3 Phase Lox/Paraffin Hybrid Motor Development Plan

July 22, 2005

The following is the one possible approach to developing a simple and inexpensive pressure fed lox/paraffin hybrid motor capable of 1500 lbf for 15 seconds to be used for the investigation of active guidance on a PSAS LV3 vehicle and the investigation of scaling for possible future vehicles.

The plan consists of three phases that distribute the cost and technical hurdles into manageable portions that continually build upon one another and have a high degree of reusability

This plan proposes a 2-year time frame to complete the work and a budget of approximately $3200.

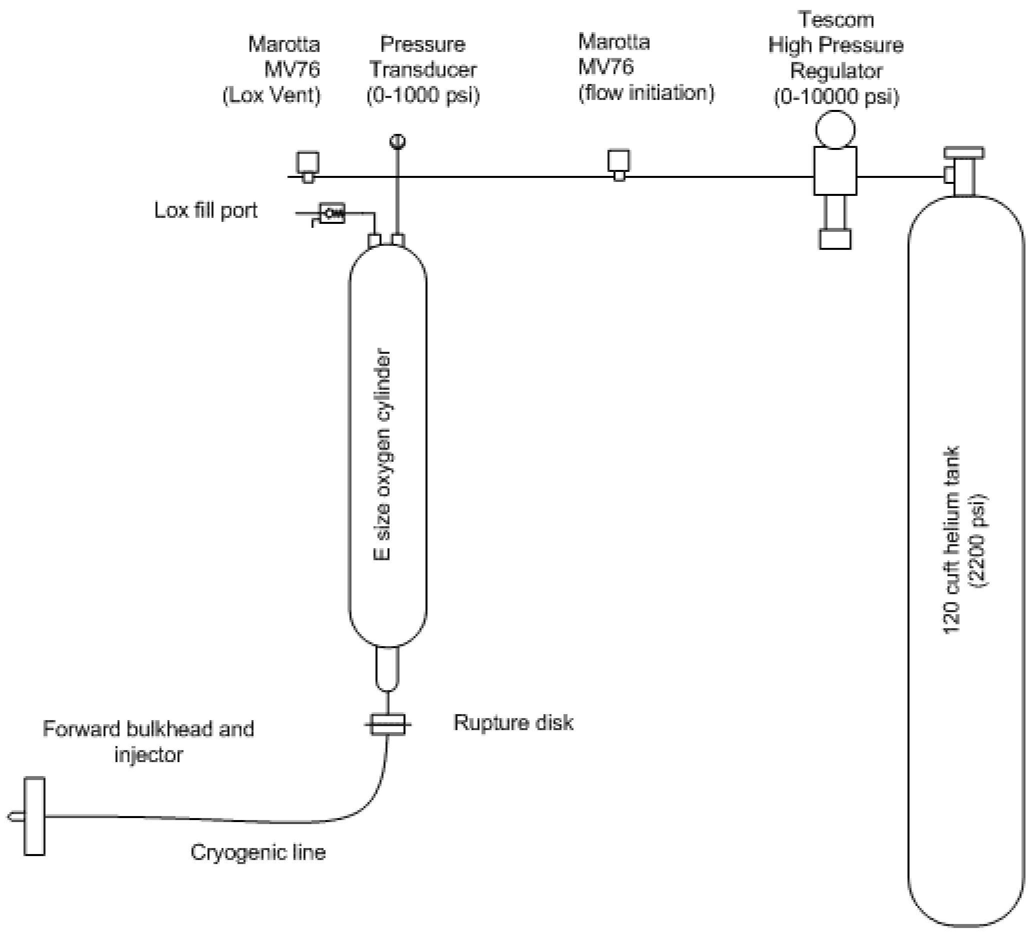
The end result will be a very simple 'low-tech booster', with nearly 100,000 Ns total impulse. The booster will allow us to fly often and at a low cost. After initial development, the motor may be duplicated for about $1000 (given enough lead time) and will have a re-occurring cost of approximately $100 per flight for expendables.

Once phase three is complete and we have a working motor for flying an LV3 vehicle, we may then wish to revisit the design and add improvements or redesign major components of the motor. This could include active thrust vector control, throttling as well as increasing performance and optimizing mass ratio.

This would be an ambitious project and easily an order of magnitude more complex than our current gox/paraffin hybrid motor that we have been developing for slightly over two years, but it is within the realm of our manufacturing and financial capabilities and would stand a high chance of being completed because of it's simple nature and well established technologies that it draws upon

Phase 1: Cryogenic familiarization and component evaluation

Time Frame: (1/1/2006 – 7/1/2006)



Overview:

This configuration will be capable of testing several systems used in a pressure fed cryogenic hybrid rocket motor. It will be inexpensive and fairly simple to construct and will a high degree of reusability for Phase 2. This test configuration will allow us to evaluate many ideas and change the design as we learn. (I.e. finding the correct injector/ valves vs. rupture disks/correct cryogenic plumbing techniques)

Operation:

A standard 120-cuft steel helium bottle at 2200 psi will be regulated down to 600 psi with a Tescom regulator. The 600 psi helium will pressurize a 5 liter cryogenic tank (liquid nitrogen for initial flow testing). A rupture disk will initiate flow to combustion chamber injector once the flow initiation Marotta helium solenoid is energized. Additional modifications will be made for helium purging, cryogenic draining and safeing of the system. That may not be illustrated here.

Purpose:

1) Familiarization with liquid oxygen safety and handling
    a. Transportation
    b. Filling
    c. Spill mitigation
    d. Draining
    e. Etc,etc….
2) Characterize helium shrinkage over lox.
3) Evaluate rupture disk performance.
4) Evaluate cryogenic plumbing techniques.
    a. Flexible lines
    b. Dissimilar material interfaces
    c. Behavior of threaded connections
5) Characterization on different injectors.
    a. Target correct flow rate
    b. Target acceptable atomization of cryogen

Parts:

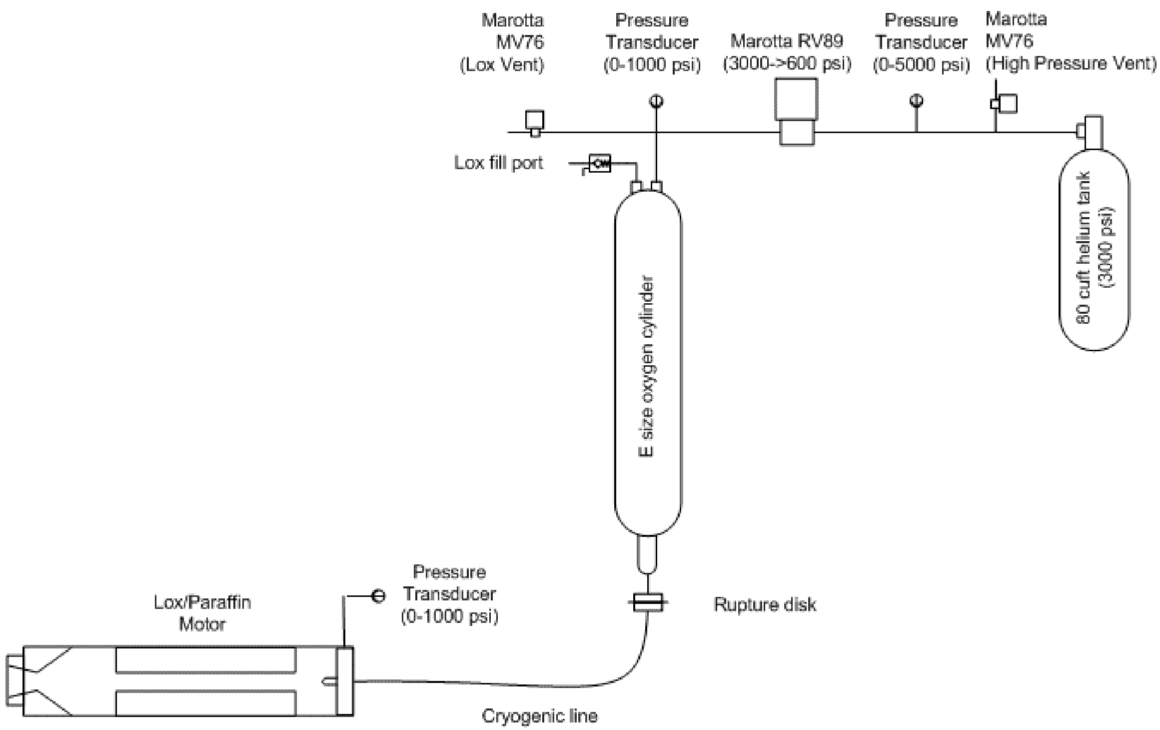
Component	Description	Have	Need	Price
Lox Tank	Standard 'E' size aluminum medical oxygen cylinder (4.5 L fluid volume?)	X		$39
Pressurant Tank	120 cubic ft welding tank with helium at 2200 psi	X		$150
Helium Regulator	Tescom 44 Series Inlet 0-10000 Outlet 0-10000	X		$100
Helium Vent	Marotta MV76		X (have source)	$40 approx.
Lox Vent	Marotta MV76		X (have source)	$40 approx
Helium Pressure Transducer	Barksdale (0-2000 psi)	X		$5
Lox Fill Valve			X (needs research)	$200 approx.
Rupture Disk	BS&B Safety Systems OSECO		X (needs research)	$50 approx.
Rupture Disk Holder	? May build?		X	$50 approx.
High Pressure Helium Line	10' Braided Stainless Steel	X (could use gox stand line)	X (ebay)	$30 approx.
Cryogenic Line	2' Liquid Oxygen Compatible		X (needs research)	$100 approx.
Assorted plumbing fittings			X	$200 approx.
Injector Bulkhead	6061 T6		X	$30 approx.
Injector	Bete?		X	$50 approx.
Funds Required			**$790.00**	

Additional Consideration:

- We will need to retrofit the cryogenic dewar we have so that we can pick up liquid nitrogen and liquid oxygen. (appox. $1 per liter)
- We will need a new test stand to hold equipment. This could be the same stand that will be used to static fire the 1000-1500 lbf motor.

Phase 2: Flight equivalent hybrid

Time Frame: (7/1/2006 – 7/1/2007)



Overview:

This configuration will simulate all the functional components of a flight article hybrid motor. Lox tank will be ¼ scale, which will allow for ¼ thrust or ¼ duration static fires. The pressurant tank pressure will be increased to 3000 psi flight article levels. We can gain experience working with and filling high pressure vessels via a Haskel, or equivalent, air booster. The flight article Marotta regulator /solenoid valve will be used so that it can be evaluated and tuned as necessary

Operation:

Similar to phase one except combustion chamber will be introduced and the helium pressure raised. In addition the Tescom Regulator and solenoid actuator will be replaced with the Marotta combination regulator and solenoid valve.

The sequence will begin with the activation of some form of ignition source in the combustion chamber. Upon confirmation of ignition source the MV89 valve will open and pressure the lox tank to 600 psi. This pressurization will cause the rupture disk to open and initiate the flow of lox to the atomizing injector and subsequently into the combustion chamber where a combustion reaction will occur with the paraffin.

Purpose:

1. Gain Experience with high pressure helium systems
2. Evaluation and Characterization of lox/paraffin
3. Lox phase change issues in combustion chamber
4. Feed system oscillations
5. Nozzle erosion at higher thrusts levels

Parts:

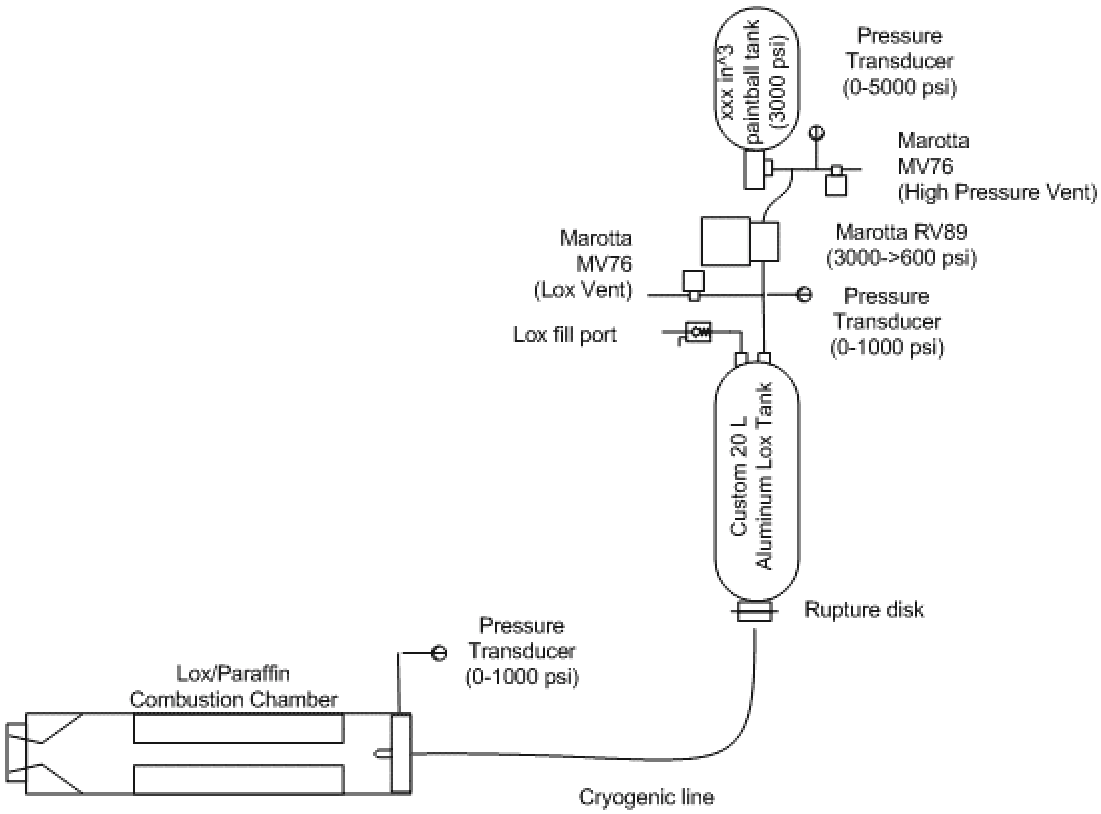
Component	Description	Have	Need	Price
Lox Tank	Standard 'E' size aluminum medical oxygen cylinder (4.5 L fluid volume?)	X		$39
Pressurant Tank	80 cubic ft filament wound tank with helium at 3000 psi	X		$100.00
Helium Regulator	Marotta RV89 Inlet 3000 Outlet 0-600	X		$60
Helium Vent	Marotta MV76	X		$40 approx.
Lox Vent	Marotta MV76	X		$40 approx
Helium Pressure Transducer	0-5000psi		X	$50
Lox Pressure Transducer	Barksdale (0-2000 psi)	X		$5
Combustion Chamber Transducer	High temperature (0-1000 psi)	X		$30
Lox Fill Valve		X		$200 approx.
Rupture Disk	BS&B Safety Systems OSECO	X		$50 approx.
Rupture Disk Holder	? May build?	X		$50 approx.
High Pressure Helium Line	10' Braided Stainless Steel	X		$30 approx.
Cryogenic Line	2' Liquid Oxygen Compatible	X		$100 approx.
Assorted plumbing fittings		X		$200 approx.
Injector Bulkhead	6061 T6	X		$30 approx.
Injector	Bete?	X		$50 approx.
Combustion Chamber Material	Aluminum, graphite, phenolic, snap-rings and seals		X	$200 approx
Haskel gas booster			X (ebay)	$1500 approx
Funds Required			**$1750.00**	

Additional Consideration:

- Ignition method will need to be worked out
- Test stand will need to be beefed-up to accommodate 1500 lbf thrust loads and sensors will need to be upgraded to a 2K lb load cell and a 5K psi helium tank transducer.

Phase 3: Flight article hybrid

Time Frame: (7/1/2007 – 1/1/2008)



Overview:

This configuration will be the static test stand version of the flight article motor. The system will use all the hardware that will be flown and resemble the final flight article motor configuration as closely as possible. The 80 cubic ft helium tank will be replaced with a smaller off the shelf high pressure tank that will be size for the appropriate volume of helium required. The 'E' size medical oxygen cylinder will be replaced with a custom made 20L lox tank with hemispherical end caps.

Operation:

Similar to phase two motor except full duration and thrust static firings will be possible with the addition of the larger lox tank.

Purpose:

1. Gain experience fabricating a lox tank
2. Evaluate OTS helium tank (paintball?)
3. Optimize
   a. Lox tank weight
   b. Helium pressurant tank weight
   c. Combustion chamber weight
   d. Component connections
4. Minimize plumbing run lengths
5. Consolidate and integrate DAQ and Sequencing electronics
6. Interface with Avionics

Parts:

Component	Description	Have	Need	Price
Lox Tank	Custom aluminum lox tank with hemispherical end caps (22 L fluid volume?)		X	$400
Pressurant Tank	xxx cubic in filament wound paint ball tank with helium at 3000 psi		X	$100
Helium Regulator	Marotta RV89 Inlet 3000 Outlet 0-600	X		$60
Helium Vent	Marotta MV76	X		$40 approx.
Lox Vent	Marotta MV76	X		$40 approx
Helium Pressure Transducer	0-5000psi	X		$50
Lox Pressure Transducer	Barksdale (0-2000 psi)	X		$5
Combustion Chamber Transducer	High temperature (0-1000 psi)	X		$30
Lox Fill Valve		X		$200 approx.
Rupture Disk	BS&B Safety Systems OSECO	X		$50 approx.
Rupture Disk Holder	? May build?	X		$50 approx.
High Pressure Helium Line	10’ Braided Stainless Steel	X		$30 approx.
Cryogenic Line	2’ Liquid Oxygen Compatible	X		$100 approx.
New assorted plumbing fittings			X	$100 approx.
Injector Bulkhead	6061 T6	X		$30 approx.
Injector	Bete?	X		$50 approx.
Combustion Chamber Material	Aluminum, graphite, phenolic, snap-rings and seals	X		$200 approx
Haskel gas booster		X		$1500 approx
Funds Required			**$600.00**	

Additional Consideration:

- Components will need to be stacked and retained similar to flight configuration
- Combustion chamber should have the ability to be oriented vertically.