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Statement of
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before the

Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
U. S. House of Representatives

Chairman Beyer, Ranking Member Babin, and members of the Subcommittee, I am honored to appear before this Subcommittee on behalf of the California Institute of Technology to discuss the Mars Perseverance Mission.

The Mars 2020/Perseverance Mission

On February 18, 2021, the Perseverance rover touched down in Mars' Jezero Crater. Roughly 3.5 billion years ago, Jezero Crater was the site of an ancient lake. Rivers flowed both into and out of its basin over an extended period of time. Orbital imagery shows that Perseverance has in fact landed right in front of what was once a river delta. Places like this can concentrate biological activity and are known to be an excellent source of preservation of organic molecules, and we have high hopes for what this location may hold for science.

The Mars 2020 mission has four science goals: 1) Explore an ancient Martian environment of astrobiological relevance and decipher its geological processes and history, including past habitability; 2) Assess the biosignature preservation potential within that geological environment and search for them; 3) Make progress toward returning scientifically selected, well-documented samples from Mars to Earth; and 4) Provide an opportunity to contribute to future human missions to Mars.

Of course, inspiration is always part of the mission. Perseverance has captured the public's excitement and imagination through the images returned from the surface; the incredible videos of the entry, descent and landing phase; and, most recently, the highly anticipated flight of the Ingenuity helicopter. And we are only 68 sols, or Martian days, into our mission.

The Mars 2020 science team consists of nearly 500 individual researchers with experiences and backgrounds that range from undergraduate students to University professors to NASA Jet Propulsion Laboratory (JPL) experts who have worked every Mars rover mission since Mars Pathfinder/Sojourner in 1997. They have diverse scientific backgrounds in disciplines such as geology, climate, biology, and planetary science. It really is an amazing team and I am honored to be part of it.

Scientific Background

All evidence points to Mars being more Earth-like in its early history, with rivers, lakes, and a large ocean potentially filling its northern hemisphere. At roughly the same time when life was starting on Earth, water also flowed across the surface of Mars. We believe that many of the same conditions we think would be required for life on Earth were present on Mars, including a chemical energy source and access to organic carbon.

On Earth, many things have changed since life began several billion years ago. Key clues to the origin of life on our planet have largely been erased by weathering, erosion, and plate tectonics. On Mars, by contrast, there is little evidence of plate tectonics and the surface has been less affected by these other processes. Thus, Mars has a much better-preserved ancient rock record. Most rocks on the surface are thought to have been formed when Mars was warmer and wetter than we find it today. Rocks on Mars could preserve key evidence of planetary formation, clues to its habitability when liquid water was present, and, potentially, signs of microscopic life.

Today, Earth is the one and only planet where we have evidence of life's origin. From a scientific perspective, if we find that life originated on Mars, this raises the possibility that life could be abundant in the universe. Conversely, if we find the opposite, we might be able to better constrain the requirements for the origin of life and better explain how life originates on a planet. From a philosophical perspective, if life is plentiful in the universe, it might bring us new perspectives on ourselves and the universe. If life is rare, we might start to realize how unique and precious life is on Earth.

Building Instruments to Find Life

In order for any new instrument to be incorporated into a payload, it has to demonstrate scientific utility and technical feasibility. This process can take many years, decades even, and requires scientists and engineers to work together to generate an integrated and robust flyable concept. The development of an instrument concept is a process in which one experiences successes sprinkled with many rejections and failures. It also comes with no guarantee of ever getting a chance to fly on a mission.

Some astrobiology instrument concepts are not sensitive enough to detect the faint traces of life expected on Mars. Some concepts simply cannot function in the harsh and complex Martian environment. Finally, even with advances in technology, some concepts simply cannot be miniaturized to fit on a rover. There is no way to know at the beginning of development which concept will survive to flight. It is clear that it really does take perseverance to get to Mars.

SHERLOC

Perseverance's payload has seven instruments that will document the landing site and analyze samples for future return to Earth. I am the Principal Investigator for an instrument called SHERLOC, which stands for Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals. SHERLOC was developed to search for clues within an astrobiologically relevant environment on Mars. Starting soon, SHERLOC will work to identify habitable environments and see what we can deduce regarding Martian history. SHERLOC was selected through the 2013 announcement of opportunity for payload elements for the Mars 2020 rover. The proposal took a year to write and was one of seven selected from a pool of over 58 instrument concepts. The concept for SHERLOC was first conceived at JPL starting in 1998 and went through multiple stages of development until the flight unit was delivered in January of 2020.

SHERLOC enables high-sensitivity detection, characterization, and spatially-resolved correlation of trace organic material within Martian outcrops. SHERLOC can identify potential biosignatures in the Martian surface and near sub-surface. It does this by combining microscopic imaging with Raman and fluorescence spectroscopy to map a postage-stamp-sized Martian sample.

Two microscopic cameras, Autofocus and Context Imager, or ACI, and Wide Angle Topographic Sensor for Operations and eNgineering, or WATSON, obtain high-resolution images of the surface to identify textures and features smaller than 30 microns. Raman spectroscopy identifies organic, chemical, and mineral components present. Fluorescence spectroscopy detects and classifies organic molecules that have aromatic ring structures. It does so within a 100 micron-spot, roughly the same size as a human hair, that is moved over a surface. To assess the presence of potential biosignatures, SHERLOC makes mineral and organic maps. These are then analyzed by the science team to determine their astrobiological significance.

The Martian surface is an inhospitable place for most organic molecules due to high ultraviolet fluctuation and oxidizing conditions. Perseverance has an abrasion tool to get to the protected interior of a rock where organic molecules have been shown by NASA's Mars Science Laboratory/Curiosity to exist. The classes of organic material that SHERLOC is sensitive to include amino acids, nucleobases, and aromatic compounds. These molecules are found in life as we know it, but a number of these have also been found in meteorites or are known to be created though other abiotic chemical processes on the Earth. This is why we would call any findings by SHERLOC "potential biosignatures" rather than claiming to have an instrument capable of unambiguous life detection.

Minerals can also be a form of biosignature. Biology can create distinctive signatures that can be observed in assemblages of astrobiologically-relevant minerals (e.g., carbonates, nitrates, phosphates, sulfates). The presence of such assemblages of minerals in association with organics can be an important component in evaluating whether something may have been produced or brought about by biological processes. SHERLOC will be looking for these types of features.

As designed, SHERLOC specifically targets minerals and organics that are indicative of Jezero Crater's watery past. These minerals can also represent key sources and sinks for elemental cycling necessary for life. Life on Earth is driven by oxidation-reduction reactions and utilizes key elements such as carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. The abundance and diversity of compounds containing these elements in a sedimentary environment are important measures of habitability.

Working Toward Sample Return

As hard as I and others have worked on SHERLOC, the rest of our instrument suite and other instruments working on the Martian surface, it is hard to identify instruments or measurements that could unambiguously identify life on a Martian sample at present. After all the work we have – and will – put into Perseverance, the best way to unambiguously determine whether life was ever present within Jezero Crater will still be to return samples to Earth. To that end, the Mars 2020 mission is designed to collect well-characterized samples that have high scientific value. When these samples are eventually returned to Earth, they will be analyzed by state-of-the-art instruments, some that cannot be flown to Mars. Some of these instruments have not even been invented yet. The combination of knowing where a sample came from and multiple lines of evidence within that sample should be able to get us closer to answering the tantalizing question of whether life exists, or ever existed, on the next planet out from the Sun.

Finally, I have given many talks at schools focusing on the Mars 2020 mission and SHERLOC in particular. I usually end those talks reminding the students that the samples that we are collecting will be arriving back on Earth in the 2030's. That by pursuing a career in science and engineering, they can help answer the questions that are currently waiting to answer. As we inspire this next generation of researchers, I imagine all the wonderful things we will be able to accomplish and all the big questions we will be able to answer.

I would be happy to answer any questions you may have.

CURRICULUM VITAE

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Education

University of Alabama at Birmingham	Ph.D.	1997	Astrophysics

A Model of the Complex Hydrocarbon Component of the Interstellar Medium: Observational and Experimental Considerations

University of Alabama at Birmingham	MS	1995	Physics
University of Delaware	BS	1990	Physics/Astronomy

Present Position:

2016-present: Deputy Division Manager, Science.
2014-present: Principal Investigator, SHERLOC.
2015-present: Principal Scientist, Jet Propulsion Laboratory. Responsibilities include conducting NASA funded research as a PI and Co-I in planetary science focusing on detection and characterization of organic molecules for the identification of potential biosignatures.

Past Positions:

2013-2016: Deputy Section Manager, Planetary Science Section, Science Division at JPL.
- Supervised a section of ~80-100 Ph.D. scientists

2009-2018: Surface Sampling System Scientist MSL SASHaP system. Supported the development of the hardware testbeds and identified samples for ambient testing until MSL landed. Participation in scientific operations focusing on properties of surface material and the acquisition and processing of samples in Gale Crater.

2003-2015: Research Scientist, Jet Propulsion Laboratory, California Institute of Technology, Pasadena California. Responsibilities include conducting NASA funded research as a PI and Co-I in planetary science focusing on detection of organic molecules off in situ platforms.

2005-2013 Group Supervisor Group 3225, Planetary Chemistry and Astrobiology group, Science Research Division, Jet Propulsion Laboratory, California Institute of Technology.
- Supervised a research group of 8 to 15 Ph.D. scientists

2001-2003: Scientist, Jet Propulsion Laboratory, California Institute of Technology, Pasadena California. Conducted NASA funded research as a PI and Co-I on the collection, extraction, detection and identification of organic molecules as part of a future *in situ* rover platform.

1999- 2001: Postdoctoral Scholar, California Institute of Technology, Pasadena California Developing analytical instrumentation techniques for the *in-situ* search for organic molecules. Conducted astrobiological experiments to help elucidate conditions organic molecules might face on extraterrestrial planets.

1997- 1999: National Research Council Post-Doctoral Scholar, Jet Propulsion Laboratory, California Institute of Technology, Pasadena California. Performed first ever

	temperature dependent absorption spectroscopy of atmospheric species. Performed electron impact studies on the atmospheric species of CO and SO_2.
1996:	Instructor, PHS110, An Overview of Space Exploration, The University of Alabama at Birmingham.
1993-1997:	Research Assistant, The University of Alabama at Birmingham, under NASA programs: Origins of Solar Systems, Exobiology, UV Astronomy, and IR Astronomy. Investigated interstellar molecules and ions which make up the interstellar medium and are responsible for several Astronomical features including the 2175 Å bump, Unidentified Infrared bands, and Diffuse Interstellar Bands (UV Astronomy, IR Astronomy and Origins of Solar Systems). Addition investigations included work on the miniaturization of a laser Raman spectrometer (PIDDP), and identification of carbonaceous material in ancient terrestrial rock samples as Martian Analogs (Exobiology).
1991-1993:	Teaching Assistant, The University of Alabama at Birmingham. Taught Classical Mechanics laboratory for majors and non-majors, Thermodynamics for majors, Electricity and Magnetism for majors, and Modern Physics for majors.

Funded Proposals:

Scanning Habitable Environments with Luminescence and Raman for Organics and Chemistry: SHERLOC. An investigation on Mars 2020 to launch August 2020.

Principal Investigator *in 9 different proposals funded under three different NASA programs PIDDP, ASTID.*

Co-Investigator *on 19 peer-reviewed proposals which were funded under 7different NASA programs: ASTEP, MIDP, PIDDP, ASTID, Vision Missions, Origins of Solar Systems, Exobiology and UV/VIS Astrophysics.*

Funded Proposals (Task Manager Co-I):

Advanced Robotic Detection of Chemical/Biological Agents, Toxic Industrial Gases and IEDS for Force Health Protection PHASE II SBIR from the Army. Small Business point of contact: IonFinity, *LLC*. 2.5 years, $225K. 2008

Miniature Electric Sniffer for Navy Vertical Take-Off Unmanned Aerial Vehicle (VTUAVS) SBIR from the Army. Small Business point of contact: IonFinity, *LLC*. 2 years, $225K. 2008.

Professional Activities:

- Editor, *Astrobiology* Journal
- Member of a multi-center ad hoc committee (*Keeping the candle lit*) for future human exploration of Mars (2010-2013).
- Member of the American Association for the Advancement of Science, the International Society of Ion Mobility Spectroscopy, the American Geophysical Union, and the American Chemical Society.
- Member of the Astrobiology Science Steering Group to define Astrobiological objectives for future Mars missions (2004)
- Member of the Mars Human Precursor Science Steering group defining risks and measurements needed for human exploration of Mars (2005)
- Worked with the University of Alabama at Birmingham's Media Relations department as science expert for local interviews with television stations and newspapers.
- Worked with education outreach at University of Alabama at Birmingham as guest lecturer at local schools (elementary, middle and high).
- Judge for the Alabama Science Olympiad (1995, 1996, 1997).

- Reviewer for Planetary and Space Science, Astrobiology, Icarus, Earth and Planetary Science Letters, Journal of Geophysical Research and Analytical Chemistry
- Reviewer for NASA Mars Fundamental Research Program (2005)
- Organized topical sessions for The Geological Society of America Annual Meeting, Lunar and Planetary Science Conference, and the American Geophysical Union Fall meetings.

Mentor:

Post Doctorial Mentor for: Joseph Razzell Hollis, Brandi Carrier, Hugh Kim, Everett Salas, and DeLing Liu.

Abbreviated List of Summer Interns: Hanieh Amoozegar, Brett Beckett,Alexa Raquel Bilek, Andrew Carnes, Juliana Capri, Nathan Figlewski, Kristina Goltz, Benjamin Hall, Samuel Long, Hugh Kim, Ernest Ryu, Alison Saltzman, Shakher Sijapati, Santosh Soparawalla, Meagan Spencer, Saman Halabian

Patents:

- Proton-Transfer Reaction/Ion Mobility Spectrometer. Developed a novel high-pressure hollow cathode ionizer for use in ambient Martian environments. Patent number: 6,794,645 B2, 21 September 2004.
- Development of an automated de-salting apparatus. NPO 45428
- Non-Contact Conductivity Measurement for Automated Sample Processing Systems. Provisional Patent CIT-5831-P.

Publications:

SHERLOC:

Detection and Degradation of Adenosine Monophosphate in Perchlorate-Spiked Martian Regolith Analogue, by Deep-Ultraviolet Spectroscopy in Astrobiology

Mars 2020 Mission Overview in Space Science Reviews

An Optical Model for Quantitative Raman Micro-Spectroscopy in Applied Spectroscopy.

Attenuation of ultraviolet radiation in rocks and minerals: Implications for Mars Science in Journal of Geophysical Research: Planets

WATSON: In Situ Organic Detection in Subsurface Ice Using Deep-UV Fluorescence Spectroscopy in Astrobiology

Deep UV Raman spectroscopy for planetary exploration: The search for in situ organics in Icarus

Mars Science Laboratory:

A look back, part II: The drilling campaign of the Curiosity rover during the Mars Science Laboratory's second and third martian years. Icarus Deep-ultraviolet Raman spectra of Mars-relevant evaporite minerals under 248.6 nm excitation in Icarus

A Look Back: The Drilling Campaign of the Curiosity Rover during the Mars Science Laboratory's Prime Mission in Icarus

Uniaxial compressive strengths of rocks drilled at Gale crater, Mars in Geophysical Research Letters

ChemCam investigation of the John Klein and Cumberland drill holes and tailings, Gale crater, Mars in Icarus

A Habitable Fluvio-Lacustrine Environment at Yellowknife Bay, Gale Crater, Mars. Science

In Situ Radiometric and Exposure Age Dating of the Martian Surface in Science

MAHLI at the Rocknest sand shadow: Science and science-enabling activities in Journal of Geophysical Research-Planets

Collecting Powdered Samples in Gale Crater, Mars; An Overview of the Mars Science Laboratory Sample Acquisition, Sample Processing and Handling System in Space Science Reviews

Instrument/Mission Development:

X-Ray Emission from Jupiter's Galilean Moons: A Tool for Determining Their Surface Composition and Particle Environment in Astrophysical Journal

Effects of Hypervelocity Impact of Molecules from Enceladus' Plume and Titan's Upper Atmosphere on NASA's Cassini Spectrometer from Reactive Dynamics Simulations in Physical Review Letters

LIFE: Life Investigation for Enceladus: A Sample Return Mission Concept in Search for Evidence of Life in Astrobiology

Miniature Mass Spectrometer Equipped with Electrospray and Desorption Electrospray Ionization for Direct Analysis of Organics from Solids and Solutions. in International Journal of Mass Spectrometry

Particle Sieving and Sorting Under Simulated Martian Conditions in Icarus

Particle Transport and Distribution on the Mars Science Laboratory Mission: Effects of Triboelectric charging in Icarus

Mojave Mars Simulant – a New Approach to Martian Soil Simulants in Icarus

RASP Based Sample Acquisition of Analogue Martian Permafrost Samples: Implications for NASA's Phoenix Scout Mission in Planetary and Space Science

Ion mobility spectrometry in space exploration in International Journal of Mass Spectrometry

Chemistry

Time Resolved Studies of Interfacial Reactions of Ozone with Pulmonary Phospholipid Surfactants Using Field Induced Droplet Ionization Mass Spectrometry in Journal of Physical Chemistry B

Interfacial Reactions of Ozone with Surfactant Protein B in a Model Lung Surfactant System in Journal of the American Chemical Society

Structural Characterization of Phospholipids Using Traveling Wave Ion Mobility Spectrometry in N2 in Analytical Chemistry

An Experimental and Theoretical Investigation into the Correlation between Mass and Ion Mobility for Choline and Other Ammonium Cations in N_2 in Analytical Chemistry

Electrospray Ionization Ion Mobility Spectrometry of Carboxylate Anions: Ion Mobilities and a Mass-Mobility Correlation in Journal of Physical Chemistry A

Effects of Drift-Gas Polarizability on Glycine Peptides in Ion Mobility Spectrometry in International Journal of Mass Spectrometry

Investigation of Drift Gas Selectivity in High Resolution Ion Mobility Spectrometry with Mass Spectrometry Detection in Journal of the American Society for Mass Spectrometry

Electrospray Ionization High-Resolution Ion Mobility Spectrometry for the Detection of Organic Compounds, 1. Amino acids in Analytical Chemistry

Astrobiology

A concept for NASA's Mars 2016 Astrobiology Field Laboratory. Astrobiology The Cell and the Sum of Its Parts: Patterns of Complexity in Biosignatures as Revealed by Deep UV Raman Spectroscopy. Frontiers in Microbiology in

The Mojave Vadose Zone: A Subsurface Biosphere Analog for Mars in Astrobiology

Analysis of Underivatized Amino Acids of Geological Interest using Ion-Pairing Liquid Chromatography/Electrospray Ionization/Tandem Mass Spectrometry in Astrobiology

Astrophysics

Laboratory Investigation of the Contribution of Complex Aromatic/Aliphatic Polycyclic Hybrid Molecular Structures to Interstellar Ultraviolet Extinction and Infrared Emission in Astrophysical Journal

Hydrogenation of Polycyclic Aromatic Hydrocarbons as a Factor Affecting the Cosmic 6.2 Micron Emission Band in Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy

Experimental Indication of a Naphthalene-Base Molecular Aggregate for the Carrier of the 2175 Angstrom Interstellar Extinction Feature in Astrophysical Journal Letters

A Laboratory Analog for the Carrier of the 3 Micron Emission of the Protoplanetary Nebula IRAS 05341+0852 in Astrophysical Journal

Plasma Processing of Interstellar PAHs into Solar-System Kerogen in Planetary and Space Science

Inference of a 7.75 eV Lower Limit in the Ultraviolet Pumping of Interstellar Polycyclic Aromatic Hydrocarbon Cations with Resulting Unidentified Infrared Emissions in Astrophysical Journal

Spectroscopy of PAH Species in the Gas-Phase in Planetary and Space Science

Aeronomy

Middle Ultraviolet and Visible Spectrum of SO2 by Electron Impact in Journal of Geophysical Research-Space Physics

High Resolution Emission Spectroscopy of the A (1)Pi-X (1)Sigma(+) Fourth Positive Band System of CO Excited by Electron Impact in Astronomy and Astrophysics

Electron-Impact Excitation/Emission and Photoabsorption Cross Sections Important in the Terrestrial Airglow and Auroral Analysis of Rocket and Satellite Observations in Physics and Chemistry of the Earth Part C-Solar-Terrestrial and Planetary Science

Temperature-Dependent photoabsorption Cross Section Measurements of O-2 at the NI Airglow and Auroral Emission Lines in Chemical Physics Letters

Full vitae, including publications, available upon request