NONREIMBURSABLE MEMORANDUM OF UNDERSTANDING

between the

Biological and Physical Sciences Division,
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

and the

Office of Biological and Environmental Research,
DEPARTMENT OF ENERGY

for Cooperation Relating to

MICROBIOME DATA ECOSYSTEMS AND COMPUTATIONAL FRAMEWORKS

I. AUTHORITY AND PARTIES

The National Aeronautics and Space Administration (NASA) enters into this Memorandum of Understanding (MOU) in accordance with its authority under the National Aeronautics and Space Authorization Act, as amended, 51 U.S.C. § 20113(e). The Department of Energy (DOE) enters into this MOU in accordance with its authority under Sec. 646 of the Department of Energy Organization Act, as amended, 42 U.S.C. § 7101, Sec. 107 of the Energy Reorganization Act of 1974, 42 U.S.C. § 5801, and Sec. 971 of the Energy Policy Act of 2005, 42 U.S.C. § 16311. NASA and DOE may be individually referred to as a "Party" and collectively referred to as the "Parties."

The programmatic authorities of each Party, along with the internal policies and procedures of each agency, define the authority of the Participants to establish and manage their respective programs.

II. PURPOSE

This MOU between the Biological and Physical Sciences Division of NASA and the Office of Biological and Environmental Research (BER) of DOE establishes a framework for cooperation between the NASA-funded GeneLab, the DOE-funded National Microbiome Data Collaborative (NMDC), the DOE-funded Systems Biology Knowledgebase (KBase), and the DOE-funded Joint Genome Institute (JGI). The MOU defines respective NASA and DOE management responsibilities that will encourage collaborations and leverage synergistic development activities between these three microbiome data ecosystems and computational frameworks in order to enable and accelerate scientific progress and avoid duplication of efforts.

NASA's Biological and Physical Sciences (BPS) Division seeks advances in the biological and physical sciences through space-based research, and studies the behavior and adaptation of physical processes, living organisms, and ecosystems to environments beyond Earth, to enable space exploration and pioneer scientific discovery. Within BPS, the Space Biology program focuses on the effects of short and long duration spaceflight environment exposure on the biology of cells,

microorganisms, plants, and animals. NASA's Space Biology goals are to: 1) effectively use microgravity and other space environment characteristics to enhance our understanding of the adaptation and function of basic biological processes in spaceflight; 2) develop a scientific and technological knowledge base that will contribute to a safe, productive human presence in space during exploration; and 3) apply the knowledge and technologies gained to improve our nation's competitiveness, education, and the quality of life on Earth. NASA's Space Biology experiments use ISS resources, ground-based microgravity analog systems, and non-ISS flight platforms to discover how the spaceflight environment impacts microorganisms, plants, and animals throughout their entire lifecycle. Furthermore, it seeks to understand biological responses through the continuum of gravity, from microgravity through hypergravity. Space Biology enables NASA to achieve the goals of fundamental and translational biology research in Space that are critical to the agency's exploration and space commercialization missions.

NASA's GeneLab, which is managed by NASA's Space Biology Program through Ames Research Center's Space Biosciences Division, is an interactive, open-access resource where scientists can upload, download, store, search, share, transfer, and analyze omics data from spaceflight and corresponding analog experiments. Users can explore GeneLab datasets in the Data Repository, analyze data using the Analysis Platform, and create collaborative projects using the Collaborative Workspace. GeneLab facilitates and improves information sharing, fosters innovation, and increases the pace of scientific discovery from extremely rare and valuable space biology experiments. Discoveries made using GeneLab have begun and will continue to deepen our understanding of biology, advance the field of genomics, and help to discover cures for diseases, create better diagnostic tools, and ultimately allow astronauts to better withstand the rigors of long-duration spaceflight. GeneLab helps scientists understand how the fundamental building blocks of life itself – DNA, RNA, proteins, and metabolites – change from exposure to microgravity, radiation, and other aspects of the space environment. GeneLab does so by providing fully coordinated epigenomics, genomics, transcriptomics, proteomics, and metabolomics data alongside essential metadata describing each spaceflight and space-relevant experiment. By carefully curating and implementing best practices for data standards, users can combine individual GeneLab datasets to gain new, comprehensive insights into the effects of spaceflight on biology. In this way, GeneLab extends the scientific knowledge gained from each biological experiment conducted in space, allowing scientists from around the world to make novel discoveries and develop new hypotheses from these priceless data.

DOE's Office of Biological and Environmental Research (BER) supports fundamental research and scientific user facilities to address diverse and critical challenges relevant to DOE's energy, environment, and basic research missions. The Biological Systems Science Division (BSSD) in BER integrates discovery- and hypothesis-driven science with technology development on plant and microbial systems relevant to national priorities in energy security and resilience. Systems biology is the multidisciplinary study of complex interactions specifying the function of entire biological systems—from single cells to multicellular organisms—rather than the study of individual isolated components. The BSSD subprogram employs systems biology approaches to define the functional principles that drive living systems, from microbes and microbial communities to plants and other whole organisms. The subprogram employs approaches such as genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of information into computational models that can be iteratively

tested and validated to advance a predictive understanding of biological systems from molecules to mesoscale.

DOE's National Microbiome Data Collaborative (NMDC; microbiomedata.org) program initiated in 2019 seeks to develop an open-access framework that facilitates more efficient use of microbiome data for applications in energy, environment, health, and agriculture. Over the past few decades, microbiome data have grown exponentially. However, the sheer amount of data available presents a significant bottleneck for analysis and interpretation. NMDC's mission is to work with the community to iteratively develop an integrated, open-source microbiome science gateway that leverages existing resources and enables comprehensive access to multidisciplinary microbiome data and standardized, reproducible data products. To tackle this data integration challenge, NMDC leverages DOE's existing data-science resources and high-performance computing systems. The NMDC's long-term goal is to develop sustainable partnerships for data integration and interoperability with other large data programs that support microbiome research. The NMDC framework is community-centric, open source, agile, integrated microbiome data ecosystem to enable comprehensive access and integration of multi-omics datasets (metagenome, metatranscriptome, metaproteome, metabolome, and environmental data) for reproducible, cross-study analyses for community dynamics, metabolic networks, and other microbe-microbe, microbe-host, and microbe-environment interactions. The guiding principles at the initiative's core are(1) making data findable, accessible, interoperable, and reusable (FAIR); (2) connecting data and compute resources; and (3) community engagement that supports open science and shared ownership.

Developed for bench biologists and bioinformaticians the DOE's System Biology Knowledgebase (KBase; kbase.us) is a software and data science platform designed to meet the grand challenge of systems biology: predicting and designing biological function, The KBase knowledge creation and discovery environment integrates a variety of data and analysis tools from the DOE and other public services into an easy-to-use platform that leverages scalable computing infrastructure and performs sophisticated systems biology analyses. KBase enables secure sharing of data, tools, methods, and conclusions in a unified, extensible system where researchers collaboratively generate, test, and share hypotheses about biological functions; perform large-scale analyses on scalable computing infrastructure; combine multiple lines of evidence to accurately model plant and microbial physiology and community dynamics, and ultimately 'publish' their work in FAIR ways. The goal for KBase is to accelerate research in DOE mission areas - into how plants, microbes and their communities transform and are transformed by the environment influencing earth's biogeochemical cycles. This requires a multiscale understanding of biological function from molecular to ecological. KBase enables scientists to analyze their own data within the context of public data and share findings across the system. KBase supports the sharing of data, workflows, and narratives among researchers/users, facilitating collaboration and accelerating the pace of scientific discovery. The ultimate goal is to build a true knowledgebase for systems biology: an integrated environment where knowledge and insights are created and multiplied.

The DOE Joint Genome Institute (JGI) scientific user facility is the world's largest genome science center dedicated to providing large-scale data production and cutting-edge genomic capabilities in energy and environmental research. JGI provides genome sequencing, DNA synthesis, metabolomics, and a host of advanced functional genomics technologies, all underpinned by a

strong data ecosystem, to a large and broad community of scientists. Data generated from these capabilities and projects is made openly available to the scientific community through the JGI flagship data systems for metagenome, microbial, viral, algal, fungal, and plant genomes (as well as other classes of omics data) in accordance with the FAIR data principles. The JGI provides web-based access to tools for comparative analysis and common data download points through its flagship data systems or genome portals. Data object identifiers are assigned to data generated at the JGI. JGI also collects Online Research Contributor iD (ORCiD) identifiers for users to ensure a clear link between the data that is generated from a proposal and the PI. JGI supports more than 10,000 data users each year.

The rationale for this MOU stems from the realization that collaboration between GeneLab, NMDC, KBase, and JGI activities could enhance scientific opportunities and benefits to DOE, NASA, and broadly other research entities. Through cross-linked data collection, access, and analysis, NASA and DOE can help minimize duplication of effort and create compatible and synergistic approaches to generating and providing access to standardized data that will be used to improve understanding of the systems biology attributes of plants, microbes, microbiomes, and environmental microbial communities. This MOU will provide a framework for GeneLab, NMDC, KBase, and JGI programs to coordinate efforts that are mutually beneficial to NASA and DOE and promote a higher scientific return on investments by the agencies, to the benefit of the broader scientific community and society.

NASA and DOE will coordinate and promote research and outreach activities related to joint efforts that effectively align with the scientific priorities and planning of each agency during the period of 2023-2028.

III. RESPONSIBILITIES

NASA will make reasonable efforts to:

- Consult at least once a year with NMDC, KBase, and JGI personnel to discuss and plan mutually beneficial coordinated efforts;
- Invite and include all relevant NMDC, KBase, and JGI personnel in GeneLab investigator and science meetings, and provide reports, if any, on the outcomes of any meetings or workshops;
- Invite JGI and NMDC to the GeneLab Microbial Analysis Working Group to integrate mutual efforts for developing genome data standards;
- Add a new milestone to the GeneLab metrics dashboard to measure engagement with NMDC, KBase, and JGI;
- Share public data management protocols utilized by GeneLab with NMDC, KBase, and JGI personnel;
- Support efforts to make GeneLab data products cross-compatible with NMDC, KBase, and JGI, and to maximize the use of cross-compatible resources for the scientific community;
- Share information about microbiome data standards and data processing approaches with NMDC, KBase, and JGI personnel;
- Coordinate GeneLab data access and availability to be hosted on NASA information technology systems as authorized by NASA System Security Plan number hosted via OA-9999-M-ARC-3253 and availability through NMDC, KBase and JGI resources;

- Coordinate with relevant technical teams from NMDC and JGI to develop joint GeneLab-NMDC-JGI standards for microbiome data processing procedures and metadata collection;
- Coordinate with relevant technical teams from KBase, NMDC and JGI on future technology development, including development of community-based metadata standards, developing workflows compatible with DOE systems (KBase, NMDC and JGI), advancing microbiome analyses for long-term ecosystem monitoring, and leveraging expertise for integrative multi-omics data generation, processing, and access;
- Coordinate with NDMC, KBase and JGI personnel to plan and organize community training activities on large-scale microbiome data standards and analyses and bioinformatics workflow development and implementation on distributed computational resources, including hosting joint webinars on how to integrate NMDC, GeneLab, KBase and JGI workflows;

DOE will make reasonable efforts to:

- Consult at least once a year with GeneLab personnel to discuss and plan mutually beneficial coordinated efforts;
- Invite and include GeneLab personnel in NMDC, KBase, and JGI investigator and science meetings, and provide reports, if any, on the outcomes of any meetings or workshops;
- Add a new milestone to the JGI, NMDC and KBase metrics dashboard to measure engagement with GeneLab;
- Share public data management protocols utilized by NMDC, KBase, and JGI with GeneLab personnel;
- Support efforts to make NMDC, KBase, and JGI data products cross-compatible with GeneLab, and to maximize the use of cross-compatible resources for the scientific community;
- Share information about microbiome data standards and data processing approaches with GeneLab personnel;
- Coordinate NMDC data access and availability through GeneLab data access (to be hosted on NASA information technology systems as authorized by NASA System Security Plan number OA-9999-M-ARC-3253);
- Coordinate with relevant technical teams from GeneLab to develop joint GeneLab-NMDC-JGI microbiome data processing procedures;
- Coordinate with relevant technical teams from GeneLab on future technology development, including development of community-based metadata standards, workflow development, for advancing microbiome analyses for long-term ecosystem monitoring, and leveraging expertise for integrative multi-omics data generation, processing, and access;
- Coordinate with GeneLab personnel to plan and organize community training activities on large-scale microbiome data standards and analyses and bioinformatics workflow development and implementation on distributed computational resources.
- An emphasis on diversity, equity, and inclusion (DEI) will underpin workforce development and engagement activities, and NMDC, KBase, and JGI personnel will coordinate open, shared exchange to drive DEI priorities.

NASA and DOE will jointly make reasonable efforts to:

- Co-organize an initial joint meeting (e.g., PI meeting or targeted community workshop) for the GeneLab, NMDC, KBase, and JGI research communities to encourage the development of synthesis products and other related community-driven collaborations.
- Employ best practices for diversity, equity, and inclusion (DEI), as described in Agency and government-wide policies and strategic guidance, in all joint engagement activities.

IV. FINANCIAL OBLIGATIONS

There will be no transfer of funds between the Parties under this Agreement and each Party will fund its own participation. All activities under or pursuant to this Agreement are subject to the availability of funds, and no provision of this Agreement shall be interpreted to require obligation or payment of funds in violation of the Anti-Deficiency Act (31 U.S.C. § 1341). Each agency will follow its applicable project and procurement rules with respect to its participation in the GeneLab, NMDC, KBase, and JGI initiatives.

This MOU is not a contract for the acquisition of supplies or services, is not legally enforceable, and shall not be construed to create any legal obligation on the part of either of/any of the Parties. This MOU shall not: (a) be used to obligate or commit funds, or as a basis for the transfer of funds; (b) constitute a commitment of any or all of the Parties to obligate any funds in support of activities herein described or implied.

V. PRIORITY OF USE

Any schedule or milestone in this MOU is estimated based upon the Parties' current understanding of the projected availability of its respective goods, services, facilities, or equipment. In the event that either Party's projected availability changes, NASA or DOE, respectively, shall be given reasonable notice of that change, so that the schedule and milestones may be adjusted or cancelled accordingly. The Parties agree that NASA's and DOE's use of its own goods, services, facilities, or equipment shall have priority over the use planned in this MOU.

VI. LIABILITY AND RISK OF LOSS

Each Party agrees to assume liability for its own risks arising from or related to activities conducted under this MOU.

VII. INTELLECTUAL PROPERTY RIGHTS – DATA RIGHTS – FREE EXCHANGE OF DATA

NASA and DOE agree that the information and data exchanged in furtherance of the activities under this MOU will be exchanged without use and disclosure restrictions unless required by national security regulations (e.g., classified information) or as otherwise provided in this MOU or agreed to by NASA and DOE for specifically identified information or data (e.g., information or data specifically marked with a restrictive notice).

VIII. RELEASE OF GENERAL INFORMATION TO THE PUBLIC AND MEDIA

NASA or DOE may, consistent with Federal law and this MOU, release general information regarding its own participation in this MOU as desired. Insofar as participation of the other Party in this MOU is included in a public release, NASA and DOE will seek to consult with each other prior to any such release, consistent with the Parties' respective policies.

Pursuant to Section 841(d) of the NASA Transition Authorization Act of 2017, Public Law 115- 10 (the "NTAA"), NASA is obligated to publicly disclose copies of all agreements conducted pursuant to NASA's 51 U.S.C. § 20113(e) authority in a searchable format on the NASA website within 60 days after the agreement is signed by the Parties. The Parties acknowledge that, if this MOU is entered into pursuant to NASA's 51 U.S.C. § 20113(e) authority, this MOU will be disclosed, without redaction, in accordance with the NTAA.

IX. TERM OF AGREEMENT

This MOU becomes effective upon the date of the last signature below ("Effective Date") and shall remain in effect until the completion of all obligations of both Parties hereto, or five years from the Effective Date, whichever comes first.

X. RIGHT TO TERMINATE

Either Party may unilaterally terminate this Agreement by providing ninety (90) calendar days written notice to the other Party.

XI. CONTINUING OBLIGATIONS

The rights and obligations of the Parties that, by their nature, would continue beyond the expiration or termination of this Agreement, e.g., "Liability and Risk of Loss" and "Intellectual B-129 Property Rights" and related clauses [and "Financial Obligations" if reimbursable] shall survive such expiration or termination of this Agreement.

XII. POINTS OF CONTACT

The following personnel are designated as the Points of Contact between the Parties in the performance of this Agreement.

Technical Points of Contact

NASA Headquarters
Biological and Physical Sciences Division
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U.S. Department of Energy
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Biological Systems Science Division
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757-560-4727

Washington, DC 20585
Ramana.madupu@science.doe.gov
201-903-1398

XIII. DISPUTE RESOLUTION

All disputes concerning questions of fact or law arising under this MOU shall be referred by the claimant in writing to the appropriate person identified in this MOU as the "Points of Contact." The persons identified as the "Points of Contact" for NASA and DOE will consult and attempt to resolve all issues arising from the implementation of this MOU. If they are also unable to come to agreement on any issue, the dispute will be referred to the signatories to this MOU, or their designees, for joint resolution after the Parties have separately documented in writing clear reasons for the dispute. As applicable, disputes will be resolved pursuant to The Department of the Treasury's Intragovernmental Transaction Guide (Treasury Financial Manual, Vol. 1, Chapter 2, Part 4700, Appendix 10 (hereinafter, the "Intragovernmental Transaction Guide")).

XIV. MODIFICATIONS

This MOU will be reviewed every five years to determine its applicability and the need for any changes. Any modification to this MOU shall be executed, in writing, and signed by an authorized representative of NASA and DOE.

XV. OTHER

This MOU does not give a third party any benefit, legal or equitable right, remedy, or claim under any agreement contained herein.

Nothing in this MOU is intended to conflict with current law, regulation, directives, or MOUs of the Parties. If a term of this MOU is inconsistent with such authority, then that term shall be invalid, but the remaining terms and conditions of this MOU shall remain in full force and effect.

This MOU shall take effect upon the date of the last signature of the Parties.

XVI. SIGNATURE AUTHORITY

Approved and authorized on behalf of each Party by:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lisa Scott carnell

Digitally signed by Lisa Scott carnell
Date: 2023.09.07 10:57:25 -04'00'

Lisa Carnell, Director
Biological and Physical Sciences Division

DEPARTMENT OF ENERGY

ROBERT ANDERSON

Digitally signed by ROBERT ANDERSON
Date: 2023.08.25 11:05:25 -04'00'

Dr. R. Todd Anderson, Acting Associate Director Office Biological and Environmental Research