

CRASH COURS Nieuwe Maanmissies

Donderdag 28 november 2019

Pieter Mestdagh

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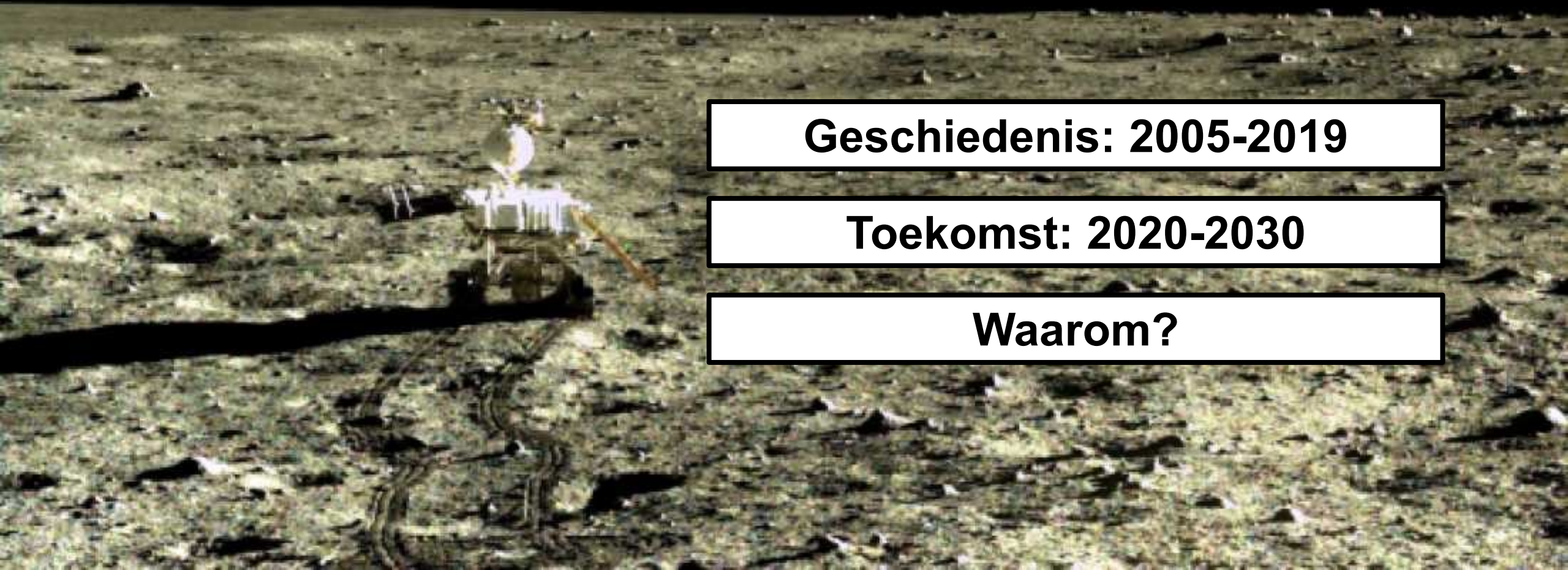
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Nieuwe Maanmissies

10:28



Geschiedenis: 2005-2019

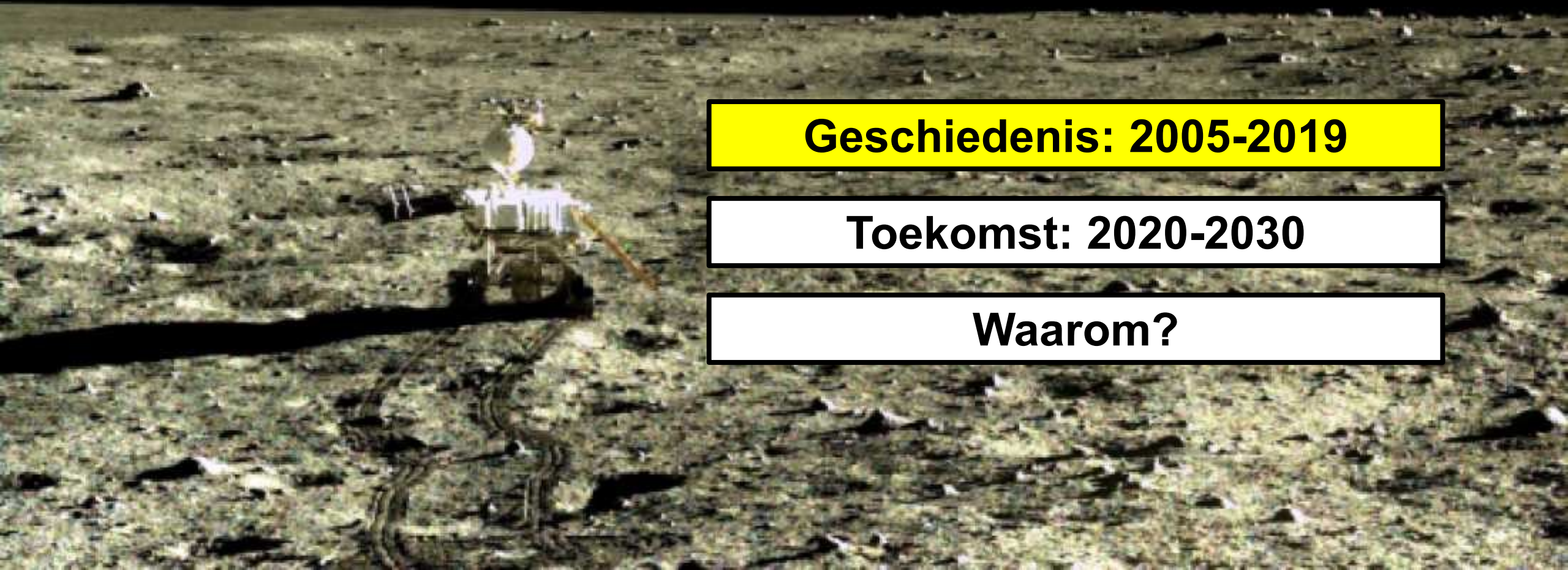
Toekomst: 2020-2030

Waarom?



Nieuwe Maanmissies

10:28

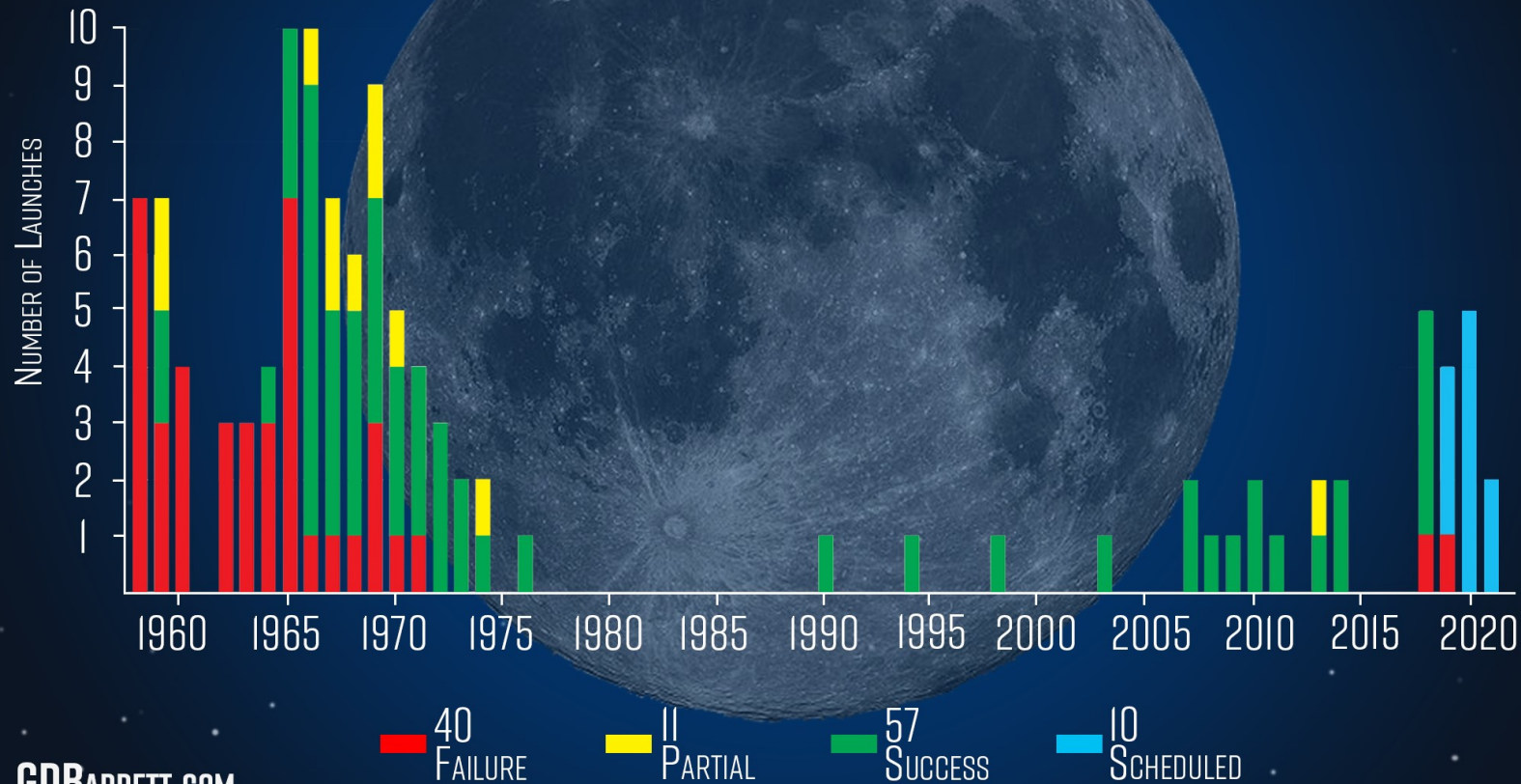


Geschiedenis: 2005-2019

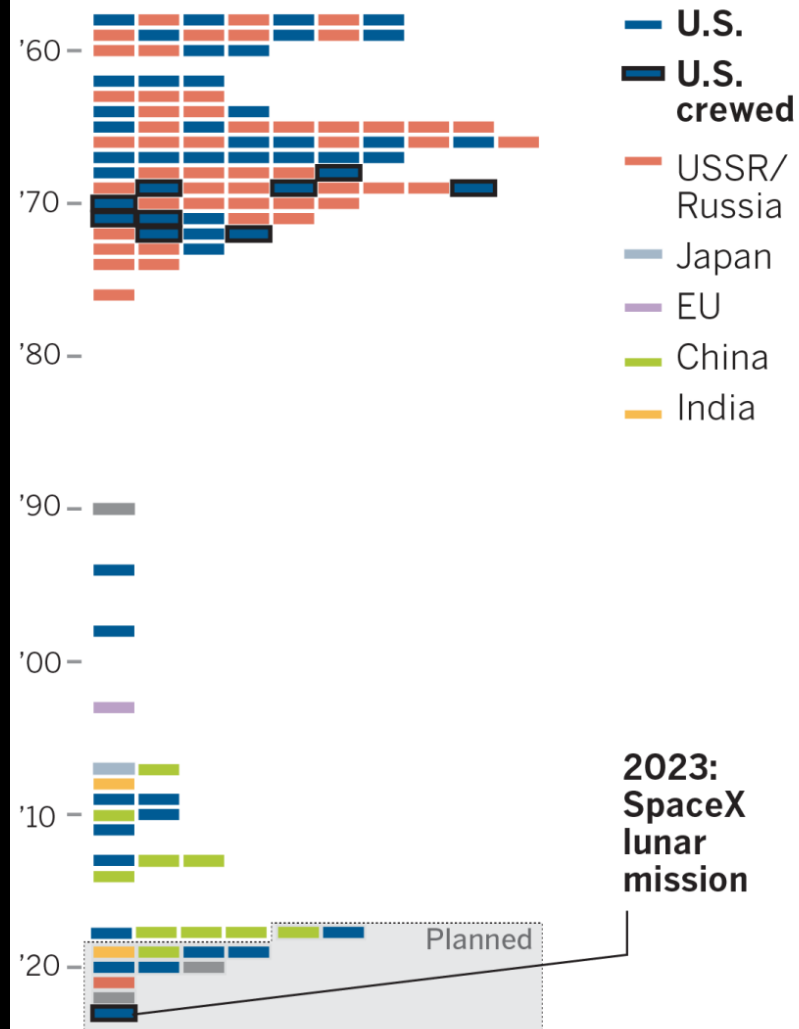
Toekomst: 2020-2030

Waarom?

EXPLORATION OF THE MOON YEARLY LAUNCHES TO THE MOON



Lunar missions over time

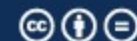


Sources: NASA; planetary.org; ISRO; JAXA; Gunter's Space Page

@latimesgraphics

The State Of NASA's Budget As Pence Seeks New Moon Landing

NASA's budget as a share of the U.S. federal budget from 1958 to 2017

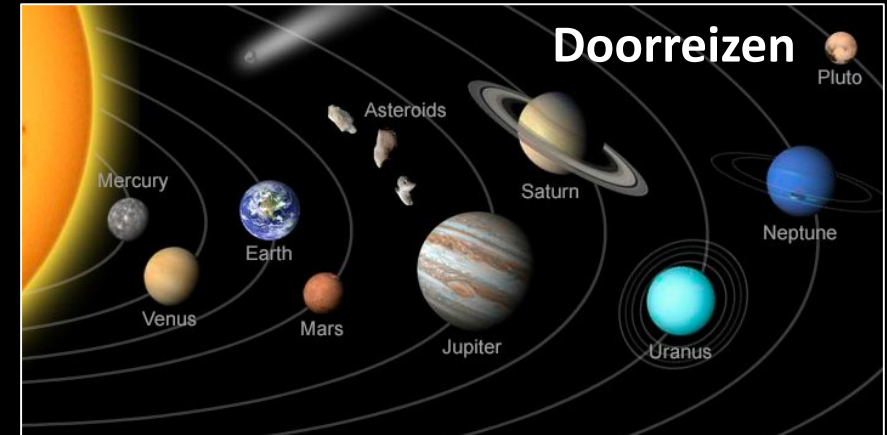


@StatistaCharts

Sources: The Guardian, Office of Management and Budget

statista

2005: goedkeuring Constellation Program

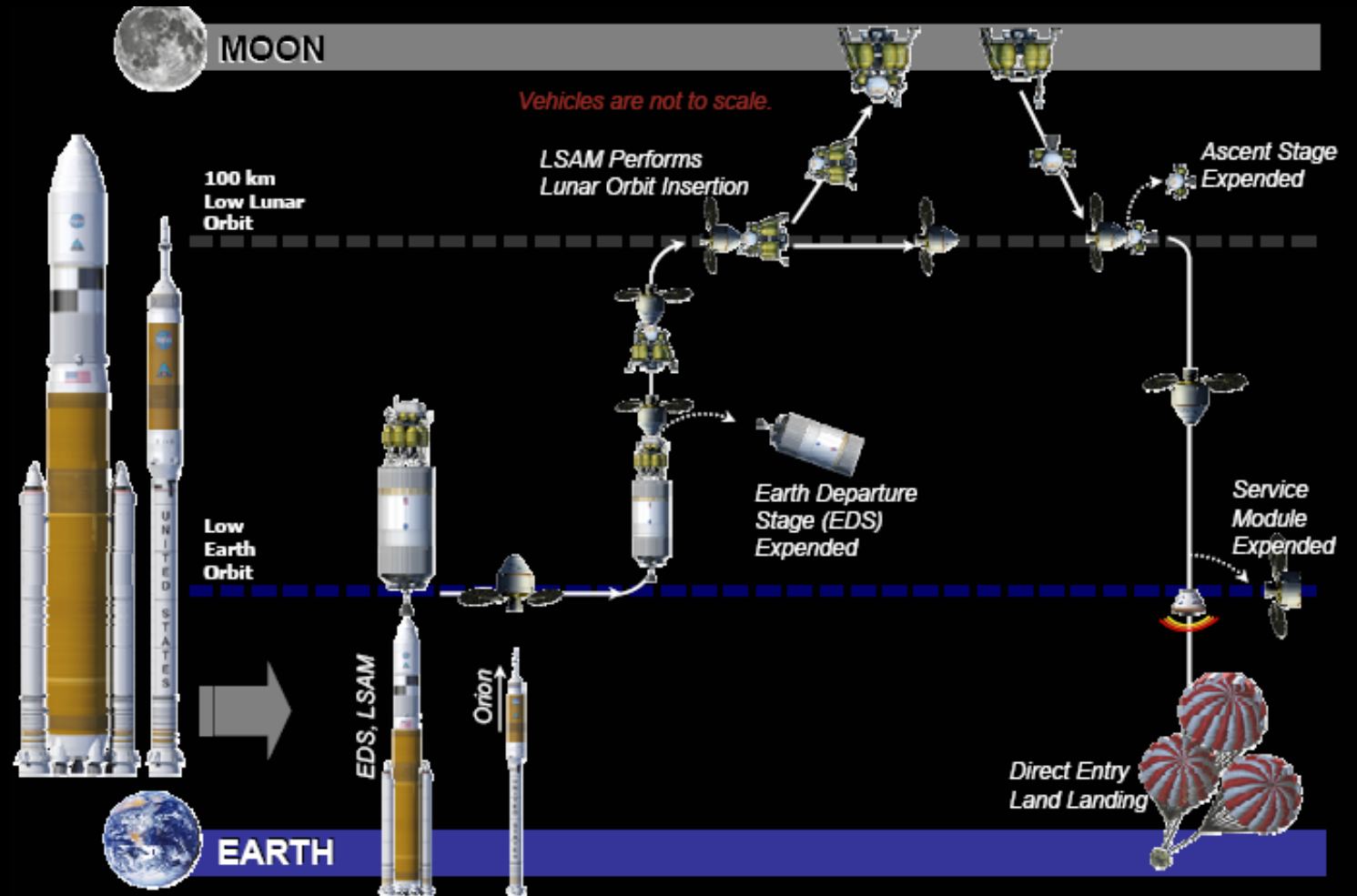
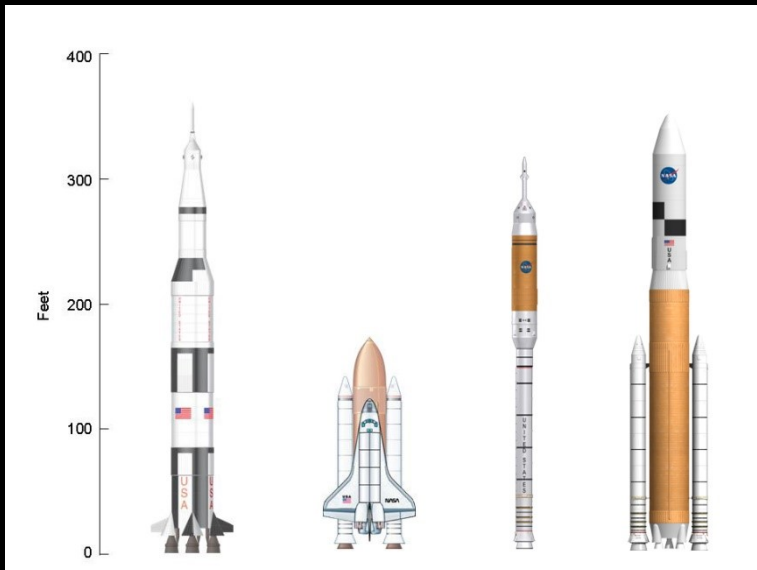


- “sustainable”
- Internationale partners
- Commerciële partners

2005: goedkeuring Constellation Program

ARES raket (CLV = Crew Launch Vehicle)

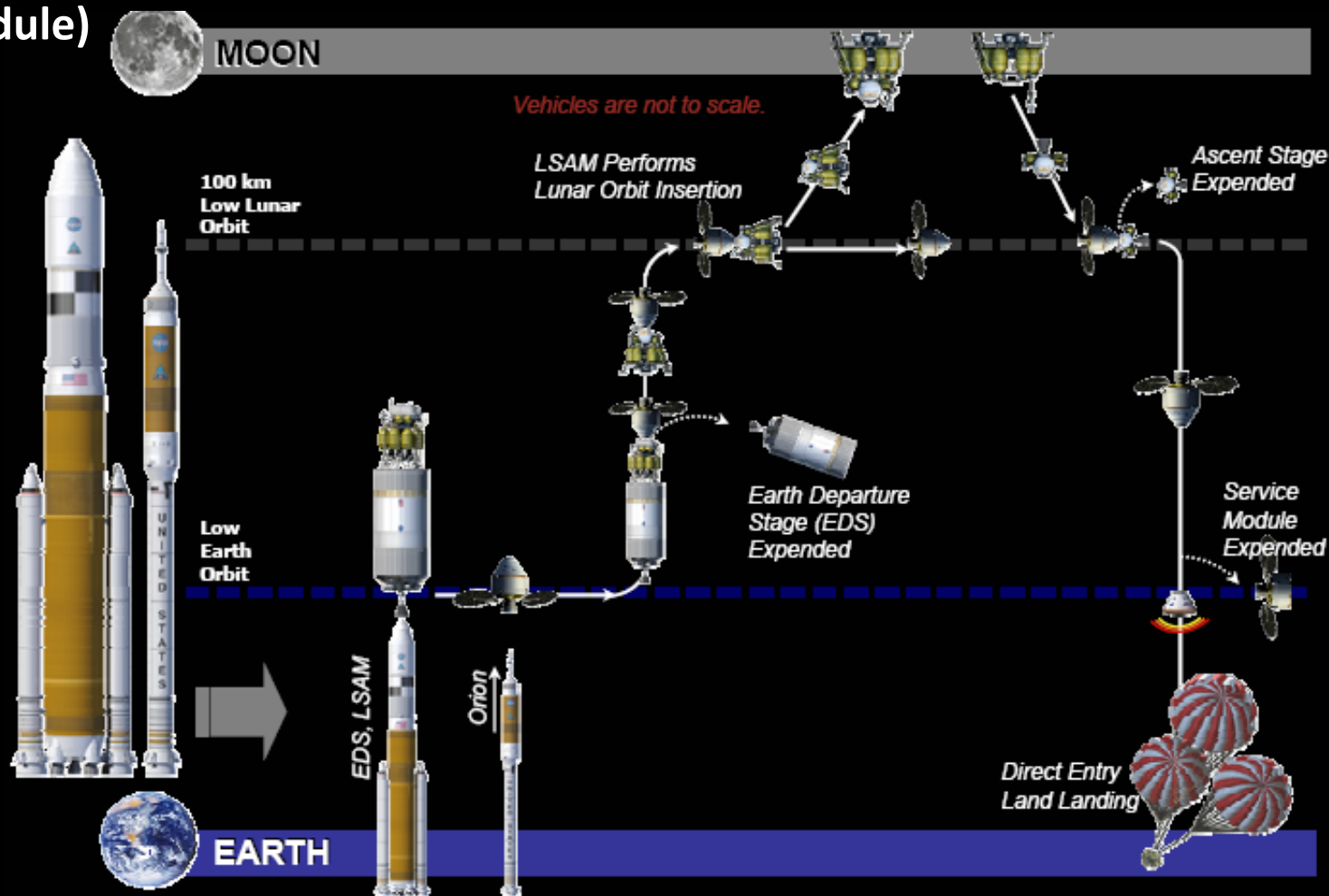
- Eerste test-lancering in 2009
- ARES I : bemanning
- ARES V : cargo
- Docking in orbit
- Zware technische problemen



2005: goedkeuring Constellation Program

ALTAIR (LSAM = Lunar Surface Access Module)

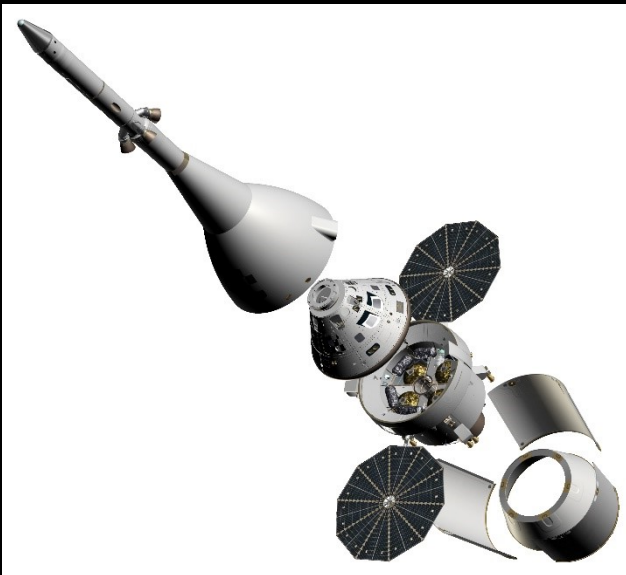
- Gepland in 2019
- 'Altair' = arend (Eagle)
- Voor 4 astronauten
- Landing terwijl Orion in orbit blijft
- ⬆ 15 m Ø 10 m
- Nooit gebouwd



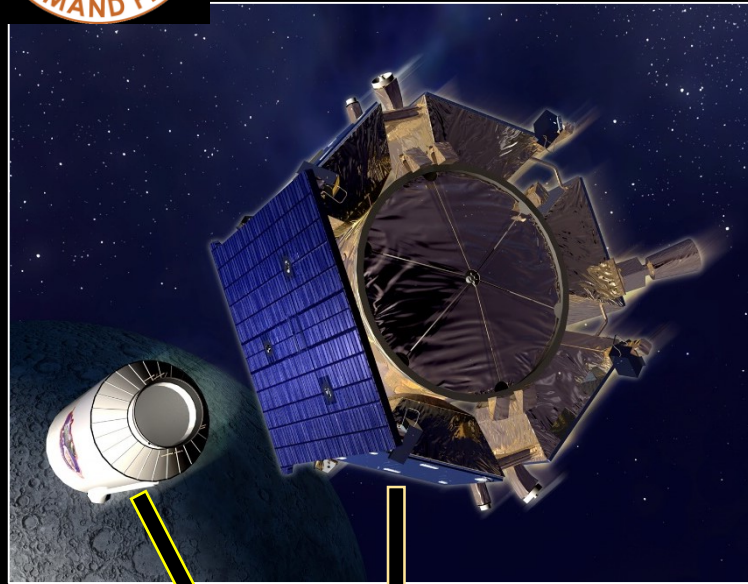
2005: goedkeuring Constellation Program

CEV = Crew Exploration Vehicle

- Vanaf 2004 als alternatief voor Shuttle
- Opdracht voor Lockheed Martin 2006: Orion CEV
- Zware vertragingen en technische problemen

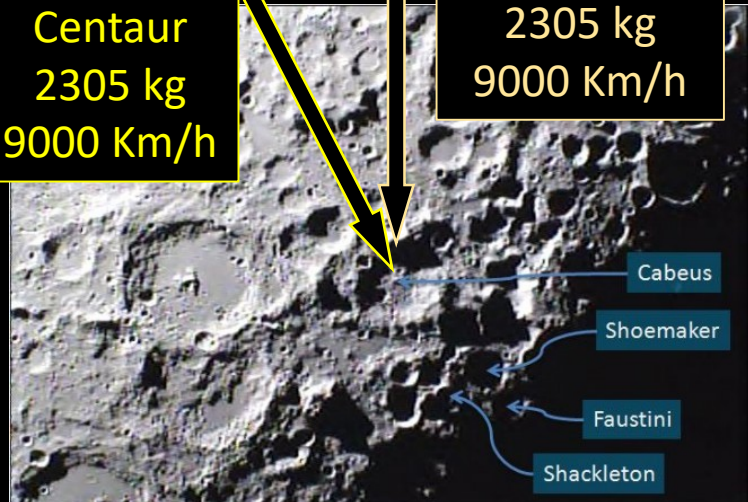


2009: LRO + LCROSS

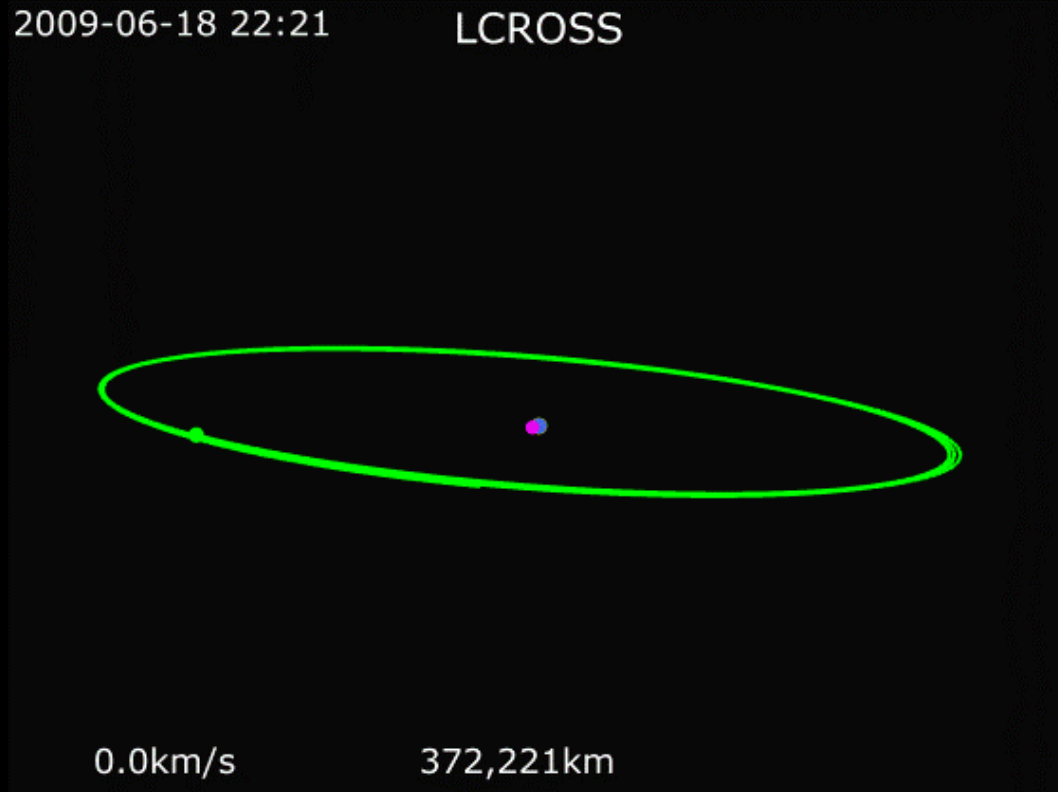


Shepherding
2305 kg
9000 Km/h

Centaur
2305 kg
9000 Km/h



2009: LRO + LCROSS



BESLUIT:

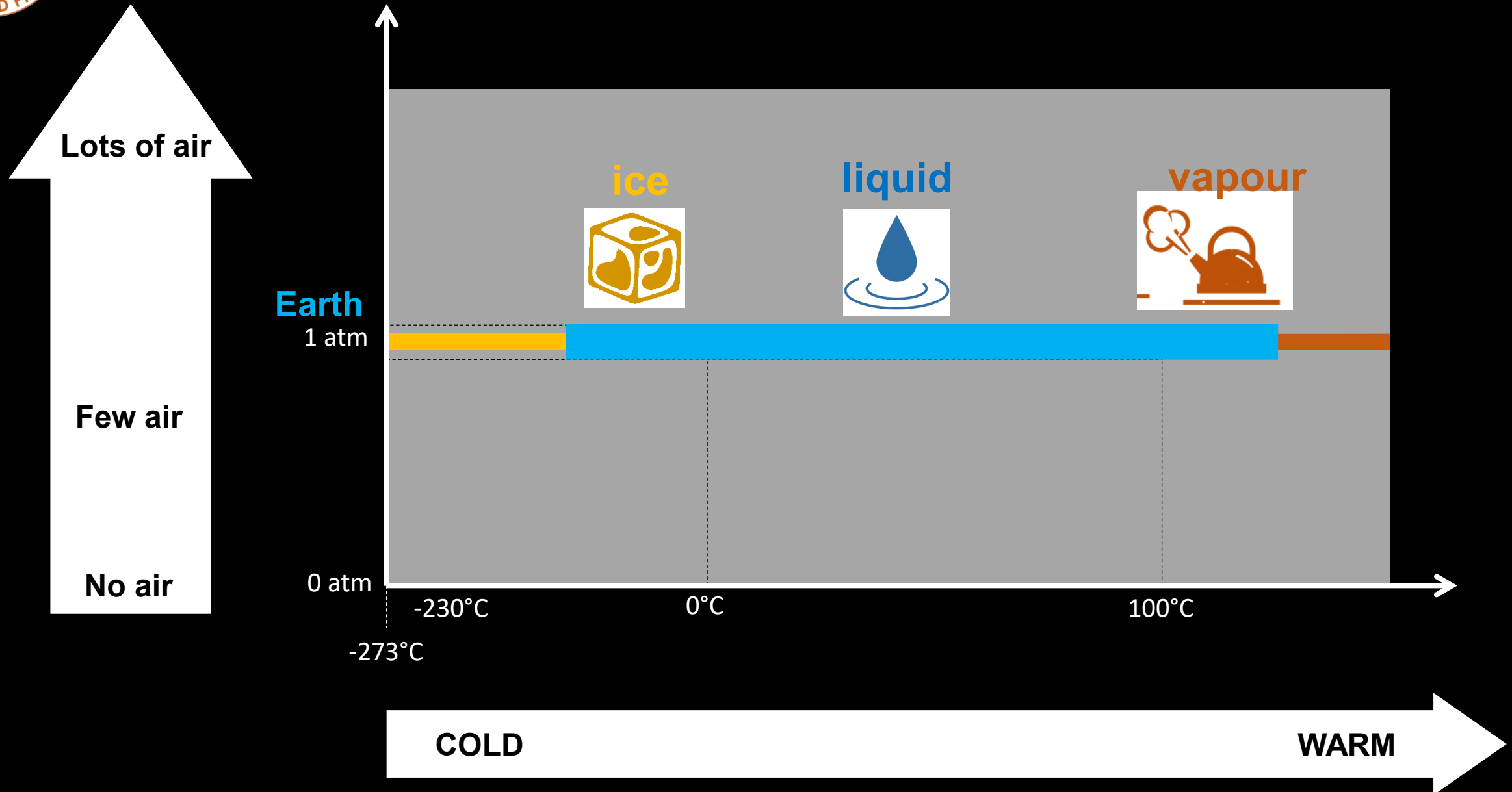
1. Ongeveer 5 à 6 % water in regoliet in Cabeus crater
2. NASA besluit om maanbasis te bouwen !

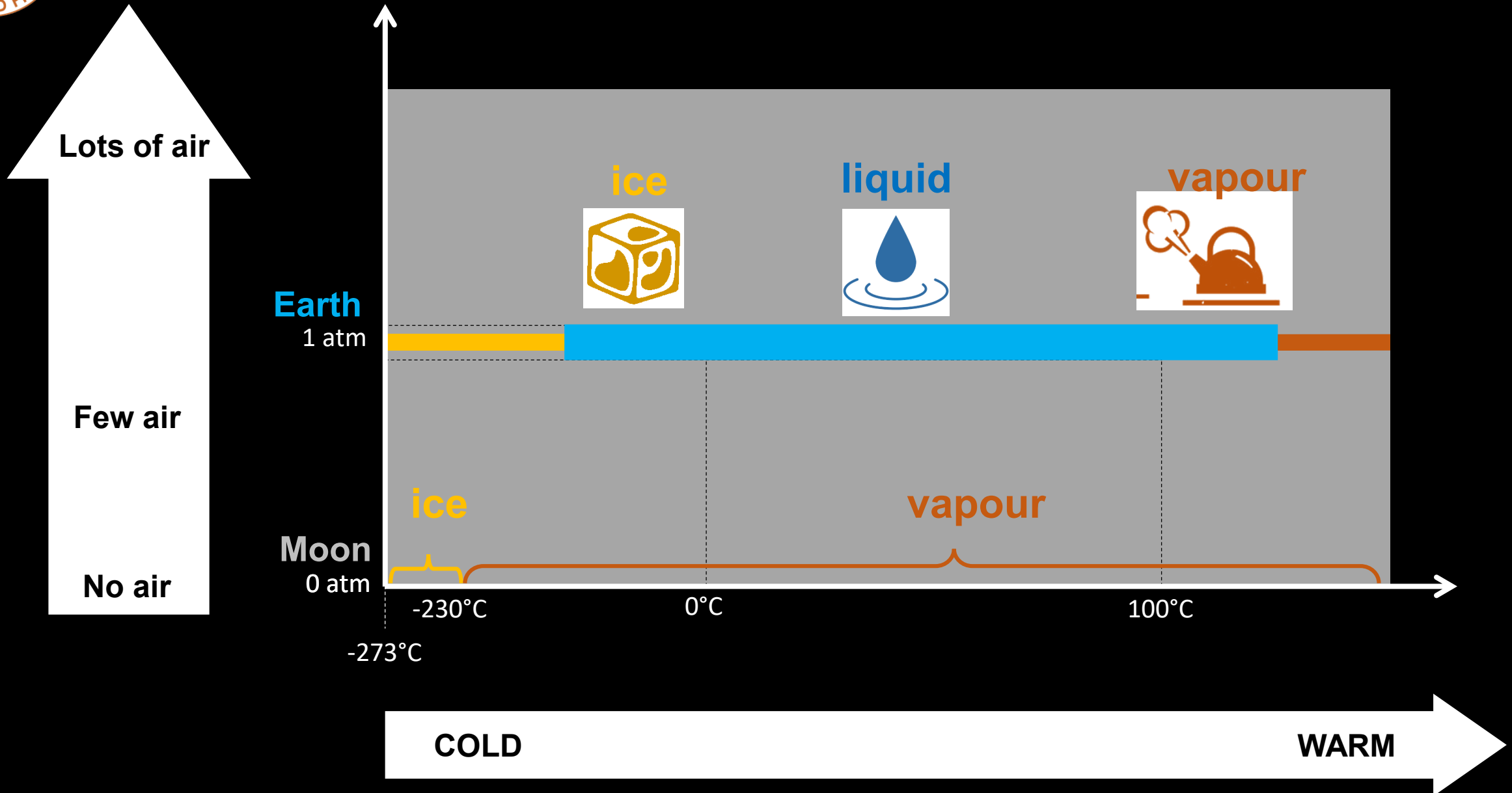
Door Phoenix7777 - Eigen werkData source:
HORIZONS System, JPL, NASA, CC BY-SA 4.0,



Geschiedenis : 2005-2019

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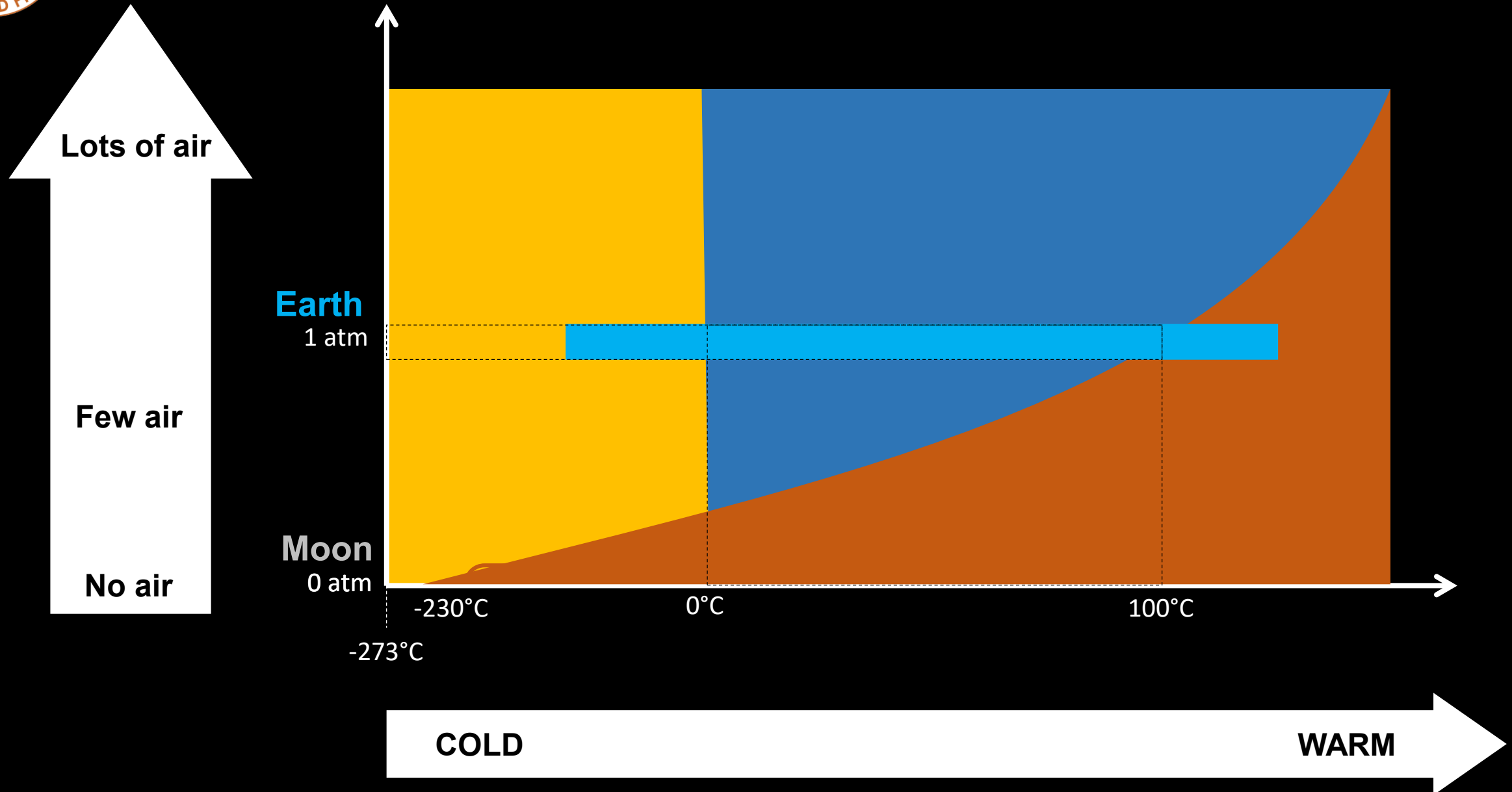






Geschiedenis : 2005-2019

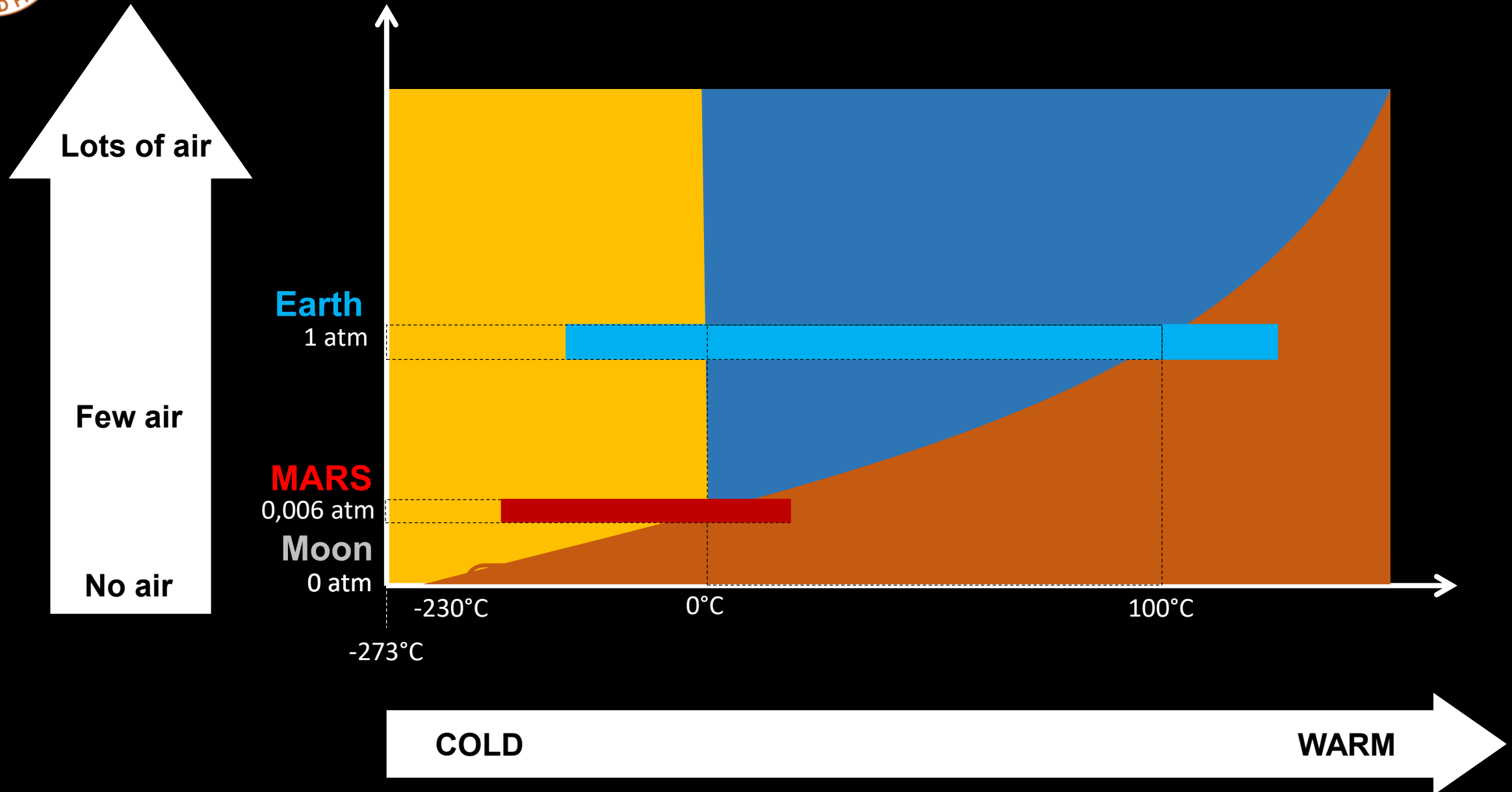
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Geschiedenis : 2005-2019

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Geschiedenis : 2005-2019

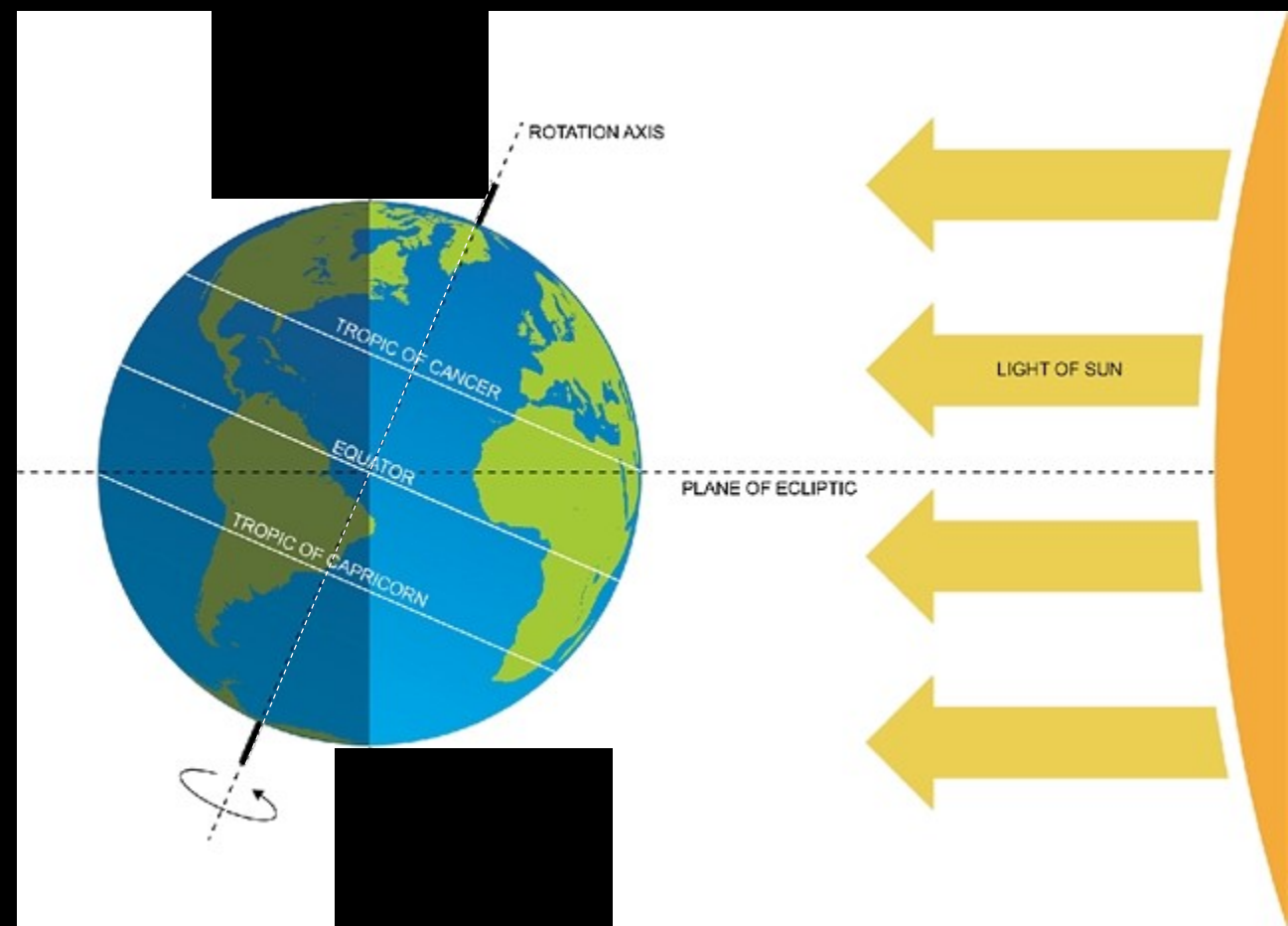
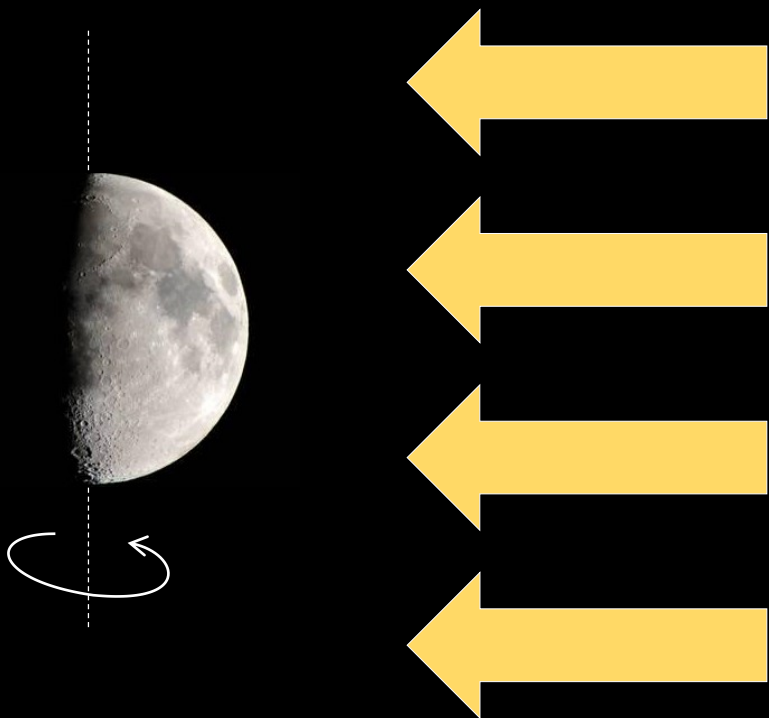
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+150°C
(2 weken)



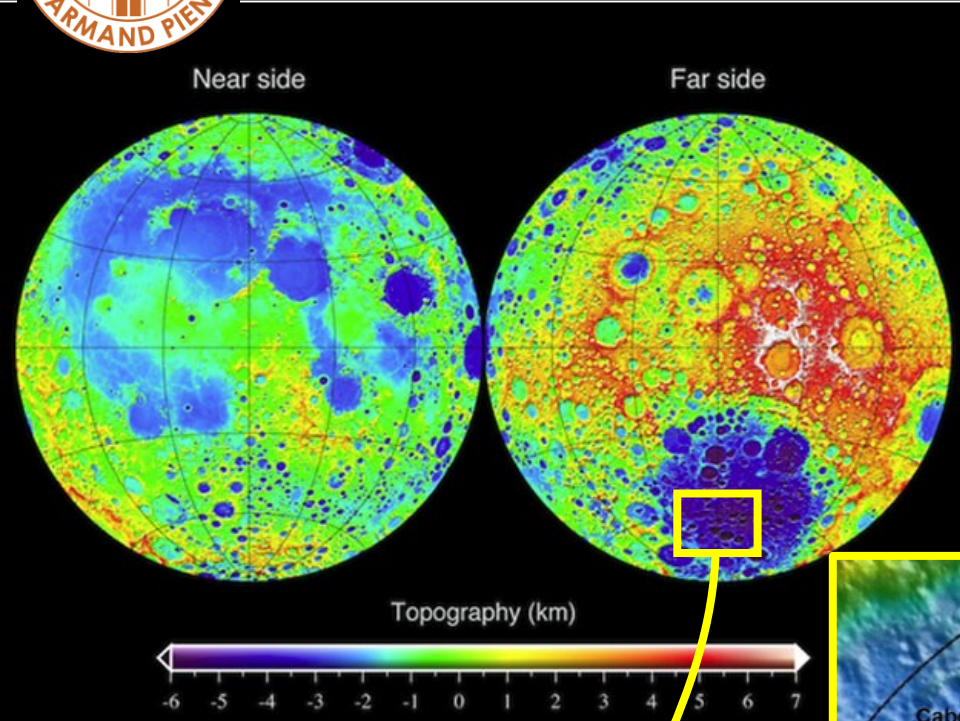
-130°C
(2 weken)

Geschiedenis : 2005-2019

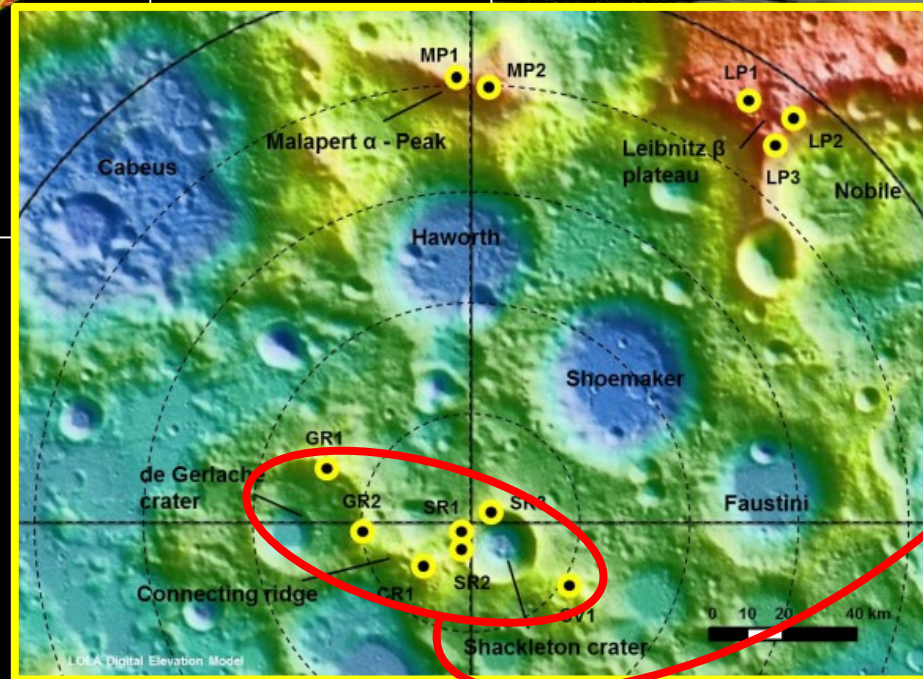


BESLUIT

Noordpool en zuidpool: altijd zonlicht (aan de horizon)



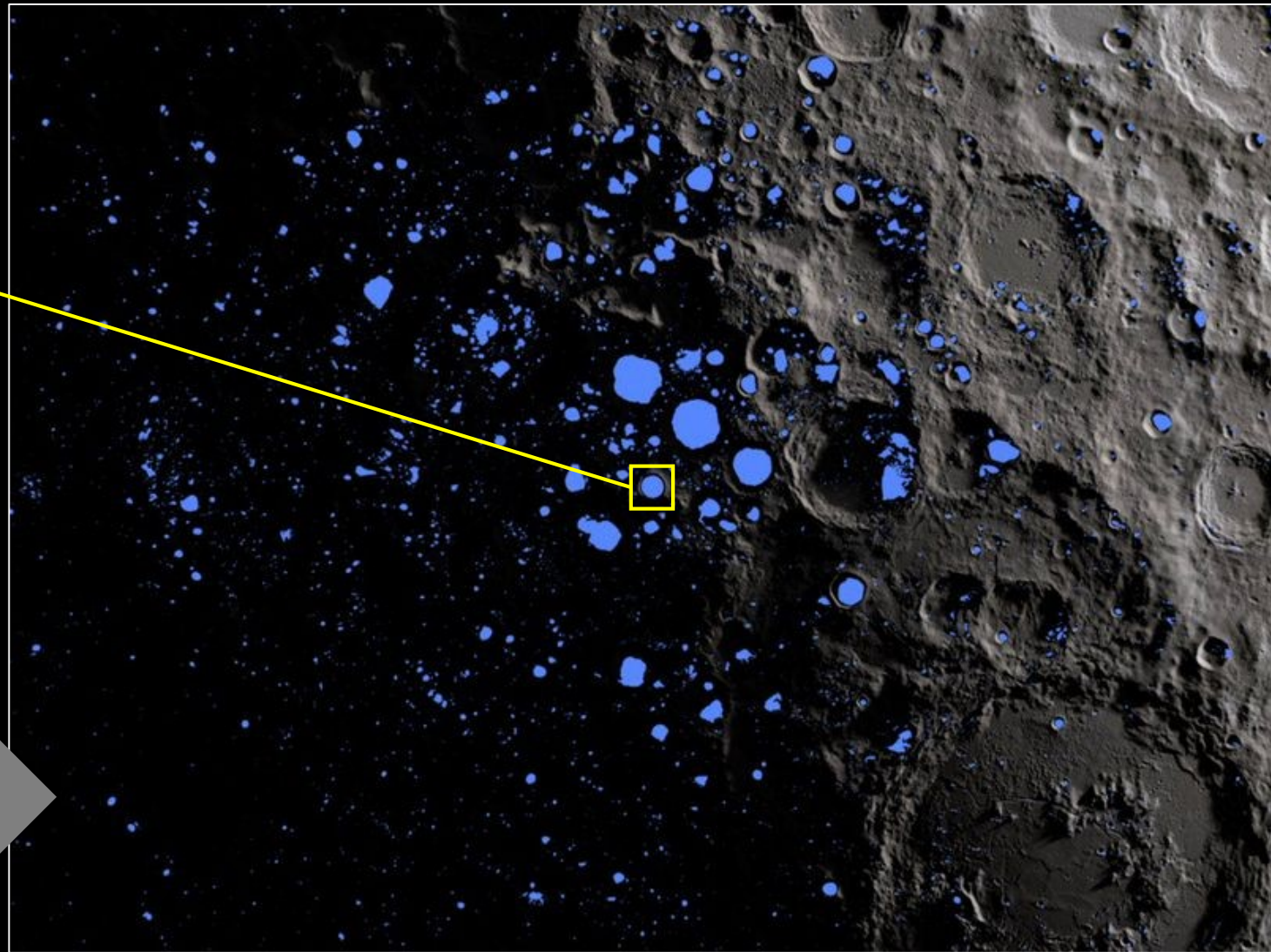
A,B,C,D :
“Peaks of Eternal Light”
(> 80%)

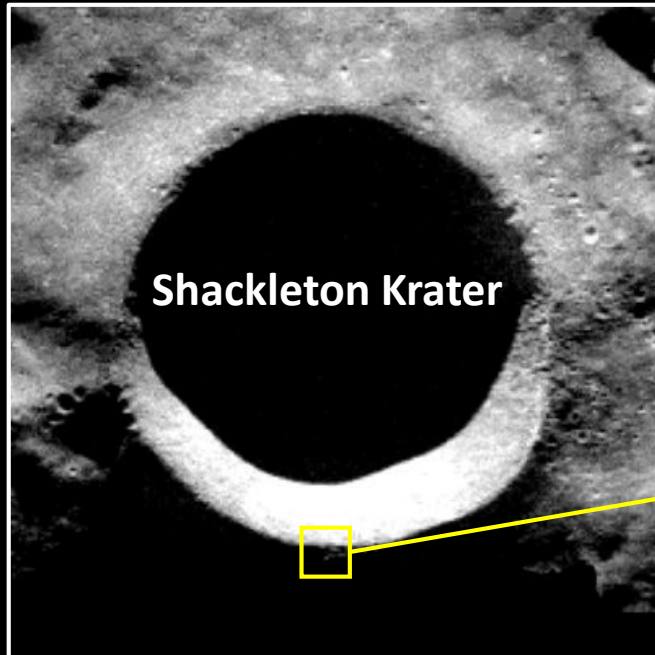




Diameter 21km

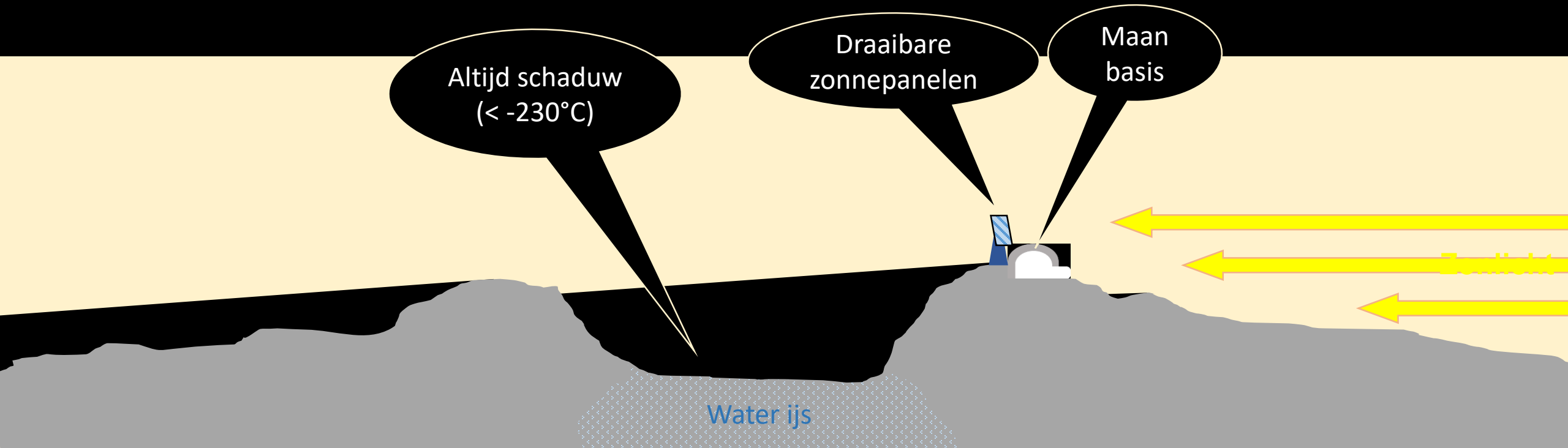
Altijd kouder dan -230°C ?
Craters of eternal darkness
WATER IJS

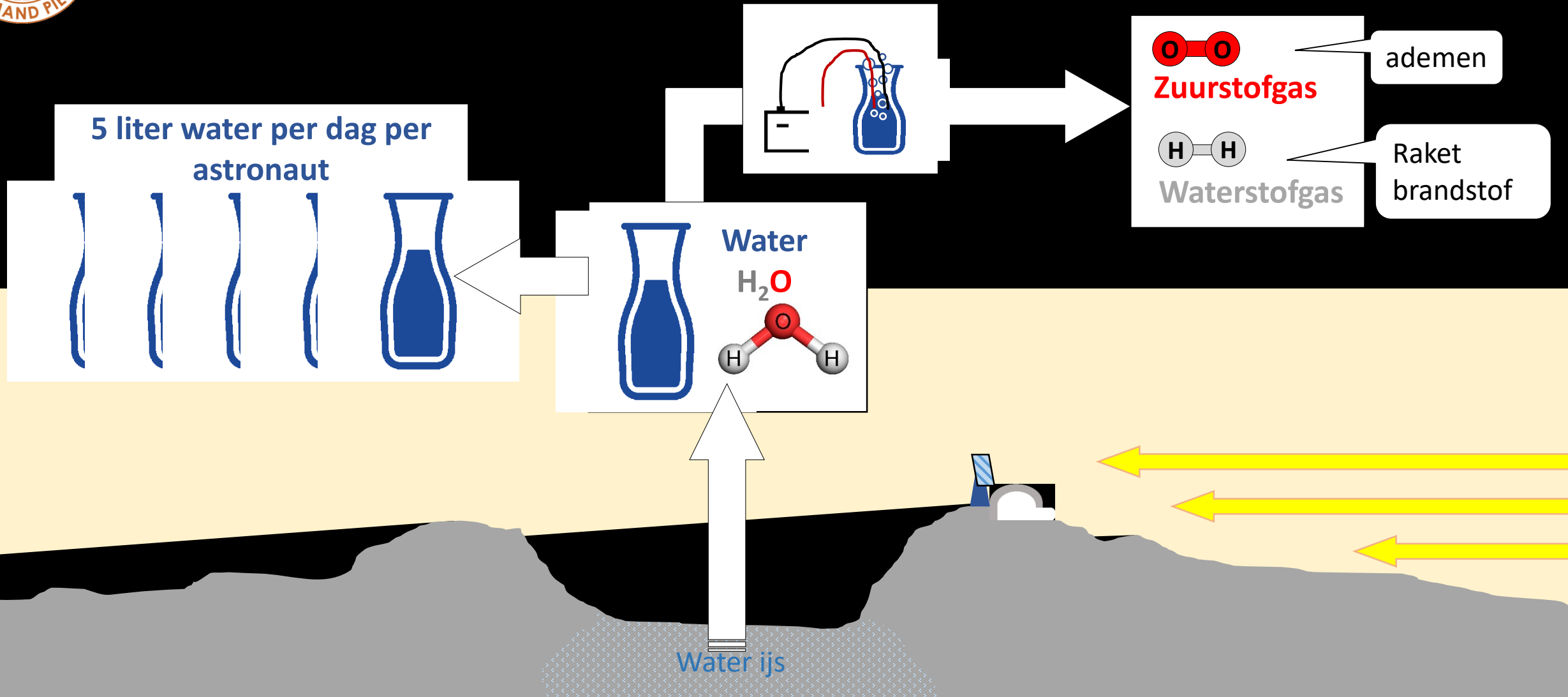




Altijd kouder dan -230°C ?
Craters of eternal darkness
WATER IJS









2010: ANNULATIE constellation program

SLS = Space Launch System

- < Space Shuttle raket
- Huidige schatting kostprijs: +/- 2 miljard \$ per lancering
- Eerste lancering: 2021 (?)

Block1 :

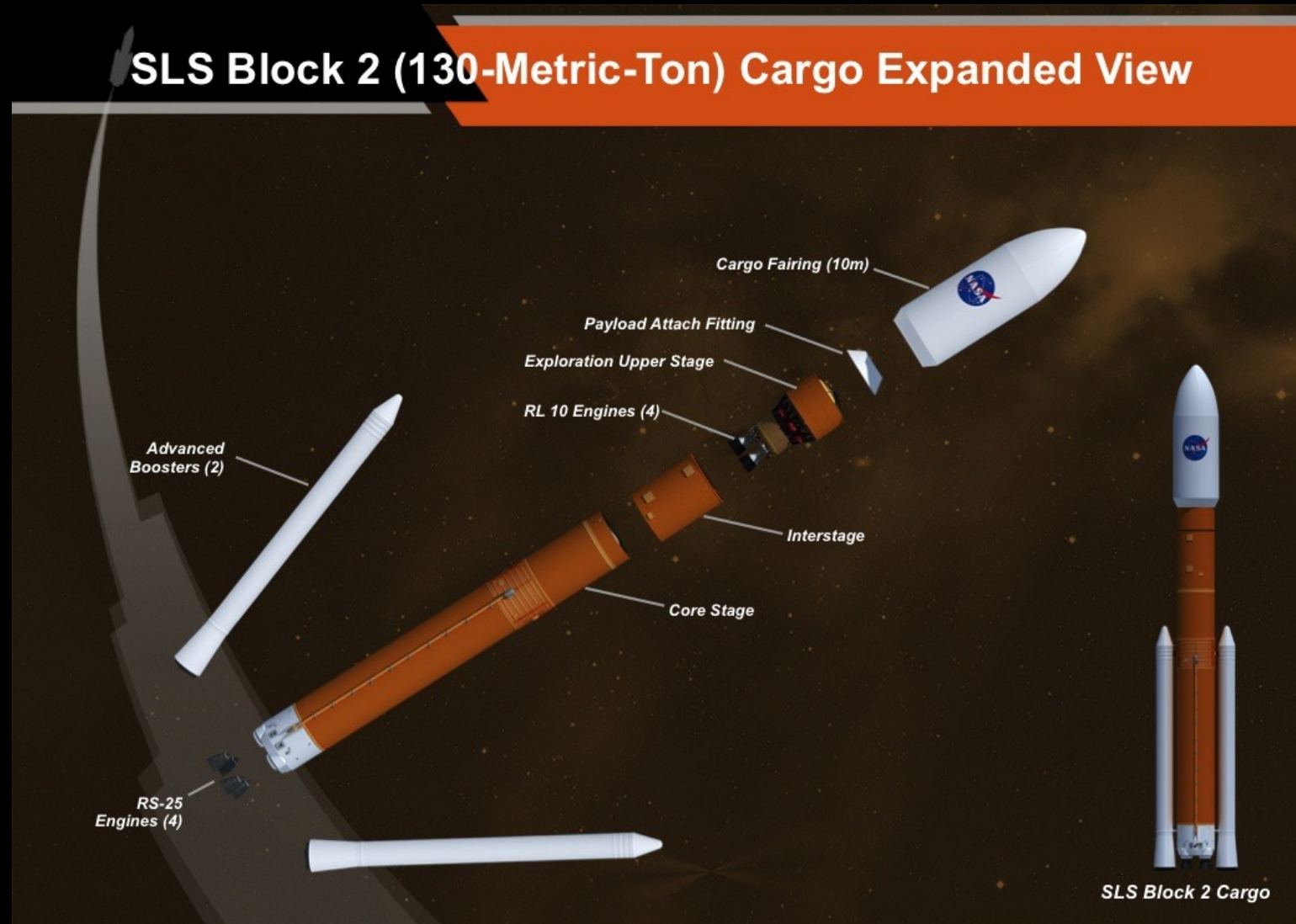
- 95.000 kg naar LEO
- 26.000 kg naar de Maan

Block2 :

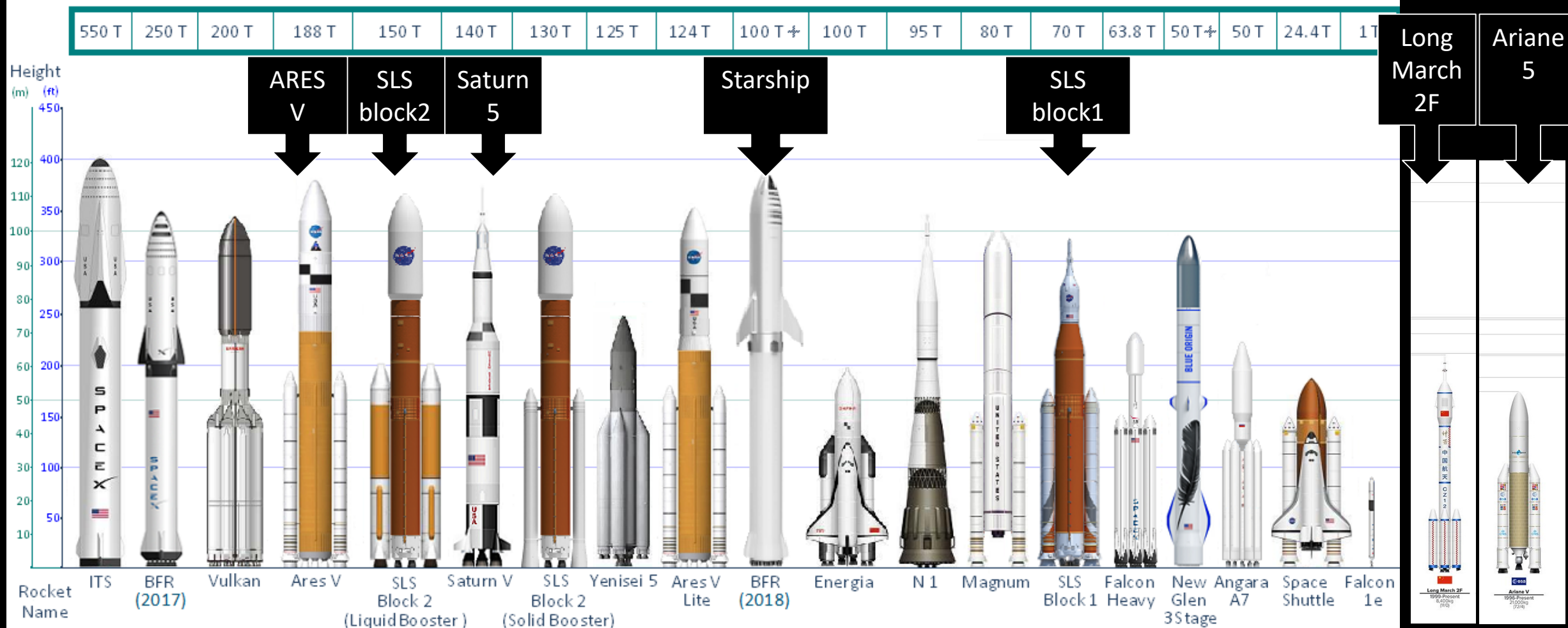
- 150.000 kg naar LEO
- 45.000 kg naar Mars

2010: ANNULATIE constellation program
SLS = Space Launch System

SLS Block 2 (130-Metric-Ton) Cargo Expanded View



Payload Mass Low Earth Orbit (LEO)



2010: ANNULATIE constellation program

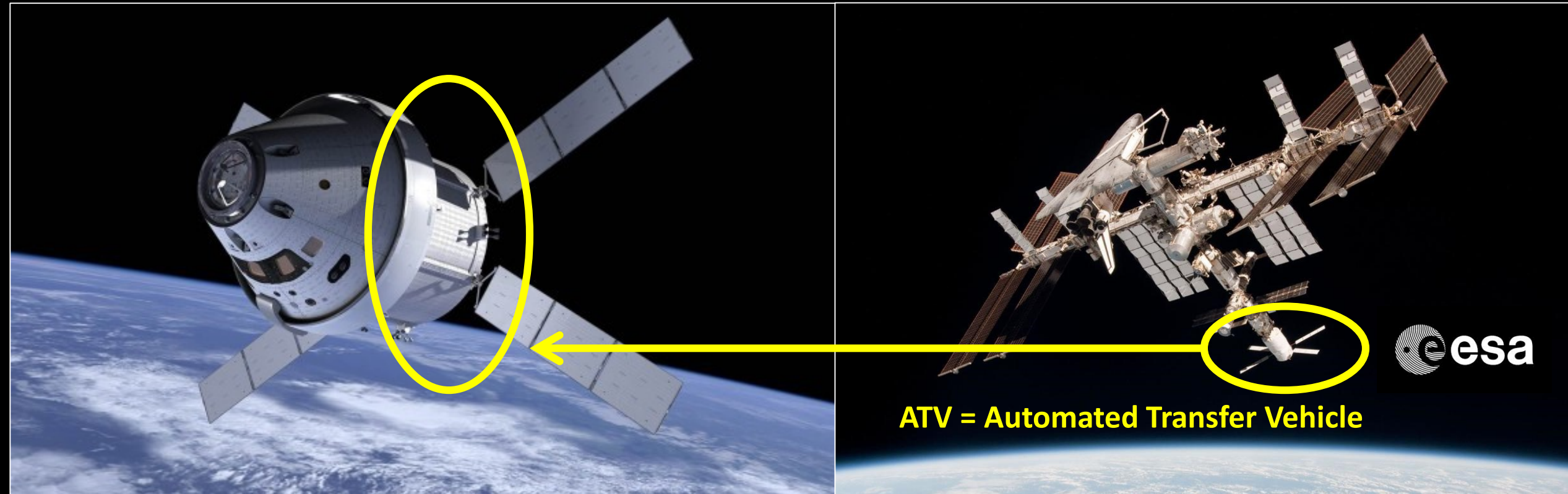
Bemanningscapsules

- ORION MPCV = Multi Purpose Crew Vehicle (herbruikbaar 10 vluchten)
- Commercial crew program



2010: ANNULATIE constellation program

ORION MPCV



2010: ANNULATIE constellation program

ORION MPCV

ORION

Mankind on the way to the Moon and beyond

ORION EUROPEAN SERVICE MODULE

For the first time, NASA will use a European built system as a critical element to power a human spaceflight mission.

1st European supply of critical functions for an American space mission:



Spacecraft propulsion



Electrical power supply



Consumable storage (water and air)



Thermal control

As prime contractor to ESA Airbus provides:



Program and subcontractor management



The propulsion subsystem



Systems engineering



Solar arrays



Assembly, integration & test of the ESM



Operations support



NASA's space launch system



EUROPEAN SERVICE MODULE



Crew Module

Crew Module Adapter



The Orion programme



For the first time in history, NASA and ESA are joining forces to launch the first of a series of missions to send astronauts beyond the moon.

The Airbus experience



The Orion European Service Module is testimony to the excellent technologies and expertise of the Airbus team demonstrated by designing and building the highly successful **Automated Transfer Vehicle**, the largest supply carrier to the International Space Station, that was used as the design base.

Airbus built up a significant heritage in human spaceflight with ESA/NASA, coming from projects like the **Columbus laboratory** and **International Space Station operations**.

AIRBUS

2010: ANNULATIE constellation program

ORION MPCV

EFT-1 (Exploration Flight Test):

5 dec 2014

- Onbemand
- DELTA IV heavy
- > 5000 km orbit: voorbij Von Allen gordel
- Re-entry 20.000 km/h (80% van re-entry snelheid Maan-missie)
- Landing in oceaan





Geschiedenis : 2005-2019

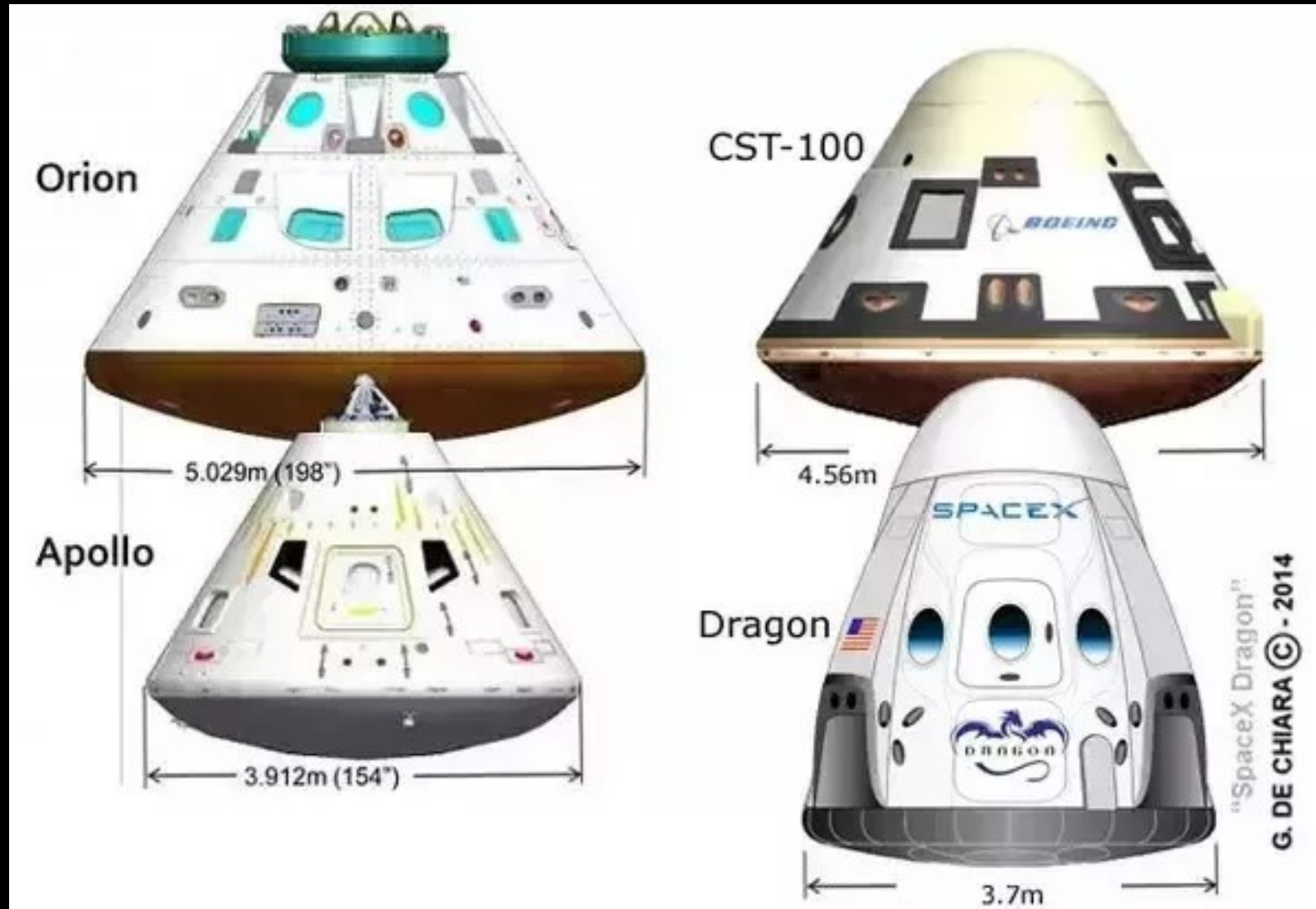
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2010: ANNULATIE constellation program

Bemanningscapsules

- **ORION MPCV = Multi Purpose Crew Vehicle**
- **Commercial crew program:**
 - Boeing : "Starliner"
 - SpaceX : "Crew Dragon"

2010: ANNULATIE constellation program

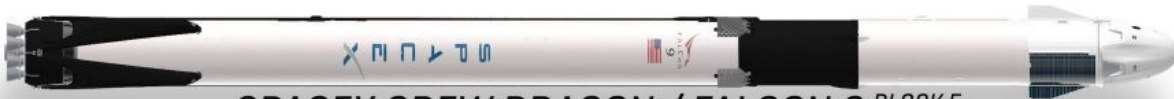


2010: ANNULATIE constellation program

BOEING STARLINER / ATLAS V^{N22}



SPACEX CREW DRAGON / FALCON 9 BLOCK 5



DEVELOPMENT COST



\$4.8 BILLION



\$3.1 BILLION



2010: ANNULATIE constellation program

ARM =
Asteroid Redirect Mission
(°2013 - †2017)

ARM = Testen ivm Marsreizen

- Stralingsbescherming buiten de Von Allen belt
- Voorstuwing met elektrische energie
- Transporteren van zware vrachten
- Ruimtepakken
- Staalnames (vb. stof onder controle)
- Gebruik van asteroiden (vb. water)
- Rendez-vous en docking
- Gebruik van Orion en SLS
- Planetary defense



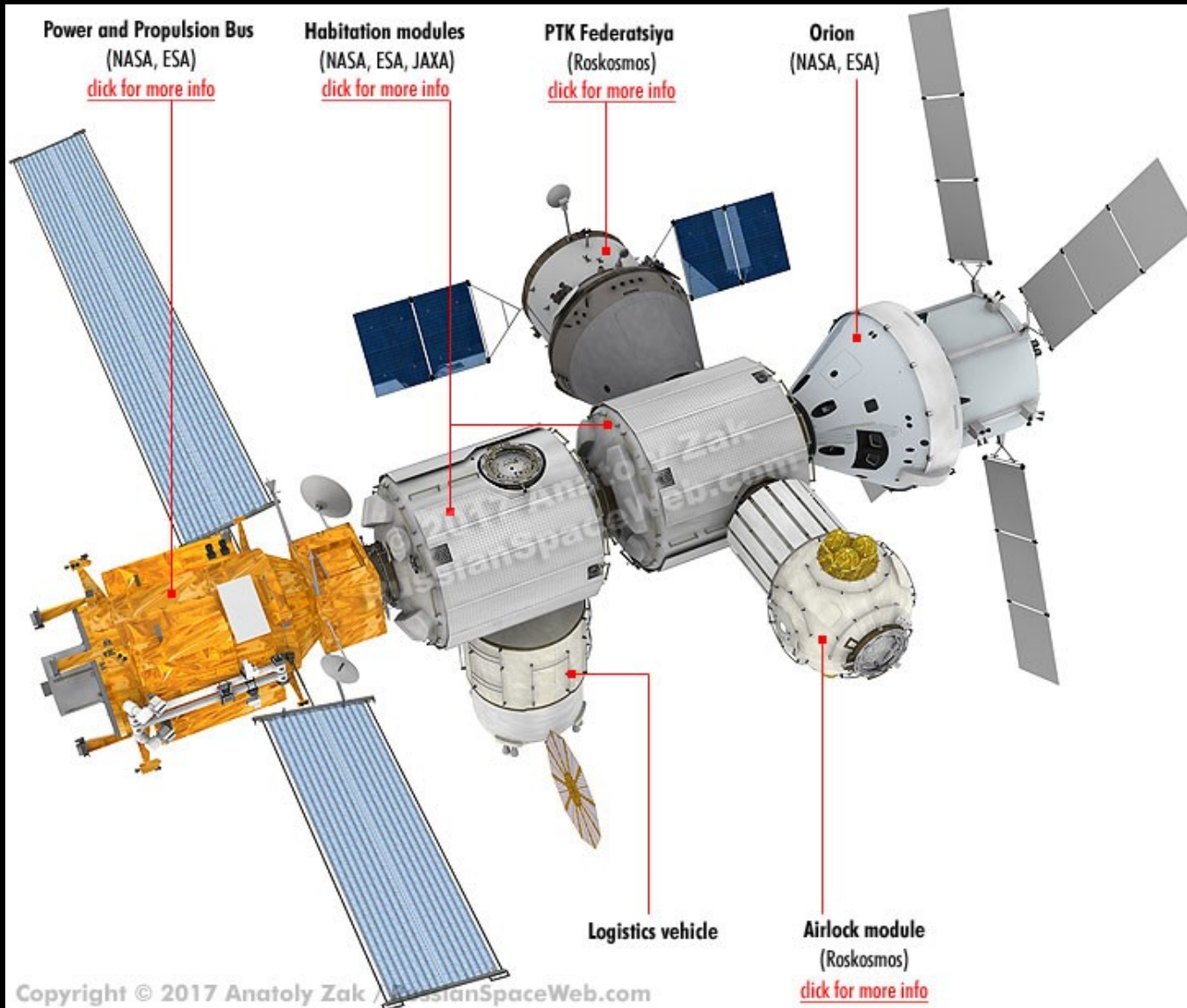
Geschiedenis : 2005-2019

10:28

2017: Space policy directive 1

Lead an innovative and **sustainable** program of exploration with **commercial and international** partners to enable human expansion **across the solar system** and to bring back to Earth new knowledge and opportunities. **Beginning with** missions **beyond LEO** the USA will lead the return of humans to the **Moon** for long term exploration and utilization, followed by human missions to **Mars** and **other destinations**.

2017: Space policy directive 1

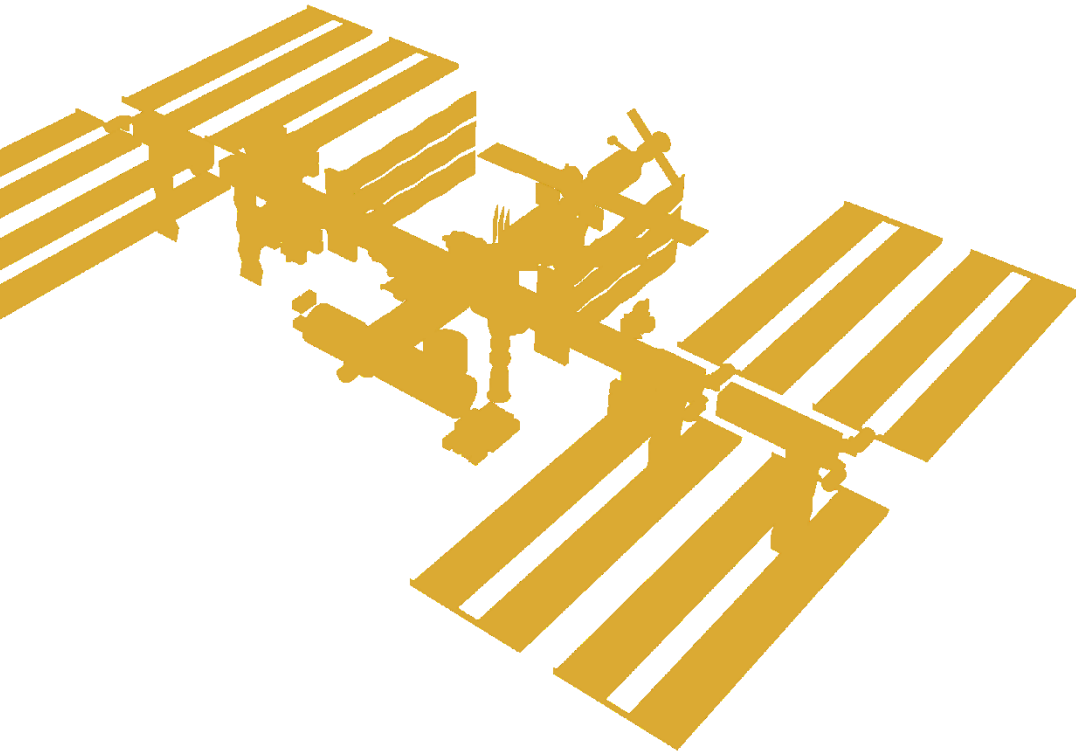


DEEP SPACE GATEWAY: vanaf 2024

- 2012: Deep Space Habitat (studies)
- 2017: ARM-onderdeel wordt Solar Electric Power and Propulsion Element (PPE)
- 2017: “LOP-G” rond de Maan
- 2018: Deep Space Gateway rondom L2

Geschiedenis : 2005-2019

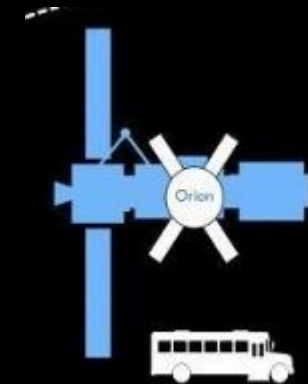
ISS
109 m



Boeing 747
71 m



Gateway
+/- 29 m



2017: Space policy directive 1

Moon lander: 2028

- Lockheed Martin



2017: Space policy directive 1



Moon base: 2030



Geschiedenis : 2005-2019

10:28

2019: ARTEMIS PROGRAM

Mike Pence (vice-president):

“American astronauts will walk on the Moon again **before the end of 2024** by any means necessary”

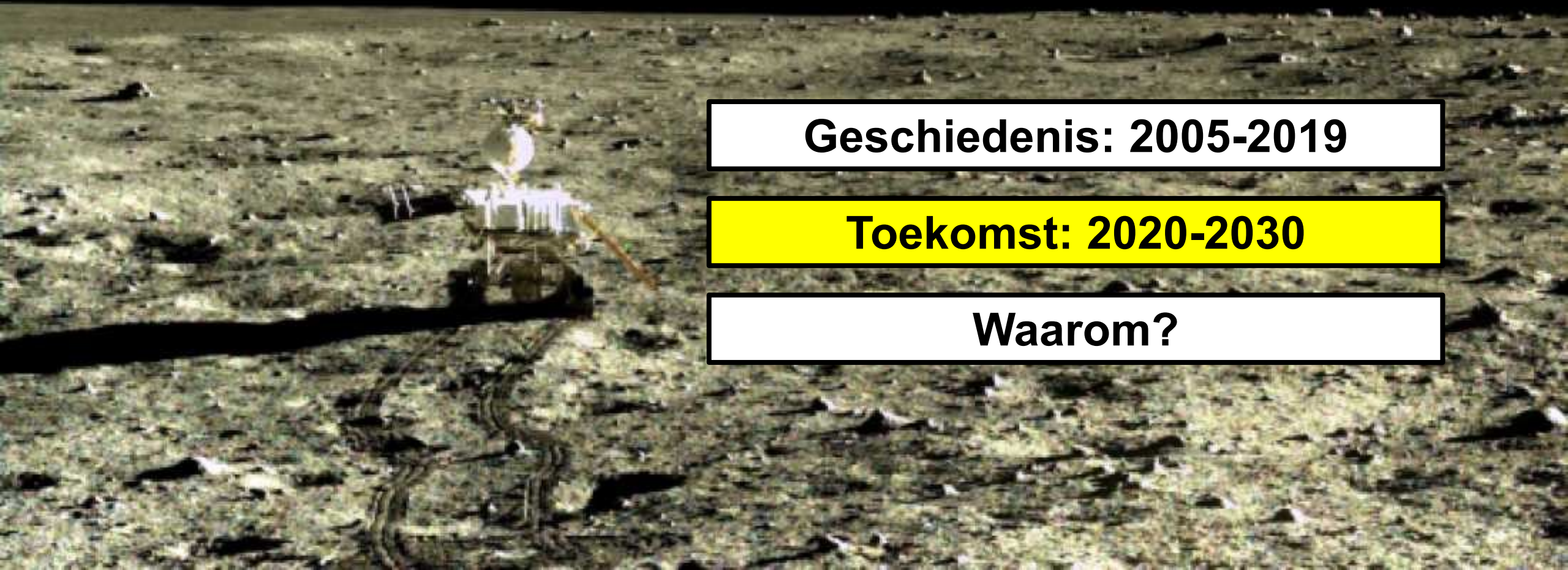
Officieel argument:

politiek risico minimaliseren (annuleringen van programma's)



Nieuwe Maanmissies

10:28



Geschiedenis: 2005-2019

Toekomst: 2020-2030

Waarom?

ARTEMIS PROGRAMMA tot 2024

**2021: Artemis I
SLS + Orion zonder
bemanning**

Artemis I: First human
spacecraft to the Moon
in the 21st century

Artemis II: First humans
to orbit the Moon in the
21st century

Artemis Support
Mission: First
high-power
Solar Electric
Propulsion (SEP)
system

Artemis Support
Mission: First
pressurized
module delivered
to Gateway

Artemis Support
Mission: Human
Landing System
delivered to
Gateway

Artemis III:
Crewed mission
to Gateway and
lunar surface

Commercial Lunar Payload Services
- CLPS-delivered science and technology payloads

Early South Pole Mission(s)

- First robotic landing on eventual human lunar return and In-Situ Resource Utilization (ISRU) site
- First ground truth of polar crater volatiles

Large-Scale Cargo Lander
- Increased capabilities for science
and technology payloads

Humans on the Moon - 21st Century

First crew leverages infrastructure
left behind by previous missions

LUNAR SOUTH POLE TARGET SITE

2020

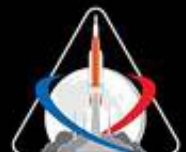
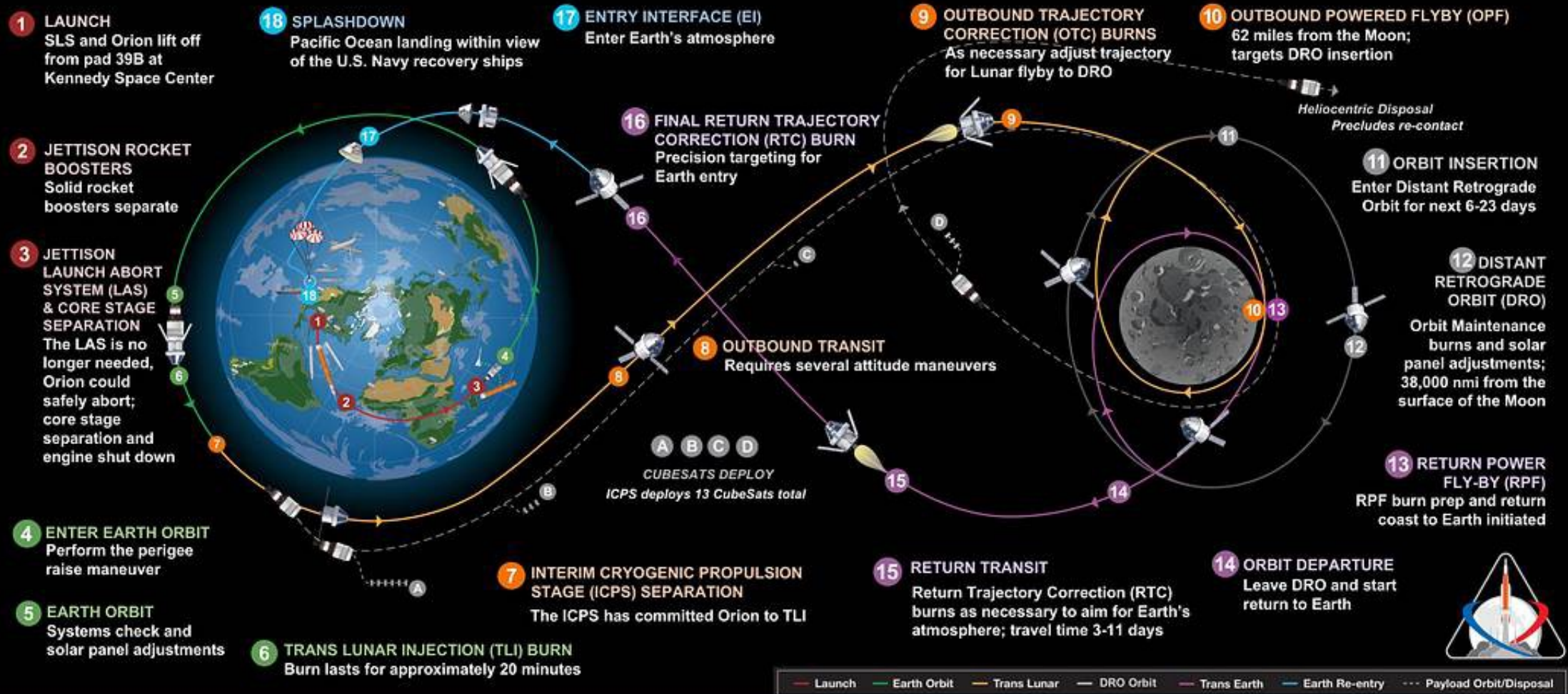
2024

ARTEMIS PROGRAMMA tot 2024



Artemis 1

The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport



Total distance traveled: 1.3 million miles – Mission duration: 26-42 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

ARTEMIS PROGRAMMA tot 2024



ARTEMIS PROGRAMMA tot 2024

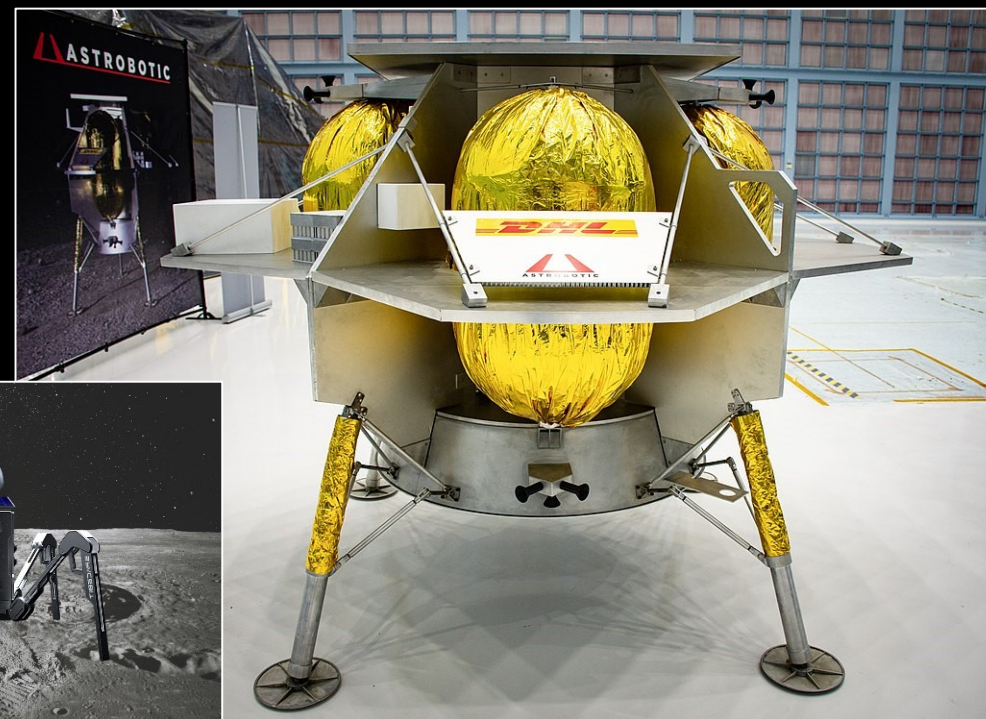


NOVA-C (2021)

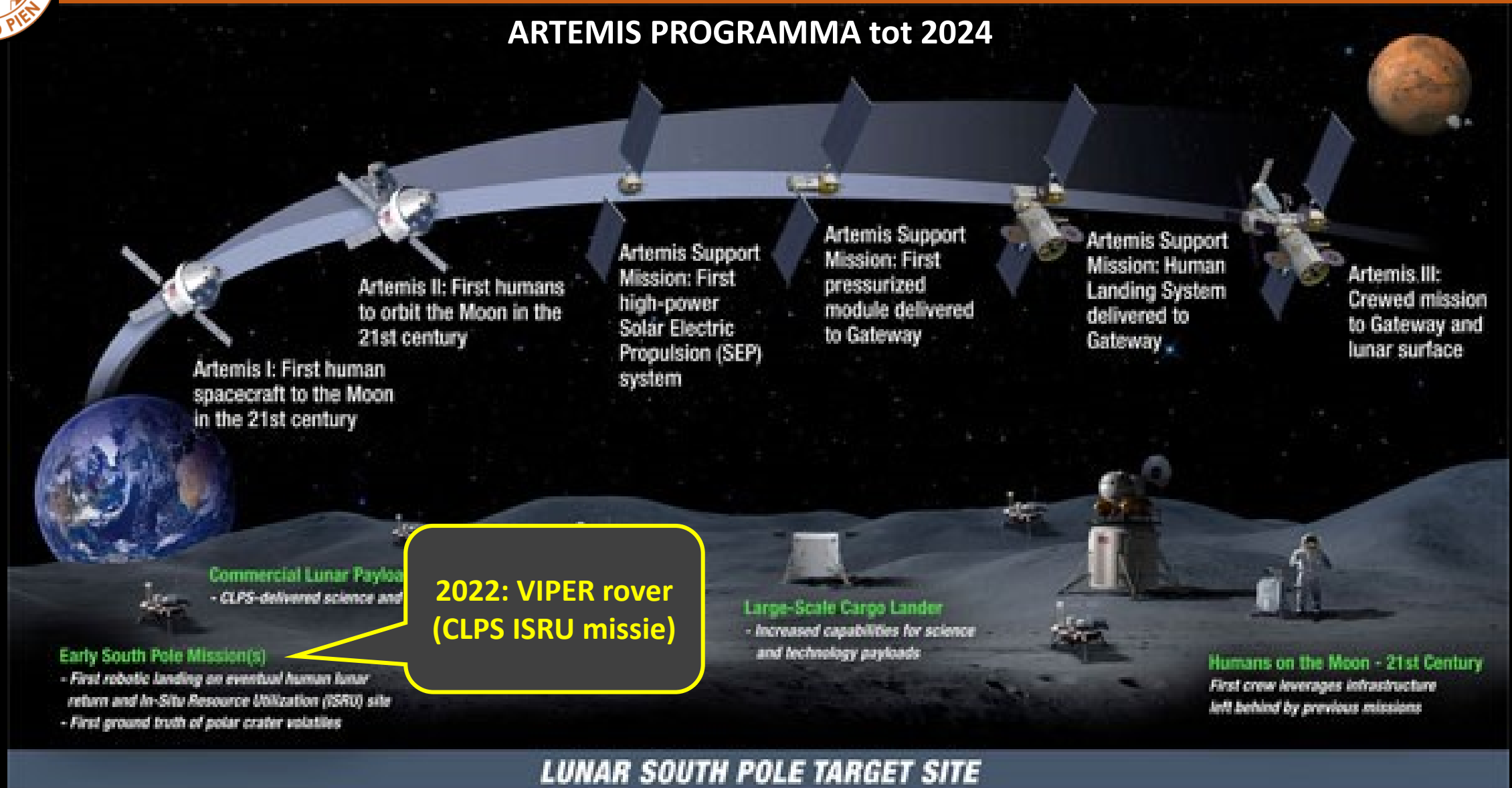
- Test lander
- Kan terug opstijgen, verplaatsen en terug landen
- Launch Falcon 9
- NASA + commercial science instruments

PEREGRINE (2021)

- Test lander
- Launch Vulcan
- Commerciële payloads, bijvoorbeeld SpaceBit



ARTEMIS PROGRAMMA tot 2024

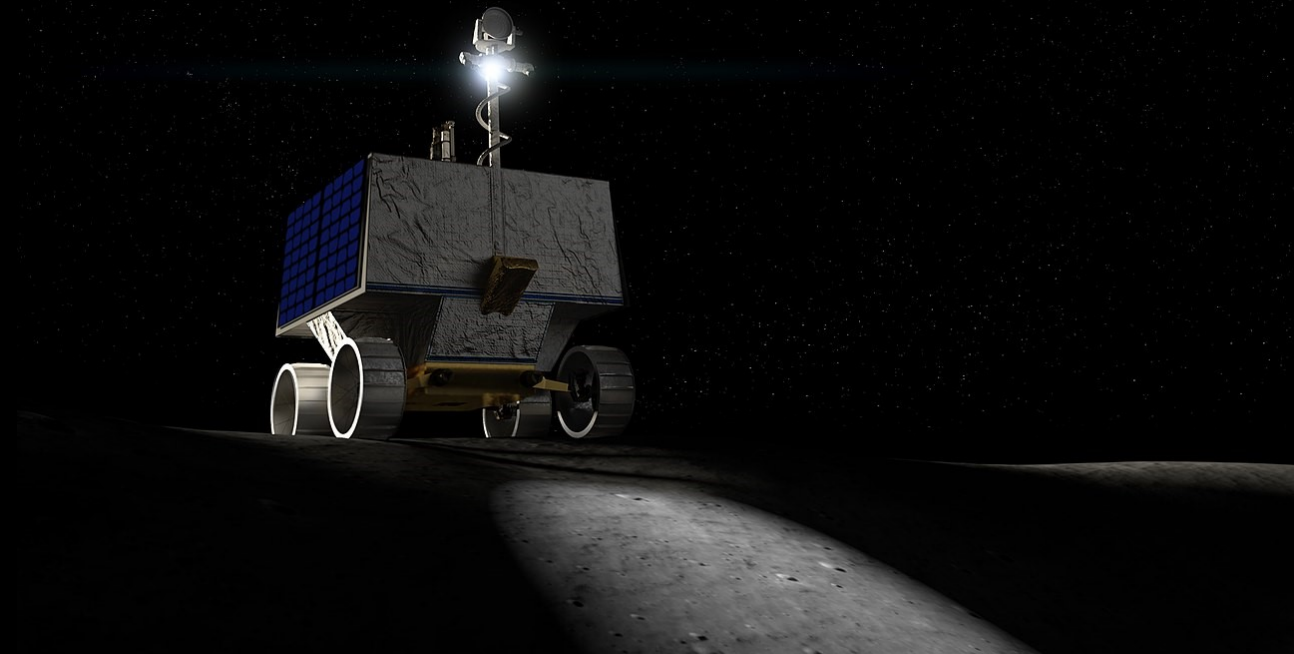


ARTEMIS PROGRAMMA tot 2024



VIPER ROVER (2022)

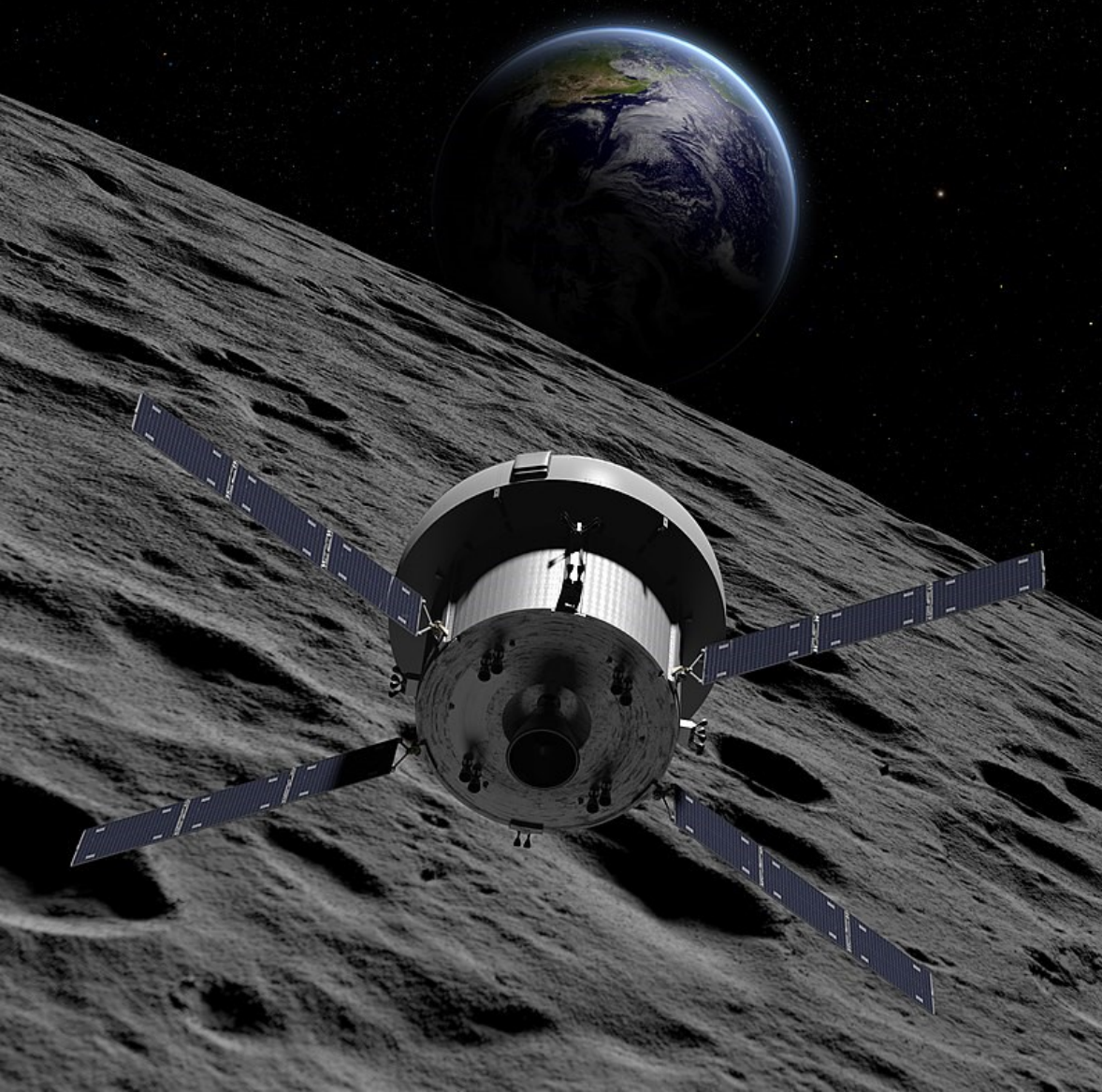
- Zuidpool onderzoek van water
- Boor tot 1 m diep
- 100 dagen, deels op batterijen alleen
- Neutronen detector, spectrometer, massa-spectrometer



ARTEMIS PROGRAMMA tot 2024



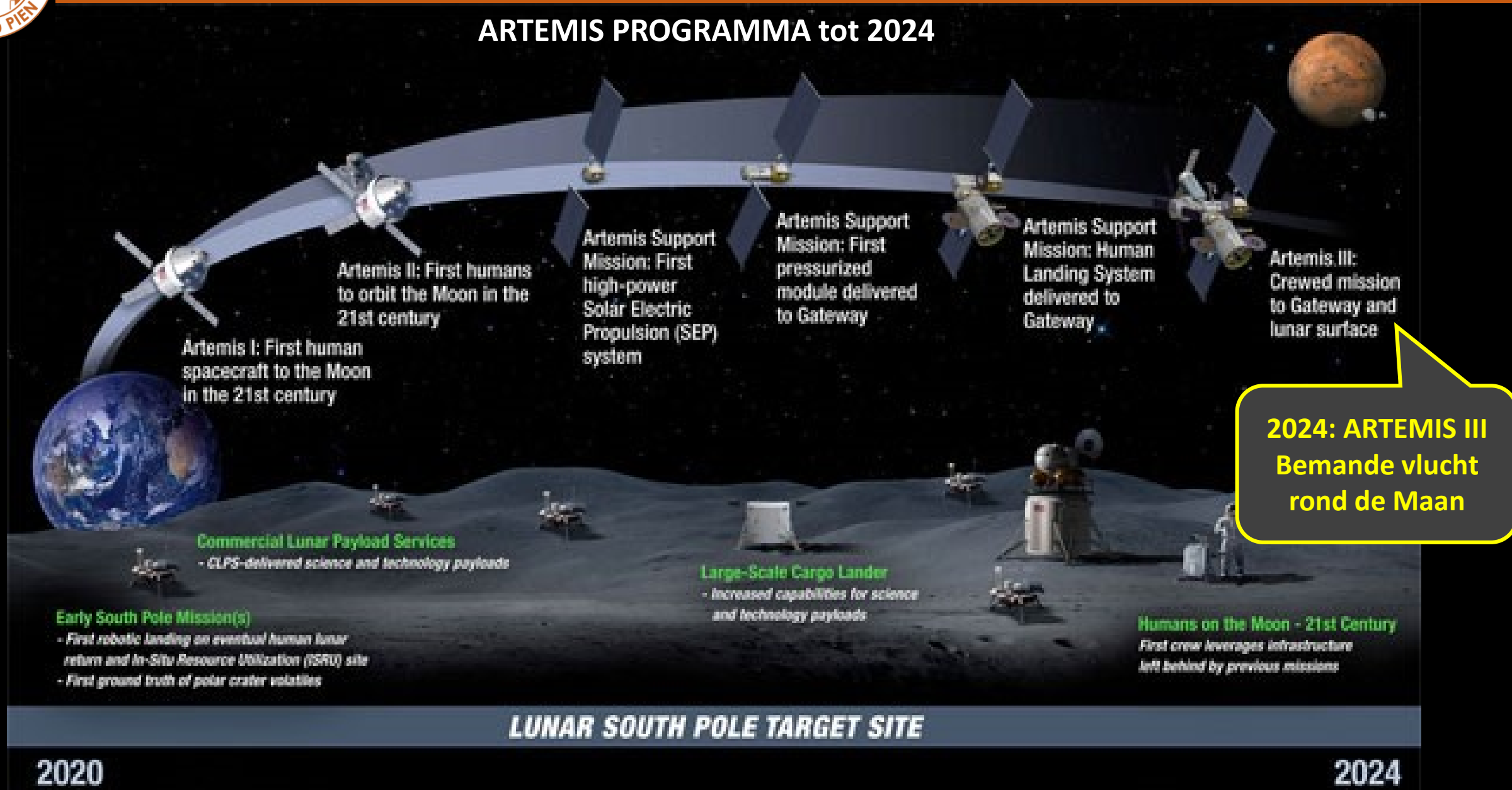
ARTEMIS PROGRAMMA tot 2024



ARTEMIS II (2023)

- 4 astronauten
- Zelfde vluchtschema als Artemis I
- Max 21 dagen
- Free return to Earth

ARTEMIS PROGRAMMA tot 2024



2024: ARTEMIS III
Bemande vlucht
rond de Maan

ARTEMIS PROGRAMMA tot 2024

ARTEMIS III

Landing on the Moon in 2024

- 1 LAUNCH
SLS and Orion lift off from Kennedy Space Center
- 2 JETTISON ROCKET BOOSTERS
Solid rocket boosters separate
- 3 JETTISON LAUNCH ABORT SYSTEM (LAS)
The LAS is no longer needed, Orion could safely abort
- 4 CORE STAGE MAIN ENGINE CUT OFF
With separation
- 5 ENTER EARTH ORBIT
Perform the perigee raise maneuver
- 6 EARTH ORBIT
Systems check and solar panel adjustments
- 7 TRANS LUNAR INJECTION BURN
Burn lasts for approximately 20 minutes
- 8 ORION OUTBOUND TRANSIT TO MOON
Requires several attitude maneuvers
- 9 ORION OUTBOUND POWERED FLYBY
- 10 GATEWAY ORBIT INSERTION BURN
Orion performs burn and rendezvous to dock with the Gateway
- 11 HUMAN LANDING SYSTEM (HLS)
Undocks from Gateway
- 12 HLS ENTERS LOW LUNAR ORBIT
Descends to lunar touchdown
- 13 GATEWAY/ORION REMAIN IN LUNAR GATEWAY ORBIT
During lunar surface mission
- 14 HLS ASCENDS LOW LUNAR ORBIT
Then to Gateway Orbit to dock with Gateway
- 15 CREW RETURNS TO ORION
Undocks from Gateway, and departs Gateway Orbit
- 16 ORION RETURN POWERED FLYBY
- 17 ORION TRANSITS TO EARTH
- 18 ENTRY INTERFACE
Enter Earth's atmosphere
- 19 SPLASHDOWN
Pacific Ocean landing within view of U.S. Navy recovery ships

National Aeronautics and Space Administration



4 astronauten naar Gateway-ORION

Gateway 2023

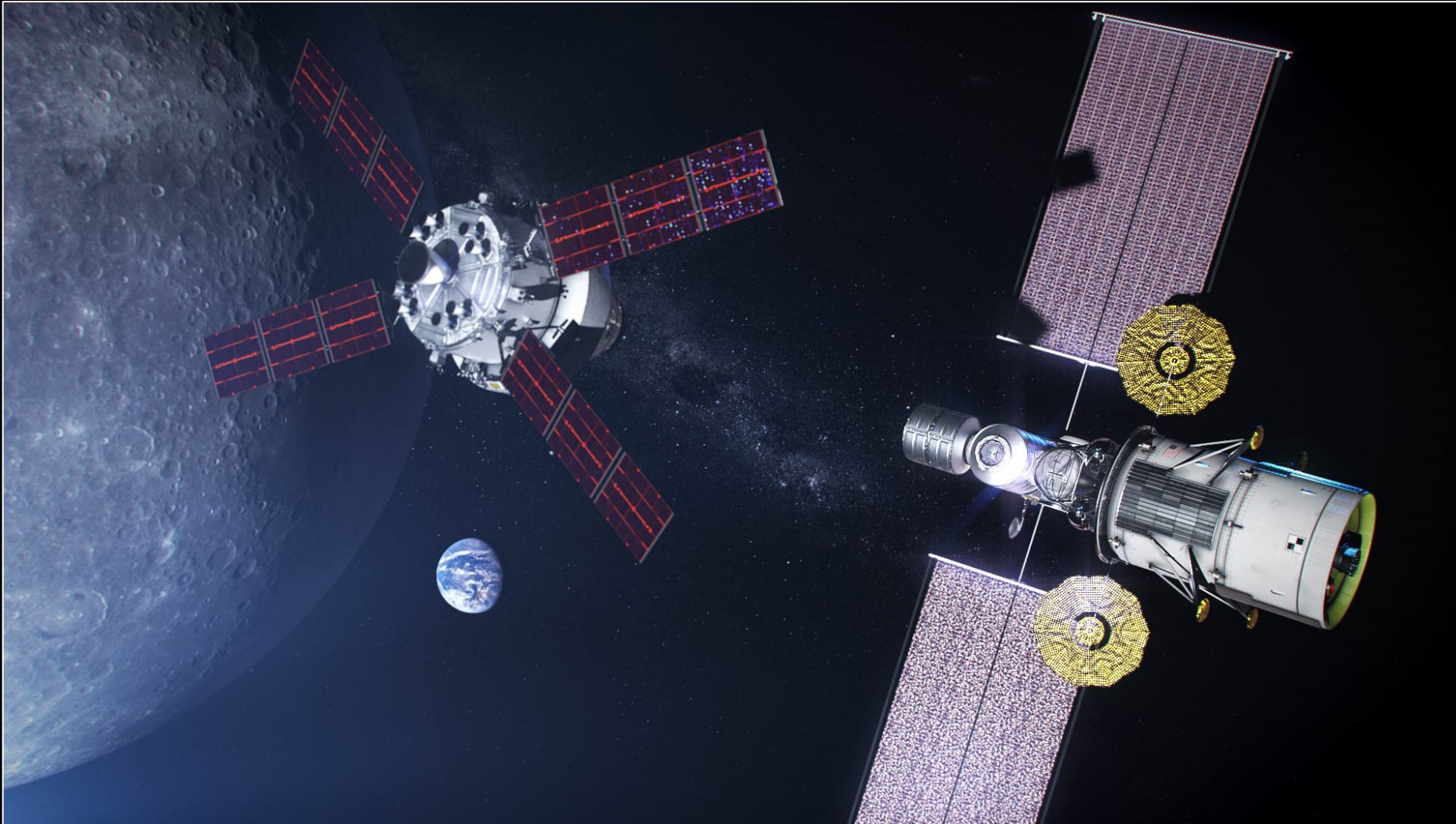
- PPE (2022)
- kleine habitat node (2023)
- HLS (2024)

Later:

- (EUR) ESPRIT
- Habitation modules
- Airlock
- Logistic modules

HLS: 2 astronauten (M/V) 6,5 dagen Shackleton Crater

ARTEMIS PROGRAMMA tot 2024



Gateway 2023

- PPE (2022)
- kleine habitat node (2023)
- HLS (2024)

Later:

- (EUR) ESPRIT
- Habitation modules
- Airlock
- Logistic modules



Toekomst : 2020-2030

10:28

ARTEMIS PROGRAMMA tot 2024

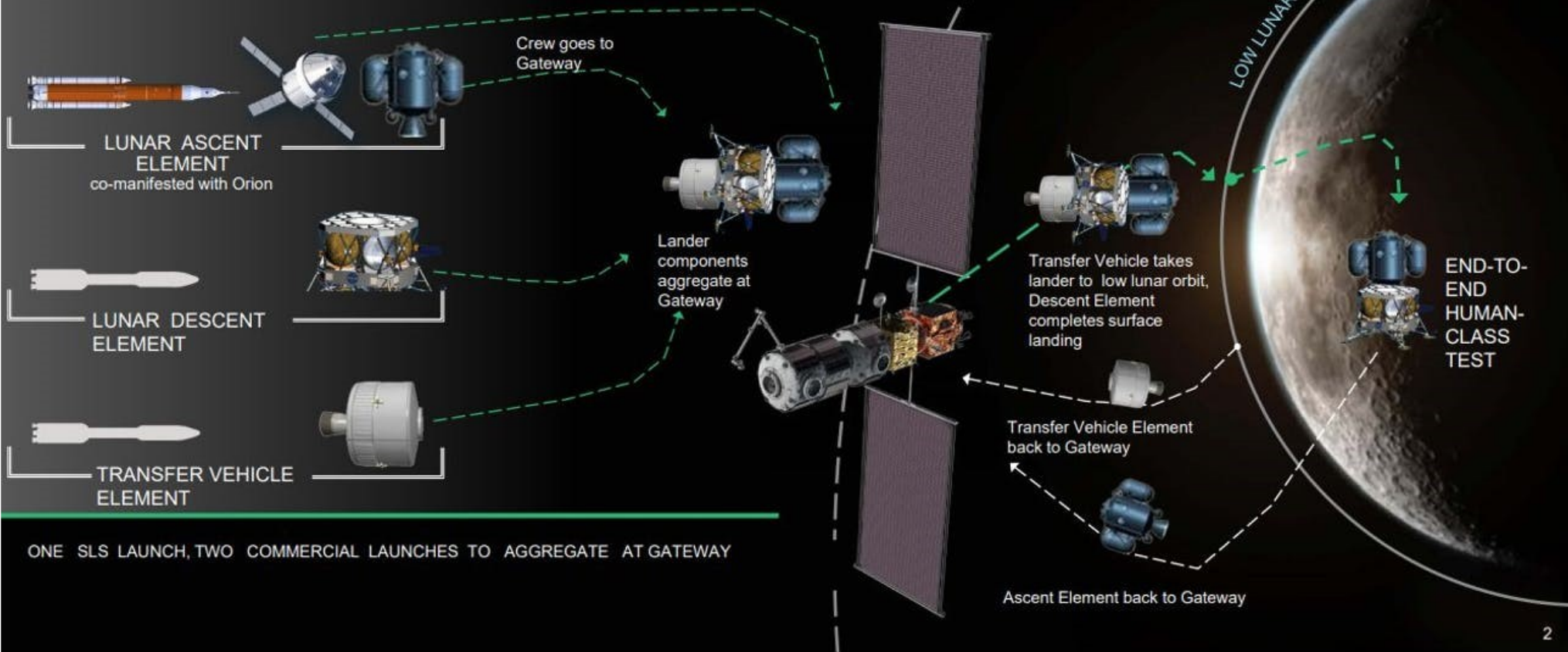


ARTEMIS PROGRAMMA tot 2024

Buildup of Notional Human Landing System Reference Architecture

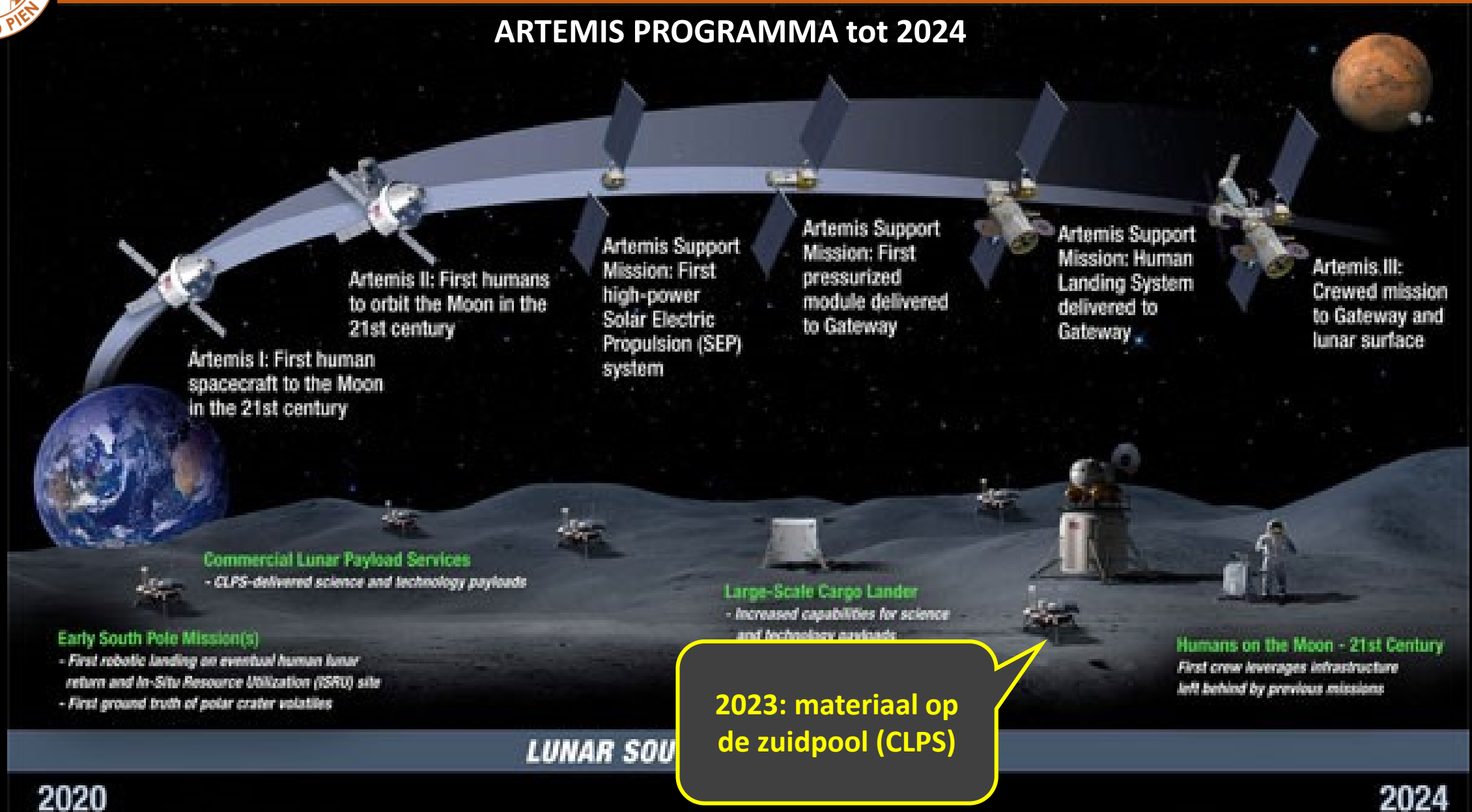
(2 of 3)

2026



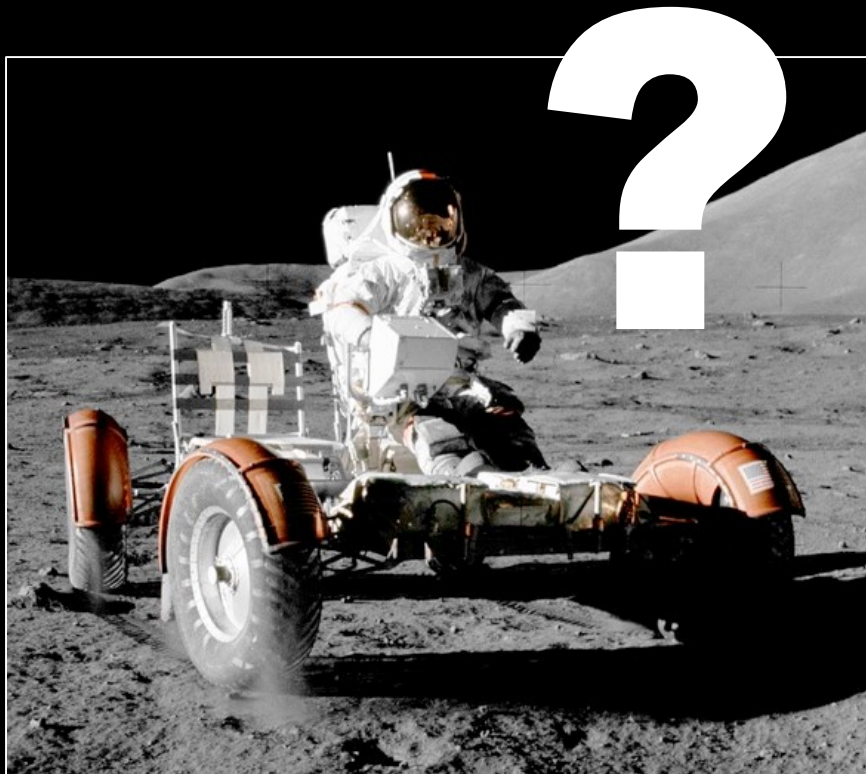
HLS
transfer + ascent vehicle:
Reusable from 2026

ARTEMIS PROGRAMMA tot 2024



ARTEMIS PROGRAMMA tot 2024

2024: unpressurized rover



> 2026: pressurized rover





Toekomst : 2020-2030

10:28

MAAN PROGRAMMA vanaf 2025

2025

- Artemis 4:
- Astronauten bouwen verder aan de gateway en landen ook op de Zuidpool

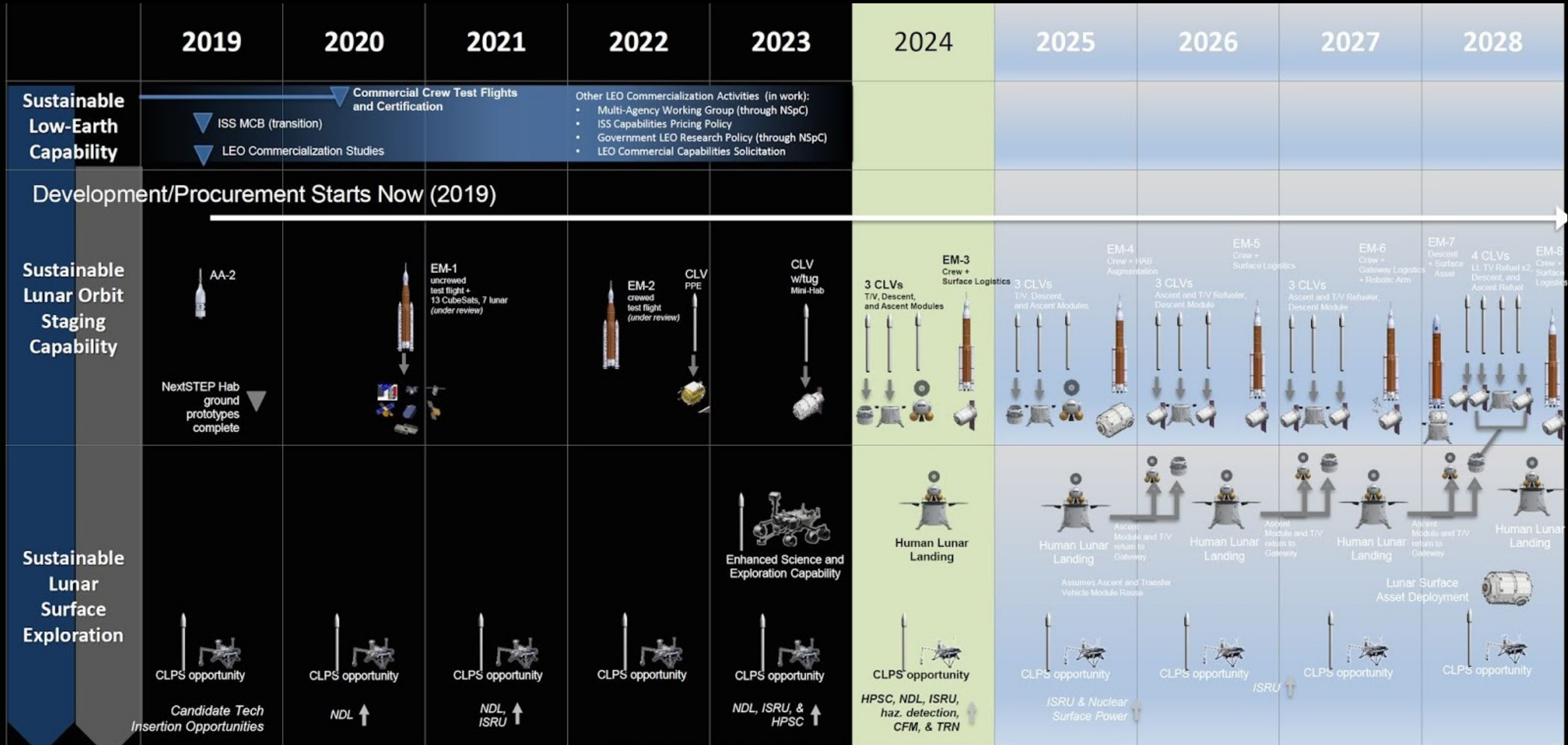
2026

- Artemis 5:
- Astronauten landen op de Zuidpool

2027

- Artemis 6:
- Astronauten landen op de Maan en installeren een robotarm op de gateway

MAAN PROGRAMMA vanaf 2025





Falcon Heavy + Crew Dragon 2



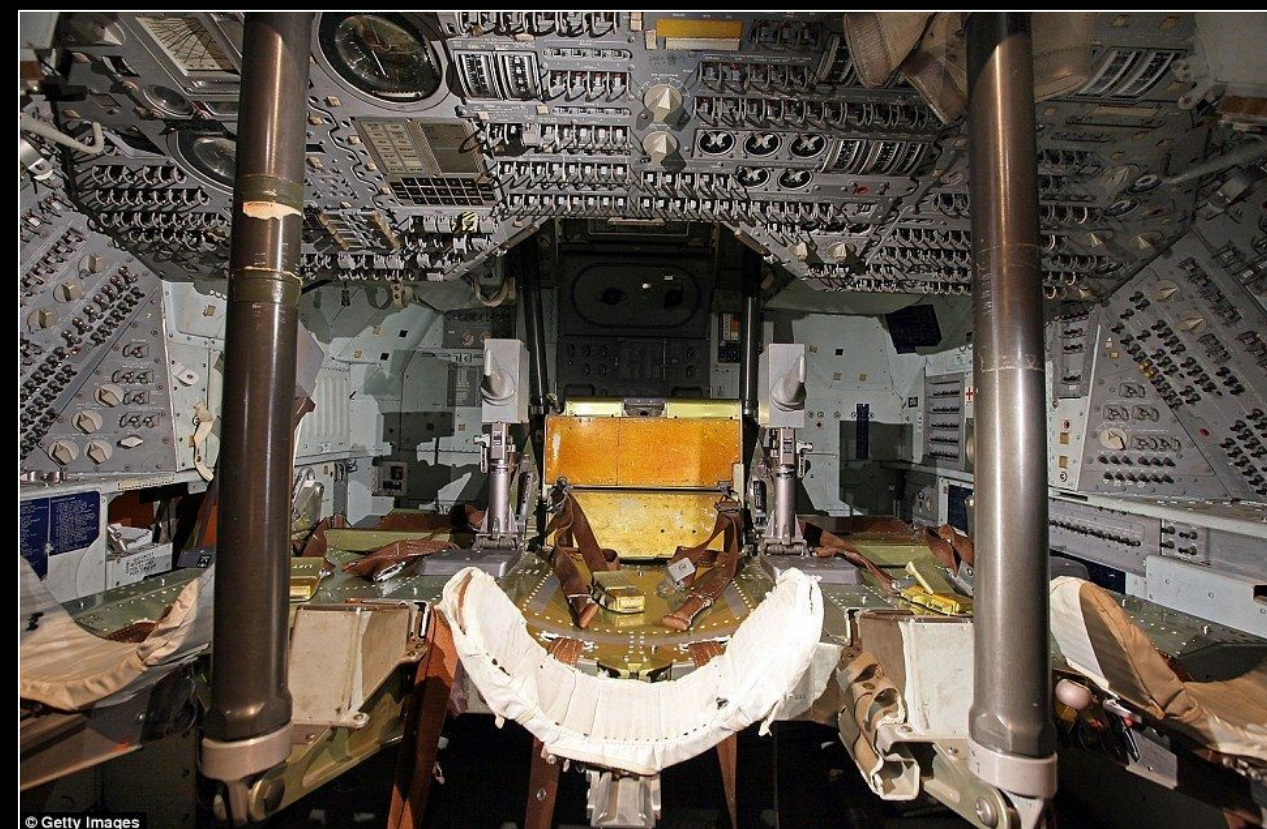
Starship

Super Heavy





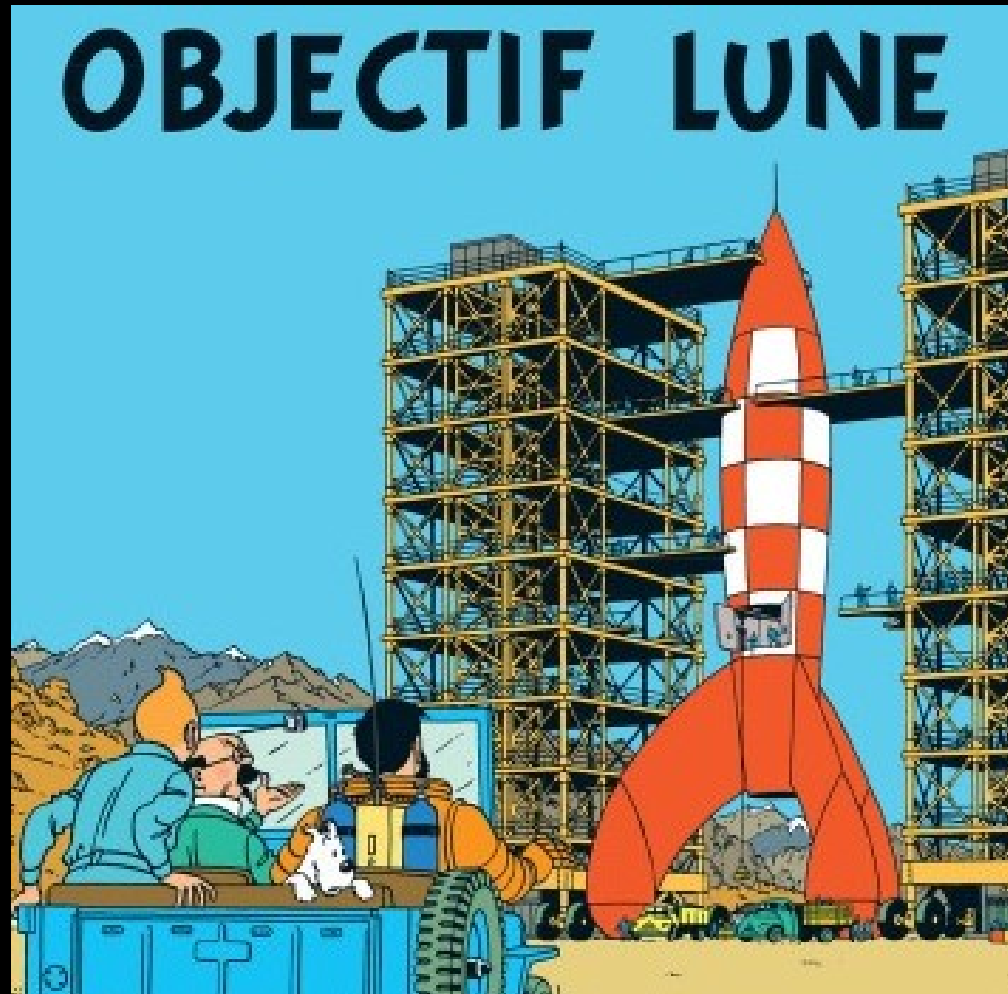
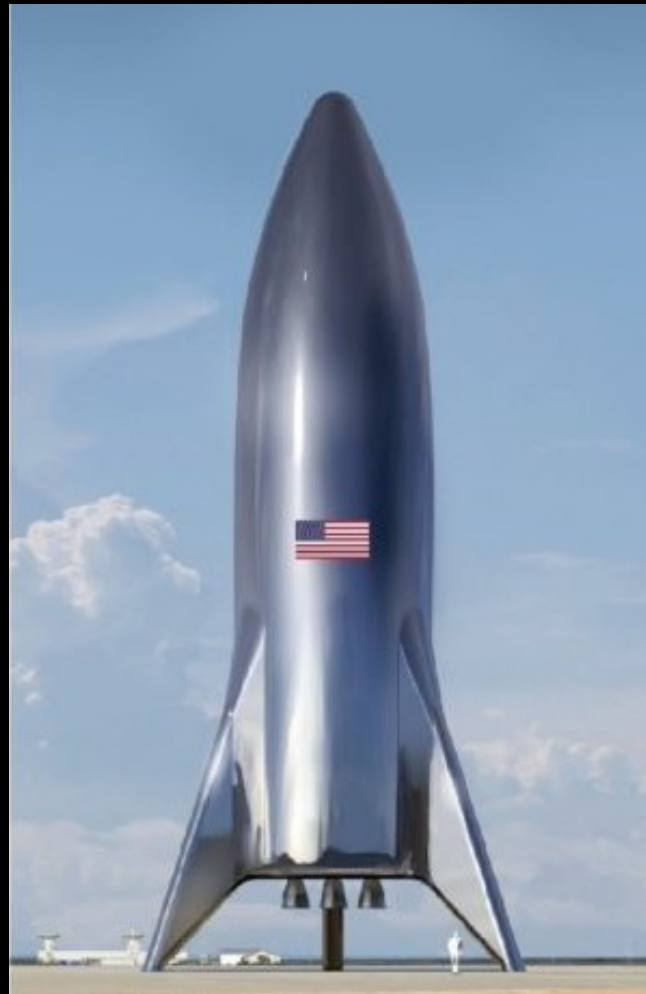
Apollo CM



Crew Dragon



STARSHIP



STARSHIP



“DEAR MOON”

- Yusaku Maezawa + 6/8 artiesten
- Contract 2018
- Vlucht rond de Maan ≥ 2023
- Drukcabine $\geq 1000 \text{ m}^3$
- Ongeveer 7 dagen



Toekomst : 2020-2030

10:28



STARSHIP

- 100-150 ton payload
- Tot 100 mensen
- Herbruikbaar ($\leftrightarrow$ SLS)
- Bijtanken in de ruimte
- +/- 5 miljard \$
- Eerste vlucht 2020 (?)
- 2022 onbemande landing op de Maan?





Toekomst : 2020-2030

10:28

STARSHIP



Starhopper (27 aug 2019) : Test 3 Raptor motoren

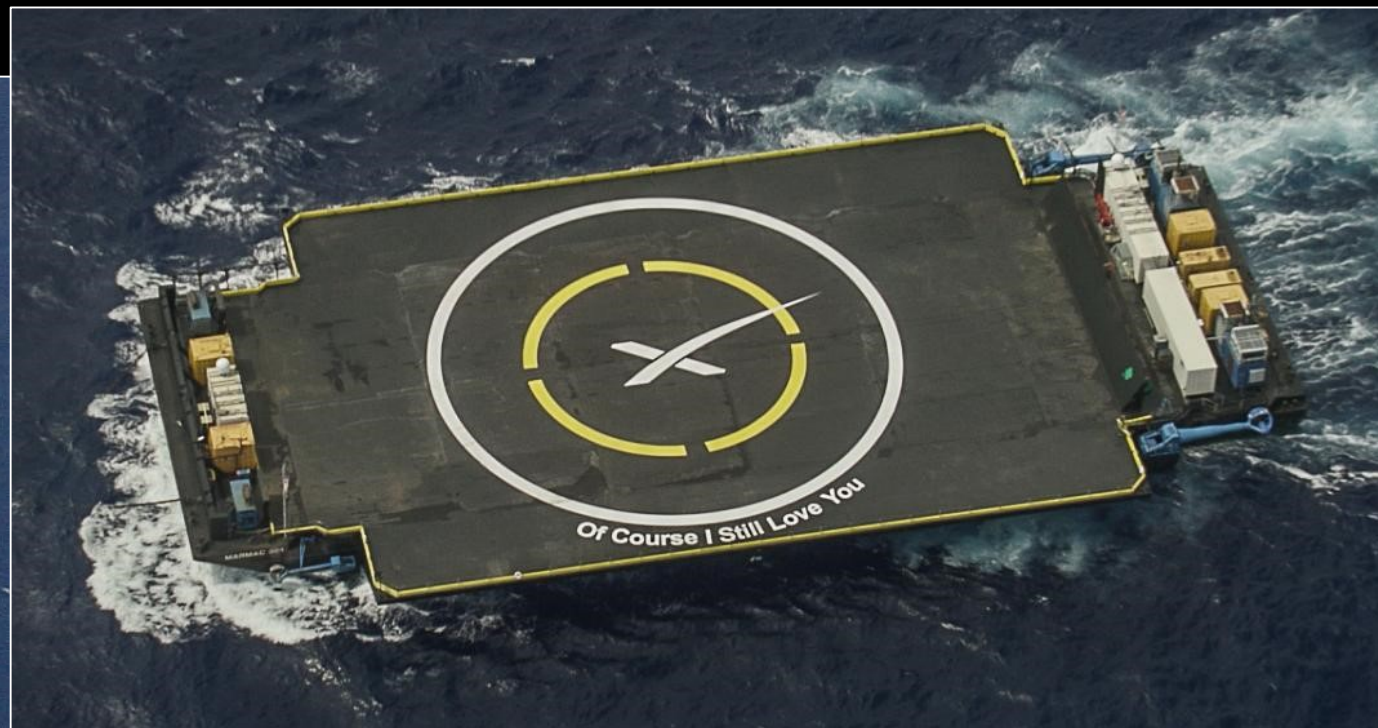
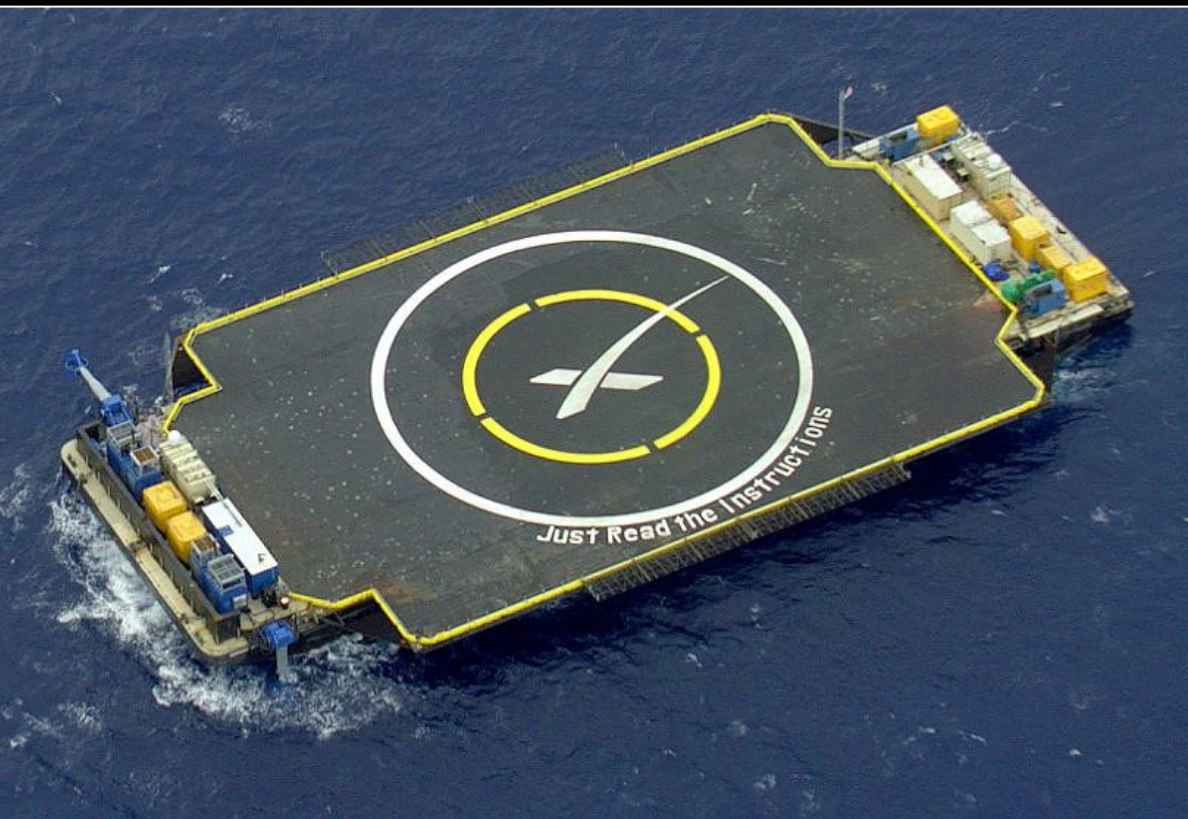




Toekomst : 2020-2030

10:28

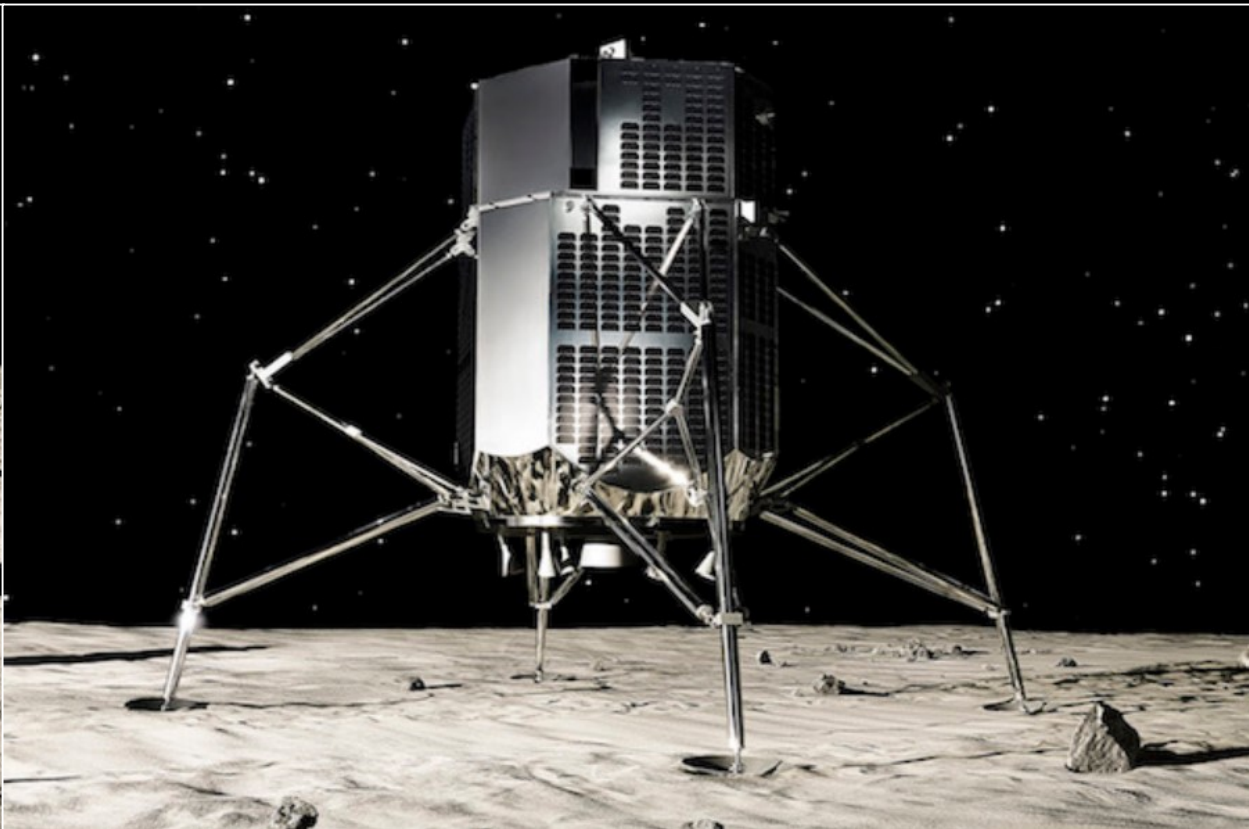
STARSHIP



Toekomst : 2020-2030

Enkele andere missies ...

iSpace (Japan)



Toekomst : 2020-2030

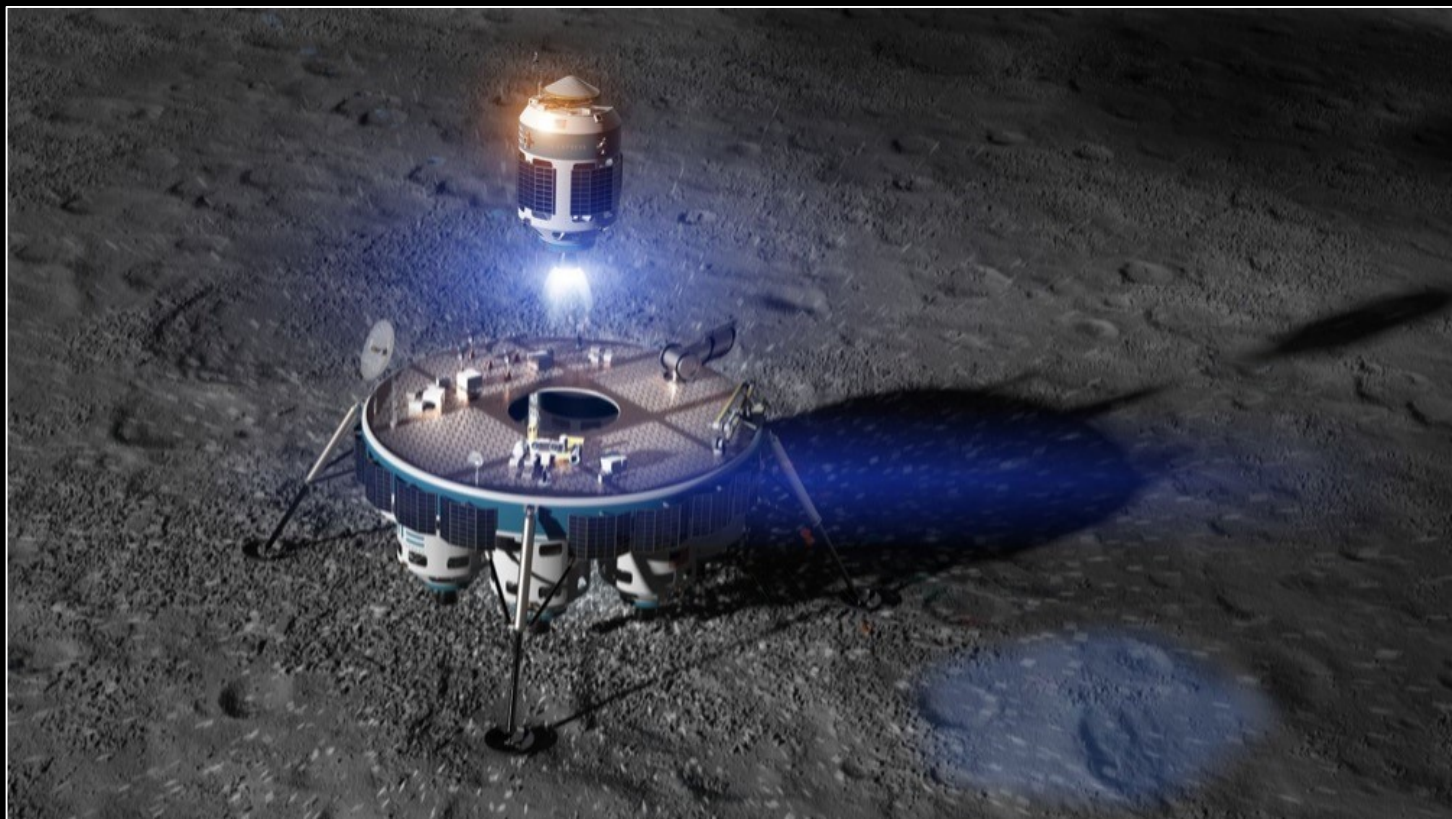
Enkele andere missies ...

Moon Express



LUNAR SCOUT

Telescoop, laserreflector, menselijk graf



LUNAR OUTPOST

Robotic outpost

'Harvest Moon': sample return

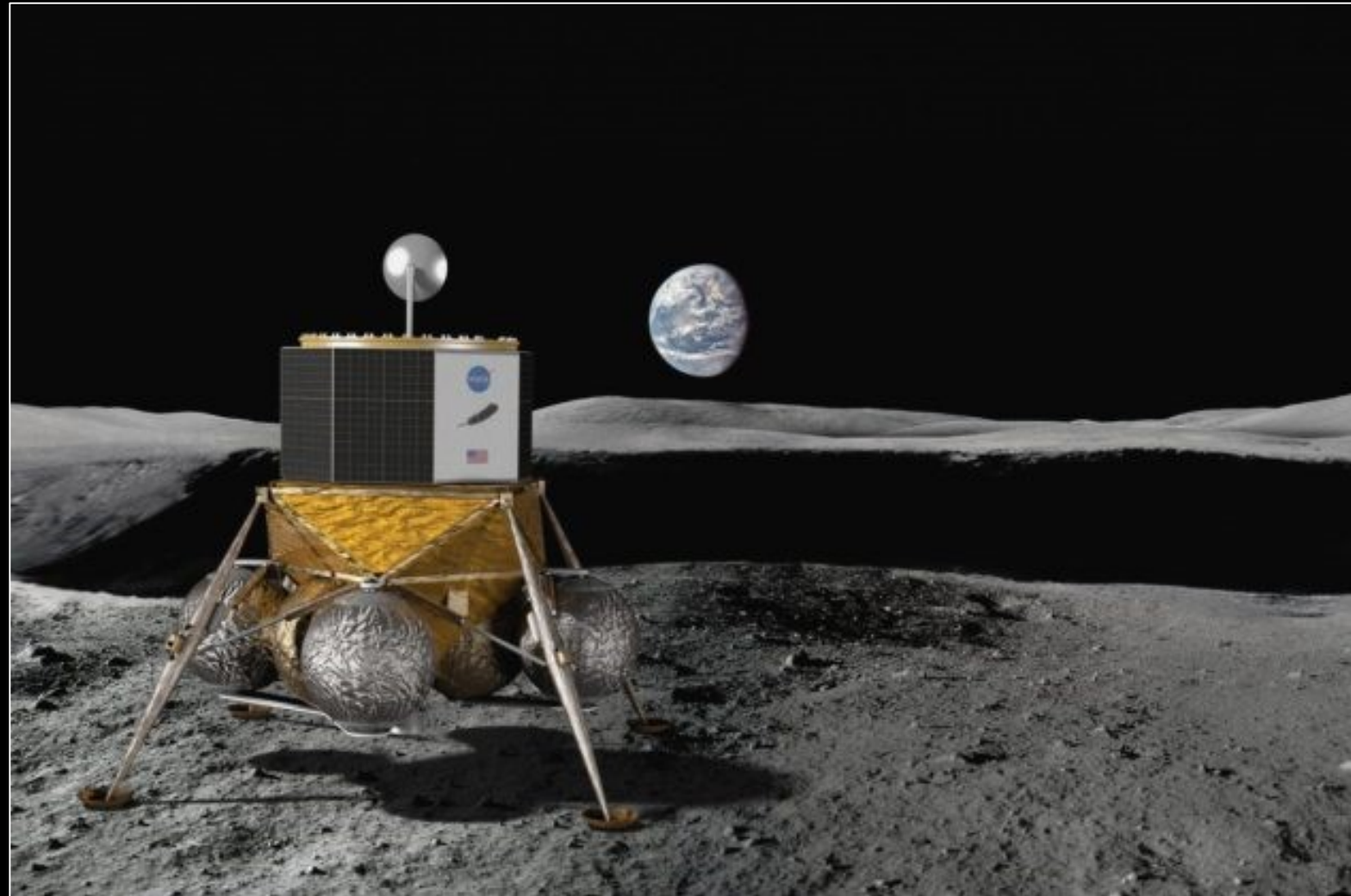


Toekomst : 2020-2030

Enkele andere missies ...

Blue Moon (Blue Origin)

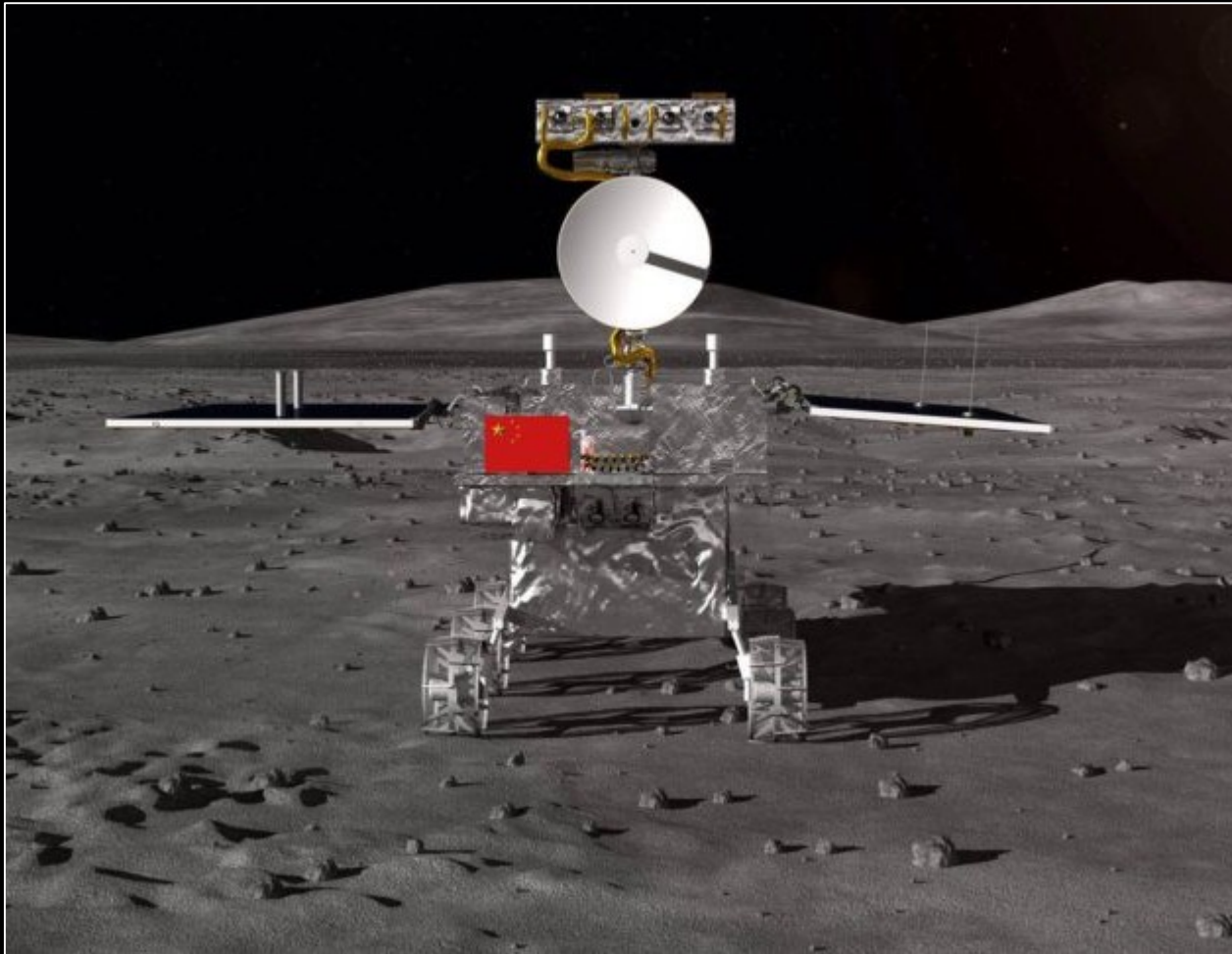
LUNAR LANDER
(herbruikbaar) om te
combineren met LOP-G



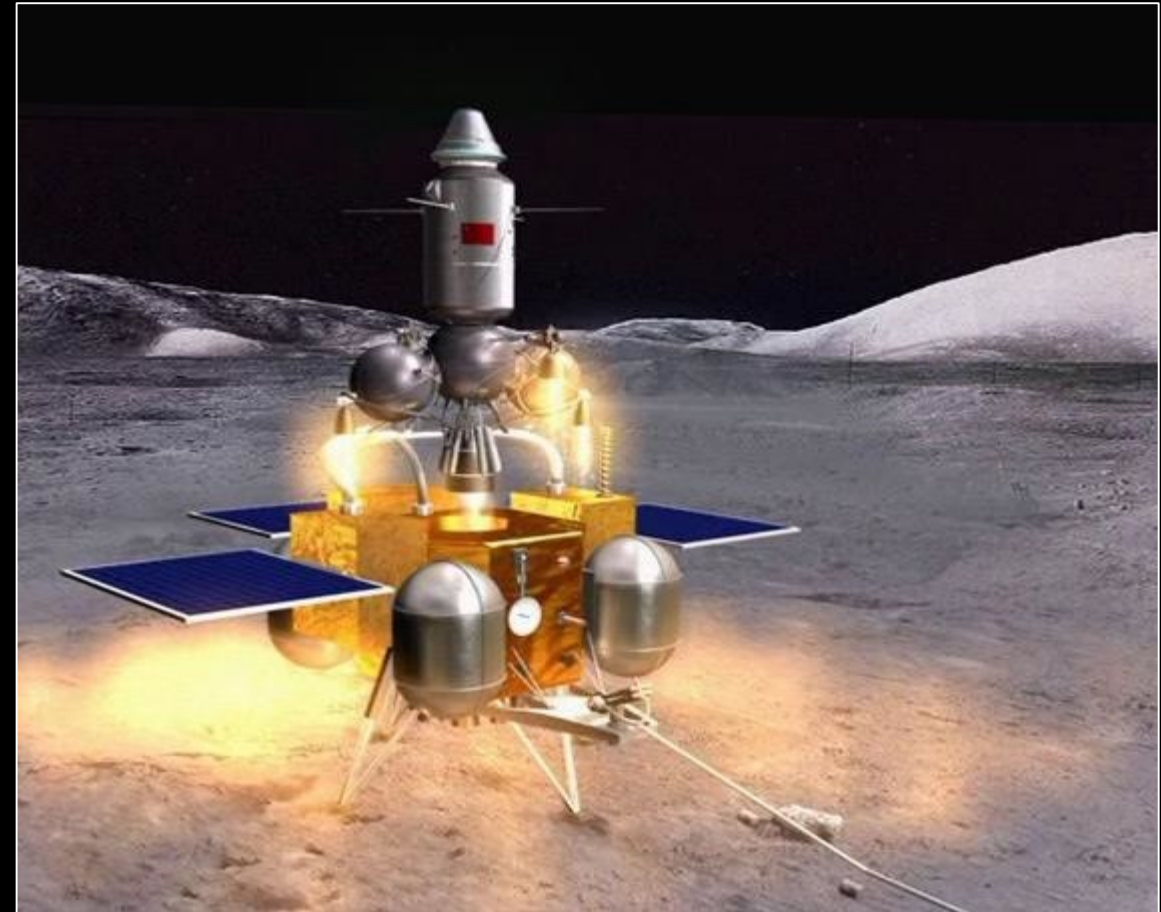
Toekomst : 2020-2030

Enkele andere missies ...

Chang'e (China)



Chang'e 4 (rover op achterkant vd maan)



Chang'e 5 (sample return)

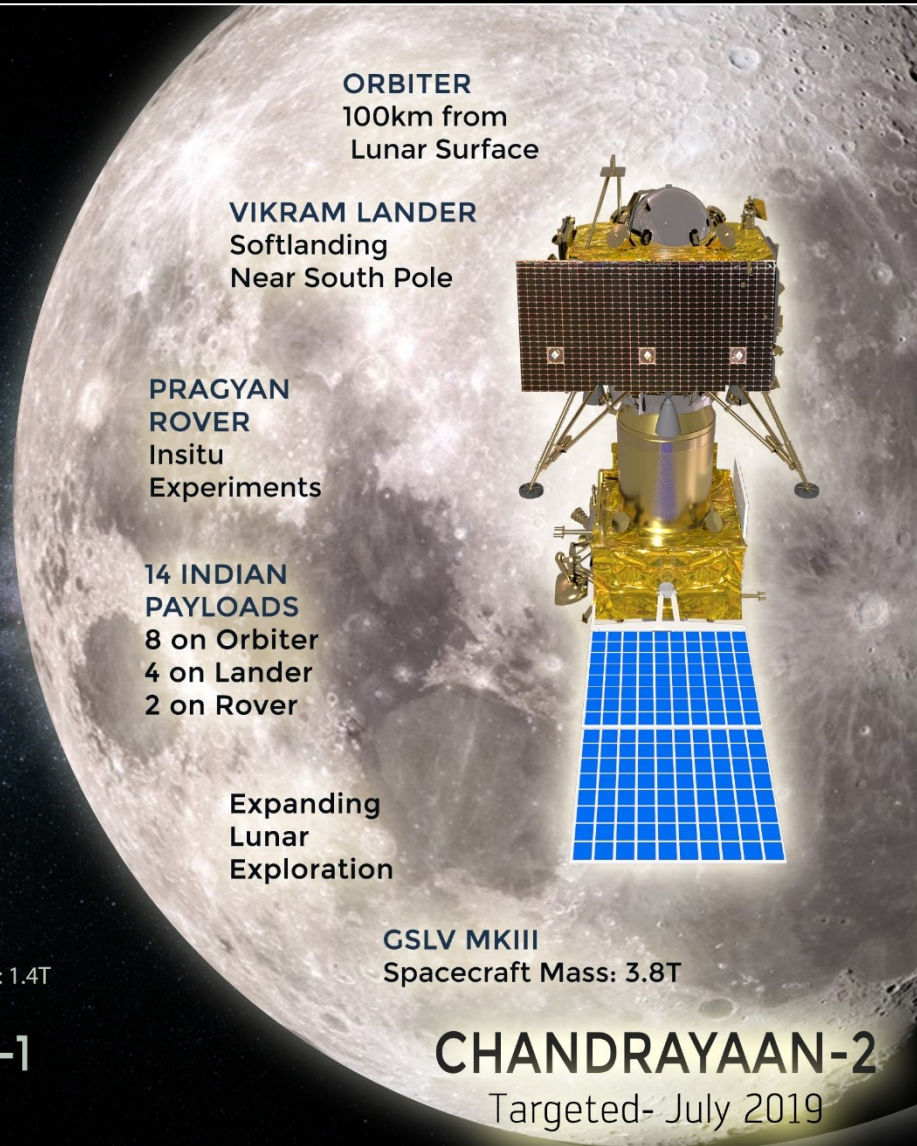
Toekomst : 2020-2030

Enkele andere missies ...

Chandrayaan (India)



**Chandrayaan-2:
Orbiter, Lander and
Rover**



ORBITER
100km from
Lunar Surface

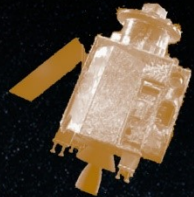
VIKRAM LANDER
Softlanding
Near South Pole

**PRAGYAN
ROVER**
Insitu
Experiments

**14 INDIAN
PAYLOADS**
8 on Orbiter
4 on Lander
2 on Rover

Expanding
Lunar
Exploration

GSLV MKIII
Spacecraft Mass: 3.8T



ORBITER
100km from
Lunar Surface

11 PAYLOADS
6 from India
3 from Europe
2 from USA

**DISCOVERY
OF WATER** on
Lunar Surface

MAPPING
of Chemicals,
3D Topography

PSLV
Spacecraft mass: 1.4T

CHANDRAYAAN-1

Oct 2008

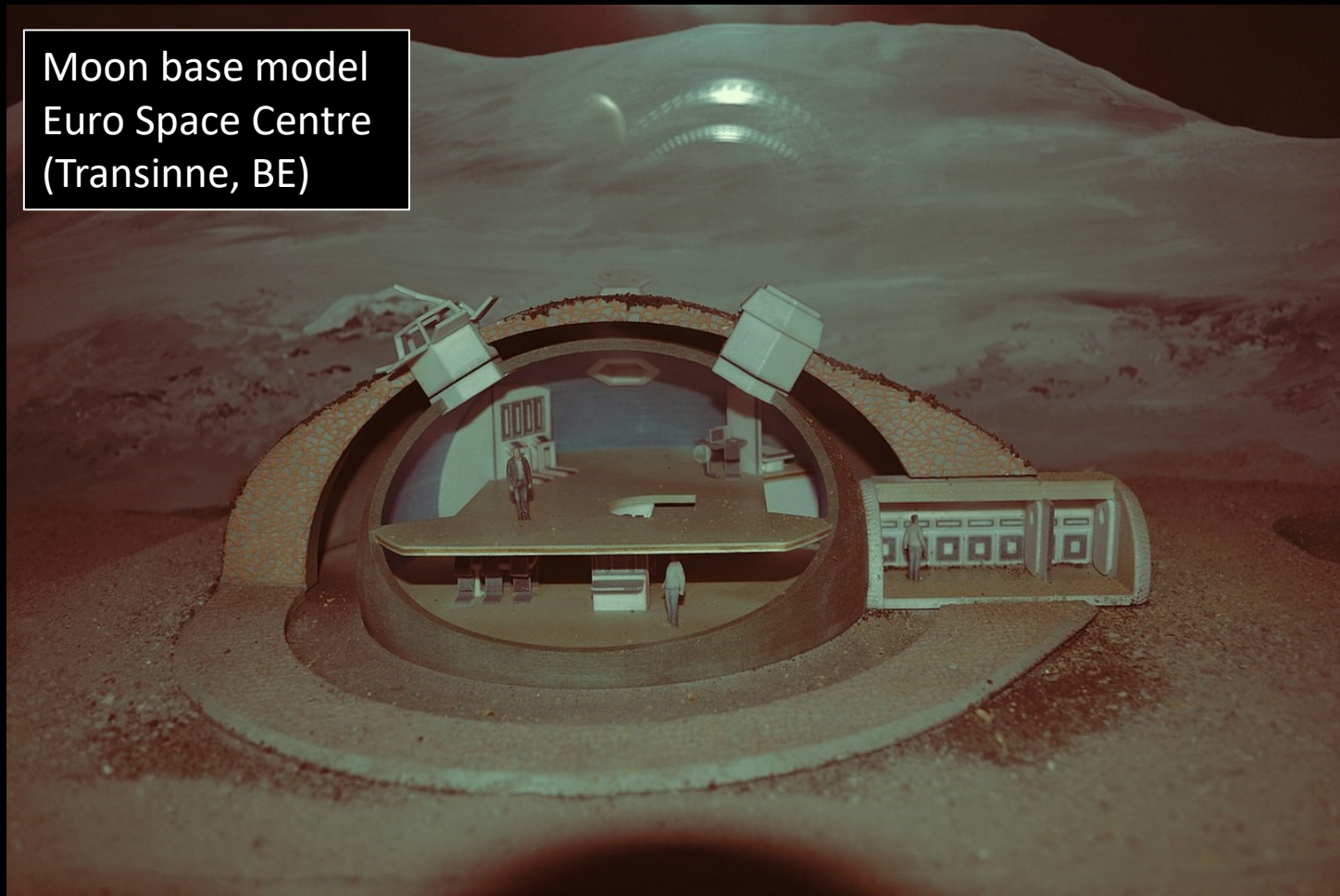
CHANDRAYAAN-2

Targeted- July 2019

Toekomst : 2020-2030

Moon BASE

Moon base model
Euro Space Centre
(Transinne, BE)



“Moon Village”

- Concept gelanceerd door ESA 2015 – opvolging ISS
- Moon Village association (Wien, AUST)

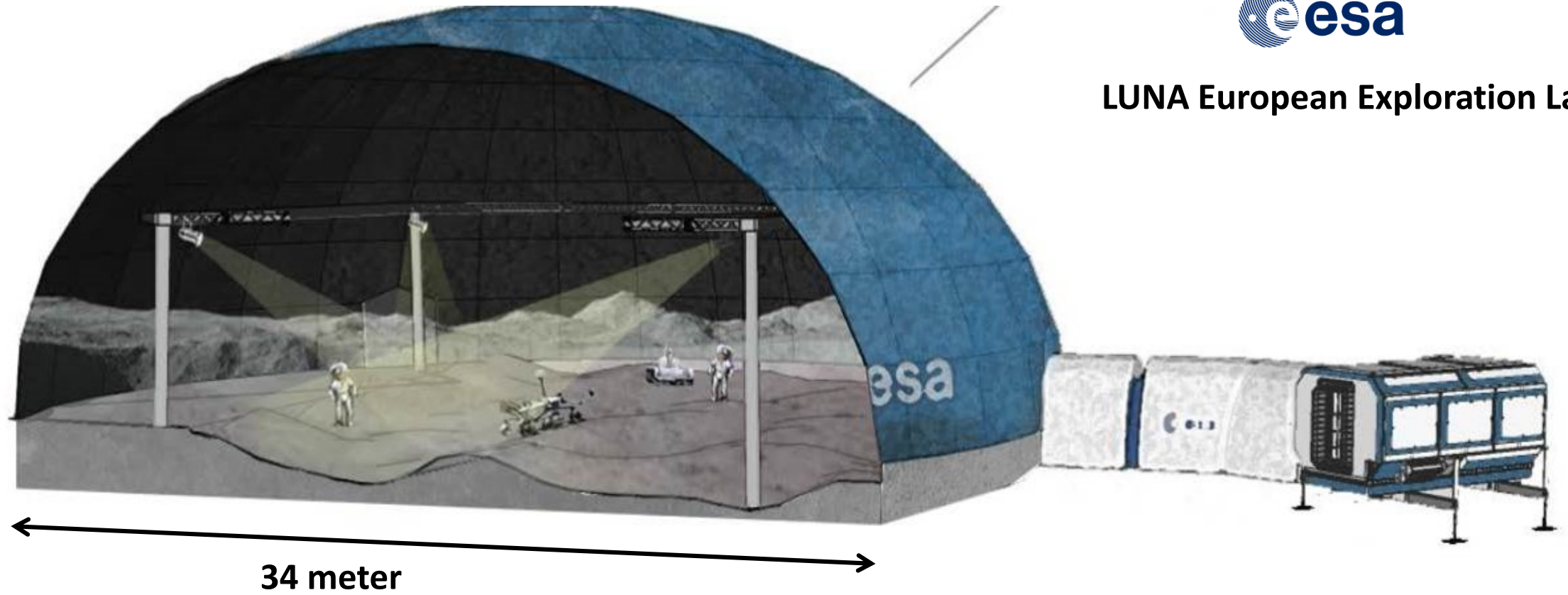
Mensen op de Maan

“Moon Village”

- SpaceShip EAC

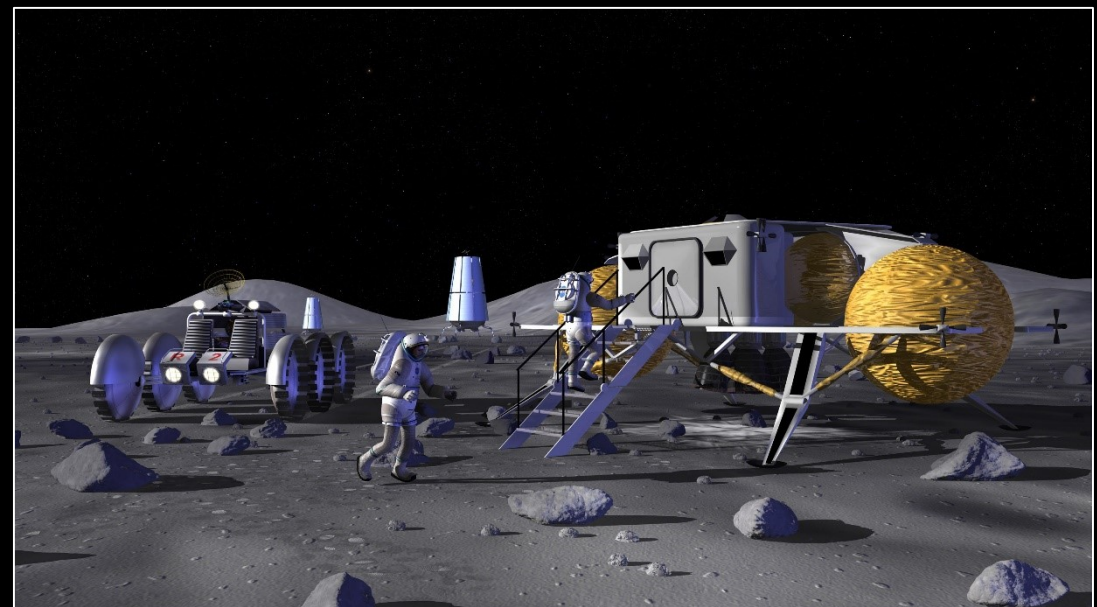
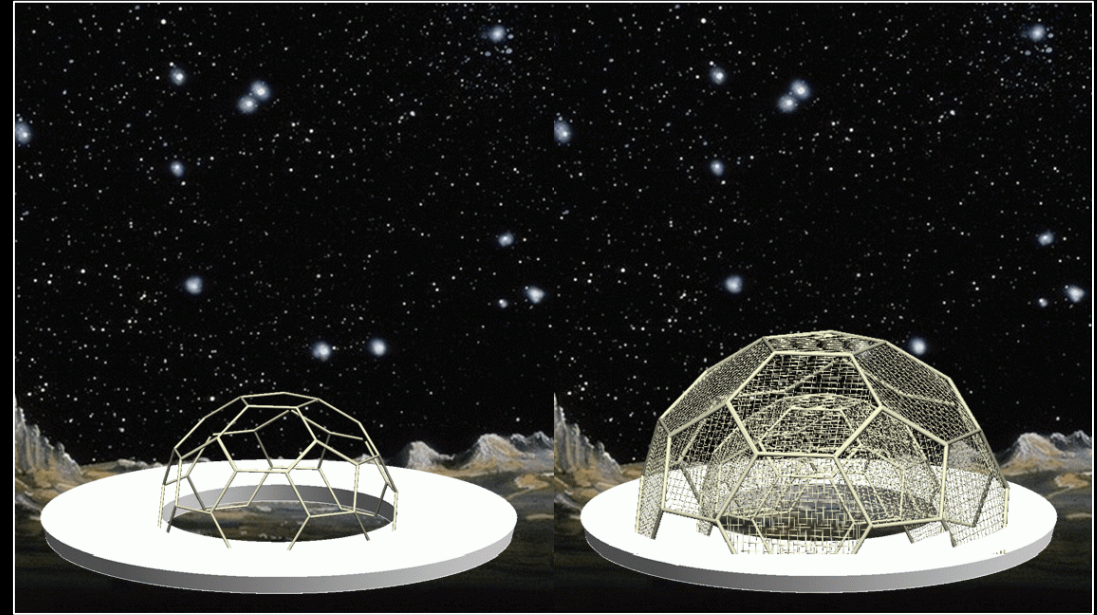


LUNA European Exploration Lab



Toekomst : 2020-2030

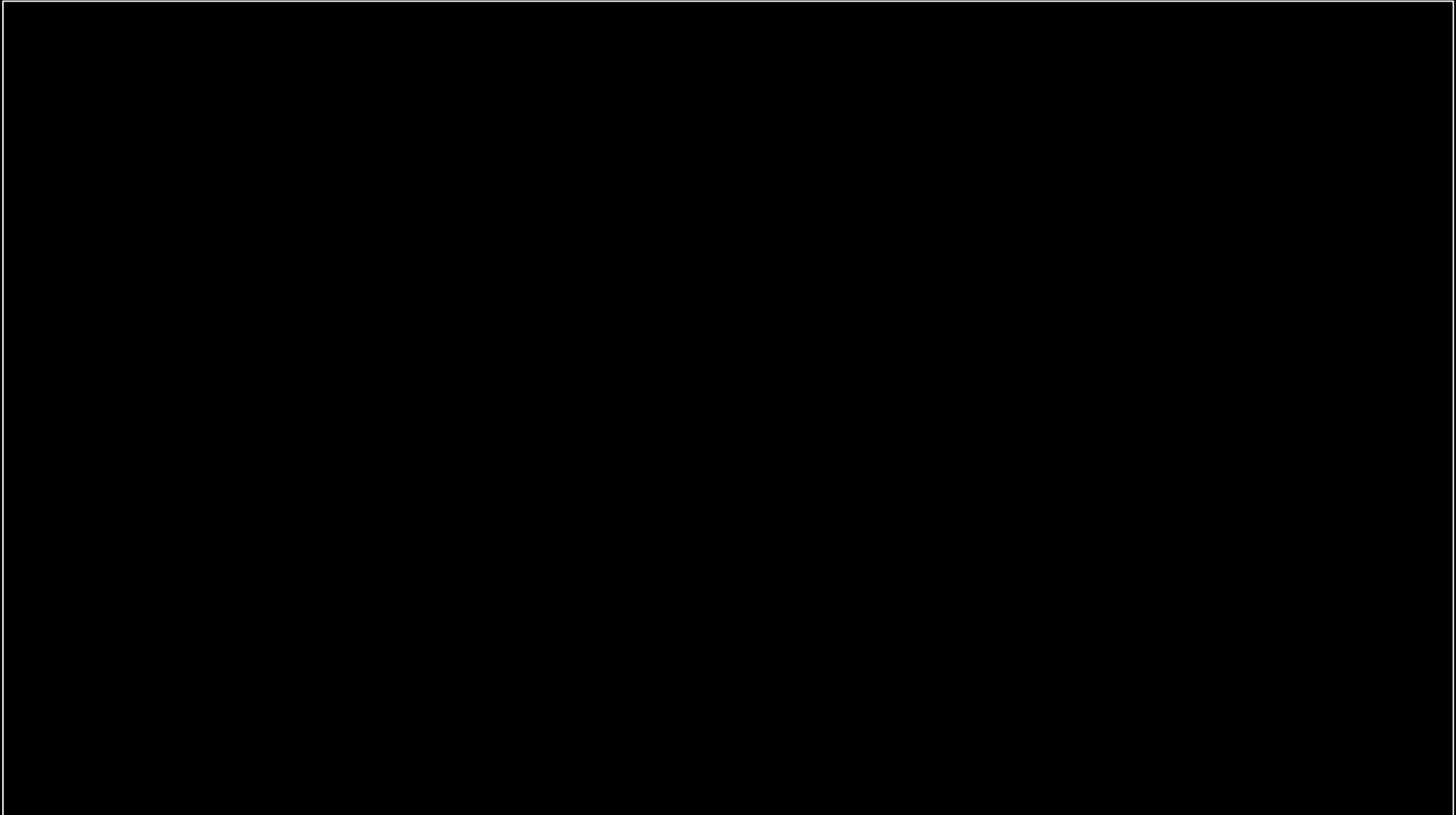
Moon BASE

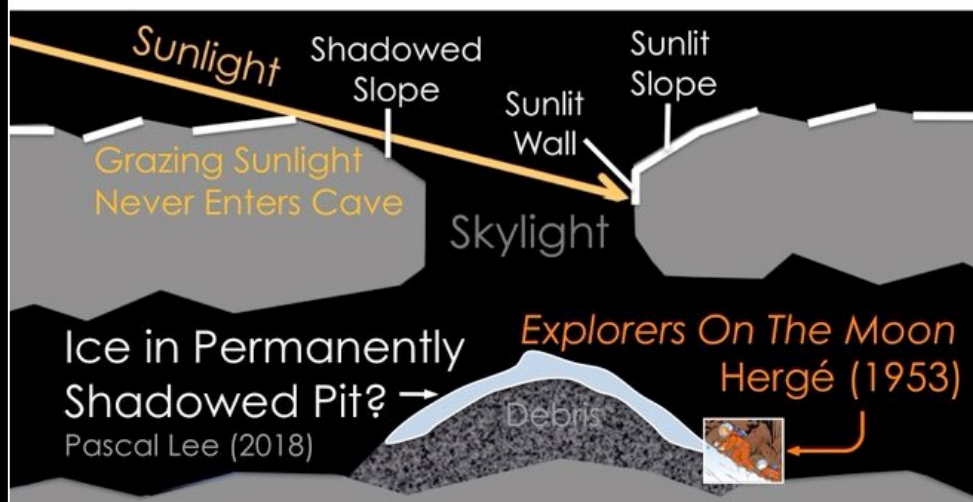
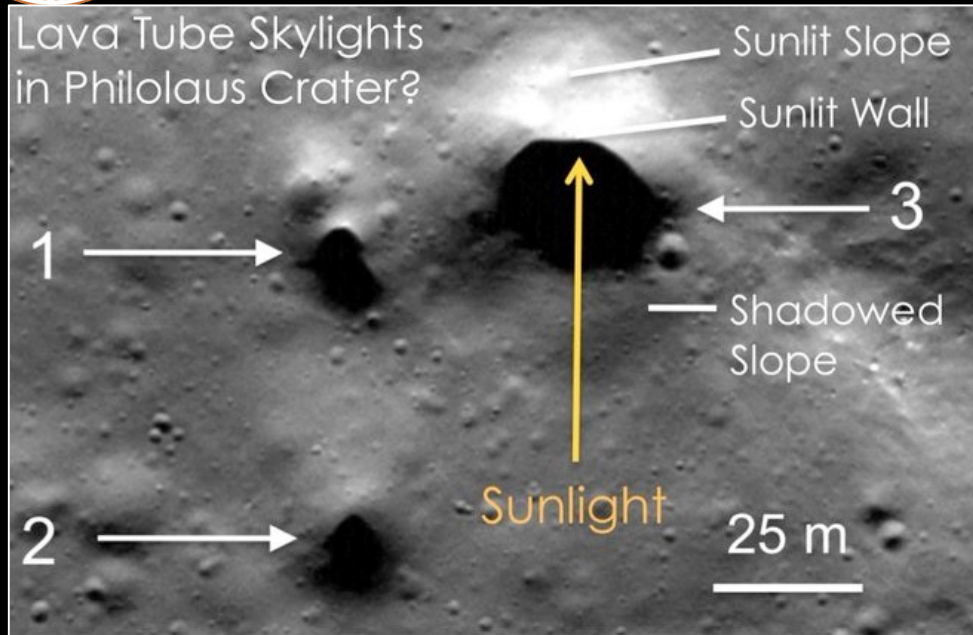




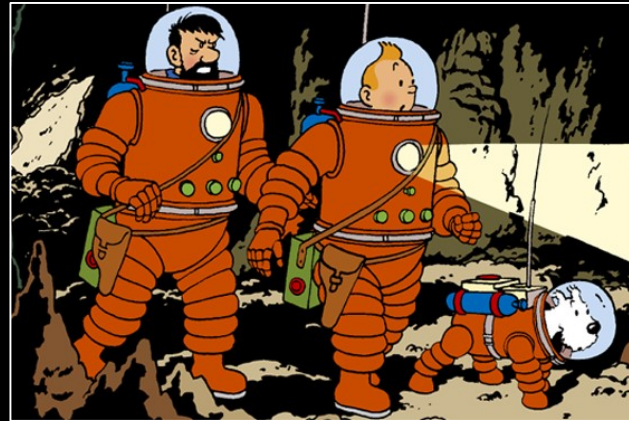
Toekomst : 2020-2030

Moon BASE

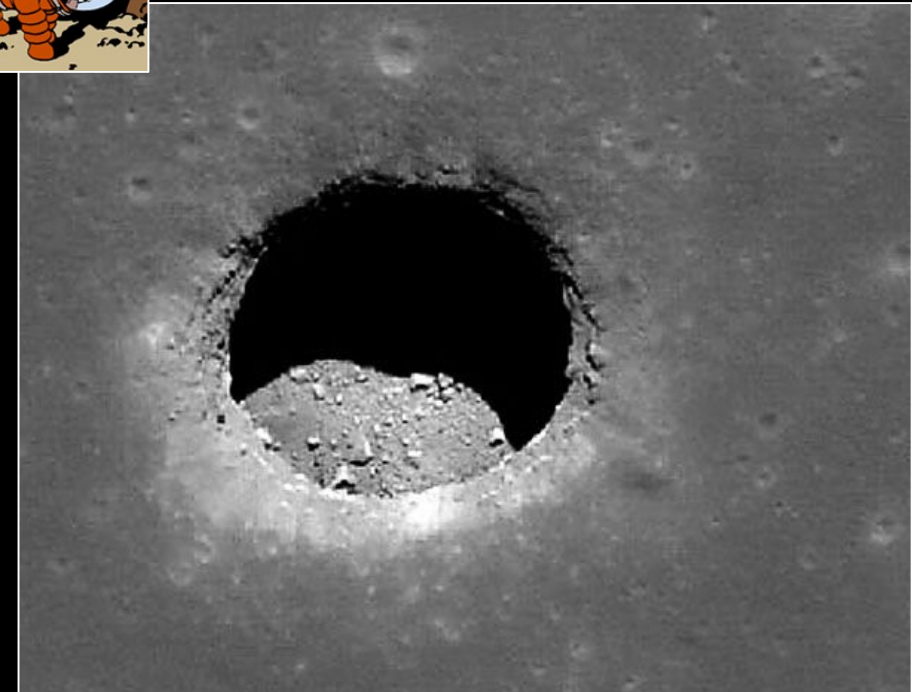
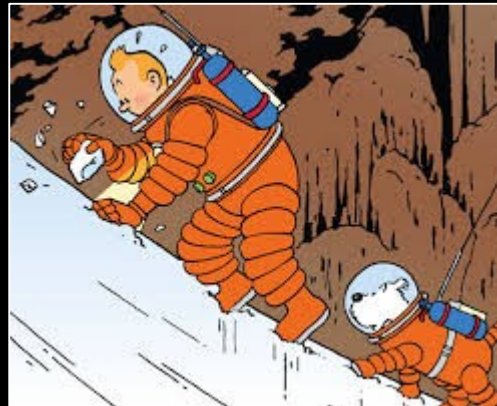




Moon base: Lavatubes ?



Goede oefening voor Mars !



Moon base: Lavatubes ?

 **Jet Propulsion Laboratory**
California Institute of Technology

 **ETI**
INSTITUTE

 **MARS INSTITUTE**

GlobeTrotter - Mars

Concept All-Terrain Inflatable Hopper for Mars Surface & Subsurface Exploration

GT could cover 1-10 km/day via Cold-Gas Thrusts & "Pop-n-Pounce".

Surface Exploration
GT could scout out extreme terrain on Mars

Subsurface Exploration
GT would freefall into pit, bounce, settle, right itself, carry out in-situ science, and fly out via known path to transmit data & continue exploring.

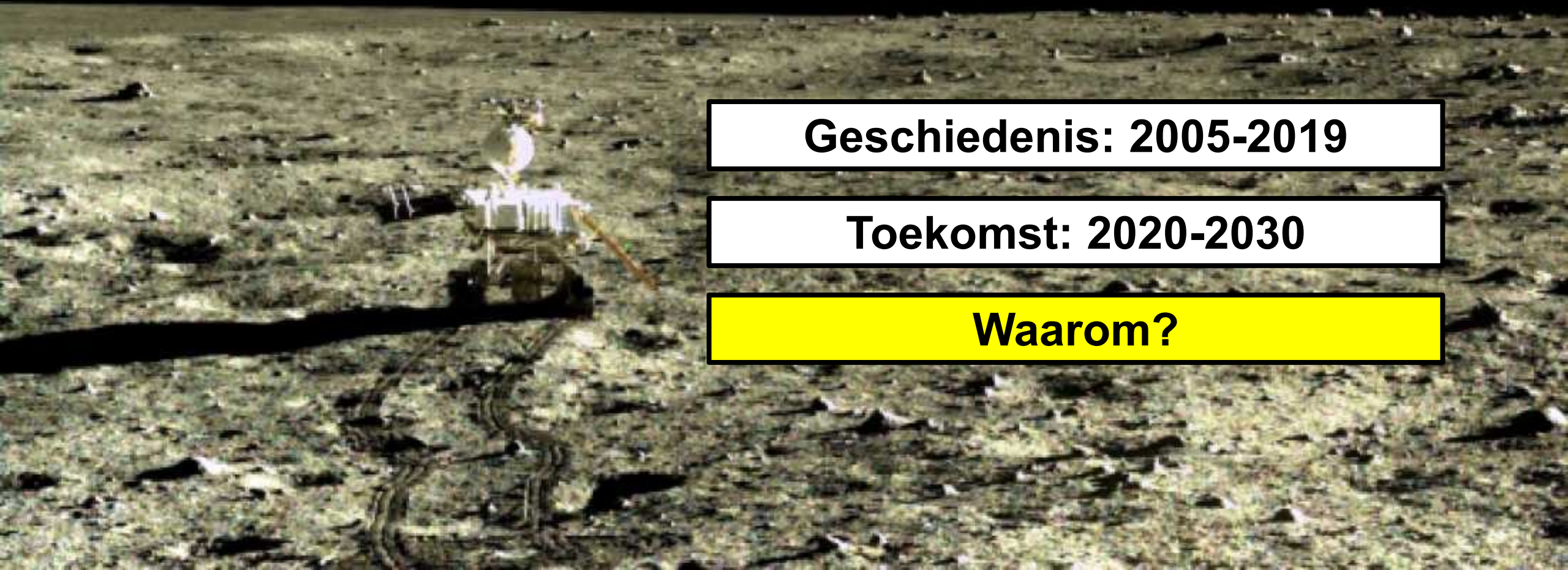
Deployed **Airbags (4)** **Stowed** **Interior** **Thrusters** **Flash** **Optics Camera & Thruster Head**

This Slide Contains Artist Concepts & Pre-Decisional Information for Planning & Discussion Purposes Only.



Nieuwe Maanmissies

10:28



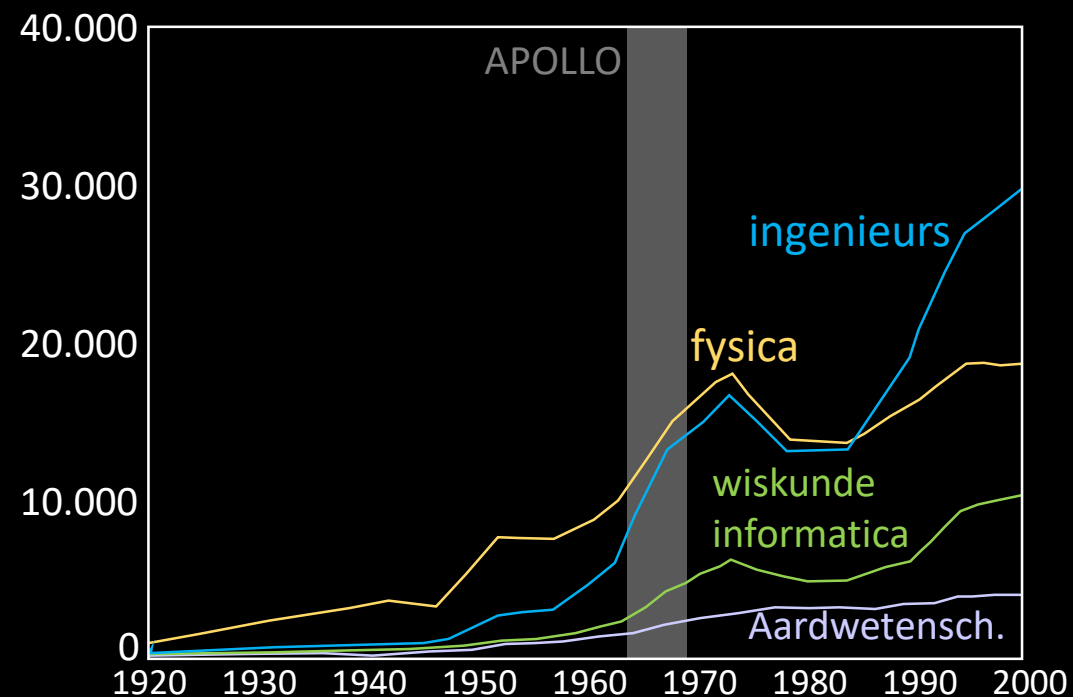
Geschiedenis: 2005-2019

Toekomst: 2020-2030

Waarom?

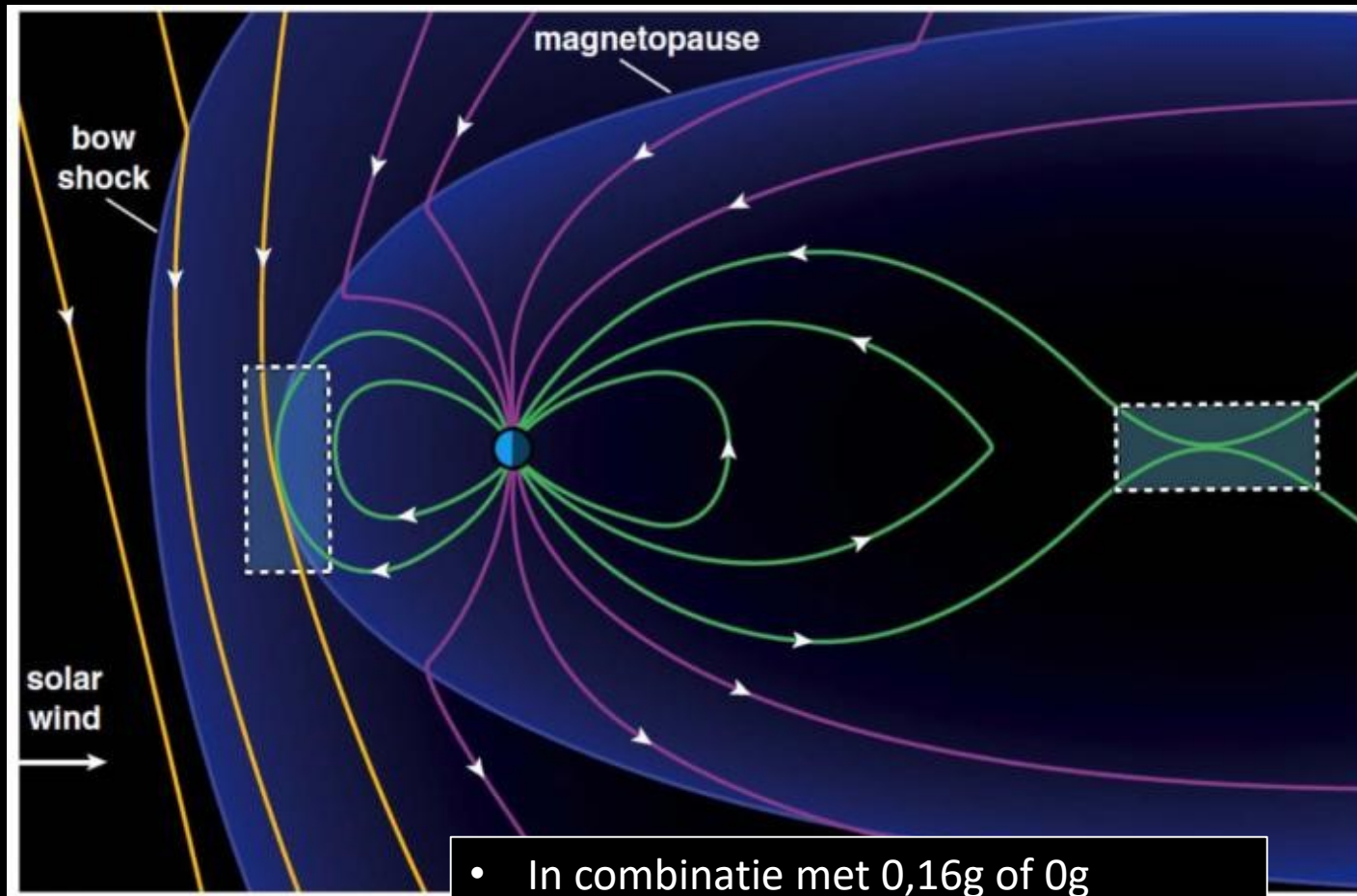
Stimulerend effect: STEM studies en STEM beroepen

Aantal afgestudeerden in de USA in wetenschappen



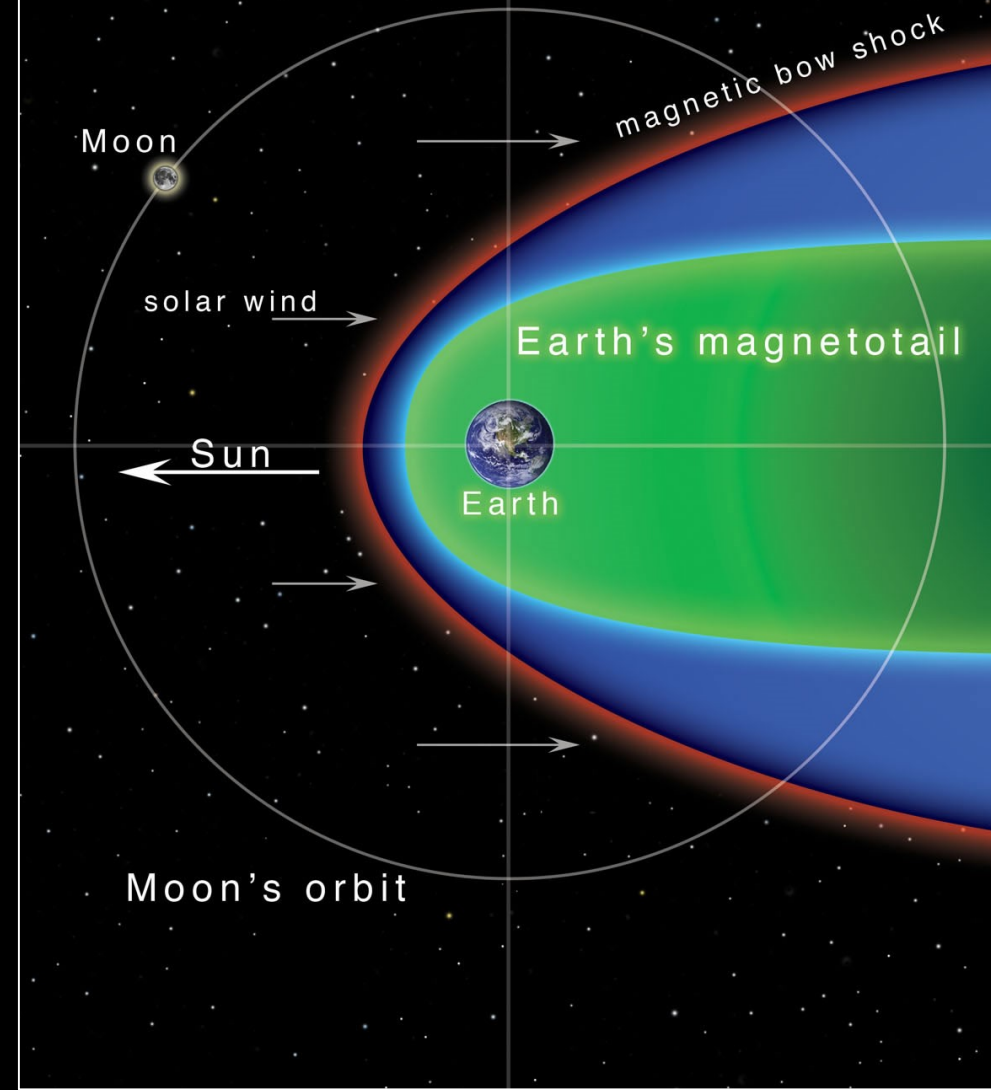
Waarom?

Wetenschap: radiation studies

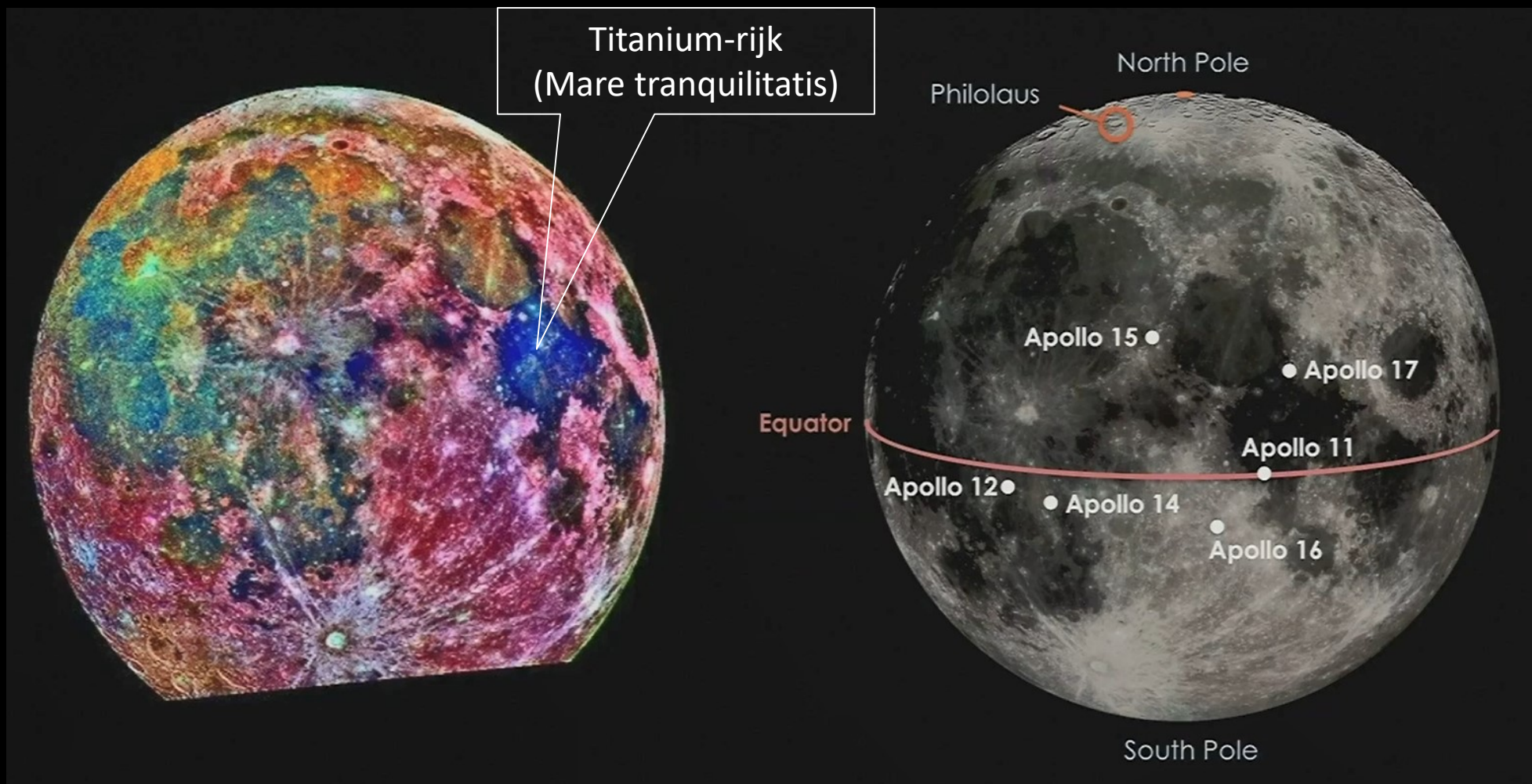


- In combinatie met 0,16g of 0g
- Voor mensen en voedsel-organismen
- Nabij water (secundaire versnelling H)

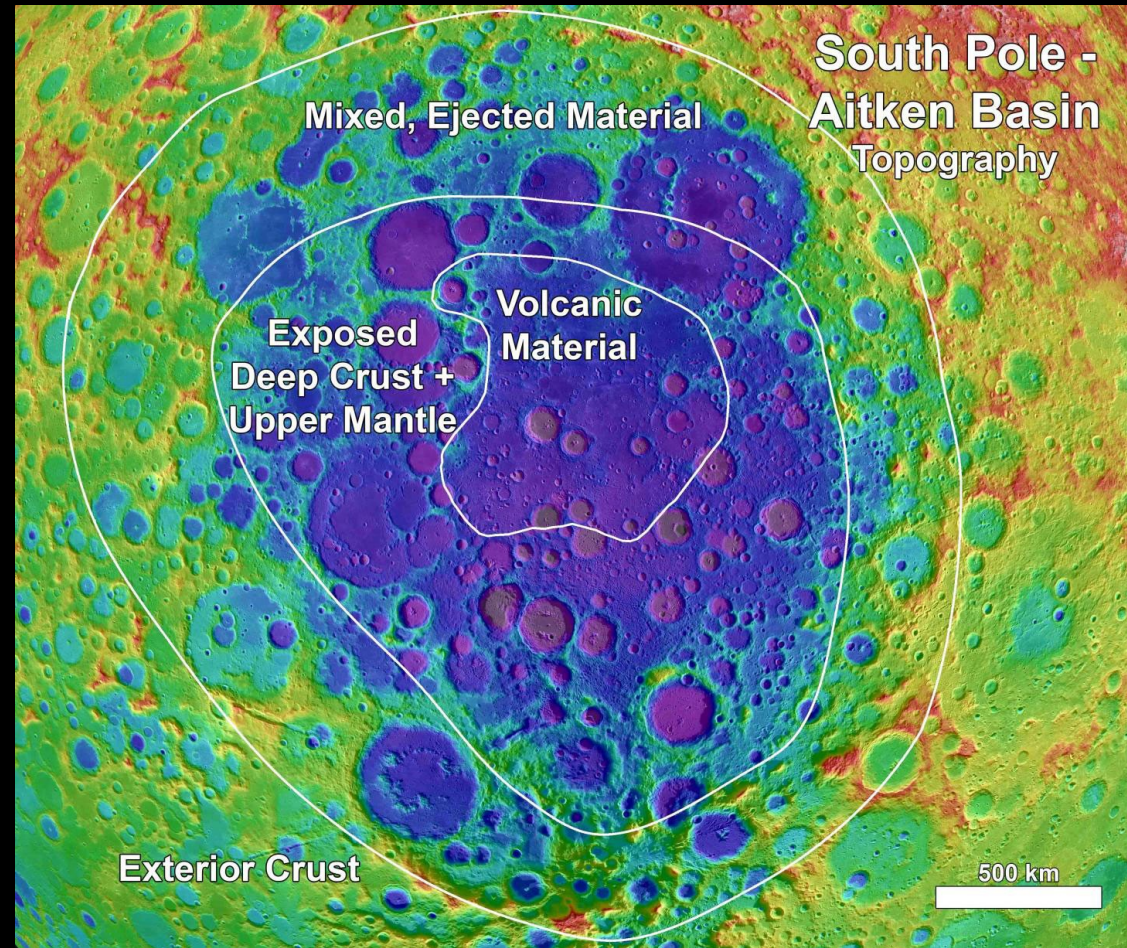
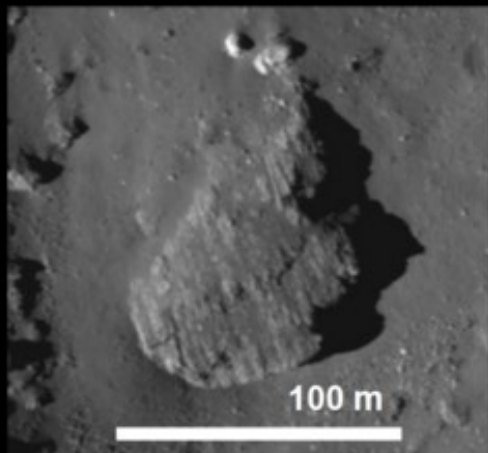
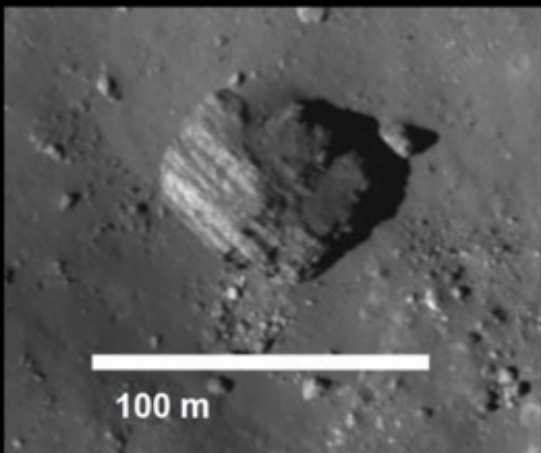
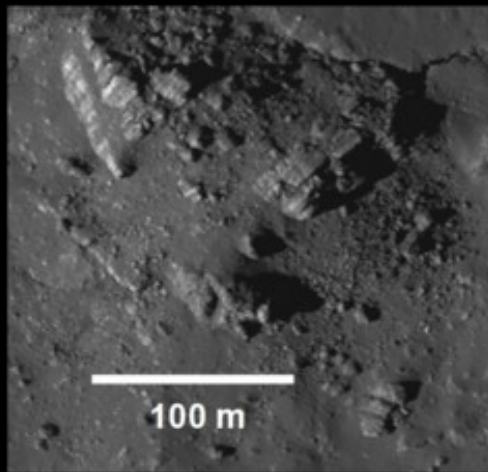
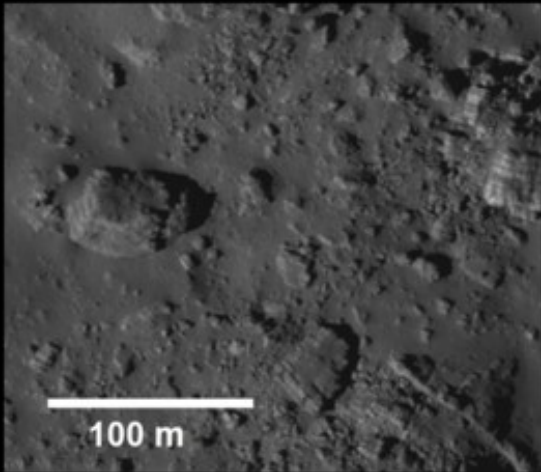
Lunar Radiation Environment



Wetenschap: MINERALOGIE



Wetenschap: geologie (oorsprong van planeten)



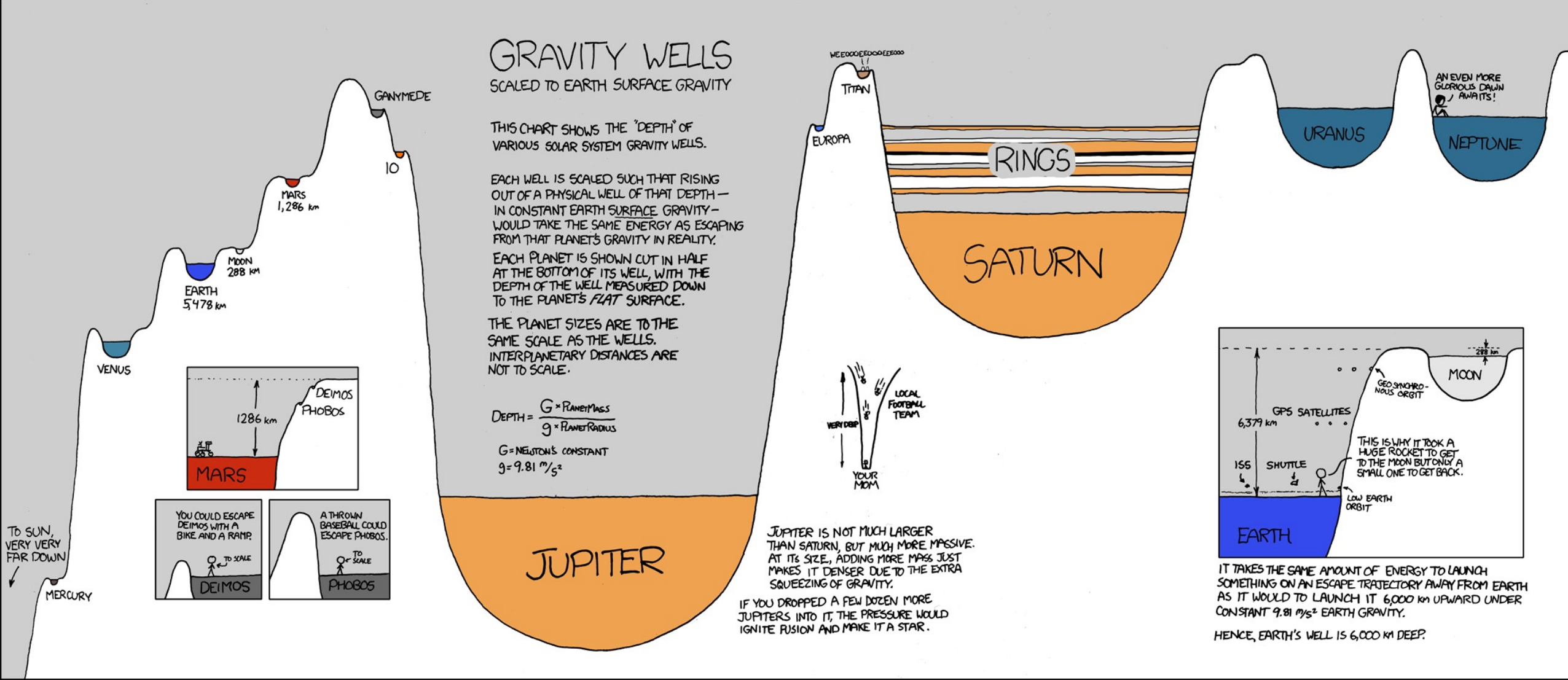
Mobiliteit oefenen

NASA rover test

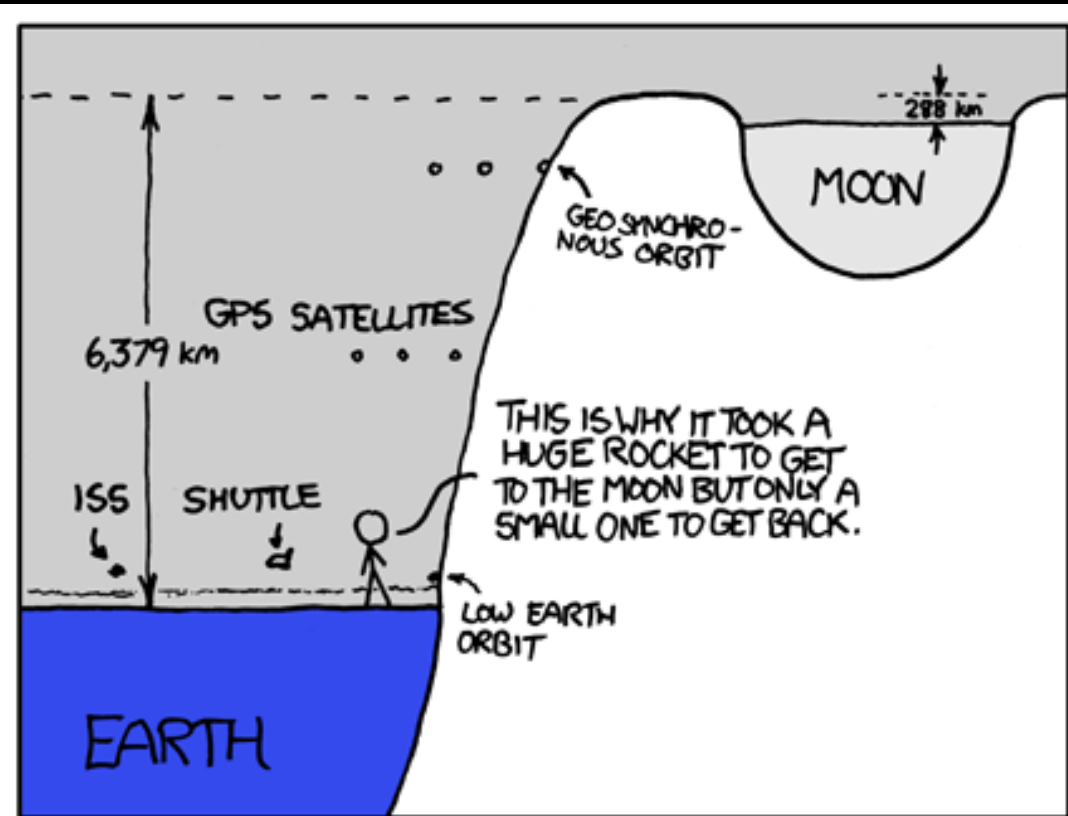
JAXA/Toyota



Gravity well



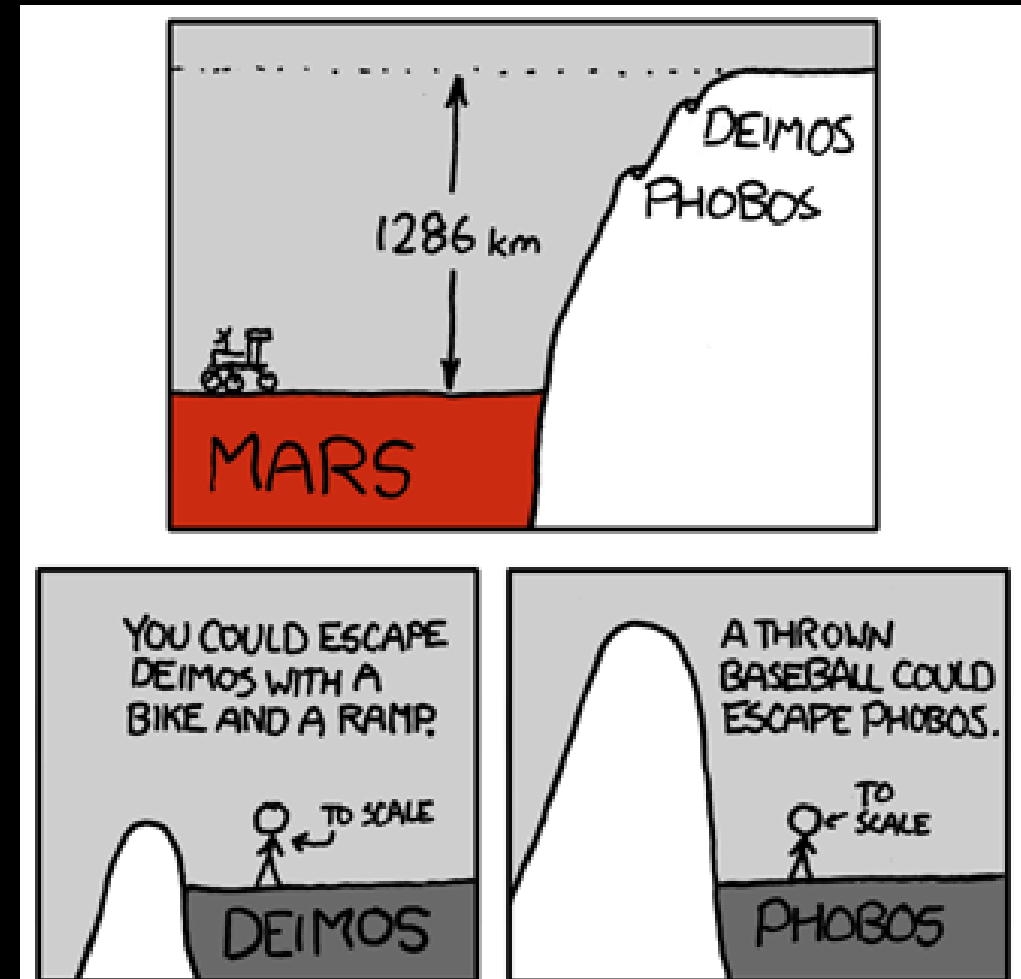
Gravity well



IT TAKES THE SAME AMOUNT OF ENERGY TO LAUNCH SOMETHING ON AN ESCAPE TRAJECTORY AWAY FROM EARTH AS IT WOULD TO LAUNCH IT 6,000 km UPWARD UNDER CONSTANT 9.81 m/s^2 EARTH GRAVITY.

HENCE, EARTH'S WELL IS 6,000 km DEEP.

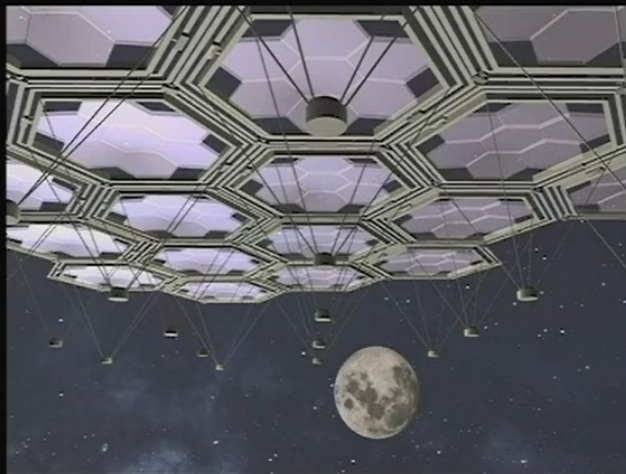
Ontsnappingsnelheid ΔV
 van de Aarde: 12 km/s ($= 43.000 \text{ km/h}$)
 Van de Gateway: 10 m/s ($= 36 \text{ km/h}$)



Bouwen in de ruimte (Gateway/Maan-oppervlak)

?ETI
INSTITUTE

Assembly, Servicing, Repair



Assemble an array telescope from light-weight parts: Nautilus Array
<http://nautilus-array.space/ndso/>



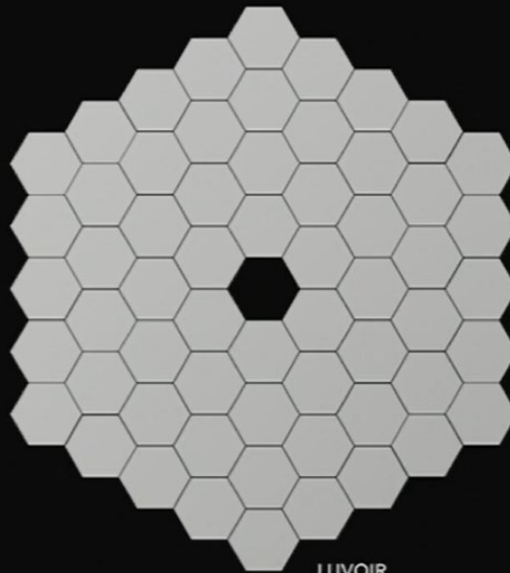
Giant telescopes are expensive to build and launch!



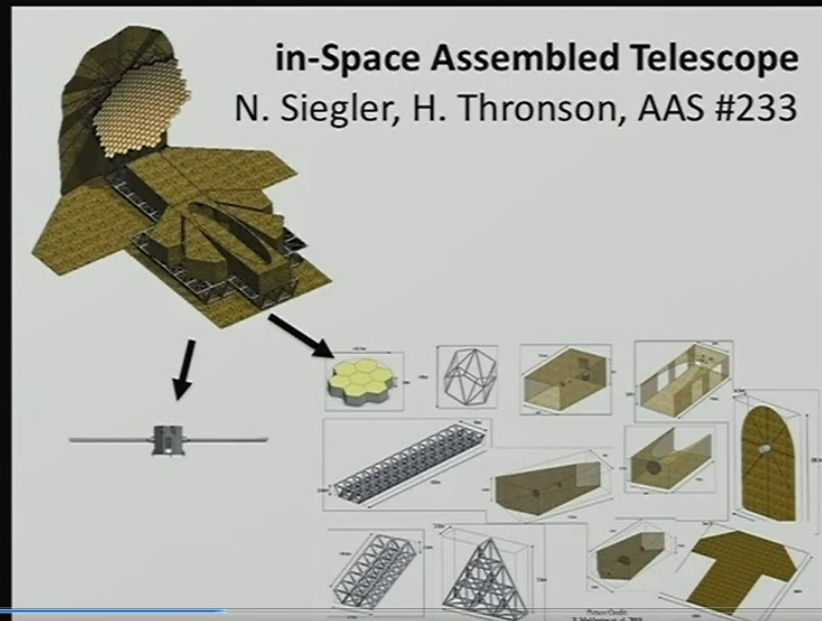
HST
2.4 m



JWST
6.5 m



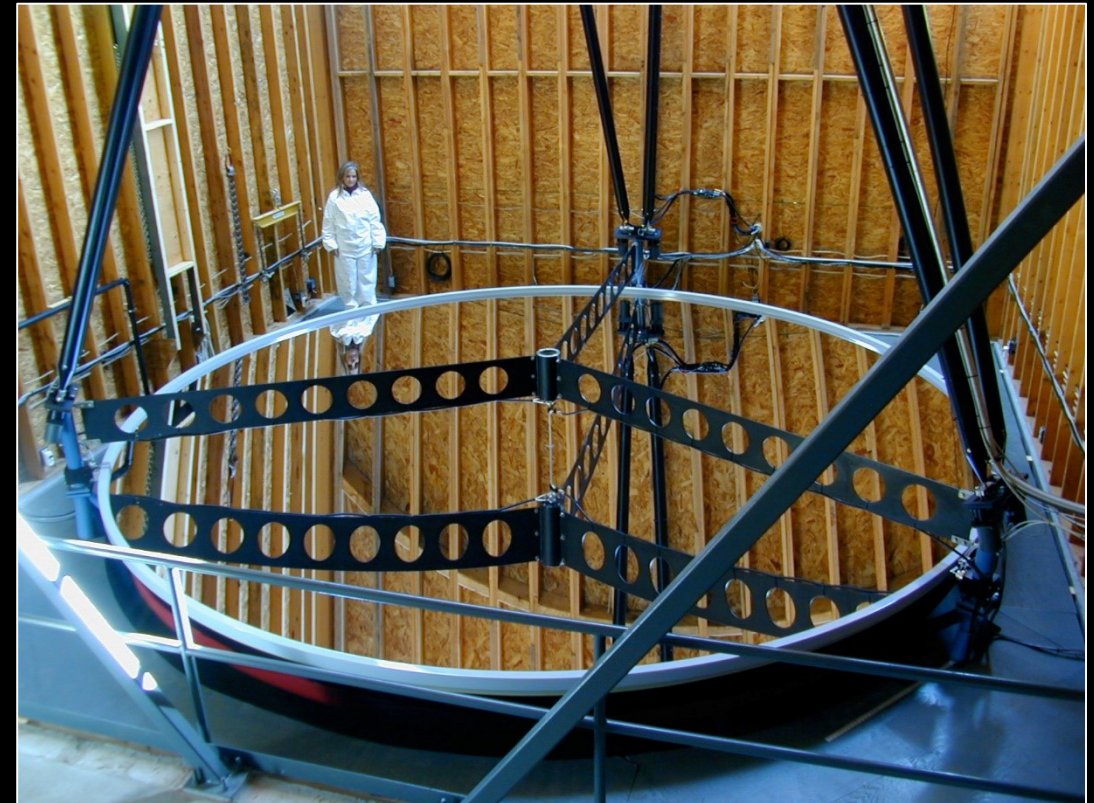
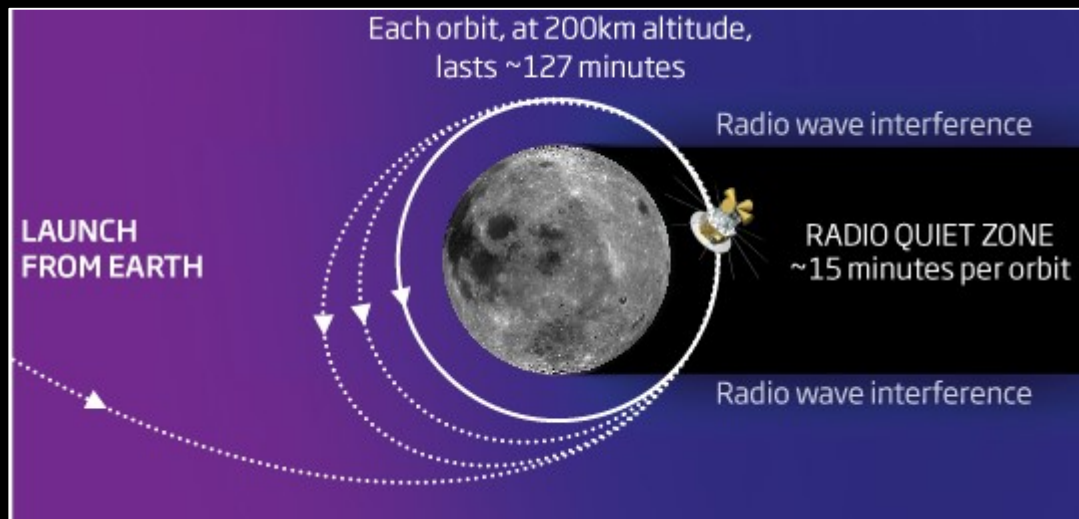
LUVOR
16 m



Bouwen in de ruimte (Gateway/Maan-oppervlak)

Telescoop op de Maan

- geen lucht
- geen EM straling filter
- geen radio-noise van de Aarde
- geen limiet op spiegel afmeting
 - Moondust ondergrond + laagje alu : 50m spiegel
 - Liquid mirror: rondraaiende vloeistof

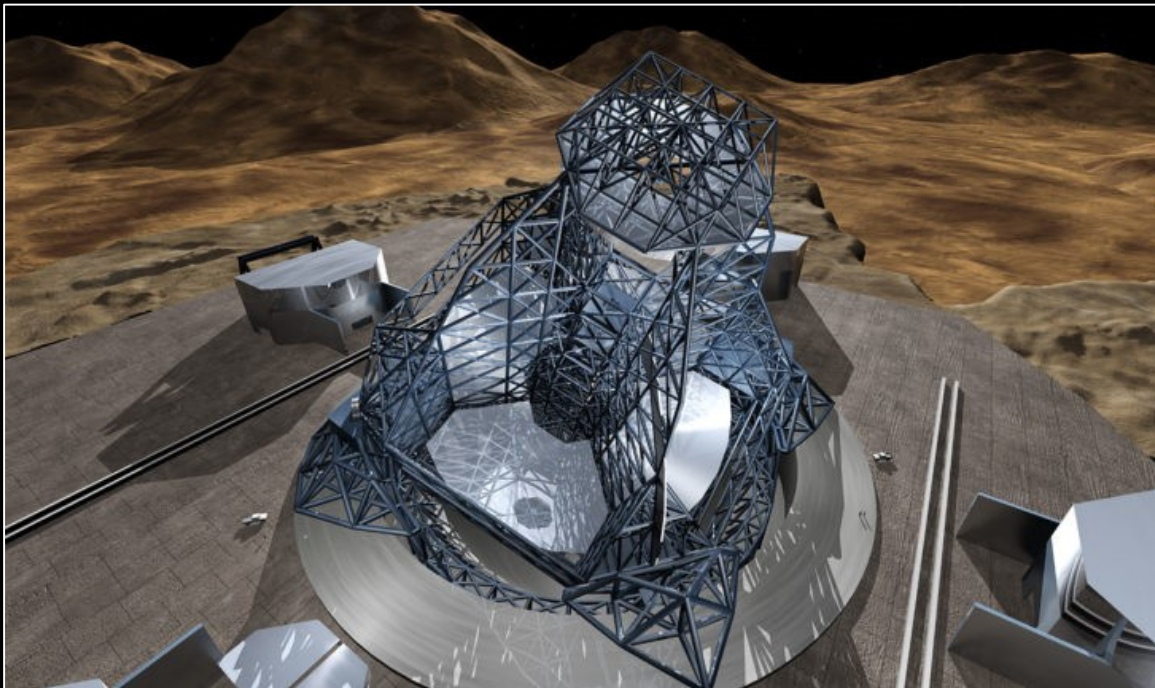


Large Zenith telescope

DARE telescope (Dark Ages Radio Explorer)

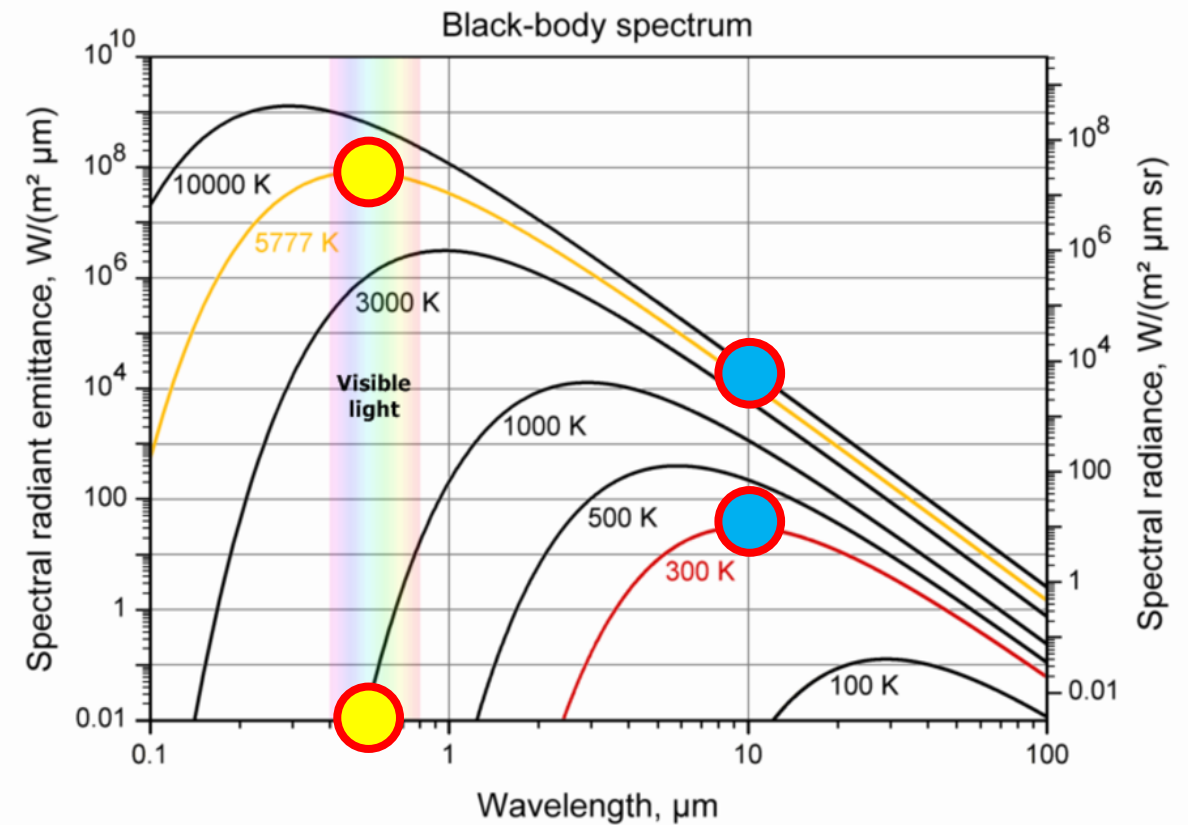
Bouwen in de Shackleton crater

- IR telescoop: zeer koud en altijd donker !



Zichtbaar licht
Zon/Aarde

IR licht
Zon/Aarde





Ruimtevaart: Waarom?

The Overview effect

Het OVERVIEW effect

Het plotse inzicht dat we op een kleine kwetsbare planeet wonen in een gigantisch heelal nadat je de Aarde vanuit de ruimte ziet.

Astronaut Ron Garan:

“Als we naar de Aarde kijken vanuit de ruimte, dan zien we een wonderlijke, onbeschrijfelijke, mooie planeet. Het ziet er uit als een levend en ademend wezen. Maar het ziet er terzelfdertijd uiterst kwetsbaar uit. Iedereen die ooit in de ruimte was zegt hetzelfde, want het is werkelijk overweldigend en ontnuchterend om die flinterdunne laag te zien, en te beseffen dat die papierdunne laag het enige is dat elk levend wezen beschermt tegen de dood, tegen de onleefbaarheid van de ruimte eigenlijk.”

I don't See any Borders



Do you?

Overview effect

picture of eclips 2 july 2019

Longjiang-2 = relay satellite of Chang'e 4





Waarom?

Het OVERVIEW effect

Het plotse inzicht dat we op een kleine kwetsbare planeet wonen in een gigantisch heelal nadat je de Aarde vanuit de ruimte ziet.

Waarom?

Ontdekkingsdrang

Goddard (eerste bouwer van een raket met vloeibare brandstof):

“The dream of yesterday is the hope of today and the reality of tomorrow.”

Christoforo Colombo:

“You can never cross the ocean unless you have the courage to lose sight of the shore.”

Konstantin Tsjolkovski:

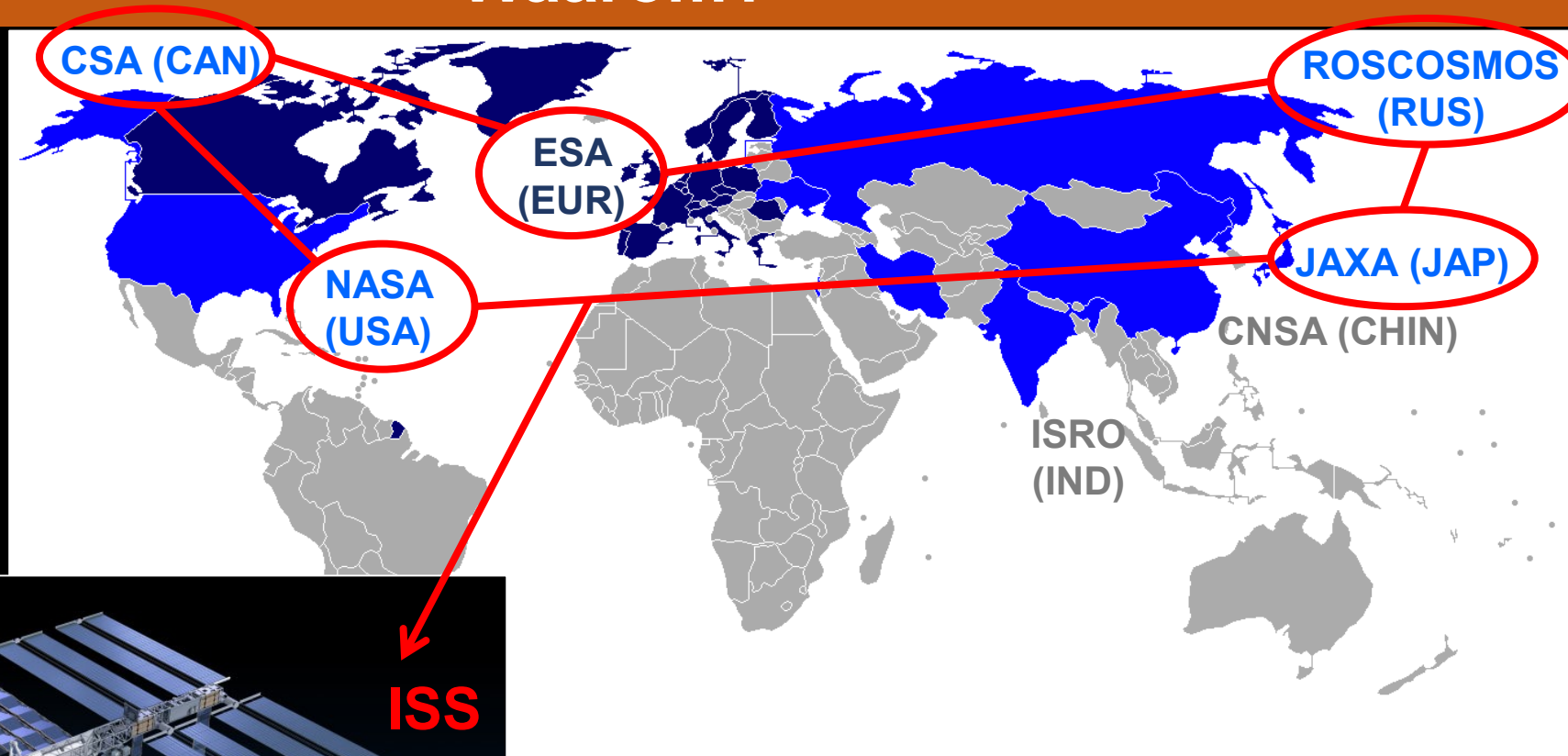
“De aarde is de wieg van de mens, maar de mens kan niet zijn hele leven in de wieg blijven wonen.”

1992: replica's van de vloot van Columbus varen voorbij het Kennedy Space Center



Internationale samenwerking

Waarom?





Waarom?

Toerisme

Drang naar avontuur

Herstel-atelier in deep space

Overlevingskans van de mensheid

Migratie

Uitbreiding wetenschappelijk proefveld

Commerciële ontginning

Ontginning : oefenen voor Mars

Kolonie voor veroordeelden en criminelen

Technische vooruitgang

Uitdaging van een generatie

“become a multi-planet species”

New space race / Competitie

Waarom niet?