

Summary of Proposal (Compile in English within 3 pages.)

Host institution: National University Corporation **Tokyo Institute of Technology**

Head of host institution: **Yoshinao Mishima**, President

Research center: **Earth-Life Science Institute (ELSI)**

Center director: **Kei Hirose**

Chief center-project officer (in December 2012): **Kei Hirose**

Administrative director: **Takashi Sakurai**

1) Project summary

ELSI aims to answer the fundamental question "when and where did life originate and how did it evolve?" This question, which originated with the Greek philosophers, has been one of the most important topics of natural science. We will focus our research on understanding the wide range of planetary processes and environments on the early Earth that may have been essential to the birth of life, and on their subsequent changes, with the main aim to study the origin and early evolution of life and persistent ecological systems in their geological context. We will use the enormous diversity of microbial biochemistries, physiologies, and ecologies as windows to identify how the biosphere has depended in detail on its planetary home from the past to the present, and to suggest the domains within chemistry and the planetary environments that are most likely to have been pivotal. We will approach the primordial environment of the Earth through explorations of diverse proxy environments on the present Earth, ranging from deep-sea and sub-surface microbial ecosystems to extraterrestrial primitive asteroids. In addition, we will critically examine the universality of these processes, to determine the uniqueness of our planet, with implications for the search for extraterrestrial life, both in the solar system and beyond.

2) Mission statement and/or center's identity

So far, discussions about the origin of life on Earth have been mostly limited to the biochemistry of proto-life forms. While the Earth environment has been described as a "cradle of life", the image of a "cradle" points to a supporting background role, rather than a dynamic interplay. In ELSI, we want to radically broaden these discussions by focusing equally strongly on both sides of Earth and Life. For one thing, life is preserved through a continuous exchange of matter and energy with the surrounding environment. For another, it is a two-way interaction: as soon as life forms are present, they start to influence the environment, just as the environment is influencing life. Our basic outlook is reflected in the name of our proposed center: ELSI stands for Earth-Life Science Institute, in which Earth sciences and Life sciences will be equally represented.

In contrast to NASA's Astrobiology Institute (NAI) whose research topics are broadly similar to ours, we emphasize the role of the Earth as a whole in the origin and evolution of life. Most importantly, ELSI will not be a virtual institute like NAI and has been firmly established as a physical entity with vigorous internal communications through a series of daily, weekly, and monthly events, following the Program for Interdisciplinary Studies at the Institute for Advanced Studies (IAS) in Princeton as a model. This IAS program has been a satellite center for ELSI.

We have strongly encouraged interdisciplinary research within ELSI, which attracts a wide variety of top scientists to visit ELSI to interact with members there and also with each other. We do not want to define job specifications too strongly beforehand. Rather, we prefer to attract top scientists first, and then to finetune the research program around their skills and interests.

We combine our research with outreach and education. The on-going Hayabusa-2 mission as well as

the future plan called MMX mission to the Mars moons, questions about the formation of Earth and the origin of life, and extraterrestrial life are of strong interest to the general public, and thus perfect for outreach. As for education, we will create a Summer Internship Program for high school students, based on nation-wide competitions in high schools in Japan. These activities will also help not only ELSI but also its host, Tokyo Tech, to further increase both its international and its domestic visibility.

3) Research fields

Target research field:

Interdisciplinary Research on Solid-Earth Science, Planetary Science, Geology, Environmental Microbiology, Microbial Genome Science, Systems Chemistry, Complex Systems Science, and Comparative Emergence

Recent progress:

Major progresses have been made recently in the three areas of early Earth environments, primordial ecological systems, and extraterrestrial life: 1) laboratory experiments that reproduce the conditions at the beginning of the Earth's history, 2) investigations of ecological systems under extreme environments, 3) empirical study of prebiotic chemistry as well as computational chemistry, and 4) theoretical modeling of planet formation and the observation of Earth-like exoplanets. Our PIs have made major contributions to the progress in all of these areas.

Our superiority:

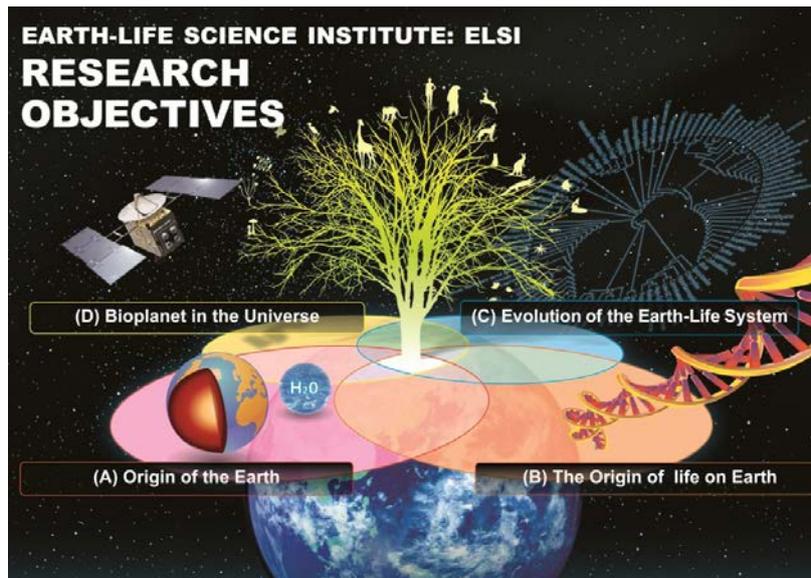
Our superiority is clear in the areas of the proposed research. We study the unique environments on the early Earth by combining the research utilizing high-pressure/high-temperature experiments, theory of planet formation, and decoding the Earth's history, all of which are areas in which research at Tokyo Tech is ahead of that at other places, nationally and internationally. In addition, we have been playing leading roles in molecular and evolutionary microbiology, in the study of wide-ranging microbial ecosystems including many in extreme environments, and in connecting the comparative analysis of microbial energetics to detailed geological contexts.

4) Research objectives

Our research will answer the following scientific questions:

- How were the environments at the beginning of the Earth's history?
- When and where did the primordial ecological system originate?
- How did the Earth and the Universe affect the evolution of life?
- How unique is our planet?

We will also contribute to the planning of explorations of the solar system and observations of exosolar systems based on the outcome of our research.



5) Outline of management

The center has been established as an independent organization inside Tokyo Tech. The center director has the authority to make all decisions related to ELSI including the appointment of all staff members, budget implementation, etc, with advice from the steering committee, Directors' office and the international advisory Board. The center has a research-oriented English-based administrative system led by the administrative director. In addition to university research administrators (assistant directors) who provide a wide range of support to researchers, a life advisor is assigned to each non-Japanese family. A PR chief is in charge of overall outreach activities. A coordinator of international initiatives seeks research funds and offers assistance with recruitment of non-Japanese scientists.

6) Researchers and other center staffs, satellites, partner institutions

[Principal Investigators] 15 (incl. 8 non-Japanese) – as of April, 2017

[Total number of researchers] 63 (incl. 25 non-Japanese) – at the end of FY2016

[Total number of staffs] 117 (incl. research assistant, excluding short visitors) – at the end of FY2016

[Main principal investigators] (affiliation)

Piet Hut (Inst. Adv. Study, Princeton/ELSI), Joseph L. Kirschvink (Caltech/ELSI), Jack Szostak (Harvard Univ.), Tetsuo Irifune (Ehime Univ.), Kei Hirose (ELSI/University of Tokyo), Shigeru Ida, John W. Herndlund, Shigenori Maruyama, Naohiro Yoshida, George Helffrich, Erich Smith, Irena Mamajanov, Yuichiro Ueno, Shawn McGlynn, Ryuhei Nakamura (Tokyo Tech)

[Satellite organizations] Ehime University, University of Tokyo, Institute for Advanced Study in Princeton, Harvard University

7) Outline of research environment

- The center will ensure that all researchers can concentrate on their research. Both of the university research administrators and life advisor will provide a full range of support to non-Japanese scientists and their families. Tenured professors were reassigned to ELSI, and exempt at least from the duty of teaching undergraduate students.
- The center will provide each PI from abroad with seed funding of JPY10 to 20M. Additional support may be given upon discussion with the center director.
- English-based research-orientated administrative systems has been created through adopting some unique new practices. The administrators are informed of the latest research results.
- Evaluation of the research activities by each scientist will be made on the basis of academic

achievements. Contributions to other activities of the Center such as public outreach will be also considered. These will reflect in the annual salary renewal.

- The university has reserved sufficient research space (about 4,973 m² f) for the center at its Ookayama Campus, which accommodates middle-sized symposia within the center.

8) Outline of indicators for evaluating a center’s global standing

We conduct a comprehensive assessment with consideration of various criteria such as levels of research activities and recognition of the institute and its researchers. It is equally important to carefully assess the progress of efforts to promote interdisciplinary research and to create a new research domain. Current assessment demonstrates that ELSI has well established as a WPI center and suggests good prospects for further development.

9) Securing research funding

By FY2016, ELSI has been continuously acquiring other competitive research funds which exceeds that of the WPI research funds. The university research administrators support researchers with winning more funds such as Grants-in-Aid for Research.

Also Tokyo Tech is applying for non-profit incorporation overseas to actively seek and stabilize further funding and donations from abroad.

10) Appropriations plan

FY	2017	2018	2019	2020	2021	Total (\$ millions)
WPI grant	6.1	6.1	6.1	6.1	6.1	30.5
Funding for previously-initiated center-building efforts (if any)	0.9	0.9	0.9	0.9	0.9	4.5
Total	7.0	7.0	7.0	7.0	7.0	35.0

(Exchange Rate: JPY/USD=100)

11) Summary of host institution’s commitment

- Tokyo Institute of Technology laid out its goal of becoming one of the world’s top 10 research universities by 2030, and has been strengthened the research management system and reformulated our research systems and environments. Our mid-term plans clearly state that ELSI will remain as an independent research organization directly under the jurisdiction of Tokyo Tech president, and therefore the university will provide long-term full support to ELSI.
- The university will provide ELSI with JPY90M every year from the President’s Discretionary Fund.
- 6 tenure-professors were transferred to ELSI and Tokyo Tech will provide necessary support of staff members.
- Tokyo Tech assured approximately 2,670 m² of research space in an existing building for ELSI-2 and additionally a new research building (ELSI-1: 5,000m²) was completed in FY2014 to become an appropriate research environment. We are prepared to provide more space depending on request of ELSI.
- Already before the end of the WPI program, Tokyo Tech as a whole will internally adopt widely those parts of ELSI’s innovative systems that will have proven to be effective.