Team #15

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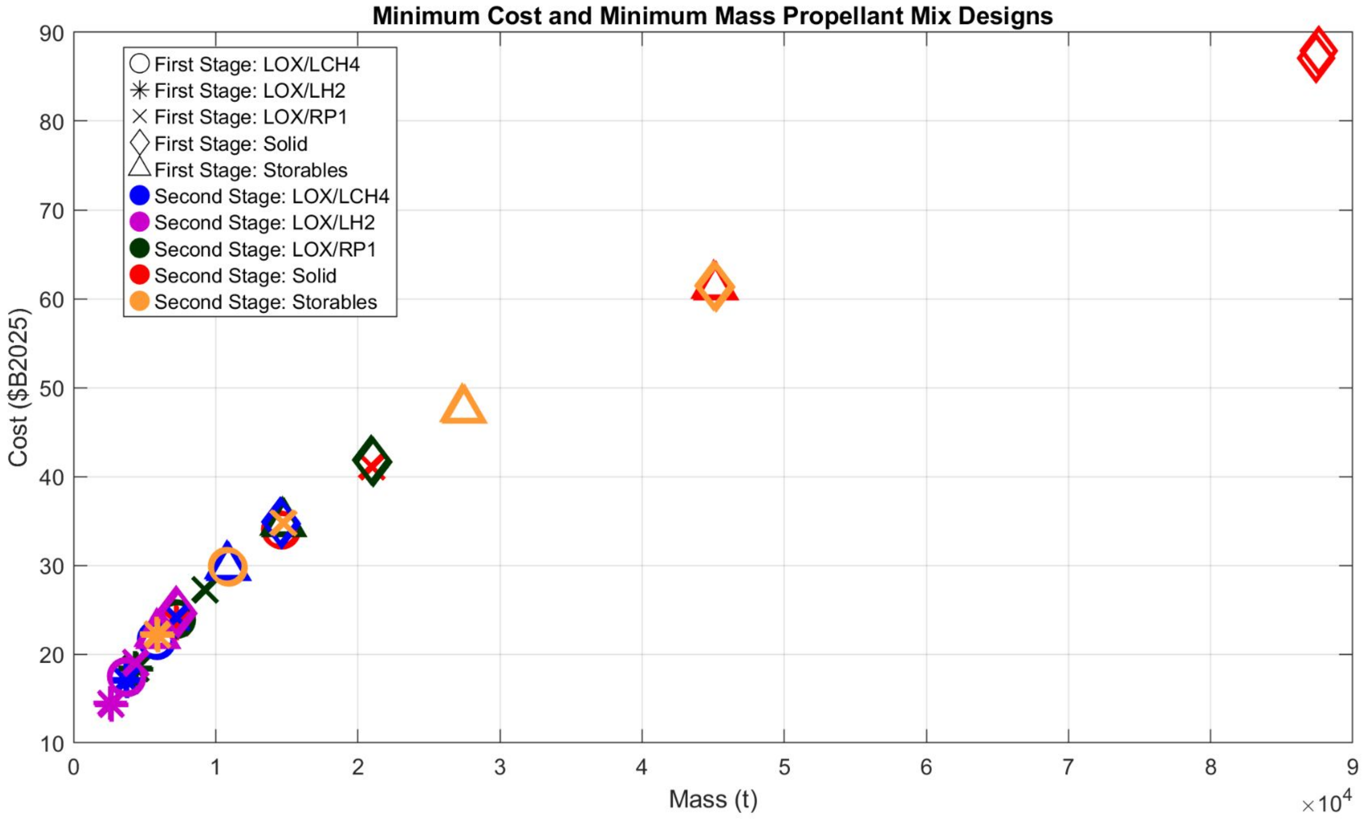
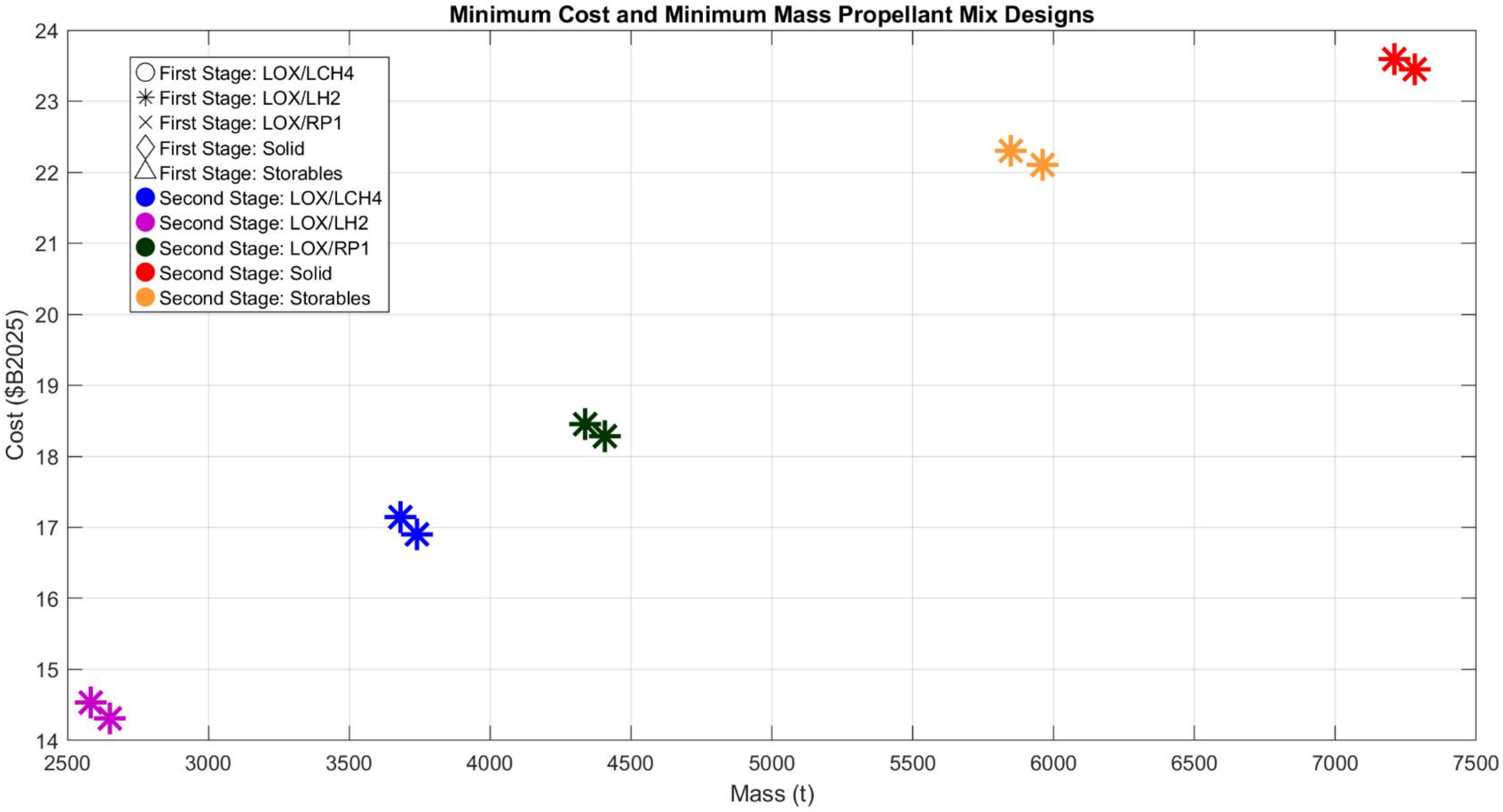
Matrix of Resposibility:

First stage prop. (columns) - Second stage prop. (rows)	LOX/LCH4	LOX/LH2	LOX/RP1	Solid	Storables
LOX/LCH4	Ben	Ben	Ben	Ben	Ben
LOX/LH2	Sara	Sara	Sara	Sara	Sara
LOX/RP1	Spyros	Spyros	Spyros	Spyros	Spyros
Solid	Sophie	Sophie	Sophie	Sophie	Sophie
Storables	Chris	Chris	Chris	Chris	Chris

Full Graph of Results



Top Mass/Cost Results



Trade Study and Conclusion

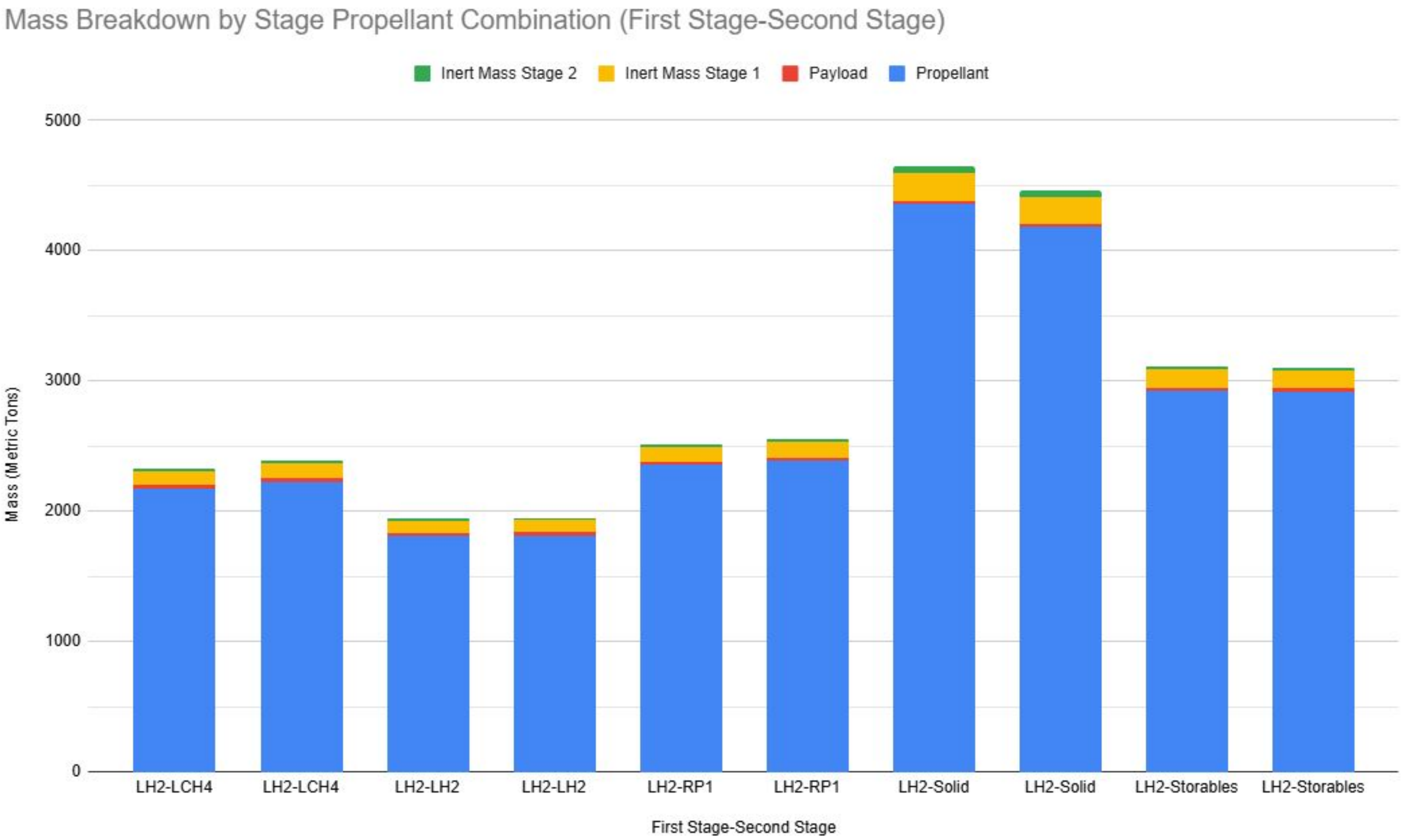
- From the data, the LOX/LH_2 + LOX/LH_2 combination was most optimized for mass and cost
  - Minimum Mass: [2582 (t), $B2025: 14.53]
  - Minimum Cost: [2650 (t), $B2025: 14.31]
- H_2 is temperamental
  - It needs cryogenic cooling, the technology for which is not available
- Higher I_{sp} in electric, but provides low thrust
  - Isp doesn't paint a full picture of how to get a launch vehicle from the ground into space
  - Future analyses will paint a fuller picture by deriving $\dot{m}$ from T2
- Our analysis is dependent on consistent **δ** = 0.08, this might not be reflective of actual performance

Driving “top” results

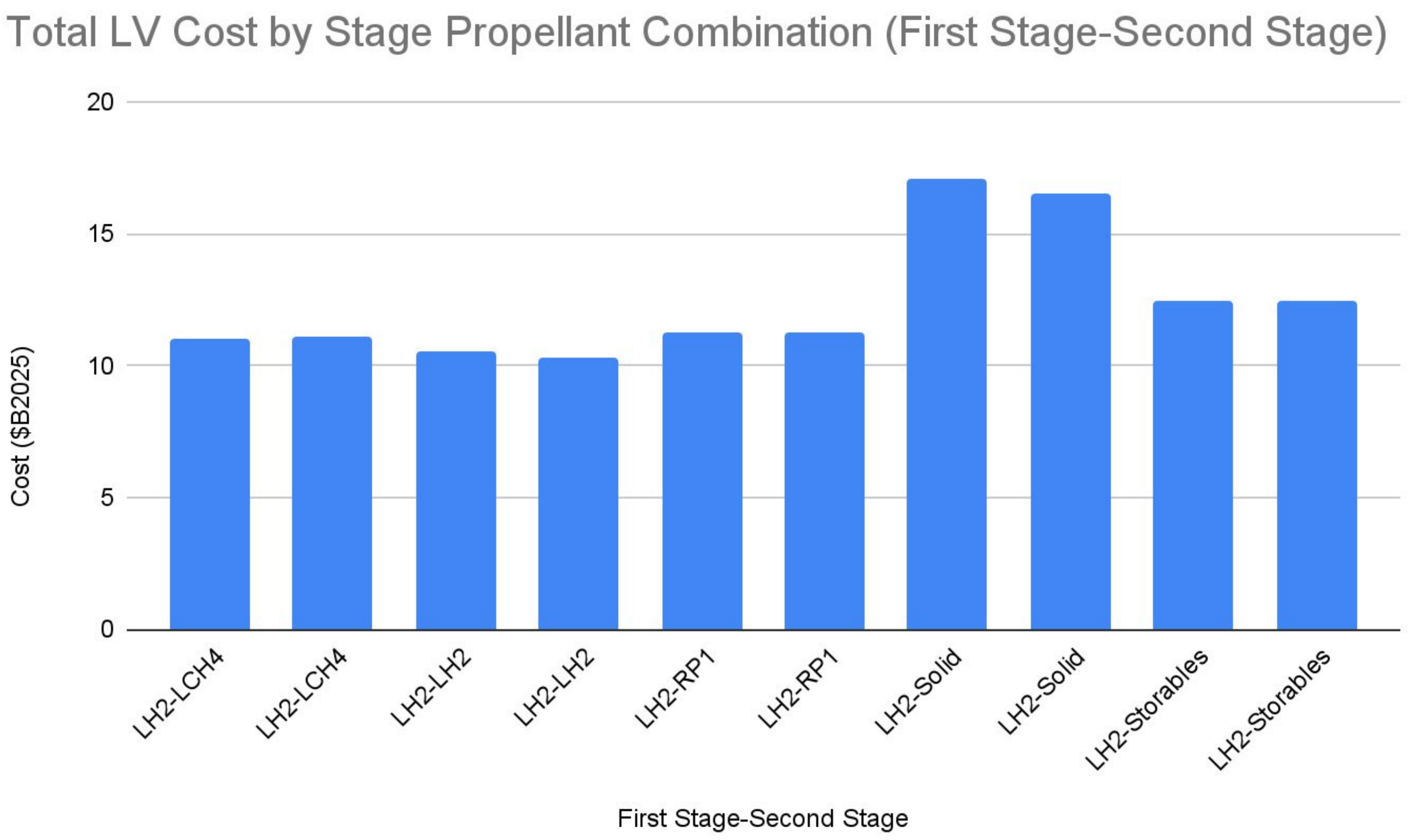
- The Isp of the first stage seems to be a strong driving force.
    - The higher the initial Isp the lower the cost and minimum mass
- In accordance with what we have learned in lecture, the higher the Isp, the higher the force per kg provided
- The Isp of the second stage also makes an impact on the minimum cost and mass as a two stage rocket uses all of its resources.
    - The second stage Isp seems to be the deciding factor if, within the subset of the first Isp, the launch vehicle will be at the top or bottom mass/cost for the group.
- Looking at the ΔV equation, I_{sp} directly correlates to its value

$\Delta V_i = - V_{e,i} * \ln(m_{f,i}/m_{in,i})$	$I_{sp} * g_o = V_e$

2.3 System Level Results



2.3 System Level Results



2.3 Optimal Mass and Cost Results

	Propellant 1st-2nd	Mass (MT)	Cost ($B2023)	Mass Margin	Propellant Storage
Min Mass	LOX/LH2-LOX/LH2	1,980	10.5	25.33%	Cryogenic
Min Cost	LOX/LH2-LOX/LH2	2,520	10.34	27.11%	Cryogenic

LOX/LH2-LOX/LH2 is the most optimal mass and cost configurations. In comparison to the next least cost and mass estimates, LOX/LH2-LOX/LCH4, the cost of LOX/LH2-LOX/LH2 is almost 1 billion dollars less. The mass of LOX/LH2- LOX/LH2 is about half of the mass of LOX/LH2-LOX/LCH4.

The mass margins are also roughly at the 30% mark that was the requirement.

2.3 Overall Optimal Design Discussion

- The optimal design out of the two optimal mass and cost results is LOX/LH2 first stage and LOX/LH2 second stage for minimum cost (X = 0.54)

- From Submission 1, it was decided that for a LV, cost should be optimized over mass, so the minimum cost should be given design preference

- We chose to minimize cost because, as stated in early lectures, the biggest hindrance from reaching space for a single-use launch vehicle, is price, since there is an inability to reuse materials and therefore a lot of material waste produced

- Minimizing the cost would also decrease the likelihood of our mission getting cancelled due to shortcomings in the budget, which is far more likely than a cancellation due to a lack of materials

2.4 Trade Study Reflection

(1) The biggest discrepancy in the study's trends is in the cost calculations. Compared with Table 1.5 some mass combinations saved upwards of 10 ($B2025) when compared to the costs of the current systems-level analysis.

(2) Cyclical calculations allowed for the optimization of mass. When doing calculations with mass margin, then the inert mass is lessened, which in turn lessens the mass necessary for the launch vehicles. There are also other portions which influenced the mass, including the calculations for systems like avionics and gimbals, which are not calculated with great detail. In this submission, we also had the opportunity to optimize for tank size which we didn't do in submission 1, allowing us to create a more constrained design for the rocket which more accurately defines the true cost and weight.

2.4 Trade Study Reflection (Continued)

(3) There are several important factors that are missing to improve this trade study.

- Engine and propellant efficiencies, as well as engine reliability. We are not taking into account real world scenarios, we assume all engines work perfectly for the whole duration of their burn time and do not leave room for failures.
- The number of engines required in the vehicle-level design might not be accounted for in the inert mass of the vehicle (number of engines physically fitting on rocket area).
- The group did not factor the possibility of engine failures due to the high range of number of engines. More engines equate to a higher possibility of failure.

All these factors could greatly hinder the performance of the lift vehicle and its DeltaV.