The Goal of Research at the Earth-Life Science Institute

Center Director of the Earth-Life Science Institute (ELSI):

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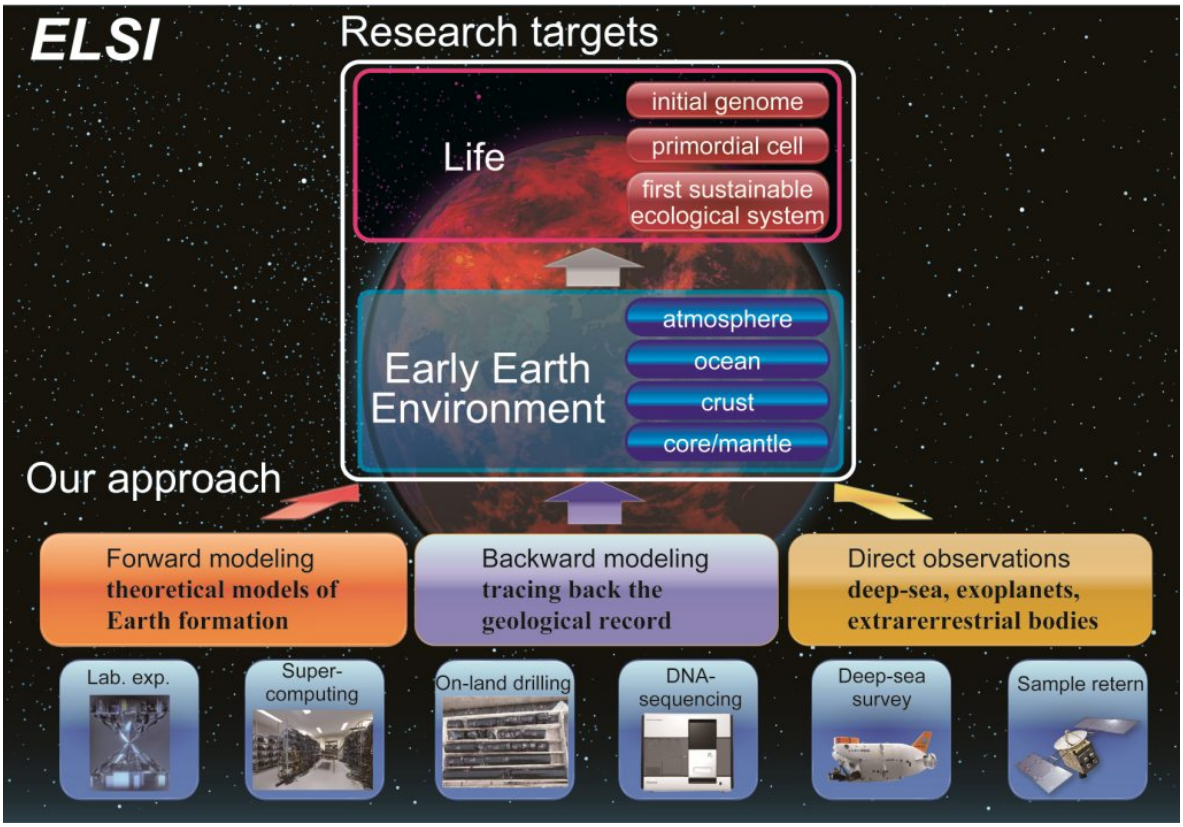
1. The Main Purpose of Research at ELSI

The main purpose of our research will be to solve one of the most fundamental questions of humankind: when and where and how were the first life forms born, and how did they evolve? This question, which originated with the Greek nature philosophers, has been one of the most important topics of natural science. However, it has remained largely dormant because of the great difficulty of making inroads into a problem with such enormous complexity together with an almost complete lack of direct observational evidence. Only the last few decades have seen various areas of science maturing enough to begin to tackle these fundamental questions head on.

The name of our proposed institute reflects this recent maturity, in which geophysics, geology, biochemistry, molecular biology as well as computer science and other fields in science are teaming up together. ELSI, or Earth-Life Science Institute, aims at bringing together scientists from all fields related to the study of the early Earth in relationship to the study of early forms of life.



What distinguishes ELSI from other institutes studying life sciences is the emphasis on the "origin of

life in context", namely on Earth, in a specific ecological system. So far, discussions about the origin of life have primarily taken off from the viewpoint of biochemistry, against the backdrop of a particular choice of natural environment, a type of rock or pool or ocean floor, but with most of the attention directed to the biochemistry of proto-life forms. We want to change that, by focusing equally strongly on both sides of Earth and Life, because life is a phenomenon that is preserved through exchange of energies and materials with the surrounding environment.

It is highly probable that the environment of the Earth around the time of the birth of life was significantly different from that of the present. For example, the Earth may have been surrounded by a sea of sulfuric acid. We will approach this problem from two directions: forwards, using theoretical models of the formation of the Earth and backwards, tracing back the geological record.

The forwards approach starts with the origin of the Earth. Through the theory of planet formation and making use of the world's cutting-edge computer simulation technology, the formation process of the Earth in the solar system will be modeled from first principles. In addition, by utilizing high-pressure/high-temperature experiments, which is Japan’s specialty, we will investigate the material’s differentiation of the Earth and replicate its core, mantle, crust, atmosphere, and oceans.

The backwards approach needs a rich data base mapping out the geological record. Fortunately, we can utilize the 165000 samples spanning the history of the Earth, stored in the Museum of Evolving Earth at Tokyo Tech. We will thus investigate changes in the environment back to 3.5 billion years ago, and estimate as best as we can the environment in the Hadean Eon. We will study “places” on the early Earth, which could have provided both energy and nutrients indispensable to life. This will help us to specify the environment that gave birth to life.

In the field of genomic science, relations between specific environmental factors and the gene pools of microorganisms are now being documented, and stored in data bases. We will utilize these to estimate the “initial genome” of life born in a special environment on the early Earth. Furthermore, we will attempt to actually reconstruct one of the initial cells by using a synthetic biological approach. In other words, we will replace the biology question for the “origin of life” with the more relevant interdisciplinary question regarding the “birth of a persistent ecological system.” An important goal in our research will be to develop these data base systems further, in order to clarify the initial ecological system that allowed a stable and persistent existence of life even under the various harsh and violent changes of the environment that happened on the early Earth.

We will complement these more theoretical approaches with research directly based on experiments and observations. One PI in our institute is in charge of a search for micro organisms in hydrothermal systems at the deep-sea floor, using the “Shinkai 6500” submersible. Another PI is in charge of an investigation of primitive asteroid using the spacecraft “Hayabusa-2”. The deep-sea floor hydrothermal system and primitive asteroid may have provided energy and material necessary for the birth of life on Earth, respectively.

As a result of the Earth-Life focus in our research, we will be able to understand what was special about the Earth, as the planet where life originated, that ultimately gave rise to our existence. As a corollary of

our research, we will contribute to a wider understanding of the universality of life and its possible modes of origin on other planets, in our solar system and beyond. We will also proactively participate in space exploration projects (such as missions to Europa and Enceladus, which have an internal ocean) as well as in projects using next-generation telescopes now under construction, in order to look for biomarkers by remote sensing of terrestrial planets outside the solar system.

2. Setting Up a Research Environment of Great Excellence

The research environment of Tokyo Tech is already quite good, and the individual results by each of the Principal Investigator are at the world's top level. However, most results so far have been obtained within well circumscribed and established research disciplines. What we need to progress further is a strong enhancement of hybrid forms of research, spanning different fields. This requires substantial effort, coupled with a willingness to lower the barriers that currently mark the boundaries of different disciplines. Our greatest challenge is how to set up a research environment that exhibits great diversity in disciplines while retaining the great excellence that Tokyo Tech has established in individual disciplines.

Interdisciplinary research has been recommended in various research programs, including the WPI program. However, translating these good intentions into actual thriving collaborations is far from trivial. For one thing, researchers trying to cross boundaries between different fields typically continue to have their offices in different buildings, making communication already much less natural and frequent. Even when well funded, in practice these barriers greatly reduce the efficiency of multi-disciplinary collaborations.

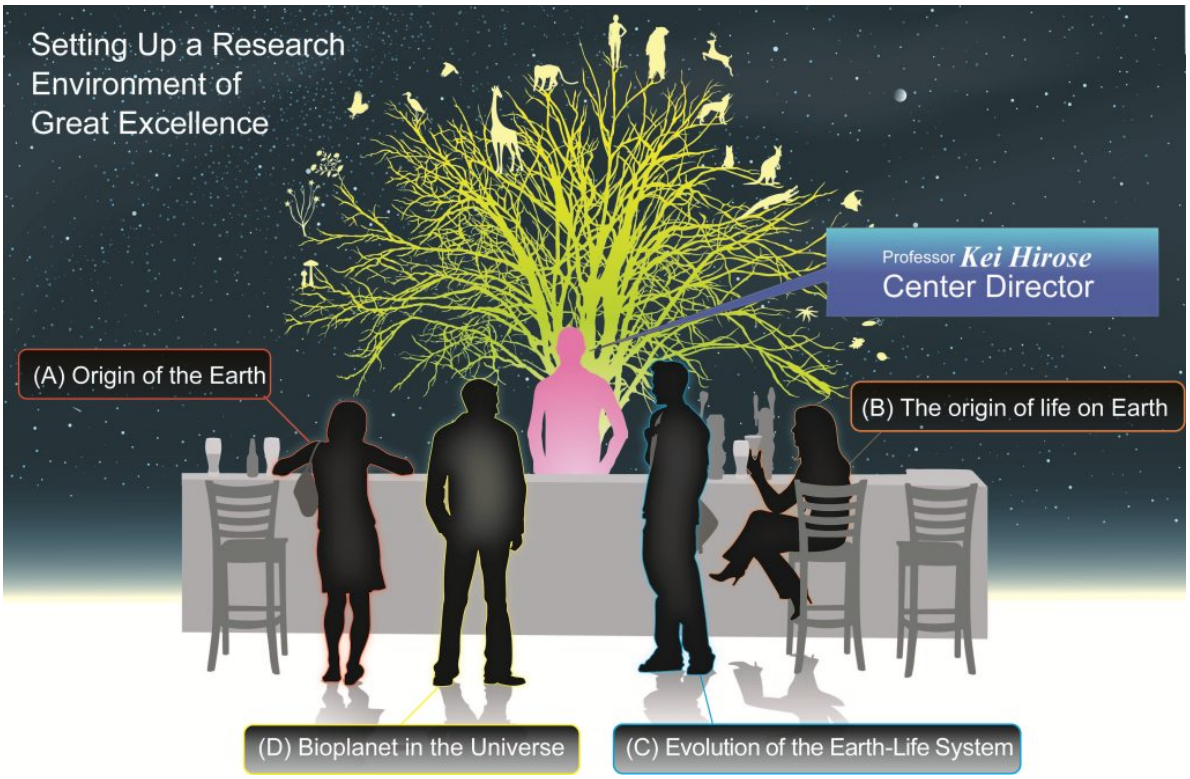
In ELSI our foremost concern is to create a physical environment which naturally encourages and in fact enforces daily communication between all its researchers. ELSI will be housed in a single building, with a Common Room in which daily activities will be organized to promote many kinds of exchanges between all researchers and staff members. However, that in itself will not be sufficient, and we know many cases in most universities where even people in adjacent offices rarely talk to each other. Something more is needed.

The well-known Institute for Advanced Study (IAS) in Princeton has four roughly equal groups of researchers in the very different areas of mathematics, natural sciences, social sciences, and historical studies. After a long period of trial and error, during the first seventy years of its existence, there was still little direct communication between these four main groups. In order to remedy this situation, ten years ago a new Program in Interdisciplinary Studies was started at IAS, which has been greatly successful in forming rich bridges between the four groups, as documented in a recent report by an external visiting committee.

Encouraged by the success of that Program of Interdisciplinary Studies, we have approached the Head of the program, Professor Piet Hut, inviting him as a PI for our new center, in a two-fold function.

First, we would like him to repeat the success of the development of his program in the environment of Tokyo Tech. Second, we would like to establish his original program at IAS as a Satellite Center for our

WPI center, encouraging two-way exchanges between both scientists and administrators between ELSI and IAS. After we explained our vision, Professor Hut enthusiastically agreed to play this double role within ELSI.



Japan is still lagging far behind Western nations in international exchanges. There exist significant obstacles that foreign researchers must overcome in order to do their research in Japan. The biggest obstacle might be a sense of alienation brought about by the language barrier. Therefore, we will thoroughly enforce the use of English as the official language at ELSI. Also, we will dispatch some of the leading administrators at ELSI to our overseas satellite center at IAS, for stays of up to several months in order to learn how the IAS functions in practice on a day-to-day basis, encouraging an atmosphere conducive to open and free ranging research. We will hire more than 30 researchers from abroad and invite famous foreign researchers on sabbatical to stay at ELSI. We will also ask Japanese researchers to visit the overseas satellite center or other collaborating organizations in order to expand their contacts through international networks.

3. Strengthening of the Public Relations Division

The success of ELSI is directly connected with its visibility. In order to attract researchers from abroad, active young and upcoming researchers as well as famous older scientists, it is essential to establish a broad awareness of ELSI, of its mission as well as its accomplishments. And in the long run, after the initial WPI funding runs out, high visibility of ELSI will increase our ability to attract competitive funds by principal researchers as well as continued support from the university and contribution from external foundations and

enterprises.

We are therefore highly motivated to make every effort to promote public relations activities within ELSI. The Center Director will reach out to the general public at every opportunity, both in Japan and abroad. Several principal researchers are serving as chairs for their relevant academic societies. Their international networks will also be helpful.

Actual public relations activities will be carried out by a group of dedicated science communicators. First of all, they will proactively share the results of research projects at ELSI. In addition to events surrounding specific publications of broader interest, they will periodically organize press conferences with general writers, journalists, and science writers. They will also hold regular seminars for the general public and summer intern programs for high school students. Fortunately, outreach activities are poised to be successful already by the very nature of ELSI, since questions like the origin of life, and life on other planets, are sure to grab the attention of the public. For example, the return of “Hayabusa” received great attention in Japan, while books and movies related to astrobiology, planets beyond the solar system, the center of the Earth, and snowball Earth have been released. Thanks to those, some of the main key words related to research at ELSI are already widely recognized.

In addition, we will make connections between the public relations activities of ELSI and those at Tokyo Tech. This will also increase awareness of Tokyo Tech itself as a top-level university within Japan. Currently, the general public in the U.S. has a much greater awareness of the existence and excellence of MIT or CalTech, compared with the awareness in Japan towards Tokyo Tech. It is high time to change that lack of awareness within Japan, as well as from outside Japan. This will be one important way in which ELSI can perform an essential service for its hosting university, Tokyo Tech. For this reason, the university’s Public Relations Division needs to be strengthened.