AES-SRP-2003-TBD
2003-09-04

Project Definition Document

Aerospace Senior Projects (ASEN 4018 & 4028)
Fall 2003 and Spring 2004

1.0 Information

1.1 Project Title

MaCH SR1 (Multi-disciplinary University of Colorado High-altitude Student Rocket): Phase II

1.2 Project Customers

None

2.0 Background and Context

Liquid bipropellant engines and solid rocket motors each have their own place in the space industry. A bipropellant engine provides high performance and controllability at the cost of increased complexity and, in the case of cryogenics, increased safety risks. A solid rocket motor can provide a large total impulse because its propellant is denser, but solid propellants have lower performance (i.e. specific impulse) and, more importantly, they can not be throttled or turned off once ignited.

A hybrid rocket engine aims to combine the reduced complexity of a solid rocket motor with the controllability and higher specific impulse of a bipropellant engine. Instead of mixing a solid oxidizer with the solid fuel, an oxidizer fluid (such as liquid oxygen or nitrous oxide) is injected into a cavity inside the fuel grain.

3.0 Objectives

There are two sets of objectives associated with this project: 1) the long-term, multi-year goals of the project 2) the short-term goals of the project for this year's group during the 2003-2004 academic year.

3.1 Multi-Year Project Objectives

3.1.1 Objective

MaCH-SR1 aims to design, build, and test a hybrid rocket capable of delivering a small payload to near space. This launch vehicle will provide the University of Colorado with its own space-launch capability.

3.1.2 Discussion

The following table outlines each phase of the MaCH-SR1 project, with each year building upon the progress made by the previous year's team.

Phase	Academic Year	Purpose	Goals and Desired Deliverables
0	2000-2001	Feasibility studies, building infrastructure, initial designs	Initial design and funding
I	2001-2002	Design, build, and test a prototype engine for proof of concept	Prototype engine (failed during static test) and supporting hardware: test stand, grain curing ovens, fuel formation process
	2002-2003	Design, build, and static test an engine capable of producing thrust of 1,000 lbf	HTPB/N2O engine capable of producing 1,000 lbs of thrust (successfully static tested)
II	2003-2004	Design, build, and static test a lighter and higher performance engine that is ready for integration with a flight vehicle	HTPB/N2O engine ready for integration with flight vehicle and capable of producing 5,000 lbf of thrust
	2004-2005	Design, build, and flight test a launch vehicle using the same engine developed by the previous year's team	Launch vehicle with 5,000 lbf HTPB/N20 engine. 1st test flight of a MaCH-SR1 engine.
III	2005-2006	Design, build, and static test an engine capable of producing thrust of 13,000 lbf and is ready for integration with a flight vehicle	HTPB/N2O engine capable of producing 13,000 lbs of thrust
	2006-2007	Design, build, and flight test a launch vehicle using the same engine developed by the previous year's team	Flight tested launch vehicle, including 13,000 lbf HTPB/N20 engine
IV	2007-2008	Design, build, and test a launch vehicle (MaCH-SR2) to be used by the University of Colorado for high-altitude research payloads (~10 lb payload)	Flight tested launch vehicle, including 13,000 lbf HTPB/LOX engine. 1st flight with a scientific payload.

3.2 Current Overall Objective

3.2.1 Objective

The objective of this year's team is to identify and resolve the short comings of the previous design with an eventual goal to design, build, and test a hybrid rocket engine ready for integration with a launch vehicle. This will begin Phase II of the MaCH-SR1 project.

3.2.2 Discussion

Due to the cost and complexities involved in building an engine of this size, the launch vehicle will be constructed by next year's team. The emphasis of this year's team will be to identify and improve upon the shortcomings of last year's engine. This year's team will perform static tests of the engine, leaving next year's team to flight-test the engine (completing Phase II of the project).

The following requirements define the successful completion of the project and are aimed at producing an engine ready for integration with a flight vehicle. In order of importance:

1) Increase thrust to weight ratio
2) Further characterize regression (burn) rate
3) Combine tanks and simplify plumbing
4) Increase thrust of the engine

4.0 Requirements and Goals

4.1 Increase thrust to weight ratio

4.1.1 Requirement

Increase the thrust to weight ratio of last year's engine from 1.2 to TBA.

4.1.2 Discussion

A primary drawback of last year's design is its relatively high mass. Since the regression rates were less well known last year, the fuel grain was considerably thicker (i.e. by a factor of three) than was required for the 15 s burn time. Reducing the grain thickness is just one area in which this year's team hopes to reduce mass which will increase the thrust to weight ratio. The team will also conduct a trade study to determine if a lighter material could be chosen for the chamber without a significant increase in cost or decrease in structural integrity. Redesigning and combining the N_2O tanks will also reduce the mass of the flight vehicle which will increase the thrust to weight ratio (see section 4.3).

4.2 Further characterize regression (burn) rate

4.2.1 Requirement

Conduct at least one successful burn at an intermediate thrust to further characterize the regression rate.

4.2.2 Discussion

The regression rate needs to be better defined in order to accurately determine how much fuel will be needed for a given burn time (e.g. 15 seconds).

4.3 Combine tanks and simplify plumbing

4.3.1 Requirement

Combine last year's two N_2O tanks into a single tank.

4.3.2 Discussion

By developing the tanks in conjunction with the engine, next year's team can focus on developing the rest of the launch vehicle.

4.4 Increase thrust of the engine

4.4.1 Objective

The requirement is to reproduce last year's thrust of 1,000 lbs of thrust, with a goal of increasing to 5,000 lbs.

4.4.2 Discussion

The team will aim to increase the thrust of the engine, but the primary emphasis is to improve on last year's design and collect additional thrust measurements.

4.5 Increase reliability of engine

4.5.1 Objective

The results of testing of the engine should be repeatable with thrust measurements roughly equal (within 15%).

4.5.2 Discussion

The reliability of the engine shall be increased by improvements in subsystem testing procedures, failure mode analysis and ignition system design.

5.0 Anticipated Engineering Expertise

Technical Expertise	**How Applied**
Precision Mechanical Design	Design and validate. Drawing, manufacturing and fabrication of parts
Electomechanical Actuators	Actuator for fuel feed system
Analog Electronics	Design and fabrication of the actuation and sensing subsystems
Data Acquisition Software	Real-time measurement subsystem
Control Software	Real-time control subsystem
Mechanical and Dynamic Test	Verification of the project
Thermal Analysis	Design, simulate and measure/test

6.0 Resources

6.1 Facilities

The project will have access to the test facilities at Pioneer Astronautics and Lockheed Martin.

6.2 Advisors

Prof. Lee D. Peterson
Office: ECAE 181
Office Phone: 303-492-1743
Lab Phone: 303-492-3576
Email: Lee.Peterson@Colorado.EDU

Prof. Jean N. Koster
Office: ECAE TBD
Office Phone: 303-492-6945
Email: Jean.Koster@Colorado.EDU

Prof. Kurt Maute
Office: ECAE TBD
Office Phone: (303) 492-1051
Email: maute@Colorado.EDU

Otto Krauss from last year's team and now a graduate student at the University of Colorado, will serve as an advisor, adding insight gained from experience from Phase I.

6.3 Funds

The CU aerospace department will provide $4,000 to the team. Additional funding will be provided by [TBD]