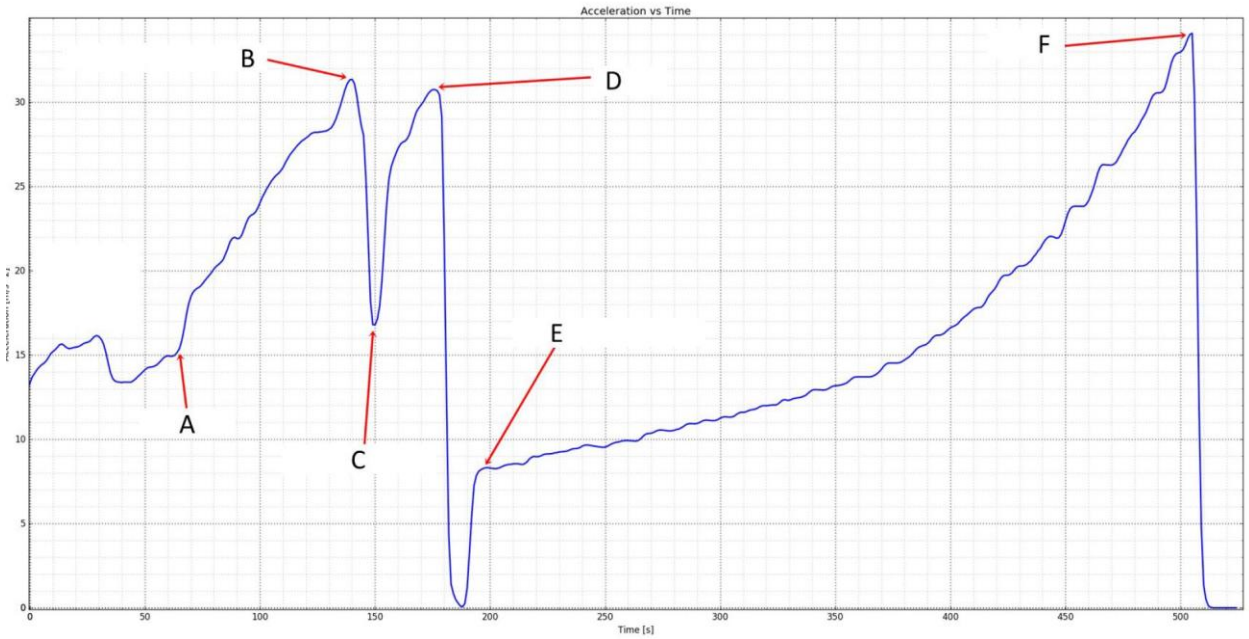
Noe Lepez Da Silva Duarte

AE 4361 – Assignment 2

1)



a) Event A occurs at T + 01:10, or at 2:37 in the video. This is the point where max Q is reached, when the rocket experiences the maximum amount of dynamic pressure. Once the rocket has passed that point, it is able to safely increase its acceleration as the atmospheric density is greatly reduced and forces applied on the rocket will always be smaller than at event A. Side boosters throttle back to full power.

b) Event B occurs at T + 02:20, or at approximately 3:55 in the video, where side boosters, which were at full throttle prior start to shut down.

c) Event C occurs at T + 02:30, or at 4:00 in the video, when the side boosters fully power off and detach from the rocket a couple of seconds later. The sharp increase in acceleration is caused by the change in rocket mass due to shedding of the two boosters, as the main stage now only has to carry the payload.

d) Event D occurs at T + 3:00, or at 4:29 in the video, when the payload detached from the Falcon heavy. As it is not attached anymore, the payload has no acceleration at this time.

e) Even E occurs at T + 3:15, or at 4:45 in the video, the main engine cuts off and the payload engine starts up, allowing the payload to start accelerating once again.

f) Event F occurs at T + 8:25, or at 10:00 in the video is the second stage engine cutoff. The payload has now completed its journey to a specified parking orbit and may or may now reaccelerate in the future to reach a desired orbit.

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2) a)

Vehicle	**Number of stages**	**Fairing diameter (m)**	**Propellant type**	
Falcon 9 (Full thrust, RTLS) [1]	2	5.2	*Stage I*	Liquid
			Stage II	Liquid
Antares (231) [2]	3	3.9	*Stage I*	Liquid
			Stage II	Solid
			Stage III	Liquid (monoprop)
Pegasus (XL w/ HAPS) [3]	4	1.27	*Stage I*	Solid
			Stage II	Solid
			Stage III	Solid
			Stage IV	Liquid (Hydrazine)
Atlas V (401) [4]	2	4.2	*Stage I*	Liquid
			Stage II	Liquid
Atlas V (501) [4]	2	5.4	*Stage I*	Liquid
			Stage II	Liquid

Propellant types found at:

[1] “SpaceX – Falcon 9,” SpaceX, Accessed 29 January 2022. https://www.spacex.com/vehicles/falcon-9/

[2] “Antares User’s guide,” Northrop Grumman, September 2020, Accessed 29 January 2022. https://www.northropgrumman.com/space/antares-rocket/

[3] “Pegasus Payload User’s guide,” Northrop Grumman, September 2020, Accessed 29 January 2022. https://www.northropgrumman.com/space/pegasus-rocket/

[4] “Atlas V,” ULA Launch, 2019, Accessed 29 January 2022. https://www.ulalaunch.com/rockets/atlas-v

b)

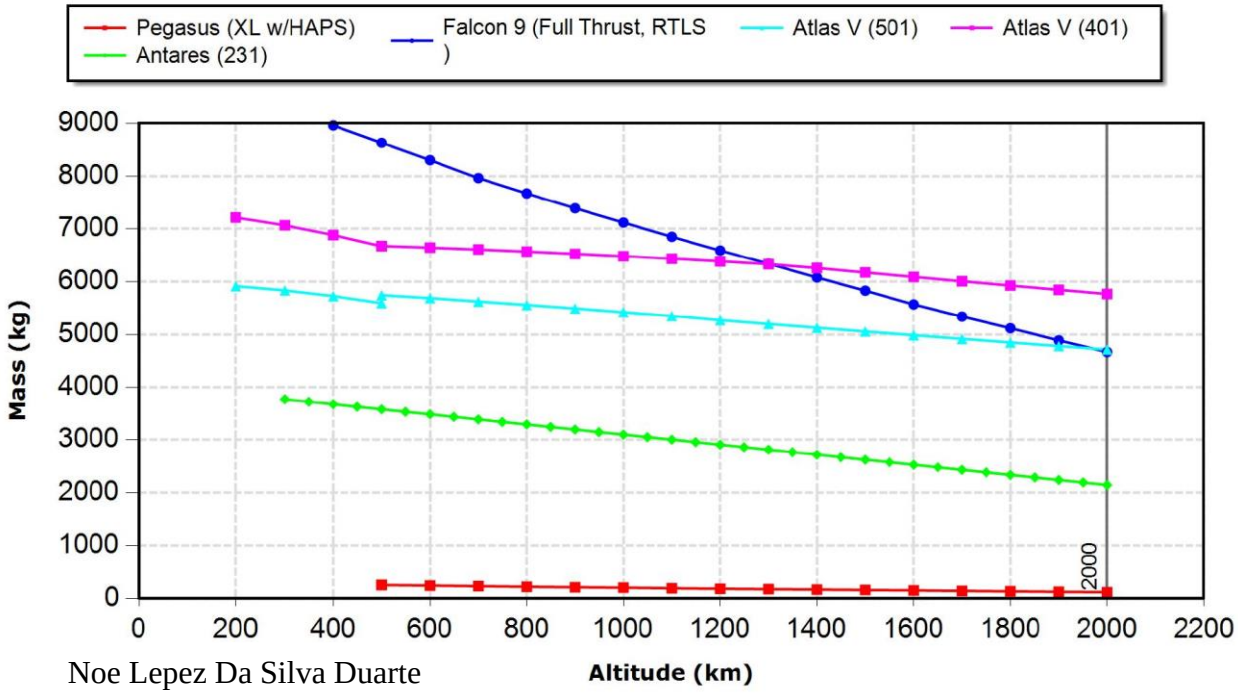

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Figure 1. Altitude vs amyloid mass for each launch vehicle

Table I. Table of payload capabilities for each launch option

Vehicle	Launch Site	Capability, kg	Fairing	Adapter
Pegasus (XL w/HAPS)	VAFB	115	50in (1.3m)	38in (967mm)
Antares (231)	WFF	2145	3.9m	47in (1194mm)
Falcon 9 (Full Thrust, RTLS)	VAFB	4670	5.2m	47in (1194mm)
Atlas V (501)	VAFB	4715	5m Short	47in (1194mm) payload separation ring with C22 adapter
Atlas V (401)	VAFB	5765	4m LPF	47in (1194mm) payload separation ring with C22 adapter

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c)

Vehicle	**Able to satisfy requirements**	**Cost ($)**
Falcon 9 (Full thrust, RTLS)	Yes	10,800,000
Antares (231)	No	-
Pegasus (XL w/ HAPS)	No	-
Atlas V (401)	No	-
Atlas V (501)	No	-

While Atlas V could carry the payload, unlike the Antares and Pegasus rockets, its minimum park orbit perigee is of 180km, more than the 170km required. Only SpaceX's Falcon 9 could carry out the mission, with its 160km minimum park orbit perigee. The launch would cost $10.8 million.

d)

Vehicle	**Able to satisfy requirements**	**Cost ($)**
Falcon 9 (Full thrust, RTLS)	No	-
Antares (231)	No	-
Pegasus (XL w/ HAPS)	No	-
Atlas V (401)	No	-
Atlas V (501)	Yes	36,000,000

Only the Atlas V (501) rocket has a fairing diameter large enough to accommodate the satellite with a diameter of 5.4m. The launch would cost $36 million.

3) a)

$$F_{axial,\mathrm{F9}} = T + W = 934{,}000 \times 9 + 9.81 \times 549{,}054 = 8{,}406{,}000 + 5.386 \times 10^6$$
$$= \mathbf{1.38 \times 10^7 N}$$

b)

$$F_{axial,\mathrm{FH}} = T + W = 934{,}000 \times 9 \times 3 + 9.81 \times 1{,}420{,}788 = 25{,}218{,}000 + 1.39 \times 10^7$$
$$= \mathbf{3.92 \times 10^7 N}$$

c)

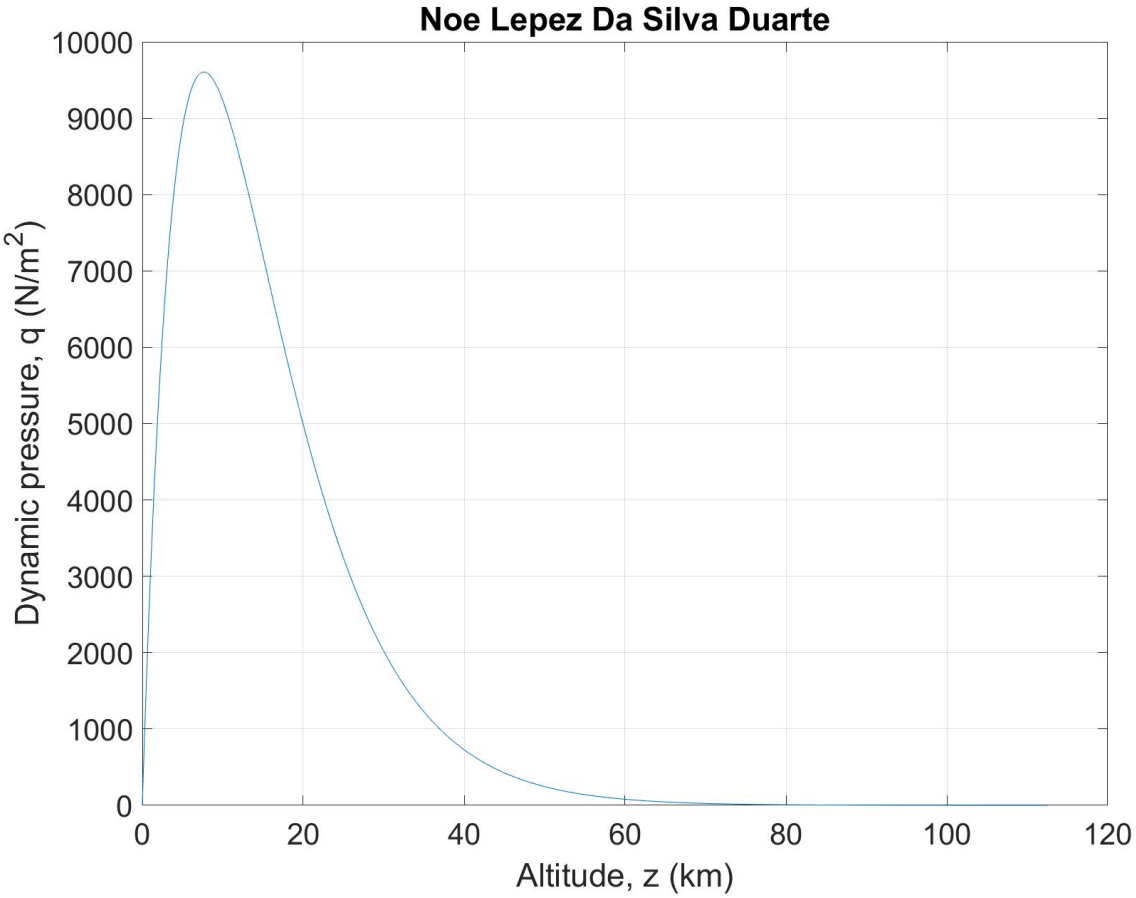

Figure 2. Plot of altitude vs. dynamic pressure for the scenario given in question 3 part c)

d)

Maximum dynamic pressure: 9605 N/m^2

At altitude: 7642m

At time: 78s

e)

Falcon 9:

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$$A = \pi \times \left(\frac{5.2}{2}\right)^2 = 21.24m^2$$

$$\mathrm{F_{qmax}} = 9605 \times 21.24 = \boldsymbol{203977N}$$

Falcon Heavy:

$$A_{booster} = \pi \times \left(\frac{3.7}{2}\right)^2 = 10.75m^2$$

$$\mathrm{F_{qmax}} = 9605 \times 21.24 + 2 \times 9605 \times 10.75 = 203977 + 2 \times 103274 = \boldsymbol{410525N}$$