alone

A Discovery Sourcebook for Astrobiology

EXECUTIVE SUMMARY

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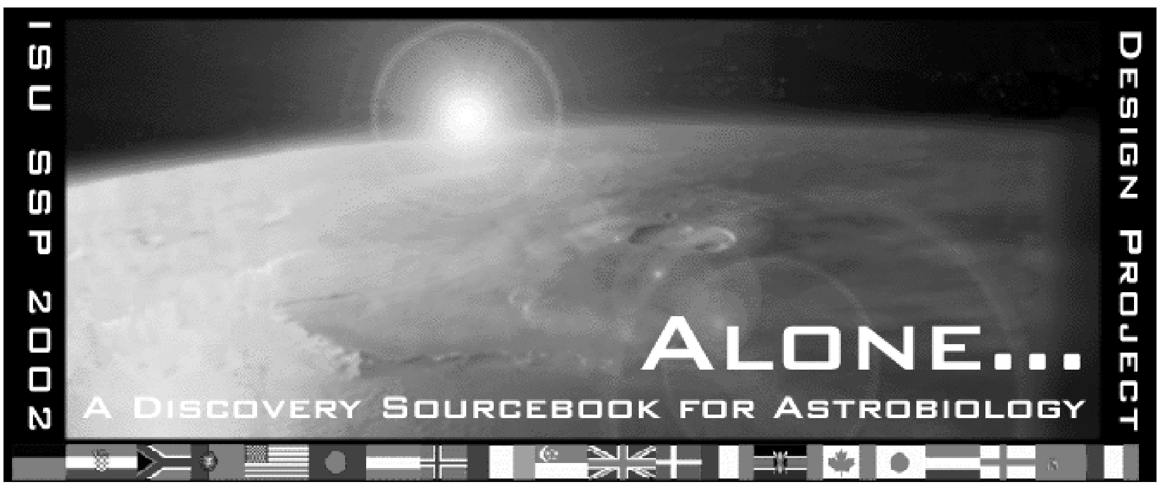
Alone? A Discovery Sourcebook for Astrobiology is the product of the International Space University Summer Session Program 2002 held at the California State Polytechnic University in Pomona. Forty-six students from twenty countries and a wide range of backgrounds came together to create this sourcebook, which represents an international, interdisciplinary, and intercultural approach to the topic of astrobiology.

The sourcebook combines the perspectives of many professional fields involved in space activities. These include space and society, business and management, engineering, life sciences, physical sciences, policy and law, satellite applications, and space systems analysis and design. Our target readers are both those with experience in astrobiology and those not yet schooled in its concepts.



As the field of Astrobiology continues to emerge, this sourcebook provides a consolidated, interdisciplinary viewpoint. By gathering sources from many fields, this book serves as a central resource of information. It also provides added value to guide decision makers, investigators, students, and the public at large.

The sourcebook addresses issues pertaining to the search for and discovery of non-Earth based life, extant or extinct, and not the study thereof.

The period of study is the past, the present and 20 years into the future.

"A man that is of Copernicus's opinion, that this Earth of ours is a planet, carry'd round and enlighten'd by the Sun, like the rest of the planets, cannot but sometimes think that it's not improbable that the rest of the planets have their dress and furniture, and perhaps their inhabitants too, as well as this Earth of ours".

Christiaan Huygens, "Cosmotheoros: or Conjectures concerning the Planetary World", London, 1698

Lying at the interface among many major branches of scientific inquiry, Astrobiology has emerged over the past ten years to become an exciting, and still evolving branch of active research.

Many space missions have been performed or planned within the astrobiology context, both before and after the consolidation of the field started in the mid-1990s. This includes the search for life in extreme conditions here on Earth, the Moon, Venus, Mars, comets, and other bodies within our solar system. These missions strike out to search the solar system for answers to one of the ultimate questions of humankind.

Is Earth unique in its ability to create and sustain life? Are we alone in the Universe?

Long before the first observations of Jupiter's moons by Galileo, humanity has looked to the stars for answers, guidance, and inspiration. The impact of astronomy on humankind is unquestioned. And its ability to relate to the public's frame of mind has been enhanced with the advent of more advanced telescopes and observatories. Astrobiology is a natural extension of this line of inquiry.

The techniques used to explore astrobiology's questions are drawn from a wide range of scientific, technical and social disciplines. The advent of the space age has brought humanity closer to investigating these questions by synthesizing across disciplines.

100 years ago, the technology to carry out this investigation was unimaginable. 50 years ago, it was not possible to bridge space and time to even start an extraterrestrial investigation. 30 years ago, the first focused space-based efforts were undertaken. Today, humankind's ability to carry out a meaningful search is truly starting to emerge.

"Any sufficiently advanced technology is indistinguishable from Magic."
Arthur C. Clarke

The organization of *Alone? A Discovery Sourcebook for Astrobiology* follows four themes:

Current State (See Chapter 2 in the sourcebook): Discusses past, present, and planned astrobiology investigations. It identifies, references, and summarizes each activity providing an overview of the objectives, progress and present status.

The Quest for Discovery (See Chapters 3, 4, & 5 in the sourcebook): Discusses life, what we think life is, where to look for life, and the experiments to use to identify life, as we know it, either extant or extinct. We discuss future space missions by identifying destinations and mission options. Finally, we discuss planetary protection and its implications on mission protocols.

Human Elements (See Chapters 6 & 7 in the sourcebook): Discusses the impact of astrobiology on the human condition through scenarios. What happens if we do find life or what happens if life finds us? This is followed by a discussion of how education can bridge the gap between astrobiology and the public by functioning as a link among many other fields of study.

Synthesis (See Chapter 8 in the sourcebook): concludes the report with a discussion of how all of the elements in the previous chapters are inseparably intertwined. We demonstrate this in a case study of a future astrobiology mission to the Jovian moon Europa.

Within the scope of the sourcebook, we have attempted to provide a comprehensive overview of past, present and planned missions seeking the conditions for and existence of life beyond Earth.

Exploration in the Solar System: Planets, Moons and Small Bodies. This section of chapter two documents the history of missions to bodies within the Solar System, as well as what is currently planned to explore the secrets of these worlds.

Extra Solar Planets: The search for extra solar planets has so far identified eighty-eight star systems believed to have planets, which are considered candidates for astrobiological investigation using ground and space based telescope facilities. The search has just begun.

Search for Extraterrestrial Intelligence: Radio telescopes have been scanning the skies for decades to pick up faint signals from our galactic neighbors. Several "Wow! Signals" were received, but all could be traced to natural or man-made phenomena.

Are we alone or just deaf?

Is everybody else silent?

What are the signals we should be looking for?

Knowing the properties of life is an important tool in the quest of finding life or the signs of life.

What is life? Simply stated, the question 'What is life?', does not have a straightforward answer. Although it is difficult to define life, it is easier to find characteristics of life as we know it.

Characteristics of Life: Seven main properties used in describing 'life':

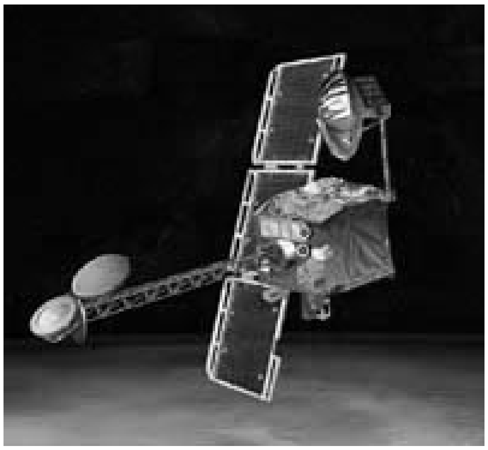
1) Structure and Boundary
2) Thermodynamic Disequilibrium With Environment
3) Energy Conversion
4) Movement
5) Adaptability
6) Replication
7) Information Transfer

Habitable Zones and Extremophiles:
What properties of the neighborhood we live in make it a Habitable Zone.

How does the study of extremophiles on Earth further define Habitable Zones? Consider conditions required to sustain life or survival limits of life. The pertinent factors include: temperature, pressure (low or high), pH, salinity, radiation quantity and quality (e.g. UV, IR).

Finding Life or Signs of Life:
Several instruments are used in a complementary strategy in the search for life. These include search for conditions required for life (e.g. water) and characteristics of life (e.g. movement). We consider instruments used in past missions (e.g. Viking) to refine search strategy and methods.

We develop a mission design option tree to identify a limited suite of future missions for finding extraterrestrial life. It constitutes a limited design space that suits any future astrobiology mission to produce science data within the 20-year timeframe.

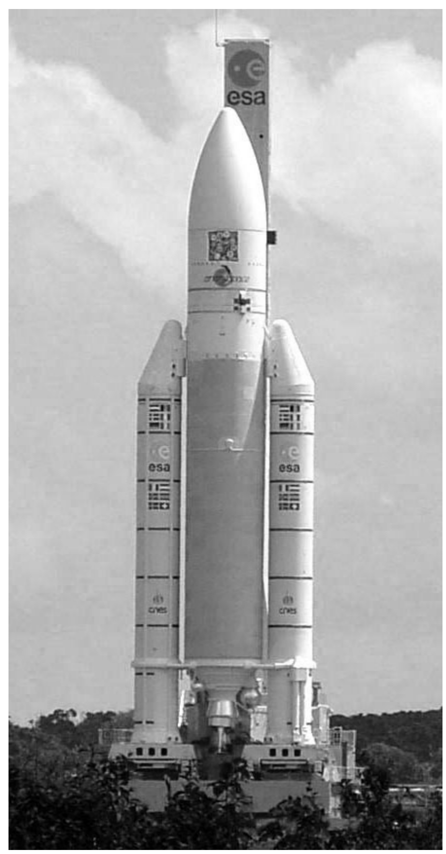


Science Objectives: We ask, ``What science on which body?", e.g. Mars, Europa, Ganymede, Titan, or comets.

Hot Targets: We identify areas of most interest on bodies within our Solar System. Mars, Europa, Ganymede, Titan, and comets are discussed.

Missions and Technology: We describe re-application of existing technologies and identification of enabling technologies that will mature in the next 20 years.

Mission Concepts: We define new mission concepts to advance and invigorate further exploration.

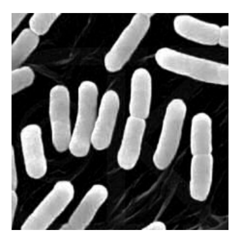


Humanity must not be reckless and insensitive in its incessant quest to explore the universe and in bringing the universe back to Earth.

Protect ANY kind of life from harm. In finding life in outer space, planetary protection dictates that we must protect this extraterrestrial form of life and also protect the Earth's biosphere from the potential harmfulness of this life form. We do not know if this situation is possible, that is why we should be prepared for any eventuality.

Forward and backward contamination definitions are fundamental in the planetary protection context.

Scientific, Ethical, and Legal reasons are motivating us in making so many efforts to avoid contamination in both ways. Science demands preventing the contamination of samples. Ethics underpins the reasons for undertaking such measures. Legal principles provide policy, to regulate our activities to have practical ways to respect the rationales that support planetary protection.



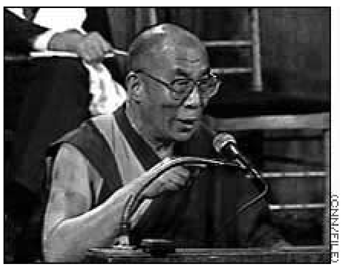
Implementation by physical means: Minimization of forward and backward contamination through bio-burden or contamination reduction methods.

We provide guidelines after having put together all the elements that constitute what is known of planetary protection today. This will help policy makers and mission designers in future decisions.

This is absolutely necessary to obtain an agreement between public, policy, and scientific communities to ensure that future astrobiology missions continue to be funded and make it off the launch pad in support of humanity's quest to explore and search for life beyond.

According to astronomer Richard M. West, *"The discovery of life outside the Earth will be the single, most dramatic event in the entire history of humanity, nothing less and nothing more."*

All parts of society will be influenced by such a discovery, such as religion, politics, culture, science and technology. With the help of scenarios some of the potential reactions can be analyzed and partially forecasted, but not entirely predicted.



Most religions will probably adapt to this new situation, as they have done with other major changes of our worldview in past centuries. On the political level governments may want to restrict the available information to control public reaction or to strengthen their position. Will nations be able to agree on a unified response in the name of humankind?

Scientific research priorities may be shifted to further analyze the findings. Public interest might quickly decrease when the impact on daily lives is small, no new developments are reported and when the discussion is held on a complex scientific/technical level.

Recommended guidelines to mitigate any adverse effects of the first contact: First, transparency and timely distribution of information should be ensured and all media should embrace responsible reporting. Public education should be given high priority to help people deal with this radical change. An international panel of experts should be assembled to correctly assess the situation and support political leaders in their decisions.

And last but not least: **DON'T PANIC!**

It is the educator's job to bridge the gap between astrobiology and the public. What society perceives as "extraterrestrial life" and what the scientists hope to find are two different things. This is especially true since the average "astrobiology" vocabulary consists of "Klingons", "Vulcans", and "Jedi Knights". Carl Sagan made the sweeping accusation that 95% of North America is scientifically illiterate. There is a general trend towards a decrease in scientific literacy among the general population. After conducting a survey of the present astrobiology resources we made a gap analysis which pointed to a need for more of the humanities in activities for children.

A Six-phase curriculum was developed to address a majority of the identified gaps:

- Gives an introduction to astrobiology to pre-assess for present knowledge on astrobiology, misconceptions and for exposure to the basic terminology
- Addresses what is needed for life on earth and beyond.
- Discusses how to look for, protect and study life.
- Examines which planets and bodies in our Solar System we think are best suited to contain evidence of life.

- Studies what is being done on a global basis to learn more about possible life outside our planet.
- Allows students to take what they have learned in the previous phases and apply it towards designing, as "life detectives", their own astrobiology mission.

Astrobiology as a common link: connecting multiple disciplines of science and humanities in a global way with emphasis on actual activities for children and implementation of a proposed curriculum.

The case study gives an example of how the various issues addressed in our sourcebook could influence and shape a possible astrobiology mission. We performed the study with emphasis on an interdisciplinary approach and we used concurrent design processes.

The mission would investigate the Jovian system, extending science obtained through previous missions, with an emphasis on Europa. We chose the Jovian satellite Europa to be our target as it represents one of the most promising places in our Solar System where we could find at least very basic and primitive forms of life. The various aspects discussed in this study could also apply in a similar form to other potential astrobiology destinations.

We show how **currently available technology** could meet the major scientific requirements to investigate Europa, and extend our understanding of the Jovian system. Also, a mission to Europa has a scientific and educational return significant enough to give it the status of a flagship mission.

Education and public outreach plays an important role in the case study, with translation and the adaptation of educational resources representing a significant step towards promoting the global appeal of the mission.

In Summary

Current State: Many missions have been performed which investigated the properties of various bodies within the solar system. It appears that missions to Mars, Jovian moons, Titan, and comets have yielded data most relevant to astrobiology.

The Quest for Discovery: Current thinking points towards looking for life as we know it. The question of how to study and characterize life beyond life as we know it is not addressed.

There are significant opportunities for astrobiology missions in the next 20 years to investigate phenomena discovered by previous exploration missions.

Techniques for planetary protection are sufficient to support current exploration efforts; however, when issues such as sample return are considered, there are gaps to be filled ranging from technical to legal to ethical.

Human Elements: The impact of a discovery of life would have a large and irreversible effect on societies around the world. Societies would adapt to these effects. Research budgets may be re-aligned to address the new questions created and public education would become an important element in bridging the gap.

Building on astrobiology's multidisciplinary nature, education programs have been proposed to increase the public's knowledge, and skills. Students become "life detectives" in their search for understanding.

Synthesis: The Jovian satellite Europa was studied as an example target as it represents one of the most promising places in our Solar System where we could find very basic and primitive forms of life. We show that currently available technologies could meet the major scientific requirements to investigate Europa and extend our understanding. Such a mission would have a scientific and educational return that is significant enough to achieve the status of a flagship mission.

This is an executive summary of *Alone? A Discovery Sourcebook for Astrobiology*, a full copy of the book is available from:

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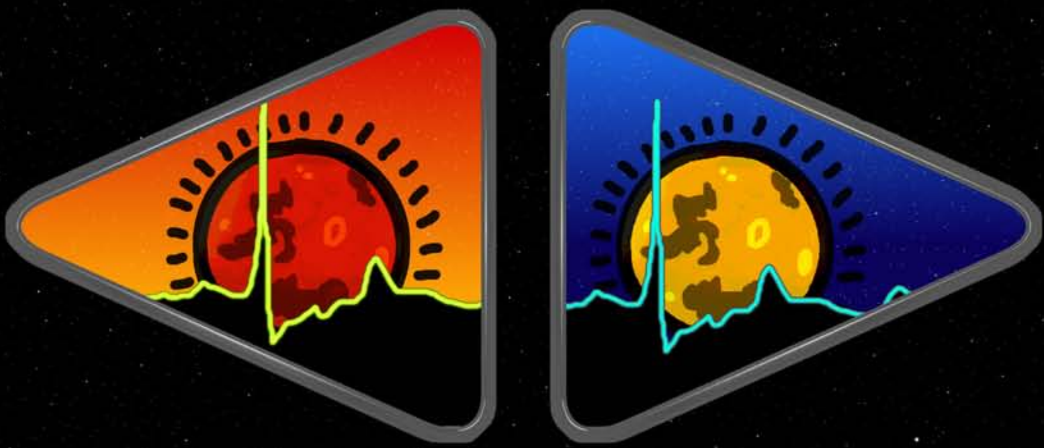

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