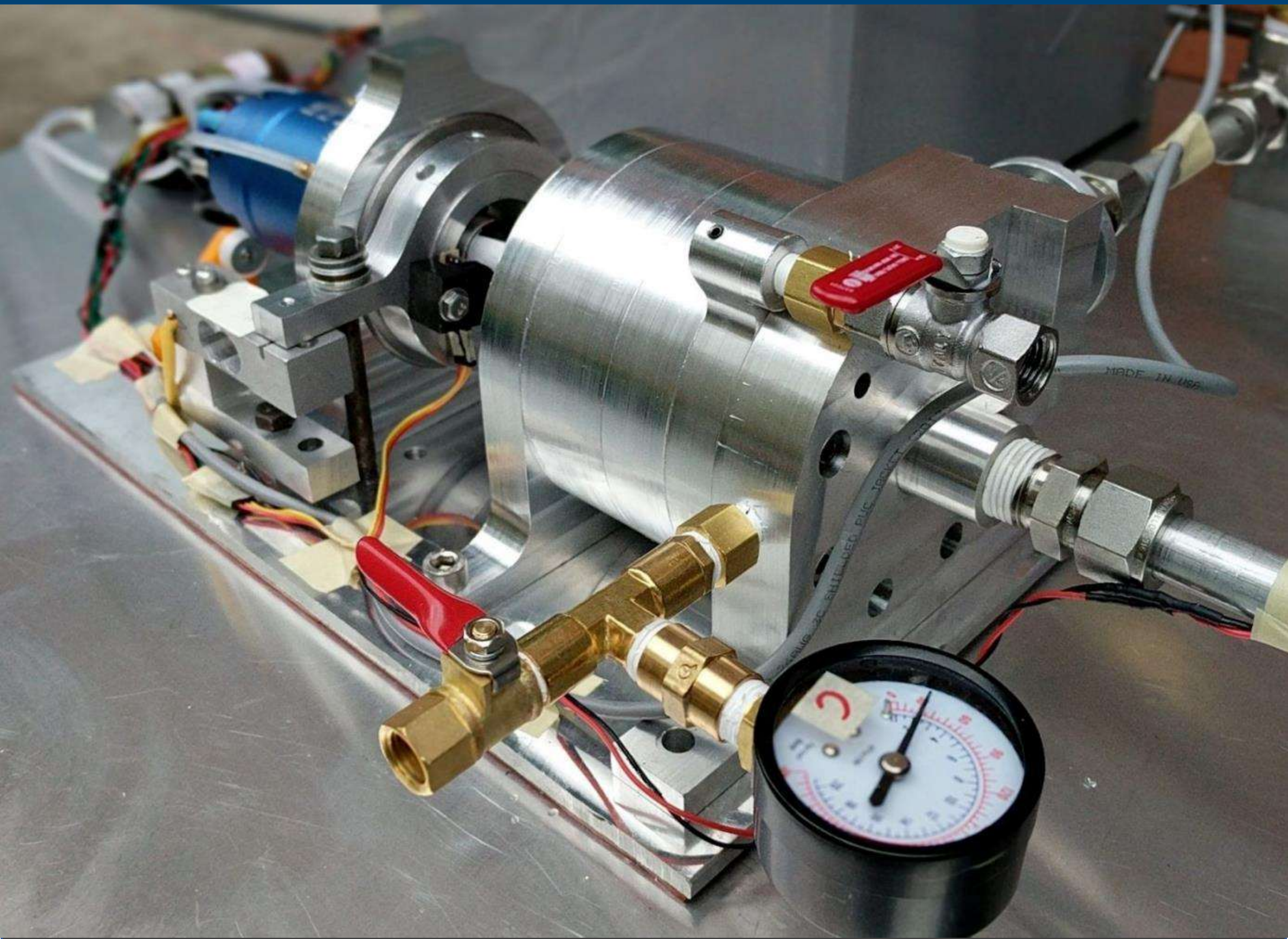
ME 491 | Fall 2018

Product Design Specifications Report



Flight Ready Electric Feed System

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Sponsored by Portland State Aerospace Society (PSAS)

DOCUMENT CONTENTS

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)

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 increase 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.

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 functional design will be followed by ANSYS vibrational and thermal analysis to show evidence of structural integrity. Once the design has been analytically verified, it will be approved and passed on to the CNC machine shop for physical fabrication. Initial machine prototypes will be machined out of inexpensive plastics for trial mock-ups before any machining out of metal will begin.

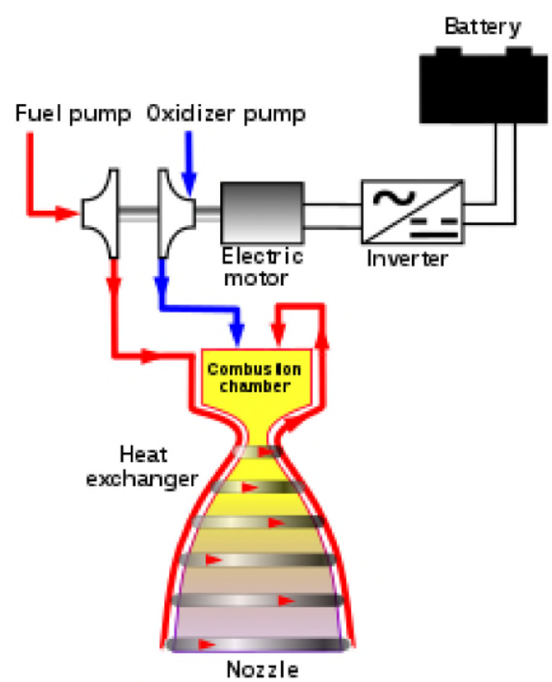

Figure 1: Overview of an EFS

The corrosive properties of liquid oxygen will 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.

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).

CUSTOMER IDENTIFICATION

Portland State Aerospace Society will be sponsoring this capstone project and is responsible for all of the given engineering requirements. *Table 1: Product Design Specifications* summarizes the customer needs and their ranking of priority upon final completion. Further, *Table 2: Customer Requirements*, 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 capstone, 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 publishing project documentation. The basic level requirements from both customers are outlined in *Table 5: Customer Requirements For PSAS 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)			
Customer Need	**Primary Customer**	**Priority**	**Time**
Must be compatible with liquid oxygen (LOX) and isopropyl alcohol	PSAS	5	*****
Must safely keep the propellants separated until injection into the engine even in the event of a pump failure	PSAS	5	*****
Must be able to be used on the PSAS engine test stand	PSAS	1	****
Must be able to operate without overhaul for multiple rocket engine test fires (≥ 10 firings)	PSAS	3	****
Must handle launch environment, including vibration and an acceleration of 10 g for 20 seconds.	PSAS	3	***
Should have embedded sensors for data acquisition, feedback, and control	PSAS	5	***
Should be plumbed efficiently to minimize pressure loss	PSAS	2	*
Must deliver propellants at 300-500 PSI from a tank at 45-70 PSI.	PSAS	4	***

Table 2: Customer Requirements

Customer Requirements							
Requirements		Primary Customer	Metrics & Targets	Metric	Target	Target Basis	Verification
Performance	LOX Compatibity	PSAS	Must be able to safely pump liquid oxygen	N/A	No damage	Customer Defined	Cold flow testing
	Fluid Separation	PSAS	Must restict fluid mixing even in the event of failure	N/A	No fluid mixing	Customer Defined	Prototyping
Installation	Manpower to test	PSAS	Manpower	# People	4 People	Customer Defined	Cold flow testing
	Time to replace spare parts	PSAS	Time	Mins	2 Hours	Team Defined	Timed after prototype built
Safety	LOX Safety	PSAS	Design with all chemical safety requirements via B11 Training	N/A	No LOX hazards	Customer Defined	Cold flow testing
	Electrical Safety	PSAS	Ensure all controls systems are safe from fluids, etc.	N/A	No electrical hazards	Customer Defined	Prototyping
Maintenance	Minimal upkeep between test fires	PSAS	No overhaul to be required between tests	Hours of Work Rqr'd	< 4 hours	Group Defined	Testing
	Replaceable Parts	PSAS	Readily Available Parts for replacement bearings, rings etc.	N/A	Off the Shelf Parts	Group Decision	Budget
Cost	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	Target Basis	Verification
Performance	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
	Launch Environment	PSAS	Must be able to withstand launch conditions	g	10	Customer Defined	Failure testing
	Pressure Gain	PSAS	Must achieve target pressure differential	psi	300-400psi	Customer Defined	Cold flow testing
Environment	Withstand Launch Environment	PSAS	Maintain operation during launch conditions	g	10g	Customer Defined	Testing
	Withstand vibration of Airframe	PSAS	Components must be designed to avoid harmonic frequency of rocket structure	Hz	TBD	Customer Defined	Simulation

CONCLUSIONS

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.

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
11 - 15	Coordinate Electric Feed System design with Engine Test Stand and Airframe
16 - 20	Begin manufacturing process for steel housing, plumbing, and airframe fixture
21 - 22	Testing cryogenic compatibility, fluid leak, and durability to cycle usage
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

Table 5: Customer Requirements For PSAS 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.
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Table 6: Electric Feed System Project Budget

Item	Description	Vendor	Award Amount	1.5:1 Cost Share
Cost Share				
In-Kind AY effort	Dr. Mark Weislogel donating his time working as PI on Project	Portland State University		$6,556
Award Budget				
304 SS Steel	The raw material used to machine pump housing	McMaster-Carr	$800	
Tooling	Pump House machine tooling	Western Precision Products Inc	$1,400	
6061 Aluminum	Raw Material to create EFS Airframe Structure	McMaster-Carr	$200	
304 SS Steel	¼" 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	
LOX Plumbing	Various LOX compatible fittings	AcmeCryo	$300	
Aluminum Piping	½" Aluminum piping for plumbing	Metals Depot	$100	
Seals	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	$150	
Heat Sink	Heat Sink for Brushless motor	Amazon	$25	
Arduino	Arduino to Controlling pump	Amazon	$50	
Sensing Equipment	Pressure Transducers and flow meters for fluid monitoring	Omega	$500	
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	1.537			