Project Haystack
The Search for Life in the Galaxy

SETI INSTITUTE

2010

SETI Institute

Mountain View, California

Library of Congress Cataloging-in-Publication Data

Project Haystack: the search for life in the galaxy / SETI Institute.
xxiv, 261 p. 22x28 em. -- (Life in the universe series)
Includes bibliographical references.
ISBN 1-56308-328-0
1. Milky Way--Study and teaching (Secondary)--Activity programs.
I. SETI Institute. II. Series.
QB857.7.P76 1996
523.1'12--dc20 95-38946
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Scope and Sequence
Life in the Universe Curriculum

This scope and sequence is designed to describe the topics presented and the skills practiced in the Life in the Universe series curriculum as they relate to factors in the Drake Equation:

$$(\mathbf{N}) = R_{*}\bullet f_{p}\bullet n_{e}\bullet f_{l}\bullet f_{i}\bullet\ _{c}\bullet L\bullet$$

In this equation, N is an estimate of the number of detectable civilizations in the Milky Way Galaxy that have developed the ability to communicate over interstellar distances. If a civilization has such an ability, it most probably arose from the *desire* to communicate. It follows that such a civilization is probably trying to communicate, just as we are trying. This was the rationale for formulating the Drake Equation, and this is the rationale for the search for extraterrestrial life.

Factors in the Drake Equation	**Related Topics**
R_* = the number of new stars suitable for the origin and evolution of intelligent life that are formed in the Milky way Galaxy each year	*Astronomy, Chemistry, Mathematics*
f_p = the fraction of these stars that are formed with planetary systems	*Astronomy, Mathematics, Physics*
n_e = the average number of planets in each system that can sustain life	*Astronomy, Biology, Chemistry, Ecology, Physics*
f_l = the fraction of life-sustaining planets on which life actually begins	*Astronomy, Biology, Chemistry, Ecology, Geology, Meteorology*
f_j = the fraction of life-sustaining planets on which intelligent life evolves	*Anthropology, Biology, Geology, Meteorology, Paleontology*
f_c = the fraction of systems of intelligent creatures that develop the technological means and the will to communicate over interstellar distances	*Language Arts, Mathematics, Physics, Social Sciences*
L = the average lifetime of such civilizations in a detectable state	*Astronomy, History, Mathematics, Paleontology, Social Sciences*

Life in the Universe Series	Topics	Skills
Grades 3-4 *The Science Detectives*	• Art • Astronomy • Chemistry • Language Arts • Mathematics • Physics	• Attribute Recognition • Cooperative Learning • Mapping • Measurement • Problem Solving • Scientific Process
Grades 5-6 *The Evolution of a Planetary System*	• Art • Astronomy • Biology • Ecology • Geography • Geology • Language Arts • Mathematics • Meteorology • Social Sciences	• Problem Solving • Cooperative Learning • Scientific Processes • Mapping • Measurement • Inductive Reasoning • Graphing
Grades 5-6 *How Might Life Evolve on Other Worlds?*	• Art • Biology • Chemistry • Ecology • Language Arts • Mathematics • Paleontology • Social Sciences	• Classification • Inductive Reasoning • Laboratory Techniques • Mapping • Microscope Use • Scientific Process • Cooperative Learning
Grades 5-6 *The Rise of Intelligence and Culture*	• Anthropology • Art • Biology • Ecology • Geography • Geology • Language Arts • Mathematics • Social Sciences • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Technique • Microscope Use • Problem Solving • Scientific Process
Grades 7-8 *Life: Here? There? Elsewhere? The Search for Life on Venus and Mars*	• Art • Astronomy • Biology • Chemistry • Comparative Planetology • Ecology • Engineering • Language Arts • Mathematics • Physics • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Techniques • Microscope Use • Problem Solving • Scientific Process
Grades 8-9 *Project Haystack: The Search for Life in the Galaxy*	• Anthropology • Art • Astronomy • Biology • Chemistry • Ecology • Geometry • Language Arts • Mathematics • Physics • Trigonometry • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Technique • Microscope Use • Problem Solving • Scientific Process

Foreword

Carl Sagan, Cornell University
1934-1996

The possibility of life on other worlds is one of enormous fascination–and properly so. The fact that it's such a persistent and popular theme in books, television, motion pictures, and computer programs must tell us something. But extraterrestrial life has not yet been found–not in the real world, anyway. Through spacecraft to other planets and large radio telescopes to see if anyone is sending us a message, the human species is just beginning a serious search.

To understand the prospects, you need to understand something about the evolution of stars, the number and distribution of stars, whether other stars have planets, what planetary environments are like and which ones are congenial for life. Also required are an understanding of the chemistry of organic matter–the stuff of life, at least on this world; laboratory simulations of how organic molecules were made in the early history of Earth and on other worlds; and the chemistry of life on Earth and what it can tell us about the origins of life. Include as well the fossil record and the evolutionary process; how humans first evolved; and the events that led to our present technological civilization without which we'd have no chance at all of understanding and little chance of detecting extraterrestrial life. Every time I make such a list, I'm impressed about how many different sciences are relevant to the search for extraterrestrial life.

All of this implies that extraterrestrial life is an excellent way of teaching science. There's a built-in interest, encouraged by the vast engine of the media, and there's a way to use the subject to approach virtually any scientific topic, especially many of the most fundamental ones. In 1966, the Soviet astrophysicist I. S. Shklovskii and I published a book called *Intelligent Life in the Universe,* which we thought of as an introduction to the subject for a general audience. What surprised me was how many college courses in science found the book useful. Since then, there have been many books on the subject, but none really designed for school curricula.

These course guides on life in the universe fill that need. I wish my children were being taught this curriculum in school. I enthusiastically recommend them.

Carl Sagan

Preface

Astronomers who search for radio signals from an extraterrestrial civilization refer to the vast cosmos as a "haystack" within which they are trying to find the proverbial "needle"–any sign of intelligent life. In *Project Haystack,* students explore the vast celestial haystack in search of just such a needle. This is the second of two guides designed for grades 8 and 9. The first, entitled *Life: Here? There? Elsewhere? The Search for Life on Venus and Mars,* engages students in a search for life within the solar system. In *Life: Here? There? Elsewhere?* students learn that "life" is not always intelligent, nor is it always easily recognizable. In fact, *Life: Here? There? Elsewhere?* concentrates on a search for microbial life. Thus, students might form a more complete perspective of the process of searching for extraterrestrial life if they complete *Project Haystack* after the first guide. However, *Life: Here? There? Elsewhere?* is not a prerequisite for *Project Haystack;* the teaching order can be reversed. Regardless, each guide can be used independently of the other.

In *Project Haystack*, students move beyond our planetary system and look to other stars for radio signals that might indicate intelligent life. This is the search that has been undertaken by the research staff at the SETI Institute (Search for Extraterrestrial Intelligence). Making contact across such large distances presents interesting challenges and limitations, which are the focus of *Project Haystack.*

Project Haystack presents engaging scenarios that depict various aspects of the SETI search. Students conduct hands-on and "minds-on" activities while exploring what it means to send and receive a message across interstellar distances. They explore and map the vast reaches of the Milky Way Galaxy. They build, test, and experiment with spectroscopes and a radio receiver, learning the importance of these tools to astronomers and their applications in the search. They are challenged to find a simulated signal that has been sent through space from somewhere in the cosmic haystack; after detecting this signal with a "radio telescope" here on Earth, they must decipher its meaning. In a final mission, students imagine the impact on our culture of receiving a message from an extraterrestrial intelligence by role-playing various special interests at a mock conference.

Each step of the way, students work in cooperative teams and build on the knowledge of previous missions to help them understand the rich complexity of searching for and receiving interstellar radio signals.

In summary, *Project Haystack* is an investigation of questions: Are there intelligent civilizations out there? Where might they be? How would they communicate with us and what would they say? How should we respond? Students should finish this unit with a sense of enthusiasm and a wealth of new knowledge, and perhaps with the thought that we are not alone in the universe after all.

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Acknowledgments

Development and publication of *Life in the Universe* was made possible by grants from the National Science Foundation (Grant #MDR-9150120), and the National Aeronautics and Space Administration Cooperative Agreement Number NCC-2-336. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the National Aeronautics and Space Administration.

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Special Acknowledgments

The SETI Institute Life in the Universe team thanks the following people for help, inspiration, insights, support, and ideas contributed over the three-year period during which this project was conducted.

Bob Arnold	Pam Bacon	Bernadine Barr	John Billingham
Linda Billings	Dave Brocker	Vera Buescher	Dawn Charles
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Introduction

Learning Objectives

Concepts

Through the activities in *Project Haystack*, students will learn about and be able to apply concepts in the following areas:

- There are inherent difficulties in the processes of sending and receiving nonverbal messages, in attempting to communicate with an intelligence that does not speak any known language.
- There are inherent difficulties in the processes of sending and receiving messages across the vast distances of interstellar space.
- Distances to objects can be measured indirectly, and this applies to calculating interstellar distances as well.
- The scale and structure of our immediate stellar neighborhood and the Milky Way Galaxy can be envisioned by the construction of models.
- There are approximately 10^{22} stars in the universe.
- Spectroscopes can be used to investigate light and the chemical elements that make up the matter of the universe, and to understand the electromagnetic spectrum.
- The chemical elements of an astronomical object can be identified by analyzing its spectrum.
- Other solar systems that might be home to evolved intelligent life can be detected indirectly through orbital motions of stars about the center of mass of binary systems.
- The Doppler effect, that is, the red-shift or blue-shift of a star, light as it recedes from or approaches Earth, can be used to measure the star's motion.
- A radio receiver can be used to detect unseen electromagnetic radiation.
- A radio signal can be separated from background noise.
- Certain planets are more likely to have life because of the type of star they orbit.

Skills

The activities are also designed to help students develop the following abilities:

- Working in teams to accomplish goals.
- Using models and laboratory simulations to understand scientific concepts.
- Conducting experiments.
- Collecting, analyzing, and interpreting data.
- Learning to build equipment that extends the range of human perception.
- Understanding that human values must always be considered in scientific investigations.

About Inquiry

It is strongly suggested that the process of inquiry be given the highest priority. These are not simply a series of exercises where students do their best and then the teacher gives them the “real” answer.

There are no definitive answers to such grand questions as:

- How many stars are out there and how would we know?
- How many of these stars might have planetary systems and what evidence do we have that other planets truly exist?
- What conditions are needed for life to begin, and how can we determine, at a distance, if those conditions exist on another planet?
- How might we detect a civilization on a planet orbiting a distant star? What technology might we use to detect this civilization?
- What might the radio signal from a galactic civilization look like, and how could we understand and interpret it?
- Where might we look in our galaxy for intelligent life?
- Should we “send a signal” and hope to be detected by extraterrestrial intelligent beings, or should we “listen” for a radio signal from them? If we choose to “send a signal,” what should we say?
- If life is found on another planet, how could the discovery affect our civilization?

In this field, questions often do not have definite yes or no answers. Therefore, all questions are good questions, and all guesses can be treated as possible answers. “How do we know?” and “How can we find out?” are the most important questions of all.

Timeline and Planning Guide

Some missions will need to be taught over several class periods, and some may take longer the first time they are presented. Each mission subdivision is designed to take one class period. Teachers may want to take two or even three class periods with some mission subdivisions. Time estimates are based on feedback from teachers during trial tests and do not include time required to read this guide or shop for materials. Actual times will depend on the particular team of students and the time spent extending these missions.

Mission 1: SETI Wants You!

Mission 1.1: Students are introduced to SETI and to their mission: to determine the point of origin and the meaning of a signal from outer space.

Mission 2: A Message from Earth

Mission 2.1: Students learn about the two *Voyager* spacecraft and the messages carried by them. They choose 10 magazine pictures to create their own collage messages depicting Earth and the

human experience, and send their messages into “outer space” (in this case to another team of students).
Mission 2.2: Students receive a picture-message from an “unknown civilization” (another team of students) and try to deduce its meaning. They experience the difficulties of nonverbal communication, even among groups that share a common origin and culture.
Mission 2.3: Students see images similar to the messages put aboard the *Voyager* spacecraft. They learn who spoke for Earth, and decide whether the entire Earth was well represented.

Mission 3: Calculating Stellar Distances

Mission 3.1: Students learn about triangulation and measure the distance to a far away object in the school yard, such as a tree, without actually traveling to the tree.
Mission 3.2: Students discover the meaning of *parallax* and learn that triangulation can be used to measure the distance from Earth to a nearby star without actually going there.

Mission 4: Calculating Stellar Travel Time

Mission 4.1: Students consider traveling to the stars. Then they discover how long it would take to travel to Sirius using different modes of transportation, including a bicycle, and consider the logistics of physically carrying a message to the stars.

Mission 5: A Model of the Milky Way Galaxy

Mission 5.1: Students see images, then draw a diagram of our immediate cosmic neighborhood by plotting the locations of stars, nebulae, and globular star clusters. They learn how far *Voyager* has traveled, reinforcing the idea that physically carrying a message to the stars will take a long, long time–even to the nearest of them.
Mission 5.2: Students see a PowerPoint show and then make a model of the Milky Way galaxy to show the size of their cosmic neighborhood diagram in comparison. This diagram will help them to see the limited extent of SETI's Targeted Search in relation to the Milky Way galaxy.

Mission 6: The Chemical Elements in Stars

Mission 6.1: Students discover that some of the same chemical elements found in life on Earth are also in the stars and the diffuse clouds of nebulae between them. They use prisms to gain an understanding of the visible electromagnetic spectrum.
Mission 6.2: Students build and use their own spectroscopes to investigate different light sources in the classroom to see what types of emission spectra they produce.
Mission 6.3: Students use their spectroscopes (and/or commercial spectroscopes) to examine the emission spectra of pure elements.
Mission 6.4: Students interpret the spectral emission patterns of stars, confirming the presence of some chemical elements that make up life on Earth, and that are necessary for life to occur.

Mission 7: Expecting Other Planetary Systems

Mission 7.1: Students speculate on the likelihood of planetary systems forming elsewhere in the cosmos. Then they investigate motions about the center of mass of star systems as a possible way to detect planets that are revolving around other suns.
Mission 7.2: Using the Doppler Effect's red shift and blue shift, students investigate "wobbles" of stars that may indicate the presence of planets.

Mission 8: Building a Radio Receiver

Mission 8.1: Students work alone, or in teams, to build their own radio receivers. They learn that both radio signals and radio "noise" (static) are always present, but neither is detectable without the proper equipment. They relate this discovery to SETI's use of radio telescopes to search for an electromagnetic signal from an extraterrestrial intelligence. This mission may take up to three class periods.

Mission 9: Separating a Radio Signal from "Noise"

Mission 9.1: Students discover the difficulties in separating radio signals from the static that always accompanies them. They pick signal patterns out of backgrounds of static and learn about the need for computational assistance in pattern recognition.

Mission 10: The Search for Extraterrestrial Intelligence

Mission 10.1: Students choose three likely stars from a list of 16 to scan with a simulated radio telescope, looking for an extraterrestrial signal. With application of their skills, and a little luck, most students will find the simulated signal.
Mission 10.2: Has a real signal arrived from a distant star system? In this simulation, students pool their efforts and narrow in on three apparent signals. They look again to verify these possible signals. They discover that a signal *has* arrived from a distant star system.

Mission 11: Do You Get the Message?

Mission 11.1: The simulated signal has arrived, but what does it say? Students learn about binary systems and cryptography, and decode the message from the stars.
Mission 11.2: Students decide how to answer the message from the stars: What do we say to them?

Mission 12: Cultural Aspects of the Search for Extraterrestrial Intelligence (CASETI)

Mission 12.1: Students see images of SETI researcher Jill Tarter talking about CASETI. Students hold a mock CASETI Conference of their own to consider their fears and concerns about the detection of an extraterrestrial intelligence.
Mission 12.2: Students produce recommendations in a "CASETI Final Report" that suggest ways in which all of humanity's responses to the discovery can be inclusive, positive, and effective.