Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions

Life Sciences Research and Technology Programs

VOLUME I

NASA Advisory Council
Aerospace Medicine Advisory Committee

June 1992

ACKNOWLEDGEMENTS

The NASA Aerospace Medicine Advisory Committee (AMAC) wishes to express sincere appreciation for the efforts of all those who participated in the development of this report, "Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions." The Committee would like to single out the contributions of Dr. Arnauld Nicogossian for his foresight and wherewithal to initiate this prescient effort and his dedication and enthusiasm to see it through completion; the hard work of the Life Sciences Division staff to help put it all together; the commitment of the AMAC Executive Steering Committee to review, revise and evaluate all the critical questions; the individual efforts of the report chapter chairmen, Dr. Cary Mitchell, Dr. Reginald Edgerton, Dr. Robert Moser, and Dr. Richard Young; and the support and encouragement from the NAC to proceed with this important undertaking.

The Committee would also like to thank the writing committee members, especially Dr. John A. Rummel, Dr. Joan Vernikos, Dr. Donald Stewart, and Dr. Fran Haddy. AMAC also wishes to express special appreciation for the participation of the representatives from the NASA Program Offices including Space Station, Space Shuttle, Technology, and Exploration.

The ability to define critical life sciences priorities for pursuing the goal of human exploration is a major accomplishment. This effort would not have occurred with out the totally committed contributions of Dr. Larry Biever and Dr. Lauren Leveton. The AMAC must express special thanks to these two fine professionals. Further the AMAC commends the efforts of all involved in making such a significant contribution to the U.S. space program. AMAC is confident that the findings and recommendations, along with the comprehensive data base will provide a strong foundation to plan our future exploration missions. We know what we have to do!

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of

Mr. Caleb B. Hurtt
Chairman, NAC
272 West Meadow Drive
Vail, CO 81657

JUN 0 3 1992

Dear K:

On behalf of AMAC, I am pleased to provide to you the enclosed report , "Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions." In the process of developing this report, AMAC deliberated with many individuals, including NASA program and project managers, scientists, and engineers, various advisory committees, and our Russian space partners. It represents a consensus among a diversity of perspectives regarding the life sciences research priorities.

This is a unique report in that it provides both a top-down and "grass roots" consensus of the internal and external life sciences communities. It is built upon a comprehensive database that serves to organize the major enabling research thrusts, integrates ground-based programs with flight resources, and provides a basis for identifying the national and international organizations and resources that must be brought to bear if we are to achieve our goal of space exploration.

The most salient finding based on a detailed analysis of all the scientific information available is, "there is no issue, *a priori*, that precludes human exploration to the Moon or Mars, if appropriately focused research is conducted and enabling technologies developed." Three major problems that must be the major focus of the biomedical life sciences program to support exploration are identified in Recommendation 1.

The AMAC will work with all elements of NASA to integrate the findings and recommendations of the report with the planning for future space missions, including the Space Station Freedom, the lunar outpost, and the mission to Mars. The report will be updated and refined as NASA plans and programs are further developed.

The efforts of the Life Sciences Division staff to create and consolidate the supporting scientific database for this report are to be commended. This database is unique in this nature and more detailed than anything produced by other science disciplines. It is a demonstration of the life sciences' intent to proceed with implementation of these strategic considerations for human space flight missions.

This report comes at a time when detailed analysis of program priorities for exploration missions can play a critical role in defining the requirements and setting the pace for future space activities. It has been a tremendous opportunity to work together with so many individuals and develop a consensus of life sciences research priorities. I am pleased to turn the report over to you and the NAC.

Sincerely,

Harry C. Holloway, M.D.
Deputy Dean

Enclosure

National Aeronautics and
Space Administration

Washington, D C.
20546

Reply to Attn of

Dr. Harry C. Holloway
Uniformed Services University of
Health Sciences
4301 Jones Bridge Road
Bethesda, MD 20814-4799

JUN 0 3 1992

Dear Harry:

You and the AMAC are to be commended for your efforts to produce such an important, useful, and timely document, "Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions." You have put forth a strong, sound and reasonable strategy for setting life sciences research priorities and making decisions that will enable human exploration missions.

The report demonstrates a thorough understanding of the resources that are required if we are to meet the challenge of human space exploration. A broad, far-reaching, and integrated plan has been developed to guide the Nation's scientists, engineers, mission planners and policy makers in their decisions and commitments to the expansion of our knowledge in space life sciences.

On behalf of the NAC, I want to express congratulations to you, the AMAC, and the Life Sciences staff for their significant efforts in planning our nation's human exploration missions. I am confident that the findings and recommendations contained in this report will provide a solid foundation for our future space missions.

Sincerely,

Caleb B. Hurtt
Chairman, NAC

National Aeronautics and
Space Administration

Washington, D C
20546

Reply to Attn of

Mr. Daniel S. Goldin
Administrator
Code A
NASA Headquarters
Washington, DC 20546

JUN 0 3 1992

Dear Dan:

I am pleased to forward with this letter the report of the NASA Advisory Council's Aerospace Medicine Advisory Committee. The report, "Strategic Considerations for Support of Humans in Space and Moon/Mars Missions," is the product of an intensive study by the AMAC, with participation from many NASA program managers, project scientists and engineers, advisory committees, and international science community. It represents an integrated consensus for establishing life sciences research priorities and making decisions that will enable human exploration missions.

This report is a template that will guide NASA scientists, mission planners and policy makers in their decisions and commitments to the expansion of our knowledge in space life sciences. It is based on an extensive database that serves to organize the major enabling research thrusts, integrates ground-based programs with flight resources, and provides a basis for identifying the national and international organizations and resources that must be brought to bear if we are to achieve our goal of space exploration.

The AMAC analysis concluded that within the confines of our current knowledge, there was no issue a priori that precludes human exploration of the Moon or Mars if appropriately focused research is conducted and enabling technologies are developed. AMAC did conclude that the three primary areas for research and technology development are: characterizing and alleviating risks from radiation, long-duration exposure to microgravity, and reliable life support systems. The AMAC analysis produced 15 findings and recommendations that either were considered "overarching" in that they affected fundamental policies concerning research and technology needs, or were categorized into one of three major thrusts: Environmental Health and Life Support Systems; Countermeasure Systems; or Medical Care Systems. The report also provides the resource requirements and milestones for life sciences deliverables.

To accomplish the strategic considerations set forth in this report, NAC strongly recommends a single focus of responsibility and accountability, within the NASA top management, for carrying out all agency life sciences/life support activities. The most effective structural solution for such focus is best decided by the agency

following review of previous committee recommendations and inputs from the Life Sciences community.

In conclusion, the report provides a strong foundation for planning our future space missions, it represents a consensus for setting life sciences research prioirities, and it offers an integrated plan for making decisions to enable exploration missions. It is a high water mark for planning the respective programs for the future. Harry Holloway and his committee members, as well as the Life Sciences Division staff and other participants have made a significant contribution to the future of the nation's space program. It is a job well done.

Sincerely,

Caleb Hurtt, NAC Chairman

Enclosures

PREFACE

The Augustine Committee developed an exciting, challenging blueprint for the future of the United States space program. They postulated that NASA has five space related operational missions: Space Science; Mission to Planet Earth; Space Utilization (goods and services made available for use on Earth); Transportation (economically reliable delivery of payloads to orbit); and Mission from Planet Earth, which culminates with President Bush's Space Exploration Initiative.

NASA also has a sixth mission, implicit in the Space Act, to develop the technology base required to assure continued American preeminence in space for the overall benefit of the nation. The debate over mission priorities, timing, and the size of the NASA budget continues within both the Administration and Congress. While it is still not clear which goals will be embraced now and in the future, whatever the choices, the nation should have the capability to execute the options chosen within predictable cost and schedule estimates.

Key to that capability will be the research and advanced technology data base that is available in the technologies critical to the chosen missions. However, over the past 20 years, NASA's investment in advanced space research and technology has been inadequate. Today's technology base is inadequate to support advanced space missions. It should be obvious that a modest increased investment in basic technologies today can reap major savings in future costs and schedules. But the program remains underfunded, at approximately two percent of the NASA budget, by a factor of nearly three.[1]

By far, the biggest challenge postulated for NASA is Mission from Planet Earth, the focus of human activity in space, culminating with permanent presence on the Moon and landings on Mars. The President proposes, Congress opposes. But the question is not really whether we, either as a nation or a planet, will make the journey. The question is when.

We should use whatever time is available before a decision to proceed is made, to reduce fundamental uncertainties and assure that enabling technologies are ready for development. For the Moon/Mars exploration missions three areas predominate — propulsion, power, and support for humans in space.

This AMAC report, now fully endorsed by the NASA Advisory Council, is a milestone in the history of human space flight. Concluding that there is no issue that precludes human exploration of Mars, it defines a focused research and technology program to address the risks of radiation, long-duration exposure to microgravity, and reliable life support systems.

Footnote 1. The Report of the Advisory Committee on the Future of the U.S. Space Program (1990) and the National Research Council Report (1987), "Space Technology to Meet Future Needs."

Good program design requires understanding and limiting the uncertainties in critical system areas. The Life Sciences research and technology programs proposed in this report will have significant impact on the requirements for radiation shielding, microgravity countermeasures, and life support consumables for long-duration, deep-space human exploration missions.

The recommendations of this report deserve strong support from NASA management.

Dr. Joseph F. Shea, Chairman
Space Systems and Technology
Advisory Committee

FOREWORD

The object of your mission is to explore the Missouri river, & such principal stream of it, as, by it's course & communication with the waters of the Pacific Ocean, may offer the most direct & practicable water communication across this continent, for the purposes of commerce.

Your observations are to be taken with great pains & accuracy, to be entered distinctly, & intelligibly for others as well as yourself, to comprehend all the elements necessary, with the aid of the usual tables, ...Other objects worthy of notice will be: the soil & face of the country; it's growth & vegetable productions; the animals of the country generally; the remains and accounts of any deemed rare or extinct; the mineral productions of every kind; volcanic appearances; climate as characterized by the thermometer, by the proportion of rainy, cloudy & clear days, by lightening (sic), hail, snow, ice, by the access & recess of frost, by winds prevailing at different seasons.

Thomas Jefferson
Instructions to Lewis & Clark
President U.S. of America
June 20, 1803

The Louisiana Purchase was one of the the most important events in world history. It was an event of such magnitude that, as Henry Adams said, its results are beyond measurement. Not only did it double the area of the United States, not only did it add to our wealth resources of incalculable value, not only did it provide a potential that was certain to make us a great power, not only did it make equally certain that we would expand beyond the Rockies to the Pacific, and not only did it secure us against foreign victory on any scale conceivable in the nineteenth century — it also provided the centripetal, unifying force that would hold the nation firm against disruptive forces from within.... There is no aspect of our national life, no part of our social and political structure, and no subsequent event in the main course of our history that it has not affected.

Bernard DeVoto
The Journals of Lewis and Clark, 1953

This report "Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions," is intended to serve as a template to guide scientists, engineers, mission planners, and policy makers in their decisions and commitments to the expansion of our knowledge in space life sciences. It develops a strong strategy for setting life sciences research priorities and making decisions that will enable human exploration missions. It is a blueprint for our future exploration in space and the challenges that NASA, other agencies, and our international partners will face as we begin this new era of exploration.

The report is organized into six sections. Section I provides the Executive Summary and contains the 15 findings and recommendations. The recommendations are presented as follows: *Overarching Recommendations* (Recommendations 1 - 11); *Environmental Health and Life Support* recommendations (Recommendation 12); *Countermeasures Systems* recommendations (Recommendations 13 & 14); and *Medical Care Systems* recommendation (Recommendation 15). In addition, the Overarching Recommendations are further categorized according to ground, flight, or both types of activities. Section II identifies resource requirements and milestones for deliverables necessary to accomplish the research required to support human exploration mission solutions described in Sections IV, V, & VI that address the research thrusts (i.e., Environmental Health and Life Support Systems, Countermeasures Systems, and Medical Care Systems). For each thrust, the constrained and robust program is described. The constrained program included those elements defined as essential and critical — "criticality 1 & 2"), and the robust program included elements of all four criticalities — "criticalities 1, 2, 3, & 4." Section III addresses the Mission From Planet Earth goal, specifically, "to maximize scientific return from exploration that will benefit the people on Earth."

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