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SpaceLab

Robin Phillips

March 2024

Maxon is a family owned business, founded in Obwalden in 1961 and currently employing >3200 people world wide (~1200 in Switzerland).

Annual turnover is ~750million CHF from ~4.5 million actuators in 16,000 different variations per year.

Headquarters in Sachseln (Switzerland).

Gearboxes designed & manufactured in Germany.

Labor intensive subassemblies and high volume motor production in Hungary.

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maxon product types:

- Motors
- Gearboxes
- Feedback devices
- Controllers

All the above both in catalog for standard use and customizable to individual customer requirements

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maxon Manufacturing Facilities

A global multi-national company with production facilities around the world.

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Photo: Alan Dyer
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Why even go to Mars?

- Closest planet where humans might be able to live
- Same surface area as Earth
- CO_2 atmosphere (could extract oxygen)
- Geologically active
- Tolerable temperature range
- Relatively easy to get to (compared to outer planets)
- Presence of water

Evolution of Martian Exploration

1600’s Telescopes

Image from a telescope with a 10 cm mirror

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Earth Based Observations (1940's-1990's)

Limited to basic large-scale geographic features

Mount Palomar - 4.5 meter mirror

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Earth Based Observations (1990 -)

Limited to basic large-scale geographic features

Hubble Space Telescope (HST) – 2.4 meter mirror

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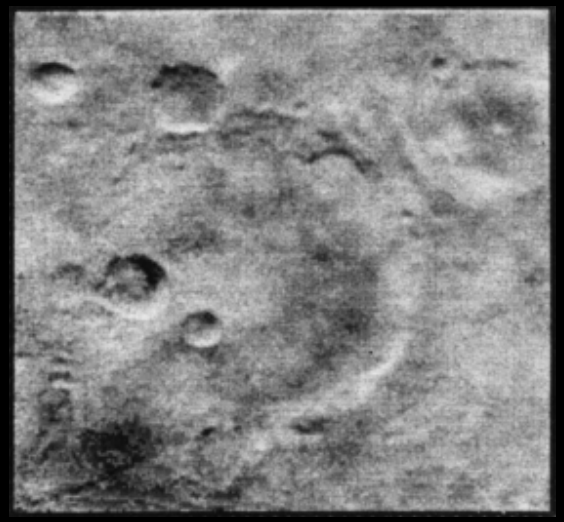
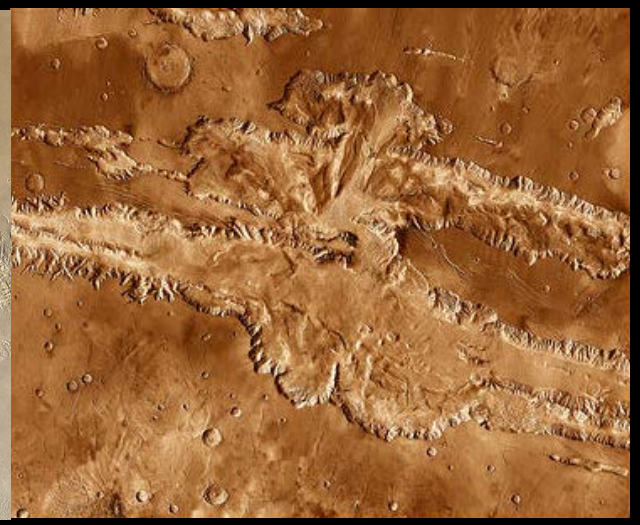
Evolution of Martian Exploration



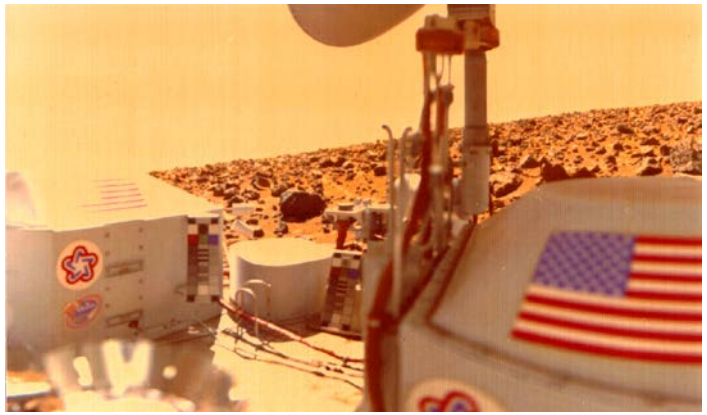
First flyby in 1964

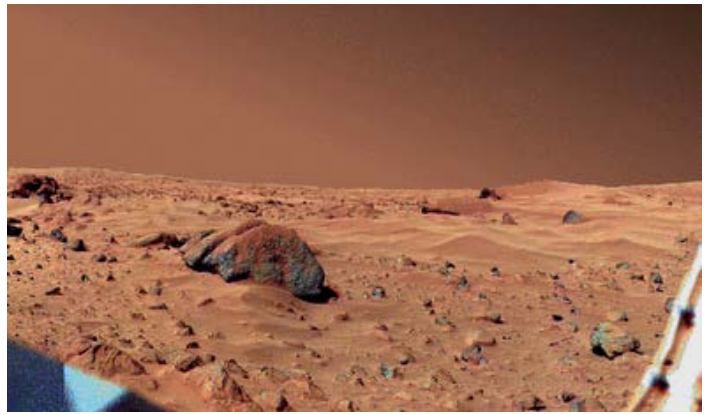


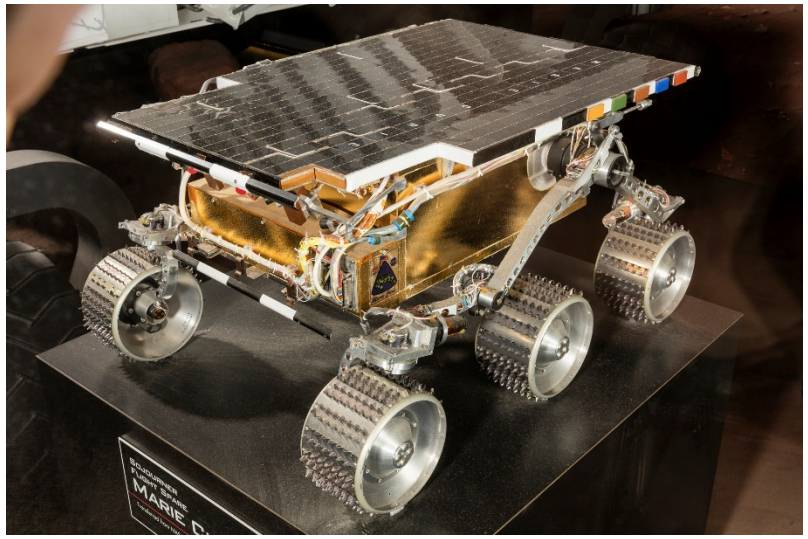
Orbiter in 1971

Evolution of Martian Exploration

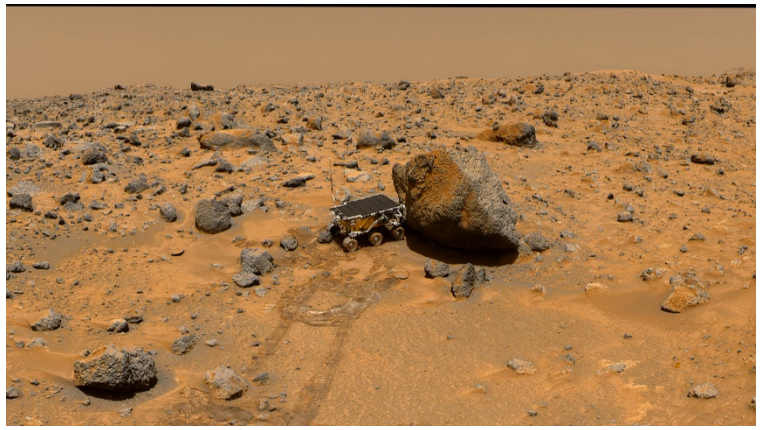
Viking landers in 1976

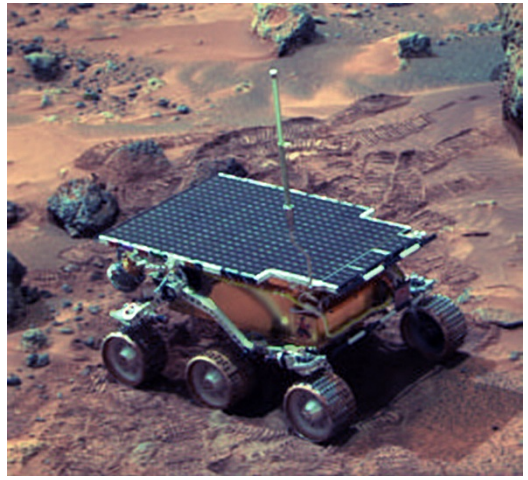


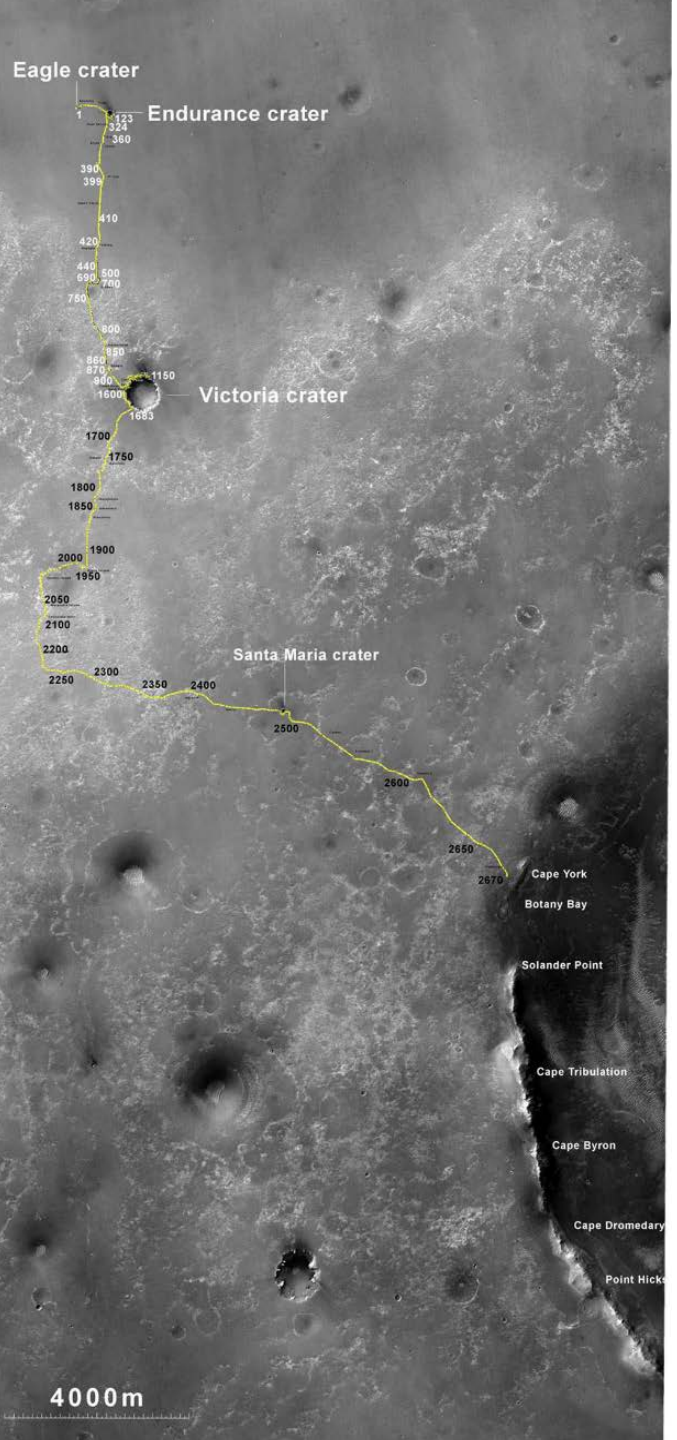




Sojourner rover in 1997







The Advantages of Rovers

- Allows access to regions that landers cannot reach (example: hazardous terrain)
- Allow for larger areas of the surface to be explored
- Relatively cheap way of moving around
- Not as complex (technically risky) or mass limited as flying
- Proven technology – 4 successful Mars missions
- Allows for multiple samples to be collected

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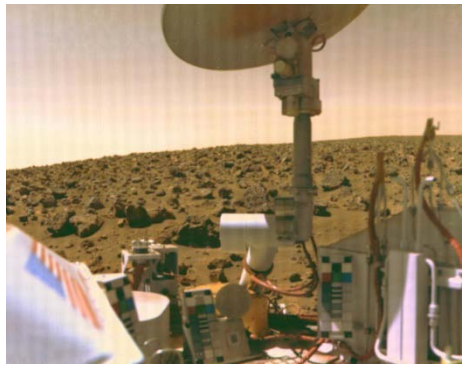
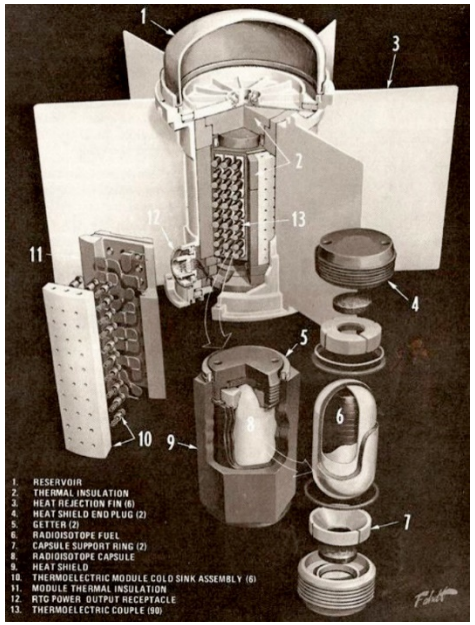
Key Rover Technologies



Designed to get the scientific instruments to their targets.



- Communication links (radio)

  Reliable, known technology since 1960s
- Power (solar, nuclear or battery)

  All proven to work on Mars since 1970s
- Camera systems (for navigation)

  Proven and reliable
- Long life drive motors

  Very little prior experience (lunar rovers in 1970s)

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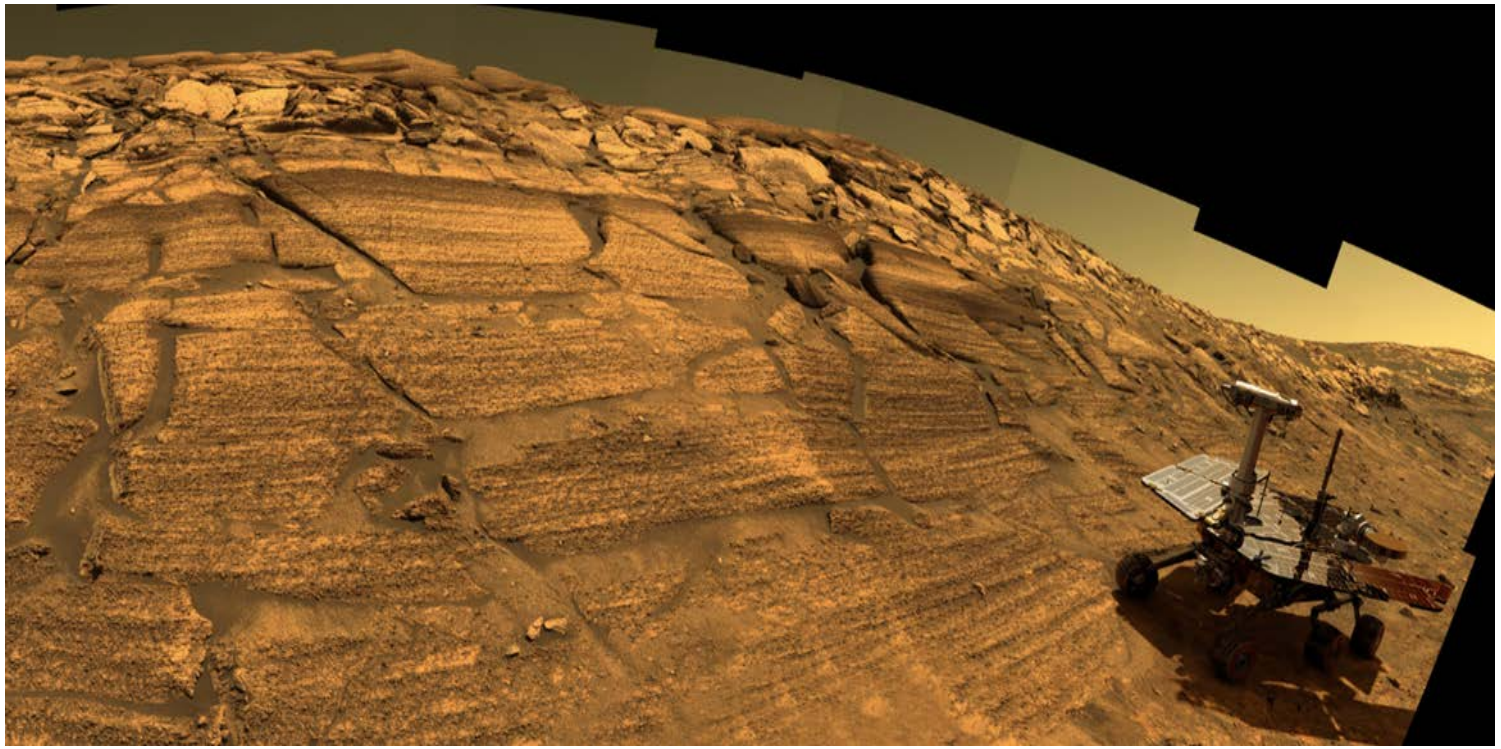
Spirit & Opportunity

2003 – Each rover was equipped with 35 maxon DC motors



Opportunity lasted 15 years and 45 kilometers before succumbing to a lack of solar power in a dust storm.

Biggest science result: Clear evidence that Mars once had running water!

RE 20 & RE 25 (+MR enc)

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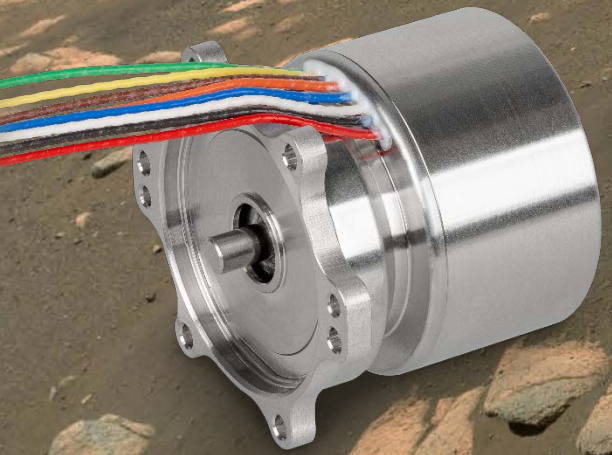
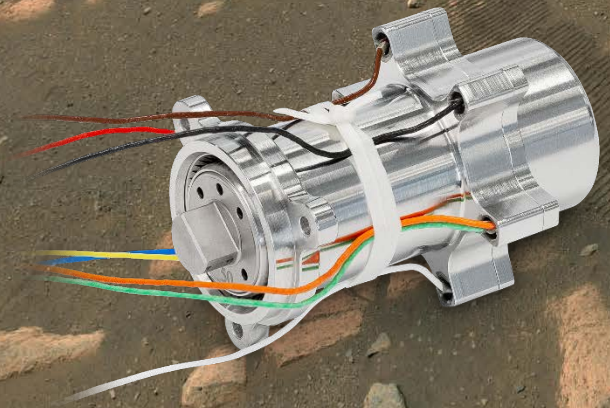
Mars 2020

Perseverance & Ingenuity

6x DCX10 motors for the helicopter swashplates



9x EC32fl motors + detent brake for the sampling & caching and helicopter deployment mechanisms



1x EC20fl motor + GP22UP gearbox for sample handling arm end effector

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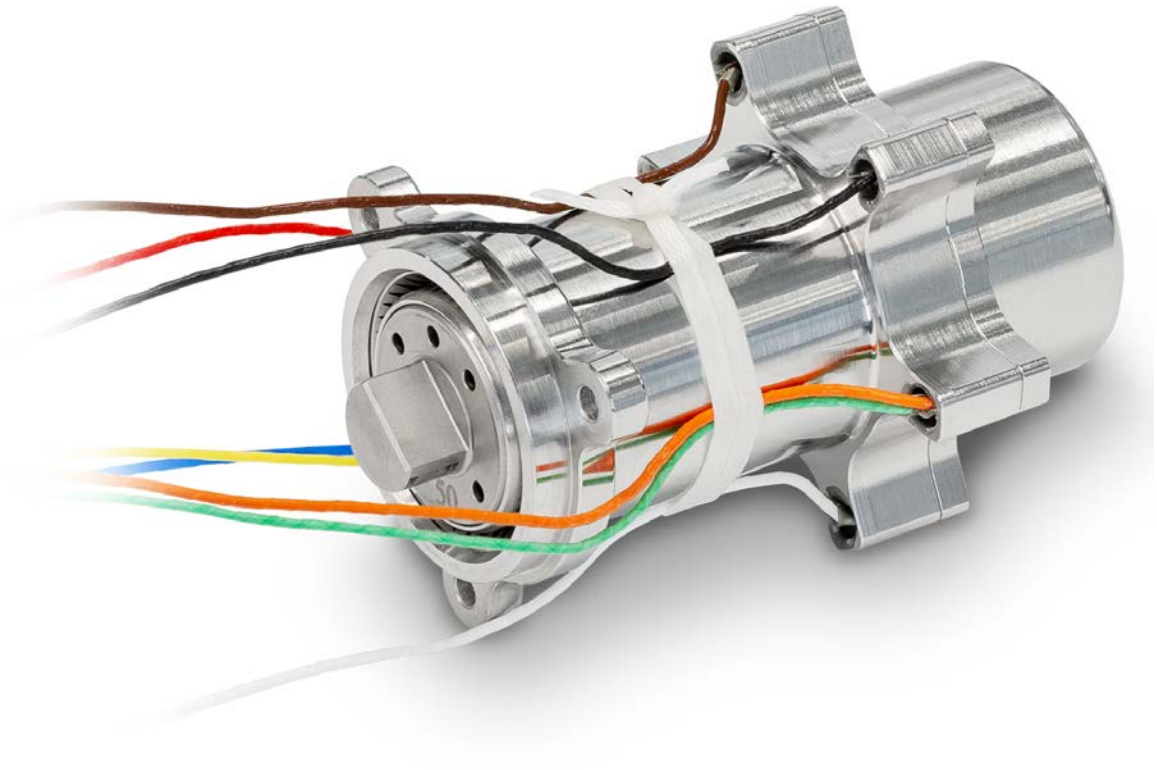
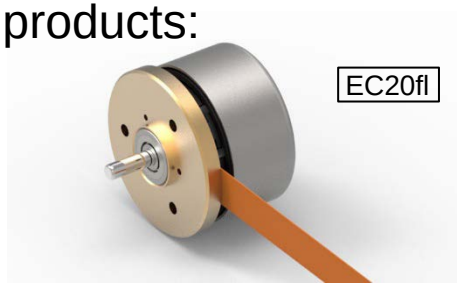
JPL Mars 2020 M24 actuator

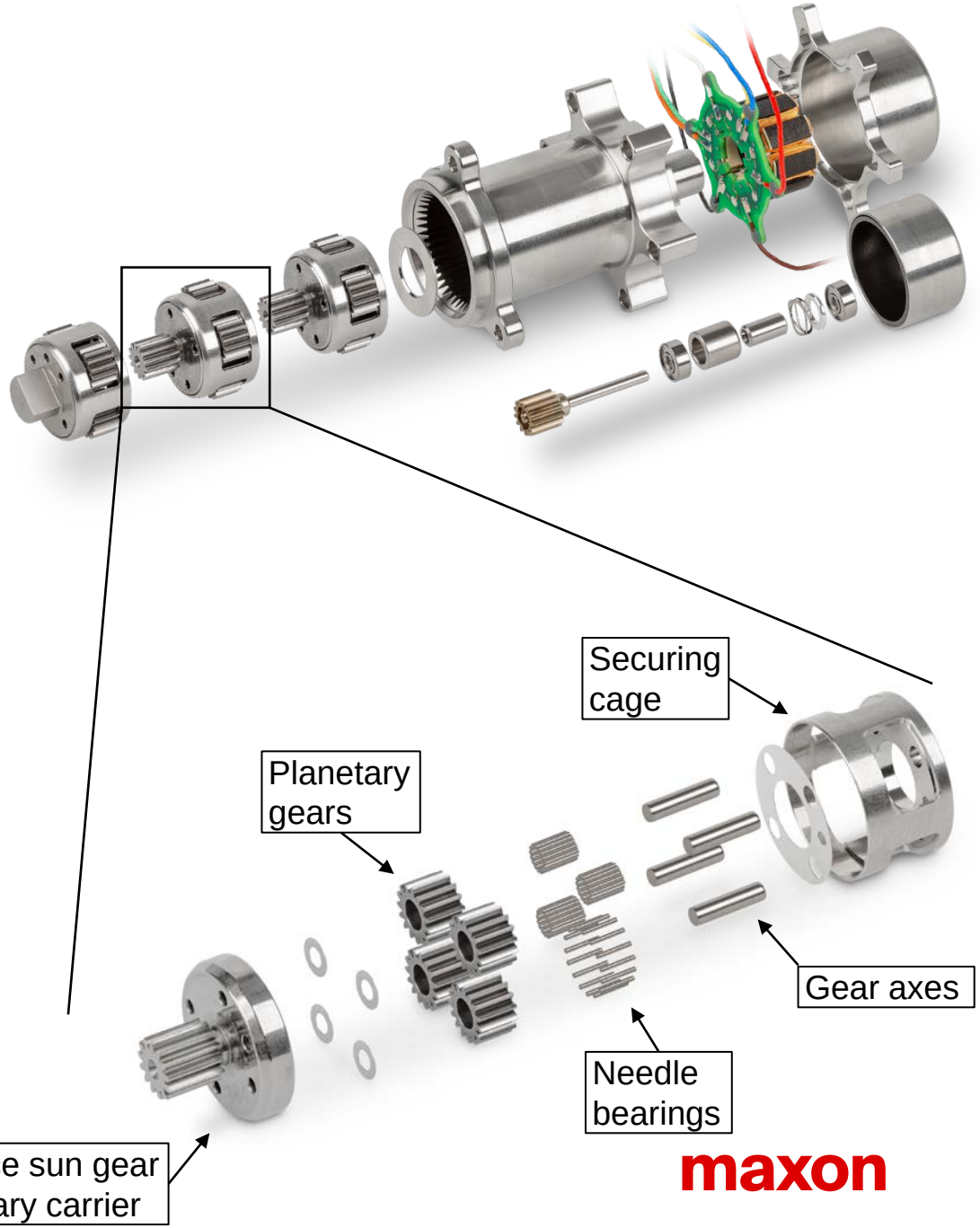


Core features are shared with the catalog standard equivalent products:

GPX22UP

EC20fl





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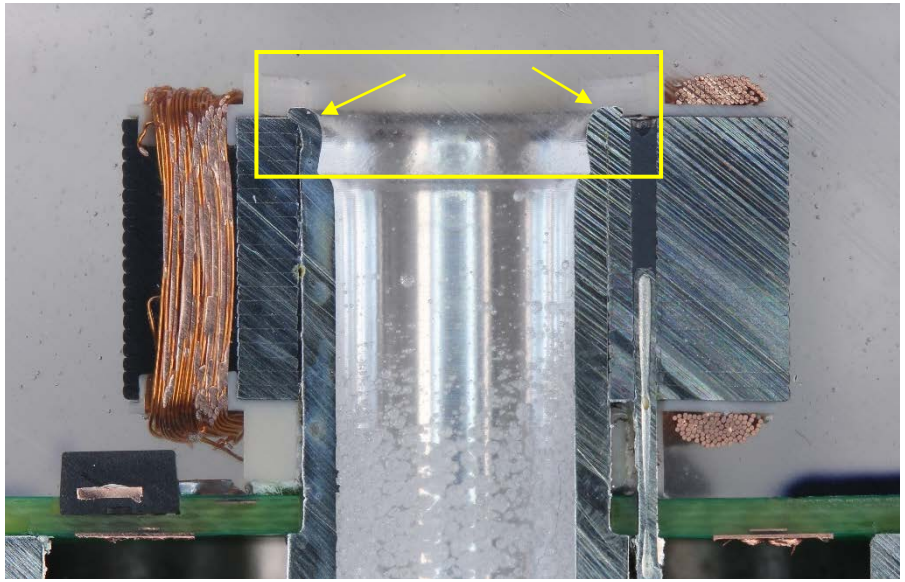
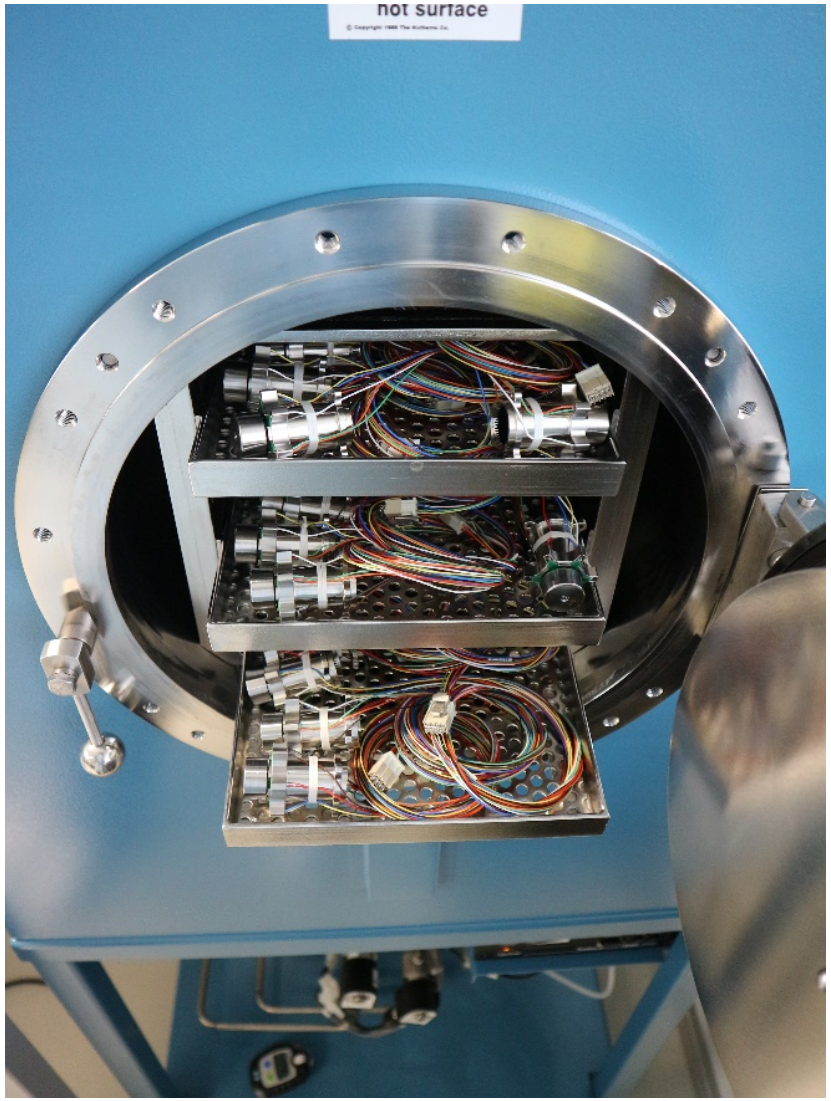
Examples of modifications to "space-rate" actuators



Radial swaging between stator and flange to hold stator in place for EC20fl (industrial standard is just glued)



Vacuum bake-out of all parts for 144 hours

Radial swaging between planetary-carrier-sun-gear and cage to eliminate welds & adhesives

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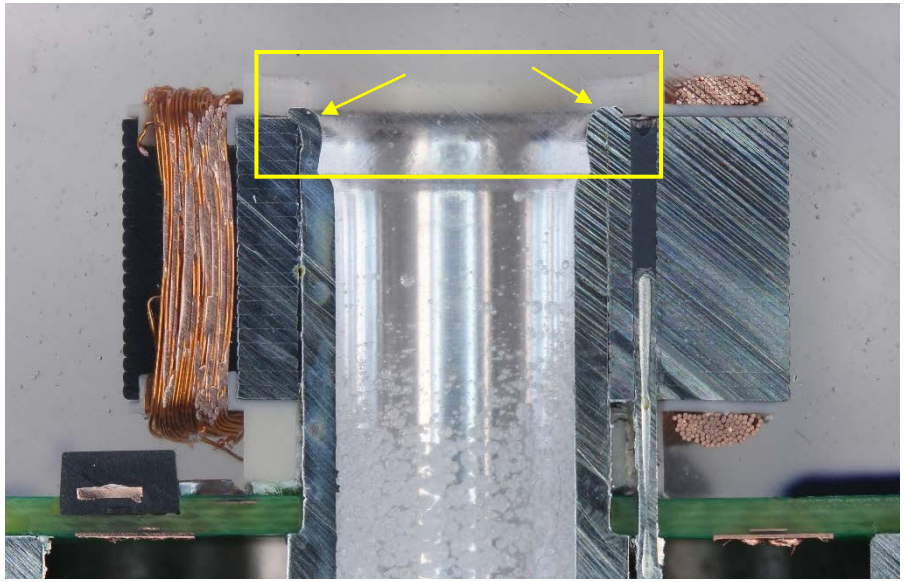
Differential expansion caused by:

- Variations in local temperature
- Materials expanding at different rates

Obwalden: -30°C to +40°C (+70°C in direct sunlight)
Mars: -130°C to +20°C (+110°C inside motor)

Examples of modifications to "space-rate" actuators



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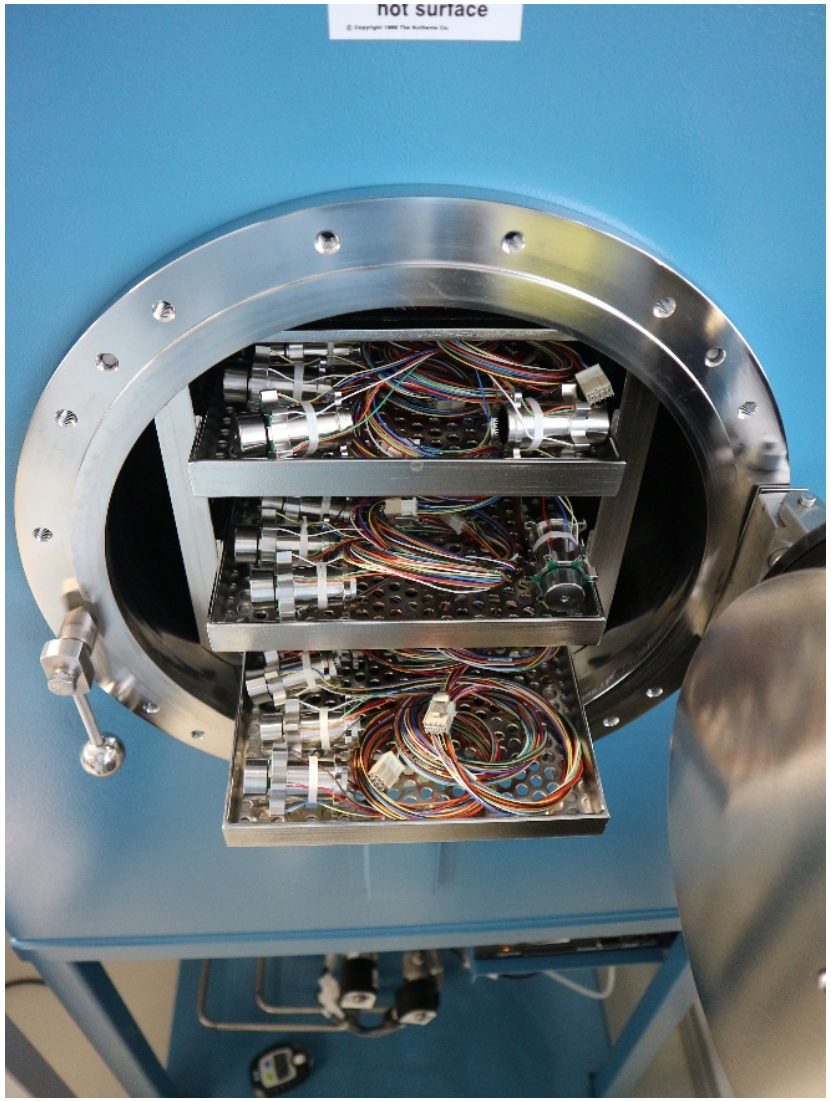

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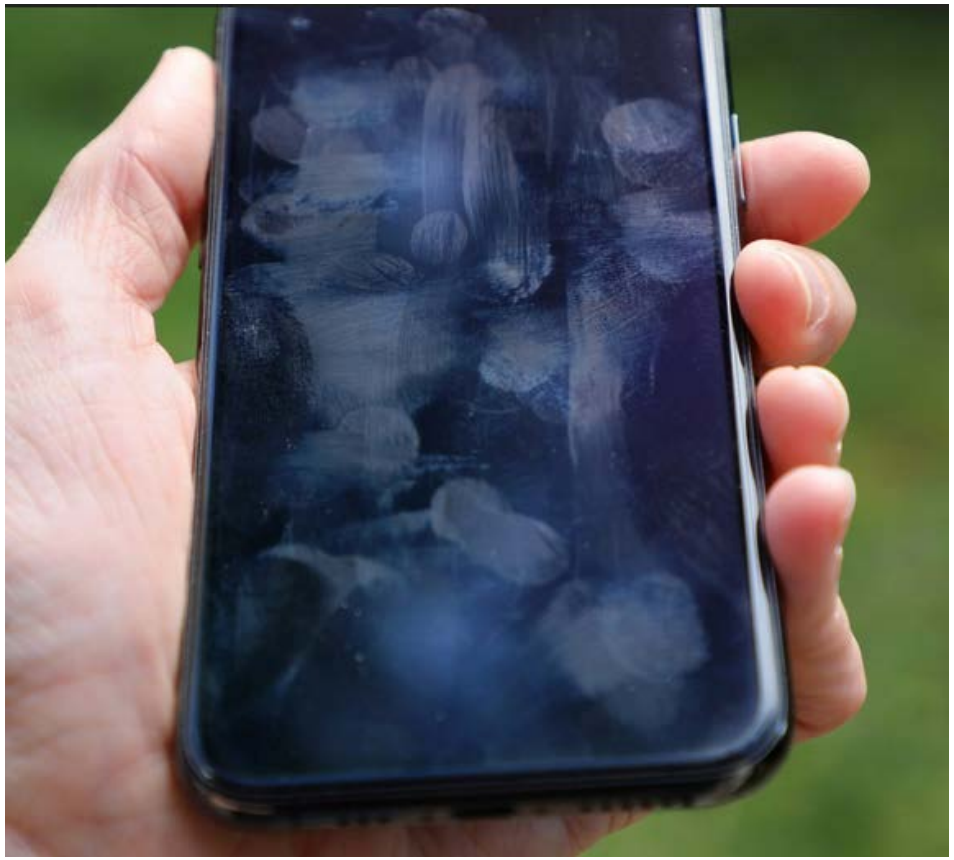

Bake-out to remove (reduce) volatiles from:

- Adhesives/Greases
- Manufacturing process contamination (oils)
- Production worker contamination (eg. fingerprints)

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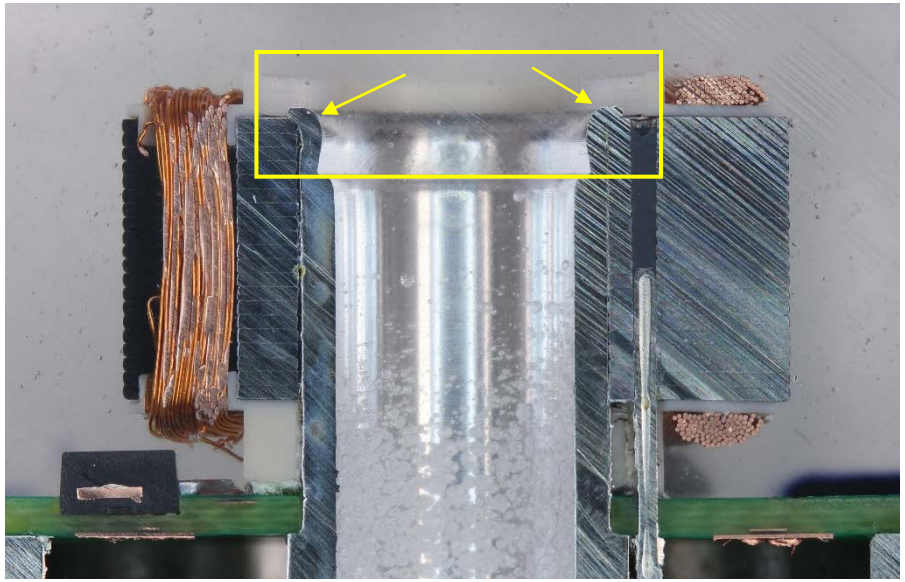
Cleanroom – Class 8

Examples of modifications to "space-rate" actuators



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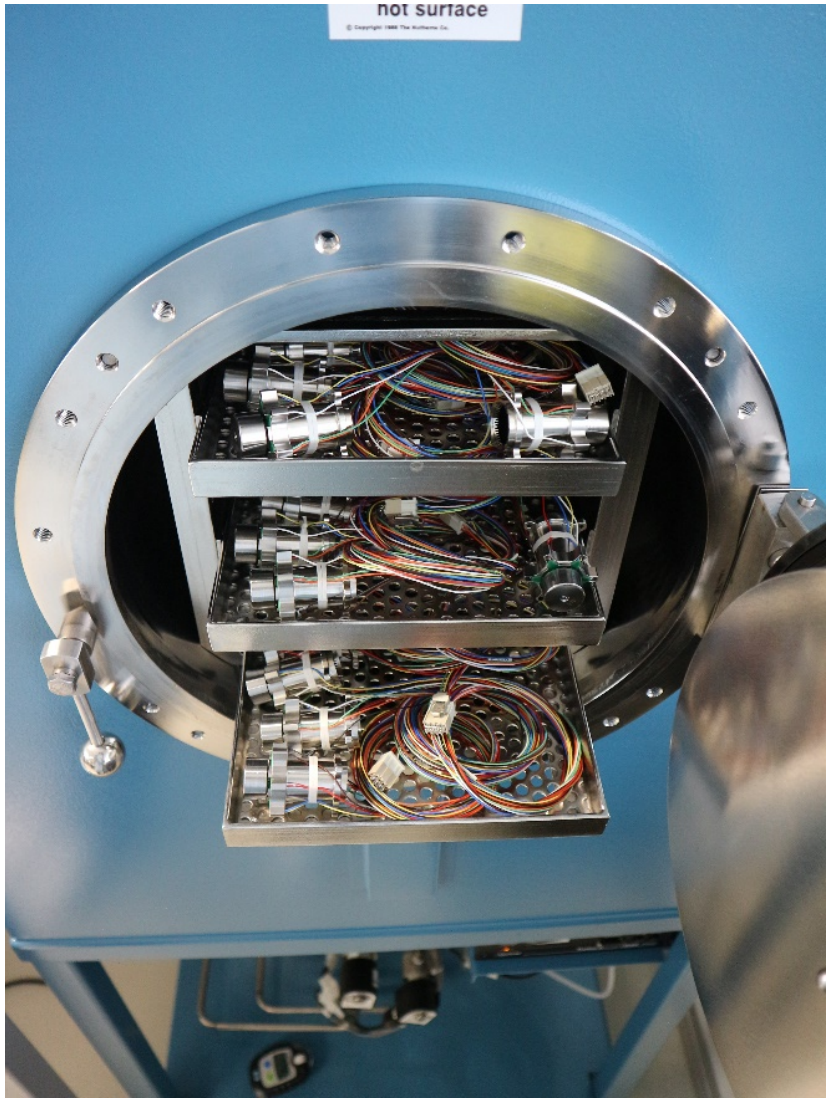

Vacuum bake-out of all parts for 144 hours

Radial swaging between planetary-carrier-sun-gear and cage to eliminate welds & adhesives

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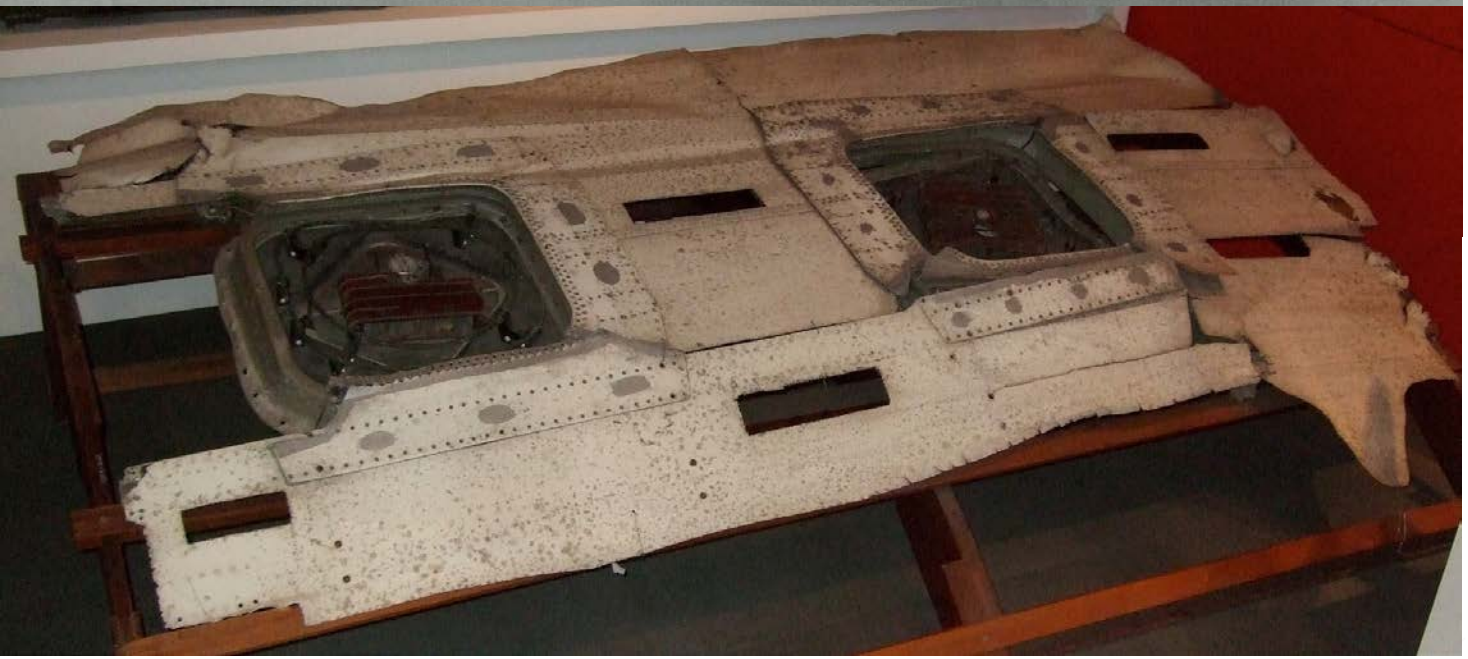
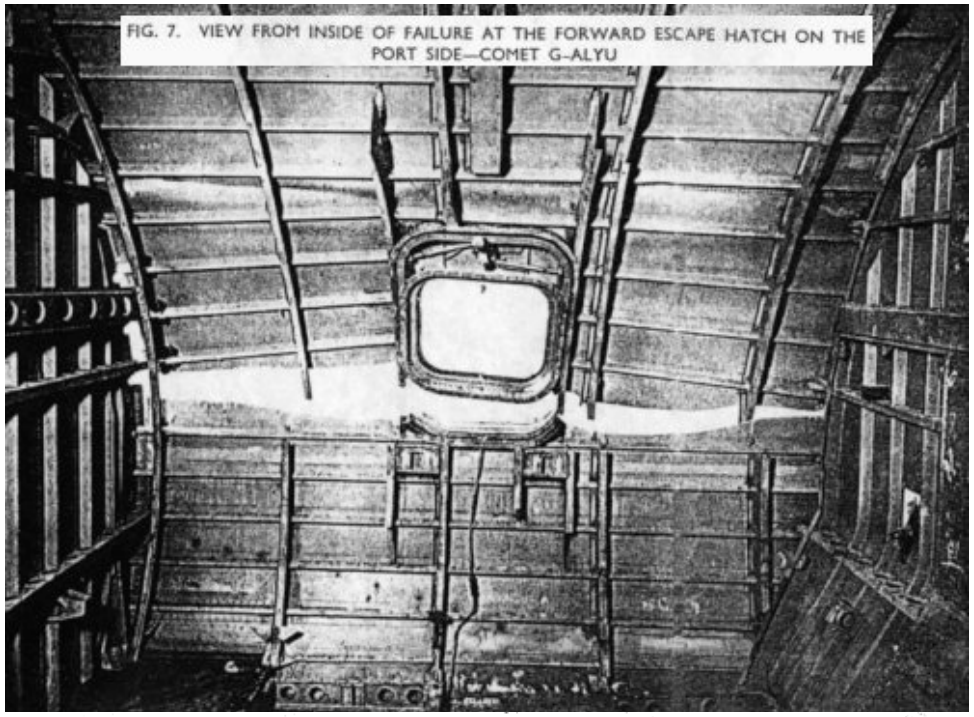
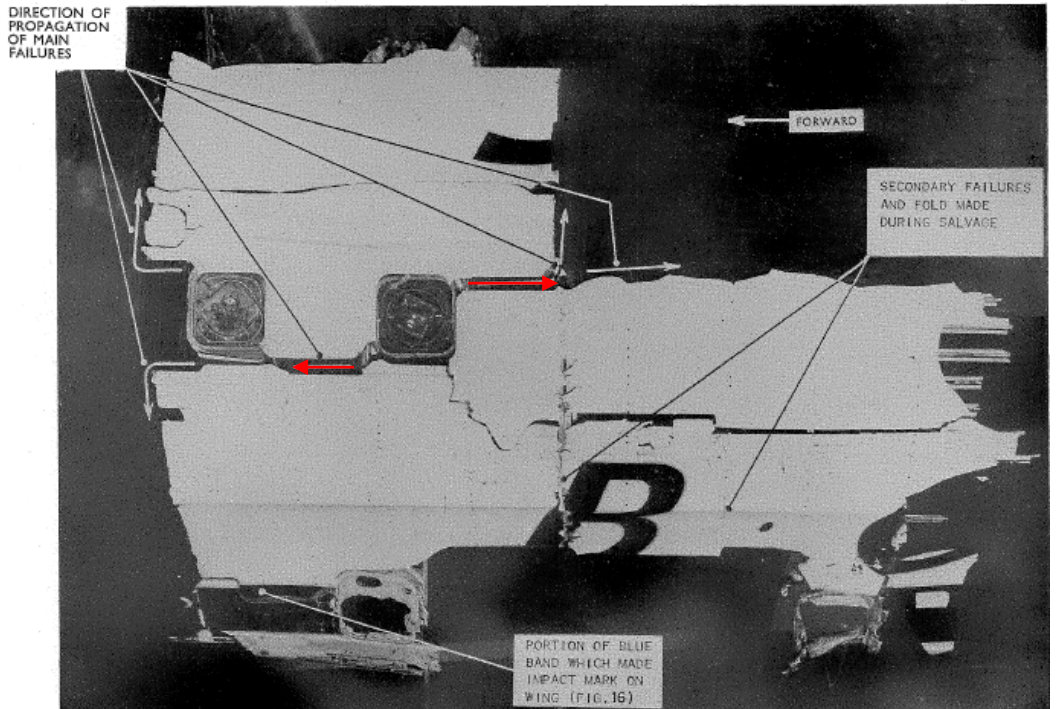
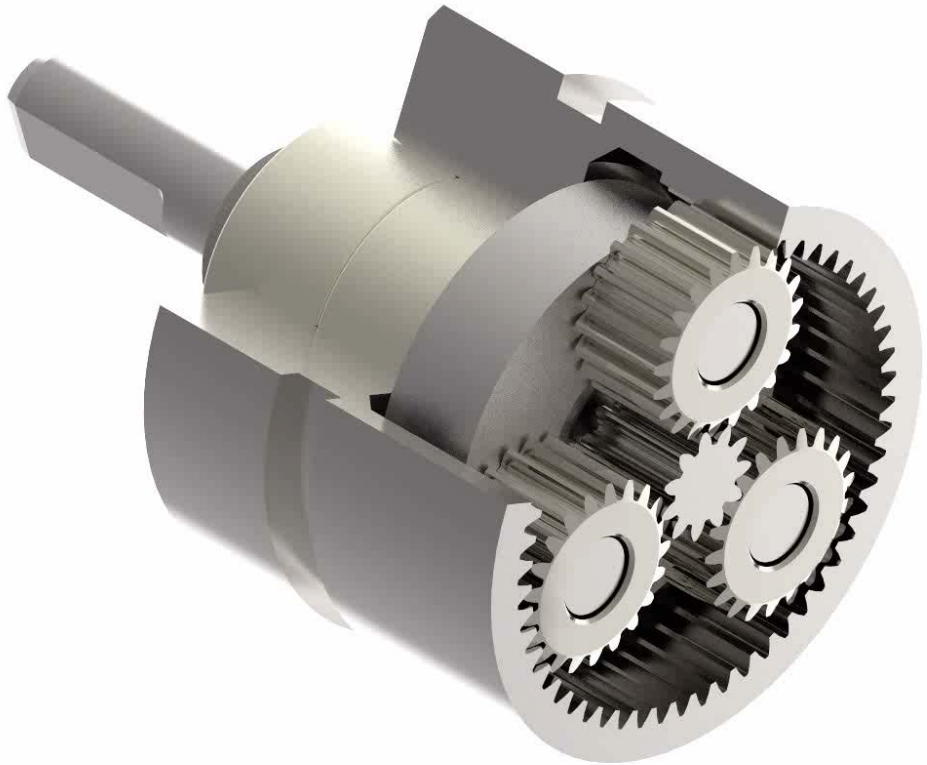
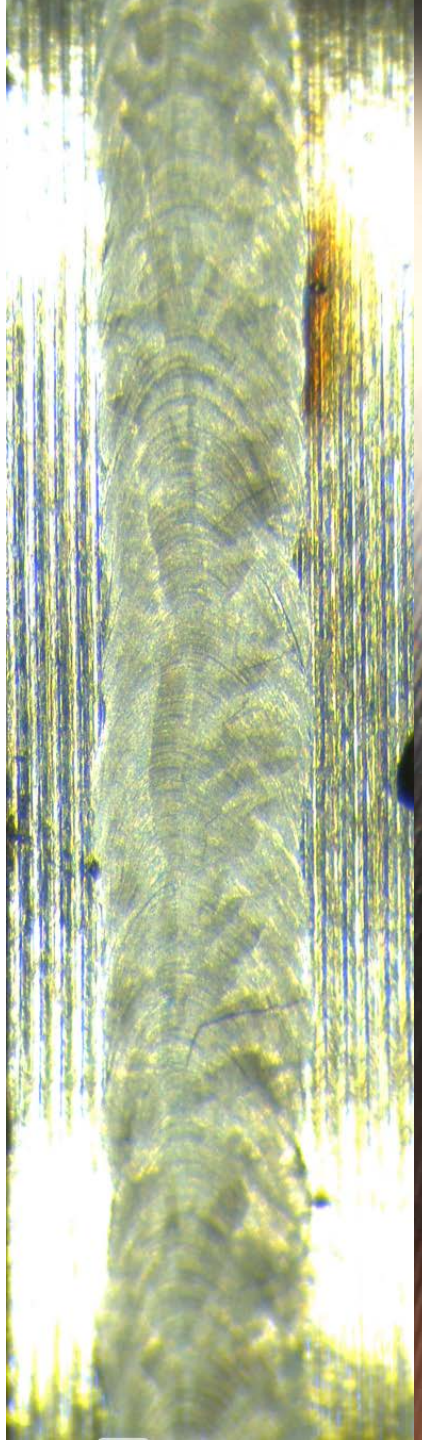


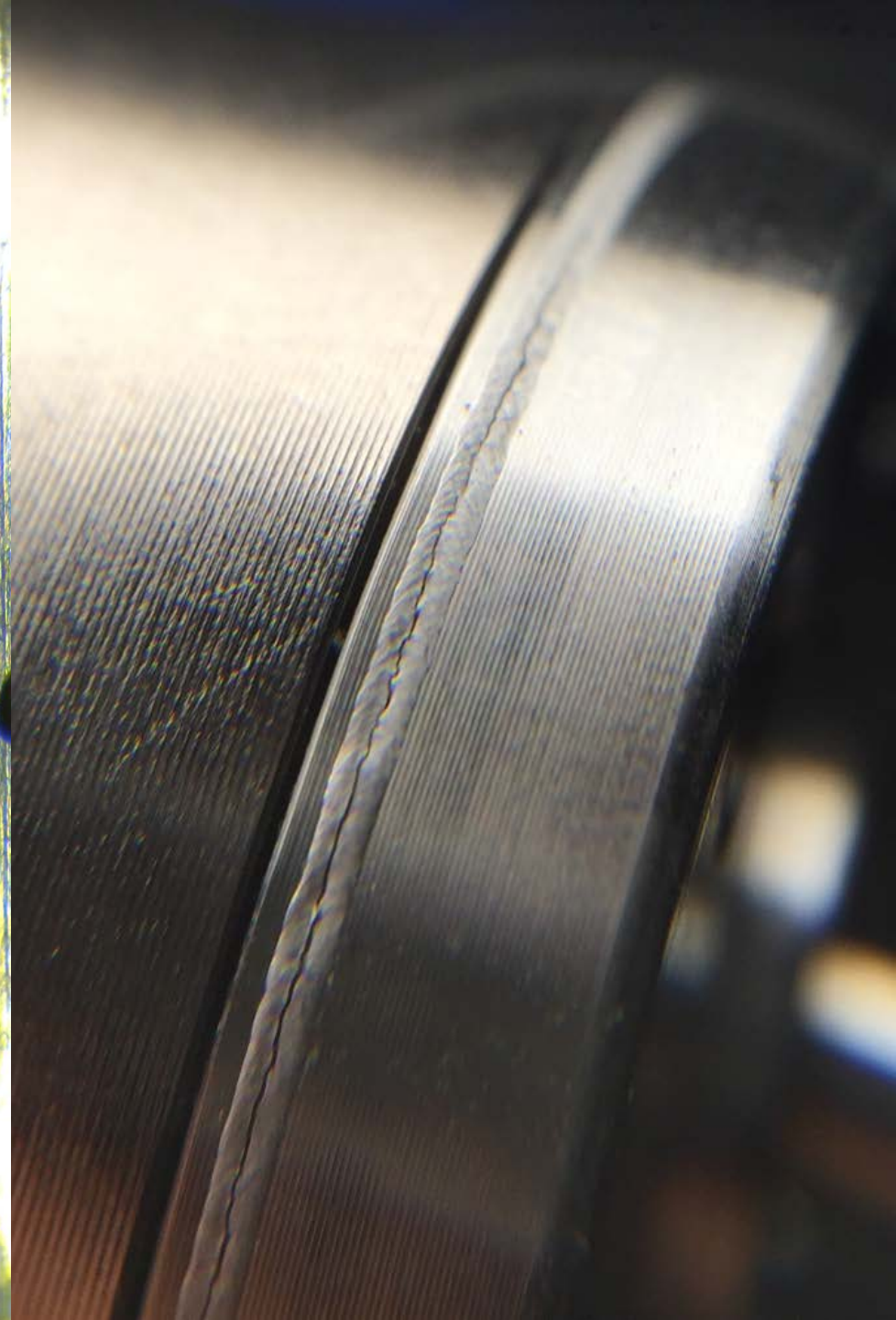




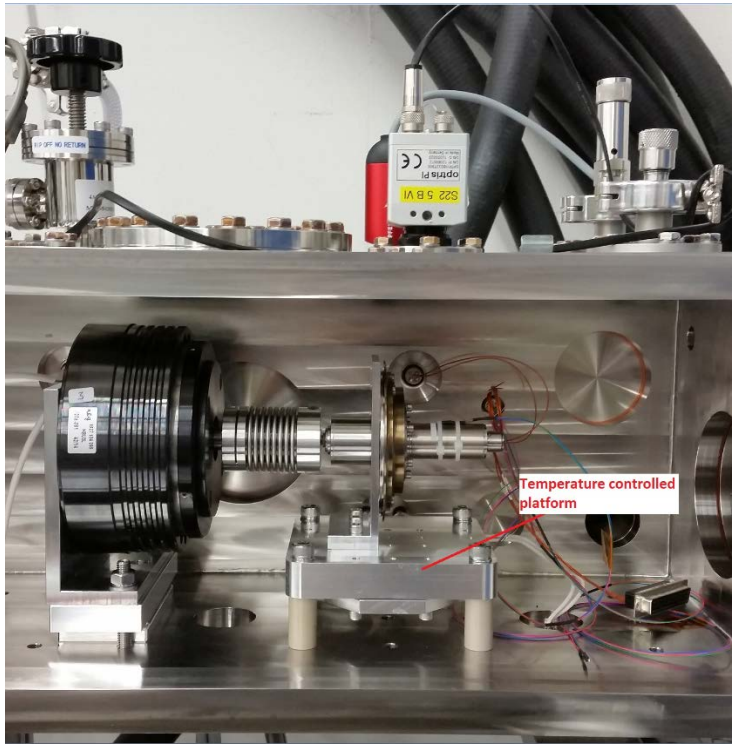
- The classic example of metal fatigue – proof that cracks spread!
- de Havilland Comet -> first passenger jet airliner
- Grounded after 3 crashes in one year



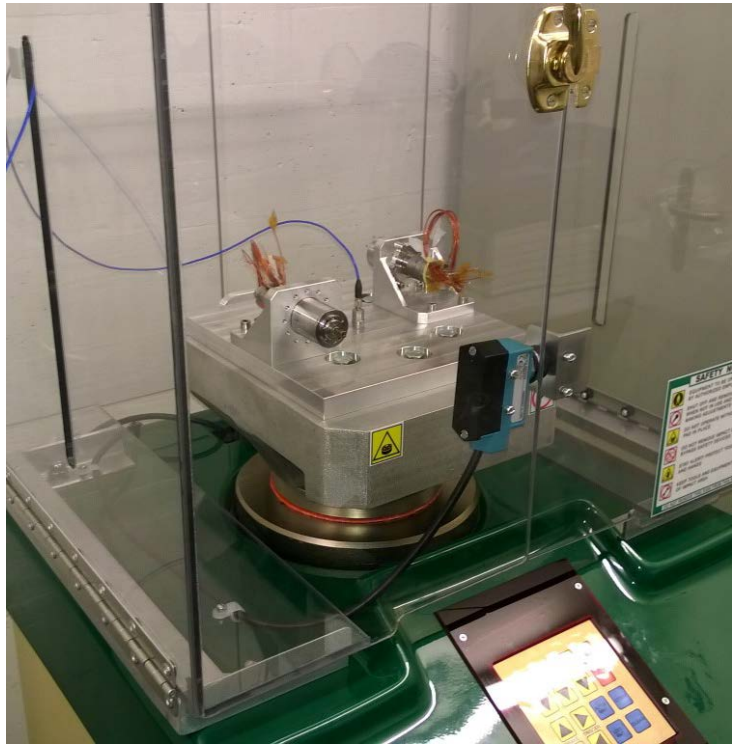




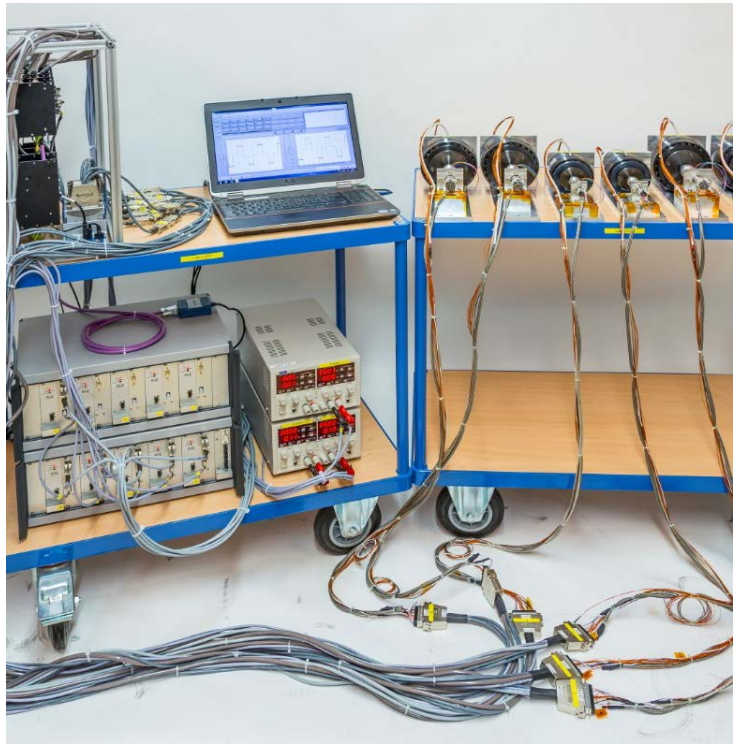
Environmental simulations to prove the design will survive the launch, travel to Mars, landing and operation.



Thermal Vacuum:
down to 10^{-9}mbar and -150°C



Shock and vibration:
up to 4,000 g



Life testing with programmable duty cycles

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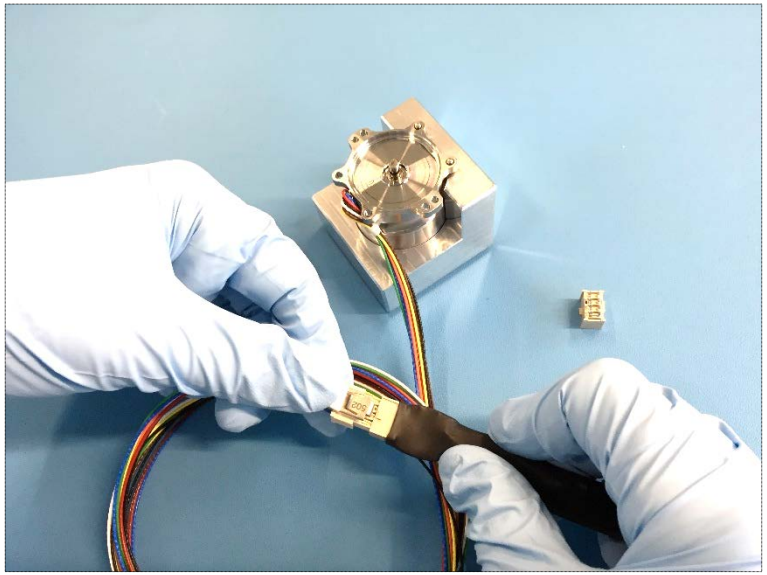
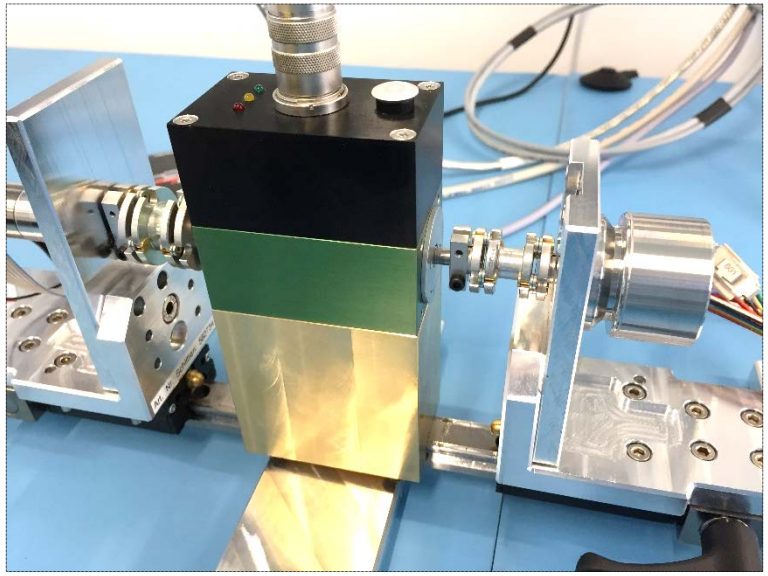
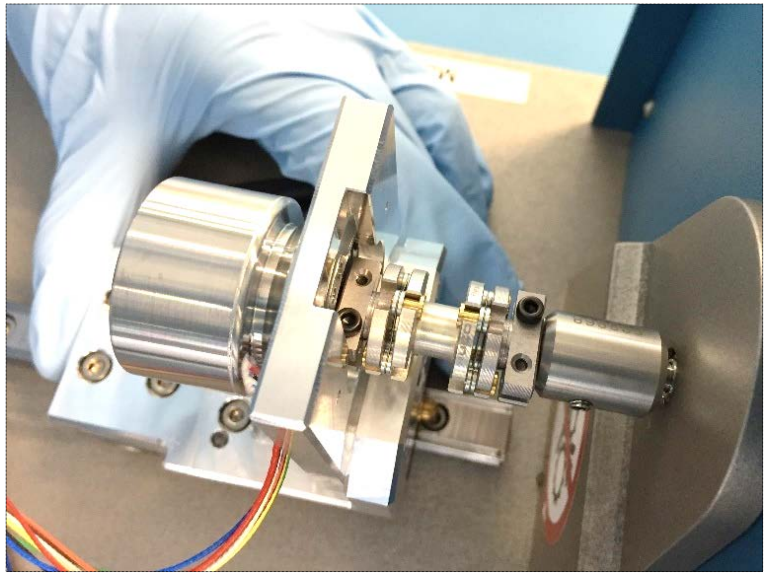
Testing – 100% acceptance testing on all units



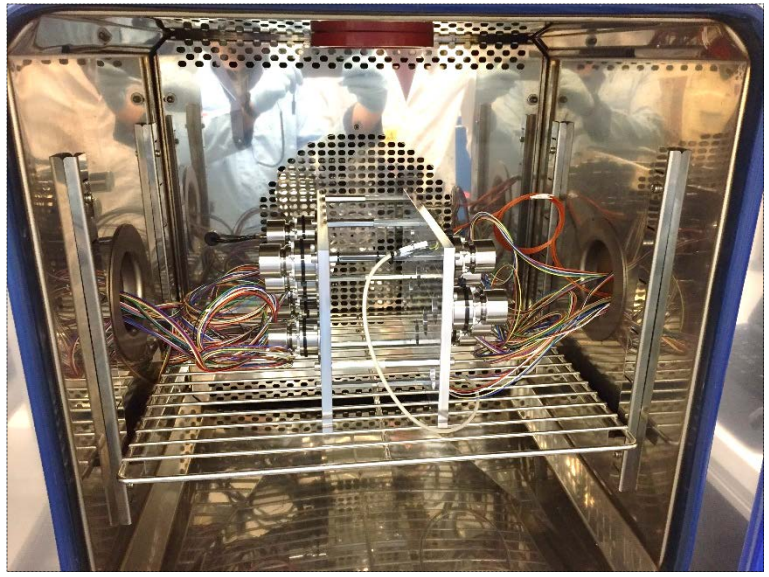
No-load and hall effect sensor test



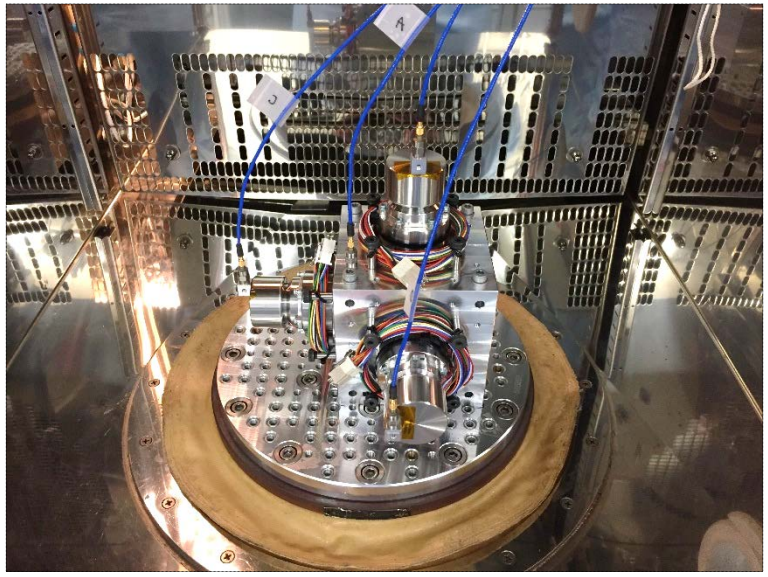
Cogging torque and torque generation characterization



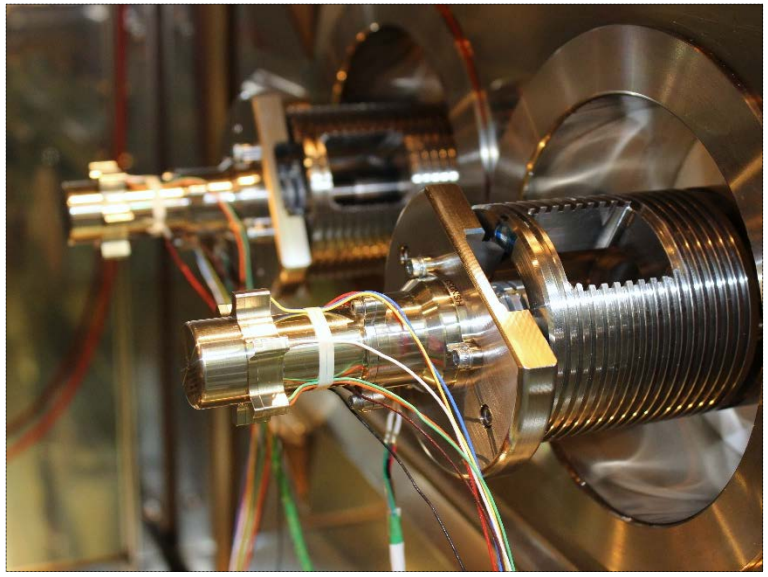
Load testing



No-load at various temperatures and start-up behavior at low temperatures

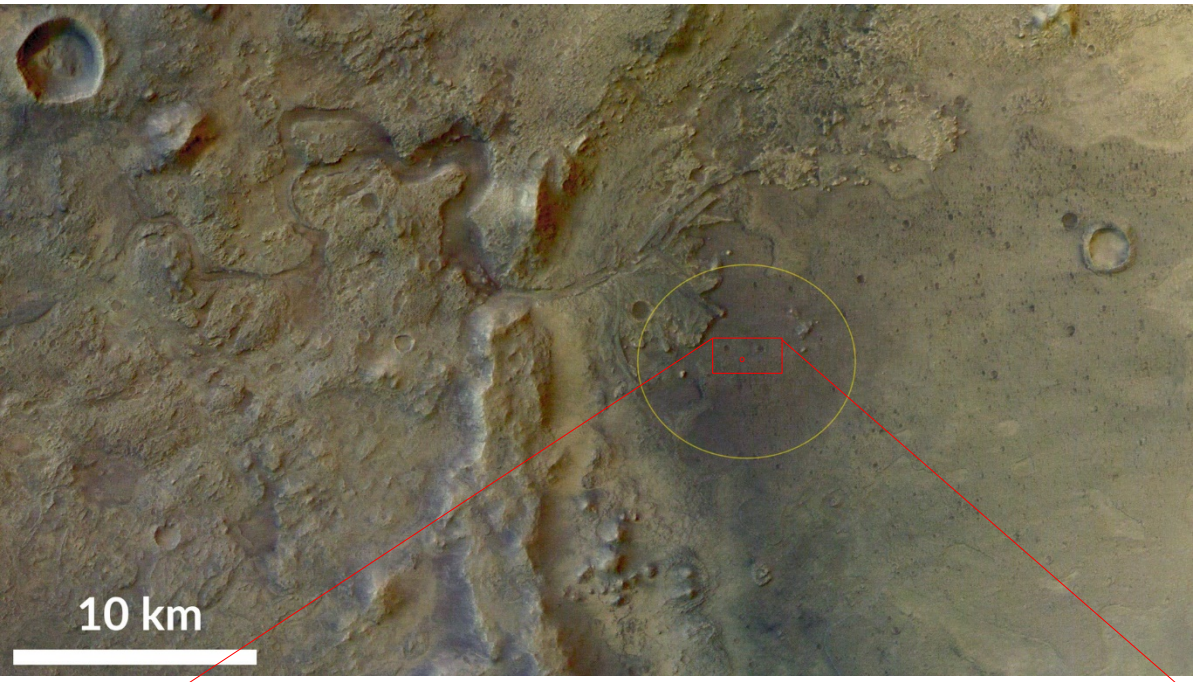


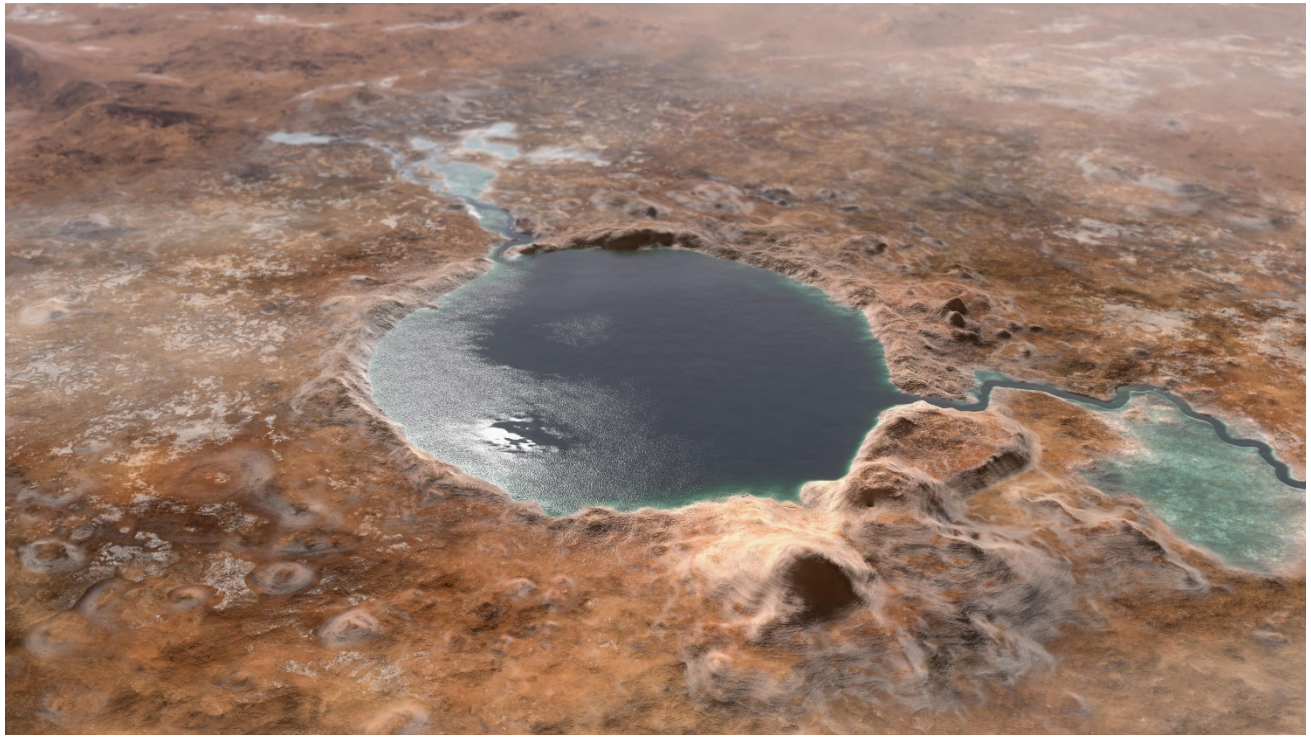
Random vibration

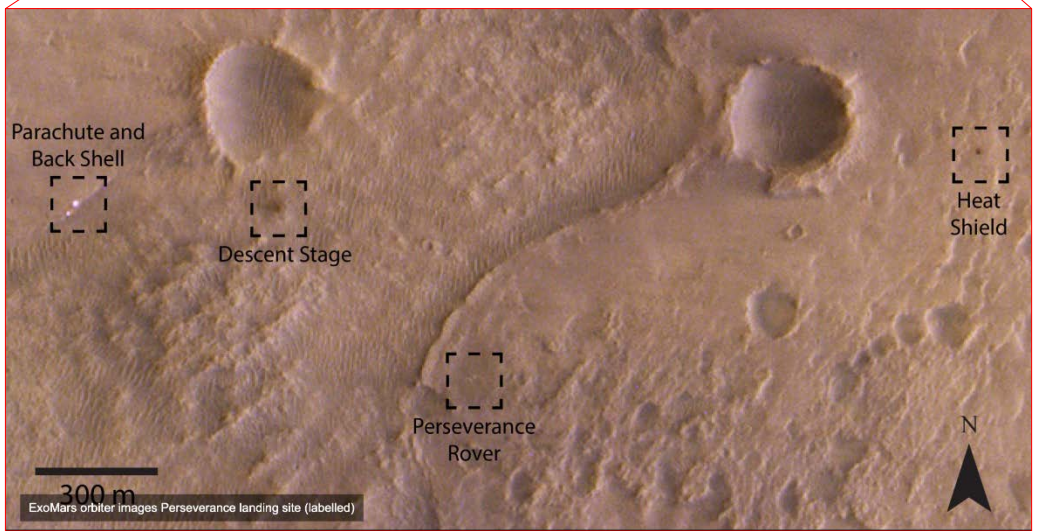


No-load, start-up sensitivity and load testing at various temperatures

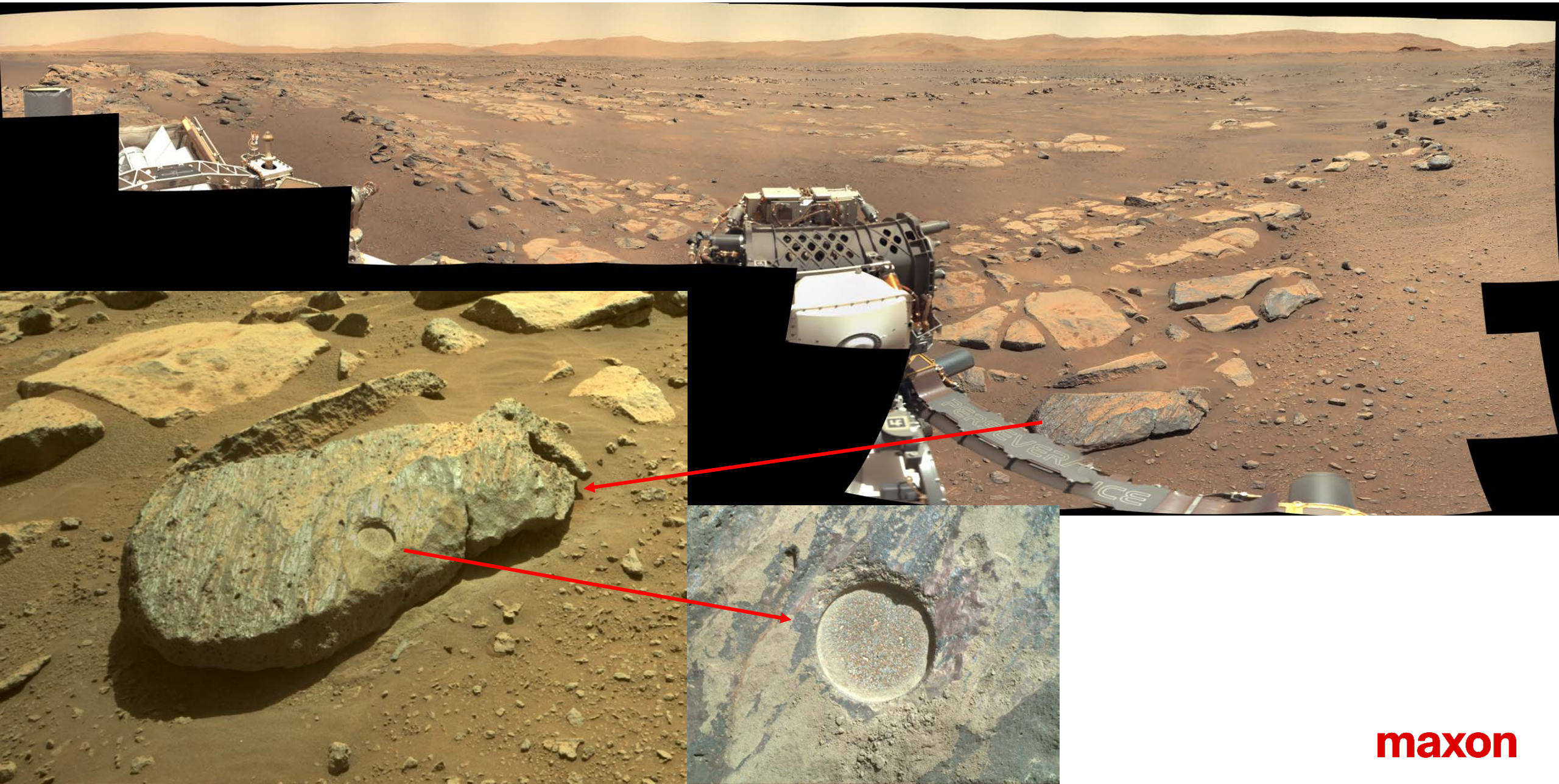
Jezero Crater







First Successful Sample



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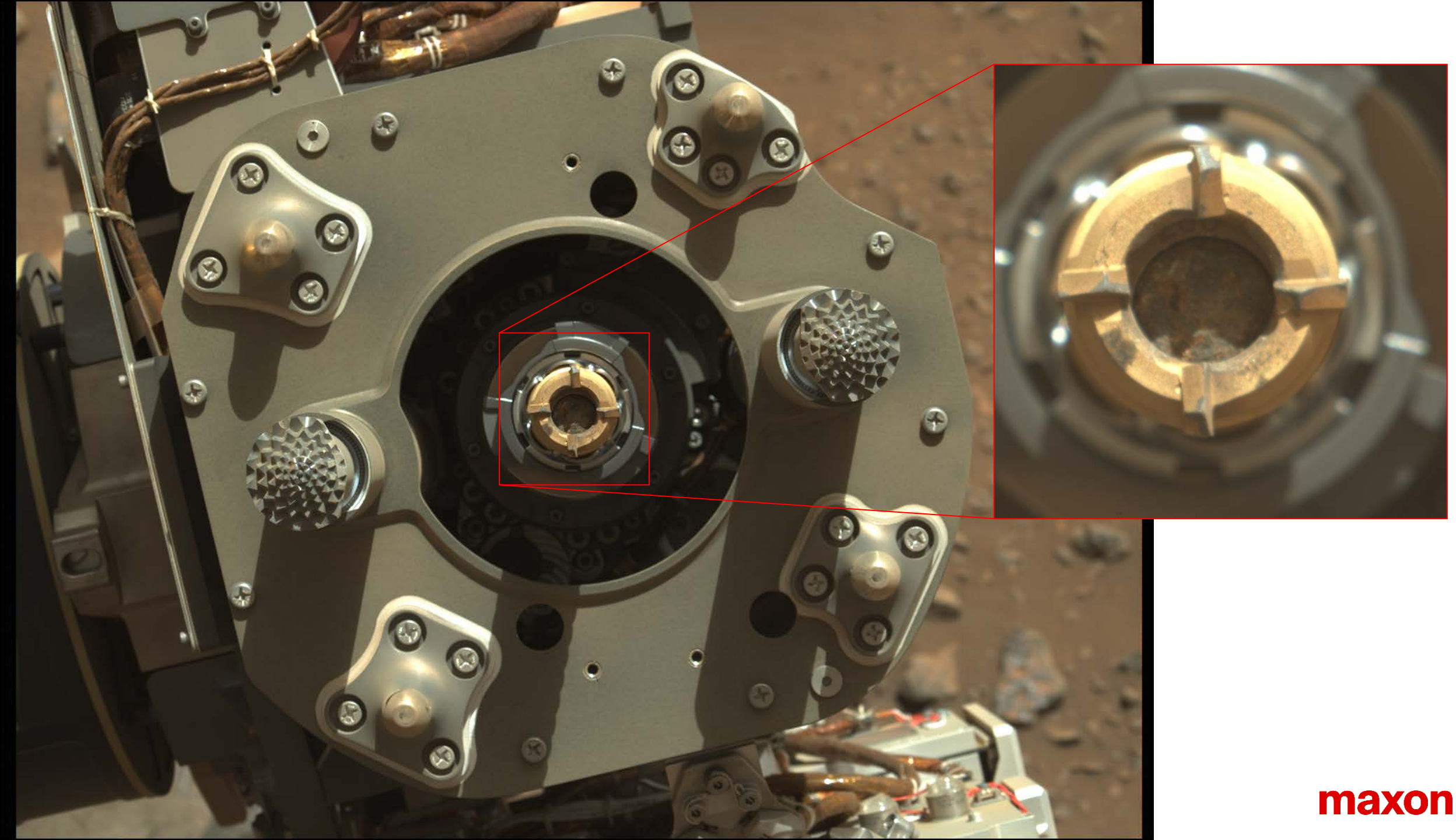

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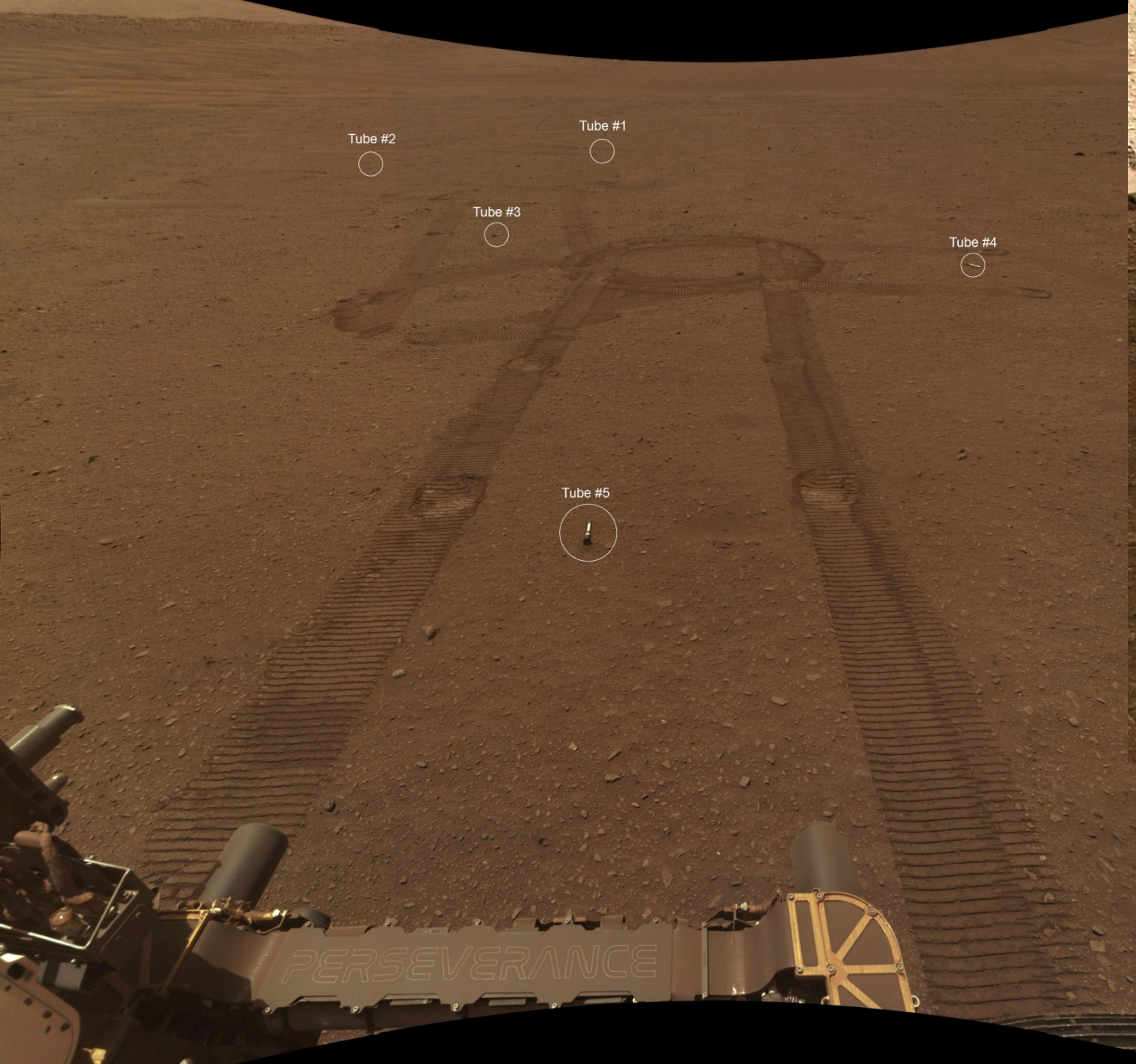

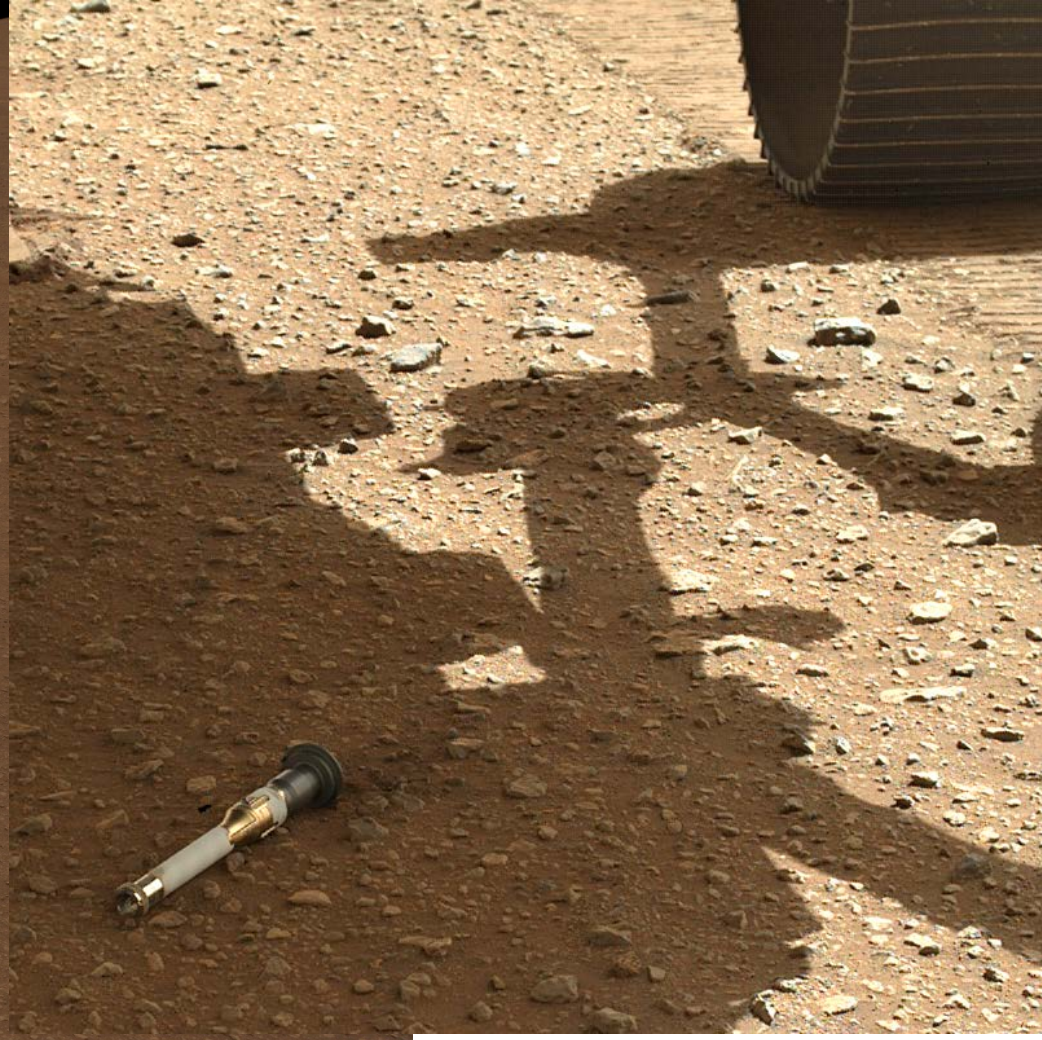

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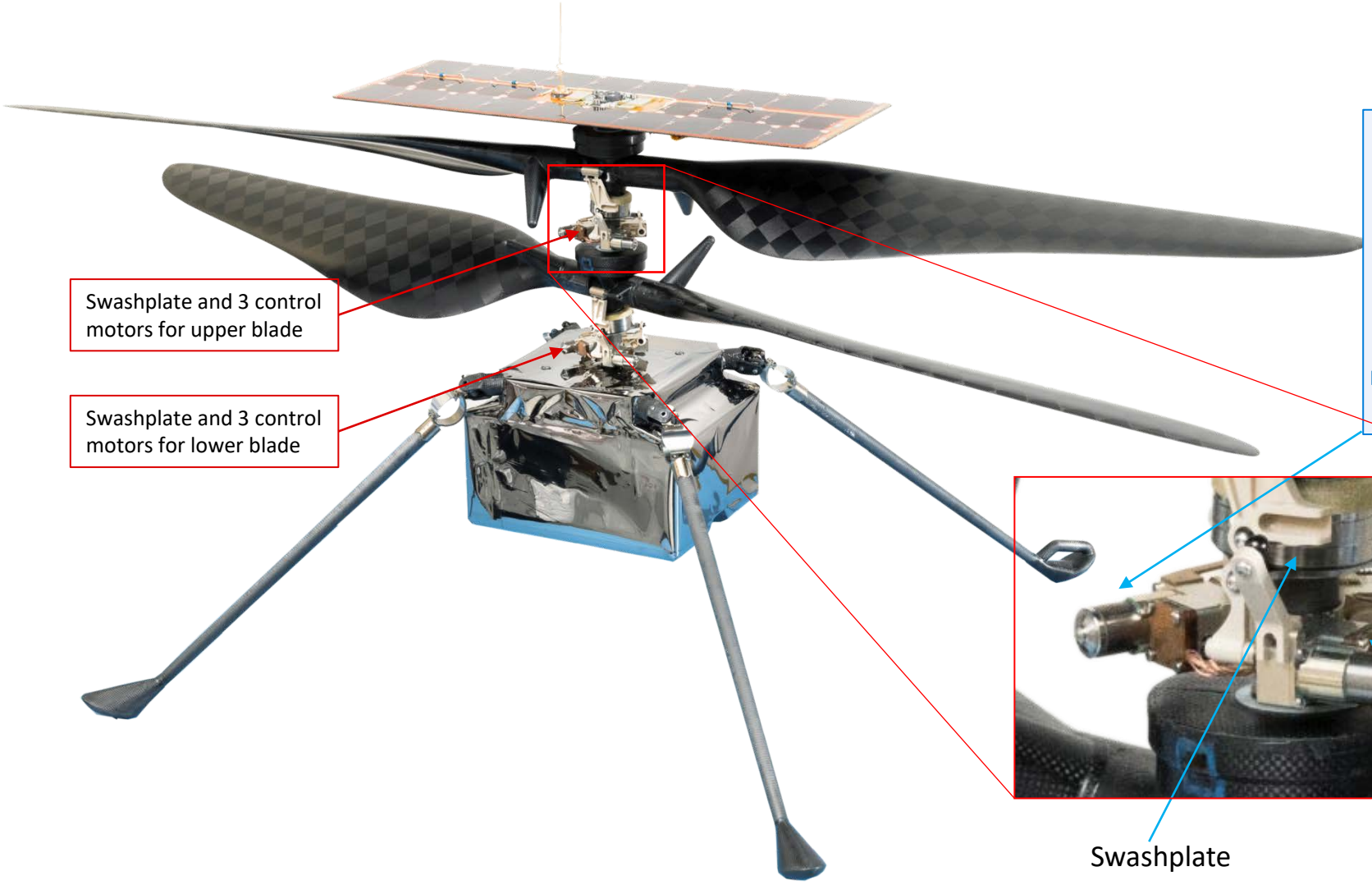
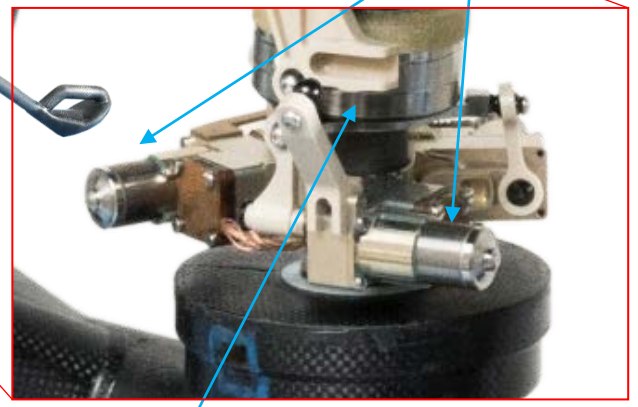
Mars helicopter “Ingenuity”

Six Brushed DC motors (DCX10 S) as swashplate actuators

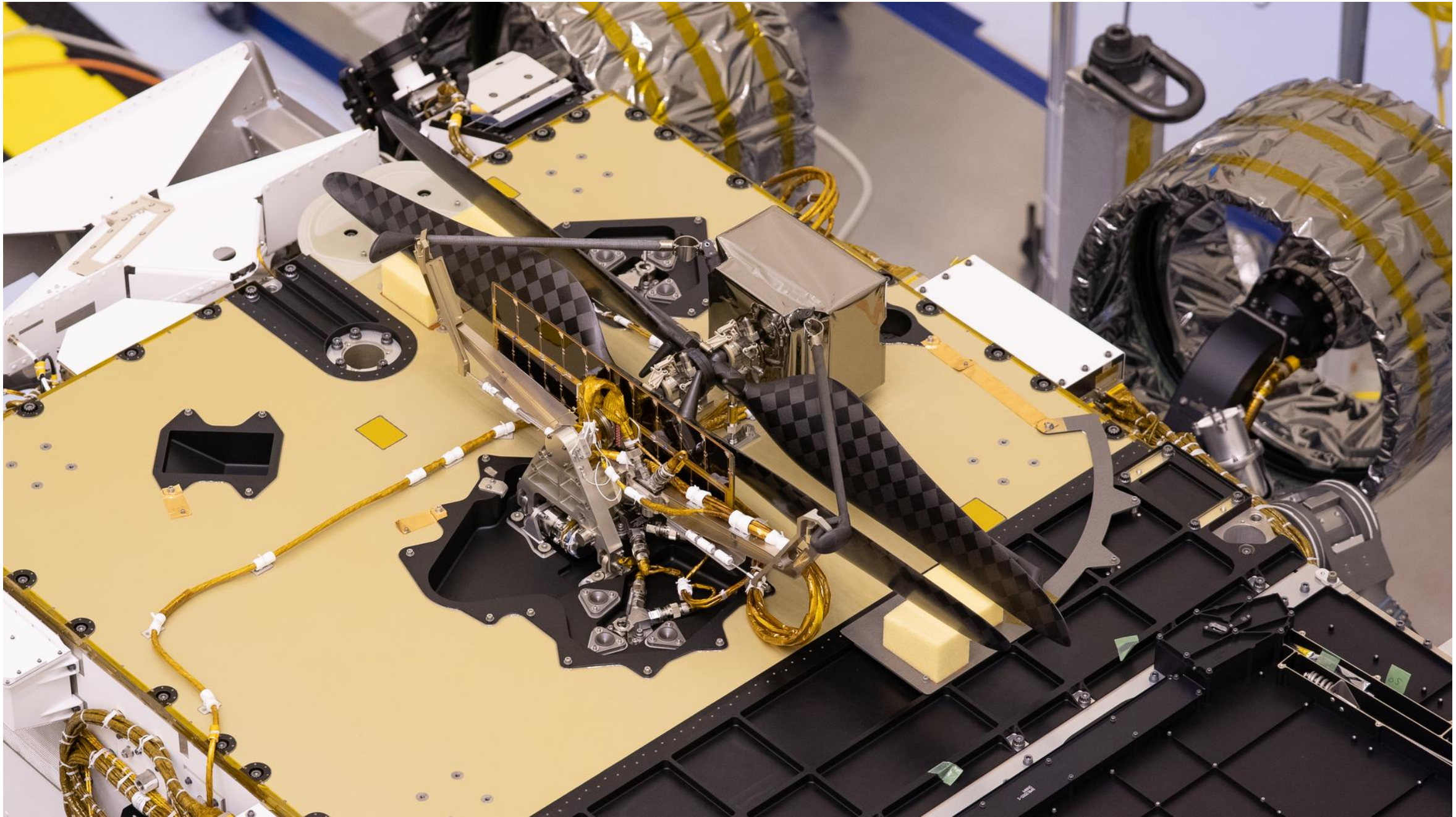




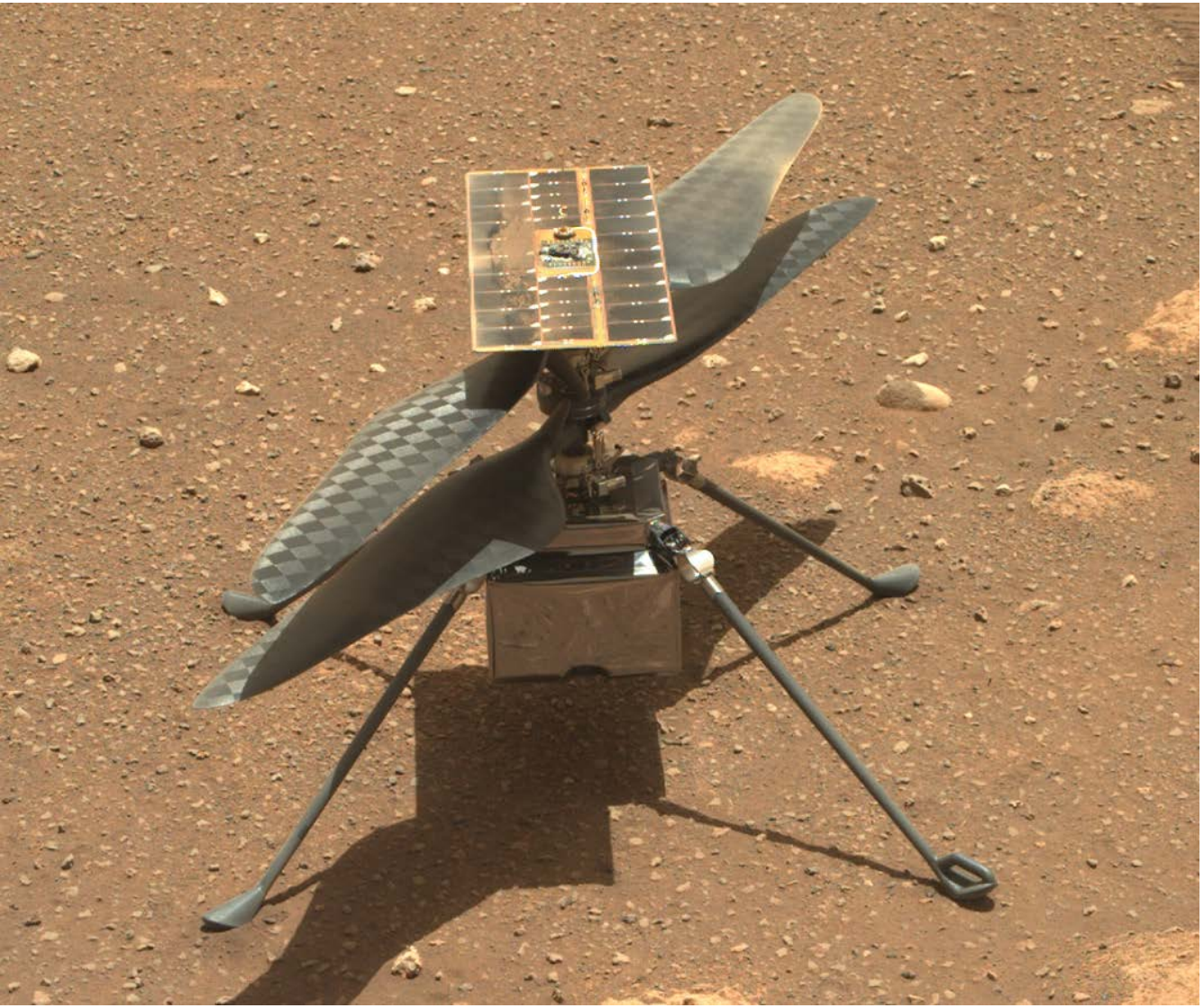
Swashplate

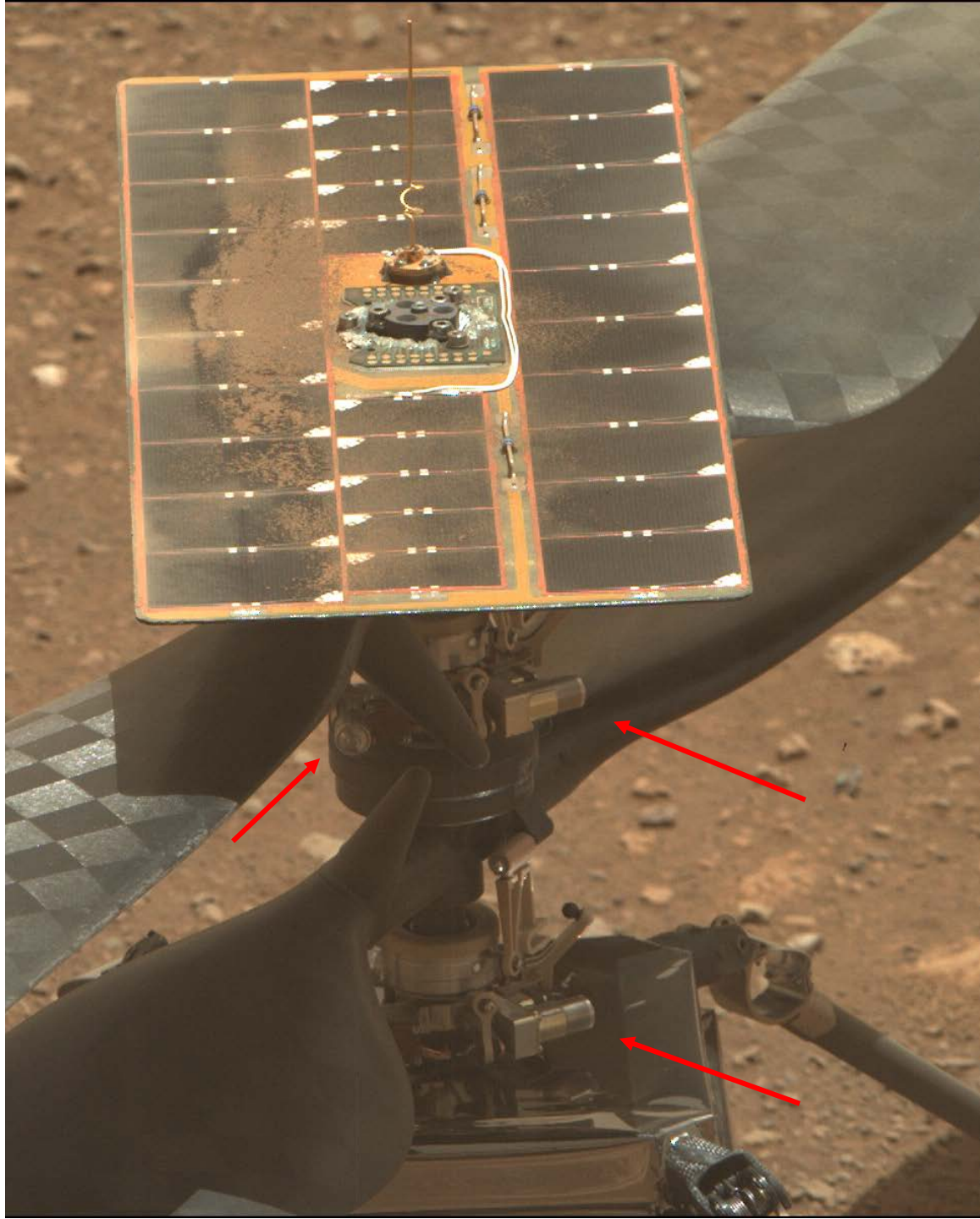
This is a mechanism found on all helicopters and is used to adjust the pitch (angle) of the rotor blades and thereby controls the movement of the vehicle.

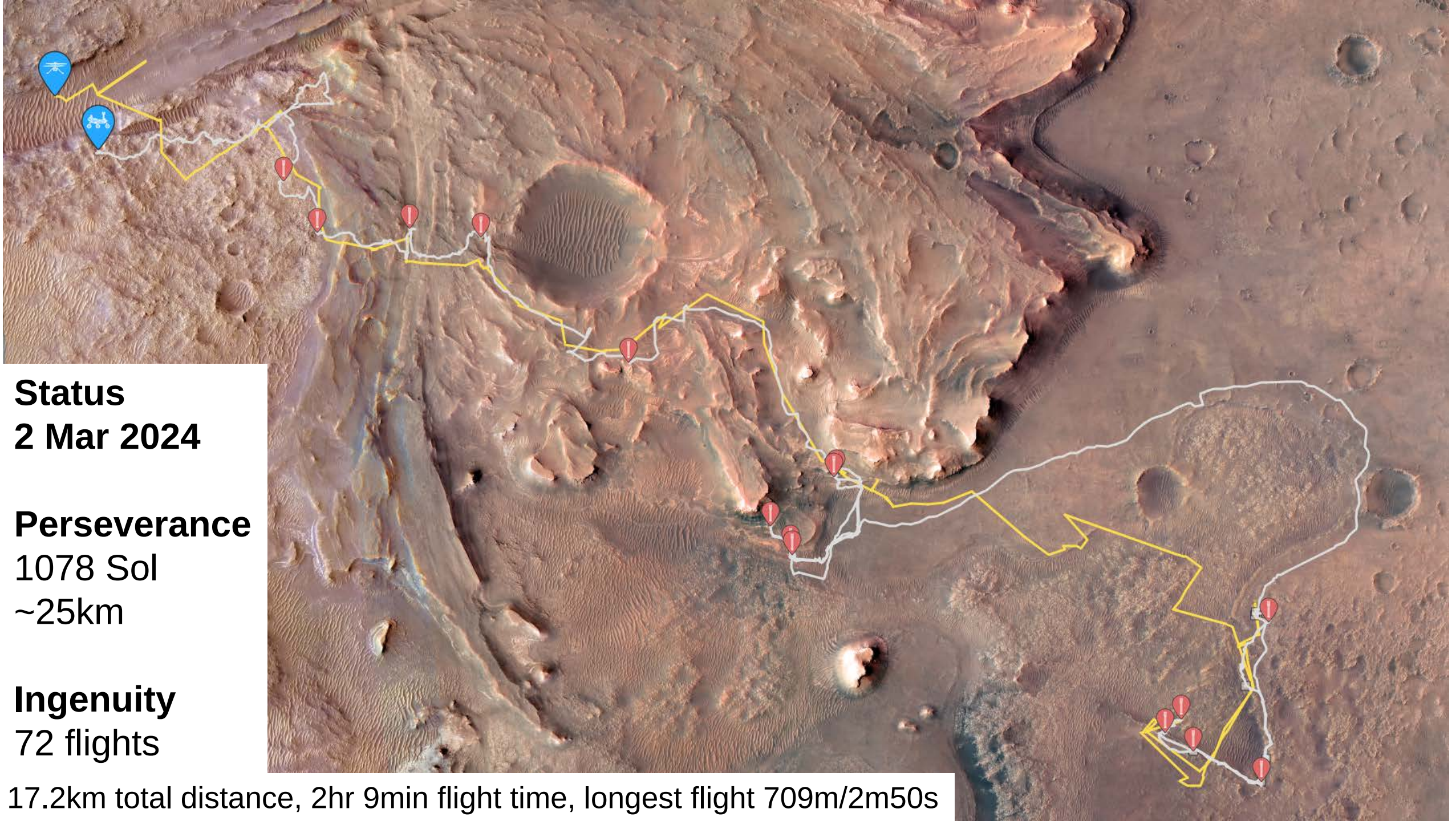
Helicopter Delivery System



Motors on Mars!







Status
2 Mar 2024

Perseverance
1078 Sol
~25km

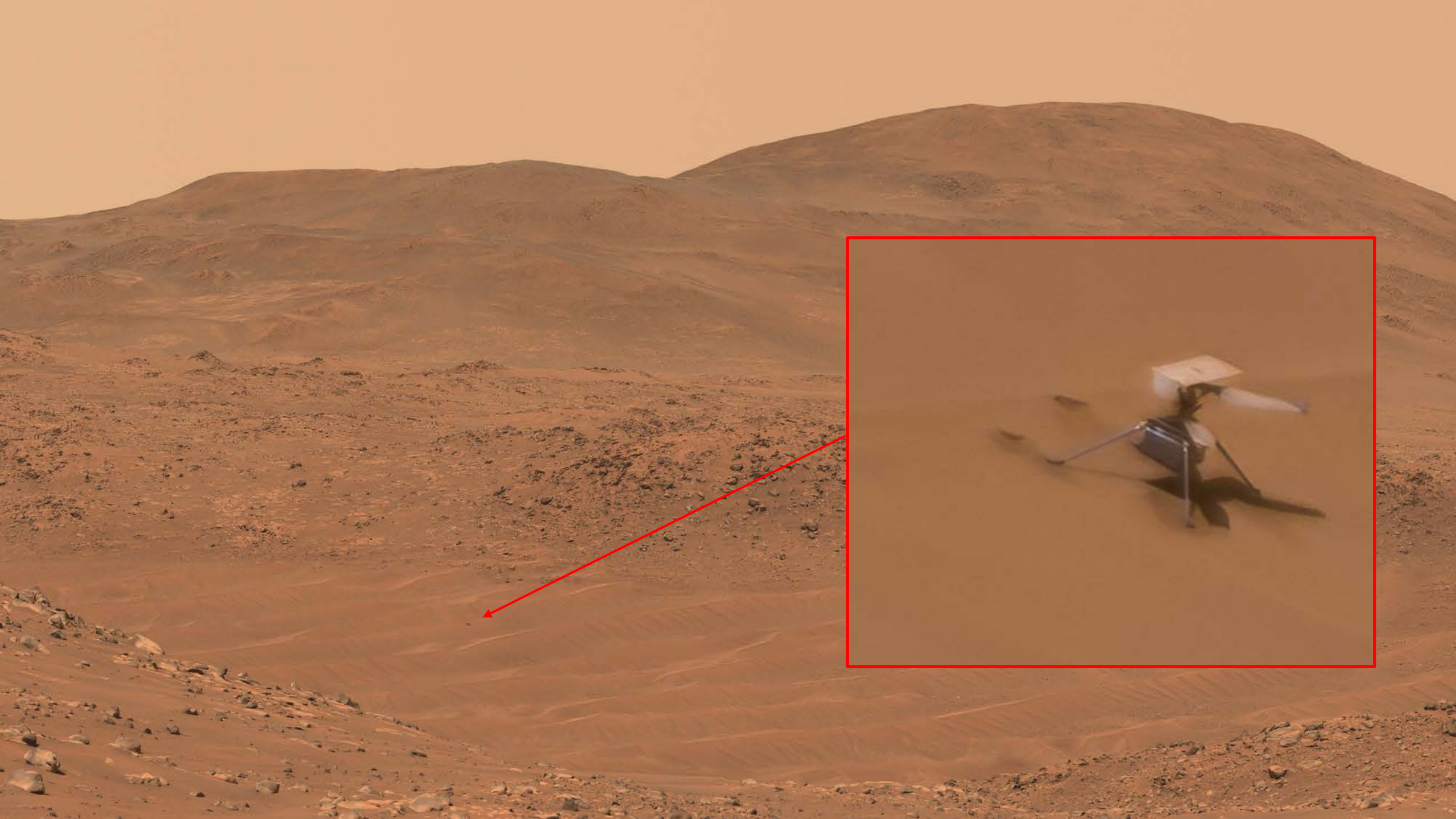
Ingenuity
72 flights

17.2km total distance, 2hr 9min flight time, longest flight 709m/2m50s

Spectacular aerial views

Helicopter is now sent on "scouting" flights to assess route for rover or decide on science targets

maxon




Earth
moon