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Sustainability Public Policy Challenges of Long-Duration Space Exploration

Marilyn Dudley-Rowley* and Thomas Gangale.†
OPS-Alaska, 2262 Magnolia Avenue, Petaluma, California USA 94952

[Abstract] The authors investigate the overarching problem of *sustainability* of long-duration space missions without which a permanent base on the Moon or exploration of Mars is impossible. To have sustainability in these exploration environments means that series of long-duration missions can be launched with a high degree of success and with a quality of life for the microsocieties that must live and work in the mission environments. Several categories of sustainability issues are discussed, among them: guaranteed and timely multi-year funding for the exploration host agencies, the existence of an "integrator function" that can fit together the findings and products of multiple and disparate research teams and technologies to generate do-able missions, regimes of preparation that answer the questions posed by all the indicators that define long-duration space exploration and which anticipate latent challenges to long-duration missions to the Moon and to Mars. If the United States is to be involved in the long-duration space effort, these regimes of preparation must include having the continuity of NASA institutional memory and the vigor of American postsecondary education. However, recent historical and political events have savaged the nation's space agency. And, approximately three decades of depredations in Academe has diminished the American brain trust available from among the nation's postsecondary institutions. In the wake of these events, several popular, but inadequate, propositions have emerged which cannot solve for sustainability issues of long-duration space exploration. Increasingly, the idea that the space endeavor is frivolous and has nothing to contribute to "on the ground" problems has risen among some scientific disciplines, especially in the social and behavioral sciences. For an integral picture that must be discerned before public policy can be adequately written concerning the national space effort as it looks to the Moon and Mars, the investigators draw upon the multiple disciplines of political science, history, international relations, aerospace and human factors engineering, aerospace architecture, organizational behavior analysis, education, and others in their discussion of long-duration space exploration sustainability.

Keywords

Sustainability, long-duration spaceflight, global warming, microsocieties, NASA institutional memory, postsecondary education, outer space production, world system of societies, slowdown in the rate of technological innovation, globalization of space, subjectivization of time, differentiation of situational reality, latent challenges, transnational organization, false progress, integrator function, NASA Channel, NASA Academy

I. Introduction

SUSTAINABILITY is the real issue in long-duration space exploration like establishing a permanent base on the Moon and running sequential human expeditions to Mars and to the terrestrial moons of the outer planets. It must also be addressed in meeting other extreme environmental challenges like global warming. Concerning long-duration space exploration, to have sustainability in these exploration environments means that series of long-duration missions can be launched with a high degree of success and with a quality of life for the crews, which are, for all intents and purposes, microsocieties that must live and work in the mission environments and over durations and autonomy of spaceflight rarely experienced by astronauts. Sustainability also means having reliable levels of

* CEO and Founding Researcher, OPS-Alaska, AIAA Member.
† Executive Director, OPS-Alaska, AIAA Member.

multi-year funding to outfit and support such a program of exploration. In addition, a brain trust of scholars, scientists, and engineers must be available for this program. Sustainability also benefits by a variety of global publics that become stakeholders in outer space production. Until we have sustainability, all we have is the moral equivalent of holding hands and singing *Kum Bah Yah.* And, we have been doing that for at least half a century while more or less thinking about outer space production and solar system development.

Long-duration space exploration is affected by a number of features than just duration, and so there are several categories of sustainability issues. These are identified and discussed in this report:

- Sustainability of long-duration space exploration within the context of the re-ordering of the world order
- Sustainability based on the duration of these missions and related issues
- Sustainability based on the requirements of the human group and being human
- Sustainability based on avenues of funding and the leading organizational structure that funnels that funding
- Sustainability based on the continuity of NASA institutional memory and the vigor of American postsecondary education

Also discussed in this report are:

- Several popular, but inadequate propositions, which cannot substitute for sustainability
- The idea that the space endeavor is silly, a concept that is held among some scientific disciplines, especially the social and behavioral sciences – sciences critical to fielding microsocieties off of the Earth and for anticipating societal effects of epochal climate change, for example
- Practical solutions to sustainability

A. A Transforming World Order Produced by Space Exploration

It is worthwhile to explore some of the history of ideas about globalization before proceeding to other issues of sustainability of space exploration. To begin, most observers of globalization investigate the role of economics regarding that phenomenon to the exclusion of other factors. However, recent history shows that the technology of space exploration has been a key driver in the production of a new world order. The manifest functions of space exploration initially were political, but the latent functions of innovations in technology that sprang from that exploration are reordering our world.[‡]

The new world order that has supplanted the Cold War era is a global social structure that is increasingly more interconnected through accessible electronic communications and rapid transportation. These advances were made possible through outer space production. In *this* world, the United States is rapidly finding its hegemony challenged by the rising technological successes of China, India, and a united Europe that understand the interdependence of the world system of societies better than does the United States. In *this* world, the United States is confounded by powerful transnational coalitions of loosely connected persons and small groups in opposition to American interests. American leaders see the individuals and small groups, but not so clearly the transnational processes that make these small fries instrumental in countering American goals. The actions that the United States is taking, while it struggles to understand the lay of the land of this new world, still in motion under its feet, may be driving an inadvertent downturn in the rate of technological innovation. More on that later.

However, it is a fact that space exploration has been the motive force in transforming global social structure, and so policy makers, industry leaders, city fathers, and academic administrators need to be educated, so that they may possess a non-trivial understanding of why that is so. And, they also need to understand why the continuation of space exploration is necessary. The innovations, processes, and alliances that emerge from the space enterprise are important to meeting the challenges of the 21st century, among which global warming is one large example. And, the new innovations, processes, and alliances, too, will come to pervade and endure because, just as the historical precedent, they will enter the practical lives of human experience of large numbers of people.

The Space Race has created this new phase of globalization and, therefore, this new phase will feed back on and shape space exploration itself, a "globalization of space."[1] Of the categories of things that drive today's globalization process, the computer and the satellite are the most seminal. For, advances in information technology increase the frequency of human interactions at an exponential rate. The speed of social change is itself partly a function of the speed and ease of these interactions. The rapid exchange and processing of information contribute to the global erosion of hierarchical structures. These hierarchical structures are the frames upon which hang tribalism, nationalistic movements, entrenched governmental bureaucracies, and most corporations and their various

[‡] Like communications satellites and miniaturization of computer components.

interconnections. The erosion of hierarchical structures will not necessarily lead to chaos and disorder, as in the total destruction of law and order. What it will most certainly lead to is the kind of chaos that physicists and mathematicians speak of, the mathematical chaos that underpins a reordering of a system. Still, abstraction aside, among human groups in the world system of societies, that might translate out as several conflicts and reformations that will take time to play out and that could lend to a slowdown in the rate of technological innovation.

The context of the reshaping world order is re-organizing the space exploration endeavor and empowering those who risk to explore. When Americans hear Chinese and Indian space authorities claim they will send humans to the Moon or launch space stations, they tend to hear with the ears of the Cold War world. They see still-highly agrarian economies with their Cold War Era eyes. As with the latent functions of the Space Race of the Cold War that produced the post Cold War transformation, the latent functions of the negotiation of this new world order will open the Cosmos to China, India, and others with whom they collaborate. For, these societies are quantum-leaping into a state of advanced industrialization on a world stage where capitalism is globalizing, where the world system of societies is interdependent, and where they can wheel and deal and buy any resource to get them where they want to go. Their large populations, rather than hold them back, drive them forward. A key feature of the post Cold War world that makes their progress possible is an interdependence among the world system of societies that requires a level of international cooperation, working in a collective way toward large-scale mutual goals, which we have seen only a few times before in history.

It is a certainty that whoever goes into space to live and work in increasingly larger groups will change everything, just like Sputnik and the Space Race changed everything. As with the historical precedent, there will be upwardly spiraling effects generated by the feedback between the requirements for long-duration space exploration and globalization as we currently experience it. On the other hand, we must make ourselves aware that the elements may be in place to drive a slowdown in technological innovation. Some societies may be advantaged by one set of social forces, and others may be disadvantaged by the other set.

B. Sustainability Based on Duration and Related Issues

Long-duration space missions that will take crews away from the Earth are a "different breed of cat" than any other kind of space mission that has gone before. This is readily apparent when one considers what the profile of a long-duration mission to Mars would actually be like. They will not be like long-term stays aboard space stations in full view of the Earth at all times and with good chances of rescue or evacuation if things go wrong. They will not be "flags and footprints" missions like the Apollo explorations of the Moon where astronauts planted a flag, cavorted their way through various activities, and came right back to Earth. And, they certainly will not be anything like a two-week shuttle mission with instant communications to Mission Control and loved ones and where every action is planned out meticulously and to-the-minute.

If sustained over a series of step-building missions, long-duration space missions away from the Earth constitute an expansion of the human ecology, leaving the planetary cradle to survive and thrive on more distant horizons. Long-duration space missions that will take us to Mars with current propulsion technology can run on the order of two years. That is with a minimal stay on the surface of Mars (about 30 sols on an opposition class mission). To maximize science objectives to Mars requires a longer stay (about 470 sols on a conjunction class mission).

The science and engineering of the human factors will rise in primary importance as these missions become more distant, autonomous, expensive, and difficult. And, we are talking about all the human factors interfaces – the human-environment interface and the human-human interface – not just the human-technology interface, which is typically the only human factors interface that short-term space exploration pays any attention to in planning and design. The historical record of polar exploration, accented by Russian and American space missions, handily demonstrates this.

Armed with a growing stratified random sample of Arctic and Antarctic expeditions and space missions, the authors and colleagues have analyzed over various expeditions, from the Apollo missions to the Moon that ranged from 13 days to early polar expeditions that spanned several years. Seven factors have emerged which seemed to coincide with the subjectivization of time and the differentiation of situational reality for the crews in the field from their baselines. "Baseline" means the expedition's base headquarters, mission control, or just "folks back home." These seven factors are:

1. Increasing distance away from rescue in case of emergency (lessening chances of "returnability");
2. Increasing proximity to unknown or little-understood phenomena (which could include increasing distance from Earth);
3. Increasing reliance on a limited contained environment (where a breach of environmental seals means death or where a fire inside could rapidly replace atmosphere with toxins);
4. Increasing difficulties in communication with Ground or Base;

5. Increasing reliance on a group of companions who come to comprise a microsociety as time, confinement, and distance leave the larger society behind, and where innovative norms may emerge in response to the new sociophysical environment;
6. Increasing autonomy from Ground's or Base's technological aid or advice; and
7. Diminishing resources needed for life and the enjoyment of life.

The presence and prevalence of these factors in each of the sample missions/expeditions are discussed in Dudley-Rowley, Whitney, Bishop, Caldwell, and Nolan 2001;[2] Dudley-Rowley, Whitney, Bishop, Nolan, and Gangale 2002;[3] Dudley-Rowley, Nolan, Bishop, Farry, and Gangale 2002[4]. The derivation of these factors was an effort to resolve the debate concerning the question of "how long" was long-duration spaceflight. The more an expedition has of these factors, the longer is its duration, so to speak. As might be expected, therefore, *the longer-duration the mission, the more difficult it is to sustain.* Or, in other words, the more it requires sustainability. That is because we are dealing with more than just providing enough consumables and just building equipment to stand up to the long journey. Establishing a permanent human presence on the Moon and the human exploration of Mars would feature more or all of these seven factors than do even temporally long-duration stays aboard the International Space Station. These missions will require a new cognitive template concerning how we plan and design them. Long-duration space crews are *microsocieties* and the whole set of human factors interfaces must be considered in planning and design.[5]

C. Sustainability Based on the Requirements of the Human and the Human Group

The human nature of the mission must be the engineering template for long-duration mission planning and design. Social and behavioral scientists, as well as architects, need to be in on the "ground floor" of these missions. The human factors will achieve an importance in such missions that will rank up there with having enough consumables and a flightworthy craft, protection from radiation, bone demineralization, muscle mass loss, and cardiovascular deconditioning. Form must follow function, not the other way around.

The comprehensive set of human factors interfaces are separately useful in thinking about issues involving the environments humans must operate in, the equipment they use, and their properties in groups and as individuals. However, overlapping the interfaces is useful because it assures integration in mission components from multiple perspectives. The integrative benefit of examining the three interfaces together has long been recognized by those working in this field, within and outside of NASA. But, so far, the resources and the circumstances have not existed to encourage the comprehensive human factors approach.

This approach is important, moreover, in consideration of the issue of *latent challenges* in long-duration venues. A latent challenge is any item, aspect, component, or process that potentially poses difficulties in the performance of mission objectives, but is something about which not much is known. They may be generated from among natural, artificial, social, and behavioral phenomena or some combination thereof.[6] An example of such a latent challenge for any crew compartment is an unexpected, unusual efflorescence of bacteria from the crewmembers' bodies that poses difficulties to their health or to the operation or maintenance of equipment. Latent challenges are either phenomena that can be conceptualized but have yet to be observed and measured, or are emergent phenomena from among some permutation of known sources. They are harder to grasp than manifest challenges of spaceflight that are easier to quantify, like spacecraft operations, communications difficulties, having enough onboard resources, and protection of crew from an airless, microgravity environment fraught with radiation and other hazards. Engineers and space program managers who have cut their teeth on a litany of short-duration projects would rather deal with these more concrete phenomena than ones that must be treated more abstractly at the present time. This resistance to deviate away from the comfort zone of the concreteness of short-duration mission phenomena does not lend to sustainable long-duration space exploration. The longer the mission, the greater the opportunity for latent challenges to emerge as outright manifest challenges.

Especially fruitful have been the ongoing discussion among the authors and their colleagues who are aerospace architects about the implications of different mission models that have run the gamut from basic survival to a high level of quality of life bounding on the "hotel in space" concept. We have estimated that if off-planet tourism ever did take off, it would set the upper-limit standards for the space human factors and top of the line human-rated engineering because of customer necessity and demand. Although space hotels are a long way off, a "Quality-of-Life" model for long-duration space missions ensures sustainability whereas a "Man-in-a-Can" model does not. A Quality-of-Life model takes into account the comfort of the crew. Of course, the comfort is not at the level of a four-star hotel or luxury cruise liner, but its redundant systems and plentitude of space and resources make it preferable and more survivable than a stripped-down "Man-in-a-Can" model. A Quality of Life model is typical of expeditions

that have scientific purposes high on their list of priorities or that take place in more mature expeditionary venues, like latter-day Antarctica.

A comprehensive human factors approach is central to this Quality-of-Life model and the optimization of long-duration missions. For sustainability, all long-duration systems must be human-rated to a high degree. Human factors considerations cannot be strapped on at the last minute or given superficial treatment, as has been seen even on the International Space Station. They are integral to the long-duration mission and must be part of mission planning, platform and equipment design, and in the selection and training of crews.

D. Sustainability Based on Avenues of Funding and Leading Organizational Structure

The question emerges: who will make the managers of space programs that can actually loft missions use a comprehensive human factors approach? Gentle persuasion through scientific presentations has not worked so far. It rather looks as if some sort of coercion or mandate from the top down will have to be levied. That would require pressure on the part of Congress and the President of the United States. Deploying those options have their inherent drawbacks. Consider the following "just-so" scenario:

Sixteen to twenty scientists[§] worldwide get together and present the case for the need to take a comprehensive human factors approach in America's effort to field human exploration to Mars. In a week or so, the scientists receive letters from the Congresspersons thanking them for the fascinating presentation. Nothing else happens. However, the President of the United States, whoever he or she is at the time of this hypothetical presentation, is extremely fascinated and has the Vice President assemble a team, including managers from NASA Headquarters, to consider what he has heard from the world's foremost scientists on the subject. Very soon, the President and Vice President hear things like, "No one has heard of these people" and "This is not human factors." Someone remembers that Carl Sagan once said that "Sociology is the cargo cult of science" and the meeting breaks up on that jolly note. Nothing happens.

We do not hold much faith in anyone pressuring space program managers to include those 16 to 20 scientists in their plans and designs for missions to Mars. NASA is a federal bureaucracy, the resistance to move quickly and change the cognitive template based on short-duration experience is too great. But, it is a moot point, anyway. The United States will not be able to freight long-duration exploration to a venue such as Mars by itself. Neither can Russia or any other nation. There can be no sustained long-duration space exploration, not even to the Moon, with a weak national commitment that amounts to moving, for all intents and purposes, a fixed supply of money from one set of space program accounts into the long-duration exploration account. With the exception of small increases, that is the current situation that obtains in the United States, on top of which are the long-term expenditures of our warfighting and occupations abroad. In Russia, money, national will, and commitment are at issue, too. The Russian long-duration space effort is a "make-work" enterprise and is accommodated through the auspices of an international non-proliferation program that spends a few million dollars a year on former Soviet scientists and engineers to keep them from leaking their weaponizable expertise and materiel to "evil axis" states and terror warlords. The fact is this: sustained and sustainable human space exploration is costly, even on the cheap. Fortunately, this cloudy outlook has a silver lining. That silver lining is this: sustainable long-duration exploration is do-able, but it will take an international effort to make it happen, and make it happen in the way that it needs to be planned and designed. Actually, something a bit more sophisticated than an international effort is needed. A *transnational* effort could make long-duration space a reality.

Now, for a crash course in what constitutes a transnational organization. A transnational organization is typically powerful, even though any one of the parties in the enterprise may not have a great deal of wealth, power, or prestige. One of the features that it has going for it is that the goals of the organization attract a core of individuals, groups, companies, and agencies that are highly committed to the success of those goals. That commitment spans the globe without regard to national boundaries. As those so committed lend their time, talents, and resources to the organizational goals, the organization begins to take on a kind of sovereignty of its own and can command resources within the national borders of many countries. Doctors Without Borders (Médicins sans Frontières) is one such transnational organization, to give a popular example. The funding and other resources come in from multiple sources, from numerous small contributors and participants on up to more substantial ones.

Long-duration space exploration (as does global warming) needs a kind of transnational organization where national space and science agencies are cooperative partners, as are every scientist, scholar, engineer, policymaker, and company committed to the goals of expanding the human ecology. The United States Congress cannot shoulder such an evolutionarily significant enterprise alone. It never will, for that body does not see space in that way. Most

[§] The approximate number of scientists and engineers in the world who study social and behavioral issues pertinent to long-duration space crews.

see it as a hole in which to throw money. Senators and representatives from states that benefit from the aerospace industry have a more positive outlook, but their practical concern is shaped by the narrower horizon of a local economy.

A space transnational organization, because it draws assets from a broader net, could conceivably amass ready assets on the scale of hundreds of billions of dollars, making it similar to the assets that must be mounted up to go to war. Those costs are between the costs racked up by the Allies during World War II (in today's dollars) and the tens of billions spent by the Coalition in the First Gulf War (an *ad hoc* transnational[**]). Few realize that the costs of a series of Mars missions, though expensive, would actually cost far less than D-Day. But, it is fair to say that freighting long-duration space missions to the Moon to establish a permanent base, and to Mars to establish a toehold there, is an effort that approximates the costs and the commitment of going to war. The same applies to meeting the challenges of global warming.

Taking long-duration space efforts into a transnational arena has many advantages. First of all, it removes the human space enterprise from its heavy reliance on the whims and limitations of the United States Congress. Secondly, it devalues the role of President of the United States as a "yea" or "nay," make or break consensus-of-one in regard to the fortunes of the space endeavor.

Now, the United States currently has a president who has a Return-to-the-Moon and Humans-to-Mars plan. But, the question is, how do-able is this plan? Let us not forget that there are costly wars and occupations that are ongoing, and that will likely go on for years. Is the Bush Moon and Mars plan really do-able? An abundance of diagnostics weighs on the side of a kind of "false progress." Among these are:

- The lapse in safety measures (that cost money) that led to a "safety complacency" that brought down the space shuttle *Columbia.*
- The fear of NASA mass lay-offs that are expected to go into effect *ca.* October 2006.
- The fact that there is no real money being raised toward the Return-to-the-Moon and Humans-to-Mars efforts.
- The near-de-orbiting of the Hubble Space Telescope.
- The long "drag time" between the last, upcoming planned shuttle flight and the production of a new American launch vehicle.
- Terminating deep space unmanned missions that are currently on the way out of the solar system**.**

False progress is an enormous hurdle to long-duration space exploration. It generates a lot of talk and little action. For the most part, for those of us old enough to have observed the course of the last several decades, talk of long-duration human space missions are very much like the fanciful and wishful reportage remembered by those of us who learned to read when the schoolchild's *Weekly Reader* was touting the exploits of the X-planes, the Mercury astronauts, and the wonderful things to come. And, perhaps some of the attitudes of the public and in Academe that we see today that do not lend positively to space exploration come from those who built up childhood dreams from being literally promised the Moon and the stars and that promise turned out to be an empty one.

The space enterprise in the hands of a transnational organization would ensure progress. An important advantage is that such an organization can be a badly needed "integrator function" that can fit together the findings and products of multiple and disparate research teams and technologies from among its many partners and collaborators around the world to generate the knowledge base underpinning long-duration exploration and how to sustain it.[††] It would minimize the kind of gatekeeping and money-hoarding that goes on among those rare funding competitions for studies relating to human spaceflight that keeps all the current information vital to long-duration space exploration from seeing the light of day.

E. Sustainability Based on the Continuity of NASA Institutional Memory and the Vigor of American Postsecondary Education

Many NASA employees point to October 2006 as a date when they expect to lose their longtime jobs and they are bailing like rats from a sinking ship through early retirement programs and looking – sadly -- for positions in the non-space work world where jobs needing skills relating to the most extreme of environments are still in short supply. These employees have the scientific and institutional history necessary to help "grow" long-duration space exploration. That growth is going to be seriously hampered when NASA is pruned back too far in terms of facilities

[**] This transnational effort is the example that Peter Drucker points to in his description of the transnational organization in his *Post-Capitalist Society* (1993).[7]

[††] Frank White made reference to this sort of tally-taking activity in *The Overview Effect.*[8]

and personnel.[‡‡] Alas, what passes as "trimmed fat" is cut from among the cadre of those scientists and engineers who are necessary to freight long-duration exploration.

Loss of NASA institutional memory is an important detraction from long-duration exploration, but so is the situation that obtains in postsecondary education. After Sputnik was orbited, American educators and government teamed up to improve curricula throughout the postsecondary milieux and grades K-12, particularly in mathematics and science. This was done in order to educate new generations for the Space Race, for, years of prosperity during the Golden Fifties had made possible good jobs not requiring a college education. However, just as soon as the federal funding spigot was turned off, after the Moon was attained, a new trend in Academe emerged as university administrators tried to run their campuses on less money. So, now, American postsecondary education is in trouble, the major reproductive organ of the creation and maintenance of science and technology in the United States. And, this is the environment that hundreds of NASA people with advanced educations and relatively esoteric work backgrounds will encounter if they are laid off *en masse*. They will shop their résumés and CVs around, aiming for tenure-track teaching jobs in high-tech universities, be turned away, apply for teaching positions with smaller and smaller colleges until, at last, they find themselves on the highways, practically living out of their cars, "freeway flying" to several part-time teaching jobs at community colleges. They will wonder if the end of civilization as we know it has come.

This trend is a truly disturbing situation having two distinct parts. One part is often known as the "Death of the Liberal Arts," but because in many American universities, particularly the smaller ones, many areas of scientific inquiry fall under "liberal arts," science and engineering suffer, too. The other part has been the deepening of the institutionalization of a gulag system in American Academe. Both trends feed back on each other in a downward spiral that, in time, can only cause America to fall behind in science and technology.

The lapse of the institution of tenure within American Academe has damned thousands upon thousands of Ph.D-holders in every discipline – the American brain trust, in essence -- to a life of piecework teaching and research. Some have referred to this as the Corporate Model of the University. It is worse than that. It is the Sweatshop Model of the University where postsecondary teachers (professors[§§]) literally work for food (grocery money).

The condition of postsecondary education in America is going backwards although surface appearances are otherwise. College instructors at every level, from the community college to the large research university, have increasingly been entrained into the "part-time" work system, that usually means full-time and over-time work with long commutes among two or more schools and few or no benefits. Percentages of these "sweatshop university, pieceworker professors" form over 80% of the teaching cadre on some campuses. And, it has little to do with another oft-cited myth that there are too many people nowadays with advanced educations. The Ph.D per capita level is probably about right for the population of a very advanced industrialized society in a globalizing world. The reason there are so few non-piecework professorial jobs is that university administrators have converted the American professoriate into a cadre that teaches courses by the piece and that has few resources to engage in scholarship that creates new innovation. This is how they are able to run their campuses without the level of federal

[‡‡] Among this body of personnel are those who have seen evaporate what vestiges there existed at NASA of human factors concerns. According to those who have had careers within NASA at the human-technology interface of the human factors, there was never really enough funding coming in to do a complete job at their interface. So, much of what is in process of disappearing is at the human-technology and human-environment human factors interfaces concerning the design and usage of spacecraft and equipment. There doesn't seem to ever have been much ensconced at NASA in the first place concerning the human-human interface of the human factors that would have required the contribution of sociologists and other social and behavioral scientists. However, any effort that touched on that interface was embedded in the work of those who toiled along the other two interfaces.

[§§] All postsecondary teachers in the United States have, in general, uniformly been known as "professors," however, as the trend to legitimate the "have-not" sector in Academe has gained force, the term "professor" is increasingly more reserved for tenure-track and tenured faculty. Untenured faculty are coming to be known by various low-level or undignified names in official campus communication: adjunct (a contraction of "adjunct professor" that previously did not have the connotation it does today), lecturer (that does not have the same meaning as in the European system), contingent, part-timer (as if some professors were field expedients or working for pin money), and temp (as if professors were being supplied by a temporary business staffing agency). This bastardization of the title of "professor" is one way to reduce the value of professors, which helps validate a caste system within Academe. The notion that untenured faculty are somehow *not* colleagues is gaining steam, too. A full tenured professor who had clawed his way out of the untenured caste recently related how he was in a faculty meeting that discussed the treatment of "part-timers" when a tenured professor blurted, "Do you mean to say we have to treat *them* as colleagues!"

funding that they had at the height of the Cold War and the Space Race. While it is true that Ph.D recipients have increased in the United States, it is also true that the demand for college educations have increased. More and higher tuitions do not seem to be enough of an offset to the paucity of federal funding that set in motion today's piecework professoriate. When the American Association of University Professors analyzed the situation in 2003, it found that, in the aggregate, 65% of the nation's postsecondary teachers were not in tenure-track positions.

This is a social problem for America of *major proportion* and is occurring at a time when several competitors for cultural, technological, and other types of hegemony are emerging on the world stage. In some states, like California, the untenured professoriate has taken on the coloration of a caste system, which seems to be the wave of the future for the rest of the country. This academic caste system places America's *brain trust* in bondage in a way that destroys creativity across all disciplines, and in time, slows the production and reproduction of science and technology. In this century, this nation will reap the poor harvest of sweatshop postsecondary education conveyed by pieceworker professors.[***] For, America's professors are trying to educate the next generations of Americans in those things that make our nation run and that reproduces and expands on our heritage at a time in history when the world has become very different from what it was before.

The authors' message here is that American academicians who are creating and reproducing knowledge are not incentivized to produce more than they possibly can on the minimal resources they currently receive. Soon, America may not have the kind of in-country brain power to sustain multi-year explorations and settlements on the Moon and Mars. Or, to produce mitigations to the effects of global warming. Or, to create new energy sources to power the nation. Or, to do any of the things that are of value to this nation and that makes the country run.

II. The Slowdown in the Rate of Technological Innovation

Long-duration space exploration requires an army of sustained knowledge troops working on the problems of such a complex enterprise. More so, do the requirements of epochal climatic and geographic change owing to global warming and the effects of supervolcanoes, tsunamis, and pandemics in an increasingly more populous world. These need a larger number of minds working on offsets of these problems.

Yet, here in the United States, one of just a few space-capable societies in the world system, the nation that took humans to the Moon, we see short-sightedness, failures of imagination, and an increasing inability to "think outside of the box." Much of this revolves around the resistance to and obstacles to American knowledge production.

There has always been an anti-intellectual strain that has run in an undercurrent in American society. The rugged individualist frontiersman with little book-learning, himself a type of "noble savage," has been exalted in the American psyche since the entrée into the New World by European settlers. In our modern popular culture, the sharp, but under-educated young man selling contraband under the radar of the law joins him. Anti-intellectualism is alive and well today and is being expressed in the paucity of federal funding to American schools and postsecondary institutions and in policies that have bottom line agendas.[†††] Because the American professoriate is the last filter to remediate and educate young minds, this downsized educational cadre are the most critical of the knowledge troops being sent into the field to train raw recruits and to fight against the decline side of oil, the effects of global warming, pandemics, threats to food plenty and security, and the pressures of China, India, and an ever-increasing interdependent world leapfrogging to advanced industrial status. The twenty-first century is so rich in challenges to the human species, it is not a time to set in motion a slowdown in the rate of technological innovation.

These several events converging in a world made much smaller by instant communications systems and rapid transportation and societally interdependent to a degree never before seen is most likely setting the stage for a slowdown in the rate of technological innovation. Such an event is counterintuitive, and it has been counterintuitive every time that it has happened in human history. Patrick Nolan and Gerhard Lenski (following V. Gordon Childe) have described these events of innovative downturn (2006, pp. 143-145)[9] that emerge despite the presence of increasing population, increased intersocietal contacts, and a greater store of information available to potential

[***] Perhaps the nation will respond when the time comes by importing in the needed know-how from other lands, a kind of "insourcing," upgrading American science, technology, and education by bringing in advanced educated cadre from places where they still value professors. The question is: where will these imported scholars come from? If China, some other East Asian countries, India, and Europe become the chosen work locales, where will outside scholars, scientists, and engineers derive from if the United States gains the reputation of being an intellectual backwater?

[†††] Colleagues from other countries in the world tell us that the diminishment in the value of academicians in their societies is playing out as well. Still, it is striking to see this phenomenon occurring in the United States.

innovators. Under such circumstances, one expects to see the production of higher rates of innovation, especially in technology. However, in rare instances, major technological advances can generate negative feedback that diminishes the effect of the force of the original innovations. Changes in social organization and ideology that were themselves consequences of technological advances can put the brakes on technological innovation and advance.

Nolan and Lenski give a concrete example of this phenomenon in the shift from horticulture to agriculture. The plow, like the microchip, created a quantum leap in human production. As an older system of militia that included all of a society's able-bodied men was replaced by a professional standing army, the power of the governing class increased. New ideologies emerged to legitimate the new system that reinforced it and made it worse. The governing class found it easier to extract most of the economic surplus from the peasantry. The peasants, in turn, lost the incentive for innovation, knowing that the governing class would appropriate any benefit deriving from it. In their tenuous position of only having the bare necessities of life, any loss could jeopardize their survival. In time, the governing class no longer had the necessary knowledge and experience with agrarian technology to produce crops, much less make innovations. Nolan and Lenski have summarized the picture (p. 144), "In short, *expertise and incentive were inadvertently divorced,* with disastrous results for technological progress." How agrarian governing classes dealt with this was to increase warfare and conquest as the best means to increase their wealth. "More than ever before, the resources of societies were turned from the conquest of nature to the conquest of people (Nolan and Lenski, p. 144)."

The test of time will bear out if we are currently seeing a slowdown of technological innovation in the United States and the world. Some compelling events form a metric to suggest that all of the elements are in place or in play for a slowdown: academic scholars and scientists reduced to lives and careers resembling those of migrant farm laborers, wars and occupations as a means to extend the horizons of capital, the inability to prepare and protect a major American city in the face of a bad storm, and a pullback from outer space production.

To make sure that we are not headed for a global technological slowdown, the United States, and indeed every space-capable society, needs to re-focus on the science and technology of outer space production. The example of global warming demonstrates the immediate, practical need. Though the approach of this phenomenon could be detected through many systematic observations from the ground, its full impact and its concomitant features can only be fully appreciated from space-based systems. Global warming is ushering in the kinds of climatic and geographic changes of epochal proportion that humanity has not seen since the onset of the Holocene. Being able to fully apprehend what is coming could minimize the environmental train wreck that is in motion.

Are we seeing a decline in the rate of technological innovation? This is a research question that needs to be operationalized and tested. But, for now, it remains an illuminating metaphor for the purposes of this report that attempts to explore the entire issue of sustainability concerning large science and technology projects like long-duration space exploration.

A. Losing Propositions to Solve for the Problem of Sustainability

Uncritical thinking about long-duration spaceflight runs rampant. In the course of the authors' researches that have related to the long-duration space mission, they were offered a close look behind five current "myths" about the future of the space enterprise. These myths are:

- The United States can get to Mars by itself.
- The Mars Direct plan will get us to Mars.
- Spaceflight on the "faster, cheaper, better plan" is the way to go.
- Commercialization of the space industry will save the day.
- Space enthusiast groups are useful in drumming up support for the space enterprise.

Already discussed above were the estimable obstacles to a traditional single-nation approach to long-duration space exploration. No one nation can get a crew to Mars, make explorations, and get them back alive without a great deal of interdependence with other nations and transnational support.

The Mars Direct plan touted by the Mars Society, a space enthusiast group, will only get any crew that attempts it killed. That is the consensus of aerospace engineers from several nations who have examined the plan. *In situ* resource utilization (ISRU) is an old concept that stretches back to the German rocketeers of World War II. It is a key feature of Mars Direct and a worthwhile aspect of long-duration space exploration. But, over-reliance on resources that *might be* available or that *might be* produced from "living off the land" can easily outstrip crew consumables and time necessary for the resources to emerge before the human crews die. Transnational input could merge the best ideas about getting to and being on Mars (and getting back) and sustaining the effort.

Mars Direct is a metaphor that matches the "faster, cheaper, better" story that has been mouthed in the past several years by NASA. Indeed, while tight budgets can indeed drive "workaround" innovation as a response to necessity, the public relations successes of cheap technological marvels are swept away by the large and devastating goose eggs of lost unmanned Mars missions and a broken up space shuttle and dead astronauts.

Much of the commercial space enterprise is more apparent than real, residing largely in the minds of "wannabes" running two or three space businesses out of their apartments. The authors know from experience from trying to bring some of their most marketable concepts to the venture capital stage that they fold when both their ideas and resolve are probed too much in depth. The transnationalization of space would bring to the table those companies and entrepreneurs that have real contributions to long-duration exploration and which have the sustainable dreams to make profits in new niches. A few like Burt Rutan who designs, builds, and flies viable airplanes and spacecraft will likely make it to the table.

Space enthusiast groups are really of not much use in promoting long-duration space efforts. In his landmark study, Michael A. G. Michaud (1986)[10] thought that pro-space organizations had specific influences over the long haul, mostly in terms of educating the public about space. However, it is interesting to note that Michaud lumped together *professional* societies, like the American Institute of Aeronautics and Astronautics (AIAA), with *enthusiast* organizations. In the authors' experience, the professional societies make all the difference. For example, the AIAA is a professional society where, in the main, standards of professional behavior are encouraged and expected and where a peer-review process vets the papers that are delivered and later published by the society. It is nothing like the enthusiast societies, whose annual meetings are more "carnival" than science conference. The networking and synergy required to expand the frontiers of science and affect policy decisions are more likely to occur in the professional science organizational venues than in the enthusiast settings where lacking are the expected professional ethics and procedures, collegial ties, critical thinking, and the know-how to freight viable projects.

This situation where myth-making and uncritical thinking flourish are in part owing to the fact that the concept of long-duration space missions has not been fully thought out by NASA and its contractors. This intellectual vacuum invites the smoke of pipedreaming to fill the void. Thinking these missions out will require the inclusion of the several social and behavioral scientists, who have done a substantial body of work already concerning long-duration crews, on the ground floor of these missions' plans and designs. Also needed is the recruitment of other social and behavioral scientists who have made significant studies on similar topics (for example, human groups that have endured extreme or disaster conditions for a long period of time). Additional mission planners and designers must come from the small pools of aerospace architects and design engineers from around the world. These are the knowledge workers whose expertise and collegial connections are necessary for the four phases of a long-duration space mission: 1) getting there, 2) being there, 3) returning from there, and 4) staying there on a permanent basis. Many design engineers work for NASA or its contractors, so are supported to greater or lesser degree in their efforts, but another challenge to sustainability emerges when one considers enlisting the aid of social and behavioral scientists and even architects and engineers who work in the academic environment.

B. Studying Space Concerns Is Silly: A Detractor For Long-Duration Space Exploration That Will Rely on Social Scientific Input

Even if NASA and other space agencies came, belatedly, with hat in hand to sociology, for instance, for its help in mission planning and design regarding a microsociety living and working in space, it will find itself a " stranger in a strange land." That is because there is a scarcity of history of connection between the space effort and sociology. The authors have found it an incredible effort bringing sociological concerns and methods into the aerospace community and *vice versa.* To sum up: *an academic interest in social phenomena concerning aerospace and other extreme environments is considered silly and frivolous.* This is the case even among those sociologists from major universities deeply participating in the scientific and technological production of the United States. Most sociologists seem to think that the expansion of the human ecology into extreme environments like space has nothing to do with the everyday world of the human condition. They just don't "get it." And, because they don't, those colleagues who *do* "get it" are considered to be harming their careers and are discouraged with various lacks of support in their efforts. This is yet another example of the divorce between incentive and expertise that is the hallmark of the slowdown in the rate of technological innovation.

During the authors' second year of their National Science Foundation-funded study of astronauts and polar explorers, the primary author (Dudley-Rowley) became the first sociologist to be admitted to the NASA Mission Specialist Astronaut Candidate active selection files in the history of human spaceflight, specifically because of the NSF-funded research and various of its spin-offs up to that point. Being allowed into those files is the first hoop that has to be cleared before call-up for medical and psychological testing for Astronaut Candidate Training. The person who had come closest to this before was a volunteer researcher on the NSF study, Dr. Stewart Whitney, a

sociologist[‡‡‡] from Buffalo, New York who taught at Niagara University, who had been selected prior to the *Challenger* disaster as one of the top Educators-in-Space for payload specialist training.

Dr. Whitney and Dr. Dudley-Rowley are old enough to remember the heyday of the Mercury, Gemini, and Apollo programs, and they considered their selections great national honors that had been bestowed on them. However, those honors translated out to quite another thing in the workaday world of academic sociology, where usually sociologists are so focused on their separate compartmentalizations within a shrinking pool of larger interests that they do not converse across sociological sub-domains.

Even though our astronaut and polar explorers research had been funded from sociology and social sciences programs of the National Science Foundation, and had direct high value in the sociological study of science and technology, in the workaday world of academic sociology, our NSF-funded study topic and our contributions to the aerospace venue were treated as if they were cranky sidelights of "serious" sociology. This reaction has applied even though we have additionally shown how the project has made important discoveries about "hot topic" sociological issues like social deviance and had high transferability of methods and findings to other venues (like clinical and criminal justice settings and terrorist networks).[§§§] Ironically, not long after being positioned to train as an Educator-in-Space payload specialist, Dr. Whitney's longtime college employer began dismantling the school's sociology program and paving the way for an all-criminal justice program to take its place.[11]

The handful of us in the social sciences involved in space research were both surprised and glad when Dr. Jim Pass, a professor at Long Beach Community College, managed to talk the American Sociological Association into letting him start an Astrosociology Section-in-Formation. Even so, at the 99th American Sociological Association meeting in San Francisco, as expected, new section-in-formation members experienced some awkward moments. At a workshop session designed for sections-in-formation to apply for small amounts of funding to have sessions at future ASA meetings, Dr. Pass introduced the Astrosociology Section. The workshop presenter asked what was the meaning of the name. Pass told her that his group's interest was "space." She shot back, "Public space?" Pass told her "No, *outer* space." *The woman visibly rolled her eyes.* A couple of months later, at the 2004 California Sociological Association meetings, in a session introducing the new ASA section-in-formation, a sociologist in the audience explained the *status quo* position, "Sociologists are interested in what is happening in the here and now and on the ground." An aim of the new section-in-formation is to convey that aerospace technologies have influenced societies more than most of the body of sociological Academe recognize – rockets, miniaturization, satellites, computers, cell phones, the Internet, *globalization*…. Social change and development being among the major concerns of sociology, it is not clear why these facts are not known better by sociologists.

In an attempt to find out details about sociologists' attitudes about the interface between society and aerospace phenomena, the authors and Dr. Pass pre-tested a survey over a segment of American Sociological Association members to better understand sociologists' attitudes about the intersection between aerospace concerns and society.[12] Some of the results are as follow.

Most of the respondents understood that the NASA budget was less than 1% of the annual national budget. However, all agreed or strongly agreed that the federal budget should be used to solve social problems on Earth before worrying about spending money in outer space. There was some concern that aerospace is much more important as a national symbol than as an economic or otherwise socially functional phenomenon.

This sample of sociologists seemed to have no trouble with the term "outer space." The phrase is a term that saw a lot of play in the dawn and early days of spaceflight, in both the scientific and the science fiction record. In the literature of international space law, it is not very clear what "outer space" means. However, Thomas Gangale, from examining several international treaties, has seen "outer space" taking on a functional definition as anything in Earth orbit or beyond.[13] This functional definition contrasts with a physical definition of a specific altitude or other similar hard coordinate. So, if diplomats are sometimes in disagreement about what "outer space" really means, what would sociologists think of when they heard the term? The survey asked the question "When I hear the phrase 'outer space,' *I immediately think of* (and we gave them several fixed-answer choices and also allowed them to write in other choices)." All but one respondent thought of scientific, industry, or policymaking images to define "outer space."

There were, in general, proactive responses to the question "Was the study of the space and society interface a needed addition to sociology?" All respondents agreed, suggesting various lines of inquiry:

- How does society help determine how space exploration priorities are carried out?

[‡‡‡] Also social psychologist and anthropologist.

[§§§] Despite the major voices in social deviance studies cautioning that deviance means more than "nuts, sluts, and perverts," sociology seems to forget that when it comes to examining the behaviors of astronauts and polar explorers in the expeditionary environment.

- How would human culture and institutions expand into space?
- What analyses could be made of group dynamics, solidarity processes, gendered/multiethnic interaction, and the social organization of life in space.
- What factors influence the public perception of space travel and the political commitment to the space program?
- How is space exploration placed in the context of the cultural and institutional settings of life on Earth?
- How does space science work express differentials in gender and work and other concerns of stratification and inequalities?
- How is the culture of space scientists constructed and reproduced?
- How does the space science community relate with general society, other scientific disciplines, academia, government, and the military?
- How can the limited environment of space provide a unique set of experimental conditions for the study of human social life.
- How do space exploration and environmental concerns connect?
- What is the role of the mass media in how the public perceives space?

It was heartening to see that a sample of sociologists could generate lines of inquiry at the space and society interface. Perhaps their proactive responses in this vein had something to do with the fact that the sample of respondents was selected from among those sociologists who are attempting to define *public* sociology. Public sociology is a developing domain of sociology that attempts to connect "ivory tower" sociology and public spheres in order to generate solutions for social problems and also to invigorate sociology. However, some of their other responses got at the heart of the disconnection between the aerospace community and sociology.

None of the respondents thought that sociologists studied the space and society interface adequately. Reasons cited were: 1) fear of having to use quantitative skills, 2) the lack of any visible public relevance or social problems involved, 3) a lack of resources leading to the aerospace community, including open access out of the belief that space activities are "top secret," 4) even the fear of being considered a "liberal or commie" by "hard" scientists, and 5) that the American space program has been presented to the public as strictly a technological phenomenon rather than a sociological one.

These reasons illuminated a failure of the "sociological imagination" as well as a failure of the space community to cultivate the engagement of sociologists. This is an important obstacle to the overall sustainability of long-duration space exploration picture. For, the know-how of sociologists and other social scientists must be accessed in order to plan and design for crews that become microsocieties in relatively autonomous, long-duration expeditions. Social psychologist Albert Harrison, who has had a long association with NASA during his career that often focused on space topics, has cautioned sociologists that "hard" scientists and engineers will just make up their own brand of sociology if sociologists are not available to meet their needs when the time comes. And, he warned, it will not be to the liking of sociologists.[14] If the record of polar and space exploration is any indication, the crews won't like it, either.

Sustainability of long-duration space exploration is a multi-faceted problem, as the authors have argued herein. The bridging of the divide between sociologists and the aerospace community is but one need to solve for sustainability. Many more efforts are needed that go well beyond what social scientists can accomplish by themselves. This would not be much of a report, if we could not propose some other solutions to the different kinds of sustainability challenges that we have seen from our vantage point.

III. Solutions To Sustainability

Perhaps it is to our benefit that Nature is forcing upon us a "moral equivalent of war" by provoking us to fight her. If global warming produces no overwhelming cataclysmic events and offers gradual chains of severe threats and disasters, then there is the chance for humanity to re-focus and reclaim its science and technological vigor before we lose too much.

The enormity of the problem justifies the metaphor of going to war. NASA and other space and science agencies around the world need to be outfitted and mobilized to meet the challenge of epochal climate change and, at the same time, be mandated to work vigorously on long-duration space exploration. Solutions for one set of problems feed the solutions for the other set. To help in this effort, hierarchies of these agencies need to be "flattened" in order to connect easily with networks in academic and commercial sectors. Seed funding and rapid avenues for partnership need to be available. One such enterprise that would be imminently useful is for commercial and academic agents to acquire certain NASA functions and enter the television media market on the scale of a CNN or

Weather Channel. In this way, NASA could make itself over as an instrument of planetary situation awareness, what some have termed "global consciousness." With a worldwide viewing audience, public diplomacy for science and technology could make the connection in the minds of individuals between the environment and space and advance the best of American interests.

Though it was certainly better during the Apollo era, NASA public relations have always been under funded and poor in quality. NASA PR does little to "sell" NASA to the public or encourage useful inputs into the agency, inputs that could bring in funding from the four corners of the Earth, rather than just from the United States Congress. One solution to accompany a re-making of NASA television is to reform NASA public relations as a real instrument that shapes American public opinion about the space enterprise and to give it real teeth in the upper echelons of NASA management.

Along with a web interface, a television channel would have the capacity to feature news about the weather throughout the world, host commentaries about natural and manmade threats of global scope and potential, and address policies and happenings that affect more of a global audience. Right now, the NASA Channel's programming is boring and meaningless to most Americans -- often footage shot in space that runs for hours, unaccented by music or by commentary. In addition, it is difficult for the average television viewer in the United States to even tune into the NASA Channel since it only seems to broadcast in a tight perimeter around NASA field centers.

And, if the United States and partners were willing to upgrade such a pitiful television channel to a world-class media operation, it would certainly be fair to use this instrument as a powerful American public diplomacy tool to say the best things about the United States that we want the world to know about us. With sufficient vision, management, and funding, the NASA Channel could broadcast to the world about American achievements that benefit us all, especially those achievements that have a connection to American science, technology, and education. The voices and images of American public diplomacy could be aired seven days a week, twenty-four hours a day, with regular engaging programming on par with or *better than* CNN, C-Span, and the History Channel. If the U.S. State Department wanted to create a "transformational diplomacy" in a short period of time, such an instrument would be a "force multiplier" in accomplishing that goal. Perhaps the army of NASA personnel about to be laid off could be employed in crafting this powerful instrument.

Much of the innovation required for multi-year sustained long-duration space missions is along the lines of the same kind of innovation needed to respond to worsening environmental conditions and their unexpected consequences. National and global efforts need to be made in earnest negotiation to form working day-to-day transnational funding, resources, and expertise relationships that make *sustained* long-duration space exploration actionable. NASA would be included as a partner agency in this transnational organization (Dudley-Rowley 2004).

Such an organization already exists to some degree and NASA already has a connection with it. And, this is the nuclear non-proliferation organization that was mentioned above. The authors suggest that NASA explore and expand its link with the International Science and Technology Center (ISTC), an intergovernmental organization headquartered in Moscow, Russia, and whose governing board is chaired by Ronald Frank Lehman II, the Director of the Center for Global Security Research at the Department of Energy's Lawrence Livermore National Laboratory.[15]

Space agencies need the wherewithal, and official expectations to conceptualize, *in depth,* increasingly longer duration space missions -- and "ground-truth" and "test-flight" on orbit inasmuch as possible these conceptualizations. Sustained long-duration space exploration cannot set sail on the hot air of political rhetoric. It has to be a set of genuine efforts that "step to" actual exploration.

In addition, needed is the establishment of an "integrator function" among the different transnational sources and multinational participations in the long-duration space enterprise. Just getting some sort of integrator function established within NASA would be a coup in the right direction. Marc Cohen, a former NASA scientist, has said:[16]

> Almost everyone in NASA is a specialist. Engineering and science education especially focus the worldview of students into smaller and smaller windows, and narrower and narrower points of view. As an agency of such specialists, it is quite common for a meeting to occur where everyone is an expert in his or her field, but nobody has the BIG PICTURE of what they are trying to accomplish together. System engineers position themselves to manage this situation, but system engineering has become just as narrow and specialized in its own way. The lack of a general shared worldview in NASA is an impediment to sharing of ideas and technology.

Dr. Cohen has suggested the establishment of a "NASA Academy" to, in part, develop integrative "big picture" thinking among NASA scientists and engineers.

Education needs to be treated as if it is among the most important things in the world. This means more funding into our schools and universities and rigorous oversight to see that it is being spent for its instructional and innovation purposes. Teachers and professors need not be pampered, but they do need job security and the resources

to train those who will succeed them in teaching subsequent generations and in the research activities that create new innovation and accelerate its rate. Deliberate attention needs to orient students to the condition of the planet and the connections between space and the terrestrial environment. This means ending the adjunct professor caste system that has come to characterize the American professoriate in the national aggregate that is jeopardizing the brain trust of this country. It may not seem like it today or even tomorrow. But, the effects of this exploitation will be evident the day after tomorrow. The loss of American scientific and technological vigor is simply not worth educating on the cheap. Something like the response following the launch of Sputnik has to happen at the federal and education interface, and efforts made to curb and remedy those activities and events at the postsecondary level that degrade the creation and reproduction of American knowledge. Once we take steps to ensure our brain trust, we need to encourage other nations to take steps as well.

Preparing for long-duration space exploration, meeting the challenges of global warming, and other scientific concerns requiring sustainability will have to include the social and behavioral sciences. Whereas the post-Sputnik refit of American education targeted math and natural sciences, sustained effort over such large-scale undertakings requires a wider participation of knowledge disciplines. Through grants, conferences, and other incentives, social and behavioral scientists and other scholars need to be made aware that their expertise is essential and that they must broaden their horizons to embrace aerospace and other extreme environmental concerns. On the other side of the coin, they must be welcomed in aerospace and "hard" science working environments. The future of space exploration and the changes that are coming in our terrestrial environment absolutely require the application of the social sciences and the humanities. This flies in the face of the *status quo* where even life sciences money for national space concerns in the United States is limping along on "keep alive" funding. The social sciences have utilized research findings to improve the human condition. These need to be brought to bear on issues of space and the environment.

These strategies represent some potential solutions in answer to the sustainability of long-duration space exploration or other complex efforts involving extremity of environment – like the problem of global warming. If the United States hopes to play a leading role in these explorations, it must consider these and similar solutions against a backdrop of a new world order – where Mumbai and Beijing are rising as centers of science, technology, commerce, and culture. And, where there is a growing impact of a United Europe and its willingness to engage the world system of societies from an understanding of its *interdependence* in that system.

We Americans, as a nation, must be serious and committed to long-duration space exploration and those other things that require knowledge for meeting environmental extremes. It must not be approached as a presidential fancy, more hobby than policy. Neither can the expansion of the human ecology depend on the budgeting whims of the U.S. Congress. For, long-duration space exploration and meeting the challenges of extremity of environment is an evolutionary and ecological choice vital for the survival of humanity. If we Americans are not serious and committed, others most certainly will be without our participation.

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