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Ingenuity flights (If) on Mars (oM)

Part 3[$$]: Exploratory Experimental Learning (EEL, If 10-13)

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Conspectus:

Ingenuity came into being thanks to a small but passionate team of NASA/JPL-Caltech. The personnel involved in the mega-task are experts with no pride, personal possession (PPP) frame except doing and doing work in the pursuit of truth seeking. Ingenuity helicopter, being inside womb of its surrogate mother (Perseverance rover), landed in Mars' Jezero Crater - a 28-mile-wide impact basin on Feb, 2021. It had space travel of 34 million miles covered in 204 days from USA (earth) to the red planet. The Jezerobasin, now dry was filled with water about 3.5 billion years ago. The choice of this area for 2020-Mars rover mission was based on educated/intelligent guess that microbial life should have existed in past. These explorations may open window in detecting and confirming of life-forms millions of years ago. Hi is continuing as aerial scout. It's, is like a slow-moving intelligent pedestrian performing surface exploration of rocks on Mars.

Layout	
1.	If-10
2.	If-11
3.	If-12
4.	If-13
SI	1. Image-gallery 2. Numerical Data

$$:K. Somasekhara Rao, R. Sambasiva Rao, Ingenuity flights (If) on Mars (oM),
Part 1 ; Ingenuity flew (If 1-5) on Mars (oM), J.Appl.Chem., 2021, 10 (3): 409-436 ;
Part 2 ; Operations Demonstrations (OD, If 5-9),J.Appl.Chem., 2021, 10 (4):569-589;

Introduction

Ingenuity helicopter (Hi) is the first powered vehicle to ever fly on another planet in the scientific history. The quadcopter was designed for four flights on Mars spread over 30 Martian days (called sols) as a proof of concept and technology demonstration. It does not at all have functions of an instrumental probe to do any science on the red planet. It captures black/white and colored images with two cameras during scheduled flights. The success of Ingenuity in the four flights viz IF-10 to

IF-13 even on rough terrane is a testimony for the design of chopper in surmounting unforeseen hurdles. Now, it is an inspiration for paying attention to next generation aero- copters like hexa-copter which is in the pipe line of brain-storming sessions.

Navigation system of Hi (Helicopter Ingenuity) : It was designed for relatively flat terrain. Thus, flying over Seitah South region is risky and a challenge even for a trial. Even, driving of Perseverance rover through the region is dangerous. But, with all this back drop, Perseverance rover team has keen interest in sampling rocks here to probe into water timeline and microbial life that should have existed in distant past.

Ingenuity flight on uneven terrene: The rocky or rippled land can distort its field of view of navigation system data of HI, with a consequence of veering in the wrong direction. Hence, uneven landscape is a challenge for Ingenuity.

South Seitah region: It is a rugged patch on the floor of Mars' Jezero Crater with lot of diversity. Seitah region is a home to boulders rocky outcrops, intriguing rocks and sandy ripples. JPL called this area a "geological wonder.". Based on that data, they believed the site could possibly be a treasure trove of complex geology, providing information that could play a valuable role as the rover team searches for signs of ancient microbial life and attempts to characterize the geology of the area and to understand the area's history. The success episodes and outcome that guides future ventures follow.

Ingenuity flight-Ten: Hi soared over a rocky region called "Raised Ridges" in Jezero Crater. Thus, this flight is nerve-wracking as Hi flew at higher altitude (39 ft), covered more horizontal distance from take-off point (764 ft) and moved with faster speed (11 mph). Further, it surpassed the 1-mile (1.6 km) mark of its total flight distance on Saturday (July 24). Hi photographed images of low-lying wrinkles, or "Raised Ridges," in the crater's surface. They may reveal new clues about Mars' watery past.The goal of flight 10 is to obtain stereo imagery of some geologic features of interest to the Perseverance rover science team.

Tenth Ingenuity flight	24th July, 2021	21:07	Sol 152
Operations			
Takeoff from	Airfield F (Landing spot of 9th flight)	18.42809°N	77.44545°E
Rose vertically	39 ft		
Loop	South and west overRaised Ridges to Airfield G		
Heading changes	Four		
Horizontal motion	764 ft (with directional changes)		
Max speed	11 mph		
Flight time	165.4 seconds		
Landed	Airfield G	18.42808°N	77.44373°E
Flight	One way		
waypoints	10 including takeoff and landing		
High resolution color images	At all waypoints		
Start of	**Exploratory Experimental Learning (EEL)**		
Ingenuity flight – 10	**Success**		

Ingenuity flight-Eleven: This one-way trip on Thursday morning (Aug. 5) ended in landing in a new airfield which is nearer to the rough terrain of the South Séítah region. From here, Hi can support the Perseverance rover by obtaining imagery of geologic features in the rough terrain of"South Seítah" area.

Eleventh Ingenuity flight	5th August, 2021	04:53	Sol 163
Operations			
Takeoff from	Airfield G (landing spot of 10th flight)	18.42808°N	77.44373°E
Rose vertically	39 ft		
Shift	North-westto Airfield H(South Séítah region)		
Horizontal motion	1,250 ft		
Max speed	11 mph		

Flight time	130.9seconds		
Landed	Airfield H	18.43278°N	77.43919°E
Flight	One way		
waypoints	10 including takeoff and landing		
High resolution color images	At all waypoints		
Continuation of	**Exploratory Experimental Learning (EEL)**		
Ingenuity flight – 11	**Success**		

Ingenuity flight-Twelve:

The success of twelfth flight over South Séítah(with risky terrane) for the little choppernow showcases that an aerial vehicle can act as a valuable scout for a ground-based rover avoiding traversing in potentially dangerous arenaalthough interesting. It also ensures higher efficiency and safety. Flight 12 covered 1,476 feet of Martian ground in 169.5 seconds and took 10 color pictures (again – all pointed northeast).helicopter just got a glimpse of during flight 12.

TwelfthIngenuity flight	16th August, 2021	12:57	Sol 174
Operations			
Takeoff from	Airfield H (Landing spot of 11th flight)	18.43278°N	77.43919°E
Rose vertically	33 ft		

Route & operations	☞ Hover ☞ shift east-northeast about 771 ft ☞ moved to the side 16 ft to get side-by-side images ☞ hover **returntrip** ☞ Keeping it's camera in the same direction, it flew back to the takeoff point ☞ hover ☞ land again at Airfield H
Horizontal motion	1,480 ft (Round trip)

Max speed	11 mph		
Flight time	169seconds		
Landed	Airfield H	18.43278°N	77.43919°E
Flight	Round trip		
High resolution color images	10 color images Camera pointing northeast		
	To help Perseverance scientists decide which features will be worthy of more study		
Continuation of	**Exploratory Experimental Learning (EEL)**		
Ingenuity flight – 12	**Success**		

Ingenuity flight-Thirteen:

Flight 13 of Ingenuity, overachieving chopper, was planned to probe into more details of information obtained from images of the 12th flight. Ingenuity was flying,in Flight 13, at lower altitude, for larger time spell and at lower speed compared to these parameters in twelfth flight. The images were captured pointing southwest while in previous flight, the camera was seeing northeastfor recording pictures. A lower altitude photography results in more depth and height information and larger time of recording outputs more details. Flight-13 covered 690 feet horizontal distance in around 161 seconds and snapped 10 color images (pointing southwest). Hi spent more than 193 Mars days by 4th September, 2021 in operation since deployment.

The image data from 12th and 13th flights were combined which provide an insight for Perseverance rover scientists and drive planners for forth coming flights. The functional activity of Hi now rendered it to be a tool for Perseverance rover in foreseeing terrane characteristics for smooth journey with minimum hurdles. It snapped 72 13-megapixel color images and 1390 black-and-white navigation camera images.

The 3D-images impart a feel of one reaching and touching raised ridges. However, The processes that led to curious lines across the surfaces of the rocks is yet a mystery. One educated guess is they are made by eons of wind and dust blowing over the rocks. The other one is they speak of story of water on Mars over geological time scales to unveil signs of ancient life on the red planet

Thirteenth Ingenuity flight	4th September, 2021	12:57	Sol 193
Operations			
Takeoff from	Airfield H (Landing spot of 12th flight)		
Objective	Concentrated on one particular ridgeline and outcrops in South Séítah		
Rose vertically	26 ft		

Route	☞ northeast for about 344 ft **return phase** ☞ landed again at Airfield H
Horizontal motion	690 ft (Round trip)
Max speed	7.3 mph
High resolution color images	10 color images Camera pointing southwest

Flight time	161seconds		
Landed	Airfield H	18.43268°N	77.43924°E
Flight	Round trip		
Continuation of	**Exploratory Experimental Learning (EEL)**		
Ingenuity flight – 13	**Success**		

Next flight(s) (If>13) plan: In the coming weeks, Ingenuity would involve in reconnaissance flights of South Séítah, a geologically interesting area for the Perseverance Rover science exploration schemes. The present activity with remote-controlled robotic machines will pave way to next decade's human-led missions. From now onwards, there is a scope for the robotic duo to work with each other leading to discoveries not dreamt off.Ingenuity (an unexpected miracle) will scout potential areas to reach the goal and filters risky terrane trips for Perseverance leading to win-to-win mechanism.

Future aerial craft technology (Fact) on Mars (oM): The second-generation MARS helicopters stretch the wings of Ingenuity both in architecture and functions. The flier will be developed on hexacopter platform. This is "Mars Science Helicopter" concept now on the table. Tzabetos, Robotics Technologist, says that it is not an official NASA mission.

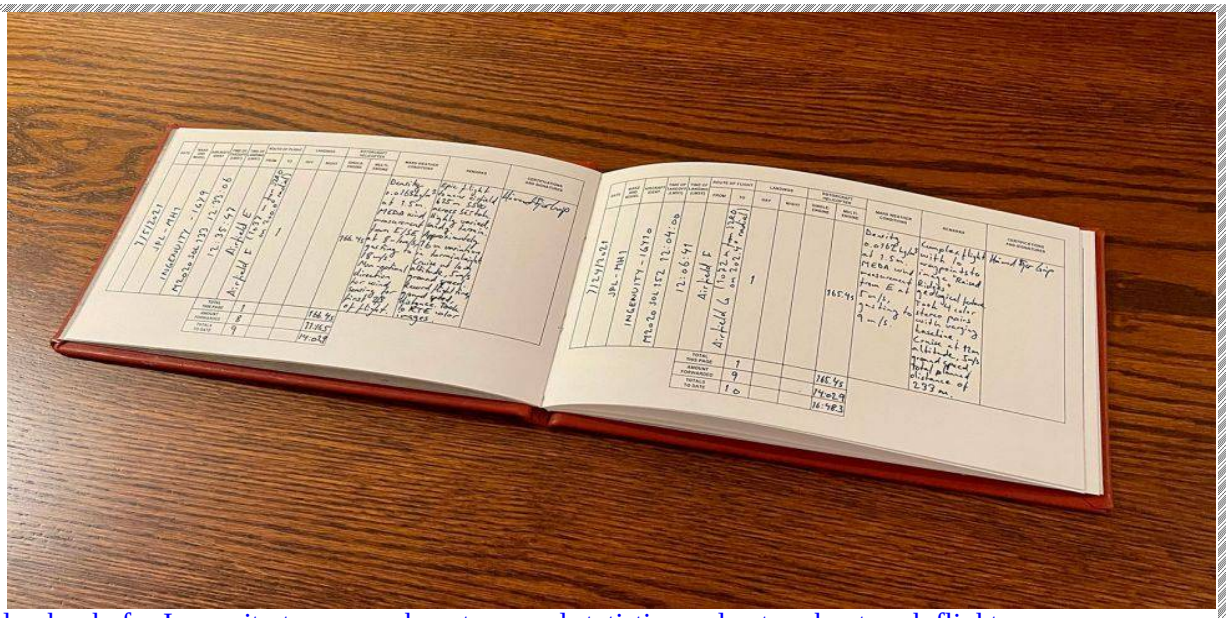
The rotor craft weighs 30 Kgs and carries 5 Kgs of scientific instrumental probes. It will cover 10 Kms per sortie and flies at higher heights. It traverses through cliffside walls, enter into deep caves and flies over difficult-to-traverse terranes. Now all these locations are inaccessible for rovers including Mars2020-Perseverance.

The hexacopter and its later advanced versions blow open the doors for truth seeking and mind-blowing adventures of human exploration of Martian environment, life in the past, feasibility of future scientific feats of increasing oxygen. They culminate into inventions, now not even imagined and new discoveries in the solar system and interstellar space of Universe. New (true) chemistry, physics, biology and applied sciences are side dishes of science of science in the main course of moving tangential to nature of nature.

SI: Supplementary Information
Image-gallery
Credit : NASA.Gov
Credit: NASA/JPL-Caltech -

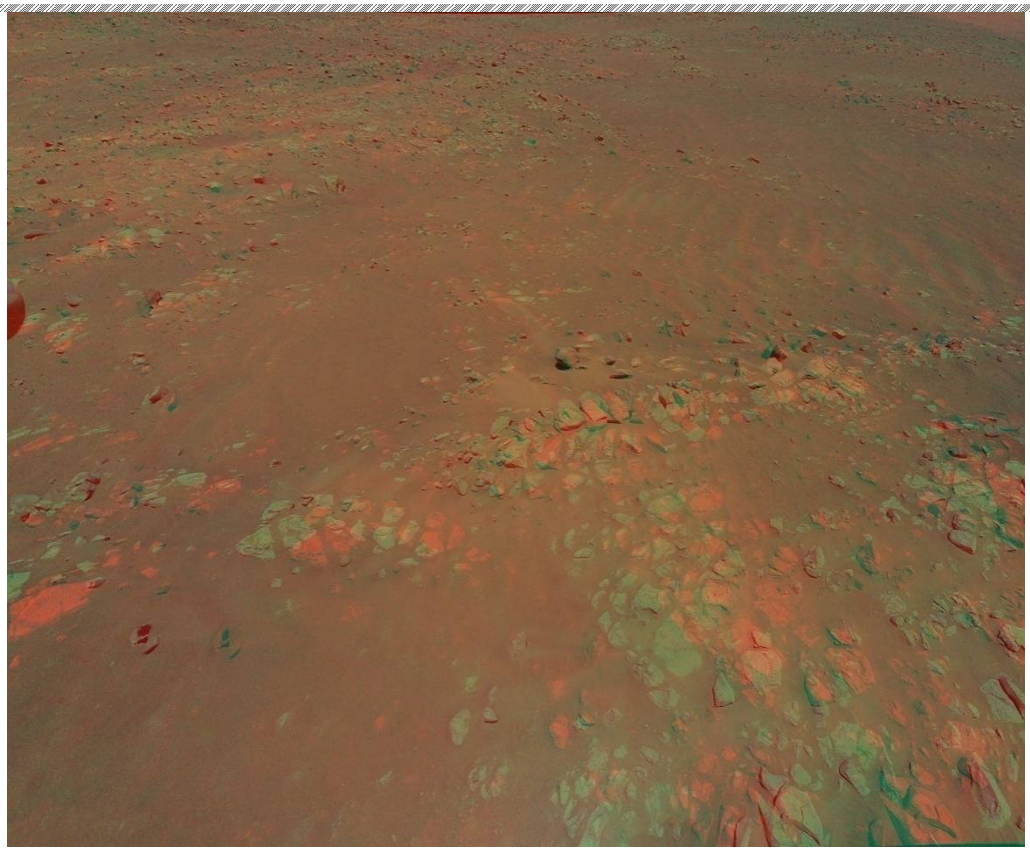
Ingenuity helicopter (Hi) sitting where the Perseverance rover dropped it, on April 5, 2021

Ingenuity flight-10

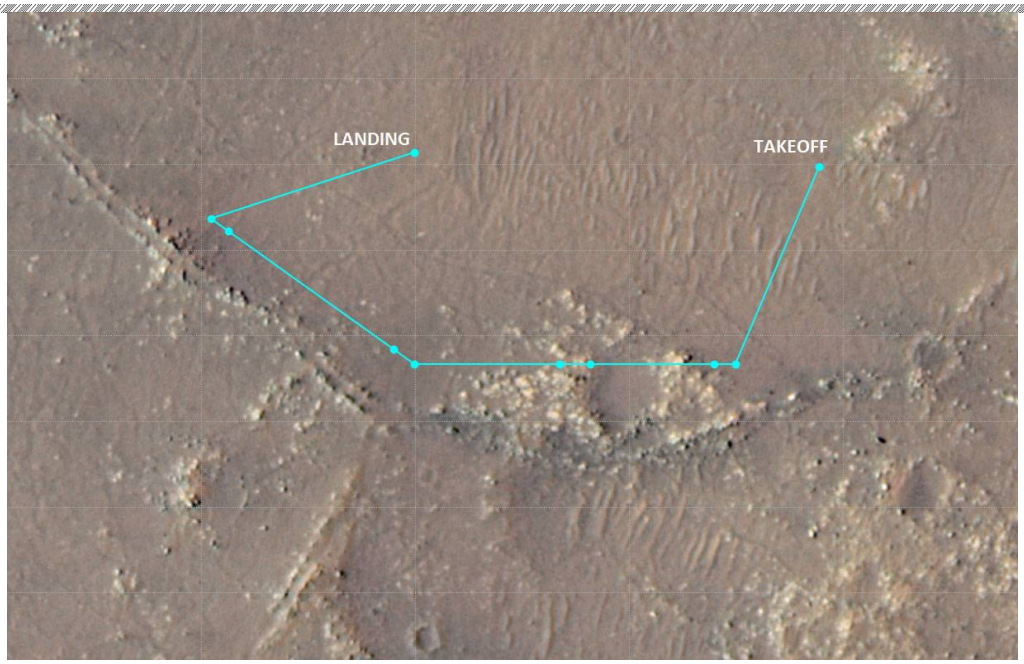


log book for Ingenuity team members to record statistics and notes about each flight ; this spread shows the entries for the helicopter's ninth and 10th flights.

Ingenuity sees its shadow during its 10th flight on July 24, 2021.



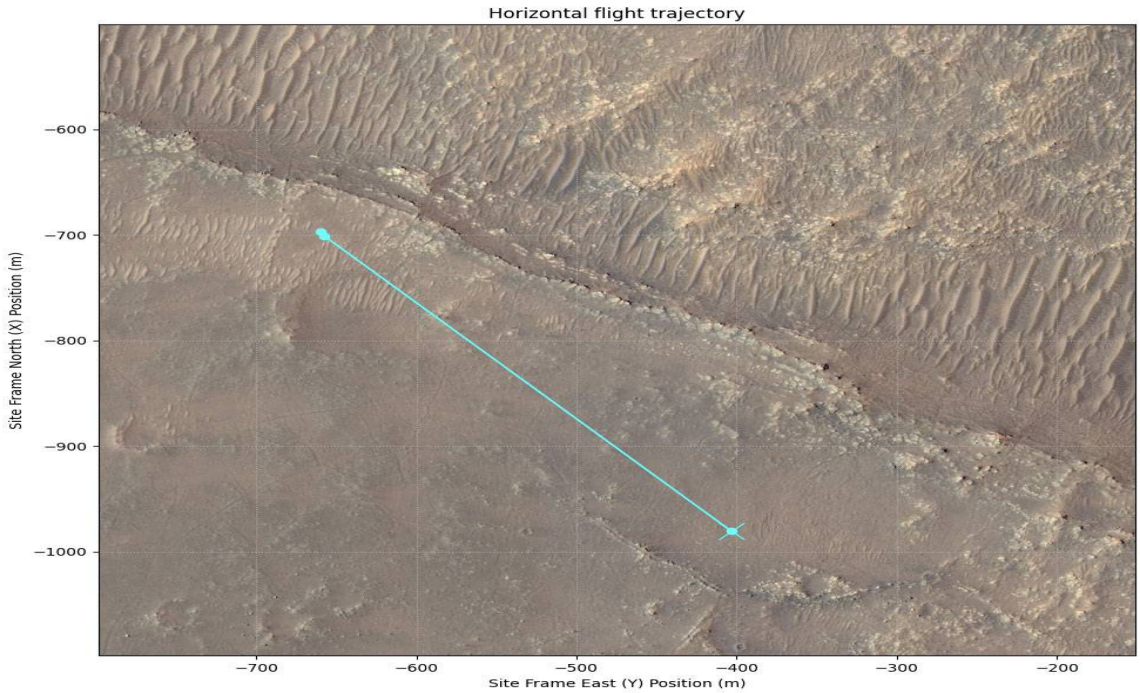
- 3D view of an area during its 10th flight at Mars on July 24, 2021
- Image was created by combining data from two images taken by the RTE camera aboard
- Ingenuity was at an altitude of 40 feet.



Ground track and waypoints of 10th flight plan

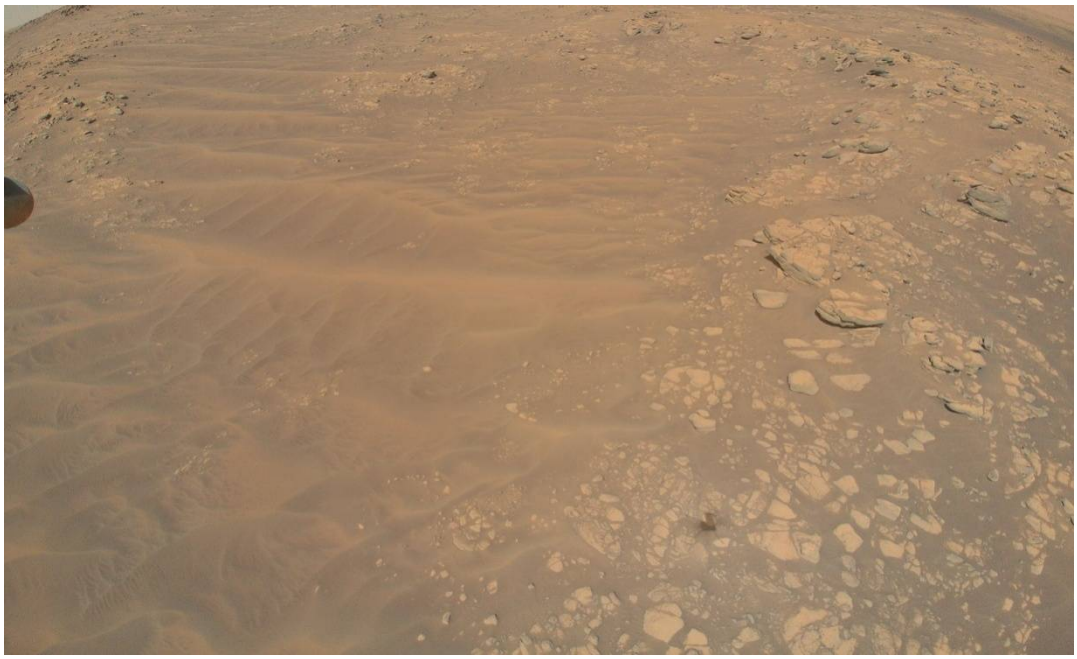
Raised Ridges; 10th flight July 24, 2021

Ingenuity flight-11

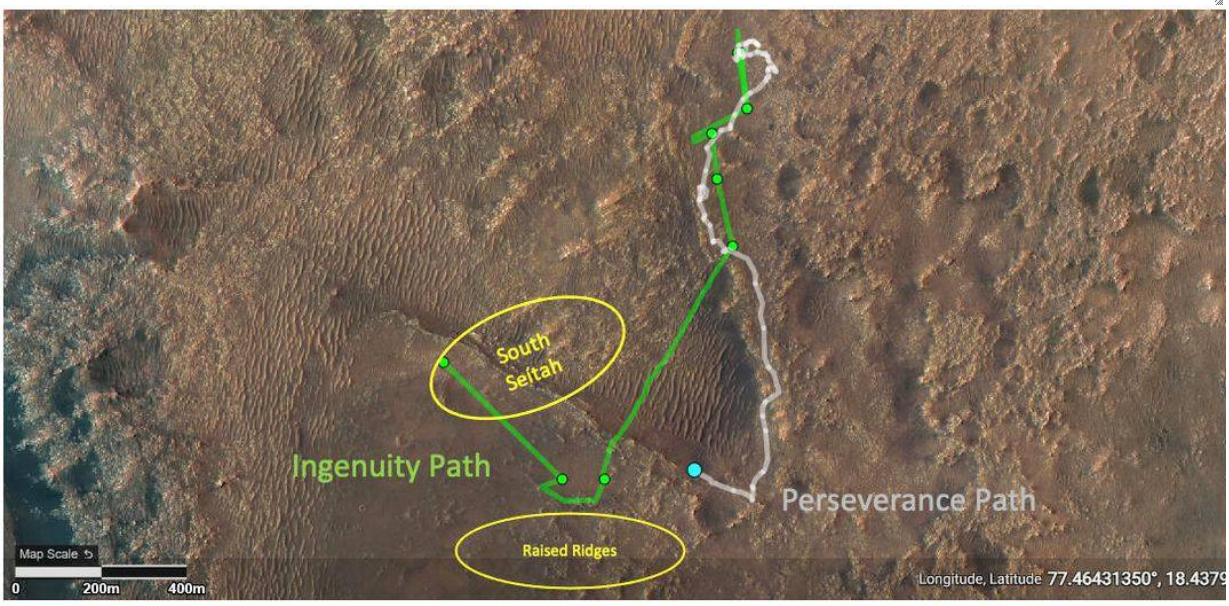


- Ground track and waypoints planned for 11th flight,
- Takeoff :pale blue dot on the lower right; new landing site: upper-left dots
- Terrain imaged by the HiRISE camera aboard NASA's Mars Reconnaissance Orbiter

Ingenuity flight-12

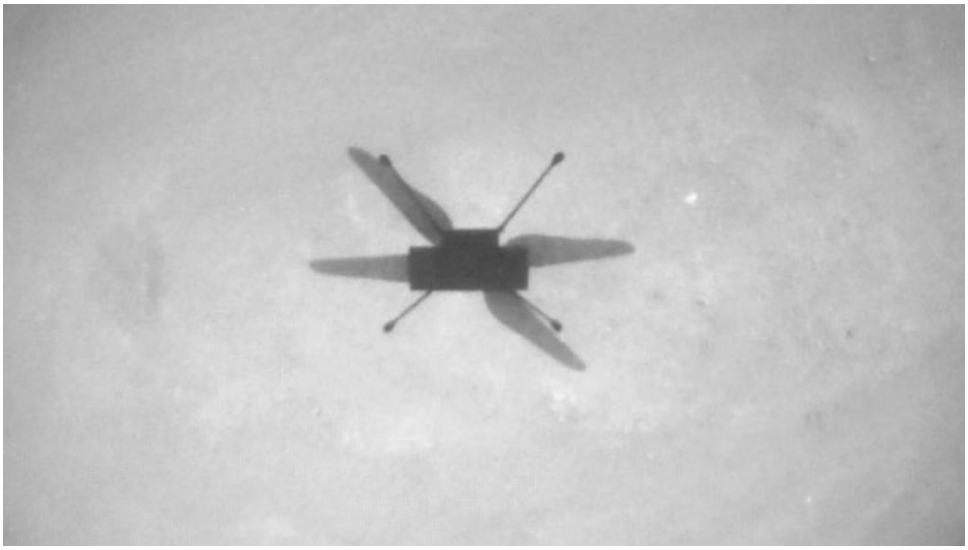


- ✓ Image of sand dunes, boulders, rocky outcrops of “South Séítah” region of Mars’ Jezero Crater
- ✓ Captured byHelicopter during its 12th flight, on Aug. 16, 2021



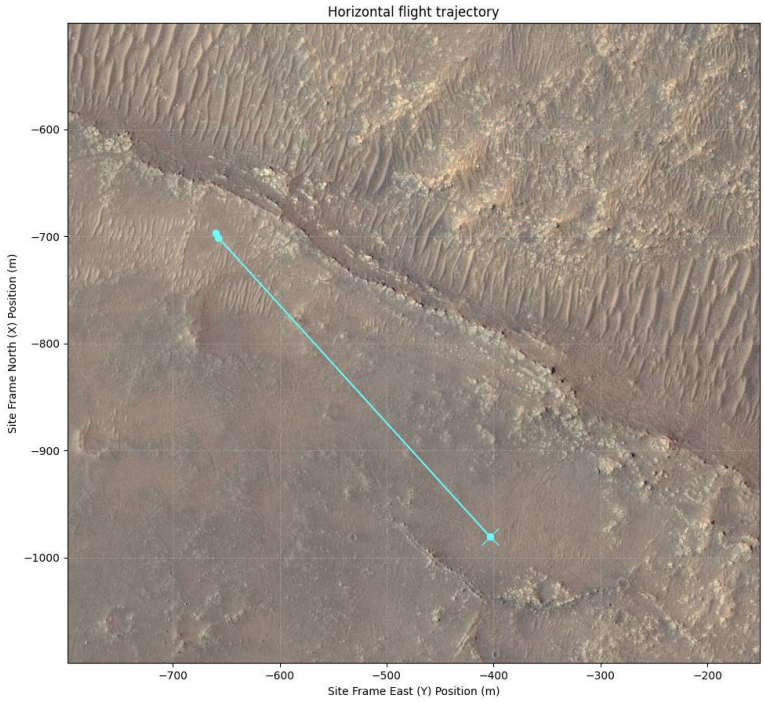
Gray: path of the Perseverance rover; green: Ingenuity helicopter
Hi aims to get a look at South Seitah for its 12th flight.

Ingenuity flight-13

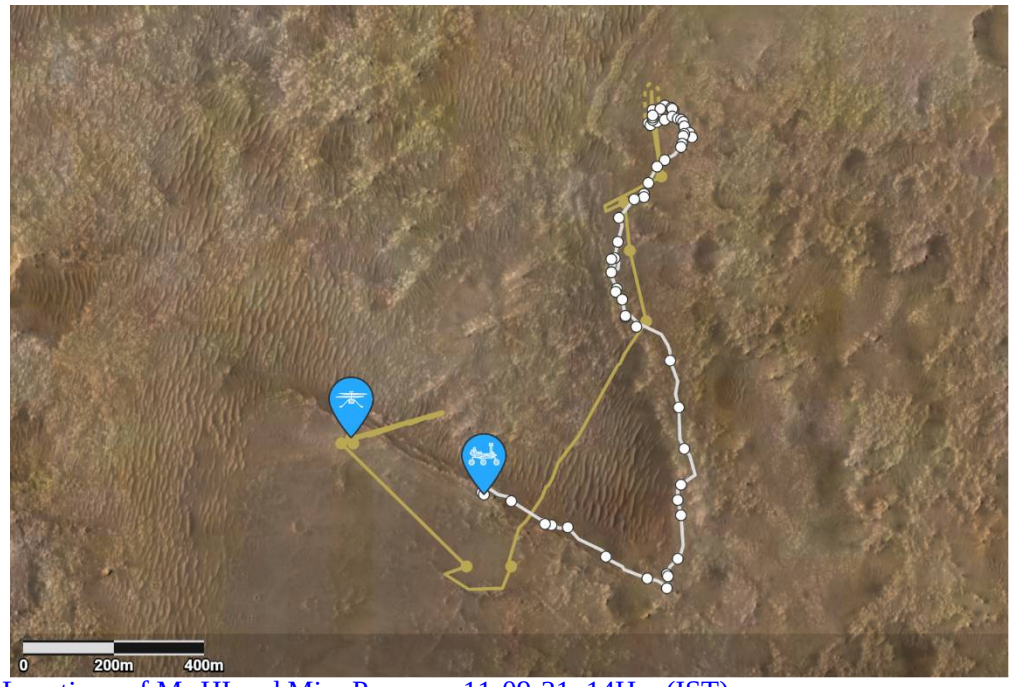


Mr Hi spotted its own shadow during its 13th flight

Mr. Perseverance rover caught sights of its chopper buddy on Sept. 4, 2021during 13th flight



13th flight of Hi -- Horizontal trajectory



✓ Locations of Mr HI and Miss Percy on 11-09-21: 14Hrs (IST)

robotic duo ***Mr. Ingenuity and Miss Percy***

Contemplated Mars Science flier hexacopter

✓ Weighing 30-kilogram)	✓ Capable of traveling up to 10 Km per flight
✓ Carrying five kilograms of science payloads	

SI: Supplementary Information-2
Numerical Data

Credit : NASA.Gov

Credit: NASA/JPL-Caltech -

Timeline of Ingenuity flight Schedules (Ifs)

Eel (Experimental exploratory learning)

Flight	Sol	Date	Time
10	152	24th July, 2021	21:07
11	163	5th August, 2021	04:53
12	174	16th August, 2021	12:57
13	193	4th September, 2021	12:57

Flight	Sol	Date
Demonstration. Technology		
1	58	April 19, 2021
2	61	April 22, 2021
3	64	April 25, 2021
4	69	April 30, 2021
5	76	May 07, 2021
Operations. Demonstration		
6	91	May 22, 2021
7	107	June 08, 2021
8	120	June 21, 2021
9	133	July 5, 2021

Sol: Martian Day starting with Ingenuity landing on MARS

Date: Calender on Earth ; Time:

Hi! Man

[Helicopter ingenuity Mars NASA]

Lab/Institute/Inc.	Function	Contribution
JPL	Built	Ingenuity Mars Helicopter
JPL	Manages	Technology demonstration project for NASA Headquarters
NASA's ☞ Science, ☞ Aeronautics Research ☞ Space Technology mission directorates	Supports	Project
☞ NASA's Ames Research Center in California's Silicon Valley ☞ NASA's Langley Research Center in Hampton, Virginia	Provided	During Ingenuity's development ✓ Significant flight performance analysis ✓ Technical assistance
☞ AeroVironment Inc. ☞ Qualcomm ☞ SolAero	Provided	Design assistance and major vehicle components
☞ Lockheed Martin Space	▪ Designed ▪ manufactured	Mars Helicopter Delivery System

https://youtu.be/Q75HetU57A?list=PLTiv_XWHnOZpzQKYC6nLf6M9AuBbng_O8

Watch NASA's Ingenuity Mars Helicopter Fly in 3D

534,694 views,May 12, 2021

Nature Creates, invents, Discovers, sustains and destroys	KLab rsr.chem1979