



Rocket Reusability

The Future of Spaceflight

Presentation by Patrick Perron and
Gabrielle Genereux

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Overview

- A Need for Reusability
- Rockets Today
- Modern Solutions for Reusability
- Implications of Reusability
- Question and Comments

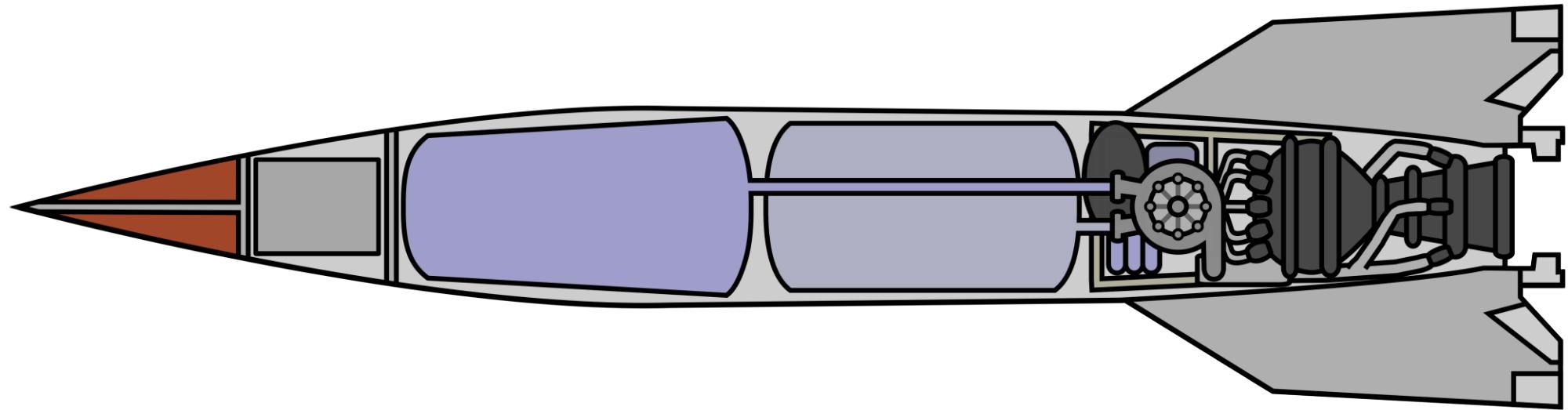


A Need for Reusability

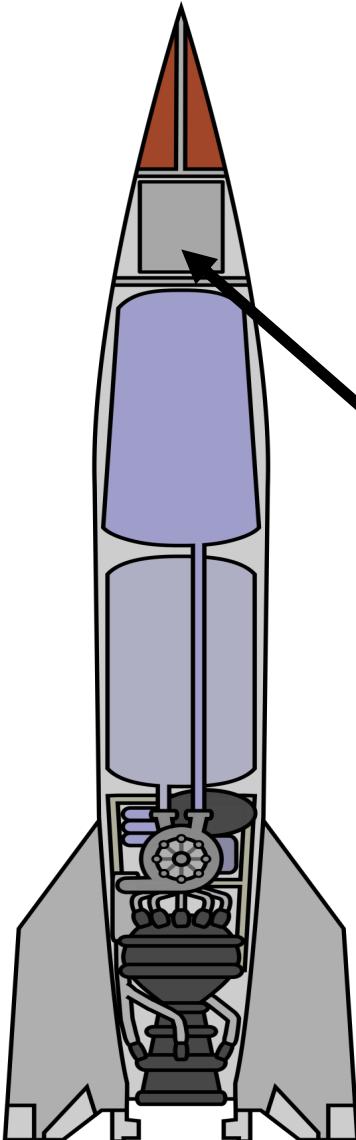
Rockets are currently the only way to space



Rockets are based on simple concepts



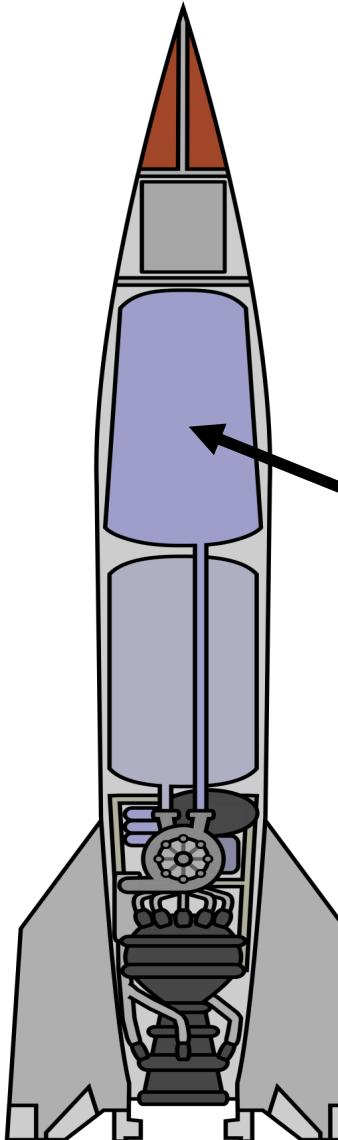
Rockets are based on simple concepts



Payload

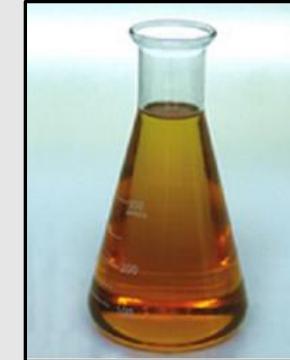


Rockets are based on simple concepts



Fuel

➤ Liquid Fuel



Kerosene



Liquid Hydrogen



Hydrazine

➤ Solid Fuel



Charcoal

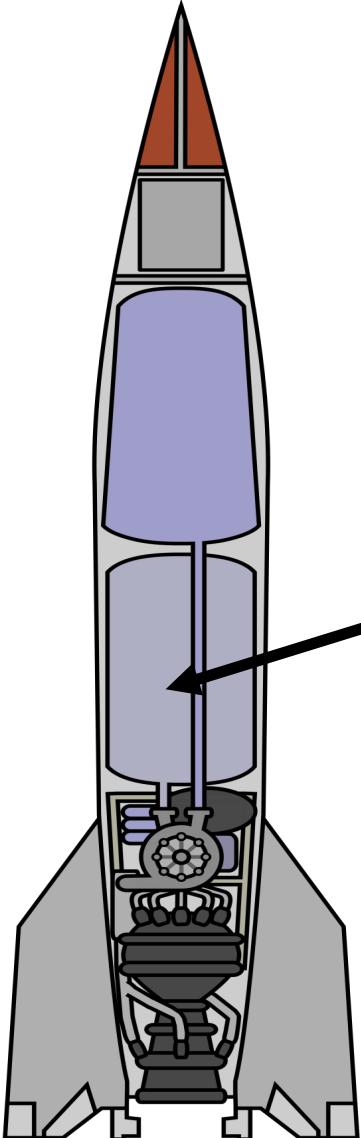


Zinc



Aluminum

Rockets are based on simple concepts



Propellant



Liquid Oxygen

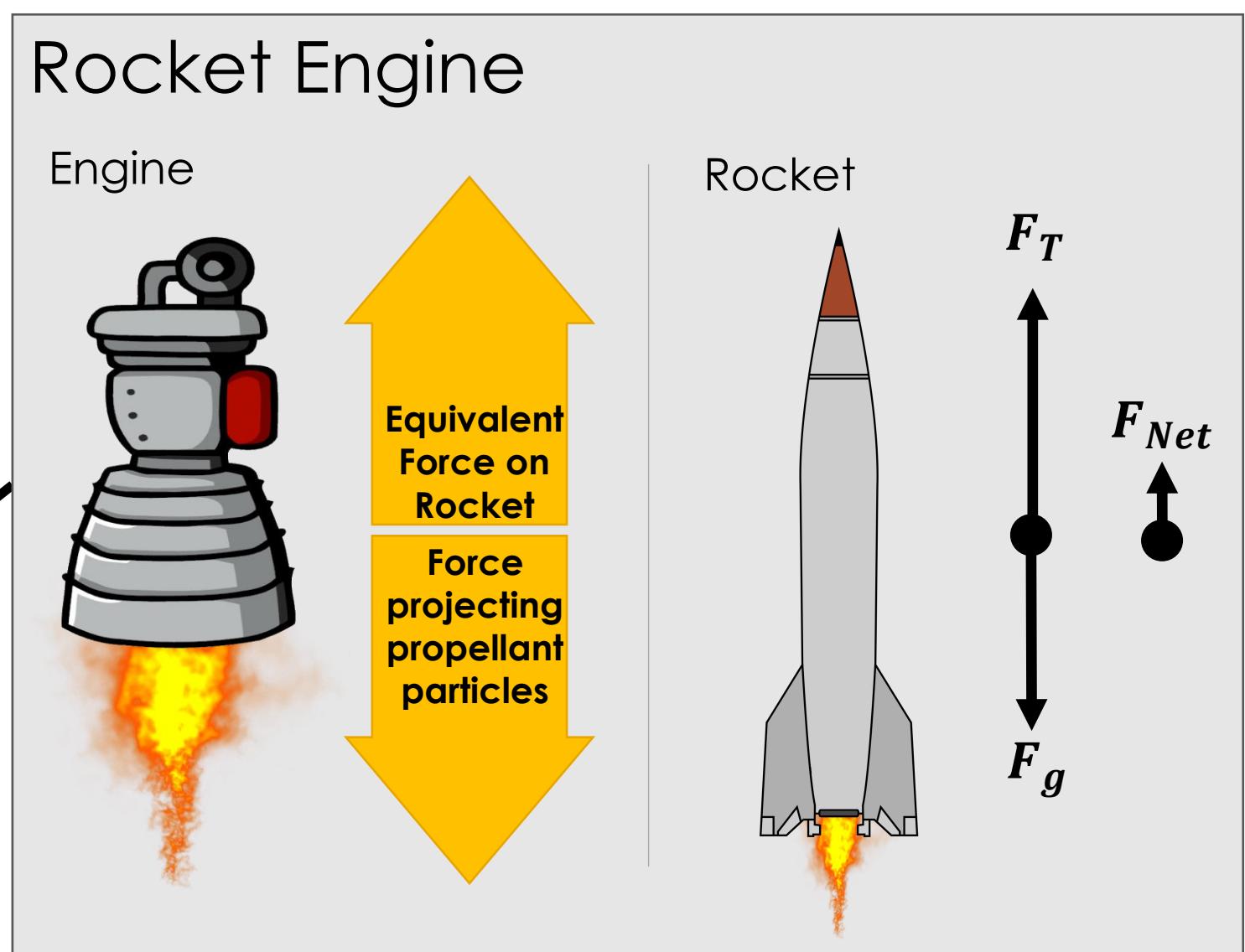
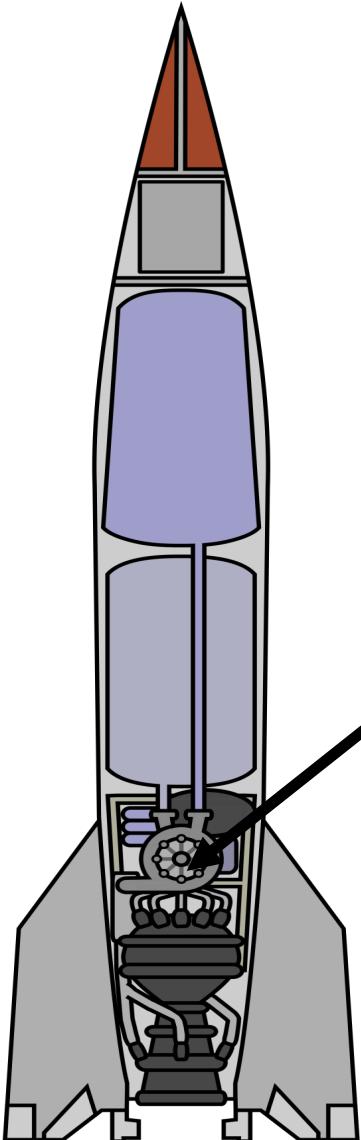


Nitrogen Gas

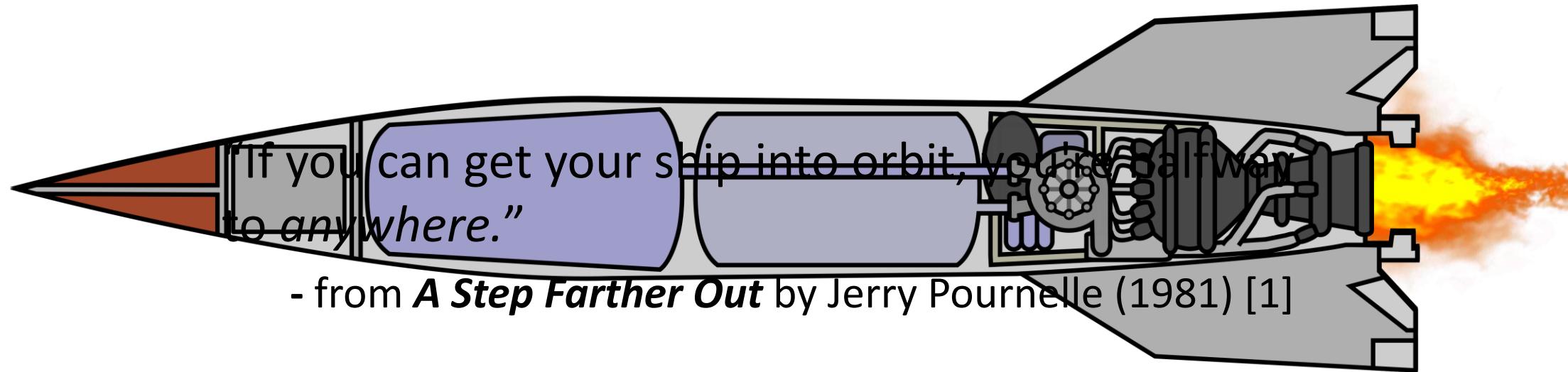


Carbon Dioxide

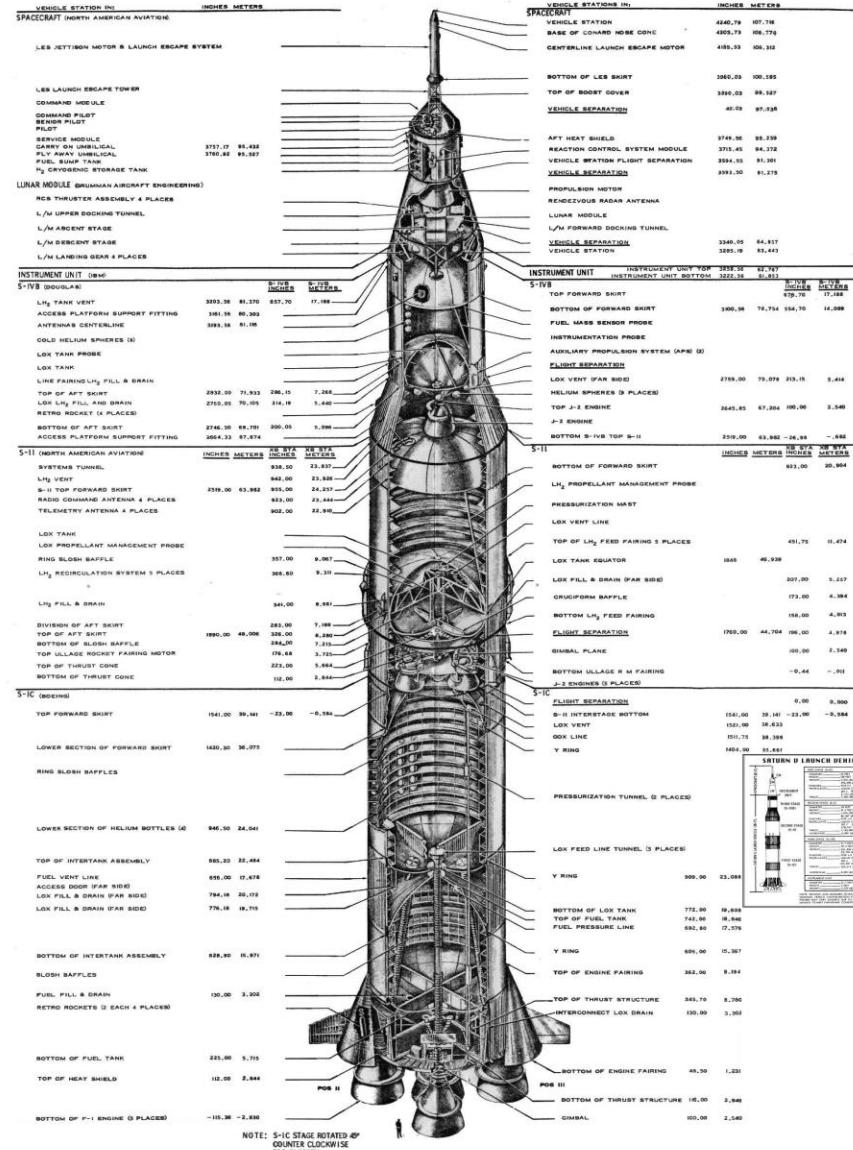
Rockets are based on simple concepts



Rockets are based on simple concepts

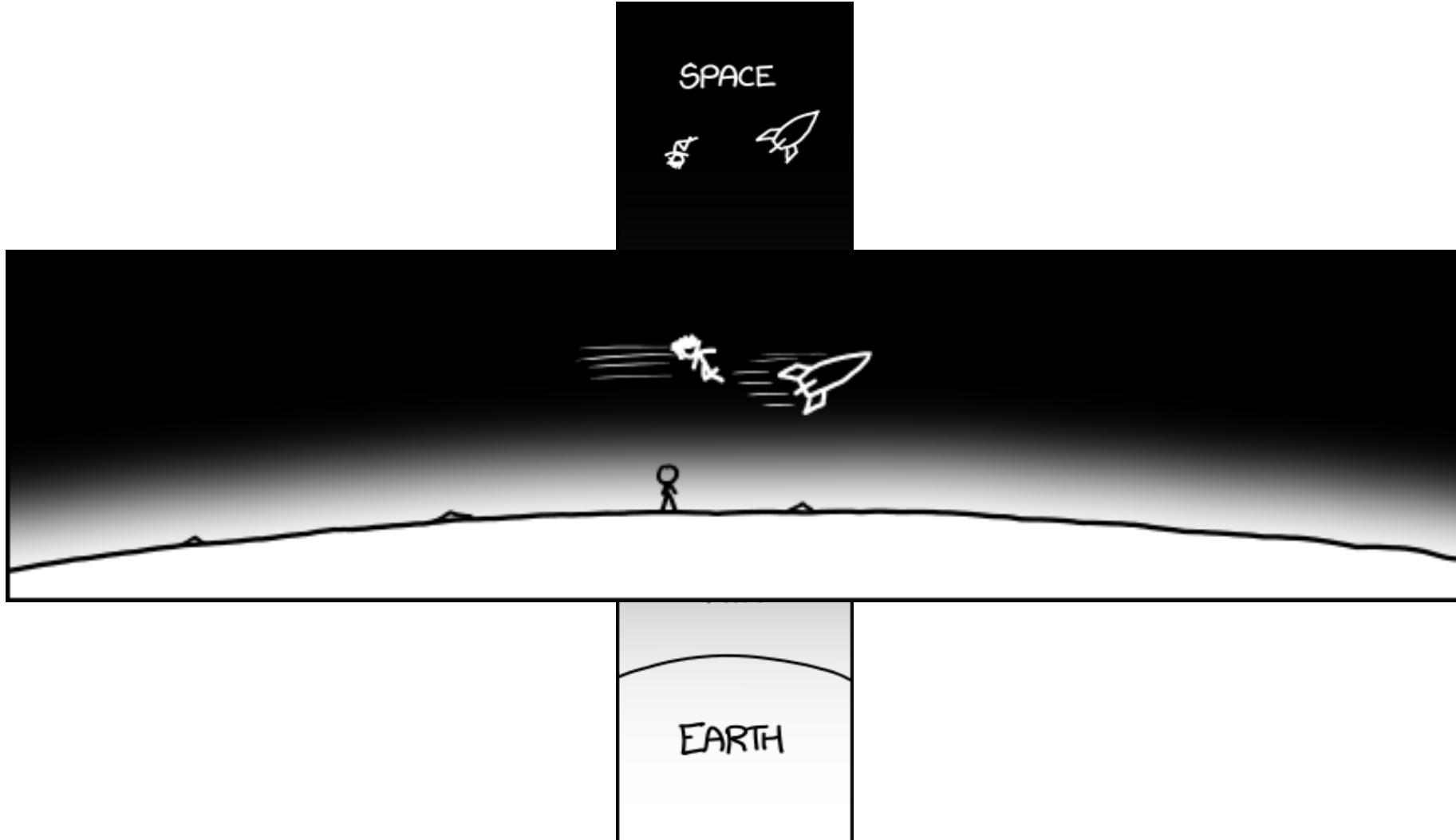


Rockets are actually complicated and expensive

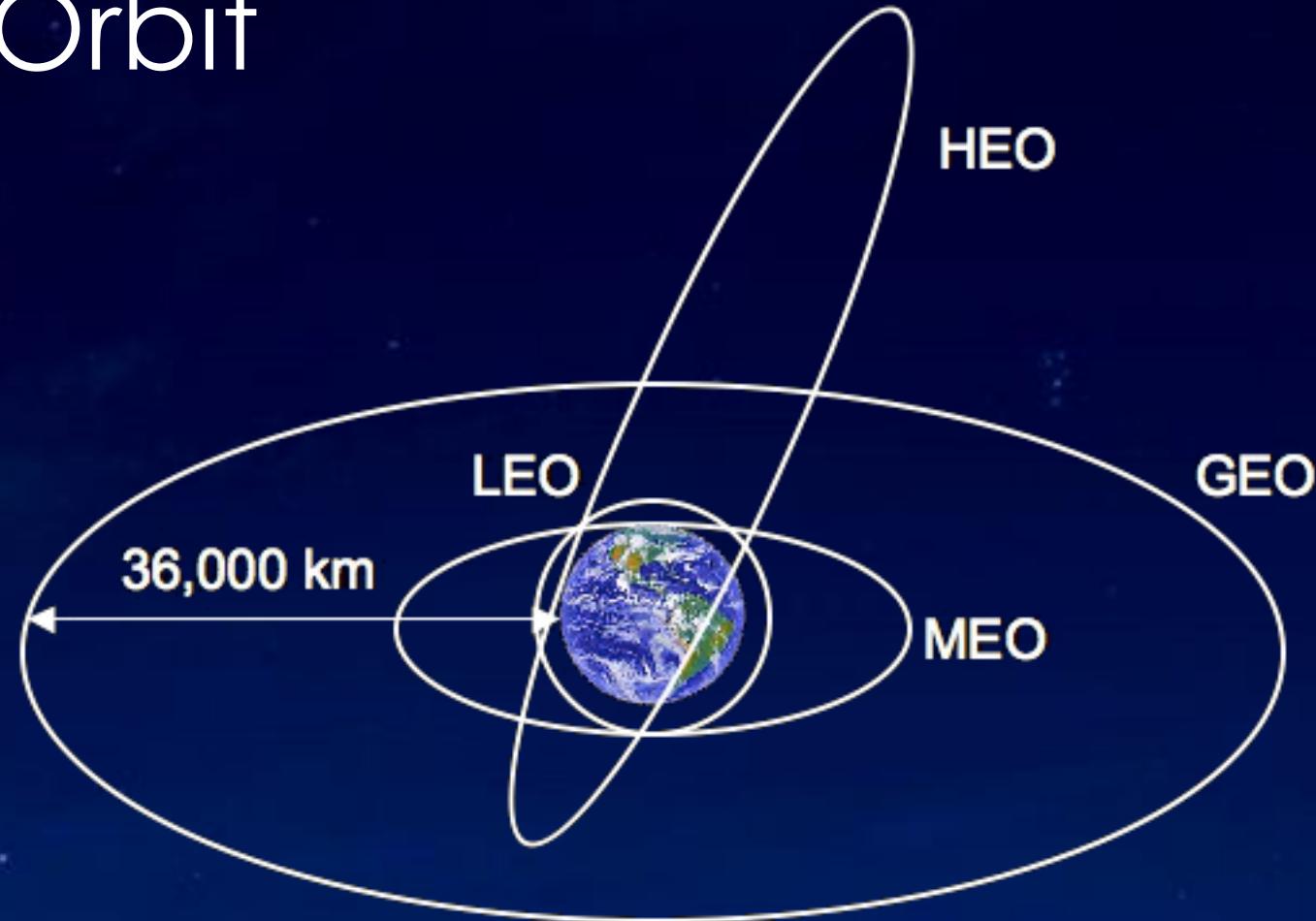


Rocket Reusability – Gabrielle Genereux and Patrick Perron

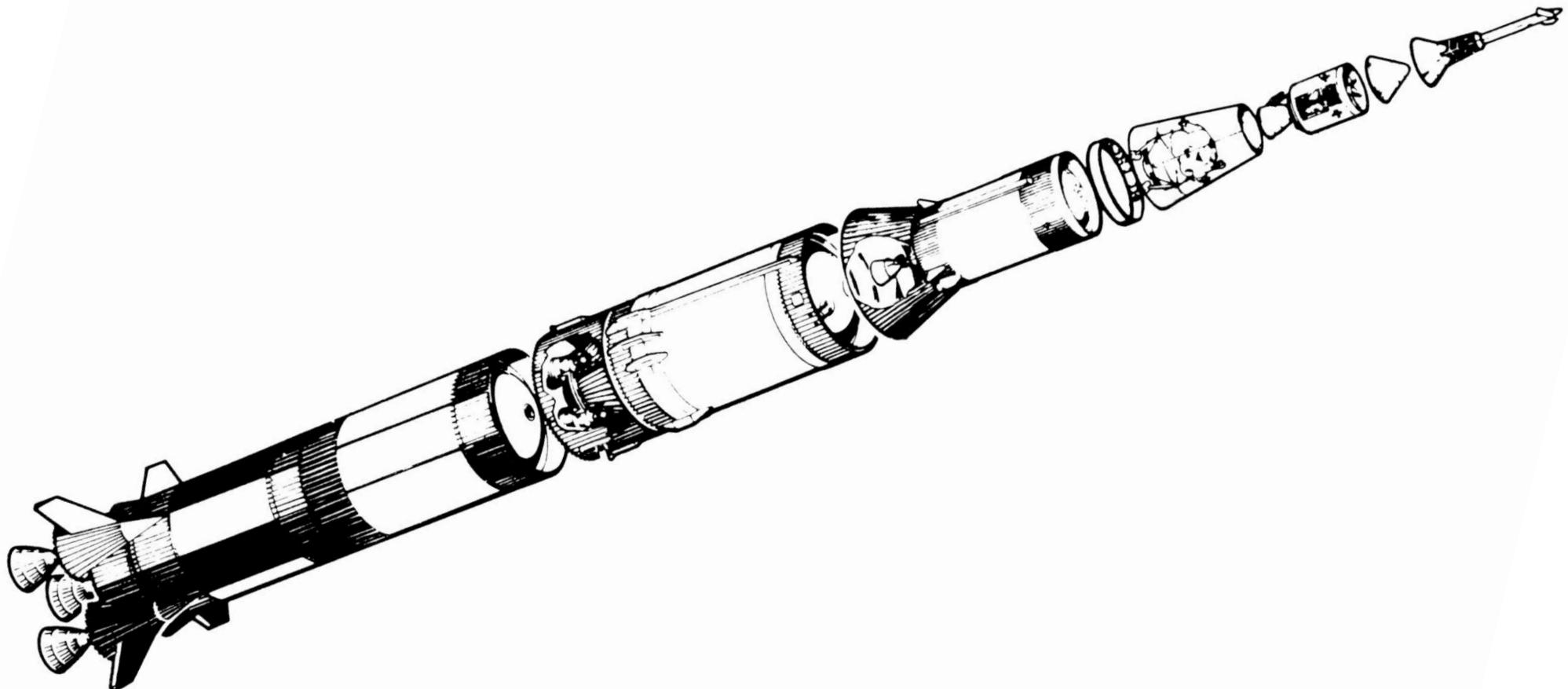
Space is not orbit



Types of Orbit



Different stages are used for different purposes



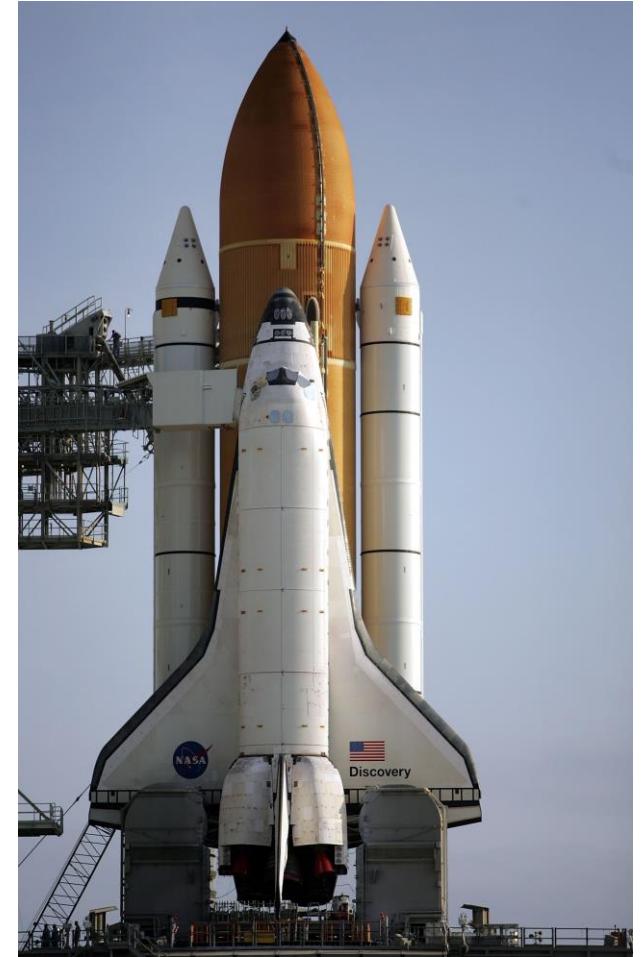
A Case for Reusability

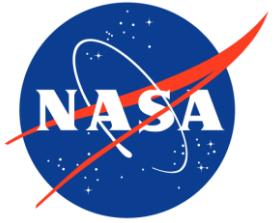
“If one can figure out how to effectively reuse rockets just like airplanes, the cost of access to space will be reduced by as much as a factor of a hundred.”

– Elon Musk, SpaceX CEO [2]

Reusable rockets are not a new concept

➤ *NASA Space Shuttle (1981 - 2011)*





Space Shuttle

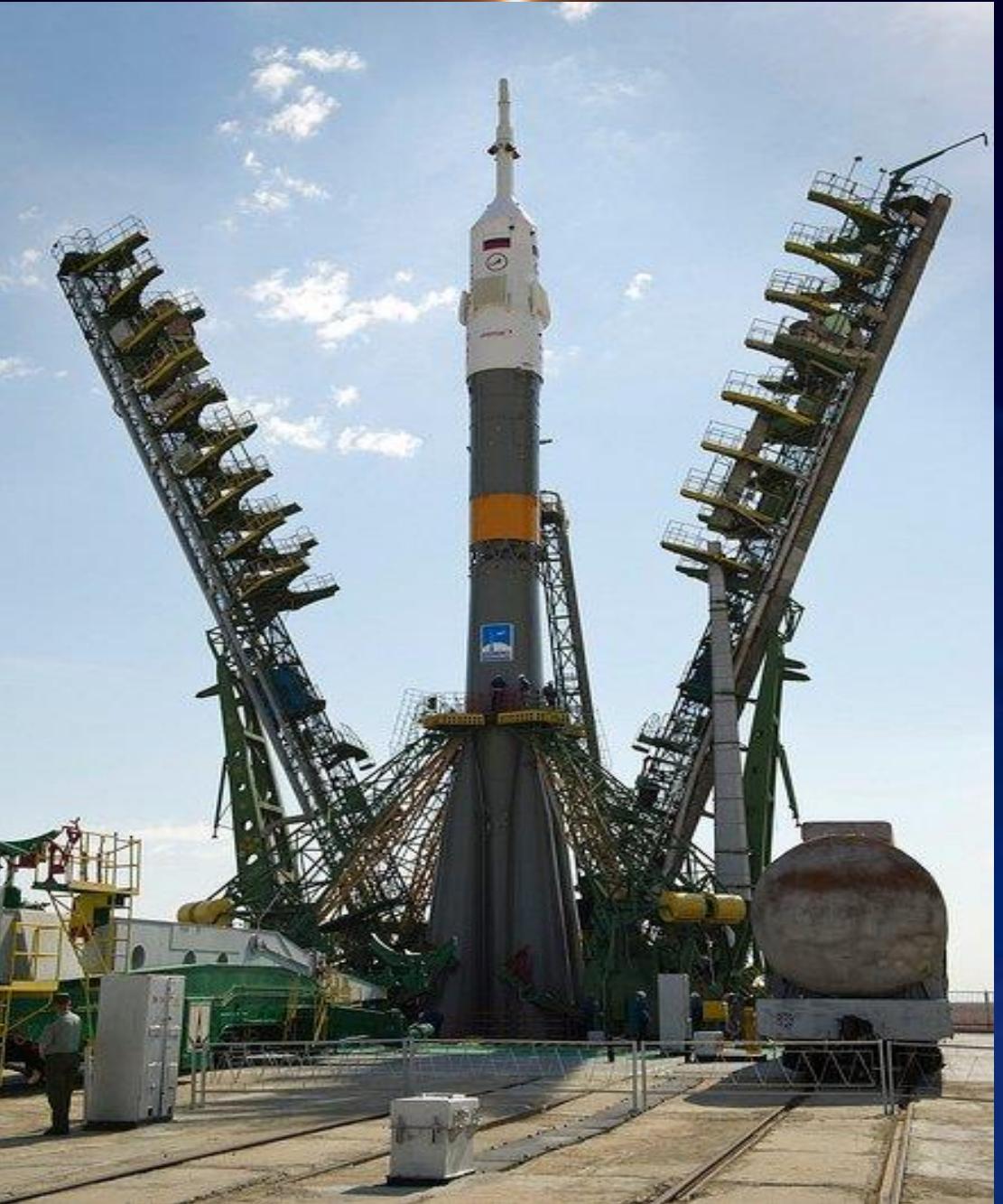


Manufacturer	<i>Boeing, Lockheed-Martin, Rockwell International, Aiant Techsystems, etc.</i>
Height	56 m
Launch Cost	450 million
Payload to LEO	27,500 kg
Payload to GTO	3,810 kg
Total Launches	135
Successful Launches	133 (99%)

[3]



Rockets Today



Soyuz-FG



Manufacturer *TsSKB-Progress*

Height 50 m

Launch Cost 70 million

Payload to LEO 7,100 kg

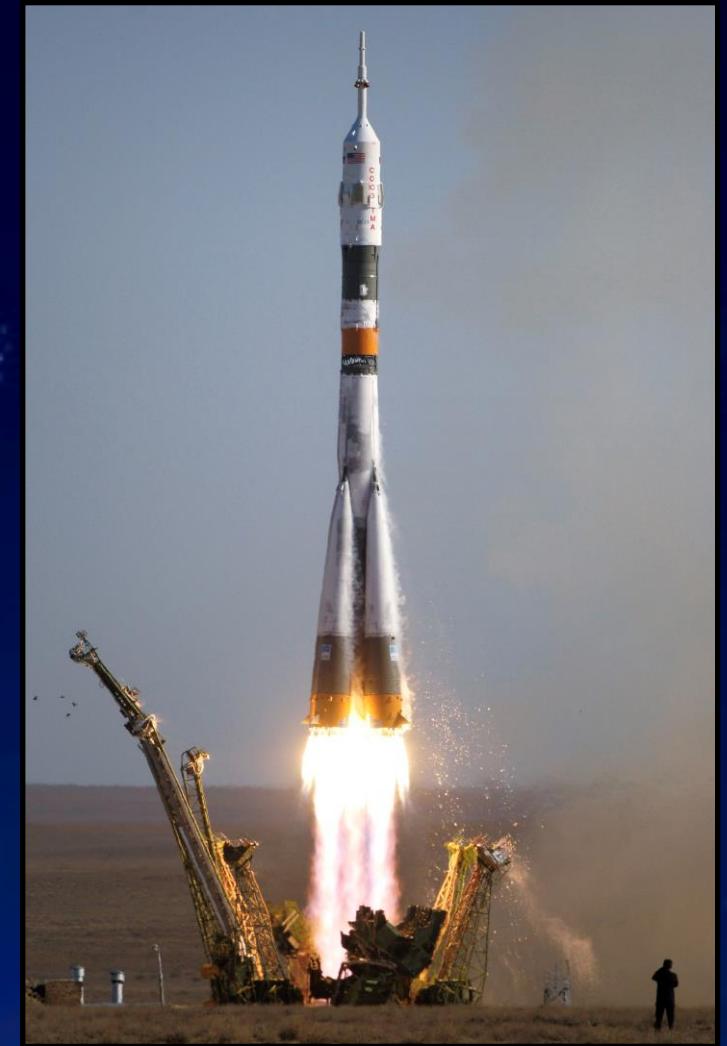
Payload to GTO N/A

Total Launches 49

Successful Launches 49 (100%)

[4]

Soyuz-FG



Ariane 5

Manufacturer *Arianespace*

Height 51 m

Launch Cost 175 million

Payload to LEO 16,000 kg

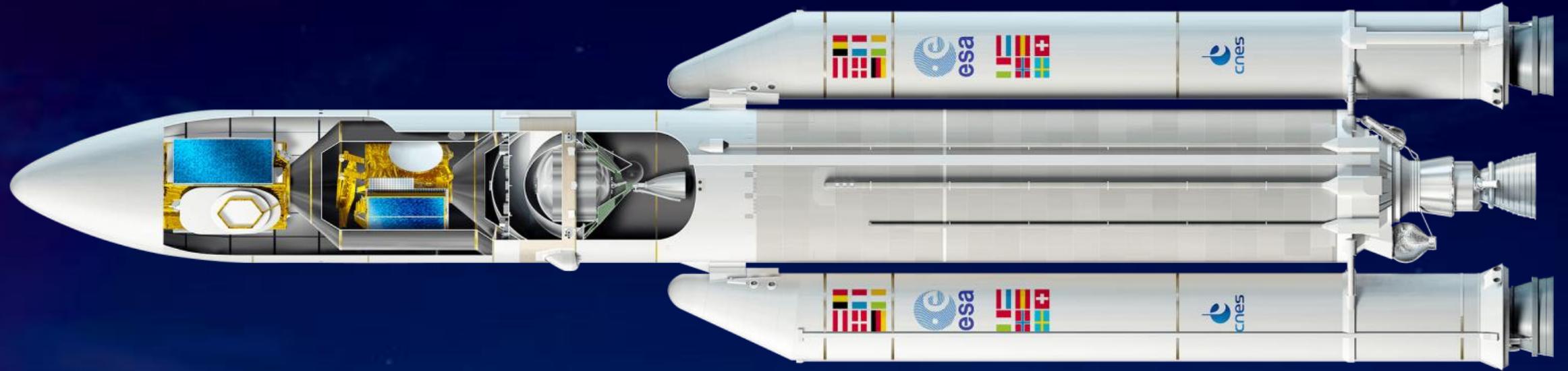
Payload to GTO 6,950 kg

Total Launches 84

Successful Launches 80 (95%)

[5]

Ariane 5

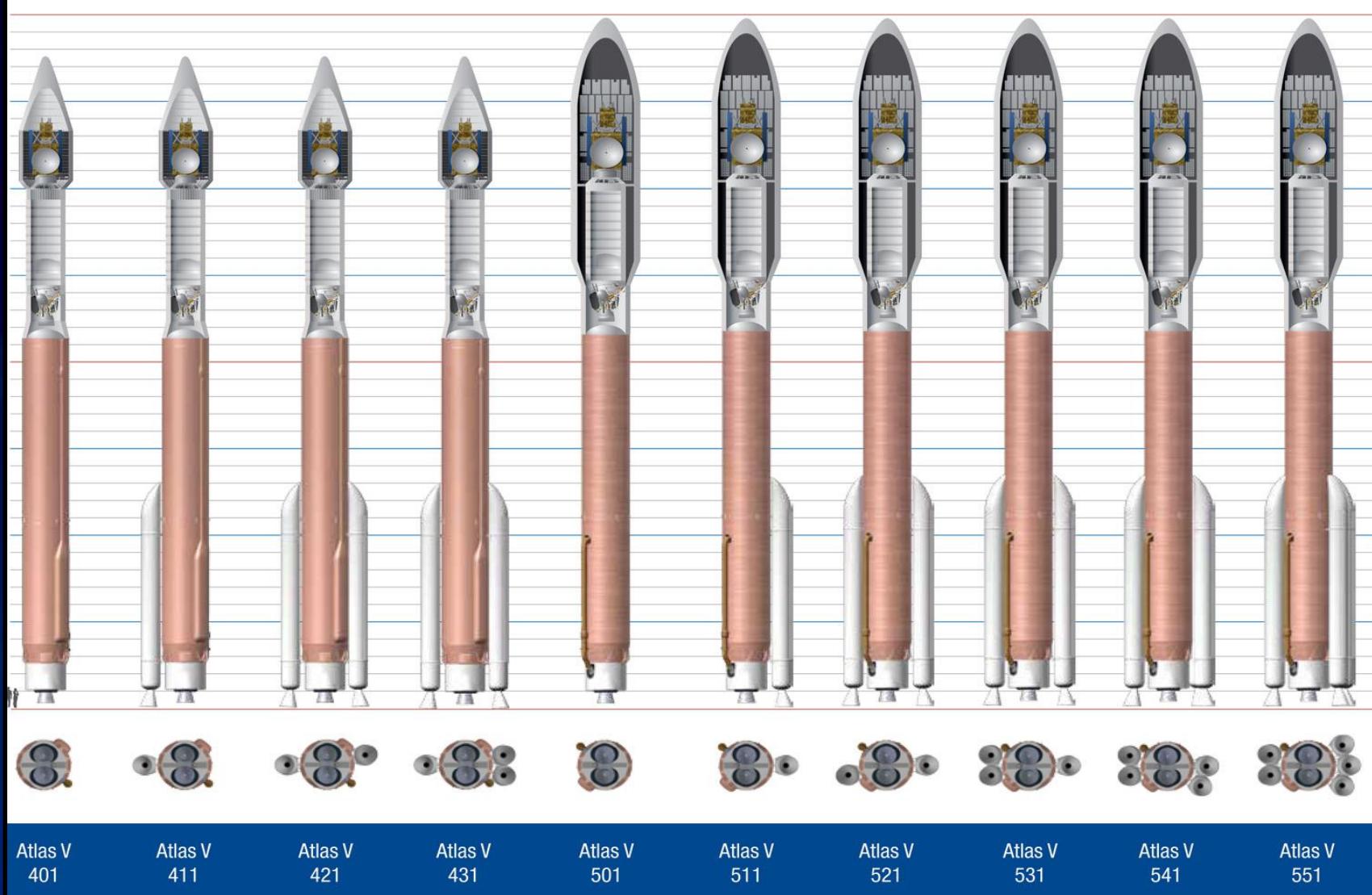


Atlas V

Manufacturer	<i>United Launch Alliance</i>
Height	58 m
Launch Cost	164 million
Payload to LEO	9,800 – 18,800 kg
Payload to GTO	4,750 – 8,900 kg
Total Launches	60
Successful Launches	59 (98%)

[6]

Atlas V Variants



[6]



Delta IV Heavy



Manufacturer *United Launch Alliance*

Height 71 m

Launch Cost 435 million

Payload to LEO 28,790 kg

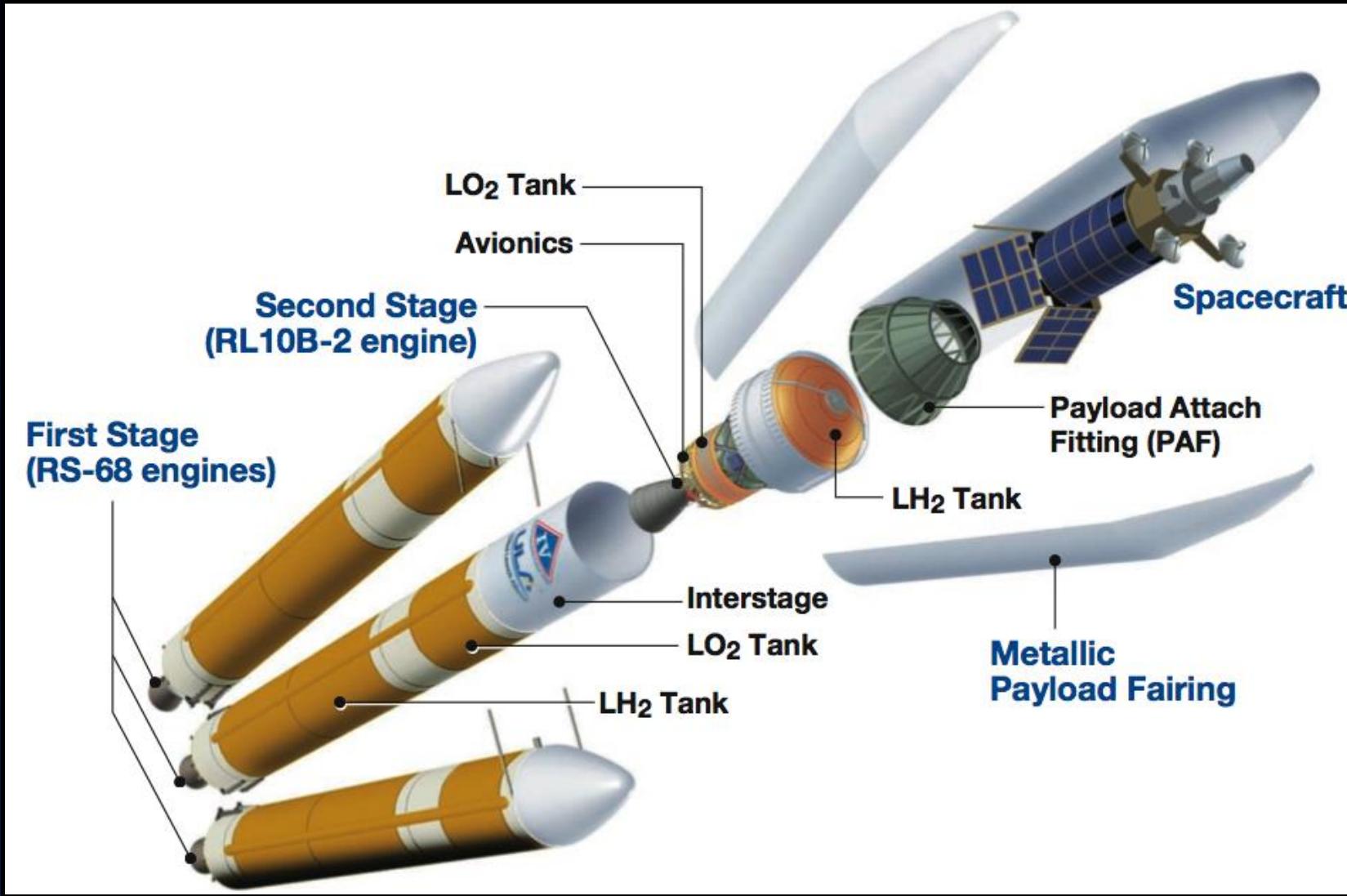
Payload to GTO 14,220 kg

Total Launches 8

Successful Launches 7 (88%)

[6]

Delta IV Heavy



[6]



Falcon 9



Manufacturer *SpaceX*

Height 68 m

Launch Cost 61.2 million

Payload to LEO 13,150 kg

Payload to GTO 4,850 kg

Total Launches 21

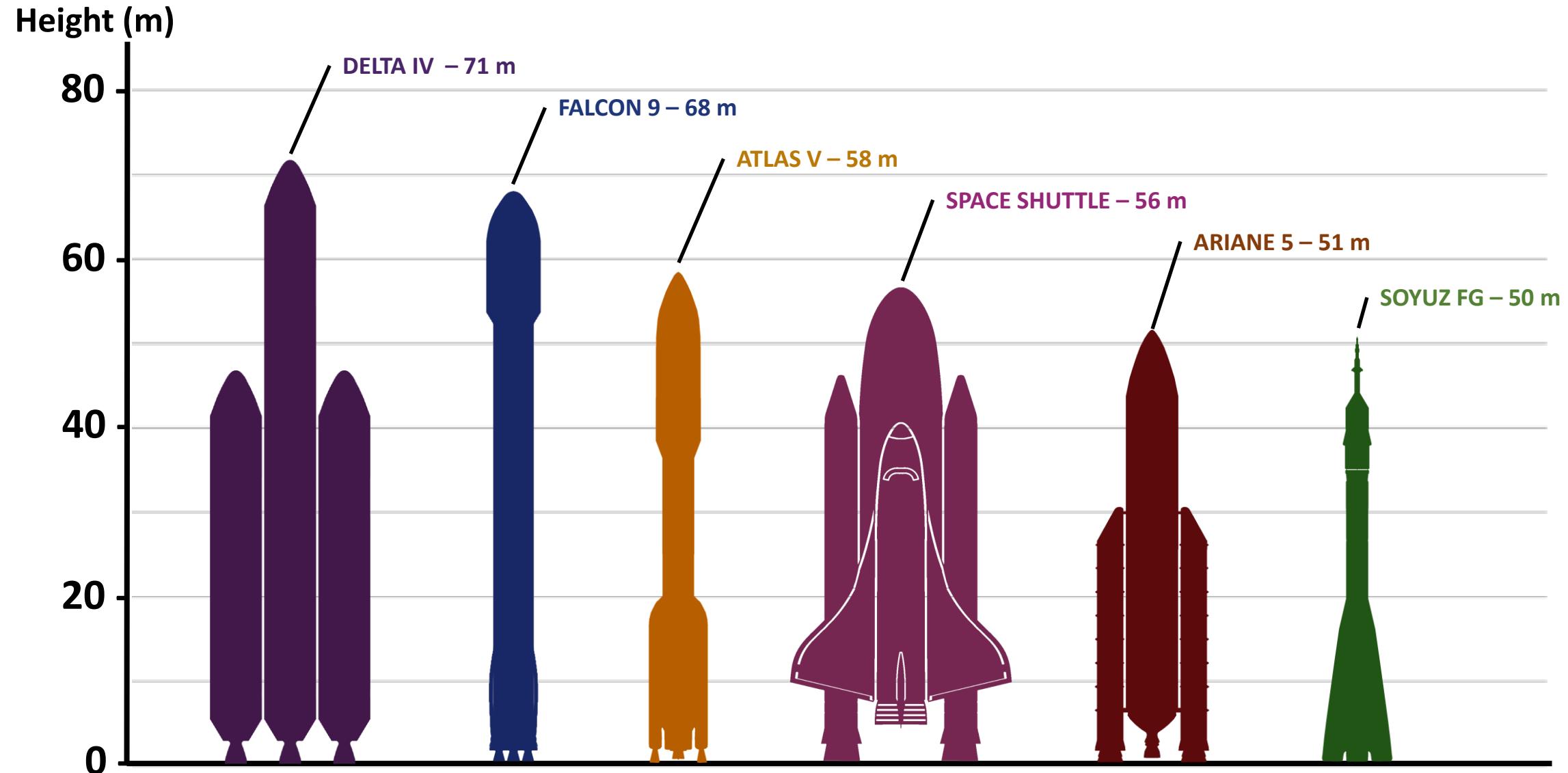
Successful Launches 19 (90%)

[7]

Falcon 9

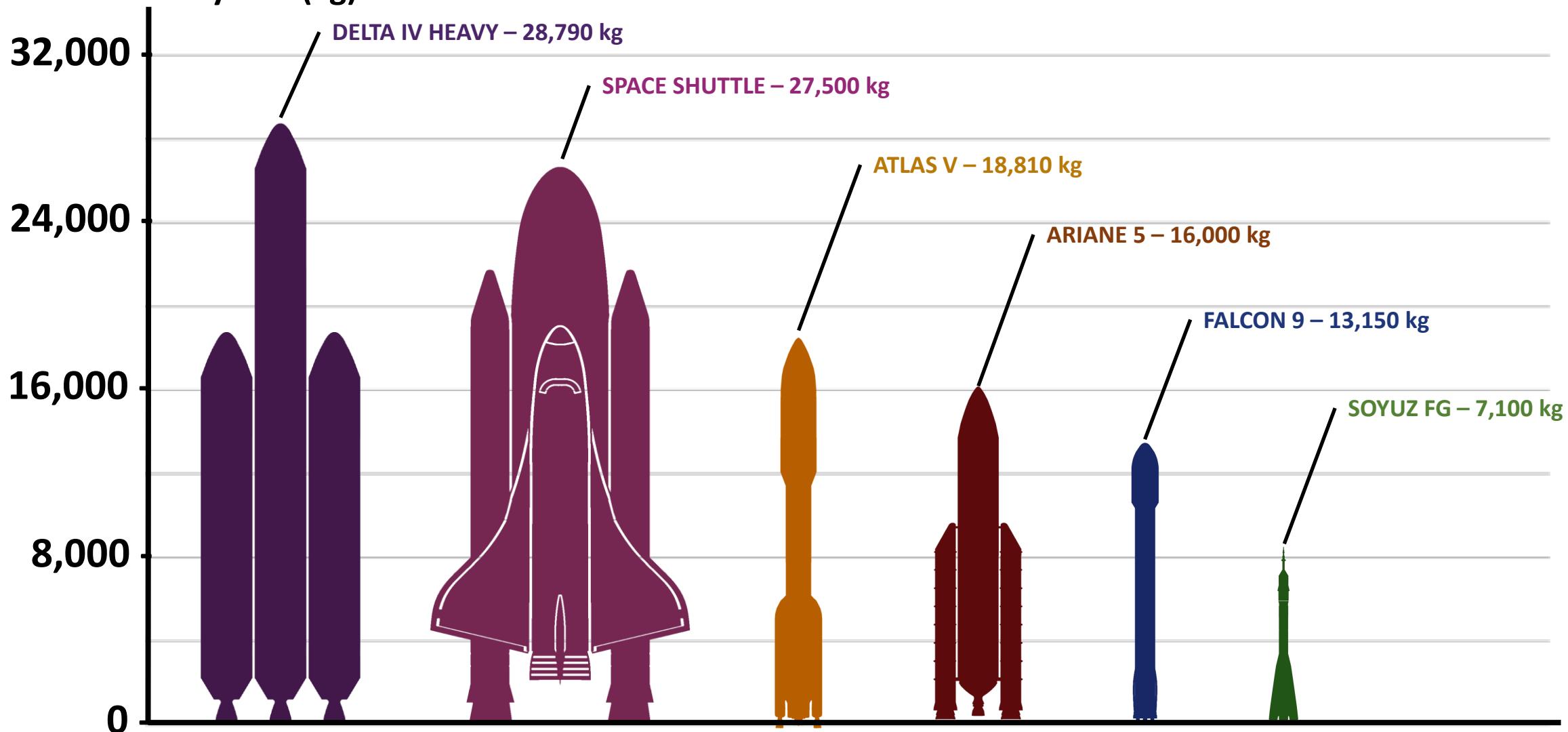


Compared by Size:

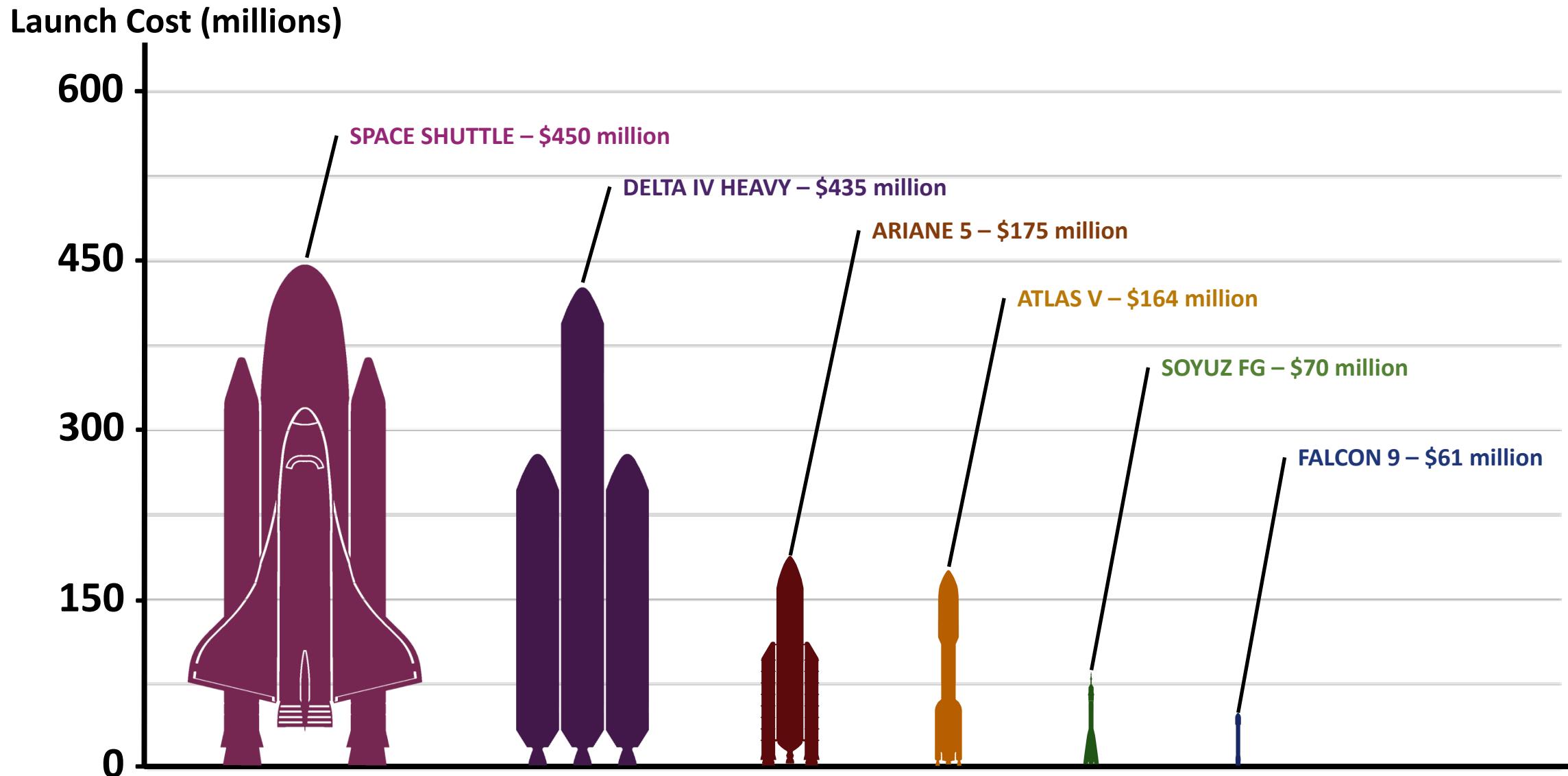


Compared by Payload to LEO:

Maximum Payload (kg)

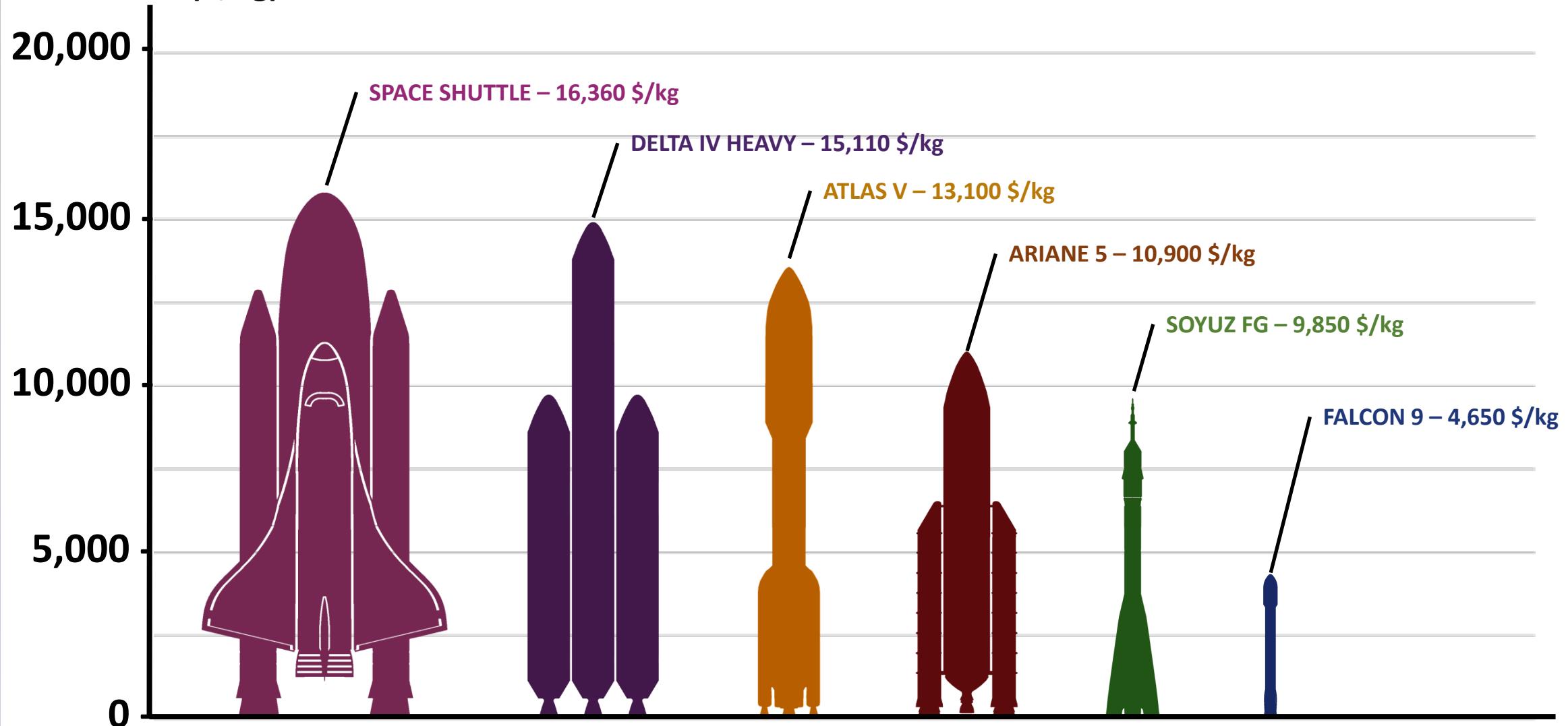


Compared by Launch Cost:



Compared by Cost per Kilogram to LEO:

Cost to LEO (\$/kg)





Modern Solutions for Reusability

Companies are developing their own reusable rocket systems



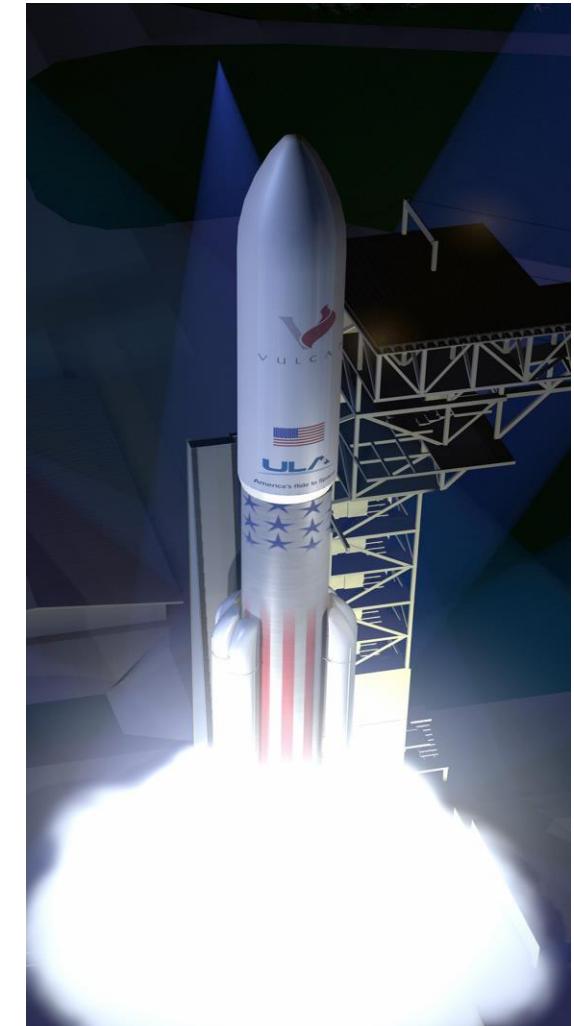
– Vulcan Rocket



– Adeline



Vulcan Rocket



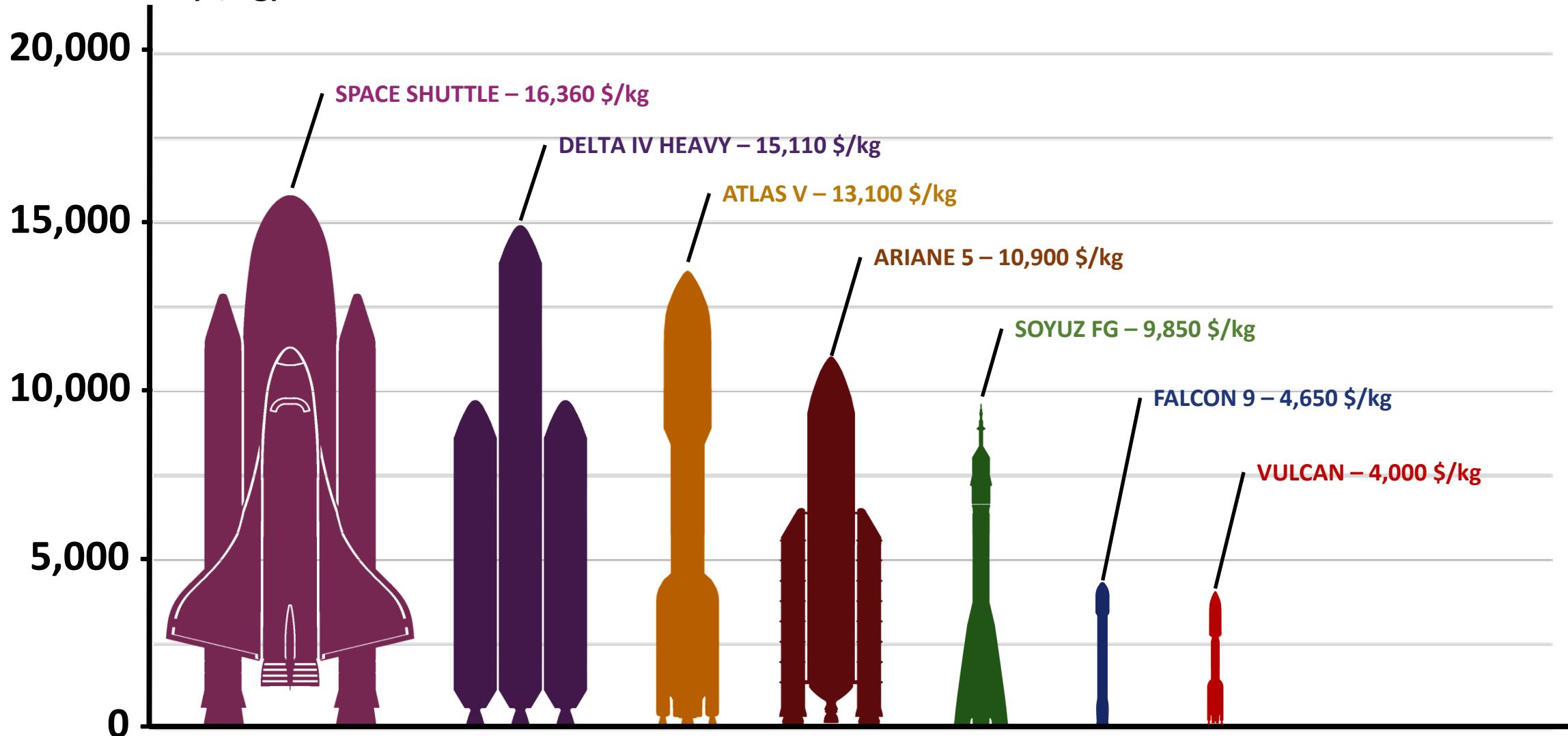
Vulcan Rocket



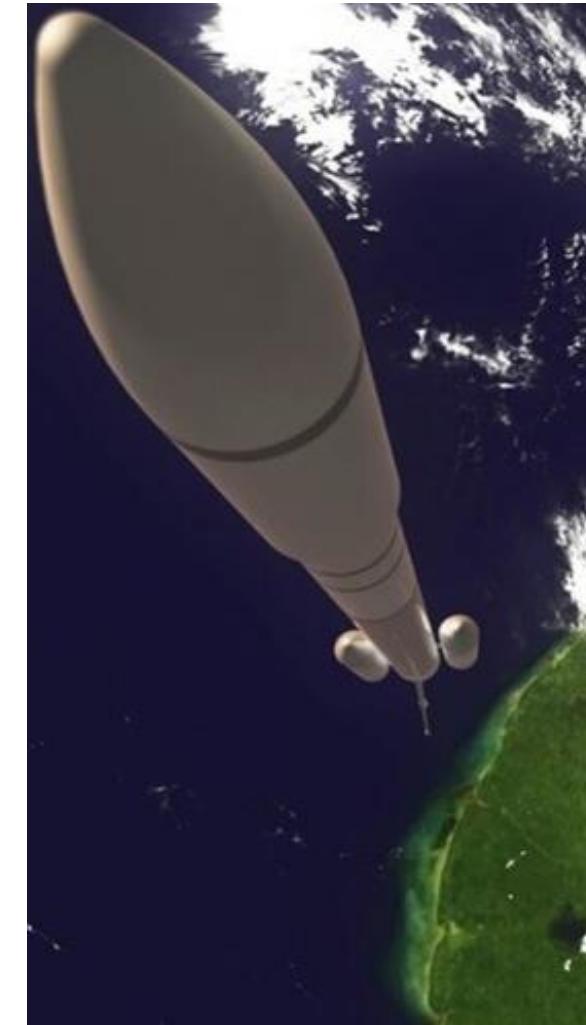
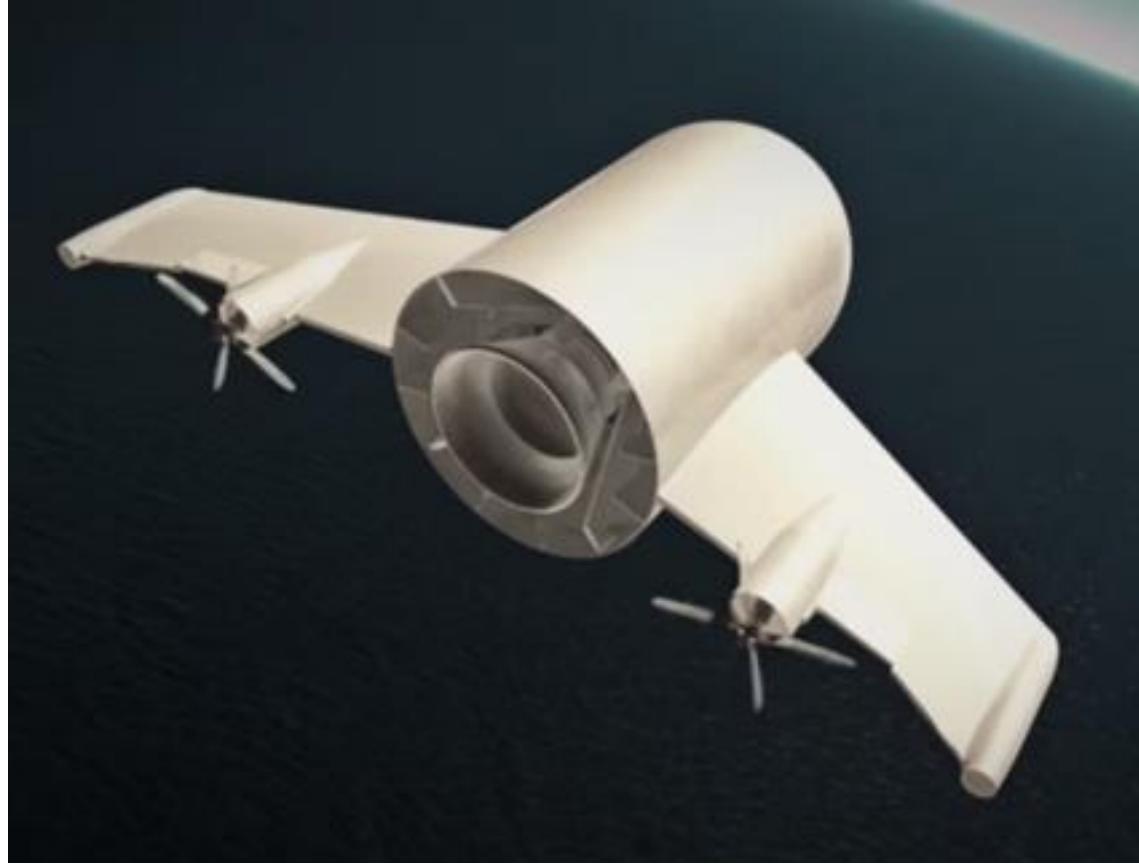
[6]

How Vulcan fares against other rockets

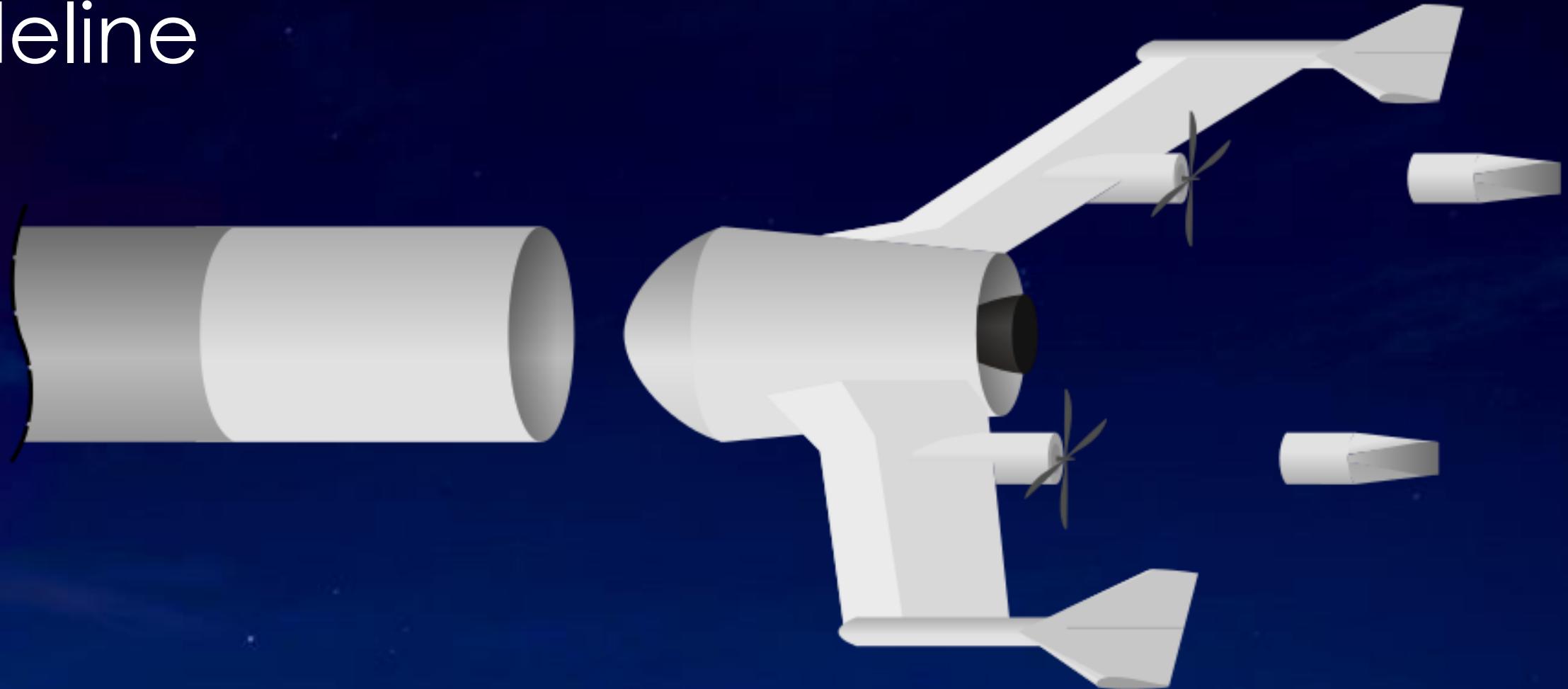
Cost to LEO (\$/kg)



Adeline



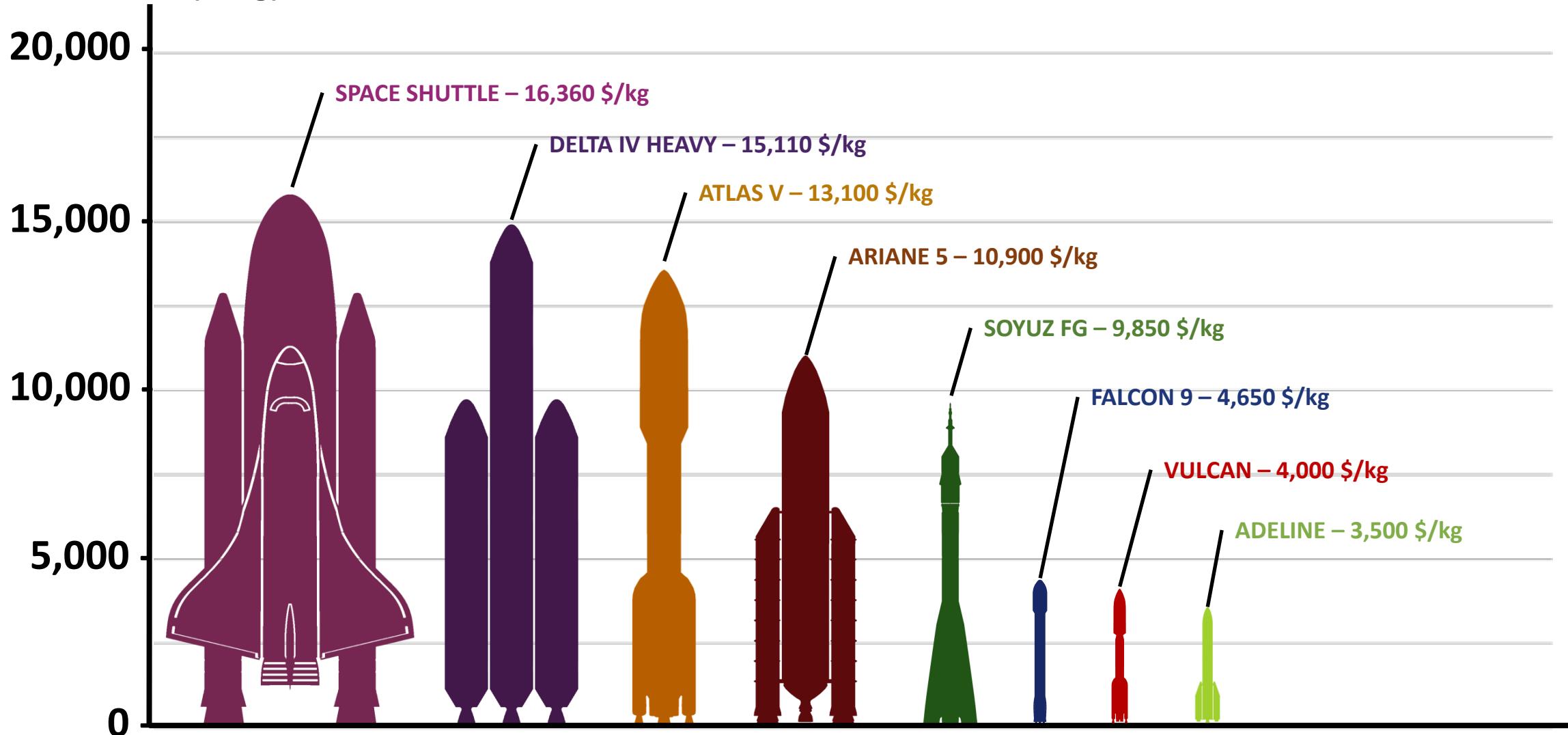
Adeline



[8]

How Adeline fares against other rockets

Cost to LEO (\$/kg)



Falcon 9-R

SPACEX



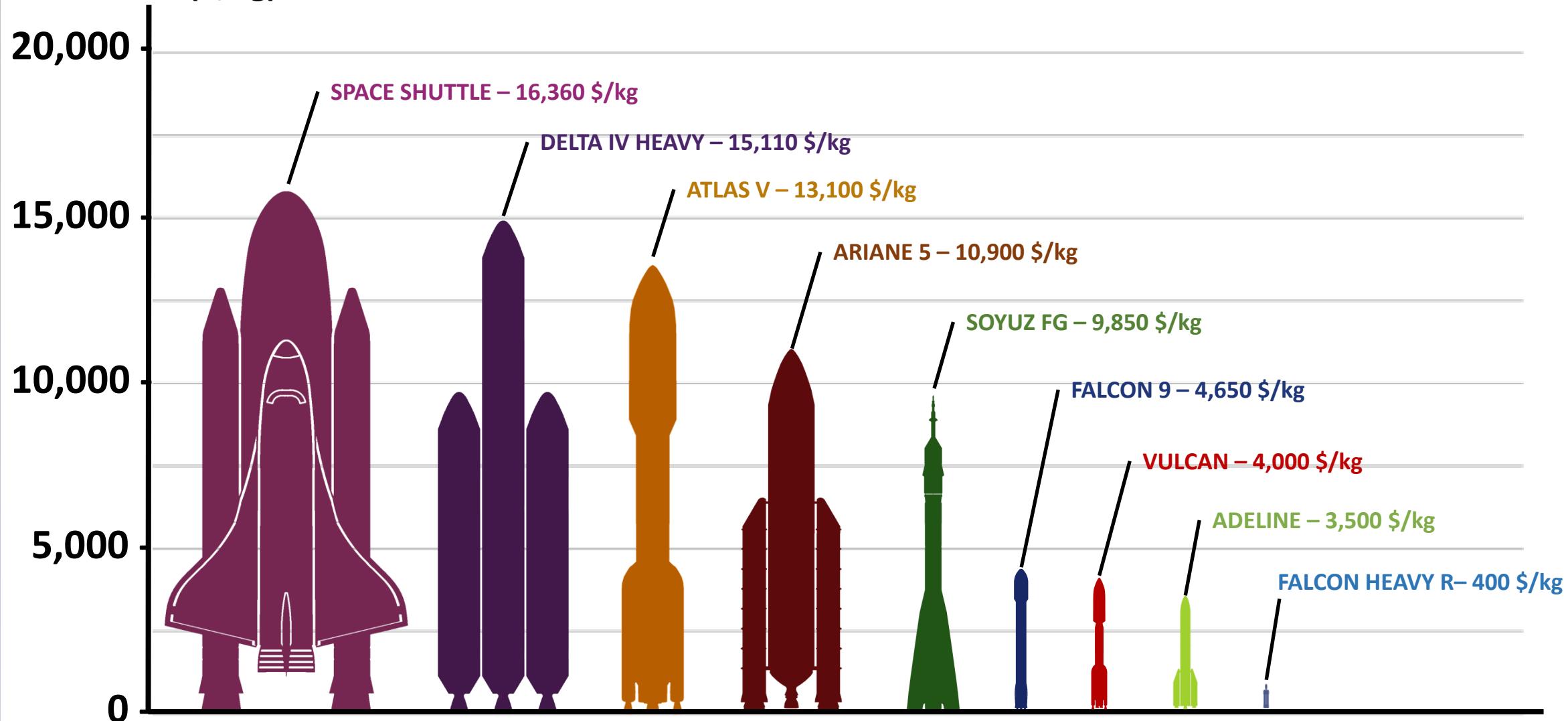
A Final Evolution for the Falcon 9

➤ *Falcon Heavy*



How the Reusable Falcon Heavy fares against other rockets

Cost to LEO (\$/kg)



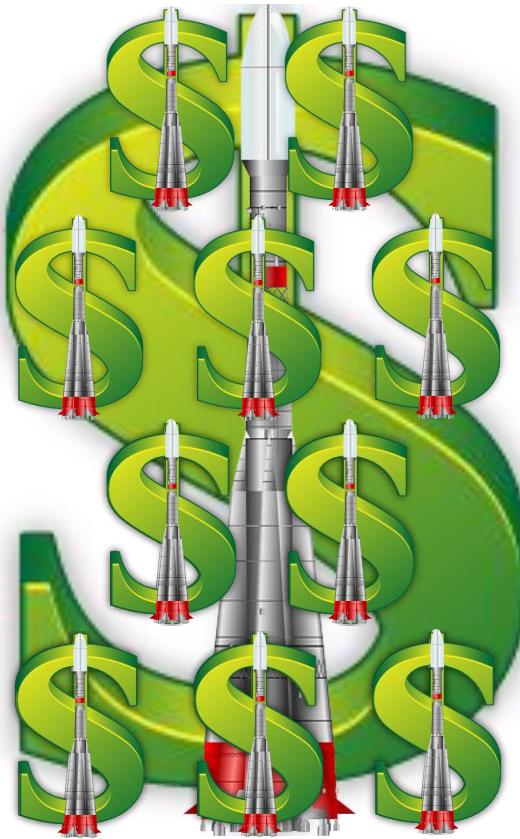
Before and after a trip to space





Implications of Reusability

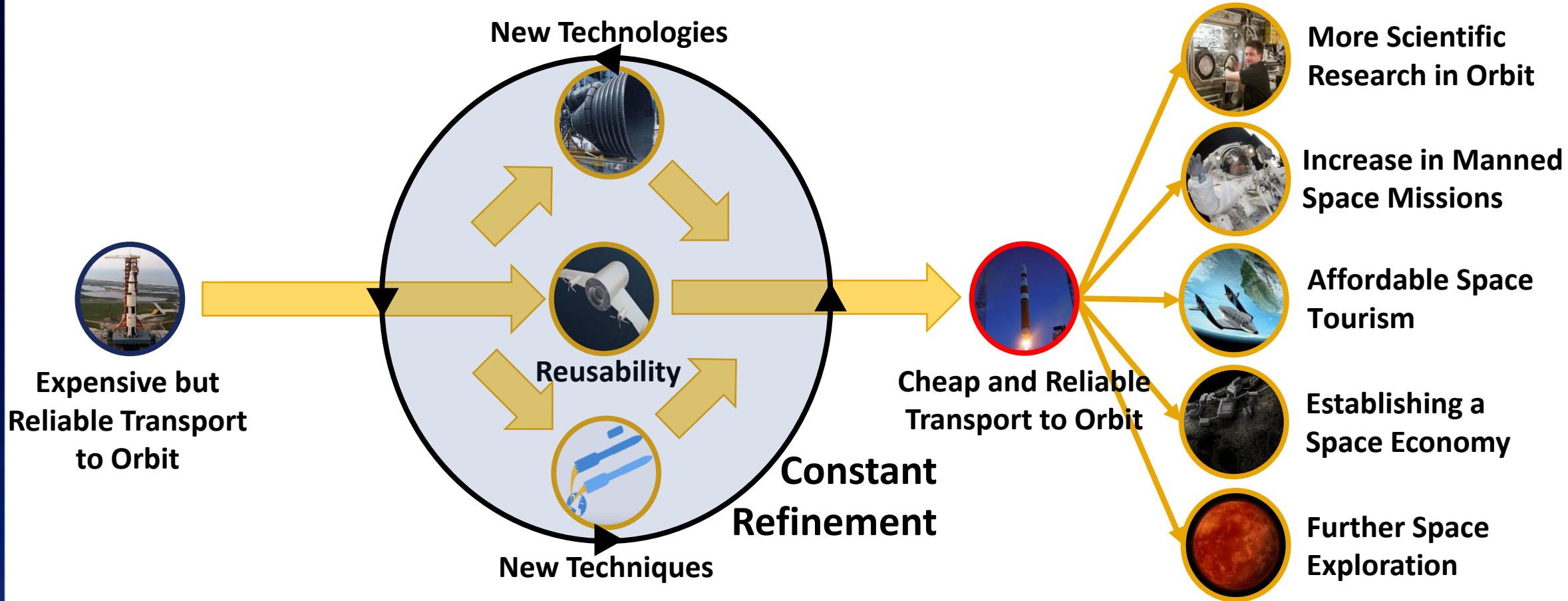
Reusability is the first step to making space affordable



"If one can figure out how to effectively reuse rockets just like airplanes, the cost of access to space will be reduced by as much as a factor of a hundred."

– Elon Musk, SpaceX CEO [2]

The future implications of reusability are remarkable



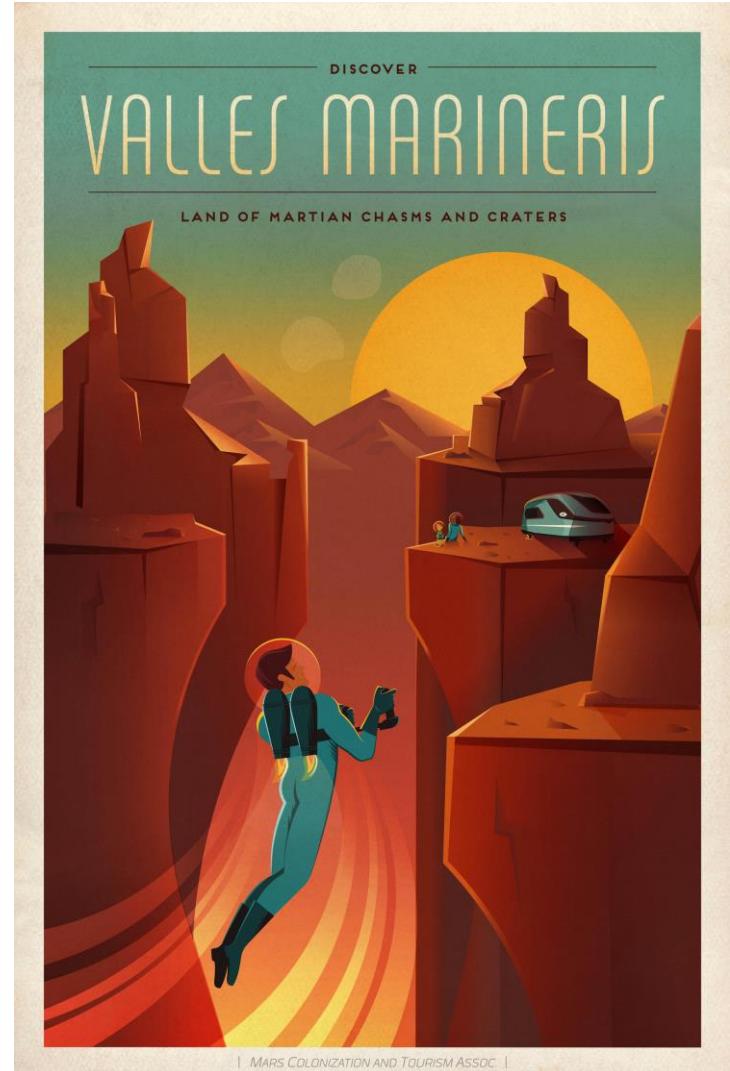
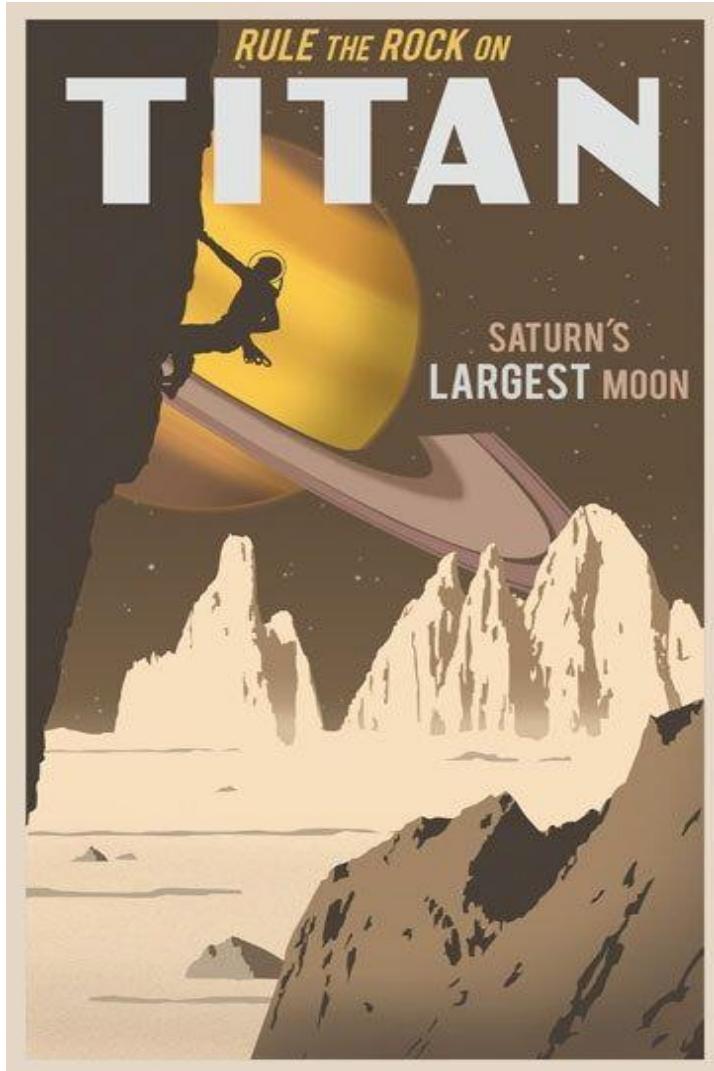
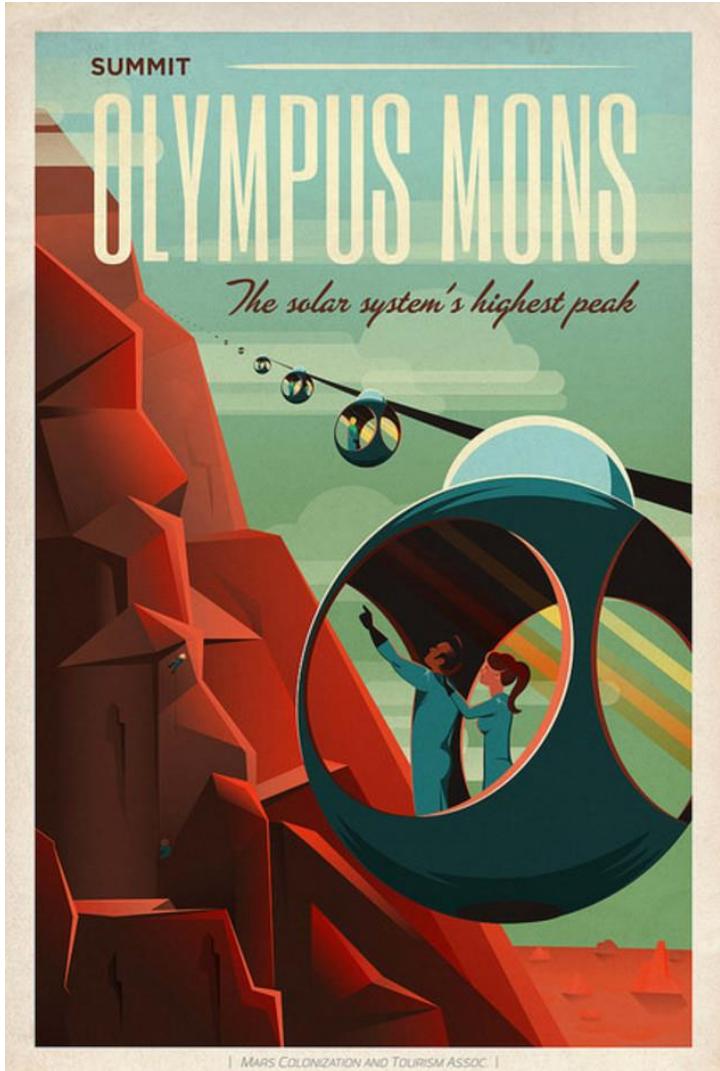
More Scientific Research in Orbit



Increase in Manned Space Missions



Affordable Space Tourism



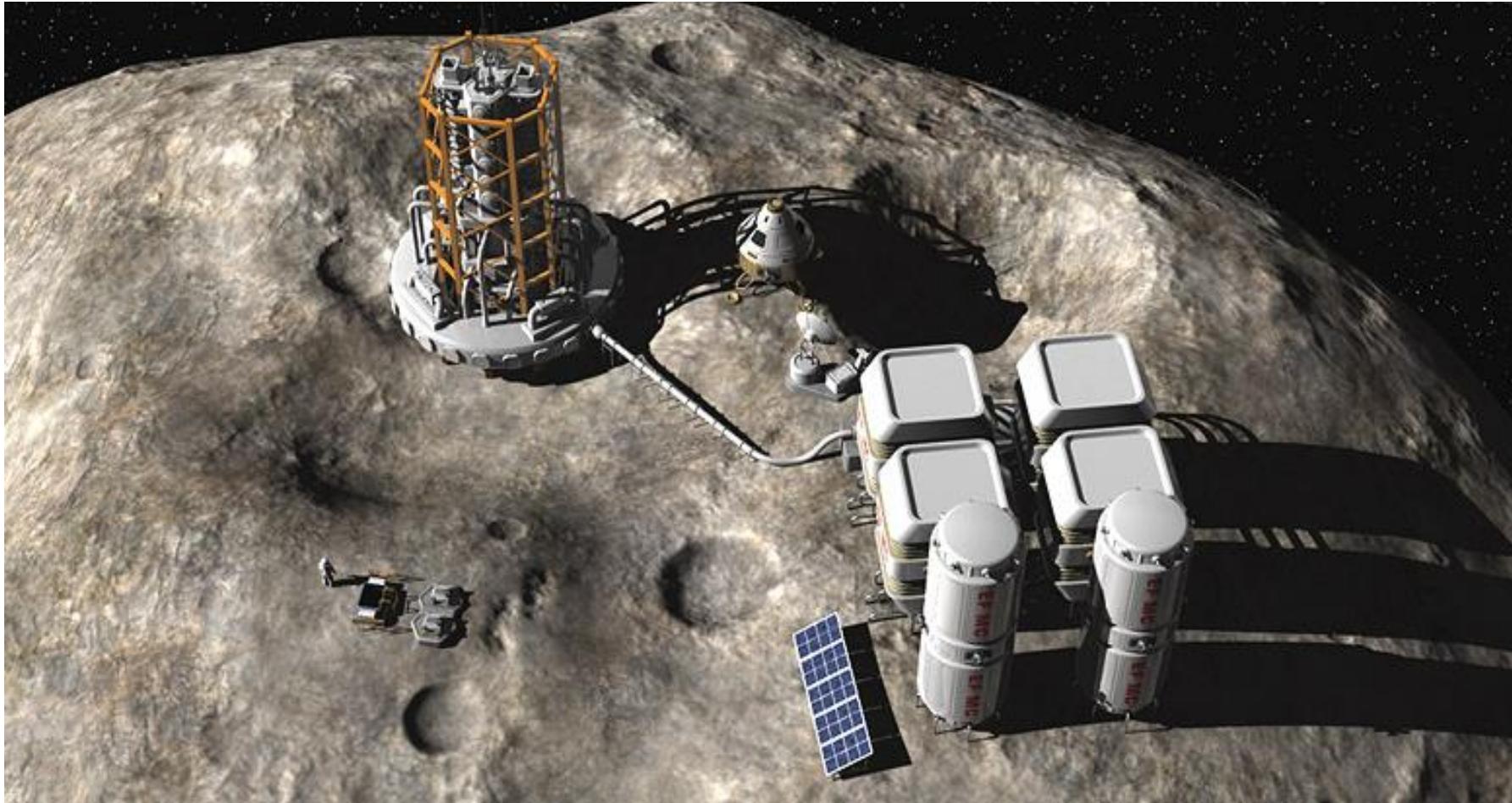
New Shepard

BLUE ORIGIN

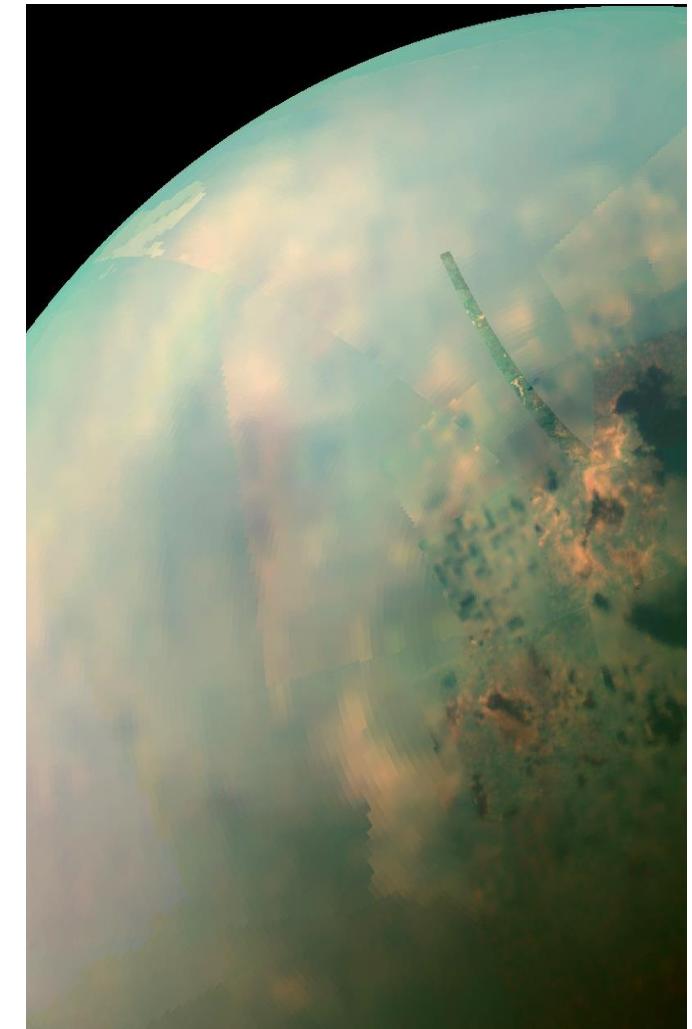


Establishing a Space Economy

➤ Mining minerals on Asteroids



Further Space Exploration





“If you can get your ship into orbit,
you're halfway to *anywhere*.”

-from ***A Step Farther Out*** by Jerry
Pournelle (1981) [1]



Questions and Comments

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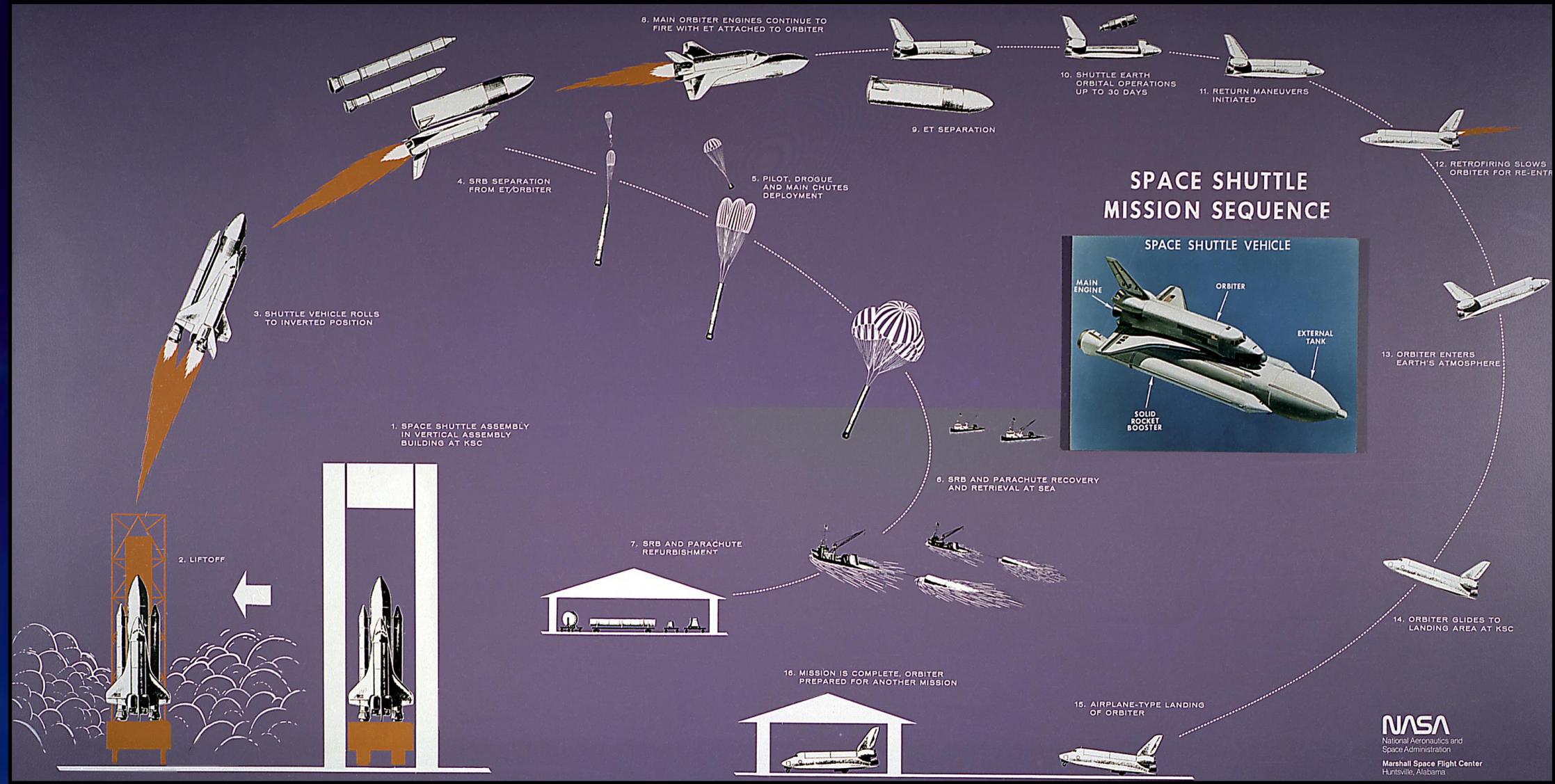
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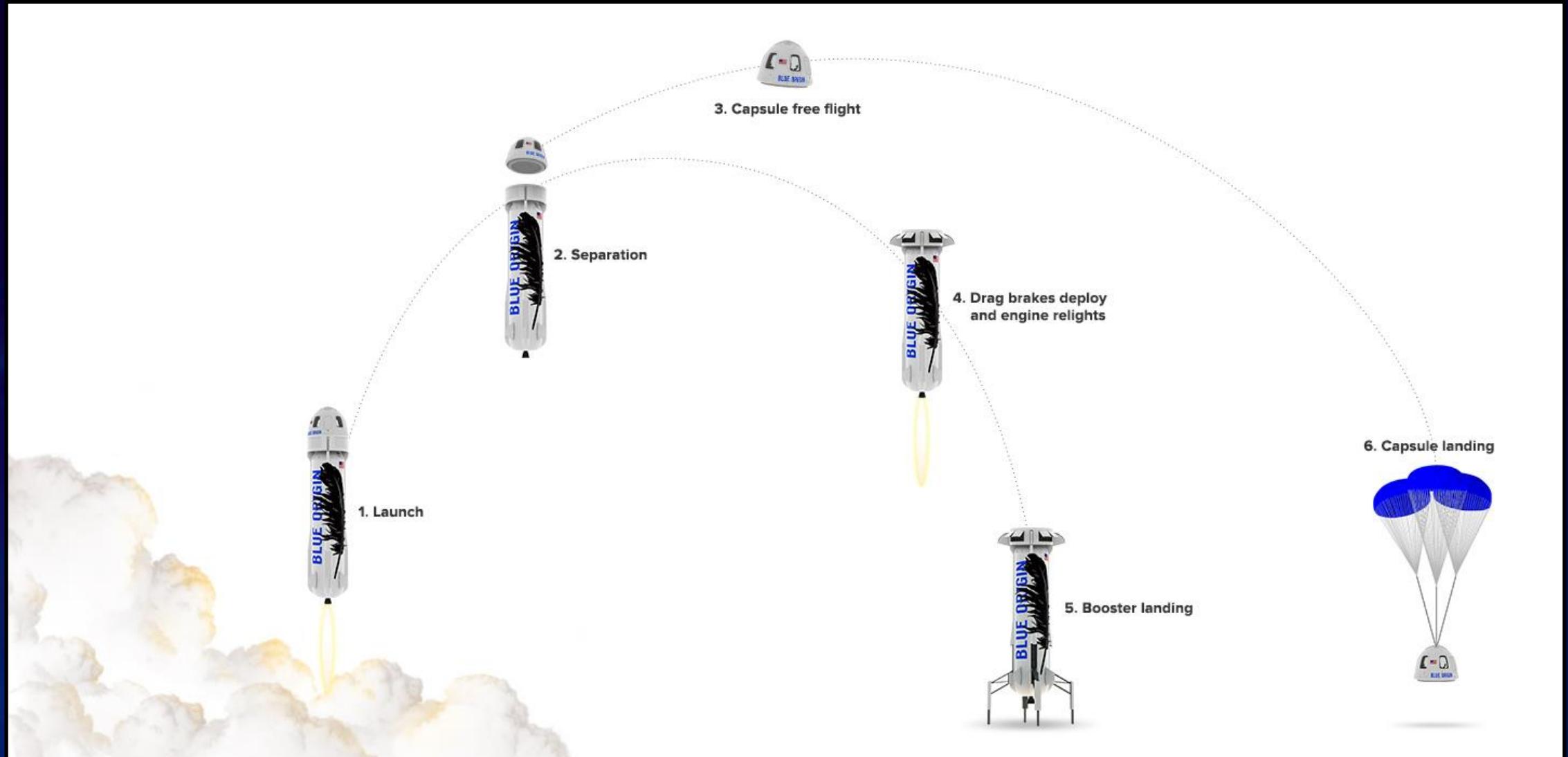
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Space Shuttle Mission Sequence



[3]

New Shepard Flight Sequence



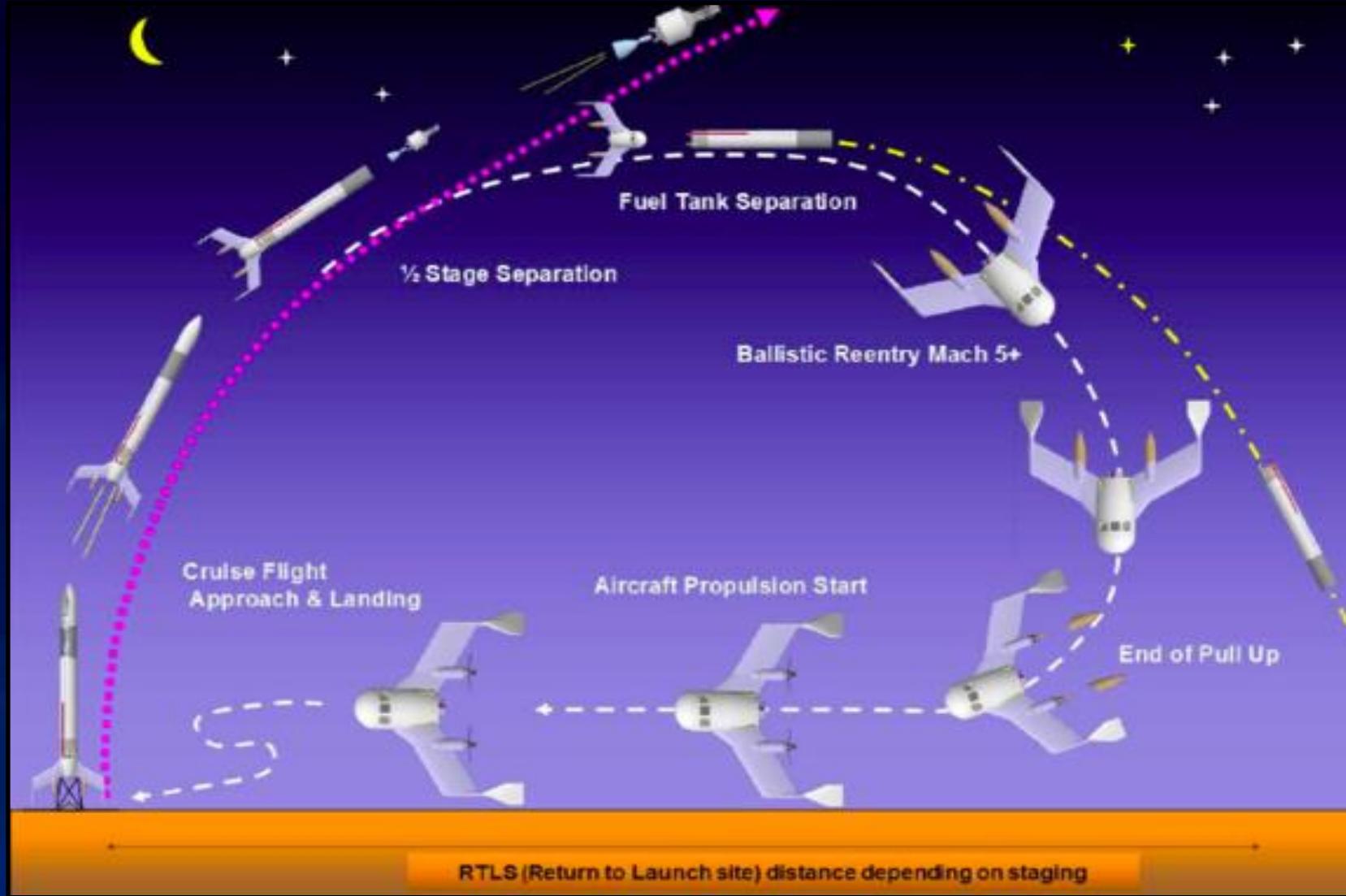
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SMART Reuse



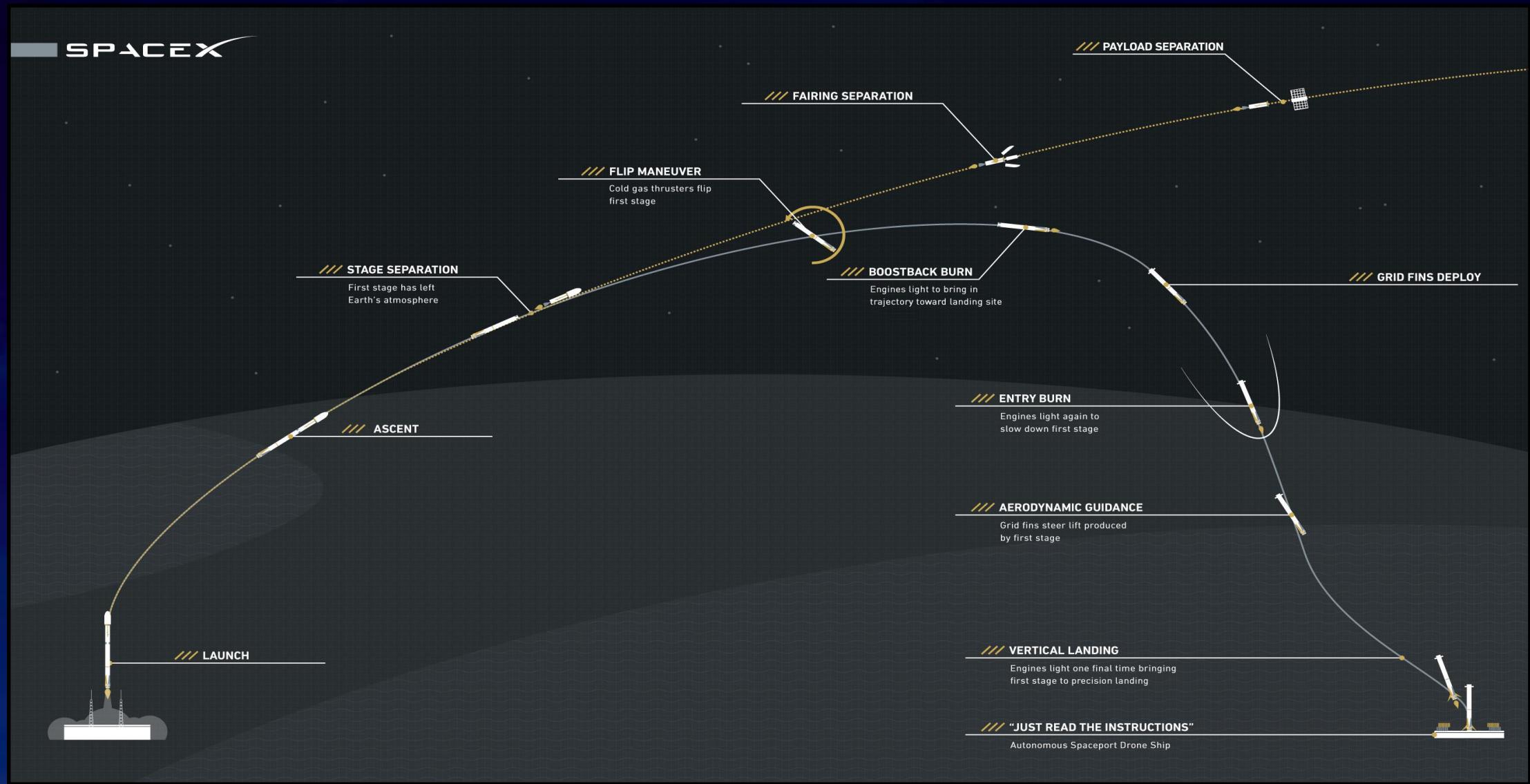
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RTLS Technology



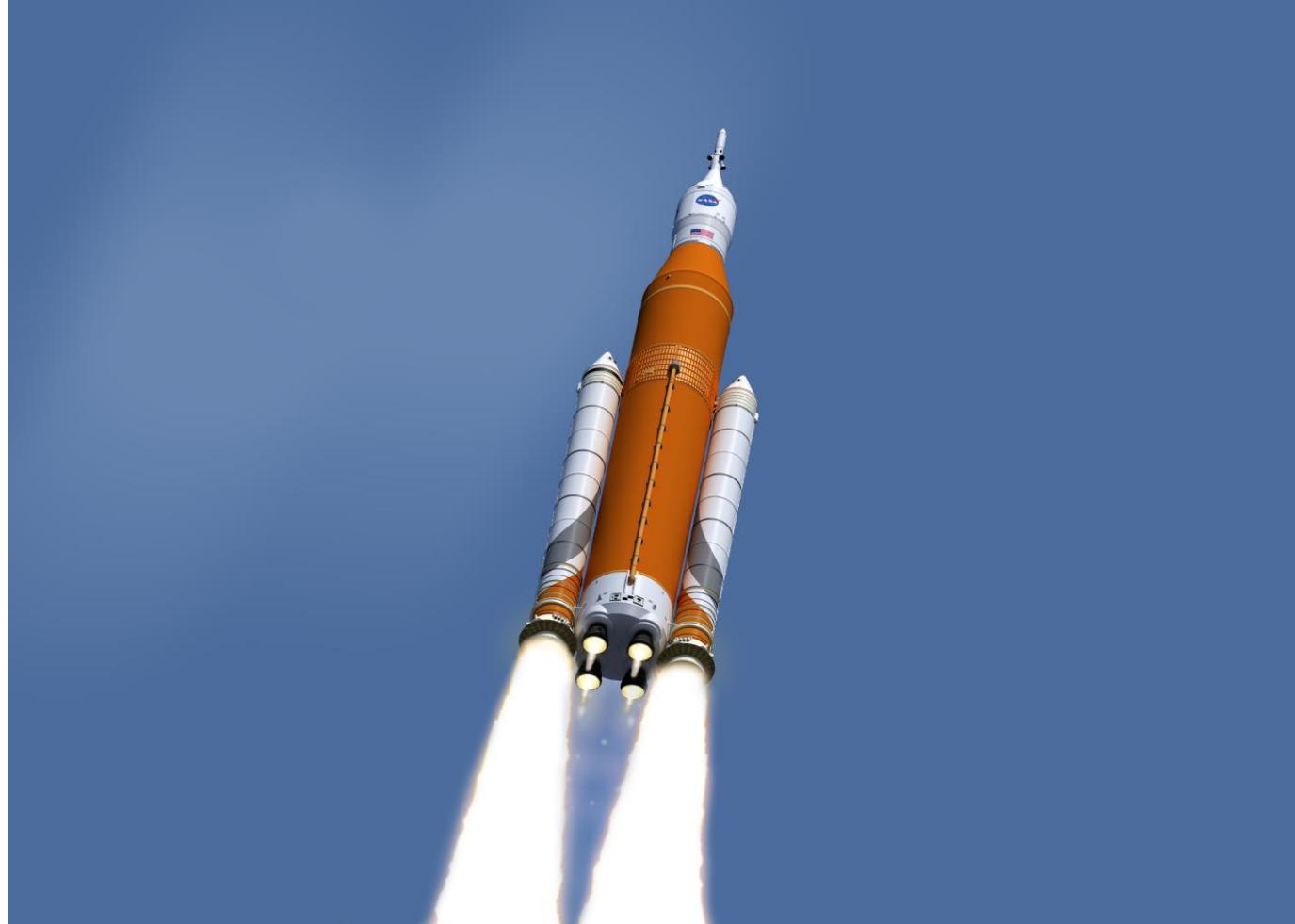
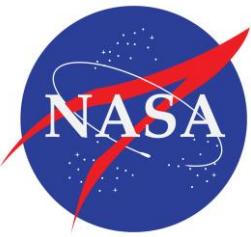
[8]

Falcon 9-R Flight Sequence



[7]

Space Launch System(SLS)



How SLS fares against other rockets

Cost to LEO (\$/kg)

