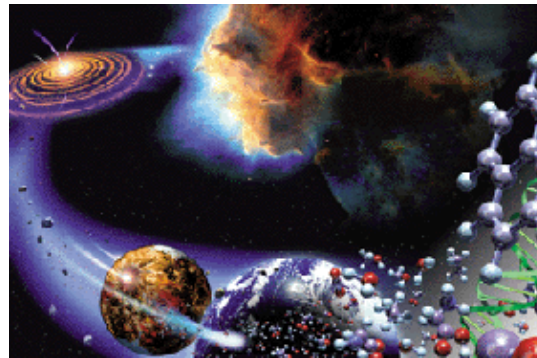
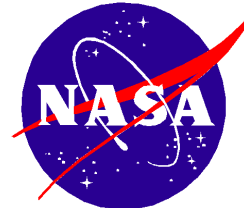


Astrobiology & Exploration: Beyond Missions & Science Exploration



Margaret S. Race, Ph.D.



COST: Missions to Habitable Worlds
Budapest - October 26-28, 2015

Astrobiology Science

Solving the Universe Puzzle, One Piece at a Time

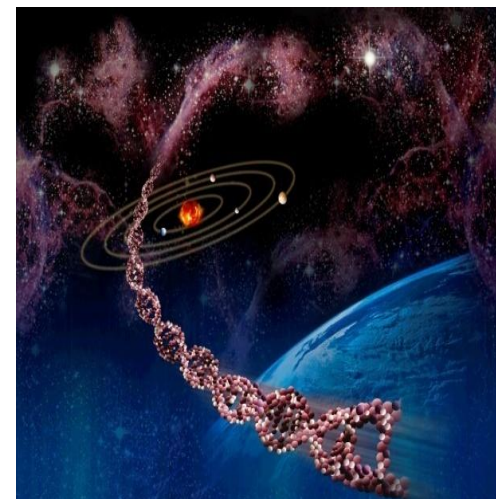
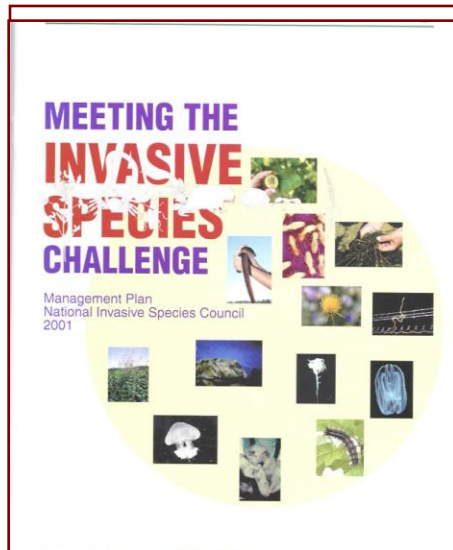


- Build on Basic Science & Concepts – On Earth & Beyond
- Develop New Perspectives about Life
 - ✓ Bio-Geo-Chemical & Cosmic Processes
 - ✓ Habitability as Current Framework
- Multidisciplinary Integration of Science & Technology
- See Differences in Approaches – and Time Frames

My Piece of the Puzzle: Ecologist's View of Interdisciplinarity

Responsible Exploration & “Mission” Success

- Coastal Biology; “GMO’s; & Mars Sample Return
- Planetary Protection & Policy (Responsible Science)
- Consider Science Data, Scenarios & Impacts
- Address Societal Context (Legal; Controls; EIS; Oversight etc)
- Interdisciplinary- Revise over Time Based on Science Advances





NOW: Consider Astrobiology & Society

*White paper for decision makers & the public
On **societal, ethical & economical aspects**
of **astrobiology research in Europe***

**Share Info on Earlier Efforts to Address / Include ‘Societal Issues’
... Learn from What Worked (or didn’t) -- Adapt & Improve**

✓“Societal” – What Do We Mean?

- Basic vs. Applied Research Where Science & Society Fit
- What Non-Science Experts/Disciplines to Include? Exclude?

✓Examine Space Science & Society over time

- 1960’s Early
- 1990’s Developing Stage
- 2005-On Maturing

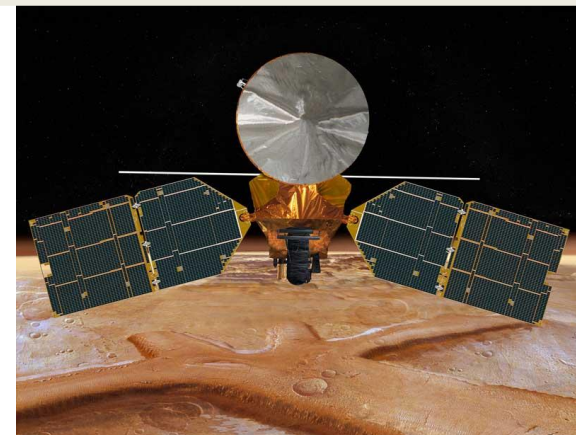
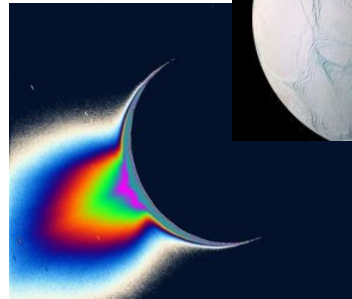
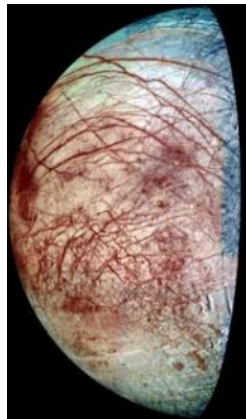
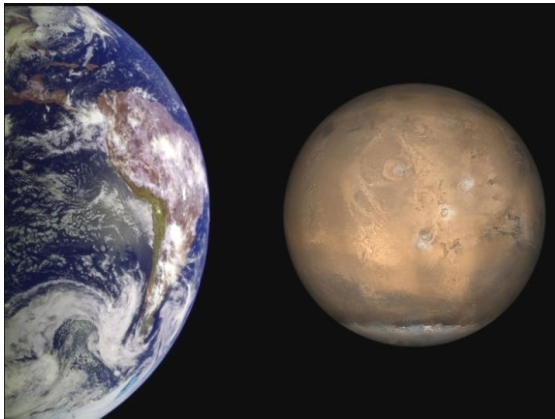
✓Before Design EAI Framework with ‘Societal’ Included

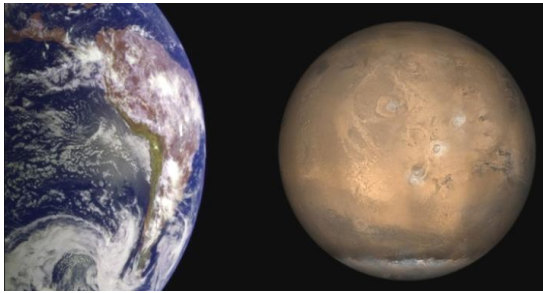
- What Are Objectives & Needs of European Astrobiology Community?
- Thoughts on Interdisciplinarity

Scientists' View: Activities in Outer Space

Basic Research/ Exploration & New Understanding

- Understand Habitability / Habitable Zones
- Conditions for Planet Formation & Emergence of Life
- Inform about Life on Earth - Search for ET Life etc
- Responsible, Ethical Pursuits, "Pure Science"





Framing the Issues: Science* in the Real World

* Any Discipline or Disciplines

Multiple Contexts:

BASIC RESEARCH Understand Habitability; Habitable Zones; Conditions for Planet Formation & Emergence of Life; Inform about Life on Earth.... And MORE

APPLIED RESEARCH - 'uses' basic science to address needs (scientists or society , activities, plans, ventures, design technologies/instruments; missions; Reduce Risks; Comply with Laws; etc. Make Money?

IMPLICATIONS OF SCIENCE ON SOCIETY

(Explain/Educate/Communicate about Impacts or Significance/Meaning of Science)

IMPACTS OF Society ON SCIENCE a Disagreements? Politics? Ignore? Withdraw Funding Support

Will Need Diverse Non-Science Experts & Researchers

BASIC RESEARCH

APPLIED RESEARCH

IMPLICATIONS OF SCIENCE ON SOCIETY

IMPACTS OF Society ON SCIENCE

Societal, Ethical & Economical aspects...?

But also... Many Others? Who to Include / Exclude?

Philosophy Law Political Science Anthropology
Psychology Theology Education Risk Analysis/Management
History Behavior Art Economics Entertainment
Mass Communications International Politics Business
Economics Languages Religious Studies Social Sciences
Ethnic Studies Emergency Preparedness Literature . etc.
etc.

Examine Astrobiology & Societal Implications over Time

- Examine: **Who What Where How Why– When**
- **Change over Time**
 - Nature of Science/Space Activities
 - Meaning/Significance of Space Research
 - Science Research & Understanding
 - Societal involvement, Context & Public Interest
 - National/ International context
 - Who's Involved? Launching/ Non-launching;
 - Implications for Future?
- **Frameworks** Adopted (Scientific & Otherwise)

The Early Space Era (1960's)

■ **Science perspective & Involvement**

- Science of Space Environment; Early Exobiology
- Human & Robotic Missions (samples returned)
- 'Spaceship Earth – Venture Off Earth (LEO,GEO)
- Early SETI (First Technol. Search for ET)

■ **Space Science Context and Activities**

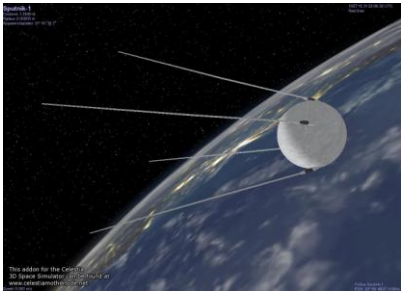
- Exploration / Discovery
- Technology Demonstration

■ **Societal/World Context**

- At Start: Cold War, Highly Competitive, Militant
- Later: Apollo & Luna missions - Space 'Race'
- New Era for Humankind

■ **Framework:**

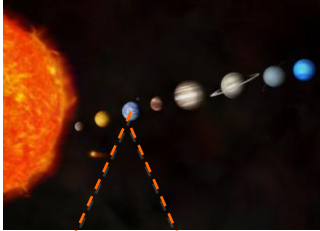
- Outer Space Treaty – International
- PP - Avoid Harmful Contamination (Protect Science)





Outer Space Treaty of 1967

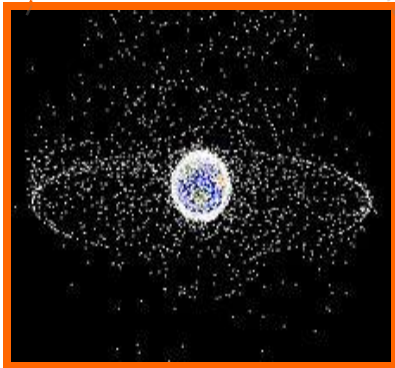
Launching Nations and Scientists



Planetary Protection

1960 1970 1980 1990 2000 2010

*Launching Nations, Human Missions,
Scientists, Satellites, Commercial, Private, Part
nerships...*



**** Liability, Harmful
Interference, Ownership, Rescue of
Astronauts, Mutual Aid, Orbital & Frequency
Assets, Space Debris ...
** No Planetary Protection**

The Intervening Years (70's+)

Science Perspective

- Exploration & Discovery (Microgravity; 'New Locations')
- Looking for ET (SETI, Mars Viking Missions/ SS)

ALSO: Plate Tectonics; Deep Sea Vents; Asteroids; Genetic Engineering, Computer Technologies

Space Context and Activities

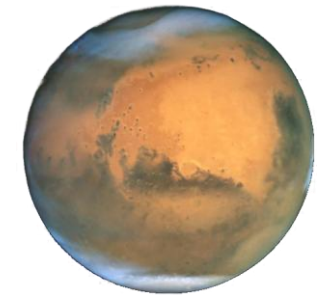
- Refinement of Planetary Protection Policy (Science)
- Legal Issues Like on Earth (liability, rescue, sharing)

Societal/World Context

- End of Apollo Program –Shift to Shuttle, Mir,
- Expansion of Sattelites and Uses of Space
- Expansion of Env. Ethics (Earth & Space)

■ Same Framework:

- Outer Space Treaty – International (GEO/LEO)
- > PP Avoid Harmful Contamination



Dawn of The Astrobiology Era - 1990's

■ **Science**

- Active SETI within NASA – Drake Equation (till '93)
- ALH84001 and Missions to Mars (rovers/orbiters)
- Follow the Water/ Ok to not just look for ET/ Galileo/Cassini
- Extremophiles & Limits to Life – Earth Analogues
- 1st Exoplanet Discoveries – and more
- Plan Mars Sample Return Missions
- Convene Astrobiology Roadmap Workshop- Interdisciplinary

■ **Space Context and Activities**

- Refinement of Planetary Protection Policy (Science)
- OST Legal Issues Focus on Earth (liability, rescue, sharing)

■ **Societal/World Context**

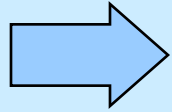
- Golden Fleece Award – Anti-SETI (Waste of \$\$)
- ALH Meteorite Excitement – Extremophiles/ Rovers

Frameworks:

- SETI Principles –Detect/ Verify/ Notify/ Communicate
- 3 Workshops on Cultural Aspects of SETI & Detection
- OST COSPAR PP Categories for >> Celestial Bodies
- ASTROBIOLOGY ROADMAP & Workshop & NAI Program



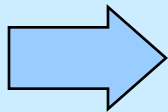
in U.S.— Cross-Disciplinary Perspective
Astrobiology Roadmap (1998; Revised 2003; 2008)
Implementation via Multiple Research and Exploration Pathways



Seven Science Goals

Outlines of Broad Domains of Investigation (10+ yrs.)

1. Understand Nature & Distribution Of Habitable Environments In The Universe
2. Explore For Habitable Environments & Life In Our Own Solar System
3. Understand The Emergence Of Life
4. Determine How Early Earth Life Interacted & Evolved w/ Changing Environment
5. Understand The Evolutionary Mechanisms And Environmental Limits Of Life
6. Determine The Principles That Will Shape Life In The Future
7. Recognize Signatures Of Life On Other Worlds And On Early Earth.



VIA Eighteen Objectives

High Priority Efforts for 3-5 years

Study of Origin,
Evolution,/Distribution &
Fate of Life in the Universe

Four Implementation Principles for Astrobiology Roadmap



Astrobiology is:

- Multidisciplinary in content and interdisciplinary in implementation,
- Encourages planetary stewardship and emphasizes planetary protection,
- Recognizes a broad societal Interest in its endeavors,
- Has a strong emphasis upon education and public outreach

Maturation of Astrobiology 2005-Now

■ **Science**

- Growing Taxonomy of Extrasolar Planets - Terrestrial
- Continuing study on moons of Jupiter/Saturn-
- Continuing Mars Exploration
 - >>Extremophiles & Limits to Life – Earth Analogues
- Special Regions/ RSL/ brines on Mars
- Missions to Icy Moons – Enceladus, Europa
- NASA Astrobiology Strategy Process – Interdisciplinary SCIENCE
- *Studies of Asteroids; Planetary Defense Activities*
- *Continuing Active SETI research; Debate over METI*

• **Context and Activities**

- Refinement of Planetary Protection Policy (Science)
- Prepare for Human Exploration – New Issues (Beyond LEO)

■ **Societal/World Context**

- Interest in Astrobiology – Active Outreach and Activities /Conferences etc.
- The Martian; Interstellar; Entertainment; Science Museums etc
- Increasing Interest by Commercial and Private Space Entities for BLEO

Maturation of Astrobiology (cont'd)

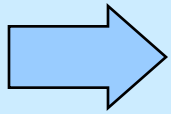
- **Increased Activities on Societal Issues-**
 - Workshop / Developed Societal Issues Roadmap/ Focus Group
 - International Conferences - Royal Society; Lund Univ. etc.
 - Conf. Sessions: AAAS, AAR, 4S, AbSciCon, Public Philosophy; CTNS etc. (Not NASA Organized)
 - NASA Supported Blumberg Chair: Library of Congress (Societal)
 - Ethics/Theology Fellowship at Princeton U.
 - National Collegiate Debate on Law & AB Issues (ET life, PP, etc)
 - Books on Societal Issues in Astrobiology and Space Missions in SS
 - Cambridge U. Press Discovery of ET Life
- **Frameworks:**
 - OST Continue COSPAR PP Categories for >> Celestial Bodies
 - Begin Think About Human Missions and Issues (beyond Sci/Tech.)
 - Astrobiology Roadmap of Societal Issues
 - 5 Major Goals – with Input by Philosophy & Ethics ;Social Sciences & Humanities; Science & Religion
 - ? May not Be Implementable...
- **New ASTROBIOLOGY Strategy - 2 yr process (Science focus)**
- Beyond Natural Sciences: Humanities & Social Science contributions to AB

Astrobiology Strategy Document - 2015

Same Big Questions:

Where Did We Come From? Where are we Going? Are We Alone?

-



Six Major Topics of Research in the Field

Outlines of Broad Domains of Investigation (10+ yrs.)

Missions and Research – Earth & SS

- 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. Coevolution of Life and the Physical Environment**
- 5. Identifying, exploring & characterizing environments for habitability and biosignatures**
- 6. Constructing Habitable Worlds**

No Operating Principles: Instead Appendix

Beyond Natural Sciences: Humanities & Social Science Contributions to Astrobiology

SEVEN AREAS:

- ☐ **What is the role for Epistemology In Astrobiology?**
Comparative Standards for evidence? Is a definition of life necessary?
- ☐ **What is the Role for Social Science in Astrobiology?**
Motivations for AB researchers? Range of interests of public towards AB?
Tools to facilitate collaborations?
- ☐ **What is the Role for Ethics in Astrobiology?** Role of definitions of life in ethical typologies? Do humans have non-Terran ethical obligations? Does AB have implications for Terrestrial environ. Ethics?
- ☐ **What is the Role for History in Astrobiology?**
Theories, perspectives & speculations about non-terrestrial life? how have technologies shaped our expanding knowledge of life in the cosmos?

Beyond Natural Sciences: Humanities & Social Science Contributions to Astrobiology (cont'd)

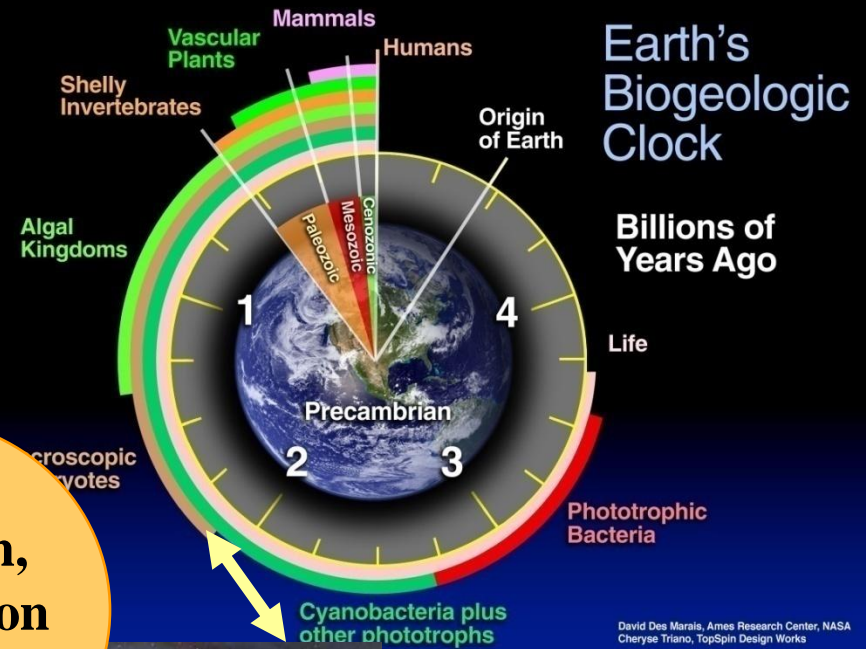
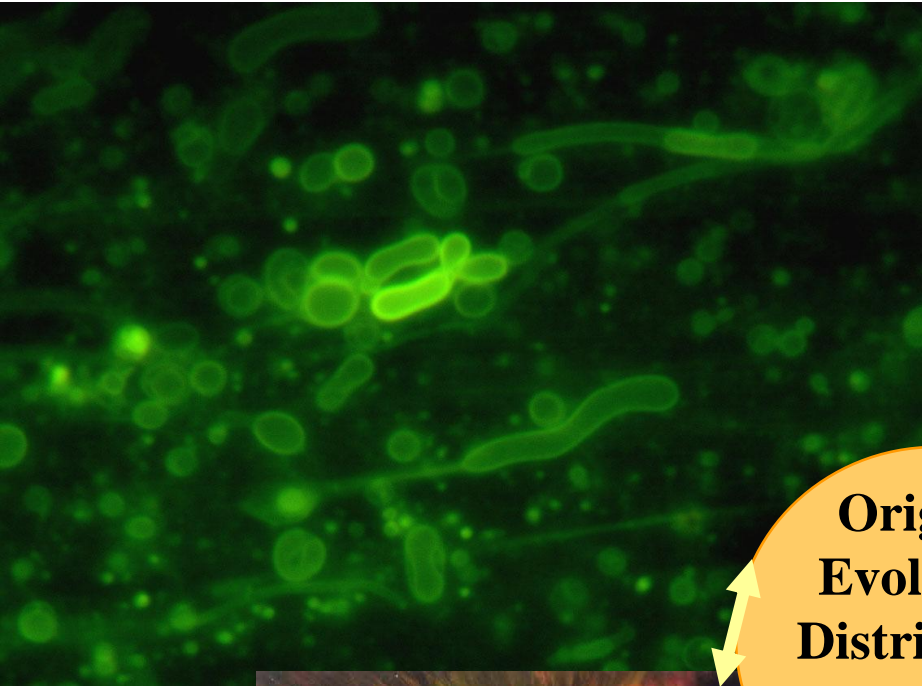
❑ What is the Role for Law in Astrobiology? Costs/benefits of compliance with PP protocols? How do discoveries impact formation & implementation of laws? Impact of AB on laws? Can NASA help create dialogue among stakeholders around issues of law, policy and compliance with space law (nationally and internationally)

❑ What is the Role for Communications in Astrobiology? Best ways to communicate time points in development of life? (origin of life, proto-cell, pre-biological, RNA world, LUCA, etc); how communicate about single word entrenched with meaning in multiple fields (e.g. stellar, chemical, evolution) Best way to communication about emerging technical terms? (e.g. habitable, biosignature, complexity?)

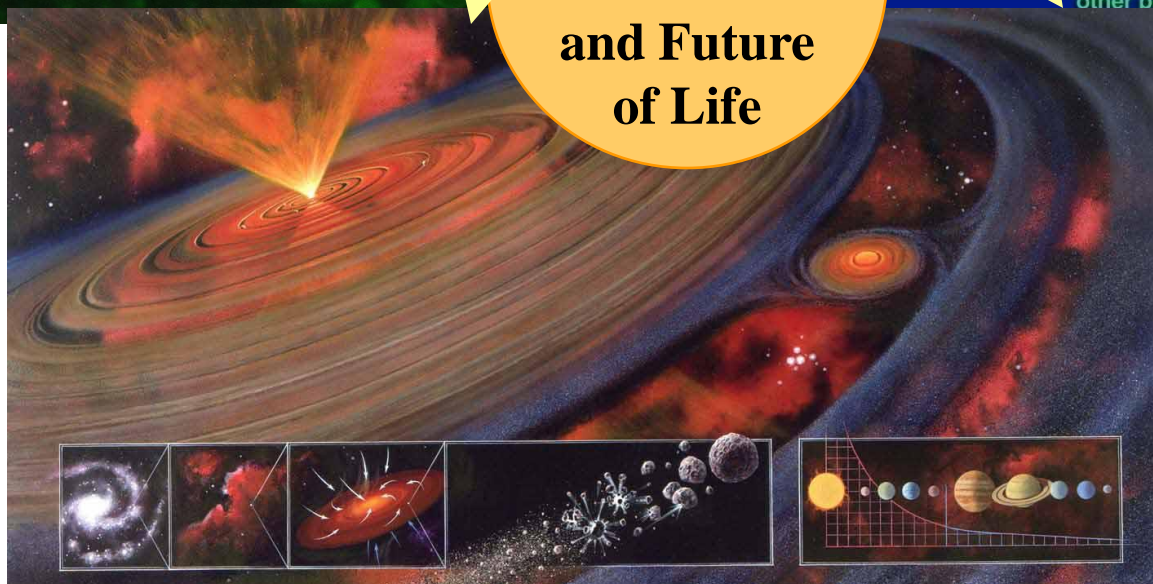
❑ What is the Role for Astrobiology in Education? Role in K-12 education? General college education? Foster AB-related thinking at grad student level?

Astrobiology Unites Disciplines to Study Life in the Universe

(multidiscipline? Interdiscipline? Trans-discipline?)



**Origins,
Evolution,
Distribution
and Future
of Life**

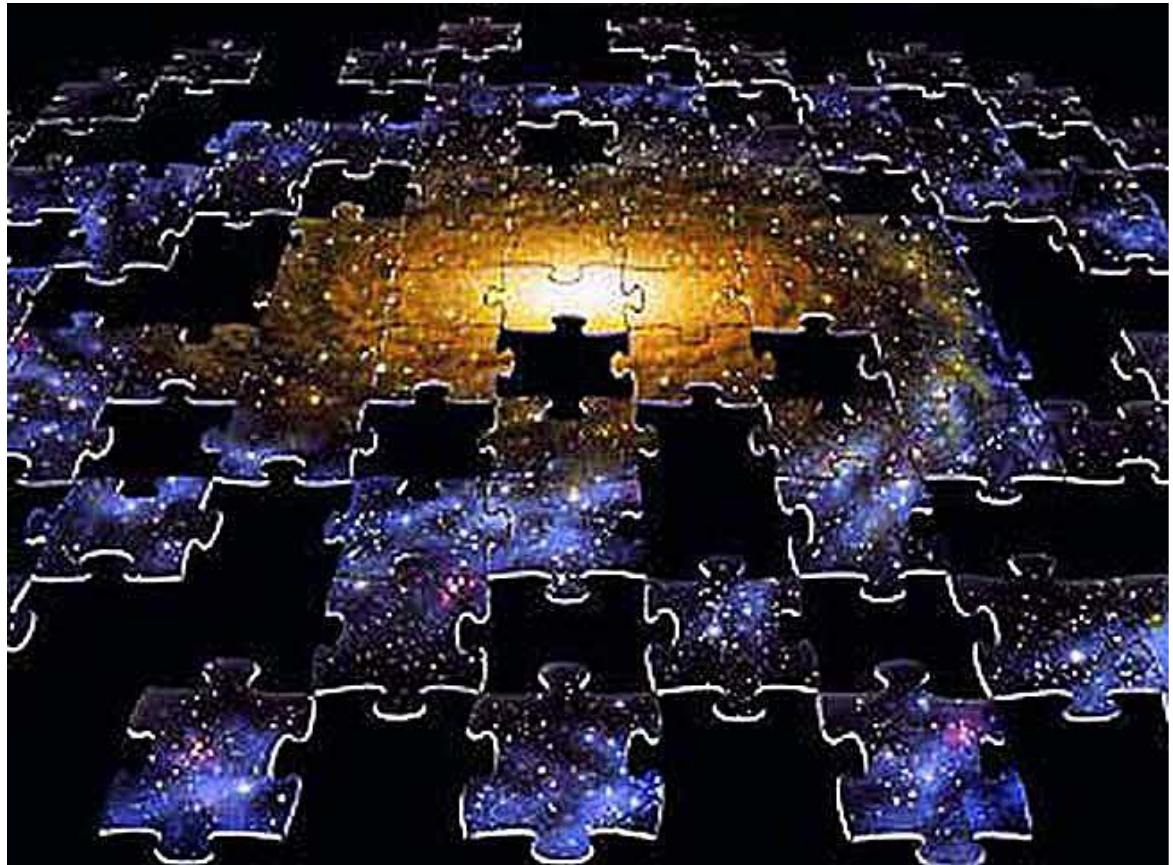


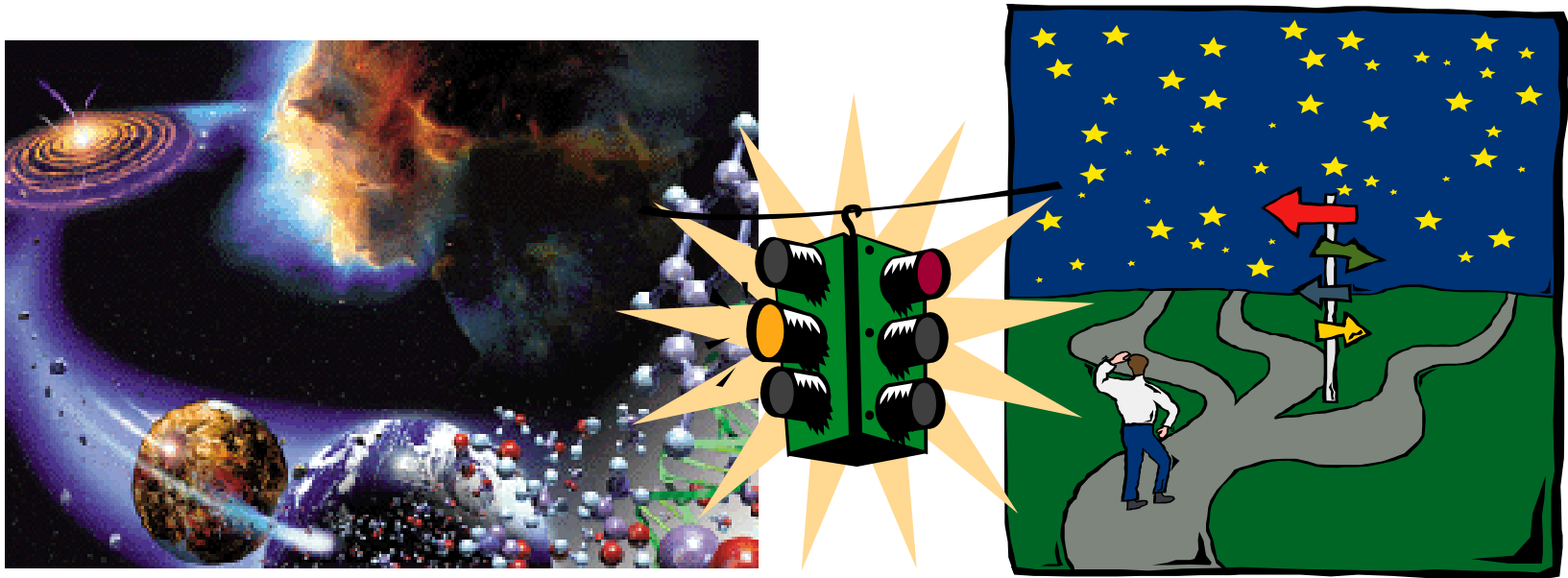
David Des Marais, Ames Research Center, NASA
Cheryse Triano, TopSpin Design Works

Astrobiology

The Cosmic Puzzle

We're All in this Together!

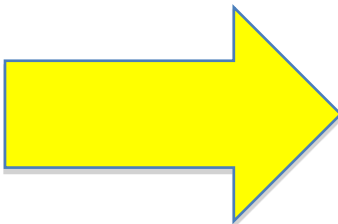




Stop & Consider

AB Unites Science Disciplines.... But How Deal With
The Impacts of Astrobiology on Society, and
The possible impacts of society upon Astrobiology as well?

Think About EAI:

- 
- European Needs & Differences?
 - Comprehensive Roadmap or Incremental Steps?
 - Entire Field? Or Just Habitability? Or Missions?
 - WHY and HOW Integrate Societal Issues?
 - Expand Research Community
 - \$\$\$