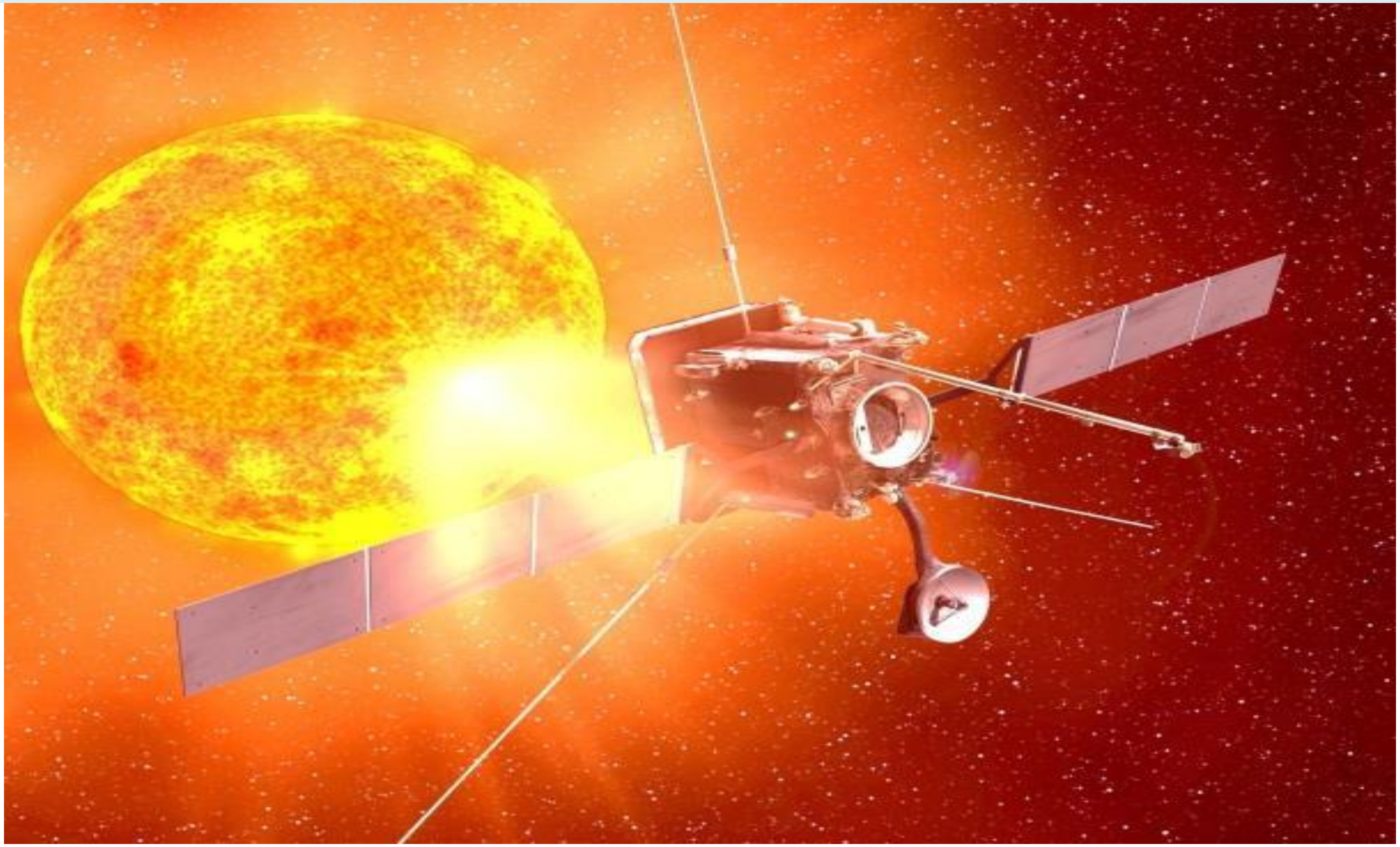
Space exploration



Tony Jorden Jan 2019

Overview

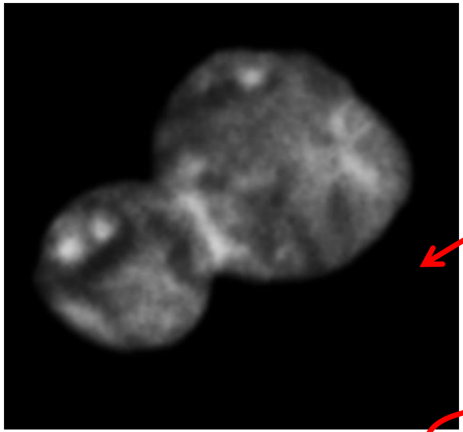
- Space Exploration in general
- Examples of missions
  … going to the Sun or Mars

Much of the material here came from Airbus … one of the largest global companies that design, manufacture, launch, and operate a range of spacecraft.

Plus, lots from Google/Wikipedia, etc.

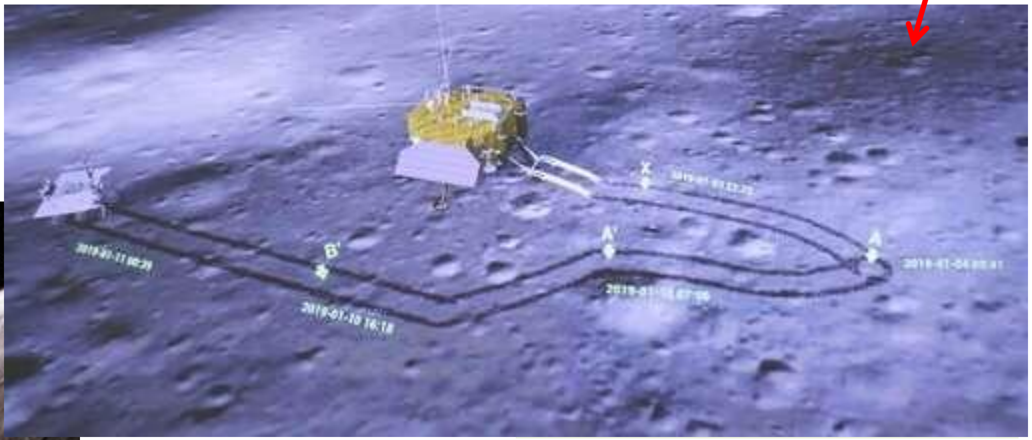
The UK space agency spends £100's millions each year. Space is estimated to provide approaching £20 billion to the economy.

Space exploration in the news….



Lots of exciting space news recently….

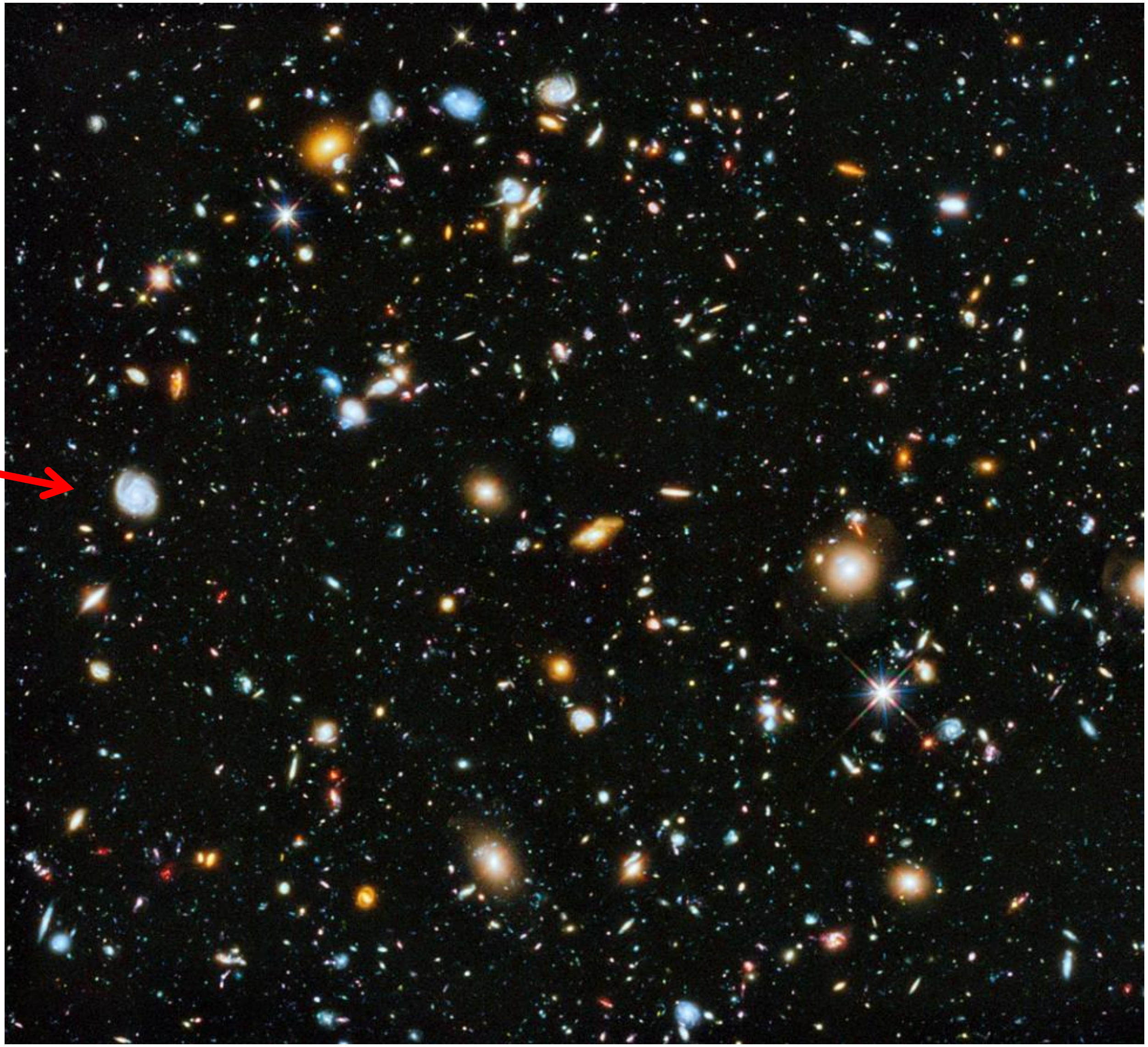
- On 3rd Jan, China's ***Chang'e-4*** mission landed the **Jade Rabbit-2** (Yutu-2) over on the far side of the moon.
- On 1 Jan, NASA's **New Horizons** satellite flew past the most primitive object ever explored, "Ultima Thule" past Pluto (4 billion miles away)
- In Dec 2018, NASA's **Insight** probe put its first instrument down on Mars.
- In Oct 2018 Europe, with Japan, launched the **BepiColombo** mission to Mercury…. arriving late 2025.



The Universe

Some part of the Universe, as seen from the Hubble Space Telescope

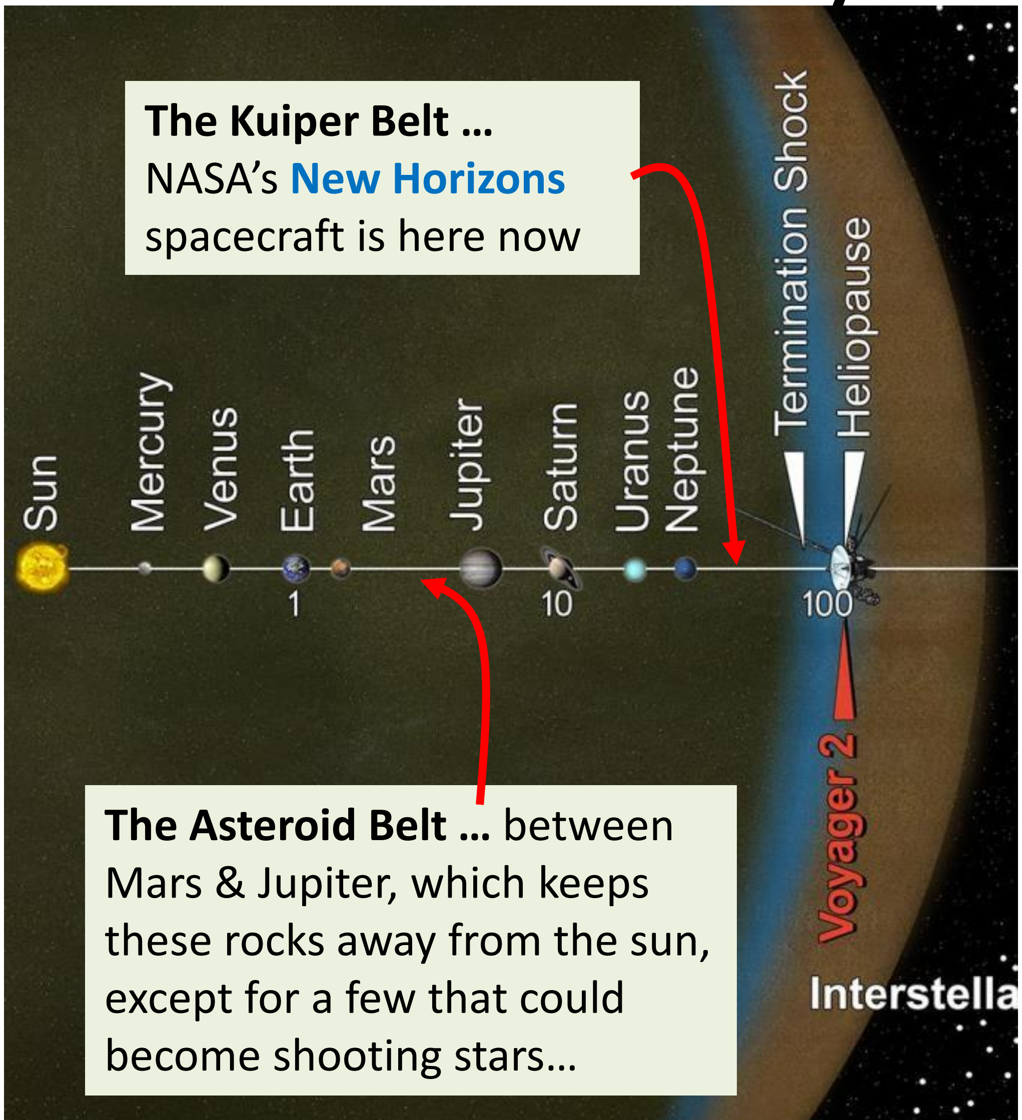
Our solar system is in a spiral galaxy (not this one!)



Our Galaxy

We live in some far-out limb of a spiral galaxy
- our 'Milky Way' galaxy.

Solar system



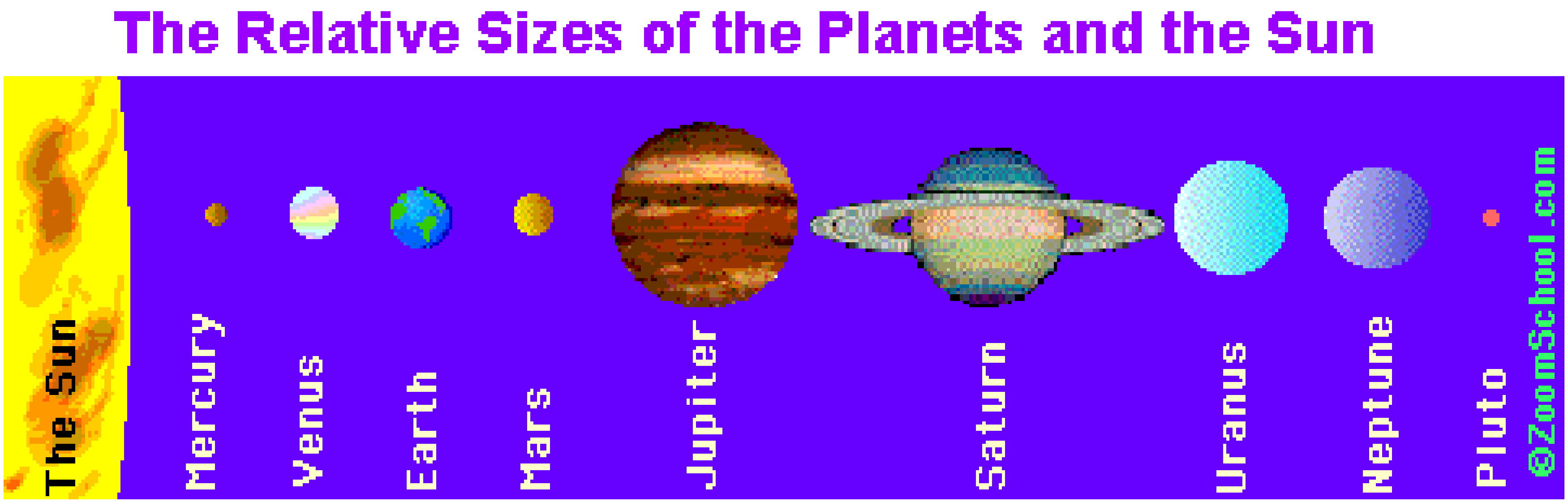
- One sun
- Eight planets,
- lots of moons,
- rocks, and more

This image has a log scale. So, Saturn is 10x further from the sun than the Earth, not twice as far.

The edge of the Solar system is 120 times as far away from the sun as the Earth. ~1 light-day

1 Earth sun average distance
= 1 AU (Astronomical Unit)
= 93 million miles/150 million km

Planet sizes



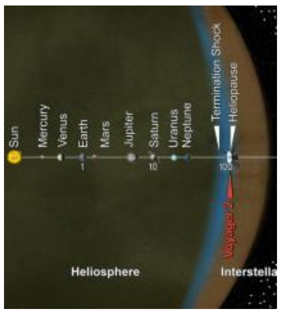
The distances shown here are NOT to scale, just the sizes…

- The sun is 1.6 million km in diameter
- Jupiter is 143 thousand km in diameter (~11x less)
- Earth is 13 thousand km in diameter (~ 11 less again)

How far to explore outside our solar system?

Voyager spacecraft, launched in Sept 1977, are now here, at 145/120 AU (13/11 billion miles away)

~ 100 AU



Our solar system

265,000 AU
40 million million km

Proxima Centauri

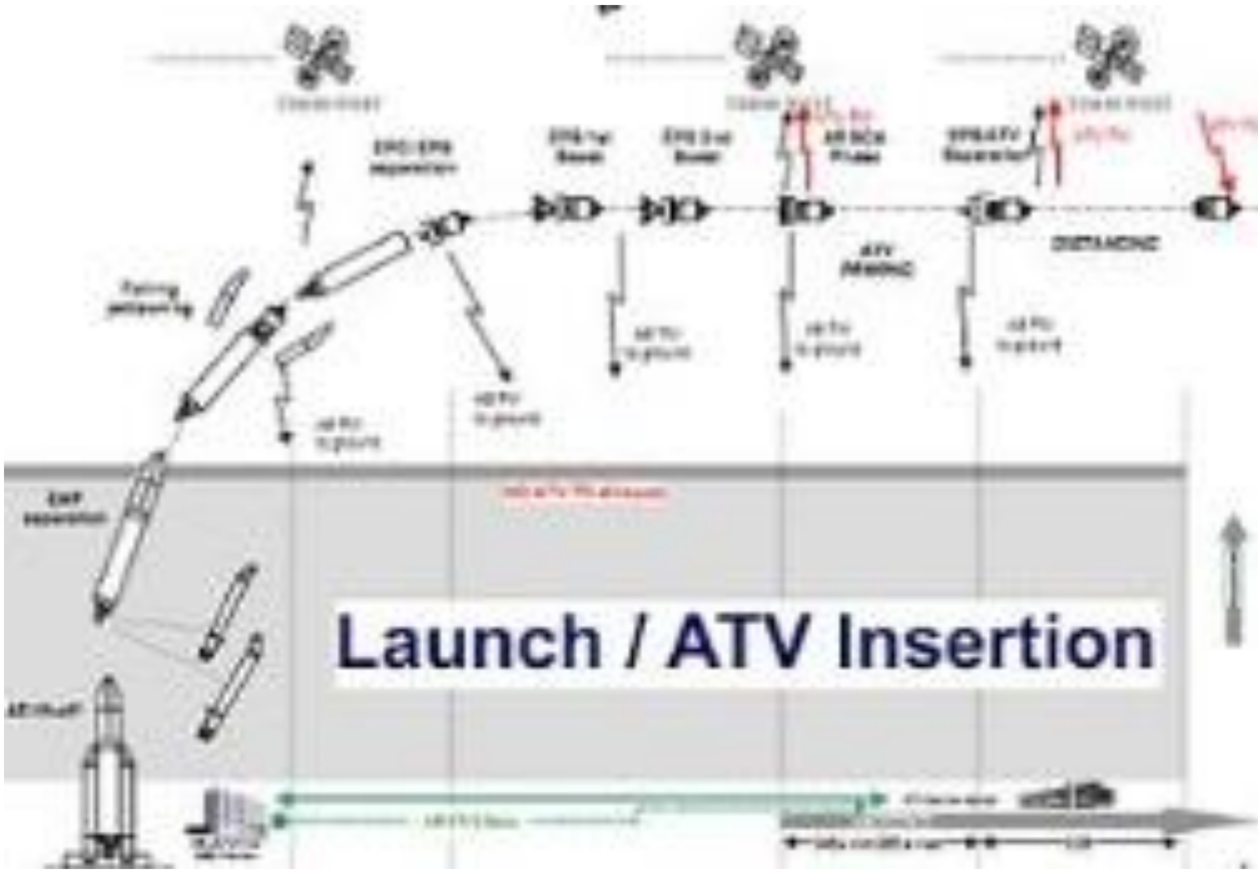
So, having reached the edge of our solar system, a spacecraft would have to travel 2650 times further to reach the next sun in our galaxy.

This would take New Horizons ~ 75000 years, if it went that way…
[New Horizons will take ~ 30 years to do 100 AU.]

The basics – Arianne 5 take-off

Physics of getting into orbit?
Launch force must exceed the force due to gravity.
So, we talk about a small **10 Newton** thruster on a satellite e.g. for manoeuvring (would provide an acceleration to match gravity for a 1 kg mass). But the space shuttle has 2 booster engines , each provides **15 Million Newtons** force.
By comparison, a commercial jet engine could be 0.6 MN – so this chemical rocket booster is 25x more powerful than a plane's jet engine…

Into Earth orbit: ‘insertion’



getting a satellite into space- or in this case an ESA ‘cargo satellite to the ISS …
for supplies and waste collection

Launchers

Sputnik.
USSR ~1957

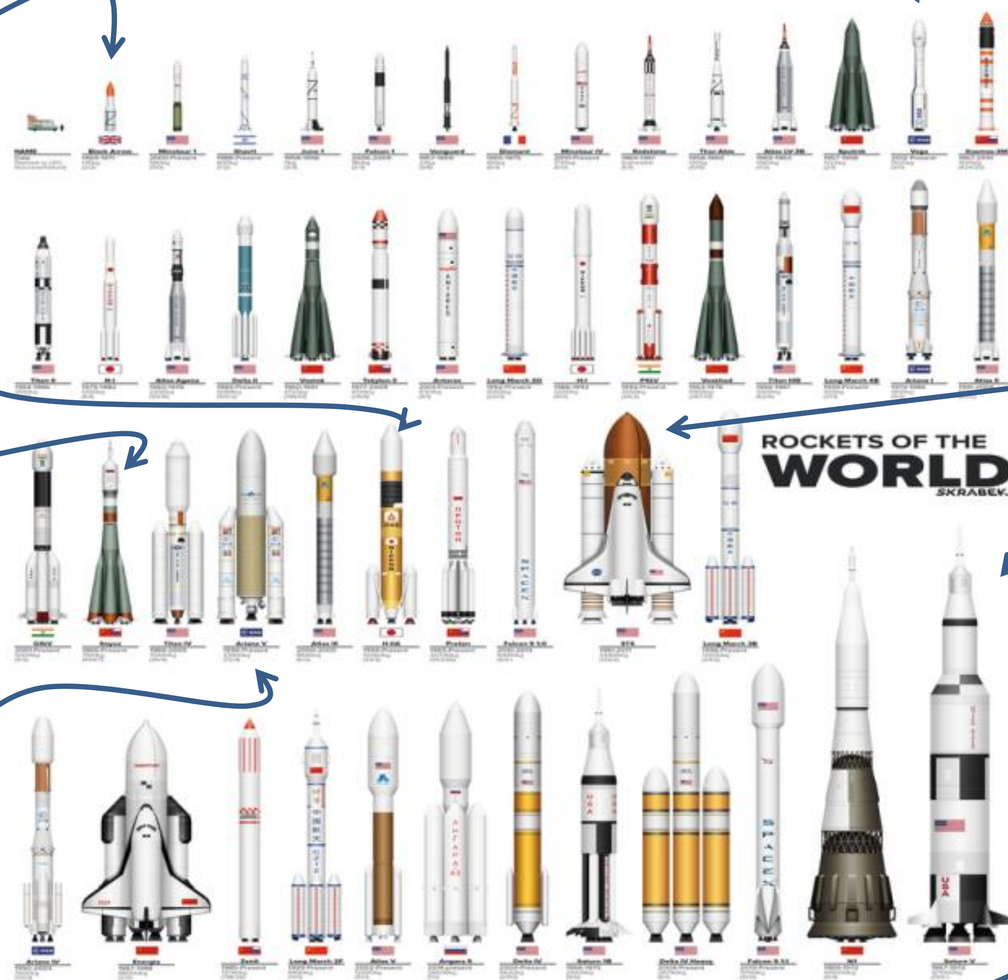
Vega
ESA - current

Black arrow.
UK ~1970

H-11A China
Current

Shuttle
Transport.
USA. To 2011

Soyuz. USSR.
1966- current



Saturn 5.
USA. ~1970

Arianne 5.
ESA - current

Delta IV heavy.
USA. current

Thanks to the Daily Mail on-line 2015

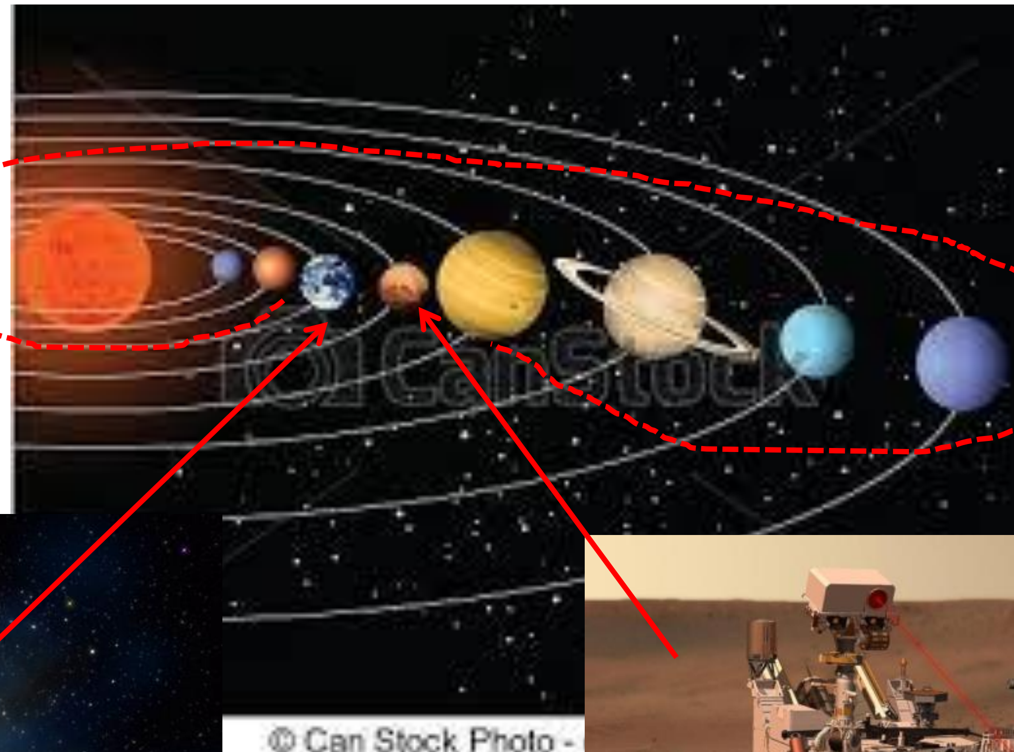
Types of missions /payloads

- **Types of mission**: (payloads)
  - Earth Observation
  - Space-science
  - services (GPS, telecoms, climate/weather)
  - exploration

- **Types of satellites:**
  Orbiting satellites / delivering landers
  - static probes / rovers.

Where shall we go?

Types of missions /payloads - *local*



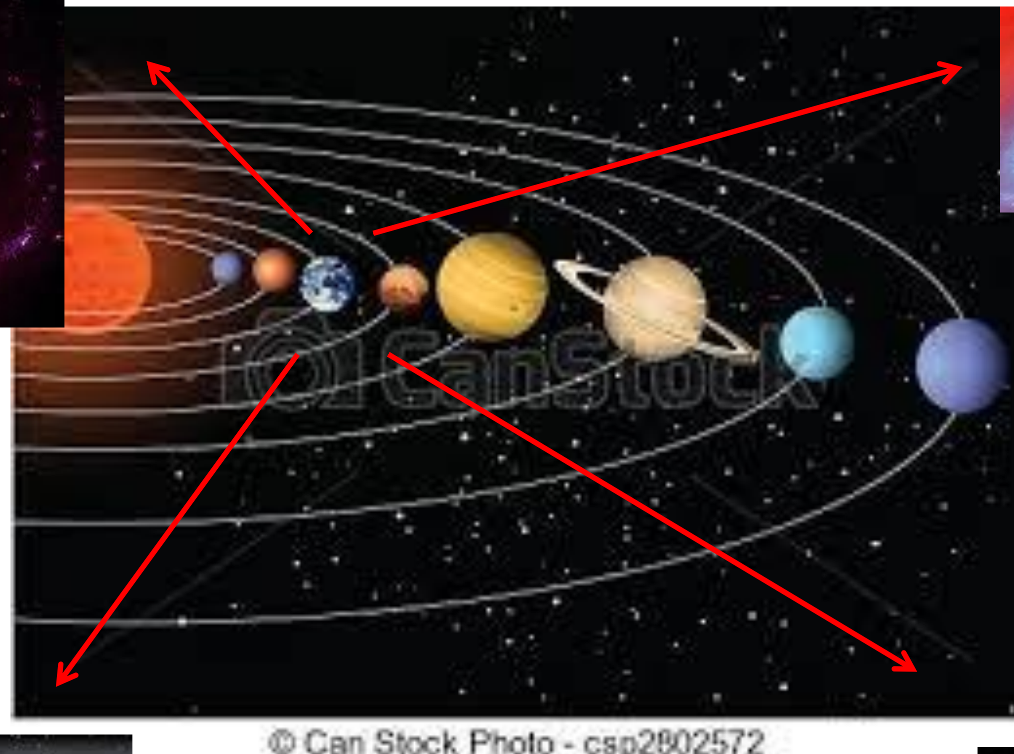
3. Rest of Solar System

1. The Earth

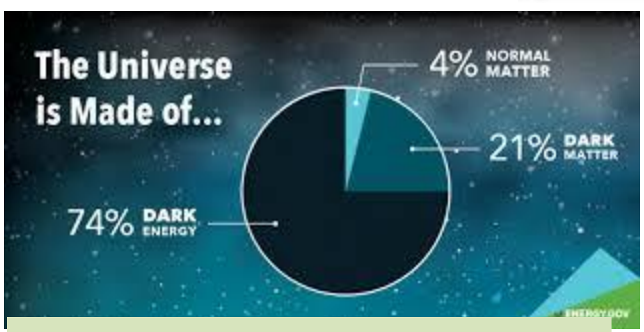
2. Mars

Types of missions /payloads - ***distant***

galaxies

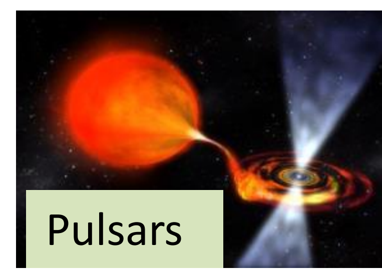


Black holes



Dark matter /dark energy

Rest of the universe....



Pulsars

Types of missions /payloads

Interlude

…. Exploring satellite building

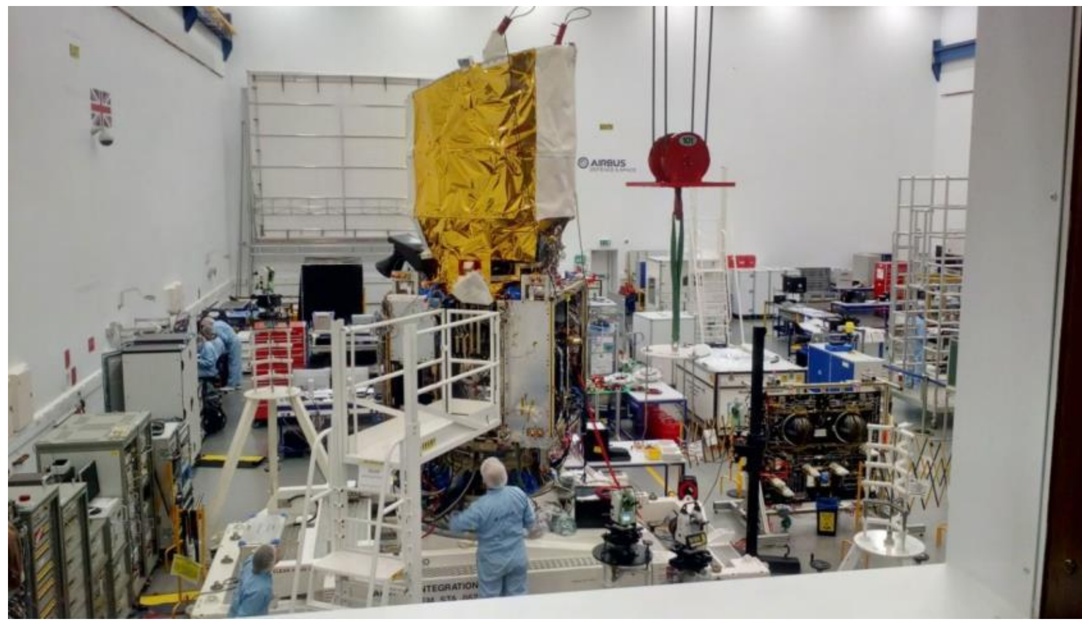
- What's it like designing and building a satellite?

Space engineers

- In UK, Airbus (space bit) has ~2500 satellite people in two main locations – Stevenage and Portsmouth
- Stevenage has rocket heritage from 1953 (Blue streak rockets) and satellites.
- The UK has built satellites over the last 50 years.

Space engineering- all geeks?

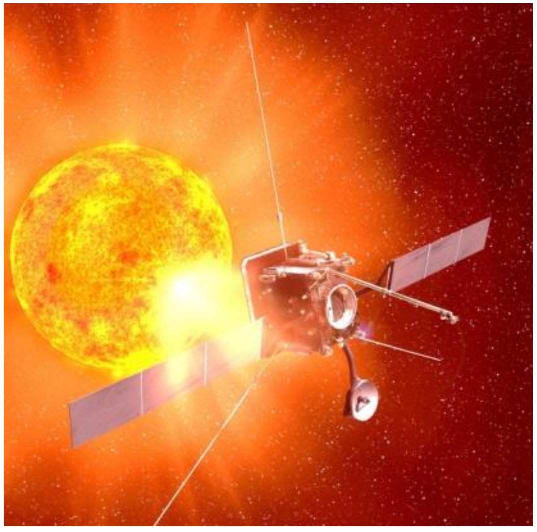
- Commercial people (contracts, agreements)
- Financial (try to keep track of the money- much from taxpayers!)
- Planning/scheduling
- Mech engineers
  & CAD specialists
- Thermal engineers
- Elec. engineers
- Power engineers
- Software engineers
- AOCS engineers
- AIVT engineers
- System engineers - Interfaces
  – to launcher & payloads & keep an eye on the mass (weight), power, does everything fit? …and much more.



AOCS= Attitude and Orbit Control Systems
AIVT= Assembly, Integration, Verification & Test

What matters most?

- Power /mass



Power

- From solar arrays
- Batteries used to store energy.
- Never enough, even for a mission to the sun.
- All equipment wants power & some power is needed to keep shadowed items warm!
- If solar arrays get too big- for more power- mass increases> Need more fuel> mass increases….

Mass

- Launcher has a maximum payload it can launch; this includes the fuel for the satellite to do its mission.
- Scientists want more mass (and power) for better instruments.
- The structure has to be strong enough, rigid, support the heatshield, cope with expansion- needs mass.

How does a mission happen?

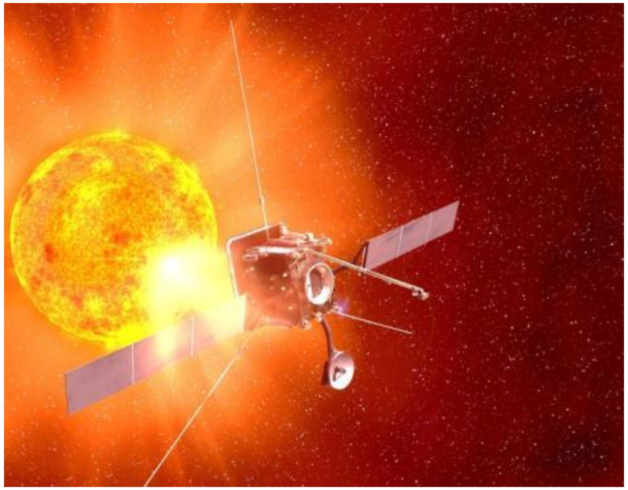
Timeline for a complex mission

Duration	Phase	Activities
5-10 years in some cases	Early ideas	• scientists • Review by ESA
2-5 years	Early studies	• Industry • scientists
1-3 years	Compare proposals	• Decide on a mission • Get funding
~ 5-8 years	Start the project	• Design • Build & test
2-10 years, or more	Start operation	• Launch • Cruise • Science operation

ESA=European Space Agency

Some missions

- Solar Orbiter
  - exploring the sun

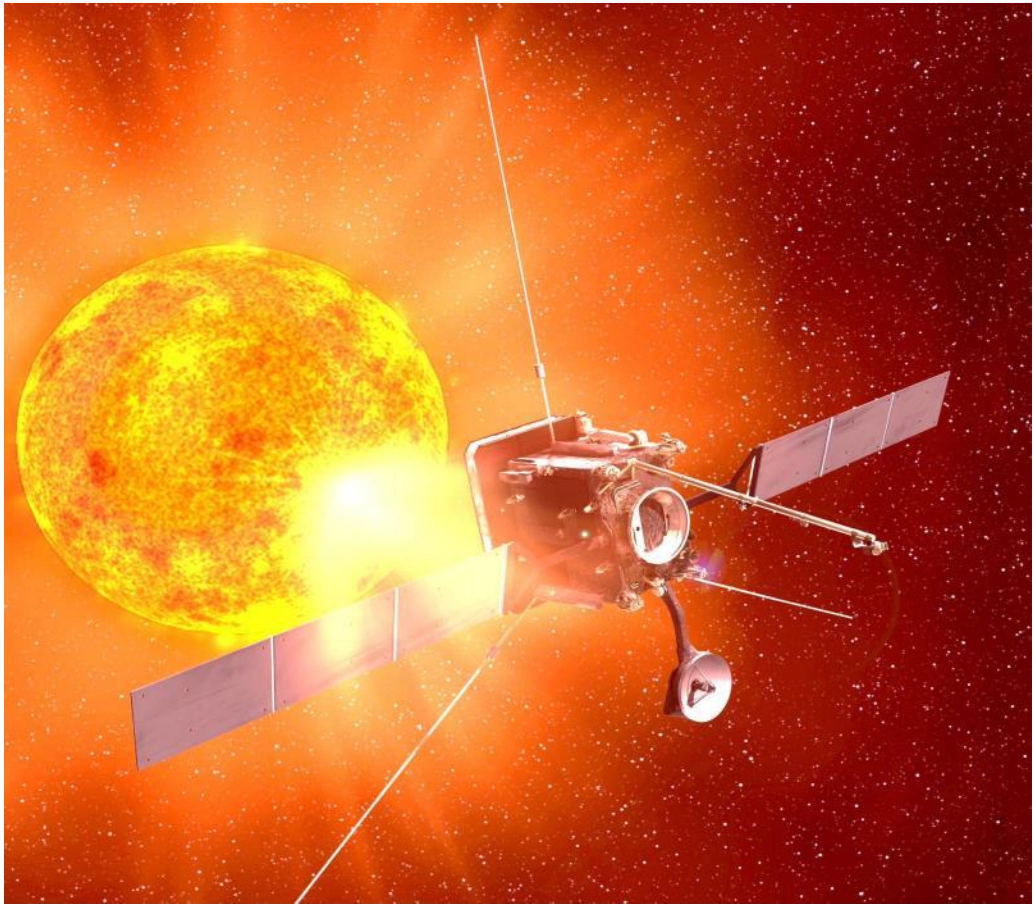


- ExoMars
  - Mars exploration

Solar Orbiter

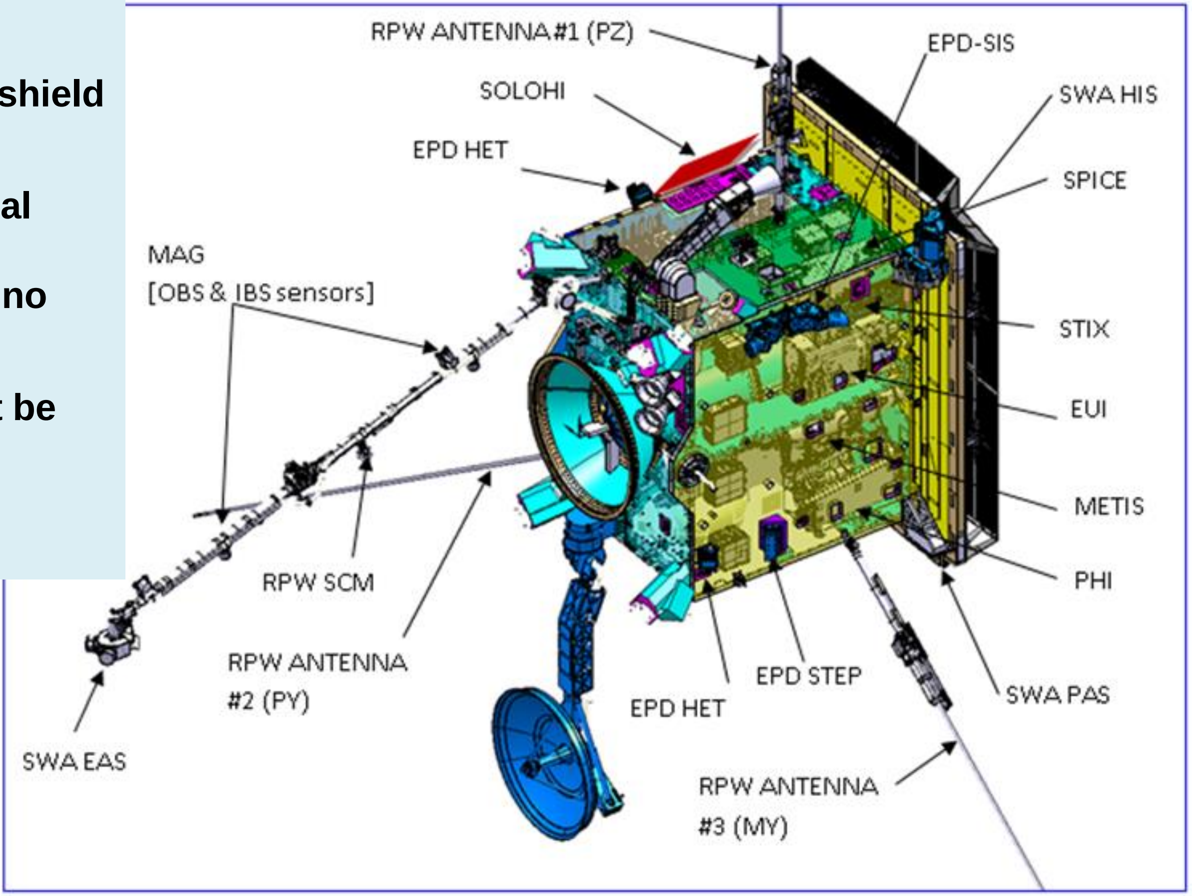
Solar Orbiter

- Close to the Sun (0.28 AU)
- Long duration observations of the same region
- Remote measurements of the Sun and corona
- Local measurements of magnetic and electric fields and particles.
- Out of the ecliptic plane…better to see the Sun's polar activity
- Measure the solar wind
- Solar eruptions

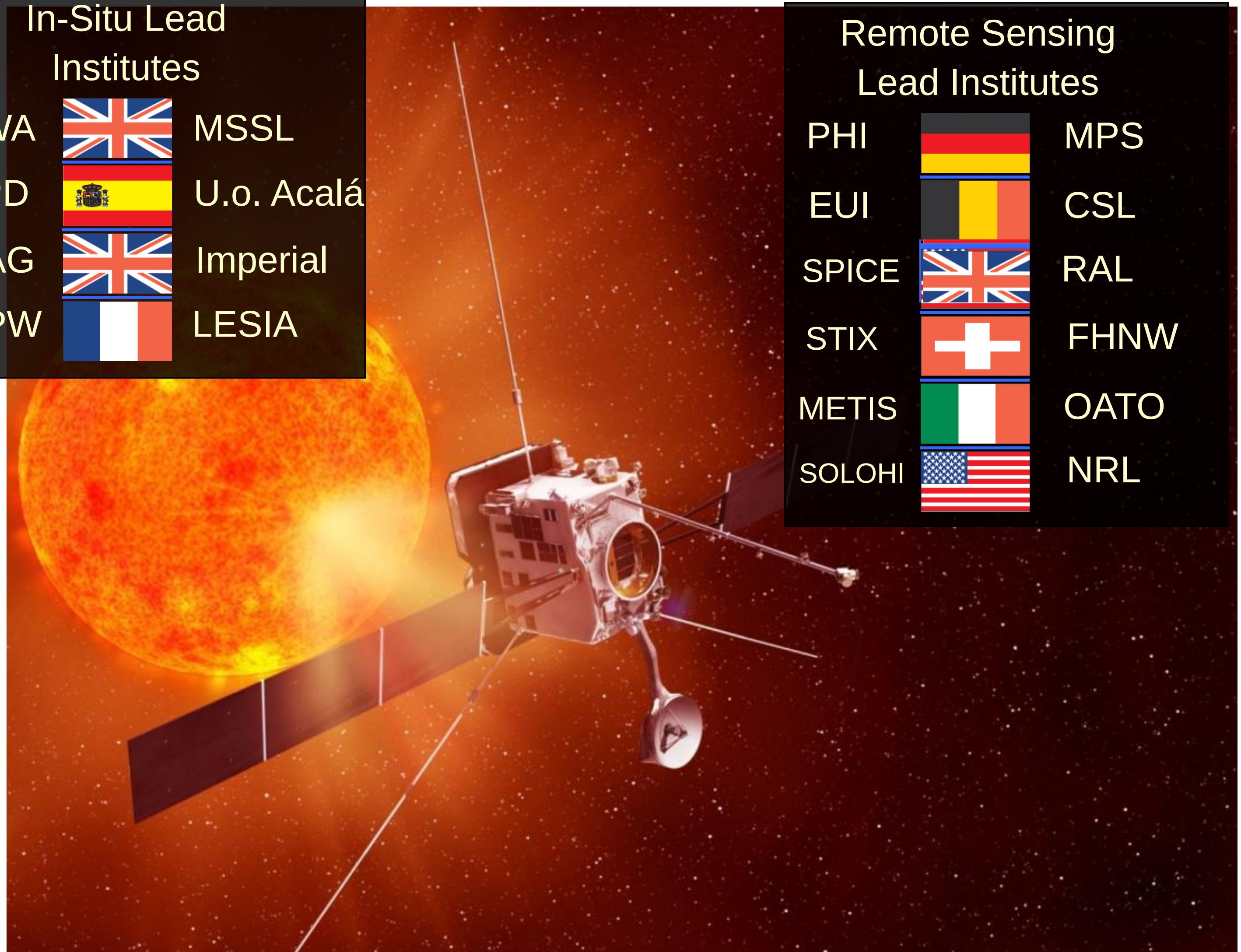


Solar Orbiter

- **Densely populated: completely packed with scientific instruments to maximise science return**
- **Thermal environment: heat-shield keeping equipment cool,**
- **Cleanliness: precision optical instruments and particle detectors/high-voltages- so no contamination.**
- **EMC (elec/mag fields): must be minimised for RF/magnetic sensors. Extreme control of spacecraft environment.**



International teams



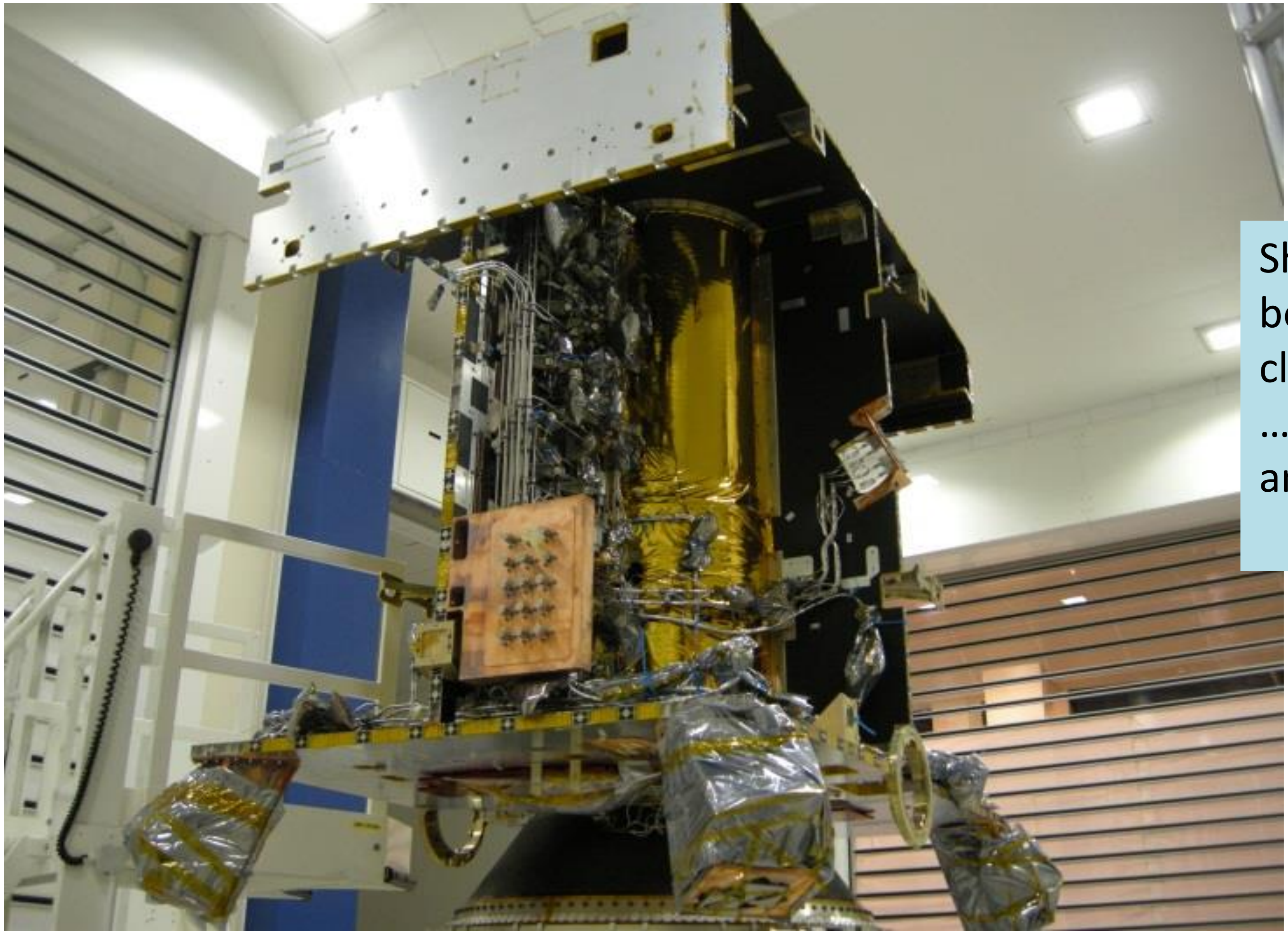
In-Situ Lead Institutes

SWA	UK	MSSL
EPD	Spain	U.o. Acalá
MAG	UK	Imperial
RPW	France	LESIA

Remote Sensing Lead Institutes

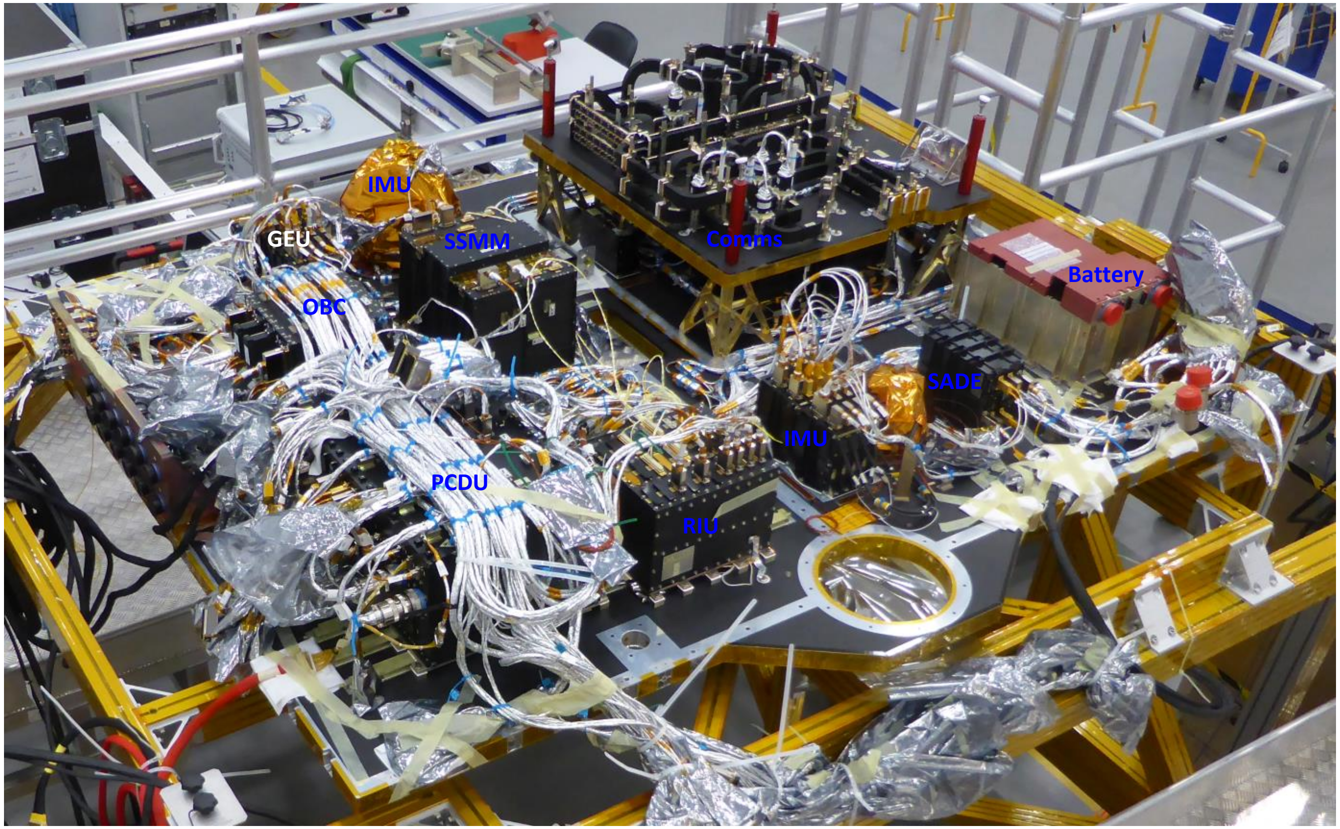
PHI	Germany	MPS
EUI	Belgium	CSL
SPICE	UK	RAL
STIX	Switzerland	FHNW
METIS	Italy	OATO
SOLOHI	USA	NRL

Solar Orbiter- being built

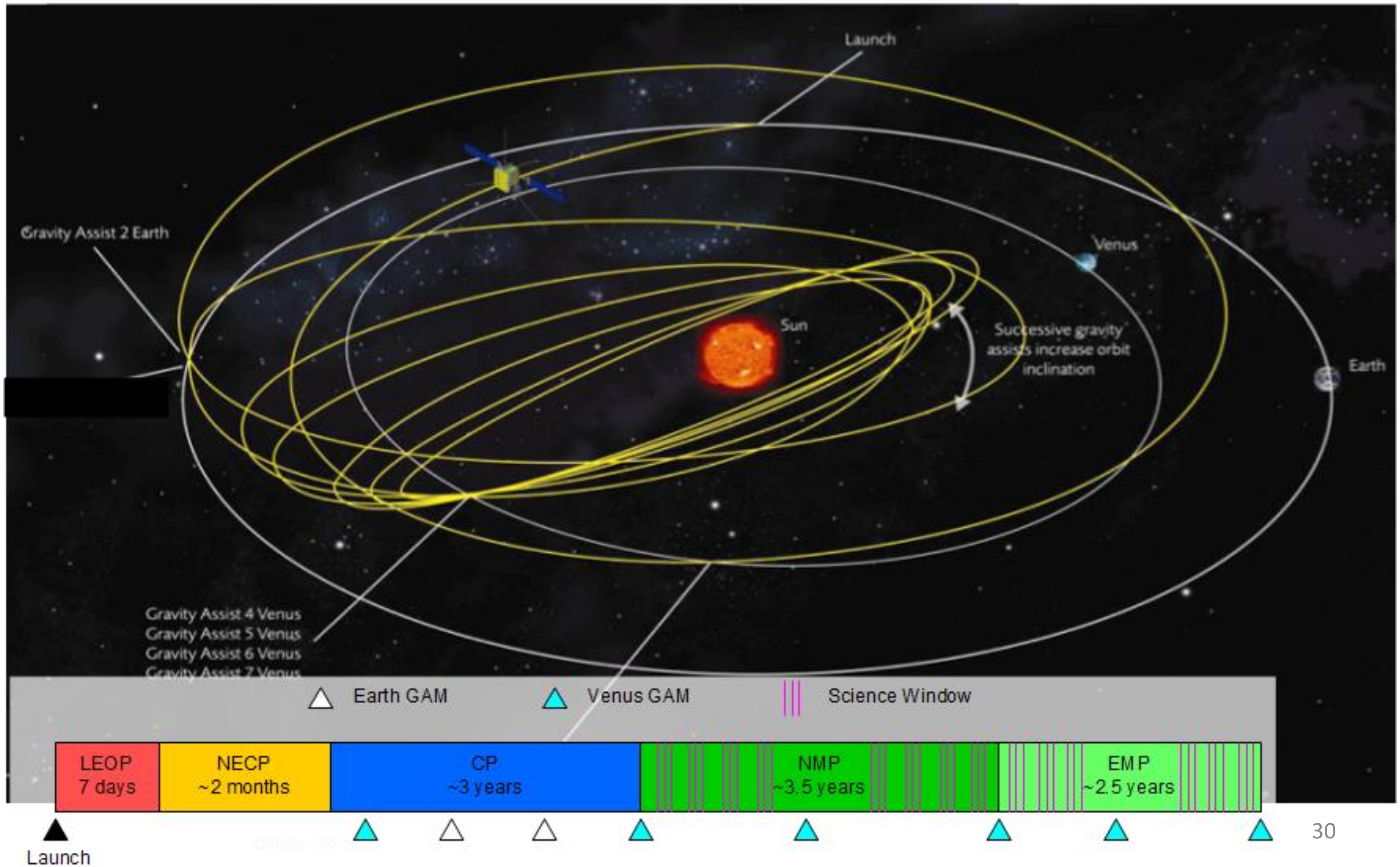


Shows the core structure being assembled in the clean room
…before testing in 2017 and 2020 launch.

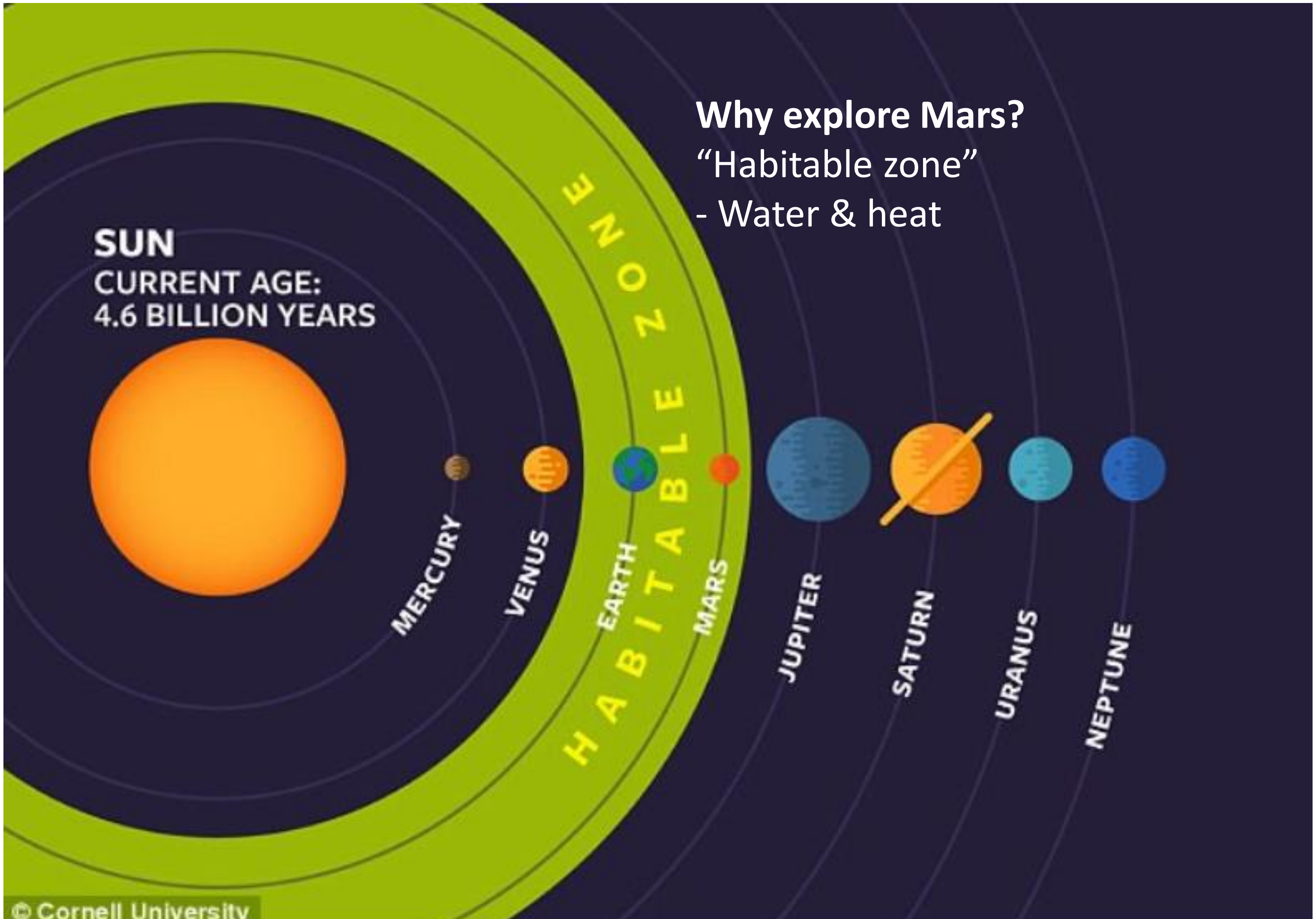
Solar Orbiter being tested



Solar Orbiter - trajectory to the sun



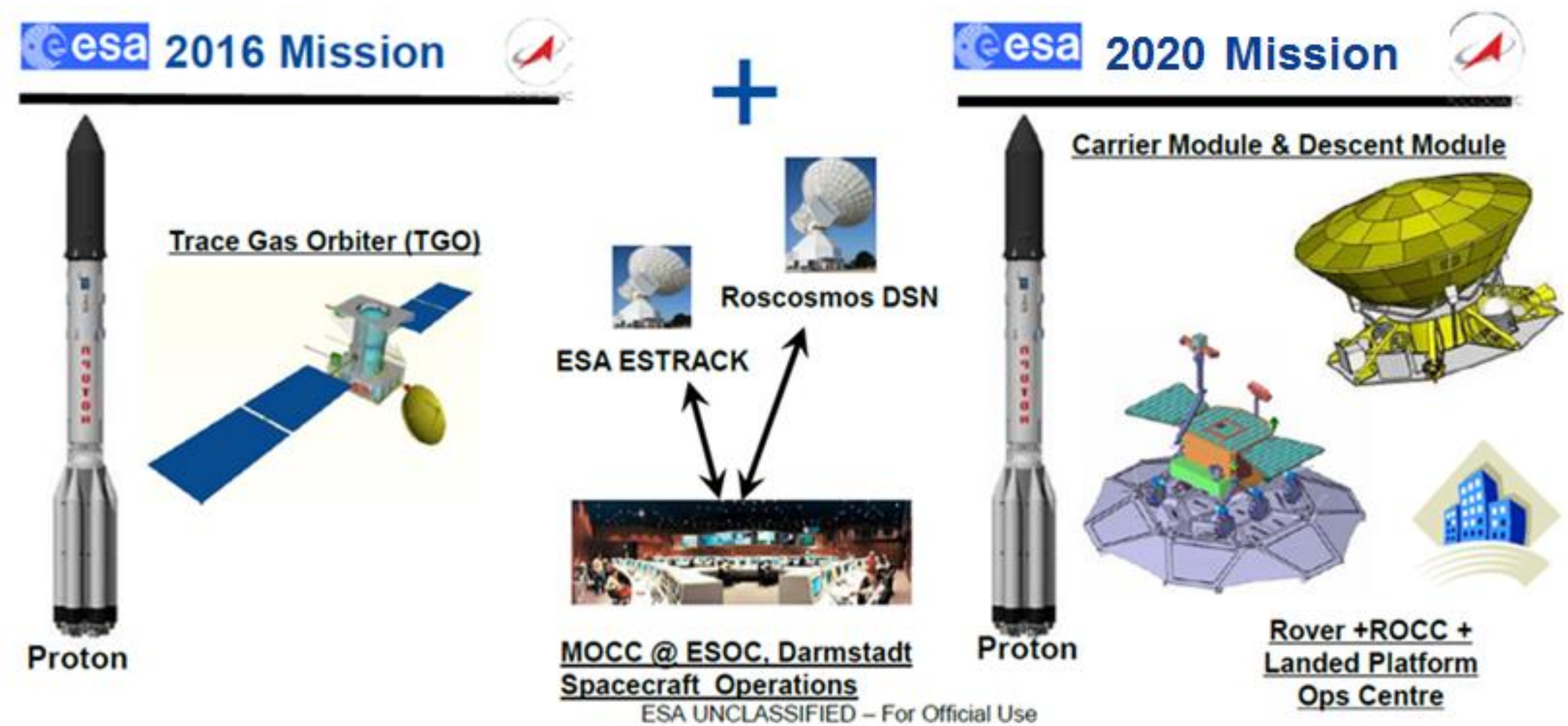
Mars



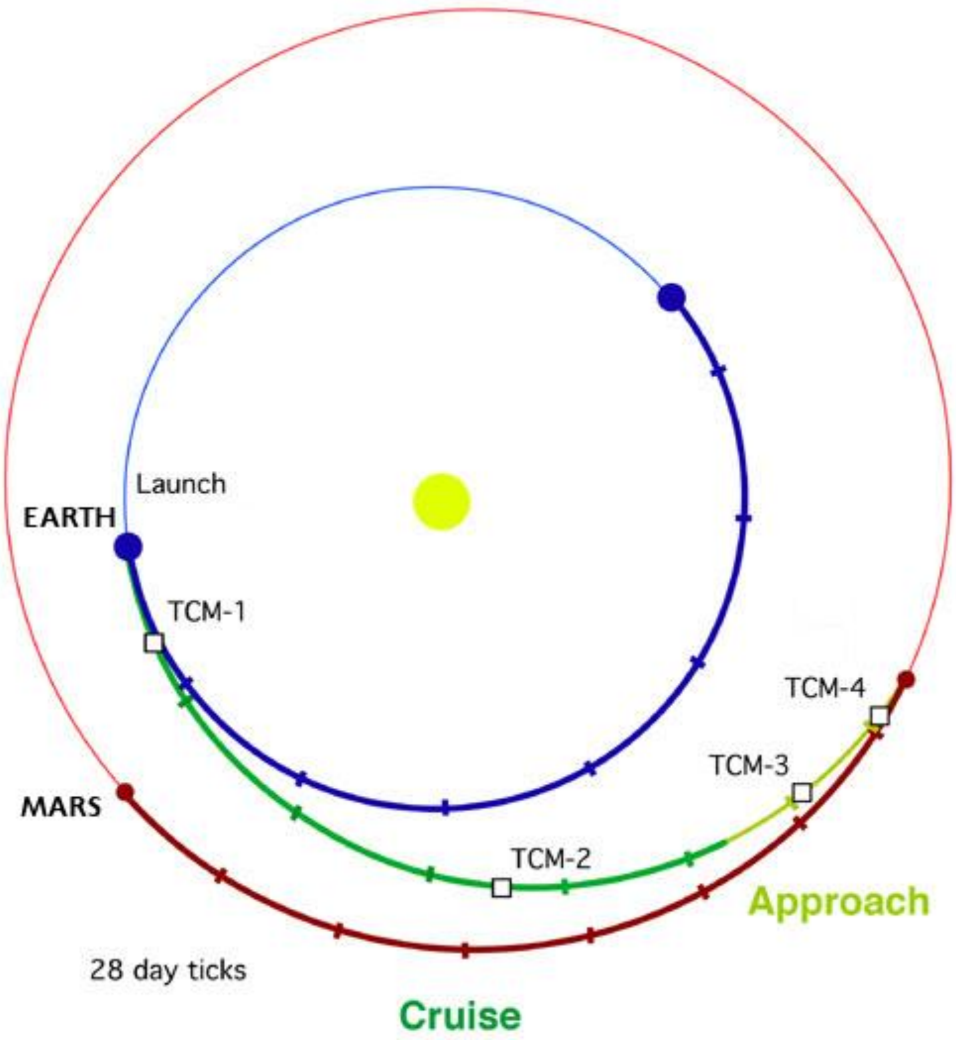
Why explore Mars?
"Habitable zone"
- Water & heat

ExoMars Mission

- **ExoMars Missions:**
  - 2016 Mars Orbiter
  - 2020 Mars Rover

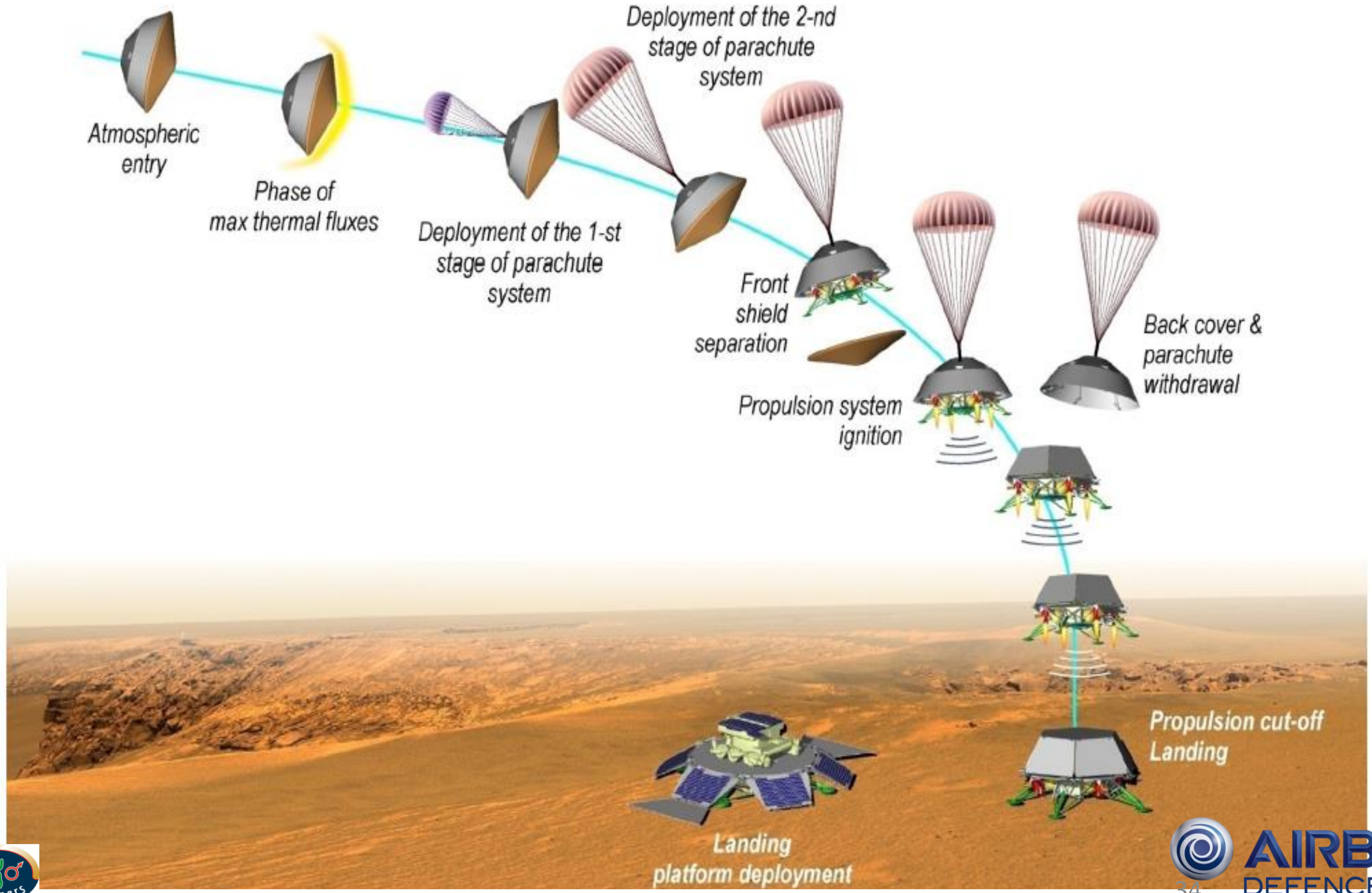


How does the rover get to Mars?



- **Mars is 30 million miles away from Earth**
- **The rover will be launched on a Proton rocket in 2020**
- **It will land on mars in 2021 after spending 9 months travelling through space.**

How does the rover land on Mars?



Exploring Mars

Martian rovers -different design features to satellites around the sun…. E.g..

- Cooler
- Less power available
- Communications depend on Earth-Mars orbits
- Dust storms on Mars.
  (Corrosive. Obscure vision)
- Gravity (1/3 earth)
- Navigation is different.

Results from a simulated traverse of the ExoMars rover through a rocky valley

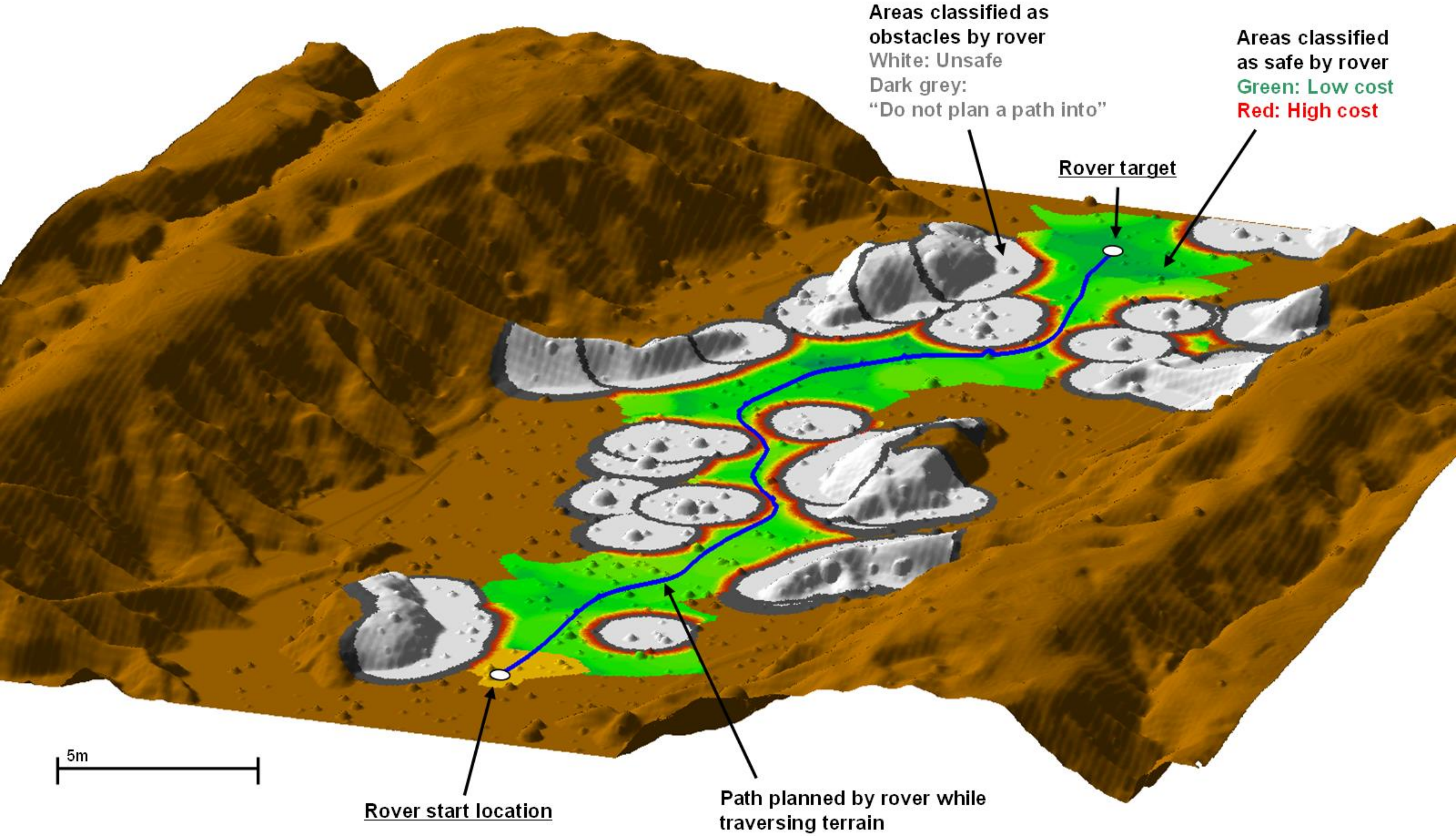
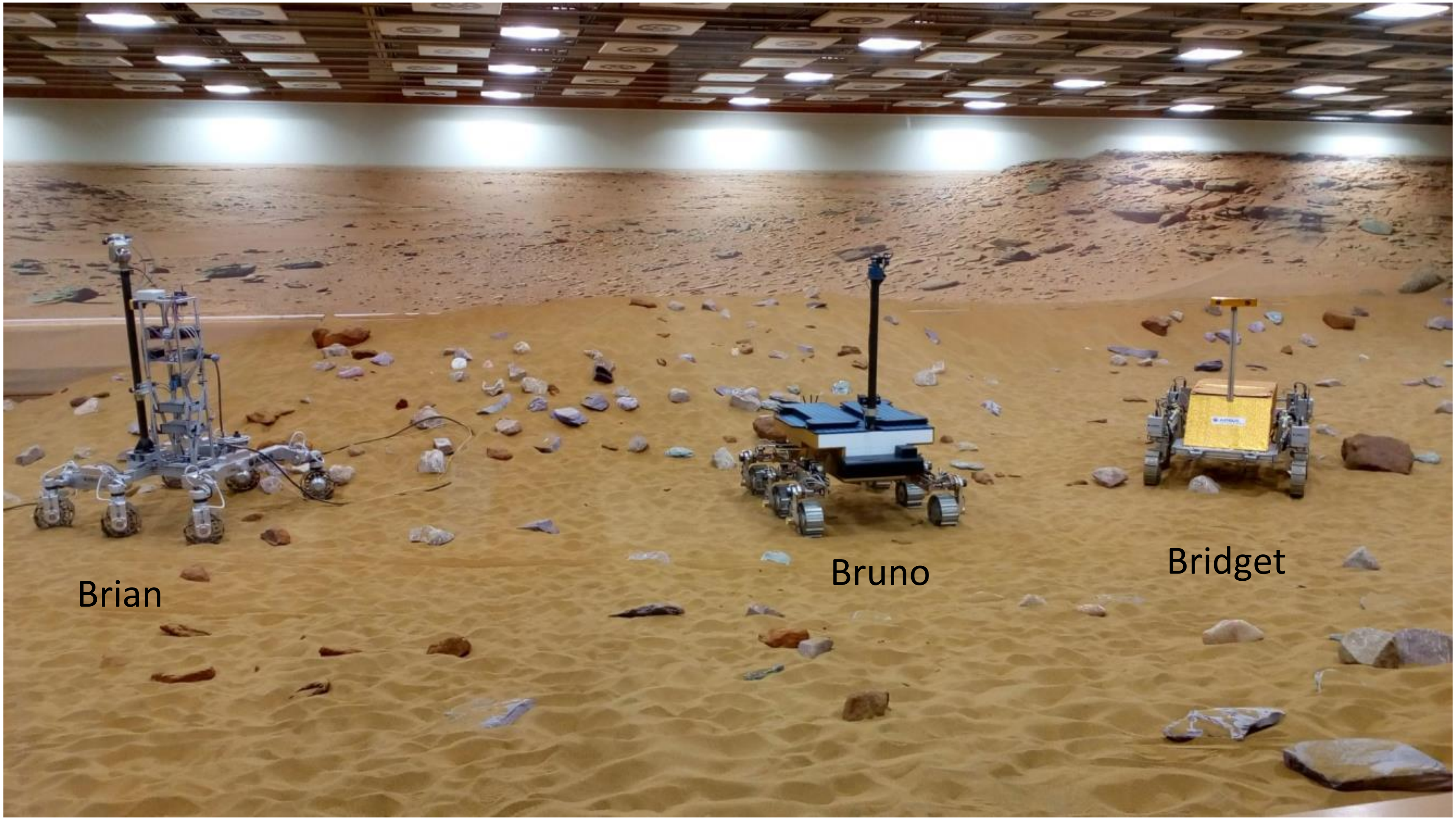
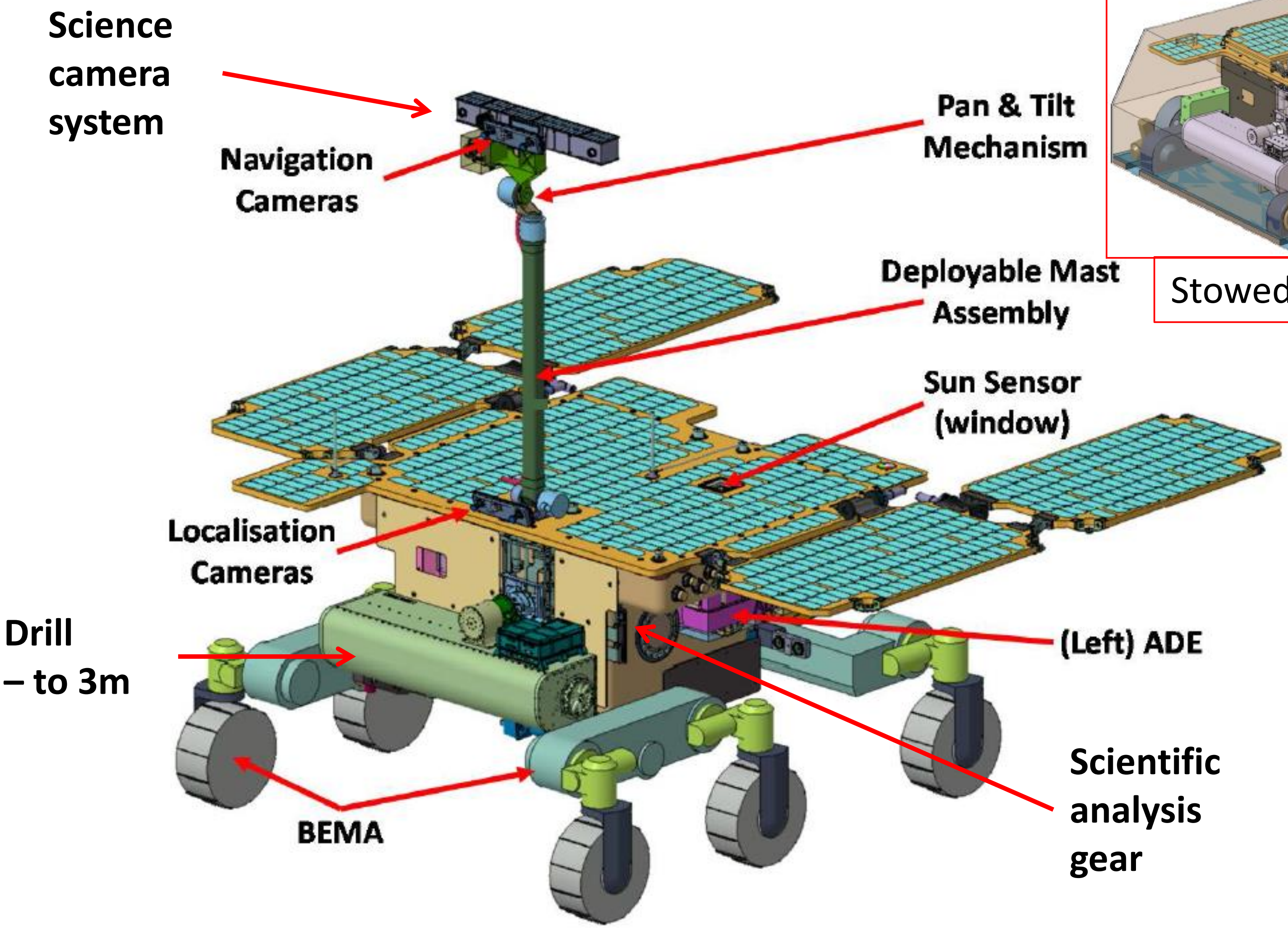


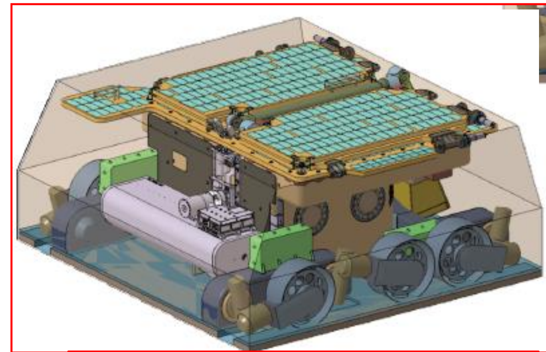
Image courtesy of ESA

Rovers – testing in Mars yard.



ExoMars rover schematic



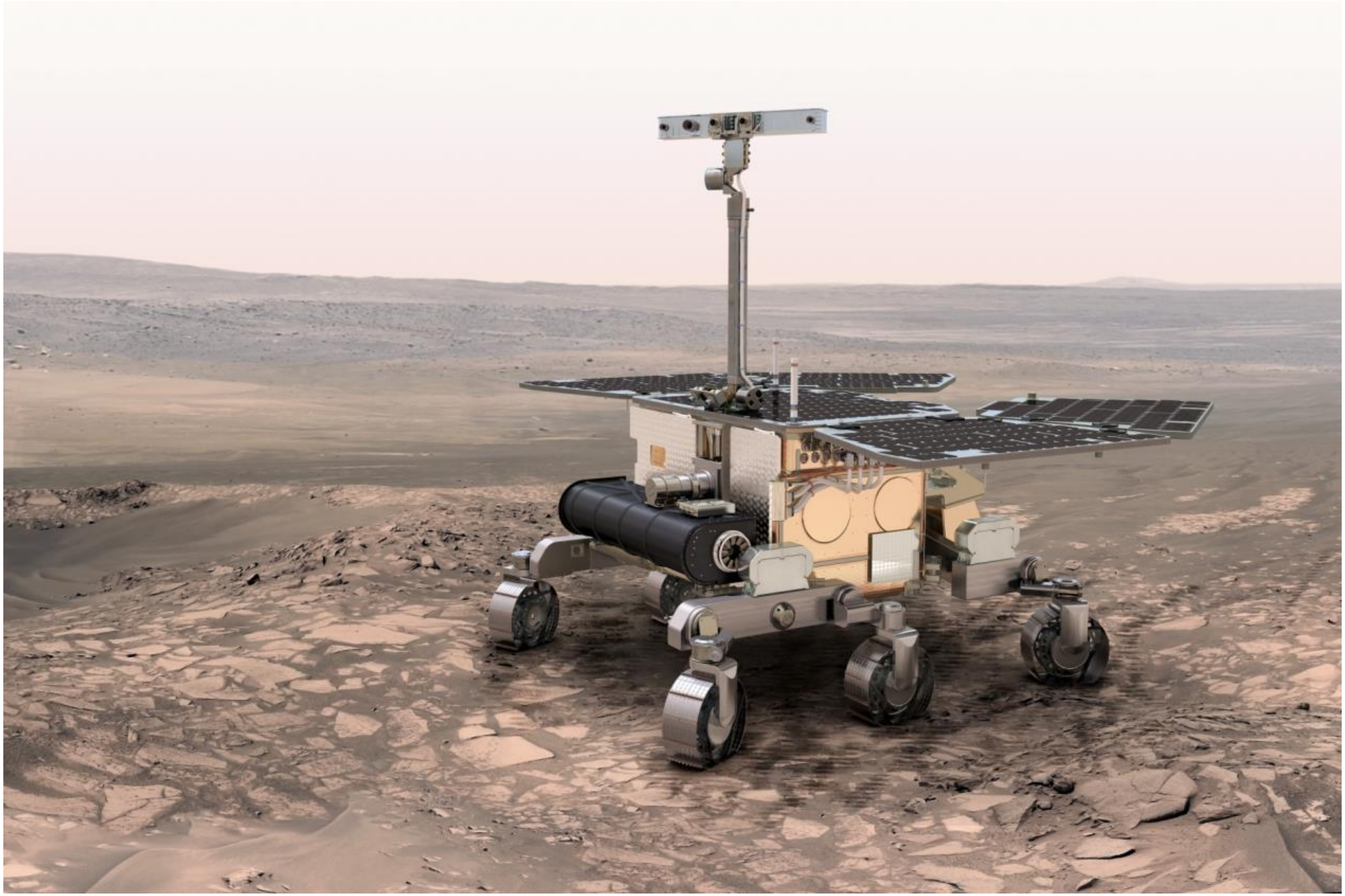


Stowed configuration

ExoMars rover instruments (payload)

- **PanCam (**Panoramic **Camera)** digital terrain mapping of Mars.
- **ISEM** - **Infrared Spectrometer** for **E**xo**M**ars- To assess the mineralogical composition of surface targets. Working with PanCam, ISEM will contribute to the selection of suitable samples for further analysis by the other instruments.
- **CLUPI** - **Cl**ose - **UP** **Imager** -acquire high-resolution colour close-up images of rocks, outcrops, drill fines
- **WISDOM** - **W**ater **I**ce and **S**ubsurface **D**eposit **O**bservation **O**n **M**ars and drill core samples - A ground-penetrating **radar** to characterise the stratigraphy under the rover. WISDOM will be used with **Adron**, which can provide information on subsurface water content, to decide where to collect subsurface samples for analysis.
- **Adron -** To search for subsurface water and hydrated minerals. Adron will be used in combination with WISDOM to study the subsurface beneath the rover and to search for suitable areas for drilling and sample collection. **A neutron spectrometer**
- **Ma_MISS** - Mars **Multispectral Imager** for Subsurface Studies -Located inside the drill, Ma_MISS will contribute to the study of the Martian mineralogy and rock formation.
- **MicrOmega -** A **visible plus infrared imaging spectrometer** for mineralogy studies on Martian samples.
- **RLS** - **Raman Spectrometer** - to establish mineralogical composition and identify organic pigments.
- **MOMA** – Mars Organic **Molecule Analyser** - MOMA will target biomarkers to answer questions related to the potential origin, evolution and distribution of life on Mars.

ExoMars rover-Mars in 2020



What next for Mars?

Cost:

- men to Mars (and back!)~ $500 billion
- Trump has authorised NASA to spend $19.5 billion

Challenges:

- Cost
- Radiation/habitation/water
- Planetary protection

How long a journey? (most efficient)

- ~9 months each way + 500 days on Mars

Sample Return: likely in 2020s

Robotics for sample return> video

Where have we landed-planets?

Body	Date/country	Mission
Mercury	Apr 2015: USA/NASA	Messenger -Intentionally crashed at end of mission.
Venus	1966- 1985. USSR.	Venera **x14** missions Vega 1 & 2 lander Some soft landings with data transmitted for ~ 1-2 hours. **First soft landing on a planet, in 1970.**
	Dec 1978: USA/NASA	Pioneer. Soft landing, data for ~ 1 hour.
Mars	1971-1974: USSR	Mars landers x3. No data after landing
	1976-2018: USA	Viking & Phoenix landers, Mars pathfinder +**Sojourner – 1st rover (1997)** MER rovers x2, Curiosity rover (2012) Insight lander (2018)
	2003: UK	Beagle 2 lander (no data).
	2016: ESA	ExoMars Schaparelli EDM lander: no data- crashed
Jupiter	2003: USA/NASA	Galileo - deliberately disintegrated in atmosphere
Saturn	2017: USA/NASA	Cassini orbiter deliberately crashed at end of mission

Not all landings are soft; some are hard=impacts, and some soft landings fail!

Ref: https://en.wikipedia.org/wiki/List_of_landings_on_extraterrestrial_bodies

Not just planets – other bodies…

Body	Date/country	Mission
Moon	1959 -1976: USSR	1st successful soft landing on the moon (1966). Luna including rover ('73) & sample return ('76)
	1962- 2009: USA/NASA	Ranger, Surveyor ,… LCROSS
	1969 - 1972	Apollo: first manned landing (Apollo 11: 20 July 1969)
	1993 - 2009: Japan	Hiten, Selene, Kaguya (intentionally crashed)
	2006: ESA	SMART-1 (intentionally crashed)
	2008: India	Chandrayaan-1 (impacted: found water)
	2009 - 2019: China	Chang'e 1 , 3, 4 (3 & 4 with rovers) 2013: 1st soft landing since USSR in 1966
Phobos (Mars)	1989: USSR	attempted landing, but failed
Titan (Saturn)	2005: ESA	Huygens probe - soft landing and data for 90 mins
Asteroids	2001: USA	NEAR Shoemaker: 16 days data
	2005 Japan 2018: Japan	Hayabusa - returned dust to Earth Hayabusa2 - 2 rovers landed
Comets	2005: USA	Impact made
	2014: ESA	Philae lander - limited success after bouncing…

Background pic.
Huygens probe
Titan.2005

Exploring without landing

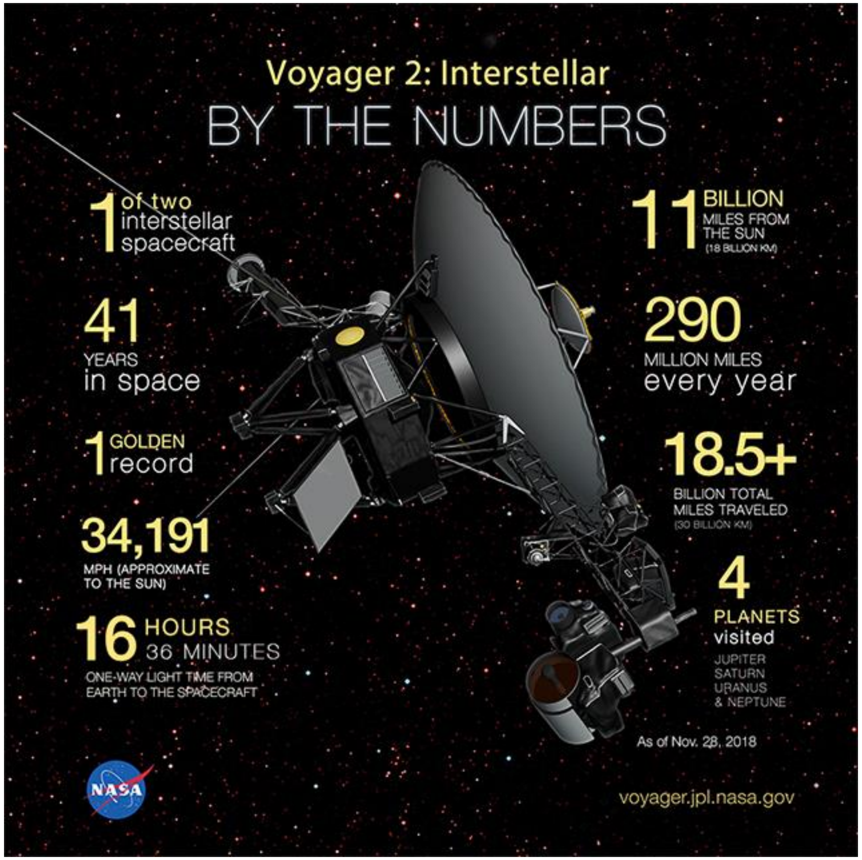
Many 'probes' have been sent to explore the solar system.
Almost 200 such missions, summarised below:

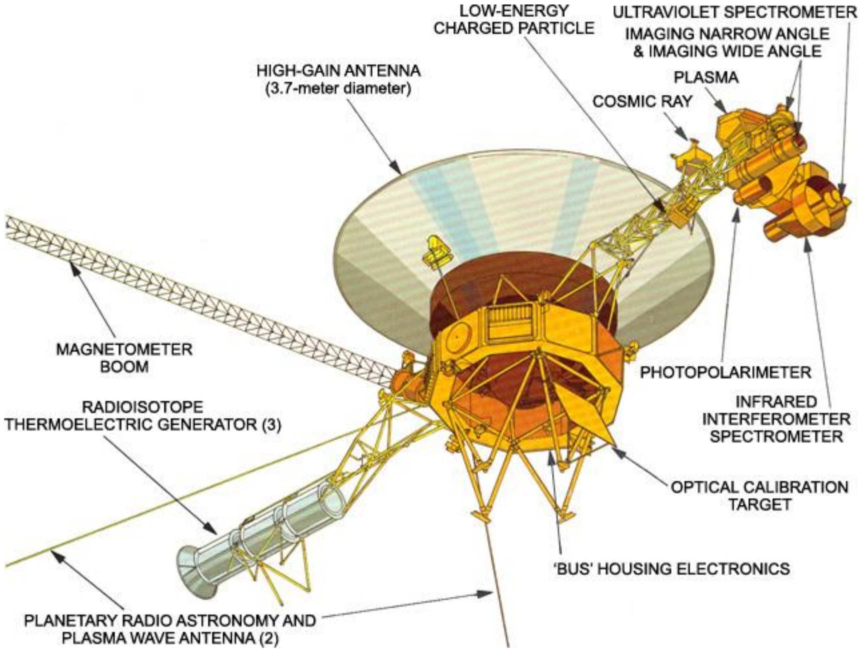
- **Sun:** 1969-present (USA, Europe). ~ 20 missions
- **Mercury**: 1974 onwards (USA, Europe, Japan). 3 missions
- **Venus:** 1961 onwards (USSR, USA). ~50 missions.
  Most failed in 60's!
- **Mars:** 1960 onwards
  (USSR, NASA, Japan, Europe, China, India) ~50 missions
- Plus **Phobos & Ceres** probes
- **Asteroids:** 1991 onward (NASA mainly). ~30 missions
- **Jupiter:** 1973 onwards (NASA, Europe). 12 missions
- **Saturn:** 1979 onwards (NASA mainly, 1 Europe). 4 missions
  Plus **Titan:** 2005 (Europe) 1 mission
- **Uranus**: 1986 (NASA). Voyager 2 1 mission
- **Neptune:**1989 (NASA). Voyager 2 1 mission
- **Pluto:** 2015 (NASA). New Horizons 1 mission
- **Comets:** 1985-2014 (NASA, Russia, India, Europe, Japan) … lots.

21 Dec 2018.
Juno mission to Jupiter- red spot & dust storms

https://en.wikipedia.org/wiki/List_of_Solar_System_probes

Voyager spacecraft (NASA) the ultimate explorer?



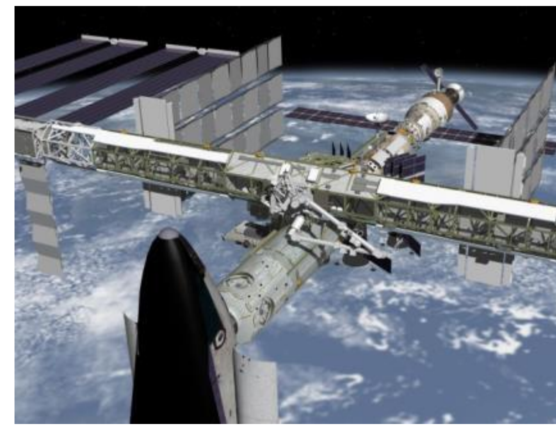


Any limits to space exploration?

- Started with looking at planets with telescopes on Earth. Galileo and before…
- Then bigger telescopes on earth -looking beyond the solar system
- Then satellites around planets and space telescopes to look deep into space.
- Satellites already at the limit of the solar system and beyond

What's next for humans in space?

- Falcon 9 (SpaceX) – privately funded rocket has launched satellites into space (2017- 2018)
  ..could take humans into space e.g. to ISS first, then the moon (2023?)
- Virgin Galactic – space tourism
  … just to the edge of space.



- But, not yet for Mars … 2030s earliest…
  … we have not even yet returned a sample of rock from Mars, let alone a human!
- Sample return NASA-ESA … 2020-2030

… questions?