

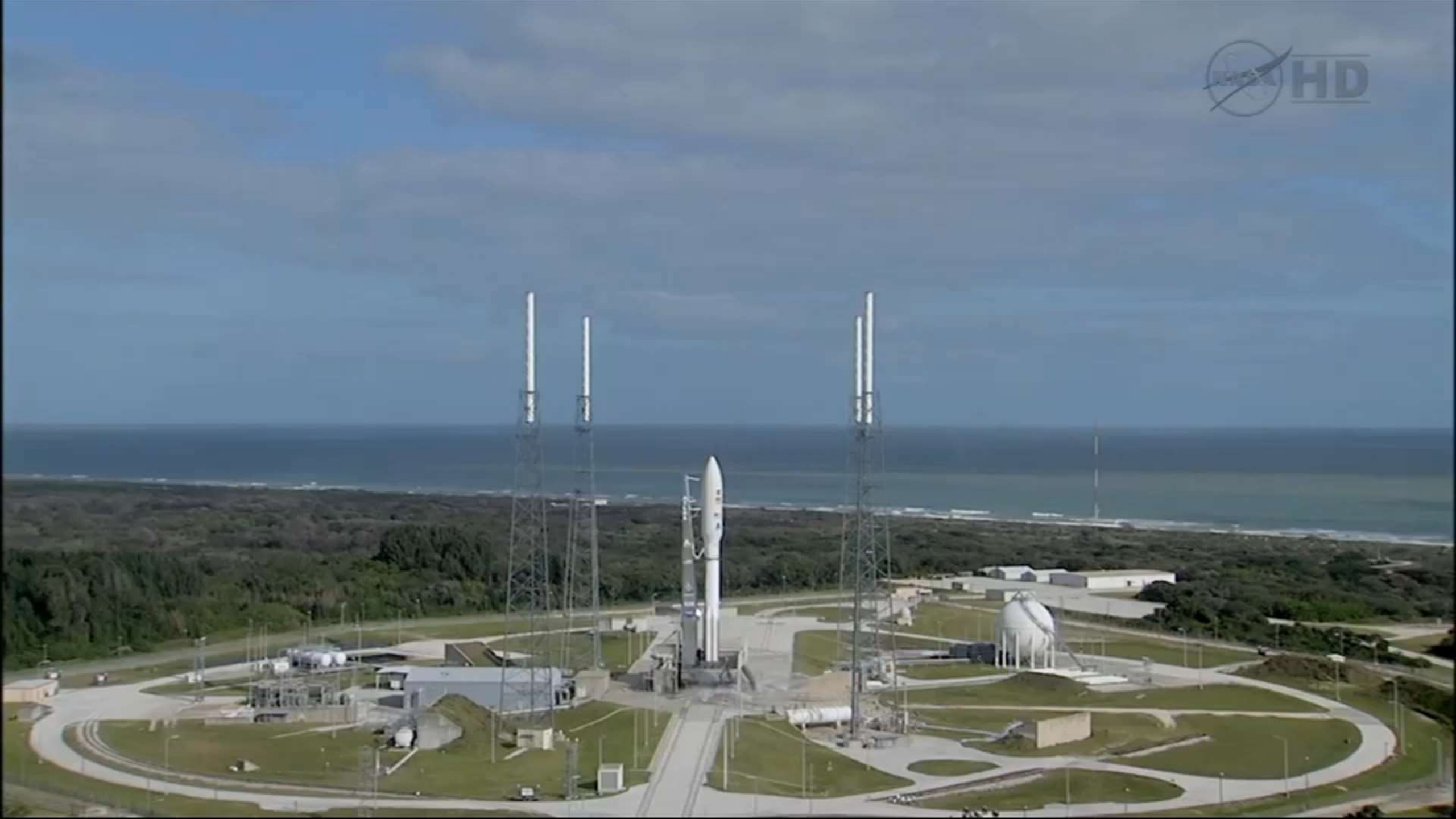


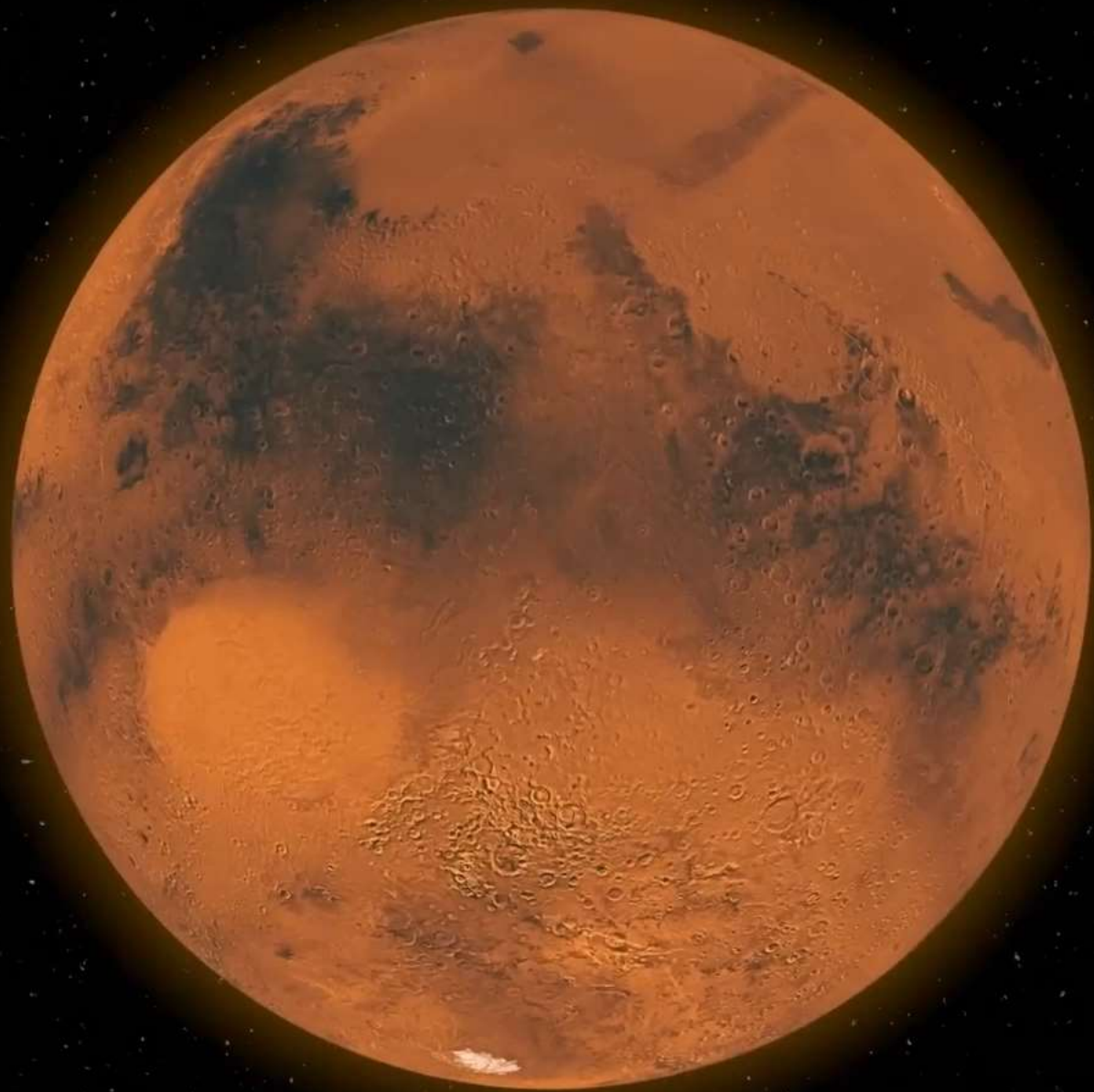
framatome

A Journey to Mars

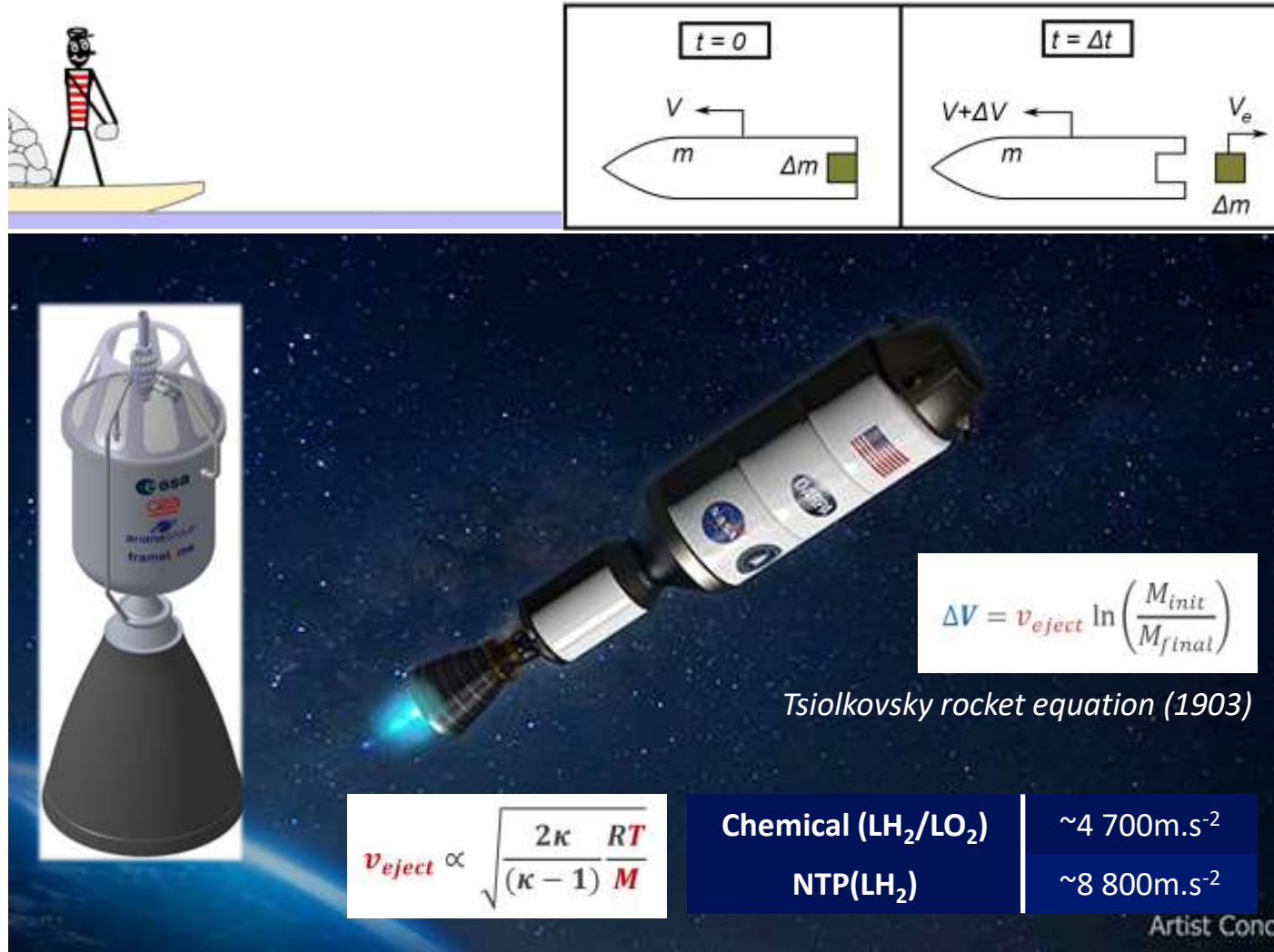
Yannick d'Escatha
Grégoire Lambert

framatome
Space

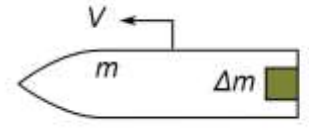




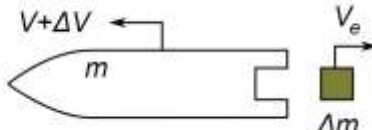
Nuclear Thermal Propulsion



$t = 0$



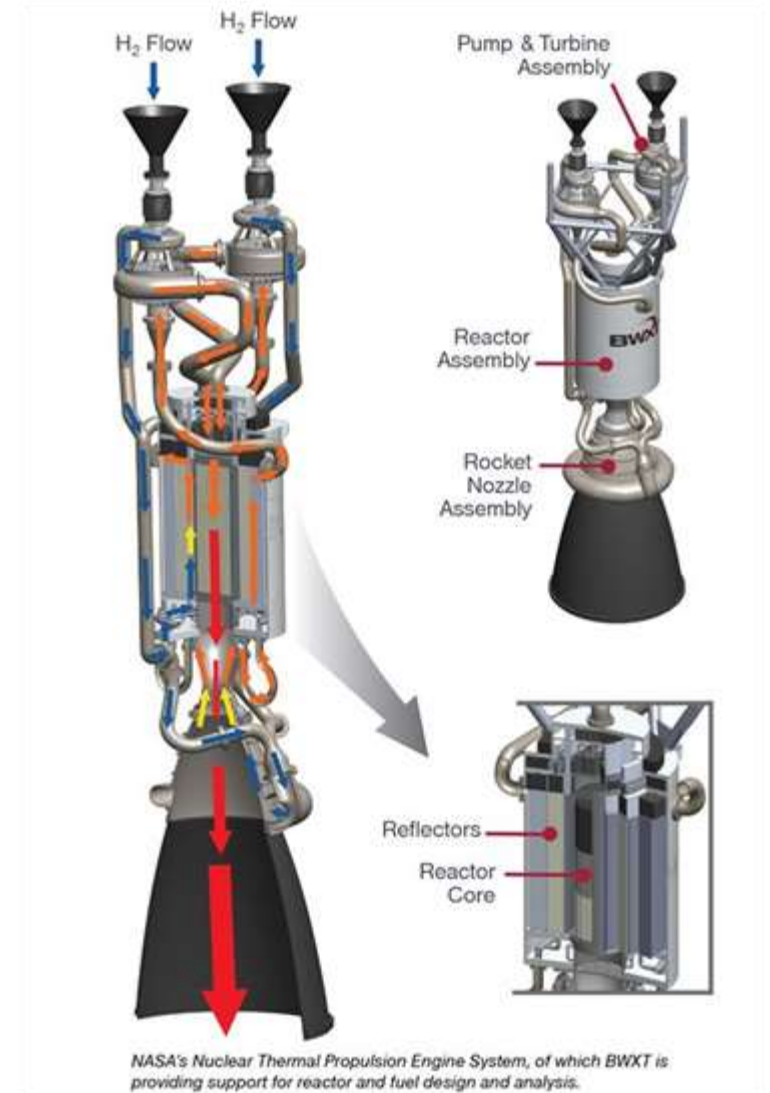
$t = \Delta t$



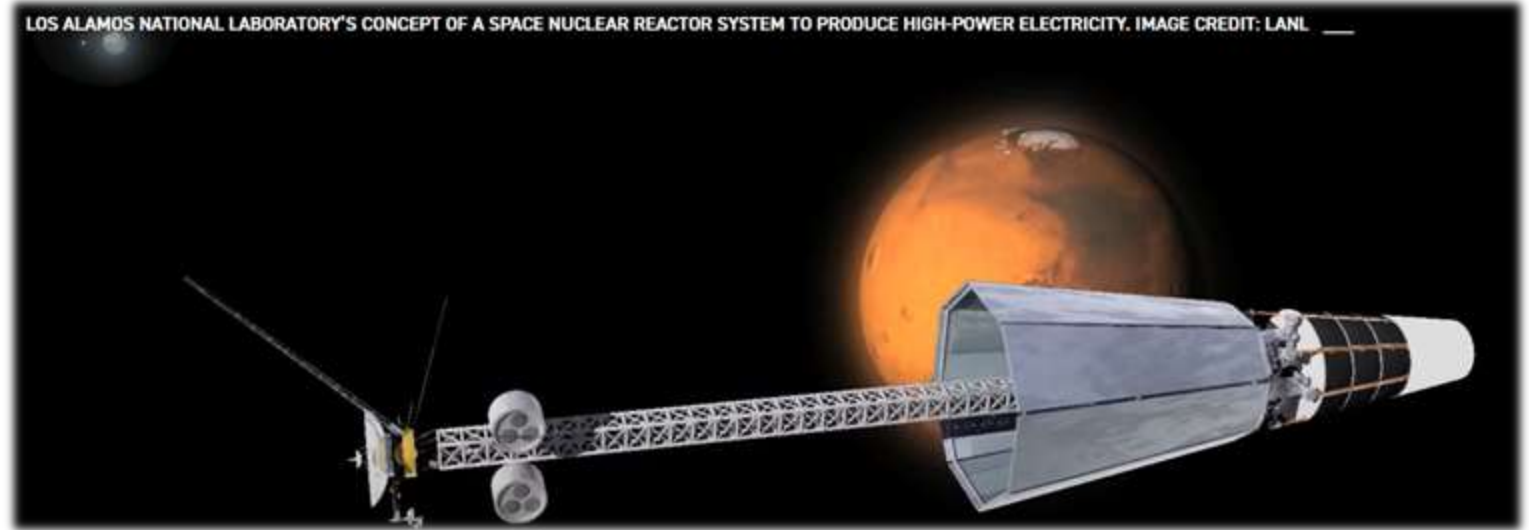
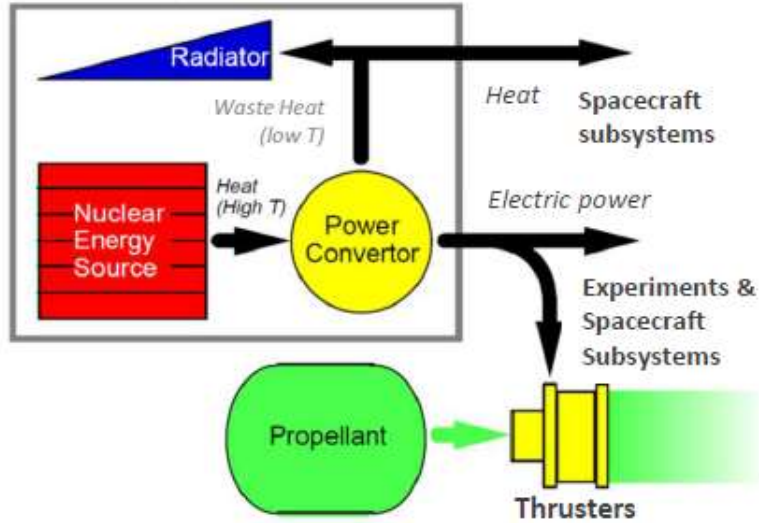
$$\Delta V = v_{eject} \ln \left(\frac{M_{init}}{M_{final}} \right)$$

Tsiolkovsky rocket equation (1903)

$v_{eject} \propto \sqrt{\frac{2\kappa}{\kappa-1} \frac{RT}{M}}$	Chemical (LH ₂ /LO ₂)	~4 700m.s ⁻²
	NTP(LH ₂)	~8 800m.s ⁻²



Nuclear Electrical Propulsion



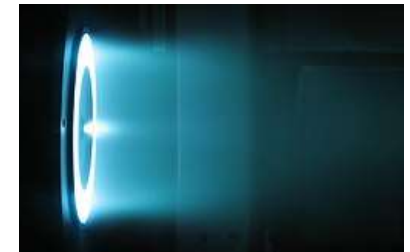
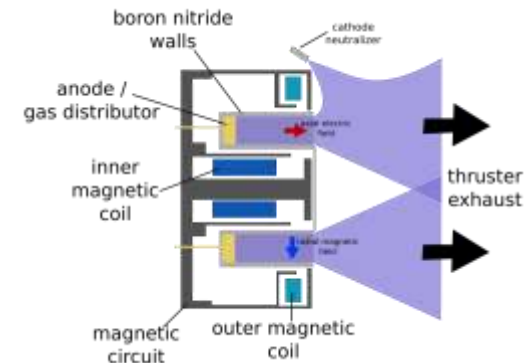
$$\Delta V = v_{eject} \ln \left(\frac{M_{init}}{M_{final}} \right)$$

Chemical (LH ₂ /LO ₂)	~4 700 m.s ⁻²
NTP(LH ₂)	~8 800 m.s ⁻²
NEP (Xe)	~29 000 m.s ⁻²

Specificity

- + High DeltaV
- Very Low Thrust
- Constant propulsion (no burst as thermal propulsion)

Hall Thruster (Test in NASA Jet Propulsion laboratory)



The Challenge of an Unforgiving World

A key step in the journey to Mars is to test a human Mars habitat. This will happen in the 2030s. But testing, surviving and ultimately thriving on the red planet – with its low gravity level, scorching temperatures, and nearly oxygen-free atmosphere – present several barriers for human colonization.

ATMOSPHERE

Today, Mars has an atmosphere pressure that's a tenth of Earth's, and it's not enough to support life. A human habitat on Mars will need to be airtight and have a way to produce oxygen and water, and eventually, perhaps even food. The impact of an atmosphere on climate is a complex one, but it's a key factor in the design of a human habitat.



TEMPERATURE

Like Earth, Mars has day and night, weather systems, and seasons, although the seasons are much more extreme. The temperature on Mars can range from -125°C to 20°C. A human habitat on Mars will need to be able to withstand these extreme temperatures.



VOLUME AND MASS

Mars is a small planet, with a volume that's only 15% of Earth's. This means that a human habitat on Mars will need to be able to store enough resources to support a human colony. The habitat will need to be able to store food, water, and oxygen.



DISTANCE

The distance between Earth and Mars is a major challenge for human colonization. The distance can range from 54.6 million km to 401 million km. A human habitat on Mars will need to be able to withstand the long journey.



NATIONAL GEOGRAPHIC

COLONIZING MARS

Could humans live on Mars? One day, perhaps. But making settlements there would be a terrifying task. The vision shown here is drawn from the National Geographic Channel's popular series on Mars. It reflects what some scientists are thinking right now, based on the latest research. There will still be a long way to go on the red planet.

Solutions for Survival

There are a number of solutions to the challenges of human Mars colonization. The first is to build a habitat that can protect humans from the harsh environment. The second is to build a habitat that can produce food, water, and oxygen. The third is to build a habitat that can withstand the long journey.

EXTRACTING WATER FROM AIR

Water is a key resource for human colonization. On Mars, water can be extracted from the air. This is done by using a process called atmospheric water extraction. The process involves using a special material to absorb water from the air. The water is then released by heating the material.



GETTING GROUNDWATER

Water is a key resource for human colonization. On Mars, water can be extracted from the ground. This is done by using a process called groundwater extraction. The process involves drilling a well into the ground and pumping water to the surface.



METHANE GENERATION

Methane is a key resource for human colonization. On Mars, methane can be generated from the atmosphere. This is done by using a process called methane generation. The process involves using a special material to absorb methane from the atmosphere.



POWER FROM THE SUN

Power is a key resource for human colonization. On Mars, power can be generated from the sun. This is done by using a process called solar power. The process involves using solar panels to convert sunlight into electricity.



PORTABLE POWER

Power is a key resource for human colonization. On Mars, power can be generated from a portable power source. This is done by using a process called portable power. The process involves using a special material to store power.



NUCLEAR POWER

Power is a key resource for human colonization. On Mars, power can be generated from a nuclear power source. This is done by using a process called nuclear power. The process involves using a special material to generate power.



MARTIAN GREENHOUSES

Greenhouses are a key resource for human colonization. On Mars, greenhouses can be built to grow food. This is done by using a process called Martian greenhouses. The process involves using a special material to grow food.



GROUP GREENHOUSE STANDARDS

Greenhouse standards are a key resource for human colonization. On Mars, greenhouse standards can be used to ensure that greenhouses are built to the same standards. This is done by using a process called greenhouse standards.



BETTER BREATHING THROUGH CHEMISTRY

Better breathing is a key resource for human colonization. On Mars, better breathing can be achieved through chemistry. This is done by using a process called better breathing through chemistry. The process involves using a special material to improve breathing.



LEARNING FROM MARS

Learning from Mars is a key resource for human colonization. On Mars, learning from Mars can be used to improve human colonization. This is done by using a process called learning from Mars. The process involves using a special material to learn from Mars.



HIDDEN GLACIERS

Hidden glaciers are a key resource for human colonization. On Mars, hidden glaciers can be used to provide water. This is done by using a process called hidden glaciers. The process involves using a special material to provide water.



MARS

To learn more about colonizing the red planet, tune in to the Channel's special event series, starting on November 1st at 8pm. For additional information, visit our website at www.nationalgeographic.com/mars.

Radioisotope Power System (RPS)

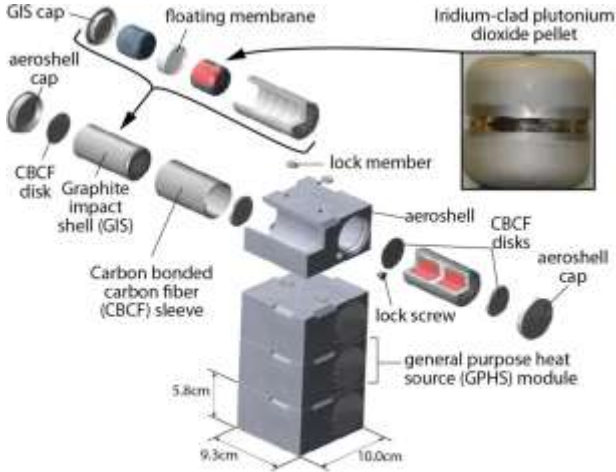
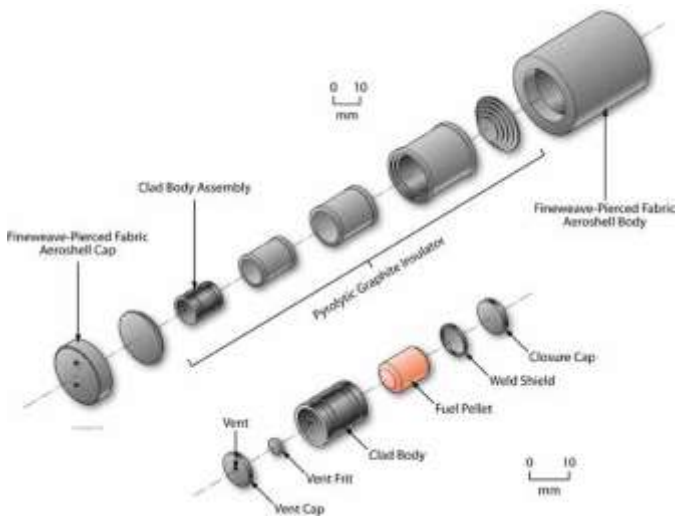
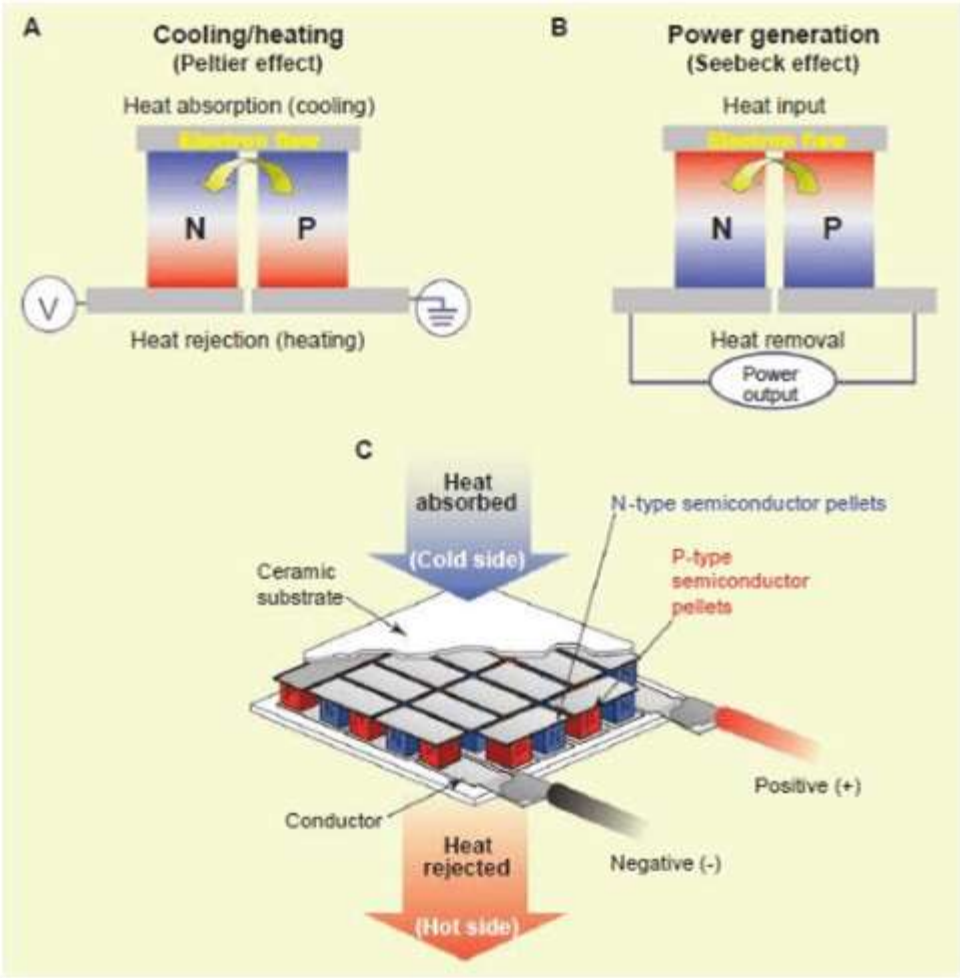
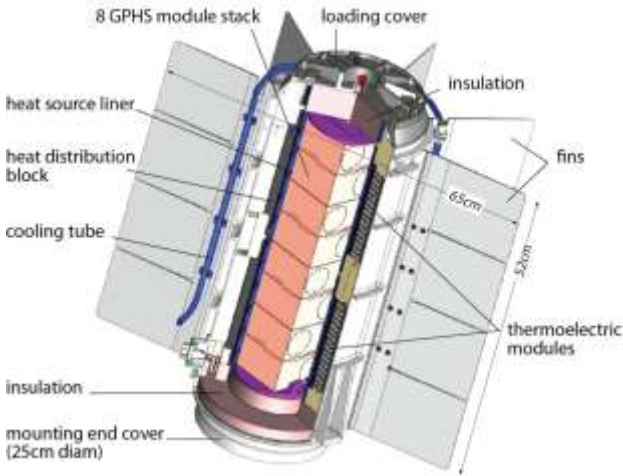


TABLE I. Attributes of Primary Candidate RHU and RTG Isotopes

Material	Shielding requirement	Power density (W _{th} /g) ¹	Half-life (years) ¹	Commercial Availability
²³⁸ Pu	Low	0.54	87.7	None ²
⁹⁰ Sr	High	0.46	28.8	Available ³
²¹⁰ Po	Low	140	0.378	None ⁴
²⁴¹ Am	Medium	0.114	432	Available ³



Fission Surface Power : an HTR

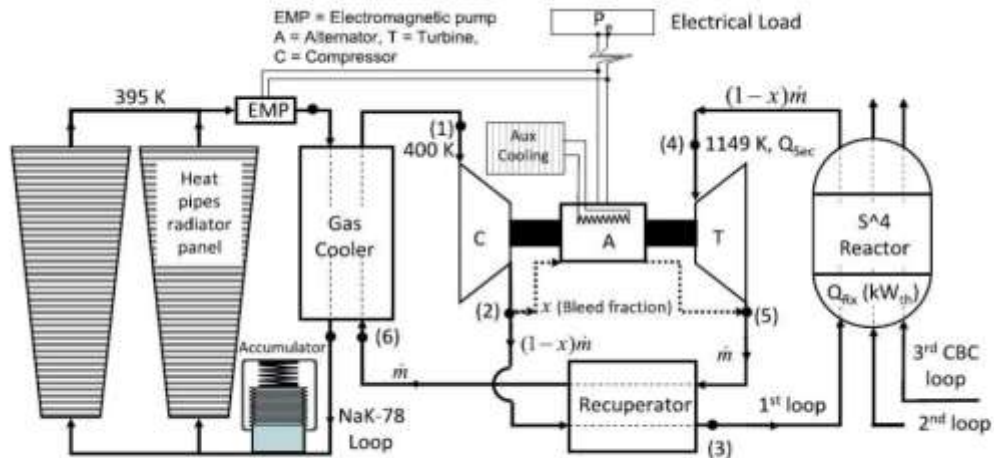
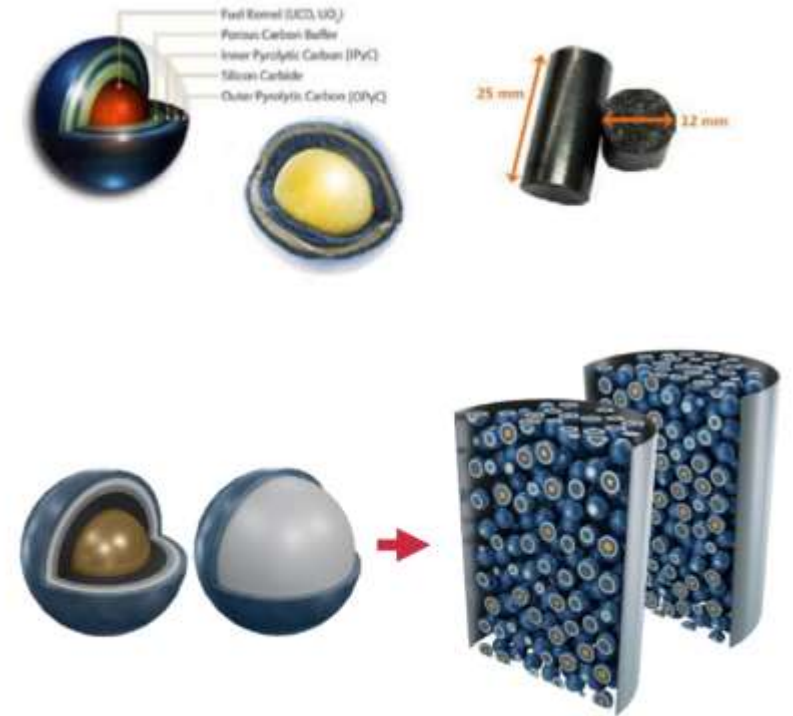


Figure 3: A CBC-space power system nominal operation parameters and layout [1].





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Thank
you