Ames Research Center

NASA

Space Science and Astrobiology

Strategic Plan 2019

Space Science and Astrobiology Division

The Space Science and Astrobiology Division at NASA Ames Research Center (NASA ARC) provides unique interdisciplinary scientific expertise and capabilities that advance human understanding of the Molecular Evolution of Galaxies, the Evolution and Formation of Planetary Systems and our Understanding of the Origin and Evolution of Life in the Universe. Our core science capabilities in theoretical, observational, experimental, and instrument development work enable NASA missions and are focused to enhance and enable the science and exploration goals of NASA and the scientific community.

The Division's scientific breadth and expertise provide the Agency with a unique interdisciplinary workforce utilizing multidisciplinary teams of astronomers, astrophysicists, chemists, microbiologists, physicists, and planetary scientists and are organized into three core science areas:

Astrophysics: Researchers study the physical and chemical properties of astronomical phenomena by observing their radiation at optical, infrared and ultraviolet wavelengths.

Planetary Systems: Researchers acquire new, fundamental knowledge about the origins of stars and planetary systems, their evolution and formation, and the importance of terrestrial planets to astrobiology.

Exobiology: Researchers study the history, distribution, and chemistry of biogenic elements in the solar system; prebiotic chemical evolution and the origin of life; and the history of Earth's early biosphere as recorded in microorganisms and ancient rocks.

Vision and Mission

Vision

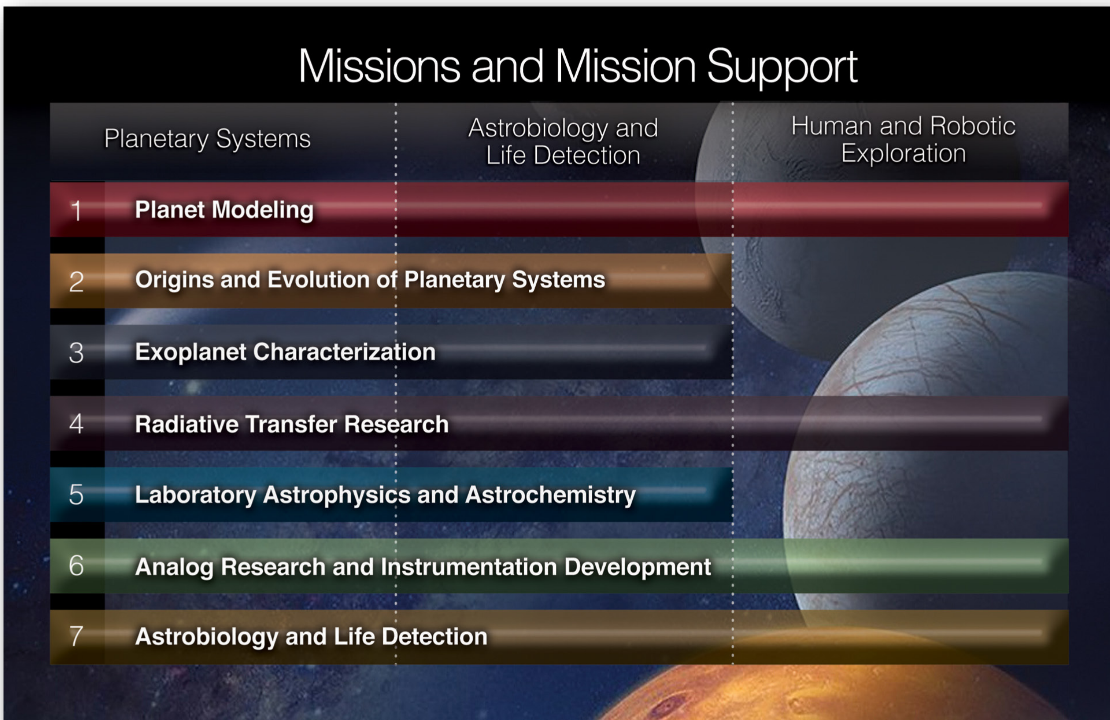
Provide science leadership and stewardship that enhances and enables the NASA community to make new scientific and technical discoveries, thus assuring the success of NASA's strategic goals and space missions.

Mission

The Space Science and Astrobiology Division will continue to provide interdisciplinary core scientific expertise and capabilities that advance NASA's goals and our understanding of the Universe.

The Division's strategic approach will focus on enabling long-term investments in our core scientific research areas. Our unique expertise will advance the Community's science knowledge while driving innovative technology and instrument concepts. The Division will pursue primary leadership roles in NASA missions and mission support activities, based on our current capabilities in the following key strategic focus areas:

- Life Detection Research and Technology
- Mission Driven Analog Research and Mission Concept Operations
- Radiative Transfer Modelling
- Laboratory Astrophysics Research
- (Exo)planetary Formation, Evolution, Characterization, and Technology Studies



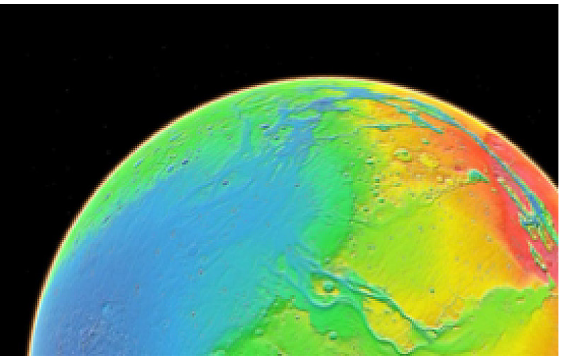
Scientific Capabilities

1. Planet Modeling

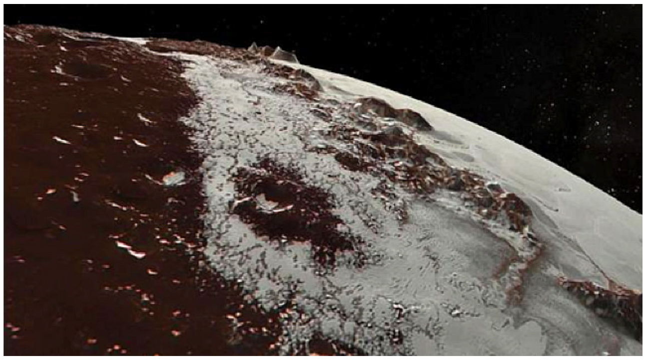
The goal of performing computer simulations of natural phenomena in a planetary environment is to define what processes and conditions are necessary for such phenomena to take place, based on existing remote sensing and in situ observations. How accurately the observations can be replicated within the simulation is dependent on the extent to which the construction of the model is grounded in the relevant physics and chemistry, and to which the physical parameters in the simulation are constrained.

The last few decades have witnessed great advancement in the complexity and spatial resolution attained by models that simulate atmospheric, landform, and geochemical processes. While this field is constantly evolving, it is presently directly and centrally applicable to a range of strategic NASA goals, and provides essential guidance in the development of upcoming planetary missions and associated technologies.

The synergistic relationship that exists between atmospheric, landform, and geochemical modeling strengthens each of them beyond what any one is capable of alone. Computer modeling of these processes fundamentally contributes to planetary research at NASA ARC and to NASA's science vision in general.



Color coding in this image of Mars represents differences in elevation, measured by NASA Mars Global Surveyor. While surface liquid water is rare and ephemeral on modern Mars.



Using actual New Horizons data and digital elevation models of Pluto and its largest moon, Charon, mission scientists created flyover movies that offer spectacular new perspectives of the many unusual features that were discovered and which have reshaped our views of the Pluto system.

Objectives

- Atmospheric and Global Climate Modeling (GCM)
- Geochemical and Spectroscopic Modeling (GSM)
- Landform Evolution Modeling (LEM)
- Establishing an Integrated Planet modeling group at ARC
- Relevance to NASA Goals and Missions

2. Origins & Evolution of Planetary Systems

Observations from Earth and space continue to demonstrate that planet formation is a poorly understood process leading to diverse outcomes, and that the protoplanetary disks in which planets form are both common and varied. Given the many future missions (e. g., SOFIA, ALMA, TESS, JWST, FINESSE, Origins, LUVOIR) focusing on star and planet formation, missions to satellites and primitive bodies (Europa, CORSAIR and Lucy), possible entry probe missions focusing on our own giant planets, and the importance of terrestrial planets to astrobiology, understanding the origins of planetary systems will always be a major focus of research at NASA.

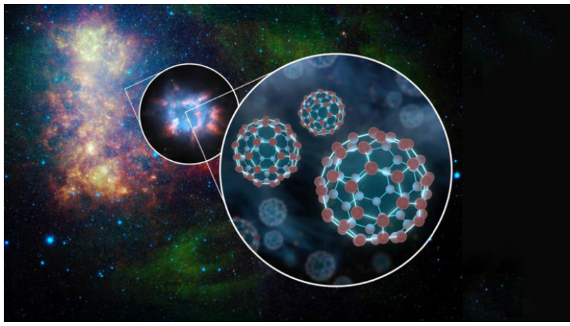
The Division "Origins" group provides NASA and the community a unique interdisciplinary resource with a broad range of expertise and a long-term perspective on major outstanding problems not commonly found in academia. Ames is recognized as having the primary agency role in this crosscutting research capability (per NPD 1000.3E chapter 6.2 and APMC 2016-09-15). The team's research covers the full range of planetary formation from the nebular gas and dust to the planets, satellites and surviving primitive bodies we see today, tying together the dsciplines of astrophysics, exoplanetary and planetary science, and meteoritics.

One new focus area will be a detailed study of The First Million Years of protoplanetary nebula evolution. A lot happened in the first Myr of our own protoplanetary nebula. Meteoritic data reveals that planetesimals had already formed by 0.1Myr in the inner nebula, and 0.4Myr in the outer nebula. It also appears that the composition of these planetesimals changed dramatically within that timeframe, but not much subsequently. It is a popular idea that a Jupiter core formed in that general timeframe, separating these regions. Models and observations show that this period is a time of elevated stellar brightness, ongoing infall from the parent cloud, and outward-flowing disk winds. This critical period has, however, received little attention because of modeling and observational challenges. We believe the time is right for a dedicated focus on including all the relevant fluid dynamics and energetics self-consistently with particle growth, drift, planetesimal formation and core formation, with a close eye to observations.

Objectives

- Understand evolution of protoplanetary nebulae
- Understand particle growth from dust to planetesimals
- Understand formation of planets, satellites and rings, and their long-term evolution and dynamics
- Integration with NASA Science missions and the scientific community

This artist image depicts a faraway solar system like our own except for one big difference. Planets and asteroids circle around not one, but two suns. NASA Spitzer Space Telescope found evidence that such solar systems may be common in the universe.



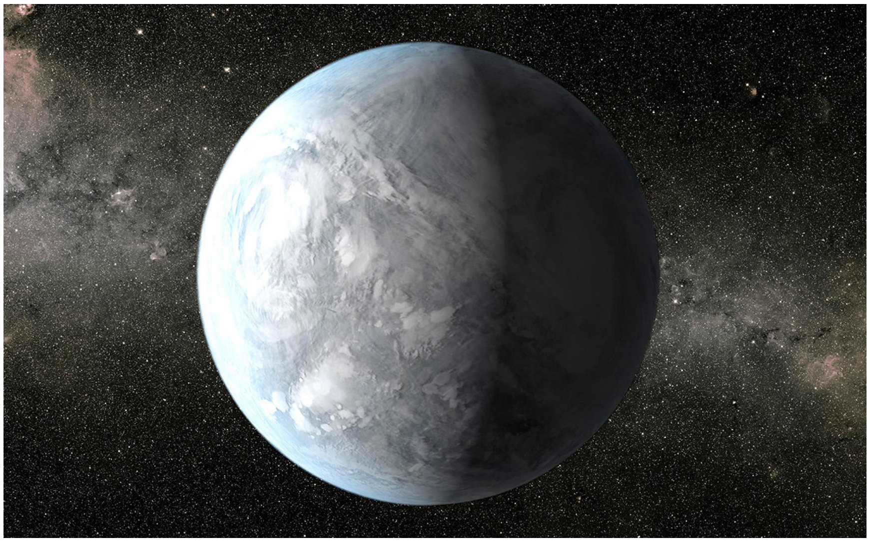
An infrared photo of the Small Magellanic Cloud taken by NASA Spitzer Space Telescope is shown in this artist illustration; an example of a planetary nebula, and a magnified depiction of buckyballs.

3. Exoplanet Characterization; Enabling NASA's Search for Life

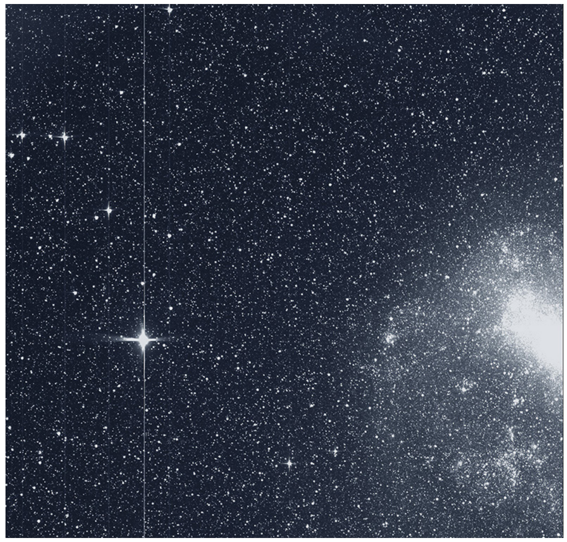
There are now over 4000 confirmed planets listed in the NASA Exoplanet Archive, and most of these were discovered via the Ames-conceived Kepler/K2 missions. We now know that most planetary systems are different from our own and the most common type planet is not one we have in our solar system. The TESS mission is now finding more transiting planets, many around nearby bright stars that are amenable to detailed characterization. The upcoming James Webb Space Telescope (JWST) and Wide Field Infrared Survey Telescope (WFIRST) missions will further add to our knowledge of exoplanets and open new windows for exoplanet characterization through spectroscopy and direct imaging observations. Ames scientists are leading important efforts to facilitate characterization of the exoplanet discoveries and helping to enable NASA's search for life in the universe.

Major Division efforts include developing an innovative high-resolution imaging capability to allow correct measurements of exoplanet radii, which lead to improved occurrence rates and atmospheric studies as well as a better understanding of exoplanetary system formation and evolution. Ames scientists are also leading efforts to characterize exoplanets through JWST spectroscopic observations using detailed atmospheric models and spectral retrieval techniques. New modeling techniques, including innovative treatments for clouds and hazes, are being developed to enable the interpretation of spectroscopic data from both JWST and WFIRST. Robust spectral characterization of a variety of exoplanets is needed to ultimately understand their diversity, formation, evolution, and how they relate to our own solar system and its planets, ultimately including Earth. Additionally, spectroscopy and direct imaging are critical in the search for biosignatures and life elsewhere in the Galaxy. These efforts are deemed as critical needs in New Worlds, New Horizons, the 2010 Decadal Survey, and the 2014 NASA strategic Science Plan. We anticipate similar needs will be highly ranked in the Astro2020 Decadal Survey as well.

In addition, Ames scientists are contributing to the scientific success of the Kepler/K2, TESS, JWST, WFIRST, and other NASA exoplanet mission concepts through unique ground-based mission support observations, exoplanet atmospheric modeling efforts, and community science activities for JWST, WFIRST, and beyond. Ames scientists develop and contribute valuable exoplanet related data, data products, and software tools to the community via public archives. These diverse, multi-faceted, and substantive efforts will help ensure that NASA will successfully meet its exoplanet discovery and characterization goals in the 2020s and beyond.



The artist concept depicts Kepler-62e, a super-Earth-size planet in the habitable zone of a star smaller and cooler than the sun, located about 1,200 light-years from Earth in the constellation Lyra.



The Transiting Exoplanet Survey Satellite (TESS) took this snapshot of the Large Magellanic Cloud (right) and the bright star R Doradus (left) with just a single detector of one of its cameras. The frame is part of a swath of the southern sky TESS captured in its "first light" science image as part of its initial round of data collection.

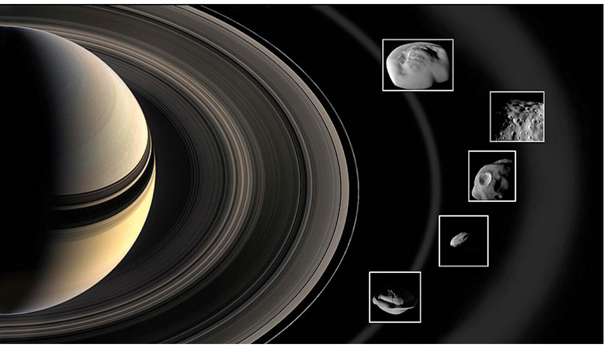
Objectives

- Provide unique leadership and contributions for exoplanet discoveries and characterization
- Validating and characterizing high-value exoplanets for JWST and beyond
- Characterizing exoplanet atmospheres with JWST
- Develop exoplanet atmosphere models
- Conduct technology development for direct imaging of exoplanets
- Determine the measurements required to assess habitability and biosignatures

4. Radiative Transfer Research

Radiative Transfer (RT) is a fundamental topic needed to interpret all remote observations spanning airless bodies, atmospheres of exoplanets and solar system bodies, protoplanetary disks, and all other astronomical objects. These complex applications require a comprehensive toolset of custom codes and extensive databases of optical properties and atomic and molecular line data. NASA Ames Research Center has a strong and unique core competency in theoretical and computational RT studies, and a long history of applying them to solar system missions. Our expertise goes beyond using currently available models/ tools to innovating new cutting-edge methodologies. We have assembled a cross-topic, "capability-focused" team to unify the existing complementary expertise, in order to facilitate progress in all individual topical areas using the same theoretical and experimental tools.

We envision a future institution where we are greater than the sum of our parts. We would like to cross fertilize our personnel and resources at Ames and make/strengthen collaborations across divisions, NASA centers, and academia. Institutions that harness interdisciplinary endeavors will be the trailblazers for future discoveries. As the scientific world becomes ever more complex and the traditional lines between disciplines fade, we need to heed the call of this future just as other institutions are, as evident at GSFC and GISS. This is attainable by facilitating interactions and implementing infrastructure geared toward cross cutting projects.



This illustration shows NASA's Cassini spacecraft in orbit around Saturn. Cassini made 22 orbits that swooped between the rings and the planet before ending its mission on Sept. 15, 2017, with a final plunge into Saturn.

During super-close flybys of Saturn's rings, NASA's Cassini spacecraft inspected the mini-moons Pan and Daphnis in the A ring; Atlas at the edge of the A ring; Pandora at the edge of the F ring; and Epimetheus, which is bathed in material that fans out from the moon Enceladus.

Objectives

- Next generation radiative transfer methods and tools
- Grow agency capabilities
- Develop smart spectral retrieval tools for complex atmospheres and surfaces

5. Laboratory Astrophysics and Astrochemistry

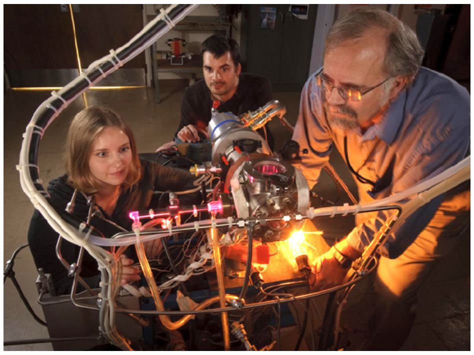
Laboratory Astrophysics plays a key and unique role in the optimization of NASA missions, both at the science conception level and at the science return level. Laboratory astrophysics is the Rosetta stone that enables translation of space mission observations into knowledge. The field of Laboratory Astrophysics and Astrochemistry consists of laboratory experiments and theoretical calculations that are key factors for the understanding of our universe by complementing astronomical observations, spacecraft missions, and modeling. Laboratory experiment and quantum calculations simulating astrophysical conditions generate data (spectra, optical constants, opacities, line lists, etc.). These data are used to interpret the observational data returned by missions and provide testable predictions to advance knowledge and guide future observation campaigns. Increasingly accurate astronomical observations provide direction for Laboratory Astrophysics and Astrochemistry measurements and calculations. Hence, confronting observations with experimental data can be a driver for new mission proposals, development of new technologies, and mission instruments.

The multidisciplinary nature of the workforce at NASA Ames (astrophysicists, astrochemists, physicists, planetary scientists, theorists, astronomers) makes it a unique environment for doing Laboratory Astrophysics and Astrochemistry research. The expertise of the Laboratory Astrophysics and Astrochemistry group at Ames, and its well-established and recognized experimental and theoretical facilities for the study of a variety of molecules and environments, will be exploited, providing an Agency capability in Molecular Universe studies (the astrophysics and astrochemistry of the interstellar medium, protoplanetary disks, etc.), Astrobiology, Solar System science, Exoplanets, and associated databases.

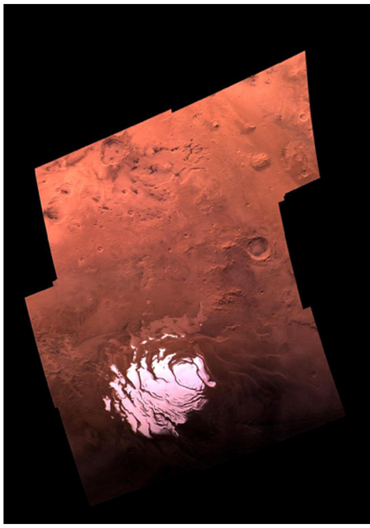
The Ames Laboratory Astrophysics and Astrochemistry group will continue to be an Agency leader in providing critical data that exoplanet, planetary atmosphere and protostellar disk modelers, astronomers, and astrobiologists require to conduct their research. The Ames group will focus their laboratory efforts on support of critical experiments and calculations, those based on the desires and needs of the space science community.

Objectives

- Establish a leading role in supporting JWST and polycyclic aromatic hydrocarbon molecules (PAHs)
- Provide new theoretical and laboratory data for the study of exoplanetary atmospheres
- Investigate astrobiological relevance of irradiated ices and ice-grain interactions
- Provide new laboratory and theoretical data for solar system exploration
- Databases and associated tools



NASA scientists Stefanie Milam, Michel Nuevo and Scott Sandford at the Ames Astrochemistry Lab studying the origin of life reproduced uracil, a key component of our hereditary material in the laboratory.



South Polar Residual Ice Cap

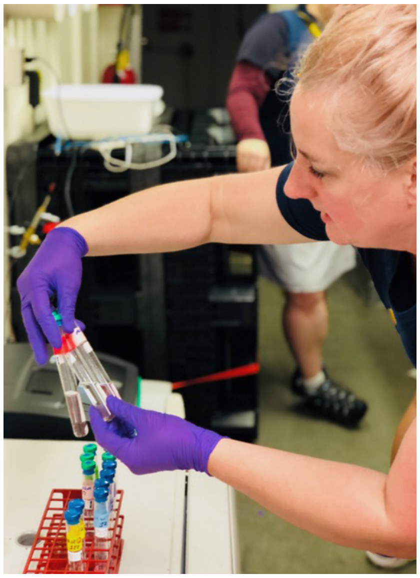
6. Analog Research & Instrumentation Development

The Agency core capability for Analog Research and Instrument Development will continue to lead innovation, mission design concepts for operations, and perform field tests in analog environments using low-cost, prototype instrumentation. The Instrument Development component will develop instruments for flight missions in the areas of life detection, planetary mineralogy and geochemistry, in situ atmospherics, and in situ resource identification and utilization. The teams' expertise, in partnership with other NASA Centers, will be focused in providing Agency leadership in science-driven robotic and human exploration missions as well as small mission instrumentation concepts.

This Analog Research core capability will advance science instrumentation from low to mid Technology Readiness Levels (TRL), preparing them for flight maturation through testing in relevant environments (for example, in vacuum over the range of temps encountered on the Moon, or at Mars surface pressures over the temp range found there), and then for mission insertion. Additionally, we will improve the Agency's Core Competency science expertise in Life Detection, Planetary Geology and Geochemistry, and expand on in-situ atmospheric measurements across SMD interests and leverage collaboration with STMD and HEOMD as well.

The Division capability for Analog Research will continue to focus on the following three science areas: (1) Exploration of new environments, selected on the basis of habitability and biosignature parameters; (2) Geologic investigations for understanding planetary systems; (3) Analog field work in support of human and robotic exploration; and will add a fourth area in 2019 that will focus on the creation of virtual, "Synthetic Worlds", in collaboration w/Code TI, based on analog data, to be used for planetary mission design and operations.

Extra-Vehicular crew members explore Kilauea volcano during science-driven Mars mission activities conducted by the BASALT Research Program.



Dr. Amy Smith conducting microbial studies onboard of the E/V Nautilus during the 2018 SUSBEA Loihi Seamount mission cruise. Her work is part of a larger study to examine specific deep-sea hydrothermal systems as analogs to Ocean World systems such as Enceladus.

Objectives

- Establish a center for analog field studies Positively affect robotic and human spaceflight utilizing terrestrial environments
- Identify, explore and characterize environments for habitability & biosignatures
- Develop and test new technologies and instrumentation
- Advocate for an ARC Instrument Development Center
- Develop instrumentation that responds to in situ resource utilization (ISRU)
- Establish a virtual analog tool in support of NASA's Moon to Mars initiative

7.

Astrobiology and Life Detection

The Space Science and Astrobiology Division was instrumental in establishing Astrobiology as a field and continues to make significant advancements in Astrobiology and Life Detection. We seek to understand the processes that provide continuity from the abiotic formation of organic molecules to the transformation of planetary environments by mature biomes. We have produced multiple biomolecules in laboratory experiments that simulate astrochemical processes in multiple environments, including laboratory and theoretical modeling of molecular clouds and radiation sources We are linking biological interactions and functions with biogeochemistry and evolutionary biology to explore the relationship between life, habitability, and the factors that constrain the production and preservation of biosignatures. We are developing bioinformatics tools for evolutionary analysis of the emergence of biosignature-relevant traits, and have studied the degradation of organic biosignatures via reactions with mineral surfaces.

In our life detection efforts, we are:

- establishing an intellectual framework to interpret the detectable products of life processes and relevant methods and instruments to detect them
- developing the capabilities necessary to bridge the gap between the abiotic formation of organic molecules and the emergence of life
- exploring the prebiotic plausibility of chemical reaction networks
- developing novel experimental systems to examine processes needed to sustain protocells and to support and shape early evolution

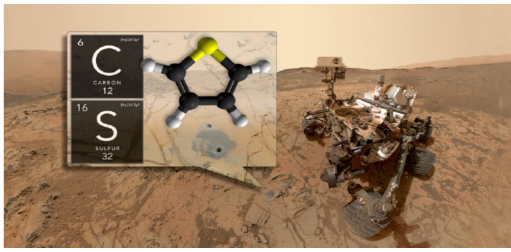
We explore the boundaries of habitability on Earth by clarifying the limits of life with respect to energy, water availability, and temperature. Our research into life detection and biosignatures in the solar system and exoplanets includes field campaigns and long-term environmental monitoring focused on novel biosignatures that have potential for remote detection on exoplanets and detection in situ by Solar System surface missions. We have investigated hopanoid biomarkers relevant to interpreting evidence of microbial metabolism in Earth's early rock record. We continue to test in situ real-time life detection assay protocols for mitigating false negatives in geobiological samples from deep subsurface, hyper-arid, high elevation extreme environments. We have deployed new instrumentation (GC-IRMS, Raman microscope system) in support of these efforts.

A key component of our work is community and programmatic service: We continue to develop the Astrobiology and Habitable Environments Database (AHED), and have maintained the ongoing effort to update "Ladder of Life Detection". We have begun to explore opportunities to inform requirements for planetary protection and contamination control (drill, sample handling), and provide literature reviews of biosignatures and astrobiology strategies.

Objectives

- Connect abiotic formation of organic molecules to emergence of life
- Biological function and habitable environments: Co-evolution of life and its environment, and production and preservation of biosignatures
- Habitability assessment, biosignatures, and life detection in the solar system and exoplanets
- Support programmatic efforts and serve research community

Lengthy detective work from data collected by NASA rover Spirit confirmed that an outcrop called Comanche contains a mineral indicating that a past environment was wet and non-acidic, possibly favorable to life.



NASA's Curiosity rover has discovered ancient organic molecules on Mars, embedded within sedimentary rocks that are billions of years old.

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https://www.nasa.gov/content/space-science-and-astrobiology-ames

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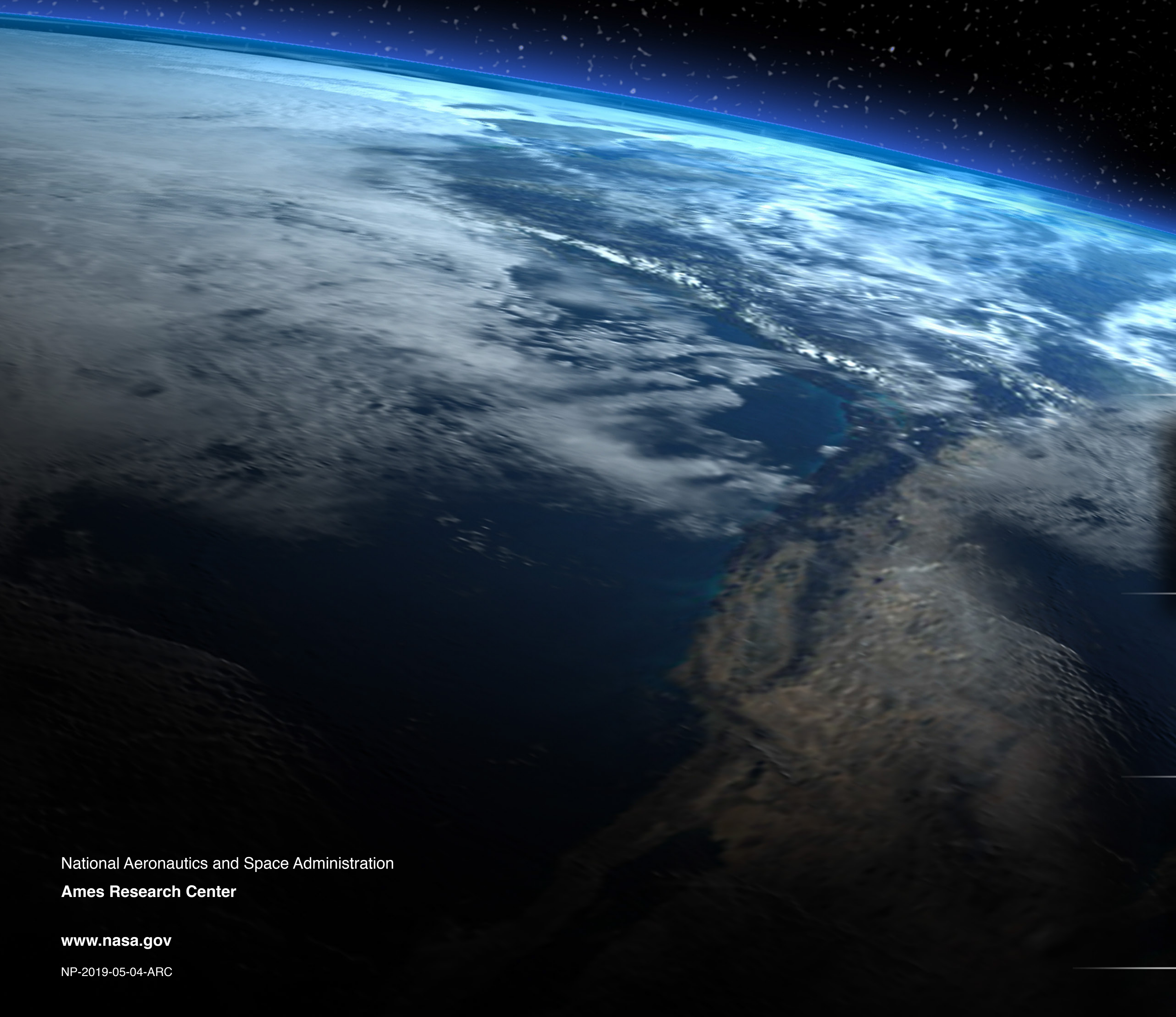

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NP-2019-05-04-ARC