

The Future of Life on Earth

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The Past, Present, and Future of Life on Earth : Scientific Connections between NASA's
Earth Science Division and Astrobiology Program

Background

Life on Earth depends upon networks of interactions between the biological and the geophysical and chemical elements of the crust, oceans, and atmosphere, which together constitute a biosphere that has been remarkably resilient to environmental challenges.

Looking back at both the recent and deep history of life on Earth and its changes through time allows us to understand some of the processes driving change in the past and develop models and other tools to make predictions about the future of life on this planet.

Viewing the components of Earth's living systems through the lens of astrobiology challenges us to consider the context for life on a planetary scale, to develop mathematical representations of stabilizing feedbacks that permit the continuity of life in the face of changing physical conditions, to understand the capacity of organisms to evolve in response to a changing environment, and to understand the limits of the stabilizing feedbacks.

Ideally these considerations will provide insight into the potential effects of many types of environmental changes, be they abrupt or unfolding on time scales ranging from seasonal cycles to millions of years.

Information Requested

This RFI requests information on areas in which research addressing the goals of one program has the potential make an impact on achieving the goals of the other. These areas include, but are not limited to, research areas that bridge the dichotomies in time scales, measurement spatial scales, or the elements of life studied by these two programs, or any other perceived dichotomies between the two programs. We seek your input on potential synergies arising from collaboration between scientists from both communities in the expectation that such collaborative work would require multidisciplinary teams from both communities.

Short Statement of the Central Idea

Human civilization on Earth is now overpopulated by nearly an order of magnitude over the natural carrying capacity of the planet, comparing to earlier Pleistocene populations of widely separated hunter gatherer bands, and later Holocene populations of Neolithic agricultural communities. Our civilization now consists primarily of many large, high density factory farms and production facilities, uniformly dispersed across nearly all the tillable areas of the planet Earth, interspersed with sprawling, high density, horizontally and vertically integrated cities and city states, each with hundreds of thousands to many millions of people living in close proximity. Besides the obvious examples of sunlight and condensing and non condensing greenhouse gases lighting and heating the surface of the planet, driving plant and animal biodiversity, through an active hydrogeological cycle and natural and agricultural productivity, the extra energy necessary to sustain the growth and progress of our civilization beyond its natural carrying capacity, is derived from the atmospheric combustion of carbon, the internal heat of the planet's molten core through fissionable materials, and the secondary methods of hydroelectric and wind generation. Just in the recent decade has thermal and electric solar energy become another supplier.

In order to solve the problems of overpopulation driven by our energy sources above and beyond the natural solar irradiance flux and geothermal energy, obtained exclusively by the unrestricted atmospheric combustion of natural wood and fiber products and carbon derived from fossil fuel sources such as coal, natural gas, crude oil and its distillates, and in order to remediate the directly associated problems of land use changes driven by over development, and disruptive climate changes as a result of increasing atmospheric carbon dioxide content, certain specific events must occur, as clearly dictated by earth sciences.

Conversely, if science as a discretionary international endeavor is expected to progress, there must also be a vibrant and growing sustainable economy capable of supporting it. The financial economy upon which our civilization depends is already on the verge of collapse, and it is dependent upon the continued combustion of carbon, contrary to its survival. Without carbon combustion to support agriculture, and with clear threats to agriculture as a result of carbon combustion, the sustainability paradox is self evident. If astrobiology and earth sciences research scientists with NASA truly desire to continue their research over long time frames, they must confront and address these issues directly, because the funding upon which it depends derives directly from success of the economy. The goals of this research effort must be economic security and value for it stakeholders.

Definition of the issues relevant to the Earth Science Division and the Astrobiology Program, identifying which components (e.g., Earth Science's Biodiversity Program and Astrobiology's Exobiology Program or the NASA Astrobiology Institute) of the two would be expected to participate.

The central idea is life sciences and biospherics divisions as primary leads in this effort, using data directly derived from the earth sciences division as the basis for any designs. To ensure short term continued success of the astrobiology and earth science programs at NASA, the list of outstanding problems in this area are as self evident as the solutions:

Systems Biology

- Environmental – Geological, Biological, Chemical and Physical
- Organisms, Materials, Structures - Composition, Integration and Diversity
- Organismal (Including Human) - Culture, Physiology, Medicine and Health
- Pathogen Identification, Culture and Abatement - Insects, Bacteria, Fungal and Viral

Energy Production, Conversion and Storage – Thermal, Optical and Electrical

- Solar Thermal and Electric for Cooking and Heating of Water, Air and Structures
- Solar Electric for Household, Industrial and Transportation Electrical Energy
- Batteries, Thermal Masses and Sinks, Reservoirs, Tanks and Containers

Fuels and Cryogenics - Production, Storage and Use

- Biofuels - Cellulose, Hydrocarbons, Plant and Vegetable Oils, Ethanol
- Carbon Dioxide, Oxygen, Nitrogen, Argon, Methane, Hydrogen and Helium

Transportation – Solar, Wind, Electric and Cryogenic

- Ground Transportation – Personal, Motorized, Highway Freight and Trucking
- Mass Transportation, Air Transport, Inland Waterways, Oceanic Transport
- Lighter than Air Ships, Horizontal and Vertical Orbital Launch Vehicles

Wind and Hydroelectric Energy from the Small to Large Scale

- Wind Power Generation, Hydroelectric Power, Sailing Vessels and Airships

Small Scale Biosphere Design and Construction

- Earth Shelter, Underground Shelters, Sanitary Systems, Water Barriers
- Space Based, Lunar and Asteroid - Closed Ecological Life Support Systems

Small to Large Scale Agricultural Production

- Greenhouses, Indoor and Outdoor Hydroponics, Gardens and Orchards
- Plant and Fiber Products, Grains and Small Scale Animal Husbandry
- Deciduous Trees, Organic Composting, Aerobic and Anaerobic Digestion

Atmospheric Carbon Sequestration and Storage

- Biological, Chemical and Physical Techniques for Carbon Removal and Storage
- Carbon Products for Sequestration – Consumer Products and Building Materials
- Artificial and Geological Carbon Sequestration and Storage Methods, Biochar

Thermal Insulation at Temperature and Liquid and Vapor Barrier Technologies

- Dewars and (Hydro)Carbon Inert Gas Aerogels, Foams, Plastics and Composites

A brief sketch of the requirements to move forward, such as:

Time line for framing activities.

Need for a critical paradigm shift in perspective for NASA astrobiology, space sciences, earth sciences, life sciences, and space exploration programs is both immediate and dire. NASA funding across the board is facing unilateral and broad funding cuts precisely for the reasons I have briefly outlined here. In particular, the research domains that are most useful in addressing these issues, life sciences and biospherics, have been eliminated or cut completely, and do not yet have a simple website presence indicating their existence. On the other hand, the astrobiology program has been supremely successful in during its short history, and its recent results and discoveries places its importance into perspective.

The astrobiology program is the ideal domain to integrate life, earth, space and natural sciences into a coherent whole, by which technological and economic problems may be openly and honestly confronted, debated, addressed and quickly and definitively solved.

Scoping workshop or community building activities.

The University of Wisconsin at Madison is home to the Wisconsin Institute of Discovery, which will soon open in a modern, newly constructed building, housing state of the art biotechnology and systems biology research laboratories. The first floor and basement of this facility is dedicated to public outreach and information, along with private discussion involving issues related to commercialization and industry transfer of new technologies. This can serve as a model for the kind of aggressive commercialization of information, knowledge, results and developed and demonstrated technologies into the private sector, which many believe is necessary develop the public and private collaboration required to reduce the costs of successfully operating modern research facilities necessary to solve these pressing national priorities. As it was with the previous governor of the state and the chancellor of the university with respect to the initiation, discussion, development and execution of the Wisconsin Institute of Discovery project in response to new and critical local, state and international human health and welfare needs, the new UW chancellor is currently in the preliminary stages of a new university commercialization paradigm in response to vitally important financial, economic and industry and job creation realities.

The astronomy department at the University of Wisconsin at Madison operates a public outreach program called 'The Space Place', in an economically disadvantaged part of the community, which has been moderately successful in engaging the interests and desires of younger generations in science, technology, engineering and mathematics education, as well as serving as a vehicle to present basic astronomical and astrobiological concepts in a 'hands on' manner further challenging and developing their critical thinking abilities.

Elementary and secondary school STEM education represents the most promising avenue of progress for implementing the large scale infrastructure changes necessary to divert the massive momentum of our civilization towards its unsustainable and unaffordable result, and creating a future where the large scale brute force operations of modern government, institutional and commercial research laboratories can solve our urgent economic issues.

Potential collaborative fieldwork if applicable.

The respondent to this RFI was born in and is a lifelong resident of Dane County in south central Wisconsin, the home of the University of Wisconsin at Madison, and is living in a profoundly intellectual, light industrial and agricultural city state community, possessing a new research institute focusing on systems biology, and a synchrotron radiation facility. The author has for the last several decades embarked on a conscious program of research, analysis, study and laboratory and field demonstration of the concepts described herein, and now fully intends to continue his education at this institution, in order to continue to pursue the obvious, necessary and critical paradigm and infrastructure changes described.

The author has spent decades in and on various Exuma Cays in the Bahamas, owns an island in the Exuma Cays, and has spent years working at a NOAA funded world class marine research center in the Exuma Cays, using its unique location at the air, sea, land interface, its relatively pristine environment with easy access, and its revealing scientific and technological challenges in the area of resources and requirements, as a simple model for space exploration and habitat development on the planet Earth. The respondent has already proposed and indeed begun development of an astronaut training facility and a commercial spaceport at this location. I intend to continue this, if and where practicable.

Identification of key data sources.

Past, current and anticipated future low earth orbit, mid altitude, geostationary, Lagrange point, and both deep space and planetary surface observations, will continue to drive our knowledge of our planet and biosphere forward, and experience gained by constructing, operating and inhabiting our low earth orbit national research laboratory – the ISS, will continue to give us perspectives we need to embark on the program of planetary change necessary to solve ongoing problems of human overpopulation, and its inevitable results.

Potential modeling or associated computing needs.

Recent technological advances in open source software, cloud computing and distributed multicore processors, along with the visual display sophistication and three dimensional modeling of the commercial gaming industry, and wideband distributed wireless, satellite and broadband optical fiber networking, are well suited to lower carbon or carbon neutral sustainable future envisioned as the ultimate goal of this interdisciplinary research effort.

Obstacles to overcome, i.e., why hasn't this been done before?

Primary obstacles to the concept of earth sciences and astrobiology as space exploration have been perspective and value. Until recently modern society has been relatively secure in its economic and cultural foundations, and moderately ignorant or forgetful of severe and numerous natural, manmade and extraterrestrial hazards that confront it on the planet. Thus many in the space advocacy community continue to support space exploration goals and techniques that consume inordinate amounts of funding, while producing little value. Until the relatively small, vocal and active space advocacy community can come to grips with realities, difficulties, costs and values of these endeavors, little progress will occur.

Modern astrobiological and earth science perspectives have obsoleted the previous large program approaches to space science, and reintroduced societal and economic value as a primary motivation for research and development, confirming our personal, national and global security as the outstanding critical requirements drivers for our continued progress.

The following is reprinted from an earlier presidential PCAST meeting submission on the topic of national space science policy not previously published with PCAST submissions.

Life on this Planet

Life on the planet Earth is currently under siege. Human population is now approaching seven billion lives. Atmospheric carbon dioxide concentration is approaching 400 ppm. The atmospheric combustion of carbon is the fuel that is driving our economic growth. We are sustaining a global human community far beyond the natural carrying capacity of the planet. We are extracting and creating a body of natural wealth, and transforming it into intangible and obsolete assets. As a direct result of these uniquely human activities, numerous species are rapidly being driven into outright extinction, habitat migration and evolutionary adaptation. To state this isn't happening - is to deny science and the reality. Human intellectual aspirations have now exceeded the resources that Earth can sustain.

The Human Condition

It is the nature of the human condition that even confronted with seemingly intractable problems, one still has faith in the knowledge that we since have also evolved into this situation slowly over a period of time, then laws of physics must be such that solutions to our ever present problems actually do exist, and are therefore discoverable. We admit to ourselves that although we do not have all the answers at this time, we will make it an urgent goal to find them, for we have already hypothesized that they, in fact, must exist.

So it is with our current problems of population, our economic growth, energy and the environment, the security of our nation, and health, welfare and education of our citizens. We have reached a crisis of conscience with the modern world - that we cannot continue down the path that we have been taking. We must change direction in order to survive. We don't know exactly where we will end up going, but methods of science have clearly given us tools to identify the hazards that lay before us, and we choose to navigate them. We understand the hazards that we must navigate are those of the planet Earth. Some of those hazards are of our own making, and others have helped make us what we are today.

The Astrophysical Universe

Through the auspices of NOAA and NASA, we have discovered previously unknown truths about our universe and the world in which we live. With that new found knowledge we have begun to understand many of the well known hazards that accompany it, and we have also uncovered a few previously unknown hazards that inhabit it, and surround us.

We are able to come to grips with these dangers, because we have confidence, *dare I say faith*, in our abilities to sift and winnow through the noise, and discover and acknowledge

those truths, which reveal themselves by our actions. We now have the abilities to look outward into the universe and examine other worlds for clues to the origin and behavior of our own world, and by doing so, we have gained a greater appreciation and insight into dangers that we face here, and the methods by which we may confront those worst fears.

We have learned to conquer those fears, by confronting our problems, and solving them. By recording our successes and failures we have codified these problem solving methods into a body of work we call science, so that they may be transmitted across borders and down through the generations, greatly increasing the success rate of subsequent solutions. The processes by which we accomplish these tasks mimic the same processes by which life evolves. Now that we have a rough understanding of our human origins, we also have the utmost confidence that evolution will proceed, hindered only by lack of knowledge of ourselves, and the planet on which we reside, in the external universe that has created us. We make the conscious decision to take control of that evolution, so that we may survive.

The Quantum Dynamical World

Through the auspices of the DOE and the NSF we have funded research in quantum and condensed matter physics that has revolutionized our lives; in the way we live; in the way we communicate; how we convert energy, move about, maintain and entertain ourselves. The flow of progress starts from theory, and moves through engineering trade studies, laboratory experiments, device development and fabrication, construction and operation of facilities, and the commercialization of services and technologies that will manufacture the products that we need to organize lives, perform our duties, and maintain our health.

Innovation, Exploration and Discovery

The entrepreneurial spirit that we know can create entirely new industries, enter and compete in evolving marketplaces, invent novel applications and supply new services, depends upon our abilities to think honestly, openly and critically about the real evidence. These abilities are available to anyone and everyone, but from the evidence we know that these critical thinking skills may be developed by enhancing our educational experiences, via virtual and real demonstration using 21st century information processing technologies. The abilities to innovate, explore and discover aspects of our natural world is an innate human characteristic, which can be nurtured and enhanced by education and experience. Not everyone is able to extend their abilities into entrepreneurship and to success in the commercial marketplace, however - they should be afforded every opportunity to do so.

Education - Mathematics, Physics, Chemistry and Biology

The vast repository of knowledge that we have at our fingertips is clear, well organized and concise. Commercial search engines and non profit encyclopedias provide nearly instantaneous access to all of human knowledge, and education in the fundamental hard sciences has been reduced to the creative design of educational software architectures, along with guided or mentored instruction, at all age levels of our educational experience. Education itself, both in learning and teaching, has become a lifelong personal endeavor, and it is vitally important that it starts at the earliest possible moment in each of our lives.

Experience - Science, Technology, Engineering and Mathematics

Complementary to the need for teaching, instruction, training, and self education through software solutions, is some actual experience in the real world of hardware and wetware; the biological and geological imperatives of living organisms and their environments, along with the technological tools and techniques, and the operational procedures for the instruments and equipment that allow us to carry out the tasks necessary to our society.

Entrepreneurship - Nanotechnology, Biotechnology and Information Technology

"What are the critical infrastructures that only government can help provide that are needed to enable creation of new biotechnology, nanotechnology, and information technology products and innovations that will lead to new jobs and greater GDP?"

The short answer is - advanced light and particle sources, and spectroscopy laboratories. Some believe we are on the verge of much deeper understanding of quantum phenomena, which will open the gates to a floodwater of innovation in materials and exotic physics. The continued funding of materials science and condensed matter physics at very specific interest points will allow the nation to direct intellectual resources to its urgent problems.

Agriculture, Construction, Manufacturing and Transportation

The infrastructure of our world is what sustains the bulk of our population, whether they are interested in science or not. The transition from advanced spectroscopy laboratories, to the astronomical instruments and deep space missions of our space programs, through all of the intermediate transitions of education, experience and entrepreneurship within all economic sectors, is the ultimate goal of our national science policy. Without the bulk of the entire efforts of our civilization to support us, there would be no scientific endeavors.

Administration, Communications, Operations and Services

The administration, operations, servicing and supplying of that infrastructure may seem mundane and ordinary, but these are the activities that every one of us participate in every day of our lives. We go about our day-to-day tasks, seamlessly and efficiently enough to take for granted the extraordinary powers of rationality and reason. We have evolved to a point in space and time, where scientific advances and astronomical discoveries can be communicated in real time to a eager public - now directly participating in that progress.

Recommendations

I recommend that you get out there and make speeches with as much thoughtfulness and sophistication as you have put into national space policy, because although the problems we face in the modern world are indeed difficult, they are not insurmountable, even if we don't have all the answers - yet. Our greatest human attribute is the acknowledgment and awareness of the problems of our society and life, which promotes the willingness among the public to make the changes that are necessary to allow us to achieve our goals. The communication and presentation of why and what we do, is vital to achieve our support.

Conclusions

It is not possible to fund a modern, high national priority, manned lunar landing program such as Apollo. Manhattan style projects of any nature are not executable in our present budget circumstances. We need to put the legacy of Constellation to rest. It may indeed be possible to make a small concession to a space shuttle and space station constituency, by including the existing SSMEs, as primary engines, and a vital component to a national heavy lift launch vehicle architecture, but that engineering exercise only has value if it yields fundamental advances in reusability that will dramatically lower space flight costs. Executive decisions of a president can make or break the solutions to national problems. The recently announced National Space Policy and NASA funding directives adhere to the highest scientific and engineering, diplomatic and national security standards, while still permitting future latitude in executive direction. That future may very soon arrive.

Space sciences, earth sciences, life sciences and the natural sciences at our government funded research laboratories have now given us the knowledge we need to identify and understand the problems that confront civilization. The time to put it into practice is now.

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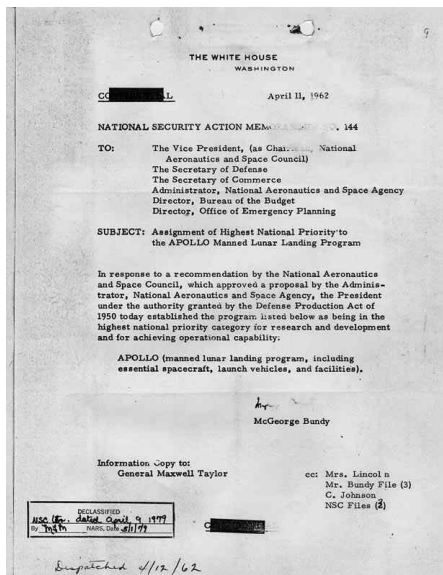
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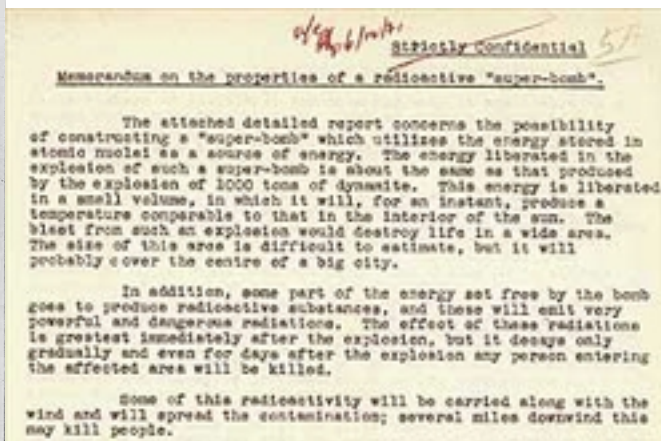
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National Security Action
Memorandum – NSAM 144



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