Testimony

President's Commission on Moon, Mars and Beyond

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Jim McMurtray is the Executive Director of the National Alliance of State Science and Mathematics Coalitions. (NASSMC). He joined NASSMC after serving for nearly 20 years as a contractor to NASA's Education Division during which time he presented lectures and workshops on space science and other aerospace related topics throughout the United States and in Mexico, Venezuela and Puerto Rico. McMurtray served as an instructor in NASA's Space Flight Participant Program in 1985, conducting seminars in space science and NASA future programs for the 114 candidates of the original Teacher in Space Project. As a representative of NASA, he was involved in the planning and execution of the first NASA/NASSMC Linking Leaders Workshop in 1996. A former planetarium director and teacher of astronomy, he has been actively involved in reform efforts in science education for over three decades. He is the author of *Barbarian Science* (1999), a book on science literacy in America, and the creator of *Starlight* (1981), a nationally distributed planetarium show on the physics of stars.

The National Alliance of State Science and Mathematics Coalitions is an umbrella organization composed of coalitions of business, education and public policy leaders in 38 states. Originally a project of the National Research Council, it became an independent non-profit organization in 1994. NASSMC supports the establishment, development and sustainability of state organizations working to improve mathematics, science and technology education. NASSMC collaborates with NASA on the Linking Leaders program to align NASA in-state resources with state-based efforts to improve mathematics, science and technology education. NASSMC also manages the Partnerships for Sustainability project in support of the NASA Explorer Schools.

I thank the Chairman and the members of the President's Commission on Moon, Mars and Beyond for the honor and the opportunity to present this testimony. I am James McMurtray, Executive Director of the National Alliance of State Science and Mathematics Coalitions.

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Science may be the most human of our behaviors. It expresses the natural curiosity that is common to all of us. It begins early in our development and continues throughout our lives. In the history of our species we have compiled much information and we have created conceptual and mathematical models to help us understand and explain the natural world. To have access and opportunity to understand this monumental body of work is the birthright of every human being.

A scientifically illiterate populace is an economic and social liability that no nation can afford. Fully functional citizenship requires literacy. Scientific literacy must be viewed as an essential element of general literacy. To go back to the Moon and on to Mars will require a national resolve that cannot be borne entirely by a small and select group of science professionals. If science and mathematics are only for the few then there is no shared national ownership of these missions of discovery and exploration. Unless they are supported by a literate electorate able to appreciate their value, these endeavors will not happen. Educating tomorrow's astronauts argues for a bold enterprise.

Our present system of teaching science to our citizens does not work for everybody because it is not designed to. The system reserves advanced science and mathematics for a small subset of the population. We reserve and isolate real science for selective dispensation to those who have proven worthy to pursue it. Advanced science and higher mathematics are for the chosen few. For the rest, it may be a painful and sterile exercise of meaningless and unrelated activities presented in a linear progression for an unknown purpose. To bring relevant science to all students will require the most profound change in our thinking. It will require a different system.

I do not believe that the system we have now will serve us well in the effort to return to the Moon and go on to Mars and beyond. It is out of step with the needs of the workplace, out of step with the needs of our society and out of step with the exploding pace of scientific discovery.

There is a very long pipeline to a career in science and it narrows quickly. Only a handful of students receive advanced instruction in science and mathematics. Those who do not continue in this pipeline are not diverted to some other path toward science literacy. They are simply removed. Science and mathematics are no longer a part of their education. They have been sorted out. Since they will not become scientists or engineers they will have no more access to science beyond the satisfaction of their own curiosity, and that curiosity will be starved of new information, new ideas and new awareness.

Sharing our science with our children for the purely human fascination that it is must be a priority. Science education must no longer be structured so that required "basic" science and mathematics instruction is limited to the first few courses in a long sequence that is designed to prepare scientists and engineers. If that is all our students get, it will not be nearly enough. It will be a foundation upon which nothing is built.

Nearly three decades ago the National Science Foundation and the National Research Council recommended fundamental systemic reform of American education. They defined systemic change as: fundamental, comprehensive and coordinated change in the policy, financing, governance, management, content and conduct of the system. Significant efforts were made, but their lasting impact on the system is hard to detect. Systemic reform is slow process and it has not happened.

A complex system eventually acquires all the characteristics of a living organism. It will develop defense mechanisms and maintain equilibrium. It will resist the introduction of anything identified as "not self." To a complex system, substantive change is indistinguishable from damage. Change will be repaired. Isolated adjustments to curriculum and instruction will not change the behavior of the system nor will they cause the system to produce different results.

Since its beginnings in the late 50s NASA has designed and undertaken its missions and programs through a technique involving the development of a Critical Path. Critical Path planning does not begin by examining where we are and finding ways to improve the current state. It begins with a desired outcome and some essential questions:
What are we trying to accomplish? What things must happen along the way? How will we know we have succeeded? A Critical Path is developed by thinking backward from the goal and designing a system that will produce exactly that result.

I propose that this strategy be applied to the design and development of a different education system. I believe that this will be far less expensive than the ever-increasing cost of high maintenance to the one we have. I believe also that this can be done with existing infrastructure and that it can be initiated while the current system continues to function.

We need not dismantle what we have but we must immediately begin the design of a replacement. Simply improving the present system will serve only to make it more efficient at doing what it does. Systems are perfectly designed and operated to produce the results they get. To change a complex system it is necessary to change many things at once. Leave key elements unadjusted and the system will "repair" itself to its former condition. Higher education is a part of this system, and therefore inextricably, a part of the problem. Our universities and colleges of education will have to change as well. To a system though, change is indistinguishable from damage. If we really did change all the elements at once, then in a very real sense, the system would be damaged beyond repair and it would be replaced with whatever might form to fill the void. So, let us not do that. Leaving this to chance is not in our interest. The environment of all systems is other systems. A new design can be implemented to operate in tandem with the present system.

The education system we have now was not designed. It just evolved. Much of its organizational structure defies explanation and has no basis in research or theory. Over the decades it has grown larger and stronger. This massive edifice effectively frustrates and subverts all attempts at adaptation or restructure. In some cases specific structural architecture is mandated by law. I believe this system is too large to change.

Educators working alone cannot design the replacement system. This will require a broad collaboration involving America's economic, scientific and social institutions. It will be designed for specific outcomes. It will exist along side the older system until it replaces it. It will replace the older system when it demonstrates that it works better. It will take all the insight and creativity that we can marshal, but it will be done.

We face a teacher shortage of crisis proportions. Our schools continue to fall short of our expectations. Our assessments define success as non-failure. Females and minorities are underrepresented in advanced science and mathematics courses. Perhaps this is because we have confined our thinking to a system in which it is held as self evident that learning can only happen in groups, that such groups must necessarily be in a classroom, that classrooms must contain no more than a given number of students, each to be presided over by a teacher trained in the very system we are trying to alter. I believe that within the present system, these problems have no solution. In a different kind of system however, they might not exist at all.

I recently learned something. Caterpillars do not grow up to be butterflies. In fact, there are no caterpillar parts at all in a butterfly. In the pupa stage, inside the chrysalis, enzymes break down the body of the caterpillar. It disintegrates completely. The resulting organic soup contains the chemical constituents necessary to grow the next phase of the organism. Information contained in the DNA of a single cell organizes this material to produce a butterfly. What emerges from the chrysalis is not a caterpillar that has grown wings, but a new system built from the recycled and reordered remains of its predecessor. Caterpillars do not transform themselves into butterflies. They are replaced by them.

What I propose here is not a new experiment but a new design. I do not know what it will look like but I am sure it will be different because it will have been designed to yield a different outcome. It will work because it will be designed specifically to produce the results we want.

Americans are capable of doing this. We have done difficult things before. While we educate tomorrow's astronauts, we must also educate for a society, a culture and an economy in which the work of astronauts has value to the larger population. Two Voyager spacecraft gave us stunning pictures of the outer planets. Robot explorers have shown us the surface of Mars. We have launched into space a telescope the size of a school bus and we have repaired it in orbit. We can also build a system that shares our scientific legacy with our children and leaves none of them behind. They will not all become scientists, mathematicians, engineers or astronauts but they will share the journey back to the Moon and on to Mars and beyond if it is also their own.