2015 NASA ASTROBIOLOGY STRATEGY DOCUMENT AND THE VISION FOR SOLAR SYSTEM EXPLORATION. L.E. Hays[1], M.H. New[2], and M.A. Voytek[2]. [1]Jet Propulsion Laboratory-Caltech, [2]NASA Headquarters.

Introduction: In 2015 the NASA Astrobiology Program released the Strategic Plan [1] to outline the goals of the research program for the next decade. The grass roots process of creating this document took over a year, involved almost 200 scientists from various aspects of the field of Astrobiology, and created an inclusive document that is 257 pages long. This document was designed to be as all-encompassing as the field of Astrobiology itself – so that any scientist who explores a field with broad astrobiological relevance can see their work reflected within the Strategy. Importantly, the structure of the document was not centered around targets (Mars, Europa, exoplanets, etc.), but instead focused on seven major topics of research in the field today.

Major Topics: The seven major topics covered in the Astrobiology Strategy are below:

1. Identifying Abiotic Sources of Organic Compounds

2. Synthesis and Function of Macromolecules in The Origin of Life

3, Early Life and Increasing Complexity

4. Co-Evolution of Life and The Physical Environment

5. Identifying, Exploring, And Characterizing Environments for Habitability and Biosignatures

6. Constructing Habitable Worlds

7. Challenges and Opportunities in Astrobiology

Within each of these topics, there is a discussion of relevant "Areas of Research" and many additionally have a section on "Challenges for the Next Ten Years".

Areas of Research: Some of the "areas of research" are quite broad, and include current and future questions that are being explored within each of the topics. Some of these questions include:

- What is the Role of the Environment in the Production of Organic Molecules? (Topic #1)
- What is the chemistry of macromolecular formation reactions? (Topic #2)
- Dynamics of the Evolution of Life: Intrinsic vs. Extrinsic factors (Topic #3)
- How Does Our Ignorance about Microbial Life on Earth Hinder Our Understanding of the Limits of Life? (Topic #4),
- "How Can We Identify Habitable Environments and Search for Life within the Solar System?" (Topic #5)
- "What are the Processes on Other Types of Planets That Could Create Habitable Niches?" (Topic #6).

Although these "areas of research" questions include activities that are ongoing and in the near-future, they are wide-ranging enough to help set the stage for long-term research goals for these interconnected topics within astrobiology, some that will take technological innovations, improvements in information and data processing or exploration of other bodies in our solar system that will unfold over the next few decades.

Challenges for the Next Ten Years: In addition to longer-ranging and more broad areas discussed above, four chapters independently call out some of the major goals for the next ten years of research. Although these are more limited in time scale and scope, they provide specific targets for the medium range astrobiology research.

The Topic 1 challenges are identified as:

- How do environments drive organic molecule production?
- Were meteorites and comets relevant to organic inventories on prebiotic Earth? Were all molecules required for the emergence of life on Earth generated endogenously, or were some necessarily provided from exogenous sources?
- What were the sources of the molecules that became the building blocks of life?
- What compounds derived from abiotic synthesis are characteristic of their sources?

The Topic 2 challenges are identified as:

- Investigate possible evolutionary paths from earliest macromolecular assemblies and polymers to contemporary DNA/RNA/protein-dominated life. Modern methods of analysis must be employed to evaluate and extend current and proposed models.
- Structures of modern biomolecules at all levels, from the primary to the tertiary, when viewed in their phylogenetic context, can inform us about biopolymer history.
- Separation of template and daughter molecules in the absence of evolved enzymes such as DNA or RNA polymerase remains a challenge.

The Topic 4 challenges are identified as:

- Investigate possible evolutionary paths from How do the different worlds of the past, present, and future Earth inform our understanding of exoplanets?

- How can we better understand the constraints on the timing and tempo of surface evolution and processes?
- What is the fidelity of proxies of biology and environment over long and complex geologic histories?
- How can biological data and geologic data be integrated through evolutionary time?
- How can we develop new approaches or modifications of current approaches to enrich and ultimately isolate organisms currently known only by their DNA sequences?
- What are the methodological challenges coordinating and synthesizing in silico data?

The Topic 6 challenges are identified as:

- Understanding how each of habitable states on Earth was maintained and the processes that governed the transitions into succeeding states provides opportunities for understanding habitable states on other planets.
- Understanding the processes that move complex systems between states is important for developing and testing hypotheses about complex cause and effect relationships (e.g., the timing of the oxygenation of the atmosphere and the evolution of oxygen production).
- Inquiries into epochs and duration of change in planetary cycles are important because the chemical systems that preceded the emergence of life needed time to form.

Relevance to Workshop Goals: Three of the Planetary Science Vision 2050 workshop goals, Origins, Workings and Life could be addressed by sections within the Astrobiology Strategy. Origins, defined as "understanding formation and evolution of solar systems (including exoplanetary systems)" should include topics addressed in the Strategy such as how early processes contribute to habitable environments throughout the solar system and other stellar systems (from Topic #6) and how these formation mechanisms deliver different compounds important to life to forming planets (from Topic #1). Workings, defined as "understanding how the processes in our solar system operate, interact, and evolve" should be related to astrobiological topics such as how the presence of life on planetary surfaces affects surface processes and how the two evolve together (from Topic #3 and Topic #4 in the Strategy). Finally, the goal relating to Life, defined as "improve our understanding of the origin and evolution of life, including Earth analogs, to guide our search for life elsewhere" is essentially parallel with the overarching goal of Astrobiology as a science. Questions about origin of chemical processes and then early life are covered in Topics #1 and #2 and partly #3. Research relating to the evolution of life is discussed in detail in Topics #3 and #4. Habitable environments throughout the solar system and beyond and their analogs are covered in Topic #5. Finally, Topic #6 expands on this idea further to entire habitable worlds and what their characteristics may be.

The detailed information in the Astrobiology Strategy, compiled by, and with ideas from, a large number of scientists with diverse research backgrounds and perspectives represents the goals of this community and the long-term vision of Astrobiology science.

Summary: The Strategy is a recently completed document that represents the long-term scientific goals of the broad and interdisciplinary Astrobiology community. This paper will focus on highlighting the areas of overlap between the suggested key research directions highlighted in the Astrobiology Strategy and the stated goals of Origins, Workings and Life of the Planetary Science Vision (PSV) 2050 Workshop.

Reference:

[1] Hays L. E. (editor-in-chief) *2015 NASA Astrobiology Strategy* (https://astrobiology.nasa.gov/uploads/filer_public/01/28/01283266-e401-4dcb-8e05-3918b21edb79/nasa_astrobiology_strategy_2015_151008.pdf)