World Premier International Research Center Initiative (WPI)
Executive Summary (For Final Evaluation)

Host Institution	Tokyo Institute of Technology	Host Institution Head	MASU Kazuya
Research Center	Earth-Life Science Institute		
Center Director	HIROSE Kei	Administrative Director	SAKURAI Takashi

Instruction:
Based on the Center's Progress Report and Progress Plan, prepare this summary within 6 pages.

A. Progress Report of the WPI Center

I. Summary

Earth-Life Science Institute (ELSI) was selected one of the WPI centers in 2012 and has been exploring the origin of the Earth and life since then. It published more than 1000 papers until the end of FY 2020 and become a world leading institute on the study of origin of life. It has made an important progress on the origin of the Earth as well, on the themes such as planet formation and its early evolutions. It also indicates some key factors for the emergence of life on Earth: water and magnetic field. On the birth of Earth-Life system, ELSI introduced a new field of study of geoelectrochemistry and a concept of "messy" chemistry to show that the origin of life cannot be studied if the experimentalist worked only in a laboratory. ELSI has also expanded its field to the coevolution of life with the Earth to see the nature of the first cell and tried to understand the nature of the first genome. These studies made scientists of ELSI to tackle the issue of how unique the Earth is. It is a question of the habitability of planets around other stars. ELSI scientists try to study the principles underlying the life to establish a universal biology, which can be used to search for extraterrestrial life.

All of those results are born from interdisciplinary research results. They are only possible by ELSI's international environment of researchers from various countries and a variety of fields.

This international research environment made organizational reforms of its host institution: Tokyo Institute of Technology (Tokyo Tech). The president had a role to appoint the director of ELSI, which was not common in a Japanese university. Many new systems of ELSI had a ripple effects to the host institution and the host institution itself supported ELSI as a "strategic and ambitious organization".

II. Items

1. Overall Image of Your Center

ELSI is the only non-virtual research institution in the world dedicated to integrated studies of the origins of planets and life. It attracts top researchers from around the globe in very diverse fields of study such as geology, geophysics, geochemistry, planetology, astronomy, organic chemistry, biology and information science. Our outreach activities, TV appearances, press releases, and internet presence have allowed ELSI to build a respected public image on the study of origin of life in Japan and abroad. ELSI has been a transformational presence at Tokyo Tech, both as an international oasis as well as a leading presence for our collective ambition to transform Japan's top science and engineering school into a globally top-ranked international university. This first period as a WPI institute, ELSI has made a considerable number of results about the origin of Earth and life. After 10 years of WPI funding, ELSI will be engaged in education more intensively launching a new graduate educational program and welcoming excellent graduate students from top level universities of all over the world.

2. Advancing Research of the Highest Global Level

ELSI set out to address an ambitious science goal: the origins of life within the context of the origin of the Earth and other planets, and has been extraordinarily successful (more than 1100 publications from 2013 to 2020) in making significant progress and yielding a wide-reaching impact in all of these areas. It addresses the following four goals:

A. Origin of the Earth – ELSI scientists reconstructed key stages in the formation of the

Earth, where and how our planet formed, what determined its composition and the changes in its internal state over time, how crucial elements responsible for the atmosphere and oceans were delivered and why they were retained, and how surface conditions responsible for life depended on these earlier stages. We developed the first integrated models of accretion and transport in circumstellar disks across scales from gas and dust, through crucial intermediates known as "pebbles," to the migrating orbits of early planets, and effects of giant impacts. By combining computer models with cosmochemical evidence, we have explained the diversity seen in the Solar System (as well as exoplanetary systems), while constraining the possible sources for light elements (C, O, Si, H, S, N) on early Earth.

Our researchers have also performed flagship work addressing questions about how to power planetary magnetic fields, connecting the deep interior of planets to the surface environment. We discovered that Earth's core incorporated much more hydrogen than previously thought. A key discovery at our world-leading high pressure experimental labs showed that early precipitation of silicon oxides from the core could have powered an early magnetic field protecting Earth's atmosphere from loss by the solar wind, providing a new solution to a major paradox in geophysics.

We have learned that the cooling rate of early planetary surfaces is highly sensitive to solar irradiance and why, even with similar starting compositions, Venus dried and fell into a greenhouse from the beginning, while Earth retained an ocean and sequestered most of its CO_2 in the subsurface.

ELSI's theorists of planet formation are trying to construct the universal model for satellite formation in and beyond the Solar System. This model will help to see the planets' formation from the information of their satellites formed. In addition, ELSI PIs Sekine and Genda are leading a Shingakujutsu project: "Aqua Planetology". The project tries to understand chemical reactions and dynamics involving water on planetary bodies to create theory to understand how to build habitable aquaplanets.

B. Birth of the Earth-Life System – We examined the origin of life as the emergence of a new geological system, accounting for the interactions between oceans, atmosphere, and solid Earth that are key ingredients for early chemical evolution. ELSI's researchers broke new ground to provide evidence for the formation and maintenance of a reducing environment on the early Earth, with important consequences for prebiotic organic chemistry. We discovered that a single late giant impact produces a secondary hydrogen atmosphere that lasts for 200 million years at the beginning of the Hadean eon. Consistent with these findings, the geochemistry team showed that complex stable isotope signatures of sulfur in ancient rocks require a high ratio of CO to CO_2 well into the Archean, a breakthrough that has eluded geochemists for decades and a crucial condition for synthesis of complex organics.

Our work builds the case that diverse planetary surface conditions are essential to the emergence of life. We studied the roles of ocean bottoms and land as sources of nutrients, the roles of the Sun, rock/water interface, and radioactive subsurface as sources of energy, the timing and extent of water delivery, and the composition of the earliest oceans and crust to predict the earliest conditions supporting prebiotic chemistry and the emergence of life. ELSI researchers developed a new field of study, "geoelectrochemistry", where bulk-phase electrical potential interacts with geological redox chemistry to produce reactive C and N compounds, which drive downstream pathways that mimic the central metabolism of all extant life on Earth. In a seminal work of ELSI scientists, the requirements for life are identified and elaborated to further extend the example of early Earth geology into a framework for the search for other habitable planets.

ELSI scientists have been studying the question of protometablism: how mineral catalysis can be driven by redox disequilibria to form the building blocks of life and help organize them into living systems. They found geoelectrochemical conditions which can be the same as on the Hadean Earth. ELSI scientists also showed the importance of secondary electronic interaction with sulfur ligands to facilitate the functional evolution from mineral- to enzyme-catalyzed systems.

The most important contribution of ELSI was only possible by bringing theorists and experimentalists together under the same roof. Life did not emerge in a controlled laboratory setting, such as a beaker. ELSI scientists have established a new robust approach to move these studies into the realm of combinatorial complexity that characterizes real planetary geochemical environments, creating novel computational and analytic methodologies, and applying these to formation, structure, and properties of functional polymer families.

C. Coevolution of Life with the Earth – We worked to identify major transitions that shaped the evolving biosphere, its architecture, modes of evolution, and dependence on

planetary conditions through time, and how bio-evolution has fed back to shape Earth's geological history.

ELSI researchers reconstructed genomes and bioenergetic systems of ancient bacteria, and shown how those changed in response to evolving planetary chemistry. We reconstructed isotopic and mineral signatures linking biological major transitions to the rock record, both for sulfur metabolism and for oxygenic photosynthesis, the biological innovation that has most impacted every surface environment on Earth. Genomes on Earth are carried by two kinds of lifecycles: one in free-living cells and the other in viruses. We have expanded worldwide knowledge of the diversity of viruses of thermophilic Archaea by nearly 100%, and are exploring the limiting conditions for single-stranded DNA and RNA viruses to understand constraints on an RNA world. ELSI now hosts one of the largest collections of Archaeal viruses of any institution in the world.

We integrated synthetic and evolutionary biology to understand elements of structure and function in early organisms. We demonstrated functional proteins translated using simpler genetic codes, and enzymes to synthesize key amino acids that do not require those acids in their sequences. We achieved increasingly complex functions in synthetic cell membranes, and coordination of molecular systems within and across them. To understand what processes drive biological innovation, we demonstrated new evolutionary paradigms for the use of external constraints as scaffolds to create novel complexity. We have also shown how catalytic imprecision can be the gateway to new functions – likely an essential mechanism in early eras of short genomes and unreliable replication.

D. "Bioplanets" in the Universe – Our studies of the history of Earth and its life reveal a unifying paradigm, of alternating stages of diversification and selection, which serves as a springboard to understand the habitability of planets around other stars and the principles that make life on them different or similar to our own.

Principles of life are essential features that can be formalized independently of the way they are expressed in Earth's biology. One such feature is heredity, without which selection cannot lead to adaptation. ELSI derived measures of capacity for heritable variation that do not depend on genes or genomes, and apply across a range of widely studied compositional models and even more general dynamical systems. Computational combinatorial methods allow us to ask which aspects of Earth-Life reflect inherent limits of chemistry, and thus may be universal. We have shown that the biological amino acids as a set cover a much wider range of properties essential to protein function than random sets of possible amino acids of similar size. Selection has made the biological set more unique because they are closer to the limits of chemical possibility.

A universal biology must explain how simple patterns of dynamical complexity create more complex patterns in a self-maintaining hierarchy. We have studied this problem for the emergence of lineages at the forming of the genetic code, showing how an era of innovation-sharing in which all components are exchanged independently can produce the error-buffering properties of the biological code, which then permit reliable protein synthesis, faithful molecular replication, and the emergence of vertical descent in a Darwinian world.

3. Feeding Research Outcomes Back into Society

As for the research outcomes of ELSI back into society, there are four examples of applications of research results. A. Kobayashi's discovery about nanocrystals of magnetite has broad applications in the field of climate control, industrial technologies of supercooling, and reducing the ice crystals in food products. Y. Kuruma and K. Fujishima studied the cell-free protein expression system for high-throughput screening and evolution of random polymers, which can be applicable to design various peptide/RNA aptamers and applicable in the pharmaceuticals and therapeutics industries. ELSI also participated in Tokyo Tech's project to offer information related to COVID-19 freely to the society. T. Mochizuki is in the "New Normal Research Map" of Tokyo Tech, which introduces the researchers whose research is related to COVID-19.

ELSI PR Office actively coordinated outreach activities. They enhanced ELSI's global visibility, by a considerable number of public lectures, events for students, videos, popular literature books. In the recent two years the number of press releases in English has led to 400 articles by foreign media per year. ELSI played a leading role for the development of science communication in Japan by providing skills for researchers, students, and PR staff.

4. Generating Fused Disciplines

ELSI researchers are independent and free to work with researchers of other disciplines. The almost all science results shown in 2-1 are interdisciplinary resulting from the

discussions of the experimentalists and theorists. Interdisciplinary teams at ELSI have tackled numerous additional challenges together, including models for the origin and circulation of water in the Earth and use of amoebas as virtual computers to solve problems that cannot be solved by conventional computers. Astrophysicists and cosmochemists got together to explain Mars' composition and orbital radius, modeled prebiotic chemistry in icy moons, formulated new approaches to studying origin of life, and ELSI researchers proposed biology inspired models for the Earth's formation, composition, and long-term evolution. From such models, ELSI researchers brought new ideas to the discussion of biomarkers on exoplanets, and proposed nitrogen cycles in planets without life, unified important ideas around the geochemical and geo electrical output of vents in deep sea, and how they power life in a deep marine environment. Researchers also explored how the geochemical availability of various metals in the early Earth environment facilitated a variety of chemical pathways for biological metabolism.

5. Realizing an International Research Environment

ELSI has established a research environment capable of attracting the world's best researchers in the field of the origin of Earth and life, mandating English in all communications involving ELSI researchers and required for all events, workshops, and institutional email lists, and recruited the majority of junior and senior researchers internationally. Today, 10 out of 20 PIs are world-class foreign researchers recruited from overseas, of which 3 are based in Tokyo full-time and 5 are staying in Japan 6 months per year. ELSI continues to recruit talent from around the world and successfully acquired a new PI from Columbia University in FY2019.

ELSI pursues a targeted strategy for the international recruitment of competitive young researchers from all over the world, which is unique in Japanese universities. ELSI PIs employ their personal international networks to source top quality graduate students and postdocs as potential candidates. ELSI's activities to invite students of our symposium speakers, hosting winter and summer schools, and active sponsorship of young researcher conferences have paid great dividends. After leaving ELSI, 60% (31 out of 52) young researchers were successful to get a promotion at the world's top research institutions following their research experience at ELSI. This is a proof that ELSI is recognized as a career-path institution. Most of them are approved to be affiliated scientists of ELSI and develop a joint collaboration between ELSI and their institutions.

ELSI actually has three overseas satellites: Institute for Advanced Study at Princeton, Harvard University and Columbia University. ELSI published 72 co-authored papers with these satellites up to the end of 2020. In addition, ELSI has an international partnership with Astrobiology Institute of NASA as a member of Japan Astrobiology Consortium.

ELSI has hosted international symposia annually, dozens of workshops, several short winter and summer schools, and has a vigorous visitor program to invite top scientists to spend time and collaborate at ELSI.

The ELSI Origins Network (EON), launched by a donation of Templeton Foundation grant, provided a concrete measure of our global visibility. EON's funding for post-docs working half time in an institution abroad and the other half time at ELSI, and establishment of a new global network in the origin-of-life research allowed ELSI to significantly expand its profile, adding leverage to the funding provided by WPI.

Almost all ELSI support staff are bilingual and they provide various services to overseas researchers: daily life support, Japanese language classes, support for acquisitions of competitive funds, pre-and post-award support of external funds, safety management training, cultural diversity training, and a confidential tool of reporting issues to the management. Laboratory safety issues are all announced in Japanese and in English.

6. Making Organizational Reforms

ELSI has introduced new organizational strategies that represent our unique "WPI" brand of science and implemented them in the university. As a "special research zone" within Tokyo Tech, new administrative systems were developed, tested, and exported to the broader university. ELSI has made significant contributions to the President's vision to become a world-leading research university. ELSI's achievements in organizational reforms can be summarized as follows:

- WPI style of top-down management under the leadership of a center Director, allowing flexibility we need to adapt to our special scientific, cultural, and logistical challenges.
- Annual evaluation of researchers and a performance-based salary system.
- Cross-appointment system to acquire top researchers. After ELSI's first case, as of 2021

March, 10 researchers in Tokyo Tech are hired using this system.
- Introduction of a new scheme in Tokyo Tech to accept donations of smaller scales but higher flexibility, leading to the "ELSI FirsLogic Astrobiology Donation Program."
- Tokyo Tech adopted English-based support in university-wide email notifications, a consultation desk for personnel matters, and safety training.
- Open and flat research organization that stimulates interdisciplinary research.
- Change in university regulations for travel insurance for business trips, and corporate credit card.
- Establishment of "Tokyo Tech USA" non-profit organization in the state of New York, enabling private donations from the US.

7. Others

(1) Participation in graduate-course education

ELSI has been making significant contributions towards nurturing the next generation of researchers by having our world-renowned scientists supervise graduate students. Therefore, in 2021 April Tokyo Tech initiated a new five-year (integrated master's and doctor's) program, the Earth-Life Science graduate major or "ELSI Course", mainly contributed by ELSI professors. The first students will join this program from April 2022.

(2) Acquisition of global funds

As mentioned in Sec.5., in July 2015, ELSI acquired research funds totaling JPY670 million (USD1=JPY122) from the John Templeton Foundation in the United States. This grant was larger in amount than what all Japanese national universities combined raised from overseas in the previous year.

(3) Activities during the pandemic of COVID-19

ELSI was quick in adapting to "a new normal". Seminars were turned into online but their frequency was maintained or even increased, and their audience was expanded by virtue of access via network. The ELSI International Symposium in January 2021 was held online and globally, covering three time zones round the clock.

B. Progress Plan

1. Mid- to Long-term Research Objectives and Strategies Based on the Center's Research Results to Date

The highlight of ELSI's 10-years of achievements is that ELSI allowed us to understand the origin of life in the context of Earth formation and evolution (or the view of the Earth-Life system) via successful fusions of multiple disciplines. Previously, geoscience or life science thought separately of Earth and life to understand their origins and evolution; however, ELSI provided an integrated view of a sequence of the origin and evolution of the Earth-Life system. ELSI's major achievements were not only to provide the view that the Earth-Life system was developed as a result of the diversifications and filter selections, but also to point out key transitions that determined the fate of the Earth-Life system in diversifications and filter selections. Some of these transitions might have been stochastic and chaotic. ELSI's scientists have been revealing the factors that control diversifications and filter selections of the Earth-Life system and that determine the fates of the Earth-Life system.

ELSI provided the view of the sequence of diversifications and filter selections toward the current Earth-Life system (called "ELSI model"); however, at the same time, this raises new fundamental questions. Are there alternative planet-life systems in the universe? Are there any other paths to reach to emergences of lives? The origin-of-life science can be universal only after understanding the possibilities of emergence of alternative lives and lifeless planets in ELSI model. Another key question on ELSI model is how we can make benchmarks for the sequence of diversification and selection? Factual evidence for large parts of key transitions that occurred on primitive Earth has been lost. On the other hand, we are now starting to know that there are multiple planetary bodies that experienced similar sequential evolution, but the evolution has been stopped or dramatically slowed down. Future space explorations to these bodies could provide factual evidence for the key transitions in the diversifications and filter selections.

While keeping existing approaches in ELSI to understand key transitions toward the emergence of our Earth-Life system, we will newly try to understand/predict the possibilities of alternative "planet-life systems" to exist anywhere in the universe. The latter new approach clearly requires institutional collaborations inside and outside Japan (e.g., JAXA, NASA, ESA, NAOJ, JAMSTEC, and RIKEN). ELSI will try to be a "think-tank hub" for space missions and telescope observations for astrobiology through providing conceptual foundations for large projects. Through the existing and new approaches, we attempt to

construct a concept of "universal biology", in which we can characterize life on Earth, or ourselves, in a wide range of physicochemical parameters of planet-life systems.

In our next decade, we would focus on tackling the following research themes on alternative planet-life systems. The first theme relates to reveal organo-chemical networks in planetary cycles. We aim to predict and interpret cycles of nutrients. Through more integrated linkages of organic chemistry experiments, geohydrological modeling, and complexity science, we will examine a variety of networks of organo-geochemical cycles depending on different geological settings (geohydrological cycles) of planetary environments. The second theme is about expansion of synthetic and theoretical biology to astronomy and planetary science. Through collaborations between synthetic biology, astronomy, and planetary sciences, we will investigate physicochemical properties of functional polymers and molecules and the possibilities of alternative functional polymers and molecules for different planetary conditions. In addition to prediction of functional polymers, prediction of ecosystem changes can be done by collaboration of theoretical biochemistry and astronomy-planetary science.

2. Management System of the Research Organization

ELSI is an independent research institution directly under the President of Tokyo Tech, and is overseen by the Director who has the authority to make all important decisions in a top-down manner. Under the Director, ELSI employs a hybrid internal system of management. ELSI's Director organizes a weekly "Director's Office" that deals with day-to-day management issues. A monthly Operations Committee composed of the directors and several PIs handles formal personnel and other matters within the university's scheme. ELSI also maintains an International Advisory Board (IAB) of world-leading scholars with extensive scientific and organizational leadership experience, which meets annually.

Tokyo Tech was selected as a Designated National University in March 2018. Our specific goals are to create a global research hub and conduct international collaborative researches, and to establish a research environment where researchers can focus on research and develop new interdisciplinary research fields. These are all areas in which ELSI has already led the way, and will continue exporting our experiences to assist the university in achieving this vision. It is also our hope to export these successes more broadly to other universities in Japan.

3. Center's Position within the Host Institution and Measures to Provide IT with Resources

Tokyo Tech defines ELSI as a permanent and independent research organization in its "Strategic Research Hubs" and has made concrete commitments to support our continued efforts. President Masu states that "Tokyo Tech is proud of ELSI. ELSI is positioned as a leader for Tokyo Tech in the concept that aims to become a world-leading research university by 2030, which marks the 150th anniversary of Tokyo Tech."

In order for ELSI to achieve and maintain a world top-level research center permanently, Tokyo Tech has committed to provide 10 full-time PIs (including 8 tenured professors), two ELSI buildings, as well as giving technical, financial, and administrative support to ELSI. Tokyo Tech will also provide financial support to students coming to the "ELSI Course" graduate program starting in 2022 April.

To support the acquisition of research funds, Tokyo Tech newly employed URA and fundraising staff, and initiated new schemes (donation program and "Education and Research Co-creation Scheme") to more actively gather funding from private donations. With these schemes, Tokyo Tech will assist ELSI in securing its financial basis.

Tokyo Tech is considering an organizational reform of creating an "Advanced Research Institute" (or Organization), with ELSI as a core member. This new organization will focus on a few specific research fields (including those of ELSI) and aims at a "world top-level" rating in any evaluation axis, such as innovation, globalization, and diversity. This reform will not only strengthen ELSI's structural foundation, but will also help spreading the systemic reforms that ELSI has implemented to the entire university.

World Premier International Research Center Initiative (WPI)
Progress Report of the WPI Center
(For Final Evaluation)

Host Institution	Tokyo Institute of Technology	Host Institution Head	MASU Kazuya
Research Center	Earth-Life Science Institute		
Center Director	HIROSE Kei	Administrative Director	SAKURAI Takashi

Common Instructions:
* Unless otherwise specified, prepare this report based on the current (31 March 2021) situation of your WPI center.
* As a rule, keep the length of your report within the specified number of pages. (The attached forms are not included to this page count.)
* Use yen (\ ) when writing monetary amounts in the report. If an exchange rate is used to calculate the yen amount, give the rate.

1. Overall Image of Your Center (write within 2 pages including this page)

Describe the Center's current identity and overall image.
- List the Principal Investigators in Appendix 2, and enter the number of center personnel in Appendix 3-1, 3-2, diagram the center's management system in Appendix 3-3, draw a campus map in Appendix 3-4, and enter project funding in Appendix 3-5, 3-6.

ELSI was launched nine years ago with the primary research target of exploring the origin of the Earth and the emergence of life in its early history, both of which are fundamental questions to humankind. Since life started under early Earth environments, the study of the origin of life is inseparable from the study of the early Earth itself. This is our primary concept and motivation for researchers in a variety of different fields in geology, geophysics, geochemistry, planetology, astronomy, organic chemistry, biology, etc. to work closely together under "one roof" at ELSI. Indeed, this concept is unique and is the reason why ELSI has earned its reputation as a world-leading institute on the study of the origin of life.

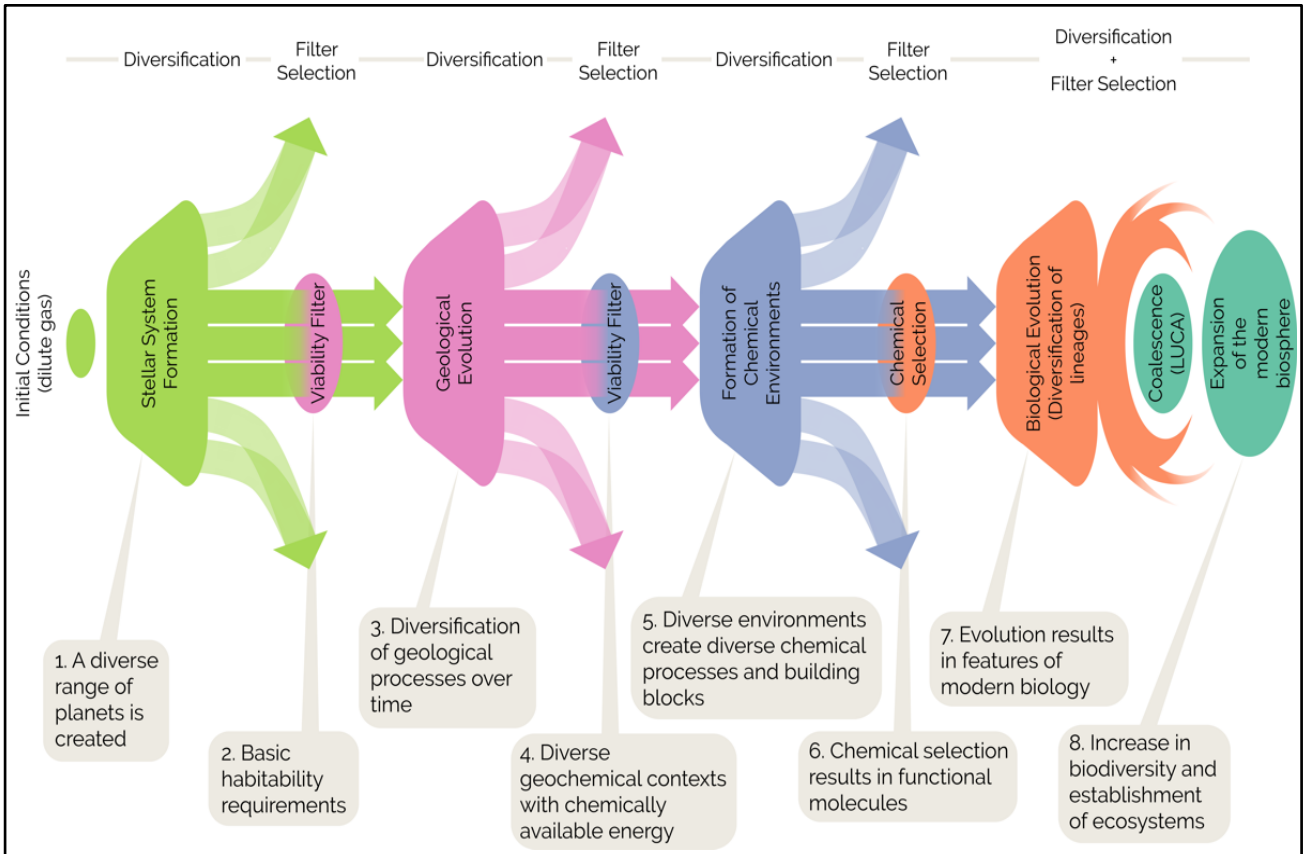
"Origins" problems in general are difficult to tackle. The Origin of Life is a far-reaching research goal. Nevertheless, ELSI has been a research "hub", in particular on the origin-of-life studies, at which active researchers got together from around the world and contributed to big questions such as "What were the initial conditions on early Earth that would support the emergence of life?", "Where did life emerge?", and "What fueled prebiotic synthesis from existing raw materials?" (see the next section for details). Note that approaches to these important questions are always interdisciplinary, and could not have happened without ELSI's unique atmosphere.

ELSI has made important progress on the origin-of-the-Earth studies as well. It is a natural outcome of the fact that ELSI was originally based on the global COE program in Earth and planetary science. ELSI has demonstrated its identity as one of forefront institutes working on planet formation and its early evolutions. The most important outcome is on the delivery of water to terrestrial planet and its fate as the Earth is a typical "water planet". The presence or absence of water on planetary surface should be one of the critical factors for the birth of life. "Why does the Earth have water?" and "Why does the Earth have so little water on the surface?" are two important questions that have been addressed at ELSI, which has distinguished teams of planet formation theory and high-pressure experiments. ELSI researchers have revealed that tens to hundreds of ocean mass of water was delivered to the growing Earth and then more than 90% of it was sequestrated in its metallic core as a consequence of metal-silicate chemical equilibrium at high pressures during core metal segregation from mantle silicate. We also showed that it is true for any planets and moons with masses more than 10% of Earth's mass, indicating that terrestrial (rocky) planets and satellites can regulate the volume of surface oceans by sequestrating water in their metallic cores. It has an important implication for the universality of life in our solar system and beyond because the coexistence of land and ocean at planet/satellite surface may be necessary for life to emerge.

Another key factor for life's emergence may be the formation and preservation of the planetary magnetic field, because oceans will be lost in its absence. This is the topic to which ELSI has made significant contributions in recent past. In this respect, Mars is the best testing board. "Was the first ~500 million years before the disappearance of the Martian magnetic field and its ocean long enough for Martian life to emerge?" should be one of the key questions regarding life on Mars. At ELSI, the sustainability of planetary magnetic fields has been examined by a team effort in high-pressure mineral physics experiments and thermal evolution simulations. We found that the scale of a magma ocean which most of terrestrial planets have at late stages of their accretion controls the sustainability of planetary magnetic fields, on which life's emergence depends.

Our diversification/selection paradigm shown below balances short-term (project) results with long-term scientific impact (process-based theory at whole-system level). While ELSI's research has been broad, we now have three focus areas; 1) early singular events for planets: moon-forming impact and long-term consequences for redox and volatile distribution on Earth, 2) organic synthesis and cycling of CHNOPS at planetary surface on geological timescales, and 3) designing proto-life systems using geologically-available materials. These will be the research areas where ELSI has institutional identity.

After 10 years of WPI funding, ELSI will expend more effort in education. We are launching a new five-year graduate educational program in Earth-Life science, which is unique in its interdisciplinarity and internationality. We will try to attract the best students in Japan and from abroad to foster the next generation scientists who tackle fundamental questions such as the origins of the Earth and life.



The ELSI model is both a theoretical framework and a roadmap for origin of life research. It captures the idea that the events from the Big Bang to life was a series of diversification's followed by selections.

2. Advancing Research of the Highest Global Level (within 15 pages)

2-1. Research results to date

Describe issues of a global level that the Center has challenged, and give the results. Select 20 representative results achieved during the period from 2012 through March 2021. Number them [1] to [20] and provide a description of each. Place an asterisk (*) in front of those results that could only have been achieved by a WPI center and explain the reason in the description.

- In Appendix 1-1, list the papers underscoring each research achievement (up to 40 papers) and provide a description of each of their significance. And in Appendix 1-4 list the center's research papers published in 2020.

ELSI's goals

The Earth-Life Science Institute (ELSI) aims to answer the fundamental question "when and where did life originate and how did it evolve?" ELSI proposes to carry out research in order to understand the origin of life in the context of planetary environments by addressing the following four goals:

(A) Origin of the Earth. Identify the key stages in the formation of the Earth, by answering questions such as: how were planets formed and how did the Earth emerge in the early Solar System, what was the composition and internal state of the early planet, and how was water delivered to the Earth.

(B) Birth of Earth-Life system. Seek the origin of life as the emergence of a new geological system, accounting for the interactions between oceans, atmosphere, and solid Earth that are key ingredients for early chemical evolution.

(C) Evolution of Earth-Life system. Investigate the co-evolution of the Earth-Life system. For example, how did life modify its environment, such as by producing an oxygen atmosphere? What are the influences and feedbacks between the solid Earth and surface environment? What is the importance of extra-terrestrial events in the Earth-Life system?

(D) "Bioplanets" in the Universe. Use the foundation of Earth-Life science as a springboard to identify habitable environments in the universe, and thereby establish a new dialogue for studies of the origin of universal life. Answer the questions: How unique is our planet? How should we search for extraterrestrial life?

2-1. A. Origin of the Earth

The story of how life emerged on Earth begins when various types of stars are formed in molecular clouds in galaxies and then planets are formed in protoplanetary disks, byproducts of star formation, orbiting around these young stars. What features of our solar system, and what characteristics of Earth and its evolution over time, led to the only known planet to support life? How was our Earth born? What are the mechanisms that created the diversity of planetary systems we know today? These questions are fundamental and essential ones for us to understand the universality and uniqueness of Earth and its biosphere. ELSI researchers have reconstructed key stages in the formation of the Earth, answering the questions where and how our planet formed, what determined its composition and the changes in its internal state over time, how crucial elements responsible for the atmosphere and oceans were delivered and why they were retained, and how surface conditions responsible for life depended on these earlier stages.

* [1] **<u>How do terrestrial planets form?</u>**

The leading models for planet formation hold that planets are born by the gradual accumulation of dust and gas inside a protoplanetary disk, beginning as the dust grains coalesce to form larger and larger rocks, and continuing as asteroids, planetesimals, and planets emerge. Previous-generation models have not adequately accounted for particle accretion from cm to km scales. In two seminal papers, Ida, Brasser and their co-workers [1,2] have developed the first integrated models of accretion and transport in stellar disks across scales from gas and dust, through crucial intermediates known as "pebbles", to the migrating orbits of early planets, and effects of giant impacts. Going further to combine approaches from separate fields, particularly N-body computational simulations together with cosmochemical evidence, they can account for the diversity seen in planetary systems – which have become observable only within the last 5 years – while also constraining the possible sources for light elements (water, C, N) on early Earth. For example, it is understood that pebbles that formed in the outer solar system could

supply volatile elements to the terrestrial planets. However, cosmochemical analysis [2] argues against this scenario, suggesting that Earth's volatiles originated in the relatively water-poor inner Solar System, explaining Earth's low volatile budget compared to some extrasolar systems. The unification afforded by pebble accretion sets the standard that in order to correctly infer how planetary systems form, detailed prescriptions of disk evolution and pebble growth, sublimation, destruction and migration are required.

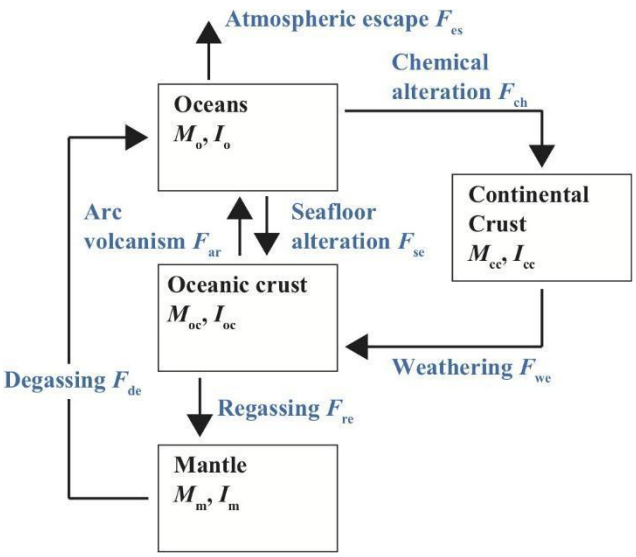
* [2] **How did the composition of the Earth's core result in a magnetic field?**

The Earth's magnetic field deflects harmful radiation that otherwise could destroy the atmosphere essential for retaining life-sustaining water on the surface. ELSI has done flagship work addressing questions about how to power magnetic fields in general, and more specifically Earth's magnetic field history. ELSI researchers have discovered that as Earth's core separated from its rocky mantle, it could have incorporated much more silicon and oxygen than had been believed, along with significant hydrogen which remains there to this day. Crucially, the early precipitation of silicon oxides as the core cooled created a vigorous buoyant stirring force, increasing the likelihood to form an early magnetic field protecting Earth's atmosphere from loss by the solar wind. Using high pressure and temperature experiments, Hirose led a team of ELSI researchers [3.4] to characterize how complex multi component liquids (namely the Fe-Si-O ternary) can provide a buoyancy source to drive dynamo activity where it would not be predicted from binary systems only. These experiments using laser-heated diamond-anvil cells characterize the liquidus phase in the iron-rich portion of the Fe-Si-O system and demonstrate that SiO2 would be the first phase to crystallize as the core cools, leaving dense iron-rich liquid behind. Addressing the same issue from a completely different field, geobiologist Kirschvink and co-workers [5] provide evidence of the timing and evolution of the geodynamo. Their work shows that magnetoaxis evolved in bacteria during the Archean, before or near the divergence between the Nitrospirae and Proteobacteria phyla, suggesting that magnetotactic bacteria are among the earliest magnetic-sensing and biomineralizing organisms on Earth. In the absence of an active geodynamo and a magnetic field it is hard to explain why microorganisms would have evolved this adaptive capability. An early origin of magnetotaxis would have created evolutionary advantages in coping with environmental challenges faced by microorganisms on early Earth; its persistence in separate lineages implies the temporal continuity of a geomagnetic field, providing a biological constraint on the evolution of the geodynamo.

* [3] **Inventory of Earth's water.**

An essential element for the origins and maintenance of life, water is unequally distributed among the terrestrial planets of our solar system. **Why does liquid water exist at the surface of the Earth and not on other planets?** One part of this question concerns delivery (see Result 1 above), but several other planetary properties also play a role. Through ELSI's work we now understand why, from similar starting compositions, Venus dried and fell into a runaway greenhouse, while Earth retained an ocean and sequestered most of its CO_2 in the subsurface. By recognizing that the cooling rate of early planetary surfaces is highly sensitive to solar irradiance at certain thresholds, changing by more than a factor of ten over the small difference of orbital radius between Earth and Venus, Hamano, Genda and Abe [6] have provided a widely-accepted explanation for why Venus lost its water and Earth did not. Hamano et al. developed an evolutionary model for magma ocean crystallization, and showed that, assuming water delivery occurs early, the crystallization timescale of a primordial magma ocean plays a major role in controlling the bulk water amount. That timescale has a strong dependence on the planet's distance from the star through the energy balance between stellar radiation and radiation from a steam atmosphere. Beyond a critical orbital distance, magma ocean crystallization takes ~1 Myr and the volatile inventory can be retained, whereas planets closer than that radius crystallize on ~10 Myr timescales and hydrodynamic escape to space has time to desiccate the planet. The sensitivity regime for magma ocean cooling provides a first-order constraint on how to establish habitable conditions on a terrestrial planet. **How much water was on the early Earth** is a question answered by Kurokawa et al. [7]. Using the deuterium/hydrogen (D/H) isotope ratio,

which reflects the global cycling and evolution of water on Earth as it fractionates through planetary processes, this paper reconstructs the early Earth's ocean volume. It models the combined effects of seafloor hydrothermal alteration, chemical alteration of continental crust, slab subduction, and hydrogen escape from the early Earth, as well as degassing at mid-ocean ridges, hot spots, and arcs. In order to produce observed isotope ratios in these improved fractionation models, secular net regassing and/or early fast plate tectonics are needed, suggesting that the volume of Earth's initial oceans – while still small in absolute magnitude – could have been 2 to 3 times larger than those on Earth today.



* [4] **How do planets form from a view point of satellites' formation**

Satellite formation is one of the keys to understand how host planets formed, because most satellites formed during or at the very end of planet formation. For example, some lunar rocks sampled in the Apollo mission gave us critical information on Hadean Earth, while there are no geological records on Hadean Earth. In this sense, satellites are kinds of fossils of host planets. ELSI's PI Genda and co-workers [8] revealed that two Martian moons can be also formed by a single giant impact on ancient Mars, which formed the huge north polar basin on Mars called Borealis basin, as our Moon was formed via giant impact. JAXA is planning to send a spacecraft to Martian moons to return their samples, which will give us much critical information on not only Martian moons but also Mars. ELSI's PI Ida [9] found that Uranian satellite system and tilted spin axis of Uranus can be formed as a consequence of a giant impact on Uranus. Formation of Uranian satellites accompany the extensive vaporization of water, which contrasts with the giant-impact model for the Earth's Moon. Now ELSI's theorists in planet formation group are trying to construct the universal model for satellite formation in and beyond the solar system.

* [5] **Aqua planetology**

In Shingakujutsu project "Aqua Planetology" which ELSI's PIs Sekine and Genda lead, they have focused to understand chemical reactions and dynamics involving water on planetary bodies, for instance, water-rock-organics interactions within planetesimals, distribution of water in the early Solar system, hydrological and biogeochemical processes on Earth and terrestrial planets, geochemical cycles, redox-pH gradients, and habitability on early Mars and icy moons. They have tried to create theory to understand how to build habitable aquaplanets.

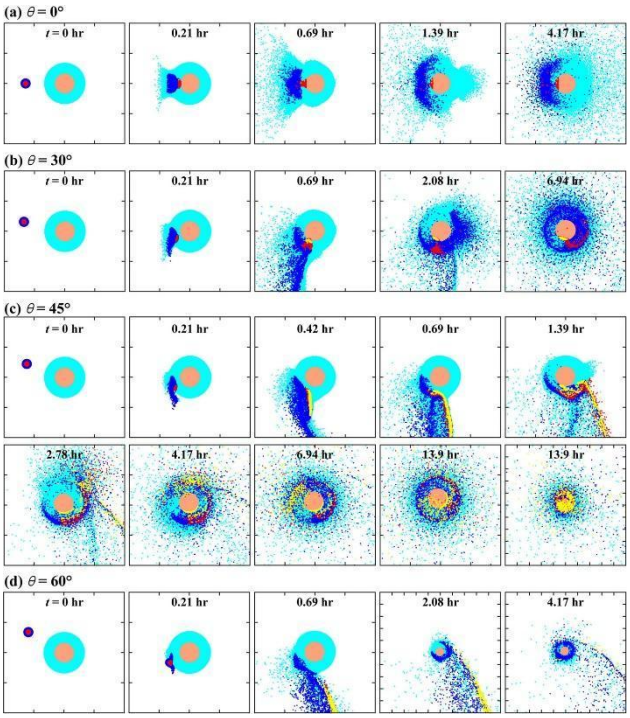
Sekine and co-workers [10] found that liquid water in lakes in Gale Crater on ancient Mars had a pH close to that of Earth's modern oceans. This new study finds surface waters on early Mars may have been habitable for microbial life. Sekine and co-workers (Kamata, Nimmo, Sekine et al. Pluto's ocean is capped and insulated by gas hydrates. 2018. Nature Geoscience, 12, 407–410) also focus on subsurface ocean in Pluto, and found that the presence of a thin layer of clathrate hydrates at the base of the ice shell can explain the long-term survival of the subsurface ocean. This new study suggests an important generic mechanism to maintain long-lived subsurface oceans in relatively large but minimally heated icy satellites and Kuiper belt objects.

2-1.B. Birth of the Earth-Life System

We seek to understand the origin of life as the emergence of a new geological system, accounting for the interactions between oceans, atmosphere, and solid Earth that are key ingredients for early chemical evolution. In order to answer the question **where and how did life emerge on Earth**, ELSI researchers have reconstructed essential characteristics of the conditions on early Earth. They go on to examine three conceptual stages in chemical evolution,

which may overlap spatially and temporally: 1) the formation of the basic inventory of chemical building blocks driven by geological environments; 2) the diversification of the abiotic chemical inventory through the formation of dynamic reaction networks with an emphasis on networks' propensity towards self-organization; 3) the formation of functional chemical assemblies within the dynamic reaction networks under geological, environmental or physicochemical selective pressures. Prebiotically plausible organic and inorganic chemical processes are numerous, and therefore the scientists explore combinatorially complex reaction spaces. Improved understanding of the breadth of chemical reactivity in planetary environments, and of selective geological and chemical processes that promoted the emergence of life-like ordered chemical reaction networks, are brought together in a new ELSI model of the origin of life.

* [6] **What were the initial conditions on early Earth that would support the emergence of life?**



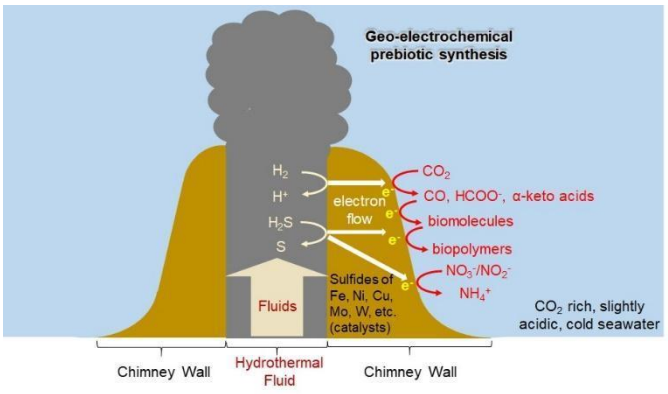
The oxidation states of carbon and nitrogen in early Earth's atmosphere are fundamental to its capacity for organic synthesis. This aspect of the state of the early Earth's atmosphere has historically remained unresolved. A highly reduced atmosphere in which methane, ammonia, and water were all major constituents was first proposed as necessary for prebiotic chemistry by the famous Miller-Urey experiments of the 1950s. However, subsequent photochemical studies showed that any methane or ammonia in the atmosphere would quickly be destroyed, and other geologically based arguments supported an atmosphere of H_2O, CO_2 and N2, which would be unfavorable for prebiotic chemistry. ELSI's researchers have pursued and reported on two lines of evidence to support a reducing environment on early Earth essential for prebiotic chemistry. First, we have discovered that mantle composition and early atmospheres can be linked through models of the frequency and size of late impactors. Genda and co-workers [11,12,13], using a hybrid numerical simulation of giant impacts and fragment dynamics, showed that a single lunar-sized body, striking the Earth between the moon-forming event at 4.51 Ga and the last terrestrial differentiation that separated silicate reservoirs at 4.45 Ga, best accounts for the "late veneer", an excess of iron-loving elements observed in the current Earth's mantle. The differentiation implied within such a large impactor then predicts core fragmentation and ejection of metallic Fe, which would have re-accreted on Earth as an iron "rain", producing a secondary hydrogen atmosphere that lasted for 200 million years at the beginning of the Hadean eon. These results for Earth suggest that giant impacts would be key events determining the redox state of early atmospheres of any terrestrial planets. Second, we have found, from the complex stable isotope signatures of sulfur, that Earth should have maintained a higher ratio of CO to CO_2 than has been expected well into the Archean, with implications for synthesis of complex organics. The source of stable sulfur isotopic anomalies recorded in ancient sedimentary rocks from 4.0 to 2.4 billion years ago has eluded geochemist for decades. Using an experimental system to mimic the atmosphere of early Earth, Ueno and his PhD student [14] succeeded in reproducing the Archean sedimentary S-Mass-Independent-Fractionation record including the rarest isotope sulfur-36. The oxidation state required in the laboratory model suggests that the early Earth's atmosphere should not have been a simple CO_2 atmosphere but must have contained more reducing gasses, most likely CO. A CO-rich

atmosphere may have been critical for prebiotic synthesis, and extends the era of reducing conditions by another 1.5 billion years beyond the episode inferred by Genda et al.

[7] **Where did life emerge?**

Challenging oversimplified narratives often assumed for a single "birthplace of life", ELSI researchers have shown that diversity and complexity of planetary surface conditions are essential prerequisites to life's emergence. We have studied the roles of ocean bottoms and land as sources of nutrients, the Sun, atmosphere, rock/water interface, and radioactive subsurface as sources of energy, the depth and timing of water delivery, and the chemistry and mineralogy of the earliest oceans and crust. Through these parameters we can say in how far Earth is special in its capacity to originate life. To address the question where life emerged on Earth, ELSI researchers consider geologically reasonable environments or networks of environments furnished with energy sources and chemical fluxes capable of initiating organic synthesis. The requirements for life are identified and elaborated in the seminal work of ELSI scientists, Maruyama, Genda, Hirose and their coworkers [15]. These researchers were the first to evaluate the contribution of the Hadean land mass as a source of essential nutrients for life. They also examined the size and the chemistry of the early ocean and the initial size of the planet, and concluded that Earth's advantages towards bearing life arise from our planet's diverse sources of inorganic nutrients. Moreover, early Earth's relatively shallow oceans and the presence of land masses allowed for nutrient concentration and recycling. Maruyama et al. have further extended the example of early Earth geology into a framework for the search for other habitable planets.

[8] **What fueled prebiotic synthesis from existing raw materials?: Atmospheric and radiative processes**



A signature of life is the harnessing of energy transduction to produce biomolecules. ELSI researchers have demonstrated the potential contribution of numerous energy sources to production of reactive C and N compounds, including the voltages produced at hydrothermal chimneys, secondary electrons liberated by ionizing γ-radiation, and atmospheric UV. We have derived the consequences for availability of species such as nitrate, ammonia, and CO in the early oceans, and shown how similar reaction pathways produce both precursors to key compounds such as nucleobases, and activators that can drive ligation of both amino acids and nucleotides. ELSI researchers Fahrenbach, Yi, Cleaves, and Hongo took advantage of Tokyo Tech's irradiation facilities that are free for internal use to study the response of organic compounds to ionizing radiation [16]. In exploring how γ-radiation can help transform simple molecules such as HCN and $HCONH_2$ into precursors of nucleic acids, they found that chloride induces the oxidation of HCN, at the same time as solvated electrons are generated. These products together open new chemical activation mechanisms for amino acids and nucleotides, furnishing potential abiotic routes to peptides and nucleic acids. A third source of energy important for prebiotic chemistry is UV radiation. Endo et al. (Endo Y, Ueno Y, Aoyama S, Danielache SO. 2016 Sulfur isotope fractionation by broadband UV radiation to optically thin SO_2 under reducing atmosphere. Earth and Planetary Science Letters 453: 9-22) demonstrated that formaldehyde and other simple organic molecules, including glyoxylic acid, can be steadily supplied from a CO atmosphere subject to solar UV radiation. The resulting steady supply of reactive organics can drive downstream pathways that mimic the central metabolism of all extant life on Earth.

[9] **What fueled prebiotic synthesis from existing raw materials?: Redox processes**

ELSI researchers have developed a new field of study within the Origin-of-Life (OoL) research, "**geoelectrochemistry**", at the interface where bulk-phase electrical potential interacts with geological redox chemistry to drive biologically relevant processes. ELSI researchers Kitadai, Nakamura, Takai, Li, Gilbert, Ueno, Yoshida, and Oono along with their colleagues have demonstrated abiogenic electrochemical reduction of CO2 to CO under geochemically plausible conditions [18]. The significance of this result is that abiogenic CO has long been proposed as a feedstock for complex organic synthesis (see Result 4 above); the efficient reduction of Kitadai et al. shows that the potentials obtained at hydrothermal vents are sufficient to drive carbon fixation. Moving forward from this work, McGlynn, Nakamura, and their collaborators showed that CO_2 reduction to formate is possible in precisely the manner first hypothesized by Dr. Michael Russel in a landmark 1994 publication [19]. By constructing a simulated hydrothermal vent in the laboratory, the researchers were able to demonstrate that a pH difference across an inorganic membrane is able to enhance the thermodynamics of carbon dioxide reduction to hydrogen in a process described by the Nernst equation.

Central to biology is the formation of activated molecules via redox reactions, and ELSI researchers led by McGlynn discovered a new redox reaction which can result in the formation of high energy thioesters of the type which can be used to drive subsequent chemical reactions such as polymerizations [20]. In that work, ferric iron was shown to act as an oxidizing agent towards thioacids, of which the di-acyl di-sulfide products can go on to act as efficient acylating agents to produce acyl thioesters.

* [10] **Protometabolism**

An important question to understand the origin of life from a chemical standpoint is "Where on Earth can the chemical potentials be sufficiently insulated from one another, such that the resulting redox disequilibrium is sufficient as an energy source to drive chemical reactions?" Understanding how mineral catalysis can be driven by redox disequilibria to form the building blocks of life and help organize them into living systems could help to understand where on Earth and/or on Earth-like planets primitive life could have emerged. ELSI scientists have been studying these issues using multidisciplinary approaches unique to ELSI, supported by the combined expertise of ELSI researchers in geochemistry, electrochemistry, and metabolic chemistry. ELSI scientist Kitadai, PI Nakamura, PI Yoshida and collaborators found that FeS minerals are converted into metallic Fe under the geoelectrochemical conditions which can be expected from the H_2-rich alkaline hydrothermal systems on the Hadean Earth [21]. The geoelectrochemically produced FeS-Fe(0) and NiS-Ni(0) mineral composite promoted various reactions such as reductive amination and certain steps in the Wood-Ljungdahl (W-L) pathway and the reductive tricarboxylic acid (rTCA) cycle, with efficiencies far superior than pure FeS [22].

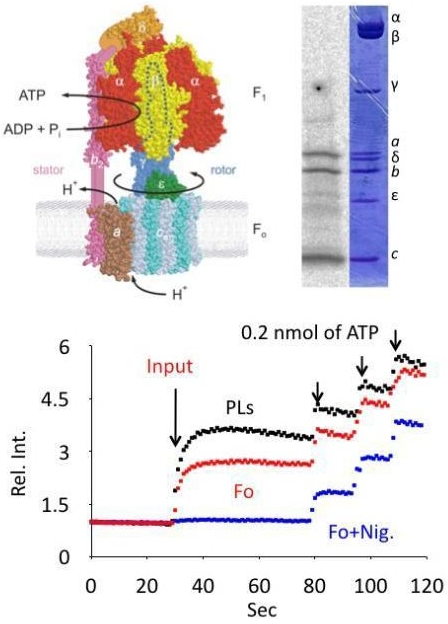
Furthermore, ELSI scientist Li and He, and PI Nakamura have investigated the conversion of nitrate to ammonia in the context of amino acid synthesis and the prebiotic nitrogen cycle. Using operando molecular spectroscopy, Li et al found that MoS_2 can generate an active intermediate which is structurally similar to the active core of biological nitrate reductase enzymes, thus allowing the mineral to catalyze ammonia synthesis in aqueous solution efficiently [23].

* [11] **Escaping the lab to understand the evolution of the early chemosphere**

This result is by far the greatest contribution that ELSI has made to the origin-of-life community and would not have been possible if theorists and experimentalists were not brought together. All Origins-of-Life researchers know that the Earth's chemosphere was and is a "messy" and dynamic environment.

However, most of the foundational research on prebiotic chemistry and the formation of the earliest biomolecules was conducted on laboratory benches in non-reactive containers, with pure substrates and under controlled conditions. ELSI researchers are moving the laboratory control of traditional OoL studies deeper into the domain of combinatorial complexity that now characterizes real planetary surface geochemistry, combining new computational and analytic methods, and applying these to formation, structure, and properties of functional polymer families. Organic chemical complexity is enormous in principle, yet living systems use only a small subset of the

possible chemical space. In biology, this restriction partly results from selection in constructed settings, such as encapsulation and enzymatic catalysis. In contrast, prebiotic chemistry was much less controlled, and in its synthesis should have accessed a more extensive combinatorial diversity of products. ELSI scientists Chandru, Guttenberg, Giri, Hongo, Butch, Mamajanov and Cleaves [24] have demonstrated this premise by invoking oligomerization of likely prebiotically abundant compounds: the α-hydroxy acids (AHA). Mixtures of five distinct species of AHA under mild, plausibly common environmental conditions, give rise to extremely high diversity dynamic combinatorial polyester libraries. These libraries contain trillions of unique oligomer sequences and are the largest combinatorial libraries deliberately prepared to date. Having demonstrated the propensity of a prebiotic chemical system towards intractable diversity, ELSI researchers have begun to organize research in a field they call "messy chemistry" that takes a complex systems approach towards prebiotic chemistry. Many model prebiotic environments produce "messy chemical systems," or large assortments of compounds through a variety of mechanisms. In that respect they are strikingly different from the controlled, high yield worlds of synthetic chemistry or enzyme-controlled biochemistry. How did such complex chemical systems give rise to biology? The answer must lie in opportunities for self-organization and function within complex chemical systems. Identifying those requires capabilities to measure and quantify the chemical complexity of a system, to monitor its dynamics, and to discern its behavior. Analytical chemistry at this level is currently undeveloped. ELSI researchers Guttenberg, Virgo, Chandru, and Mamajanov have made the pioneering case that it should be an area of research focus for the global OoL community [25]. The paper addresses the disconnect between the OoL research using restricted and controlled chemical models from the likelihood that chemical systems plausibly involved in the origins of terrestrial life produced a wide range of compounds via a wide range of mechanisms. This work is significant because it advocates a branch of OoL research concentrating systematically on the overall behavior, function, and properties of complex chemical systems. Understanding mechanisms of monomer coupling, and finding plausible prebiotic conditions for peptide and nucleic acid synthesis, do not on their own account for the formation of particularly sequenced and folded biopolymers in the absence of enzymatic machinery.



[12] **Formation of biomolecules.**

Biopolymers, such as proteins and nucleic acids, play essential roles in modern biology. Proteins perform catalytic and structural functions, and nucleic acids store and transcribe genetic information. Abiotic formation of biopolymers is a mostly unsolved problem, despite extensive effort by scientists in the origins-of-life field. Several groups of ELSI researchers have approached the question of biopolymer synthesis from different angles and have made significant advances toward understanding the process.

First, ELSI researchers Fahrenbach, Hongo, Aono, Szostak along with coworkers from other institutions explored the prebiotic synthesis of 2-aminoimidazole, a superior activating group for non-enzymatic RNA polymerization [24]. The researchers demonstrate a straightforward and prebiotically plausible synthesis of 2-aminoimidazole that shares a common mechanistic pathway with that of 2-aminooxazole, a key intermediate in synthesis of the nucleotides themselves. In one system they gthus suggest a reaction network that could lead both to RNA monomers and to their subsequent chemical activation. Second, ELSI researchers Kitadai, Umemoto, Usui and their colleagues conducted a combined theoretical, computational and experimental study of abiotic glycine polymerization on metal oxide surfaces. (Kitadai et al. 2017. Glycine polymerization on oxide minerals. Origins of Life and Evolution of Biospheres 47, 123-143) On the basis of calculations of affinities, and of the orientation of aggregations of glycine molecules on a collection of metal oxide

surfaces, the researchers ranked these minerals from most to least favorable for catalysis. Such data help to survey and constrain prebiotic conditions conducive to the formation of peptides.

ELSI researchers Yi, Cleaves and Fahrenbach demonstrated RNA precursor synthesis from a simple mixture of ammonium, sodium chloride, and HCN, with cyanide as the only carbon source. The reaction sequence combined radiolysis and dry down – two geochemical possibilities on the early Earth, and avoided "hands on" chemical approaches, demonstrating that relevant prebiotic precursors could be formed under reasonable geochemical conditions without sophisticated laboratory setups [25].

2-1.C. Coevolution of Life with the Earth

ELSI researchers have identified major transitions that shaped the evolving biosphere: its architecture and modes of evolution, its dependence on planetary conditions through time, and how biological evolution has fed back to shape Earth's geological history. We integrate methods from synthetic and evolutionary biology to understand the problems of structure and function that were solved by early organisms.

[13] **Understanding the nature of the first cell.**

Using synthetic biology to understand the problems that living systems solved, ELSI researchers have implemented increasingly complex functions for synthetic cell membranes, and shown what is required for the intricate coordination of molecular systems within and across them. Kuruma's research aims to reproduce the emergence of cellular life in the laboratory. He has achieved several milestones in developing a new artificial system for synthesizing the protein and lipid components of an artificial cell in a system free of cell extracts containing only purified chemical species [26]. In this work, membrane protein complexes (ATP synthase and the Sec Translocon), which are essential for cell function, were synthetically expressed and translated, and their activities were confirmed. This new technique is likely to be adopted by researchers in synthetic biology and medicine, and will improve our understanding of the abiogenesis of components in cell membranes and the origins of complex membrane function.

It is possible that membraneless compartments were a precursor to membranes involved in molecular segregation in early life. In this paper, ELSI researchers showed that poly-hydroxy acids can polymerize to form colloids capable of binding small molecules and proteins. Furthermore, the colloids can scaffold a lipid bi-layer, hinting at a possible prebiotic bridge between membrane-less and membrane containing life [27].

[14] **Understanding the nature of the first genome: "What were the genomes of the first community like?"**

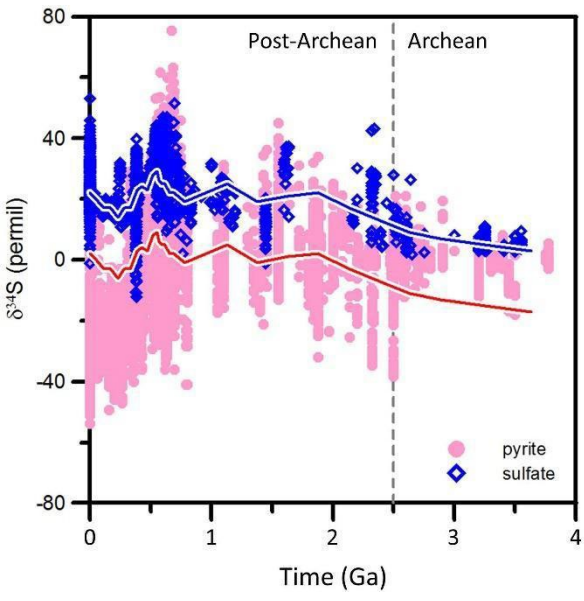
Bioinformatics approaches can be used to gain insight into the most probable gene content of the last universal common ancestor (LUCA) of life on Earth. Using the tools of molecular phylogenetics, many researches have made claims about the protein coding gene repertoire of ancient life. Berkemer and McGlynn [28] tested the antiquity of different categories of proteins by constructing and analyzing thousands of phylogenetic trees which code for known protein families; they found that protein families involved in informational processes retain phylogenetic signal to a greater degree than those involved in metabolism, suggesting that the modular arrangement of metabolism with its attendant horizontal gene transfer has erased the ability to bioinformatically infer with confidence the metabolic capacity of the LUCA. Furthermore, Berkemer and McGlynn tested a hypothesis first developed by Woese and Fox in their seminal 1977 paper on the progenote; Berkemer and McGlynn discovered a set of protein families which show a signal of rapid evolutionary rates at or before the time of the separation of the archaea-bacteria domains. Finally, they conducted a re-analysis of a recent and famous work and found that the results of the former study were at a level of accuracy such to be expected by chance, tempering strong claims about the physiology of early life as observed from the perspective of molecular phylogenetics.

[15] **Geochemical and Genomic Co-evolution**

ELSI researchers have reconstructed genomes and bioenergetic systems of ancient bacteria, and shown how those have changed in response to evolving planetary chemistry and Life's own capacity to maintain ever larger and more reliable molecular systems. By reconstructing some of the deepest branching clades of chemolithoautotrophic bacteria (and perhaps modern representatives of the oldest genomes) we have begun to answer the question **"What were the major transitions in bioenergetic systems, what drove them, and how did they affect the spread of life?"**. Giovannelli et al. published the genome and analyzed the metabolism of Thermovibio ammonificans, a chemolithoautotrophic bacterium at the base of the phylum Aquificae, finding evidence for enzymes from both of the most ancient carbon fixation pathways, the reductive TCA cycle and the Wood Ljungdahl pathway [29]. Their work is the first empirical indication of the coalescence of these two pathways, which had been proposed in 2016 by ELSI PI Smith. Giovannelli et al. also argue that an organism ancestral to the Aquificae catalyzed the reductive TCA cycle with multifunctional enzymes (a hypothesis suggested by results from the laboratory of former ELSI researcher Kameya), addressing the question **"How were ancient enzymes and genomes different from modern ones, and can we reconstruct models of ancestral phenotypes?"**. The combination of enzyme multifunctionality with inherent redundancy in pathways such as the TCA cycle may have been critical to establishing the earliest metabolisms, by enabling complex metabolic functions to be achieved with limited numbers of genes

ELSI researchers have investigated the relationships between genome composition and environment, using the photosynthetic and hot spring dwelling Thermosynechococcus genus as a model system [30]. Although the Thermosynechococcus are a widespread and cosmopolitan group of microbes inhabiting waters of variable pH, sulfide, iron, and salt content, they do not appear to show major genomically observable signals of this habitat flexibility. Instead, as a taxonomic group, they are remarkably similar, suggesting that cyanobacteria have an innate ability to thrive in widespread environments such as those on the early Earth. The small genome size and genetic similarity between Thermosynechococcus members is consistent with a hypothesis of a last cyanobacterial common ancestor of similar genetic composition.

[16] **Evidence for major transitions.**



ELSI researchers have reconstructed isotopic and mineral signatures linking biological major transitions to the rock record, both for sulfur metabolism and for oxygenic photosynthesis, the biological innovation that has most impacted every surface environment on Earth. McGlynn and co-authors measured the sulfur kinetic isotope effect of the enzyme adenosine phosphosulfate reductase (APR), which is present in all known microbes that perform sulfate reduction (believed to be an ancient metabolism), catalyzing the first reductive step in the pathway [31]. Based on these results, they reinterpret the sedimentary sulfur isotope record over geological time to understand the redox couples available to drive microbial metabolisms. Archean sediments lack fractionation exceeding the APR value of 20‰, indicating that sulfate reducers had access to ample electron donors to drive their metabolisms. Large fractionations in post-Archean sediments suggest a decline of favorable electron donors as aerobic and other high potential metabolic competitors evolved. These findings link cellular biochemistry and physiology with the rock record of life on Earth. The later evolution of oxygenic photosynthesis on planet Earth is probably the most dramatic example of biological alteration of the earth system. Remarkably, only one group of organisms is known today to produce oxygen from water: the oxygen-producing Cyanobacteria, which are unique in possessing dual photosystems, one containing the water oxidizing manganese cluster. Together with co-authors at Caltech, Kirschvink discovered ancient manganese oxide deposits which predate the great oxidation event on Earth [32].

They explain these features by proposing that a light-driven microbial manganese oxidizing physiology preceded the water-oxidizing chemistry found in Cyanobacteria. Both the protein of the Mn-dependent oxygen-evolving complex, and large-scale pre-oxygenic deposition of manganese oxides, would then be due to light driven manganese oxidation chemistry.

[17] **Role of viruses in evolution**

The evolutionary history and dynamics of genomes on Earth are carried by two major genetic lifecycles: one associated with free-living cells and the other with viruses. ELSI researcher Mochizuki and his co-workers have expanded the global scientific knowledge of the diversity of viruses of thermophilic Archaea by nearly 100%, and ELSI now hosts one of the largest collections of Archaeal viruses of any institution in the world. Their work explores the limiting growth conditions for single stranded DNA viruses and for RNA viruses, characterizing the limits of the viral life form and also fundamental constraints on an RNA world. One surprising recent finding is that convergent evolution of structure appears to have resulted in multiple morphologically similar, yet evolutionarily unique viruses [33]. These advances were made by developing an in-house culturing capability for hyperthermophilic viruses, and relying on screening techniques capable of identifying viruses that do not elicit strong phenotypic responses on the host organism.

[18] **Emergent properties of evolution**

What processes drive biological innovation? Two ELSI Origins Network (EON) postdocs have demonstrated new paradigms for the way evolution uses external constraints as scaffolds for the creation of novel complexity. In each case, loosely-controlled mechanisms with local feedbacks create the contexts for higher-level adaptation. By studying an arms race between bacteriophage and its host, Petrie et al. [34] demonstrated a new mechanism of molecular evolution that could function even in organisms with short or unstable genomes. In their experiment, mutations in a host recognition gene of phage λ led to protein bistability enabling the gene product to interact with two host receptor proteins. Flexible host recognition by pleiotropy may enable sequences to traverse fitness barriers in the absence of better-known processes such as gene duplication followed by functional divergence. As for the case of multifunctionality in core metabolism (see Result 11 above), adaptive mechanisms that require fewer or less specific enzymes were likely even more important in the deep past than they are today, because error catastrophes from unreliable replication or translation would have limited genome length in the earliest stages of life. Hoyal Cuthill [35] found the same paradigm repeated in the evolution of development, as animals in the age before complex regulatory programs used fractal growth rules to transduce feedbacks from nutrient limits into variable, adaptive phenotypes. The evolution of multicellular organisms created the possibility for phenotypes and ecological roles that are unavailable to unicells. Remarkably, however, the study of animals from the Cambrian radiation suggests much more diversity of body plans among early animals than among those on Earth today. The two questions implied are how such regulatory complexity burst so suddenly into existence, and whether either regulatory systems or the phenotypes they produced were more variable in the Cambrian than they are today. To understand how complex forms could be produced with only limited regulation, Hoyal Cuthill studied rangeomorphs, the dominant animals of the Ediacaran transition. She combined computerized tomography of fossils with numerical models of shape-limited diffusion to infer that they obeyed a local nutrient-controlled growth law. Her simulations reproduce the diverse phenotypes of rangeomorphs as reflections of different environmental nutrient densities and flows, and highlight physical mechanisms that large organisms can use to circumvent environmentally imposed nutrient limitation.

2-1.D. "Bioplanets" in the Universe.

Our studies of the history of Earth and its life reveal a unifying paradigm, of alternating stages of diversification and selection, which serves as a springboard to understand the habitability of planets around other stars and what principles may make life on them different or similar to our own. Working on those questions has also allowed us to tackle the issue of how unique our planet is. While the papers presented above focus on specific observations within our solar system, they permit

us to understand the place of the Earth in the universe. If our planet's orbital distance (c.f. Hamano), volatile delivery history (c.f. Genda, Brasser), mineralogy (c.f. Ballmer, Hirose; see Fusion section below) all contributed to generate the conditions that led to the origins of life, what is the probability of generating similar conditions on other terrestrial bodies elsewhere? To understand whether life is likely even given these conditions, we must address the difficulty that the emergence of Life anywhere will be an outcome of bootstrapping.

[19] **Theory in the origin of the Genetic Code.**

We seek to understand why the genetic code is nearly universal across all organisms, and why the arrangement of the codons in the standard codon table is highly non-random. The rise of biological complexity is generally viewed as a transition from initial dependence on properties of particular chemicals, to emergent relations that are abstracted further from chemical detail and become more distinctively biological. The consolidation of a fixed amino acid inventory and a universal assignment of amino acids to trinucleotides in the genetic code was a major horizon in this transition, and the subject of our founding questions **"What were the genomes of the first community like?"** and **"What was the nature of the first genetic systems employed in the "progenote?"**. ELSI researchers address both aspects of the code. Cleaves and colleagues [36] studied the diversity and specificity of amino acids adopted by Life as a question of chemical possibilities (see result 15 above). Virgo, Fujishima, Kiga and collaborators [37] considered the emergence of the genetic code as a dynamical process, showing that optimization of the amino acid assignments can occur as a result of interactions between and within cells, prior to the emergence of vertical descent. They extend a theory of the robustness of the code due to Carl Woese, the first to emphasize the importance of horizontal gene transfer for establishment of the code, to a model that does not require the accurate preservation of information that it is invoked to explain.

* [20] **Towards universal biology.**

"Universal biology" must explain how simple patterns of dynamical complexity can create more complex patterns in a self-maintaining hierarchy. A concrete instance of this problem is the emergence of lineages, studied in the work of Froese et al. [37]. The researchers show how an era of innovation-sharing, in which all components are exchanged independently, can produce the error-buffering properties of the biological code, which then permit reliable protein synthesis, faithful molecular replication, and the emergence of vertical descent in a Darwinian world.

To better understand the possibility of life on other planets, Eric Smith et al [38] used network expansion algorithms to evaluate the ability of microbes found on Earth to prosper on Enceledus. They found that none of the 307 microbial genomes analyzed harbored reaction networks which were predicted to result in the production of viable biomass. A key result of this study was the ability to identify which specific compounds on a planetary body could result in the ability of these organisms to prosper, this providing a list of priority detection targets for future missions in space.

A core group of experimentalists and theorists study the principles underlying life in order to conceptualize its essential features independently of the way they are realized in Earth's biology. Cleaves and co-workers [36,39] have made use of computational combinatorial methods that allow us to ask which elements of Earth-Life may be universal because they reflect limits inherent in chemistry. They use exhaustive enumeration tools to compile libraries with thousands of possible amino acids, and then compare the coverage of biologically important chemical properties by our coded amino acids, to the coverage by randomly-sampled sets of 20 acids from the combinatorial libraries. They conclude that the biological amino acids as a set have been strongly optimized by selection for coverage. In moving the coded set away from random assemblies and closer to the limits of chemical possibility, evolution has made them more nearly predictable from first principles. Guttenberg et al. (2015. Transferable Measurements of Heredity in Models of the Origins of Life. PLoS One, 10, e0140663.) have worked to formalize the concept of heredity, without which selection cannot lead to adaptation, in terms not limited to its instantiation in Earth-Life. They have derived tests for the presence of heredity that do not depend on the roles of genes or genomes, and which quantify the capacity for heritable variation across a range of widely studied compositional models and even more general dynamical systems. These results are early examples of ELSI's commitment

to expanding the scope of a universal theory of biology. Furthermore, this concept of heredity allowed for the identification of the evolutionary capacity of prebiotic autocatalytic chemical systems [40], establishing a scaling law for the number of distinct chemical attractors and contributing to resolving the debate about whether compositional heredity (GARD) is evolvable. We plan to understand why all levels of biological organization arise, from organisms to communities to biospheres as a whole, and which part each level carries, of the information and functions that define living states. We will show which biosignatures may be derived from constraints on overall functions, without dependence on details that may vary between biospheres, supporting a new generation of experimental search for life in the universe.

2-2. Research environment including facilities and equipment

Describe the degree to which the Center has prepared a research environment appropriate for a world premier international research center, including facilities, equipment and support systems, and describe the functionality of that environment.

(1) ELSI Buildings 1 and 2

In addition to ELSI-2 (Ishikawadai building No.8: 2, 670 m^2) that was the existing building refurbished in 2012, ELSI-1 (Ishikawadai building No.7: 5,000 m^2) was newly built in 2015. The laboratories and researcher's office space have been expanded and an environment comfortable for researchers has been realized. Both buildings have a large communication space which helps bring research activities into the open, encouraging interactions, and removing potential "language barriers" and "cultural barriers" among researchers and staff, thereby promoting an attractive international environment and facilitating interdisciplinary research. In 2018, ELSI Hall in ELSI-1 was renamed "Mishima Hall" to commemorate Tokyo Tech's former president, Prof. Yoshinao Mishima, whose immense efforts contributed to the creation of ELSI. This hall is used for small size symposia to bring researchers outside ELSI together with ELSI researchers. In 2021, ELSI also created a video studio in ELSI-2 for the convenience of online meetings and lectures which became indispensable because of the COVID-19 pandemic.

(2) Research equipment owned by ELSI

* Full and modern microbiology research facilities include fluorescence microscopy, fluorescence activated cell sorting, FPLC, multiple UPLC, and incubators spanning nearly the known temperature range of life.
* Earth history simulator system (Cray XC30): A 960-core supercomputer manufactured by Cray has been used to study the physical state of the Earth core material by first-principles computation, and to perform numerical simulations on the Earth's mantle and formation of the Moon, planets, and galaxies.
* High resolution isotope-ratio mass spectrometer (Thermo Scientific 253 Ultra): The origin of a molecule is coded in the stable isotopes of hydrogen to sulfur that constitute the molecule. This device, with only a few existing in the world, of which ELSI has one, can analyze molecules containing multiple heavy isotopes, and provides new indicators of life and conditions in early Earth and the Solar System.
* Scanning SQUID microscope: This device, installed in a magnetically shielded class-100 clean room (3-m cube), can measure the vertical component of the magnetic field on a room temperature or cooled sample with 20 μm spatial resolution and 10^{-16} A^2 magnetic moment sensitivity. This is a powerful device for paleomagnetic research.
* Diamond anvil cell: A device for measuring physical properties of a sample under ultra-high pressure by sandwiching the sample with diamond pieces. Since diamond is transparent, by illuminating it with a laser and heating the sample, it is possible to reproduce an environment deep in the Earth with ultra high pressure and temperature.

(3) Research facilities at satellite organization (Geodynamics Research Center (GRC), Ehime University)

* 3000-ton multi-anvil ultra-high pressure device: This is the world's largest DIA-type device, and is used for phase equilibrium studies, material synthesis, melting experiments, and ultrasonic wave velocity measurements under high-pressure and temperature.
* 6000-ton multi-anvil ultra-high pressure device: Samples of large volume (> 1 cm^3) can be pressurized with this world-largest multi-anvil device. This device is used for sample synthesis of

large-volume aggregate and single crystal, and for the synthesis of nano-polycrystalline diamond and other novel materials.

2-3. Competitive and other funding

Describe the results of the Center's researchers to date in securing competitive and other research funding.

- In Appendix 3-6, describe the transition in acquiring research project funding.

ELSI has been exceptionally successful in securing research funds including the Grant-in-Aid for Science Research (KAKENHI), sponsored research funds, collaborative research funds, and university grants/operating subsidies. The most notable external funds include (* indicates international grant/fund):

(1) Grant-in-Aid for Specially Promoted Research "Materials property and evolution of Earth's core": JPY332,150,000 (2012-2015)

(2) Grant-in-Aid for Scientific Research on Innovative Areas "Hadean bioscience" JPY 1,079,400,000 (2014-2019)

(3) Grant-in-Aid for Scientific Research on Innovative Areas "Interaction and coevolution of the core and mantle" JPY1,091,100,000 (2015-2020)

(4) Grant-in-Aid for Scientific Research on Innovative Areas "Aqua planetology" JPY10,7940,000 (2017-2022)

(5*) The research fund from the John Templeton Foundation "ELSI Origins Network (EON) for research into the origins of life" JPY670,000,000 (2015-2018)

(7*) Grant-in-Aid for Specially Promoted Research "Behavior of liquids under high pressure and the early evolution of the Earth" JPY503,750,000 (2016-2021)

(8*) Research fund from the Department of the Interior "Testing the hypothesis of magnetite-mediated radio wave reception and possible transmission in human and animal neurophysiology" JPY5,400,000 (2017-present)

(9*) Research Grant from the Human Frontier Science Program (HFSP) for "Exploration of the structure/function space of prebiotic to biological proteins" for Kosuke Fujishima and other co-researchers JPY 116,550,000 (2019-2021)

(10) "FirstLogic", Inc. donation program for Kosuke Fujishima JPY 24,000,000 (2019-2021)

2-4. State of joint research

Describe the results of joint research conducted with other research organizations both in and outside Japan.

ELSI's collaborative reach penetrates all of Japan and the world, a fact that is clearly revealed by examining co-authorship affiliations in our publications (top collaborations are shown in the right figure) which presently includes at least 58 countries. In addition to the collaborations with researchers at ELSI satellites, ELSI has been carrying out joint research with scientists at other institutes under formal mutual agreements, and beyond with informal collaborations made by individual researchers. In addition to the satellite institutes at the beginning of ELSI (Ehime University, Institute for Advanced Study in Princeton, Harvard University's Origin of Life Initiative), two new satellites have been established; the Department of Earth and Planetary Science, University of Tokyo, in 2017, and Columbia Astrophysics Laboratory of Columbia University in 2018. The former is collaborating with research on the Earth's interior and surface conditions and Solar System objects, and the latter in the field of astrobiology and material physics. Y. Sekine joined ELSI as PI from the University of Tokyo in June 2018, and M. Voytek joined ELSI as Executive Director and PI from Columbia University in August 2018, and the relationship with satellites has become even tighter. R. Wentzcovitch, one of ELSI's founding PIs who couldn't previously relocate to Tokyo due to family constraints, has now re-joined as a PI based at our Columbia University satellite in New York. T. Matsuura recently came to ELSI as PI from Osaka University. His specialty is to create molecular systems using artificial cells.

ELSI has a close relationship and formal research cooperation agreement with the Institute of Space and Astronautical Science (ISAS/JAXA), and contributes to the solar system exploration plan of ISAS from the theoretical and scientific planning side. T. Usui moved from ELSI to ISAS as a professor in July 2018, and maintains a close relationship. Two original ELSI PIs, M. Fujimoto and H. Kuninaka (presently ELSI Fellows), are now in leadership positions at ISAS/JAXA and maintain close relationships with ELSI members. ELSI's H. Genda is a primary science team member for the upcoming MMX sample return mission to one of Mars's moons. E. Tasker of ISAS/JAXA is an affiliated scientist of ELSI (spending 1 day/week at Tokyo Tech) and collaborates on joint PR/outreach efforts between ELSI and JAXA, enhancing the visibility of ELSI and JAXA together.

ELSI also has a research cooperation agreement with Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and original ELSI PI K. Takai of JAMSTEC is an ELSI fellow (PI until FY 2016) and collaborating with ELSI researchers. He recently joined with ELSI's K. Fujishima in a deep sea submersible to study vent environments. In 2019, Y. Kuruma and N. Kitadai moved from ELSI to JAMSTEC and joined Takai's group as tenure-track researchers, which further strengthens the joint research between the two institutes. In 2020, A-PI H.J. Cleaves began a joint research with our former A-PI, A. Fahrenbach in the University of New South Wales, with funding from the Australian Research Council.

The National Astronomical Observatory of Japan (NAOJ) and the Astrobiology Center (ABC) of the National Institutes of Natural Sciences (NINS) are collaborating with ELSI in the study of extrasolar planets. ELSI and NINS Astrobiology Center have established the Japan Astrobiology Consortium (JABC), and JABC has a research cooperation agreement with NASA Astrobiology Institute. ELSI members such as PI S. Ida have been involved in international projects involving the Subaru telescope aimed at exoplanet studies, and discussions are taking place for collaborations with the ALMA telescope which is operated by NAOJ and their American/European partners.

The ELSI Origins Network (EON) project (2015-2018) supported 12 postdocs who actively collaborated with their supervisors at their respective overseas research institutes on the origin-of-life studies, hosted 9 internationally attended workshops, and supported an active visitors program which hosted 25 graduate students and 63 senior researchers from around the world to come to ELSI to conduct research. EON also awarded 8 Seed Grants, many of which had collaborative components involving ELSI members.

2-5. Appraisal by society and scientific organizations

Describe how society and/or scientific organizations in and outside Japan have recognized the Center's research achievements.

- To substantiate the above evaluation, list the main awards received and invitational/Keynote lectures given by the Center's researchers in Appendix 1-3.

(1) Awards and fellowships

ELSI researchers from different career stages are held in high esteem at their respective levels. Senior researchers such as PIs have received awards including the Medal of Honor with the Purple Ribbon. They have also become fellows of notable societies such as the Royal Institute of Navigation, JpGU, and AGU. Meanwhile young researchers have also received awards that target young professionals, such as the IUPAC-SOLVAY International Award for Young Chemists and the JpGU Nishida Prize.

(2) Invitations for Lectures

ELSI researchers, from senior to early-career, have been invited to deliver a considerable number of invited presentations at international academic conferences. These are listed in Appendix 1-3-2.

(3) Collaborative workshops with domestic and international institutions

Along with satellite institutions including Harvard University and Ehime University, ELSI has held a total of 25 research conferences such as collaborative workshops. The details are discussed in Sec. 5-2.

(4) Competitiveness of ELSI's young researchers

ELSI's young researchers are transitioning into widely visible early-career research scientists during their time at ELSI. This can be witnessed through their being invited to give prominent talks at major international conferences in their field as well as through their continuing employment after ELSI (see Appendix 4-4). This success is partly due to ELSI's high profile and ability to attract researchers

of the very highest caliber who are already likely to become academic leaders later in their careers. It is also partly due to efforts by senior ELSI PIs in mentoring, feedback, and career guidance. We take advantage of our International Advisory Board members when they visit and organize meetings for young researchers to interact with them. ELSI provides opportunities for young researchers to lead study groups, operate committees, and apply for funds to organize workshops, which helps to raise their international profile and attract recruiters and job offers from around the world. Finally, compared to others in their cohort, ELSI researchers are far more exposed to interdisciplinary discourse and research, which builds an important skill of communicating their science clearly to others. ELSI experience makes them more confident in presenting their science even in a more specialized context, and is an important asset in their career growth.

(5) Long-term visits by senior scientists

Another sign of international recognition is through the number of senior scientists who want to take time out of their busy schedules to come spend an extended amount of time at ELSI. ELSI is growing its reputation as an exciting institute with world-class scientists. 23 visitors of a professor level have come to spend over 1—3 months at ELSI since our inception. Separate from long visits, ELSI also has been able to attract world-renowned scientists to come to ELSI and deliver lectures and interact with our researchers. Some big names in ELSI's domain are: George Whiteside, Simon Conway Morris, Andrew Knoll, Robert Blankenship, David J. Stevenson, Steven Benner, Loren Williams, James Kasting, to name a few.

(6) External review of PIs

In FY2018, for the first time, ELSI conducted an external review led by our International Advisory Board (IAB) of our senior PIs. From the review reports, it is clear that the international community regards our PIs highly. Method of external review was as follows: 14 PIs submitted their self-evaluation report by December 2018, and IAB (6 members) assigned one member to each PI. The IAB recommended three referees per PI; those referees are world-renowned researchers in the field of each PI. The task force for review led by Executive Director M. Voytek sent the self-evaluation report of the PIs to the referees for review. The review was made on the following five points: (1) contributions to the WPI mission, (2) scientific contributions, (3) innovativeness and originality, (4) interdisciplinarity and collaborations, and (5) overall assessment. The review reports were collected by January 2019, and the IAB produced the evaluation summary in February. Such external reviews are an important part of building a robust institute with strong scientific leadership as well as a form of networking that gains ELSI credibility from its scientific communities.

(7) ELSI's press releases to the world

The number of ELSI's press releases published in English has largely increased, mainly due to the new Communications Director appointed in November 2018. In 2019 and in 2020 ELSI has delivered respectively 32 and 14 press releases in English.

(8) 9th International Symposium "Science in Society"

In February 2021, ELSI held its 9th annual International Symposium. The fully virtual event was hosted in three time zones (Asia/Pacific, Europe/Africa, Americas) to capture ELSI's international audience. The event received 686 registrants due to its well designed program and high profile speakers. The four-day event ran successfully, backed by an innovative platform which allowed early access to plenary talks, smooth transition to breakout sessions, and easy capabilities for qualitative Q&A and interactive discussions.

3. Feeding Research Outcomes Back into Society (within 2 pages)

3-1. Applications of research results

Describe the applications created from research results, their effect in spawning innovation, intellectual properties (IPs) obtained, and joint research activities conducted with corporations, etc.

(1) A. Kobayashi's discovery that nanocrystals of magnetite are among the most potent ice nucleation sites in nature has broad applications for: use of magnetite's passive ability to nucleate ice in the field of climate control, design of industrial technologies to exploit the bulk control of supercooling, and engineering methods to minimize the damage on plant and animal food products by ice crystals during freezing. This is an important discovery that will improve the quality and capacity for food preservation and storage, an important issue facing the global food supply chain.

(2) With funding from pharmaceutical companies, Y. Kuruma and K. Fujishima studied the cell-free protein expression system to establish high-throughput screening and evolution of random polymers (including peptides and RNA) for the purpose of understanding the function and evolvability of primitive biopolymers with regards to the origin of life study. Their research is applicable to design various evolvable peptide/RNA aptamers targeting various macromolecules or even chemical compounds, allowing potential application in the pharmaceuticals and therapeutics industries.

(3) ELSI is connecting with Tokyo Tech's Office of Research and Innovation, Industry Liaison Division to get their input on which companies might be best fits to ELSI research's industrial applications and what possible funding opportunities might be established with industry.

(4) Tokyo Tech provided to the public a list of publications and other contributions by Tokyo Tech researchers relevant to the COVID-19 pandemic. ELSI PI J. Kirschvink is in the list of publicly offered publications relating to COVID-19 on the website of Tokyo Tech.
https://www.ura.titech.ac.jp/covid19/listofresearchpapers/index.html
Also, ELSI researcher T. Mochizuki is introduced in New Normal Research Map of Tokyo Tech as a virologist who implements research on Treatments and Vaccines of COVID-19. https://www.ura.titech.ac.jp/nn-researchmap/

3-2. Achievements of Center's outreach activities

* Describe what was accomplished in the center's outreach activities during the period from 2012 through March 2021 and how the activities have contributed to enhancing the center's "globally visibility." In Appendix 5, describe the concrete contents of these outreach activities and media reports or coverage of the activities.

ELSI PR Office actively coordinates outreach activities to showcase our science contributions: (some major highlights)

(1) "The Miracle of Hakuba and Science" (FY2014): a public lecture to connect with the local community in Hakuba by sharing ELSI's field research conducted in the area.
(2) Kavli IPMU-ELSI-IRCN Joint Annual Public Lecture (FY2015-2020): initiated in 2015 between Kavli IPMU and ELSI, later joined by IRCN, is an effort to enhance collaboration between WPI institutes.
(3) Research reading for students (FY2016): students at Fukushima Prefectural Iwaki High School, a Super Science High School (SSH), practiced their comprehensive reading in English and analytical thinking abilities with ELSI's T. Mochizuki by reading research papers in English.
(4) Science and Art projects (FY2016-FY2020): ELSI continues to explore the connection between science and art by bringing artists with ELSI researchers. The outcome art expressions are displayed in ELSI-1 building for visitors (public and scientific) as part of the ELSI tour.
(5) Study on accuracy-readability trade-offs (FY2016-FY2017): the study researched differences in accuracy and readability of scientific information in the areas of education, public relation and science communication, and proposed a new methodology on Accuracy-Readability Index.
(6) Video interviews of ELSI researchers to present interdisciplinary science (FY2016-FY2020): an interviewer presented the same set of questions to several ELSI researchers to convey the interdisciplinary aspect of ELSI by highlighting how ELSI research is connected.
(7) The movie "The Whole History of the Earth" (both in English and Japanese) was created by the Hadean Bioscience project. A series of 9 movies have been uploaded on YouTube. Total views of movies both for English and Japanese versions have reached more than 2.3 million.
(8) 29 popular science books have been written/co-written by ELSI members. Notable mentions are: PI E. Smith's book "Origin of Life" which won the 2017 Marsh Award for Best Earth Science Book, PI J. Kirschvink's book "A New History of Life" (2015) published in three languages and was on the Japanese best-seller list, and H. Cleaves' "A Brief History of Creation" (2015) has sold over 50,000 copies to date.
(9) Number of press releases in English and Japanese (FY2012-FY2020) increased over the years, especially in English which has led to wider coverage from foreign media reaching more than 400 outlets per FY (FY2019-FY2020).

(10) ELSI has positioned itself as a leader in science communication by providing skills for researchers, students, and PR staff. ELSI has hosted the Japan Scicom Forum in 2018, 2019 (and 2021), organized SciComm in Practice symposium in 2019 (and 2021) and sessions for WPI institutions.
(11) A push towards standardization of outreach is carried out by introducing the 'Science Evaluation Outreach Evaluation Framework' to evaluate in-person and virtual outreach activities (FY2019-FY2020).

4. Generating Fused Disciplines (within 3 pages)

4-1. State of strategic (or "top-down") undertakings toward creating new interdisciplinary domains

Describe the content of "top-down" measures taken by the Center to advance research by fusing disciplines. For example, measures that facilitate doing joint research by researchers in differing fields.

(1) Efforts to acquire external interdisciplinary research funding

Raising funds for interdisciplinary research is absolutely essential for ELSI's science. However, most traditional funding is targeted to specialized subjects rather than broadly integrative fusion. An exception is the "Shingakujutsu" category of JSPS Kakenhi grants, which offer large scale funding for broad collaborations (involving many fields, investigators, and multiple institutions). ELSI has been successful in raising funds from the following 3 programs:

- Hadean Bioscience (FY2014-2019) was proposed by PI (and Vice Director at the time) K.en Kurokawa. About 500 million yen was allocated for ELSI members. The aim of this research project was to create a new academic area to identify when, where, and how life was created through a combination of cutting-edge planet earth science, life science, and organic chemistry, with a focus on the Hadean era (i.e. the earliest era following the birth of the Earth).
- Co-evolution of the Core and Mantle Toward Integrated Deep Earth Science, (FY2015-2020) led by ELSI-Ehime satellite Affiliate Faculty T. Tsuchiya as the PI (approx. 1.09 billion yen for five years). This programarea aims atto constraining the evolution of both the core and mantle as the system that dominates the dynamics in deep Earth.
- Aqua Planetology (FY2017-2022) was launched under the leadership of ELSI Professor and PI Y. Sekine. The proposal effort also involves members at ISAS/JAXA and aims to constrain how volatile delivery and history to a planet/moon influences the early environment and possibility for organic processes leading to life.
- ELSI's greatest success in external fundraising for interdisciplinary research was the launch of the ELSI Origins Network (EON), which began in July 2015 with support from the US-based John Templeton Foundation (33 months, total USD 5.6 million). Founding PI and Councilor P. Hut led the development of the proposal and used his longstanding network to negotiate with the foundation and establish the program at ELSI. This program came at a critical time when ELSI's early stages of WPI funding was not increasing at the levels we had previously planned for and ELSI wanted to increase momentum to become an international hub for origins research.

(2) Internal funding mechanisms for interdisciplinary science

ELSI also established the "Director's Fund" to help fulfill funding needs within the institute that could not be covered by other large grants. This is particularly helpful to the large number of ELSI's junior non-Japanese researchers, who are not well known inside Japan and struggled initially in obtaining JSPS Kakenhi funds. This fund has been used to launch some of ELSI's most promising laboratory experiments, and helped lift the careers of many young scientists who would not otherwise be able to fund their work.

4-2. State of "bottom-up" undertakings from the center's researchers toward creating new interdisciplinary domains

Describe the content of "bottom-up" measures taken by the Center to advance research by fusing disciplines. For example, measures that facilitate doing joint research by researchers in differing fields.

Study Groups: Early on ELSI established interdisciplinary study groups that focused on various aspects of Earth-Life science. The "magma oceans" group focused on unifying planetary accretion and early geological environments, "cycles of life on planets" (CycLoPs) examined bio-geochemical

cycles involving both geological and biological processes, "mineral selection" brought together organic chemists and mineralogists, while "origin of life" brought together all fields represented in the institute to tackle our biggest unifying question. ELSI researchers were able to learn the best strategies to communicate and collaborate across discipline boundaries, which helped ELSI to achieve a very broad and open-minded science culture. All graduate students of ELSI faculty are required to regularly attend at least one study group.

ELSI Youchien: The "kindergarten" (youchien) concept was launched entirely on the initiative of junior researchers at ELSI who saw the need to explain our broad science to one another in the very simplest terms, and to cement the learning process by using hands-on demonstrations. Hands-on demonstrations were presented in fields ranging from chemistry to fluid dynamics, helping young researchers to understand one another's fields.

ELSI All-Hands Institutional Strategy Meeting: In February 2017 we organized our most ambitious internal strategy meeting by bringing all researchers together to consider fusion science directions across all of our science domains. A key outcome of this effort was the "cross-fertilization" that takes place between different fields when researchers begin to understand the common hurdles to progress in each domain. Once they achieve this realization they can swap strategies, tools, and insights between domains in ways that unlock new ideas and catalyze advances across multiple fields simultaneously.

ELSI International Symposia: ELSI has held 9 international symposia to showcase our research in broadly interdisciplinary themes and to bring world-leading scientists together to share our perspectives and insights. This is one of our best opportunities to bring famous researchers to ELSI, both to join in our interdisciplinary conversations as well as to showcase ELSI to global leaders. Their impressions of ELSI, shared with all of their colleagues and networks, have been a key ingredient to ELSI's recognition as an interdisciplinary institution of unprecedented breadth.

ELSI Workshop Series: ELSI has leveraged WPI support to host dozens of smaller scale workshops with the aim of addressing particular questions relevant to our science and/or to generate a specific product (strategy, book, journal issues, etc.). A good example of an interdisciplinary meeting is the "Planet Diversity" workshop. It brought together a small group (~30) of international researchers in different fields related to different themes. The workshop reflects ELSI's institutional efforts: support for early-career scientists, cultivation of a new network of the next leading generation of scientists, and achieving gender balance (50/50) in both its organizing team as well as attendees.

Open Research Labs at Tokyo Tech: As described previously by former President Mishima, Tokyo Tech was inspired by ELSI to launch an interdisciplinary fusion center, Tokyo Tech World Research Hub Initiative (WRHI), in the broader university.

Interdisciplinary Courses: New courses were created in departments of Earth and Planetary Science (EPS), Materials and Chemical Technology (MCT) and Life Science and Technology (LST). It allows ELSI faculty to interact with students in those departments and contribute to teaching courses in those departments. They grew by the following steps.

In 2018 ELSI organized two research/education collaboration meetings in the Ookayama and Suzukakedai campuses in order to catalyze new interdepartmental and interdisciplinary collaborations with members of MCT and Institute of Innovative Research (IIR), a Tokyo Tech research center formed in 2016 whose goal is to synthesize new collaborations that will create new interdisciplinary fields.

Starting in April 2019, all Tokyo Tech graduate-level courses began to be taught in English. As such, ELSI members have been solicited to teach a course in LST on the origin and evolution of life. Traditionally, ELSI members have had strong ties with EPS, but this new course allowed biology and chemistry-focused researchers the opportunity to build stronger ties with those in the life sciences. In FY2020, three faculties of ELSI have already been affiliated to LST and have started giving lectures. Another PI will be affiliated to MCT in FY 2021.

4-3. Results of research in fused research fields

Describe the Center's record and results by interdisciplinary research activities yielded by the measures described in 4-1 and 4-2.

- In Appendix 1-2, list up to 20 of the Center's main papers on interdisciplinary research that substantiate the above record of results, and describe their content.

ELSI was founded on the idea that origin(s) of life is not a challenge that can be tackled by any single discipline of natural science, because life emerges and evolves as an open system and the questions that need to be addressed therefore span many fields. However, following this plan requires fusion between fields ranging from astrophysics to microbiology, and the intersection of different research cultures, languages, tools, and strategies. In fact, the scope is so broad that we also needed to assemble the right people from around the world, since no single nation has the right combination of expertise and social chemistry to enable the dramatic levels of fusion the ELSI sought to achieve. Creating a broadly inter-disciplinary environment at ELSI also required reform of administrative procedures and work customs to encourage collaboration. Thus achieving fusion in our case was not independent of the other pillars of the WPI program, all were necessary to advance our ambitious science goals.

Kurokawa et al. (2018) assembled a broadly interdisciplinary team consisting of an atmospheric scientist, an isotope geochemist, a geophysical modeler, a seismologist, and a cosmo-chemist to generate a unique new constraint on the origin and circulation of water in the Earth since formation.

Aono et al. (2013) rallied micro-biologists, mathematicians, and chemists to find a novel way of using a living amoeba as a virtual computer to solve chemistry problems that are otherwise impossible to solve using conventional computers.

Brasser et al. (2017) brought together astrophysicists and isotope chemists to show that Mars likely formed rapidly in the early solar system and relatively far from the Sun in comparison to the other terrestrial planets, helping to explain many of Mars' distinct features.

Kimura and Kitadai (2015) combined thermal evolution models of icy moons with organic chemical modeling to show how the kinds of polymerization necessary for the building blocks of life can be assembled in these unique and potentially habitable environments.

Scharf et al. (2015) brought together a team ranging from astrophysicists, geologists, chemists, planetary scientists, biologists, artificial life researchers, and philosophers to formulate a new approach to studying origin of life.

Ballmer et al. (2017) proposed a biology-inspired model for the Earth's formation, composition, long-term evolution, and deep circulation. Their so-called BEAMS hypothesis promises to solve many paradoxes in the Earth sciences and unifies the fields of geophysics and geochemistry.

Rein et al. (2014) brought together atmospheric chemists and astronomers to show that the range of possible interpretations of spectrally characterized chemical disequilibrium (a proposed biosignature) on exoplanets can be a false positive, and provided a model to show how a better search for such biosignatures might be conducted.

Laneuville et al. (2018) included a microbiologist, a planetary scientist, and a geochemist who modeled how nitrogen cycling would proceed on terrestrial planets without life, a seminal study to establish the baseline for one of the bio-essential elements.

Yamamoto et al. (2018) unified important ideas around the geochemical and geoelectrical output of deep sea vents and how they power life in a deep marine environment.

Moore et al. (2017) explored how the geochemical availability of various metals in the early Earth environment facilitated a variety of chemical pathways for biological metabolism.

Barry et al. (2019) showed the dual importance of life, and the Earth in controlling the global elemental cycles. The study indicated that microbial chemolithotrophy, contributed to a small but noticeable amount of carbon uptake in the system.

Guttenberg et al. (2017) addressed the disconnect, between Origin of Life research using restricted and controlled chemical models, and the likelihood that the kinds of chemical systems involved in the origins of terrestrial life produced a wide range of compounds via a wide range of mechanisms.

McGlynn (2020) is a chapter in a book where the author integrated the kinetic and equilibrium isotope geochemistry into biological activity hierarchies of enzymes, cells, and whole ecosystems.

Ramirez (2020) used data from laboratory experiments to determine solar limits on the formation of complex life based on respiration in the universe.

Guttenberg et al. (2021) used algorithmic analyses of mass spectrometry data to identify relational distributions between organic carbon molecules. The technique will be useful on Earth, and during space missions.

Yoshida et al. (2020) applied new analytical techniques on the sulfur isotopes of carbonyl sulfide, which can be produced biologically during oxygenic photosynthesis and also anthropologically. and were able to demonstrate the relevance and occurrence of this anthropological source of COS emission into the atmosphere.

Ooka, McGlynn, and Nakamura (2019) quantified how much energy gain can be achieved in redox processes occurring at a deep-sea hydrothermal vent, and demonstrated that sufficient reducing power is available for carbon reduction starting from carbon dioxide.

Tasker, Laneuville, and Guttenberg (2019) combined forces to gain information on planetary masses through a deep learning approach, and were able to develop a new code that could estimate a planet property, given the other known bulk and orbital properties.

5. Realizing an International Research Environment (within 4 pages)

5-1. International Circulation of Best Brains

5-1-1. Center's record of attracting and retaining top-world researchers from abroad

Describe the participation of top-world researchers as PIs and their stays as joint researchers at the Center.

- In Appendix 3-2, give the number of overseas researchers among all the Center's researchers, and the yearly transition in their numbers. In Appendix 4-2 give the achievements of overseas researchers staying at the center to substantiate this fact.

ELSI's management has been working hard to realize the requirements to be a WPI research center, including (1) establishing an attractive research environment capable of attracting the world's best minds, (2) mandating English in all communications involving ELSI researchers, and (3) recruiting the majority of our junior and senior researchers from outside Tokyo Tech (and abroad). Today, 10 out of 20 PIs are world-class foreign researchers recruited from overseas. Three of these ten foreign PIs are currently based in Japan full-time. This number is a testament to ELSI's quality as a research center at which the world's top-class scientists gather, rather than a mere fulfillment of number requirements (which ELSI easily exceeds). Recruitment of talented bilingual secretarial staff was also crucial to assist ELSI researchers in handling official paperwork and documents, purchasing items for research, and supporting our numerous visitors from abroad.

5-1-2. Employment of young researchers at the Center and their job placement after leaving the Center

Describe the Center's employment of young researchers, including postdoctoral researchers, and the positions they acquire after leaving the Center.

- Enter the following to substantiate the facts provided above:
  - In Appendix 4-3, describe the Center's state of international recruitment of postdoctoral researchers, the applications received, and selections made.
  - In Appendix 3-2, give the percentage of postdoctoral researchers employed from abroad
  - In Appendix 4-4, describe the positions that postdoctoral researchers acquire upon leaving the Center.

ELSI has pursued a targeted strategy for the recruitment of internationally competitive young researchers that is unique in Japanese universities. A recruitment committee headed by a foreign PI put in place an active solicitation of applicants and a review system that incorporates feedback from experts from various areas of research covered at ELSI. In ELSI's initial recruitment, international advertisements were placed in journals including JST (JREC-IN), Nature, and Science as a way to get our new institute global visibility. In addition to announcements in mailing lists of relevant academic societies and communities, ELSI PIs constantly communicate with their outside colleagues to source top quality graduate students and postdocs as potential candidates. Recruitment efforts are also carried out in key meetings of ELSI's fields. ELSI's esteemed visitors bring their students and postdocs to ELSI's annual International Symposia and events are organized for them to get to know ELSI researchers. When world-renowned speakers are invited but decline, ELSI uses this as an opportunity to ask them to send top early-career researchers they know to speak. This is also an effective way to achieve gender balance and give opportunities to young scientists. ELSI's winter and summer schools have brought a number of successful applicants. These coordinated efforts including detailed support by ELSI's administrative staff to alleviate anxiety over relocating to Japan have led to maximizing the quality of recruitment. The employment period at ELSI is typically three years. However, young researchers with exceptional results may extend their stay by two years based on the outcomes of the annual evaluation. As shown in Appendix 4-4, 31 out of 52 young researchers hired by ELSI have been promoted at the world's top research institutions following their research experience at ELSI. This is proof that ELSI is recognized as a career-path institution.

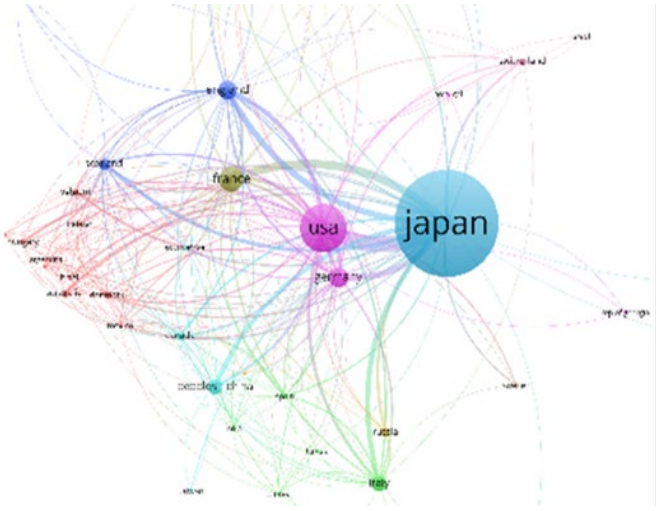
5-1-3. Overseas satellites and other cooperative organizations

- In Appendix 4-1, describe the state of cooperation with overseas satellites and other cooperative organizations. In Appendix 4-5, describe the state of the Center's agreements concluded with these organizations.

In 2012, ELSI established formalized international satellites with the Institute for Advanced Study and Harvard University. For these satellites we have shared post-doctoral positions (Cleaves, Witkowski, and Ishihara for IAS, Fahrenbach for Harvard). In 2018 the third overseas satellite at Columbia University was established. It connects their Astrophysics Laboratory (in particular through Executive Director M. Voytek, C. Scharf, the Director of the Astrobiology Center, and R. Wentzcovitch, Professor of Materials Science and Applied Physics, and Earth and Environmental Science) to ELSI. NASA's Goddard Institute for Space Studies (GISS) is located at the Columbia campus and their researchers collaborate with the university's astrobiology activities and are frequent visitors to ELSI. These satellites have provided intellectual engagement and support in a wide range of fields involving astronomy and astrophysics, Earth and planetary sciences, microbiology, synthetic biology, cosmochemistry, prebiotic chemistry, and astrobiology. Through these overseas alliances, we have developed collaborations in areas of research, education, and other scholarly activities.

Normally ELSI has an active exchange of researchers and students and the co-hosting of meetings and workshops with our overseas partners but with COVID, this year's activities were limited. We did have two joint appointment agreements with shared salary or local living costs between ELSI and our overseas partners. ELSI sent a researcher (R. Yi) to our collaborator Prof. Charles Liotta's lab at Georgia Tech for 10 months. Yi was able to be trained in techniques unavailable to be mentored at ELSI while ELSI gained tight working ties to our colleagues working in origins of life at Georgia Tech through him. ELSI researcher N. Virgo spent over a year at the Max Planck Institute for Mathematics in the Sciences, which forged closer working ties between the two institutes in the field of Complex Systems and the origin of cognition. Over virtual venues, ELSI has continued activities with our overseas collaborators. ELSI PIs organized a session at JpGU with our close Arizona State University collaborators. A workshop on *Feedbacks between Mantle Composition, Structure, and Evolution* was convened by ELSI members and close colleagues at ETH/Zurich, the Centre for Earth Evolution and Dynamics (CEED) of University of Oslo, and University College London.

Thus far, we have exchanged researchers and students (total 45) and co-hosted workshops (6) and symposia in order to advance the understanding of the origin of life on Earth and the possibility of life elsewhere in the universe. Furthermore, as a result of the Satellites' activities, 72 collaborative papers have been published in 2013-2020 with our overseas satellites (13 with Harvard University and 1 with Columbia University in 2020).



We have also established formalized collaborations with cooperative organizations from 23 research institutes and universities around the world, and are in discussion or in the process of formalizing Memorandums of Understandings with at least 7 more. These ongoing collaborations have grown from the initial five satellite and partner institutions. The strength of these interactions can be measured not only by the number of joint papers that have been published but by the number of individuals from these institutions that have applied for our internationally advertised research scientist positions and from the number of successful applicants (5) who came from either our satellites or cooperative organizations. Most notably, Tony Jia from our Harvard satellite and a postdoc of PI Jack Szostak, Harrison Smith and Kristin Johnson from Arizona State University, our cooperative organization.

In the case of satellite Institute for Advanced Study (IAS), an institute known for its excellent operation and support for international researchers, cooperation extended beyond research to the sharing of leadership and administrative know-how (fund-raising, outreach, visitor support).

5-2. Center's record of holding international symposia, workshops, research meetings, training meetings and others

- In Appendix 4-6, describe the main international research meetings held by the Center.

(1) Annual international symposium

Annually, ELSI holds an international symposium on the origin of life research and its related fields. Every year, more than 100 researchers from more than 10 countries participate in presentations and debates. In FY2020 the 9th ELSI International Symposium was held under the theme of 'Science in Society' to address the role of science in society and, by extension, how researchers should prioritize their time between research and societal engagement. The symposium covered context of science in policy, advocacy, funding, administration and communication. The symposium adapted to the COVID-19 circumstances and was hosted virtually with an organizing team expanded in three time zones (Asia/Pacific, the Americas, and Europe/Africa) to cover a truly global effort. ELSI's annual public lecture, always held during the symposium period, was also moved online this year. This online medium inspired us to take advantage and plan a more dynamic and lasting Q&A activity (Ask a Scientist a Question) utilizing YouTube Chat as well as making the questions and answers accessible post event.

(2) International Workshops

In 2014, A. Fahrenbach organized a joint workshop with Harvard University. In 2015, the Phobos, Deimos, and Mars workshop allowed ELSI researchers to join the JAXA MMX mission (T. Usui and H.i Genda), which will launch in 2024. This was followed by a major Strategies for Origin of Life Workshop, which produced a highly cited concept paper about how to go forward with origin of life research. This meeting got ELSI and Tokyo Tech mentioned in the widely circulated popular US magazine, The Atlantic. The Magma Oceanology workshop in 2016 was the first step in a significant change in the field of magma oceanology, and resulted in high profile papers in Nature and Science. In 2017 ELSI hosted a young researcher day workshop organized by young ELSI researchers for their young researcher visitors. It was a day of sharing their research to one another and networking. Later on, in 2017, ELSI hosted workshops in Biosignatures and Life Detection Technology, produced a White Paper on the future of life detection technologies cited by USA National Academies of Science Astrobiology Strategy Roadmap Document, which will be a leading source of inspiration for future astrobiologists. In FY 2020, all the 37 workshops were held online and announced internationally. There were considerable numbers of lecturers connected from overseas and Japanese institutions outside of Tokyo thanks to the online system.

(3) Conferences

ELSI members have been awarded a number of keynote seminars in major international conferences such as the Goldschmidt Conference, Astrobiology Graduate Conference (AbGradCon), American Geophysical Union Meeting, and the Geochemical Society of Japan. ELSI also has organized a variety of sessions at those conferences, as well as in major domestic scientific society meetings such as the Japan Society of Cell Synthesis Research (Kuruma) and the Biophysical Society of Japan (BSJ) meeting (Kiga). The 2018 ALife Conference, the foremost international conference on the topic, was held in Tokyo. Owing to the international acclaim as a global research hub, ELSI was chosen to be the host of two international astrobiology conferences in 2020: Astrobiology Australasia Meeting and AbGradCon, a major young researcher-focused conference co-sponsored by NASA and attended by researchers from all six continents. This was the first time ever that AbGradCon would be held in Asia, ELSI being selected as the ideal host. Under the COVID-19 situation Astrobiology Australasia Meeting was held virtually. AbGradCon has been postponed to 2021, still with ELSI as host, with the decision recently made for it to be held virtually.

5-3. System for supporting the research activities of overseas researchers

Describe the Center's preparations to provide an environment conducive for overseas researchers to concentrate on their work, including for example living support in various languages or living support for their families.

(1) Relocation and daily life support (including VISA acquisition)

ELSI provides relocation support including VISA acquisition, housing arrangement, and day-care enrollment to enable researchers to concentrate on their work, even before coming to Japan. Once here, we assist in setting up bank accounts and registering in ward offices. In addition to start-ups and daily life support, we provide information and detailed advice on the change of status of residence (permanent residence application), preparation for children's schooling, etc. We also assist in making necessary arrangements to go back to the researcher's home country, such as tax matters and social insurance. We provide necessary support to even our visitors to adapt to circumstances including various unexpected problems or challenges. ELSI has also contracted with a 24 hour telephone translator service for medical-related communication needs for our international researchers. The know-how of support accumulated from the beginning of ELSI to the present will be applied to future ELSI visitors and staff, and will also be shared with the whole university.

(2) Japanese language classes

An important part of living support is to provide Japanese language classes for researchers to learn conversation skills for daily life. ELSI's philosophy is to not only provide support but to do so in ways of diversity recognition so that a researcher may integrate oneself into Japanese life. ELSI holds classes of different proficiency levels at the institute to meet the abilities of our interested researchers. In addition to Japanese language classes, E-learning teaching materials are introduced to support Japanese language proficiency improvement. Recently, Japanese lessons have been moved to one-on-one online options for our interested researchers and this has received strong appreciation from them.

(3) Childcare service

Tokyo Tech opened a nursery school, "Tekuteku Nursery School," in the International House near the ELSI in April 2017, and gives priority of use to ELSI staff and visitors. Therefore, researchers who arrive at Tokyo Tech with children in need of immediate childcare will be able to focus on their research in ease. In addition, the university has established women's resting rooms in the ELSI-1 and ELSI-2 buildings to provide a safe environment for female staff especially for childcare needs and rest.

(4) Support for acquisition of competitive funds

ELSI hosts Kakenhi seminars in English conducted by Japanese PIs with abundant experience in obtaining Kakenhi. In addition, translation services are provided by Japanese researchers, graduate students, and ELSI and Tokyo Tech URA staff to assist with application documents. Implementing such support has increased successful applications.

(5) Safety management training

In collaboration with Tokyo Tech's General Safety Management Section of the Office of Campus Management, ELSI hosts a lecture on safety in lab experiments in English, mainly for foreign researchers. Automated external defibrillators (AEDs) were installed in ELSI-1 and ELSI-2 buildings in 2016, and AED training sessions in English and Japanese are held every year since then. (It was not held in FY2020 because of COVID-19.)

(6) Maintenance of accommodation facilities

Tokyo Tech has given priority to ELSI to use 20 rooms in the International House, an accommodation facility on campus. ELSI's foreign researchers and their families can use them for up to a year, giving them ample time to find a place to live off campus. In addition, four other accommodation facilities on campus for international researchers and students have been renovated for their use.

5-4. Others

Describe the Center's policy for sending Japanese researchers overseas to gain international experience, and give examples of how the Center is working to create career paths for its researchers within a global environment of researcher mobility.

(1) GIFT (Global Impact Fund for Travel) Program was established by the Director's Office to strategically disseminate ELSI's research to scientific communities abroad where ELSI's presence is limited. ELSI researchers can apply to get support for an individual or small group to attend to publicize ELSI's research and what ELSI is like as an institution. GIFT is a way for ELSI to support Japanese and other researchers who might not otherwise be able to get travel support for meetings such as through invitations.

(2) ELSI Origins Network (EON) Program Design: EON was funded to create a global network for origins-of-life research with ELSI as a hub. A key design of the program was to require EON postdoctoral researchers to spend half of their contracted term at an overseas institution to pursue their planned research. With acceptance from hosting overseas institutions as a prerequisite for the EON postdoctoral application, ELSI was able to secure forward-thinking young researchers with the willingness to gain international experiences as well as collaborative relations with overseas supervisors. One result was that early career ELSI members, many of them Japanese, made research visits to EON overseas institutions to continue their collaborations with EON postdocs, and this provided them with opportunities to further strengthen their international network and skills. Many of these researchers found tenure-track positions in Japanese institutions.

6. Making Organizational Reforms (within 3 pages)

6-1. Decision–making system in the center

Describe the strong leadership that the director is giving on the Center's operation and its effect, and the division of roles and authority between the Center and its host institution.
- In Appendix 3-3, draw a concrete diagram of the Center's management system.

(1) Roles of the institute director and the president of the host institution

Appointment of the ELSI Director is the responsibility of the President of Tokyo Tech, but all other important decisions are made by the ELSI Director. ELSI directors meet monthly with the University executives (President, Vice Presidents in charge of Research and Financial Affairs) in order to maintain close coordination between the University and ELSI.

(2) Decision-making system in the institute

The Director has the right to make decisions on all matters that pertain to ELSI except for the Director's own appointment. The Director is also responsible for the administration and management of the Administrative Division, with support from the Executive Director and the Administrative Director. This system with concentrated functions to the Director guarantees flexible and quick decision-making.

The Director's Office, the Operations Committee, and other various committees assist the Director's decision-making (see Appendix 3-3). The Director's Office meets weekly and makes day-to-day operations of the institute by sharing the latest situation of the institute among the members and by instructing appropriate committees to address various issues in managing the institute. The Operations Committee is composed of the directors and several PIs, and meets regularly once a month; it discusses personnel affairs and various institutional regulations, and gives advice and support to the Director.

ELSI has an International Advisory Board (IAB) whose members are internationally recognized scholars who have leadership and management experience. The Director receives advice from the IAB on important aspects of running the institute.

6-2. Arrangement of administrative support staff and effectiveness of support system

Describe the assignment of the Center's administrative support staff who have English language and other specialized skills, effort made in establishing the support system, and the system's effectiveness.

Under the leadership of the Director, ELSI has established an Administrative team of 20 staff overseen by an Administrative Director who has extensive experience in international research activities. Majority of ELSI staff are fluent in English, are highly skilled and have abundant experience in meeting the unique challenges of a WPI institute. The secretarial office has been centralized into one room, and a secretary in charge has been assigned to each research unit as a contact point, based on the requests from researchers, to realize one-stop service for researchers. Following ELSI's system to consolidate the secretarial office, the university formulated the "Policy on the Concentration of Accounting Jobs in Labs" to centralize and monitor accounting-related work.

6-3. System reforms advanced by WPI program and their ripple effects

Concisely itemize the system reforms made to the Center's research operation and administrative organization, and describe their background and results. Describe the ripple effects that these reforms have on the host institution. (If any describe the ripple effects on other institutions.)

(1) Top-down decision making

As stated in Sec. 6-1, ELSI has adopted a top-down decision-making system. The President of Tokyo Tech, using ELSI as a model, is initiating and establishing a flexible research system not constrained by conventional Japanese traditions.

(2) Promotion of the "World Research Hub" to develop international research activities

Tokyo Tech had already carried out research reforms, including the establishment of the Institute of Innovative Research (IIR) in April 2016, which integrated the existing four research institutes and several research centers. Furthermore, an organization "Tokyo Tech World Research Hub Initiative (WRHI)" has been established in IIR, aiming at promoting interdisciplinary research and creating innovative science and technology. WRHI uses ELSI as a model case and utilizes its know-how, like the allocation of an open communication space, and has been trying to invite top-level foreign researchers and to promote fusion in research. Tokyo Tech plans to propagate the success of ELSI's system to WRHI and IIR, and to further extend it to the entire university, in order to realize its goal of becoming a "global research hub".

(3) Introduction of performance-based pay system

ELSI adopts its own performance-based pay system to recognize and incentivize excellence. This is also necessary when trying to competitively recruit from an international pool of high-caliber applicants. In ELSI's Annual Evaluation, all researchers report their research activities and are evaluated on the criteria of scientific value as well as contribution to ELSI's WPI goals. Researchers who are recognized as having performed particularly excellent research, especially of an interdisciplinary nature, are given the Award and a salary raise in the next year.

(4) Introduction of cross-appointment system

In order to acquire top level researchers, ELSI working with Tokyo Tech established a cross-appointment system. Tokyo Tech applied this system for the first time to an ELSI PI. As of March 2021, 10 researchers in Tokyo Tech are being hired using this system.

(5) Reduction of work-related payments by ELSI researchers

In order to increase efficiency and reduce credit burden to our researchers, ELSI requested Tokyo Tech to change the university's regulation to allow for a corporate credit card. It was introduced in April 2016 to ELSI as its first case in the university. ELSI also negotiated with Tokyo Tech to allow travel insurance for business travel to be paid by the institute's budget, not by the individual researchers as the rule had been. In response, Tokyo Tech changed the accounting rule for travel insurance for business trips.

(6) University notifications and services in Japanese and English

Globalization is an important goal for Tokyo Tech. As a result of ELSI's feedback and requests to Tokyo Tech to accommodate the university's international members, most notification mails from Tokyo Tech administration are now both in English and Japanese. Tokyo Tech has also established an English-language consultation desk for personnel matters and a counseling service using English. The General Safety Management Section of the Office of Campus Management delivers a lecture, bi-annually at ELSI's Mishima Hall, on campus safety in English to staff and students engaged in lab work.

(7) Cultural diversity training course

Lack of awareness on differences in cultural background may sometimes lead to miscommunication, misunderstanding and even emotional conflicts. In order to avoid such situations, ELSI carried out lectures on cultural diversity and awareness by professional lecturers in FY2018. The same lectures were delivered three times and the majority of ELSI staff had received this awareness training.

6-4. Support by Host Institution

The following two items concern the support that the host institution provides the Center. Describe the measures that the host institution has taken to sustain and advance the Center's project. That include those items of support that it committed to at the time of the initial project proposal submittal or in its revised commitment following the project's interim evaluation.

6-4-1. Record of host institution support and its effects

In Appendix 6-1, describe the concrete measures being taken by the host institution.

(1) Human resource support to ELSI

Tokyo Tech had already assigned eight tenure positions to ELSI until FY2018, and one more tenure-track post was given to ELSI in FY2020. This reflects Tokyo Tech's strategic mid- and long-term plan to promote education and research in Tokyo Tech with ELSI playing a vital role. At the start of ELSI in 2012, tenured professors assigned to ELSI were exempted from undergraduate education duties. In order not to hinder undergraduate education, three faculty posts were provided to the original divisions of three ELSI professors by the President's discretion. Tokyo Tech has assigned two administrators to ELSI at the beginning, and in addition assigned one more administrator to ELSI in FY2018, showing even stronger support to ELSI.

(2) Provision of research spaces

Tokyo Tech provided an existing building (2,670 m^2) on the campus to ELSI at the beginning (ELSI-2). In addition, the university provided a site and completed a new research building (ELSI-1: 5,000 m^2) in FY2014. These two generous buildings represent the strong support of the host institution that is a requirement of a WPI center.

(3) Financial support

ELSI receives 90 million yen annually from Tokyo Tech, which was the same amount of budget received by the former GCOE program that led to the conception of ELSI. Tokyo Tech also covers the salary of three PIs and two full-time administrative staff. In 2018, Tokyo Tech increased the support for one more additional administrative staff.

(4) Accommodations for international staff and set up of daycare service

As mentioned in 5-3, ELSI reserves priority on 20 rooms in Tokyo Tech's International House for foreign researchers. In addition, Tokyo Tech continues its efforts to secure accommodations for foreign researchers, and also opened a nursery school in April 2017 within the International House.

(5) Support for research fund acquisition

The Office of Research and Innovation of Tokyo Tech supports ELSI researchers to secure funding through information collection, training lectures, interview rehearsals, and practical assistance in submission to external funding sources. In 2017, the university supported ELSI to establish a non-profit organization, Tokyo Tech USA, incorporated in the state of New York, in order to obtain donations and research funds from overseas companies and research funding organizations. Tokyo Tech continues to provide basic funds to maintain Tokyo Tech USA.

Responding to ELSI's request, Tokyo Tech established a new, more flexible and smaller-scale system of donation program to enhance education and research through donations from private companies. ELSI received JPY 24 million donation from a private company and established the "ELSI FirstLogic Astrobiology Donation Program". This funding was used to hire a research associate professor and support his research activities.

6-4-2. Position of the Center within the host institution's mid-term plan

To Appendix 6-2, excerpt the places, in the host institution's "Mid-term objectives" and/or "Mid-term plan" that clearly show the positioning of the WPI center within its organization.

Tokyo Tech clearly defined ELSI in its Second Mid-term Plan (FY2010-2015). In its Third Mid-term Plan starting from FY2016, Tokyo Tech stated "By providing the Presidential discretionary resources, we will promote research in ELSI, focusing on the early earth, and aiming to link and unravel the origin and evolution of the earth and life." The President also recognized ELSI as a "strategic and ambitious organization". In addition, in the organization management rules of the National University Corporation Tokyo Institute of Technology, ELSI is defined as a leading member (a special research zone) of the Strategic Research Hubs directly under the President.

6-5. Others

Describe efforts advanced to foster young researchers (e.g., start-up funding, autonomous research environment) and to enlist female researchers.
In Appendix 3-1, 3-2, give the transition in the number and ratio of female researchers.

(1) Efforts to foster young researchers

ELSI provides start-up funds of about 500,000 yen/year to young researchers so that they can begin their research before acquiring external funds. For the start-up funding to be allocated, ELSI requires young researchers to apply annually to at least one external grant (regardless of the result).

This requirement is a form of professional training to grow capabilities necessary for acquiring competitive funds. If they need more resources, they may apply for the "Director's Fund", which is an internal research budget allocated by the Director's Office.

(2) Appointment of female researchers

ELSI has steadily increased appointment of female researchers. As shown in Appendix 3-1, the gender ratio today is 20% (15% among PIs, 24% among non-PI researchers excluding those in satellite institutes). ELSI has a Global Environment Team (GET) which is composed of volunteer staff and tracks our performance in achieving gender balance in conference speakers, organizing committees, and recruitment. GET works with the university's Gender Equality Section for exchange of information and feedback to meet international standards for gender equality and awareness.

7. Others

In addition to the above 1.-6. evaluation items, note any of the Center's leading activities, distinctive features or other important points that denote its status as an "internationally visible research center."

(1) Participation in graduate-course education

ELSI has been making significant contributions towards nurturing the next generation of researchers by having our world-renowned scientists supervise graduate students. In April 2021, Tokyo Tech initiated a new five-year (integrated master's and doctor's) program, the Earth-Life Science graduate major or "ELSI Course" in the School of Science and the School of Life Science and Technology, mainly contributed by ELSI professors. The first students will join this program from April 2022.

(2) Acquisition of global funds and ELSI Origins Network (EON) project

In July 2015, ELSI acquired research funds totaling JPY670 million (USD1=JPY122) from the John Templeton Foundation in the United States. This grant was larger in amount than what all the national universities combined raised from overseas in the previous year. The ELSI Origins Network (EON) project was established using this grant. EON was able to build an international network of origins of life research with ELSI as a hub and to progress the science. This success has led to the establishment in May 2017 of a non-profit, tax-deductible organization "Tokyo Tech USA, Inc." mentioned in 6-4-1(5), to be able to more easily raise grants and funds from abroad, especially from the U.S. under advantageous 'domestic' tax-deductible treatment.

(3) Collaboration in science outreach with WPI centers

In February 2021, ELSI hosted the 9th WPI Science Symposium with the title "'Life' in the 21st Century." This was the very first online symposium in the 9 years, and proved very successful by introducing several new features; collection of questions in advance via network, real-time Q&A sessions via network, and answering almost all of the questions by the most well-matched/qualified WPI researchers and making them available on the ELSI web page. The WPI PR committee gave a very high rating to these new achievements. Since FY2015 ELSI has been co-hosting an annual joint public lecture "Quest for Origins" with Kavli Institute for the Physics and Mathematics of the Universe (Kavli-IPMU) and (from FY2018) International Research Center for Neurointelligence (IRCN). The combination of the fundamental topics of universe, Earth and life, and brain science always attracts many audiences. The 9th symposium was held in February 2021 via an online format.

(4) Leadership in science communication

As an integral part of our internationalization efforts, ELSI is focused on playing a leadership role in science communication conducted in English in Japan. Sharing research progress across the world increases visibility and recognition for domestic scientists and science conducted in Japan. In November 2018 ELSI hired a non-Japanese Communications Director, and since then we have been able to make as many as 30 press releases a year. This also has contributed significantly to the globalization and visibility of the PR activity of Tokyo Tech.

In 2018 and 2019 ELSI hosted the Japan Scicom Forum. This forum is an event to bring together communicators, writers, scientists, journalists and selected experts from abroad to share ideas and to inspire and boost the cohesion of science communication in Japan. (The next forum was postponed because of COVID-19.)

(5)ELSI Weekly Seminars

ELSI Weekly Seminars are opportunities for ELSI researchers to invite their collaborators and visitors to present their work. The seminars are held on Fridays at 15:30 in Mishima Hall, followed by 'Izakaya',

an informal socializing format to continue the discussion with the speaker. During the COVID-19 pandemic, the seminars were moved online and ELSI members invited speakers from abroad to present their work. The online version allowed for more participants, and some seminars gathered more than 100 participants, expanding the ELSI network and community.

(6) Science communication training

ELSI recognizes the importance of providing researchers with relevant skills to communicate their research with fellow researchers, students, public and funding agents. 'Scientific Communication in Practice' symposium was co-organized with EURAXESS Japan in FY2019, and 'Effectively Communicating your Research' training workshops were organized with Nature in FY2020.

8. Center's Response to Results of FY 2020 Follow-up (including Site Visit Results)

* Describe the Center's response to results of FY 2020 follow-up. Note: If you have already provided this information, please indicate where in the report.

1) ELSI should clarify to what extent the questions and assumptions in its original roadmap have been answered and confirmed by the center's research. This will be crucial in bridging the Earth and Life research in ELSI's first decade across to the research plan for its second decade and beyond.

Our original 10-years research goals are to explore A) formation of the Earth, B) origin of life, C) evolution of Earth-Life system, and D) bioplanet in the universe. The targeted more specific questions, including the founding questions, are described and answered in section 2-1 "Research results to date". We have found three key steps in the scenario of life emergence, which are going to be interdisciplinary research focus areas in the next decade (see section 1 "Overall Image of Your Center" for details).

2) ELSI should also provide more concrete and detail strategies regarding its universal biology project, which is one of the center's future plans. Center director Hirose states that universal biology includes studies on artificial cells, machine learning and artificial intelligence; however, the Program Committee wonders whether such universal biology will be a proper target in ELSI's future plan.

Universal biology asks fundamental questions like "what is life?" ELSI's (original) mission is to study the origins of life in the context of the origin of Earth. Recent discoveries of many extrasolar planets will someday lead to the detection of life there, which may take unknown forms. At the other extreme are studies on artificial cells, machine learning and artificial intelligence. ELSI's researchers have already been carrying out such studies connected to universal biology. One of the most visible successes would be the ELSI sponsored 2017 symposium on universal biology. Our plan for an expansion of universal biology research presented in the WPI extension proposal will unfortunately not be realized, but theoretical approaches to origin of life research will continue to guide our research.

3) The Program Committee would also like to hear a clear and concrete plan regarding the management of ELSI after the end of WPI funding. Important issues are: the directorship of ELSI, the outlook for funding, the composition and number of researchers, and the position of ELSI within Tokyo Tech.

ELSI's plan is for Prof. Yasuhito Sekine to take over as the incoming Director after the WPI funding. He is currently a PI of ELSI and has led the efforts on planning the research strategy of ELSI for the next decade. The host university will continue supporting ELSI for at least five years from FY2022. In addition, we will start ELSI's own graduate course from FY2022, in which we will collaborate with companies and seek support for students from them. For the composition and number of researchers,

see our Progress Plan. We have been in discussion with Tokyo Tech regarding the position of ELSI after WPI funding.

Appendix 1-1 List of Papers Underscoring Each Research Achievement

* List papers underscoring each research achievement [1] ~ [20] listed in the item 2-1 "Research results to date" of 2. "Advancing Research of the Highest Global Level" (up to 40 papers) and provide a description of the significance of each (within 10 lines).
* For each, write the author name(s); year of publication; journal name, volume, page(s), and article title. Any listing order may be used as long as format is the same. If a paper has many authors, underline those affiliated with the Center.
* If a paper has many authors (say, more than 10), all of their names do not need to be listed.
* Place an asterisk (*) in front of those results that could only have been achieved by a WPI center.

* [1] **How do terrestrial planets form?**

*1. Ida S, Guillot T, Morbidelli A. 2016. The radial dependence of pebble accretion rates: A source of diversity in planetary systems-I. Analytical formulation. Astronomy & Astrophysics 591, A72.

The paper studies "pebble accretion", a recent alternative to planetesimal accretion in which centimeter-to-meter sized icy grains migrating in planetary disks can control the early phases of planet formation. This analytical treatment shows that pebble accretion occurs in different regimes and can produce diverse planetary systems, consistent with the diversity observed in exoplanet surveys. Therefore, disk structure must be specified, and pebble growth, sublimation/destruction and migration must be considered, to predict the effects of pebble accretion as a planet-forming process.

2. Matsumura S, Brasser R, Ida S. 2017. N-body simulations of planet formation via pebble accretion. I. First results. Astronomy and Astrophysics 607, A67.

This is the first paper that examines exoplanet formation through pebble accretion. It presents an integrated formation model incorporating all of: pebble accretion, gas accretion, eccentricity and inclination damping, type I and type II migration, and the effects of sublimation. Disc parameters on which the process depends, including stellar metallicity, the disc mass, and the disc's viscosity, are all surveyed. Important results include measures of the sensitivity of type-I migration to details of the disc model, and predictions of the dependence of formation efficiencies of planets on the stellar metallicities, not only for giant planets, but also for Earths (Es) and Super-Earths (SEs). A surprising prediction is of more ejected Es/SEs than has been expected – as many as one per every two low-mass ejected planets comparable to Mars – with implications for observations by WFIRST.

* [2] **How did the composition of the Earth's core result in a magnetic field?**

*3. Nomura R, Hirose K, Uesugi K, Ohishi Y, Tsuchiyama A, Miyake A, Ueno Y, 2014. Low core-mantle boundary temperature inferred from the solidus of pyrolite. Science 343, 522-525.

The precise relationship between temperature and melting of the lowermost mantle constrains the structure and heat flow across the core-mantle boundary, and is key to the thermal structures of both the mantle and the core. Using high-pressure, high-temperature three-dimensional x-ray microtomographic imaging experiments, the authors found that the temperature of the core-mantle boundary should be about 400 K lower than was previously estimated. Such a large depression is impossible without hydrogen in the core, suggesting that a large amount of H may have been incorporated into metals from a hydrous magma ocean at the time of core formation. The experimentally determined maximum melting point of 3570 K also suggests that some phases typically thought to lose stability in the lowermost mantle, such as $MgSiO_3$-rich post-perovskite, may be more widely distributed than expected.

*4. Hirose K, Morard G, Sinmyo R, Umemoto K, Hernlund J, Helffrich G, Labrosse S. 2017. Crystallization of silicon dioxide and compositional evolution of the Earth's core. Nature 543, 734-738.

This was the first high-pressure/temperature experiment showing that SiO_2 crystallizes first from a Fe-Si-O liquid. The resulting buoyancy force would strongly stir the core and expand the parameter range producing a geodynamo. This is a flagship work addressing questions about how to power magnetic fields in general, and more specifically Earth's magnetic field history. Because the presence or absence of a terrestrial magnetic

field affects the retention or loss of planetary atmosphere due to the early energetic solar wind, expanding the parameter range in which a geodynamo is expected affects our understanding of whether the Earth's condition is uncommon or normal.

*5. Lin W, Paterson GA, Zhu Q, Wang Y, Kopylova E, Li Y, Knight R, Bazylinski DA, Zhu R, Kirschvink LJ, Pan Y. 2017. Origin of microbial biomineralization and magnetotaxis during the Archean. Proceedings of the National Academy of Sciences 114, 2171-2176

Although magnetotactic behavior is known in many groups of organisms, its evolutionary origin is obscure. This paper presents evidence that magnetotaxis evolved in bacteria during the Archean, before or near the divergence between the Nitrospirae and Proteobacteria phyla, suggesting that magnetotactic bacteria are one of the earliest magnetic-sensing and biomineralizing organisms on Earth. An early origin of magnetotaxis would have provided evolutionary advantages in coping with environmental challenges faced by microorganisms on early Earth; its persistence in separate lineages implies the temporal continuity of geomagnetic field, providing a biological constraint on the evolution of the geodynamo.

* [3] **Inventory of Earth's water.**
6. Hamano K, Abe Y, Genda H. 2013. Emergence of two types of terrestrial planet on solidification of magma ocean. Nature 497, 607-610.

The paper develops an evolutionary model of magma ocean crystallization to show how cooling rate governs loss or retention of water delivered early in planet formation. Because the timescale for crystallization depends sensitively on stellar irradiance, a strong divergence can arise between Venus-like and Earth-like fates, demonstrating the existence of critical orbital thresholds for habitability.

*7. Kurokawa H, Foriel J, Laneuville M, Houser C, Usui T. 2018. Subduction and atmospheric escape of Earth's seawater constrained by hydrogen isotopes, Earth and Planetary Science Letters, Volume 497:149-160

The hydrogen isotopic deuterium/hydrogen (D/H) ratio reflects the global cycling and evolution of water on Earth as it fractionates through planetary processes. This paper reconstructs the early Earth's ocean volume as a function of time using D/H ratio constraints in the mantle and oceans. It models the combined effects of seafloor hydrothermal alteration, chemical alteration of continental crust, slab subduction, and hydrogen escape from the early Earth, as well as degassing at mid-ocean ridges, hot spots, and arcs. Improved fractionation models suggest that in order to produce observed isotope ratios, secular net regassing and/or early fast plate tectonics are needed, and that the volume of Earth's initial oceans could have been 2 to 3 times larger than those on Earth today.

* [4] **How do planets form from a view point of satellites' formation**
8. Rosenblatt P, ... Genda H et al. 2016. Accretion of Phobos and Deimos in an extended debris disc stirred by transient moons. Nature Geoscience 9, 581–583.

This work shows that two Martian moons, Phobos and Deimos, can be formed a single giant impact on ancient Mars. Observational constraints, especially their orbits are rather consistent with giant impact scenario. JAXA is planning to send a spacecraft to martian moons to return their samples, which will give us much critical information on not only martian moons but also Mars. In terms of comparative satellite formation studies, martian moons formation is a key to understand the origin of our Moon.

9. Ida S et al. 2020. Uranian satellite formation by evolution of a water vapour disk generated by a giant impact. Nature Astronomy 4, 880–885.

This work shows that Uranian satellite system and tilted spin axis of Uranus can be formed as a consequence of a giant impact on Uranus. This model is the first to explain the configuration of Uranus' moon system, and

it may help explain the configurations of other icy planets in our Solar System such as Neptune. Beyond this, we have now discovered thousands of planets around other stars, and observations suggest that many of the newly discovered planets known as super-Earths in exoplanetary systems may consist largely of water ice and this model can also be applied to these planets.

* [5] **Aqua planetology**

10. Fukushi K, Sekine Y et al. 2019. Semiarid climate and hyposaline lake on early Mars inferred from reconstructed water chemistry at Gale. Nature Communications 10, 4896.

This study provides evidence that some early Martian minerals were formed in watery environments that were salty and near neutral pH, similar to Earth's modern oceans, by constraining the properties of pore water within lacustrine sediments of Gale Crater on Mars. Salinity, pH, and redox states are fundamental properties that characterize natural waters. These properties of surface waters on early Mars reflect palaeoenvironments, and thus provide clues on the palaeoclimate and habitability. This study shows surface waters on early Mars may have been habitable for microbial life.

* [6] **What were the initial conditions on early Earth that would support the emergence of life?**

*11. Genda H, Brasser R, Mojzsis SJ. 2017. The terrestrial late veneer from core disruption of a lunar-sized impactor. Earth and Planetary Science Letters 480, 25-32.

This work shows that the late veneer impact on Earth, which occurred around 4480 Myr ago, most likely resulted in a temporary 90-bar H2 atmosphere on the Earth that lasted about 200 Myr. Such an atmosphere would have produced a highly reducing surface environment that facilitated accumulation of reduced organics, more similar to the conditions in the original Miller-Urey atmosphere models of prebiotic synthesis than would have held on the same planet without the veneer-forming impact. The paper was a focal topic in a 2018 conference in the United States concerning connections between planet formation conditions and prebiotic organosynthesis.

*12. Genda H, Sasaki T, Ueno Y, Iizuka T, Ikoma M. 2017. Ejection of iron-bearing giant-impact fragments and the dynamical and geochemical influence of the fragment re-accretion. Earth and Planetary Science Letters 470, 87-95.

The paper conducts a numerical simulation of late giant impacts including fragment dynamics of the impactors and the effects on orbital evolution of protoplanets. The simulations show that the mass fraction of metallic iron in giant-impact fragments of differentiated bodies ranges from ~1 wt% to ~25 wt%. It solves problems concerning the eccentricity of Earth's orbit, the excess of Highly Siderophile Elements in the crust following core differentiation, and possible strong early reduction of the Earth's CO_2-H_2O atmosphere.

*13. Brasser R, Mojzsis SJ, Werner SC, Matsumura S, Ida S. 2016. Late veneer and late accretion to the terrestrial planets. Earth and Planetary Science Letters 455, 85-93.

The paper shows that the late veneer on Earth - a phase of late accretion that occurred when the Earth's crust was mostly molten and which therefore delivered the highly-siderophile elements to the mantle – is best explained by the impact of a single, lunar-sized object that struck Earth around 4480 Myr ago. The large size of the impactor, implying differentiation, also implies core fragmentation and a massive pulse of reduced iron at Earth's surface, with large consequences for atmospheric redox as well as the element abundances explained directly. Consequences for redox are developed in Genda et al. 2017 EPSL 470 and 480).

*14. Endo Y, Ueno Y, Aoyama S, Danielache SO. 2016 Sulfur isotope fractionation by broadband UV radiation to optically thin SO_2 under reducing atmosphere. Earth and Planetary Science Letters 453, 9-22.

The paper succeeds in reproducing the Archean sedimentary S-Mass-Independent-Fractionation record including ^{36}S, and demonstrating that the early Earth's atmosphere should not have been a simple CO_2

atmosphere but must have contained more reducing gasses, most likely CO. A CO-rich atmosphere may have been critical for prebiotic synthesis, and provides a key constraint for earlier Earth's environment/ecosystem. The mechanism responsible for such moderately reducing conditions for a long interval in the Archean remains to be solved, but part of the answer may come from the earlier strongly-reducing conditions derived by (Genda et al. 2017 EPSL 470) in connection with the late veneer.

[7] **Where did life emerge?**

*15. Maruyama S, Ikoma M, Genda H, Hirose K, T Yokoyama, M Santosh. 2013. The naked planet Earth: most essential pre-requisite for the origin and evolution of life. Geoscience Frontiers 4, 141-165.

The paper argues that no single local environment or process should be sought for the emergence of life, but that it likely depended on diverse planetary environments and an extended period in early Earth's maturation. The argument reflects ELSI's earliest emphasis that highly interdisciplinary science is required to sensibly address the Origin of Life problem, and refers to essential bottlenecks including sources of chemical activation such as solvated electrons which may be generated in several ways on a young planet.

[8] **What fueled prebiotic synthesis from existing raw materials?: Atmospheric and radiative processes**

*16. Adam ZR, Hongo Y, Cleaves HJ, Yi R, Fahrenbach AC, Yoda I, Aono M. 2018. Estimating the capacity for production of formamide by radioactive minerals on the prebiotic Earth. Scientific Reports 8, 265.

The paper investigates the plausibility of formamide accumulation on early Earth, as a more favorable solvent than water for the synthesis and stabilization of organic compounds. It reports the conversion of aqueous acetonitrile (ACN) via hydrogen cyanide (HCN) as an intermediate into formamide by γ-irradiation under conditions mimicking exposure to radioactive minerals. The authors estimate that a radioactive placer deposit could produce 0.1-0.8 mol formamide per square kilometer per year, whereas a fission zone like the Oklo reactors could produce 0.1-1 mol per square meter per year. Radioactive mineral deposits may have been favorable settings for prebiotic compound formation through emergent geologic processes and formamide-mediated organic chemistry.

[9] **What fueled prebiotic synthesis from existing raw materials?: Redox processes**

*17. Kitadai N, Nakamura R, Takai K, Li Y, Gilbert A, Ueno Y, Yoshida N, Oono, Y. 2018. Geoelectrochemical CO production: Implications for the autotrophic origin of life. Science Advances 4, eaao7265.

The paper addresses a requirement in many autotrophic Origin of Life hypotheses for high pressures of CO as a source of carbon and reducing potential for prebiotic organic synthesis. Simulating a geoelectrochemical environment in deep-sea hydrothermal fields, the authors demonstrate CO production with up to ~40% Faraday efficiency on CdS in CO_2-saturated NaCl solution at ≤−1 V vs. Standard Hydrogen Electrode. Such potentials would readily have been generated in the H_2-rich, high-temperature, and alkaline hydrothermal vents that were probably widespread on the early komatiitic and basaltic ocean crust.

*18. Hudson R, …McGlynn SE, … Nakamura R, et al. 2020. CO_2 reduction driven by a pH gradient. Proceedings of the National Academy of Sciences 117, 22873-22879.

In this paper it was shown that CO_2 reduction to formate is possible in precisely the manner first hypothesized by Dr. Michael Russel in a landmark 1994 publication. By constructing a simulated hydrothermal vent in the laboratory, the researchers were able to demonstrate that a pH difference across an inorganic membrane is able to enhance the thermodynamics of carbon dioxide reduction to hydrogen in a process described by the Nernst equation.

19. Sanden SA, Yi R, Hara M, McGlynn SE. 2020. Simultaneous synthesis of thioesters and iron–sulfur clusters in water: two universal components of energy metabolism. Chemical Communications 56, 11989-11992.

Central to biology is the formation of activated molecules via redox reactions. In this paper a team led by McGlynn discovered a new redox reaction which can result in the formation of high energy thioesters of the type which can be used to drive subsequent chemical reactions such as polymerizations. Ferric iron was shown to act as an oxidizing agent towards thioacids, of which the di-acyl di-sulfide products can go on to act as efficient acylating agents to produce acyl thioesters.

* [10] **Protometabolism**

20. Kitadai N et al. 2019. Metals likely promoted protometabolism in early ocean alkaline hydrothermal systems. Science Advances 5, eaav7848.

The paper presents an experimental study of oligomerization of alpha-hydroxy acids, a class of plausibly abundant prebiotic monomers, to form vast, likely sequence-complete libraries that are stable for significant amounts of time. These libraries contain trillions of unique oligomer sequences, and are the largest deliberately prepared to date. Dependence on temperature, concentration, salinity, and presence of congeners are studied, to survey geochemical settings on the primitive Earth and other solar system environments.

21. Li Y et al. 2020. Enzyme Mimetic Active Intermediates for Nitrate Reduction in Neutral Aqueous Media, Angewandte Chemie 59, 9744-9750.

The paper presents that a pentavalent $MoV(=O)S_4$ species served as an enzyme-mimetic active intermediate for the nitrite reduction reduction (NRR). Potentiometric titration analysis revealed that a redox synergy among MoV−S, S radicals, and $MoV(=O)S_4$ likely play a key role in stabilizing $MoV(=O)S_4$, showing the importance of secondary interactions in facilitating NRR. The first identification and characterization of an oxo- and thiolate-ligated Mo intermediates pave the way to the molecular design of efficient enzyme mimetic NRR catalysts in aqueous solution.

22. He D et al. 2020. Atomic-scale evidence for highly selective electrocatalytic N−N coupling on metallic MoS_2. Proceedings of the National. Academy of Sciences 117, 31631-31638.

The paper presents atomic-scale evidence on how metallic MoS_2 shows significantly higher selectivity compared to the semiconducting phase during multielectron reduction of nitrite to nitrous oxide. Namely, a reaction intermediate specific to metallic MoS_2 increases the selectivity by decoupling the proton and electron transfer steps. This has previously been shown to be a universal mechanism to enhance selectivity, and therefore, this work opens directions of the application of 2D materials toward selective electrocatalysis.

* [11] **Escaping the lab to understand the evolution of the early chemosphere**

*23. Chandru K, Guttenberg N, Giri C, Hongo Y, Butch C, Mamajanov I, Cleaves HJ. 2018. Simple prebiotic synthesis of high diversity dynamic combinatorial polyester libraries. Communications Chemistry 1, 30.

The paper presents an experimental study of oligomerization of alpha-hydroxy acids, a class of plausibly abundant prebiotic monomers, to form vast, likely sequence-complete libraries that are stable for significant amounts of time. These libraries contain trillions of unique oligomer sequences, and are the largest deliberately prepared to date. Dependence on temperature, concentration, salinity, and presence of congeners are studied, to survey geochemical settings on the primitive Earth and other solar system environments.

[12] **Formation of biomolecules.**

*24. Fahrenbach AC, Giurgiu C, Tam CP, Li L, Hongo Y, Aono M, Szostak JW. 2017. Common and potentially prebiotic origin for precursors of nucleotide synthesis and activation. Journal of the American Chemical Society

139, 8780-8783.

The paper demonstrates a prebiotic synthesis pathway for 2-aminoimidazole, a superior activating group in non-enzymatic RNA polymerization, which shares a common mechanism with that for 2-aminooxazole, a key intermediate in prebiotic nucleotide synthesis. Inputs consist of only glycolaldehyde, cyanamide, phosphate and ammonium ion, while pH and ammonium concentration determine which product is favored. The common synthetic origin of 2-aminoimidazole and 2-aminooxazole and their distinct reactivities are suggestive of a reaction network that could lead to both the synthesis of RNA monomers and to their subsequent chemical activation for reactions such as ligation.

*25. Yi R, Cleaves, HJ, Fahrenbach A. 2020. A continuous reaction network that produces RNA precursors. Proceedings of the National Academy of Sciences 117, 13267-13274.

In this paper ELSI researchers Yi, Cleaves, and Fahrenbach demonstrated RNA precursor synthesis from a simple mixture of ammonium, sodium chloride, and HCN, with cyanide as the only carbon source. The reaction sequence combined radiolysis and dry down – two geochemical possibilities on the early Earth, and avoided "hands on" chemical approaches, demonstrating that relevant prebiotic precursors could be formed under reasonable geochemical conditions without sophisticated laboratory setups.

[13] **Understanding the nature of the first cell.**

*26. Kuruma Y, Ueda T. 2015. The PURE system for the cell-free synthesis of membrane proteins. Nature Protocols 10, 1328-1344.

This paper describes how membrane protein complexes, which are essential to the viability of cells, can be artificially synthesized starting from gene expression in a cell-free system. Using a reconstructed cell-free extract known as the PURE system, ATP synthase and the Sec Translocon were artificially synthesized and their activities were determined. The demonstrated technique improves the possibility of making functional membranes in artificial cells, on the way to reproducing the emergence of cellular life in the laboratory.

*27. Jia TZ, Chandru K, Hongo Y, Afrin R, Usui T, Myojo K, Cleaves, HJ. 2019. Membraneless polyester microdroplets as primordial compartments at the origins of life. Proceedings of the National Academy of Sciences. 116, 15830-15835.

It is possible that membranless compartments were a precursor to membranes involved in molecular segregation in early life. In this paper, ELSI researchers showed that poly-hydroxy acids can polymerize to form colloids capable of binding small molecules and proteins. Furthermore, the colloids can scaffold a lipid bi-layer, hinting at a possible prebiotic bridge between membrane-less and membrane containing life.

[14] **Understanding the nature of the first genome: "What were the genomes of the first community like?"**

*28. Berkemer SJ, McGlynn SE. 2020. A New Analysis of Archaea–Bacteria Domain Separation: Variable Phylogenetic Distance and the Tempo of Early Evolution. Molecular Biology and Evolution. 37, 2332–2340.

This paper analyzed the bacterial, archaeal, and inter-domain evolutionary history of thousands of gene families. The authors found that protein families involved in informational processes retain phylogenetic signal to a greater degree than those involved in metabolism, suggesting that the modular arrangement of metabolism - with its attendant horizontal gene transfer - has erased the ability to infer with confidence the metabolic capacity of the LUCA. Furthermore, Berkemer and McGlynn tested a hypothesis first developed by Woese and Fox in their seminal 1977 paper on the progenote; they discovered a small set of protein families which show a signal of rapid evolutionary rates at or before the time of the separation of the archaea-bacteria domains. Finally, they conducted a re-analysis of a famous recent work and found that the results of this former study were at a level of accuracy such to be expected by chance, tempering strong claims about the

physiology of early life as observed from the perspective of molecular phylogenetics.

[15] **Geochemical and Genomic Co-evolution**

*29. Giovannelli D, Sievert AM, Hügler M, Markert S, Becher D, Schweder T, Vetriani C. 2017. Insight into the evolution of microbial metabolism from the deep-branching bacterium, Thermovibrio ammonificans. Elife 6, e18990

The paper performs a phylogenetic and functional reconstruction of the core metabolism of the thermophilic, chemoautotrophic bacterium Thermovibrio ammonificans. The authors identify two distinct groups of genes: one encoding enzymes that do not require oxygen and use substrates of geothermal origin; the second apparently a more recent acquisition reflecting adaptations to cope with the rise of oxygen on Earth. They also report the first bioinformatic evidence for joint presence of enzymes from the two oldest carbon fixation pathways -- the Wood-Ljungdahl and reductive TCA pathways -- in a single organism. They infer that the ancestor of the Aquificae was a hydrogen oxidizing autotroph with a hybrid pathway for CO2 fixation, and that as more efficient terminal electron acceptors became available, this lineage acquired genes that increased its metabolic flexibility while retaining ancestral metabolic traits.

30. Barry PH, … Giovanelli D, Nakagawa M et al. 2019. Forearc carbon sink reduces long-term volatile recycling into the mantle. Nature 568, 487-492.

As an example of this highly interdisciplinary and renowned work, ELSI researchers Nakagawa and Giovannelli, together with an international team, investigated the fate of carbon in a subduction zone [6] with isotopes, microbiology, and geological techniques. Their work indicated that subducted carbon becomes sequestered due to the formation of the mineral calcite. Furthermore, the study indicated that microbial chemolithotrophy, contributed to a small but noticeable amount of carbon uptake in the system. This result shows the dual importance of life, and the Earth, in controlling the global elemental cycles, and allow for a recalibration of carbon budgets associated with slab subduction.

[16] **Evidence for major transitions.**

*31. Sim MS, Ogata H, Lubitz W, Adkins JF, Sessions AL, Orphan VJ, McGlynn SE. 2019. Role of APS reductase in biogeochemical sulfur isotope fractionation. Nature communications 10, 44.

This paper reports the sulfur kinetic isotope effect of the enzyme adenosine phosphosulfate reductase (APR), which is present in all known organisms conducting microbial sulfate reduction, and catalyzes the first reductive step in the pathway. The authors use these measurements to reinterpret the sedimentary sulfur isotope record over geological time. Archean sediments lack fractionation exceeding the Apr value of 20‰, indicating that sulfate reducers had access to ample electron donors to drive their metabolisms. Large fractionations in post-Archean sediments suggest a decline of favorable electron donors as aerobic and other high potential metabolic competitors evolved. These findings link cellular biochemistry and physiology with the rock record of life on Earth.

*32. Johnson JE, Webb SM, Thomas K, Ono S, Kirschvink JL, Fischer WW. 2013. Manganese-oxidizing photosynthesis before the rise of cyanobacteria. Proceedings of the National Academy of Sciences 110, 11238-11243.

To illuminate the evolutionary history of biological water-splitting photosynthesis, this paper examines the behavior of the ancient Mn cycle using drill cores through an early Paleoproterozoic succession (2.415 Ga) preserved in South Africa. The cored strata contain substantial Mn enrichments (up to ~17 wt %) well before strata associated with the rise of oxygen at ~2.2 Ga, and the enrichments are hosted exclusively in carbonate mineral phases derived from reduction of Mn oxides. Independent proxies for O2 show that the original Mn-oxide phases were not produced by reactions with O2 but with some other strong oxidant, suggesting that the oxidative branch of the Mn cycle predated the rise of oxygen and was a transitional

photosystem from which the water-oxidizing complex of photosystem II evolved.

[17] **Role of viruses in evolution**

*33. Rensen EI, Mochizuki T, Quemin E, Schouten S, Krupovic M, Prangishvili D. 2016. A virus of hyperthermophilic archaea with a unique architecture among DNA viruses. Proceedings of the National Academy of Sciences 113, 2478-2483.

This paper reports the isolation and characterization of a filamentous archaeal DNA virus, Pyrobaculum filamentous virus 1 (PFV1), infecting the hyperthermophilic archeon Pyrobaculum, which has striking structural similarity to the human RNA ebolavirus. PFV1 exhibits a type of virion organization not previously observed in DNA viruses, but superficially similar to that of negative-sense RNA viruses of the family Filoviridae, including Ebola virus and Marburg virus. Its genome, containing 39 predicted ORFs, most of which do not show similarities to sequences in public databases, forms a new viral family and suggests convergent evolution of virus structure. The results provide new insights into the diversity of architectural solutions used by filamentous viruses.

[18] **Emergent properties of evolution**

*34. Petrie KL, Palmer ND, Johnson DT, Medina SJ, Yan SJ, Li V, Burmeister AR, Meyer JR. 2018. Destabilizing mutations encode nongenetic variation that drives evolutionary innovation. Science 359, 1542-1545.

Evolutionary innovations are often achieved by repurposing existing genes to perform new functions; however, the mechanisms enabling the transition from old to new remain controversial. This paper shows that the mutations in bacteriophage λ's host-recognition gene J that confer enhanced adsorption to λ's native receptor, LamB, along with the ability to access a new receptor, OmpF, do so by creating conformational bistability of J. They thus function by generating multiple phenotypes from a single genotype. The results show how nongenetic protein variation can catalyze an evolutionary innovation, a mechanism that may have been even more important in the early stages of life when genome length and replication accuracy were limited.

*35. Hoyal Cuthill JF, Morris SC. 2017. Nutrient-dependent growth underpinned the Ediacaran transition to large body size. Nature Ecology & Evolution 1, 1201-1204.

The paper seeks to explain the enigmatic fractal growth patterns of the Ediacaran fauna known as rangeomorphs, as a result of the way the most primitive developmental programs interacted with environmental resource flows and constraints. Using micro-computerized tomography and photographic measurements, alongside mathematical and computer models, the authors demonstrate that growth of rangeomorph branch internodes declined as their relative surface area decreased, suggesting that frond size and shape were directly responsive to levels of oxygen and other nutrients. The results show that a scale-invariant growth algorithm can generate both complex and adaptive shapes by using physiological and ecological feedbacks.

[19] **Theory in the origin of the Genetic Code.**

*36. Ilardo, M, Meringer M, Freeland S, Rasulev B, Cleaves HJ. 2015. Extraordinarily adaptive properties of the genetically encoded amino acids. Scientific Reports 5,9414.

The paper uses computational chemistry methods to assess how thoroughly the biologically coded amino acids cover a range of physico-chemical properties associated with adaptedness. The biological amino acid alphabet is compared to random sets of amino acids drawn from a computationally generated compound library containing 1913 alternative amino acids that lie within the molecular weight range of the encoded amino acids. The results of the property comparison indicate that the set of 20 genetically encoded amino acids has been selected as a largely global optimum, suggesting that any aqueous biochemistry would use a very similar set.

*37. Froese T, Campos JI, Fujishima K, Kiga D, Virgo N. 2018. Horizontal transfer of code fragments between protocells can explain the origins of the genetic code without vertical descent. Scientific Reports 8, 3532.

The paper refines a widely-held view originally due to Carl Woese, that early cellular evolution was dominataed by horizontal exchange of cellular components among loosely organized protocells collectively termed a "progenote". Using an iterated learning model, the authors simulate communal evolution based on horizontal transfer of code fragments, possibly involving pairs of tRNAs and their cognate aminoacyl tRNA synthetases or a precursor tRNA ribozyme capable of catalyzing its own aminoacylation. This model is the first to show explicitly that regularity, optimality, and (near) universality of a genetic code could have emerged entirely via horizontal interactions, without presupposing some form of vertical inheritance.

* [20] **Towards a universal biology.**

38. Smith DE et al. Seeding Biochemistry on Other Worlds: Enceladus as a Case Study. 2021. Astrobiology 21(2) [DOI: 10.1089/ast.2019.2197]

Smith et al. used network expansion algorithms to evaluate the ability of microbes found on Earth to grow on Enceledus. They found that none of the 307 microbial genomes analyzed harbored reaction networks which were predicted to result in the production of viable biomass. A key result of this study was the ability to identify which specific compounds on a planetary body could result in the ability of these organisms to prosper, this providing a list of priority detection targets for future missions in space.

*39. Meringer M, Cleaves HJ, Freeland SJ. 2013. Beyond terrestrial biology: Charting the chemical universe of α-amino acid structures. Journal of Chemical Information and Modeling 53, 2851-2862.

This paper uses computer software based on graph theory and constructive combinatorics in order to conduct an efficient and exhaustive search of the chemical structures for possible α-amino acids consistent with two definitions of relevance to biological coded proteins. The paper presents two virtual libraries of α-amino acid structures corresponding to these different approaches, comprising 121 044 and 3 846 structures, respectively. This demonstration of functionally defined and exhaustive molecule sets suggests a simple approach to exploring much larger, as yet uncomputed, libraries of interest.

*40. Virgo N, Guttenberg N. 2015. Heredity in Messy Chemistries. Artificial Life Conference Proceedings 13, 325-332.

This paper makes a connection between the distribution of independent autocatalytic sets in random chemical networks and percolation phase transitions in connected graphs. The number of distinct autocatalytic sets that offer escape from a fixed chemical profile determines the capacity of a chemical system for hereditary dynamics. Maximizing the number of such escape routes identifies a critical density of interactions between reactants, which maximizes the evolutionary capacity of an autocatalytic chemical system. The evolutionary capacity at criticality in random networks scales logarithmically with their total chemical diversity. Autocatalytic chemistries likely supported an early phase of chemical evolution, and the hereditary capacity of this phase should have determined whether a transition to later, more complex, sequence-based mechanisms was achievable.

Appendix 1-2 List of Papers of Representative of Interdisciplinary Research Activities

* List **up to 20 papers** underscoring each interdisciplinary research activity and give brief accounts (within 10 lines).
* For each, write the author name(s); year of publication; journal name, volume, page(s), and article title. Any listing order may be used as long as format is the same. If a paper has many authors, underline those affiliated with the Center.
* If a paper has many authors (say, more than 10), all of their names do not need to be listed.

1. Kurokawa H, Foriel J, Laneuville M, Houser C, Usui T. 2018. Subduction and atmospheric escape of Earth's seawater constrained by hydrogen isotopes, Earth Planet. Sci. Lett., 497, 149-160.

   The hydrogen isotopic deuterium/hydrogen (D/H) ratio reflects the global cycling and evolution of water on Earth as it fractionates through planetary processes. This paper reconstructs the early Earth's ocean volume as a function of time using D/H ratio constraints in the mantle and oceans. It models the combined effects of seafloor hydrothermal alteration, chemical alteration of continental crust, slab subduction, and hydrogen escape from the early Earth, as well as degassing at mid-ocean ridges, hot spots, and arcs. Improved fractionation models suggest that in order to produce observed isotope ratios, secular net regassing and/or early fast plate tectonics are needed, and that the volume of Earth's initial oceans could have been 2 to 3 times larger than those on Earth today.

2. Aono M, Naruse M, Kim SJ, Wakabayashi M, Hori H, Ohtsu M, Hara M. 2013. Amoeba-Inspired Nanoarchitectonic Computing: Solving Intractable Computational Problems Using Nanoscale Photoexcitation Transfer Dynamics. Langmuir, 29, 7557-7564.

   Machine learning, artificial intelligence, neural networks, etc., are among the most significant advances in modern technology, and already these novel approaches are changing the world and opening new opportunities. These techniques are rooted in mimicry of real natural processes, utilizing the tools that nature used to produce life from non-life, or to cause major revolutions in the history of life. Aono et al. take this approach even further, using actual biological functions to perform computational tasks that are impossible to solve on today's massive computers. This is an ELSI-inspired way of thinking, in that the way to solve challenging questions is to find inspiration in the natural world.

3. Brasser R, Mojzsis SJ, Matsumura S, Ida S. 2017. The cool and distant formation of Mars. Earth and Planetary Science Letters, 468, 85-93.

   The presence of Mars has long presented an enigma for planet formation models, in reconciling its distant orbit with the proximity (and early migration) of the gas giants. Some models proposed Mars formed closer to the Sun, and was later scattered outward to its present position, which predicts that it should have a similar chemical composition to the Earth. This collaboration combines planetary formation theory and cosmo-chemical constraints to argue that Mars could have formed at orbital radii similar to its present-day position in the solar system, and offers new constraints on the dynamical conditions in that must have prevailed in the early solar system.

4. Kimura J, Kitadai N. 2015. Polymerization of building blocks of life on Europa and other icy moons. Astrobiology, 15, 430-44.

   Icy moons such as the Galilean satellite Europa are heated internally by tidal forces driven by orbital dynamics, instead of relying on solar radiation. This may significantly expand the "habitable" zone by producing environments conducive for life. This collaboration between planetary and thermodynamical modelers examined the energetics of polymerization that could be driven in these environments. They find that polymerization of complex organics (building blocks of life) should be energetically favored in moons like Europa.

5. Scharf C, Virgo N, Cleaves HJ, Aono M, Aubert-Kato N, Aydinoglu A, Barahona A, Barge LM, Benner SA, Biehl M, Brasser R, Butch CJ, Chandru K, Cronin L, Danielache S, Fischer J, Hernlund J, Hut P, Ikegami T, Kimura J, Kobayashi K, Mariscal C, McGlynn S, Menard B, Packard N, Pascal R, Pereto J, Rajamani S, Sinapayen L, Smith E, Switzer C, Takai K, Tian F, Ueno Y, Voytek M, Witkowski O, Yabuta H. 2015. A Strategy for Origins of Life Research, Astrobiology 15, 1031-1042

   A major challenge in origin of life studies is how to frame the problem in a way that allows for practical strategical decisions to be made, such as establishing key priorities and grand challenges as a target for researchers across many disciplines. This paper was the result of a workshop held at ELSI, combining scholars from artificial life, planetary science, life science, chemistry, astrophysics, and philosophy. Numerous key roadblocks were identified, and strategies for addressing these were mapped out and implemented as part of ELSI's organizational strategy.

6. Ballmer M, Houser C, Hernlund JW, Wentzcovitch RM, Hirose K. 2017. Persistence of strong silica-enriched domains in the Earth's lower mantle. Nature Geoscience, 10, 236-240.

   Mantle convection is the flow and circulation of rock through the Earth's deep mantle, a process that is intimately connected to plate tectonics. While fluid-like models of this process have been used extensively in the past, there are many inconsistencies between the predictions and both geochemical and seismological observations. This study introduces the idea of memory effects in deep mantle dynamics by a combination of chemical heterogeneity and its feedbacks on rock rheology. The Bridgmanite-Enriched Ancient Mantle Structures (BEAMS) model can resolve all of the outstanding paradoxes in deep Earth science, including seismically imaged stagnant slabs of subducted lithosphere, persistence of an unmixed reservoir rich in primordial noble gases, and the fixed geographical positions of hot mantle plumes that trace out volcanic hot spots like Hawaii.

7. Rein H, Fujii Y, Spiegel DS. 2014. Some inconvenient truths about biosignatures involving two chemical species on Earth-like exoplanets. Proceedings of the National Academy of Sciences, 111, 6871-6875

   Chemical disequilibrium in a planetary atmosphere is commonly invoked as a potential biomarker in a planet, since abiotic processes alone are thought to run close to equilibrium and only biological processes can maintain a perpetually reactive state. This study shows that this approach can be fooled by the presence of a moon orbiting a planet, which has its own atmosphere with a distinct composition. Since it is impossible to rule out the presence of a moon using currently available observations, such a biomarker is not reliable.

8. Laneuville M, Kameya M, Cleaves HJ. 2018. Earth Without Life, A Systems Model of a Global Abiotic Nitrogen Cycle. Astrobiology, 18 (7)

   Nitrogen plays a major role in biotic processes and is the main component of Earth's atmosphere. This paper develops a kinetic mass-flux model of nitrogen cycles on early Earth before the emergence of life. The model suggests that significant concentrations of reactive nitrogen species, including nitrate and ammonia, would have been present in the early oceans, with implications for prebiotic chemistry and metabolic reactions of early life.

9. Yamamoto M, Nakamura R, Takai K. 2018. Deep sea hydrothermal fields as natural power plants. ChemElectroChem, 5 (16), 2162-2166.

   Deep sea hot springs are special environments with abundant heat, chemical, and (it turns out)

electrical energy. This collaboration between geobiologists and an electrochemist analyzed these energy flows and the possibility to create new kinds of chemical reaction networks and a new hypothesis of electricity-sustained life.

10. Moore EK, Jelen BI, Giovannelli D, Raanan H, Falkowski PG. 2017. Metal availability and the expanding network of microbial metabolisms in the Archaean eon. Nature Geoscience, 10 (9), 629.

    The chemistry of life is driven by redox (electron transfer) which is catalyzed by enzymes that contain transition metals. As Earth's environmental conditions have changed, so have the availability of transition metals to operate specific metabolic processes. This study found that the diversity of metals used in enzymes has increased over time, suggesting that such changes in environmental conditions strongly influenced life on Earth.

11. Barry PJ, de Moor JM, D Giovannelli D et al. 2019. Forearc carbon sink reduces long-term volatile recycling into the mantle. Nature, 568 (7753), 487-492

    Nakagawa and Giovannelli, together with an international team, showed the dual importance of life, and the Earth in controlling the global elemental cycles. They investigated the fate of carbon in a subduction zone with isotopes, microbiology, and geological techniques. Their work indicated that subducted carbon becomes sequestered due to the formation of the mineral calcite. Furthermore, the study indicated that microbial chemolithotrophy, contributed to a small but noticeable amount of carbon uptake in the system. This result shows the dual importance of life, and the Earth, in controlling the global elemental cycles, and allow for a recalibration of carbon budgets associated with slab subduction.

12. Guttenberg N, Virgo N, Chandru K, Scharf C, Mamajanov I. 2017. Bulk measurements of messy chemistries are needed for a theory of the origins of life. Philosophical Transactions of the Royal Society A, 375, 20160347

    The paper addresses the disconnect, between Origin of Life research using restricted and controlled chemical models, and the likelihood that the kinds of chemical systems involved in the origins of terrestrial life produced a wide range of compounds via a wide range of mechanisms. The authors propose that experimental approaches to the origins of life should be expanded to include the study of 'functional measurements', which means inclusively studying bulk properties of chemical systems and their interactions with other compounds, structure-formation and other behaviors, even in cases where the precise composition and mechanisms are unknown.

13. McGlynn SE. 2021. Biological Isotope Fractionation and Earth History, from Enzymes, to Cells, to Ecosystems. Metals, Microbes, and Minerals. The Biogeochemical Side of Life, 59-80

    In this book chapter, McGlynn integrated the kinetic and equilibrium isotope geochemistry into biological activity hierarchies of enzymes, cells, and whole ecosystems. By understanding how atoms and their isotopes flow through these different hierarchies, it is possible to gain insight into the type, magnitude, and energetic state of life biological processes by measuring isotope ratios. A longer-term goal is to decode the evolutionary relationships which may underly and control kinetic isotope fractionation at the enzyme level.

14. Ramirez RM. 2020. A Complex Life Habitable Zone Based on Lipid Solubility Theory. Scientific Reports, 10, 7432

    Understanding the limits of habitability is foundational to the search of life in the universe. In this paper, Ramirez used data from laboratory experiments – in combination with an energy balance derived estimate for the habitable zone – to determine solar limits on the formation of complex life based on respiration in the universe.

15. Guttenberg N, Chen H, Mochizuki T, Cleaves HJ. 2021. Classification of the Biogenicity of Complex Organic Mixtures for the Detection of Extraterrestrial Life. Life, 11(3), 234

Although we think we know life when we see it, it remains difficult to definitively differentiate historical instances of microbial life from chemical processes. Furthermore, it is reasonable to think that life on other planets would not be recognized as microbial life is on Earth. To enable differentiation of life from non-life, Guttenberg, Mochizuki, and Cleaves used algorithmic analyses of mass spectrometry data to identify relational distributions between organic carbon molecules. The derived understanding of these relationships allows for the identification of biological from abiological materials. The technique will be useful on Earth, and during space missions.

16. Hattori S, Kamezaki K, Yoshida N. 2020. Constraining the atmospheric OCS budget from sulfur isotopes. PNAS, August 25, 117 (34), 20447-20452

    Isotope fractionation can provide evidence for the occurrence of both biological and abiological processes. In this paper, Yoshida et al applied new analytical techniques on the sulfur isotopes of carbonyl sulfide, which can be produced biologically during oxygenic photosynthesis and also anthropologically. Using this approach, the authors were able to demonstrate the relevance and occurrence of this anthropological source of COS emission into the atmosphere.

17. Ooka H, McGlynn S, Nakamura R. 2019. Electrochemistry at deep-sea hydrothermal vents: utilization of the thermodynamic driving force towards the autotrophic origin of life. ChemElectroChem, 6, 1316-1323

    All life on Earth gains energy from electron transfer processes. However, it remains unknown what the first electron donor/acceptor pairs were in the earliest life forms. In this paper, McGlynn and Nakamura quantified how much energy gain can be achieved in redox processes occurring at a deep sea hydrothermal vent. The authors demonstrated that sufficient reducing power is available for carbon reduction starting from carbon dioxide.

18. Tasker EJ, Laneuville M, Guttenberg N. 2019. Estimating Planetary Mass with Deep Learning. The Astronomical Journal, 159 (2), 41.

    ELSI researchers Tasker, Laneuville and Guttenberg combined forces to gain information on planetary masses through a deep learning approach. By taking advantage of expertise in both planetary science, and machine learning, they were able to develop a new code that could estimate a planet property, given the other known bulk and orbital properties. By estimating missing values in the exoplanet catalogue, a greater understanding of both the known planets can be acquired and used to develop a better and more complete picture of how planets like our own formed.

Appendix 1-3

Major Awards, Invited Lectures, Plenary Addresses (etc.) (within 2 pages)

*Prepare the information below during the period from the start of the center through March 2021.

1. Major Awards

*List main internationally-acclaimed awards received/unofficially announced in order from the most recent.
*For each, write the recipient's name, the name of award, and the date issued.
In case of multiple recipients, underline those affiliated with the center.

Date	Recipient's name	Name of award
2020	Naohiro Yoshida	Clair C. Patterson Medal
2020	Naohiro Yoshida	Geochemistry Fellow
2018	Naohiro Yoshida	Medal of Honor with Purple Ribbon
2018	Naohiro Yoshida	American Geophysical Union Fellow
2017	George Helffrich	American Geophysical Union Fellow
2016	Kei Hirose	Fujihara Award
2016	Tetsuo Irifune	Robert Wilhelm Bunsen Medal
2015	Tetsuo Irifune	Medal of Honor with Purple Ribbon
2015	Joseph Kirschvink	Geological Society of America Fellow
2015	Joseph Kirschvink	Royal Institute of Navigation Fellow
2014	Joseph Kirschvink	George P. Woollard Award
2014	Shigenori Maruyama	GSA Honorary Fellow
2014	Tetsuo Irifune	A. E. Ringwood Medal
2014	Albert C. Fahrenbach	IUPAC-SOLVAY International Award for Young Chemists
2014	Shigenori Maruyama	Fellow of the American Geochemical Society
2014	Kei Hirose	Fellow of The European Association for Geochemistry
2014	Kei Hirose	Fellow of the American Geochemical Society

2. Invited Lectures, Plenary Addresses (etc.) at International Conferences and International Research Meetings

*List up to 20 main presentations in order from most recent.
*For each, write the lecturer/presenter's name, presentation title, conference name and date(s)

Date(s)	Lecturer/Presenter's name	Presentation title	Conference name
Sep. 7, 2020	Tetsuo Irifune	Application of multi-anvil LVP technology to ultrahigh pressure synthesis of transparent nano-ceramics	Europe High Pressure Group International Meeting (online)
Jun. 24, 2020	Naohiro Yoshida	Frontier modes of light element isotopic substitution as a key for origin studies: Patterson Medal lecture	Goldschmidt Conference 2020 (virtual)
May 15,	Yasuhito Sekine	Recurring Slope Lineae on Earth:	JpGU-AGU joint

2020		Implications for hydrological cycles and potential habitability on Mars	meeting
Jan. 15, 2020	Shigeru Ida	Orbital migration, pebble vs planetesimal accretion - Implication for Observation of Exoplanet Atmosphere -	ARIEL Science conference, ESTEC, Netherlands
Dec. 12, 2019	George Helffrich	Transfer of SiO_2 from the core to the mantle and its fate in the Earth in early and present times	AGU Fall Meeting 2019
Dec. 11, 2019	Tetsuo Irifune	Synthesis of transparent nano-ceramics under ultrahigh pressure	Materials Research Meeting-2019
Dec. 09, 2019	Kei Hirose	SiO_2 and molten silicate release from the core; implications for dynamo and material transport from the core to mantle	AGU Fall Meeting 2019
Sep. 12, 2019	Shawn McGlynn	New insights into microbial iron cycling at a marine ferrous carbonate hot spring	Marine Biotechnology Conference 2019
Jan. 14-19, 2018	Shigenori Maruyama	Nine Requirements for the Birth Place of Life and Three-Step Evolution of First Life	Gordon Research Conference, "Origins of Life"
Aug. 21, 2017	Piet Hut	When Will Science Become Fully Empirical?	International Society for Theoretical Psychology, Biennial Conference
Jul. 16-21, 2017	Jack Szostak	The Nonenzymatic Copying of RNA Templates	18th ISSOL Meeting
Jun. 26 – Jul. 1, 2016	Kei Hirose	Keynote: Deep Mantle Melting in the Past and at Present	Goldschmidt Conference 2016
Jan. 19, 2016	Masashi Aono	Oligopeptide formation in geysers	Gordon Research Conference, "Origins of Life"
Dec. 14-18, 2015	Kirschvink, J.L. & Kobayashi, A.	Biophysical Puzzles Concerning Magnetite-Based Magnetoreception in the Common Nematode, *Caenorhabditis elegans*	AGU Fall Meeting 2015
Nov. 15, 2015	David Eric Smith	Phase transitions in the origin of the biosphere	Carnegie Workshop "Reconceptualizing the Origin of Life"
Jul. 7-10, 2014	Tetsuo Irifune	Multi-anvil high-pressure technology and mineralogy of the deep mantle	Australian Earth Sciences Convention 2014
Jan. 12-17, 2014	Yuichiro Ueno	Archean geology and its Implications	Gordon Research Conference, "Origins of Life"

Appendix 1-4 2020 List of Center's Research Results

Refereed Papers

- List only the Center's papers published in 2020. (Note: The list should be for the calendar year, not the fiscal year.)

(1) Divide the papers into two categories, A and B.
   A. WPI papers
      List papers whose author(s) can be identified as affiliated with the WPI program (e.g., that state "WPI" and the name of the WPI center (WPI-center name)). (Not including papers in which the names of persons affiliated with the WPI program are contained only in acknowledgements.)
   B. WPI-related papers
      List papers related to the WPI program but whose authors are not noted in the institutional affiliations as WPI affiliated. (Including papers whose acknowledgements contain the names of researchers affiliated with the WPI program.)

      Note: On 14 December 2011, the Basic Research Promotion Division in MEXT's Research Promotion Bureau circulated an instruction requiring paper authors to include the name or abbreviation of their WPI center among their institutional affiliations. From 2012, the authors' affiliations must be clearly noted.

(2) Method of listing paper
   - List only refereed papers. Divide them into categories (e.g., original articles, reviews, proceedings).
   - For each, write the author name(s); year of publication; journal name, volume, page(s), and article title. Any listing order may be used as long as format is consistent. (The names of the center researchers do not need to be underlined.)
   - If a paper has many authors (say, more than 20), all of their names do not need to be listed.
   - Assign a serial number to each paper to be used to identify it throughout the report.
   - If the papers are written in languages other than English, underline their serial numbers.
   - Order of Listing
      A. WPI papers
         1. Original articles
         2. Review articles
         3. Proceedings
         4. Other English articles

      B. WPI-related papers
         1. Original articles
         2. Review articles
         3. Proceedings
         4. Other English articles

(3) Submission of electronic data
   - In addition to the above, provide a .csv file output from the Web of Science (e.g.) or other database giving the paper's raw data including Document ID. (Note: the Document ID is assigned by paper database.)
   - These files do not need to be divided into paper categories.

(4) Use in assessments
   - The lists of papers will be used in assessing the state of WPI project's progress.
   - They will be used as reference in analyzing the trends and whole states of research in the said WPI center, not to evaluate individual researcher performance.
   - The special characteristics of each research domain will be considered when conducting assessments.

(5) Additional documents
   - After all documents, including these paper listings, showing the state of research progress have been submitted, additional documents may be requested.

A. WPI papers

1. Original articles

1. Afrin, Rehana; Yano, Taka-aki; Jia, Tony Z.; Cleaves, H. James, II; Hara, Masahiko, Unbinding events of amino acids and peptides from water-pyrite interfaces: A case study of life's origin on mineral surfaces. Biophysical Chemistry, 260, 106338 (2020).
2. Ay, Nihat; Polani, Daniel; Virgo, Nathaniel, Information Decomposition Based on Cooperative Game Theory. Kybernetika, 56, 979-1014 (2020).
3. Bartlett, Stuart; Wong, Michael L., Defining Lyfe in the Universe: From Three Privileged Functions to Four Pillars. Life (Basel, Switzerland), 10, 42 (2020).
4. Basili, Marco; Quero, Grazia Marina; Giovannelli, Donato; Manini, Elena; Vignaroli, Carla; Avio, Carlo Giacomo; De Marco, Rocco; Luna, Gian Marco, Major Role of Surrounding Environment in Shaping Biofilm Community Composition on Marine Plastic Debris. Frontiers in Marine Science, 7, 262 (2020).
5. Batyrova, Khorcheska A.; Khusnutdinova, Anna N.; Wang, Po-Hsiang; Di Leo, Rosa; Flick, Robert; Edwards, Elizabeth A.; Savchenko, Alexei; Yakunin, Alexander F., Biocatalytic in Vitro and in Vivo FMN Prenylation and (De)carboxylase Activation. ACS Chemical Biology, 15, 1874-1882 (2020).

6. Berkemer, Sarah J.; McGlynn, Shawn E., A New Analysis of Archaea-Bacteria Domain Separation: Variable Phylogenetic Distance and the Tempo of Early Evolution. Molecular Biology and Evolution, 37, 2332-2340 (2020).
7. Bertran, Emma; Ward, Lewis M.; Johnston, David T., Draft Genome Sequence of Desulfofundulus thermobenzoicus subsp. thermosyntrophicus DSM 14055, a Moderately Thermophilic Sulfate Reducer. Microbiology Resource Announcements, 9, e01416-19 (2020).
8. Bertran, Emma; Ward, Lewis M.; Johnston, David T., Draft Genome Sequence of Acidianus ambivalens DSM 3772, an Aerobic Thermoacidophilic Sulfur Disproportionator. Microbiology Resource Announcements, 9, e01415-19 (2020).
9. Bertran, Emma; Ward, Lewis M.; Johnston, David T., Draft Genome Sequence of Desulfobacter hydrogenophilus DSM 3380, a Psychrotolerant Sulfate-Reducing Bacterium. Microbiology Resource Announcements, 9, e00203 (2020).
10. Bindi, Luca; Bendeliani, Aleksandra; Bobrov, Andrey; Matrosova, Ekaterina; Irifune, Tetsuo, Incorporation of Mg in phase Egg, $AlSiO_3OH$: Toward a new polymorph of phase H, $MgSiH_2O_4$, a carrier of water in the deep mantle. American Mineralogist, 105, 132-135 (2020).
11. Brasser, R., Efficient tidal dissipation in Deimos. Icarus, 347, 113791 (2020).
12. Brasser, R.; Mojzsis, S. J., The partitioning of the inner and outer Solar System by a structured protoplanetary disk. Nature Astronomy, 4, 492-499 (2020).
13. Brasser, R.; Werner, S. C.; Mojzsis, S. J., Impact bombardment chronology of the terrestrial planets from 4.5 Ga to 3.5 Ga. Icarus, 338, 113514 (2020).
14. Brovarone, Alberto Vitale; Butch, Christopher J.; Ciappa, Alessandra; Cleaves, Henderson J., II; Elmaleh, Agnes; Faccenda, Manuele; Feineman, Maureen; Hermann, Joerg; Nestola, Fabrizio; Cordone, Angelina; Giovannelli, Donato, Let there be water: How hydration/dehydration reactions accompany key Earth and life processes. American Mineralogist, 105, 1152-1160 (2020).
15. Brovarone, A. Vitale; Sverjensky, D. A.; Piccoli, F.; Ressico, F.; Giovannelli, D.; Daniel, I, Subduction hides high-pressure sources of energy that may feed the deep subsurface biosphere. Nature Communications, 11, 3880 (2020).
16. Chandru, Kuhan; Jia, Tony Z.; Mamajanov, Irena; Bapat, Niraja; Cleaves, H. James, II, Prebiotic oligomerization and self-assembly of structurally diverse xenobiological monomers. Scientific Reports, 10, 17560 (2020).
17. Chandru, Kuhan; Mamajanov, Irena; Cleaves, H. James, II; Jia, Tony Z., Polyesters as a Model System for Building Primitive Biologies from Non-Biological Prebiotic Chemistry. Life (Basel, Switzerland), 10, 6 (2020).
18. Chun, Yewon; Kim, Dohee; Hattori, Shohei; Toyoda, Sakae; Yoshida, Naohiro; Huh, Jinhee; Lim, Ju-Hee; Park, Ji-Hyung, Temperature control on wastewater and downstream nitrous oxide emissions in an urbanized river system. Water Research, 187, 116417 (2020).
19. Despotovic, Dragana; Longo, Liam M.; Aharon, Einav; Kahana, Amit; Scherf, Tali; Gruic-Sovulj, Ita; Tawfik, Dan S., Polyamines Mediate Folding of Primordial Hyperacidic Helical Proteins. Biochemistry, 59, 4456-4462 (2020).
20. Elardo, Stephen M.; Laneuville, Matthieu; McCubbin, Francis M.; Shearer, Charles K., Early crust building enhanced on the Moon's nearside by mantle melting-point depression. Nature Geoscience, 13, 339-343 (2020).
21. Fonda, Emiliano; Polian, Alain; Shinmei, Toru; Irifune, Tetsuo; Itie, Jean-Paul, Mechanism of pressure induced amorphization of SnI4: A combined x-ray diffraction-x-ray absorption spectroscopy study. Journal of Chemical Physics, 153, 64501 (2020).
22. Fraccia, Tommaso P.; Jia, Tony Z., Liquid Crystal Coacervates Composed of Short Double-Stranded DNA and Cationic Peptides. ACS Nano, 14, 15071-15082 (2020).

23. Fujinawa, Tamaki; Sato, Tomohiro O.; Yamada, Takayoshi; Nara, Seidai; Uchiyama, Yuki; Takahashi, Kodai; Yoshida, Naohiro; Kasai, Yasuko, Validation of acetonitrile (CH_3CN) measurements in the stratosphere and lower mesosphere from the SMILES instrument on the International Space Station. Atmospheric Measurement Techniques, 13, 2119-2129 (2020).
24. Fukushi, Keisuke; Imai, Eigo; Sekine, Yasuhito; Kitajima, Takuma; Gankhurel, Baasansuren; Davaasuren, Davaadorj; Hasebe, Noriko, In Situ Formation of Monohydrocalcite in Alkaline Saline Lakes of the Valley of Gobi Lakes: Prediction for Mg, Ca, and Total Dissolved Carbonate Concentrations in Enceladus' Ocean and Alkaline-Carbonate Ocean Worlds. Minerals, 10, 669 (2020).
25. Garber, Arkadiy I.; Nealson, Kenneth H.; Okamoto, Akihiro; McAllister, Sean M.; Chan, Clara S.; Barco, Roman A.; Merino, Nancy, FeGenie: A Comprehensive Tool for the Identification of Iron Genes and Iron Gene Neighborhoods in Genome and Metagenome Assemblies. Frontiers in Microbiology, 11, 37 (2020).
26. Garrick-Bethell, Ian; Miljkovic, Katarina; Hiesinger, Harald; van der Bogert, Carolyn H.; Laneuville, Matthieu; Shuster, David L.; Korycansky, Donald G., Troctolite 76535: A sample of the Moon's South Pole-Aitken basin? Icarus, 338, 113430 (2020).
27. Godin, Paul J.; Ramirez, Ramses M.; Campbell, Charissa L.; Wizenberg, Tyler; Nguyen, Tue Giang; Strong, Kimberly; Moores, John E., Collision-Induced Absorption of CH_4-CO_2 and H_2-CO_2 Complexes and Their Effect on the Ancient Martian Atmosphere. Journal of Geophysical Research - Planets, 125, e2019JE006357 (2020).
28. Goto, Kosuke T.; Sekine, Yasuhito; Shimoda, Gen; Hein, James R.; Aoki, Shogo; Ishikawa, Akira; Suzuki, Katsuhiko; Gordon, Gwyneth W.; Anbar, Ariel D., A framework for understanding Mo isotope records of Archean and Paleoproterozoic Fe- and Mn-rich sedimentary rocks: Insights from modern marine hydrothermal Fe-Mn oxides. Geochimica et Cosmochimica Acta, 280, 221-236 (2020).
29. Grasby, Katrina L.; Jahanshad, Neda; Painter, Jodie N. et al., The genetic architecture of the human cerebral cortex. Science, 367, eaay6690 (2020).
30. Gréaux, Steeve; Zhou, Youmo; Kono, Yoshio; Yamada, Akihiro; Higo, Yuji; Irifune, Tetsuo, Thermoelastic Properties of $K_{0.7}Na_{0.3}AlSi_3O_8$ Hollandite and $NaAlSi_2O_6$ Jadeite: Implication for the Fate of the Subducted Continental Crust in the Deep Mantle. Minerals, 10, 261 (2020).
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2. Review articles

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Mercury's Surface and Composition. Space Science Reviews, 216, 66 (2020).

144. Seyler, Lauren; Kujawinski, Elizabeth B.; Azua-Bustos, Armando; Lee, Michael D.; Marlow, Jeffrey; Perl, Scott M.; Cleaves, Henderson James, II, Metabolomics As an Emerging Tool in the Search for Astrobiologically Relevant Biomarkers. ASTROBIOLOGY, 20, 1251-1261 (2020).
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151. Yi, Ruiqin; Fahrenbach, Albert; Hongo, Yayoi, Radiolytically Driven Chemical Evolution. Journal of Geography - Chigaku Zasshi, 129, 837-851 (2020).
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3. Proceedings

4. Other English articles

153. Brasser, Ramon, Clues to late accretion from Venus's atmosphere. Nature Geoscience, 13, 258-259 (2020).
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155. Irifune, Tetsuo, Preface: A brief history of nano-polycrystalline diamond. High Pressure Research, 40, 1-2 (2020).
156. Maruyama, Shigenori; Ebisuzaki, Toshikazu; Isozaki, Yukio; Kurokawa, Ken, Overview of the Special Issue "The Hadean World (Part III): Emergence of Life and Early Evolution". Journal of Geography - Chigaku Zasshi, 129, 745-749 (2020).
157. Mochitate, Katsumi; Nagano, Reiko; Toya-Nakajima, Yukiko, Bared Basement Membrane Substrata: Design, Cellular Assembly, Decellularization and Application to Tissue Regeneration and Stem Cell

Differentiation. In "Decellularized Extracellular Matrix: Characterization, Fabrication and Applications", ed. T.Yamaoka and T.Hoshiba, Royal Society of Chemistry, 51-76 (2020).
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160. Virgo, Nathaniel, The necessity of extended autopoiesis. Adaptive Behavior, 28, 23-26 (2020).
161. Witkowski, Olaf; Ikegami, Takashi; Virgo, Nathaniel; Oka, Mizuki; Iizuka, Hiroyuki, Artificial Life Next Generation Perspectives: Echoes from the 2018 Conference in Tokyo Editorial Introduction to the ALIFE 2018 Special Issue. Artificial Life, 26, 1-4 (2020).

B. WPI-related papers

1. Original articles

2. Review articles

162. Chiang, Yin-Ru; Wei, Sean Ting-Shyang; Wang, Po-Hsiang; Wu, Pei-Hsun; Yu, Chang-Ping, Microbial degradation of steroid sex hormones: implications for environmental and ecological studies. Microbial Biotechnology, 13, 926-949 (2020).

3. Proceedings

4. Other English articles

Appendix 2　FY 2020 List of Principal Investigators

NOTE:

*Underline names of principal investigators who belong to an overseas research institution.

*In the case of researcher(s) not listed in the latest report, attach a "Biographical Sketch of a New Principal Investigator"(Appendix 2a).

*Enter the host institution name and the center name in the footer.

<Results at the end of FY2020> **Principal Investigators Total: 20**

Name	Age	Affiliation (Position title, department, organization)	Academic degree, Specialty	Effort (%)*	Starting date of project participation	Status of project participation (Describe in concrete terms)	Contributions by PIs from overseas research institutions
Kei HIROSE	53	Director, Tokyo Institute of Technology, Earth-Life Science Institute Professor, The University of Tokyo, Department of Earth and Planetary Science	Ph.D., High-pressure Geoscience	90	From start	Main stays at the center, other than that, at Tokyo University Satellite.	
Mary VOYTEK	62	Executive Director, Tokyo Institute of Technology, Earth-Life Science Institute Professor, Columbia University Senior Scientist, NASA	Ph.D., Biology and Ocean Science	40	From August,2018	Stay at the center until July 2020, Joins a videoconference from NASA two Times a week from August 2020	・Collaborative research promotion with Columbia Univ.
Shigenori MARUYAMA	71	Professor, Earth-Life Science Institute, Tokyo Institute of Technology	Ph.D., Geology, Tectonics, History of Life and the Earth	80	From start	Usually stays at the center	
Shigeru IDA	60	Professor, Earth-Life Science Institute, Tokyo Institute of Technology	Ph.D., Planetary Sciences, Planetary Physics	80	From start	Usually stays at the center	

Piet HUT	67	Full professor, Institute for Advanced Study, Princeton, Program of Interdisciplinary Studies Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Theoretical Astrophysics, Interdisciplinary Studies	50	From start	Stays at the center for five months, other than that, at Princeton Satellite	・Accept young ELSI scientists to the Satellite (5 months, 7 months) ・Facilitate interdisciplinary research - Organize Workshops - Recruit young scientists
Naohiro YOSHIDA	66	Professor, Earth-Life Science Institute, Tokyo Institute of Technology	Doctor of Science, Environmental Chemistry, Global Change Analysis	100	From start	Usually stays at the center	
Tetsuo IRIFUNE	66	Professor, Ehime University, Geodynamics Research Center	Ph.D., High-pressure geosciences, Materials sciences	66	From start	Usually stays at Ehime Satellite	
Joseph Lynn KIRSCHVINK	67	Professor, California Institute of Technology, Division of Geological and Planetary Sciences Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Geobiology, Paleo-magnetism, Biophysics, Neurobiology	50	From start	Stays at the center for five months, regularly communicates with us by email	・Research fieldwork and prepare customize equipment for research
Jack William SZOSTAK	68	Investigator, Howard Hughes Medical Institute Professor of Genetics, Harvard Medical School Professor of Chemistry and Chemical Biology, Harvard University Alex. A. Rich Distinguished Investigator, Department of Molecular Biology, Massachusetts General Hospital	Ph.D., Molecular biology Synthetic biology	60	From start	Usually stays at Harvard Satellite	・Accept a young ELSI scientist to the Satellite (5 months) ・Mutual dispatch of young scientists between two institutes

John HERNLUND	48	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Geophysical Modeling, Fluid and Solid Dynamics	100	From August, 2013	Usually stays at the center from August 2013	
George HELFFRICH	68	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Geological Sciences	85	From July, 2014	Usually stays at the center from July 2014	
Eric SMITH	55	Professor, Tokyo Institute of Technology, Earth-Life Science Institute External Professor, Santa Fe Institute Senior Research Scientist, Georgia Institute of Technology	Ph.D., High-energy/particle Physics	80	From February, 2015	Stays at the center for Six months, regularly communicates with us by email	・Research fieldwork and prepare customize equipment for research
Irena MAMAJANOV	45	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Physical Chemistry	100	From January, 2016	Usually stays at the center from January 2016	
Yuichiro UENO	46	Professor, Tokyo Institute of Technology, Department of Earth and Planetary Sciences	Doctor of Science, Geochemistry	60	From April, 2016	Usually stays at the center from April 2016	
Shawn McGLYNN	37	Associate Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Evolutionary biology, Microbial biochemistry	80	From April, 2016	Usually stays at the center from April 2016	
Ryuhei NAKAMURA	44	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Doctor of Science, Electrochemistry	80	From April, 2017	Usually stays at the center from April 2017	

Hidenori GENDA	46	Associate Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Planet formation	80	From April, 2018	Usually stays at the center from April 2018	
Yasuhito SEKINE	42	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Planetary Science, Astrobioloby, Evolution of Earth and planets	80	From June, 2018	Usually stays at the center from June 2018	
Renata WENTZCOVITCH	64	Professor, Columbia University	Ph.D., Geophysicist	20	From June, 2019	Usually stays at Columbia Satellite	
Tomoaki Matsuura	49	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D in Biotechnology	80	From September, 2020	Usually stays at the center from September 2020	

Principal investigators unable to participate in project in FY 2020

Name	Affiliation (Position title, department, organization)	Starting date of project participation	Reasons	Measures taken
Not applicable				

Appendix 2a Biographical Sketch of a New Principal Investigator

(within 3 pages per person)

Name (Age)

Tomoaki Matsuura (49)

Affiliation and position (Position title, department, organization, etc.)

Professor, Earth-Life Science Institute, Tokyo Institute of Technology

Academic degree and specialty

Effort 80%

* Percentage of time that the principal investigator will devote to working for the center vis-à-vis his/her total working hours.

Research and education history

Education

April/1996-March/1999 Osaka University, Japan, Ph.D in Biotechnology

April/1994-March/1996 Osaka University, Japan, M.Sc. in Biotechnology

April/1991-March/1994 Osaka University, Japan, B.Sc. in Biotechnology

Research

Sep/2020-Present Professor, ELSI, Tokyo Institute of Technology

Jun/2010-Aug/2020 Associate Professor; Department of Biotechnology, Osaka University

Apr/2010-Mar/2015 Group Leader of ERATO project, JST

Jan/2007-May/2010 Specially Appointed Associate Professor, Department of Bioinformatic Engineering, Osaka University

Feb/2003-Dec/2006 Assistant Professor, Department of Biotechnology, Osaka University

Feb/2003-Mar/206 PRESTO researcher, JST

May/1999-Jan/2003 Postdoctoral researcher, Universität Zürich

Achievements and highlights of past research activities

Tomoaki Matsuura has contributed in constructing artificial cells in bottom-up. In all living cells, protein synthesis occurs inside a compartment consist of phospholipids. He succeeded in constructing a molecular system which mimics the living cells in this respect only with defined components, and developed a method to analyze the biochemical reaction of the living cells using fluorescence activated cell sorter (FACS). In brief, he encapsulated in vitro transcription-translation system (IVTT) and the DNA encoding a protein of interest inside a cell-sized liposome (>1 μm), and particularly focused on synthesizing membrane proteins that are very important molecules to connect intra and extracellular space. As this artificial cell is made by a bottom-up approach, various features of the cell can be altered, including cell size, phospholipid composition, and intra- and extra cellular components. For example, the relationships between vesicle volume and membrane protein function were revealed using various proteins. The artificial cells were used to characterize the function of computational designed membrane proteins, which was only possible with the artificial cell and FACS.

He also for the first time succeeded in adding the evolvability to the artificial cell. This allowed the in vitro evolution of various membrane proteins, an important subject in the field of biotechnology.

Achievements

(1) International influence * Describe the kind of attributes listed below.

a) Recipient of international awards

- 52nd Encouragement Award of the Society for Biotechnology, Japan (Saito Award), 2016
- Japanese Society of Enzyme Engineering Awards for Encouragement, 2009

b) Member of a scholarly academy in a major country

- Society of Biotechnology Japan, The Biophysical Society of Japan, the Japanese Society of Enzyme Engineering, the Society of Cell-free Science, and the Japanese Society for Cell Synthesis Research.

c) Guest speaker or chair of related international conference and/or director or honorary chairman of a major international academic society in the subject field

- Invited speaker at Protein Engineering Canada 2018 (University of British Columbia, Vancouver, Canada, 2018), The 17th KIAS Conference on Protein Structure and Function (Korea Institute for Advanced Study, Seoul, Korea, 2017), Gordon Research Conferences in Proteins (Boston, U.S.A., 2015), Young Investigators Talk session in Protein Society Meeting 2014 (SanDiego, U.S.A., 2014)

d) Editor of an international academic journal

- Scientific Reports, Journal of Biochemistry (Tokyo), Biophysics and Physicobiology

e) Peer reviewer for an overseas competitive research program (etc.)

- Marsden Fund, Royal Society of New Zealand
- Netherlands Organization for Scientific Research (NWO) for a Vidi grant

(2) Receipt of major large-scale competitive funds (over the past 5 years)

- Apr, 2017–Mar, 2021: Grant-in-Aid for Scientific Research (A) from Japan Society for the Promotion of Science (JSPS), ¥38 million, PI: Tomoaki Matsuura, Research title: Combining computational design and directed evolution for creating novel artificial membrane proteins.
- Apr, 2016-Mar, 2019: Impulsing Paradigm Change through Disruptive Technology Program (ImPACT) (JST), ¥60 million, PI Tomoaki Matsuura (PM: Hiroyuki Noji), Research title: Development of membrane protein engineering method using a liposome reactor.
- Apr, 2013-Mar, 2016: Grant-in-Aid for Scientific Research (B) (JSPS), ¥18.9 million, PI: Tomoaki Matsuura, Research title: Constructing a method for directed evolution of membrane proteins entirely in vitro.
- Dec, 2015-Mar, 2018: TaNeDS Project (Daiichi-Sankyo Corporation), ¥17 million, PI: Tomoaki Matsuura, Research title: Development of high-throughput screening method for transporter activity using cell-free protein synthesis.

(3) Major publications (Titles of major publications, year of publication, journal name, number of citations)

1. Xu, C., Lu, P., Gamal El-Din, T. M., Pei, X. Y., Johnson, M. C., Uyeda, A., Bick, M. J., Xu, Q., Jiang, D., Bai, H., Reggiano, G., Hsia, Y., Brunette, T. J., Dou, J., Ma, D., Lynch, E. M., Boyken, S. E., Huang, P. S., Stewart, L., DiMaio, F., Kollman, J. M., Luisi, B. F., Matsuura, T., Catterall, W. A., and Baker, D. (2020) Computational design of transmembrane pores. ***Nature*** 585, 129-134 (Google Scholar citation = 13)
2. Noba, K., Ishikawa, M., Uyeda, A., Watanabe, T., Hohsaka, T., Yoshimoto, S., Matsuura, T., and Hori, K. (2019) Bottom-up Creation of an Artificial Cell Covered with the Adhesive Bacterionanofiber Protein AtaA. ***J Am Chem Soc*** 141, 19058-19066 (Google Scholar citation = 2)
3. Dwidar, M., Seike, Y., Kobori, S., Whitaker, C., Matsuura, T., and Yokobayashi, Y. (2019) Programmable Artificial Cells Using Histamine-Responsive Synthetic Riboswitch. ***J Am Chem Soc*** 141, 11103-11114 (Google Scholar citation = 24)
4. Matsuura, T., Tanimura, N., Hosoda, K., Yomo, T., and Shimizu, Y. (2017) Reaction dynamics analysis of a reconstituted Escherichia coli protein translation system by computational modeling. ***Proc Natl Acad Sci U S A*** 114, E1336-E1344 (Google Scholar citation = 30)
5. Soga, H., Fujii, S., Yomo, T., Kato, Y., Watanabe, H., and Matsuura, T. (2014) In vitro membrane protein synthesis inside cell-sized vesicles reveals the dependence of membrane protein integration on vesicle volume. ***ACS Synth Biol*** 3, 372-379 (Google Scholar citation = 52)
6. Kazuta, Y., Matsuura, T., Ichihashi, N., and Yomo, T. (2014) Synthesis of milligram quantities of proteins using a reconstituted in vitro protein synthesis system. ***J Biosci Bioeng*** 118, 554-557 (Google Scholar citation = 42)
7. Fujii, S., Matsuura, T., Sunami, T., Kazuta, Y., and Yomo, T. (2013) In vitro evolution of alpha-hemolysin using a liposome display. ***Proc Natl Acad Sci U S A*** 110, 16796-16801 (Google Scholar citation = 95)
8. Matsuura, T., Kazuta, Y., Aita, T., Adachi, J., and Yomo, T. (2009) Quantifying epistatic interactions among the components constituting the protein translation system. ***Mol Syst Biol*** 5, 297 (Google Scholar citation = 55)
9. Matsuura, T., Yamaguchi, M., Ko-Mitamura, E. P., Shima, Y., Urabe, I., and Yomo, T. (2002) Importance of compartment formation for a self-encoding system. ***Proc Natl Acad Sci U S A*** 99, 7514-7517 (Google Scholar citation = 36)
10. Matsuura, T., Miyai, K., Trakulnaleamsai, S., Yomo, T., Shima, Y., Miki, S., Yamamoto, K., and Urabe, I. (1999) Evolutionary molecular engineering by random elongation mutagenesis. ***Nat Biotechnol*** 17, 58-61 (Google Scholar citation = 89)

(4) Others (Other achievements indicative of the PI's qualification as a top-world researcher, if any.)

A member of Japanese-France Frontier of Science Symposium (JF-FoS)

Appendix 3-1 FY 2020 Records of Center Activities

1. Researchers and other center staffs, satellites, partner institutions

1-1. Number of researchers and other center staffs

* Fill in the number of researchers and other center staffs in the table blow.

* Describe the final goals for achieving these numbers and dates when they will be achieved described in the last "center project."

a) Principal Investigators

(full professors, associate professors or other researchers of comparable standing)

(number of persons)

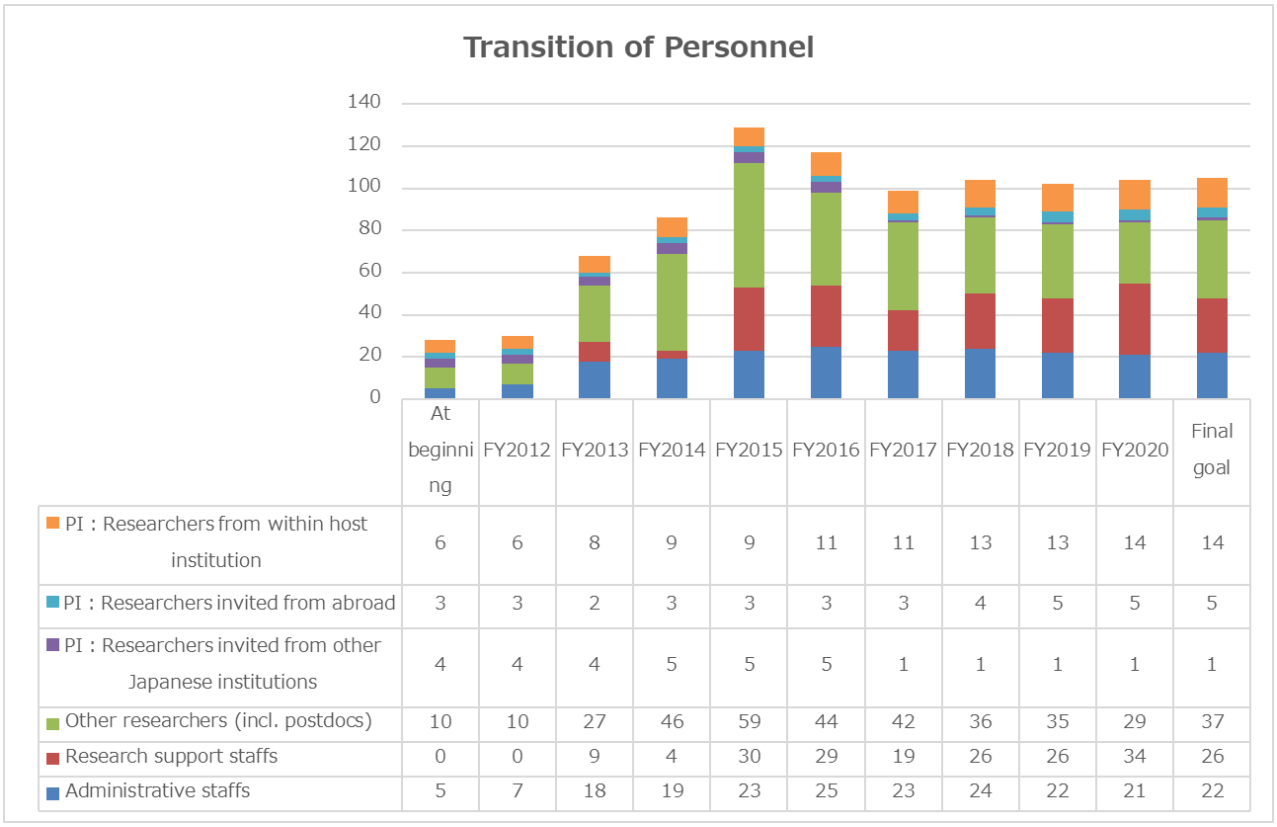
	At the beginning of project	At the end of FY 2020	Final goal (Date: March, 2022)
Researchers from within the host institution	6	14	14
Researchers invited from abroad	3	5	5
Researchers invited from other Japanese institutions	4	1	1
Total principal investigators	13	20	20

b) Total members

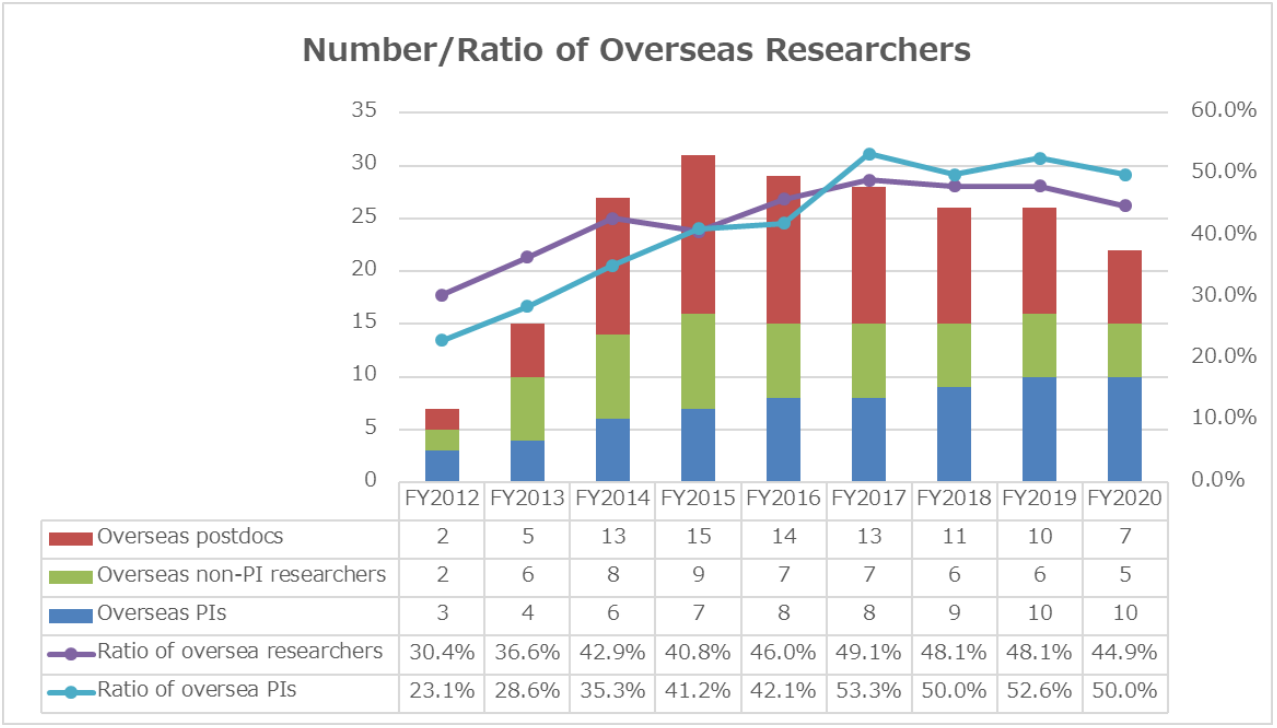
	At the beginning of project		At the end of FY 2020		Final goal (Date: March, 2022)	
	Number of persons	%	Number of persons	%	Number of persons	%
Researchers	23		49		57	
Overseas researchers	3	13	22	45	28	49
Female researchers	0	0	10	20	12	21
Principal investigators	13		20		20	
Overseas PIs	3	23	10	50	10	50
Female PIs	0	0	3	15	3	15
Other researchers	10		14		33	
Overseas researchers	0	0	5	36	17	52
Female researchers	0	0	3	21	8	24
Postdocs	0		15		4	
Overseas postdocs	0	0	7	47	1	25
Female postdocs	0	0	4	27	1	25
Research support staffs	0		34		26	
Administrative staffs	5		21		22	
Total number of people who form the "core" of the research center	28		104		105	

Appendix 3-2　Annual Transition in the Number of Center Personnel

*Make a graph of the annual transition in the number of center personnel since the start of project.

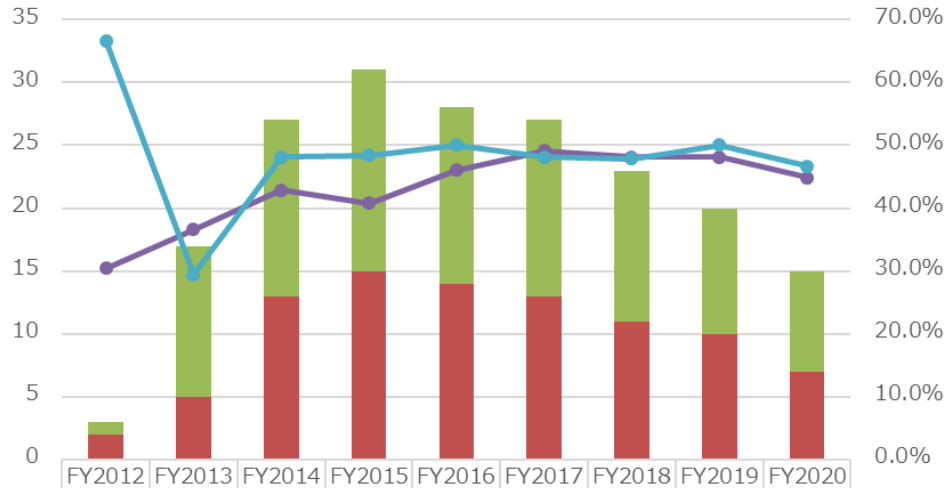


	At beginning	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	Final goal
PI : Researchers from within host institution	6	6	8	9	9	11	11	13	13	14	14
PI : Researchers invited from abroad	3	3	2	3	3	3	3	4	5	5	5
PI : Researchers invited from other Japanese institutions	4	4	4	5	5	5	1	1	1	1	1
Other researchers (incl. postdocs)	10	10	27	46	59	44	42	36	35	29	37
Research support staffs	0	0	9	4	30	29	19	26	26	34	26
Administrative staffs	5	7	18	19	23	25	23	24	22	21	22



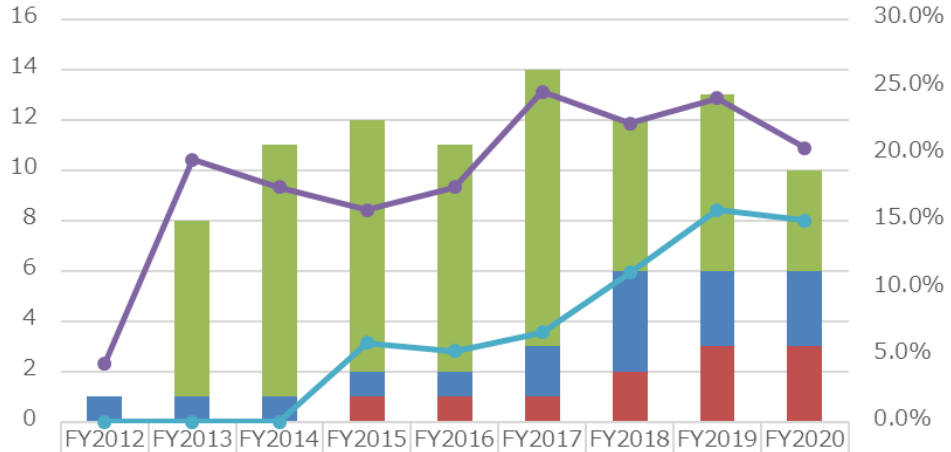
	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Overseas postdocs	2	5	13	15	14	13	11	10	7
Overseas non-PI researchers	2	6	8	9	7	7	6	6	5
Overseas PIs	3	4	6	7	8	8	9	10	10
Ratio of oversea researchers	30.4%	36.6%	42.9%	40.8%	46.0%	49.1%	48.1%	48.1%	44.9%
Ratio of oversea PIs	23.1%	28.6%	35.3%	41.2%	42.1%	53.3%	50.0%	52.6%	50.0%

Number/Ratio of Overseas Postdoc



	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Japanese postdocs	1	12	14	16	14	14	12	10	8
Overseas postdocs	2	5	13	15	14	13	11	10	7
Ratio of oversea researchers	30.4%	36.6%	42.9%	40.8%	46.0%	49.1%	48.1%	48.1%	44.9%
Ratio of overseas postdocs	66.7%	29.4%	48.1%	48.4%	50.0%	48.1%	47.8%	50.0%	46.7%

Number/Ratio of Female Researchers

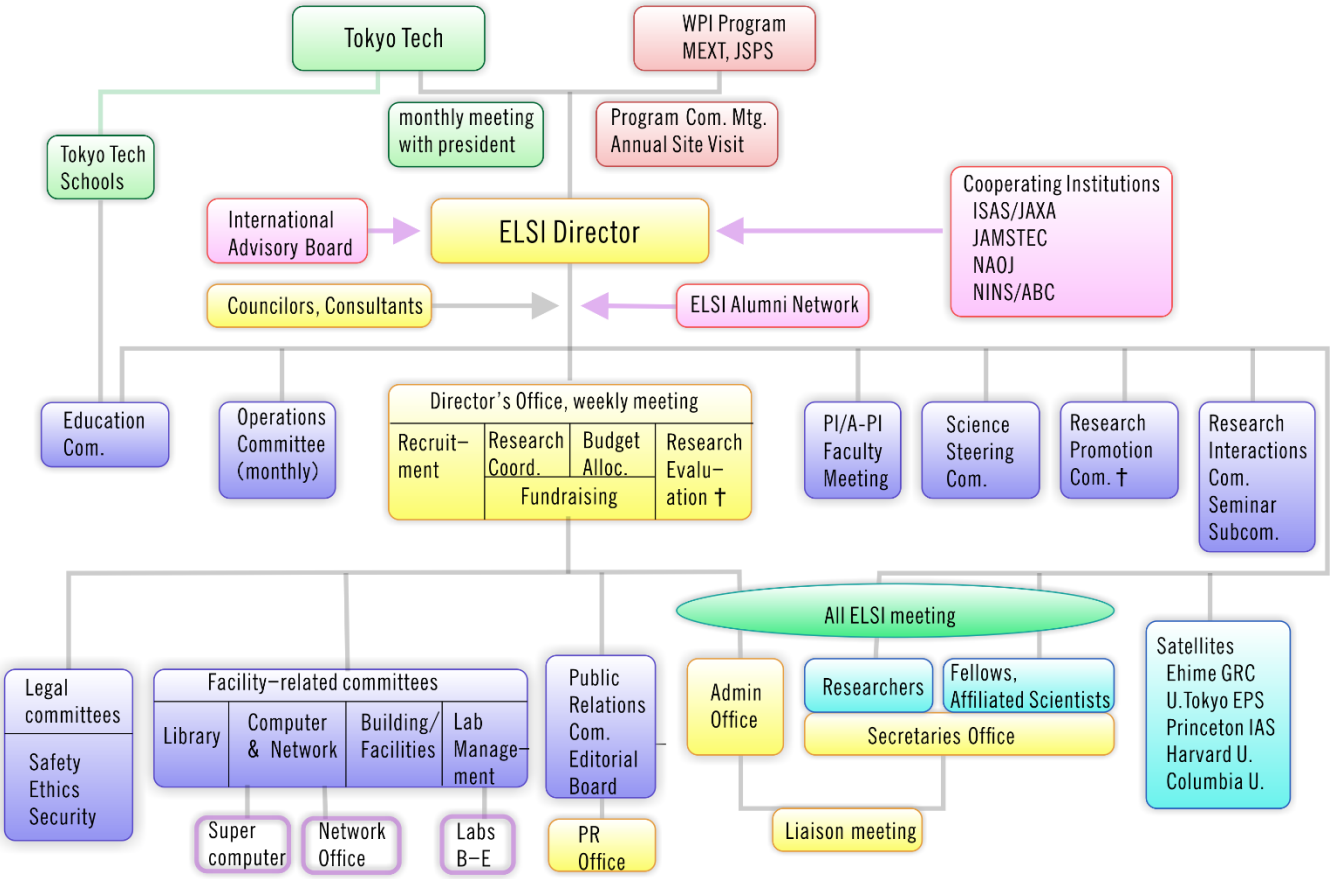


	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Female postdocs	0	7	10	10	9	11	6	7	4
Female non-PI researchers	1	1	1	1	1	2	4	3	3
Female PIs	0	0	0	1	1	1	2	3	3
Ratio of female researchers	4.3%	19.5%	17.5%	15.8%	17.5%	24.6%	22.2%	24.1%	20.4%
Ratio of female PIs	0.0%	0.0%	0.0%	5.9%	5.3%	6.7%	11.1%	15.8%	15.0%

Appendix 3-3 Diagram of Management System

- Diagram the center's management system and its position within the host institution in an easily understood manner.
- If any changes have been made in the management system from that in the latest "center project" last year, describe them. Especially describe any important changes made in such as the center director, administrative director, head of host institution, and officer(s) in charge at the host institution (e.g., executive vice president for research).

As the current management scheme is working efficiently, we will basically keep the same organizational structure for FY2022. We are proposing a change of the Center Director starting from FY2022.



Appendix 3-4　Campus Map

- Draw a simple map of the campus showing where the main office and principal investigator(s) are located.

Ookayama Campus Map

Appendix 3-5 Project Expenditures in FY2020

1) Overall project funding

* In the "Total costs" column, enter the total amount of funding required to implement the project, without dividing it into funding sources.
* In the "Amount covered by WPI funding" column, enter the amount covered by WPI within the total amount.
* In the "Personnel," "Project activities," "Travel," and "Equipment" blocks, the items of the "Details" culumn may be changed to coincide with the project's actual content.

(Million yens)

Cost items	Details (For Personnel - Equipment please fill in the breakdown of fiscal expenditure, and the income breakdown for Research projects.)	Total costs	Amount covered by WPI funding
Personnel	Center director and administrative director	25	10
	Principal investigators (no. of persons):14	132	99
	Other researchers (no. of persons):24	163	131
	Research support staffs (no. of persons):20	57	57
	Administrative staffs (no. of persons):16	74	55
	Subtotal	451	352
Project activities	Gratuities and honoraria paid to invited principal investigators (no. of persons):0	0	0
	Cost of dispatching scientists (no. of persons):0	0	0
	Research startup cost (no. of persons):31	9	3
	Cost of satellite organizations (no. of satellite organizations):2	29	29
	Cost of international symposiums (no. of symposiums):1	6	6
	Rental fees for facilities	83	83
	Cost of consumables	20	9
	Cost of utilities	0	0
	Other costs	21	23
	Subtotal	168	153
Travel	Domestic travel costs	0	0
	Overseas travel costs	2	2
	Travel and accommodations cost for invited scientists (no. of domestic scientists):0 (no. of overseas scientists):0		
	Travel cost for scientists on transfer (no. of domestic scientists):7 (no. of overseas scientists):0	2	2
	Subtotal	4	4
Equipment	Depreciation of buildings	13	0
	Depreciation of equipment	0	0
	Subtotal	13	0
Research projects (Detail items must be fixed)	Project supported by other government subsidies, etc. *1	30	
	KAKENHI	144	
	Commissioned research projects, etc.	33	
	Joint research projects	4	
	Ohers (donations, etc.)	35	
	Subtotal	246	0
Total		882	509

Costs (Million yens)

WPI grant in FY 2020	516
Costs of establishing and maintaining facilities	0
Establishing new facilities (Number of facilities: 0, 0 m²)	0
Repairing facilities (Number of facilities: 0, 0 m²)	0
Others	0
Costs of equipment procured	7
Rackmount calculation server (Number of units:1)	4
Others	3

*1. Funding sources that include government subsidies (including Enhancements promotion expenses (機能強化促進経費), National university reform reinforcement promotion subsidy (国立大学改革強化推進補助金) etc.), indirect funding, and allocations from the university's own resources.
*2 When personnel, travel, equipment (etc.) expenses are covered by KAKENHI or under commissioned research projects or joint research projects, the amounts should be entered in the "Research projects" block.

2) Costs of satellites

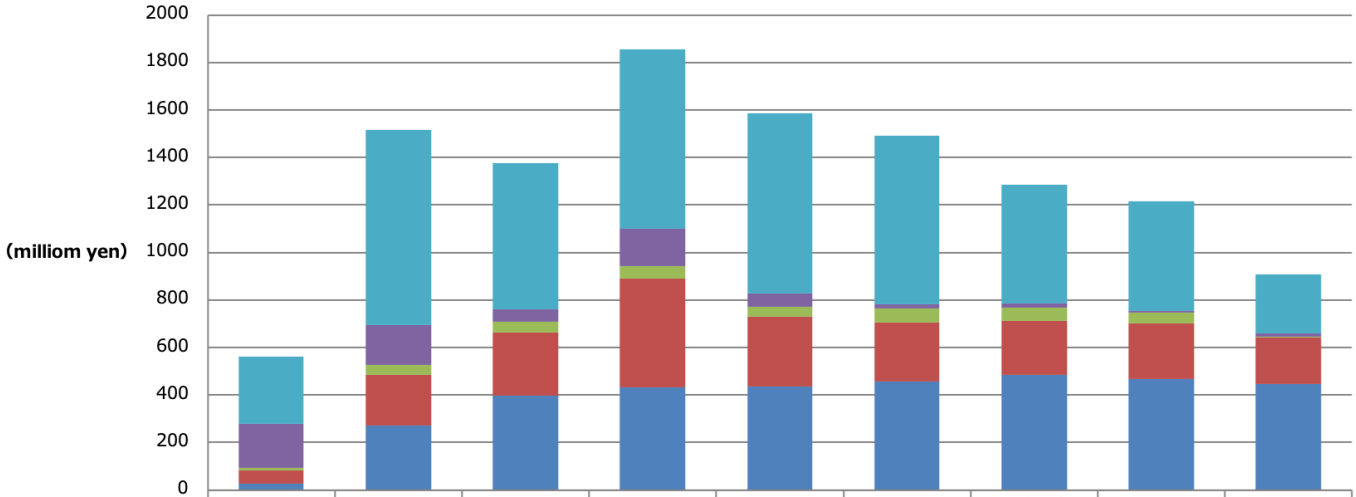
(Million yens)

Cost items	Details	Total costs	Amount covered by WPI funding
Personnel	Principal investigators (no. of persons):1		
	Other researchers (no. of persons):2		
	Research support staffs (no. of persons):0		
	Administrative staffs (no. of persons):1		
	Subtotal	12	12
Project activities	Subtotal	16	16
Travel	Subtotal	0	0
Equipment	Subtotal	0	0
Research projects	Subtotal	0	0
Total		28	28

Appendix 3-6　Annual Transition in the Amounts of Project Funding

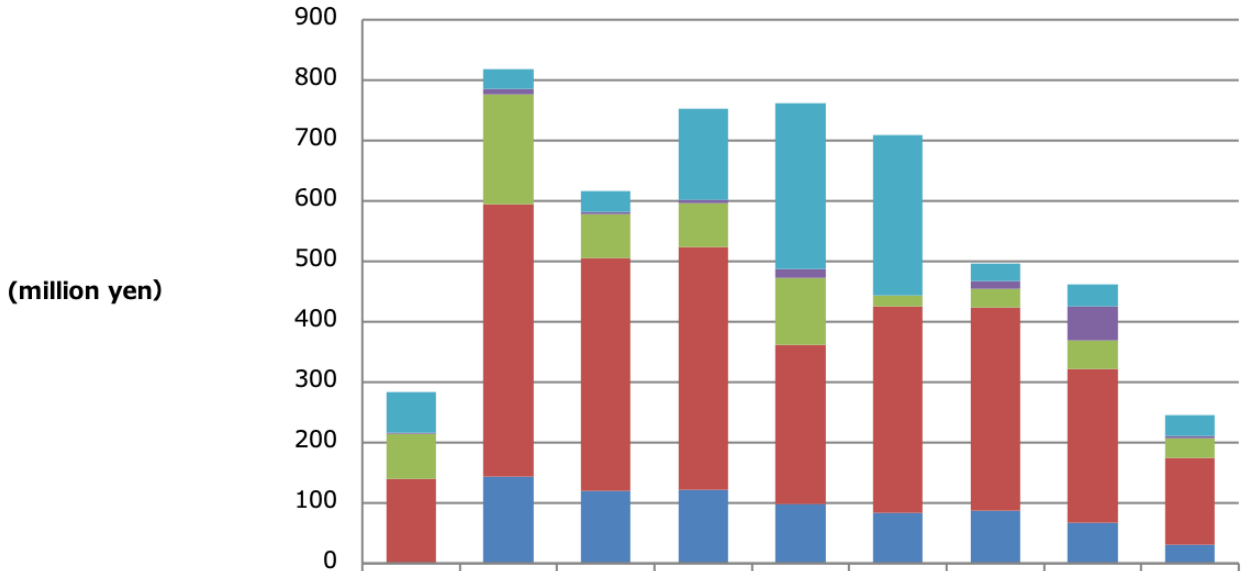
*Make a graph of the transition in the number of overall project funding.

Transition of Project Expenditures



	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Research Projects	284	819	616	753	762	709	497	461	246
Equipment	183	168	54	159	54	15	18	7	17
Travel	11	43	44	53	42	63	56	45	3
Project Activities	56	212	266	455	295	247	227	233	194
Personnel	27	273	397	434	435	456	486	469	447

Transition of Research Project Expenditures



	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Ohers (donations, etc.)	68	34	35	152	275	266	30	36	35
Joint research projects	1	9	2	5	14	0	13	56	4
Commissioned research projects, etc.	75	182	74	72	111	18	31	48	33
KAKENHI	140	450	385	403	265	341	336	254	144
Project supported by other government subsidies, etc. *1	0	144	120	121	97	84	87	67	30

*1 Definition is as shown in Appendix 3-5 (Project Expenditures)

Appendix 4-1 FY 2020 Status of Collaboration with Overseas Satellites

- If satellite and partner institutions have been established, fill in required items of the form below.

1. Satellites and partner institutions

- List the satellite and partner institutions in the table below (including the domestic satellite institutes).
- Indicate newly added and deleted institutions in the "Notes" column.

<Satellite institutions>

Institution name	Principal Investigator(s), if any	Notes
Institute for Advanced Study, Princeton	Piet Hut	
Harvard University		
Columbia University	Renata Wentzcovitch	

< Partner institutions>

Institution name	Principal Investigator(s), if any	Notes
NASA	Mary Voytek	

- If overseas satellite institutions have been established, fill in required items on the form below. If overseas satellite institutions have not been established, it is not necessary to complete the form.

2. Coauthored Papers

- List the refereed papers published in FY 2020 that were coauthored between the center's researcher(s) in domestic institution(s) (include satellite institutions) and overseas satellite institution(s). List them by overseas satellite institution in the below blocks.
- Transcribe data in same format as in Appendix 1-4. Italicize the names of authors affiliated with overseas satellite institutions.
- For reference write the Appendfix 1-4 item number in parentheses after the item number in the blocks below. Let it free, if the paper is published in between Jan.-Mar. 2021 and not described in Appendix 1-4.

Overseas Satellite 1 **Harvard University** (Total: 13 papers)

1. [7] Bertran, Emma; *Ward, Lewis M.*; Johnston, David T., Draft Genome Sequence of Desulfofundulus thermobenzoicus subsp. thermosyntrophicus DSM 14055, a Moderately Thermophilic Sulfate Reducer. Microbiology Resource Announcements, 9, e01416-19 (2020).
2. [8] Bertran, Emma; *Ward, Lewis M.*; Johnston, David T., Draft Genome Sequence of Acidianus ambivalens DSM 3772, an Aerobic Thermoacidophilic Sulfur Disproportionator. Microbiology Resource Announcements, 9, e01415-19 (2020).
3. [9] Bertran, Emma; *Ward, Lewis M.*; Johnston, David T., Draft Genome Sequence of Desulfobacter hydrogenophilus DSM 3380, a Psychrotolerant Sulfate-Reducing Bacterium. Microbiology Resource Announcements, 9, e00203 (2020).
4. [29] Grasby, Katrina L.; Jahanshad, Neda; Painter, Jodie N. et al. (total 360 authors including six authors from Harvard), The genetic architecture of the human cerebralcortex. Science, 367, eaay6690 (2020).
5. 144. Seyler, Lauren; Kujawinski, Elizabeth B.; Azua-Bustos, Armando; Lee, Michael D.; *Marlow, Jeffrey*; Perl, Scott M.; Cleaves, Henderson James, II, Metabolomics As an Emerging Tool in the Search for Astrobiologically Relevant Biomarkers. ASTROBIOLOGY, 20, 1251-1261 (2020).
6. [111] Tasker, Elizabeth J.; Ishimaru, Kana; Guttenberg, Nicholas; *Foriel, Julien*, Earth-Like: An education & outreach tool for exploring the diversity of planets like our own. International Journal of Astrobiology, 19, 264-275 (2020).
7. [121] *Ward, Lewis M.*; Bertran, Emma; Johnston, David T., Draft Genome Sequence of Desulfovibrio sulfodismutans ThAc01, a Heterotrophic Sulfur-Disproportionating Member of the Desulfobacterota. Microbiology Resource Announcements, 9, e00202-20 (2020).
8. [122] *Ward, Lewis M.*; Bertran, Emma; Johnston, David T., Genomic sequence analysis of Dissulfurirhabdus thermomarina SH388 and proposed reassignment to Dissulfurirhabdaceae fam. nov. Microbial Genomics, 6, 390 (2020).
9. [123] *Ward, Lewis M.*; Fischer, Woodward W.; McGlynn, Shawn E., Candidatus Anthektikosiphon siderophilum

OHK22, a New Member of the Chloroflexi Family Herpetosiphonaceae from Oku-okuhachikurou Onsen. Microbes and Environments, 35, ME20030 (2020).
10. [134] Zhao, Daniel; *Bartlett, Stuart*; Yung, Yuk L., Quantifying Mineral-Ligand Structural Similarities: Bridging the Geological World of Minerals with the Biological World of Enzymes. Life (Basel, Switzerland), 10, 338 (2020).
11. Adam, Zachary R.; *Fahrenbach, Albert C.*; Jacobson, Sofia M.; *Kacar, Betul*; Zubarev, Dmitry Yu, Radiolysis generates a complex organosynthetic chemical network. SCIENTIFIC REPORTS 11,1, - (2021).
12. *Butch, Christopher J.*; Meringer, Markus; Gagnon, Jean-Sebastien; *Cleaves, H. James, II*, Open questions in understanding life's origins. COMMUNICATIONS CHEMISTRY 4,1, - (2021).
13. *Ward, L. M.*; Johnston, D. T.; Shih, P. M., Phanerozoic radiation of ammonia oxidizing bacteria. SCIENTIFIC REPORTS 11,1, - (2021).

Overseas Satellite 2 **Columbia University** (Total: 1 paper)

1. [133] Zhang, Ning; Shi, Shundi; Wang, Xuanting; Ni, Wenhao; Yuan, Xiaohong; Duan, Jiachen; Jia, Tony Z.; Yoo, Barney; Ziegler, Ashley; Russo, James J.; Li, Wenjia; Zhang, Shenglong, Direct Sequencing of tRNA by 2D-HELS-AA MS Seq Reveals Its Different Isoforms and Dynamic Base Modifications. ACS Chemical Biology, 15, 1464-1472 (2020).

Overseas Satellite 3 **Institute for Advanced Study, Princeton** (Total: 0 paper)

3. Status of Researcher Exchanges

- Using the below tables, indicate the number and length of researcher exchanges in FY 2020. Enter by institution and length of exchange.
- Write the number of principal investigator visits in the top of each space and the number of other researchers in the bottom.

Overseas Satellite 1: Institute for Advanced Study, Princeton

<To satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2020	0	0	0	1	1
	0	0	1	0	1

<From satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2020	0	0	0	1	1
	0	0	0	0	0

Overseas Satellite 2: Harvard University

<To satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2020	0	0	0	0	0
	0	0	0	0	0

<From satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2020	0	0	0	0	0
	0	0	0	0	0

Overseas Satellite 3: Columbia University

<To satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2020	0	0	0	0	0
	0	0	0	0	0

<From satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2020	0	0	0	0	0
	0	0	0	0	0

Appendix 4-2 FY 2020 Visit Records of Researchers from Abroad

* If researchers have visited/ stayed at the Center, provide information on them in the below table.
* Enter the host institution name and the center name in the footer.

Total: 1

	Name	Age	Affiliation		Academic degree, specialty	Record of research activities (Awards record, etc.)	Time, duration	Summary of activities during stay at center (e.g., participation as principal investigator; short-term stay for joint research; participation in symposium)
			Position title, department, organization	Country				
1	Ajay Verma		master course student, Indian Institute of Science Education and Research	India	biology		20200401 - 20200622	short term stay for joint research by BS MS Dual Degree Program
2								
3								
4								
5								
6								
7								
8								
9								
10								

Appendix4-3 Postdoctoral Positions through Open International Solicitations

* In the column of number of applications and number of selection, put the total number (upper), the number and percentage of overseas researchers in the < > brackets (lower).

Fiscal year	number of applications	number of selection
FY 2012	N/A	N/A
	< , %>	< , %>
FY 2013	134	10
	<125, 93 %>	<8, 80 %>
FY 2014	N/A	N/A
	< , %>	< , %>
FY 2015	72	8
	<52, 72 %>	<6, 75 %>
FY 2016	39	3
	<25, 64 %>	<2, 67 %>
FY 2017	60	7
	<37, 62 %>	<3, 43 %>
FY 2018	58	4
	<34, 59 %>	<3, 43 %>
FY 2019	6	0
	<5, 83 %>	<0, 0%>
FY 2020	5	1
	<3, 60%>	<0, 0 %>

Appendix 4-4 Status of Employment of Postdoctoral Researchers

Enter the information below during the period from the start of the center through the end of FY 2020.

- For each person, fill in the spaces to the right. More spaces may be added.
- Leave "Position as of April 2021" blank if unknown.
- Enter the host institution name and the center name in the footer.

Japanese Postdocs

Employment period	Position before employed at WPI center		Next position after WPI center		Position as of April 2021*	
	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located
2013.4.1-2015.10.31	The University of Tokyo・Graduate Student	Japan	Postdoctoral Program Fellpw・NASA-GISS	USA	National Astronomical Observatory of JAPAN・Associate Professor	Japan
2013.4.1-2016.3.31	RIKEN・Researcher	Japan	Tokyo Institute of Technology・Research Staff	Japan	Tokyo Institute of Technology・Researcher	Japan
2013.4.1-2016.3.31	Tokyo Institute of Technology・Research Staff	Japan	National Institute of Genetics・Researcher	Japan		
2013.4.1-2016.3.31	Tokyo Institute of Technology・Research Staff	Japan	Kyushu University・Researcher	Japan	National Astronomical Observatory of JAPAN・Specially Appointed Assistant Professor	Japan
2013.4.1-2015.8.31	JAMSTEC・Researcher	Japan	Okayama University・Researcher	Japan		
2014.4.1-2016.3.31	Tokyo Institute of Technology・Graduate Student	Japan	Ehime University・Researcher	Japan	Kyoto University・Program-Specific Associate Professor	Japan
2014.4.1-2015.9.30	Hiroshima University・Postdoctral Researcher	Japan	JAMSTEC・Technical Scientist	Japan	JAMSTEC・Researcher	Japan
2014.4.1-2015.7.31	Tokyo Institute of Technology・Graduate Student	Japan	The University of Tokyo・Assistant Professor	Japan	Yale University・Associate Research Scientist	USA
2014.6.1-2015.3.31	Tokyo Institute of Technology・Post-doctoral fellow	Japan	Tokyo Institute of Technology・Research Staff	Japan	KOSEN Kumamoto college・Associate Professor	Japan
2014.4.1-2016.3.31	Tokyo Institute of Technology・Research Staff	Japan	AIST・Researcher	Japan		

2014.4.1-2014.8.31	Tokyo Institute of Technology・Research Staff	Japan	RIKEN・Researcher	Japan	Hosei University・Reserch Assistant	Japan
2014.4.1-2014.8.31	Tokyo Institute of Technology・Graduate Student	Japan	Carnegie Institution for Science・Postdoctral Researcher	USA	ELSI,Tokyo Institute of Technology・Specially Appointed Assistant Professor	Japan
2015.4.1-2016.3.31	Hiroshima University・Graduate Student	Japan	Kyushu University・JSPS Postdoctoral Fellowships	Japan	Tokyo Institute of Technology・Assistant Professor	Japan
2015.4.1-2015.6.30	Nagoya University・Graduate Student	Japan	Niels Bohr Institute・Postdoctral Researcher	Denmark	Kyoto University・Assistant Professor	Japan
2015.4.1-2015.9.30	Tokyo Institute of Technology・Graduate Student	Japan	JASRI・Researcher	Japan	JASRI・Researcher	Japan
2014.4.1-2017.3.31	Ritsumeikan University・Visiting scholar	Japan	JAMSTEC・Researcher	Japan	JAMSTEC・Researcher	Japan
2013.4.1-2016.9.30	Hokkaido University・Researcher	Japan	Osaka University・Assistant Professor	Japan	Hokkaido University・Rrofessor	Japan
2015.10.1-2016.10.31	The University of Tokyo・Project Researcher	Japan	The University of Tokyo・Project Researcher	Japan		
2015.4.1-2017.8.31	Toyama University・Researcher	Japan	The University of Tokyo・Assistant Professor	Japan	University of Tokyo・Assistant Professor	Japan
2015.7.1-2018.3.31	Tokyo Institute of Technology・Specially Appointed Assistant Professor	Japan	Tokyo Institute of Technology・Researcher	Japan	ELSI,Tokyo Institute of Technology・Specially Appointed Assistant Professor	Japan
2015.4.1-2017.7.31	Tokyo Institute of Technology・Graduate Student	Japan	JAMSTEC・Researcher	Japan	National Institute for Environmental Studies・Researcher	Japan
2017.4.1-2018.3.31	YHouse・Core membr	USA	Ritsumeikan University・Associate Professor	Japan	Ritsumeikan University・Associate Professor	Japan
2015.10.1-2018.10.31	Riken・Senior Technical Scientist	Japan	Tokyo Institute of Technology・Specially Appointed Assistant Professor	Japan	OIST・Technical Staff	Japan
2017.4.1-2018.7.31	Ehime University・Researcher	Japan	TADANO LTD.・Researcher	Japan		

2018.4.1-2018.5.31	Tokyo Institute of Technology・Graduate Student	Japan	Chiba Institute of Technology・Associate Staff Scientist	Japan	Chiba Institute of Technology・Researcher	Japan
2018.4.1-2018.9.30	Tokyo Institute of Technology・Graduate Student	Japan	Utrecht University・Researcher	Nederlands	RIKEN・Researcher	Japan
2019.4.1-2019.5.31	Tokyo Institute of Technology・Graduate Student	Japan	University of Bern・Researcher	Switzerland	National Centre of Competence in Research PlanetS・Researcher	Japan
2019.4.1-2020.3.31	Kyushu University・Post-doctoral Fellow	Japan	Kyushu University・JSPS Postdoctoral Fellowships	Japan	Kyushu University・JSPS Postdoctoral Fellowships	Japan
2013.4.1-2020.3.31	National Astronomical Observatory of Japan・Researcher	Japan	Kabushiki gaisha Jacos・Staff	Japan		
2019.4.1-2020.3.31	Nagoya University・Graduate Student	Japan	Tokyo Institute of Technology・JSPS Postdoctoral Fellowships	Japan	Tokyo Institute of Technology・JSPS Postdoctoral Fellowships	Japan

Overseas Postdocs

Employment period	Position before employed at WPI center		Next position after WPI center		Position as of April 2021*		Nationality
	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located	
2013.3.8-2014.3.31	The University of Arizona・Senior Research Scientist	USA	The University of Tokyo・Associate Professor	Japan	The University of Tokyo・Specially Appointed Associate Professor	Japan	USA
2014.9.1-2015.7.31	University of Hawaii・PostDoctral Researcher	USA	Chief research officer・ETH	Switzerland	Univ.College London (ETH Zurich)・Lecturer (Visiting Scientist)	UK	Germany
2013.11.1-2017.2.28	Tokyo Institute of Technology・Research Staff	Japan	Tokyo Institute of Technology・Specially Appointed Assistant Professor	Japan	Tokyo Institute of Technology・Assistant professor	Japan	France
2014.8.5-2016.6.30	University of Oregon・Researcher	USA	Araya Brain Imaging・Data Science Manager	Japan	Cross Compass Ltd.・Researcher	Japan	USA
2016.2.1-2017.2.28	Ochanomizu University・Project Assistant Professor・Japan	Japan	Ochanomizu University・Assistant Professor	Japan	Ochanomizu University (Department of Information Sciences)・Assistant professor	Japan	France

2014.5.1-2017.4.30	Yokohama National University・Graduate Student・Japan	Japan			University of Chemistry and Technology, Prague Post Docs	Czech	Malaysia
2015.5.1-2017.6.30	Georgia Institute of Technology・Graduate Student・USA	USA	Tokyo Institute of Technology・JSPS Postdoctoral Fellowships	Japan	NANJING University・Associate Professor	China	USA
2015.9.24-2017.9.23	University of Southern Denmark・Graduate Student・Denmark	Denmark	University of Southern Denmark・Assistant Professor	Denmark	University of Southern Denmark・Assistant Professor	Denmark	Denmark
2016.2.1-2018.1.31	Max Planck Institute for Solar System Research・Postdoctoral Research Scientist・Garmany	Germany	Gateway House・Fellow	India	Gateway House・Fellow	India	India
2016.2.1-2018.1.31	UC San Diego・Postdoctoral fellow・USA	USA	University of California, San Diego・Assistant Teaching Professor	USA	University of California, San Diego・Assistant Teaching Professor	USA	USA
2016.3.1-2018.2.28	University of Cambridge・Postdoctoral Research Associate	UK	University of Cambridge・Visiting Researcher	UK	University of Essex・Faculty-track research fellowship	UK	UK
2016.4.1-2018.3.31	University of California, Los Angeles・Graduate Student	USA	Lawrence Livermore National Laboratory・Postdoctoral Research Staff・USA	USA	Lawrence Livermore National Laboratory・Postdoctoral Research Fellow	USA	USA
2016.4.1-2018.3.31	Ecole Polytechnique・Postdoctral Researcher	France	California Institute of Technology・Postdoctoral Researcher・USA	USA	California Institute of Technology・Postdoctoral Researcher	USA	UK
2016.4.1-2018.3.31	Institute of Advanced Studies, Princeton・Visiting Scholar	USA	University of Naples "Federico II"・Assistant Professor	Italy	University of Naples "Federico II"・Assistant Professor	Italy	Italy
2017.9.1-2018.2.28	University of Oxford・Postdoctral Researcher	UK	University of Southampton・Research Fellow	UK	University of Southampton・Research Fellow	UK	UK

2013.9.1-2018.8.31	Harvard University・Postdoctoral	USA	University of New South Wales・Lecturer	Australia	University of New South Wales・Lecturer	Australia	USA
2017.4.1-2018.8.28	Tokyo Institute of Technology・JSPS Postdoctoral Fellowships	Japan	Nantes University・Marie Skłodowska-Curie actions Individual Fellowship fellow	France	Nantes University・Marie Skłodowska-Curie actions Individual Fellowship fellow	France	France
2018.10.1-2019.7.28	The University of Tokyo・Reseacher	Japan	University of Washington・postdoctoral fellow	USA	University of Washington・postdoctoral fellow	USA	Ethiopia
2018.11.19-2019.11.30	Araya Inc・Data Science Manager	Japan	Cross Compass Ltd.・Researcher	Japan	Cross Compass Ltd.・Researcher	Japan	USA
2019.4.1-2020.1.31	Sony Computer Science Laboratories, Inc. ・Associate Resercher	Japan	Sony Computer Science Laboratories, Inc. ・Associate Resercher	Japan	Sony Computer Science Laboratories, Inc. ・Associate Resercher	Japan	France
2018.10.1-2020.6.30	University of Tronto・Postdoctoral researcher	Canada	National Central University・Assistant Professor	Taiwan	National Central University・Assistant Professor	Taiwan	Taiwan
2019.12.1-2021.1.31	National University of Singapore・Graduate Student	Singapore	University of Oxford・Postdoctoral researcher	UK	University of Oxford・Postdoctoral researcher	UK	Turkey

Appendix4-5 List of the Cooperative Research Agreements with Overseas Institutions

*Prepare the information below during the period from the beginning of the Center through March 2021.

1. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: March 31, 2015
   Counterpart of an Agreement: Georgia Institute of Technology
   Summary of an Agreement: Under the umbrella of the Tokyo Tech/Georgia Tech MoU, ELSI is strengthening its collaboration with their Center for Chemical Evolution (CCE), through their PIs Loren Williams and Martha Grover, to expand on 'messy chemistry', ELSI's hallmark approach to studies in origin and evolution of a biotic chemosphere. In recent years, ELSI has laid the groundwork for a broad-based experimental and computational study of combinatorial chemistry in systems that are regulated by geo-energetic boundary conditions and that have limited catalytic support. Collaboration, mutual visitorships, sabbaticals with CCE are planned to strengthen ELSI's efforts. ELSI and CCE are also interested in creating course material for the chemical origin of life.

2. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: June 29, 2015
   Counterpart of an Agreement: Prof. Daniel Merkle, Dept. of Mathematics and Computer Science, Univ. of Southern Denmark
   Summary of an Agreement: Prof. Merkle will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Jakob Andersen as he pursues research on computational chemistry methods for prebiotic chemistry. Academic mentorship and the provision of work space will be provided while Andersen spends half of his two-year EON postdoctoral program at U. of Southern Denmark. As an EON Affiliate Institute Supervisor, Prof. Merkle will attend EON annual meetings at ELSI and share his expertise with other ELSI researchers. Outcomes: Through Prof. Merkle and shared postdoc Andersen, ELSI hosted a computational chemistry workshop that brought experts in computer algorithms together with experts on prebiotic chemistry to identify common goals for research, the first time that this has been done ever, to our knowledge.

3. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: July 06, 2015
   Counterpart of an Agreement: Prof. Dennis Liotta, Dept. of Chemistry, Emory University
   Summary of an Agreement: Prof. Liotta will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Chris Butch as he pursues research on the evolution of nucleic acid polymerase enzymes. Academic mentorship and the provision of work space will be provided while Butch spends half of his two-year EON postdoctoral program at Emory University. As an EON Affiliate Institute Supervisor, Prof. Liotta will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers. Outcomes: Dr. Liotta's group, which mainly focuses on medicinal chemistry, is building on ELSI researcher K. Petrie's groundbreaking results on protein evolution.

4. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: July 17, 2015
   Counterpart of an Agreement: Prof. Constantine Vetriani, Dept. of Biochemistry and Microbiology, Rutgers University
   Summary of an Agreement: Prof. Vetriani will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Donato Giovannelli as he pursues research on the distribution and ecology of microorganisms deeply rooted in the tree of life. Academic mentorship and the provision of work space will be provided while Giovannelli spends half of his two-year EON postdoctoral program at the Deep-Sea Microbiology Laboratory at Rutgers Univ., a center of expertise in the microbiology of extremophiles. As an EON Affiliate Institute Supervisor, Prof. Ventriani will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers. Outcomes: this has been a particularly active collaborative relationship, with Prof. Vetriani and Giovannelli inviting ELSI research scientist Nakagawa to spend time at Rutgers to

learn new lab techniques. ELSI and Rutgers members are continuing to submit proposals to develop extremophile models which are the best models for early life.

5. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: September 12, 2015
   Counterpart of an Agreement: Prof. Nicholas Bredeche, Dept. of Computer, Science, Institut des Systèmes Intelligents et de Robotique (France)
   Summary of an Agreement: Prof. Bredeche will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Nathanael Aubert-Kato as he pursues research on the emergence of agency in chemical reaction systems. Academic mentorship and the provision of work space will be provided while Aubert-Kato spends half of his two-year EON postdoctoral program at ISIR. As an EON Affiliate Institute Supervisor, Prof. Bredeche will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers.

6. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: September 15, 2015
   Counterpart of an Agreement: ETH Zurich
   Summary of an Agreement: Under the umbrella of the Tokyo Tech/ETH Zurich MoU, ELSI is in discussion with their Geochemistry/Petrology Institute in areas of High Pressure Geology and Planetary Geochemistry, and the Geophysics Institute in areas of Planetary Magnetism and Seismology/Geodynamics to formally expand our collaborative activities. In addition to ongoing work on Mars core properties at ETH, ELSI would contribute expertise in areas as the coupling of N-body and pebble accretion models to planetary geochemistry, modeling of planetary atmospheres, their signatures in exoplanet observations, and early atmosphere interaction/evolution with magma oceans, the generation and maintenance of early magnetic fields in pre-planetary bodies, and the interaction of early planetary atmospheres with planetary magnetic fields to assess retention and loss of atmospheric components. ETH sends strong applicants to the ELSI research scientist call and a graduate student from ETH is spending time at ELSI on a JSPS fellowship. There is discussion of an ELSI PI spending a few months at ETH to further promote those collaborative activities.

7. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: October 01, 2015
   Counterpart of an Agreement: Dr. Joseph Nuth, Senior Scientist for Primitive Bodies, NASA Goddard Institute for Space Studies
   Summary of an Agreement: Dr. Nuth will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Chaitanya Giri as he pursues research on the nature of organic astromaterials of possible relevance to the origins of life. Academic mentorship and the provision of work space will be provided while Giri spends half of his two-year EON postdoctoral program at NASA Goddard. As an EON Affiliate Institute Supervisor, Dr. Nuth will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers.

8. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: October 02, 2015
   Counterpart of an Agreement: Prof. Kenneth Nealson, Dept. of Earth Sciences and Biological Sciences, University of Southern California
   Summary of an Agreement: Prof. Nealson will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Nancy Tseng Merino as she pursues research on the identification of novel extremophile microorganisms. Academic mentorship and the provision of work space will be provided while Tseng Merino spends half of her two-year EON postdoctoral program at Univ. of Southern California. As an EON Affiliate Institute Supervisor, Prof. Nealson will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers.

9. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: October 18, 2015

Counterpart of an Agreement: Prof. Yuk Yung, Dept. of Planetary Science, California Institute of Technology
Summary of an Agreement: Prof. Yung will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Stuart Bartlett as he pursues research on the emergence of complexity. Academic mentorship and the provision of work space will be provided while Bartlett spends half of his two-year EON postdoctoral program at Caltech. As an EON Affiliate Institute Supervisor, Prof. Yung will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers. Outcomes: Prof. Yung's group is now exploring fundamental questions concerning the origin of life and the phenomena of learning in chemical systems in addition to planetary science as a result of the shared postdoc with ELSI, increasing the overlapping activities between them and ELSI.

10. Name of an Agreement: Memorandum of Understanding
Dates of an Agreement: November 30, 2015
Counterpart of an Agreement: Prof. Justin Meyer, Section of Ecology, Behavior and Evolution, University of California, San Diego.
Summary of an Agreement: Prof. Meyer will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Katherine Petrie as she pursues research on the mode of evolution of bacterial-virus pathogen-host relationships. Academic mentorship and the provision of work space will be provided while Petrie spends half of her two-year EON postdoctoral program at UCSD. As an EON Affiliate Institute Supervisor, Prof. Meyer will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers. Outcomes: Prof. Meyer said of ELSI's funding for shared postdoc Petrie and its interdisciplinary atmosphere allowed her to pursue controversial ideas, which resulted in a paper accepted in Science that will have significant impact on the fields of evolutionary biology and origins research.

11. Name of an Agreement: Memorandum of Understanding
Dates of an Agreement: December 7, 2015
Counterpart of an Agreement: Prof. Simon Conway Morris, Dept. of Earth Sciences, University of Cambridge
Summary of an Agreement: Prof. Conway Morris will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Jennifer Hoyal Cuthill as she pursues research on the nature of Precambrian biological evolution. Academic mentorship and the provision of work space will be provided while Hoyal Cuthill spends half of her two-year EON postdoctoral program at the Univ. of Cambridge. As an EON Affiliate Institute Supervisor, Prof. Conway Morris will also attend EON annual meetings at ELSI and share his expertise with other ELSI researchers.

12. Name of an Agreement: Memorandum of Understanding
Dates of an Agreement: January 12, 2016
Counterpart of an Agreement: Prof. Lynn Rothschild, Evolutionary biologist and astrobiologist, NASA's Ames Research Center
Summary of an Agreement: Prof. Rothschild will act as an Affiliated Institute Supervisor to ELSI Origins Network (EON) postdoc Dr. Kosuke Fujishima as he pursues research on the synthesis and selection of amino acid and RNA in prebiotic systems. Academic mentorship and the provision of work space will be provided while Fujishima spends half of his two-year EON postdoctoral program at NASA's Ames. As an EON Affiliate Institute Supervisor, Prof. Rothschild will also attend EON annual meetings at ELSI and share her` expertise with other ELSI researchers.

13. Name of an Agreement: Affiliate international Partner of the NAI
Dates of an Agreement: July 15, 2016
Counterpart of an Agreement: NASA Astrobiology Institute (NAI) with Japan Astrobiology Consortium (JABC)
Summary of an Agreement: ELSI launched the Japan Astrobiology Consortium in cooperation with the National Institutes of Natural Sciences' Astrobiology Center, and signed a partnership agreement with NASA's Astrobiology Institute. The mission of JABC is to develop the field of

astrobiology, establish a community of researchers in astrobiology, to support especially young researchers, and to be the hub for international relationships. The partnership between NAI and JABC will focus initially in (1) the exchange of early career scientists and astrobiology summer schools; (2) the organization of Workshops Without Walls; and (3) research collaborations involving members of NAI and the JABC.

14. Name of an Agreement: Temporary Assignment Contract
Dates of an Agreement: July 17, 2018
Counterpart of an Agreement: Columbia University
Summary of an Agreement: Agreement to forge closer ties to Columbia University as an affiliate institution of ELSI, which will help to enable collaborative activities like joint planning and sponsorship of workshops, symposia or courses and other ELSI or CAL hosted events as well as facilitating the exchange of visiting researchers at all professional stages.

15. Name of an Agreement: Memorandum of Understanding
Dates of an Agreement: March 18, 2019
Counterpart of an Agreement: The Australian Center for Astrobiology/School of Chemistry, University of New South Wales
Summary of an Agreement: To forge closer ties with the Australian Center for Astrobiology (ACA), a powerhouse of geoscience research and also the only astrobiological research institute in Australia. ACA is an associate member of the NASA Astrobiology Institute, of which ELSI is an active Affiliate International Partner through the Japan Astrobiology Consortium. Scientific collaborative opportunities in prebiotic chemistry and early Earth geological scenarios, leveraging ELSI and UNSW's research experiences and resources available at UNSW, will be pursued under coordination with former ELSI associate principal investigator Albert Fahrenbach who is now a Lecturer at UNSW School of Chemistry. Other potential activities include: personnel exchange/visits, jointly organized international workshops, joint development of origins of life curriculum and sharing of pedagogical materials, sabbatical stays between UNSW and ELSI academic staff. There is already a plan for an ELSI researcher to go spend time at UNSW.

16. Name of an Agreement: Joint Appointment Agreement
Dates of an Agreement: March 23, 2019
Counterpart of an Agreement: Max Planck Institute for Mathematics in the Sciences
Summary of an Agreement: To share in the hiring of research scientist Dr. Nathaniel Virgo (50% FTE for ELSI) through which closer ties between MPI MiS and ELSI will be forged in the field of complex systems and the origin of cognition.

Under Preparation

In addition, as our collaborative networks deepen and expand, we are in the process of setting up Memorandum of Understandings with the following institutions below and expect them to be signed in the coming months:

1. Name of an Agreement: Memorandum of Understanding
Dates of an Agreement: in the coming months
Counterpart of an Agreement: Arizona State University (ASU)’s School of Earth and Space Exploration
Summary of an Agreement: Director Lindy Elkins-Tanton has two strong groups of interest for ELSI: the Habitability and Exoplanets group with Drs. Hilairy Hartnett and Steve Desch, both having spent 2 months at ELSI, have numerous collaborations with ELSI researchers; and the Universal Biology group with Dr. Sara Walker, where one of the shared fundamental questions ELSI will explore is whether biology is governed by general principles and not tied to specific chemical instantiations. In addition, ASU’s Center for Meteorite Studies houses the world’s largest university-based meteorite collection. ELSI would like to further build collaborations with those already working on these astromaterials. ASU and ELSI already have strong collaborative research ties, further strengthened by them sending competitive candidates to ELSI's research scientist calls. Two of our recent hires have come from ASU.

2. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: in the coming months
   Counterpart of an Agreement: Penn State Astrobiology Research Center (PSARC)
   Summary of an Agreement: PSARC is a part of the NASA Astrobiology Institute. Dr. Katherine Freeman and Dr. Hiroshi Ohmoto (Director of PSARC) will collaborate on developing novel approaches to detecting and characterizing life, investigate biosignatures in mission-relevant ecosystems and ancient rock and evaluate the potential for biosignatures in extraterrestrial settings.

3. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: in the coming months
   Counterpart of an Agreement: Heidelberg Initiative for the Origins of Life (HIFOL), Max Planck Institute for Astronomy
   Summary of an Agreement: Dr. Thomas Henning will lead collaborative work with ELSI. HIFOL facilitates a wide range of interdisciplinary theoretical, experimental, and observational research covering the fields of astronomy, physics, geosciences, chemistry, biology and life sciences, overlapping with ELSI. MoU will explore collaborative activities like joint planning and sponsorship of workshops, symposia or courses and other ELSI or HIFOL hosted events as well as facilitating the exchange of visiting researchers at all professional stages.

4. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: in the coming months
   Counterpart of an Agreement: University of Illinois at Urbana-Champaign
   Summary of an Agreement: Dr. Nigel Goldenfeld is the director of the NASA Astrobiology Institute for Universal Biology. ELSI's research to date has focused on the molecular systems that realized the principles of life on Earth. ELSI's next phase will seek to define the theoretical and empirical science of a Universal Biology. Dr. Goldenfeld and close collaborator Dr. Kunihiko Kaneko of U. Tokyo are leading the only two existing institutes on Universal Biology worldwide, and will provide valuable guidance to our five research areas looking to define that science.

5. Name of an Agreement: Memorandum of Understanding
   Dates of an Agreement: in the coming months
   Counterpart of an Agreement: University of Arizona
   Summary of an Agreement: with Affiliated ELSI PI Betul Kacar (previously at Harvard, and an active collaborator with ELSI), we will continue to pursue the reconstruction of the deep history of biochemistry and bioenergetics. Collaboration with Dr. Dante Lauretta, PI of OSIRIS-Rex, the asteroid Bennu's sample return mission, and his team will bring further cosmochemistry expertise to ELSI on possible molecular precursors to the origin of life and the Earth's oceans.

Appendix4-6 Holding International Research Meetings

* Indicate up to twenty of most representative international research conferences or symposiums held from the start of the center through March 2021 and give the number of participants using the table below.

Date	Meeting title and Place held	Number of participants
March 27-29, 2013	The 1st ELSI International Symposium	From domestic institutions: 116 From overseas institutions: 26
March 24-26, 2014	The 2nd ELSI International Symposium "Origin &Evolution of the Earth-Life System"	From domestic institutions: 102 From overseas institutions: 43
January 13-15, 2015	The 3rd ELSI International Symposium "Life in the Universe"	From domestic institutions: 103 From overseas institutions: 41
January 12-15, 2016	The 4th ELSI International Symposium "Early Earth, Venus & Mars Three Experiments in Biological Origins"	From domestic institutions: 100 From overseas institutions: 49
July 25-26, 2016	Symposium on the Origin of Consciousness	From domestic institutions: 85 From overseas institutions: 24
January 11–13, 2017	The 5th ELSI International Symposium "Expanding Views on the Emergence of the Biosphere"	From domestic institutions: 78 From overseas institutions: 89
July 26-28, 2017	EON Workshop "Sensors, Motors and Behavior at the Origin of Life"	From domestic institutions: 19 From overseas institutions: 26
January 9-11, 2018	The 6th ELSI International Symposium "Building Bridges from Earth to Life: From Chemical Mechanism to Ancient Biology"	From domestic institutions: 80 From overseas institutions: 72
May 14-18, 2018	Workshop "Puzzles and Solutions in Astrobiology"	From domestic institutions: 49 From overseas institutions: 35
January 7-11, 2019	The 7th ELSI International Symposium "Comparative Emergence"	From domestic institutions: 69 From overseas institutions: 43
February 2-7, 2020	The 8th ELSI International Symposium "Extending Views of Catalysis"	From domestic institutions: 72 From overseas institutions: 38
January 25-28, 2021	The 9th ELSI International Symposium "Science in Society"	Total registration: 687 Online attendees: approx. 300

Appendix 5 List of Achievements of Center's Outreach Activities between FY 2012 – 2020

* Using the table below, show the achievements of the Center's outreach activities from FY2012 through FY2020 (number of activities, times held).

*If there are any rows on activities the center didn't implement, delete that (those) row(s). If you have any activities other than the items stated below, fill in the space between parentheses after "Others" on the bottom with the name of those activities and state the numbers of activities and times held in the space on the right. A row of "Others" can be added, if needed.

Activities	FY2012 (number of activities, times held)	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
PR brochure, pamphlet	0	1	4	2	2	2	1	6	2
Lectures, seminars for the general public	0	12	15	12	25	20	13	9	8
Teaching, experiments, training for elementary, secondary and high school students	0	1	9	10	11	8	4	2	4
Science cafe	0	1	1	0	1	4	0	1	2
Open house	0	0	7	0	1	1	0	0	0
Participating, exhibiting in events	0	1	8	3	3	4	4	4	1
Press releases	3	3	13	14	17	8	17	32	14
Publications of the popular science books	0	7	4	10	5	3	0	2	2
Others (Science communication, Science article, Podcast, Movie)	0	0	0	0	0	1	1	10	24

Appendix 5 List of Media Coverage of Projects Carried out between FY 2012 – 2020

* Select main items of press releases, media coverage, and reports for FY 2012-2020 (especially by overseas media)

1) Japan

No.	Date	Type of the media (e.g., newspaper, magazine, television)	Description
1	2021/03/31	Online News (PR Times)	An article that reports Keio Astrobiology Camp 2021 for which FirstLogic was a sponsor. This also explains that the winners of the e-porter competition will have an opportunity to do a research internship at ELSI Fujishima lab.
2	2021/03/04	TV(THE Toppa File)	The Toppa File: in this programme, ELSI scientist Yuichiro Ueno explains how the gas, that is artificially added smell, can become odorless when going through soil.
3	2021/03/03	Online News (ICT Kyoiku News)	This article introduces that ELSI scientist Ryuhei Nakamura will appear for the online lectures called Mirai Hakken Kouza (Future Discovery Course) of Toshin Online School.
4	2021/03/01	Print News (Tentoumushi)	Is emigration to Mars possible?; in this article, ELSI Director Kei Hirose is interviewed and talks about Mars.
5	2021/02/27	Online News (PR wire)	This article introduces that ELSI scientist Ryuhei Nakamura will appear for the online lectures called Mirai Hakken Kouza (Future Discovery Course) of Toshin Online School.
6	2021/02/27	Online News (CNET Japan)	This article introduces that ELSI scientist Ryuhei Nakamura will appear for the online lectures called Mirai Hakken Kouza (Future Discovery Course) of Toshin Online School.
7	2021/02/19	Print News (Sankei Shimbun)	The know-how of Hayabusa is expected to contribute to the sample collection of US spacecraft; in this article ELSI scientist Kosuke Fujishima comments on how Japan leads in the field of sample return.
8	2021/02/19	TV (Nihon TV)	ELSI scientist Yasuhito Sekine comments on Mars exploration in the morning TV programme called Sukkiri! as NASA's Mar's probe Curiosity successfully landed on the planet.
9	2021/02/19	Online News (Mitsubishi Electronic DESPACE)	Life crosses the universe; this is one of the serial articles written by ELSI scientist Yasuhito Sekine for Mitsubishi Electric's website DSPACE.
10	2021/02/19	Online News (J-Cast News)	NASA's unmanned rover successfully landed on Mars for the first time, looking for traces of life ... could it be a future migration destination?; this is an article related to the TV programme called Sukkiri! and ELSI scientist Yasuhito Sekine's comment is introduced.
11	2021/01/21	Online News (FirstLogic)	What determines the size of life?; this is one of the serial articles written by ELSI scientist Yasuhito Sekine for Mitsubishi Electric's website DSPACE.
12	2020/12/18	Online News (Jiji.com)	An article that announces FirstLogic Inc., which supports ELSI-FirstLogic Astrobiology Donation Program, visited ELSI. It also says that they will release a video on the visit on YouTube.
13	2020/12/18	Online News (PR Times)	An article that announces FirstLogic Inc., which supports ELSI-FirstLogic Astrobiology Donation Programme, visited ELSI. And they will release a video shot on the visit on YouTube.
14	2020/12/18	Online News (Mitsubishi Electronic DESPACE)	"Hayabusa 2" and the recipe of life; this is one of the serial articles written by ELSI scientist Yasuhito Sekine for Mitsubishi Electric's website DSPACE.
15	2020/11/18	Online News (Mitsubishi Electronic DESPACE)	The dawn of a new era of Mars exploration — a rover named "Patience"; this is one of the serial articles written by ELSI scientist Yasuhito Sekine for Mitsubishi Electric's website DSPACE.
16	2020/10/27	Online News (Astrobiology Center, National Institutes of Natural Sciences)	DNA-Peptide Interactions Create Complex Behaviors Which May Have Helped Shape Biology; an article on a research by two scientists and one of them is ELSI scientist Tony Z. Jia.
17	2020/10/22	TV (NHK BS Premium)	Cosmic Front☆Next - Ocean World The unknown appearance of the solar system; In this programme, ELSI scientist Yasuhito Sekine talks.
18	2020/10/15	Online News (Mitsubishi Electronic DESPACE)	Was Venus the Star of Life — What is a Biomarker? ; this is one of the serial articles written by ELSI scientist Yasuhito Sekine for Mitsubishi Electric's website DSPACE.
19	2020/09/16	Online News (Asahi Shimbun Globe)	In this article, ELSI scientist Tomohiro Mochizuki was introduced as one of two Japanese scientists who are called 'virus hunters.'

20	2020/09/16	Online News (Mitsubishi Electronic DESPACE)	A perspective called astrobiology; this is the first of a serial articles written by ELSI scientist Yasuhito Sekine for Mitsubishi Electric's website DSPACE.
21	2020/09/15	Online News (Asahi Shimbun Globe)	ELSI scientist Tomohiro Mochizuki assisted this interview of French evolutionary biologist Patrick Forterre on virus.
22	2020/09/14	Online News (Friday Digital)	We may find extraterrestrial life soon; ELSI scientist Yasuhito Sekine talks about the possibility of finding live (or its traces) on Mars and other planets.
23	2020/09/14	Online News (Yahoo! News)	We may find extraterrestrial life soon; ELSI scientist Yasuhito Sekine talks about the possibility of finding live (or its traces) on Mars and other planets.
24	2020/09/03	Online News (Publishing companies and Asahi Shimbun)	ELSI scientist Shigeru Ida writes about a creation of new values learned from exoplanets.
25	2020/09/01	Print News (Hitotoki)	ELSI affiliated scientist Daigo Shoji is interested in the culture related to the moon and a hare, and his comment in this topic is introduced in this article.
26	2020/08/26	Print News (Nihon Keizai Shimbun)	This article introduces ELSI - how it started as one of WPI centers, and its features including the internationality and administrative support system- and it's research. Comments by ELSI Director Kei Hirose and ELSI scientist Hidenori Genda are used in this article. A research on Mars by a research team including ELSI scientist Yasuhito Sekine is also mentioned.
27	2020/08/26	Online News (Nihon Keizai Shimbun)	This article introduces ELSI - how it started as one of WPI centers, and its features including the internationality and administrative support system- and it's research. Comments by ELSI Director Kei Hirose and ELSI scientist Hidenori Genda are used in this article. A research on Mars by a research team including ELSI scientist Yasuhito Sekine is also mentioned.
28	2020/08/26	Online News (Yomiuri Shimbun)	In this article, ELSI scientist Kosuke Fujishima comments on a research conducted by non-ELSI team.
29	2020/08/26	Online News (Nifty News)	In this article, ELSI scientist Kosuke Fujishima comments on a research conducted by non-ELSI team.
30	2020/08/26	Online News (Yahoo! News)	In this article, ELSI scientist Kosuke Fujishima comments on a research conducted by non-ELSI team.
31	2020/08/26	Online News (auone)	In this article, ELSI scientist Kosuke Fujishima comments on a research conducted by non-ELSI team.
32	2020/08/25	Print News (BMA Journal)	ELSI scientist Kosuke Fujishima's interview titled 'What are we going to the universe for?' is included in this edition of BMA Journal.
33	2020/08/25	Online News (excite News)	This article introduces the contents of August edition of BMA journal, which is the only business model general magazine in Japan. In this edition, ELSI scientist Kosuke Fujishima's interview is included.
34	2020/08/09	Print News (Kanagawa Shimbun)	An article on an online lecture event at Seika Gakuen. In this event, ELSI scientists Mayuko Nakagawa and Hiroyuki Kurokawa gave lectures.
35	2020/08/06	Online News (NewsPicks)	ELSI scientist Shigeru Ida writes about exoplanets.
36	2020/07/27	Print News (Nihon Keizai Shimbun)	ELSI researcher Hidenori Genda comments on MMX project and sample return.
37	2020/07/25	TV (TV Tokyo)	Admachikku Tengoku: Ookayama was the featured town of the day and Tokyo Tech was chosen as No, 1 of Ookayama. ELSI was shown as a new research institution of Tokyo Tech and ELSI Director Kei Hirose introduced ELSI.
38	2020/07/11	TV (NHK Ｅtele)	Science Zero: For this programme, ELSI scientist Tomohiro Mochizuki provided virus images. The title of the programme was 'the identity of virus we want to know in the age with-COVID19'
39	2020/07/04	TV (NHK Ｅtele)	Re-air of Science Zero: ELSI researcher Hidenori Genda and ELSI's affiliated scientist Ryuki Hyodo were interviewed for NHK's popular science programme Science Zero. The theme was sample return from the moon of the Mars.
40	2020/06/28	TV (NHK Ｅtele)	Re-air of Science Zero: ELSI researcher Hidenori Genda and ELSI's affiliated scientist Ryuki Hyodo were interviewed for NHK's popular science programme Science Zero. The theme was sample return from the moon of the Mars.
41	2020/05/22	Online News (Business Insider)	A simple animation by two scientists reveals what Earth's surface is made of — and how we only see 0.5% of the planet: an article that introduces an animation that shows what Earth's surface consists of. This was created by two scientists, one of whom is ELSI scientist Christine Houser.
42	2020/05/21	Online News (Mainichi Shimbun)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
43	2020/05/14	Print News (Yomiuri Shimbun)	Solving the mystery of universe with Sapphire- an article on gems that are used for scientific researches and ELSI Director Kei Hirose introduces the diamond anvil cell and how it is used for his research.

44	2020/05/13	Online News (Sputnik)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
45	2020/05/11	Online News (Academist)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
46	2020/04/23	Online News (Nihon Keizai Shimbun)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
47	2020/04/23	Online News (Jpubb)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
48	2020/04/15	Online News (Yahoo! News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
49	2020/04/15	Online News (Hanjo Hanjo)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
50	2020/04/15	Online News (Sorae)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
51	2020/04/15	Online News (Gadget Tsushin)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
52	2020/04/10	Print News (Nihon Sangyo Shimbun)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
53	2020/04/10	Online News (Zaikei Shimbun)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
54	2020/04/10	TV (Hoso Daigaku)	Open university lecture series by ELSI scientist Naohiro Yoshida
55	2020/04/09	Online News (Biglobe News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
56	2020/04/09	Online News (Slask Gear Japan)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
57	2020/04/08	Online News (Nihon Keizai Shimbun)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
58	2020/04/08	Online News (Nazologie)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
59	2020/04/06	Print News (Asahi Shimbun)	An article about viruses that is not limited to those that causes sickness: ELSI scientist Tomohiro Mochizuki's research is introduced in this article.
60	2020/04/06	Print News (Kyoiku Shimbun)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
61	2020/04/06	Online News (Asahi Shimbun)	An article about viruses that is not limited to those that causes sickness: ELSI scientist Tomohiro Mochizuki's research is introduced in this article.
62	2020/04/03	Print News (Nihon Keizai Shimbun)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
63	2020/04/03	Online News (Nihon Keizai Shimbun)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida.
64	2020/04/02	Online News (Yahoo! News)	Planets with high pressure may have larger habitable zone than previously thought: an article on a research by ELSI scientist Ramses Ramirez.
65	2020/04/02	Online News (Sorae)	Planets with high pressure may have larger habitable zone than previously thought: an article on a research by ELSI scientist Ramses Ramirez.
66	2020/04/01	Print News (Science)	This article highlights ELSI scientist Yasuhito Sekine as a researcher and introduces his research in the field of Astrobiology.
67	2019/9/30-10/3	Radio (Bay FM)	ELSI scientist Yasuhito Sekine had a series of interviews for this radio programme for four days.
68	2020/03/18	Online News (Sorae)	When the sea was there, Mars had a warm and semi-dry climate; an article on a research by a research group led by ELSI researcher Ramses Ramirez. The research group also includes ELSI affiliated scientist Tomohiro Usui.
69	2020/03/10	Online News (Nikkan Gendai)	A review of a book by ELSI scientist Shigeru Ida 'Habitable Universe.'

70	2020/03/01	Print News (Nikkei Shimbun)	This article introduces the latest research on the geomagnetism and ELSI Director Kei Hirose's research is introduced. Also, Shigeru Ida (ELSI Vice Director) gives a comment in this article.
71	2020/02/28	Online News (J-Wave News)	A report article on the radio programme 'Earthology' in which Shigeru Ida was a guest speaker.
72	2020/02/24	Radio (J-Wave)	ELSI scientist Shigeru Ida was a guest speaker in this radio programme.
73	2020/02/20	Print News (Mainichi Shimbun)	The next exploration which JAXA launches in 2024 is decided on Mars "Phobos." In this article, ELSI researcher Hidenori Genda and a research by a research group including him is mentioned. The research paper discusses that the amount of debris deposited on Phobos is more than 10 times more than previously thought.
74	2020/02/20	Online News (Mainichi Shimbun)	The next exploration which JAXA launches in 2024 is decided on Mars "Phobos." In this article, ELSI researcher Hidenori Genda and a research by a research group including him is mentioned. The research paper discusses that the amount of debris deposited on Phobos is more than 10 times more than previously thought.
75	2020/01/31	Print News (Kagaku Shimbun)	The amount of debris deposited on Phobos is more than 10 times more than previously thought; an article on the research by a research group led by ELSI affiliated scientist Ryuki Hyodo. The research grope also includes ELSI scientist Hidenori Genda and ELSI affiliated scientist Tomohiro Usui.
76	2020/01/31	Print News (Yomiuri Chu-kosei Shimbun)	A report on the Tokyo Tech lecture for Junior high school and high school students. In this article, lectures by ELSI scientist Yasuhito Sekine and ELSI affiliated scientist Tomohiro Usui were introduced.
77	2020/01/29	Online News (Sorae)	The storm caused by the protoplanet determined the appearance of the planetary system; an article on a research by a research team including ELSI scientist Hiroyuki Kurokawa.
78	2020/01/21	Online News (Niko Niko News)	Why does the structure of the planets change at the boundary between Mars and Jupiter? A new theory has appeared; an article on a research by a research team including ELSI scientist Ramon Brasser.
79	2020/01/20	Online News (Nikkei Shimbun)	First active fault zone found on Mars; in this article, ELSI scientist Christine Houser's comment on 'Insight', a seismometer that landed on Moon in 2018, is used.
80	2020/01/19	Online News (Jiji.com)	Elucidating the history of Mars by satellite exploration - Expectations are rising for the first collection of samples ; an article on a research by a research group led by ELSI affiliated scientist Ryuki Hyodo. The research group includes ELSI scientist Hidenori Genda and ELSI affiliated scientist Tomohiro Usui.
81	2020/01/19	Online News (Yahoo! News)	Elucidating the history of Mars by satellite exploration - Expectations are rising for the first collection of samples ; an article on a research by a research group led by ELSI affiliated scientist Ryuki Hyodo. The research group includes ELSI scientist Hidenori Genda and ELSI affiliated scientist Tomohiro Usui.
82	2020/01/18	Online News (Norimono News)	Elucidating the history of Mars by satellite exploration - Expectations are rising for the first collection of samples ; an article on a research by a research group led by ELSI affiliated scientist Ryuki Hyodo. The research group includes ELSI scientist Hidenori Genda and ELSI affiliated scientist Tomohiro Usui.
83	2020/01/17	Print News (Nikkann Kougyo Shimbun)	News on ELSI scientist Betul Kacar admitted to the NASA team.
84	2020/01/17	Online News (Nikkei Shimbun)	Interview and lab visit of ELSI scientist Kosuke Fujishima.
85	2020/01/09	Online News (Nikkei Shimbun)	Interview and a lab visit of ELSI scientist Kosuke Fujishima.
86	2020/01/04	Print News (Nikkei Shimbun)	In this article about artificial cells, ELSI's affiliated scientist Yutetsu Kuruma is introduced.
87	2020/01/04	Online News (Nikkei Shimbun)	In this article about artificial cells, ELSI's affiliated scientist Yutetsu Kuruma is introduced.
88	2020/01/01	Print News (Hills Life)	ELSI scientist Kosuke Fujishima answers to the questions such as what his research is and if he thinks the capitalism will last forever. (he is one of six interviewees who are asked the same questions.)
89	2020/01/01	Print News (Healthist)	Special feature article 1-Space and Life Intro Interview: 'Does "Extraterrestrial Life" Change the Universal Principles of Biology' by ELSI scientist Kosuke Fujishima. Extraterrestrial life "exists" if we part from human-centered thinking by ELSI Scientist Shigeru Ida.
90	2019/12/27	Online News (Nihon Keizai Shimbun)	Interview and a lab visit of ELSI scientist Kosuke Fujishima.
91	2019/12/26	Online News (Nihon Keizai Shimbun)	Interview and a lab visit of ELSI scientist Kosuke Fujishima.
92	2019/12/25	Online News (Nihon Keizai Shimbun)	Interview and a lab visit of ELSI scientist Kosuke Fujishima.
93	2019/12/24	Online News (Nihon Keizai Shimbun)	Interview and a lab visit of ELSI scientist Kosuke Fujishima.
94	2019/12/14	Online News (Kankou Keizai Shimbun)	A 'Hot spring escapist' refers to an ELSI's press release (in 2014) in which Happo Hot spring in Nagano was said to have a possibility to help us solve the mechanism of how a life was born on early Earth.
95	2019/11/14	Online News (Zaikei Shimbun)	Discovery that overturns the conventional view that ocean acidification leads to an increase in nitrous oxide; an article on the research by a research group including ELSI scientist Naohiro Yoshida

96	2019/11/13	TV (Hokuriku Asahi Housou)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
97	2019/11/10	TV (NHK E-tele)	Science Zero - ELSI researcher Hidenori Genda and ELSI's affiliated scientist Ryuki Hyodo were interviewed for NHK's popular science programme Science Zero. The theme was sample return from the moon of the Mars.
98	2019/11/08	Radio (JFN)	ELSI scientist Yasuhito Sekine was interviewed for a radio programme.
99	2019/11/07	Print News (Mainichi Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
100	2019/11/04	Radio (Tokyo FM)	Public talks in collaboration with radio programmes (Tokyo TM and JFM). ELSI researcher Kosuke Fujishima was one of the speakers.
101	2019/11/01	Print News (The Rotary Club of Tokyo East)	Transcription of a public lecture by ELSI scientist Yasuhito Sekine.
102	2019/11/01	Online News (Yahoo! News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
103	2019/11/01	Print News (Nikkann Kougyo Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
104	2019/11/01	Online News (Mainavi News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
105	2019/10/30	Online News (Jiji.com)	Announcement of public talks in collaboration with radio programmes. ELSI researcher Kosuke Fujishima was one of the speakers.
106	2019/10/29	Online News (Biglobe news)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
107	2019/10/29	Print News (The Japan Times)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
108	2019/10/29	Online News (Zaikei Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
109	2019/10/29	Online News (Daigaku Journal Online)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
110	2019/10/28	Online News (Nippon.com)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
111	2019/10/28	Online News (The Japan Times)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
112	2019/10/28	Online News (Nikkann Kougyo Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
113	2019/10/28	Print News (Nikkann Kougyo Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
114	2019/10/28	Online News (Newswich)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
115	2019/10/27	Online News (Tokyo Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
116	2019/10/27	Print News (Tokyo Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
117	2019/10/26	Online News (NHK News Online)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
118	2019/10/26	TV (NHK News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
119	2019/10/26	Print News (Chunichi Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
120	2019/10/26	Online News (Chunichi Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
121	2019/10/26	Print News (Nihon Keizai Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.

122	2019/10/26	Print News (Hokkoku Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
123	2019/10/26	Print News (Yomiuri Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
124	2019/10/25	Online News (47News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
125	2019/10/25	Online News (Biglobe news)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
126	2019/10/25	Online News (Excite News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
127	2019/10/25	Online News (Jiji.com)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
128	2019/10/25	Online News (Jiji.com)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
129	2019/10/25	Online News (Livedoor News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
130	2019/10/25	Online News (Nifty News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
131	2019/10/25	Online News (Asahi Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
132	2019/10/25	Online News (Iwate Nippo)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
133	2019/10/25	Online News (Kyoto Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
134	2019/10/25	Online News (Sanin Chuo Shimpo)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
135	2019/10/25	Online News (Sankei News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
136	2019/10/25	Online News (Sanyo Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
137	2019/10/25	Online News (Shikoku Shinbunsha)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
138	2019/10/25	Online News (Shinano Mainichi Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
139	2019/10/25	Online News (Shimotsuke Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
140	2019/10/25	Online News (Chiba Nippo)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
141	2019/10/25	Online News (Tokyo Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
142	2019/10/25	Online News (Touou Nippo)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
143	2019/10/25	Online News (Tokushima Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
144	2019/10/25	Online News (Nara Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
145	2019/10/25	Online News (Nikkei Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
146	2019/10/25	Online News (Fukui Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
147	2019/10/25	Online News (Hokkaido Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.

148	2019/10/25	Online News (Minami Nihon Shimbun (373 Nerws.com))	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
149	2019/10/25	Online News (Miyazaki Nichinichi Shimbun)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
150	2019/10/24	Online News (Risemamu)	Announcement of a public lecture organised by Tokyo Tech in which Hidenori Genda (ELSI scientist) was a coordinator and Yasuhito Sekine (ELSI scientist) and Tomohiro Usui (ELSI affiliated scientist) gave lectures.
151	2019/10/11	Online News (Yomiuri Shimbun)	Announcement of a public lecture organised by Tokyo Tech in which Hidenori Genda (ELSI scientist) was a coordinator and Yasuhito Sekine (ELSI scientist) and Tomohiro Usui (ELSI affiliated scientist) gave lectures.
152	2019/10/03	Online News (Excite News)	Announcement of public talks in collaboration with radio programmes. ELSI researcher Kosuke Fujishima was one of the speakers.
153	2019/10/03	Online News (Jiji.com)	Announcement of public talks in collaboration with radio programmes. ELSI researcher Kosuke Fujishima was one of the speakers.
154	2019/10/03	Online News (PR Times)	Announcement of public talks in collaboration with radio programmes. ELSI researcher Kosuke Fujishima was one of the speakers.
155	2019/10/01	Print News (Newton)	Find traces of life on Saturn's moon Titan! ; an article which ELSI scientist Yasuhito Sekine assisted.
156	2019/10/01	Print News (Bijutsu Techo)	In this special feature article, an artist from the art team 'Me' proposed four art work concepts that could be created in the outer space, and ELSI scientist Yasuhito Sekine gave advices on them.
157	2019/09/12	Online News (Gadget Tsushin)	A promotional article on the upcoming event called 'Universe Conference - can we go to the universe before we die?' in which ELSI scientist Kosuke Fujishima talks.
158	2019/08/30	Online News (Sorae)	The moon may have been born from the Earth's magmatic ocean; an article on a research by a research group including an ELSI researcher Takayuki Saitoh and an ELSI fellow Junichiro Makino.
159	2019/08/21	Print News (Sankei Shimbun)	ELSI scientist Yasuhito Sekine comments that this is a new era that should be called the eve of the discovery of extraterrestrial life
160	2019/08/21	Online News (Sankei Shimbun Web)	ELSI scientist Yasuhito Sekine comments that this is a new era that should be called the eve of the discovery of extraterrestrial life
161	2019/08/19	Online News (Sorae)	Timeline suggests 'giant planet migration' was earlier than predicted; an article on a research by a group of scientists including ELSI researcher Ramon Brasser.
162	2019/08/19	Online News (Yahoo! News)	Timeline suggests 'giant planet migration' was earlier than predicted; an article on a research by a group of scientists including ELSI researcher Ramon Brasser.
163	2019/08/18	Online News (Biglobe news)	Timeline suggests 'giant planet migration' was earlier than predicted; an article on a research by a group of scientists including ELSI researcher Ramon Brasser.
164	2019/08/18	Online News (Zaikei Shimbun)	Timeline suggests 'giant planet migration' was earlier than predicted; an article on a research by a group of scientists including ELSI researcher Ramon Brasser.
165	2019/07/03	TV (Fuji TV)	Tokudane! - In this TV programme ELSI Scientist Yasuhito Sekine comments on NASA's announcement that highly concentrated methane was found on Mars
166	2019/06/30	Online News (Nikkann Kougyo Shimbun)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
167	2019/06/26	Online News (Biglobe news)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
168	2019/06/26	Online News (Zaikei Shimbun)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
169	2019/06/25	Online News (Jiji.com)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
170	2019/06/25	Online News (Norimono News)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
171	2019/06/25	Online News (Yomiuri Shimbun)	In this article, ELSI scientist Yasuhito Sekine comments on NASA's announcement that highly concentrated methane was found on Mars.
172	2019/06/25	Online News (Yahoo! News)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
173	2019/06/24	Online News (Biglobe News)	An article on a new theory on the origins of life by a group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.

174	2019/06/24	Online News (Livedoor News)	An article on a new theory on the origins of life by a group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
175	2019/06/24	Online News (Zaikei Shimbun)	An article on a new theory on the origins of life by a group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
176	2019/06/06	Print News (Asahi Shimbun)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
177	2019/06/05	Online News (Academist Journal)	An article on creating an artificial cell, written by ELSI affiliated scientist Yutetsu Kuruma.
178	2019/05/30	Print News (Yomiuri Shimbun)	An articles in which the latest research on the universe is introduced using a popular animation as a tool. In this article, the research on Enceladus by a group of scientists led by ELSI scientist Yasuhito Sekine is introduced.
179	2019/05/29	Online News (Daigaku Journal Online)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
180	2019/05/26	Online News (Mainichi Shimbun)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
181	2019/05/25	Online News (Mainichi Shimbun)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
182	2019/05/23	TV (NHK)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
183	2019/05/22	Online News (Biglobe News)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
184	2019/05/22	Online News (Zaikei Shimbun)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
185	2019/05/22	Online News (Nihon Keizai Shimbun)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
186	2019/05/21	Online News (NHK News Web （Hokkaido News Web）)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
187	2019/05/21	Online News (Jiji.com)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
188	2019/05/21	Online News (Jiji.com)	ELSI's fellow scientist Masashi Aono was introduced as a representative of a company that developed a robot learned from the ecology of amoeba.
189	2019/05/21	Online News (Norimono News)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
190	2019/05/10	Online News (PC Watch)	The moon may have been born from the Earth's magmatic ocean; an article on a research by a research group including an ELSI researcher Takayuki Saitoh and an ELSI fellow Junichiro Makino.
191	2019/05/09	Print News (Nikkei Sangyo Shimbun)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
192	2019/05/03	Online News (Sankei Shimbun Web)	Scientists have synthesized artificial cells capable of independently performing photosynthesis in the laboratory; an article on a research by a research group including ELSI scientist Yutetsu Kuruma.
193	2019/04/19	Print News (Kagaku Shimbun)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
194	2019/04/16	Online News (Nikkei Business Online)	An interview of ELSI scientist Kosuke Fujishima on astrobiology.
195	2019/04/14	Print News (Sankei Shimbun)	This article mentions ELSI scientist Junko Kominami's calculation of how the Ultima Thule was born
196	2019/04/14	Online News (Daigaku Journal Online)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
197	2019/04/11	Print News (Nikkei Sangyo Shimbun)	Scientists have synthesized artificial cells capable of independently performing photosynthesis in the laboratory; an article on a research by a research group including ELSI scientist Yutetsu Kuruma.
198	2019/04/05	Online News (Rakumachi Fudosan Toushi Shimbun)	An article about a lecture given by ELSI scientist Kosuke Fujishima for the workers of the FirstLogic, Inc.. FirstLogic is the company that supports FirstLogic Astrobiology Donation Program, and Fujishima is the Principal Investigator of the Programme.

199	2019/04/03	Print News (Kagaku Kougyou Nippo)	Scientists have synthesized artificial cells capable of independently performing photosynthesis in the laboratory; an article on a research by a research group including ELSI scientist Yutetsu Kuruma.
200	2019/04/01	Print News (Nikkei Science)	This article introduces ELSI scientist Yasuhito Sekine's hypothesis about how the Ultima Thule was born.
201	2019/3/4 2019/3/5 2019/3/6 2019/3/7 2019/3/8 2019/3/11	web article (NATIONAL GEOGRAPHIC Japanese edition)	Dr. Fujishima was interviewed about his research of astrobiology.
202	2018/12/26	TV (NHK "Matayoshi Naoki No Heureka!")	Prof. Ida appeared to talk about what life is.
203	2018/10/13 2018/10/14 (rerun) 2018/10/28 (rerun)	TV (The Open University of Japan)	Prof. Maruyama appeared to give a lecture about evolution of life.
204	2018/10/6 2018/10/7 (rerun) 2018/10/27 (rerun)	TV (The Open University of Japan)	Prof. Maruyama appeared to give a lecture about origins of the Earth and life.
205	2018/7/25 2018/7/27 (rerun) 2019/1/23 (rerun)	TV (NHK "Matayoshi Naoki No Heureka!")	Prof. Ida, Dr. Fujishima, and Dr. Mochizuki appeared to talk about possibility of extraterrestrials. The ELSI building was also introduced.
206	2018/4/2 2018/4/23 2018/5/14 2018/7/31 2018/8/22	Magazine(web article) (Kodansha Bluebacks)	Specially appointed associate professor Yutetsu Kuruma was interviewed about his research on synthesis biology.
207	2017/12/06	Magazine(web article) (AXIS)	The collaboration project among scientists and creators called 'Creators Meet Scientists' organized by ELSI was reported.
208	2017/10/27	web article (Newsweek Japan edition)	It reported that Dr. Fujii and her colleagues developed a new method of knowing the possibility of a planet reserving water.
209	2017/04/06	Magazine (Nikkei Science)	It was reported a new hypothesis by Dr. Genda and his colleagues regarding how the marks observed on the Pluto were created.
210	2016/12/07	Magazine (WIRED)	It was reported that Dr. Fujishima had won WIRED Audi Innovation Award 2016.
211	2016/11/28	Newspaper (The Mainichi Newspapers)	It was reported that ELSI had been donated 5.5 million dollars by an US foundation among many universities in Japan suffering from their serious financial situation.
212	2016/07/03	TV (NHK "Science ZERO")	Scientific simulation movie made by Dr. Saito was introduced in the program.
213	2016/05/28	newspaper (The Yomiuri Newspapers)	It was reported that the 57th Fujihara Prize was given to the Center Director, Prof. Hirose.
214	2016/04/21	TV (NHK BS)	Scientific simulation movie made by Dr. Saito was introduced in the program "Cosmic Front - NEXT "Mystery of Globular Clusters - Ancient Cities of the Universe"
215	2016/02/14	TV (NHK E Tele)	Science ZERO "Birth of a Planet! Giant Impact"
216	2016/01/16	magazine (Bungeishunju)	Bungeishunju February Issue <New Leader Conditions> 125 Outstanding Persons Enlivening Japan
217	2015/12/04	TV (NHK BS1)	Catch! The global perspective: "Why is biohacking spreading around the world?"
218	2015/10/01	TV (NHK BS Premium)	Cosmic Front☆NEXT "Mystery of Earth's Birth"

219	2015/08/08	Newspaper, Web articles (Mainichi News, Yahoo! News, LabOnline	Tokyo Institute of Technology: American Foundation Makes 670 Million Yen Donation. Tokyo Institute of Technology Earth-Life Science Institute obtains about 670 million yen in research funding from American charitable foundation! A new search for the origin of life
220	2015/06/05	Television (NHK BS Premium)	<Cosmic Front> Virtual Space Tour—An unusual planet
221	2015/05/04	TV (TV Asahi)	<Miracle Earth> Treasure buried in Sahara Desert—The meteorite hunter 1,500 km
222	2015/04/13	TV (NHK "Close-up Gendai")	ELSI's research was introduced in the article "Found at Last!? Scientists Grapple with Life Beyond Earth".
223	2015/04/10	Television (NHK BS Premium)	<Cosmic Front> Virtual Space Tour—Adventure! Milky way galaxy.
224	2015/02/24	Newspaper (Nihon Keizai Shimbun The Tokyo Shimbun)	Understanding the ultra-deep sea ecosystem Unique ecosystem found beyond 6 km depth.
225	2015/02/17	TV (NHK World)	The Leading Edge: Not Just a Pretty Face! The Birth of the Super Diamond
226	2015/2/19 2015/2/26	Newspaper (Zaikei Shimbun The Mainichi Shimbun)	Earth-like planets are likely to form around Sun-like stars - Tokyo Institute of Technology runs a simulation. M-type dwarf planet, "different environment from Earth"
227	2014/12/14	Newspaper (Nihon Keizai Shimbun)	Theory: Large amounts of hydrogen in the Earth's core.
228	2014/8/25 2014/8/26 2014/9/1	Newspaper (Nishi Nihon Shimbun Nihon Keizai Shimbun The Sankei Shimbun)	Waseda University discovers a new mineral in Central Asia —a type of tourmaline. Tourmaline with micro-diamond discovered by Waseda University in Central Asia New mineral discovered in Central Asia: Waseda University and Tokyo Institute of Technology discover a type of tourmaline
229	2014/7/16 2014/8/14	Newspaper (The Mainichi Shimbun Nihon Keizai	"The Earth's depth unlocked" from the laboratory. An unknown mineral created under high pressure.
230	2014/7/3 2014/9/8	Newspaper (Ehime Shimbun The Asahi Shimbun)	Professor Irifune of Ehime University wins Australian Geological Society "Ringwood Award." Winner of Australian Geological Society Ringwood Award, "I followed the footsteps of my heroes."
231	2014/6/6 2014/6/23	Newspaper (Chunichi Shimbun Kyoto Shimbun	A satellite shines in the shadow. Discovered during observation of Jupiter. National Astronomical Observatory of Japan: Satellite observed shining behind Jupiter.
232	2014/5/31 2014/6/6 2014/6/22	Newspaper (Zaikei Shimbun Kagaku Kogyo Nippo Nihon Keizai Shimbun)	Indicates gene evolution from algae to land plants. How did plants evolve from sea to land?
233	2014/5/26 2014/6/26 2014/12/27	Magazine (Newton)	Birth and evolution of the solar system Evolution of universe told by colliding galaxies– Exoplanets Grand Prix The complete map of the galaxy
234	2014/04/16	Newspaper (Nihon Keizai Shimbun The Mainichi	Water on Mars—Reduced by half in 400 million years. "Underground Ice." Mars: Water reduced to half in 400 million years since the birth of the planet. Is there a large quantity of ice underground?
235	2014/01/31	Newspaper (Mainichi Shimbun)	Ueno, Y "Methane: Providing a Clue to Solving the Origin of Life." Kurashi Navi No. 13
236	2014/01/17	Newspaper (Tokyo Shimbun)	Hirose, K "The Existence of Large Amounts of Water upon the Birth of Earth." Comprehensive Section No. 12
237	2013/07/25	TV (NHK BS Premium)	Ida, S "Uranus and Neptune." Cosmic Front.
238	2013/07/07	TV (NHK ETV)	Irifune, T "It Is More Than Beautiful! The Birth of Super Diamonds." Science Zero.
239	2013/05/25	Magazine (Nikkei Science)	Saitoh, T "Focusing on the Galactic Center This Fall."
240	2013/05/14	TV (NHK BS Premium)	Hirose, K "Secrets of Explosion of Planets, the Earth, and Life." Cosmic Front.
241	2013/05/12	Newspaper (Nihon Keizai Shimbun)	Hirose, K & Maruyama, S "What is the 'Rock Theory' to Explain the Origin of Life?" Science Section
242	2013/05/02	Newspaper (Mainichi Shimbun)	Maruyama & S, Takai, K "The Origin of Life: The Ocean or the Space."

243	2013/03/21	Newspaper (Nikkei et al.)	The evolution of the gas cloud G2 was simulated. The cloud was discovered last year at the center of the Milky Way and is approaching a black hole at the center of the galaxy. It was shown that the gas cloud will shine brightly in the infrared band around the summer of 2013. (Makino)
244	2013/03/21	TV (TV Asahi "Morning Bird")	A simulation movie demonstrating the evolution of a gas cloud approaching a black hole located in the center of the Milky Way was introduced in a segment that was about two minutes long. (Makino)
245	2013/02/18	Newspaper (Nihon Keizai Shimbun)	Saturn probe data were applied to the mystery of the galactic cosmic ray acceleration. The incontrovertible results are announced in Nature Physics. (Fujimoto)
246	2013/02/14	Newspaper (Yomiuri Shimbun)	Exploratory research in high-pressure geoscience, Kei Hirose (Director, Tokyo Institute of Technology Earth–Life Science Institute): "Journey to the Center of the Earth."
247	2012/10/31	Newspaper (Yomiuri Shimbun et al.)	Tokyo Institute of Technology to shed light on the environment of the early Earth; Professor Kei Hirose (44) Three university groups selected for the world's most advanced research center, Ministry of Education, Culture, Sports, Science and Technology

2) Overseas

No.	Date	Type of the media (e.g., newspaper, magazine, television)	Description
1	2021/03/31	Online News (SpaceRef)	AbGradCon 2021 Update: Registration Extended; in this article ELSI is mentioned as an event hosting institution.
2	2021/03/09	Online News (EOS)	A New Understanding of the Mid-Atlantic Ridge and Plate Tectonics; in this article, ELSI scientist Christine Houser gives a comment on collecting seismic data from ocean.
3	2021/02/18	Online News (ceo world biz)	In this article, Tokyo Tech is named as No. 5 of Top universities to study Engineering and Technology, and ELSI is referred as one of the research facilities Tokyo Tech maintains.
4	2021/02/09	Online News (National Geographic)	Why are people so dang obsessed with Mars?; in this article, ELSI scientist Ramses Ramirez comments on the photographs taken by Mariner 9.
5	2021/02/02	Online News (Quanta Magazine)	Rumbles on Mars Raise Hopes of Underground Magma Flows; in this article, an ELSI scientist Christine Houser comments on the seismometer that NASA sent to Mars.
6	2021/01/08	Online News (Planetary News)	An article announcing the acceptance of applications for NASA Astrobiology Graduate Conference (AbGradCon)2021, which will be hosted by ELSI.
7	2020/12/23	Online News (Nature Asia)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
8	2020/12/15	Online News (Popular Mechanics)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
9	2020/12/14	Online News (IFL Science)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
10	2020/12/13	Online News (Scitech Daily)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
11	2020/12/11	Online News (Popmech)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
12	2020/12/11	Online News (Europa Press)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
13	2020/12/11	Online News (Lab Manager)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
14	2020/12/10	Online News (Newswise)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
15	2020/12/10	Online News (Agenparl)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
16	2020/12/10	Online News (Bioengineer.org)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
17	2020/12/10	Online News (Phys.org)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
18	2020/12/10	Online News (Sciencenewsnet.in)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.

19	2020/12/10	Online News (Scienmag)	Artificial intelligence finds surprising patterns in Earth's biological mass extinctions; an article on a research by a research team led by former ELSI EON Project postdoc and current ELSI affiliated scientist Jennifer Hoyal Cuthill. The research team also includes ELSI affiliated scientist Nicholas Guttenberg.
20	2020/11/20	Online News (Sputnik)	Another Darwinian theory of life validated by scientists nearly 200 years later ; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
21	2020/11/10	Online News (NTV)	Turkish scientist will lead the team that will guide NASA's search for life in the universe; An article about ELSI scientist Betul Kacar
22	2020/10/29	Online News (Mirage News)	Scientists discover new organic compounds that could have helped form the first cells; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
23	2020/10/28	Online News (Newswise)	Scientists discover new organic compounds that could have helped form the first cells; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
24	2020/10/28	Online News (Bioengineer.org)	Scientists discover new organic compounds that could have helped form the first cells; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
25	2020/10/28	Online News (Lab Manager)	Scientists discover new organic compounds that could have helped form the first cells; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
26	2020/10/28	Online News (Phys.org)	Scientists discover new organic compounds that could have helped form the first cells; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
27	2020/10/28	Online News (Sciencenewsnet.in)	Scientists discover new organic compounds that could have helped form the first cells; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
28	2020/10/28	Online News (Scienmag)	Scientists discover new organic compounds that could have helped form the first cells; an article on a research by a research team including ELSI scientists Tony Z. Jia, Irena Mamajanov, Niraja Bapat, and James Cleaves.
29	2020/10/20	Online News (News Break)	New study shows how complex metabolism may have self-assembled from simple precursors; an article on a research by an all ELSI research team. The research was led by Sebastian Sanden, and others are Ruiqin Yi, Masahiko Hara, and Shawn McGlynn.
30	2020/10/19	Online News (Mirage News)	DNA-Peptide Interactions Create Complex Behaviors Which May Have Helped Shape Biology; an article on a research by two scientists and one of them is ELSI scientist Tony Z. Jia.
31	2020/10/19	Online News (WorldNewsEra)	New study shows how complex metabolism may have self-assembled from simple precursors; an article on a research by an all ELSI research team. The research was led by Sebastian Sanden, and others are Ruiqin Yi, Masahiko Hara, and Shawn McGlynn.
32	2020/10/19	Online News (Science Codex)	New study shows how complex metabolism may have self-assembled from simple precursors; an article on a research by an all ELSI research team. The research was led by Sebastian Sanden, and others are Ruiqin Yi, Masahiko Hara, and Shawn McGlynn.
33	2020/10/19	Online News (Phys.org)	New study shows how complex metabolism may have self-assembled from simple precursors; an article on a research by an all ELSI research team. The research was led by Sebastian Sanden, and others are Ruiqin Yi, Masahiko Hara, and Shawn McGlynn.
34	2020/10/16	Online News (Lab Manager)	DNA-Peptide Interactions Create Complex Behaviors Which May Have Helped Shape Biology; an article on a research by two scientists and one of them is ELSI scientist Tony Z. Jia.
35	2020/10/14	Online News (Phys.org)	DNA-Peptide Interactions Create Complex Behaviors Which May Have Helped Shape Biology; an article on a research by two scientists and one of them is ELSI scientist Tony Z. Jia.
36	2020/10/14	Online News (Sciencenewsnet.in)	DNA-Peptide Interactions Create Complex Behaviors Which May Have Helped Shape Biology; an article on a research by two scientists and one of them is ELSI scientist Tony Z. Jia.
37	2020/10/14	Online News (Bioengineer)	DNA-Peptide Interactions Create Complex Behaviors Which May Have Helped Shape Biology; an article on a research by two scientists and one of them is ELSI scientist Tony Z. Jia.
38	2020/10/14	Online News (Scienmag)	DNA-Peptide Interactions Create Complex Behaviors Which May Have Helped Shape Biology; an article on a research by two scientists and one of them is ELSI scientist Tony Z. Jia.
39	2020/10/12	Online News (Mirage News)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
40	2020/09/26	Online News (SOL Haber Portali)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
41	2020/09/18	Online News (Geology Page)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
42	2020/09/18	Online News (Tech Explorist)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
43	2020/09/14	Online News (Business Insider Italia)	A simple animation by two scientists reveals what Earth's surface is made of — and how we only see 0.5% of the planet: an article that introduces an animation that shows what Earth's surface consists of. This was created by two scientists, one of whom is ELSI scientist Christine Houser.
44	2020/09/10	Online News (Noticias de la Ciencia y la Technologia)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.

45	2020/09/09	Online News (Popmech)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
46	2020/09/09	Online News (Phys.org)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
47	2020/09/09	Online News (Space Daily)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
48	2020/09/09	Online News (Azom Material)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
49	2020/09/08	Online News (Scienmag)	Study discovers process that may have produced first organic molecules for life on Earth: an article on a research by a research team including ELSI scientists Shawn McGlynn and Ryuhei Nakamura.
50	2020/09/06	Online News (Corrriere Adoriatico.it)	A project of Donato Giovannelli, a former ELSI EON project postdoc and current ELSI affiliated scientist, is financed with 2.1 million euros by ERC Starting Grant.
51	2020/09/03	Online News (Il Mattino)	A project of Donato Giovannelli, a former ELSI EON project postdoc and current ELSI affiliated scientist, is financed with 2.1 million euros by ERC Starting Grant.
52	2020/09/03	Online News (Il Resto del Gargano)	A project of Donato Giovannelli, a former ELSI EON project postdoc and current ELSI affiliated scientist, is financed with 2.1 million euros by ERC Starting Grant.
53	2020/08/27	Online News (Noticias de la Ciencia y la Technologia)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
54	2020/08/20	Online News (Bioengineer)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
55	2020/08/20	Online News (Genetic Engineering & Biotechnology News)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
56	2020/08/20	Online News (Phys.org)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
57	2020/08/20	Online News (Scienmag)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
58	2020/08/20	Online News (Sciencenewsnet.in)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
59	2020/08/20	Online News (Scitech Daily)	Small enzyme-mimicking polymers may have helped start life: an article on a research by an all-ELSI research team. Team is led by Irena Mamajanov, and other members are Melina Caudan and Tony Z. Jia.
60	2020/08/06	Online News (Science Daily)	Scientists identify missing source of atmospheric carbonyl sulfide: an article on a research by a research team including ELSI scientist Naohiro Yoshida.
61	2020/07/05	Online News (Satakunnan Kansa)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
62	2020/07/02	Online News (Eurasia Review)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
63	2020/07/01	Online News (Mirage News)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
64	2020/07/01	Online News (Infinity News)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
65	2020/06/29	Online News (Suara.com)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
66	2020/06/29	Online News (ZAP)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
67	2020/06/27	Online News (Aventuras Na Historia)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
68	2020/06/26	Online News (Mega Curioso)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
69	2020/06/26	Online News (Universe Today)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
70	2020/06/25	Online News (Cambio16)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.

71	2020/06/25	Online News (RT)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
72	2020/06/25	Online News (cnBeta)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
73	2020/06/25	Online News (BGR)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
74	2020/06/25	Online News (Instalki.pl)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
75	2020/06/25	Online News (Linformatique)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
76	2020/06/25	Online News (Space.com)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
77	2020/06/24	Online News (Muy Interesante)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
78	2020/06/24	Online News (Tunis Daily News)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
79	2020/06/24	Online News (Eos)	This article introduces the paper written by ELSI Director Kei Hirose and Vice Director Joh Hernlund.
80	2020/06/24	Online News (Fox News)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
81	2020/06/24	Online News (Daily Hunt)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
82	2020/06/24	Online News (First Post)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
83	2020/06/24	Online News (MSN)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
84	2020/06/24	Online News (News. 21.BY)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
85	2020/06/24	Online News (Yahoo! News)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
86	2020/06/24	Online News (charter97.org)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
87	2020/06/24	Online News (El Confidencial)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
88	2020/06/24	Online News (Numerama)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
89	2020/06/24	Online News (4ever Science)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
90	2020/06/24	Online News (Fanpage)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
91	2020/06/24	Online News (Mashable India)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
92	2020/06/24	Online News (Noticias de la Ciencia y la Technologia)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
93	2020/06/24	Online News (sb Dirty South Soccer)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
94	2020/06/23	Online News (ABC)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
95	2020/06/23	Online News (ABC de Sevilla)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
96	2020/06/23	Online News (DNA)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.

97	2020/06/23	Online News (Hindustan Times)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
98	2020/06/23	Online News (La voz digital)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
99	2020/06/23	Online News (Siasat Daily)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
100	2020/06/23	Online News (The Indian Express)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
101	2020/06/23	Online News (Republic World)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
102	2020/06/23	Online News (Daily Hunt)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
103	2020/06/23	Online News (LatestLY)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
104	2020/06/23	Online News (Sputnik)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
105	2020/06/23	Online News (International Business Times)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
106	2020/06/23	Online News (Japan Herald)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
107	2020/06/23	Online News (IFL Science)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
108	2020/06/23	Online News (Lega Nerd)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
109	2020/06/23	Online News (Media Inaf)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
110	2020/06/23	Online News (Meteo Web)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
111	2020/06/23	Online News (Moon Daily)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
112	2020/06/23	Online News (Olhar Digital)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
113	2020/06/23	Online News (Science Alert)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
114	2020/06/23	Online News (Science Bulletin)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
115	2020/06/23	Online News (Spektrum.de)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
116	2020/06/23	Online News (US Times Now)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
117	2020/06/22	Online News (Eastern Mirror)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
118	2020/06/22	Online News (Independent)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
119	2020/06/22	Online News (Telangana Today)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
120	2020/06/22	Online News (India TV)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
121	2020/06/22	Online News (DaijiWorld.com)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
122	2020/06/22	Online News (News Beezer)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.

123	2020/06/22	Online News (Free News)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
124	2020/06/22	Online News (New Kerala)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
125	2020/06/22	Online News (Somag News)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
126	2020/06/22	Online News (7th Space)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
127	2020/06/22	Online News (Futura Sciences)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
128	2020/06/22	Online News (Heritage Daily)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
129	2020/06/22	Online News (Infosurhoy)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
130	2020/06/22	Online News (Nanowerk)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
131	2020/06/22	Online News (Notizie Scienfitiche.it)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
132	2020/06/22	Online News (Phys.org)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
133	2020/06/22	Online News (Science Daily)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
134	2020/06/22	Online News (SciTech Daily)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
135	2020/06/22	Online News (Tech Explorist)	Scientists provide new explanations for the far side of the Moon's strange asymmetry: an article on a research by a research group including ELSI scientist Matthieu Laneuville.
136	2020/06/15	Online News (Notizie Scienfitiche.it)	The research by a research team led by ELSI scientist Ruiqin Yi was picked as one of the three 'other notices' of the week (8-14 June, 2020). The research team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
137	2020/06/09	Online News (Chemie.de)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
138	2020/06/08	Online News (Bioengineer)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
139	2020/06/08	Online News (Science Codex)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
140	2020/06/08	Online News (Scienmag)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
141	2020/06/07	Online News (Twittersmash)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
142	2020/06/05	Online News (Scitech Daily)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
143	2020/06/04	Online News (Forbes)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
144	2020/06/04	Online News (Astrobiology Web)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
145	2020/06/03	Online News (TVN)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
146	2020/06/03	Online News (AB-News Russia)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
147	2020/06/03	Online News (Phys.org)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.
148	2020/06/03	Online News (Space Daily)	Study reveals continuous pathway to building blocks of life: an article on a research by a research team led by ELSI scientist Ruiqin Yi. The team also includes ELSI scientist James Cleaves and ELSI affiliated scientist Albert Fahrenbach.

149	2020/05/29	Online News (Los Angeles Times)	An article include a story on a research on decontamination and restoration of polypropylene microfiber N95 medical masks and respirators by a research team including ELSI scientist Joseph Kirschvink.
150	2020/05/29	Online News (Mirage News)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
151	2020/05/24	Online News (Sputnik)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
152	2020/05/24	Online News (Tecnoticias)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
153	2020/05/23	Online News (MSN)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
154	2020/05/20	Online News (Muy Interesante)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
155	2020/05/20	Online News (The Hindu Business Line)	ELSI affiliated scientist Chaitanya Giri's comment is introduced in the article on Moon agreement and India.
156	2020/05/20	Online News (Sapo Tek)	This article introduces an animation by two scientists, one of whom is ELSI scientist Christine Houser. This animation reveals what Earth's surface is made of.
157	2020/05/17	Online News (Поиск)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
158	2020/05/15	Online News (Mirage News)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
159	2020/05/15	Online News (EarthSky)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
160	2020/05/15	Online News (Labiotech)	This article mentions the research conducted by ELSI affiliated scientist (ELSI scientist at the time of publication) Yutetsu Kuruma regarding application of synthetic biology to photosynthesis to produce artificial cells.
161	2020/05/15	Online News (Space ref)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
162	2020/05/14	Online News (Sci-News.com)	Paleontologists Find Strange Ball-Like Structures in 80-Million-Year-Old Fossils: an article on a research led by ELSI affiliated scientist Jennifer Hoyal Cuthill.
163	2020/05/13	Online News (Independent)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
164	2020/05/13	Online News (Metro)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
165	2020/05/13	Online News (Mirage News)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
166	2020/05/13	Online News (What's New)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
167	2020/05/13	Online News (IFL Science)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
168	2020/05/13	Online News (Media Inaf)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
169	2020/05/13	Online News (Nanowerk)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
170	2020/05/13	Online News (Phys.org)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
171	2020/05/13	Online News (Sci Tech Daily)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
172	2020/05/13	Online News (Science Daily)	Scientists create breakthrough simulation of the inside of Mars, which could reveal the secret of how it was formed: an article on a research by a research team including ELSI Director Kei Hirose.
173	2020/05/12	Online News (Vice)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
174	2020/05/12	Online News (Pulse Nigeria)	A simple animation by two scientists reveals what Earth's surface is made of — and how we only see 0.5% of the planet: an article that introduces an animation that shows what Earth's surface consists of. This was created by two scientists, one of whom is ELSI scientist Christine Houser.

175	2020/05/12	Online News (Business Insider)	A simple animation by two scientists reveals what Earth's surface is made of — and how we only see 0.5% of the planet: an article that introduces an animation that shows what Earth's surface consists of. This was created by two scientists, one of whom is ELSI scientist Christine Houser.
176	2020/05/12	Online News (Sapo Tek)	A simple animation by two scientists reveals what Earth's surface is made of — and how we only see 0.5% of the planet: an article that introduces an animation that shows what Earth's surface consists of. This was created by two scientists, one of whom is ELSI scientist Christine Houser.
177	2020/05/12	Online News (Teslarati)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
178	2020/05/11	Online News (der Standard)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
179	2020/05/11	Online News (International Business Times)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
180	2020/05/11	Online News (Gizmoposts24)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
181	2020/05/10	Online News (Telset)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
182	2020/05/09	Online News (Portal Jember)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
183	2020/05/08	Online News (Evrim Ağacı)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
184	2020/05/08	Online News (Noticias de la Ciencia y la Technologia)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
185	2020/05/08	Online News (Sott)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
186	2020/05/07	Online News (Telset)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
187	2020/05/06	Online News (Fox News)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
188	2020/05/06	Online News (News 18 Buzz)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
189	2020/05/06	Online News (Republic World)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
190	2020/05/06	Online News (Sputnik)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
191	2020/05/06	Online News (4ever science)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
192	2020/05/06	Online News (Dual Dove)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
193	2020/05/06	Online News (Mashable India)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
194	2020/05/06	Online News (Webby Feed)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
195	2020/05/05	Online News (intallaght)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
196	2020/05/05	Online News (Vice)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
197	2020/05/05	Online News (New York Post)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
198	2020/05/05	Online News (International Business Times)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
199	2020/05/05	Online News (UOL)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
200	2020/05/05	Online News (Genetic Literacy Project)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.

201	2020/05/05	Online News (Live Science)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
202	2020/05/04	Online News (Green Style)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
203	2020/05/04	Online News (Vice)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
204	2020/05/04	Online News (ICI (Radio Canada))	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
205	2020/05/04	Online News (Sky Tg 24)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
206	2020/05/04	Online News (MSN)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
207	2020/05/04	Online News (Notizie In)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
208	2020/05/04	Online News (Centrometeoitaliano)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
209	2020/05/04	Online News (Everyeye.it)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
210	2020/05/04	Online News (Media Inaf)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
211	2020/05/04	Online News (Science Alert)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
212	2020/05/03	Online News (Sputnik)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
213	2020/05/03	Online News (Mega Curioso)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
214	2020/05/02	Online News (Suara.com)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
215	2020/05/02	Online News (hitechno)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
216	2020/05/01	Online News (News. 21.BY)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
217	2020/05/01	Online News (charter97.org)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
218	2020/05/01	Online News (Inverse)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
219	2020/05/01	Online News (N+1)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
220	2020/05/01	Online News (Sci News)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
221	2020/04/30	Online News (Forbes)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
222	2020/04/30	Online News (National Geographic Indonesia)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
223	2020/04/30	Online News (RPP)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
224	2020/04/30	Online News (Daily Hunt)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
225	2020/04/30	Online News (First Post)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
226	2020/04/30	Online News (Gatra.com)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.

227	2020/04/30	Online News (New Kerala)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
228	2020/04/30	Online News (Astrobiology News)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
229	2020/04/30	Online News (Daily Space)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
230	2020/04/30	Online News (Inverse)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
231	2020/04/30	Online News (Olhar Digital)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
232	2020/04/30	Online News (Space.com)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
233	2020/04/29	Online News (Newsweek)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
234	2020/04/29	Online News (Publimetro Mexico)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
235	2020/04/29	Online News (ERR.ee)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
236	2020/04/29	Online News (MSN)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
237	2020/04/29	Online News (Newswise)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
238	2020/04/29	Online News (Notimerica)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
239	2020/04/29	Online News (ANI)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
240	2020/04/29	Online News (Prensa Latina)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
241	2020/04/29	Online News (7th Space)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
242	2020/04/29	Online News (IFL Science)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
243	2020/04/29	Online News (Justdial)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
244	2020/04/29	Online News (Kopalnia Wiedzy)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
245	2020/04/29	Online News (Lab Manager)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
246	2020/04/29	Online News (Naked Sciences)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
247	2020/04/29	Online News (Nanowerk)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
248	2020/04/29	Online News (Phys.org)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
249	2020/04/29	Online News (Phys.org)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
250	2020/04/29	Online News (SyFywire)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
251	2020/04/29	Online News (Tech Explorist)	4-billion-year-old nitrogen-containing organic molecules discovered in Martian meteorites: an article on a research by a research group including ELSI scientist Atsuko Kobayashi and ELSI affiliated scientist Tomohiro Usui.
252	2020/04/28	Online News (Mirage News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida

253	2020/04/27	Online News (Physics World)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
254	2020/04/27	Online News (Science Spring)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
255	2020/04/26	Online News (Scitech Daily)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
256	2020/04/24	Online News (Leipziger Internet Zeitung)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
257	2020/04/24	Online News (Laboratory Equipment)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
258	2020/04/24	Online News (Vbio)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
259	2020/04/23	Online News (Life)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
260	2020/04/23	Online News (Ciel et Espace)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
261	2020/04/23	Online News (Space Daily)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
262	2020/04/22	Online News (Astrobiology web)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
263	2020/04/22	Online News (Bioengineer)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
264	2020/04/22	Online News (GIT)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
265	2020/04/22	Online News (Heritage Daily)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
266	2020/04/22	Online News (IDW)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
267	2020/04/22	Online News (Innovations Report)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
268	2020/04/22	Online News (Phys.org)	Life's earliest evolution was more complicated than previously suspected: an article on a research by a research team including ELSI scientist Shawn McGlynn.
269	2020/04/17	Online News (Epoch times)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
270	2020/04/15	Online News (Science Daily)	Journey to the center of the Earth - First of its kind experiment uses diamond anvils to simulate the Earth's core: an article on a research by a research team including ELSI Director Kei Hirose.
271	2020/04/12	Online News (Astronomer rocks)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
272	2020/04/11	Online News (Astroblogs)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
273	2020/04/09	Online News (Popular Science)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
274	2020/04/09	Online News (Sciences et Avenir)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
275	2020/04/09	Online News (Somag news)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
276	2020/04/09	Online News (Advanced Science News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
277	2020/04/09	Online News (Canaltech)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
278	2020/04/09	Online News (Everyeye Tech)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida

279	2020/04/09	Online News (Foxtime)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
280	2020/04/09	Online News (Futura Sciences)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
281	2020/04/09	Online News (Infosurhoy)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
282	2020/04/09	Online News (Science Mag.cz)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
283	2020/04/09	Online News (Tekk.tv)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
284	2020/04/09	Online News (Webtekno)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
285	2020/04/08	Online News (Revista planeta)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
286	2020/04/08	Online News (Aydinlik)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
287	2020/04/08	Online News (Prensa Libre online)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
288	2020/04/08	Online News (Thanhnien)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
289	2020/04/08	Online News (iNews.id)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
290	2020/04/08	Online News (Vesti.ru)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
291	2020/04/08	Online News (Yahoo! India News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
292	2020/04/08	Online News (Breakingnews.fr)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
293	2020/04/08	Online News (cnBeta)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
294	2020/04/08	Online News (Epoch times)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
295	2020/04/08	Online News (Mynet)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
296	2020/04/08	Online News (Agencia ID)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
297	2020/04/08	Online News (BGR)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
298	2020/04/08	Online News (Centauri Dreams)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
299	2020/04/08	Online News (Fredzone)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
300	2020/04/08	Online News (Global News Hut)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
301	2020/04/08	Online News (Guru Meditation)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
302	2020/04/08	Online News (Instalki.pl)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
303	2020/04/08	Online News (Langitselatan)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
304	2020/04/08	Online News (Medical Daily)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida

305	2020/04/08	Online News (Serialpressit)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
306	2020/04/07	Online News (Galileu)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
307	2020/04/07	Online News (Online Focus)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
308	2020/04/07	Online News (ABC)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
309	2020/04/07	Online News (ABC de Sevilla)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
310	2020/04/07	Online News (Kibris Postasi)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
311	2020/04/07	Online News (Republika)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
312	2020/04/07	Online News (Sentinel Assam)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
313	2020/04/07	Online News (Colombia.com)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
314	2020/04/07	Online News (ERR.ee)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
315	2020/04/07	Online News (Fox News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
316	2020/04/07	Online News (Romania24)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
317	2020/04/07	Online News (Wion)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
318	2020/04/07	Online News (Blinkwire)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
319	2020/04/07	Online News (First Post)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
320	2020/04/07	Online News (News Beezer)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
321	2020/04/07	Online News (Newsgram.com)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
322	2020/04/07	Online News (Yahoo! Finance)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
323	2020/04/07	Online News (DC News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
324	2020/04/07	Online News (Gatra.com)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
325	2020/04/07	Online News (Japan Herald)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
326	2020/04/07	Online News (La voz de Cadis)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
327	2020/04/07	Online News (Numerama)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
328	2020/04/07	Online News (Astronomi.news)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
329	2020/04/07	Online News (Livescience.com)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
330	2020/04/07	Online News (Richard Dawkins Foundation)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida

331	2020/04/07	Online News (Scitech Daily)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
332	2020/04/07	Online News (Slask Gear)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
333	2020/04/07	Online News (Space Daily)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
334	2020/04/07	Online News (TechExplorist)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
335	2020/04/07	Online News (Tom's Guide)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
336	2020/04/07	Online News (Wissenschaft)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
337	2020/04/06	Online News (Outlook India)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
338	2020/04/06	Online News (Business Standard)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
339	2020/04/06	Online News (Can India)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
340	2020/04/06	Online News (el nuevo dia)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
341	2020/04/06	Online News (Ultimahora)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
342	2020/04/06	Online News (News 18)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
343	2020/04/06	Online News (News 24)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
344	2020/04/06	Online News (Republic World)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
345	2020/04/06	Online News (RPP)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
346	2020/04/06	Online News (RT)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
347	2020/04/06	Online News (Zee Business)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
348	2020/04/06	Online News (Daiji World)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
349	2020/04/06	Online News (Daily Hunt)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
350	2020/04/06	Online News (Daily News X)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
351	2020/04/06	Online News (News Beezer)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
352	2020/04/06	Online News (Notimerica)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
353	2020/04/06	Online News (Yahoo! News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
354	2020/04/06	Online News (ANI)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
355	2020/04/06	Online News (Sputnik)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
356	2020/04/06	Online News (India New England News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida

357	2020/04/06	Online News (International Business Times)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
358	2020/04/06	Online News (New Kerala)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
359	2020/04/06	Online News (New Kerala)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
360	2020/04/06	Online News (Social News XYZ)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
361	2020/04/06	Online News (7th Space)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
362	2020/04/06	Online News (Global Science)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
363	2020/04/06	Online News (Heritage Daily)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
364	2020/04/06	Online News (IFL Science)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
365	2020/04/06	Online News (Phys.org)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
366	2020/04/06	Online News (Science Codex)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
367	2020/04/06	Online News (Science Daily)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
368	2020/04/06	Online News (Scifi News)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
369	2020/04/06	Online News (Sott)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
370	2020/04/06	Online News (Space.com)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
371	2020/04/06	Online News (Tech Times)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
372	2020/04/06	Online News (The Daily Galaxy)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
373	2020/04/06	Online News (The Tecake)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
374	2020/04/06	Online News (Webby Feed)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
375	2020/04/02	Online News (N+1)	Japanese astronomers explain oddities of planet Uranus; an article on a research by a research team led by ELSI scientist Shigeru Ida
376	2020/04/01	Online News (The Planetary Society)	This is a transcript of the podcast, in which ELSI scientist Ramses Ramirez is interviewed on Mars and on his view on the future Mars exploration.
377	2020/03/31	Online News (pro-physik.de)	The birth of a satellite in a disk of water vapor ; an article on a research by a research group led by ELSI scientist Shigeru Ida
378	2020/03/30	Online News (Welt der Physik)	Evaporating ice as the key; an article on a research by a research group led by ELSI scientist Shigeru Ida
379	2020/03/01	Online News (The Planetary Society)	In this article ELSI scientist Ramses Ramirez is asked to answer the questions regarding Mars.
380	2020/02/13	Online News (Sciworthy)	Reconstruction of cysteine biosynthesis using engineered cysteine-free enzymes; an article on a research by a research group led by ELSI scientist Kosuke Fujishima.
381	2020/02/02	Online News (SciTech Daily)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
382	2020/01/28	Online News (Archyde)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.

383	2020/01/24	Online News (The Digital Wise)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
384	2020/01/23	Online News (Science Daily)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
385	2020/01/23	Online News (Yahoo India News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
386	2020/01/22	Online News (Democratic Underground)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
387	2020/01/22	Online News (Eurasia Review)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
388	2020/01/22	Online News (Express)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
389	2020/01/22	Online News (icosmos)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
390	2020/01/22	Online News (iflscience)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
391	2020/01/22	Online News (Invest records)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
392	2020/01/22	Online News (MANA FN)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
393	2020/01/22	Online News (Mirage News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
394	2020/01/22	Online News (Newsbreak)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
395	2020/01/22	Online News (Tech Explorist)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
396	2020/01/22	Online News (Telangana Today)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
397	2020/01/22	Online News (The Independent)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
398	2020/01/21	Online News (Astrobiology News)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
399	2020/01/21	Online News (Mirage News)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
400	2020/01/21	Online News (Phys.org)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
401	2020/01/21	Online News (ZME Science)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
402	2020/01/20	Online News (MNS)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
403	2020/01/18	Online News (HaberVakti)	News on ELSI scientist Betul Kacar admitted to the NASA team.
404	2020/01/18	Online News (Karadeniz)	News on ELSI scientist Betul Kacar admitted to the NASA team.
405	2020/01/18	Online News (Posta)	News on ELSI scientist Betul Kacar admitted to the NASA team.
406	2020/01/17	Online News (Aksam)	News on ELSI scientist Betul Kacar admitted to the NASA team.
407	2020/01/17	Online News (BirGun)	News on ELSI scientist Betul Kacar admitted to the NASA team.
408	2020/01/17	Online News (BirGün Gazetesi)	News on ELSI scientist Betul Kacar admitted to the NASA team.

409	2020/01/17	Online News (Digital Age)	News on ELSI scientist Betul Kacar admitted to the NASA team.
410	2020/01/17	Online News (Dirilis Postasi)	News on ELSI scientist Betul Kacar admitted to the NASA team.
411	2020/01/17	Online News (Haber Port)	News on ELSI scientist Betul Kacar admitted to the NASA team.
412	2020/01/17	Online News (Haberler.com)	News on ELSI scientist Betul Kacar admitted to the NASA team.
413	2020/01/17	Online News (Haberler.com)	News on ELSI scientist Betul Kacar admitted to the NASA team.
414	2020/01/17	Online News (Hjaber 61)	News on ELSI scientist Betul Kacar admitted to the NASA team.
415	2020/01/17	Online News (Litelist)	News on ELSI scientist Betul Kacar admitted to the NASA team.
416	2020/01/17	Online News (Milliyet)	News on ELSI scientist Betul Kacar admitted to the NASA team.
417	2020/01/17	Online News (Ortadogugazetesti)	News on ELSI scientist Betul Kacar admitted to the NASA team.
418	2020/01/17	Online News (Shiftdelete)	News on ELSI scientist Betul Kacar admitted to the NASA team.
419	2020/01/17	Online News (Sputnik)	News on ELSI scientist Betul Kacar admitted to the NASA team.
420	2020/01/17	Online News (Ulsal Kanar)	News on ELSI scientist Betul Kacar admitted to the NASA team.
421	2020/01/16	Online News (Click Lancashire)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
422	2020/01/16	Online News (Physics World)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
423	2020/01/16	Online News (Science Times)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
424	2020/01/16	Online News (Tunis Daily News)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
425	2020/01/15	Online News (Mashable India)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
426	2020/01/15	Online News (Sputnik)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
427	2020/01/15	Online News (Ultimahora)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
428	2020/01/14	Online News (CNN)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
429	2020/01/14	Online News (Eurasia Review)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
430	2020/01/14	Online News (FMR Journal)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
431	2020/01/14	Online News (Notizia de la Ciencia y la Technologia)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
432	2020/01/14	Online News (Republica)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
433	2020/01/14	Online News (Sci-News.,com)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
434	2020/01/14	Online News (Space Daily)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.

435	2020/01/14	Online News (Techlife)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
436	2020/01/14	Online News (The Times Hub)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
437	2020/01/13	Online News (Astrobiology Magazine)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
438	2020/01/13	Online News (Cooperativa.cl)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
439	2020/01/13	Online News (Daily Mail)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
440	2020/01/13	Online News (Independent)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
441	2020/01/13	Online News (Invest Record)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
442	2020/01/13	Online News (La Vanguardia)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
443	2020/01/13	Online News (Livescience.com)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
444	2020/01/13	Online News (Notimerica)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
445	2020/01/13	Online News (Phys.Org)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
446	2020/01/13	Online News (Room)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
447	2020/01/13	Online News (Sci Tech Daily)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
448	2020/01/13	Online News (Science Daily)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
449	2020/01/13	Online News (Science Market News)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
450	2020/01/13	Online News (SciTech Daily)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
451	2020/01/13	Online News (Space.com)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
452	2020/01/13	Online News (Sputnik)	How the solar system got its 'Great Divide,' and why it matters for life on Earth; an article on the research by a research team including ELSI scientist Ramon Brasser.
453	2019/12/29	Online News (Scientific American)	In this article, the author Caleb Schalf mentions to ELSI as an institution he was involved.
454	2019/12/24	Online News (National Geographic)	First active fault zone found on Mars; in this article, ELSI scientist Christine Houser's comment on 'Insight', a seismometer that landed on Moon in 2018, is used.
455	2019/12/12	Online News (Technology Networks)	A paper by a research group led by ELSI scientist James Cleaves was chosen as one of the top 10 Genomics News Stories of 2019 in this article. The research team also includes ELSI affiliated scientist Christopher Butch.
456	2019/12/10	Online News (Many Worlds)	How long were the wet periods on early Mars, and was that water chemically suitable for life?: this article introduces ELSI scientist Yasuhito Sekine and his research in relation with the paper by a research group including him.
457	2019/11/14	Online News (Next Shark)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
458	2019/11/14	Online News (Phys.org)	Lifelike chemistry created in lab search for ways to study origin of life; an article on a research by a group of researchers including ELSI scientist James Cleaves
459	2019/11/14	Online News (Science Daily)	Lifelike chemistry created in lab search for ways to study origin of life; an article on a research by a group of researchers including ELSI scientist James Cleaves
460	2019/11/13	Online News (Market Research Feed)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.

461	2019/11/12	Online News (Grenzwissenshaft-aktuell)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
462	2019/11/12	Online News (Livescience.com)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
463	2019/11/12	Online News (News Beezer)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
464	2019/11/12	Online News (Technology Networks)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
465	2019/11/12	Online News (ZME Science)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
466	2019/11/11	Online News (7th Space)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
467	2019/11/11	Online News (Astrobiology News)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
468	2019/11/11	Online News (Long Room)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
469	2019/11/11	Online News (Nano Werk)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
470	2019/11/11	Online News (Newswise)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
471	2019/11/11	Online News (Phys.org)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
472	2019/11/11	Online News (РиА Новости)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
473	2019/11/11	Online News (Science Daily)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
474	2019/11/11	Online News (SciTech Daily)	DNA is only one among millions of possible genetic molecules; an article on a research by a research group led by ELSI scientist James Cleaves. The research group also includes ELSI affiliated scientist Christopher Butch.
475	2019/11/07	Online News (Mirage News)	Japan's MMX Martian Moon Probe is Unlikely to Bring Back Dangerous Martian Microbes; an article on a research by a Japanese research team including ELSI Scientists Hidenori Genda and Ryuki Hyodo.
476	2019/10/29	Online News (Liberty Times Net)	There was a salt lake on ancient Mars and Mars was suitable for life; an article on a research by a research group including ELSI scientist Yasuhito Sekine.
477	2019/09/27	Online News (OS WOW News)	An article about the visit of Cambridge students to Tokyo Tech. It mentions that they visited ELSI and got an overview on interdisciplinary researches conducted at ELSI.
478	2019/09/17	Online News (Mirage news)	Scientists find biology's optimal 'molecular alphabet' may be preordained; an article on a research by a group of researchers including ELSI scientist James Cleaves and ELSI affiliated scientists Richard Gillams and Christopher Butch.
479	2019/09/15	Online News (astrobiology web)	ELSI's name is referred as one of the supporting institution of AbGradCon 2019.
480	2019/09/11	Online News (English Forward)	Scientists find biology's optimal 'molecular alphabet' may be preordained; an article on a research by a group of researchers including ELSI scientist James Cleaves and ELSI affiliated scientists Richard Gillams and Christopher Butch.
481	2019/09/11	Online News (Science 2.0)	Scientists find biology's optimal 'molecular alphabet' may be preordained; an article on a research by a group of researchers including ELSI scientist James Cleaves and ELSI affiliated scientists Richard Gillams and Christopher Butch.
482	2019/09/10	Online News (7th Space)	Scientists find biology's optimal 'molecular alphabet' may be preordained; an article on a research by a group of researchers including ELSI scientist James Cleaves and ELSI affiliated scientists Richard Gillams and Christopher Butch.
483	2019/09/10	Online News (Astro)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
484	2019/09/10	Online News (Phys.org)	Scientists find biology's optimal 'molecular alphabet' may be preordained; an article on a research by a group of researchers including ELSI scientist James Cleaves and ELSI affiliated scientists Richard Gillams and Christopher Butch.
485	2019/09/10	Online News (Science Daily)	Scientists find biology's optimal 'molecular alphabet' may be preordained; an article on a research by a group of researchers including ELSI scientist James Cleaves and ELSI affiliated scientists Richard Gillams and Christopher Butch.
486	2019/09/09	Online News (SciTech Daily)	Scientists find biology's optimal 'molecular alphabet' may be preordained; an article on a research by a group of researchers including ELSI scientist James Cleaves and ELSI affiliated scientists Richard Gillams and Christopher Butch.

487	2019/08/22	Online News (European Association of Geochemistry blog)	An interview of ELSI scientist Yuichiro Ueno.
488	2019/08/20	Online News (Asian Scientist)	A new theory on the origins of life by group of researchers led by ELSI scientist Norio Kitadai. The research group also includes ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
489	2019/08/20	Online News (BioBioChile)	Chilean astrobiologist makes measurements in the Atacama Desert to propose an analogous model of Mars; in this article, ELSI scientist Yasuhito Sekine is mentioned as one of the fellow scientists in the team who arrived in the desert.
490	2019/08/20	Online News (El Mostrador)	Chilean astrobiologist makes measurements in the Atacama Desert to propose an analogous model of Mars; in this article, ELSI scientist Yasuhito Sekine is mentioned as one of the fellow scientists in the team who arrived in the desert.
491	2019/08/19	Online News (Media Inaf)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
492	2019/08/19	Online News (Science Alert)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
493	2019/08/14	Online News (Debate Report)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
494	2019/08/14	Online News (Metro)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
495	2019/08/14	Online News (Space.com)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
496	2019/08/14	Online News (Weather Herald.com)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
497	2019/08/13	Online News (Tekniikan Maailma)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
498	2019/08/13	Online News (The Daily Galaxy)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
499	2019/08/12	Online News (Breitbart)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
500	2019/08/12	Online News (Europa Press)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
501	2019/08/12	Online News (Phys.org)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
502	2019/08/12	Online News (Science Daily)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
503	2019/08/12	Online News (Science Times)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
504	2019/08/12	Online News (UPI.com)	Timeline suggests 'giant planet migration' was earlier than predicted; the research by a group of scientists including ELSI researcher Ramon Brasser.
505	2019/08/07	Online News (Blue Marble Space Institute of Science)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
506	2019/08/04	Online News (SuperPosition)	This article mentions a paper which resulted from a workshop run by ELSI
507	2019/08/03	Online News (YouTube: CdeCiencia)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
508	2019/07/29	Online News (Science X)	In this article, a study by a research group by led by ELSI scientists Tony Z. Jia is introduced as one of the best paper of a week. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
509	2019/07/27	Print News (New Scientist)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
510	2019/07/25	Online News (Bionity.com)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
511	2019/07/25	Online News (Chem Europe.com)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.

512	2019/07/25	Online News (Justdial)	A new theory on the origins of life by group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
513	2019/07/25	Online News (Nature World News)	A new theory on the origins of life by group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
514	2019/07/25	Online News (Phys.org)	A new theory on the origins of life by group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
515	2019/07/25	Online News (pravda.ru)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
516	2019/07/25	Online News (Science Daily)	A new theory on the origins of life by group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
517	2019/07/25	Online News (Tech Explorist)	A new theory on the origins of life by group of researchers led by ELSI scientists Norio Kitadai. The research group also include ELSI scientists Ryuhei Nakamura and Naohiro Yoshida, and ELSI fellow Ken Takai.
518	2019/07/25	Online News (Tech news)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
519	2019/07/24	Online News (cnBeta)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
520	2019/07/24	Online News (Debate Report)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
521	2019/07/24	Online News (Index)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
522	2019/07/24	Online News (New Atlas)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
523	2019/07/24	Online News (Space Daily)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
524	2019/07/24	Online News (YJC)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
525	2019/07/23	Online News (Astrobiology web)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
526	2019/07/23	Online News (Lotgain)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
527	2019/07/23	Online News (Mirage News)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
528	2019/07/23	Online News (N+1)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
529	2019/07/23	Online News (Notizie Scientifiche)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
530	2019/07/23	Online News (Phys.org)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
531	2019/07/23	Online News (Science Codex)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
532	2019/07/23	Online News (Science Daily)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
533	2019/07/22	Online News (LongRoom)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
534	2019/07/22	Online News (New Scientist)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.
535	2019/07/22	Online News (Science News)	Droplets of simple molecules may have helped kick-start life on Earth; an article on a research by a research group led by ELSI scientist Tony Z. Jia. The research group also includes ELSI researcher Kuhan Chandru, Yayoi Hongo, Rehana Afrin, James Cleaves, and ELSI affiliated scientist Tomohiro Usui.

536	2019/06/27	Online News (Scientias.nl)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
537	2019/06/27	Online News (Space Daily)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
538	2019/06/25	Online News (7th Space)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
539	2019/06/25	Online News (Futurism.com)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
540	2019/06/25	Online News (Newswise)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
541	2019/06/25	Online News (Phys.org)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
542	2019/06/25	Online News (Physics World)	An article on AbSciCon 2019, for which ELSI is one of the sponsors and named in the article.
543	2019/06/25	Online News (Science Daily)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
544	2019/06/24	Online News (SciGlow)	Tokyo Tech-led study shows how icy outer solar system satellites may have formed; an article on a research by a group of researchers including ELSI scientists Hidenori Genda and Ryuki Hyodo.
545	2019/06/18	Online News (7th Space)	An article on a research in which biological evolution was used to inspire machine learning; the research was conducted by a group of researchers led by ELSI scientist Nicholas Guttenberg. The research group also includes ELSI scientist Nathaniel Virgo.
546	2019/06/18	Online News (Science Daily)	An article on a research in which biological evolution was used to inspire machine learning; the research was conducted by a group of researchers led by ELSI scientist Nicholas Guttenberg. The research group also includes ELSI scientist Nathaniel Virgo.
547	2019/06/18	Online News (Tech Explore)	An article on a research in which biological evolution was used to inspire machine learning; the research was conducted by a group of researchers led by ELSI scientist Nicholas Guttenberg. The research group also includes ELSI scientist Nathaniel Virgo.
548	2019/06/14	Print News (Science)	An article written by ELSI scientist Shigeru Ida on the origins of Saturn's rings and moons.
549	2019/05/30	Online News (EOS)	ELSI affiliated scientist Maxim Ballmer is named as one of the outstanding reviewers in 2018 by American Geophysical Union.
550	2019/05/29	Online News (Air and Space)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
551	2019/05/29	Online News (Sci-News.com)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
552	2019/05/24	Online News (xinhuanet.)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
553	2019/05/23	Online News (EarthSky)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
554	2019/05/23	Online News (International Business Times)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
555	2019/05/23	Online News (Moneycontrol.com)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
556	2019/05/23	Online News (MSN)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
557	2019/05/23	Online News (Spiegel Online)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
558	2019/05/23	Online News (Universe Today)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
559	2019/05/22	Online News (ERR.ee)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
560	2019/05/22	Online News (Firstpost)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
561	2019/05/22	Online News (Forbes)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura

562	2019/05/22	Online News (Futura-Sciences)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
563	2019/05/22	Online News (Il Post)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
564	2019/05/22	Online News (MSN)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
565	2019/05/22	Online News (MSN)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
566	2019/05/22	Online News (The Indian Express)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
567	2019/05/22	Online News (Tree Hugger)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
568	2019/05/21	Online News (Business Insider)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
569	2019/05/21	Online News (Business Insider India)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
570	2019/05/21	Online News (Business Standard)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
571	2019/05/21	Online News (cnBata)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
572	2019/05/21	Online News (Dresdner Neueste Nachrichten)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
573	2019/05/21	Online News (Elbe-Jeetzel-Zeitung)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
574	2019/05/21	Online News (Eurasia Review)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
575	2019/05/21	Online News (Fanpage)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
576	2019/05/21	Online News (Gizmodo Australia)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
577	2019/05/21	Online News (Gottinger Tageblatt)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
578	2019/05/21	Online News (Le Scienze)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
579	2019/05/21	Online News (Markische Allgemeine)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
580	2019/05/21	Online News (Mitteldeutscher Rundfunk)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
581	2019/05/21	Online News (MSN)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
582	2019/05/21	Online News (Naked Science)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
583	2019/05/21	Online News (Newswise)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
584	2019/05/21	Online News (PBS)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
585	2019/05/21	Online News (Peiner Allgemeine Zeitung)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
586	2019/05/21	Online News (RT Network)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
587	2019/05/21	Online News (Scientific American)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura

588	2019/05/21	Online News (Scitech Daily)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
589	2019/05/21	Online News (Space Daily)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
590	2019/05/21	Online News (Tech Times)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
591	2019/05/21	Online News (The Daily Galaxy)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
592	2019/05/21	Online News (The Deccan Herald)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
593	2019/05/21	Online News (Value Walk)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
594	2019/05/21	Online News (Wolfsburger Allgemeine)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura
595	2019/05/20	Online News (2News)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
596	2019/05/20	Online News (7th Space Family Portal)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
597	2019/05/20	Online News (Astronomy Magazine)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
598	2019/05/20	Online News (Benzinga)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
599	2019/05/20	Online News (CNN News)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
600	2019/05/20	Online News (CTV News)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
601	2019/05/20	Online news (Daily Mail)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
602	2019/05/20	Online News (Discover)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
603	2019/05/20	Online News (Fox News.com)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
604	2019/05/20	Online News (Gizmodo)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
605	2019/05/20	Online News (Independent)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
606	2019/05/20	Online News (KUAM)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
607	2019/05/20	Online News (Medical Daily)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
608	2019/05/20	Online News (MSN)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
609	2019/05/20	Online News (New Scientist)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
610	2019/05/20	Online News (Newsweek)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
611	2019/05/20	Online News (Science alert)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
612	2019/05/20	Online News (Science Daily)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
613	2019/05/20	Online News (Space.com)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.

614	2019/05/20	Online News (spektrum.de)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
615	2019/05/20	Online News (The Week)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
616	2019/05/20	Online News (Ticker Tech)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
617	2019/05/20	Online News (TMC Net.com)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
618	2019/05/20	Online News (Wall Street Online)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
619	2019/05/20	Online News (WBOC 16)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
620	2019/05/20	Online News (WFMJ)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
621	2019/05/20	Online News (wissenschaft.de)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
622	2019/05/20	Online News (Yahoo! Finance)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
623	2019/05/20	Online News (РИА Новости)	Gas insulation could be protecting an ocean inside Pluto; a research by a research group including ELSI scientist Yasuhito Sekine and ELSI's affiliated scientist Jun Kimura.
624	2019/05/09	Online News (Tele Ambiente)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
625	2019/05/03	Online News (Foggia Reporter)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
626	2019/05/03	Online News (L'immediato)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
627	2019/05/02	Online News (Tekneko)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
628	2019/05/02	Online News (Universe Today)	When the Impact that created the Moon happened, the early Earth was still a ball of magma; an article on a research by a research group including an ELSI researcher Takayuki Saitoh and an ELSI fellow Junichiro Makino.
629	2019/05/01	Online News (Corriere Nazionale)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
630	2019/05/01	Online News (Nature)	This article mentions the conference 'Re-Conceptualizing the Origins of Life' and refers to ELSI as one of the institutions from which researchers attended the conference.
631	2019/04/30	Online News (Galileo)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
632	2019/04/30	Online News (Il Valore Italiano)	This article mentions an event held at ELSI, Italina research Day 'New Frontiers of Marine Science and Technology.'
633	2019/04/29	Online News (adnkronos)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
634	2019/04/29	Online News (Agenzia Internazionale Stampa Estero)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
635	2019/04/29	Online News (In Salute News)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
636	2019/04/29	Online News (Italiaambiente)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
637	2019/04/29	Online News (MeteoWeb)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
638	2019/04/29	Online News (Momento Italia)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
639	2019/04/29	Online News (Prensa Latina)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.

640	2019/04/29	Online News (Republica)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
641	2019/04/29	Online News (Science Daily)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
642	2019/04/29	Online News (Secolo d'italia)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
643	2019/04/29	Online News (TyN Panamá)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
644	2019/04/26	Online News (health Thoroughface)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
645	2019/04/26	Online News (R & D Magazine)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
646	2019/04/25	Online News (Futurity)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
647	2019/04/25	Online News (Medical News)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
648	2019/04/24	Online News (Europa Press)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
649	2019/04/24	Online News (Newswise)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
650	2019/04/24	Online News (Phys.org)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
651	2019/04/24	Online News (Science Daily)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
652	2019/04/24	Online News (Tech Central)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
653	2019/04/24	Online News (UNM Newsroom)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI Scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
654	2019/04/23	Online News (AZO Cleantech)	Microbes may act as gatekeepers of Earth's deep carbon; an article on a research by a group of international researchers including a ELSI scientist Mayuko Nakagawa and ELSI affiliated scientist Donato Giovannelli.
655	2019/04/17	Online News (Asian Scientist)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
656	2019/04/10	Online News (Astrobiology web)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
657	2019/04/08	Online News (ZAP AEIOU)	Scientists have synthesized artificial cells capable of independently performing photosynthesis in the laboratory; an article on a research by a research group including ELSI scientist Yutetsu Kuruma.
658	2019/04/05	Online News (Phys.org)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
659	2019/04/04	Online News (BrightSurf.com)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
660	2019/04/04	Online News (Science Daily)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
661	2019/04/04	Online News (Tunisiesoir News)	Tokyo Tech scientists including three ELSI researchers discovered deep microbes' key contribution to Earth's carbon cycle; an article on a research led by ELSI scientist Alexis Gilbert. The research group also includes ELSI scientist Naohiro Yoshida and Yuichiro Ueno.
662	2019/04/01	Online News (cnBata)	Scientists have synthesized artificial cells capable of independently performing photosynthesis in the laboratory; an article on a research by a research group including ELSI scientist Yutetsu Kuruma
663	2019/04/01	Online News (News Sina)	Scientists have synthesized artificial cells capable of independently performing photosynthesis in the laboratory; an article on a research by a research group including ELSI scientist Yutetsu Kuruma
664	2019/03/03	magazine (Science Magazine)	Dr. Christine Houser wrote the article "Earth's rugged lower mantle"

665	2019/02/19	web article (Nature's Research highlights)	Dr. Mochizuki's research was introduced in the article "The giant Medusavirus turns defenseless cells to 'stone' ".
666	2019/01/15	magazine (Science)	Dr. Ramone Brasser's research was mentioned in the article "Seeing the Dawn - Evidence lines up to offer a new view of how life on our planet may have emerged"
667	2019/01/11	web article (Discover)	Dr. Gréaux and Prof. Irifune's research was mentioned in the article "Recreating the Intense Conditions of the Earth's Mantle Solves A Long-standing Geological Mystery"
668	2019/01/09	web article (Nature NEWS AND VIEWS)	Dr. Gréaux and Prof. Irifune's research was mentioned in the article "High-pressure experiments cast light on deep-Earth mineralogy"
669	2018/11/09	web article (Cosmos)	Dr. Chaitanya Giri's research was introduced in the article "The tech we're going to need to detect ET".
670	2018/09/20	web article (Evolution News & Science Today)	Dr. Jennifer Hoyal Cuthill's research was introduced in the article "More Excuses for Cambrian Non-Evolution".
671	2018/06/29	magazine(web article) (Forbes)	Dr. Daigo Shoji's study on using artificial intelligence to understand volcanic eruptions from tiny ash was reported.
672	2018/06/13	magazine(web article) (R&D Magazine)	Research of Dr. Kuhan Chandru and Dr. Jim Cleaves was introduced in the article "Study Reveals Simple Chemical Process That May Have Led to the Origin of Life on Earth".
673	2018/05/08	newspaper(web article) (Boston Business Journal)	Research of Dr. Atsuko Kobayashi and Dr. Joseph Kirschvink was introduced in the article "Oscillating nanophase magnetite controls ice nucleation".
674	2018/05/02	web article (Science Daily)	Dr. Ramses Ramirez's research was introduced in the article "Recent work challenges view of early Mars, picturing a warm desert with occasional rain".
675	2018/04/30	magazine(web article) (Forbes)	A graduate student Irene Bonati and Dr. Keiko Hamano's opinions were introduced in the article "Magma Oceans Could be Key To Life In Cosmos".
676	2018/04/18	web article (Cosmos)	Prof. Shigenori Maruyama's research was introduced in the article ""Nuclear geyser" may be origin of life".
677	2018/04/03	web article (Genomics Research)	Dr. Katerine Petrie's research was introduced in the article "Virus Follows New Evolutionary Path".
678	2018/04/18	magazine(web article) (Science)	Dr. George Helffrich's opinion was introduced in the article "By listening for quakes on Mars, NASA lander will prove Red Planet's interior".
679	2018/04/05	magazine(web article) (Scientific American)	Dr. Ramses Ramirez's opinion was introduced in the article "Are Water Worlds Habitable?"
680	2018/03/31	magazine(web article) (Forbes)	Dr. Ramses Ramirez's research on planets' potential habitable zones was introduced on the Forbes website.
681	2018/03/29	newspaper(web article) (Times of San Diego SAN FRANCISCO CHRONICLE)	Dr. Katherine L. Petrie was reported about her study that discovery of a surprise multitasking gene helps explain how new functions and features evolve.
682	2018/03/20	web article (nature)	Dr. Yuka Fujii's opinion was introduced in the article about exoplanet exploration.
683	2017/05/09	web article (NASA Astrobiology website)	ELSI is featured in this article "Research Center a Hub for Origins of Life Studies" as being a hub for Origins of Life research
684	2017/02/03	web article (Huffington Post)	5th ELSI International Symposium was mentioned in the article titled "The New Evolutionary Biology".
685	2017/02/03	web article (Nature Astronomy)	ELSI's workshop about exoplanets was reported in the article.
686	2017/02/03	web article (Huffington Post)	5th ELSI International Symposium was mentioned in the article titled "The New Evolutionary Biology".
687	2017/02/03	web article (Nature Astronomy)	ELSI's workshop about exoplanets was reported in the article.
688	2017/02/02	web article (Nature's Research highlights)	Dr. Genda's paper was introduced in the article "Pluto's dark equator explained".
689	2016/07/07	web article (Nature Planetary Science)	Dr. Genda's research about formation of Martian moons was focused in the article "This week's Research Highlights".
690	2016/05/25	newspaper (web article) (Washington Post)	Dr. Jennifer Hoyal Cuthill's research published in the Proceedings of the Royal Society B was introduced in the article "These animals relied on each other for 100 million years. Now
691	2016/02/05	magazine (Nature Digest)	ELSI's research was introduced in the article "<News in Japan> Birth of New Site for Searching Space for Key to the Origins of Life!".

692	2016/01/04	magazine (Scientific American)	ELSI's research was introduced in the article "The Search for the Origin of Life".
693	2015/11/11	magazine (The Atlantic)	ELSI Origins Network's (EON) roadmapping workshop held at ELSI was covered in detail in this popular magazine article "Inside a New Effort to Discover Life's Origins"
694	2015/10/05	TV, newspaper, web article (BBC, Huffington Post, Science News etc.)	Dr. George Helfrich's research was introduced in the article "The tsunami that engulfed an island. Ancient Tsunami Was Nearly As Tall As The Eiffel Tower, Scientists Say" of Huffington Post, and other media.
695	2015/07/16	TV (GrassRoots Community Network)	Dr. Eric Smith's research was introduced in the program "Aspen Science Highlights - "New Theories on the Origin of Life"".
696	2015/02/16	web article (GlobeNewswire)	ELSI's research was introduced in the article "Mysteries of Cosmic Oceans and Dunes: Planetary Research Shows That Earth-Like Planets are More Likely to Orbit Sun-Like Stars Rather Than Lower-Mass Stars"
697	1905/07/06	TV/Radio (France Télévisions)	ELSI's research was introduced in the program "La Compagnie Des Taxi-Brousse: SynBio."
698	2014/12/08	web article (Nature Geoscience Online)	ELSI researcher's commentary "Deep water cycle: Mantle hydration" was posted in the media.
699	2014/11/21	web article (Science 2.0)	ELSI's research was introduced in the article "Deep-Earth Carbon Could Have Sparked Origin Of Life On Earth".
700	2014/11/21	web article (Nature World News)	ELSI's research was introduced in the article "Deep-Earth Carbon Offers Clues to Origins of Life".
701	2014/10/30	magazine (MEDISTER)	ELSI's research was introduced in the article "Young pioneers in geophysics creating a new experimental system with new technology".
702	2014/10/28	web article (Deutschlandfunk)	ELSI's research was introduced in the article "Junge Vulkane auf dem Mond"
703	2014/10/16	Newspaper (LE FIGARO)	ELSI's research was introduced in the article "Des éruptions sur la Lune au temps des dinosaures".
704	2014/07/23	web article (GIZMODE)	ELSI's research was introduced in the article "Currently the most detailed map of Mars".
705	2014/07/15	magazine (INTERNATIONAL BUSINESS TIMES)	ELSI's research was introduced in the article "Mars Interactive Maps Go Beyond Just Data And Visualization".
706	2014/07/14	magazine (U.S. Geological Survey)	ELSI's research was introduced in the article "New Global Geologic Map of Mars".
707	2014/04/28	web article (Science)	ELSI's research was introduced in the article "False Signs of Life on Alien Worlds".
708	2014/03/22	web article (SCOOP Independent News)	Prof. Hut's research was introduced in the article "Origins of Life and Herding Cats".
709	2013 Fall	Newsletter (Institute for Advanced Study, Princeton IAS Magazine)	Prof. Hut's research was introduced in the article "Origin of Life."
710	2013/09/13	Newspaper (The Science News)	Dr. Sekimoto-Sasaki's research was mentioned in the article "Stress Response Control in Plants."
711	2013/03/22	web article (SCOOP Independent News)	Prof. Hut's research was introduced in the article "Origins of Life and Herding Cats."
712	2013/03/14	web article (SCOOP Independent News)	Prof. Hirose's research was introduced in the article "Tokyo Origin of Life Talks: Core of Earth —Beyond".
713	2013/01/21	magazine (Science & Technology, Concentrates)	Dr. Cleaves's research was introduced in the article "Mass Spectrometry Imaging of Granite".

Appendix6-1 Host Institution's Commitment (Fund, Personnel)

1. Contributions from host institution

(1) Fund, Personnel

* Regarding "Fund" entry, describe with reference to the items in the Progress Report (Jisseki-hokoku-sho) based on Article 12 of the Grant Guidelines (Kofu-yoko).

* Don't include competitive funding obtained by researchers (used as research project funding)

(FY 2012-2020)

<Fund> **(million yen)**

Fiscal Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Personnel	16	82	129	153	114	110	105	103	95
Faculty members	14	66	111	132	94	84	83	82	75
Full-time	14	66	105	91	72	84	83	82	75
Concurrent	0	0	6	41	22	0	0	0	0
Postdocs	0	0	0	0	0	0	0	0	0
RA etc.	0	0	0	1	0	0	1	1	1
Research support staffs	0	0	1	1	1	0	1	0	0
Administrative staffs	2	16	17	19	19	26	20	20	19
Full-time	2	16	17	18	19	26	16	16	15
Concurrent	0	0	0	1	0	0	4	4	4
Project activities	0	83	81	241	87	36	45	69	42
Travel	0	6	15	8	10	33	11	12	1
Equipment	0	6	26	133	29	3	3	1	9
Research projects	284	819	616	502	762	709	497	461	246
Total	300	996	867	1037	1002	891	661	646	393

<Personnel> **(person)**

Fiscal Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Personnel	9	10	19	28	18	12	14	15	15
Faculty members	8	8	16	18	11	9	9	9	8
Full-time	8	8	13	11	8	9	9	9	8
Concurrent	0	0	3	7	3	0	0	0	0
Postdocs	0	0	0	0	0	0	0	0	0
RA etc.	0	0	0	2	0	0	2	3	4
Research support staffs	0	0	1	4	4	0	0	0	0
Administrative staffs	1	2	2	4	3	3	3	3	3
Full-time	1	2	2	2	3	2	2	2	2
Concurrent	0	0	0	2	0	1	1	1	1

Appendix6-1 Host Institution's Commitment

1. Contributions from host institution

(2) Provision of land and/or building(s), lab space, etc.

Tokyo Tech renovated the existing building (2,670 m^2) on the campus and provided to ELSI at the beginning (Ishikawadai No.8 building, ELSI-2) in FY 2012. In addition, the university provided a site and completed a new research building (Ishikawadai No.7 building, ELSI-1: 5,000 m^2) in FY2014.

2. System under which the center's director is able to make substantive personnel and budget allocation decisions

Tokyo Tech has defined ELSI as a "special research zone" directly under the President. Namely, ELSI reports directly to the President, and aims to establish and develop a flexible research system that does not follow the conventional practices and management system in Japan. Furthermore, Tokyo Tech recognizes ELSI as a front-runner in research and reform that attracts researchers from around the world and raises international recognition. In ELSI, the Director has the authority to make decisions on important management and operation issues of the institute. As a result, the Director can carry out organizational reform, recruitment of young researchers through international recruitment, personnel management of staff, and budget allocation efficiently and effectively.

3. Support for the center director in coordinating with other departments at host institution when recruiting researchers, while giving reasonable regard to the educational and research activities of those departments

After ELSI was approved as a WPI center, an agreement was set by Tokyo Tech that five full-time professors were assigned to ELSI and they were exempted from the undergraduate education. As a measure to alleviate possible difficulties in the undergraduate education due to this transfer, Tokyo Tech assigned three faculty posts by the President's discretion to the department where the vacancy occurred. This has made it easier for professors from outside ELSI to be able to participate in ELSI's activities.

4. Revamping host institution's internal systems to allow introducing of new management methods

(e.g., English-language environment, merit-based pay, cross appointment, top-down decision making unfettered by conventional modes of operation)

(1) Development of support environment in English
In ELSI, administrative tasks, committee meetings, and various training courses are basically conducted in English. ELSI has been requesting Tokyo Tech that some of these internationalization measures should be incorporated within the campus, and as a result most notification mails from Tokyo Tech administration are now both in English and Japanese. Tokyo Tech has also established an English-language consultation desk for personnel matters and a counseling service using English. In addition, ELSI has assigned a full-time staff member in charge of daily life support to assist non-Japanese researchers in various aspects even before they arrive in Japan.

(2) Introduction of annual evaluation and performance-based pay system
ELSI adopts its own performance-based pay system. In the Annual Evaluation Meeting, all researchers report their research activities and are evaluated. Researchers who are recognized as having performed particularly excellent research are given the "Director's Appreciation Awards" and salary raise in the next year.

(3) Introduction of cross appointment system
In order to acquire top-level researchers, ELSI with the help of Tokyo Tech established a cross

appointment system. Tokyo Tech applied this system for the first time to an ELSI PI. Since then Tokyo Tech has hired many researchers using the cross appointment system.

(4) Top-down decision making
As stated in (2), ELSI adopts a top-down decision-making system in which the Director decides on management and operation including personnel and budget execution. Tokyo Tech is promoting the construction, establishment and development of a flexible research system that is not tied to conventional practices and operating systems in Japan, using ELSI as a model.

(5) Support for fundraising
An NPO "Tokyo Tech USA" was established in the United States in 2017 in order to obtain donations and research funds from overseas companies and research support organizations.
In response to a request from ELSI, Tokyo Tech established a new system of donation program to enhance education and research through donations from private companies. ELSI received JPY 24 million donation from a private company and established the "FirstLogic Astrobiology Donation Program".

(6) Monthly meeting with the President's Office
The ELSI directors (Director, Executive Director, and Administrative Director) meet monthly with the University executives (President, Vice Presidents in charge of Research and Financial Affairs) in order to maintain close coordination between the University and ELSI. Requests from ELSI are seriously considered and often actions are quickly taken.

5. Utilities and other infrastructure support provided by host institution

(*In addition to those listed in the item 1. "Contributions from host institution")

ELSI has secured 20 rooms in the International House close to ELSI with priority to foreign researchers at ELSI. A nursery school was opened in April 2017 in the International House, which will assist researchers who need childcare services.

6. Support for other types of assistance

Tokyo Tech has appointed Dr. Mary Voytek, Senior Scientist of NASA Astrobiology Program, as Special Advisor to the President and Executive Director of ELSI. This appointment was based on the IPA (Intergovernmental Personnel Act) program of the US Federal Government. She has introduced world-standard management style to ELSI and promoted system reform, which would lead to the foundation for ELSI to be a world top-level and self-sustainable research organization.
In order to apply interdisciplinary and international research capabilities cultivated at ELSI to the education of graduate students, Tokyo Tech established a new five-year (master plus doctor) graduate program, the "Earth and Life Science Course" or "ELSI Course", in the School of Science and the School of Life Science in April 2021. Graduate education led by ELSI faculty will start when new students are admitted to this course in April 2022.

Appendix6-2 The Host Institution's Mid-term Plan

* Excerpt the places in the host institution's "Mid-term objectives" and/or "Mid-term plan" that clearly show the positioning of the WPI center within its organization.

Tokyo Tech's Mid-term Plan

[The second term: April 01, 2010 – March 31, 2016]
(Mid-term goal)
2. Research goals
(1) Targets on research level and research accomplishments
I-2-2. Tokyo Tech will enhance the values created at this university and actively develop multidisciplinary and new areas, in order to attract researchers from Japan and all over the world and to lead science and technology researches.
(Mid-term Plan)
(1) Measures to achieve the goals of research level and research results
[25-2] As the World Top-Level Research Center, Earth-Life Science Institute will focus on the early earth to promote research aiming to unravel the origin and evolution of the earth and life, and Tokyo Tech will promote organizational reform to assist the institute.

[The third term: April 01, 2016 – March 31, 2022]
(Mid-term goal)
2. Research goals
(1) Targets on research level and research accomplishments
1-2-2. Tokyo Tech will enhance the values created at this university and actively develop multidisciplinary and new areas, in order to attract researchers from Japan and all over the world and to lead science and technology researches.
(Mid-term Plan)
(1) Measures to achieve the goals of research level and research results
[15] The president will provide resources to ELSI, the WPI center, to promote research to unravel the origin and evolution of the earth and life with focusing on early earth.

In this medium-term goal and medium-term plan, Tokyo Tech positions ELSI as a "strategic and ambitious institute".

World Premier International Research Center Initiative (WPI)
Progress Plan (For Final Evaluation)

Host Institution	Tokyo Institute of Technology	Host Institution Head	MASU Kazuya
Research Center	Earth-Life Science Institute		
Center Director	SEKINE Yasuhito	Administrative Director	SAKURAI Takashi

* Write your report **within 6 pages**.
* Use yen (¥) when writing monetary amounts in the report. If an exchange rate is used to calculate the yen amount, give the rate.

1. Mid- to Long-term Research Objectives and Strategies Based on the Center's Results during Funded Period

Describe new challenges in the Center's research objectives and plans after the funding period ends. If major adjustments will be made in the Center's operation, such as newly set research themes/objectives or a change in the director, describe the strategic background to the adjustments.

1. ELSI's achievements during the funded period

The highlight of ELSI's 10-years of achievements is that ELSI allowed us to understand the origin of life in the context of Earth formation and evolution (or the view of the Earth-Life system) via successful fusions of multiple disciplines (Fig. 1). Earth was formed in the early Solar System as a by-product of a star formation, and the composition and amounts of volatiles on Earth's surface were determined in consequences of early evolution of the protoplanetary disk and partitioning of elements among the core, mantle, crust, and atmosphere. On the surface of early Earth, like heat engines, geohydrological cycles were driven by heat from external (sun light and impacts) and internal heat sources (radiogenic elements). These abiotic geohydrological cycles occurred in global or regional scales (e.g., deep-sea hydrothermal vents and continental hot springs) and gradually developed to organo-geochemical cycles and, eventually, to biogeochemical cycles on early Earth. The biogeochemical cycles were largely affected by environmental changes induced by external and internal geological perturbations that occurred on Earth, which resulted in evolving biospheres. Changing biosphere (including human sphere), in turn, affected biogeochemical cycles. Previously, geoscience or life science thought separately of Earth and life to understand their origins and evolution; however, ELSI provided an integrated view of a sequence of the origin and evolution of the Earth-Life system.

ELSI's major achievements were not only to provide the view that the Earth-Life system was developed as a result of the diversifications and filter selections, but also to point out key transitions that determined the fate of the Earth-Life system in diversifications and filter selections (Fig. 1). These transitions include giant impacts and magma-ocean solidification, formation of a planetary system having oceans, emergence of functional polymers and molecules, transfer of geochemical cycles to early metabolic cycles, and self-organization (Fig. 1). Some of these transitions might have been stochastic and chaotic. ELSI's scientists have been revealing the factors that control diversifications and filter selections of the Earth-Life system and that determine the fates of the Earth-Life system (Fig. 1).

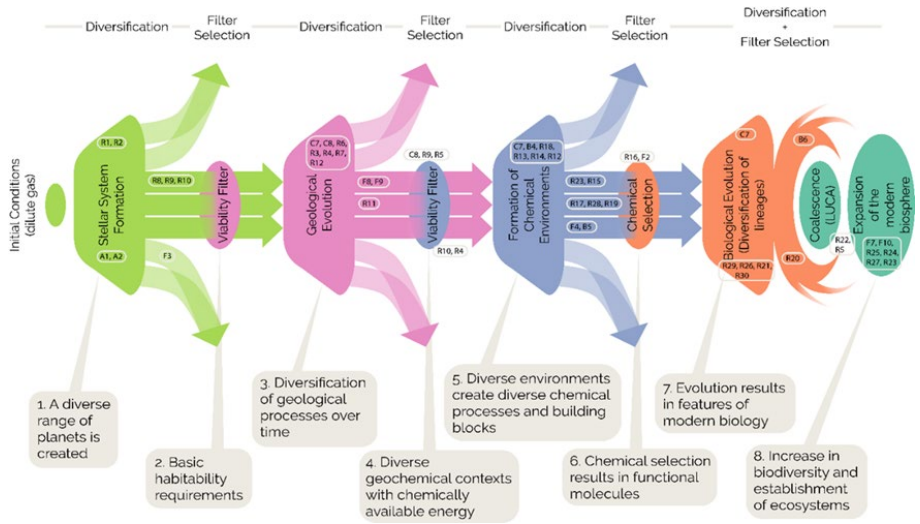


Fig. 1. ELSI's new framework developed in the first 10 years. The origin of the Earth-Life system can be understood as a sequence of diversifications and filter selections from formation of a star and planets to modern biosphere.

2. Long-term research objectives

In the first 10 years, ELSI provided the view of the sequence of diversifications and filter selections toward the current Earth-Life system (called "ELSI model"; Fig. 1). However, at the same time, this raises new fundamental questions. Are there alternative planet-life systems in the universe? Are there any other paths to reach to emergences of lives? If we find lifeless planets, how can we characterize them and what can we learn from them in the context of ELSI model's framework? Earth is the only one planet that we know the existence of life. Revealing of the origin of life on Earth may be more like the study of one specific history. The origin-of-life science can be universal only after understanding the possibilities of emergence of alternative lives and lifeless planets in ELSI model.

Another key question on ELSI model is how we can make benchmarks for the sequence of diversification and selection? The sequence shown in Fig. 1 is irreversible, and factual evidence for large parts of key transitions that occurred on primitive Earth has been lost. On the other hand, we are now starting to know that there are multiple planetary bodies that experienced similar sequential evolution, but the evolution has stopped or dramatically slowed down. These bodies include Mars, C-type asteroids, and some of icy bodies (the so-called ocean worlds) in the Solar System. Thus, future space explorations to these bodies could provide factual evidence for the key transitions in the diversifications and filter selections.

After the first 10 years, we will tackle the new fundamental questions concerning ELSI model described in Sec. 1.1 above. Namely, while keeping existing approaches in ELSI to understand key transitions toward the emergence of our Earth-Life system (Fig. 1), we will newly try to understand/predict the possibilities of alternative "planet-life systems" to exist anywhere in the universe. The latter new approach clearly requires institutional collaborations inside and outside Japan (e.g., JAXA, NASA, ESA, NAOJ, JAMSTEC, and RIKEN). ELSI will try to be a "think tank" for space missions and telescope observations for astrobiology through providing conceptual foundations for large projects. In other words, ELSI will provide a program of hypothesis-driven missions and observations with Japanese and international mission-design agencies. Through the existing and new approaches, we attempt to construct a concept of "universal biology", in which we can characterize life on Earth, or ourselves, in a wide range of physicochemical parameters of planet-life systems.

3. Mid-term (next decade) research objective

The time range to construct universal biology would exceed a few decades. In our next decade, we, thus, would focus on tackling the following research themes on alternative planet-life systems. These researches will be done by in-house collaborations among astronomy, geoscience, chemistry, and life science, and will maximize science values of space missions and telescope observations planned by mission-operation agencies.

The first two themes relate to reveal organo-chemical networks in planetary cycles. In first, we aim to predict and interpret cycles of nutrients. Earth is an open system that is composed of multiple subsystems (e.g., core, mantle, atmosphere, ocean, and biosphere). These subsystems exchange materials, information, and energy driven by internal and external heat, which can keep the system dynamic. The next step for this work is to extend the acquired knowledge of Earth's system to alternative systems with different boundary conditions, including planets and satellites in the Solar System, Hadean Earth, and exoplanets. The goals include constructing models of global (or regional) cycling of major nutrients and bioessential metals. The output results of the models are used to predict and interpret the observations from space missions, field samples of Archean era, and telescope observations. More close institutional collaborations with NASA, JAXA, and NAOJ will be organized to promote such research.

In second, we investigate organo-geochemical cycles in habitable environments. Through more integrated linkages of organic chemistry experiments, geohydrological modeling, and complexity science, we will examine a variety of networks of organo-geochemical cycles depending on different geological settings (geohydrological cycles) of planetary environments. For instance, geohydrological modeling will predict changes in pH, Eh, temperature, and pressure in a hydrological cycle. Organic chemistry will provide a variety of combinations of reactants and products under the reaction conditions achieved in the cycle. Through network analyses, complexity science will compare the resulting organo-geochemical networks to Earth's biochemical or metabolic networks. This would make unequalled contributions in the origin-of-life study and astrobiology because this will provide knowledge on linkages between the properties of Earth's life and alternative lives and planetary environments.

The last two themes are about expansion of synthetic and theoretical biology to astronomy and planetary science. Similar to Earth system, life system is composed of subsystems (e.g., functional polymers and molecules). The approaches of synthetic biology, thus far, focused on the systems that realized the

principles of extant Earth's life. However, depending on aqueous chemistry and pressure-temperature conditions achieved on planets or satellites, thermodynamic stability of functional polymers and molecules would be different. Through collaborations between synthetic biology, astronomy, and planetary sciences, we will investigate physicochemical properties of functional polymers and molecules and the possibilities of alternative functional polymers and molecules for different planetary conditions. Through artificial experimental evolution, we can test survivability and evolution of a variety of functional polymers and molecules. This approach would be useful to predict alternative forms of life in habitable worlds on early Earth and beyond, which will allow us to propose biomarkers in future space missions.

In addition to prediction of functional polymers, prediction of ecosystem changes can be done by collaboration of theoretical biochemistry and astronomy-planetary science. Ecosystems, or biosphere, is an open system that can exchange materials, information, and energy with the surrounding environments. Thus, ecosystems can evolve in response to short-term and long-term environmental changes. At the same time, evolving ecosystems can affect the surrounding environments. Thus, ecosystems and environments have multiple feedback mechanisms. A good example on Earth may be the Great Oxidation Event and emergence of eukaryotes. Considering early Mars, Hadean Earth, icy moons, and exoplanets around M-type stars, planetary habitable environments could have evolved more dynamically than Earth through atmospheric and water escape, stellar activities, and changes in tidal heating. With combinations of theoretical biology, geology, and astronomy, we will investigate changes in the size and complexity of biogeochemical networks in response to environmental changes. The close collaborations of theoretical biology and geology also allows us to predict the long-term expressions of evolution in biospheres on future Earth and beyond.

2. Management System of the Research Organization

2-1. Describe the Center's Research Organizational Management System that will Execute the Research Strategy and Plan Described above.

- In Appendix 1-1, list the PIs who will ensure that the Center's project is sustained and advanced after the funding period ends.
- In Appendix 1-2, enter the number of Center personnel (researchers, research-support staff, and administrative staff) in FY 2022
- In Appendix 2, diagram the Center's organizational management system.

In the first decade, ELSI's organization of scientists (i.e., PIs, A-PIs, and researchers) was basically flat (Fig. 2). This flat system guaranteed a research diversity within the institute. In this system, there were also low barriers to collaborate with other researchers of different disciplines, enhancing chances of creating interdisciplinary researches. ELSI's current lab units, in which lab managers managed experimental works in the units, helped for young researchers to start up their researches effectively in this system.

However, the issues in the system were also becoming clearer, which needs to be improved in the next decade (Fig. 2). First, freedom and flatness of this system sometimes led to isolated scientists within the institute. This calls for a need to make one research network within the institute in the next decade with approximate half of current funding levels and, thus, less number of scientists. Second, ELSI will have graduate students. They are not categorized in the present system and will not be flat to PIs (i.e., supervisors). The number of graduate students will reach 50-60, which will be almost twice those of scientists in the next decade. In the current system, the roles of PIs, A-PIs, and researchers for increasing students are unclear. Lastly, a lot of efforts, funds, and people are needed to manage and maintain the lab units. In the next decade, the lab unit system needs to be reconsidered.

While keeping the research diversity and interdisciplinarity in the next decade, ELSI needs to make one compact and effective research network within the institute. To this end, the roles of PIs, A-PIs, researchers, and students need to be clarified in ELSI's organization (Fig. 2). PI's responsibilities are to anchor core research themes with long-term programs, to acquire stable funding to support junior project researchers and students as well as experimental facilities, to manage the education program, and to facilitate collaborations and joint projects across themes. Fixed-term A-PIs (and researchers) are engines of innovation. A-PI's responsibilities are to be key bridges across disciplines. A significant criterion in hiring/mentoring A-PIs is their ability to work in/with projects in more than one theme area, to expand diversity and originality of research topics, to provide flexibility and interdisciplinarity to ELSI research, and to maintain exchange and collaboration within Japan and internationally. Through co-supervision by PIs and A-PIs, graduate students can be actual bridges to connect PIs and A-PIs, making one research network in the institute.

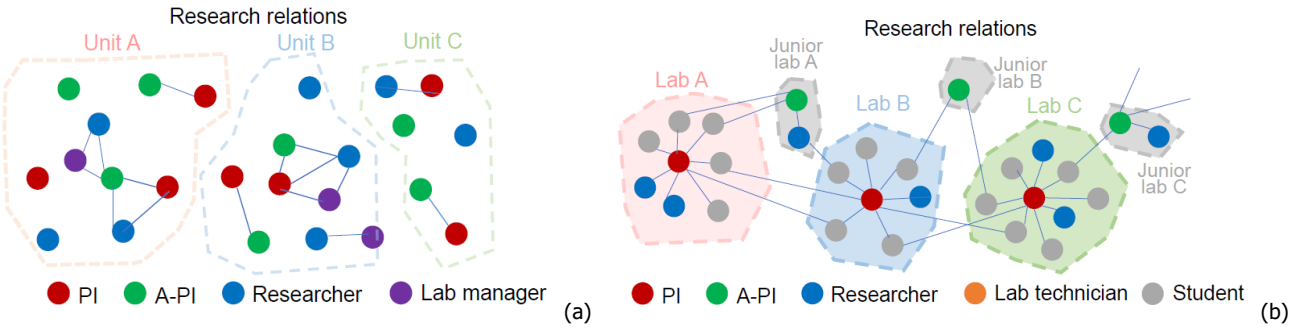


Fig. 2. ELSI's organization in the first decade (a), and in the next decade (b)

Specific job expectations for each category of ELSI members include:

PIs – 1. Administration, 2. Acquisition of large research grants and donations, 3. Management of an education program for graduate students and ones' laboratories (ELSI's own special curriculum and/or contributions in collaboration with the existing departments), 4. Engagement in inter-institute collaborations, 5. Supervision of early career postdocs and students, 6. Promotion of in-house collaborations.

A-PIs – 1. Initiation of interdisciplinary research (in-house and inter-institute collaborations), 2. High levels of research activity, 3. Connecting PIs' research, 4. Co-supervision of graduate students with PIs.

Researchers/graduate students – 1. Research activity under supervision by PIs (and A-PIs). We will look for opportunities for jointly-mentored researchers for projects spanning disciplines, as a way to increase group overlap and communication.

In addition to these existing categories, a new category of Science Coordinator will be created to achieve effectiveness and efficiency in research and institutional development. The science coordinator will make one research network in a compact ELSI. This science coordinator will be the person who keeps on top of all the research taking place at ELSI and use the information to promote fusions among PIs and A-PIs to acquire large grant and support from industries, and to develop institutional collaborations inside and outside Japan. In addition to the science coordinator, the director and administration director will actively participate in such development roles.

Science coordinators – 1. Develop fusion of multiple disciplines through promoting collaborations between PIs' (A-PIs') research, 2. Connecting in-house research projects with international/domestic institutional collaborations, 3. Promoting and coordinating in-house research projects, aiming to acquire funds from JSPS and industries.

2-2. Initiatives and Plans that will Impel System Reforms

Describe the Center's action plan that embodies the basic policies of the University Reform Plan, and the Center's plan and strategies that lead to host institution reforms either directly or via ripple effects (also to other institutions, if applicable). Describe also the Center's strategies for fostering and securing the next generation of researchers (e.g., introduction of tenure tracks), and the system reform for enhancing the Center's organizational management, such as the implementation/verification PDCA system.

Tokyo Tech was selected as a Designated National University in March 2018. Tokyo Tech has a vision of becoming one of the world's top university for science and technology, and one of its specific goals is to create a global research hub where top researchers gather and carry out international joint research and to establish a research environment where scientists — including the younger generation — can focus on developing new interdisciplinary research fields. ELSI has already achieved these goals, by implementing a top-down decision-making system, open and international research environment, and a new administrative system including the cross-appointment scheme. Adopting these practices are a necessary step for Tokyo Tech to realize its vision as a Designated National University. Furthermore, by spreading these reforms to other universities, we will be able to contribute to establishing a world-class research environment in Japanese universities. Specifically, we will work on the following items:

(1) Reform in organizational management

ELSI is positioned as a front-runner in the research renovation of Tokyo Tech, in that it attracts researchers from around the world by raising its international visibility. The ELSI director has the capacity to make decisions on all aspects of the institute except for the appointment of the director him/herself. With such a system, the director can carry out organizational reform, employment of

researchers by international recruitment, and budget allocation effectively, and can design a flexible organizational system that is not restricted by conventional practices. ELSI will propose that this system be adopted in more research organizations within Tokyo Tech.
(2) Open and international research environment, and promotion of interdisciplinary research
ELSI offers an open and internationalresearch environment where scientists can pursue creative research regardless of age, gender, nationality, or cultural background, and are actively engaged in interdisciplinary research. As a result, ELSI has attracted new members or visitors with excellent talent. As the truly interdisciplinary and international environment of ELSI has become widely known, more and more researchers visit ELSI and conduct joint research. Currently the percentage of non-Japanese researchers at ELSI is 41%. We will maintain and improve this environment, and further invite world-class international researchers to conduct and promote the fusion of diverse scientific fields and guide Tokyo Tech in its efforts to fulfill its goals.
(3) Reform of personnel and salary systems
* Cross-appointment system: in order to acquire a prominent researcher to lead the origin-of-life research, ELSI requested that Tokyo Tech formulate a cross appointment system. ELSI applied the system for the first time at Tokyo Tech in 2014, and as of January 31st, 2019, 22 people were employed at Tokyo Tech by this system. The application of the cross-appointment system will further grow in the future.
* Annual evaluation, performance-based salary system: ELSI introduced a performance-based salary system, which is new to Tokyo Tech. ELSI conducts annual evaluations where young researchers are reviewed by mentors assigned to them. Those conducting excellent research are given "Director's Achievement Awards" and a salary raise. This system will continue at ELSI, and is being considered in research institutes in Tokyo Tech.
(4) Support system for foreign researchers
ELSI has assigned a full-time staff member for daily-life support of non-Japanese researchers, who start receiving support from ELSI when their employment is finalized, i.e. well before their arrival in Japan. In response to a request from ELSI, Tokyo Tech has enhanced and strengthened several services for non-Japanese researchers, such as English instructions on the university web pages, relevant e-mail notices in English, personnel consultation in English, counseling in English, and expansion and maintenance of the International House. These efforts will continue and propagate to increase information accessibility.
(5) Participation in graduate-course education
ELSI makes a significant contribution toward nurturing the next generation of researchers by having its world-renowned scientists supervise graduate students. Currently, ELSI professors are participating in primarily graduate-course education in the School of Science and the School of Life Science. Starting 2021 April, an ELSI professor will participate in the School of Material Science. ELSI will also be collaborating with all schools in Tokyo Tech by giving lectures and teaching courses in English.
In 2021 April, a new 5-year graduate-course program, "Earth and Life Science Course" or "ELSI Course" was established by ELSI professors and their collaborators in Tokyo Tech. This course will start accepting students from 2022 April, and ELSI's expertise in international and interdisciplinary researches will be fully utilized in this education program. Financial support is prepared so that the students can concentrate in their studies.
ELSI has been contributing to the internationalization of Tokyo Tech and the development of postgraduate education programs by accepting excellent foreign students recruited through ELSI's overseas network, e.g. ETH in Switzerland, University of Hong Kong, National Central University (Taiwan), Kaiserslautern Technical University (Germany), and National Autonomous University of Mexico. ELSI's international network and commitments to education will boost interdisciplinary research both at ELSI and other schools/institutes within Tokyo Tech.
(6) Cultural diversity and gender equality
ELSI held the first "Cultural Diversity" training courses in FY2018 for all staff to develop cultural awareness and prevent harassment and discrimination. ELSI will continue them in the future.
The Global Environment Team (GET) was assembled at ELSI to support its goals of achieving gender balance on par with international standards. The team tracks hiring at ELSI and participation in the events it hosts in order to evaluate the balance of gender, Japanese/non-Japanese and theoretical/laboratory among researchers, and provides guidance on issues related to gender balance when requested by ELSI members and committees. The activity of GET is in parallel with the Gender Equality Promotion Section of Tokyo Tech, and these collaborative efforts will be promoted more in the future.

3. Center's Position within Host Institution and Measures to Provide It with Resources

Describe the Center's future plans with regard to the following points after the funding period ends.

3-1. From a Mid- to Long-term Perspective, the Position of the Center within the Organization of the Host Institution

Describe where the Center will be placed within the host institution's overall organizational strategy under the leadership of the institution's head.

- In Appendix 3, diagram the Center's position within the organization of the host institution, and describe that positioning using excerpts from the institution's mid- to long-term plan. If the plan has not been established yet, describe the consideration being given to the Center's positioning.

In the third mid-term plan (Appendix 3), Tokyo Tech clearly defines ELSI as "a highly strategic and ambitious organization". Tokyo Tech has announced active support for making ELSI a permanent and independent research organization in its "Strategic Research Hubs". Former President Mishima stated that ELSI is "a springboard for Tokyo Tech to leap to a world-class science and technology university". The current President Masu states that "Tokyo Tech is proud of ELSI, considering that it has established a collaborative research network consisting of world top-class researchers and offers a truly international research environment. ELSI is positioned as a leader for Tokyo Tech in its concept that aims at becoming one of the top 10 research universities by 2030, which marks the 150th anniversary of Tokyo Tech."

Spreading ELSI's proactive system to the entire university will contribute to Tokyo Tech becoming a top 10 research university. Under this vision, Tokyo Tech will strategically invite and hire outstanding researchers from around the world for the "improvement of global recognition of research results". ELSI — at which about half of the researchers are from outside Japan as a result of global recruitment — is listed as a brilliant example of Tokyo Tech, and it has become an integral part of the university achieving its goals as a Designated National University.

3-2. Host Institution's Action Plan for Sustaining and Advancing the Center as a World Premier International Research Center (e.g., Positioning, Financial Resources)

- In Appendix4, describe the host institution's resource allocation plans for the Center, including the allocation of posts (in both its research and administrative divisions).

To maintain ELSI's position as one of the world's leading research centers after the completion of the WPI program, Tokyo Tech has guaranteed that it will provide 10 full-time PIs and supporting staff necessary for the operation of the institute. In addition, Tokyo Tech will continue to support ELSI with the presidential discretionary budget and provide space for laboratories, meeting rooms, and offices. ELSI has already been assigned eight tenure positions for full-time PIs. These are the results of Tokyo Tech positioning ELSI as a key institute in its mid- and long-term strategic plans for strengthening education and research. In the newly-established "Earth and Life Science" course, Tokyo Tech has already prepared a scheme to financially support the graduate students enrolled in this course.

In response to a request from ELSI, Tokyo Tech established a new system of "donation program" to enhance education and research through donations from private companies. This is different from the existing donation-based courses, has more freedom and can start on a smaller scale. ELSI received a first-of-its-kind JPY 24 million donation from a private company and established the "FirstLogic Astrobiology Donation Program". This donation has been used to hire one researcher and fund his/her research expenses. We will continue to increase the acquisition of research funds like this from corporate donations. ELSI is also developing communication channels to industrial partners and investors. If they become interested in basic researches conducted at ELSI, they may become willing to invest toward research or to support young researchers. In order to obtain research funds from overseas companies and organizations, the NPO Tokyo Tech USA was established in 2017 in the United States. With this, we are working actively to acquire funding to support ELSI activities from organizations outside of Japan.

Appendix 1 List of Principal Investigators (for Progress Plan)

* If the number of principal investigators exceeds 10, add rows as appropriate.
* Give age as of 1 April 2022
* For investigators who cannot participate in the center project from FY 2022, indicate the time that their participation will start in the "Notes" column.
* Enter the host institution name and the center name in the footer.

	Name	Age	Current affiliation (position title, organization, department)	Academic degree and current specialties	Effort(%)*	Notes (Enter "new" or "ongoing")
1	Yasuhito SEKINE	43	Director, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Planetary Science, Astrobioloby, Evolution of Earth and Planets	80	ongoing
2	Kei HIROSE	54	Professor, Tokyo Institute of Technology, Earth-Life Science Institute Professor, The University of Tokyo, Department of Earth and Planetary Science	Ph.D., High-pressure Geoscience	30	ongoing
3	Mary VOYTEK	63	Professor, Tokyo Institute of Technology, Earth-Life Science Institute Professor, Columbia University Senior Scientist, NASA	Ph.D., Biology and Ocean Sciences, Astrobiology	25	ongoing
4	Shigeru IDA	61	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Planetary Sciences, Planetary Physics	80	ongoing
5	John HERNLUND	49	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Geophysical Modeling, Fluid and Solid Dynamics	80	ongoing
6	Eric SMITH	56	Professor, Tokyo Institute of Technology, Earth-Life Science Institute External Professor, Santa Fe Institute Senior Research Scientist, Georgia Institute of Technology	Ph.D., High-energy/particle Physics	80	ongoing
7	Yuichiro UENO	47	Professor, Tokyo Institute of Technology, Department of Earth and Planetary Sciences	Ph.D., Geochemistry	60	ongoing

8	Shawn McGLYNN	38	Associate Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Evolutionary Biology, Microbial Biochemistry	80	ongoing
9	Ryuhei NAKAMURA	45	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Electrochemistry	80	ongoing
10	Hidenori GENDA	47	Associate Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D., Planet Formation	80	ongoing
11	Tomoaki Matsuura	50	Professor, Tokyo Institute of Technology, Earth-Life Science Institute	Ph.D in Biotechnology	80	ongoing

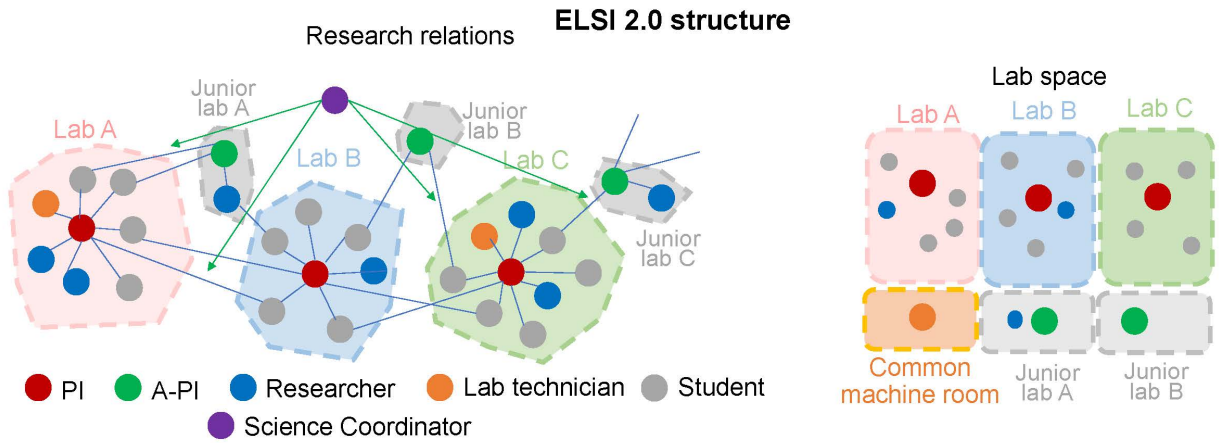
*Percentage of time that the principal investigator devotes to working for the center vis-à-vis his/her total working hours.

Number of Center Personnel

			FY2022	
			Number of persons	%
Researchers			37	
	Overseas researchers		13	35
	Female researchers		6	16
	Principal investigators (PIs)		11	
		Overseas PIs	4	36
		Female PIs	1	9
	Other researchers		19	
		Overseas researchers	6	32
		Female researchers	3	16
	Postdocs		7	
		Overseas Postdocs	3	43
		Female Postdocs	2	29
Research support staffs			16	
Administrative staffs			12	
TOTAL			65	

Appendix 2 Diagram of Center Management System

- Diagram management system after the funding period ends in an easily understood manner.
- If you are planning to change your organization management system and/or its position within the host institution in or after FY 2022 compared to their description in Appendix 3-1 of Activities report, show the changes in the diagram. Especially describe any important changes being planned in such as the center director, administrative director, head of host institution, and officer(s) in charge at the host institution (e.g., executive vice president for research).



- ✓ Making one research network within the institute (no isolation)
- ✓ Governance and responsibility of PIs increased (not flat relationships)
- ✓ Roles of PIs, A-PIs, Researchers, and students are clarified

- ✓ PI's roles: Fund acquirement to maintain labs, lab management, supervising researchers/students, collaborations with other PIs/A-PIs (a half of students is encouraged to do collaborative researches)
- ✓ A-PIs roles: Interdisciplinary cores, fund acquirement (+ sub-supervising students)
- ✓ Researchers' roles: Research activities, organizing study groups
- ✓ Students' roles: Research activities, actual bridges to connect labs

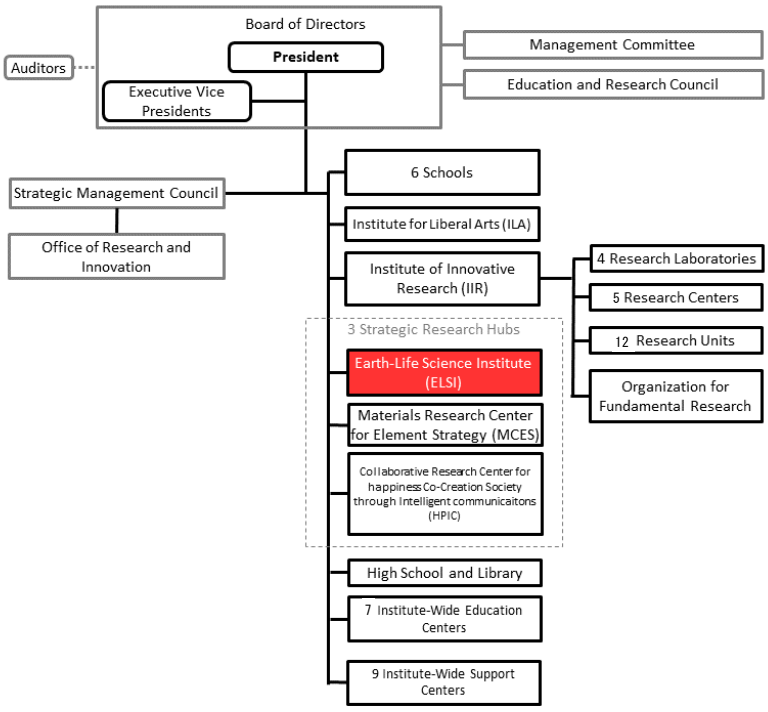
Appendix 3　Position of the Center within Host Institution

* Diagram the Center's position within the organization of the host institution, and describe that positioning using excerpts from the institution's mid- to long-term plan. If the plan has not been established yet, describe the consideration being given to the Center's positioning.

●Excerpt from Tokyo Tech's Third Mid-term Plan
(Mid-term goals)
2. Research goals
(1) Targets on research levels and outcomes
I-2-2. Tokyo Tech will promote the application of the values created at this university to society, and actively promote fusion between various research fields and develop new areas in science and technology.
(Mid-term Plan)
2. Measures to achieve research goals
(1) Measures to achieve the goals on research levels and outcomes
【15】The Earth-Life Science Institute (a WPI center) will focus on the early Earth and conduct research on the origin and evolution of the Earth and life, and Tokyo Tech will support the institute by providing resources at the President's discretion.
In Tokyo Tech's annual plan since FY2016, ELSI has been categorized under "strategic and ambitious goals and plans".

●Status of organizational reform
Tokyo Tech reorganized the research institutes in April 2016 and established a more integrated Institute of Innovative Research (IIR). As the next step, the President's Office and ELSI are discussing a plan to establish a new organization "Advanced Study Institute" or "Advanced Study Organization". This organization will focus on the research areas including those of ELSI and is expected to achieve a world top-level status in innovation, globalization, and diversity in research. Through this reform, Tokyo Tech plans to propagate the success of ELSI's system to the entire university. This is possible by not only maintaining and strengthening the current ELSI, but also by establishing a research hub that can further spread the system reforms that ELSI has implemented to the entire Tokyo Tech.

● Current position of ELSI
ELSI is given the status of "special research zone" in Tokyo Tech under the direct control of the President, and is designated as one of the three "Strategic Research Hubs" institutes defined in the Organization Management Regulations of Tokyo Tech. In addition, ELSI is entitled to be able to submit budget requests to the government through the university.



Appendix 4. Resource Allocation Plan for Sustaining and Advancing the WPI Center

Annual Plans (FY 2022 – FY 2026)					
<Fund >					**(million Yen)**
Fiscal Year	**2022**	**2023**	**2024**	**2025**	**2026**
- Funding from host institution	**388**	**380**	**372**	**362**	**352**
(details)					
Personnel	**299**	**316**	**331**	**343**	**343**
Project activities	**74**	**49**	**26**	**4**	**4**
Travel	**2**	**2**	**2**	**2**	**2**
Equipment	**3**	**3**	**3**	**3**	**3**
Other research projects	**10**	**10**	**10**	**10**	**0**
Costs of Satellites	**0**	**0**	**0**	**0**	**0**
- Funding from external sources	**346**	**356**	**366**	**376**	**387**
Total	**734**	**736**	**738**	**738**	**739**
<Personnel> **					**(person)**
Fiscal Year	**2022**	**2023**	**2024**	**2025**	**2026**
Total number of Personnel	(65)	(75)	(85)	(95)	(105)
- PIs	(11)	(11)	(11)	(11)	(11)
Full-time	(8)	(8)	(8)	(8)	(8)
Concurrent	(3)	(3)	(3)	(3)	(3)
- Other researchers	(19)	(19)	(19)	(19)	(19)
- Postdocs	(7)	(7)	(7)	(7)	(7)
- Research support staffs	(16)	(26)	(36)	(46)	(56)
RAs etc.	(13)	(23)	(33)	(43)	(53)
- Administrative staffs	(12)	(12)	(12)	(12)	(12)

- Use yen (¥) when writing monetary amounts. If an exchange rate is used to calculate the yen amount, give the rate.
- When entering amounts, round down numbers to the first decimal.
- When funding is stated in a range between two amounts, explain the reason for the lower and upper amounts and fluctuations between them.

** When the host institution covers the expense, enter the amount in parentheses.

< Measures to be implemented from FY 2022>

– Strategy and action plan for allocating personnel (posts) , space, and others measures required for the Centers' Progress.

(1) Strategy and action plan for allocating human resources and space

* Tokyo Tech will secure eight tenured professor and associate professor positions after the WPI funding period, so that ELSI will remain a world top-class research center permanently. In total ten full-time PIs (including the above-mentioned eight tenured faculty members) will be appointed.
* Two full-time administrative staff (Tokyo Tech official employees) and a couple of contract-based supporting staff necessary for the smooth operation of ELSI will be appointed in order to secure good research enrironment.
* A laboratory manager will be appointed to maintain and safely manage the world-class lab facilities and experimental instruments.
* To maintain the research environment suitable for a world-class research center, Tokyo Tech will allocate the two ELSI buildings to the institute.
* Tokyo Tech will assign ELSI faculty members to the graduate schools so that they can supervise graduate students. A new course on Earth and Life Science led by ELSI faculty members in the School of Science and the School of Life Science is established in 2021. Graduate students enrolled in this course will be financially supported by the institute so that they can concentrate on course

studies.

(2) Strategy and action plan for other measures

* Tokyo Tech has given to ELSI the status of "special reseearch zone", a permanent and independent research organization. Tokyo Tech's mid-term plan clearly states that ELSI will be supported directly with the President's discretionary resources. This is because ELSI is an important leading example for Tokyo Tech's vision to become one of the world's top 10 research universities by 2030. ELSI will also play a key role for Tokyo Tech to fulfill the status of designated national university.
* Tokyo Tech will increase its fundraising efforts in cooperation with the Kuramae Alumni Association and develop strategic activities to solicit donations. Tokyo Tech will be able to support ELSI more effectively by seeking large-scale industry-university cooperation in the areas of new or interdisciplinary research fields and support for young researchers.
* Tokyo Tech has assigned URA staff to the Office of Research and Innovation, to provide various support for obtaining external funds (information for available funds, tutorial sessions to write good proposals, etc.). ELSI will be able to improve its support to the researchers and be more successful in obtaining external funds under the strong support from the Office of Research and Innovation.