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Sampling in Mars (Sim) Jezero crater [(1)]

Part 1: Mars rock sample (Mrs)Perseverance collection-1(PC-1)

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Conspectus:

Mars-2020-Rover (Mr-2020)), a part of NASA Moon-to-Mars-Exploremission, landed on Mars Jezero crater on 18thFeb.2021. The given name was Perseverance (with pet name Percy or Mr.Percy) The launching was on 30thJuly, 2020, at 7:50 a.m. EDT f rom Launch Complex 41 at Cape Canaveral Air Force Station, Florida. Mr.Perseverance was launched on an Atlas V-541 rocket, one of the largest rockets available for interplanetary flights. Miss(Mars informative (intelligent) science system). Percy carried Ingenuity (first powered helicopter of 1.8 Kgs with four rotors) in its womb all the way from earth to Mars for feasibility study of flying on Mars with at extreme hostile temperatures, thin atmosphere and treacherous dust devils.

Helicopter Ingenuity (Hi) made the debut flight (IF-1) on April 2021 with a sequence of steps viz. Take-off from Mars surface -flying vertically 10 feet – hovering–landing by touching the ground surface. It covered zero feet of horizontal distance during flight. This historic achievement of powered robotic Chopper (without human intervention) flying for 39.1 sec on another planet in our solar system was a great gratification to the scientific-team at JPL-Caltech/NASA. Perseverance had functions all through the flight schedule (IF1 to IF9) of Ingenuity, the first being imaging of complete flight from take-off to landing. The other master piece job is to be not far away from ingenuity.

Perseverance started its preparations for executing exhaustive test bed of operations, functions of command-control chores, its science-doing modules, robotic operations of drilling holes, filling sample tubes with rock and regolith, sealing samplers and storing them back in their place. The first sampling operation was not successful in August 2021. The rover moved to a new area called "Citadelle". And SCS successfully filled the sample tube with Mars rock powder in this attempt in the first week of September, 2021.

	Layout
1.	**Moon Exploration missions (Mem)**
2.	**NASA's Moon to Mars exploration (MME)**
3.	**Mars exploration (ME)**
4.	**Perseverance (Miss/Mr/Mrs Percy)**
5.	**Failure in First Rock sample (FRS) on Mars (Om)**
6.	**Successful Collection of First Rock sample (FRS) on Mars (Om)**
7.	**Sample Caching System**
8.	**Future course of action -- Mars mission**
9.	**Appendices**

1 Moon Exploration missions (Mem): Of the twelve America's moonwalkers (the first two being astronauts of Apollo 11, NASA), four of are still alive. They are Aldrin (Apollo 11), David Scott (Apollo 15), Charles Duke (Apollo 16), and Harrison Schmitt (Apollo 17). Now, Artemis is an ongoing space mission run by NASA first crewed Moon mission since Apollo 17 in 1972. The target of Artemis mission (AM) is landing the first female astronaut and next male astronaut on the Moon's South Pole by 2024.

Apollo 8 (December 21–27, 1968): In the NASA propelled space exploration mission (SEM), Apollo-8 was the first human crewed space craft to leave low Earth orbit. Also, it is the first human spaceflight to reach another astronomical object, namely the only one-Moon-of-earth. The three astronauts—Frank Borman, James Lovell, and William Andersorbited the moon in Apollo-8 without coming out or landing on the celestial body. The Apollo-8 mission ended with success and peace reaching motherland on our planet earth.

Apollo 11: The spacecraft with three astronauts, Neil Armstrong, (Command Module Pilot), Michael Collins (Command module pilot) and Edwin Buzz Aldrin (Lunar ModulePilot) blasted off towards the Moon on July 16, 1969. After four days, travelling 240,000 miles, Eagle lunar landing module, guided manually by Armstrong, touched the surface of moon. The landing site is on a plain near the southwestern edge of the Sea of Tranquillity (Mare Tranquillitatis). On 20th July, 1969, Armstrong stepped off the ladder onto the lunar surface, communicating his voice message ("That's one small step for (a) man, one giant leap for mankind.") back to Earth. This happened he being a commander of space ship. Aldrin followed Armstrong down the ladder20 minutes later. Two astronauts collected Moon rocks and brought the samples for analysis in laboratories. They walked upon it, installed scientific instruments and snapped many photos. They collected 21.6 kilograms of surface material, including 50 rocks, samples of the fine-grained lunar regolith (or "soil"). Also, two core tubes that included material from up to 13 centimeters below the Moon's surface were in the collection. Interestingly, they had a meal, slept for a few hours (nap) and rejoin Collins and the CSM in lunar orbit.

The trio returned from moon-orbit and reached safe to mother-Earth after splash down landing in Pacific Ocean about 800 nautical miles southwest of Hawaii and 12 miles from the recovery ship, the USS Hornet. The clock time elapsed for ever-memorable Apollo-11 journey from launching to landing was eight days, three hours, 18 minutes and 35 seconds.

The knowledge is instrumental in enduring scientific advancement and had impact in many fields of human endeavor. The name of Armstrong remains forever in annals of space book written on pages of time with golden nib as first person ever to plant boots on lunar surface, of course dusty.

2. NASA's Moon to Mars exploration (MME): Mars 2020 Perseverance mission is a current project and is part of MME approach. It includes Artemis (2024) missions to the Moon that will help to prepare for human exploration of the Red Planet.

3. Mars exploration (ME) : Curiosity and Perseverance are on-going NASA's missions exploring Mars. Perseverance rover with Ingenuity helicopter in it was launched on July 30, 2020. The self-driving six-wheeled robot after a 203-day journey of traversing 472 million kilometers landed on the red planet at Jezero Crater floor on February 18, 2021. The crater harbored a big lake and a river delta in the ancient past. This mission is first-of-its-kind to collect and cache Martian rock and regolith (broken rock and dust) in ultra-clean titanium-sample-tubes. The ulterior motto is achieving greatest benefit to humankind by seeking evidence for signs of ancient life on Mars.

4. Perseverance (Miss/Mr/Mrs Percy): The configuration of Perseverance is based on Mars Science Laboratory's Curiosity rover of 2012. Mr. Percy is a robotic Geo-scientist. The Superman is a car-sized, about 10 feet long (not including 7 feet protruding robotic arm), 9 feet wide, and 7 feet tall, machine weighing 1,025 kilograms. This rover hosts set of state-of-knowledge-instruments and Sample Caching System (SCS), besides oxygen manufacturing unit from carbon dioxide [2,3]. Perseverance appears to be like one robot for a naked eye. But an expert perceives it as acollection of ensemble robots, sensors, cameras, diverse electronic gadgets working together in Mars-2020 rover with clock precision through his third eye. Tracing all eventual possibilities, hurdles, hazards and solutions for tasks is herculean job in real sense. But all most all have been tried first in JPL, NASA. If they don't work, the work flow was changed, altered or new one adopted because, no change is possible after launching of rover.

Lunar Exploration Timeline (Let) –This decade

2021		
SELENE-3	2021	Orbiter and Lander with Rover plus sample return ascent vehicle
Luna 26	2021	Orbiter
2022		
Luna 27	2022	Lander
Artemis II	2022	Orbiter
2024		
Artemis III	2024	Lander
2026		
Luna 28	2026	Lander
2028		
Luna 29	2028	Lander

Metaphorically, rover modules are comparable in function to any living creature. On board Scientific instruments (MEDA, MOXIE, PIXL, RIMFAX, SHERLOC) and 23 state-of-art-cameras (Mastcam-Z) view all (Siva) around and inside Martian rocks using different ranges of electro-magnetic radiation. This is, of course without need to collect the samples. The role of astronauts in Apollo-11 mission, is now played by Miss (Mars intelligent sampling system) Perseverance in reaching sampling site, drilling holes in rocks, sampling, sealing and storing. It carries out most complex operations in cleanest manner ever done on either on our mother earth or ano, ther planet.

Rover journey from landing site to sampling spot

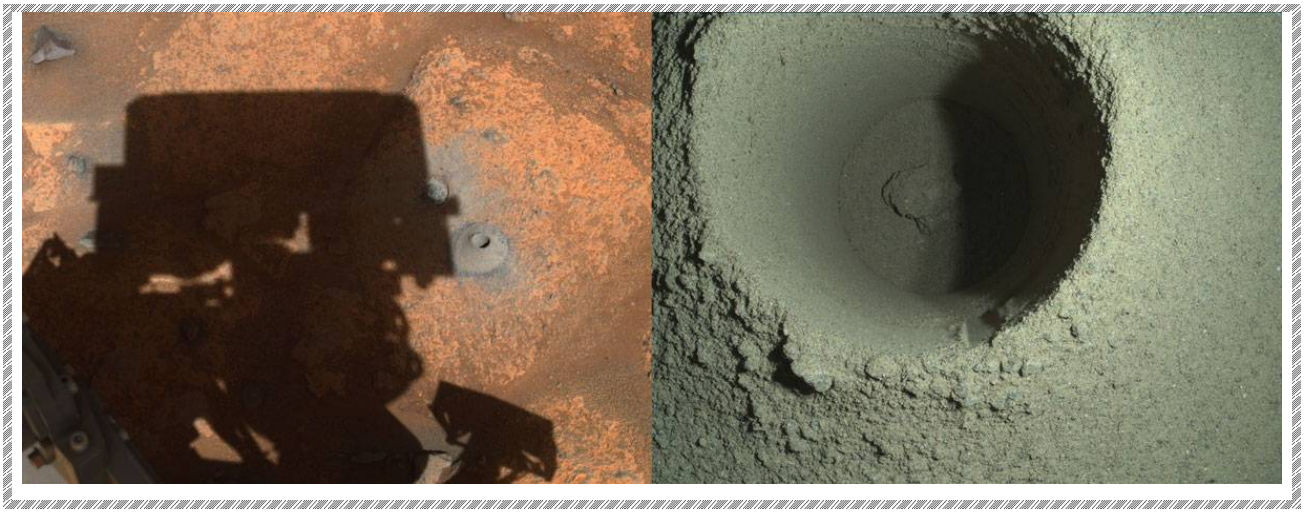
Mr. Perseverance moved towards south from landing site "Octavia E. Butler".

Journey of Perseverance across the floor of Mars' Jezero Crater since landing on Feb. 18, 2021 .Imagegrapher : High Resolution Imaging Experiment (HiRISE) aboard NASA's Mars Reconnaissance Orbiter ; September 10, 2021

5. Failure in First Rock sample (FRS) on Mars (Om): It's attempt to collect rock sample from at a drill hole called "Roubion" in first week of August was a failure.

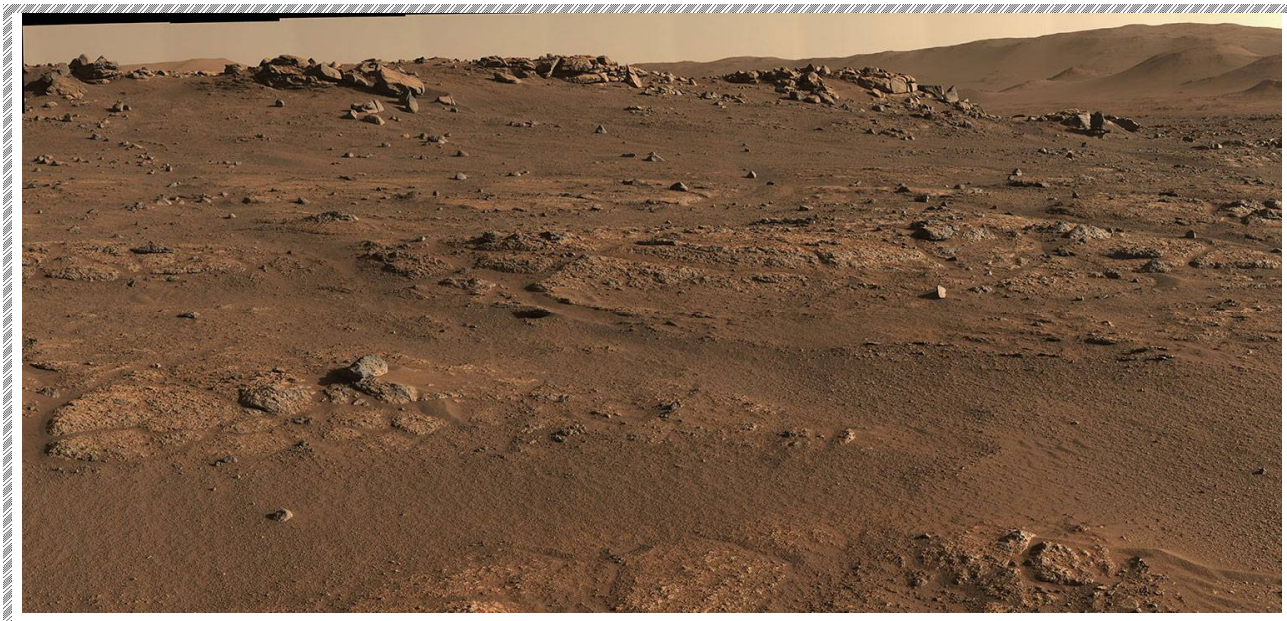
Failure of
First rock sampling on Mars with Percyusing SCS

Credit: NASA/JPL-Caltech



Left: Drill hole from Perseverance's first sample-collection attempt and shadow of the rover; borehole: 2.7 centimeters in diameter. image-grapher: rover's navigation camera
Right image ;: composite image of Perseverance's first borehole on Mars; generated using multiple images taken by the rover's WATSON imager

Credits: NASA/JPL-Caltech/MSSS.



Roubion - The Problematic Weathered Paver Stone Perseverance Failed to Core

Log book of operations and outcome in

Failed rock sample collection (FRSc)

JPL communicated to Perseverance

- Commands for sol 164
  For task:target Roubion; first sample acquisition

Percy to JPL

- After few hours (At 2 AM PDT, 6th August, 2021)
- First data from the coring operation
  - ✓ Corer had achieved the full commanded depth (7 centimeters)
  - ✓ Image of the hole on Mars surrounded by the cuttings pile (material produced around the borehole during coring)

JPL

- ✓ Human Expert scientists (**HEs):**seen image; So far, so good

- About 6 hours later

Percy to JPL

- Engineering telemetry
- An image from the CACHECAMinside the Adaptive Caching Assembly (ACA, the tube processing hardware)

✓ Transferred the sample tube from the Corer to the ACA

JPL

✓ **HEs**:confirmed

Percy to JPL

✓ Sealed the sample tube
✓ Successfully placed it in storage –

JPL

! **HEs**:a huge first-time success
! The team was elated.

Percy to JPL

? Volume measurement and post-measurement image arrived indicating that the sample tube was empty

JPL

- Reality is no rock- in sample tube

🕮 Team quickly transitioned to investigation mode

? It is the basis of science and engineering

☞ **HEs**: After two days ---
☞ Combing data and adding more observations

☞ **HEs**:
▶ **Inferences**
✓ Corer performance during both the abrasion and coring activities: There are no unusual responses. The comparison was made with data from successful Earth-based testing (> 100 cores drilled in a range of test rocks
✓ Some material is visible in the bottom of the hole.
✓ The material from the desired core is likely either in the bottom of the hole, in the cuttings pile, or some combination of both.
✓ No clear-cut furtherdistinction due to measurement uncertainty

? **Opinion**: Science and engineering teams believe that the uniqueness of this rock and its material properties are the dominant contributor to the difficulty in extracting a core from it

✓ It appears that the rock was not robust enough to produce a core.
✓
? Conclusion:The hardware performed as commanded but the rock did not cooperate this time

JPL future plan of Percy activity

✓ Head to the next sampling location in South Seitah,

- the farthest point of this phase

✓ **Hope:**Based on rover and helicopter imaging to date, there is a likelihood tocome across sedimentary rocks there that are anticipated
- They will align better with earlier Earth-based test experience.

Small failure but big success! or **Small success but big failure?**
- ✓ A specific result is never guaranteed no matter how much one prepares
- ✓ Science and engineering have progressed
  - First complete autonomous sequence of sampling system on Mars within the time constraints of a single Sol. achieved
- ✓ Positive thinking: This bodes well for the pace of remaining science campaign

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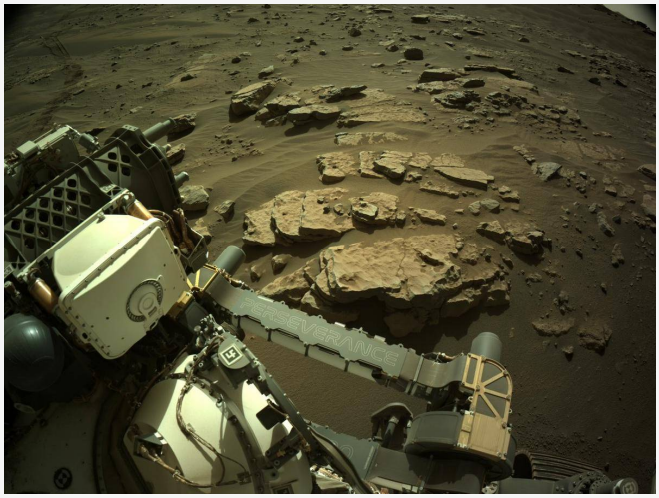
Credit: Chief Engineer for Sampling & Caching at NASA/JPL

The task of Mrs.SCSis 'not the hole-in-one' typeactivity, and it is breaking new ground in fact. Thus, risks and failures are passing clouds in nature's course. The post-mortem investigations brought to light many eye-opening bits of knowledge, one being that rock material was too crumbly to provide a core sample. Telemetry data revealed that the drill and bit were engaged as planned, post-coring the sample tube was processed as intended, and even moved to seal area. But no rock was collected during the initial sampling activity. There are many such great surprises in Mars exploration in yesteryears.

Earlier similar dead-ends, road-blocks traffic-jams: In 2008, the Phoenix mission sampled soil that's "sticky" and difficult to move into onboard science instruments.Multiple tries of course resulted in success. Curiosity has drilled into rocks that turned out to be harder and more brittle than expected. The heat probe on the InSight lander, known as the "mole," was unable to penetrate the Martian surface as planned.

6. Successful Collection of First Rock sample (FRS) on Mars (Om): Mr. Perseverance started the walk towards northwest along "Artuby" ridge and reachedthe area "Citadelle".

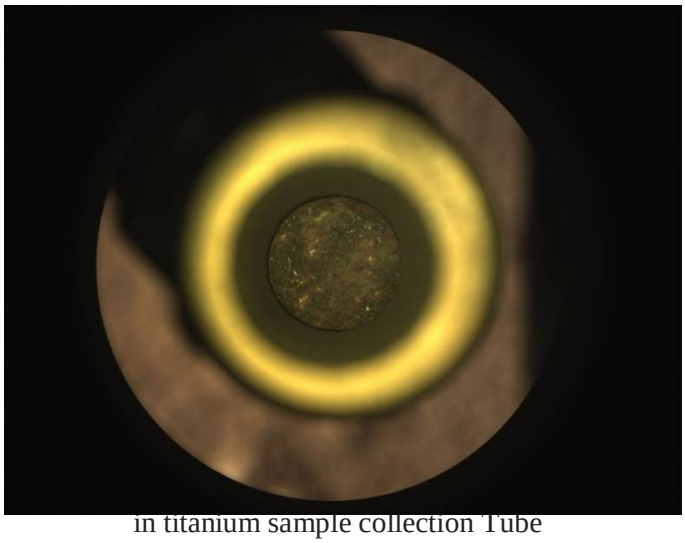


On the Road Again: Perseverance Heads to South Séítah

The first core was tried from a block of rock named Rochette," at the drill hole called "Montdenier". NASA scientists confirmed the successful sampling operation from several images transmitted to ground (earth) station by Mr. Percy.

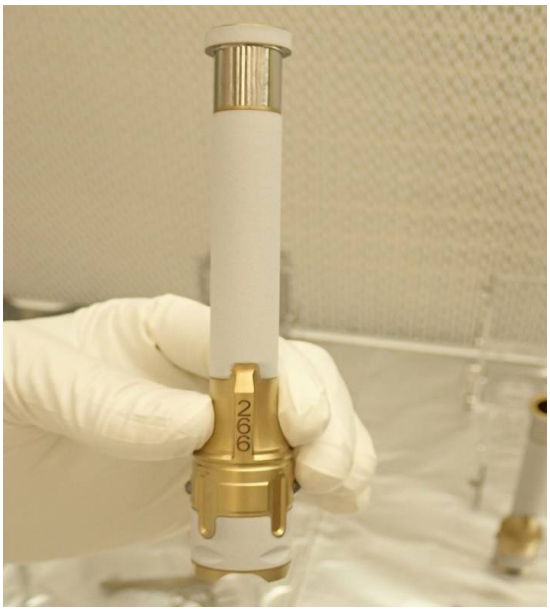
Perseverance's First Cored Mars Rock

Credits: NASA/JPL-Caltech



in titanium sample collection Tube
(image taken on Sept. 6, 2021)

sealed inside its titanium container tube
(image taken by CacheCam).



Sample tubes (STs)

- Sample tube number 266
- Laser-etched serial number helps science team identify the tubes and their contents

- Made mainly of titanium
- Weighs <57 grams
- Length <6 inches
- A white exterior coating
  - ! guards against heating by the Sun potentially changing the chemical composition of the samples after Perseverance deposits the tubes on the surface of Mars

- ✓ Total sample tubes 43
- ✓ 38 Samples from a variety of geologic units and surface materials.
- ✓ 5 samples are “witness tubes”
- ✓ Prior to launch they were loaded with materials geared to capture molecular and particulate contaminants. They’ll be opened one at a time on Mars to witness the ambient environment primarily near sample collection sites. So, the science team can catalog any impurities that may have traveled with the tube from Earth or contaminants from the spacecraft that may be present during sample collection.

Mile stones in robotic-operations in FRS by SCS

- ✓ Perseverance drilled the hole called "Montdenier" in the rock nicknamed "Rochette"
- ✓ Acquired the rock core
  - o It is slightly thicker than a pencil
- ✓ Rover vibrated it to clear any material stuck between coring bit and sample tube within bit
- ✓ Rover then conducted additional imaging to double-check that it retained the rock
- ✓ This image processed to enhance contrast

CacheCam image Taken before Launching shows some small rocks inside a sample tube

- ! Two holes; rover's drill obtained chalk-size samples from rock nicknamed "Rochette."
- ! Hole on the left side: known as "Montagnac" ; drilled on Sept. 7,2021
- ! Hole on the right : known as "Montdenier"; drilled on Sept. 1,2021.
- ! Round spot under right hole: place where the rover abraded part of the rock's surface, nicknamed "Bellegarde,"
- ! Tailings (or cuttings) from the Montdenier coring activity slid over Bellegarde

🕮 Image-grapher (IG): NASA's Perseverance rover on Sept. 7, 2021, PDT

Thecomplete automatic collection of rock-samples on another planet with robotsis first-in-the-human-Science-history. This is a remarkable success of 2.7 billion USD saga of NASA to probe into secrets of nature. The outcome shed light on nature with ingenious perseverance of human brain through STEM(science technology evolution/engineering mathematics/methods). The entire task, from autonomously drilling a hole up to sealing sample tubes and keeping them back in rack, is commendable.

The communication transmitting time from earth to Mars is more than 5-20 (8 on average) minutes either to send commands or receive telemetric data/status report in case of catastrophic movements. Thus, real time human modification of operations or intervention when once perseverance procedure starts is not possible in this mission.

The second, or paired, sample of Montdenier was taken out at the drill hole called "Montagnac." "Séítah". This will be a future terrane area of Mars-2020-rover for exploration in the first few weeks.

Science window
At
Nature (Swan)

7. Sample Caching System: SCS comprises of three-robots. It is the most complicated, sophisticated and complex robotic system ever built. This gives a first impression of a steamer-trunk-sized labyrinthine collection of motors, planetary gearboxes, encoders and other devices all meticulously functioning together at Swiss watch precision. The subtle contrast is that the chronometer has around 400 components while SCS contained 3000 modules.

JPL (NASA) brought out two identical pieces viz. engineering test model (ETM) and flight model (FM) with seven years effort. It is true that equipment wears out or breaks faster on Earth than on Mars. The test team has a high priority task of putting ETM through its paces. The un-successful target of breaking functionality at end of the day is a testimony and message to its twin SCS-FM about its robustness and sustainability on better land (Mars surface). The engineering test model remained here (JPL, USA) on Earth and the flight model travelled all the way to Jezero crater on Mars to do Science.

Function: Sample Caching System will collect 35 core rock samples each of 15gms from the rocky surface of Mars. It carefully seals them in very sterile, clean sample tubes and leave them there in depots. The eventual transport to Earth will be in future mission of NASA and ESA by the year 2026.

Anatomy of SCS:
Robot-1: It has a vividly eye-catching 7-foot-long five-jointed arm bolted to the front of the rover's chassis. The arm carries a large turret including a rotary percussive drill which collects core samples of Mars rock and regolith (broken rock and dust).Then, we put that core sample in the bit carousel.

Robot-1I:The second robot called bit carousel built into the front of the rover and does the job of ultimate middleman for all Mars sample transactions. It will provide drill bits and empty sample tubes to the drill. Later, thismoves the sample-filled tubes into the rover chassis for assessment and processing. For appearance, it looks like a small flying saucer or an extra-terrestrial version of a 1960s slide projector.

Robot-1II: It is the 1.6-foot-long sample handling arm ("*T. rex* arm"). Located in the belly of the rover. This robot picks up where the bit carousel leaves off, moving sample tubes between storage and documentation stations as well as the bit carousel.

8. Future course of action -- Mars mission: The samples return saga from Mars to earth in 2026 and follow-up Humans exploring on Mars will be the first-leap, The (multi-dimensional) dream (with third eye open) of habituality of humans on Mars may turn in to realityin the next century.

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Videos	
https://mars.nasa.gov/system/video_items/5953_JPL-20200529-MARSf-0001-Mars_Sample_Caching-MEATBALL-1080.mp4	2min -- sampling -three robot system of SCS--MSc
https://youtu.be/yqqaW8DCc-I	Insane Engineering of the Perseverance Rover
https://youtu.be/j3Q-roxYkkY	NASA's Perseverance Mars Rover Equipped with Ultra-Clean Sample Tubes

Abbreviations and Acronyms

Mars-2020 rover	Perseverance : Given Name Percy: Pet name Mr Percy is younger brother of Curiosity
Mars-2020-Helicopter	Ingenuity,

Mrs	Mars rock sampling
Mr	Mars rover
Miss	Mars intelligent sampling system Sample catch system (SCS)

Mr.	Mars rover. Perseverance	Mars rover Percy
Mrs	Mars rock sampling. Perseverance	Mars rock sampling. Percy
Miss	Mars intelligent sampling system. Perseverance	Mars intelligent sampling system Percy
Percy	Male name or rarely female name	

9. Appendices

Land marks in Annals of NASA

Mark	Machine	On	Year	by		
First	Aeroplane	Earth	1903	Flying in air		Wright brothers [Wilbur, Orville Wright]

Orville Wrightserved on NACA for 28 years
NASAwas created from the National Advisory Committee on Aeronautics in 1958

After 60+ years

First	Apollo-8	Moon	1967		NASA	
First	Apollo-11	Moon	1969	Stepping on Moon surface	NASA	Neil Armstrong B
First				Astronauts collection of rock samples on moon		
First				Bringing them to earth analysed		

After 50+ years

First	Ingenuiity – Mars Helicopter	Mars Jezero crater	2021	Controlled power Flying in Martian air	Mara-2020-Rover + Quad copter	No Human presence, intervention or supervision
First	Perseverance—Complex robotic			Mars Rock sampling		

	machine ever made					
After 5+ years						
	Rovers Landers	Mars to earth	2026		NASA + ESA	Bringing Rock samples of 2021 to Earth
	Hexa copter		20??		NASA	Aerial exploration Science probes
After 10+ years						
	Fliers	Mars	> 2030		NASA	Humans explore science

Goals of Perseverance's missions on Mars

- ☞ Astrobiology
  - ? Signs for ancient microbial life
- ! Geology of Mars inJezero region
- ! Past climate
- ! Pave way to human exploration of red planet
- ! Contemplated Human life style of Emerging Kid(s) on Moon, Earth, Mars (Mem) etc.
- ✓ At the moment : To collect and cache Martian Rock regolith (broken rock and dust)

Outcome

- 🕮 Jaw-dropping discoveries,
- 🕮 Eye brow-rising inventions,
- 🕮 Mind-blocking futurology,
- 🕮 Obsessive sensuous comforts,
- 🕮 Unperturbed psychological peace,
- 🕮 Balanced food, health and environment,
- 🕮 pareto-optical ambitionsImpact on PCB Sets

🕮 (Phyiscs, chemistry, biology) (science, engineering technology systems

Timeline of Mars Samples collection and samples Return to earth Program

Phase I	Perseverance	! Flying to Mars with catching robots ! Sample collection	NASA
Phase II	Fetch Rover + Rocket	! Retrieve collected samples ! Package them into orbit	NASA + ESA
Phase III		! Capture the orbiting package	NASA + ESA

		! Return it to earth	
Phase IV		🕮 Analysis 🕮 Interpretation 🕮 Future mission designs	

Autonomous drilling Task

Drilling hole in rock

- 🕮 The number of operations robotic arm rover features a
- 🕮 Coring drill which cut out cylindrical core samples from Martian surface.

Sample Storing immediate

- 🕮 Sample collection
- 🕮 ROBOT head mates drill bit carousel,
- 🕮 Robot transfers the bit and sample tube into rotating carousel
- 🕮 Takes it to belly of rover
- 🕮 Here another robot arm resides
- 🕮 Arm pulls sample tube out of drill bit
- 🕮 Takes multiple images of sample tube before and calculating the volume of the sample

Sample Storing long term

- 🕮 It stores sample tube in one of the 42 slots under the belly of the rover,
- 🕮 Sample tubes with samples will remain until the rover deposits them at a designed catching spot on the surface of Mars

Samples transfer Mars → Earth

- ! Another rover, designated by ESA, will be sent to Mars in 2026
- ! Perseverance (the current rover) will deliver the samples back to its NASA designed LANDER
- ! NASA designed lander will load them into a MARS ascent vehicle.
- ! Blasting the samples into orbit, %% where ESA earth return vehicle will be waiting for it
- ! Rock samples will be broght to earth from Mars
- ! State-of-knowledge (Physical, chemical, bio-chemical) analysis

Functional modules in robot-computer-machine vs living human expert

Function	Human (Living creature)	Perseverance
Structure that protects functional modules (organs)	Body	Material body
To process information	Brain	Computers
Temperature controls	Bio sensors -- physiology	Internal heaters, a layer of insulation etc
Movement of head	Neck and head	A mast for the cameras to give the rover a human-scale view
Seeing Hearing	Eyes and ears	Cameras and instruments that give the rover information about its environment
A way to extend its reach and	Arm and hand	Robotic arm and "hand"

collect rock samples for study		
Parts for mobility	Legs	Wheels and legs:
Electrical power	Metabolism	Batteries and solar power
Communications	Tongue	Antennas for "speaking" and "listening"

To drill a hole into the rock with SCSon Mars

Autonomous sample collection

- Drilling a hole into Mars rock
- Pulling out intact core samples
- Sealing them hermetically in hyper-sterile vessels

Step-by-Step robotic-operations in SCS

Drilling & sampling

- Rotary percussive drill takes a core sample
- It will turn around
- Dock with one of the four docking cones of the bit carousel
- Bit carousel rotates that mars-filled drill bit and a sample tube down inside the rover to a location

Moving **SA**mple Tube (Sat)

- Sample handling arm can grab it.
- Arm pulls the filled sample tube out of the drill bit
- Takes it to a camera inside the Sample Caching System

Image of Sat

- Sample tube is imaged

Volume assessment

- Small robotic arm moves it to the volume assessment station
- A ramrod pushes down into the sample to gauge its size
- Go back
- Take another image

Pickup plug for Sat

- Pick up a seal — a little plug — for the top of the sample tube
- go back
- Take yet another image

Sealing

- Sample Caching System places the tube in the sealing station
- Seals the tube with the cap hermetically
- Take the tube out

Return Sat to sample rack

- Return it to storage from where it first began.

Bit carousel of Mars 2020-	sample acquisition and surface analysis

➔ Nine drill bits

%% Abrader bit is used to scrape top layers of
rocks to expose un-weathered surfaces %

📖 Two for abrading

%% coring and regolith bits are used to place Martian samples
in a clean sample collection tube %

📖 One for regolith (rock and soil)
📖 Six for coring.

Knowledge based Expert system for robotic work flow

If	Mars Rover (Mr. Percy) is ready to drill		
Then	Carousel whirrs into action		
If	Core sampling		
Then	A sample tube is inserted inside the appropriate bit Carousel moves the combination into position for the drill		
	If	Sample tube has been filled	
	Then	Robotic arm returns the drill bit and tube to the carousel	&
		they wend their way to processing stations and storage	
	end		
end			
If		goal is to abrade	
Then		carousel maneuvers the appropriate bit into position	&
		drill at the end of the rover's robotic arm can extract it	
	If	Drilling's done	
	Then	Bit goes back into carousel	
	end		
end			

Typical Vehicles of NASA in astronomical explorations

NASA	National Aeronautics and Space Administration	

JPL	Jet propulsion Laboratory	
ESA	European Space Agency	

Satellites[1]
Orbiters
Ground surface
Landers
Rovers
Air
Ingenuity
Hexacopters
[1]Machine (launched into space) which goes around in the orbit of a planet (or moon)

Knowledge flow	
Moon-Explore-Mars	Mem
Mars-Explore-Moon	Mem
Mem to Mem	Mem2 Mem
Moon-Earth	Me
Mars-Earth	Me
Me to Me	Me2Me
Me2Mem2Me	

Rovers on Mars	
Curiosity	NASA
Perseverance	
Zhurong	CNSA#
# : China National Space Administration	

Landers on Mars

Curiosity	Rover	NASA	2011
InSight Mars Lander	Rover		2018
Perseverance rover	Rover		2021
Tianwen-1	China		2021

High-tech instruments on Perseverance rover (PR)	
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

Orbiter	Mars	Odyssey-2001
Mission Facts		
Mission Status		Currently Operating, 22Sep,2021; 13:35
Mars Orbit Insertion		October 24, 2001
Launched		April 7, 2001
Launch Site		Cape Canaveral Air Force Station, Florida
Time in orbit lapsed		19Y 10M 29D 05H 45min 35 Sec