

# Hvorfor Mars?





# NASAs Perseverance rover mission – første del af ”Mars Sample Return”

Dansk Forening i Stockholm , 2023-09-30

Morten Bo Madsen, Niels Bohr Institutet, Københavns Universitet



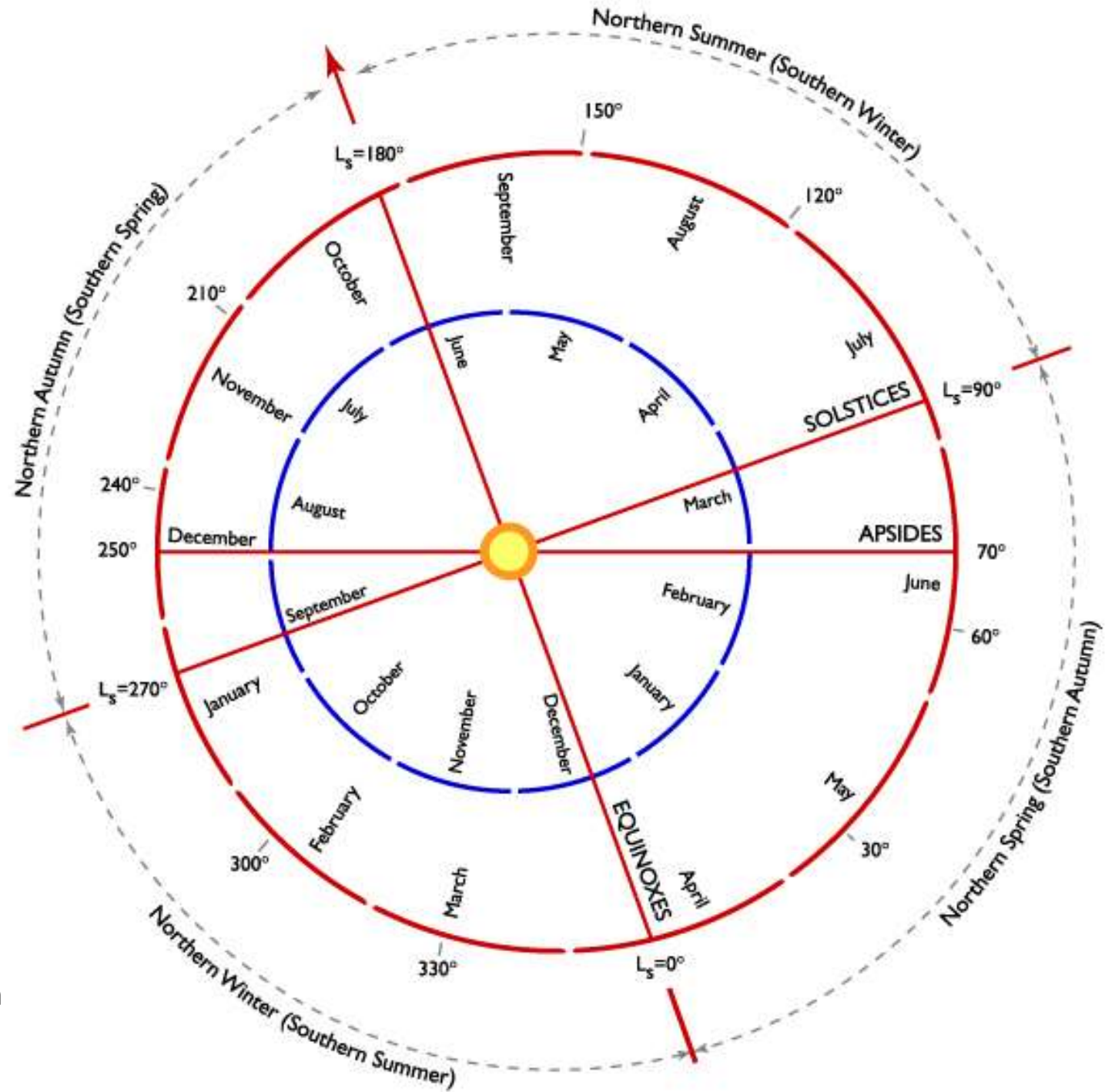
**Marsdag (Sol):**  
24 t 39 m

**Marsår:**  
1.88 Jord-år  
668 Sols

**Halv storakse:**  
1.52 AU\*

**(Nuværende)  
Aksehældning:**  
25.2°

\*1 AU = 149.597.871 km





# Hvordan kommer data (herunder billeder) retur fra Mars?

NASA Jet Propulsion Laboratory | California Institute of Technology  
**DEEP SPACE NETWORK NOW** LAST UPDATED: SEP 29 8:27 AM (UTC) [DSN home](#) [i](#)

Station	Antenna	SOHO	M010	MVN	MRO	M010	ACE
<b>MADRID</b> SEP 29 10:28 AM							
	63	65	53	54	55	55	56
<b>GOLDSTONE</b> SEP 29 1:28 AM							
	14	24	25	26			
<b>CANBERRA</b> SEP 29 6:28 PM							
	43	34	35	36			

**TARGET: MARS ODYSSEY** [i](#)

[VIEW ANTENNA](#) [VIEW SPACECRAFT](#) [VIEW WORLD MAP](#)

[M010](#) [MVN](#) [MRO](#)

**SPACECRAFT**

**NAME**  
Mars Odyssey

**RANGE**  
380.00 million km

**ROUND-TRIP LIGHT TIME**  
42.25 minutes

**ANTENNA**

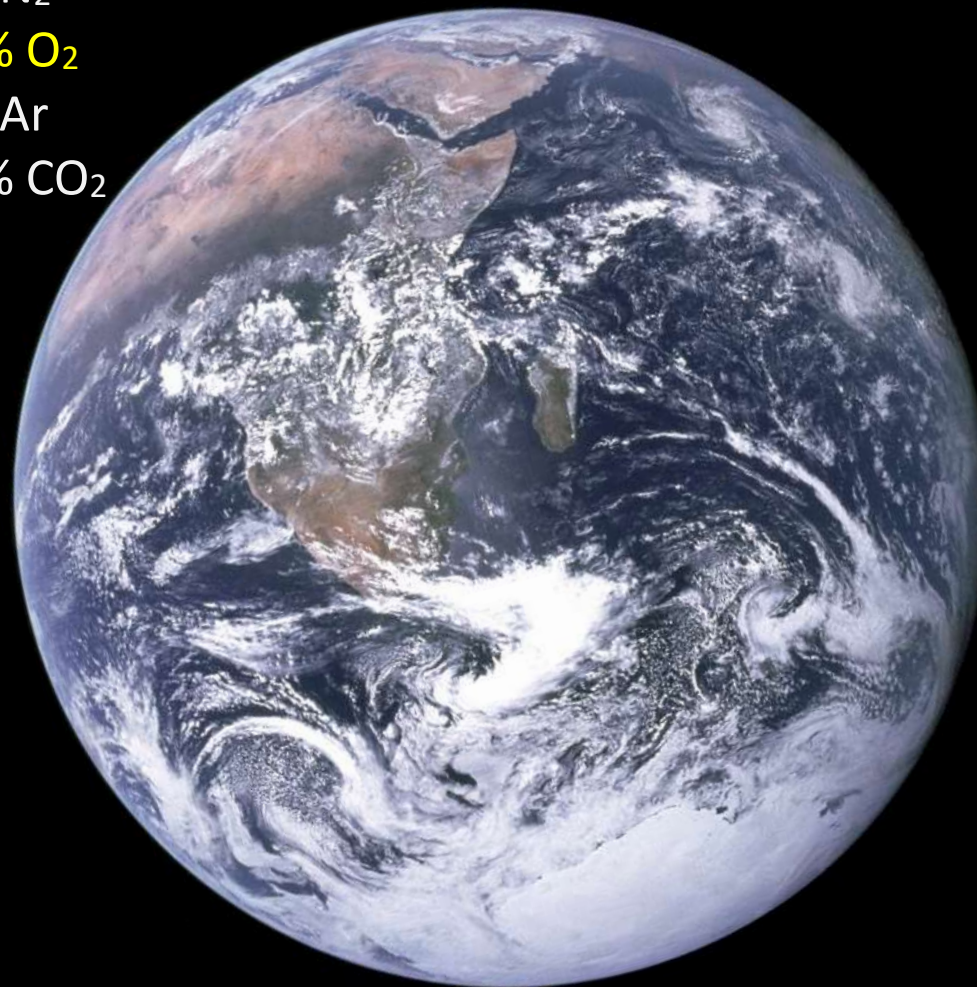
**NAME**

[+ more detail](#) [about DSN](#) [contact us](#)

# Jorden sammenlignet med Mars

Overfladetryk: 1013 mBar  
**101,3 kPa**

Atmosfære: 78,1 % N<sub>2</sub>  
**20,95 % O<sub>2</sub>**  
0,93 % Ar  
0,041 % CO<sub>2</sub>



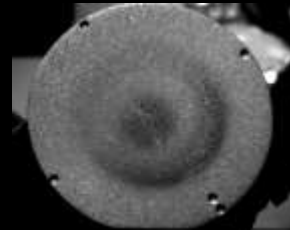
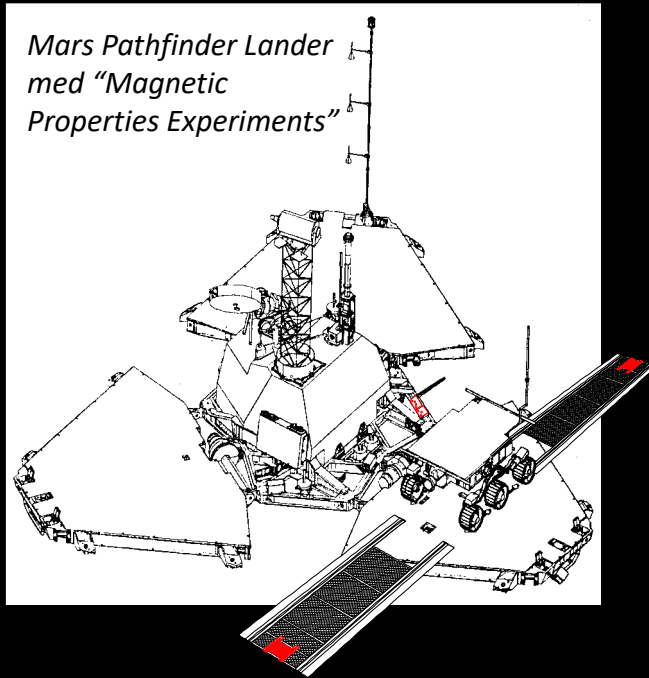
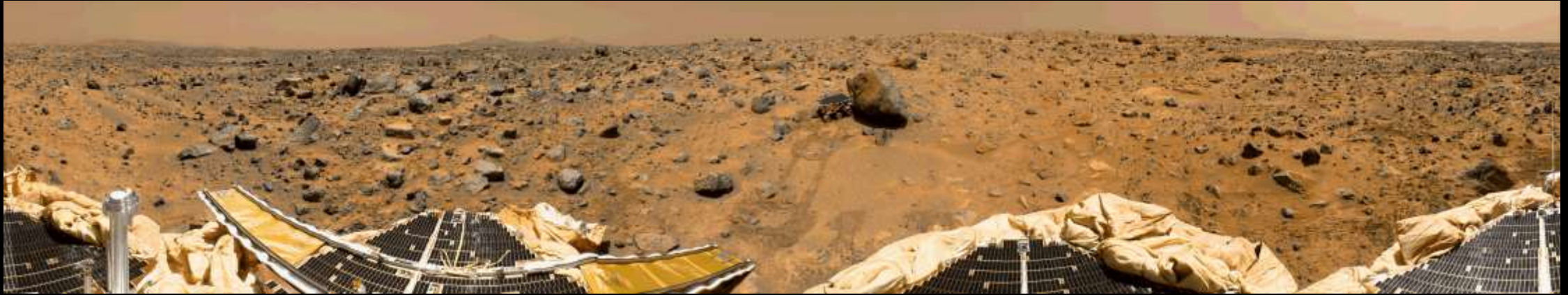
Overfladetryk: 1 - 9 mBar  
**100-600 Pa**

Atmosfære: **95,97 % CO<sub>2</sub>**  
1,93 % Ar  
1,89 % N<sub>2</sub>  
**0,146 % O<sub>2</sub>**  
0,056 % CO

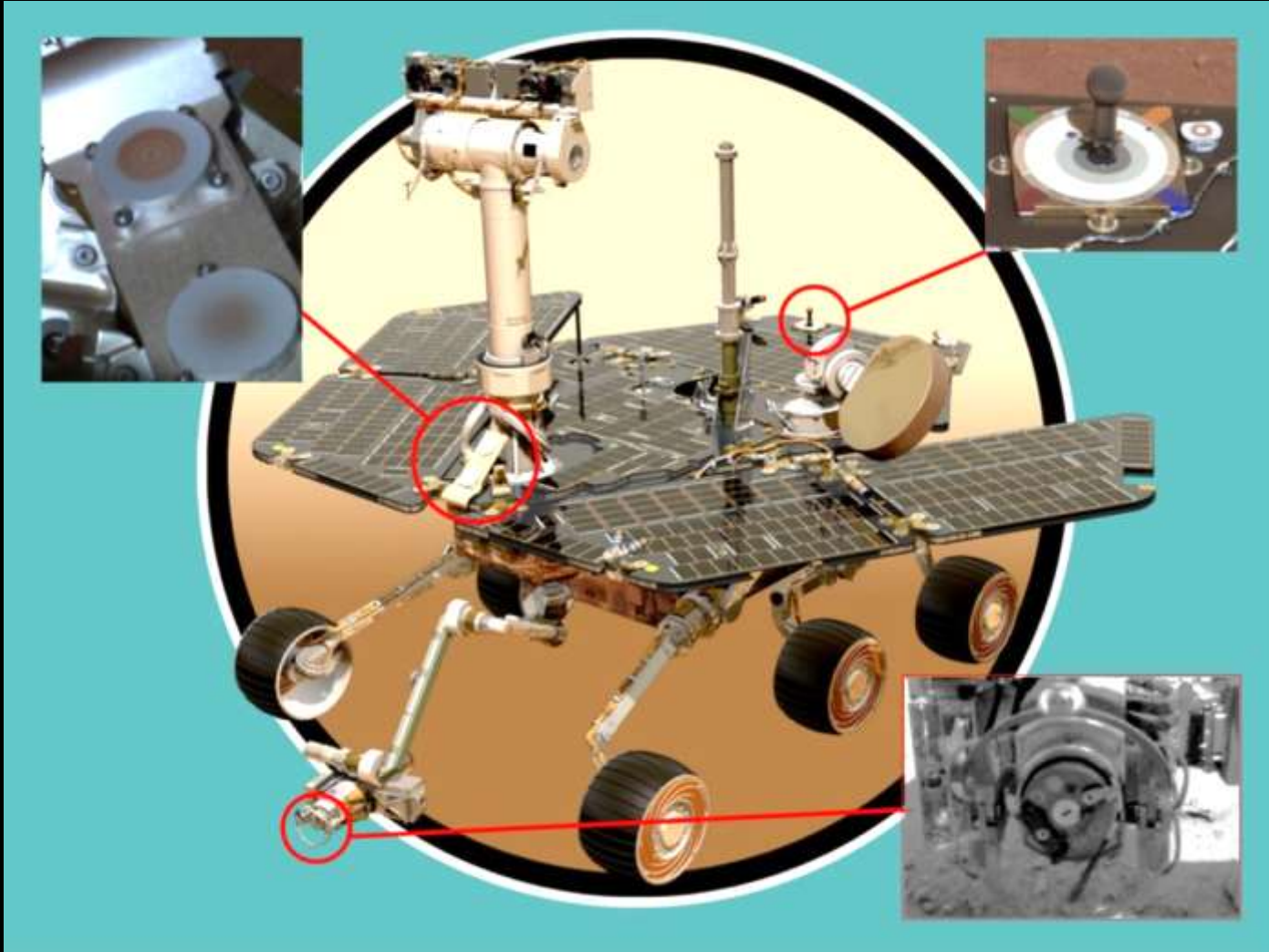


Mars' masse: 0,107 M<sub>J</sub>  
Radius: 0,532 R<sub>J</sub>  
Areal: 0,283 A<sub>J</sub>  
Tyngdeacc.: 0,377 g<sub>J</sub>





# Spirit og Opportunity (2003/2004) medbragte forskellige magnet-eksperimenter



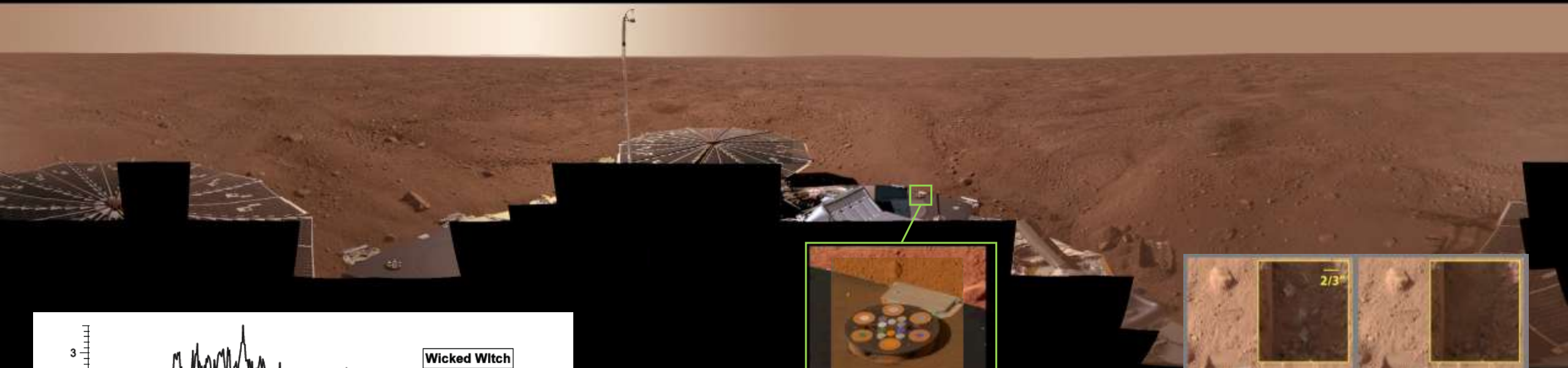
Alt undtagen een lille plet bliver støvet

**Førte til invitation til NBI-deltagelse på NASAs Phoenix lander (2007).**

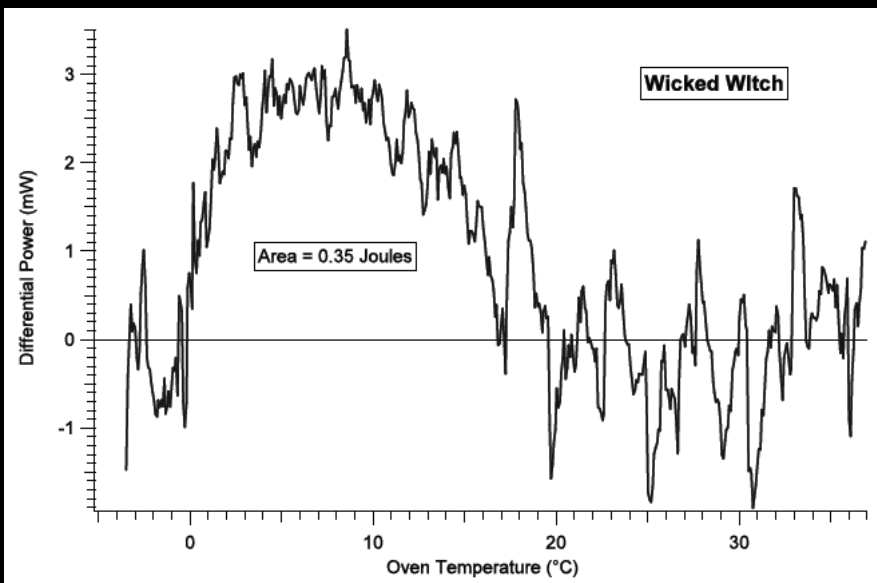
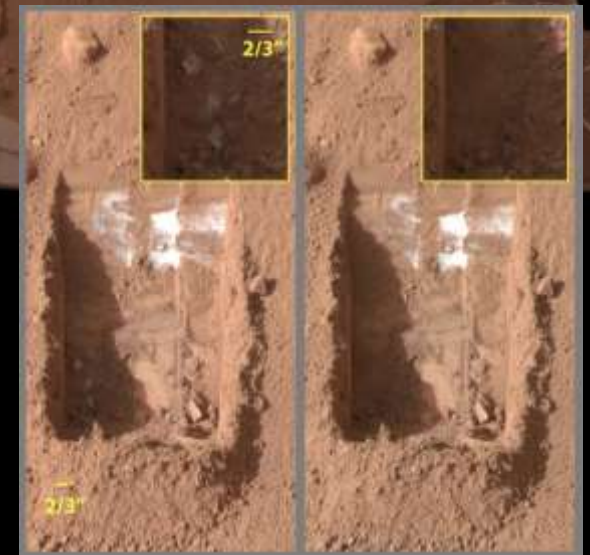
Øverst til højre: små magneter tæt ved caltarget. To store magneter kan nås med instrumenterne på robot-armen og ses fra Pancam. Magneter i RAT samler støv dannet under slibning.



# 2008 Phoenix, Vastitas Borealis



Phoenix catches at sol 104.

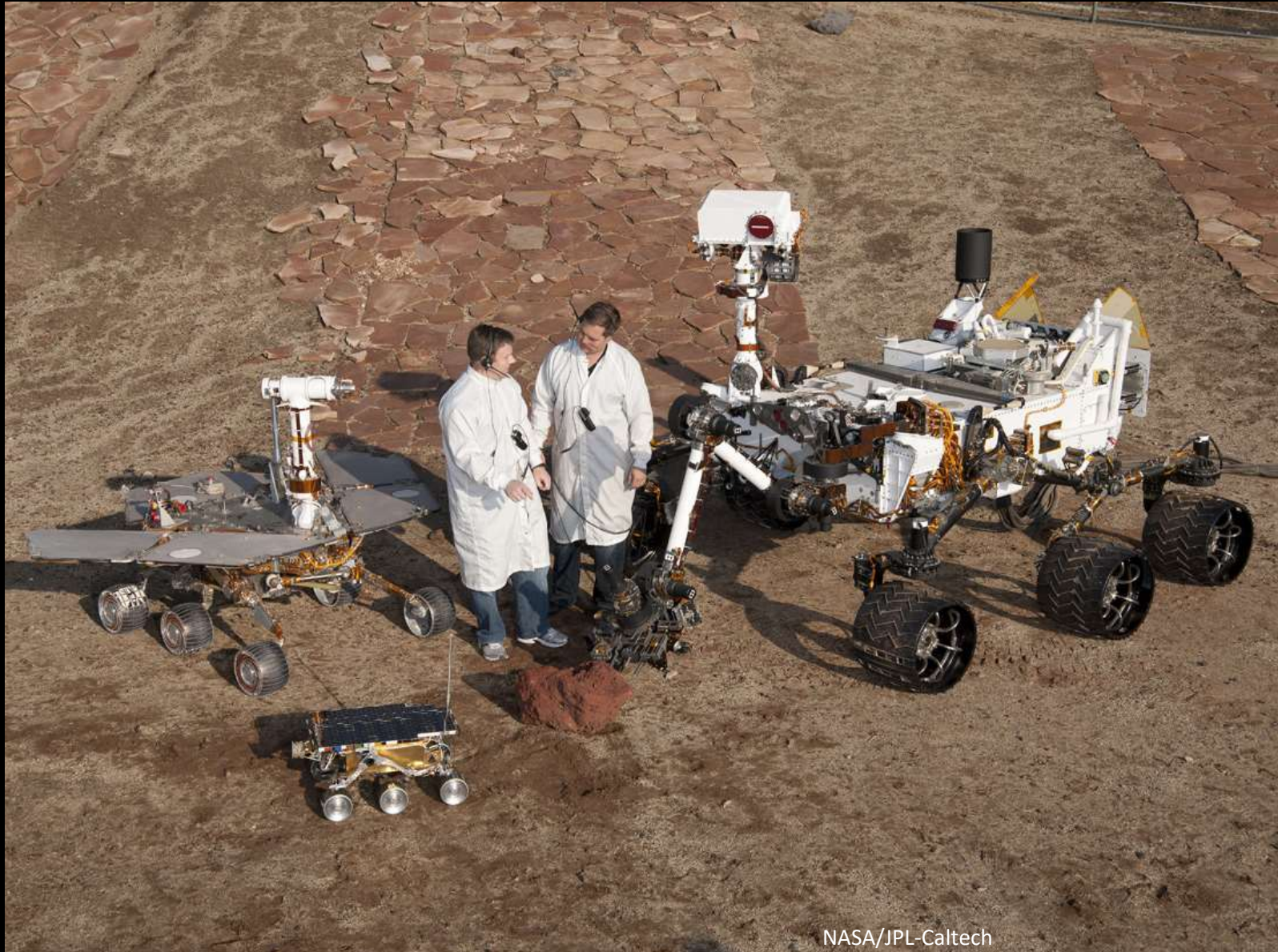


Phoenix viste at der er **vand(-is)** under overfladen OG at en oxidant (opdaget af Viking), der findes i regolitten (Mars-”Jorden”) er en **perchlorat-forbindelse**.



# Curiosity's mål:

Undersøg et udvalgt sted på Mars som en mulig habitat for liv – nu eller i fortiden

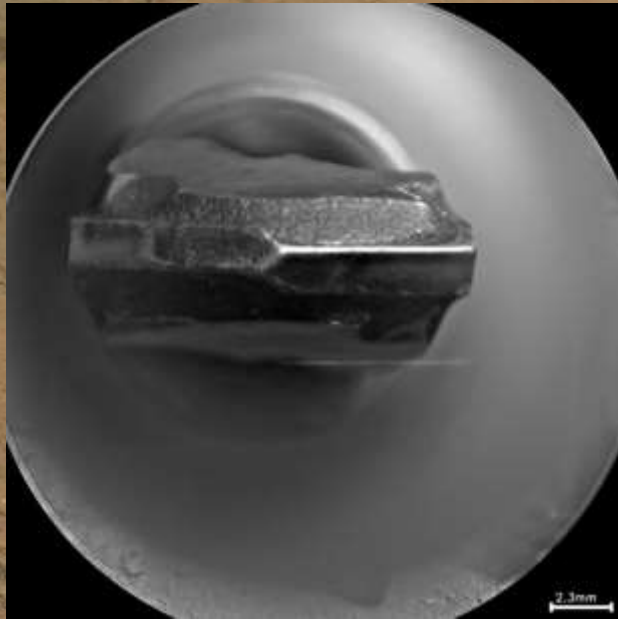






Curiosity "selvportræt" optaget sol 177 vha. MAHLI





Billeder: NASA/JPL-Caltech/MSSS

16 mm diameter borehuller (64 og 16 mm dybe)

Billeder: NASA/JPL-Caltech/MSSS/Univ. de Nantes





Curiosity “selvportræt” ved Mont Mercou, sol 3070 (60 Mahli-billeder)

Billeder: NASA/JPL-Caltech/MSSS



# Curiosity: Paraitepuy Pass (Sol 3563)



# Curiosity: Marker Band Valley (Sol 3684), 1/2



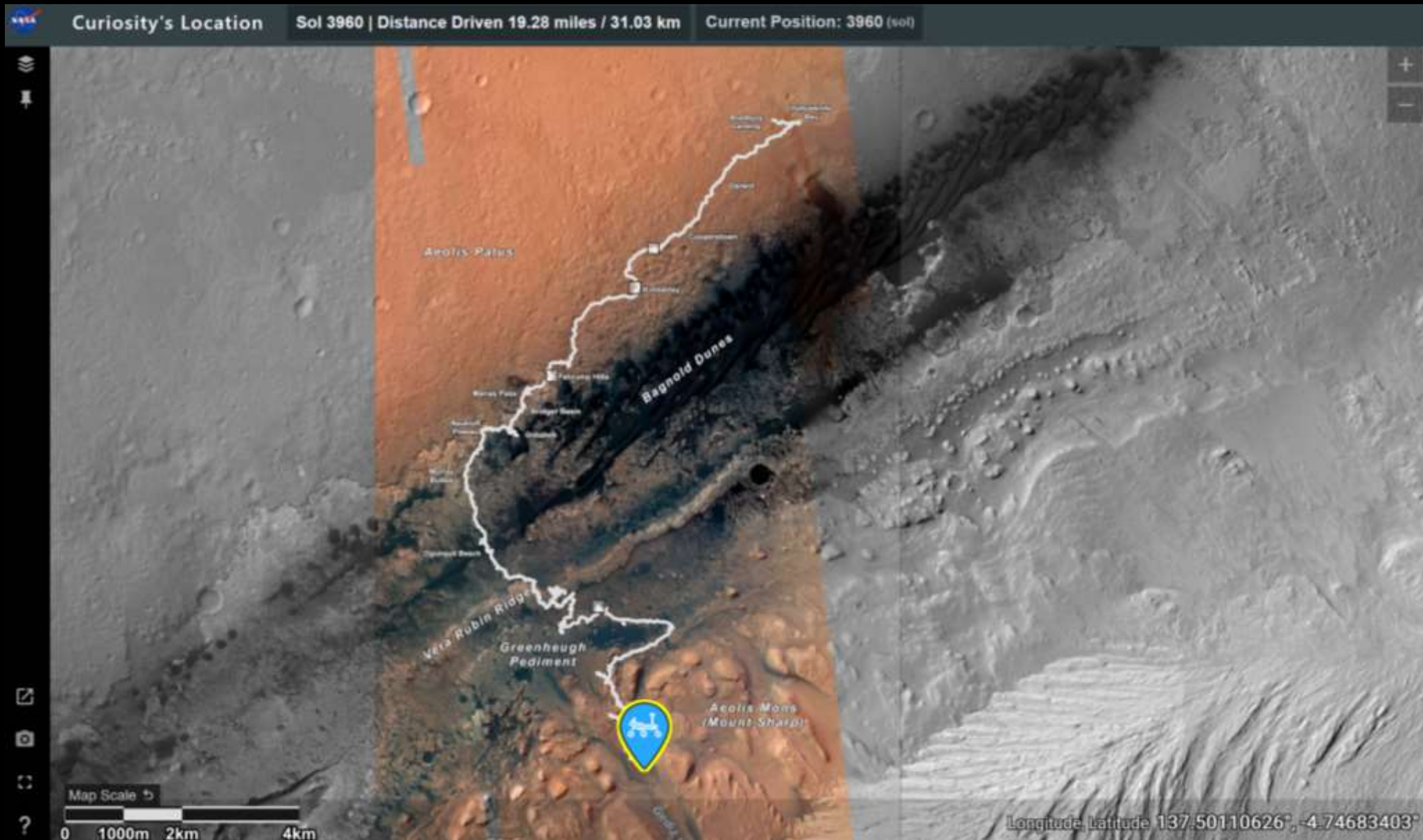


# Curiosity: Marker Band Valley (Sol 3684), 2/2





# Hvor er Curiosity nu (Sol 3960)?



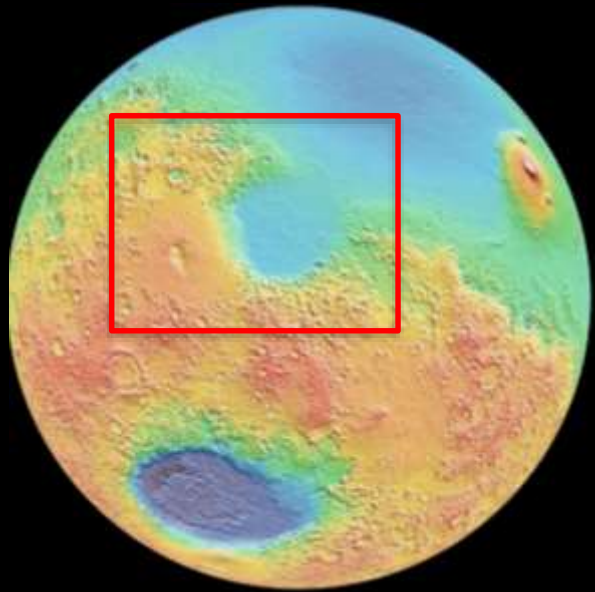




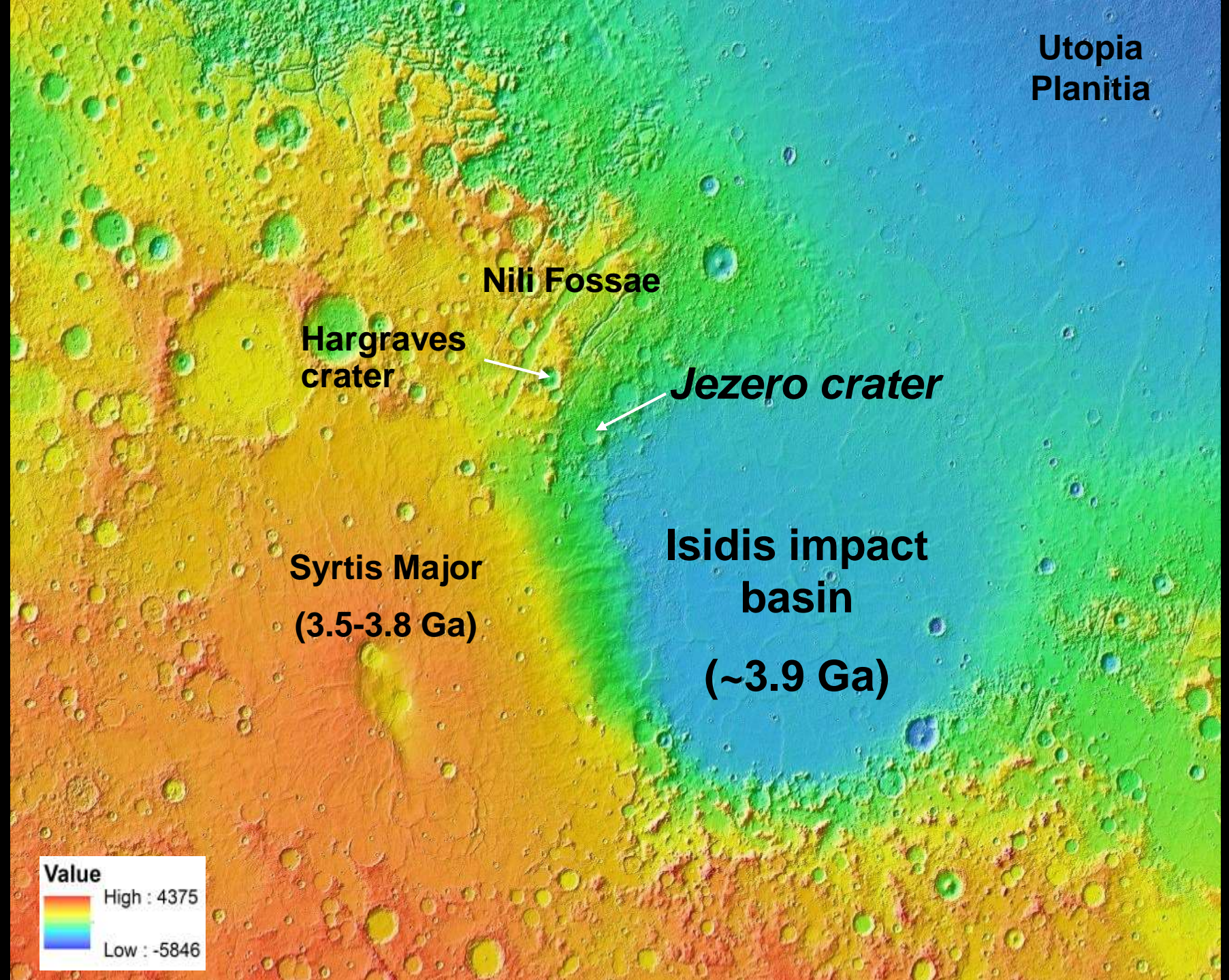
## Solnedgang på Mars (Curiositys Mastcam)



Perseverance er  
nu i arbejde i  
Jezero-krateret ...



Billeder: NASA/JPL-Caltech





# Hvorfor Jezero-krateret?

Videnskabelige mål med Returnerede prøver (ikke komplet)

- **Liv**
  - Undersøg om deltaet i Jezero indeholder **biosignaturer** og søg **indikationer af fortidigt liv på Mars**
- **Geokronologi**
  - Forsøg at bestemme **alderen af grundfjeldsmaterialer**
- **Kulstofcyklus**
  - Undersøg **Mars' kulstof-cyklus** vha. geokemisk analyse af delta og kystnære aflejringer og carbonater
- **Tidligt Mars-Klima**
  - Undersøg **tidspunktet for "regn"** og atmosfære-tæthed og atmosfære-tab vha. analyser af prøver fra deltaet

# Deltaet i Jezero-krateret





# Instrumenter til recognoscering og indsamling af prøver

**Mastcam-Z**  
Zoomable Panoramic Cameras

**SuperCam**  
Laser Micro-Imager

**MEDA**  
Weather Station

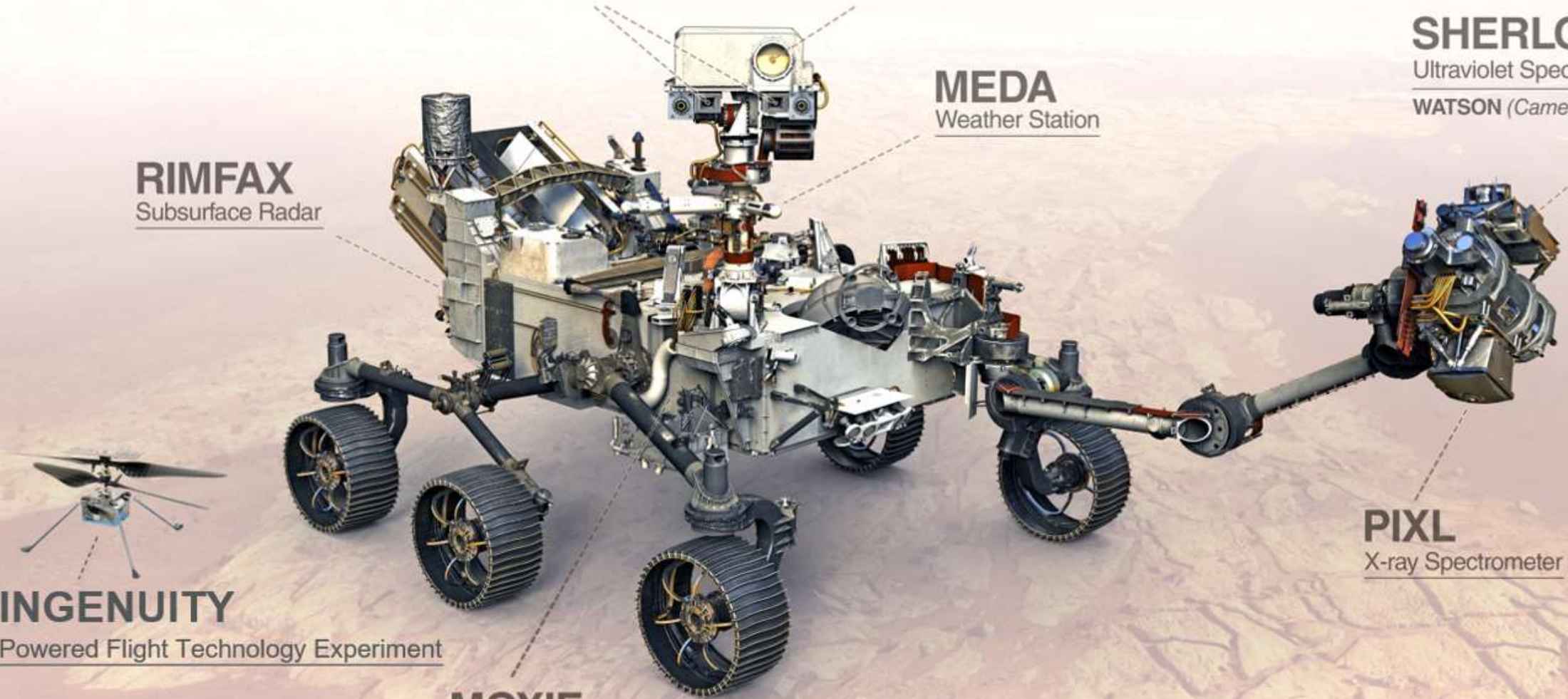
**SHERLOC**  
Ultraviolet Spectrometer  
**WATSON (Camera)**

**RIMFAX**  
Subsurface Radar

**PIXL**  
X-ray Spectrometer

**INGENUITY**  
Powered Flight Technology Experiment

**MOXIE**  
Produces Oxygen from Martian CO<sub>2</sub>



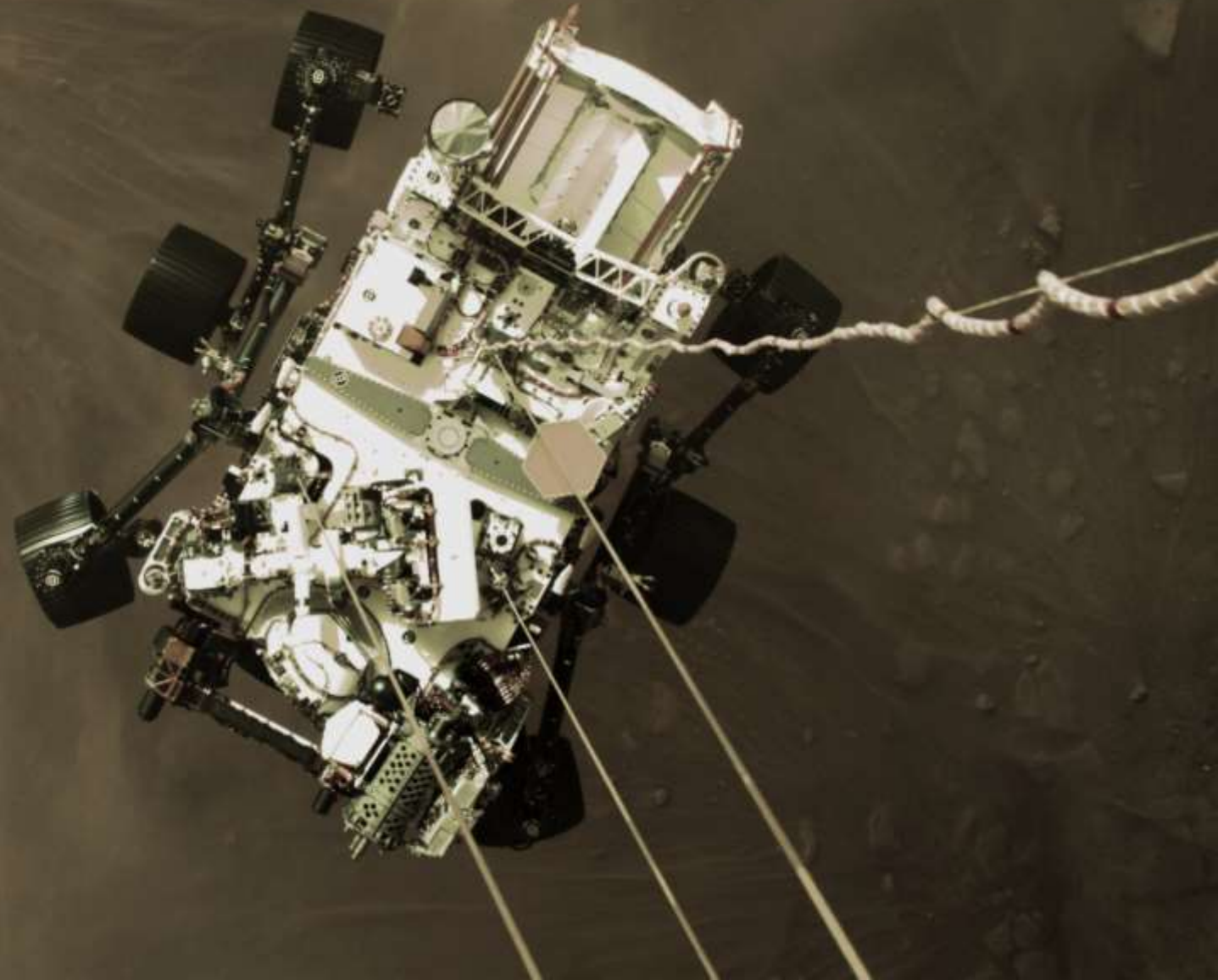


# Senere afhentning og returnering af prøver til Jorden





# Perseverance landede 18. februar 2021



# Tre rekognosceringsinstrumenter og en vejrstation



**SHERLOC**  
Ultraviolet Spectrometer  
**WATSON (Camera)**

**PIXL**  
X-ray Spectrometer

**MOXIE**  
Produces Oxygen from Martian CO<sub>2</sub>



**INGENUITY**  
Powered Flight Technology Experiment

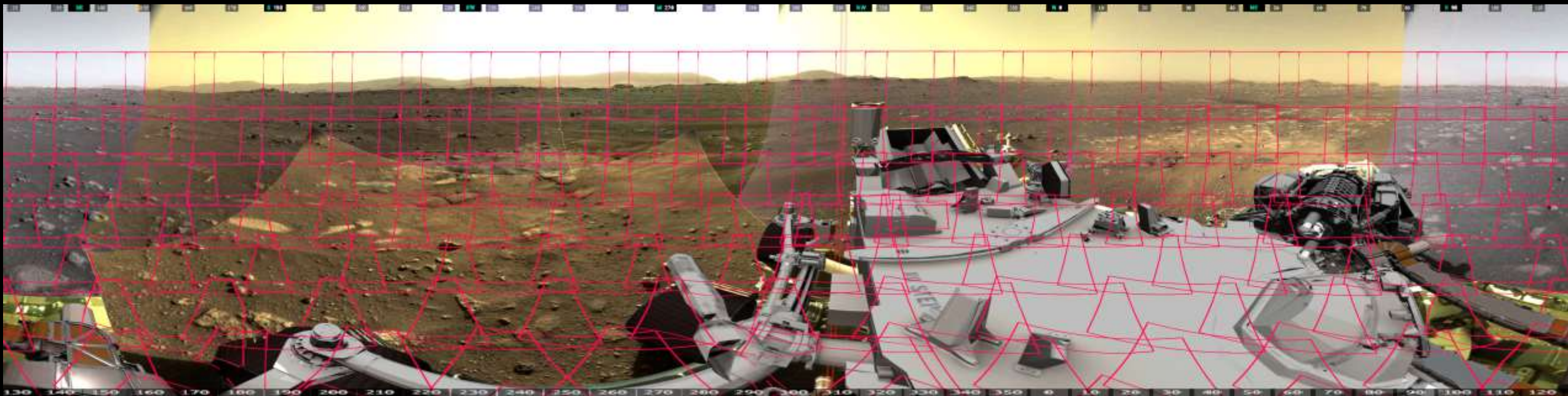


Hvordan ser der så ud i Jezero-krateret?



Sol 0003: Første 360-graders panorama vha. Mastcam-Z

Sådan er Sol 0003 Mastcam-Z panoramaet optaget:





# Første Perseverance-publikation i Science:

Science

RESEARCH ARTICLES

Cite as: N. Mangold *et al.*, *Science*  
10.1126/science.abc4051 (2021).

## Perseverance rover reveals an ancient delta-lake system and flood deposits at Jezero crater, Mars

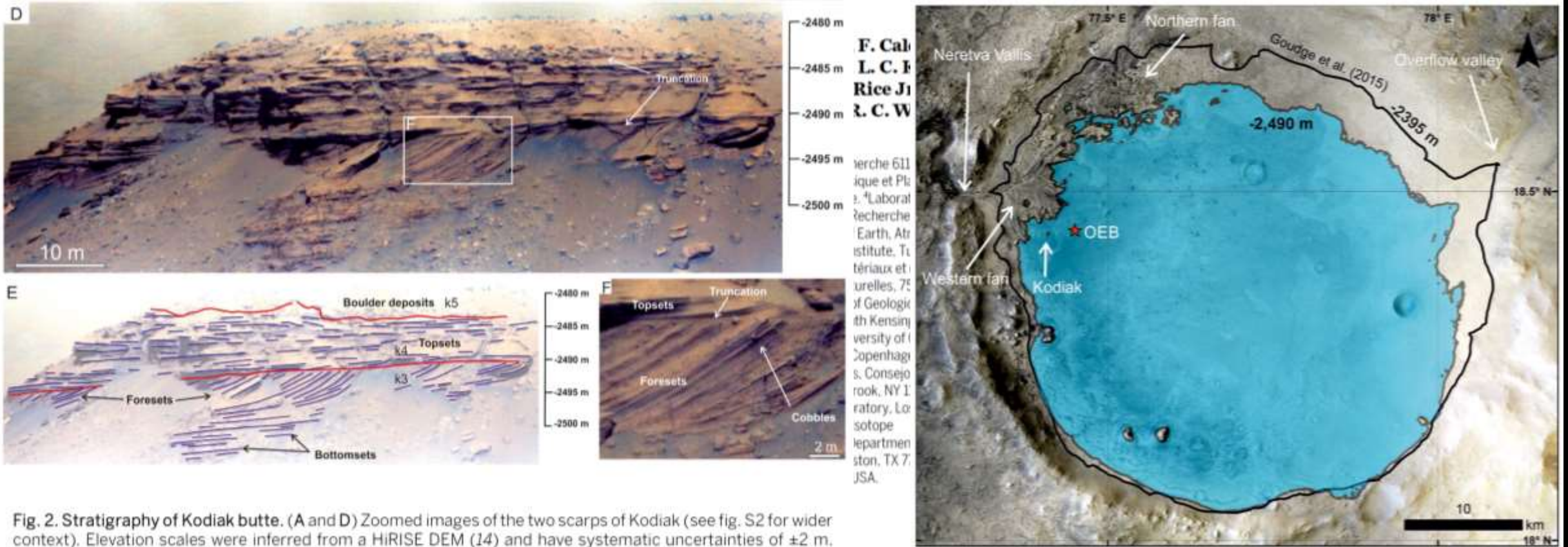
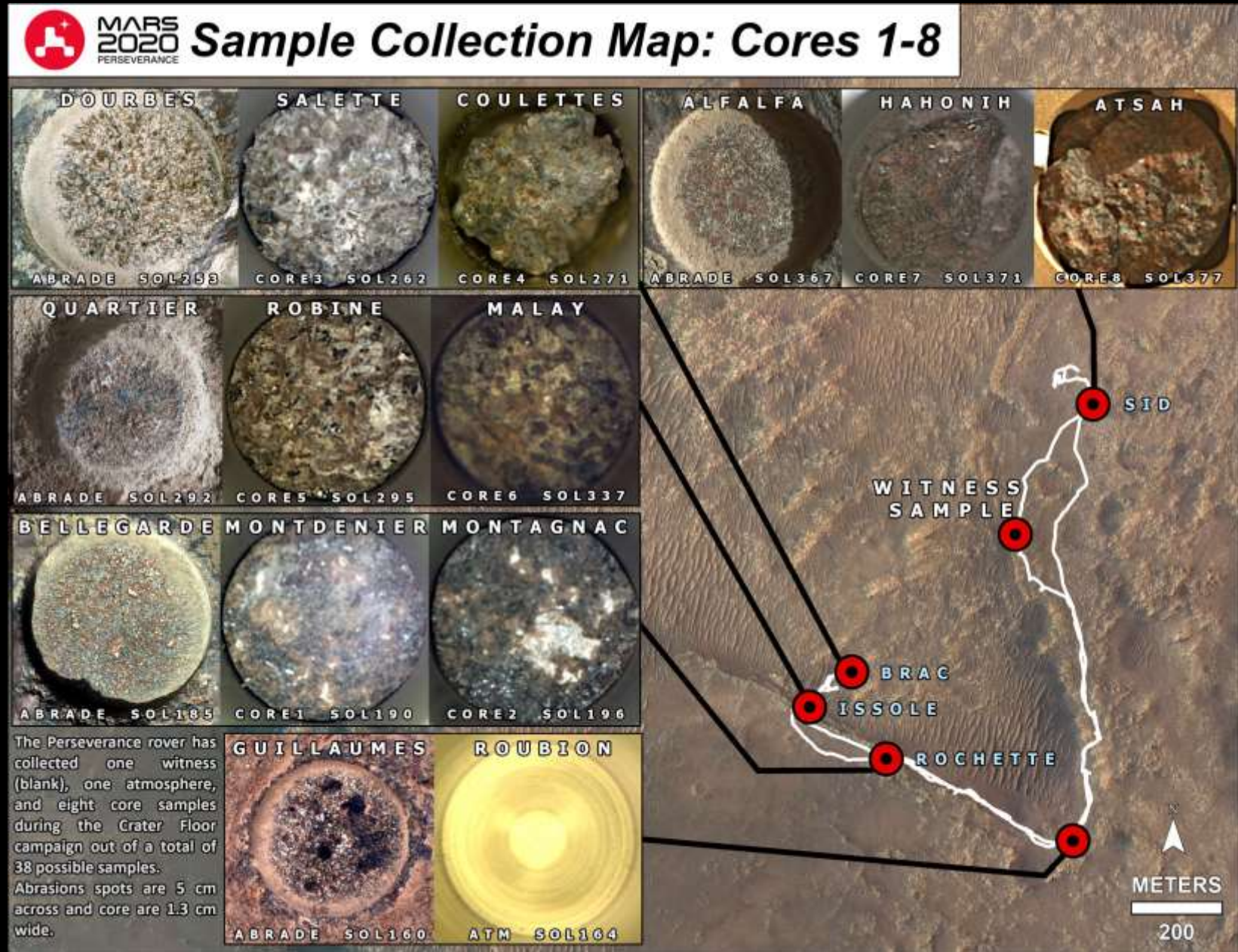


Fig. 2. Stratigraphy of Kodiak butte. (A and D) Zoomed images of the two scarps of Kodiak (see fig. S2 for wider context). Elevation scales were inferred from a HiRISE DEM (14) and have systematic uncertainties of  $\pm 2$  m.



# Slibninger – og prøver indsamlet pr. Sol 480





# NASAs Perseverance Rover: Første prøver indsamlet.



Billeder: ASU; MSSS; NASA/JPL-Caltech



# Plan for udforskning af “krater-gulvet” og videre frem ...



Three Forks

Octavia E. Butler Landing Site

Seitah-N

Seitah-S

CF-Fr

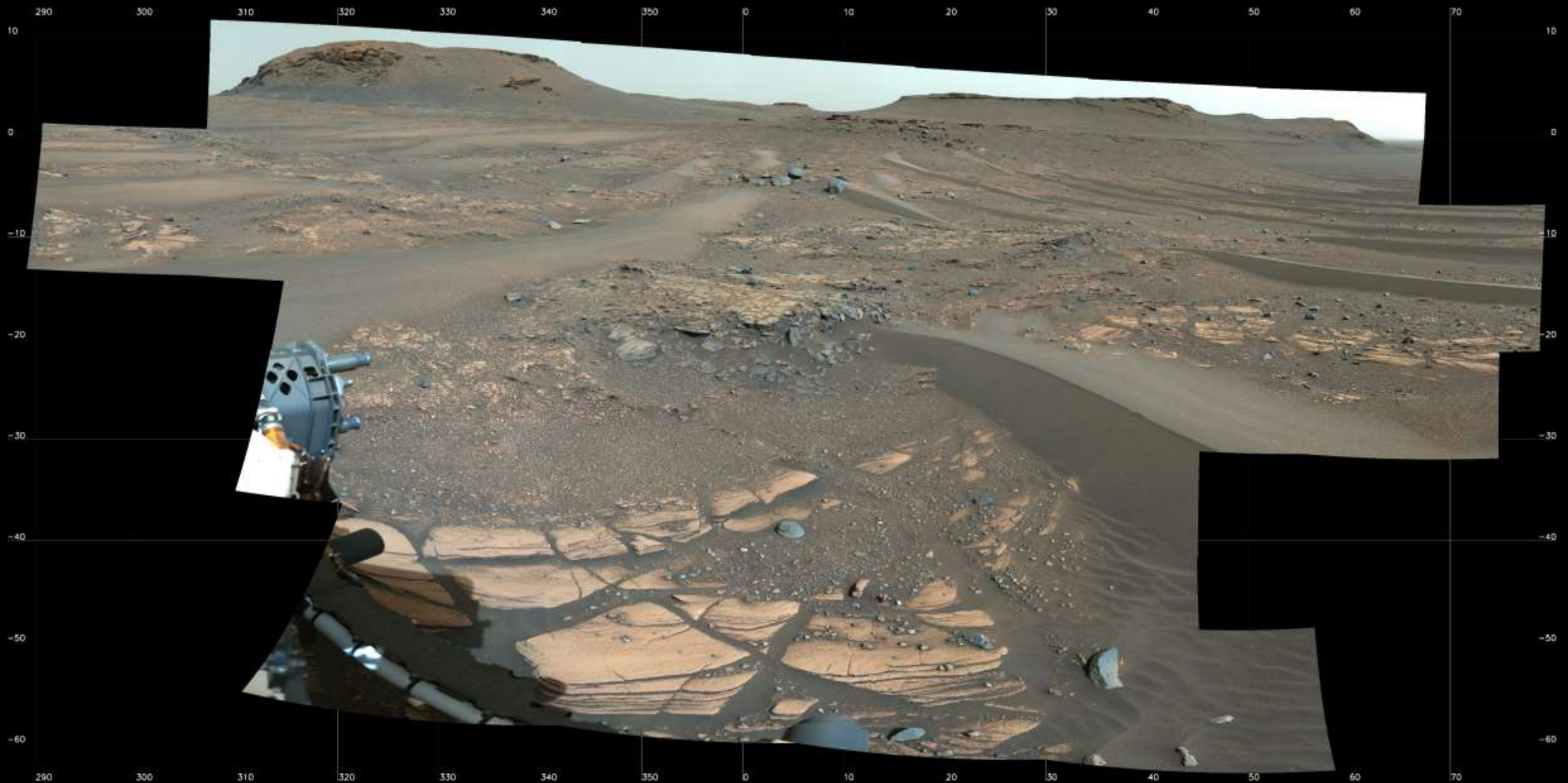
Raised Ridges

Map Scale 0 200m 400m

Longitude, Latitude 77.39876747°, 18.43564



# Perseverance: Enchanted Lake (Sol 0425)



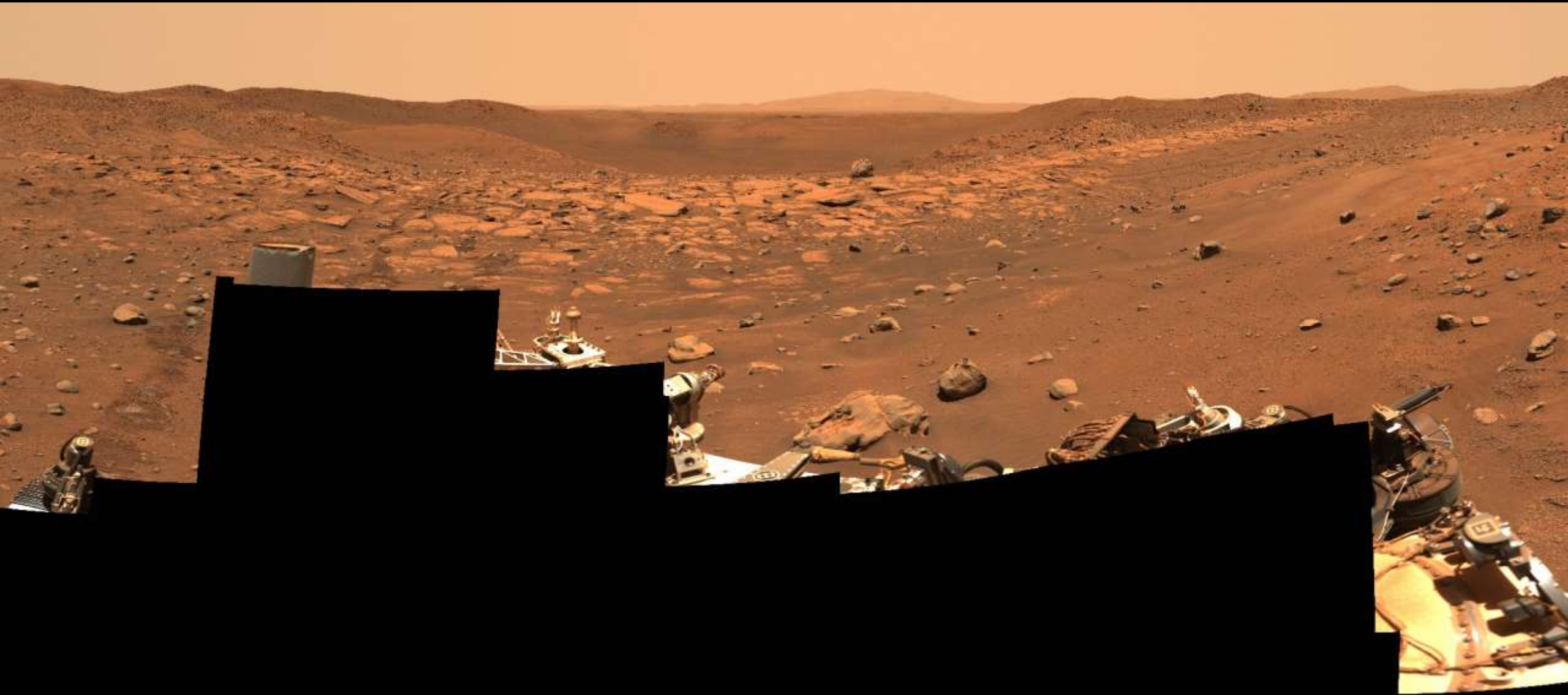
Første prøverør med  
boreprøve anbragt på  
overfladen til senere  
afhentning (historisk):

Prøven "Malay" lagt ned  
2022-12-21





# Perseverance: Belva krater (Sol 0791), 1/3

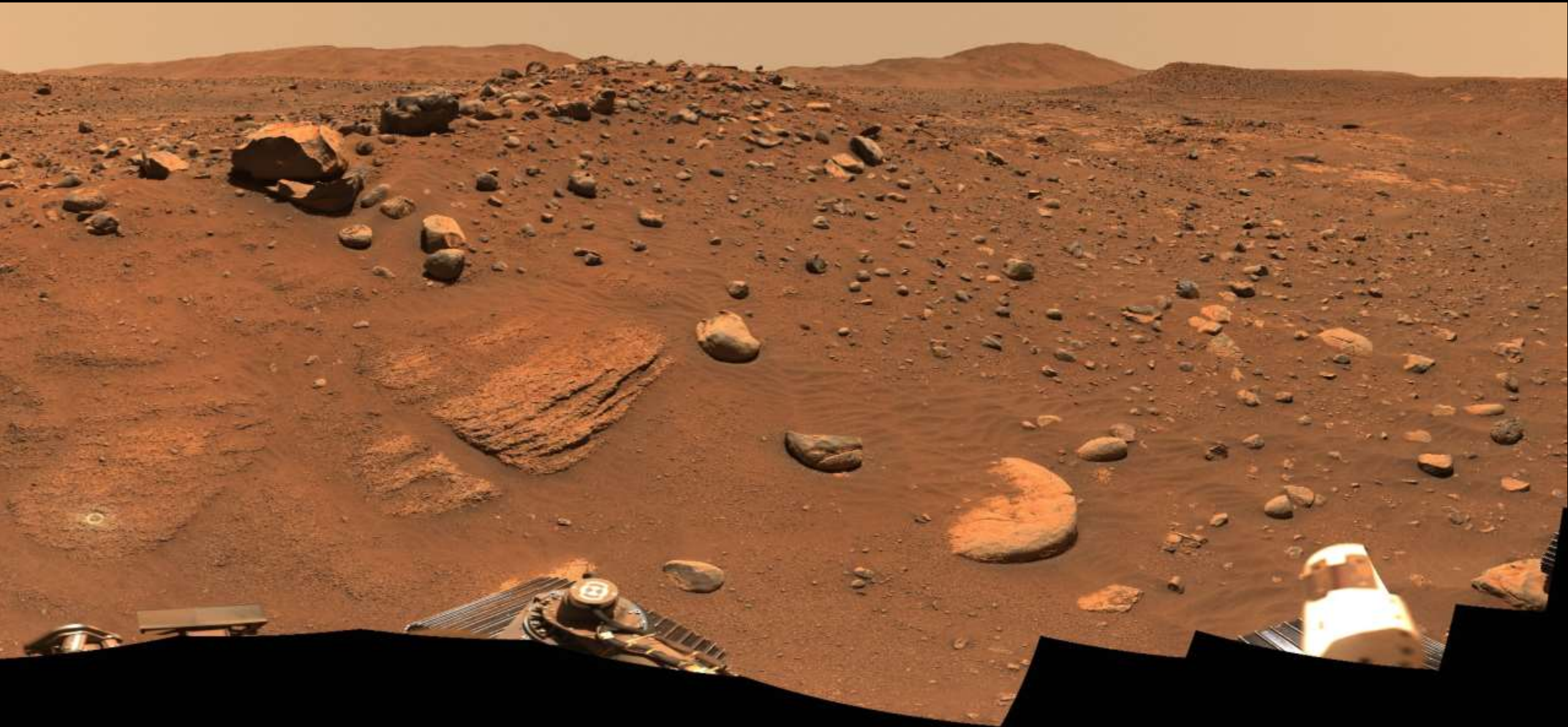


# Perseverance: Belva krater (Sol 0791), 2/3





# Perseverance: Belva krater (Sol 0791), 3/3





# Perseverance: Stone\_Man\_Pass (Sol 0817), 1/2



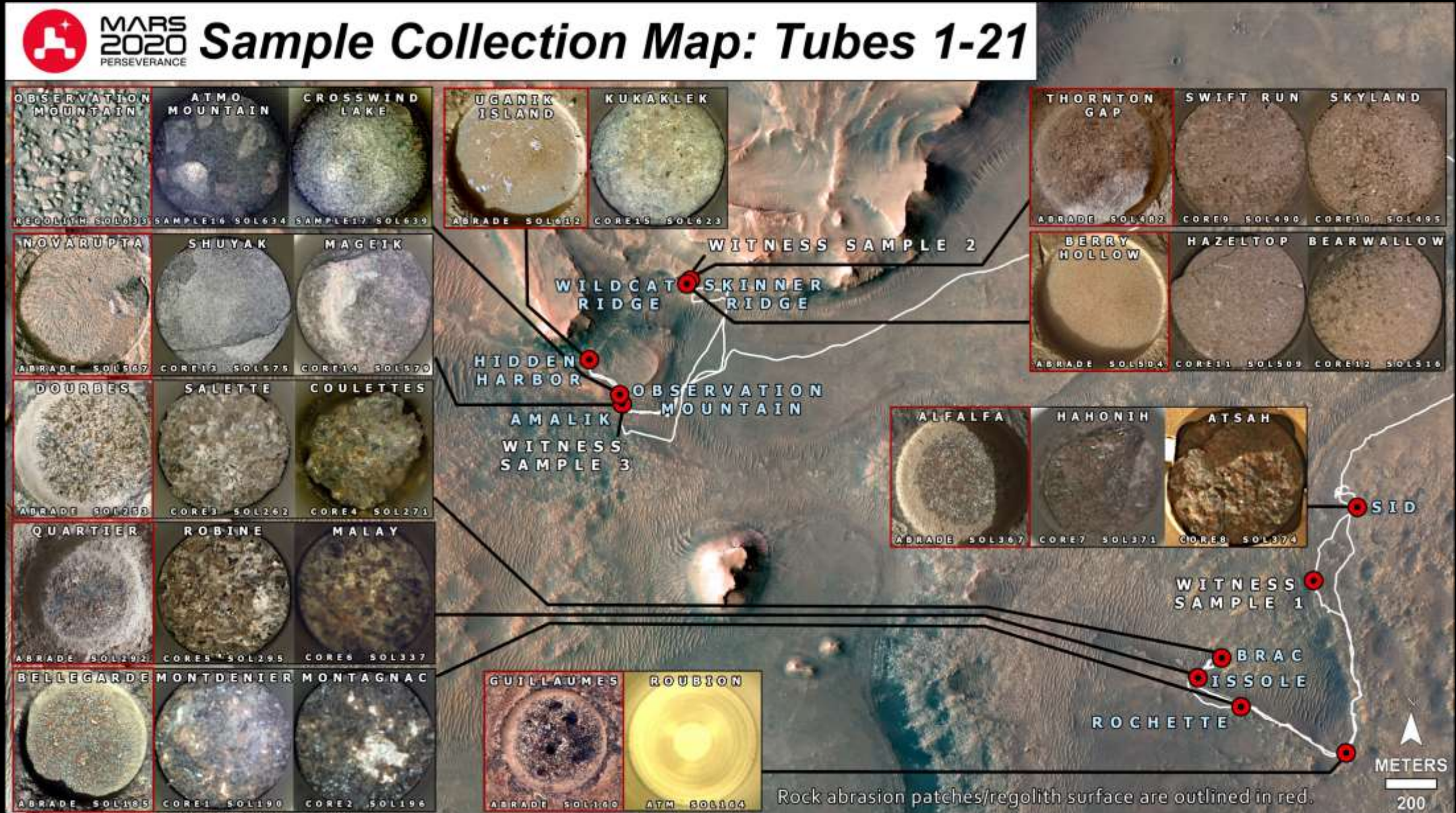


# Perseverance: Stone\_Man\_Pass (Sol 0817), 2/2





# Slibninger – og prøver indsamlet pr. Sol 639



21 tubes include 3 witness-samples (contamination control). Billeder: Arizona State Univ.; MSSS; NASA/JPL.

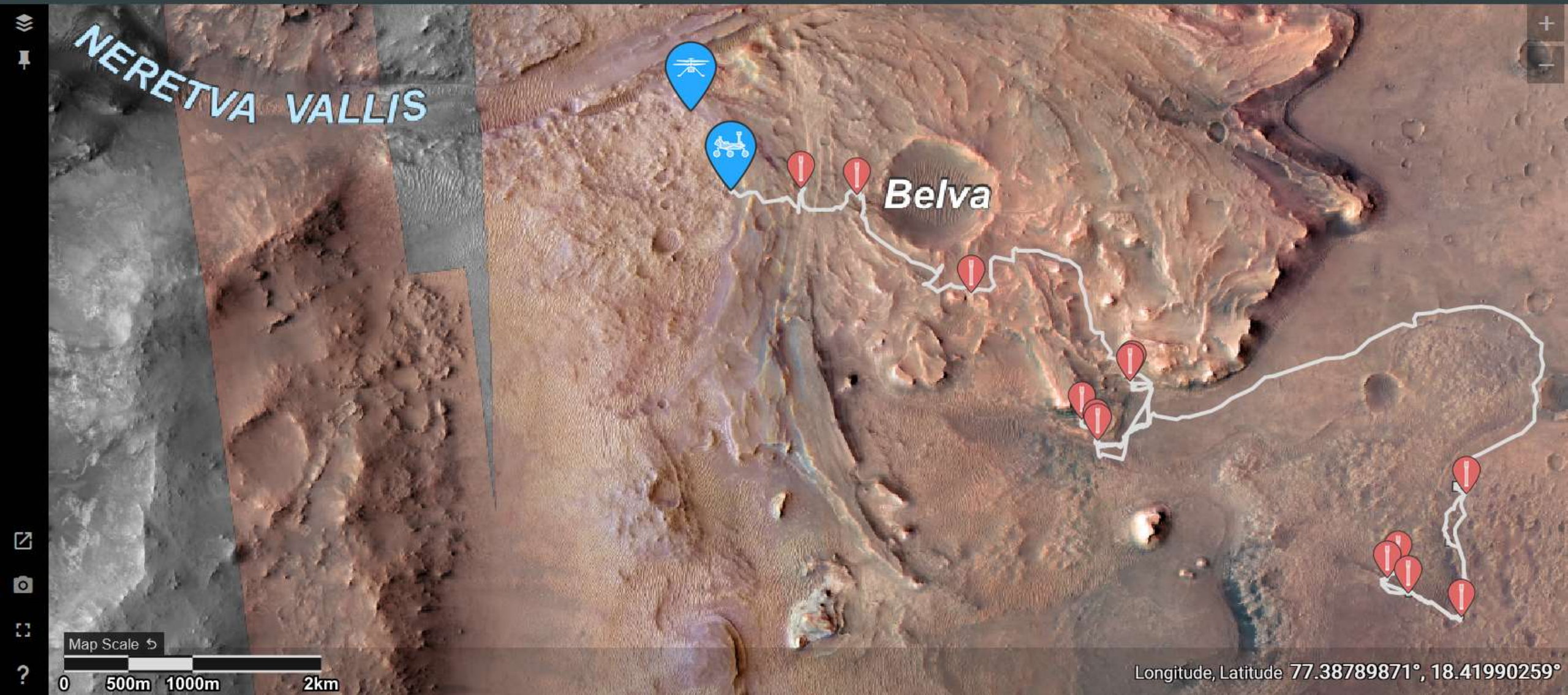


# Hvor er Perseverance nu?



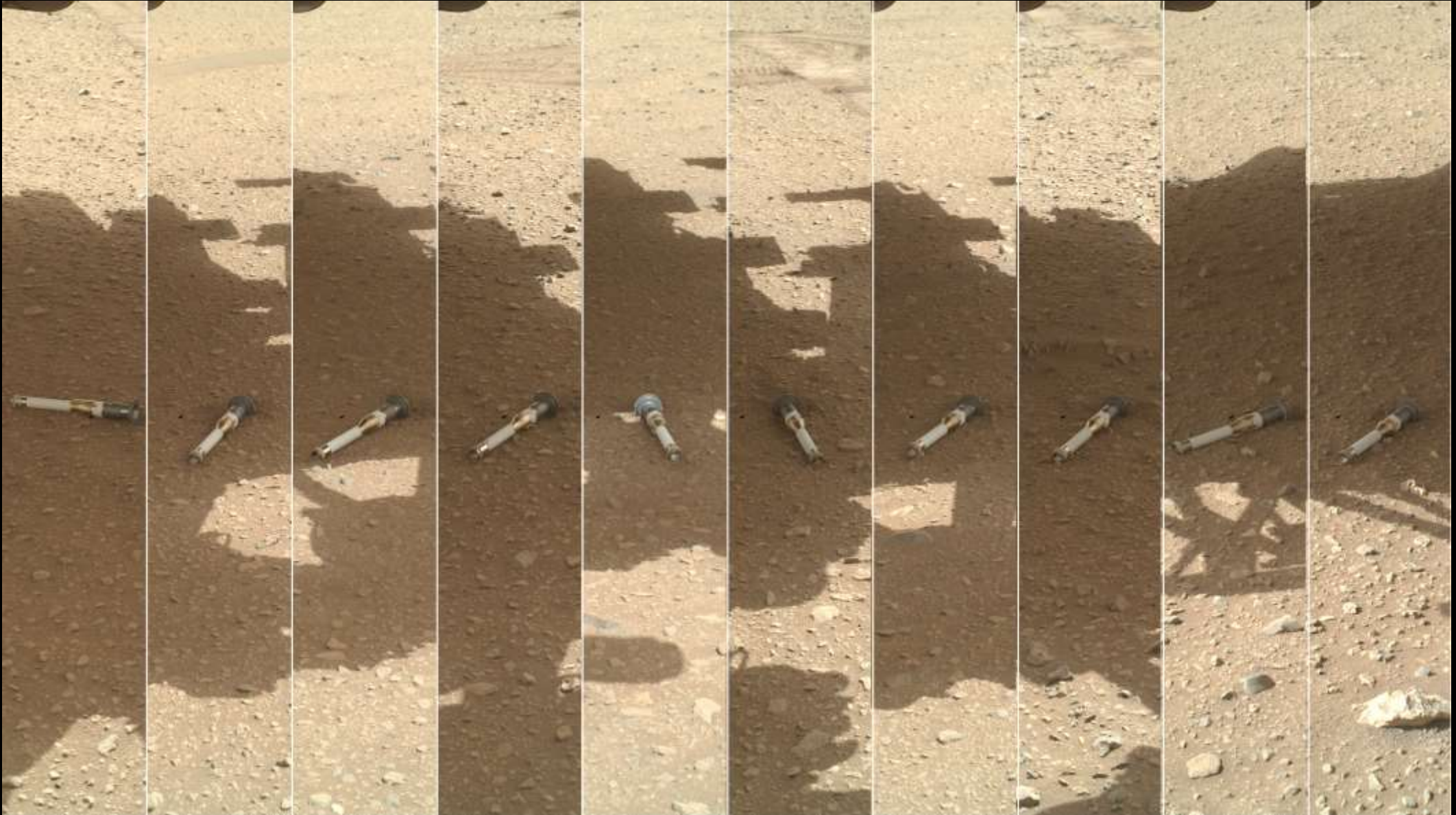
Perseverance's Location

Latest Drive: Sol 911 | Total Distance 12.798 miles / 20.597 km

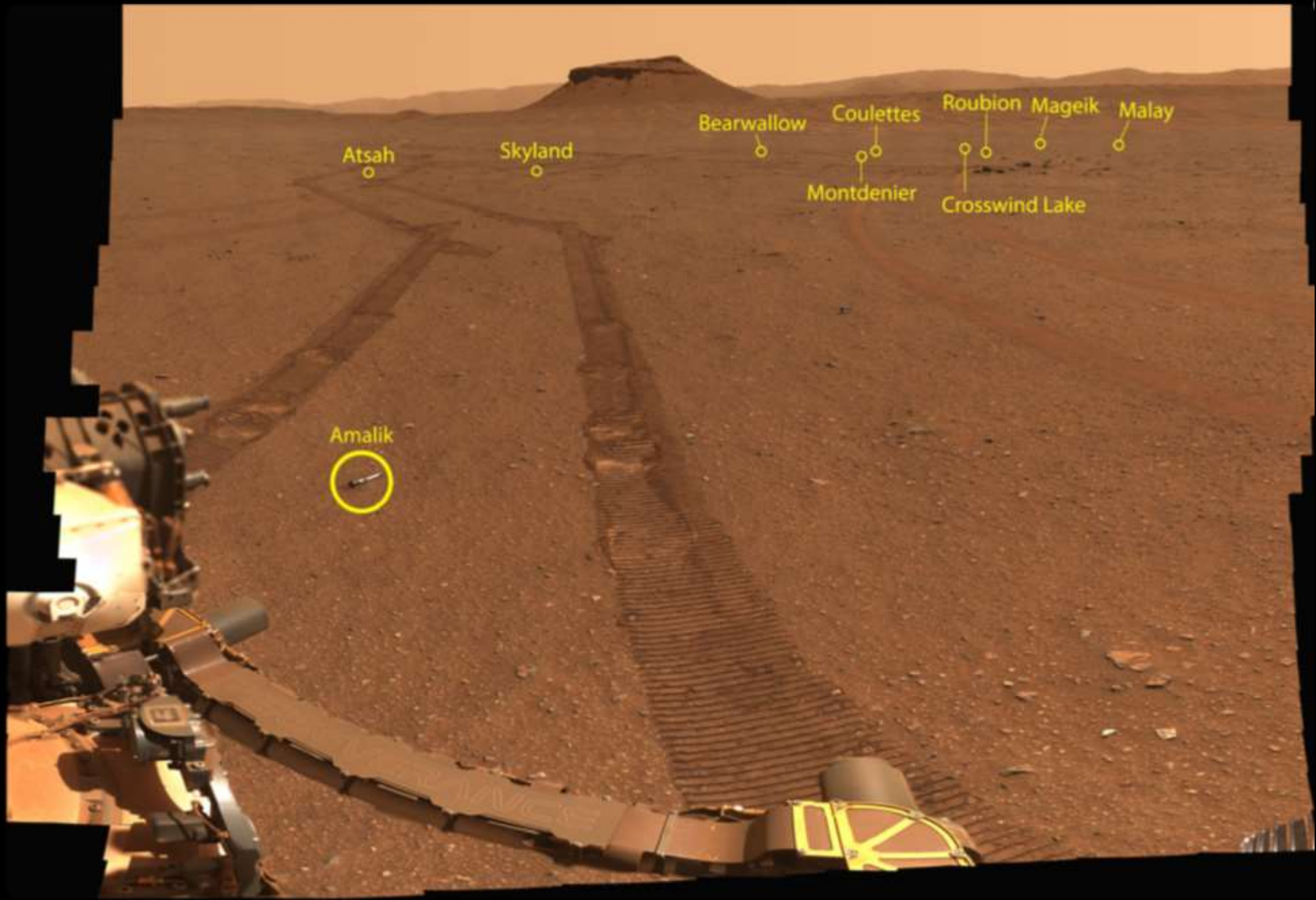




# Boreprøver deponeret af Perseverance ved Three Forks Depot

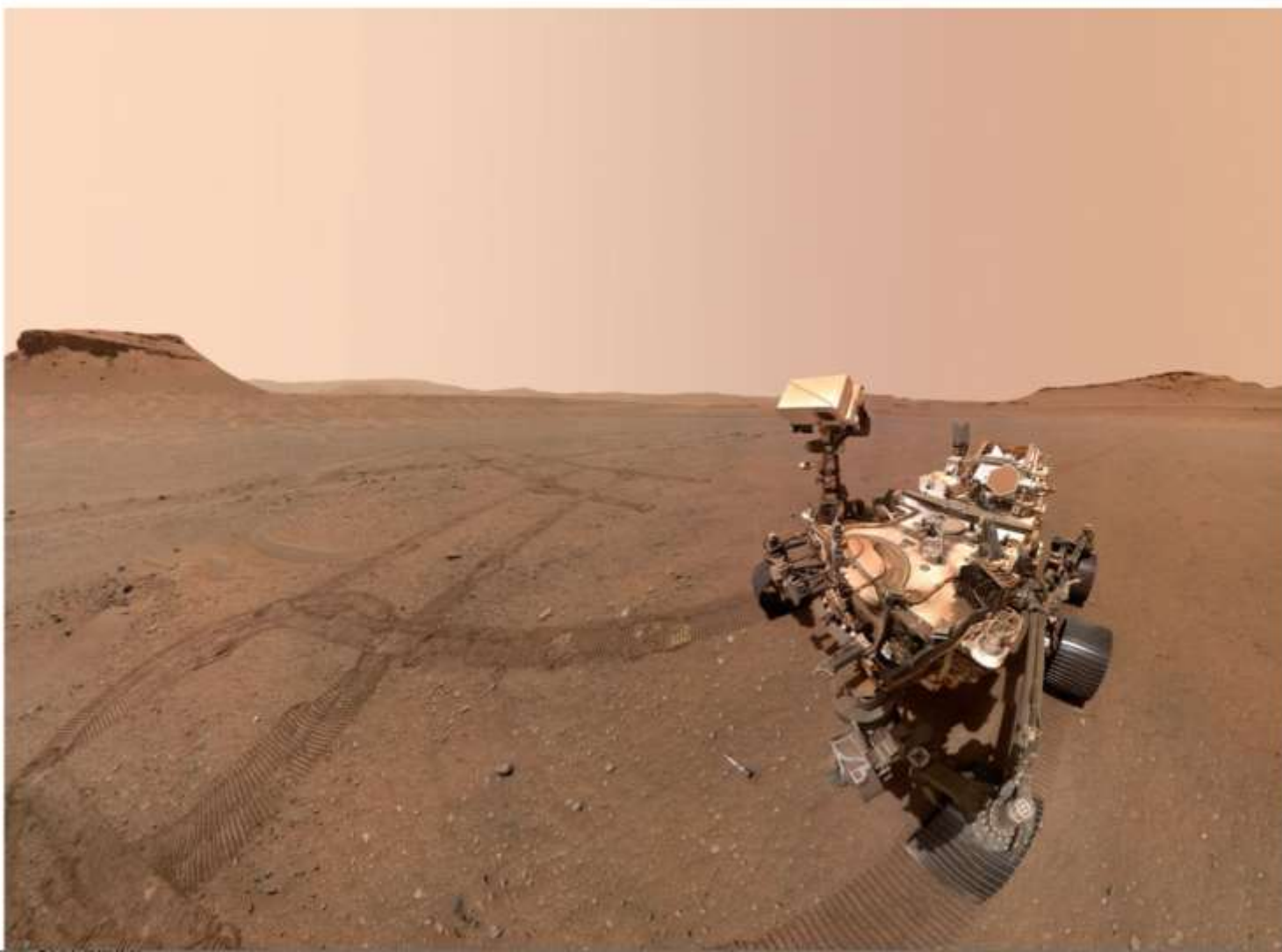








# NASA's Perseverance Rover Completes Mars Sample Depot



## Related Links

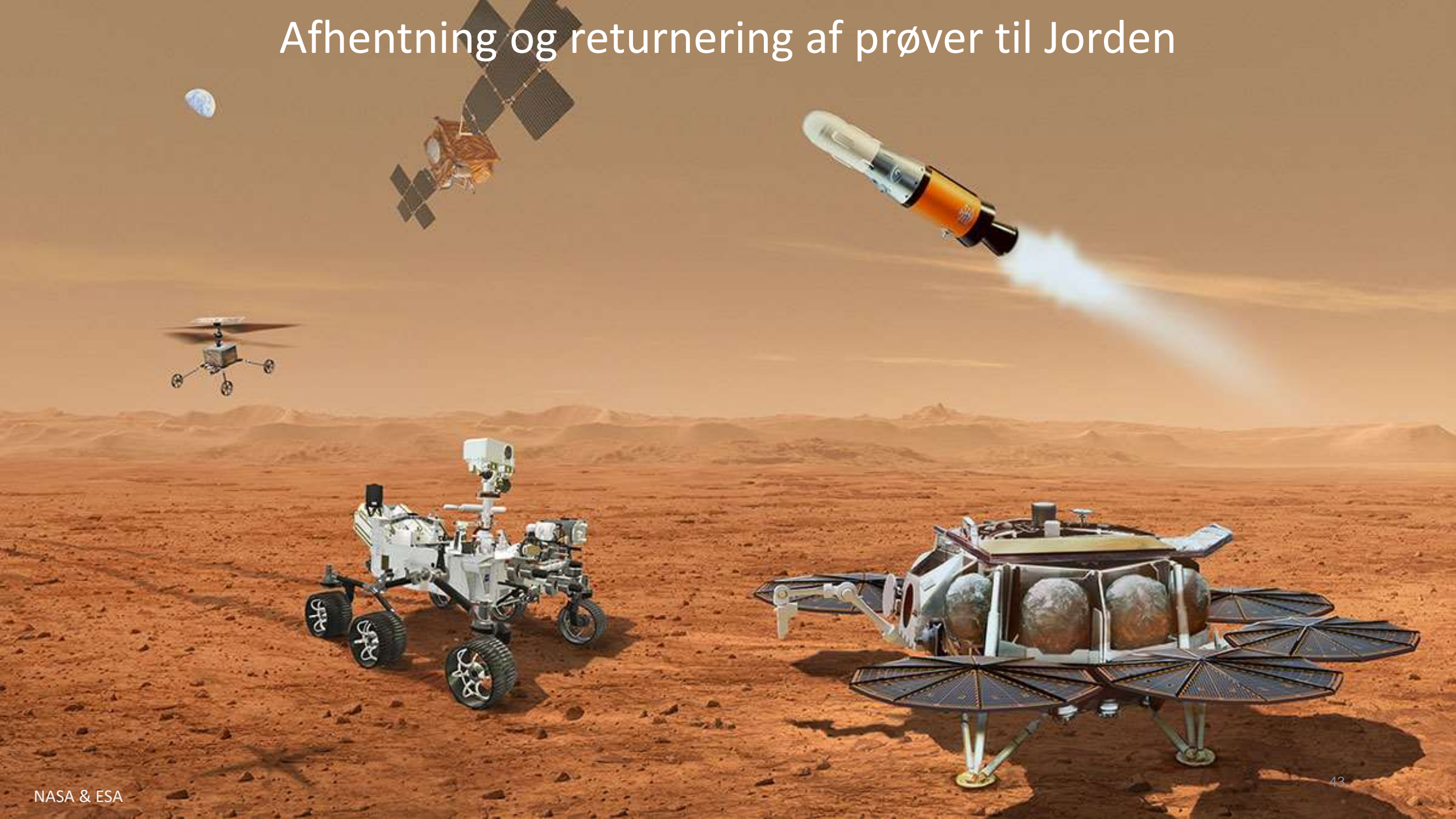


[Keep Track of Perseverance's Samples >](#)





# Afhentning og returnering af prøver til Jorden





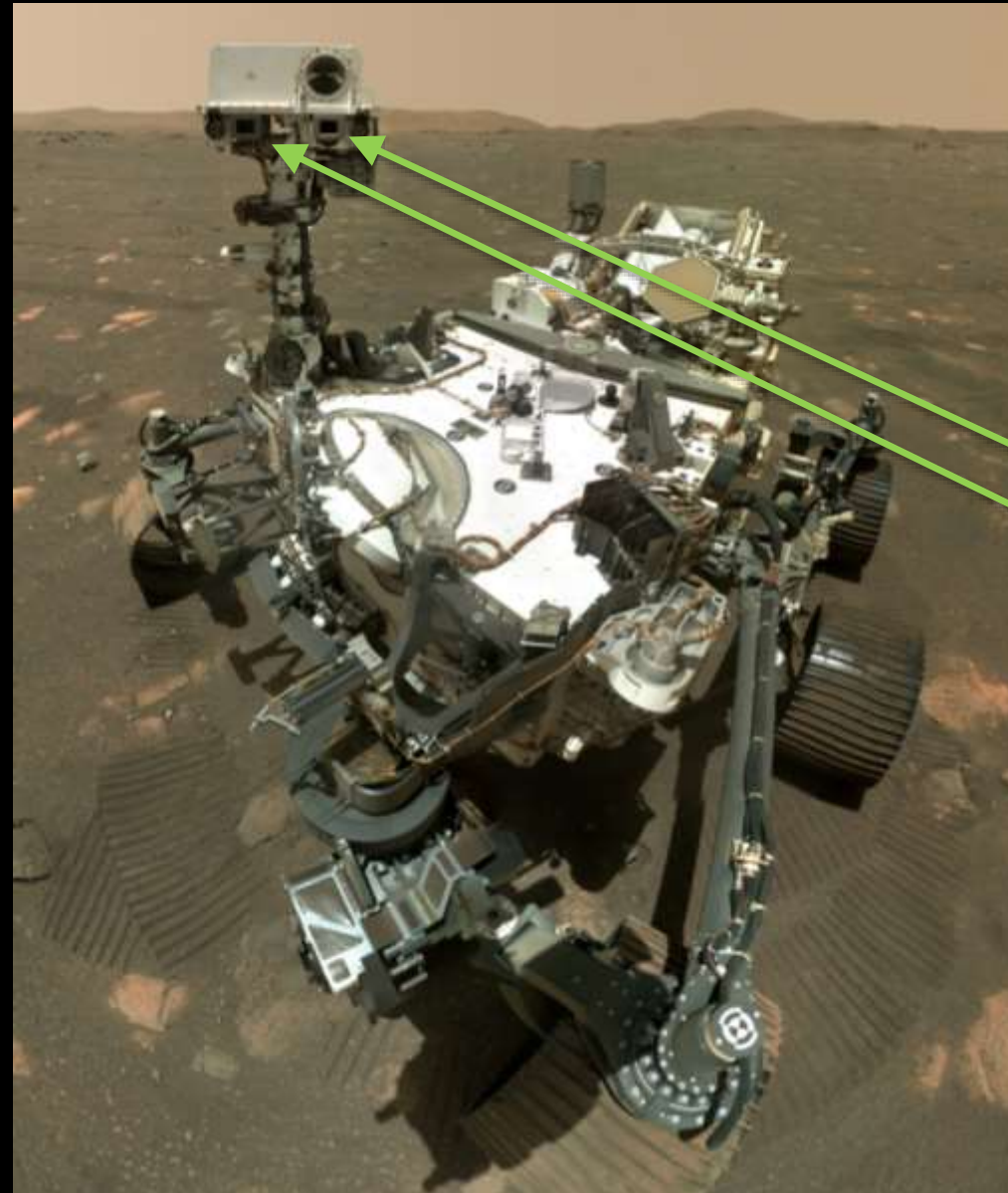
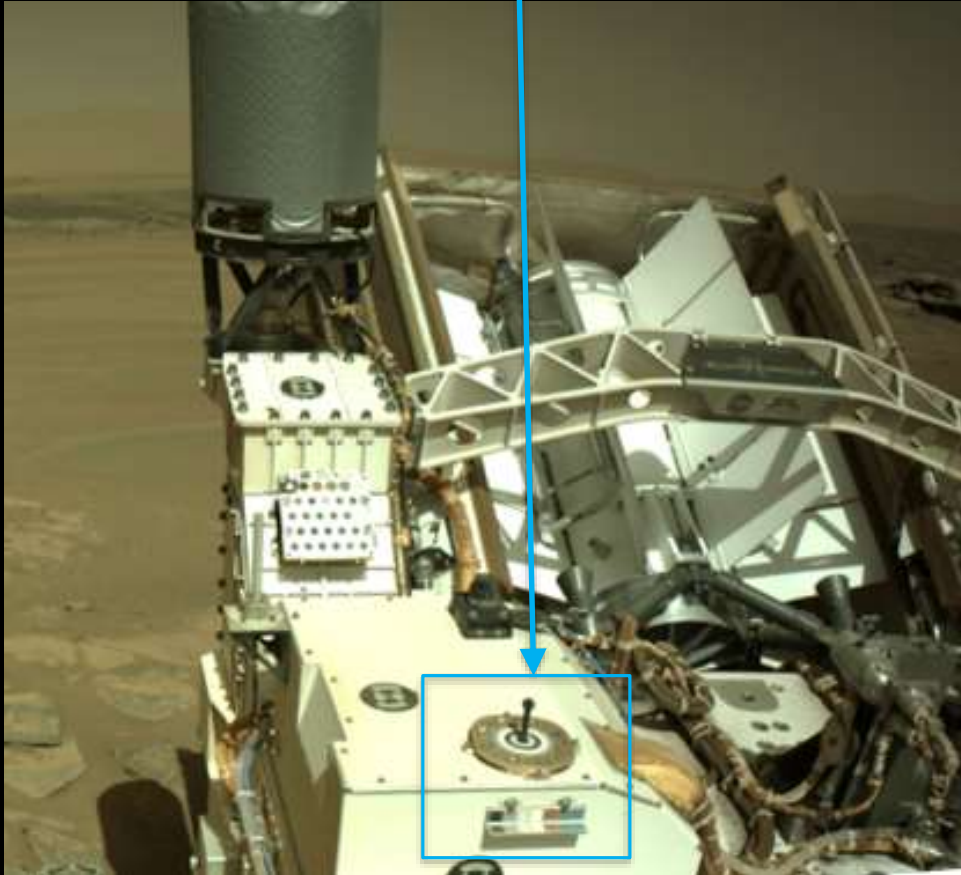
# Astronomi fra Mars-overfladen





# Kalibrering af farvebilleder fra Mastcam-Z

NBI har leveret kalibreringstargets til Mastcam-Z



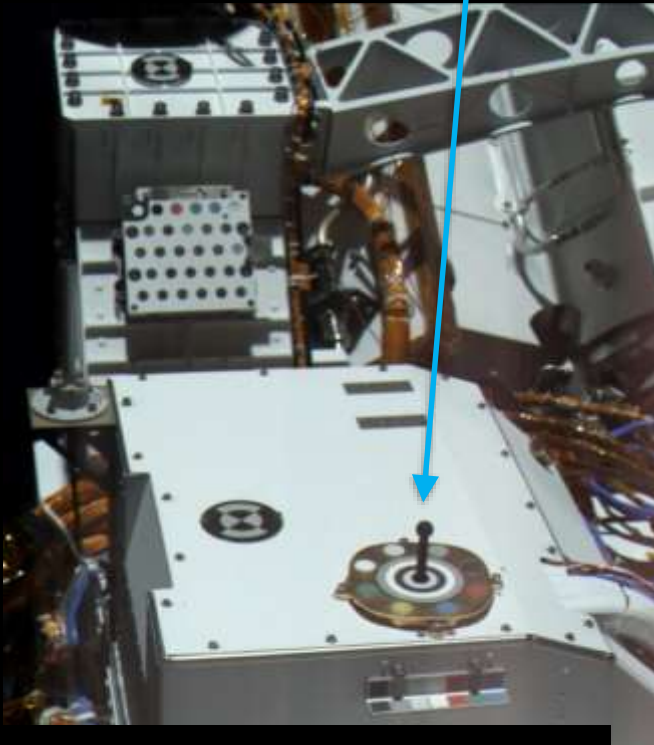
Mastcam-Z:  
Multispektralt,  
stereoskopisk  
kamera med  
zoom og video.





# Mastcam-Z Calibration Target

Mastcam-Z: NBI har leveret  
Multispektral, kalibreringstargets til MC-  
stereoskopisk Z  
kamera med  
zoom og video.



Marsprojektet er støttet af:  
**CARLSBERGFONDET**

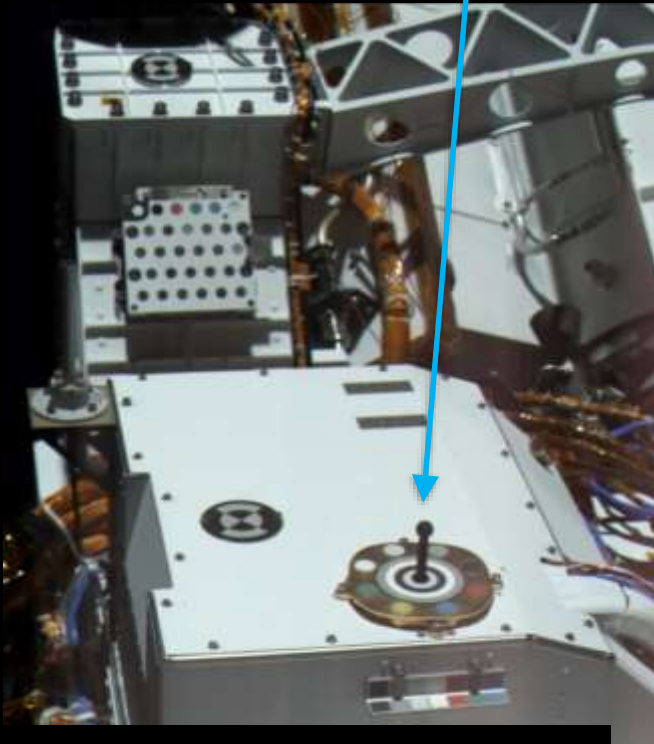


Billeder: NBI-UCPH; Arizona State Univ.; MSSS; NASA/JPL; LANL.



# Mastcam-Z Calibration Target

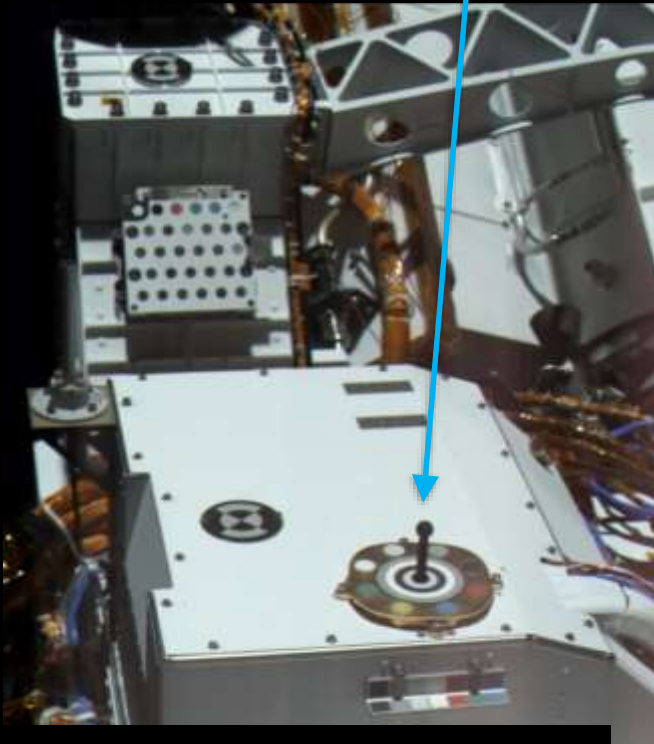
Mastcam-Z: NBI har leveret  
Multispektral, kalibreringstargets til MC-  
stereoskopisk Z  
kamera med  
zoom og video.





# Mastcam-Z Calibration Target

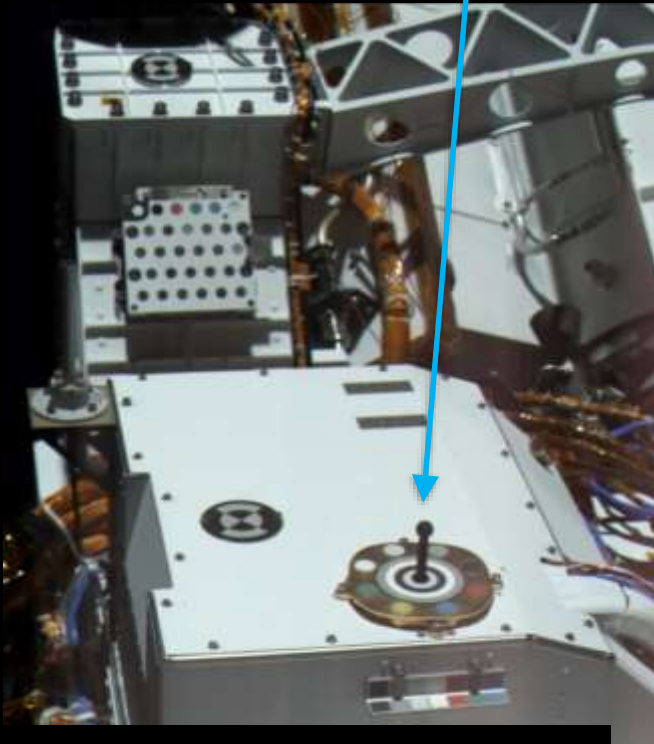
Mastcam-Z: NBI har leveret  
Multispektral, kalibreringstargets til MC-  
stereoskopisk Z  
kamera med  
zoom og video.





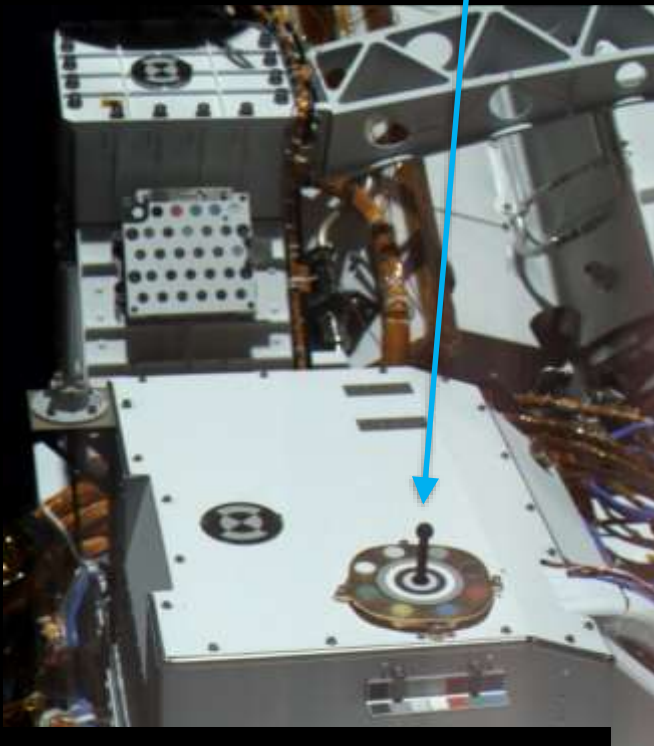
# Mastcam-Z Calibration Target

Mastcam-Z: NBI har leveret  
Multispektral, kalibreringstargets til MC-  
stereoskopisk Z  
kamera med  
zoom og video.



# Mastcam-Z Calibration Target

Mastcam-Z: NBI har leveret  
Multispektral, kalibreringstargets til MC-  
stereoskopisk Z  
kamera med  
zoom og video.

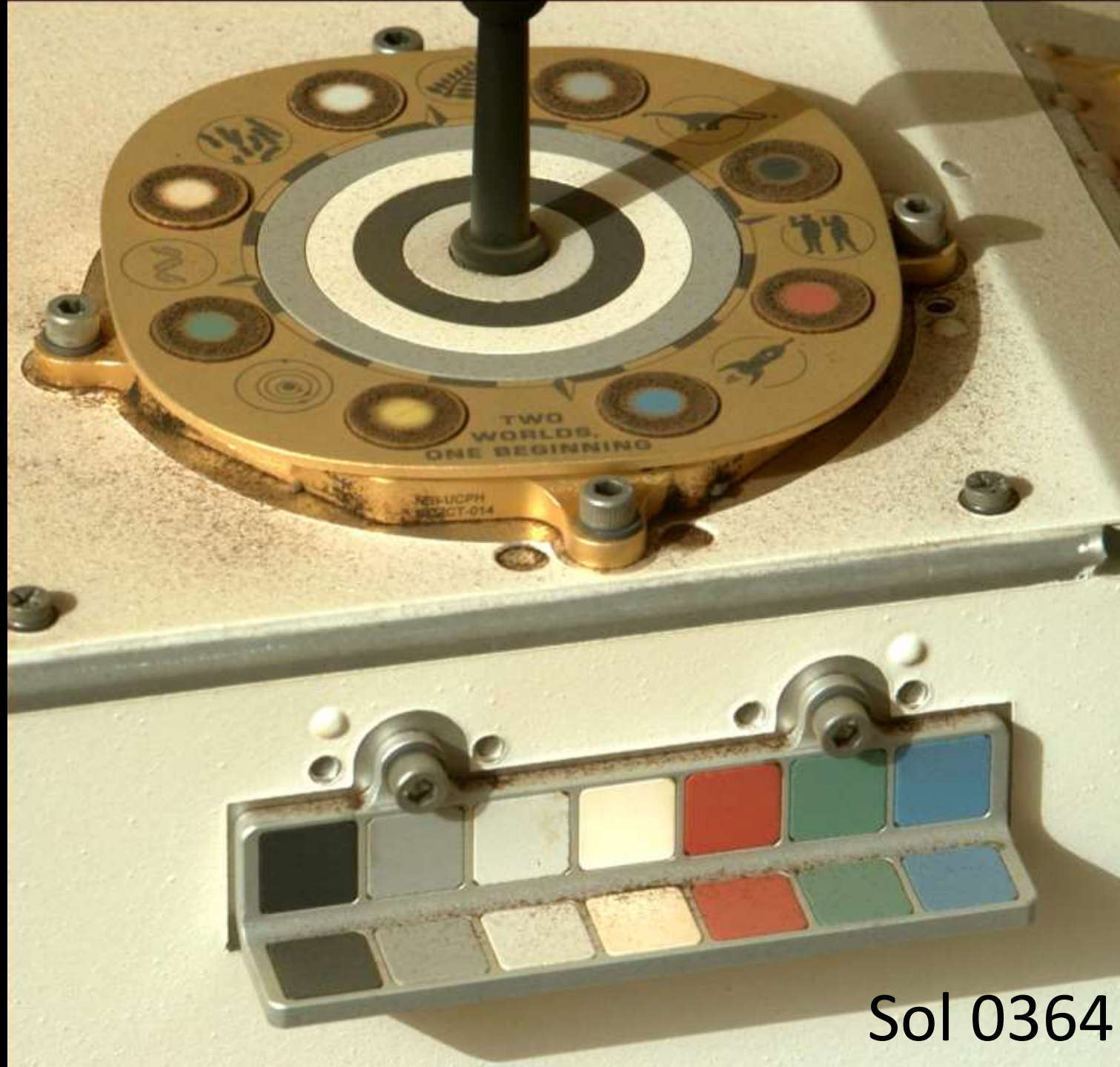




Sol 0002



Billeder: Arizona State  
Univ.; MSSS; NASA/JPL;  
NBI-UCPH.



Billed: Arizona State Univ.; MSSS;  
NASA/JPL; NBI-UCPH.

Sol 0364





Billed: Arizona State Univ.; MSSS;  
NASA/JPL; NBI-UCPH.

Sol 0663



# Mastcam-Z calibration targets (fra NBI)

Antal billeder af cal-targets i alle filtre til og med sol 550: **3816**



ZLF\_0023\_0668982767\_596FDR\_N0030770ZCAM03003\_0630LMJ01



ZL0\_0252\_0689307944\_443ECM\_N0080000ZCAM03014\_048085J01

Støv opsamlet på skyggemasten

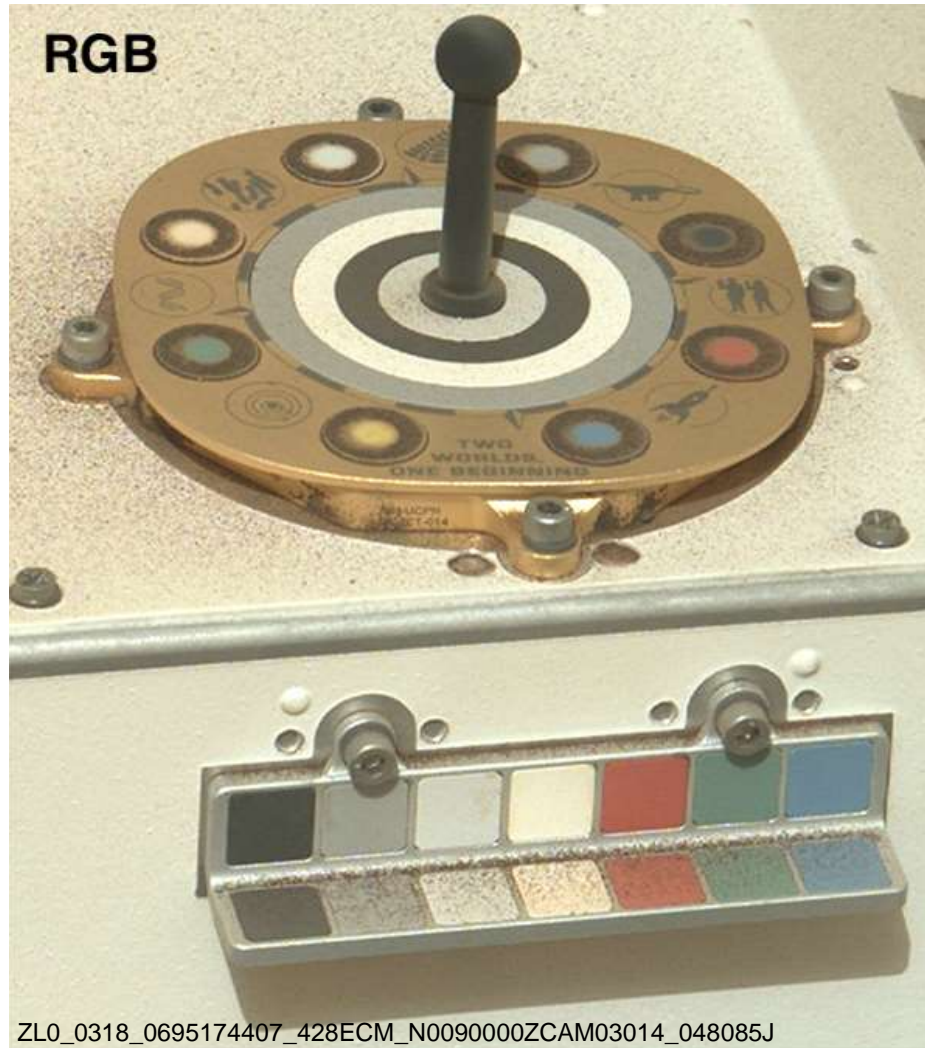


ZLF\_0534\_0714343914\_239FDR\_N0261222ZCAM03014\_048085J01



# Støv på cal-targets

Billeder: NASA/JPL-Caltech; ASU; MSSS; NBI-UCPH – Marco Merusi



Kontakt-information: Morten Bo Madsen, mbmadsen @ nbi.ku.dk, <https://nbi.ku.dk/english/research/astrophysics/mars/> og links - til NASAs Perseverance rover-mission og den danske deltagelse:

<https://mars.nasa.gov/news/9483/nasa-releases-independent-reviews-mars-sample-return-report/> MSR Indep. Rev. Board Rep (230919)  
<https://mars.nasa.gov/mars2020/news/> Seneste nyt fra Perseverance  
<https://mars.nasa.gov/mars2020/> Alt tilgængeligt om Perseverance  
<https://mars.nasa.gov/mars2020/multimedia/raw-images/> Friske billeder fra Perseverance  
<https://mars.nasa.gov/mars2020/mission/where-is-the-rover/> Her kan man følge turen til Mars og rundt i Jezero-krateret  
<https://mars.nasa.gov/technology/helicopter> Om Ingenuity (Mars-helikopteren)

Fra "The Planetary Society": <https://www.planetary.org/articles/calibrating-mars>  
Fra hjemmesiden for Mastcam-Z: <https://mastcamz.asu.edu/mars-in-full-color/>  
Fra JPLs hjemmeside: <https://www.jpl.nasa.gov/news/news.php?feature=7796>

Et par nyhedsmeddelelse fra Carlsbergfondet, som er vores største økonomiske støtte i arbejdet på Mars:

<https://www.carlsbergfondet.dk/da/Nyheder/Formidling/Maanedensforsker/Morten-Bo-Madsen-har-deltaget-i-seks-NASA-missioner>  
<https://www.carlsbergfondet.dk/da/Nyheder/Nyt-fra-fondet/Nyheder/Video-Bliv-klogere-paa-Perseveranceroveren-og-Marsmissionen>

Her et par links til nogle af originalartiklerne om instrumenter om bord på Perseverance:

<https://doi.org/10.1007/s11214-020-00774-8> Mastcam-Z Calibration Target  
<https://doi.org/10.1007/s11214-020-00764-w> SuperCam Calibration Target  
<https://doi.org/10.1007/s11214-020-00777-5> SuperCam Body Unit  
<https://doi.org/10.1007/s11214-020-00782-8> The Mars Oxygen ISRU Experiment (MOXIE)  
<https://doi.org/10.1007/s11214-020-00767-7> Planetary Instrument for X-ray Lithochemistry (PIXL)  
<https://doi.org/10.1007/s11214-020-00783-7> Perseverance Sampling and Caching Subsystem

Andre nyttige links:

[www.nasa.gov/mars](http://www.nasa.gov/mars)  
<https://nbi.ku.dk/english/research/astrophysics/mars/>  
[www.marslab.dk](http://www.marslab.dk)  
<https://www.space.dtu.dk/>  
<https://www.sciencestories.dk/da>  
<https://www.nasa.gov/directorates/spacetech/niac/index.html>  
<https://spinoff.nasa.gov/>

Generel link til NASA's Mars-missioner  
Mars-gruppen ved NBI  
Mars SimuleringsLaboratoriet, Aarhus Universitet  
DTU-Space, som bidrager til PIXL-instrumentet på Perseverance  
Aktuelt (og vigtigt) om naturvidenskab  
NASA Innovative Advanced Concepts Program  
Presentation of recent spinoffs of NASA developed technology