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Knowledge Inn (in nature). 18

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Ingenuity flew (If) on Mars (oM)$$ Part 1……

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Conspectus: Ingenuity flew on Mars on 19th April, 2021. Ingenuity is a 1.8 Kgs helicopter designed by JPL (Jet propulsion laboratory), NASA, USA. It is a stand-alone module developed for technology demonstration and not any scientific explorations. This was transported to Mars keeping it inside Perseverance, MARS-2020 rover. The Ingenuity helicopter did its job (of flying in Martian atmosphere in five scheduled planedtrips) beyond expectations of NASA-Ingenuity-design-operations-expert-team. This prompted Perseverance group to come out with an extended task schedule while Perseverance will execute pre-approved exploration tasks viz. looking for water, life and sample collection. The helicopter is not only ingenious in its five brainy flight operations, but also lived one month (100 years equivalent of expected life of human being on earth) under Mars' harsh environmental night temperatures, low density atmosphere, radiation, dust-devils and so on.

$$: Dedicated to the title "J. Applicable Chemistry" during its decadal publication year

1. Time line of Scientific explorations on Mars

Time line of typical Mars missions (NASA)		
Historial (1850-1960)	**Year**	
Science Fiction	1880	
Scientific proposals	1940 onwards	
First Mission (1M NO 1)	1960 Oct 10	Launch failure
1961-2021		
Achievement	Date	Mission
First flyby of Mars	15 July 1965	Mariner 4
First spacecraft to orbit another planet	14 November 1971	Mariner 9
First successful Mars lander	20 July 1976	Viking 1
First aerodynamic flight on another planet	April 19, 2021	Mars 2020

2. Ingenuity flights on Mars

Anatomy of Ingenuity** → Form and Function!	

Name(s) of robot flying on Mars	
Selected	➔ *Ingenuity (**)*
Generic	➔ MARS 2020 Helicopter
Pet	➔ Ginny (##)

Total mass	1.8 kg
Mass of Batteries	273 g
Height	1 ft 7 in

Fuselage (body):	5.4 in × 7.7 in × 6.4 in
Landing legs	1 ft 3.1 in
Diameter of Rotors	4 ft
Power	350 watts

Flight characteristics of Ingenuity	
Rotor speed	2400 rpm
Blade tip speed	<0.7 Mach
Battery capacity	35–40 Wh

Components	Performance exceedance
Specially designed rotors	Spin much faster than in practice on earth
Innovative batteries solar cells	For recharging
Solar panel to recharge batteries	➔ Six Sony Li-ion cells with 35–40 Wh ➔ Nameplate capacity: 2 Ah

Ingenuity—Hardware chips and software

- Qualcomm Snapdragon 801 processor
- Linux operating system

Ingenuity—sensors cameras

- Tilt sensors
- LaserAltimeter
- Gyros
- Visual Odometry
- Hazard Detectors
- Inertial sensors
- solar tracker camera integrated to JPL's visual inertial navigation system

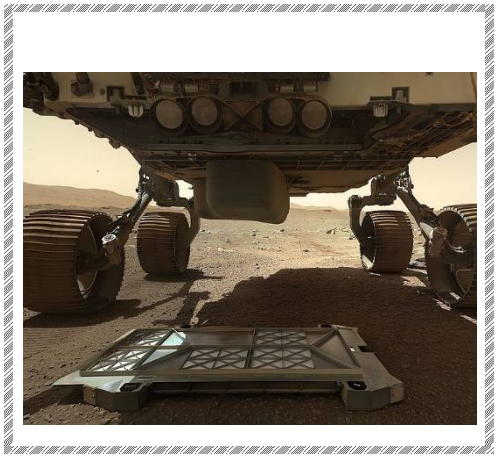
** The name Ingenuity proposed by Vaneeza Rupani was accepted by NASA
- ➔ Rupani submitted an essay into NASA's "Name the Rover" contest
- ➔ She was a girl in 11th grade at Tuscaloosa County High School in Northport, Alabama

Ginny is pet name entered later

Transportation of Ingenuity from USA (Earth) to Jezero (MARS)

NASA.Gov

- ✓ Ingenuity was attached to the belly of NAS A's Mars 2020 Perseverance rover

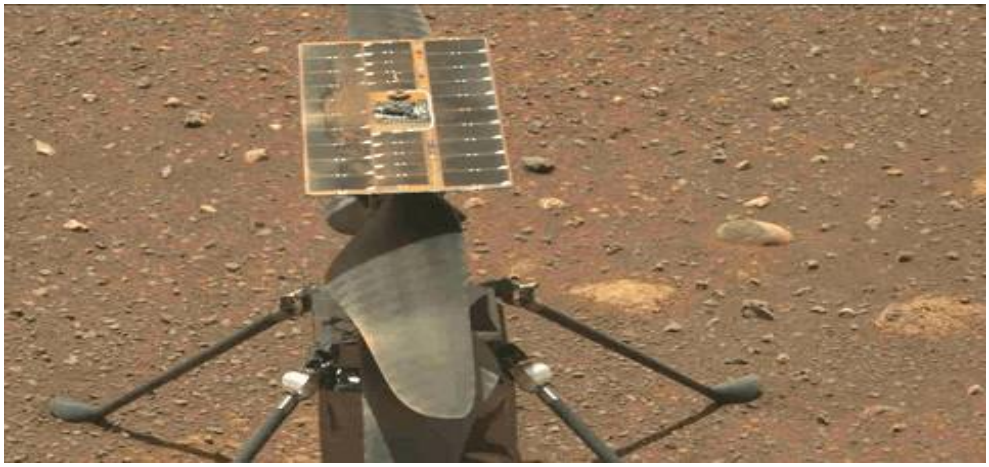


Perseverance + ingenuity (Earth To Mars)				
Launch site	30 July 2020	11:50:00 UTC	Cape Canaveral, Air Force Station, Florida, SLC-41, USA	Earth

Landing (Arrival) site	18 February 2021	20:55 UTC	Jezero crater 18.447°N ;774508°E Octavia E. Butler Landing	MARS
Activity	Date	Time	Site	Planet
	Time		Space	
Perseverance Activity in Space Time Domain				

Landing and lifting sites of Ingenuity helicopter on MARS		
✓ Ingenuity landed with NASA's Perseverance rover	Inside the 28-mile-wide Jezero	2021, Feb. 18
✓ The solar-powered rotorcraft deployed from the rover's belly on		2021, April 3
Perseverance was parked 262 feet from the helicopter's takeoff and landing site to avoid catastrophes		

Testing health and functionality of Ingenuity to take up scheduled flights on Mars		
Ingenuity's rotor blades unlocking	**Success** on	April 8, 2021
Low-speed (spinning at 50 rpm) rotor spin test	**Success**	



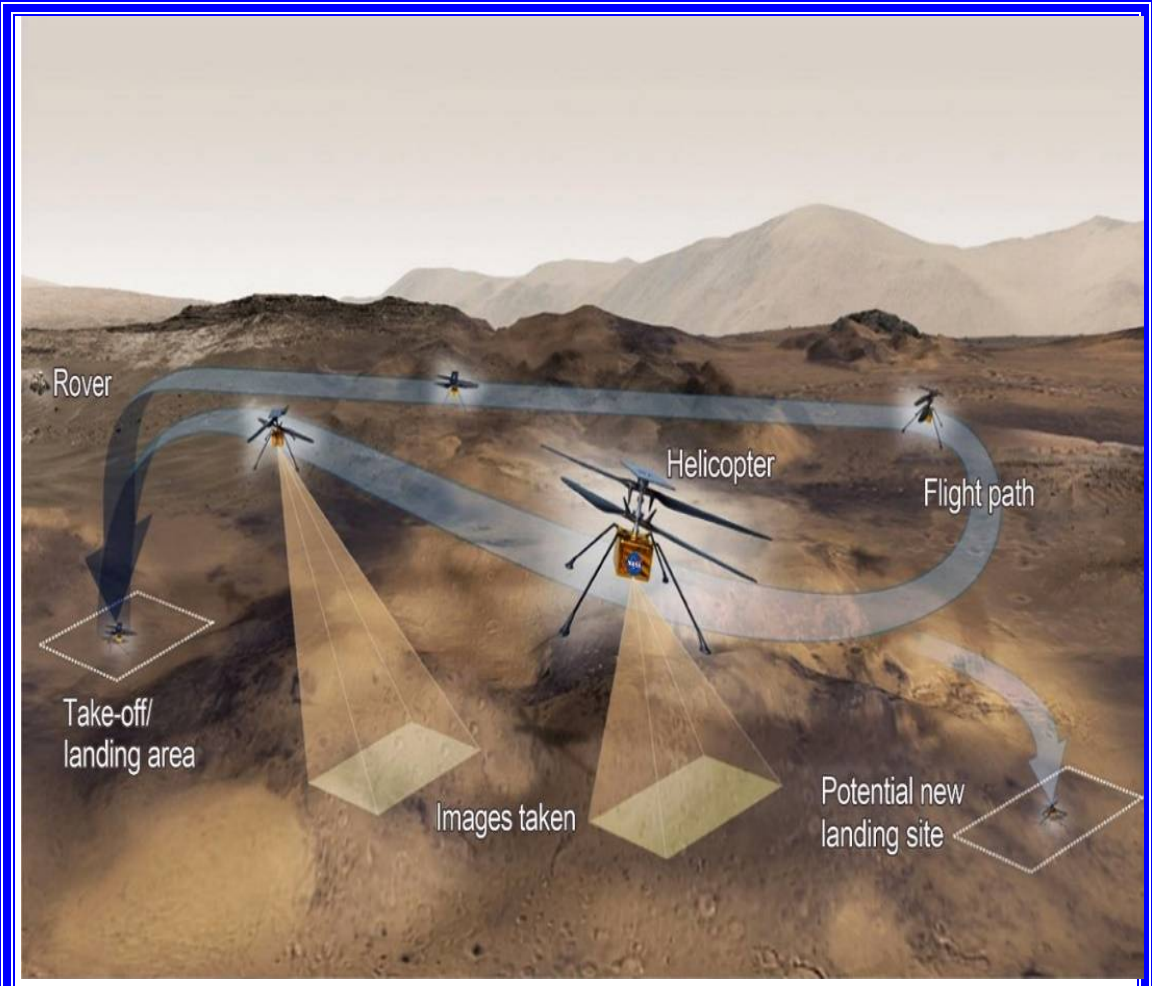
A high-speed spin (2400 rpm) test	**Failed** due to expiration of a watchdog timer	9 April
Software update with a patch to correct problem	Remedy-developed	12 April
Update was not used	Only 85 % chance of Adapted command sequence to work correctly	

High (2400 rpm) rotor blades spinning test	**Success**	April 17, 2021

I to V IF tests	**Schedule**	19^{th} April to 7^{th} May **2021**

Flight environment	Low dense (1% that of Earth's,[1.2 kg/m^3]) atmosphere

Activity	Flight#	Site on MARS
➔ Take-off	✓ IF-I to IF-V	! Wright Brothers Field[#]
➔ Landing	✓ IF-I to IF-IV	! Wright Brothers Field[#]
	✓ IF-V	! Airfield B
# This site is named after Wright Brothers[$] as a tribute for their contributions		
$ Wilbur and Orville Wright conducted the first powered, controlled aircraft flight in atmospheric air here on Earth in **1903**		



Powered flight on Mars

Historic first ever helicopter flying on another planet other than Earth

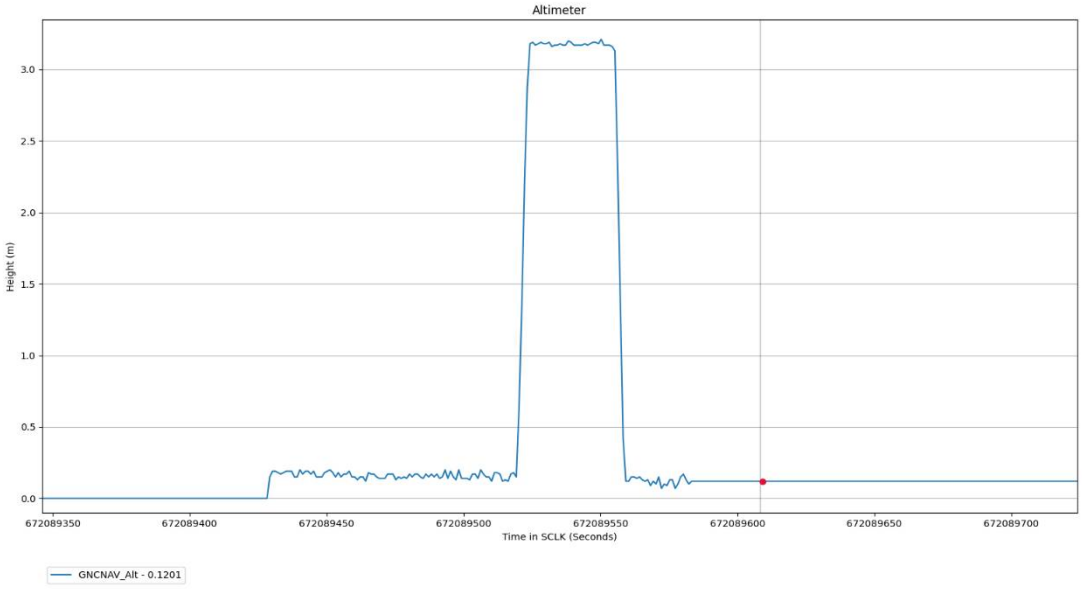
Iff	IF-1 success	&
	IF-2 success	&
	IF-3 success	&
	IF-4 success	&
	IF-5 success	&
Then	Demonstration of Ingenuity Technology task (phase) **Success**	

IFF	If and only if (Mathematical logical Strong condition)
IF	Ingenuity flight

Return or Round-trip flight	**One-way-trip flight**
➔ **Forward Flight** ➔ **Return flight** ➔ **Landing at start-point**	➔ **Forward Flight** ➔ **Landing at new site**
Ex: Ingenuity's First-to-Fourth fifth flights	Ex: Ingenuity's Fifth flight
Forward Flight 📖 Rest 📖 Take off vertically 📖 Hover 📖 Rotation 📖 Horizontal movement	**Return flight** 📖 Stop 📖 Rising height 📖 Turn(s) to face camera 📖 Head back 📖 B/W color photographic, 3D-image recording 📖 Move back
Landing at start-point 📖 Stop at center of take off field 📖 Landing 📖 Rest	**Landing at new site** 📖 Move to destination point 📖 Landing 📖 Rest

Ingenuity flight failure (IFF)		
High-speed spin **test failed**	April 9,2021	
Reason (IF1F)	Expiration of a watchdog timer ($$)	
Re-trial scheduled		
Attempted again on	April 17, 2021	**Passed** full-speed spin test
$$: **A measure to protect helicopter** from **incorrect operation in unforeseen conditions**		

First Ingenuity flight	April 19, 2021	7:34 UTC
Operations		
Takeoff	Rose vertically about	10 feet
Hovered	Rotating clockwise 96 degrees in place in a planned maneuver (yaw from 0 to +90°)	
Landed	Flight time	39.1 seconds
	Distance	0 feet
Start of	**technology demonstration phase**	
Ingenuity flight -1	**Success**	



Ingenuity Helicopter 1st Flight Altimeter Data
Time 672 089 350 to 672 089 550 SCLK (sec)

Second Ingenuity flight	22 April 2021	09:33 UTC
Operations		
Takeoff	Rose vertically about	16 feet
Hovered	For a short while at the same altitude	
Tilt	5 degrees (westward) →allows rotors to accelerate it 2 meters sideways	
Horizontal motion	Starts with max airspeed 0.5 m/s Stop horizontal motion	

Recording photos	snapshots uses horizon facing colour camera	
Rotation	Counter clock-wise in phase [yaw from +90° to 0° to -90° to -180°] in 3 steps	
Horizontal motion	Towards take-off site	
Landed	Flight time	51.9 seconds
	Distance	28 feet
Continuation of	**technology demonstration phase**	
Ingenuity flight -2	**Success**	

Third Ingenuity flight	25 April 2021 at 11:31 UTC	
Operations		
Takeoff	Rose vertically about	16 feet
Hovered	For a short while at the same altitude	
Tilt	North	
Horizontal motion	164 ft meters being at same height (#) Reaches a max speed of two meters per second	
Rotation	180^{o}	
Horizontal motion	Towards take-off site	
Landed	Flight time	80 seconds
	Round-trip distance	330 feet
Continuation of	**technology demonstration phase**	
Ingenuity flight -3	**Success**	
#:downward-facing black and white camera Ingenuity keep track of its position above the ground		

Ingenuity flight failure (IFF)		
Fourth flight scheduled on	April 29, 2021,14:12 UTC **Failed**	
Reason (IF4F-Cause)	Helicopter failing from transition to flight mode.	
Fixing bug		
Rectified (IF4F-Fix)	Cause of failure	
Re-trial scheduled		
Attempted again on	April 30, 2021	

Fourth Ingenuity flight	April 30, 2021	14:49 UTC
Operations		
Takeoff	Rose vertically about	16 feet
Hovered	For a short while at the same altitude	
Tilt	South	
Horizontal motion	436 ft meters being at same height (#)	
	Reaches a max speed	3.5 meters/sec
Rotation	180^{o}	
Horizontal motion	Towards take-off site	
Photo capturing	➔ One image for every four feetafter flying 272 feet ➔ Total snaps :60 ➔ Color images while hovering at the point on 436 ft	
Landed	Flight time	117 seconds
	Round-trip distance	873 feet
Continuation of	**technology demonstration phase**	
Ingenuity flight -4	**Success**	

Fifth Ingenuity flight	May 7, 2021	19:26 UTC
Operations		
Takeoff	Rose vertically about	16 feet
Hovered	For a short while at the same altitude	
Tilt	South	
Horizontal motion	429 ft meters being at same height (#)	
	Reaches a max speed	3.5 meters/sec
Flew	To higher altitude	33 feet
Photo capturing	Few high-res color images of its landing site	
	Site of Landing Airfield B	
Landed	Flight time	108 seconds
	Distance covered	429 feet
End of	**technology demonstration phase**	
Ingenuity flight -5	**Success**	

Ingenuity took this color image from an altitude of 33 feet
During fifth flight on May 7, 2021 (Credit: NASA/JPL-Caltech.)

Automated robotic module, Ingenuity,now on Mars is functional without Expert scientists' intervention from Earth except a few command sequences in advance

Exceedance of Ingenuity: performance in flights, health-as-on-date and functional state	
Power system (Batteries + solar panel)	Providing more than required energy ! to keep heaters going on at night (-90°) ! to fly during the day
Expected life	✓ One month under harsh Mars environment
Rotor system	✓ Doing just fine or better
Performance of IF-3	✓ Exceeded tests conducted on Earth

Since	Demonstration of Technology task (phase) **Success**	&
	Exceed expectations of Team	&
	Ingenuity is in functionally fit state	&
	Ingenuity is in good health even after its expected life of 30 days	&
Extension of	**Ingenuity flight (**If) programs for a few months 📖 Operational demonstration Ingenuity 📖 Supporting Perseverance rover's science mission	

Next week flight schedule of Ingenuity Second Phase : Operations Demonstrations

Sixth Ingenuity flight	Operations demonstration phase	Next week of 19th May ,2021
Takeoff	Will rise vertically about	33 feet

Heading towards	Southwest	
Horizontal motion	492 feet	
Top groundspeed expected	9 mph	Or 4 meters per second
Acquiring color imagery	Area south about 50-66 feet	
Fly further	About 164 feet northeast	
Will Land	"Field C"	Time aloft will be 140 seconds.
	New base of operations @	
Ingenuity flight -6	**Awaited**	

- Perseverance rover will not record images of the helicopter in flight,
- Reason: rover requires time to prepare for the start of its science_mission's operations

@ First time the helicopter will land at an airfield which ws not surveyed from air during a previous mission

Operational demonstration of future IFs (Ingenuity flights)> IF-6

- Aerial observations of areas not accessible by a rover
- Stereo imaging from atmospheric altitudes
- Transport of small amounts of material
- Scout ahead of the Perseverance rover
  - → To assist in its search for past signs of microbial life

Distant future

- ! Scoping out best paths for explorers to traverse
  - ! Machines, humans
- ! Extension of benefits in future aerial exploration on other planets

For greatest benefit to humankind

.

Physiological Psychological and environmental health, wealth and peace

Perseverance Explorations on Mars

Referred as Percy affectionately

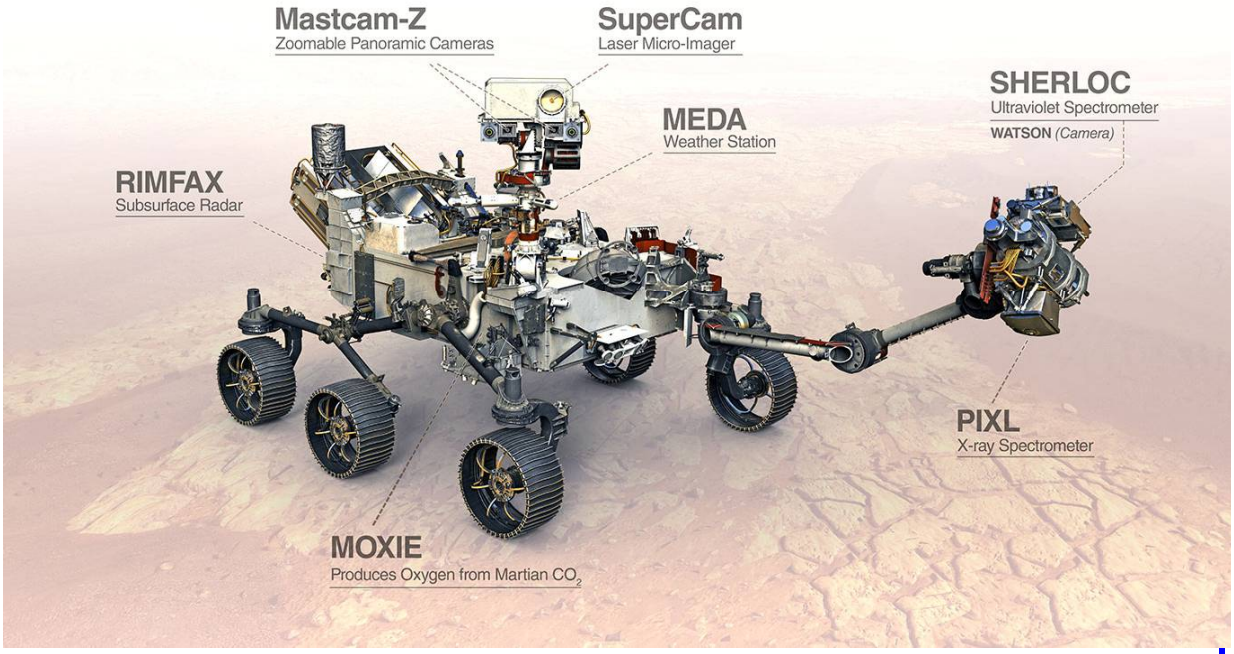
Goals of Perseverance
NASA's first Astrobiology-focused mission

- Searching for signs of ancient life
- Mars' geology and climate: Data Collection
- First leg to realize a round trip to Mars
- Collection and storing of promising samples of rock, soil on Mars surface
- Probing into current weather, winds, radiation, dust
- To demonstrate implications/utility of technologies which pass test of utility
- Samples will be brought to Earth in 2026 for detailed study

Instruments on Perseverance

MEDA	Mars Environmental Dynamics Analyzer
MOXIE	Mars Oxygen ISRU Experiment
PIXL	Planetary Instrument for X-ray Litho-chemistry
RIMFAX	Radar Imager for Mars' Subsurface Experiment
SHERLOC	Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals
Mastcam-Z	Placed in rover's head-like mast; Z stands for zoom

Cameras	#
Engineering	9
Science	7
Entry Descent Landing	9
Total	23

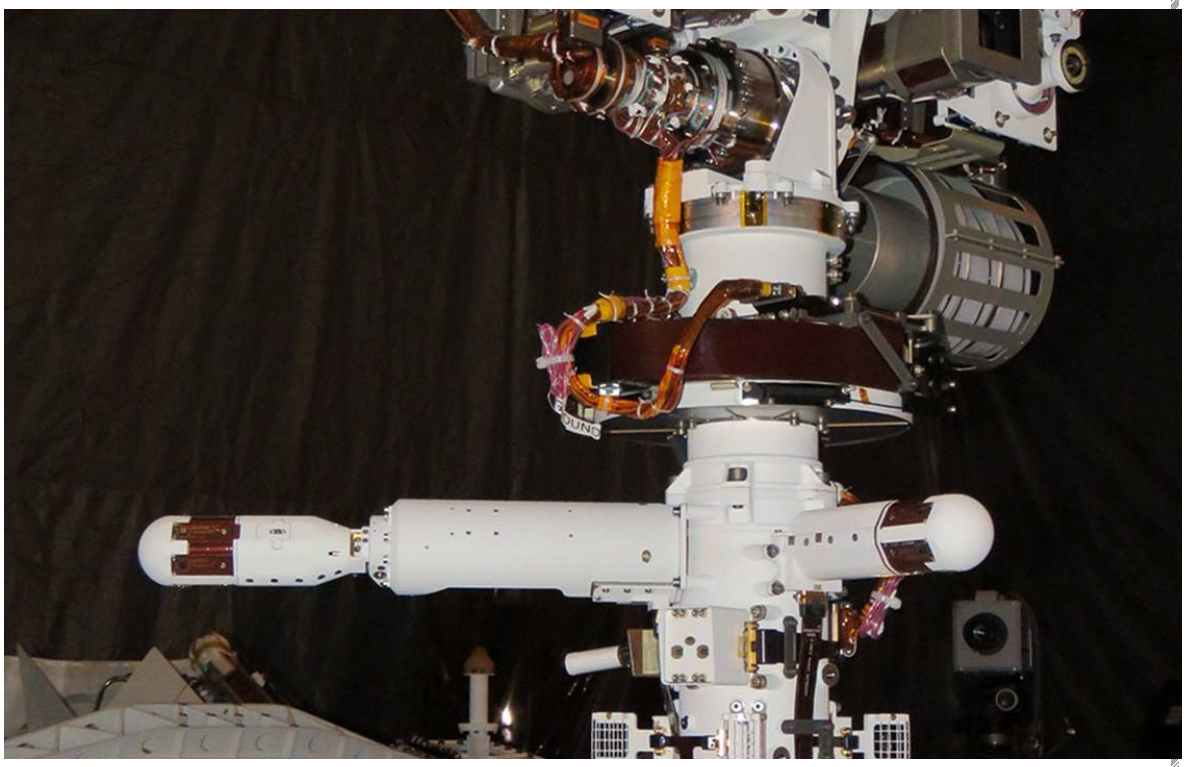


Instrument	Function
SHERLOC	o SHERLOC, an instrument on the end of the rover's robotic arm o Ultraviolet (UV) laser spectrometer o Provides fine-scale imaging o Determines fine-scale mineralogy and detect organic compounds. o First UV Raman spectrometer to fly to surface of Mars→ provides complementary measurements with other instruments in payload ➔ Hunts for sand-grain-sized clues in Martian rocks ➔ Camera takes close-up pictures of rock textures while working in tandem with WATSON
PIXL	o X-ray fluorescence spectrometer with high-resolution camera o Determines fine scale elemental composition materials on Martian surface o Detailed detection and analysis of chemical elements than ever before
MOXIE	o Mars Oxygen In-Situ Resource Utilization Experiment o Produces oxygen from Mars' carbon dioxide atmosphere o Future prospective production of oxygen ➔ for rocket propellant, ➔ also for breathing of human explorers to land and survive on Mars
MEDLI2	o Mars Entry Descent, Landing Instrumentation-2 o Next-generation version of what flew on the Mars Science Laboratory mission

MEDA	▪ Mars Environmental Dynamics Analyzer instrument suite ▪ Provides information on ➔ Weather, climate, surface ultraviolet radiation, dust ➔ Monitoring of temperature, wind speed /direction, pressure, relative humidity, dust size/shape
SuperCam	▪ Imaging, chemical composition analysis, mineralogy data ▪ Detects presence of organic compounds in rocks and regolith from a distance
RIMFAX	▪ A ground-penetrating radar ▪ Provides centimeter-scale resolution of the geologic structure of the subsurface

Mastcam-Z	Primary science camera on NASA's Perseverance rover ▪ Assesses mineralogy of the Martian surface ▪ Assists rover operations ▪ These cameras allow science team to piece together geologic history of the site
✓ High-definition, two-cameras	
✓ Multispectral, stereoscopic imaging instrument	
✓ Observes textural, mineralogical, structural, morphologic details in rocks in rover's field site	

Resolution:	➔ 1600 × 1200 photoactive pixels ➔ (1648 × 1214 total)
Function:	➔ Local geomorphology, ➔ chemistry, navigation
Power consumption	➔ 7.5 W standby ➔ 11.8 W imaging (per camera)



Mars Environmental Dynamics Analyzer (MEDA) measures					
Date	Air Temperature		Pressure (Pa)	Sunrise	Sunset
May 19, 2021	-3°F	-114°F	758.4	05:41:21	18:32:29
May 16, 2021	-3°F	-114°F	757.7	05:42:58	18:32:50
May 14, 2021	-12°F	-115°F	755.8	05:44:03	18:33:04
May 12, 2021	-9°F	-115°F	757.1	05:45:09	18:33:17
May 10, 2021	-9°F	-114°F	755.2	05:46:15	18:33:31

4. Future Science based human venturesfor discovery of life on Mars

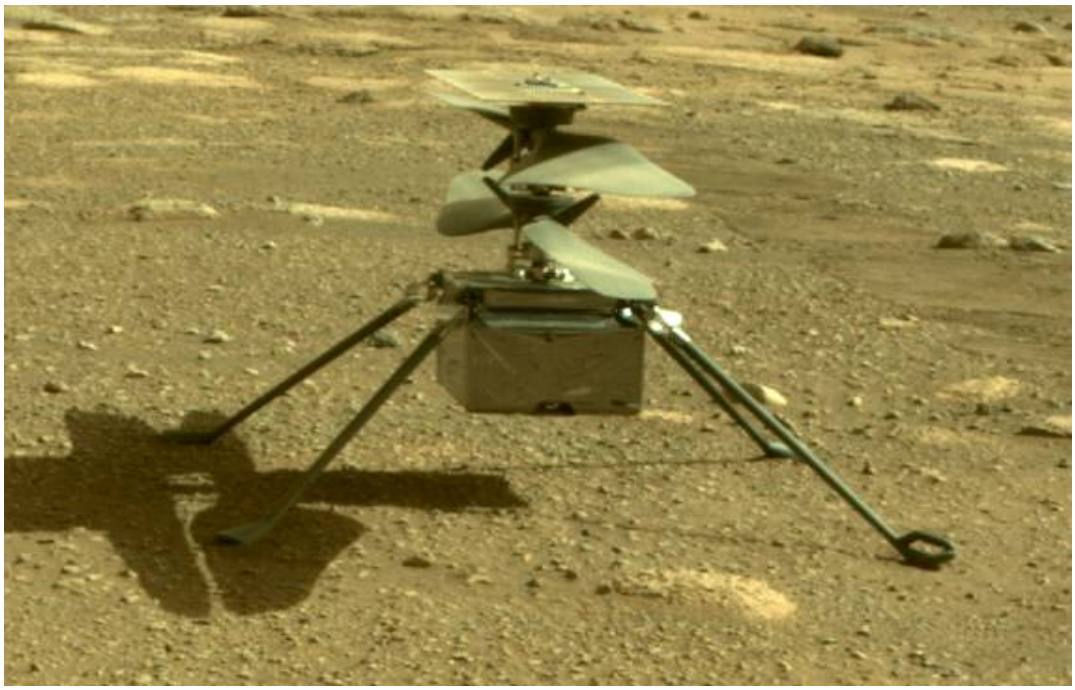
Proposal mission	Year Launch
Mars Orbiter Mission 2 (Mangalyaan 2)	2024 (ISRO, INDIA)[
Starship Demo mission	2022 or 2024
Icebreaker Life	2026
Mars sample-return mission	2026

SI: Supplementary Information
Image-gallery

Credit : NASA.Gov

Credit: NASA/JPL-Caltech -

Ingenuity-Helicopter



Ingenuity helicopter
after deployment on Martian surface by the Mars 2020 Perseverance rover ;
7 April 2021

Creator[#]-Preserver-User (CPU) of Ingenuityflights (CPU-If)

Creator	NASA (USA) Designed, developed		
Object	Non-life functional Helicopter named Ingenuity		
Use	Flights	Space :	On Mars
		Time:	19th April to 7th May 2021

#: Biological father is responsible for passage of genes to progeny
Academic father is responsible for passage of knowledge to learners

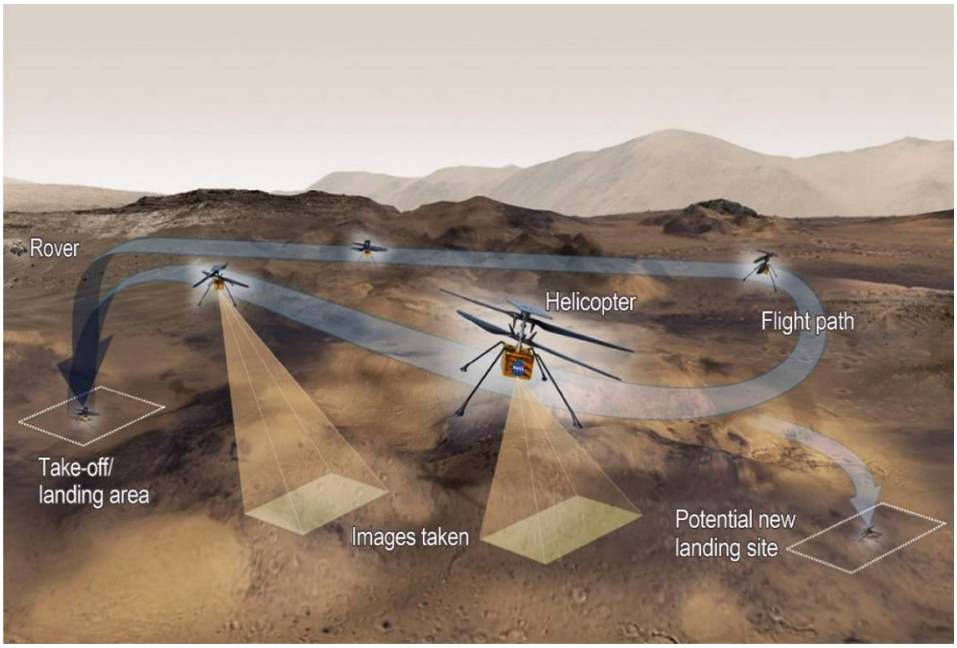
Perceiver (non-life)	NASA's Perseverance	
Perceived	Object – Dynamics	Fourth Ingenuity Flight
	Vision	Video
	Sound	Audio
	Time	May 2021
	Space	Mars

Creator of Perceiver	NASA/JPL, USA (Earth)
Transporter of Perceiverfrom Earth to MARS	NASA
Credit	NASA, USA

Launched on July 30, 2020, at 7:50 a.m. EDT;
from Launch Complex 41 at Cape Canaveral Air Force Station, Florida

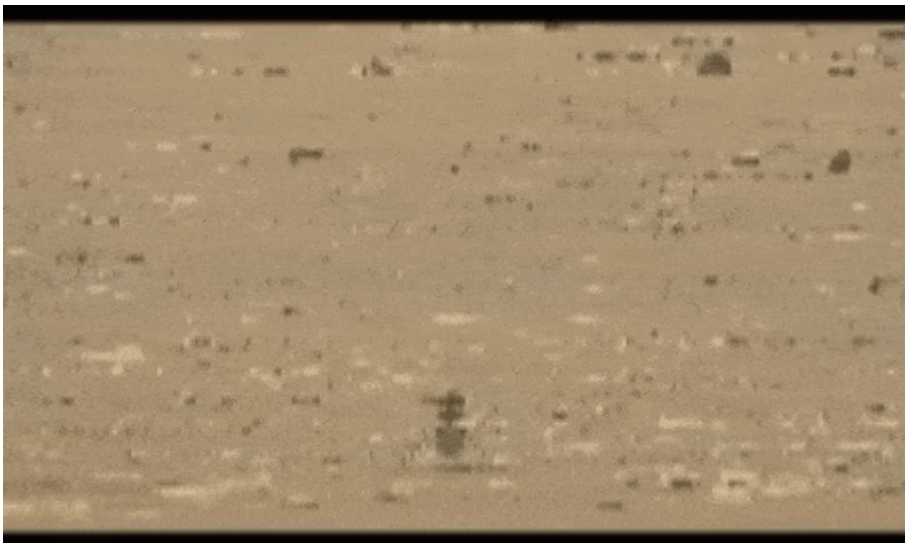
- ➔ Perseverance launched on an Atlas V-541 rocket
- ➔ Atlas V is one of the largest rockets available for interplanetary flight

NASA's Mars Perseverance rover makes its final descent to the Red Planet



Ingenuity- Mars-Helicopter-Flights and Activities –
Spacial pano Zone

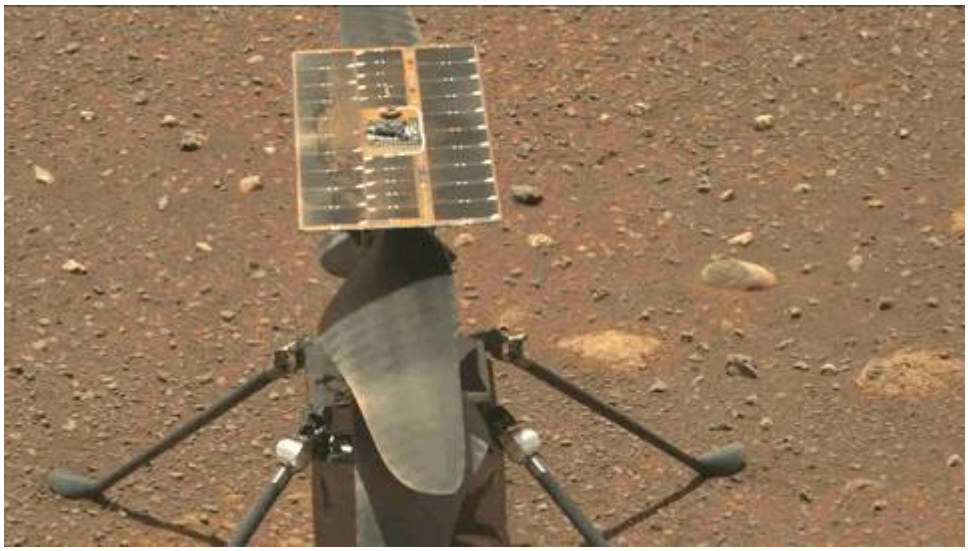
Aircraft certification of Ingenuity to fly on Mars



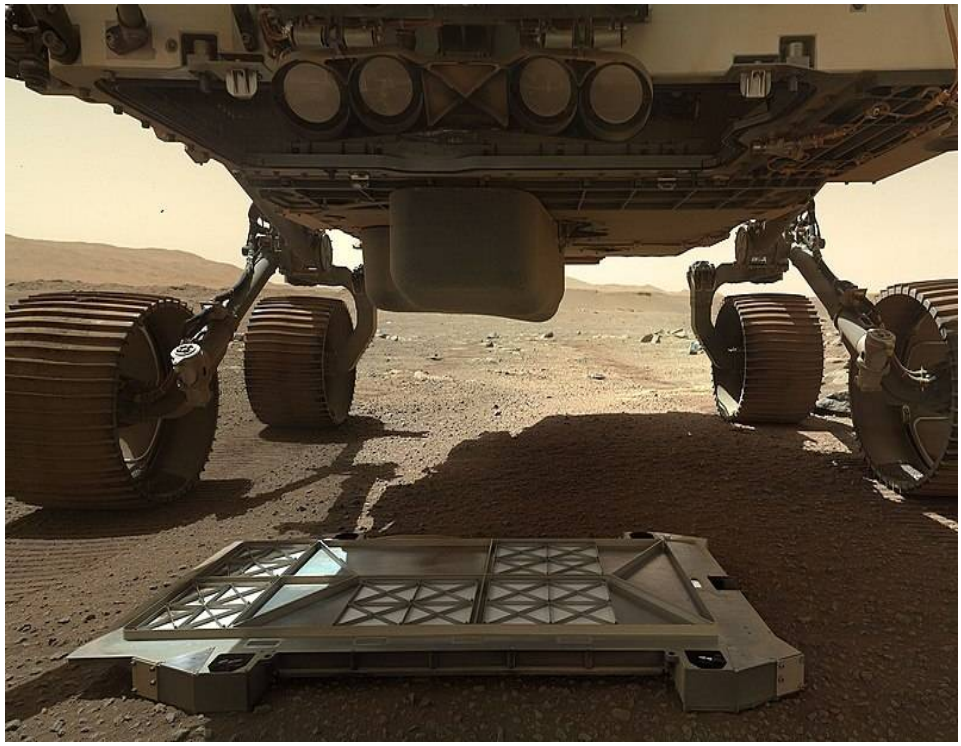
Ingenuity Helicopter's 1st Flight
(19 April 2021)

Ingenuity captured by NavCams while
it was hovering for 30 seconds in 1st flight

Ingenuity at new Airfield B (7 May 2021)[

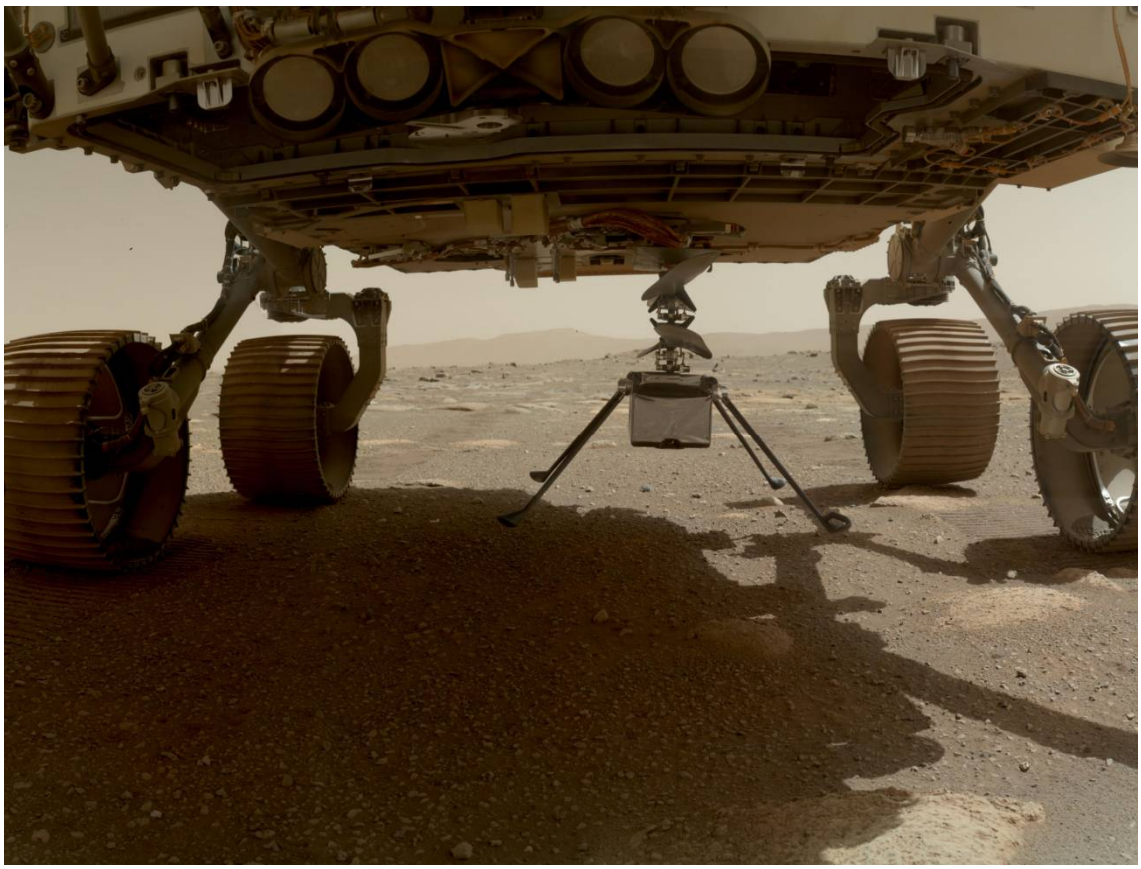


Ingenuity_Helicopter_Rotor_Blades_Unlocked_for_Flying

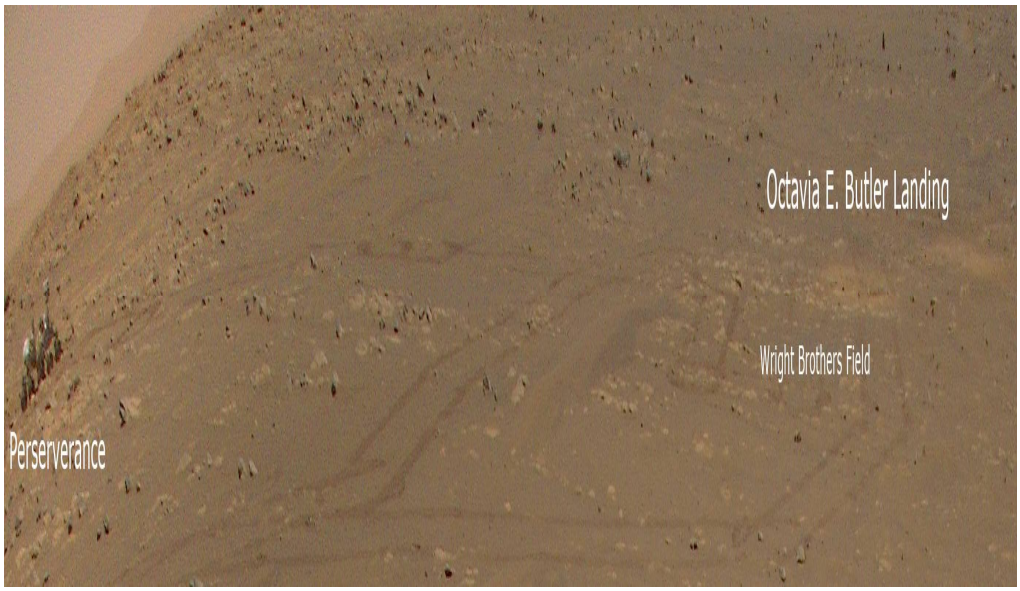


Ingenuity Stowed Inside Debris Shield at the belly of Perseverance rover
Before Separating from Rover 17 March 2021

NASA's Mars Perseverance rover
This image acquired using its SHERLOC WATSON camera, located on the turret at the end of the rover's robotic arm
Mar. 28, 2021 (Sol 37) at the local mean solar time of 14:13:16

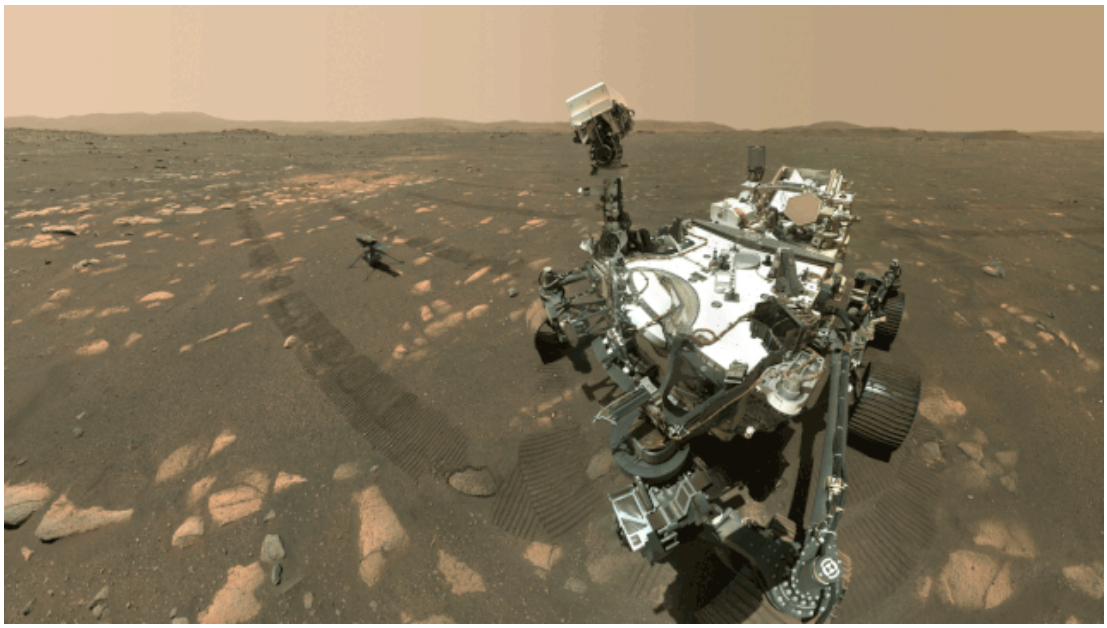


Ingenuity Helicopter with fully deployed legs (cropped) 1 April 2021

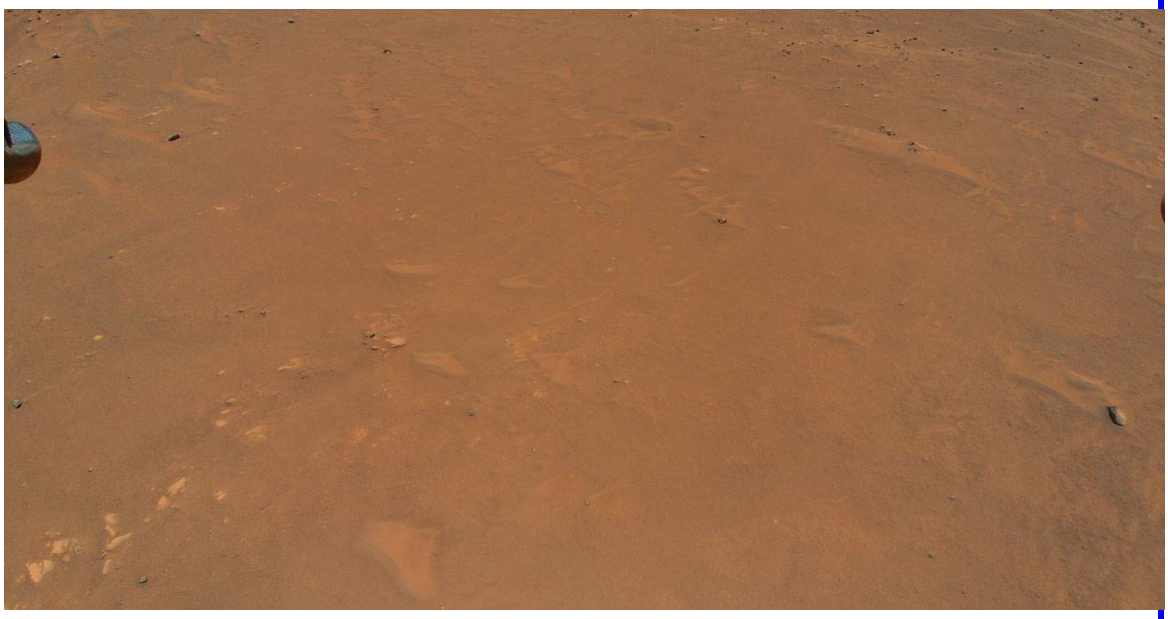


The Ingenuity helicopter views Perseverance rover (left)
about 279 ft away and 16.4 ft high in the air (25 April 2021)

Ingenuity was photographed by Perseverance
on April 7, 2021 (sol 46)



Perseverance took a Selfie of it and ingenuity with its Camera, 7 April 2021



Ingenuity fifth flight on May 7, 2021
Helicopter took this color image from an altitude of 33 feet ; Credit: NASA/JPL-Caltech.

Knowledge

K(nowledge) now (is) by (past) Learning through EDucation (tools) of Genetically evolved Species (instant live humans of 2020s)

Nature is the best chemist of all times --- F Arnold, NL in Chem 2018

KNowLab
rsr.chem1979