ASTR 4800 - Space Science: Practice & Policy

Today: *Robotic Exploration of Mars*

- Next Class: *The Astrophysics Decadal Survey.*
- *Reading*: Skim Decadal Survey that is linked to the class website for Oct. 19.
- Name & bio of your interviewee is due to me via E-mail by Wednesday, Oct. 19.

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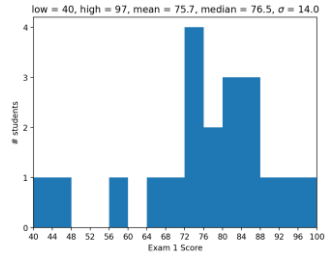
Exam #1 Results



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Robotic Exploration of Mars

By: Nolan Ales and Anna Casillas

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A Brief Introduction to Mars

- Launch window of 26 months due to alignment
- ~33.9 million miles away from Earth
- Communication delay up to 24 minutes one way
- Atmospheric density less than 1% that of Earth's
- Used to have a magnetic field; very weak/no magnetic field today
- Weather on Mars

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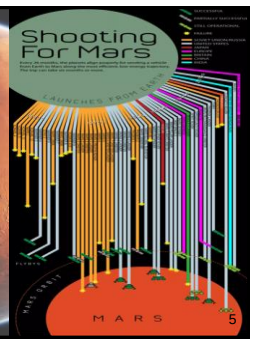
History of Robotic Exploration of Mars

- Out of 55 missions up to 2019, only 25 were deemed successful… ~45% success rate!
- But, since 2001, 12 out of the 16 missions have been successful
- Today, international array of 13 spacecrafts (one lander, 8 orbiters, 3 rovers, one helicopter)

Question: Why is it so hard to land on Mars?



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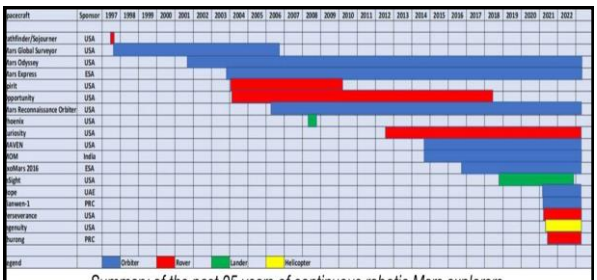

Summary of the past 25 years of continuous robotic Mars explorers.

Source: https://www.nasa.gov/feature/25-years-of-continuous-robotic-mars-exploration-from-pathfinder-to-perseverance

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Early History of Robotic Exploration of Mars

NASA Mariner Program:

- Mariner 4: Nov. 1964, achieved first Mars flyby and 21 images
- Mariner 6 -7: transmission of 201 total photos, led to creation of surface relief map, info on Martian gravity and magnetic fields
- Mariner 9: May 1971, orbited Mars, transmitted images and atmospheric pressure and temperature readings, evidence of liquid water, discovers volcanoes and Valles Marineris

USSR:

- launched 19 probes from Oct. 1960 to Nov. 2011, all failed
- Mars 1: Nov. 1962, achieved first interplanetary orbit, communications failed
- Mars 3: May 1971, soft landed but transmission interruption 14.5 seconds in

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NASA's Robotic Exploration of Mars History

Viking Program: two orbiters and two landers

- Viking 1 and 2 launched Aug. 1975, successful orbit and landing on Mars
- Found floods of water carved valleys, suggested rain fell in Southern Hemisphere, biological experiments for existence of microorganisms proved inconclusive

Mars Global Surveyor: replaced failed Mars Observer

- launched Nov. 1996, began primary mapping mission 1999 in nearly polar orbit
- functioned until Nov. 2006 and communications lost 2007

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NASA's Robotic Exploration of Mars History

Mars Pathfinder and Sojourner Rover: launched Dec. 1996, 1st operational rover

- Images from gullies and debris flow suggest current source of liquid water
- Magnetic field localized in crust

Mars Odyssey: launched April 2001, found water and volcanic activity

- Gamma Ray Spectrometer found hydrogen, confirming vast deposits of water ice in Northern Pole

Spirit and Opportunity Rovers: launched June & July 2003

- search for evidence of past flowing water, geology primary objective

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Current Robotic Exploration of Mars

- NASA's Curiosity Rover: Nov. 2011, explored habitability of Mars
  - Found nutrients and energy sources to support microbes, methane and organic compounds
- NASA's Perseverance Rover and Ingenuity Helicopter: July 2020, to explore Jezero Crater and look for signs of life, 1st helicopter on another plane
- NASA's InSight: May 2018, stationary lander investigating deep interior
- China's Zhurong Rover: July 2022, look at water content in soil and Martian climate, 1st non American rover on another planet
- 8 orbiters surveying planet

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Class Exercise!

What are the benefits of sending humans to Mars over rovers?

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NASA's Curiosity Accomplishments

- 1982 lbs, size of a car, 7-ft arm
- Can travel 295 ft/hr
- Radioisotope power system utilizing plutonium
- Landed at Gale Crater
- Determined Gale Crater could have supported past microbial life
- "Seven Minutes of Terror" as the rover landed on Mars

Mission Elapsed Time 10:10:17:10:31:59

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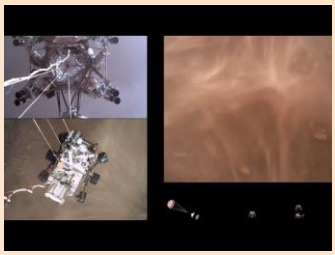
Perseverance Landing Video (~ 3 minutes)



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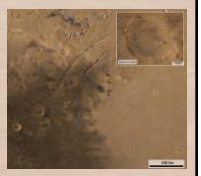
Science Objectives for NASA's Perseverance Rover

Objective A: Geology

- Study rocks and landscape to reveal history
- Characterize processes that formed and how they modified the geological area
- Jezero Crater: orbiters confirmed presence of clay minerals and carbonates which indicates area was flooded with water



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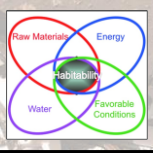
Science Objectives for NASA's Perseverance Rover

Objective B: Astrobiology

- Determine if environment was habitable, with liquid water and chemical building blocks
- Search for materials with high biosignature preservation potential for evidence of past life



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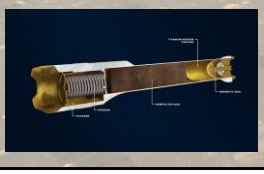
Science Objectives for NASA's Perseverance Rover

Objective C: Sample Caching

- Find and collect most promising samples that represent geographic diversity
- Ensure compliance with future needs in order to retrieve samples
- Perseverance has 38 empty tubes to store soil and rock samples in



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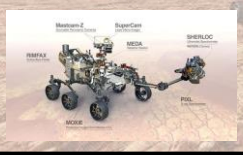
Science Objectives for NASA's Perseverance Rover

Objective D: Prepare for Humans

- Produce oxygen from Martian atmosphere to use for propellant and breathing
- Characterize atmospheric dust sizes and morphology
- Validate global atmospheric models through surface weather conditions
- Test space suit material against environment



Question: Which of these objectives do you believe be the most important?

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NASA's Ingenuity Helicopter

- Challenges include: low gravity, thin atmosphere, and data-delay due to distance
- Autonomous flight (all systems algorithmically powered by AI)
- Relies on Perseverance for relay, and helps guide Perseverance
- Max. height = 15 ft. Max flight time = 90s. 4lbs (Earth) = 1.5lbs (Mars)
- Heat of motors limits flight time (1 degree C per second!)
- First successful mission of its kind

TIME ON MARS
01 : 07 : 27 : 05 : 04 : 39
YRS MOS DAYS HRS MINS SECS

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Ingenuity Helicopter Video (35 seconds)

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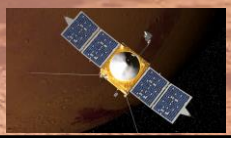
Mars Atmosphere and Volatile Evolution (MAVEN)

- Launched Nov. 2013
- Second mission selected for NASA's Mars Scout Program
- Bruce Jakosky of CU's LASP proposed and led mission until 2021
- Orbiter to study upper atmosphere and ionosphere to examine how solar wind is stripping gases and other volatile compounds
- Act as communications relay satellite for rovers



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NASA's InSight Stationary Lander

- Was unable to drill further than a few centimeters into Martian soil
- Helped learn about the Martian soil and ground structure
- Brought first seismometer to Mars
- Measures tectonic activity and meteorite impacts on Mars
- Mission was extended to Dec. 2022, but dust accumulation on solar panels

Mission Elapsed Time 04:05:08:21:14:16

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China's Zhurong Rover

- China the only other country to land (successfully) on Mars
- ~ 530 lbs, 6-wheels, 4 solar panels, and 6 different scientific instruments
- Magnetometer

The mission is aimed at assessing:

1. Topography and geological structure
2. Physical characteristics of geology and atmosphere
3. Soil structure… water ice?
4. Chemical composition

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United Arab Emirates Hope Mars Mission

- Reached Mars Feb. 2021
- Examines weather and atmosphere layers to learn more about Mars' climate over time

- Will further MAVEN's work by studying Mars from higher orbit (22,000 x 44,000 km orbit vs 4,500 x 150 km orbit)
- Studies hydrogen and oxygen that leak into space from the atmosphere, which gives insights to Mars' past with water

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Future Missions

USA + Europe: collection of Perseverance rover's samples, current estimations of launch in 2026 and Mars arrival in 2028

- NASA-led Sample Retrieval Lander to launch retrieved samples into Mars orbit
- ESA-led Earth Return Orbiter to rendezvous with samples in Mars orbit

Europe and Russia: ExoMars rover and lander, planned to launch 2022

Japan: JAXA plans to return 2024, sample return mission from Mars' Moon Phobos

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NASA's Goal to Get Humans on Mars

NASA outlined the goal of getting humans to Mars by 2030 in the bipartisan NASA Authorization Act (2010) and U.S. National Space Policy (2010).

Question: Given what we know about NASA's budget, do you think 2030 is a reasonable timeline?

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Sources:

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