Resilient Mobile Space Launch System

VECTOR

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Summary

This project will develop a conceptual design for a TEL (transporter, erector, and launcher) and a launch vehicle. The TEL will transport, erect, and launch the launch vehicle, and will follow standard Department of Transportation requirements so it can operate on standard US highways and roads. It will also hold down the launch vehicle at 100% thrust level before release and can be set up within 8 hours of arrival at the launch site. The launch vehicle will be capable of launching a 200 lb payload to a 500 km, sun-synchronous polar orbit and will have a reusable first stage. It will also utilize existing LOX/hydrocarbon engines. Lastly, a flame deflector is needed to divert the exhaust and heat from the engine thrust.

Our design solution for the launcher is to develop a 40 ft rocket with a 6 ft diameter that uses a combination of existing rocket engines. The TEL's design will feature a low cab vehicle equipped with hydraulics with the rocket situated and locked on top of the cab. Upon arrival to its launch location, the launch site will be drilled into the ground and the rocket erected to its proper position.

The preliminary CAD of the rocket and transporter is finished and the prototype of the clamp needed to hold down the platform is in development. The rocket sizing and values are also calculated and it will be ran through a simulation soon. The dimensions of the flame deflector are also finalized based on the rocket dimensions.

Key Features

TEL:

- Transporter - vehicle manually operated by a driver that transports the launch system, erector, and dry launch vehicle
- Clamp - An anchoring mechanism that is able to hold the rocket down while it reaches 100% thrust, then simultaneously releases all points, freeing the rocket
- Hydraulic Erector - Transitions the launch vehicle from horizontal to vertical using hydraulics and provides a support structure when vertical and during this process
- Launch Pad - Platform where the launch vehicle will sit before initial launch after being fully erect to 90 degrees
- Drilling Mechanism - component that drills launch pad into ground before initial launch and holds it down at 100% thrust
- Flame Deflector - component that protects entire system from taking structural damage caused by extremely high temperatures by redirecting engine exhaust away from surrounding subsystems

Launch Vehicle:

- Fairing - the structure that houses and protects the payload from aerodynamic forces, environmental conditions, and vibrations during launch and after stage separation.
- Dry Structure - the skirts and the interstage; the structural components of the launch vehicle that do not directly interact with the propellants.
- Wet Structure - the propellant tanks; the structural components of the launch vehicle that directly interact with the propellants.
- Propulsion - the engine, feed system, and pressurization system; the components that provide the launch vehicle with the thrust necessary to launch to the desired orbit.
- Recovery System - the landing legs; the components responsible for ensuring the safe and controlled recovery of the launch vehicle's first stage after stage separation.

References and Acknowledgements

Kibbey, T. (2019, June 3). *Small launch vehicle sizing analysis with solid rocket examples - NASA technical reports server (NTRS)*. NASA. https://ntrs.nasa.gov/citations/20190027424

National Aeronautics and Space Administration. (1990, June 20). *Flame Deflector Design, Standard For*. NASA. https://standards.nasa.gov/sites/default/files/standards/KSC/B/0/ksc-std-z-0012b.pdf

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Engineering Analysis

Key Rocket and Mass Fraction Equations:

Tsiolkovsky Rocket Equation

$$\Delta VT = g_o\left(I_{spV1} Ln\left(\frac{W_{p1}+W_{p1rec}+We_1+Wp_2+We_2+WF+WP_L}{W_{e1}+W_{p1rec}+Wp_2+We_2+WF+WP_L}\right)+I_{spV2}Ln\left(\frac{W_{e2}+W_{p2}+W_{PL}}{W_{e2}+W_{PL}}\right)\right)$$

Kibbey Mass Fraction Equation

$$f_i = f_{i,vp,rep}\left(\frac{\rho_p}{\rho_{p,ref}}\right)^{-1}. +. C_fFW_P + C_{mpref}\left(\frac{wp}{Wp,ref}\right)^{-2/3}$$

Mass Ratio with Propellant Mass Figure

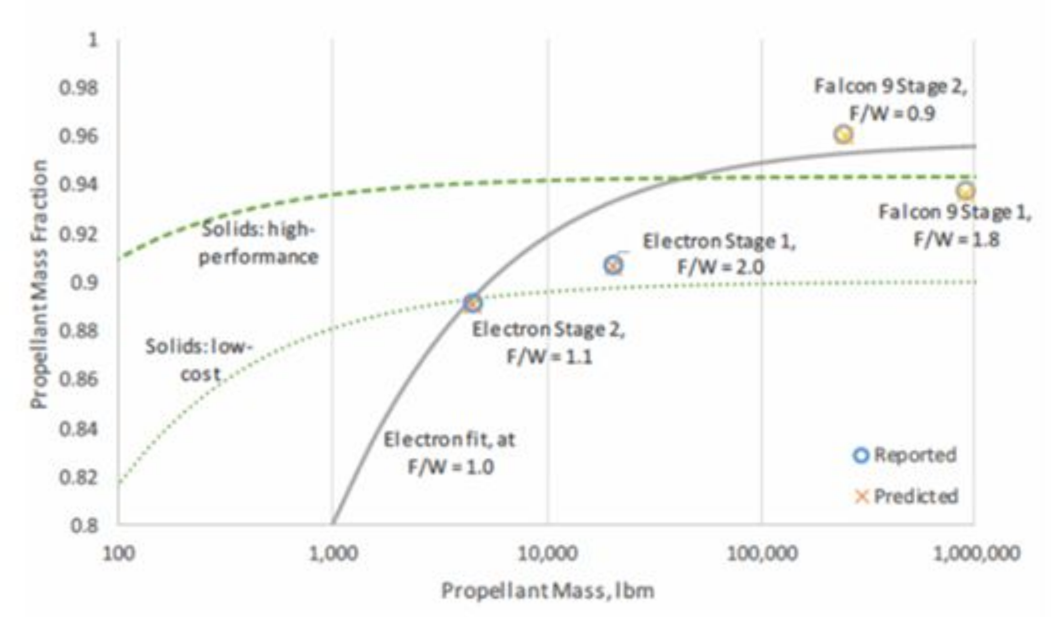


Figure 7. Falcon 9 and Electron Stages: Data with Model

Rocket Stage and Tank Sizing:

Two Stage Ideal Velocity	32097	ft/s
Payload	200	lbs
Fairing	500	lbs
Stage 1 Wet Mass	36520	lbm
Stage 1 Dry Mass	3636	lbm
Stage 2 Wet Mass	6968	lbm
Stage 2 Dry Mass	942	lbm
Two Stage Gross Weight	52419	lbm
Stage 1 Mass Fraction	0.072412	
Stage 2 Mass Fraction	0.10018	

Mixture Ratio (LOX:RP1)	2.3:1	
Stage 1 LOX Weight	25,453	lb
Stage 1 RP1 Weight	11,067	lb
Stage 2 LOX Weight	4,856	lb
Stage 2 RP1 Weight	2,112	lb
Stage 1 LOX Tank Volume	368	ft^3
Stage 1 RP1 Tank Volume	226	ft^3
Stage 2 LOX Tank Volume	70.2	ft^3
Stage 2 RP1 Tank Volume	43.1	ft^3

Engine Selection:

Stage 1: 4x Firefly Lightning Engine (thrust of 15,759 lbf each)
- Ideal thrust to weight ratio of 1.15 to 1.25

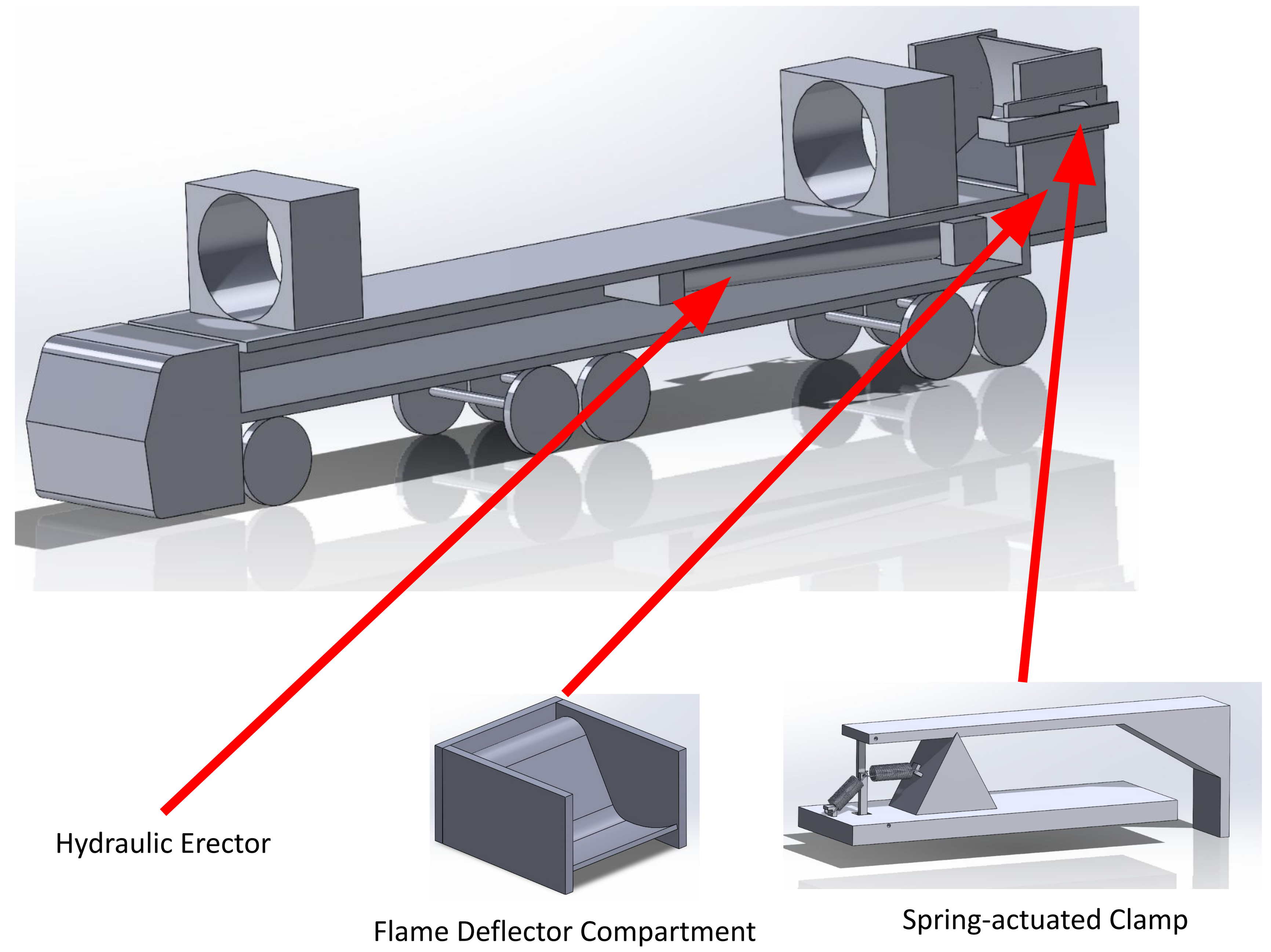
Stage 2: 1x ABL E2 Engine (thrust of 12,100 lbf each)
- Ideal thrust to weight ratio of 0.9 to 1.1

Improvements

Due to the large & complex scope of our project, we still need to fine tune the current subsystems and go more in-depth by researching the subsystems we haven't covered yet such as avionics and the ground control station. Since we have been very limited with the public information & data we could find, we have to keep testing through simulations and troubleshoot until the whole system is successful. To achieve this, we will work hand-in-hand with our sponsor Jeff and he will run our calculations through the advanced software that he has access to.

Final Design

TEL CAD:



Launch Vehicle CAD: