Mars Helicopter Technology Demonstration on Mars 2020 Rover

Matt Golombek

J. Balaram, J. Maki, N. Williams, H. Grip, and M. Aung

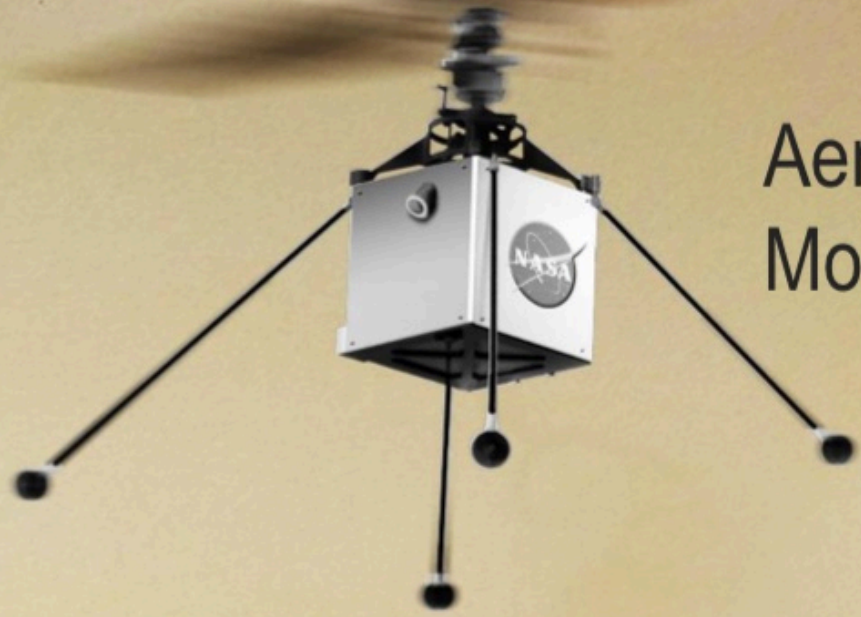
Jet Propulsion Laboratory, California Institute of Technology

Jet Propulsion Laboratory
California Institute of Technology

Aerial Mobility

Spacecraft
in Orbit

Rovers on
Surface



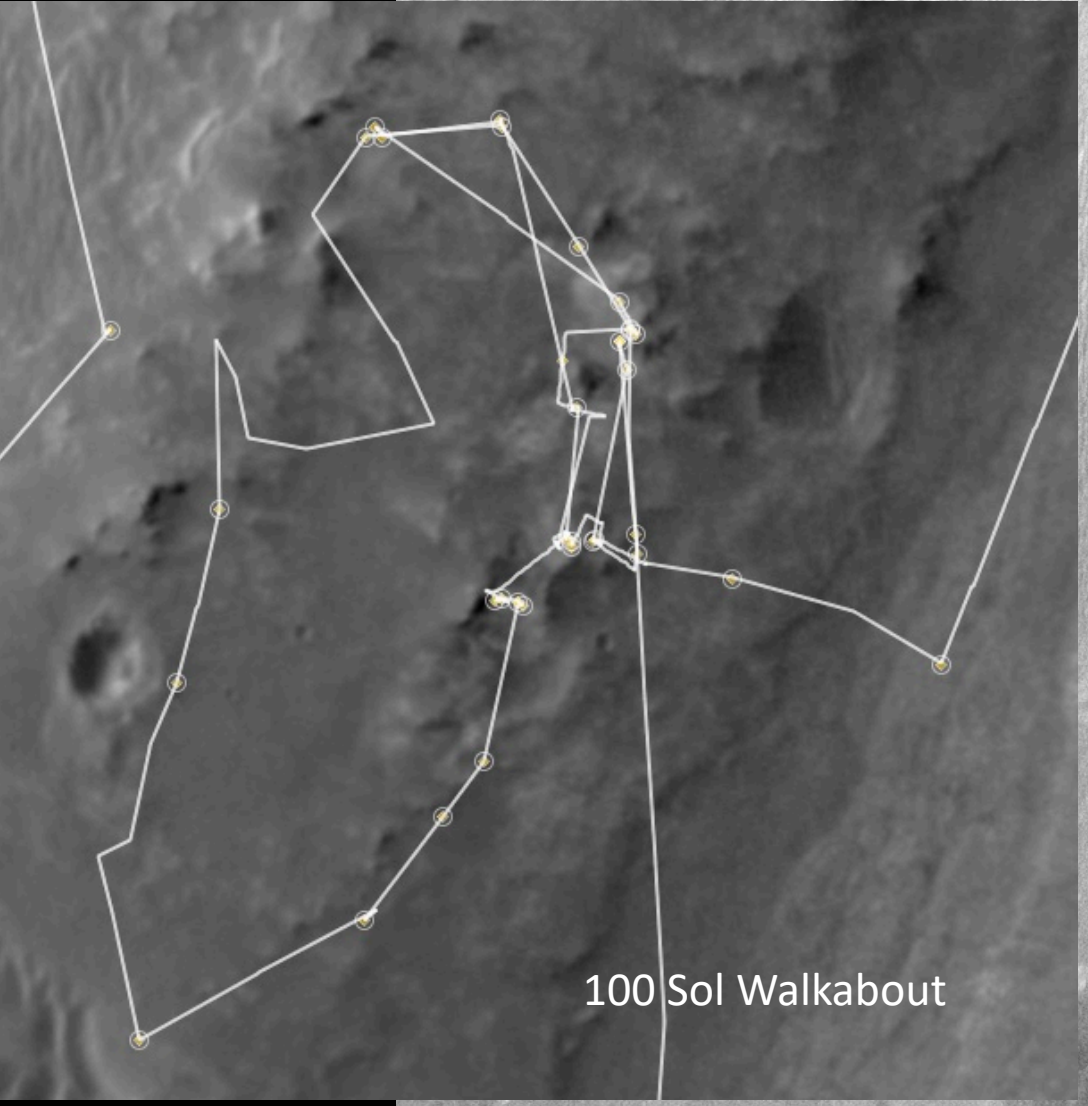
Aerial
Mobility

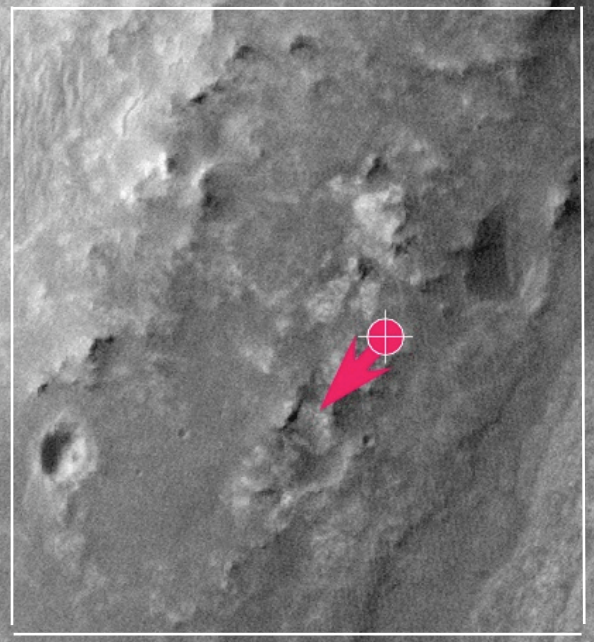
Mars Helicopter Potential Benefit to Rover Mission

- Scouting for Rover Regional Geology
  - Increase Number and Diversity of Geologic Units
- Identify Best Locations for Rover to Sample
  - Identify Key Outcrops for InSitu Analysis
  - 10x better than orbital images
  - HiRISE orbital images ~30 cm/pixel
  - Rover Experience – want 3 cm/pixel
- Improved Rover Operations
  - Identify Safe and Efficient Traverse Paths for Rover (3x Further Drives)

Cape York

Endeavour Crater Rim

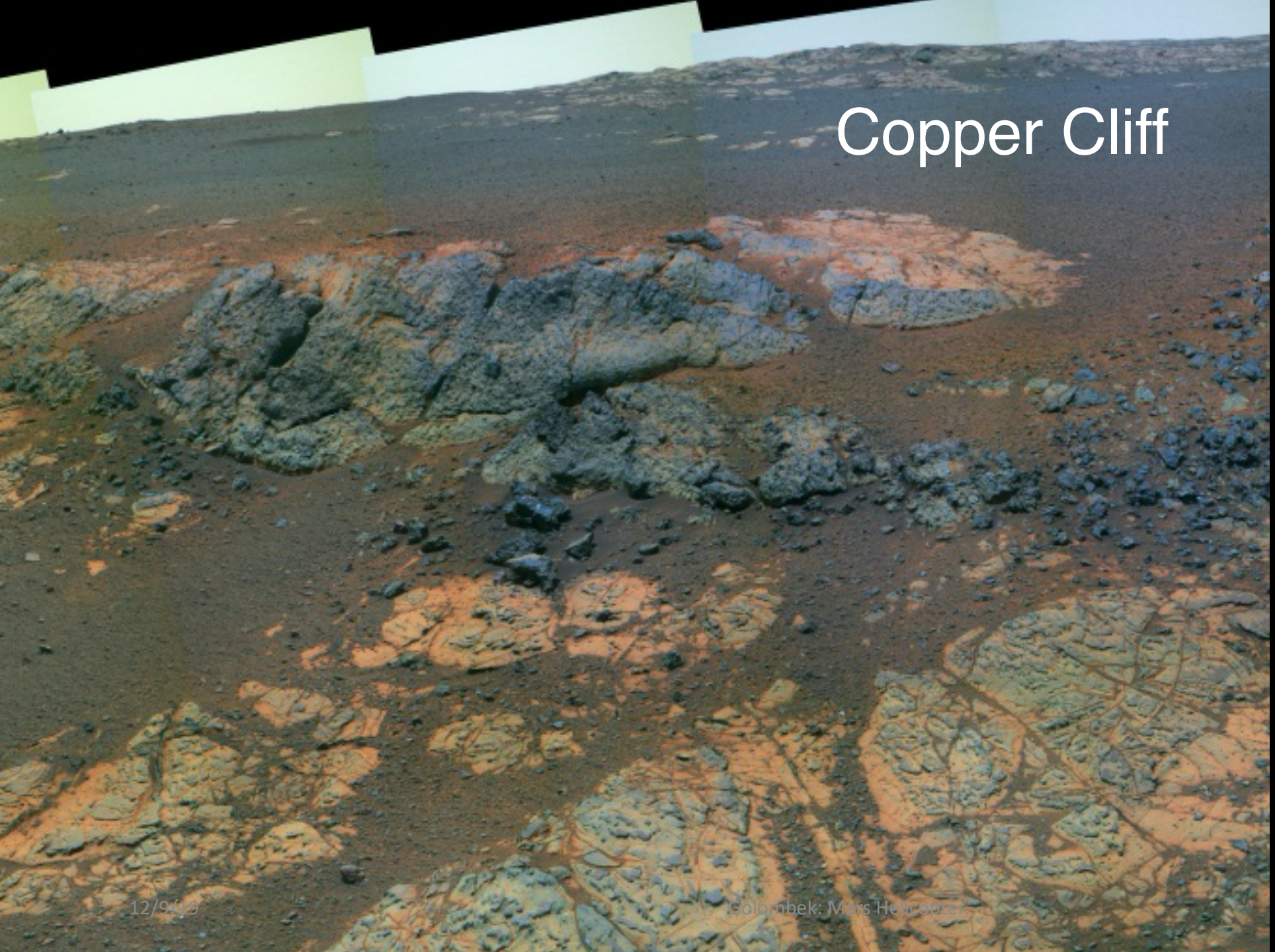




50 m

Opportunity Rover Drove 27 km in 4.5 years

30 cm/pixel HiRISE



Shoemaker Formation - Impact Ejecta

Matijevic Formation - Pre-impact

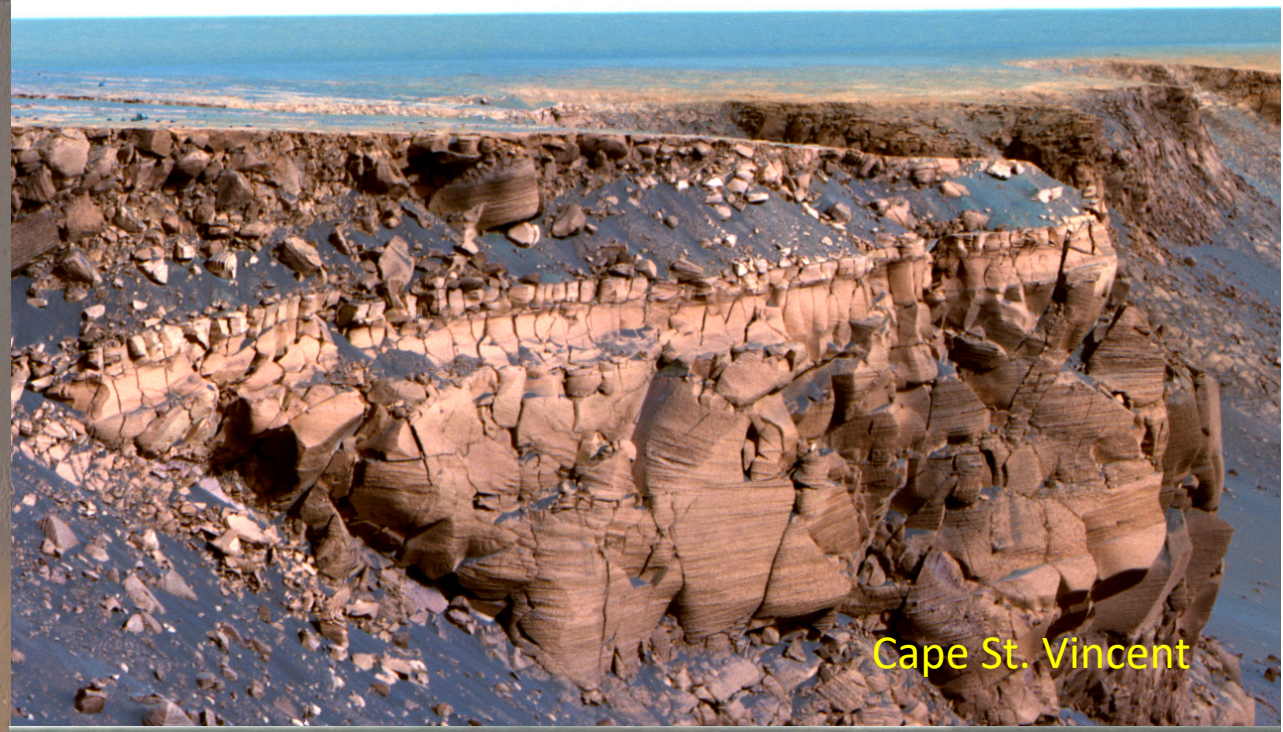
Victoria Crater

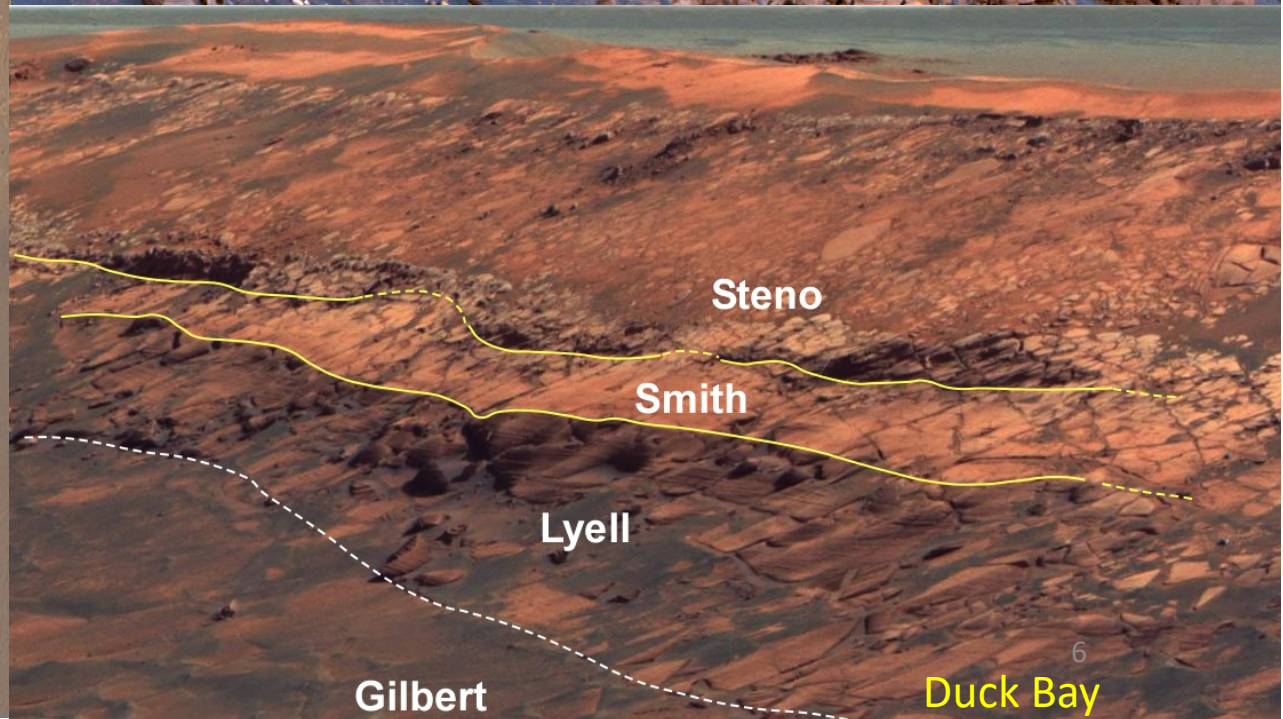
340 Sols Scouting NW Rim

Imaging to Find Ingress Point

Mapping Stratigraphy

Opportunity Rover Drove 6 km in 1.8 years

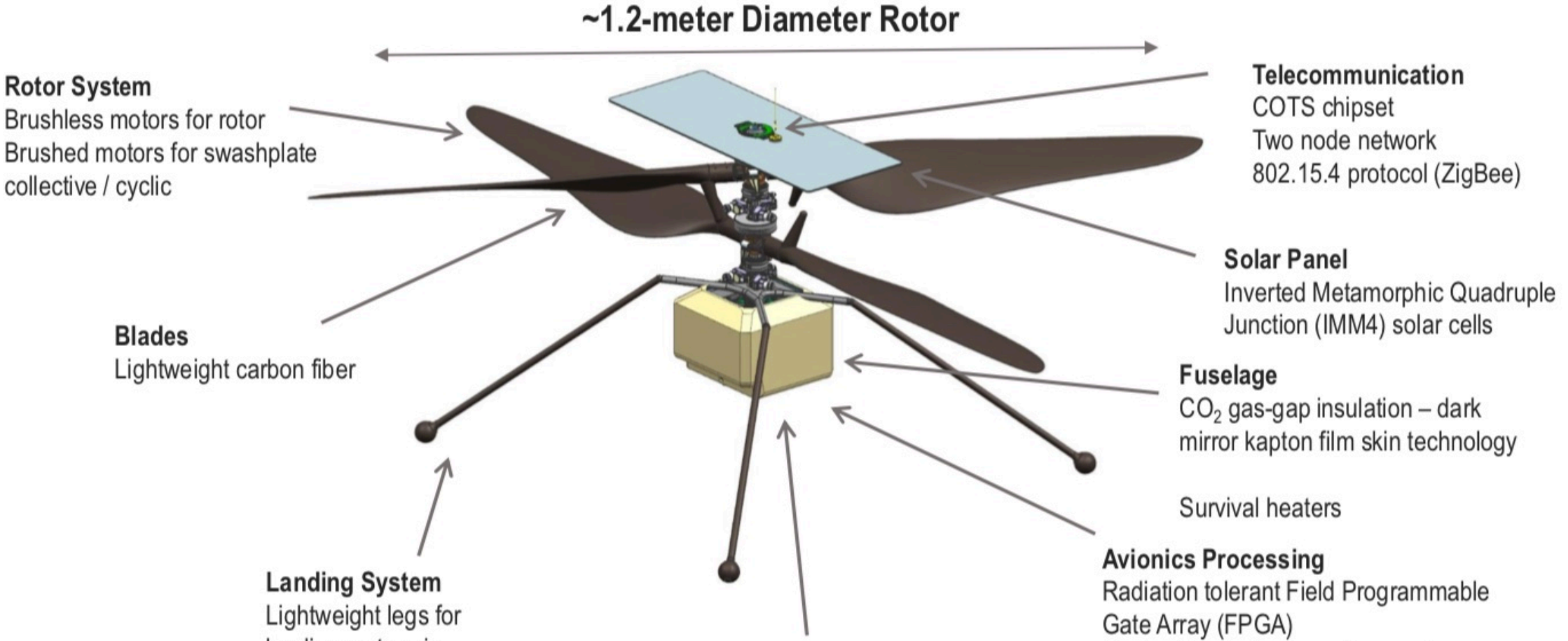




Overview

- Nominal flights
  - 1-3 minute duration
  - 600 meter range
  - ~5 meter above ground
  - Up to one flight every 3 sols
- High-resolution color images of terrain
  - Nadir Navigation Camera B&W 0.3 Mpixel
  - Color 13 Mpixel Side Looking Camera
- Helicopter
  - Rotor blades: 1.2-meter diameter
  - Chassis: 14 cm Cube
  - Mass ~1.8 kg
  - Power: ~220 W
- Telecommunication
  - Transmit data from Helicopter to Rover during flight but primarily while landed

Key Helicopter Features

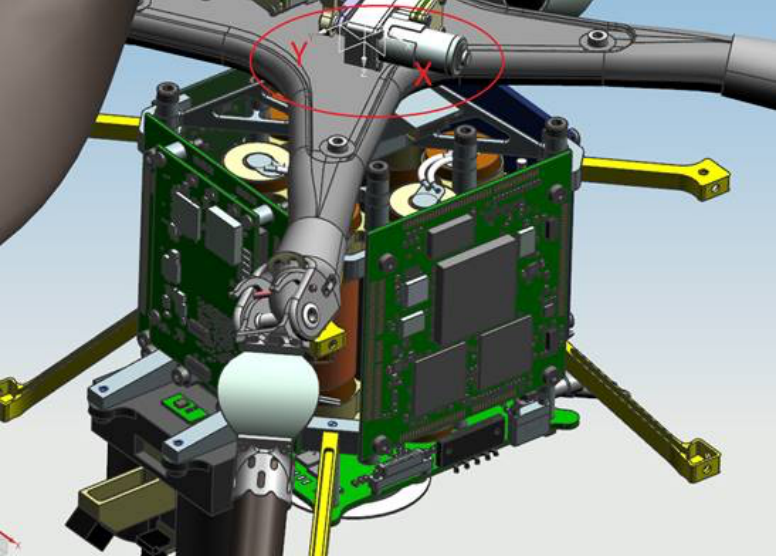


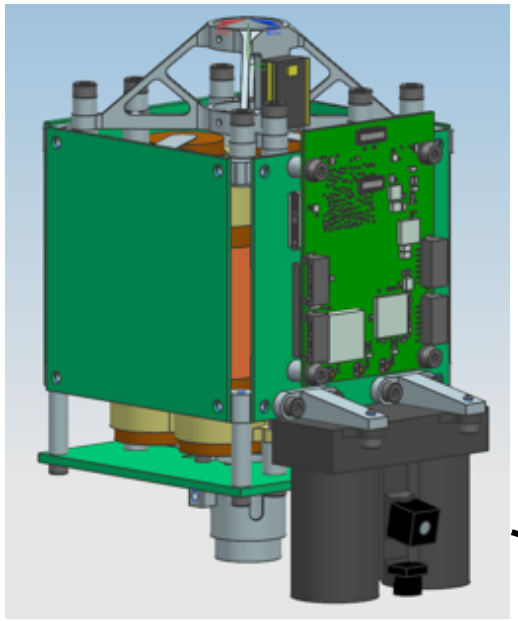
Total Mass < 1.8 Kg

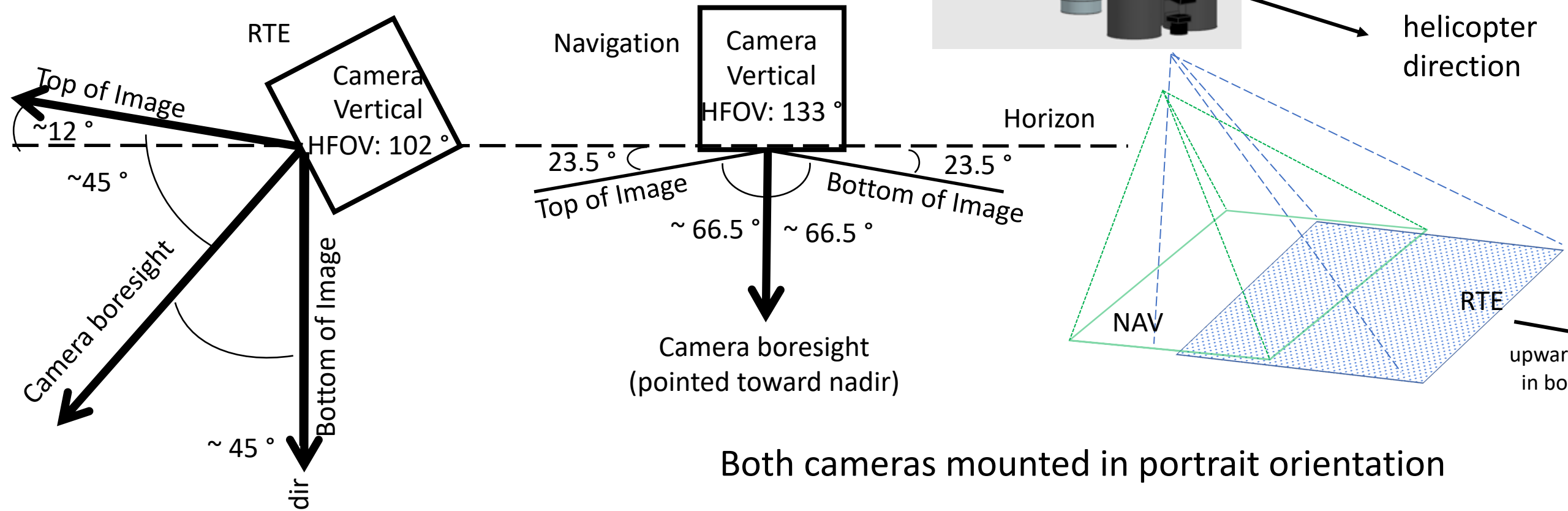
Rotor Speed: 1900-2800 RPM

Blade Tip Mach Number: < 0.7

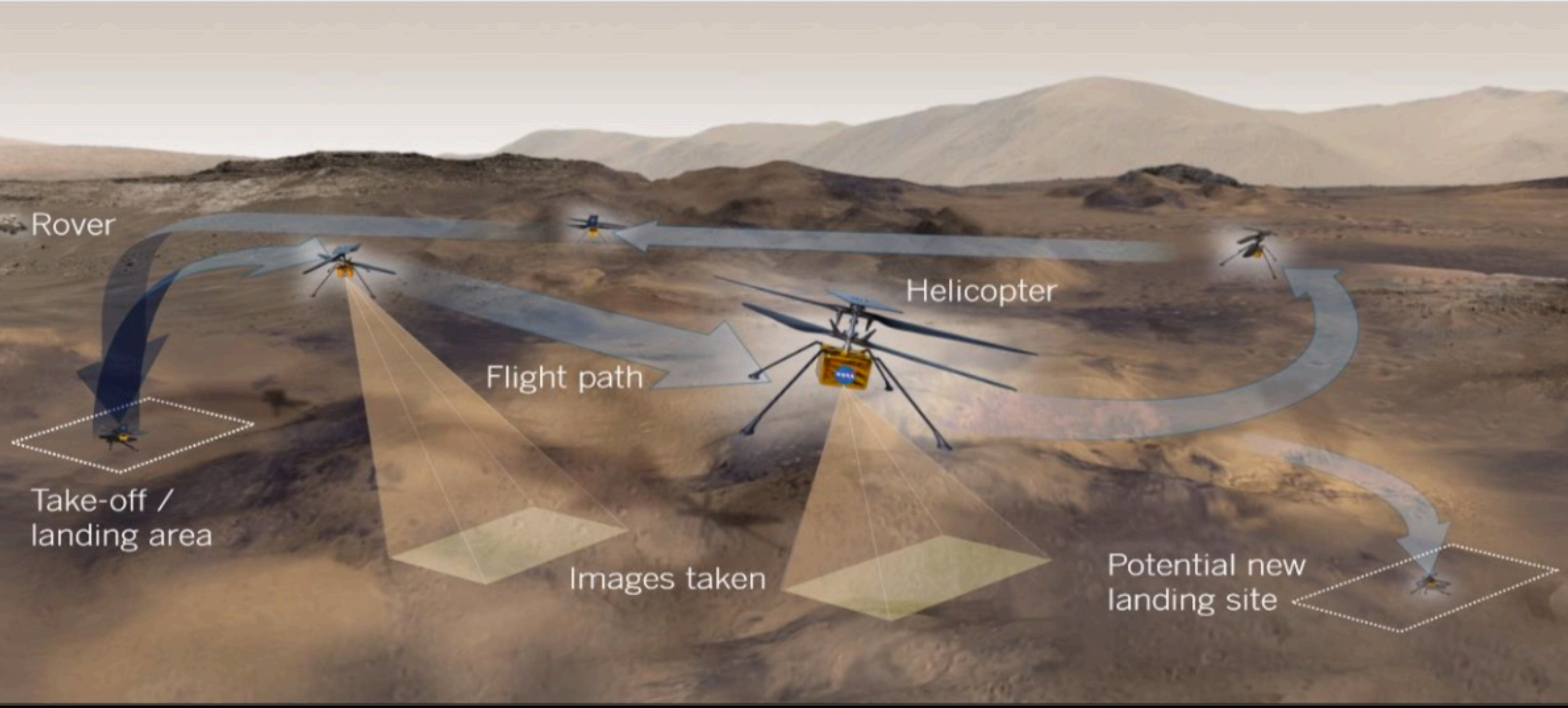
Helicopter Cameras







Both cameras mounted in portrait orientation



Example Flight Path

Helicopter Flights

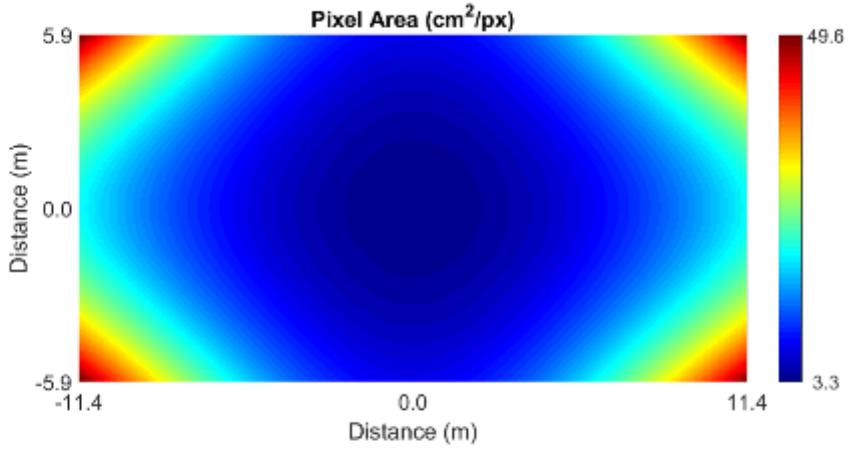
30 Day Mission

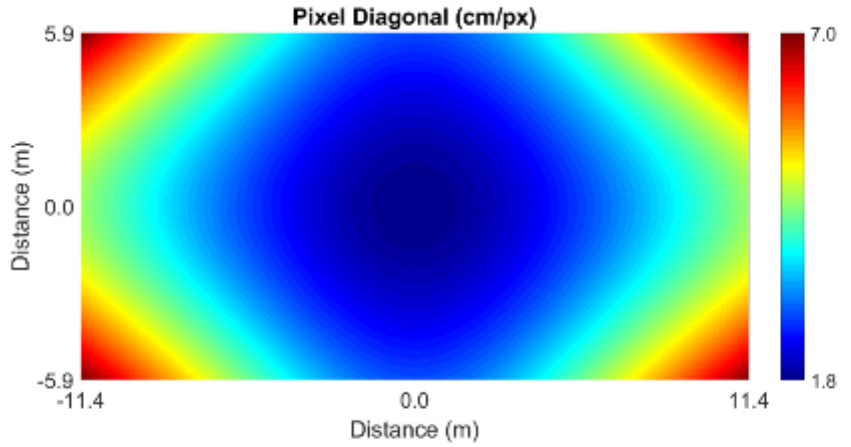
#	Flight Description		Test Conditions
1	Baseline Case 	**Ascend, hover, land** - *Up/down to ~3m AGL*	Least windy time-of-day e.g 11 am
2	Baseline Case 	**Fly higher & fly ~5m laterally** *- ~5m AGL* *- Slow lateral motions*	Same terrain in view during entire flight
3	Baseline Case 	**Fly 50m out-and-back Take images of potential new landing sites**	New terrain in view as flight progresses Potentially fly in moderate wind conditions

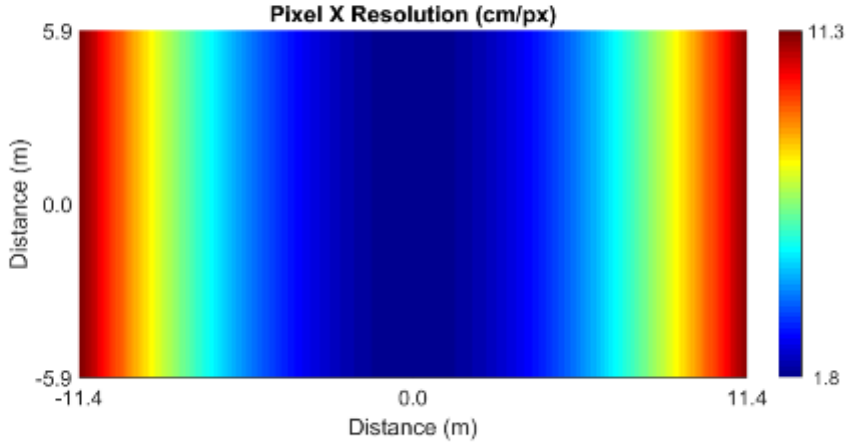
#	Flight Description		Test Conditions	Mission Concept Tests
4,5	Mission & Stretch Case 	**Fly to new landing site**	New terrain in view as flight progresses	Multi-site operations
		**Fly 100s m**	Potentially fly in moderate wind conditions	Recon hard-to-access target
		Fly in higher winds Fly in early morning or late evening Fly over rough terrain Fly at higher altitudes	Late afternoon eddy wind formations Low sun angle lighting Challenging slopes and rocks	"All weather, All-terrain" flights

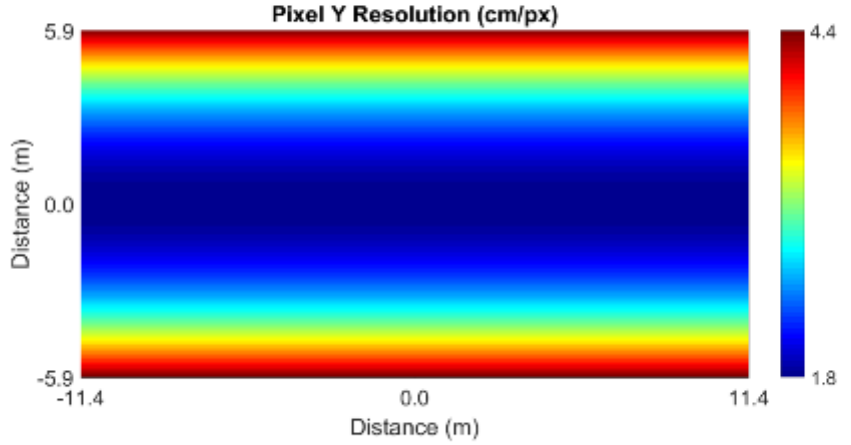
Helicopter Navcam Image Coverage/Resolution

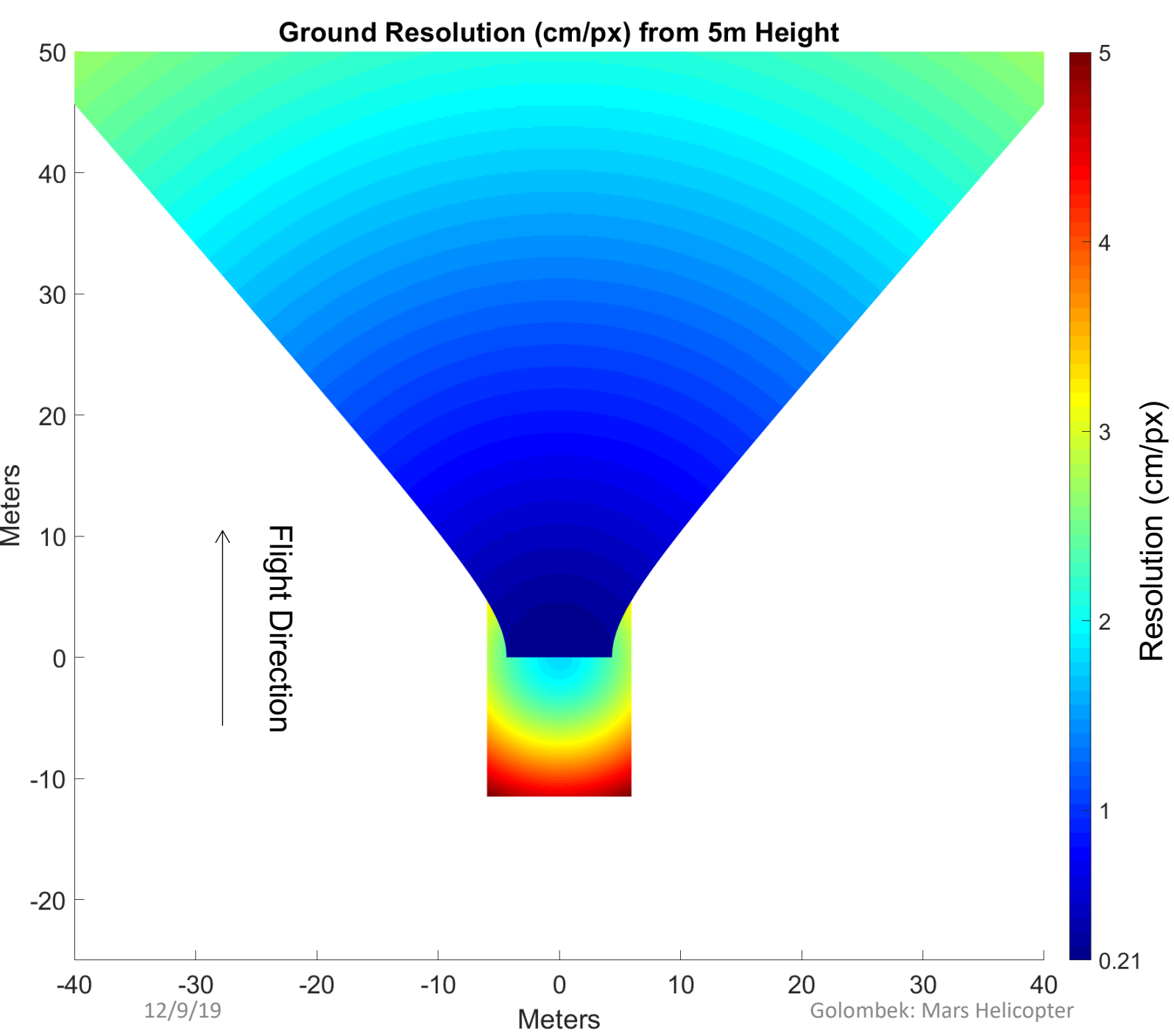
5 m Altitude - ~2 cm/pixel over ~10x20 m Area





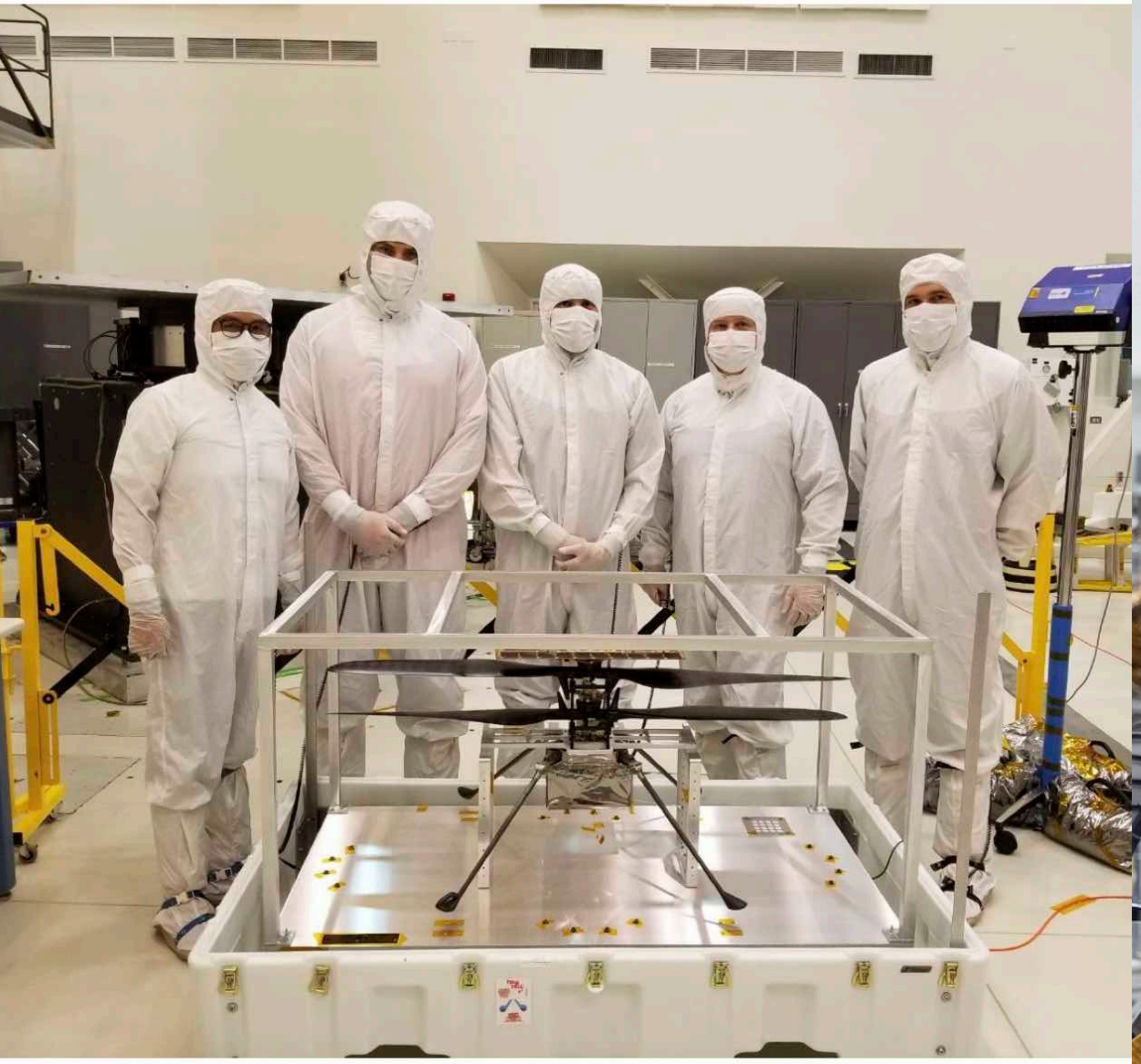




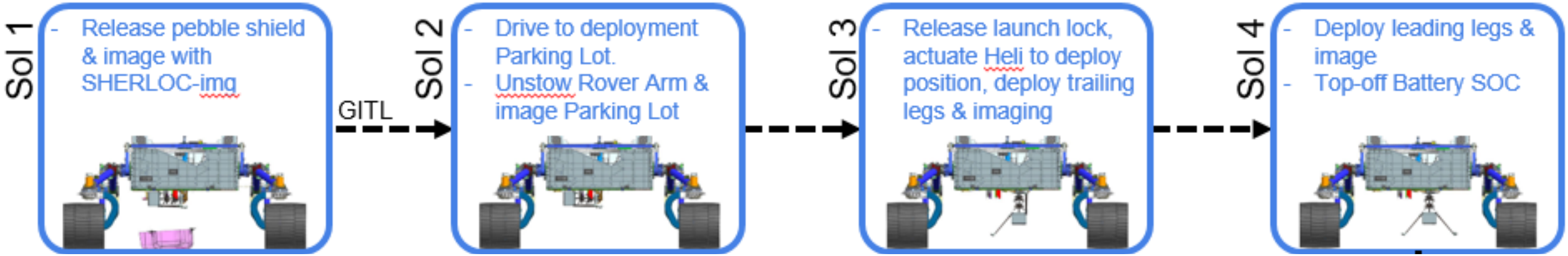


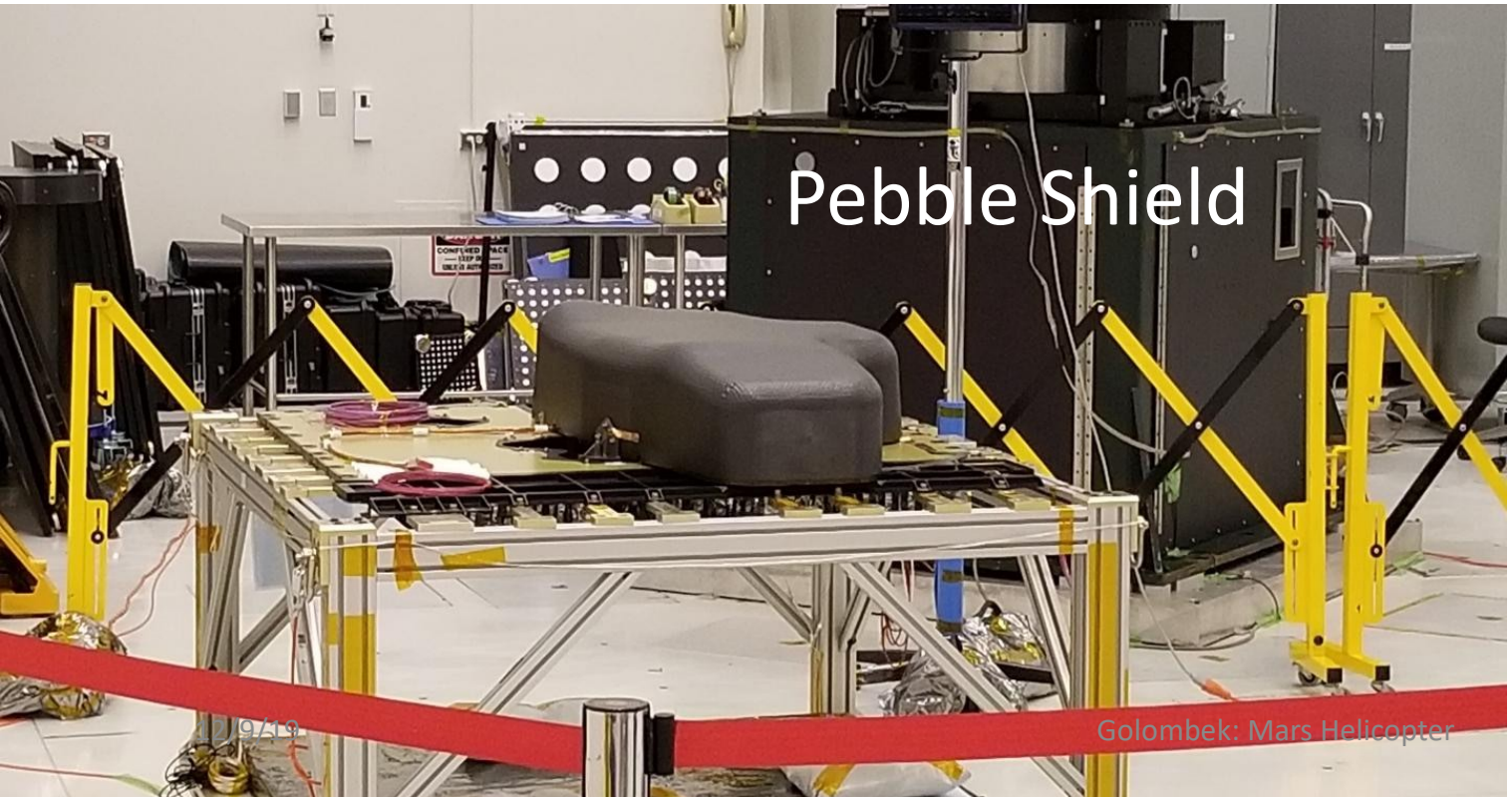
RTE Color Camera
13 Mpixel
0.23 mrad/pixel

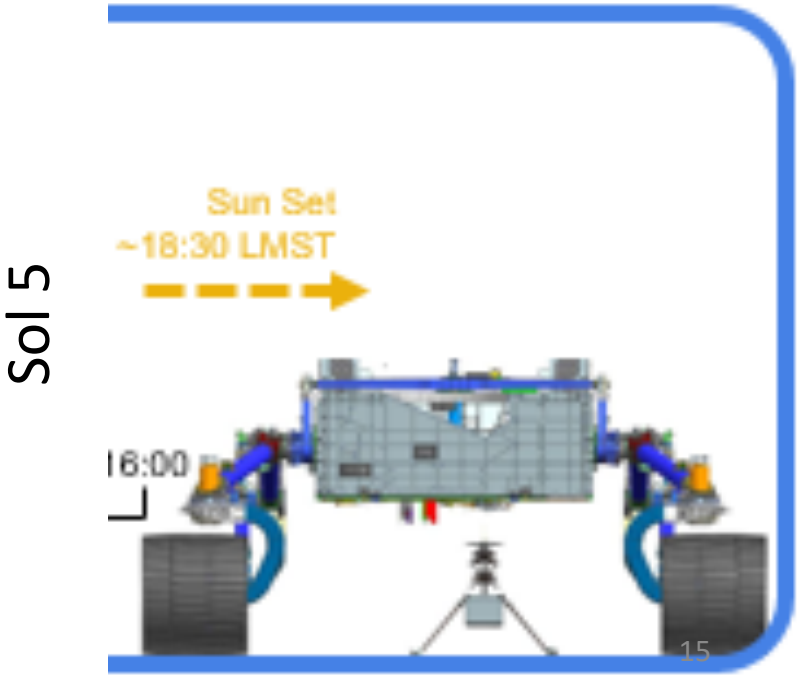
Navigation Camera
640x480 pixels
0.3 Mpixel
3.6 mrad/pixel



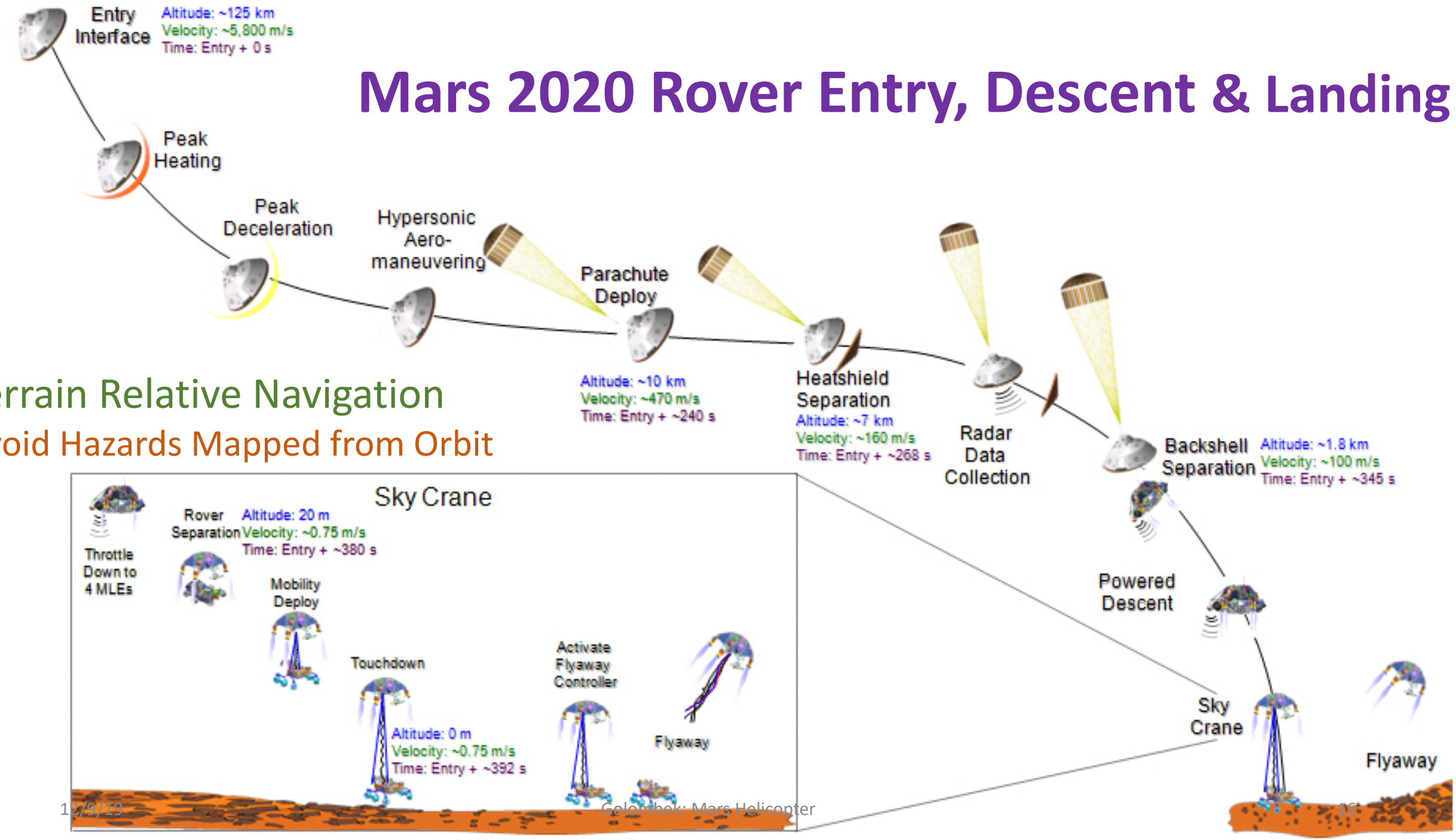
Deployment Sequence





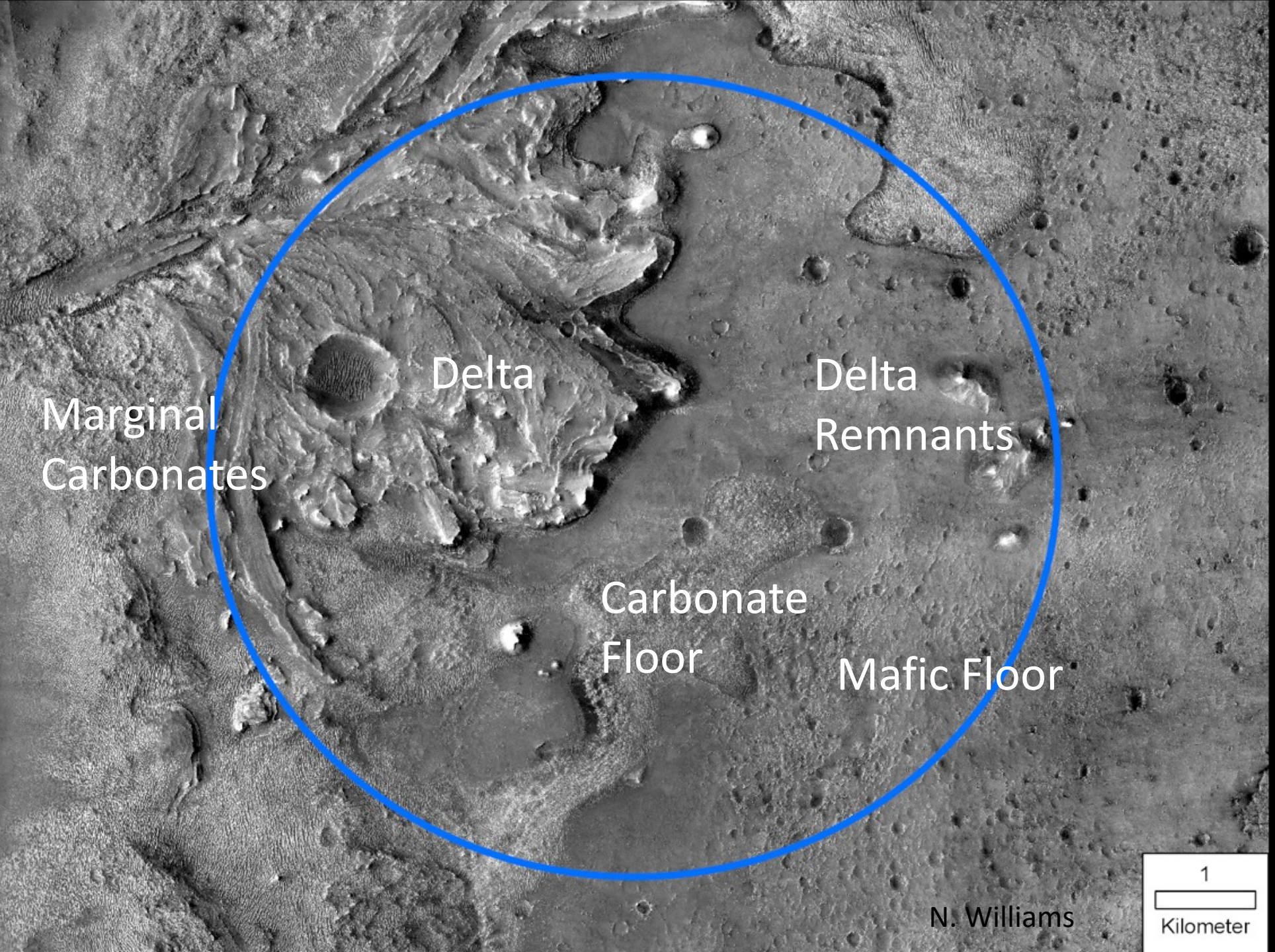


Mars 2020 Rover Entry, Descent & Landing



Terrain Relative Navigation

Avoid Hazards Mapped from Orbit

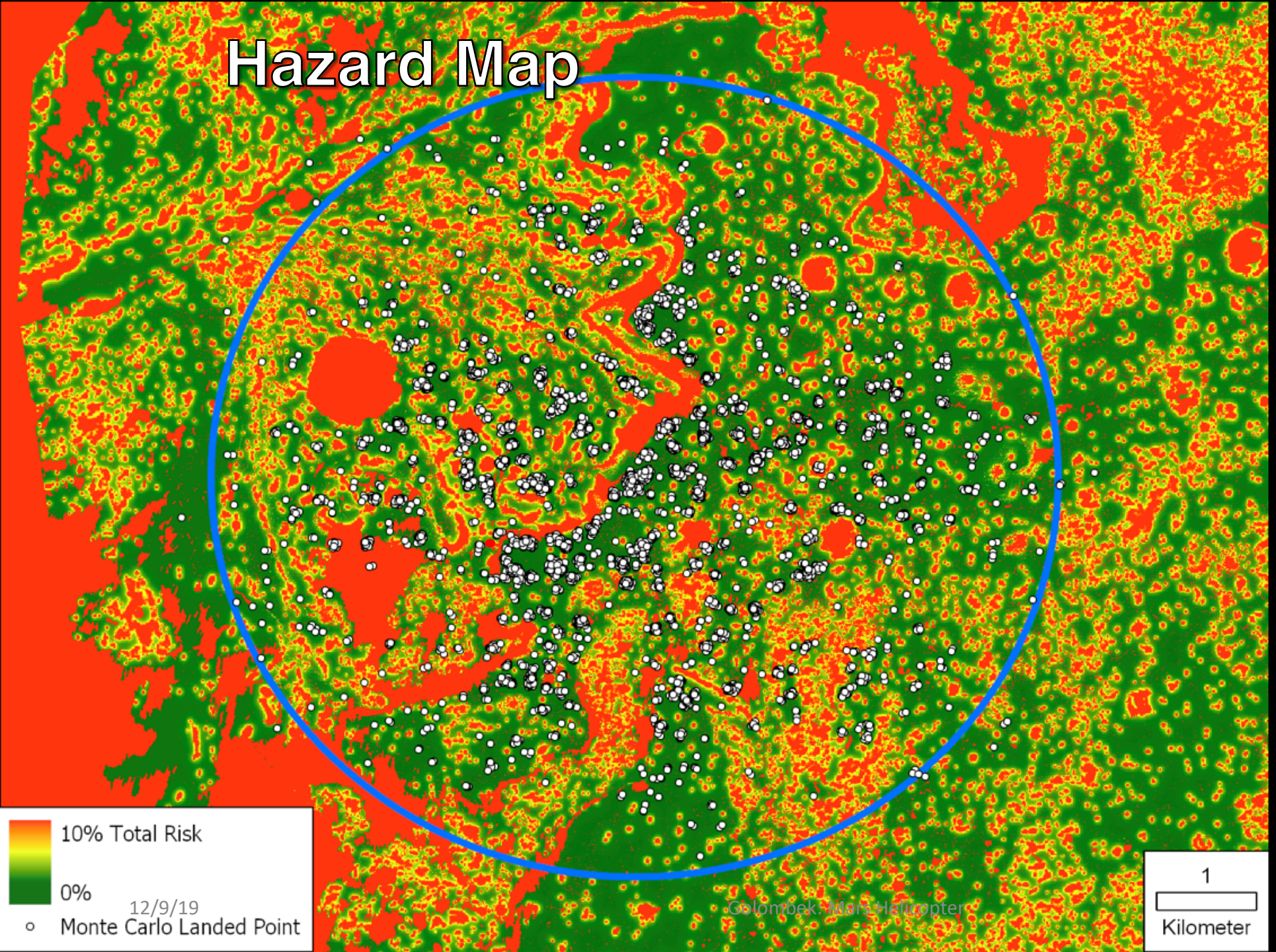


Jezero crater

Mars 2020 Rover Landing Site

Science Targets

Hazard Map

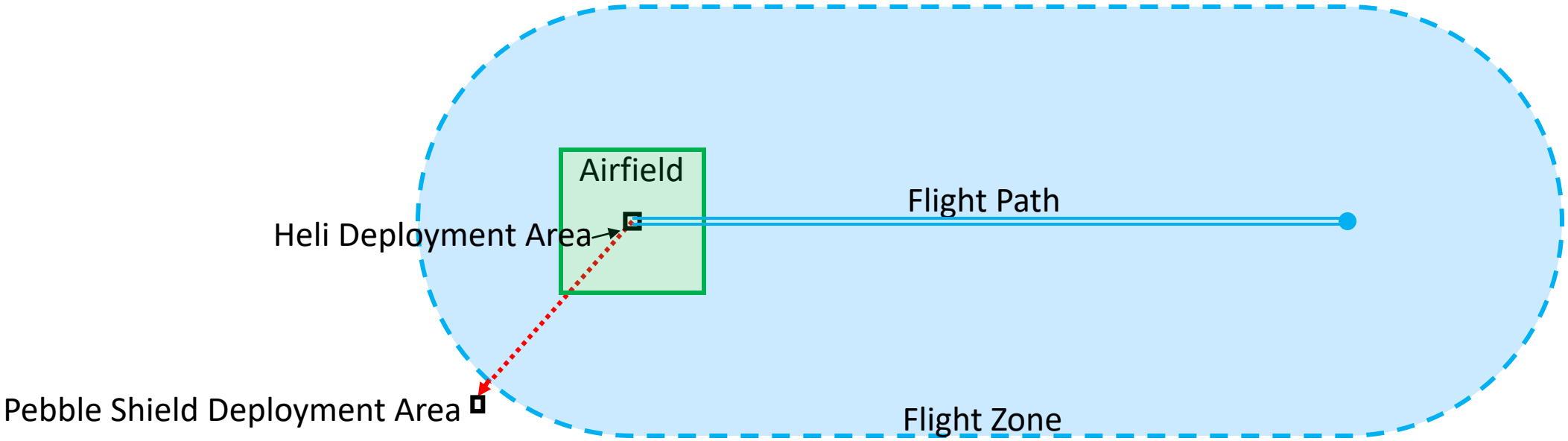


Rocks
Slopes
Inescapable
Hazards

Terrain
Relative
Navigation

Landed
Points in
Safest
Terrain

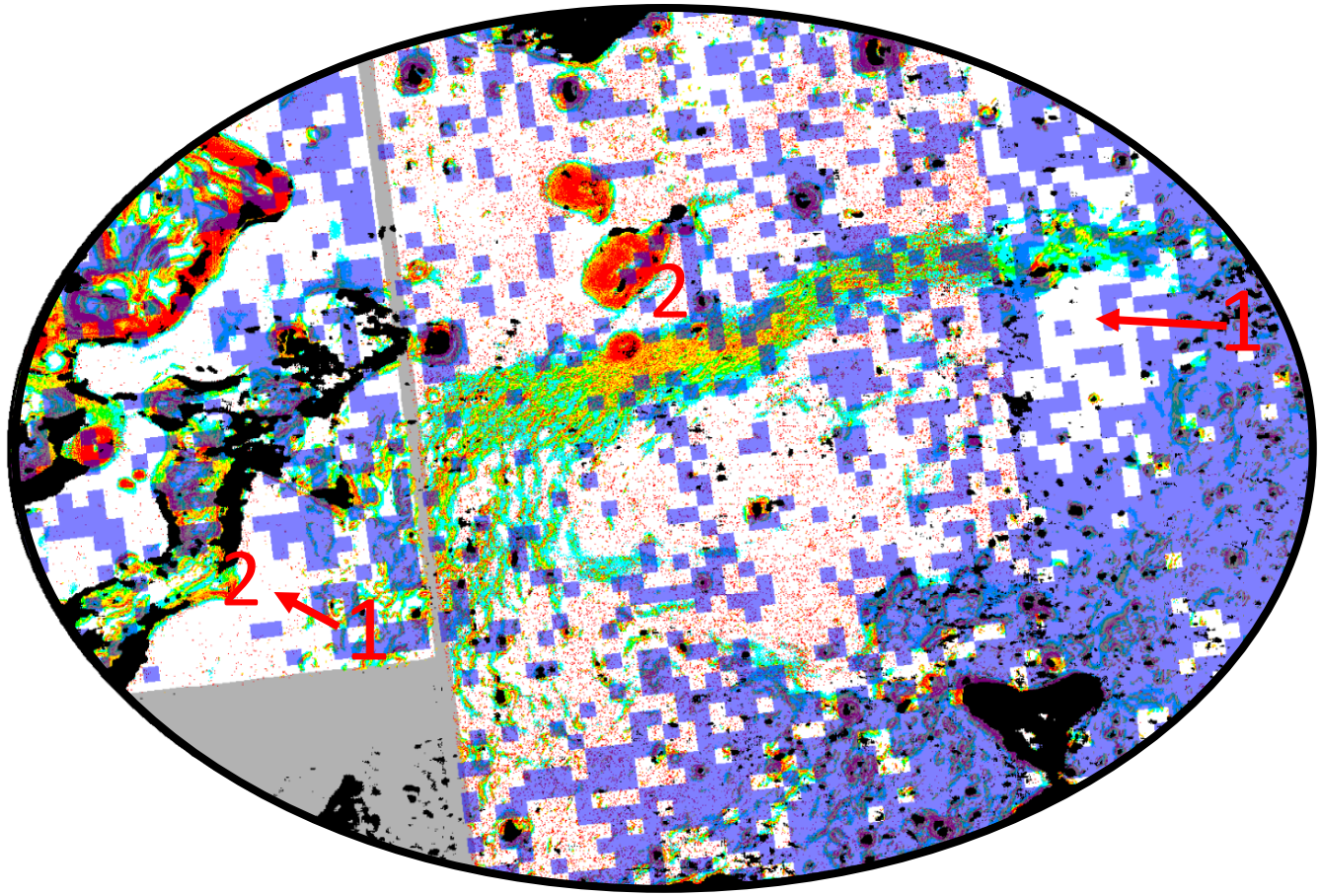
Helicopter and Pebble Shield Deployment, Airfield and Flight Path/Zone Requirements



Symbol	Region	Size/Location	Slope	Rock Tolerance
	Pebble Shield Deployment Area	≥15m from Heli Dply., 3m x 3m area	<10° over rover lengthscale	5cm Maximum Ground Clearance Reduction
	Heli Deployment Area	3m x 3m area	<5° over rover and heli lengthscale	No rocks ≥1cm high, 5cm Max Ground Clearance Reduction
	Airfield	10m x 10m area	<5° over heli lengthscale	Req: Few (≤3) rocks ≥5cm high Desire: no rocks >1cm high
	Flight Path & Flight Zone	15m on each side of flight path	<6° over 2m <4° over 10m <2° over 20m <1.5° over 40m <1° over 80m	Desire: Few (~3) rocks/relief ≥5cm high per 100m^2 Desire no rocks >1cm high

v.1

Potential Helicopter Airfields & Flight Zones



Localize Rover after Landing
Decide Direction to Traverse
Which Potential Airfields
Could be Science Considerations
Rover Image Airfields/Flight Zones
Evaluate Airfields/Flight Zones
Meet Requirements?
Deploy Helicopter
Commence 1 Month Helicopter Mission

>5% Rock CFA
Inescapable Hazards
No DEM coverage

>5° Slope Across 2 m (9.4% Area)
>3° Slope Across 10 m (11.4% Area)
>2° Slope Across 20 m (16.6% Area)
>1.5° Slope Across 40 m (20.7% Area)
>1° Slope Across 80 m (29.5% Area)

N
3
KM

Mars 2020 Rover

Launches July 2020

Lands February 2021

Mars Helicopter Flies

After Rover Checkout, Select Airfield

April-June 2021