



Rocket 101

IPSL Space Policy & Law Course

Andrew Ratcliffe

Head of Launch Systems
Chief Engineers Team

Contents

- Background
- Rocket Science Basics
- Anatomy of a Launch Vehicle
- Where to Launch?
- Future of Access to Space
- LaunchUK

Contents

- Background
- **Rocket Science Basics**
- Anatomy of a Launch Vehicle
- Where to Launch?
- Future of Access to Space
- LaunchUK

Rocket Science Basics (1)

- Three key concepts :
 - Payload : Item delivered by the launch vehicle
 - Thrust → Newton's Third Law : For every action there is an equal but opposite reaction
 - Delta-V : Total velocity change that must be imparted on a vehicle – attitude change to launching to orbit
- How does this relate to the sizing of a launch vehicle?

$$\Delta V = I_{sp} g_0 \ln \left(\frac{m_{initial}}{m_{final}} \right)$$

ΔV = Total velocity change (m/s)

I_{sp} = Specific impulse (s) measures the performance of the rocket

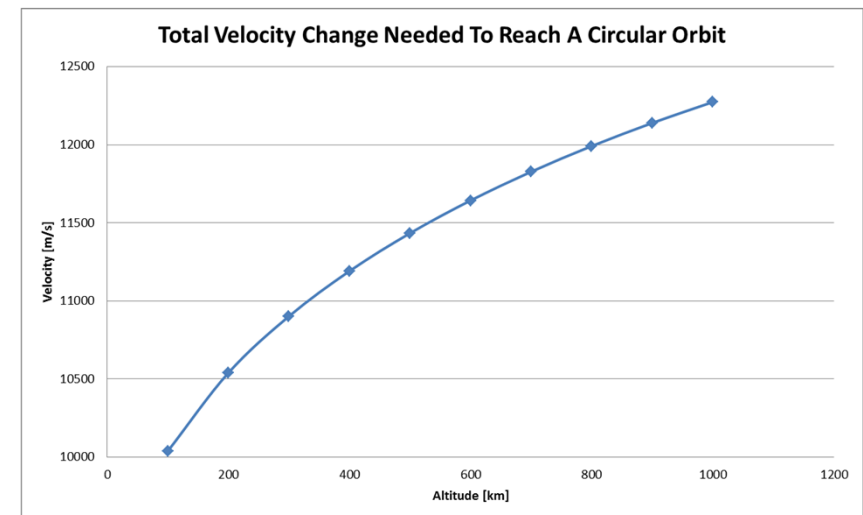
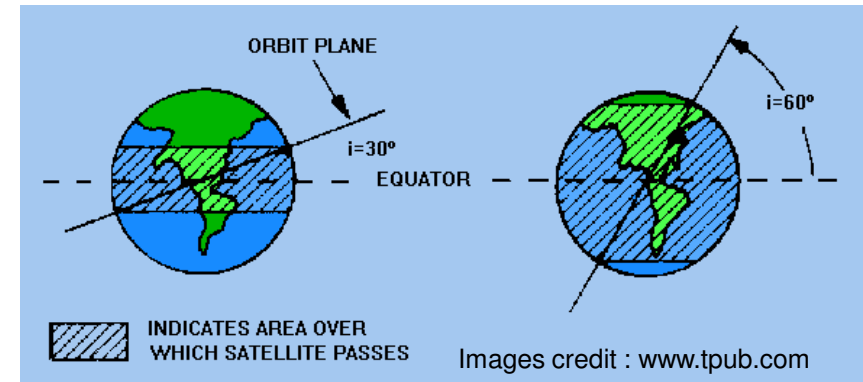
g_0 = constant – 9.81 m/s²

$m_{initial}$ = Initial mass (kg) – mass propellant + m_{final}

m_{final} = dry mass (kg)

Rocket Science Basics (2)

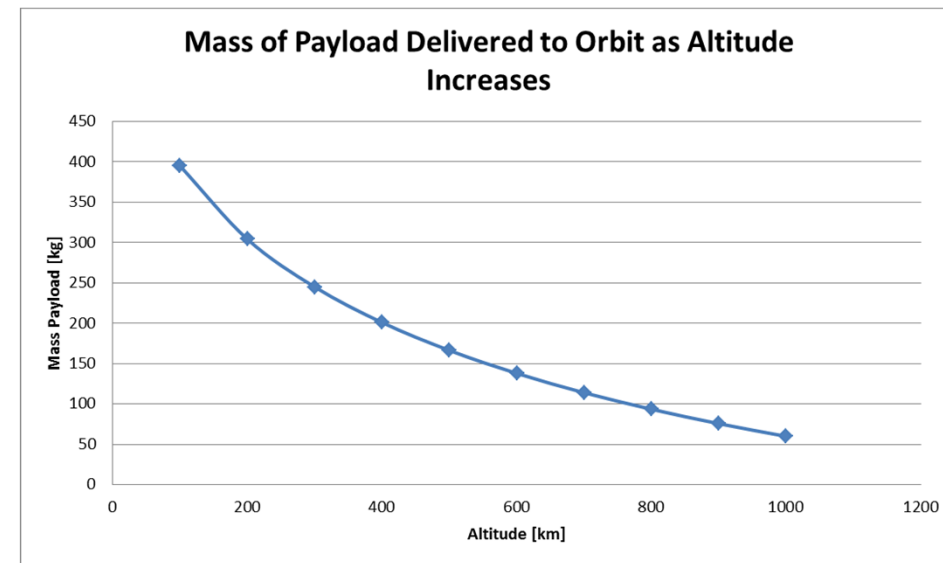
- Orbit : If it has enough tangential velocity it will not fall into the body but will instead continue to follow the curved trajectory caused by that body indefinitely. The object is then said to be orbiting the body.
- Orbit defined by 2 key parameters :
 - Inclination : Angle between the orbital plane and the equator (degrees)
 - Altitude : The height of the orbit above the Earth's surface (km)
- Total $\Delta V = \text{Kinetic Energy} + \text{Potential Energy} + \text{Losses} \rightarrow$ Higher the orbit altitude the harder it is to get there (see graph right)
- Q. So... what does this mean when I compare launch vehicles?



Rocket Science Basics (3)

- Q. So... what does this mean when I compare launch vehicles?
- A. Mass of payload that can be delivered to orbit reduces as the altitude increases
- → Must always compare launch vehicle performance to the same orbit!

- Q. So how can I increase my payload to orbit?
 - Increase performance of the rockets (I_{sp})
 - We will see this briefly later when considering the anatomy of a launch vehicle
 - Reduce the mass of the rocket
 - Improve the materials technology used
 - Get rid of unneeded mass as the vehicle travels to orbit = staging

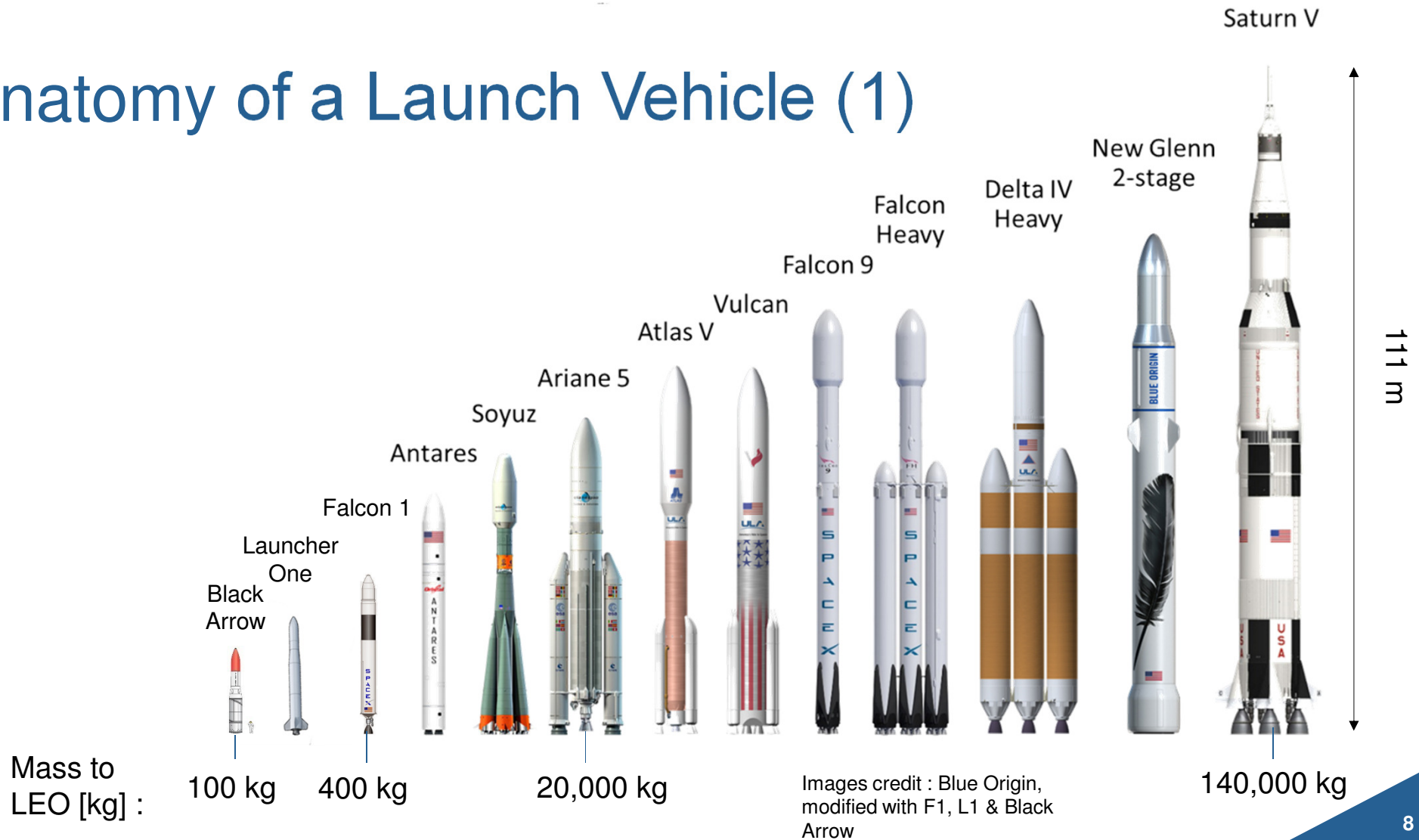


$$\Delta V = I_{sp} g_0 \ln \left(\frac{m_{initial}}{m_{final}} \right)$$

Contents

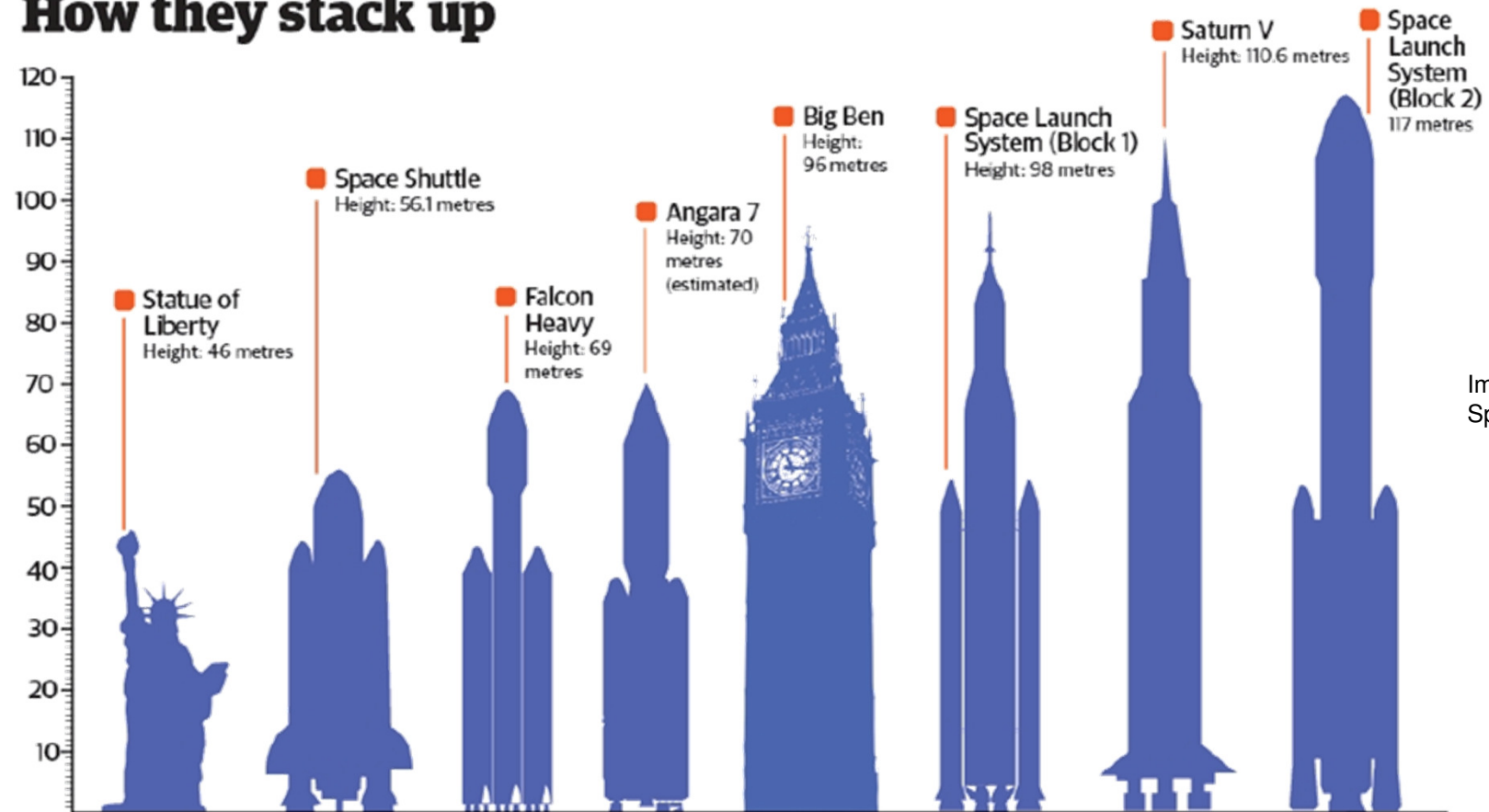
- Background
- Rocket Science Basics
- **Anatomy of a Launch Vehicle**
- Where to Launch?
- Future of Access to Space
- LaunchUK

Anatomy of a Launch Vehicle (1)



Anatomy of a Launch Vehicle (2)

How they stack up



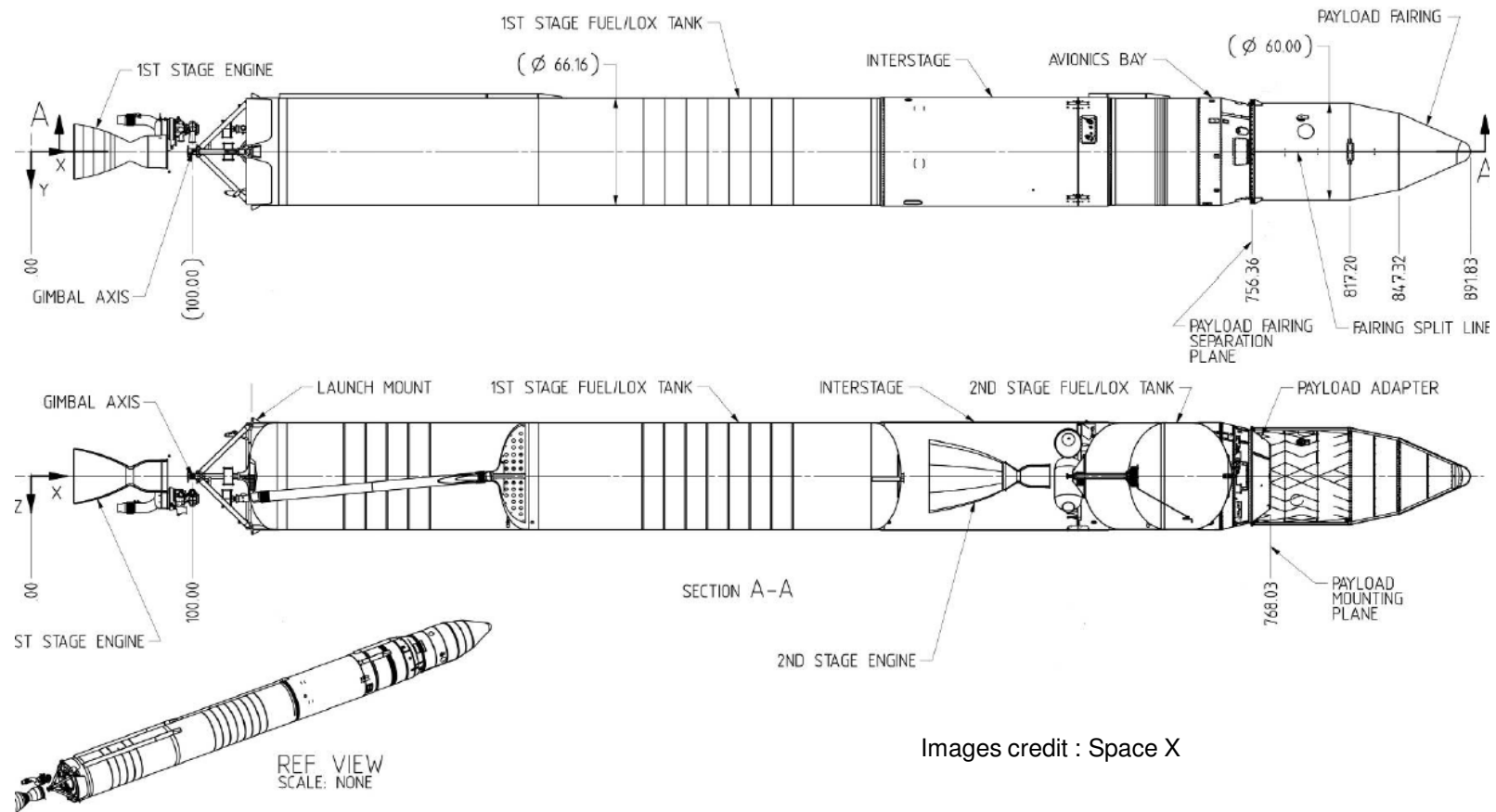
Images credit :
Space Answers

Anatomy of a Launch Vehicle (4)



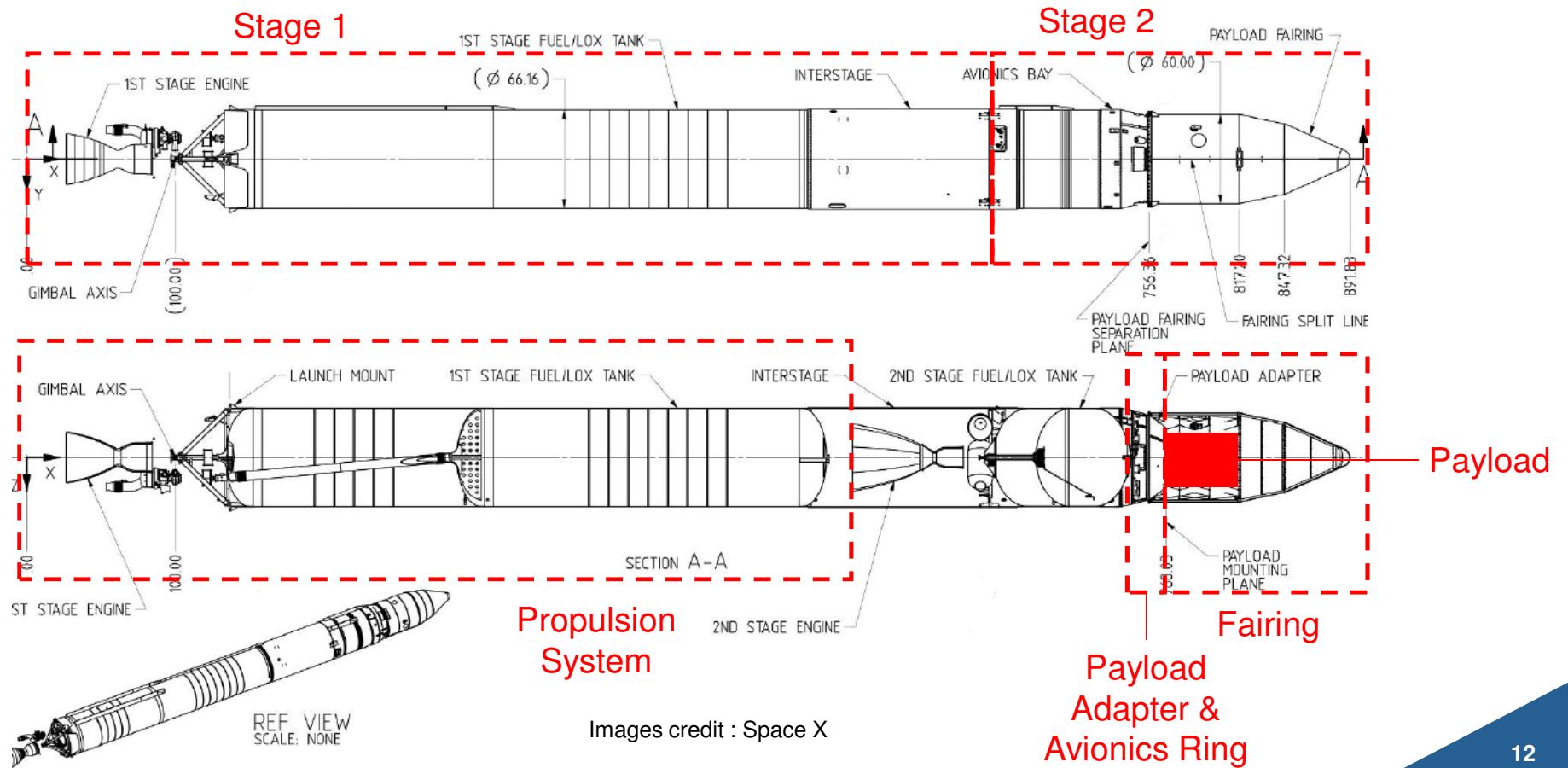
Images credit : Space X

Anatomy of a Launch Vehicle (5)



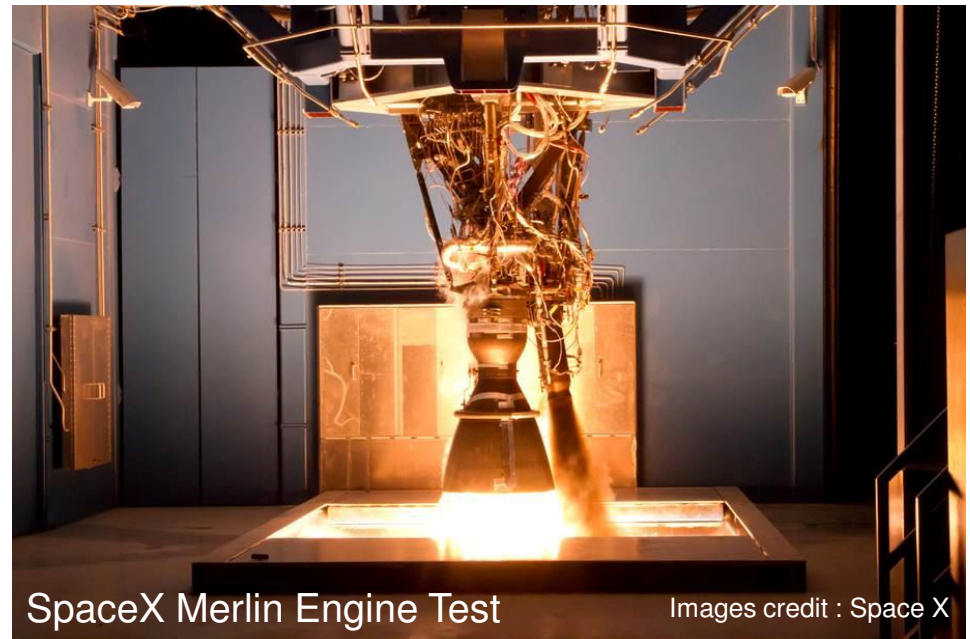
Images credit : Space X

Anatomy of a Launch Vehicle (5)



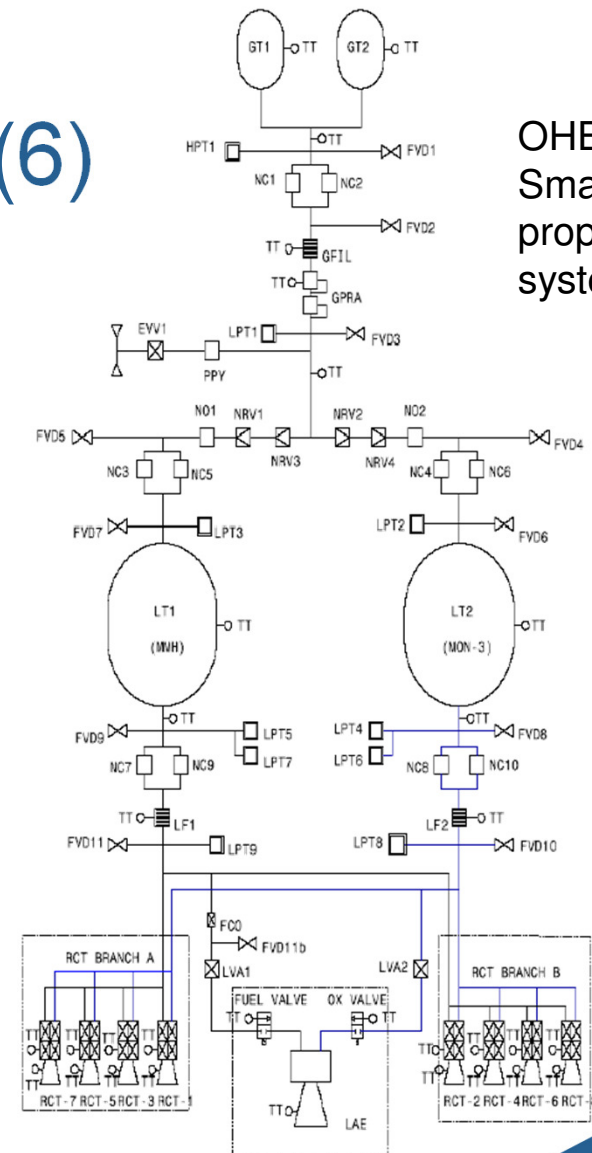
Anatomy of a Launch Vehicle (6)

- Name : 1st Stage Propulsion System
- Function : Provide sufficient thrust to accelerate the launch vehicle to approximately 2.6 km/s
- # of units :
 - 1st stage propulsion system
 - 2nd stage propulsion system
 - Attitude control (hot gas)
- Type : Pressure fed, liquid bi-propellant
 - Fuel : Kerosene
 - Oxidiser : Liquid Oxygen (LOx)
 - Performance : approx. 300 sec
- Key Components :
 - Pressurant tank (Helium)
 - Fuel tank
 - Oxidiser tank
 - Thrust vector control
- Alternatives :
 - Solid rocket motors
 - Hybrid propulsion systems



Anatomy of a Launch Vehicle (6)

- Name : 1st Stage Propulsion System
- Function : Provide sufficient thrust to accelerate the launch vehicle to approximately 2.6 km/s
- # of units :
 - 1st stage propulsion system
 - 2nd stage propulsion system
 - Attitude control (hot gas)
- Type : Pressure fed, liquid bi-propellant
 - Fuel : Kerosene
 - Oxidiser : Liquid Oxygen (LOx)
 - Performance : approx. 300 sec
- Key Components :
 - Pressurant tank (Helium)
 - Fuel tank
 - Oxidiser tank
 - Thrust vector control
- Alternatives :
 - Solid rocket motors
 - Hybrid propulsion systems



OHB-System
Small GEO
propulsion
system

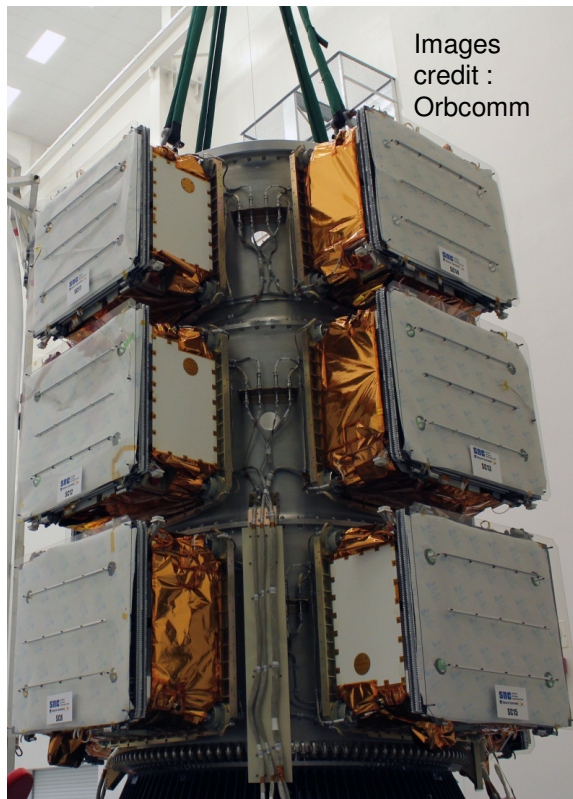
Images credit :
OHB-System

Anatomy of a Launch Vehicle (7)

- Name : Payload Adapter
- Function : Interface between the payload and the launch vehicle, responsible for ejecting the satellite once it reaches orbit
- # of units :
 - Single payload, single adapter (right)
- Type :
 - Adapter is defined by the diameter of the interface – multiple diameters available
- Key Components :
 - Payload adapter structure
 - Clamp band
 - Electrical supply, purge ... TBC by customer
- Alternatives :
 - Depends on the payload provider – tailored to their need or the launch opportunity



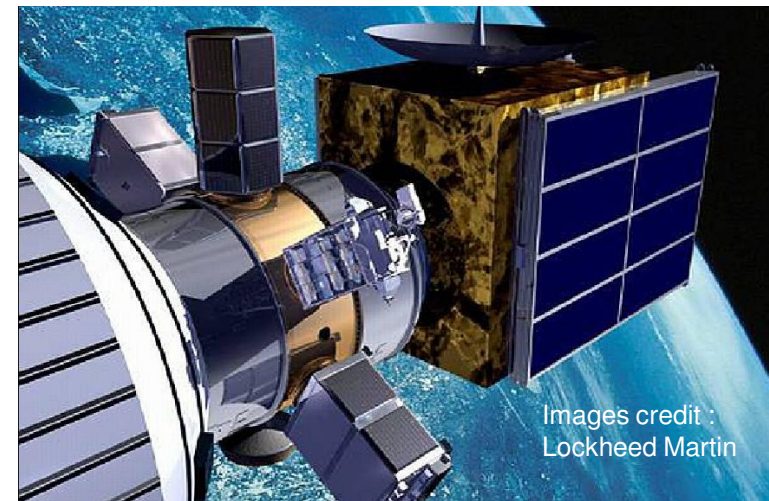
Anatomy of a Launch Vehicle (8)



Cluster : Orbcomm launch on
Falcon 9



Dual launch : Ariane-5 dual
launch for GEO



Rideshare/Piggy back :
ESPA ring

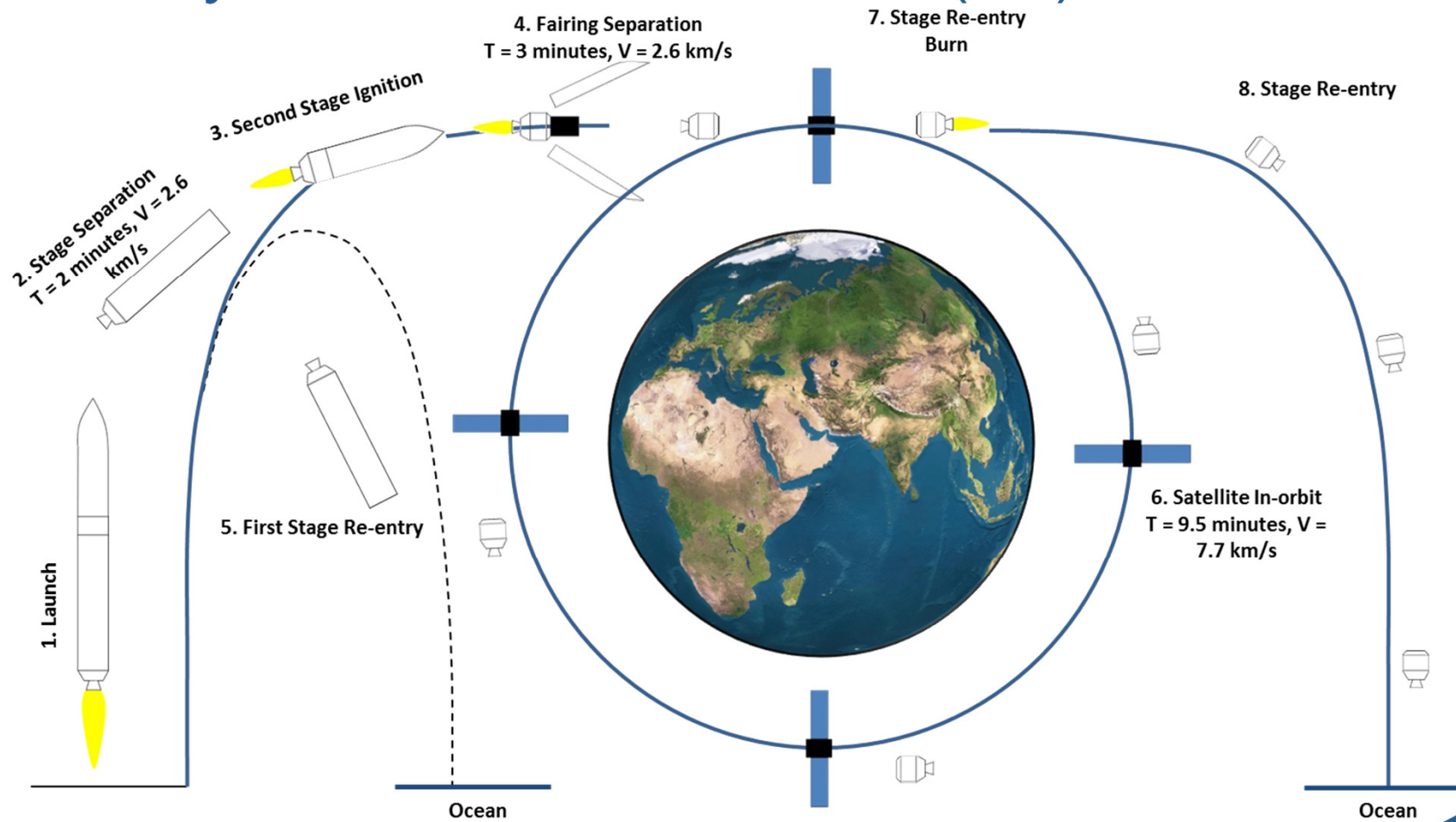
Anatomy of a Launch Vehicle (9)

- Name : Fairing
- Function : Protect the satellite during the initial launch phases and ejects itself once it is no longer needed
- # of units :
 - 2 clam shells
- Type :
 - Separate structure
- Key Components :
 - Structural shell
 - Separation system
- Alternatives :
 - No fairing e.g. crew capsules

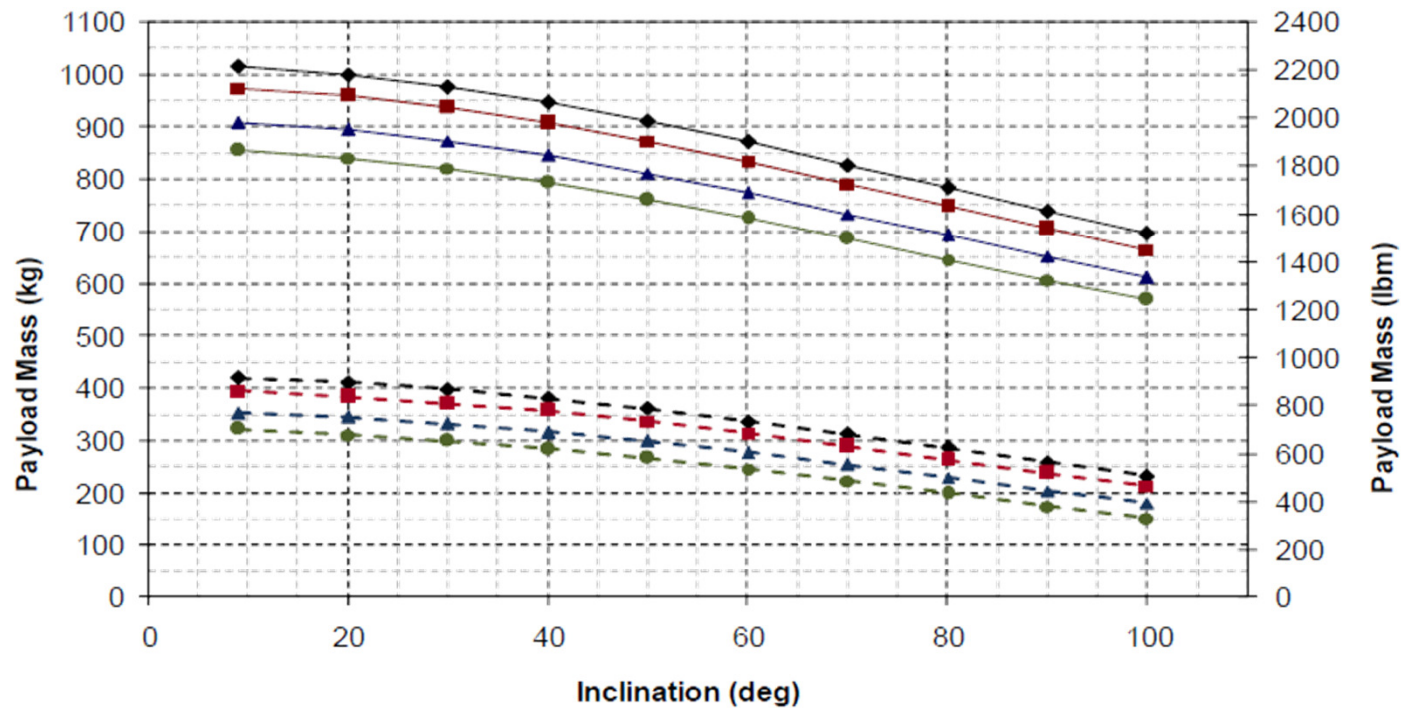


Lockheed Martin MOUS satellite encapsulation

Anatomy of a Launch Vehicle (10)



Anatomy of a Launch Vehicle (11)



Courtesy SpaceX user guide



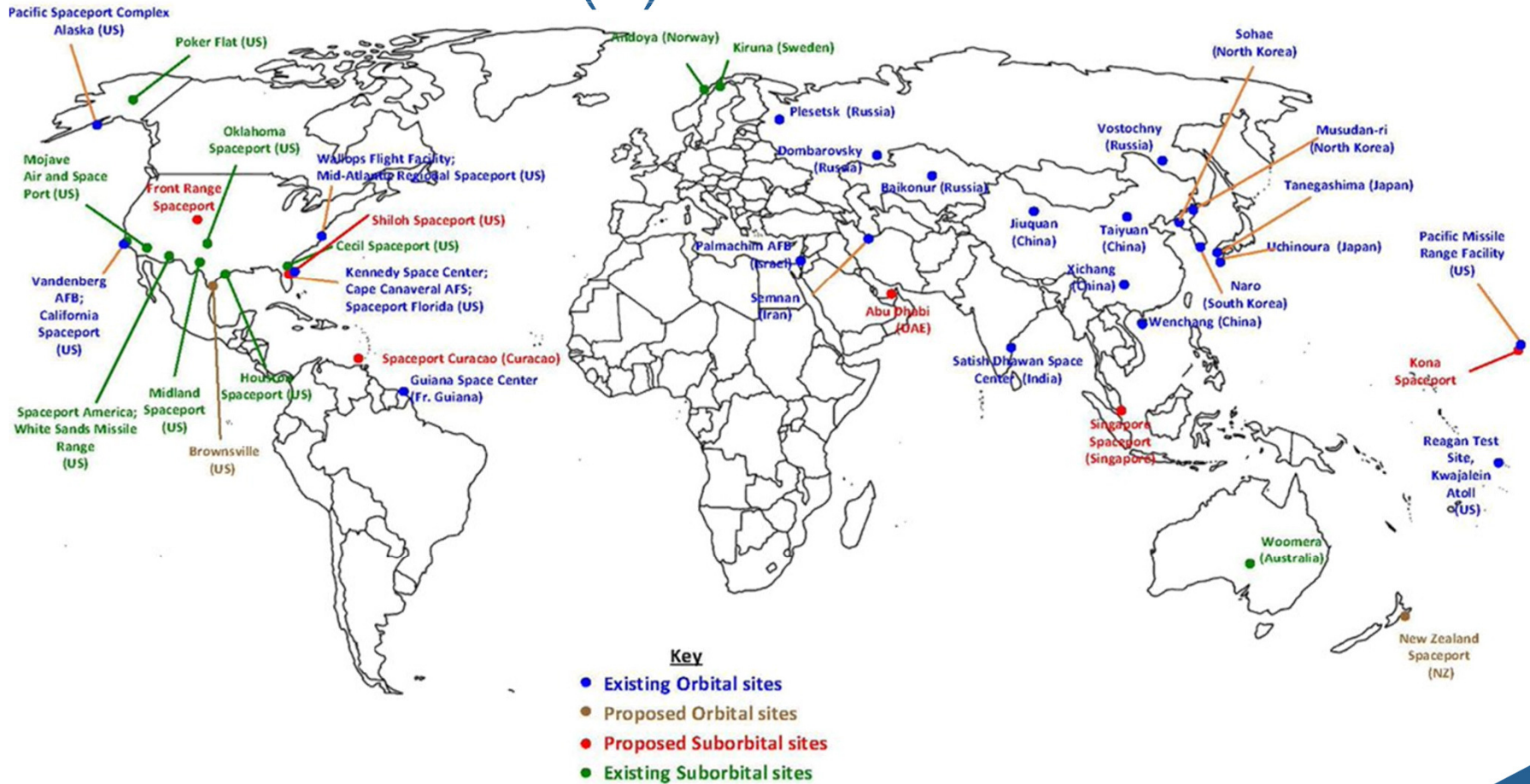
Anatomy of a Launch Vehicle (12)



Contents

- Background
- Rocket Science Basics
- Anatomy of a Launch Vehicle
- **Where to Launch?**
- Future of Access to Space
- LaunchUK

Where to Launch? (1)



Source: FAA July 2016

Where to Launch? (2)



Courtesy SpaceX

Contents

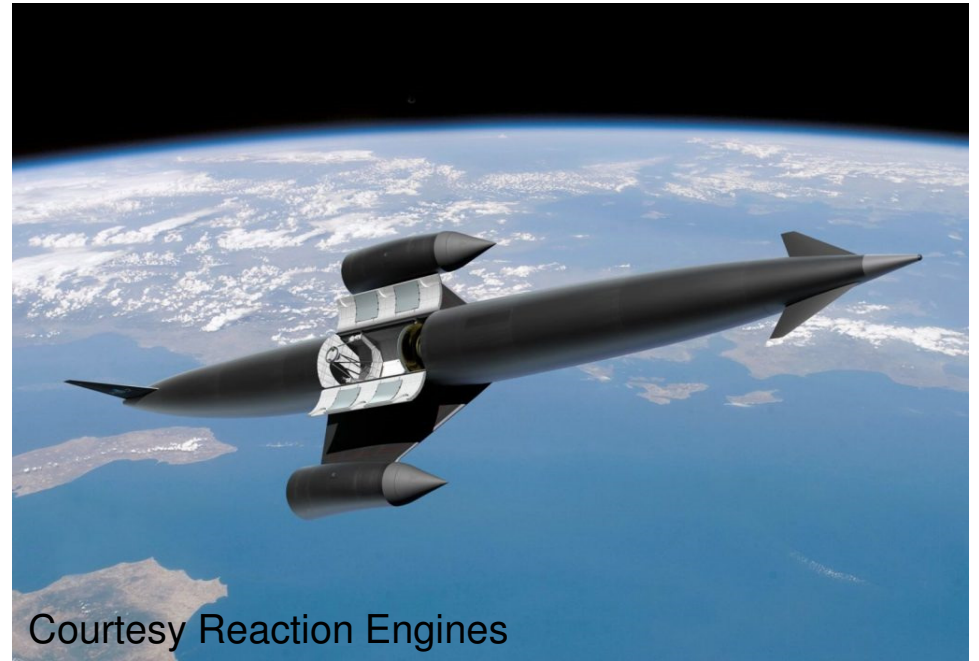
- Background
- Rocket Science Basics
- Anatomy of a Launch Vehicle
- Where to Launch?
- **Future of Access to Space**
- LaunchUK

Future of Space Access (1)



Courtesy SpaceX

Partial Reuseability (SpaceX F9 landing on a barge)



Courtesy Reaction Engines

Full Reuseability (Reaction Engines Skylon)

Future of Space Access (2)



Courtesy bisbos.com

Contents

- Background
- Rocket Science Basics
- Anatomy of a Launch Vehicle
- Where to Launch?
- Future of Access to Space
- **LaunchUK**

Seizing new opportunities

- The UK Government aims to grow the UK's share of the global space market to 10% by 2030.
- We are supporting UK industry to seize new opportunities for growth – including in two growing commercial markets:

Small satellite launch

- Planned satellite constellations will generate increasing demand for small satellite launch.
- An estimated £25bn global market to sustain these networks over 20 years.

Sub-orbital flight

- Sub-orbital flights provide a unique environment for science experiments.
- Companies are also targeting the tourist market.
- An estimated £10bn global market.

Creating an enabling environment

Regulatory framework

- We intend to legislate for a new regulatory framework to ensure UK spaceflight activities are safe.

Sustainable market

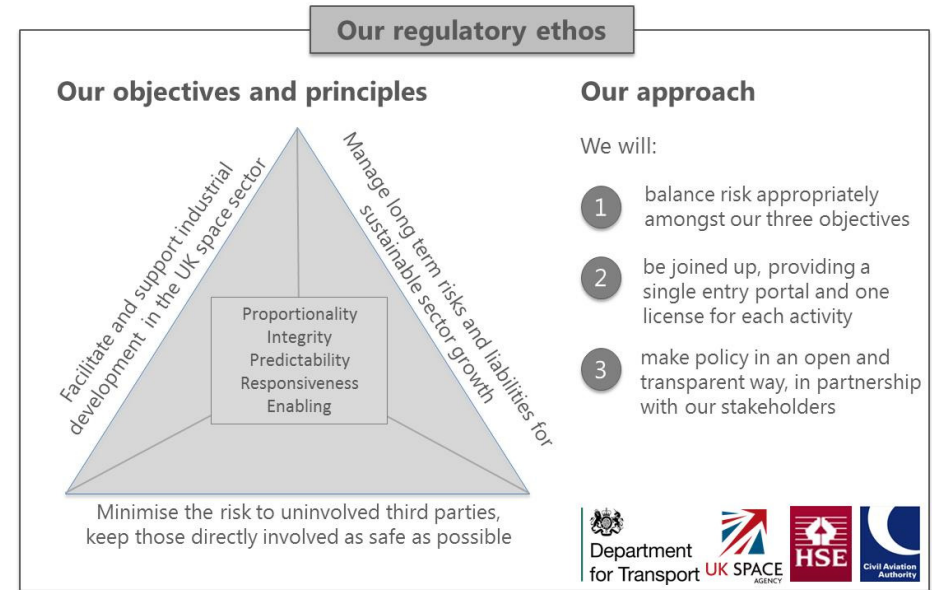
- We are engaging with industry to encourage sustainable interest in the operation and use of UK spaceport services.

International engagement

- We are learning from other nations' experiences, and will use our global links to help companies who want to operate in the UK.

Regulatory Framework

- So where are we at the moment? UK Space Agency regulate overseas launch and payload operations by UK companies and UK nationals under the Outer Space Act 1986.
- The Space Industry Bill (formerly the Spaceflight Bill) introduced to the House of Lords in June 2017 → first step in the process to create new laws and a regulatory framework to enable exciting new technologies to operate safely from the UK.
- Key : Joint initiative by the Department for Transport, UK Space Agency and Civil Aviation Authority supported by the Health and Safety Executive → Builds on existing expertise and regulations
- The bill introduces measures on :
 - Licensing of space, satellite operations, sub-orbital activities and of spaceports
 - Range control: the equivalent of air traffic control for launching vehicles into space
 - Ensuring safety and security
 - Addressing liabilities, insurance and cost recovery
 - Compliance oversight, enforcement and appeals
- Next steps, a period of scrutiny within Government and engagement with industry and other interest groups to develop the detailed regulations



What's in the Spaceflight Bill?

Regulations Definitions, duties, prohibitions	Range Definitions, services, licensing	Operator licenses Operators, spaceports, T&Cs	Delegation Appointment of other regulators
Participants & staff Consent, fitness, qualifications/training	Safety Safety regulations, accidents, assistance	Security Exemptions, byelaws, assistance	Enforcement Compliance, directions, powers
Liabilities Indemnities, insurance	Land powers Rights, restrictions, displacement	Sanctions Offences, penalties, defences, sanctions	Appeals Panel, rights, circumstances
	Miscellaneous Charging, advice, other countries	General Amendments, interpretation, commencement	



Any Questions?

Andrew Ratcliffe

Head of Launch Systems
Chief Engineers Team

andrew.ratcliffe@ukspaceagency.bis.gsi.gov.uk