COSPAR- 02-A-00039

SEARCH FOR EXTRATERRESTRIAL LIFE: A MULTI-DISCIPLINARY PERSPECTIVE

Astrobiology Design Project Team
International Space University
Summer Session 2002
Pomona, USA

53rd International Astronautical Congress
10-19 Oct 2002/Houston, Texas

COSPAR 02-A-00039

SEARCH FOR EXTRATERRESTRIAL LIFE: A MULTI-DISCIPLINARY PERSPECTIVE

Astrobiology Design Project Team, Summer Session 2002, International Space University

ABSTRACT

The search for extra-terrestrial life has been going on ever since humans realized there was more to the Universe than just the Earth. This quest has taken many forms including, but not limited to: the quest for understanding the biological origins of life on Earth; the search of the radio spectrum for signs of extra-solar intelligence; the deployment of robotic probes to other planets to look for microbial life; and the analysis of meteorites in search of chemical and fossil remnants of extra-terrestrial life. These searches so far have yielded hints, but no unambiguous proof of life with origins from off Earth. Technical advances and new (though not conclusive) evidence of extinct microbial life on Mars have created a new enthusiasm for astrobiology in many nations. However, the next steps to take are not clear, and should a positive result be returned, the follow-on missions are yet to be defined. This paper strives to answer the following questions:

(a) What is the full set of dimensions along which we can search for extra-terrestrial life?

(b) What activities are currently underway by the international community along each of these dimensions?

(c) What are the most effective next steps that can be taken by the international space community in order to further this search (from a policy, sociological and mission point of view)?

(d) Should a positive result be returned along any of the dimensions in (a), what is the appropriate follow-on mission?

(e) How do we ensure that these missions do not contaminate an alien biosphere or endanger our own?

The team working on this project has attempted to answer these questions putting particular emphasis on ways to perform cost-effective exploration while addressing contamination concerns. The outlook is limited to missions looking for water/carbon life and its supporting environments that may be performed within the next 20 years.

INTRODUCTION

Over the past decade, astrobiology has emerged as an exciting and evolving field of research, drawing from a wide range of scientific, technical and social disciplines. Astrobiology, also termed exobiology, "includes the study of the origin, evolution and distribution of life in the Universe." [1] Policy decisions by the US government, NASA and ESA in the mid-1990s have led to a concerted effort by space agencies around the world to define and develop astrobiology programs. Several missions have been conducted to answer one of the ultimate questions facing humankind - Is Earth unique in its ability to create and sustain life? Are we alone in the universe? Curious minds around the globe have pondered over these isuues for centuries but there are significant differences in the way various societies, cultures and religions have attempted to answer these questions. The advent of the space age has made it possible for us to conduct a meaningful search for extraterrestrial life. In addition, the discovery of life in extreme environments on our home planet have opened up new avenues for finding life in locations never before throught possible. High powered telescopes, remote sensing satellites, landers, robotics, in situ investigation, sample return and human investigation are some of the capabilities currently under investigation.

DEFINITION AND CHARACTERISTICS OF LIFE

The initial step in the search for life is to define it. However, the simply stated question ‘what is life?’ does not have a straightforward answer. Over the past centuries, many great minds have tried to define life but to no avail. We are in a similar situation as scientists were in the 18th century when they attempted to define water as “an odorless, colorless, thirst-quenching liquid”, which is true, but inadequate. The development of molecular theory helped to resolve this issue and now water is referred to as H_20. Although it is difficult to define life, it is relatively easier to discuss the characteristics of ‘life as we know it’, for instance structure and boundary, thermodynamic disequilibrium, energy conversion, movement, adaptability, replication etc. In our search for life, it is important to deal with the extreme conditions that life forms, similar to terrestrial organisms, can tolerate. This is a very important aspect as it sets the physical boundaries for the conditions within which life could have evolved and within which life can be sustained.

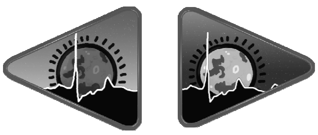


Figure 1: The initial step in the search for life is to define it.

If there is extraterrestrial life it may be either extinct or extant. Evidence of extinct lifeforms can be preserved in rock or ice as fossils. As far as, extant life forms are concerned there can be two distinct types of evidence. First, growing life can be recognized directly, for instance via the detection of metabolic activity. The second type of evidence involves dormant life, which may be spatially or temporally separated from a hospitable niche and in a nongrowing, but surviving stage, from which it could in principle be resuscitated for detection. In the detection of both extant and extinct life, the possibility of nonliving indicators should be considered, e.g. the presence of geochemical tracers (organic or inorganic remnants or products) in environments that are hostile to life, but which would be indicative of life existing in other places or at other times (e.g. biogenic gases, biogenic minerals, complex organic molecules indicative of living systems and footprints). Of great importance in the search for life is the selection of sites that are most likely to yield favorable results. These will include both protected environments that are niches favorable to life or those places where evidence of hidden life or extinct life may be found near to the surface of the planet. Perhaps the most valid critique of the Viking experiments is that they were conducted at the wrong place. Life’s fundamental requirements for liquid water, energy and nutrients should be used as a basis while searching for extinct or extant extraterrestrial life.

To maximize chances of unambiguous results pertaining to the existence of either extinct or extant life, it is imperative to choose a suite of instruments that would reduce the number of alternative interpretations. Remote sensing provides a first step in identifying extraterrestrial bodies where conditions that can support life exist or existed. Once these bodies are identified the next step is to actually send a spacecraft there and conduct in situ analysis. Although a sample return mission enables us to conduct a more thorough investigation, they are also very costly. Thus, it reasonable to bring back to Earth only those samples that are most interesting from a scientific point of view.

PAST, PRESENT AND PLANNED MISSIONS

Humankind has always asked the question, “are we alone?” Throughout the last decades of the 20th century, the answer has alternated between a resounding “yes” to a pensive “maybe not”. But it is in our nature to continue the quest for finding extraterrestrial life. Past, present and planned missions seeking the existence of life beyond Earth include satellites and probes sent to other worlds, remote sensing of other worlds and galaxies, and transmissions to and from other worlds. Earth-based searches include the analysis of meteorites found on Earth and sample collection from the atmosphere using balloons.

So where should we be looking for life? And how should we be searching? There is no direct answer. From what we already know, life can be present and has existed in very harsh environments. The returning of the camera from the lunar missions has shown that dormant life can be revived. The search for extrasolar planets using powerful ground and space-based telescopes has identified eighty-eight bodies, which are potentially candidates for being life-bearing locations. However, there is no guarantee that life exists on these bodies. The continued development of other search tools such as DARWIN will help us to to broaden our horizons.

The search within our own solar system has proved more interesting. This can be partially attributed to easier access. Many missions have been sent to Mars and Venus. Europa and Titan have also shown promise. The missions that have traveled there to date have identified the presence of water. The surface features also indicated that some kind of liquid flows were once present. But did these bodies undergo biological evolution? We have already gathered substantial data on the objects within our solar system and this is continuing to grow. However, the more we learn, the more we realize that our exploration is still in its intitial phases.

Utilizing radio telescopes, we have been scanning the skies in search of transmissions from other civilizations. So far the search has not yielded any signals that prove the existence of extraterrestrial civilizations. Though some spurious signals have been received, at no point have the candidate measurements been replicated. Hence this cannot be considered as conclusive scientific proof of extraterrestrial transmissions.

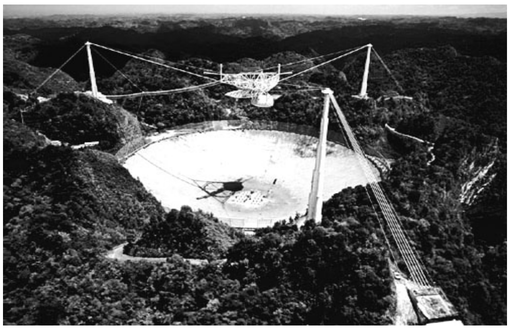


Figure 2: The radio telescope at Arecibo, Puerto Rico is used to conduct SETI investigations

Comets are now known to contain large quantities of volatiles, including organic compounds and a rich variety of microparticles of various types (pure organic particles, silicates, sulfides, and mixed particles). Instead of being bright like a surface made of ice, the nucleus of a comet is "dark", which suggests there may be a significant amount of organic material such as formaldehyde (an organic molecule) on the surface.

Dust mass spectrometers, which have examined comet nuclei, have detected material similar to the composition of carbonaceous chondrites meteorites. Cometary water, carbon monoxide and carbon dioxide ions have been detected on comets, from interplanetary missions. It is theorized that the chemical building blocks of life and much of Earth's water came from asteroids or comets that bombarded the planet in its youth.

Exploring the composition of small bodies in our Solar System will help us to understand the conditions required for the formation of complex molecules such as sugars and aminoacids - the latter being the building block of proteins- necessary for the existence of life as we now it on Earth.

Missions to Mars and Europa are also ideal search grounds. Earlier missions have provided significant data that can be drawn upon. The detection of hydrogen at the poles of Mars and ice on Europa gives weight to the argument that life might be or might have been there in some form. It should also be noted that our own moon is also a potential target on which astrobiology research can be performed. The lunar surface has been peppered with small bodies. The lunar prospectors have indicated the existence of water at the poles. Though this needs to be confirmed by a secondary mission, performing a gamma ray spectroscopy of the polar region may also be useful.

FUTURE MISSIONS:

Astrobiology encompasses not only the search for life itself, extant or extinct, but also the determination of the conditions necessary for life, the specification of its required building blocks, the way life can spread over different environments, and even the future and destiny of existing life. The celestial bodies of interest for astrobiology missions include Mars, Europa, Ganymede, Titan, comets, asteroids, as well as, interplanetary and interstellar dust. All of these objects are unique and interesting astrobiology targets, each with extensive rationales for astrobiology exploration. Mars is interesting because it shows evidence of past volumes of surface water and is in the habitable zone of the solar system. The Galilean moons such as Europa are thought to have liquid water oceans and an oxygen atmosphere whilst Ganymede is assumed to have oceans, a magnetic field, auroras, and a complex geological history. Titan is a place to study how the pre-biotic conditions for life might have evolved. Comets and asteroids are studied because they may harbor chemicals and materials that comprise the building blocks of life, and even life.

MARS

Searching for extinct and extant Martian life is a major part of missions planned and underway to Mars. Any search strategy should be based on these criteria and on the geological, geophysical and geomorphologic properties of the area of interest. Some proposed targets for astrobiology missions are: Gusev Crater to allow biotic and fossilization potential and give information on the hydrology over geological periods of time and climate changes; Valles Marineris for its hydrological and geological history; gullies, young sites with potential periodically subsurface liquid water as Nirgal Vallis and Gorgonum Chaos.

The paradigm for exobiology exploration of Mars can be discussed in the context of three different scenarios of exploration and corresponding roadmaps.
Senario 1: *A discovery of evidence or extinct leads to an international Mars Program fueled by public as well as scientific interest.*
Roadmap: A long-term exploration strategy is proposed with a modular and scalable program composed of a base station and a set of five rovers interacting with each other and with the base.

Scenario 2: *The technical success of the low cost Mars Express/Beagle II mission leads to a Mars race.*
Roadmap: This scenario is likely to prompt a greater interest for Mars exploration. There would be a need to answer questions like: How old is this fossil? Does life still exist on Mars? To answer these questions, a new strategy could be formulated, but probably not before the 2007 launch opportunity. The first idea may be to try to return to the same place (precise landing capabilities needed), with a rover and an appropriate suite of instruments.

Scenario 3: *With Chinese Human flights, a moon program is underway and a permanent lunar base foreseen. NASA tries to turn away attention from these new Chinese missions by initiating a new challenging Mars Program, with or without international collaboration.*
Roadmap: Keeping the budget constraints in mind, a remote sensing mission that can detect subsurface liquid water with an orbiter is proposed. Discovery of life would have far reaching consequences on the existing Mars program, and consequences are difficult to predict today. There might be a desire among scientists to undertake a sample return mission in order to gain a better understaning of the life form. Besides technical challenges, issues regarding public perception and planetary protection issues would also have to be considered. A sample return mission may take place in 2011 or later.

EUROPA

Europa poses unique challenges for potential astrobiology missions. The reasons for sending astrobiology missions to Europa are very compelling as more evidence is collected in favor of the existence of extensive oceans. This, together with evidence supporting significant energy sources, suggests that Europa may hold many astrobiological surprises. The main science objectives for Europa should include determining the presence and phase of any oceans, quantifying geothermal activity and chemically characterizing its potential biosphere. Future missions to Europa should initially consist of remote sensing missions designed to characterize Europa’s surface layers in great detail and determine potential landing sites for lander missions. The lander missions would probably be a suite of many types of robotic landers, some designed to perform surface in-situ experimentation, some designed to penetrate the thick ice layers, and some to carry on down and explore the possible oceans. Among the technologies that would have to be developed for ice penetration missions are compact high-energy power sources and novel communications.

GANYMEDE

Ganymede has several features that make it a potentially interesting astrobiological target including subsurface oceans, permanent magnetic field, complex geological history, non-ice material on and within the crust and internal heat source. Life could have developed there in the past, when a subsurface ocean was believed to have extended closer to the surface and left fossils or even dormant (micro-bacterial) life within the ice crust. Different processes could have elevated evidence for life to the surface of the moon making them more accessible for the purposes of our astrobiology missions. The technology needs and mission types for Ganymede are quite similar to the ones envisaged for Europa. Furthermore, Ganymede is a less harsh, and more easily accessible environment than Europa, making it a more attractive target for future astrobiology missions.

TITAN

Titan is believed to resemble the conditions that were dominant during the early stages of evolution on Earth. Titan could therefore be perceived as a natural laboratory for studying the chemical evolution of complex organic systems in a planetary environment. Titan could possibly help us learn more about the origin, evolution and distribution of life. Remote sensing missions would have to take into account Titan's thick atmosphere. Orbiters equipped with radar and infrared instruments with higher resolution than Cassini can be employed to effectively search for life on Titan. Furthermore, in-situ measurements can be conducted to gain a better understanding of the chemistry and physics of Titan's atmosphere, landmasses and liquids (e.g. laser Doppler anemometry) in conjunction with theoretical modeling.

COMETS OR METEORITES

Comets are thought to hold many of the primordial ingredients for life. Therefore, it is very important to gain an understanding of the role, if any, of comets in the origin of life. From the past and present missions, including Earth-based programs, the composition of comets is identified using spectroscopy and conducting remote analyses. However, no space probe has yet brought any comet samples back to Earth for further study. Sample return and in situ missions will enable us to better investigate the exact chemistry of comets.

NEW SPACE TECHNOLOGIES

New space technologies that are of relevance to astrobiology missions include propulsion systems such as solar sails and magnetic and ion engines. A significant reduction of mass and size is highly desirable to make astrobiology missions more feasible. This has generated an interest in the research and development of Micro Electro-Mechanical-Systems (MEMS)-based spacetechnologies. Furthermore, safe and precise landing technologies are needed for in situ investigations.

PLANETARY PROTECTION

The constraints for planetary protection, or contamination control, pertaining to the design and execution of astrobiology missions are defined by a combination of ethical, legal, scientific, and common sense principles. The lessons learned from the history of Earth's exploration, where civilizations and ecosystems have been lost due to infestations of disease and uncontrolled organisms, cry out for us to proceed with caution as we continue humanity's exploration of the universe. The possibility that we may discover extraterrestrial life causes us to contemplate our responsibility to respect and protect that life. The search for scientific clues to explain the origin of our universe beckons us to proceed with systematic scientific discipline. And the overall concern for the welfare of Earth's populations demand that we implement well-planned precautions as we bring samples of the universe into Earth's biosphere for detailed study.

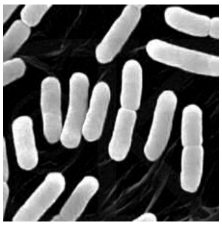


Figure 3: Contamination should be addressed from ethical, legal and scientific perspectives

The general definition of contamination used to outline planetary protection guidelines is *"the uncontrolled or un-catalogued transfer of biological material, potential life forms, or other potentially hazardous substances onboard a spacecraft".* This definition recognizes the impossibility of completely sterilizing a spacecraft and focuses instead on the ability to understand and anticipate the resultant consequences of a controlled transfer. The *"unintentional release of biological materials or pathogens into an extraterrestrial environment from earth"* is referred to as *forward contamination* and the *"unintentional release of possible alien life or pathogens into Earth's biosphere"* is termed *backward contamination*. [1]

Ethical considerations are becoming more important as space exploration increases. Recent commentators have looked at space from a variety of angles; as a dimension, as an instrument, and as perception. From the Anthropocentric Dimension looking at Nature as a utility for human ends no matter what the cost, to the Cosmocentric Dimension, which treats the Cosmos as a priority, the section on ethics considers how humans should act and whether they have any choice the further they go from Earth.

The basis of planetary protection has been established in international law and national policies. This includes the current legal framework based on the Outer Space Treaty of 1967 and the Moon Treaty of 1979. However, few States have enshrined these agreements into their own laws and prefer to rely on policies and directives issued by the United Nations. The International Council of Scientific Union's Committee on Space Research (COSPAR) is the important body providing policies and protocols for planetary protection. COSPAR interacts with and provides advice to the United Nation's Committee on Peaceful Uses of Outer Space (COPUOUS) as well as interacting with national space agencies to influence the content of the detailed policy and guidelines used directly for the planning of astrobiology missions.

Methods for planetary protection fall into two categories. The first category, forward contamination, looks at bio-burden or contamination reduction methods: cleaning processes that physically remove biological material or pathogens from the spacecraft and sterilization processes that kill most material which cannot be removed by cleaning. The second category, backward contamination, looks at containment methods which are used for sample return scenarios where it is desired to transport live specimens, if they exist, and for locations on the spacecraft where design constraints prevent the use of cleaning or sterilization techniques.

EDUCATION

From an educator's viewpoint, astrobiology is a common link connecting the multiple disciplines of science and humanities. Astrobiology involves biology, astronomy, geology, physics, chemistry, technology, social sciences, sociology and other disciplines. Therefore, as a tool in the classroom it is a useful mechanism to show how the sciences and humanities are all interconnected. It can be used as an overall theme to tie different disciplines together and to transition from one subject to the next. It facilitates the cross fertilization of various fields of science, technology and the humanities in a manner that is interesting and relevant to all human beings.

A survey of the existing astrobiology education resources for all international space agencies and governments was conducted. A sample of school science and humanities curriculums was also taken and compared from three global regions for their relevance to astrobiology disciplines. From these products and the findings a gap analysis was carried out to identify areas of improvement and creative concepts for making a more integrated, international and focused curriculum.

Figure 4: Astrobiology connects multiple disciplines of science and humanities

Based on the analysis, the United States currently has the most comprehensive web-based sources for overall astrobiology education. However, these multiple sources taken collectively or individually do not provide the focused multi-disciplinary curriculum aligned with the international efforts planned in the next decade with respect to search for extinct or extant life within our solar system. Similarly, other space agencies such as ESA, NASDA and CSA do not have a consolidated, focused or aligned astrobiology curriculum, web-based or otherwise. Integrated classroom curriculums in the specific areas of science and humanities that make up astrobiology are also lacking. Other informal means of educating and energizing our youth on the subject matter at hand (for example, children's science museums or youth science clubs/organizations) are not currently being employed on any recognizable scale. These gaps coupled with a growing concern in the declining number of students interested in pursuing careers in science and engineering point to a need to develop a consolidated Program. This Program should take the emerging and exciting field of astrobiology and deliver it in a way kids can relate to and interact with for the benefit of their development.

The specifics of the gap analysis point to the need for the following: 1) activities that promote open mindedness with regard to new things such as the impact of finding life on other planets; 2) media literacy using critical thinking skills so that students can distinguish between what Hollywood portrays and what the Science community presents; 3) pre-assessment activities that gauge students present knowledge of astrobiology and help correct any misconceptions; 4) vocabulary exercises and relevant facts that give students the vocabulary to discuss astrobiology better cross curricular links for lessons; 5) more emphasis must be applied to the humanities; 6) practical hands-on lessons that pertain to critical aspects of future missions the international community is pursuing; 7) lessons on planetary protection and Earth/terrestrial body contamination; 8) focused 10 to 14 year old outreach subject matter aligned to current Space Agencies' 10 year plans in astrobiology exploration in order to foster the future thinkers that will influence direction beyond these plans; 9) multiple learning environments, formal and informal, that are conducive to enhancing scientific hands-on critical thinking skills; and 10) an integrated and international approach that minimizes costs, risks and duplication while maximizing the sharing of data.

A six-phased curriculum outline can be used to address a majority of the identified gaps. This multi-disciplined subject matter should be delivered in three environments: 1) computer web-based; 2) classroom hands-on curriculum: and 3) hands-on learning center exhibits that travel from children's museums. The curriculum phases are intended to ensure all the related sciences and humanities encompassing astrobiology are addressed in an inviting manner. The suggested curriculum is intended to be a guide for further development as the Program evolves through the efforts of subject matter and delivery experts. The phases are intended to be modular and scalable such that the complete classroom Program can be tailored to the needs of the students. The Program resources could be used to take as little as one or two days per phase or as much as a year to complete all aspects.

The six curriculum phases are as follows:

- **Phase 1** is an introduction to astrobiology for exposure to the basic terminology, misconceptions created by the media about alien life forms and the idea that space in general, and astrobiology specifically, addresses issues that span beyond science into the humanities.

- **Phase 2** addresses what is needed for life on earth.
- **Phase 3** discusses how to look for, protect and study life.
- **Phase 4** examines which planets/bodies in our Solar System are best suited to contain evidence of life.
- **Phase 5** studies what we globally are doing to learn more about possible life outside our planet.
- **Phase 6** allows the students to take what they have learned in the previous phases and apply it towards designing, as "life detectives" their own astrobiology mission.

Focused strategies should be considered for: 1) promoting the proposed outreach concept to a target set of sponsors who will finance the prototype program; 2) teaming for the development of the outreach products from concept through to a six phase prototype package; 3) field testing the prototype products for feedback and improvement; and 4) implementing a building block approach for regional, national, continental and global program adoption.

<u>IMPACT ON HUMANITY</u>

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." [2] It is difficult to argue that the finding of extraterrestrial life would have no impact on most aspects of our lives. Author Kendrick Frazier has asserted that "Our religions are not the only of our institutions built upon an unjustifiably self-centered sense of our own importance" [3] and that it is therefore reasonable to assume that many aspects of daily life will be greatly impacted by the discovery of alien life and the subsequent perceived shift of humanity's role in the universe. However most of our institutions are fairly resilient and are unlikely to disintegrate when we find extraterrestrial life. An individual's response in such an event would depend on his cultural, religious and social background and the political/military environment under which he operates. The impact will also vary significantly if the extraterrestrial life discovered is near versus far or simple versus intelligent.

HISTORICAL BACKGROUND

We can gain valuable insight about the possible impact of finding extraterrestrial life by examining historical examples where humanity thought that contact was established with alien species. Examples include the discovery of microbial life in ALH84001, the discovery of "channels" on Mars in 19^{th} century, the discovery of pulsars in 1967 and the War of the Worlds broadcast in 1938. Reactions varied from mass hysteria (e.g. the wide-spread panic caused by the radio broadcast of the War of the Worlds) to indifference outside of the scientific community.

Figure 5: World religions will probably adjust to accommodate the finding of extraterrestrial life

SCENARIOS

Four scenarios were generated to explore a range of possible religious, philosophical, political, military, economic, scientific, technological, cultural and social impacts in the event of the discovery of extraterrestrial life.

<u>Life on Mars (Discovery of near and simple lifeforms)</u>

A crewed Mars mission in 2020 has discovered bacterial life that is likely native to Mars and is returning a sample to Earth for further investigation.

There is likely to be a lot of media hype surrounding the contamination of the crew return vehicle. However, initial public interest is likely to fade away fairly quickly and people will return to more immediate concerns. Governments will probably focus their efforts on minimizing backward contamination, as well as, informing and reassuring the public. The Martian bacterial samples might answer important questions regarding the nature of life. If it is determined that the Martian microbe originated independently of terrestrial life forms it would imply that life is fairly abundant in the Universe. The anthropocentric doctrines of the Abrahamic religions (Christianity, Judaism and Islam) will probably adjust to accommodate the finding of extraterrestrial life.

<u>The "Wow! Signal" (Discovery of distant and intelligent lifeforms)</u>

A simple radio signal composed of a count from 1 to 11 has been received from the vicinity of a sun like star 110 light years away.

An international panel of experts from a wide range of fields is likely to be convened to decipher the message and formulate an official response. The decoding process might take years and may yield little result in the absence of a "Rosetta stone". Nations might cooperate or compete with each other in this endeavor. The military is likely to play a significant role is controlling dissemination of information and taking measures to prevent mass frenzy. Abrahamic faiths will have to address questions regarding the souls and salvation of alien species. Eastern religions like Hinduism and Buddhism, on the other hand, are compatible with the notion of multiple inhabited worlds. Public funds are likely to be channeled towards SETI research, astronomy and enabling technologies required for sustained presence in space include advanced propulsion systems, communication systems, power systems and life sciences.

<u>They're here! (Discovery of near and intelligent lifeforms)</u>

An extraterrestrial craft is detected during the search for Near Earth Objects. It has entered Earth orbit but has not responded to our efforts to communicate with it.

If left unchecked parts of the media might blow the story out of proportion and create widespread panic. In developed nations life might temporarily come to a standstill (in an extreme case society may disintegrate) but in some developing countries this event may cause little stir. An international coalition may be formed to deal with the crisis and militaries will be put of high alert. The science and technical community may cooperate to gain a better understanding of the alien technology or to communicate with the aliens. It can be argued that this community may have to face the most radical changes, as much of our current technology could become obsolete and many of our current scientific theories may become invalid overnight. This event may lead to an increase in the number of doomsayers and cultists.

<u>Exoplanet Life (Discovery of distant and simple lifeforms)</u>

The Next Generation Space Telescope has observed the atmosphere of a terrestrial planet of a nearby sun-like star and determined that the atmospheric chemical abundances indicate the presence of life.

The studied impacts are a muted variation of the impacts in the near/simple scenario with some exceptions. The interstellar distance assumed might pose some difficulties in further scientific investigation but it is also likely to remove some, if not all, of the concerns regarding the possibility of transmission of potentially harmful microbes to Earth.

GUIDELINES:

A set of guidelines was put together in an effort to minimize negative impacts in the case of a discovery of extraterrestrial life.

- Transparency and timely distribution of information should be ensured.
- Public education and awareness should be given high priority.
- Media, as well as religious and social groups should embrace responsible reporting.
- An individual's response to the discovery of extraterrestrial life will depend to a great extent on his political/military, social, cultural and religious environment. These factors have to be taken into account when formulating strategies.
- Religion should provide counsel and comfort.
- An international panel of experts from a wide range of fields should be assembled to correctly assess the situation at hand.
- An international agreement with treaty status should be established to deal with issues pertaining to the discovery of extraterrestrial life.
- And last but not the least: DON'T PANIC!

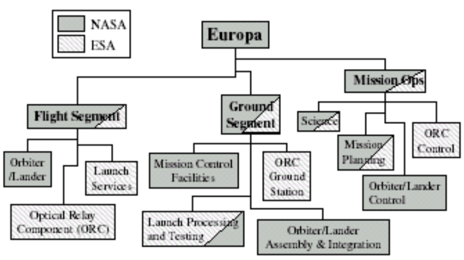
CASE STUDY: ASTROBIOLOGY MISSION TO EUROPA

The Jovian satellite Europa was chosen to be the mission target as it represents, together with Mars, comets and probably the Saturnian satellite Titan (for prebiotic chemistry), one of the most promising places in our Solar System where we could find at least very basic and primitive forms of life, either in living or fossil form. The choice was also driven by the fact that potential missions to Europa have not been well studied.

The scientific objective is to map at least 80% of the surface of Europa, and to identify possible hot targets. This means to detect locations that are relatively warm and where the ice crust is relatively thin. High-resolution images with an optical camera shall be taken to get more information about the surface structure of the Galilean moons, especially Europa. Chemical abundances on the surface and in the ice of Europa will be investigated. The mission aims to find prebiotic building blocks, or perhaps even signs of dormant or extinct life. The mission was designed under the assumptions:

- The mission should happen within the following 20 years.
- The mission should be feasible using existing launch and communication facilities.
- The mission should be conducted as a joint NASA/ESA project.
- The budget limitations for the whole mission should fit into the frame of a so called ”flagship/cornerstone” mission.

Program Management:
Work Breakdown Structure



The payload should include a radar for subsurface mapping, an infrared camera to search for warmer spots on Europa, ultraviolet and extreme ultraviolet spectrometer to provide a better understanding of plasma processes on Jupiter and the Galilean moons and a high resolution optical camera. Lander will be equipped with a passive seismic sounder to gather information about the tectonic activities on Europa and the cryobot will have a miniaturized gas chromatograph and a mass spectrometer.

Overall Europa Program Schedule

Cost Breakdown: Europa Mission

Phase A, B, C/D Cost Summary in FY '02$M		
	Cost	% Total
Project Management	62.4	2.0
Outreach[1]	5.0	0.2
Project and Mission Engineering	140.8	4.5
Bus	156.0	5.0
Instrument Support	31.2	1.0
Orbiter, Lander[1]	1875.0	59.9
Launch Mission Operations[1]	20.0	0.6
A, B, C/D Sub total without LV	2290.4	73.2
Reserves at 20%	458.1	14.6
Launch Vehicle[1]	200.0	6.4
A,B,C/d total with LV and reserves	2948.5	94.2

Phase E and Overall Mission Cost Summary in FY '02$M		
	Cost	% Total
Project Management	31.2	1.0
Science (3 years)	63.0	2.0
Mission Operations (6 years)	63.8	2.0
Phase E Subtotal	158.0	5.0
Reserves at 10%	15.8	0.5
Phase E Total	173.8	5.6
Phases A, B, C/D Total	2948.5	94.2
Mission Total (Phases A through E)	3120.0	99.7
with GSO Optical Communications	3130.0	100.0

The principle generally known as the “Precautionary Principle” is one that has grown over the years in response to perceived high-risk ventures, which have failed. In essence, the mission should be considered in its entirety. So in addition to the technical matters, legal, political and educational issues should also be considered. Negative public reactions due to a lack of public information can lead the authorities to deem the mission too risky and in the extreme, could lead to cancellation.

CONCLUSION

The possibility for the discovery of extraterrestrial life and the consequences of that discovery make astrobiology a very compelling field of study. Here on Earth, the list of extreme locations where life has been found is growing. However, a leap forward is required in the study of regions beyond Earth. Imagine a day when we gather direct physical evidence of simple, near life or an instance when data from an orbiting observatory with resolution of the Terrestrial Planet Finder provides circumstantial evidence of life outside the Solar System! This would advance the quest for discovery, and who knows where it would take us next. Our paper considers life that is similar to terrestrial life forms. However, one of the most interesting long-term questions is: are there life forms that we currently are not familiar with; life that is not dependent on conditions that exist on our carbon and water rich Earth? This would transform the way we define and understand life. Currently, the sciences and the humanities are just beginning to tackle these questions.

REFERENCES

[1] ESA, Exobiology in the Solar System and the Search for Life on Mars, ESA Publications Division, ESTEC, Noordwijk, The Neatherlands, 1999

[2] Richard M. West. *Consequences of Discovery of Life*. Online, October 2001. URL: http://www.lifeinuniverse.org/noflash/ Discoveryconsequences-09-05.html, Last accessed: Aug 12, 2002.

[3] James L. Christian. *Extraterrestrial Intelligence*. Prometheus Books, 1976.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude and appreciation to the individuals and organizations that contributed their time, expertise, and facilities to assist in making this project possible.

Design Project Co-chairs: David Miller and Lloyd French

Teaching Assistant: Weng Ang

Project Advisor: Jim Burke

Faculty and Guest Lecturers: Phillipe Achilleas, Sheryl Bishop, Jim Dator, Ben Finney, Jim Funaro, John Logsdon, Ray Williamson, Penny Boston, David Bushmann, Pam Conrad, George Dyson, Ken Edgett, Arthur Lonne Lane, Chris McKay, Mark Helmlinger, Jeffrey Morris, Dave Morrison, Ken Nealson, François Raulin, Douglas Vakoch, Kasthuri Venkateswaran, Michel Viso

Authors

Nadia AFRIN	MA Student in Science, Technology and Public Policy George Washington University, USA	BANGLADESH
Isaiah ALVARADO	Cal Poly Pomona, USA	USA
Tonje Nanette ARNESEN	Master Student MSS 02/03, International Space University, Strasbourg, France	NORWAY
Tobias BOHNKE	PhD Student The Ångström Space Technology Centre (ÅSTC), Uppsala, Sweden	DENMARK
Philomena BONIS	Science and Technology Teacher Waterloo Region District, School Board, Canada	CANADA
Simon CLUCAS	Spacecraft Radiation Threats & Effects Specialist QinetiQ Space Department, UK	UNITED KINGDOM
Gary DAVIS	Jet Propulsion Laboratory, USA	USA
Samantha DUCKETT	Legal & Business Consultant	UNITED KINGDOM
George DYKE	MD Robotics, MSS Operations Analyst, Canada	CANADA
Jennie ECKARDT	Stanford University, San Francisco, USA	USA
Steven ERICKSEN	Control System Developer Interstates Control Systems, Inc., USA	USA
Alicia EVANS	Boeing Satellite Systems, USA	USA
Vera Assis FERNANDES	PhD Student Planetary Science (Luna Geochronology) Dept. of Earth Science University of Manchester, UK	PORTUGAL (acquired: USA)
Talmon FEUERSTEIN	Master Student MSS 02/03, International Space University, Strasbourg, France	CANADA
Astrid FOSSUM	Ph.D. Student Institute of Theoretical Astrophysics, Norway	NORWAY
Gloria GARCIA-CUADRADO	Bachelor in Physic and PH.D Student Institute of Space Studies of Catalonia (IEEC), Barcelona, Spain	SPAIN
Oliver GERLER	Master of Engineering, PhD Student University of Technology Graz, Austria	AUSTRIA
Tilman GLOTZNER	Etas GmbH, Germany	GERMANY
Gerardine Meishan GOH	LLM Student Faculty of Law, University College London, UK	SINGAPORE
Masato GOTO	Masters Student MSS 02/03, International Space University, Strasbourg, France	JAPAN
Joao GRACIANO	M.S. in Physics Engineering Actively looking for a job	PORTUGAL
Andrea GUIDI	Aerospace Engineer, Italy	ITALY
Jason GUTH	Financial Consultant	UNITED KINGDOM
Christian L. HARDCASTLE	ISS Chief Test & Operations Engineer, Boeing, UK	USA
Martin HOUSTON	Masters Student University of Washington, USA	USA
Atsuyo ITO	Law Student, The Netherlands	JAPAN

Christophe JACQUELARD	EADS - Launch Vehicles, France	FRANCE
Kip JOHNSON	US Air Force – 1st Lieutenant National Space Society – member, USA	USA
Bobby KAZEMINEJAD	European Space Agency, Planetary Missions Division, The Netherlands	AUSTRIA
Jasmin LETENDRE	Robotic Engineer, Master Student University of Sherbrooke, Canada	CANADA
Walter MEISSL	Masters Student, Physics Vienna University of Technology, Austria	AUSTRIA
Brian MOFFAT	AMTS Systems Design: Space Science and Remote Sensing COM DEV Inc, Canada	CANADA
Sven MÜNCHEBERG	Senior Project Engineer Kayser-Threde GmbH, Munich, Germany	GERMANY
Nelson MUTAI	Bachelors Degree in Law, Pupilage in Eldoret-Ngala and co. Directorate of Civil Aviation Aeronautics, Kenia	KENYA
Oeystein OLSEN	PhD student University of Oslo, Norway	NORWAY
Jari PAKARINEN	University of Oulu, Finland	FINLAND
Bojan PECNIK	PhD Student Max-Planck-Institut fűr extraterrestrische Physik, Germany	CROATIA
Fernmarie RODRIGUEZ	B.S. Physics, M.S. Mechanical Engineer University of Puerto Rico at Mayaguez	PUERTO RICO / USA
Arthur SCHEUERMANN	ExtraVehicular & Crew Systems Manager Boeing KSC, USA	USA
Isabelle SCHOLL	Systems and Networks Manager Institut d'Astrophysique Spatiale-CNRS, France	FRANCE
Stefan SCHRODER	Student Astronomical Institute "Anton Pannekoek", Amsterdam,The Netherlands	THE NETHERLANDS
Aaron J. SWANK	Aerospace Engineer Stanford University, USA	USA
Bruno SYLVESTRE	B. Eng. (Mechanical), École Polytechnique de Montréal, Canada MSS 02-03 Student, International Space University, Strasbourg, France	CANADA
Frank VAN LIEMPT	Ir. Mechanical Engineer Dutch Space, The Netherlands	THE NETHERLANDS
Edrich YAU	Topsat Comms Engineer QinetiQ Space Department, UK	UNITED KINGDOM
Kris ZACNY	PhD Student University of California, Berkeley, USA	SOUTH AFRICA