MEDICAL AND HEALTH POLICY FORMULATION FOR HUMAN EXPLORATION OF THE SOLAR SYSTEM

Part I: Ethical Considerations in Scarce Resource Allocation for Health and Medical Systems Development and Operation

March 30, 2006

Prepared by the Office of International Medical Policy
School of Public Policy
George Mason University
“To set foot on the soil of the asteroids, to lift by hand a rock from the Moon, to observe Mars from a distance of several tens of kilometers, to land on its satellite or even on its surface, what can be more fantastic? From the moment of using rocket devices a new great era will begin in astronomy: the epoch of the more intensive study of the firmament”

Konstantin E. Tsiolkovsky, 1896

Apollo 17 – Commander Eugene Cernan checking the Lunar Rover. and Astronaut Harrison Schmidt in front of the Split Rock. December 1972. NSSDC/nasa.gsfc.gov images

Mars Sunset and Spirit Rover Tracks - NASA/JPL/OSU/Cornell images
Research Team

Roger Stough, Principal Investigator
Arnauld Nicogossian, Project Coordinator
Desmond J. Lugg
Thomas Zimmerman
Danielle Mutone-Smith
Karen Plante
Rosann Wise

This research was partially supported through a National Aeronautics and Space Administration grant 600300. The views expressed are those of the authors, and do not necessarily reflect those of the sponsor.
Acknowledgements

We are grateful to Dr. Paul Root Wolpe for preparing the NASA discussion paper on ethics and resource allocation for space medicine. This discussion paper was distributed to the workshop participants on July 29, 2005.

Appreciation is extended to Dr. Ellen Baker, Mr. Jeffrey Bingham Dr. Roger Crouch, Dr. Randy Howe, Dr. Roger Launius and Mr. Maxwell Stearns for their thoughtful and insightful review of this report. We also appreciate the comments and editing provided by Dr. Holly K. Krull.
# TABLE OF CONTENTS

RESEARCH TEAM ................................................................. 3

ACKNOWLEDGEMENTS ............................................................ 4

THE OFFICE OF INTERNATIONAL MEDICAL POLICY ................. 6

SUMMARY .............................................................................. 7

INTRODUCTION........................................................................ 9

  Human Space Missions Challenges ....................................... 10

  National Space Policy in the post-Apollo Era ......................... 15

  Research Funding and Prioritization Issues ......................... 17

RESULTS .................................................................................. 23

DISCUSSION .......................................................................... 24

CONCLUSIONS ....................................................................... 27

REFERENCES .......................................................................... 33

ATTACHMENT I: PARTICIPANTS LIST FOR THE JULY 29 AND SEPTEMBER 15, 2005 WORKSHOPS ................................................................. 38

ATTACHMENT II: QUESTIONS FROM THE NASA AND GMU DISCUSSION PAPERS .................................................................................. 40

ATTACHMENT III: NASA CHIEF HEALTH AND MEDICAL OFFICER REQUIREMENTS GUIDANCE ......................................................... 44

ATTACHMENT IV: ASSESSMENT OF THE SURVEY RESULTS .......... 48

ATTACHMENT V: PROFESSIONAL AND MEETING SELF EVALUATION... 50
The George Mason University School of Public Policy (GMU/SPP) emphasizes interdisciplinary and alternative approaches to public policy. In addition to offering seven master's degrees and the largest Ph.D. program in Public Policy in the Nation, SPP maintains a variety of hands-on research activities conducted through several research centers. From global issues, such as peacekeeping and electronic commerce, to regional issues, such as land use and transportation management in Northern Virginia, SPP is an important academic institution for inquiry into public policy formulation and development of innovative solutions.

Established by SPP in 2004, the Office of International Medical Policy (OIMP) provides leadership and focus for the study and teaching of global medical and public health practices and policies. From its inception, OIMP was intended to complement and enhance the SPP training and research portfolio. OIMP emphasizes academic studies into global health challenges, interdependencies, and security.

The mission of the Office of International Medical Policy is to provide a health and medical policy focus for the School of Public Policy and to facilitate interdisciplinary and international research and training activities within and outside the George Mason University.
Summary

This report addresses ethical aspects of policy formulation and practices in resource allocation for the design, development, and operation of health and medical systems for human exploration of space. In the preparation of this report, the research team sampled National Aeronautics and Space Administration (NASA) practices, reviewed relevant experiences, and extracted lessons applicable to future government supported human space exploration endeavors. The nascent industry investments and funding of human space flight activities have not been addressed in this report. However, some of the findings contained in this report could benefit future space tourism practices.

Framing the discussion and conclusions are the ethical considerations of resource allocation to health and medical care in support of human exploration of space. Based on the appropriated 2006 budget for NASA, biomedical research will remain constrained by the access to space. Hopefully, adequate resources for ground and flight, clinical and preventative medicine programs in support of astronaut health will be preserved. In the foreseeable future, without additional investments in biomedical flight research, new breakthroughs in medical technology for human space flight are unlikely. During the 1990s and early 2000s, the research community generated many hypotheses regarding human physiology, performance, and use of countermeasures, some of which now require access to a space laboratory for validation. A process for prioritization of the hypothesis validation studies should be adopted and implemented immediately in order to further reduce the health and medical risks to human space exploration missions beyond the Low Earth Orbit (LEO).

Performance and health are dynamic phenomena and subject to rapid fluctuations in the artificially created and alien environments of space. Thus, evolving health and medical risks should be considered and incorporated into the overall planning phase(s) of each space mission. All mission-related health and medical care resources should be prioritized and allocated efficiently. Availability of on orbit resources, the ability to replenish the expendable medical supplies, and the training and skills of the providers will ultimately determine the extent and the quality of an expedition’s health care systems. In some instances, it will be impossible or unwise to use all the scarce medical supplies available to an expedition to administer a full measure of care to a gravely ill or injured crew, if re-supply or rescue is not possible. Such decisions will require real-time participation of physicians and, as appropriate, bioethicists. Alleviation of suffering based on a triage principle might be indicated in such situations. To communicate and promote realistic expectations, stakeholders, policy makers, explorers, and their families should be made aware of the extent and availability of health and medical care capabilities prior to each exploration mission.

Ethics notions such as justice or priority to the worst off or fair shares cannot be readily adapted or applied to the decision process leading to the prioritization of the health and medical needs of space travelers. On the other hand, the principle of maximization of the health and medical care for a given outcome, and to some degree equity, can be applied when allocating resources and formulating health policy. The overall intent is to ensure that foreseen health risks encountered in the exploration of space are adequately addressed. This decision process might not allow for enough redundancy using available
resources to address unforeseen health and medical risks that could emerge as the exploration proceeds. The risk reduction strategy using the maximization approach should always include considerations and provisions for the long term explorer’s health and quality of life beyond the successful accomplishment of the mission objectives.

The research team developed a process on Ethical Considerations in Health and Medical Resource Allocations which can serve as a model for ethics based decision making process. The strategy used is predicated on the stratification of risks leading to the formulation of policies designed to ensure efficiency in the utilization of resources without compromising safety. A continuous evaluation process that will assure the efficacy and safety of established policies and practices should be embedded in the process. Health and medical risks (including exploration technology) should be monitored frequently and dealt with in a timely fashion to reduce the likelihood of illness and/or injury.
Introduction

Venturing into uncharted territories carries risk to the health and well-being of the explorers. Throughout history, explorers have been considered a special breed of individuals, who contributed knowledge and wealth, and expanded the physical boundaries of the world in which we live. Explorers as a group risk their health and sometimes lose their life in the process. Bernardino Ramazzini, the father of occupational medicine and public health describes such a group, the sailors and rowers, in his famous Diseases of the Workers, first published in 1700:

“Of all the arts that contribute greatly to the happiness of mankind and to maintaining intercourse, navigation contributes most, for it has united East and West, North and South, and good things that Nature had made particular to this or that country navigation has made common to all. This very ancient art, by Hercules!, was so highly rated that its inventors were worshipped with honors almost divine; for example the Argonauts who sailed all the way to Colchis counted among Heroes and the ship Argo was raised to the skies by poets...chronic diseases also attack them (sailors), but they do not suffer from them as long as do those whose occupation is on land, for a ship is not a good place to ministering to chronic diseases...”

Though written over 300 years ago, the observation that a ship is not a good place to ministering to chronic diseases is quite applicable to the conditions and limited health care resources available onboard the modern space ships.

The robotic exploration of our Solar System, the human landings on the Moon, and the beginnings of the permanent habitation in the Low Earth Orbit (LEO) were the hallmarks of the 20th Century technological achievements. Today space exploration is a societal undertaking bound by the United States Space Act of 1959 and space policies in other space-faring nations, including the United Nation’s Charter and Treaty of 1963. Intellectually, humans have always been fascinated by three scientific questions: what is out there, are we alone in the universe, and what is our destiny? Finding the answers, however, will be not an easy task and will require exploration of the universe by both humans and robots. It will take leadership, political support, determination, and extensive scientific, biological, medical, and technological preparations on Earth and in LEO. The new vision of exploration expands the U.S. Space Policy mandate by providing an early blueprint for the human journey into the Solar System. This vision is supported by the Congressional legislations H.R. 3070 and S.1281.

In the 21st Century, humans will continue to face unprecedented challenges in order to leave the biosphere and undertake missions to the Moon and Mars. Just as it has allowed humans to explore and change our home planet, technology, the substitute for biological adaptation, is the key to the exploration and future space settlements settlement.

Given the complexity of the health and medical policies formulation surrounding space exploration, the School of Public Policy, George Mason University, in cooperation with the NASA Office of the Chief Health and Medical Officer (OCHMO), has undertaken a three-part study addressing the:
Human Space Missions Challenges

Planning for a safe and productive exploration of the Solar System requires bringing together three elements: environment, spacecraft and humans. The space environment offers a number of challenges: variable gravity, constant radiation, extremes in temperature and pressure, and on other planets, a new physical and chemical environment—perhaps even an entirely new ecosystem. The very nature of exploration means that crews will be hundred of thousands of miles from Earth, at distances that make instant communications impossible and, in some cases, timely relay of information to Earth difficult. For the Moon and Mars exploration missions, space travelers not unlike the early explorers on Earth will be cut off from their natural and social habitat.

The spacecrafts and habitats must be properly constructed to provide a **portable biosphere**—a home away from home, providing environmental control and life support. Pressure and gas composition must be maintained with correct proportions of oxygen and nitrogen. Humidity, temperature, and airflow must remain at proper levels. Radiation must be kept at a minimum. Recycling of resources and wastes must be accommodated. The craft’s constrained interior must be designed in a way that allows both working and personal space.

Mission designers and program managers place a major reliance on engineering tools designed to maintain health, protect against the **maladaptation of space flight**, and exposures to extreme toxicological and environmental conditions within and outside of the space vehicle. **Prevention** is an important principle, since the medical care in space will always be constrained. Spacecraft system design must account for constraints imposed by power and mass, communication delays, and the inability to quickly return to Earth, while at the same time keeping in mind human factors for ease of use. Future exploration crews will require safe habitats to keep them alive, provide sustenance and ensure useful performance in alien environments of other planets. Crews will also need new means of transportation suitable to different atmospheres, surfaces, and changing gravity and climates of new worlds.

The human element will continue to rely on the technology to provide a safe haven for working and living beyond the confines of the Earth’s biosphere. Extended stays in microgravity may adversely affect the functioning of the body (35, 55, 56). For instance, autonomic dysfunction leading to orthostatic intolerance is encountered after exposure of human beings to microgravity (52). Preliminary data suggests that “gene” regulation is affected by gravity (42, 43). It is proposed that on Earth, gravitational cues turn genes “on” and “off.” When away from Earth these gravity-sensitive genes do not receive gravitational cues and are not expressed (48, 57). Space explorers must face a use-it-or-lose-it biological scenario. When astronauts do not use their weight-bearing bones or gravity-fighting muscles in microgravity, bone loses mass and muscles atrophy (51, 54).
Perhaps in the future such space-borne genes, if properly characterized, may be fooled into thinking that gravity still exists, leading them to behave normally to maintain bone and muscle health. However, this will require significant investment in long lead research and technology development.

Mission planners must factor in protective countermeasures to limit or prevent full microgravity adaptation from taking place, in order to assist with the return to a planetary (Mars or Earth) gravity level. Considerations should be given to the insertion of artificial gravity technology, to create full or partial Earth-like gravity into the crew exploration transport vehicle based on the unique mission needs (Mars missions, specifically).

While it is important to ensure that all protective technologies overcome environmental challenges and perform efficiently, they must also carry a measure of self-sufficiency. The destinations of exploration missions will be miles away from home and will take months to reach. Turning around and coming home will not be an option. Communications will not be instantaneous. It can take between 4 to 22 minutes for a crew on Mars, our next-door neighbor, to send a message to Earth. A reply from Mission Control would take another 4 to 22 minutes. Essentially, exploration crews will be on their own for real-time decisions. Provisions must be made to treat life-threatening accidents and illnesses on such journeys that take a crew millions of miles away from the nearest hospital.

The scope and extent of medical support for human exploration class missions has been the subject of study and debate by the national and international biomedical community. Significant time and resources continue to be devoted to the formulation and planning of research to be conducted on the ground and in space to sustain human expeditions in LEO and beyond (2, 32-35). In the meantime, the experience base with long duration human space flight continues to accrue. To date 439 individuals on 247 missions, a total of 971 crew members, including three Chinese Taikonauts and three paying tourists, have flown in space. This group comprises individuals from over 30 countries. Fifty-five cosmonauts and astronauts participated in long duration missions lasting from 3 to 14 months. Eighteen explorers lost their life as a result of spaceship systems failures. Unlike Ramazzini, who had the experience of centuries of clinical observations available to him, little is known about the health and diseases during long term residence on space stations and other planetary surfaces.
Drawing on the results of biomedical investigations conducted over the last three decades, models of human acclimatization\(^1\) and biological changes in response to the space environment can be conceptualized. Such a concept is presented in Figure 1 and can help with the mission planning and design of future health maintenance and medical care systems.

Figure 1: Concepts of physiological responses following exposure to space flight environment

During space flight in LEO, microgravity develops, not because of the true absence of gravity, but as a result of a continued free fall generated by the spacecraft acceleration counteracting the Earth’s gravitational force. Exposure to the microgravity environment of space flight will result in a rapid acclimatization in some of the body systems, such as the heart and circulatory system, respiratory system, and neuro-sensory and neuro-motor systems. However, the resulting hypovolemic syndrome by Earth’s health standards is fully compatible with performance and function in space. The hypovolemic syndrome experienced by space travelers includes a decrease in total body fluids, inability to regulate postural blood pressure, loss in the number of circulating red blood cells and changes in the vascular capacitance in the lower extremities (reduced circulating volume). In this context the hypovolemic syndrome involves the cardiovascular, pulmonary, and neurological systems. Conversely, other body systems continue to demonstrate persistent and accelerated losses or alterations even by Earth’s health standards, taking into consideration normal physiological aging process. These changes are complex and not well understood. Bone, muscle, endocrine, and immune systems

\(^1\) Acclimatization allows the organism to exist in its new environment and is usually reversible.
alterations are primarily manifested in long duration missions (greater than 16 days), and can be described as a **chronic metabolic disorder**. While the acclimatization process requires active monitoring to preclude the aggravation of latent diseases, the pathological changes dictate active intervention to prevent overt chronic disorders in space or upon return to Earth. In long duration missions lasting six months or longer, injuries or illness events can be complicated and aggravated by the acclimatization or pathophysiological processes. Four such illnesses did occur in crew members during space flight. Despite therapeutic interventions, three evacuations from the space stations back to Earth were required.

**Figure 2: Concept of physiological responses upon return from space flight to Earth’s gravity field**

Upon return to Earth, space-induced changes manifest themselves as **cardiovascular and neuro-sensory/motor compromise** and a **latent asthenia and debilitation**, both requiring medical intervention and rehabilitation lasting weeks to months (Figure 2). There is a diagnosable malaise and fatigue associated with return to Earth (49). We need to accurately label the health status of the returning astronauts. For example, the American Society of Anesthesiologists’ (ASA) physical status classification of patients undergoing surgery, though imprecise, can convey the overall clinical status for medical providers’ communication purposes (58, 59, and 60). Recently the use of such classification as a medical risk prediction tool has been challenged; however, no new scale has yet been developed. A similar nomenclature should be developed for space medicine purposes when conveying astronaut health status upon return from space flight (at least during the first 7 days). Using this categorization the majority of long duration crews can be assigned to either class 1 and 2 categories (see Table 1). In only a few isolated instances
have individual space travelers met the class 3 physical status, primarily those who did not adhere to the prescribed exercise regimen. While class 1 and 2 patients have no major compromises, the ASA class 3 patients can have serious systemic disease but are not incapacitated (see Table 1). Additionally, astronauts who have recently returned to Earth may respond differently to anesthetics and thus may be at higher risk of complications during and following surgical procedures (50). For the first couple of days upon return to Earth, space travelers are functioning at the boundaries of their physiological reserve and require close observation and care. This is a care-intensive phase that requires a sizable medical infrastructure, which will not be initially available at the landing sites on other planetary surfaces (specifically, Mars).

Table 1: *American Society of Anesthesiologists Physical Status Classification*

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Healthy patient, no medical problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 2</td>
<td>Mild systemic disease</td>
</tr>
<tr>
<td>Class 3</td>
<td>Severe systemic disease, but not incapacitating</td>
</tr>
<tr>
<td>Class 4</td>
<td>Severe systemic disease that is a constant threat to life</td>
</tr>
<tr>
<td>Class 5</td>
<td>Moribund, not expected to live 24 hours irrespective of operation</td>
</tr>
</tbody>
</table>

The biological changes and clinical manifestations of the space acclimatization process are graphically represented in Figure 3. Proactive medical interventions and vigorous physical training are required, throughout the mission, to maintain the physiological reserve and ability to transition from microgravity back to Earth’s gravity. NASA’s space medicine program has developed a set of protocols, technologies, and procedures to successfully address these challenges in LEO and upon return to Earth.

![Figure 3: A schematic representation of the time course of the physiological adaptation and pathophysiologic responses to space flight](image)

Adapted from: Nicogossian (4, 46, and 47)

Obviously, such health maintenance and medical care protocols require the participation of multidisciplinary teams of national and international medical experts and are inherently people and technology intensive. NASA’s medical care delivery in space is
also heavily dependent on the use of telemedicine and tele-monitoring of the environment and crew health by flight surgeons in the mission control centers on Earth.

A wealth of knowledge and experience with disease management on Earth has been amassed. Diagnostic, preventive, and therapeutic standards have been adopted or are being investigated. Experimental and practical knowledge in estimating health risks and intervention strategies are being developed. Processes governing acclimatization and adaptation to remote and hostile environments on Earth (36-38), including care of illnesses and injuries were extensively studied in the 20th Century. Drawing judiciously on this knowledge and experience, coupled with what has been learned from the human exposures to space flight, health and medical policies can be formulated to protect future space explorers. Crew size limitations on future space expeditions will require the development of novel health and medical care technologies, as people-intensive life-saving technologies used on Earth are not available (unless fully automated) in space. Fortunately, the majority of preventive programs designed to protect the health of space flight crews can be easily implemented and sustained, since the astronauts still work and reside on Earth, more so than in space.

However, this situation might be reversed in the future: explorers might spend more time in space than on Earth. Today’s research should address the issue of permanent residency away from the Earth. Our experience dictates that the further away one moves from Earth, the more complex the delivery of health maintenance and medical care will become. A minimal risk, if unchecked, can become life-threatening with time, when a return might take days, if not months, or may be impossible.

**National Space Policy in the post-Apollo Era**

On January 14, 2004, President George W. Bush, in his speech at NASA Headquarters in Washington, DC, presented the renewed vision for space exploration. The outlined roadmap has the potential to become one of the most ambitious and far reaching enterprises of the 21st Century with immense socioeconomic and technological implications.

NASA has sought a mandate for the return to the Moon and a human mission to Mars since before the end of the Apollo era in the 1970s. The last two Apollo missions were cancelled because of the lack of appropriated budget, and the remaining resources were redirected toward the Skylab research space station and the first international piloted space mission, the Apollo-Soyuz Test Project.

During the decade of the 1980s continued reductions in the space budget, lack of political support, and competing domestic and discretionary priorities left NASA with only the Space Shuttle for the human space flight program. The research and technical achievements of the Space Shuttle, launching and retrieving astronomical and Earth observing platforms, repairing satellites, and carrying the European Space Agency research laboratory _Spacelab_ missions (28, 29), captured global imagination, and led to the approval of the International Space Station Project (ISS) by President Ronald Reagan.
in 1984. The ISS was intended to serve as a laboratory test bed and a stepping stone for future human exploration missions.

The end of the Cold War and the desire to ensure non-proliferation of missile and weapons of mass destruction technology led to the partnership with the Soviet Union/Russia in the development of the ISS and the joint Space Shuttle-Russian MIR Station research project. Despite NASA’s continued attempts to rekindle the spirit of human exploration of the Solar System, the U.S. human space flight program was destined to remain a LEO enterprise for the next two decades (25, 26, and 27).

In 1989, President George H.W. Bush announced his Space Exploration Initiative during a speech commemorating the 20th anniversary of the Apollo 11 moon landing. The Initiative proposed sending humans back to the Moon, and ultimately sending astronauts on to Mars. In 1990, President Bush established a Committee on Space Exploration, which recommended that NASA should focus on Space and Earth sciences, while transitioning human exploration to a “go-as-you-pay” strategy. The President ordered NASA to implement these recommendations, which affected the human space exploration program and NASA’s biomedical research, viewed as inextricably intertwined with the health of the human in space and not a discipline in its own right. ISS development and associated budgetary and political problems resulted in the relegation of human exploration beyond the LEO to an uncertain future. In 1996, the Clinton administration removed from the National Space Policy all mention of human exploration beyond the LEO.

President George W. Bush’s 2004 “Renewed Spirit of Discovery: the President’s Vision for the U.S. Space Exploration” has set the stage for a space journey moving humans away from the LEO and into the Solar System. The new Vision, Congressional support, and associated budget increases have been a welcomed change for the proponents of an expanded National Space Policy.

The charge to develop new and safer space ships carrying humans into the Solar System, establishing “highways to space, with outposts on the Moon and beyond,” presents NASA with excitement and a challenge in the aftermath of the Space Shuttle Columbia tragedy in 2003. This has been a boost to the Agency, which has suffered repeated budgetary cuts, was short on resources and technical expertise, and has not developed a new human piloted vehicle for nearly 30 years.

Humans have not left the near-Earth region for 32 years, since the Apollo 17 mission in December 1972, and NASA is facing a major challenge to “re-tool and re-invent the spirit of human space flight” from a LEO to a deep space exploration strategy. Much has to be relearned, reinvented, and retested. New technologies and management practices are required to address the design, development, and testing of the next generation of heavy lift launchers and crafts to transport safely crew and cargo to the ISS and beyond (1, 30).
Currently, NASA is evaluating the means and technologies necessary to achieve the exploration vision articulated by President Bush, giving a high priority for the design and development of a Crew Exploration Vehicle (CEV). The CEV will replace the Space Shuttle, deliver humans to the International Space Station, and subsequently to the Lunar Surface Access Module (LSAM) and to the Mars transit vehicle. NASA has a monumental task, of conducting research and development while vying for resources. NASA must also balance a robust robotic planetary exploration program to map “places for humans to go, work, conduct scientific enquiry, prospecting for resources and ultimately settle our Solar System.” Robotic explorers are essential for probing alien environments, identifying physical threats and hazards, cataloguing extraterrestrial resources, and identifying potential challenges, if not overt risks, to human health and performance.

Research Funding and Prioritization Issues

Biomedical research in NASA has not been immune to the ups and downs of resource competition and cutbacks encountered in other federal programs. During the Skylab era in the 1970s, biomedicine at NASA enjoyed significant support to study human responses and endurance to extended space flights. The decade following the Apollo era found NASA life sciences research under-funded, with the exception for neuro-vestibular and radiobiology disciplines. Prior to the resumption of human space flight using the Space Shuttle, significant life sciences resources were focused on the study of cardiovascular function, space neurophysiology, and motion sickness problems, all of which could negatively affect crew performance during the first days of flight and during the reentry and landing phases of the piloted Space Shuttle. The advent of the Spacelab module as a space-based research laboratory, the NASA-Russian joint Space Shuttle-MIR project, and the International Space Station (ISS) programs in the late 1990s and early 2000s saw an influx of additional resources and the creation of an independent Office of Life and Microgravity Sciences. However, NASA biomedicine continued to be focused on short duration mission research, with very few resources allocated to long duration space flight research. During the NASA-Russian joint Space Shuttle-MIR project, experiments that could have been done to assess long duration space flight could not be performed because MIR could not accommodate experimental hardware designed for the Space Shuttle and Spacelab. Subsequent onboard fire and collision with a cargo space ship further degraded the research environment on MIR. ISS was intended for the research into the understanding of the role on biological processes, to serve as a test bed for the physiological effects of space flight and medical care, and the premier platform for hypothesis testing and validation of countermeasures. In the last decade of the 20th Century, NASA developed a strong partnership with the National Institutes of Health (NIH) addressing both space- and Earth-based health challenges. The partnership fostered research and technology development, with both agencies contributing resources for joint peer-reviewed projects (44). Unfortunately, this important link and relationship has weakened since 2001.

Reliable spacecraft life support, countermeasures to physiological deconditioning, nutrition, and human factors (including psychosocial adaptation to extended sojourn in
closed and isolated environments) are essential ingredients for safe and successful long duration missions, especially if logistics are difficult and returns or aborts are complex and expensive. The prevailing assumption is that the sustenance, health, and safety of the human explorer are integral to the success of space missions. Indeed, in the NASA management practices, the developer/operator (program/project manager) is responsible for ensuring crew comfort and performance. The space medicine experts provide inputs on crew health and safety needs prior, during, and after each mission. The amount of resources, both research and operations, allocated to the crew health is dependent on the mission type, the perceived risks, and the readiness level of the health and medical technology to be incorporated into the spacecraft design or operation. In many instances, given the number of environmental and health support systems uncertainties, prioritization does occur, and with constrained resources, deferring or canceling cost-effective life support and long-lead technological developments. As planning horizons were affected by resource availability, uncertainties, and a growing lead time for technology development, NASA has deferred the necessary biological research until the ISS becomes operational. For example, during the last two decades, research into the closed loop bioregenerative life support system, to reduce logistics, and the more advanced high-pressure extravehicular suit, to minimize the risk of bends, were initiated and then cancelled. These cancellations preclude timely technology readiness for exploration class missions and increase reliance on less optimal systems.

Figure 4: Allocation of resources to health and medical programs as a percent of the total NASA budget

Historical funding, as a percentage of the total NASA budget, for four health and medical research and development programs is shown in Figure 4. Funding associated with programs and other medical management functions, such as occupational medicine, were
not included in these percentages. Repeated consolidation of projects, personnel, and resources, from one presidential budget submission to the next, makes the comparison difficult. The 2005 and 2006 percentages reflect estimates of the full-cost accounting, representing research or operational activities, including institutional (facility operations and employee salaries) and administrative costs. Recently, the biomedical research program underwent a series of management realignments, consolidations, and adjustments. *It is assumed that the overall buying power of the life sciences research portfolios has decreased.*

In 2006, NASA received $16.5 billion, a 2% increase over the 2005 budget. This increase is specifically earmarked for exploration research and development as well as the completion and use of the ISS. The 2007 Presidential budget request for NASA is $16.8 billion, or about a 1% increase when supplemental funds for hurricane relief are included. *While the support to the health and medical care technology research required for LEO and early Moon missions has been mostly maintained, it appears that the trend is toward deferral or elimination of the long lead research activities required for Lunar habitats and Mars missions.*

In September 2004, the Congressional Budget Office (CBO) released an analysis and estimates of the projected fiscal implications of the implementation of the exploration program outlined in the Vision for Space Exploration. Figure 5 summarizes the budgetary needs through the year 2020, the proposed date for the return to the Moon as presented in the CBO report (31).

![Figure 5: The Fiscal requirements for the implementation of the Vision (31)](image)

- Historical Average Cost Growth in Human and Near Term Robotic Exploration
- Human Lunar Exploration
- Space Shuttle
- Robotic Support Missions
- ISS
- Aeronautics and Other Science Missions and Activities

*a. Near-term robotic exploration missions are missions to the Moon or Mars that are explicitly funded as line items in NASA’s budget projection. (Farther-term missions are funded out of general robotic exploration budget categories.)  
b. The International Space Station (ISS) category includes transport to the ISS.*
This analysis does not address the associated health and medical activities, including research. However it does acknowledge that NASA has developed a set of top level requirements, which are represented in Table 2.

- Implement a safe, sustained, and affordable robotic and human program to explore the solar system and beyond and to extend the human presence across space;
- Acquire a transportation system for space exploration to convey crews and cargo from the Earth's surface to exploration destinations and return them safely;
- Finish assembling the International Space Station--by the end of the decade, according to NASA's plans--including the U.S. components that support the President's space exploration goals and the components that are being provided by foreign partners;
- Pursue opportunities for international participation to support U.S. space exploration goals; and
- Seek commercial arrangements for providing transportation and other services to support the International Space Station and exploration missions beyond low-Earth orbit.

Table 2: The 2004 NASA Top Level Requirements for Human Exploration Missions (CBO report)

Imbedded in these strategies for a safe, sustained, and affordable program is the presupposition that the explorer’s health will be maintained throughout the missions. It is not clear at this time if the availability of health and medical capabilities will be adequate or if long-term (lifetime) medical implications, including the quality of life of the space explorer, will be adequately addressed given the austere fiscal environments.

The CBO report acknowledges the constrained budget and suggests that the goals of the Vision could be accomplished either through “increase in budget allocations, stretching schedules and/or reapportioning resources within and among different projects within the agency.” Unless new funding is made available, resources allocated to the biomedical research and medical technology development will remain constrained or will even decline. Thus, the adoption of an ethical and rational process to address risk stratification should be enunciated and agreed upon by all the stakeholders and policy makers.
Methodology and Approach

The research team utilized two distinct approaches:

1. **Internal reviews** to

   (1) Search for available data and information in the open literature using the following words and phrases to guide the literature search:
   - Bioethics and space exploration
   - Ethics of exploration and/or space exploration
   - Rationing medical resources in space exploration missions
   - Space exploration and rationing health care
   - Health care resource allocation for space missions

   (2) Develop a bibliographic database relevant to the research project

   (3) Prepare position papers to frame the issues for future discussions.

Two draft discussion papers were produced for the workshop on Health and Medical Care Policies and Practices in Allocating Resources for Human Space Exploration, which was held on July 29, 2005 at GMU. One paper entitled “Bioethics and Exploration – Setting Bioethics Policies for Space Flight Beyond Low Earth Orbit” was developed by Dr. Paul Root Wolpe, the NASA Chief of Bioethics in the OCHMO. The GMU research team prepared a review paper that provided a historical background and information on resource allocation practices by NASA, including mission planning, fiscal constraints, medical policy formulation, and associated ethical concerns. The GMU position paper served as the basis for the present report. The issues and concerns from both papers were combined into a survey divided along the lines of general ethics, mission planning, policy and ethical considerations, and the survey was provided to the workshop participants (Attachments II). The consolidated responses to this survey are presented in Attachment IV. Attachment V contains the self assessment by the participants of their areas of competence and satisfaction with the workshop.

Three ethical issues associated with health and medical resource allocation practices, as related to the space program, were presented to the participants to further guide the discussions:

**Issue 1- Allocation of Resources**: Should resources be distributed to the matters of highest priority in order to achieve the maximum benefit for a given expenditure? Specifically, should priority be given to the provision of spacecraft’s life support, which includes food, water, safe breathable atmosphere, sanitation and hygiene, protection against external hazards such as debris and micrometeorites, ionized and non-ionized radiation, health maintenance and physical fitness (countermeasures to the physiological deconditioning), and, finally, limited medical care?

**Issue 2- Role of Other Agencies**: Should NASA actively seek partnerships with other federal agencies to share resources and distribute responsibilities? Several
federal agencies receive much greater budgets for research into biomedical issues of health, disease, aging, and gender. For example, the NIH and the Veteran’s Administration (VA) provide approximately 100 and 30 times more funding, respectively, than NASA for research into osteoporosis. Should NASA limit its research to the unique needs raised by the space exploration? Should NASA reprioritize and refocus its own biomedical research efforts, capitalizing on the knowledge generated by other medical research organizations?

**Issue 3- Ethics in Priority Setting:** What influence should bioethical considerations have on mission and program planning? While biomedical research contributes to the space medicine knowledge and requirements enable space exploration, health maintenance and care rely heavily on engineering and technology to ensure explorers’ well-being and useful function. Many aspects of the **physiological adaptation** to extreme environments are made possible and realized through **technological adaptation**. Unfortunately, budgetary constraints have resulted in less than optimal engineering developments that can affect crew health. For example, unreliable exercise devices result in continued bone and muscle loss in space; degraded spacecraft acoustical environment can produce fatigue and human errors. Significant biomedical research efforts have been expanded to find physiological solutions to technical shortcomings. In many instances, the remedial efforts are directed toward satisfying immediate mission safety needs by providing interim solutions to the problem, which relies heavily on the human element, as opposed to the apparent technological solution, which is too costly to implement given constrained resources. This approach invariably results in long and unproductive biomedical research activities while increasing the health risks for the crews. Should such an approach to medical risk mitigation be reevaluated?

2. Two **external review(s)** were held with the participation of subject matter experts, including experts from NASA (Attachment I). The first review was in the format of a workshop on Health and Medical Care Policies and Practices in Allocating Resources for Human Space Exploration, held on July 29, 2005. A subset of the participants from this workshop was invited to a report assessment meeting held on September 15, 2005. All proceedings from the two meetings were for non-attribution. Inputs and discussions were based on the materials developed as a result of internal reviews and were presented by the research team. Findings, discussions, and individual opinions were evaluated for relevancy and incorporated into the final recommendations. The July 29, 2005 meeting consisted of three panels addressing:

1. Current practices for resource allocation to space exploration medical care capabilities;
2. Legal and economic considerations in resource allocation practices; and
3. Ethical and societal considerations in resource allocation.
Results

Five search engines and five key phrases were used for the literature search. The findings of this search are summarized in Table 3.

<table>
<thead>
<tr>
<th>Search Phrases/Search Engines</th>
<th>Google</th>
<th>Alta Vista</th>
<th>PubMed</th>
<th>ProQuest</th>
<th>Lexis Nexis</th>
<th>Science Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioethics and space exploration</td>
<td>39,900</td>
<td>29,500</td>
<td>1(Russian)</td>
<td>1</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Ethics of Exploration</td>
<td>1,860,000</td>
<td>1,030,000</td>
<td></td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rationing medical resources in space exploration</td>
<td>11,700</td>
<td>1,680</td>
<td>0</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Space exploration and rationing health care</td>
<td>18,000</td>
<td>2,440</td>
<td>0</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space exploration and ethics</td>
<td></td>
<td></td>
<td>5</td>
<td>75</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Space flight and ethics</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Results of the Literature Search

This search failed to reveal any pertinent information on the issues under review. However, three reports in the area of space law and strategic direction for space policy, were prepared under the auspices of the American Astronautical Society (15, 16, 17) were identified. Two of the reports (16, 17) represent the consensus statements by the national and international aerospace societies, agencies, and academic communities. Though the reports address legal, commercial, and other implications of access to space and exploration, and recommend a vigorous and vibrant space activity, none proposes resource allocation processes and practices for the development of health and medical capabilities. It is interesting to note that the report entitled “Space for America” (16) contains the following statement:

“‘To ensure that space travel and long-duration human space missions are planned and conducted with confidence, the federal government should:

- Maintain and expand a vigorous program in life sciences with emphasis on environmental factors in space travel.
- Conduct research on social and psychological factors affecting human performance in highly structured work groups.’”
The European Space Agency, in partnership with UNESCO, has created a special committee to address the issues dealing with ethics in space. Topics covered range from commercial activities and ownership of property to bioethics of extraterrestrial life and biomedical research (18). However, none of the materials addressed the specific space bioethics and support to clinical issues discussed in this report.

Discussion

Based on the information garnered from the literature, the research team concluded that:

There is a lack of information about the ethical principles for resource allocation to health and medical activities in space exploration undertakings.

1. The ethical principles should be addressed early in the mission planning process.
2. The ethical principles should be addressed for each phase of exploration.
3. Policy makers and stakeholders assume that the environmental, physical, and physiological health support systems are inherent to and included in the overall resources of the spacecraft/habitat development.

Given an accelerated developmental schedule, the design of a new crew space vehicle will require the incorporation of the best space medicine knowledge and practices, with little latitude and time for the conduct of additional biomedical experiments, either on the ground or on the ISS (2). Research targeting areas such as development of more reliable medical support hardware, protocols and procedures (exercise equipment, medical diagnostic and therapeutic equipment, and environmental monitoring hardware), and improved countermeasures to space flight deconditioning should be rapidly implemented to fill the gaps in knowledge. This type of research should be done on a competitive basis, using peer review, and involving the best experts in the field. Participation of other agencies, such as NIH, can improve the chances for success. The National Space Biomedical Research Institute, funded by NASA, can be a valuable asset in addressing the existing knowledge gaps.

Fortunately, significant experience in space medicine has been accumulated over the last four decades of human space flight. This wealth of information encompasses: crew selection, training, and preventive care; habitability of spacecrafts; extravehicular activities; countermeasures, physiological responses to reduced gravity exposures, management of medical events, and post flight rehabilitation, and return to duty after short and long duration space missions in LEO (3-5). Exploration targeted environmental observations and health hazard assessments are being updated continuously through the planetary robotic missions.

Three major bioengineering and technological capabilities will be required to support and safeguard the physical and psychological health of the humans exploring space; these have been repeatedly emphasized by several presidential commissions for space exploration (26, 27, and 39):
1. Habitability and closed loop life support, including water, food production and preservation (especially fibers and fresh vegetables), habitat toxicological and microbiological control, and psychosocial well-being. Radiation “climate” forecasting and protection, and maintenance of a healthy atmosphere and gas composition over long periods of time without major reliance on re-supply from Earth.

2. Countermeasures to protect against the high threats and health risks from deleterious effects of space flight, absence of or reduced gravity, penetration by meteorites and space debris, solar flares, protection against extraterrestrial life forms, if any, and evolved Earth microorganisms adapting to new environments.

3. Care capability commensurate with the medical skills and training of a small and diverse group of explorers.

The above list is not intended to be an all-encompassing description of the expected needs encountered during human exploration missions to the Moon and Mars. However, the three categories are major health requirements and prerequisites for exploration missions beyond LEO and should be prioritized and considered during mission planning. The NASA OCHMO prepared and released, in December 2004, guidance for health and medical requirements for exploration class missions (Attachment III). This guidance addresses the major components of the health and medical care prerequisites for future exploration class missions and requests the Life Science Directorate, at the NASA Lyndon B. Johnson Space Center, to develop specific health and medical standards to support the guidance.

The workshop experts, using survey results and discussion, concluded that in order to ensure proper allocations, the exploration risks should be prioritized and resources provided accordingly. Risk assessments should take into account the tradeoffs between acceptable risk and the value of the mission. Specific points made by the workshop participants were:

1. Risk assessment is not easily determined, because of inherent individual subjective differences in acceptable magnitudes and categories of risks.
2. A standardized process for health and medical risk definition and prioritization should be available to NASA. Astronauts and stakeholders should be part of the process.
3. Means of transport, logistics, and equipment included on the space vehicle should be part of the equation of risk determination. For example, medical care supplies must be incorporated into the volume and mass constraints of the payload, regardless of whether or not they are used during a space flight mission. The volume and mass of any medical supplies takes away from allowances for another needed system. This must be taken into account when balancing the health of astronauts with the risk of the mission.
4. All identified risks should be addressed on Earth and during the early planning phases of the exploration.

Workshop participants felt that crew health and safety should be the highest priority within the resource allocation process. Execution of informed consent documents by the
crew members prior to space flight might be beneficial in clarifying mission uncertainties and expectations. There was concern expressed regarding the ethics of prescribing medications in space, since any treatment in space might be investigational in nature and proper consents should be developed to cover this eventuality. Depending on the type of emergency situation, an informed consent may not be appropriate, and patients needing immediate medical attention should be treated regardless of the availability of an informed consent.

Ethical considerations should take into account NASA’s institutional culture. Improved data analysis and greater scientific input should be part of the risk assessment for exploration missions. The legal and economic implications of the resource allocation process and practices are broad and should be subjected to continuous scrutiny. At each step, questions regarding cost and how much stakeholders are willing to pay, including the impact of catastrophic events, should be raised and carefully evaluated. Realistic scenarios should address the potential adverse impacts of constraints imposed on health and medical care systems, with constraints not to exceed the limits of acceptable risks. Investing in preventative care will be always less costly and minimize the too often compounded risks.

The salient conclusions from the expert discussions can be summarized as follows:

1. A dialogue with the stakeholders, including the public, should be continued in a proactive fashion to educate and inform about the risks and benefits of space exploration with humans.

2. Potential scenarios and evidence-based outcomes should be researched, catalogued, and disseminated to assess the level of expectations and risk acceptability by the stakeholders and the public.

3. Transparency and accountability to the public should be enhanced to continue to garner public support.

4. The determination and clarification of regulations governing NASA health and safety programs on Earth, i.e., Federal Drug Administration rules for use of medications or Occupational Safety and Health Administration workplace health and safety practices, should also be addressed and applied to space exploration as appropriate.

A total of 29 participants completed the survey/questionnaire, which was extracted from the two position papers. The survey was not administered until after the workshop discussions had taken place. The majority of participants acknowledged that the laws and rights applied to space explorers will be different from the accepted norms in the Earth setting. This is consistent with the historical precedents of establishing colonies and settlements by the ancient civilizations, such as Phoenicians and Greeks (but not necessarily the Romans), the International Maritime Laws, and the different treaties promulgated by the United Nations committees dealing with the peaceful uses of outer space (40).
The survey was divided into three issues (as presented on pages 21-22) dealing with mission planning strategies and principles of allocation of resources, development of medical policies, and ethical considerations for addressing resource allocation. In each of the three categories, the lowest ranked items (undecided or disagree) were associated with very large standard deviations and as such indicated a significant divergence of opinions on the issue.

The participants felt that the meeting did achieve the stated objectives but that the consensus on some issues, such as the need of space ambulances, priority to develop a rescue capability, or contributions by other federal agencies in addressing medical issues of exploration, could not be reached. Lack of full consensus is attributed to the novelty of the subject and the divergence of individual opinions on how much of the knowledge or resources would be adequate in order to minimize the risk of exploration. The participants of the first workshop strongly supported and gave consistent high ratings for:

1. Developing medical policies addressing loss of life;
2. Using triage and amelioration of suffering in a situation of constrained medical resources;
3. Integrating engineering and medical ethics during the planning and design phases of space exploration missions;
4. Allocating resources to ensure preservation of health and well-being of the explorers;
5. Developing clear understanding of medical lines of authority and inclusion of medical personnel as crew members for exploration missions;
6. Providing regular briefings of the crews and families about mission risks; and
7. Recognizing that the exploration mission’s medical care will be limited and some injuries and illnesses will not be treatable.

Some of the other information and ratings are presented in Attachment V.

Conclusions

Sojourn into an extreme environment, and space in particular, is a risky undertaking (8-14), and deserves properly tailored health and medical capabilities, backed by carefully crafted policies to ensure the highest probability of mission success and explorer well-being. An action plan for productive and safe human enterprise into extreme environments is complex but must be well-thought out and funded adequately in order to develop specific health and medical requirements for incorporation into the design of new space vehicles and habitats (14).

Except for a few instances (for example, the Apollo-Soyuz Test Project), cost overruns and constrained resources have plagued the development of large human piloted space projects, which often span decades, several administrations and congressional appropriation cycles. Resource allocation by the Federal Government and appropriations by the Congress are done on a yearly basis and shortfalls lead to modification of the hardware before its completion and launch. This invariably results in the degradation of the system performance, greater reliance on ground controllers and crews, and increased
acceptance of technological threats and operational risks. On occasion, constrained funding has led to the re-evaluation and under-funding of the high priority biomedical research and human support systems. Errors occur, albeit infrequently, because of acceptance of certain risks or inadequate resource availability, with potential catastrophic results to life and systems. More often temporary and costly fixes are implemented during the operational phases of space missions, resulting in suboptimal habitability situations and degraded performance of the crew and system.

So far, NASA medical and aerospace engineering communities have been able to ensure the health and well-being of all space crews; no NASA mission has been aborted or life lost due to a medical event. However, given the atmosphere of constrained resources, tight schedules, and competing priorities, such a track record cannot be guaranteed in the future.

Due to constraints in schedules and time, prospective health and medical risk factors may not be researched fully—a practice which may lead to further inadequacies in technology, resources, or available logistics. Enabling research for human exploration is not a stable and sustained effort and as such is subject to specific mission needs, schedules, budgetary and political pressures, and vagaries.

Too often there is a tendency to limit medical care, services, and supporting technology because of the dependence on the ability to mount a rescue mission, which is difficult to execute for missions beyond LEO. Assuming or hoping for continued “good health status” of the crews based on prior experience might be misleading. Fortunately, given the ability of the human physiology to compensate, such practices rarely lead to major diseases or accidents; they often result in the poor use of available resources and in the inadequate provisioning of exploration teams, which can be dangerous in the case of unforeseen medical emergencies. Enabling technology and systems developed to support explorations must be robust and capable to protect the crews from major environmental risks.

Human exploration of the extreme environment is achieved through safe and rapid technological adaptation rather than slow and too often incomplete physiological adaptations. It is expected that safe technology should not present human explorers with additional health and medical risks. Given the above constraints, bioethical considerations should be an integral part of the health and medical care policy formulation process including resource allocation in the formulation of budgets (14).

The GMU research team has developed a policy formulation algorithm, presented in Figure 6, which can be readily adapted to the assessment of risks and establishment of resource allocation priorities. It is imperative that ethical considerations are addressed by the mission planners and program implementers as an integral part of the risk

---

2 A recent study by the National Academies noted that there is a need to develop and provide adequate support to space medicine in the planning phases of exploration missions beyond the LEO (2).
stratification process. Such risk stratification process will address the known and mission unique hazards associated with the three major exploration components: the human, the system, and the environment of the journey and the destination. The policy formulation algorithm foresees inputs and reviews by the different stakeholders. The purpose of the algorithm is to clearly identify health and medical risks prior to resource allocations. The risks, in turn, should be stratified and then assessed for the likelihood of occurrence and degree of criticality. Resource allocation can proceed accordingly.

Figure 6: An Algorithm for Health and Medical Policy Formulation Process

The policy formulation algorithm integrates the three elements of space flight architecture: human, system, and environment, as presented in Figure 6. The process involves identifying within each element the important problems, assessing the risks to the human explorers, prioritizing and mitigating the risks, and designing a protective and life sustaining system around the human explorer that alleviates the perceived risks. Policy formulation must begin by assessing the current knowledge base. Additionally, this must be a continuous and reiterative process. The “Environment-Human-System” algorithm can be adapted to a systematic medical policy formation process. Each of the individual facets can be translated into a sequence of steps. The algorithm and its steps are intended to assure careful study of the essential components integral to human space flight and exploration. The major component—the environment, the human factors, and system—become the landmarks for the process.

The first step is to define the environmental characteristics of the destination. Transition to and from this new environment and associated physical changes need to be clearly articulated. Further, the environment within the space exploration vehicle must be analyzed. An inventory of the critical factors of both environments that present threats
and risks to human health and survival must be developed. The full human responses to
the space environments and the engineered systems are complex and not completely
understood. Critical biomedical experiments and simulations are required to assess
perceived risks, and mitigating procedures and policies need to be formulated. Mission
planners and expedition participants should consider these resultant policies and
requirements while preparing for each mission.

Individual physiological and psychosocial differences present special considerations to be
incorporated into the algorithm. The current knowledge base should be investigated for in
space flight experiences or those experiences from analog environments. The catalogued
risks posed by the flight and exploration need to be mitigated and managed. Where
possible, the risks should be managed through selection and training.

Competent technology-based systems provide protection that makes space exploration
possible. The purpose of the system is to transport, serve as a habitat and protect against
the environment, and provide for the needs of humans. The design of the system will
determine the limits of its function and performance and the needs for human
intervention. A global assessment needs to be made of the system’s design and
performance from the perspective of both physiological and psychological concerns.

The final aspect of the process is to form and effectively communicate the policy options
and alternatives generated from a comprehensive and systematic investigation of all the
available evidence. Once implemented, the policy and procedures adopted for each
mission must be re-evaluated in light of the environmental, human, and system elements.
This reiteration is important to improve the success of each mission.

In 2000, NASA established the OCHMO with the oversight and review function for all
the biomedical and occupational health activities within the Agency. This office has the
responsibility for the health and medical policy formulation and development of
requirements and standards, and is the focal point for international medical interactions.
The OCHMO is in the process of establishing health and medical standards and
associated requirements to be incorporated into new spacecraft design. Tools such as
health risk assessment, evolution, and disposition over time will be required to further
provide an insight into the rational resource allocations for missions as complex as the
expeditions beyond LEO, where risks will be difficult to fully quantify and account for in
the planning stages and systems design.

The GMU research team finds that current practices for health and medical policy
formulation by NASA have shown significant progress since 2000. Additional modest
resource investments for the OCHMO to develop medical analytical risk modeling
capability, and as feasible incorporation of a probabilistic risk assessment, can markedly
improve NASA ability with the evaluation, communication, and mitigation of health risks
in exploration missions.

Protection of human life and habitat should be the highest priority for mission designers
and operators. This should be part of the mission success criteria. Informing the space
explorers and their families, stakeholders, and the public of the medical risks in a timely
fashion, and as appropriate, the extent to which medical care will be feasible, should be a matter of policy to be executed prior to each mission. The different modes of practice (approach) and their respective outcomes in time and cost effectiveness to be applied for future exploration missions are presented in Figure 7. Practices relying on health maintenance and prevention are more desirable than the sole reliance on medical and or surgical care.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Maintenance</td>
<td>Long timeframe, cost effective</td>
</tr>
<tr>
<td>Prevention</td>
<td>Moderate time frame, affordability</td>
</tr>
<tr>
<td>Care</td>
<td>Near term, costly</td>
</tr>
</tbody>
</table>

Figure 7: Health, Prevention, or Care

Such notions as *justice* or *priority to the worst off* or *fair shares* cannot be readily adapted or applied to decisions leading to the prioritization of the health and medical needs of space travelers. On the other hand, the principles of *maximization* of the health and medical care for a given outcome (45), and to some degree *equity*, can be incorporated into the decision process leading to resource allocation and health policy formulation. Such an approach can improve the chances for known health risk mitigation encountered in the exploration of space. The risk reduction strategy using the *maximization* principle should also address the long term explorer’s health and quality of life beyond the successful accomplishment of the mission objectives. A process based on these principles for resource allocation has been proposed by the research team. This process is predicated on the stratification of risk leading to policies designed to ensure the *efficiency* in the use of resources without compromising *safety*. Continuous evaluations to determine the *efficacy* and *safety* of the existing policies and practices should be an integral part of this process.

Health and medical risks should be frequently monitored and addressed, since performance and health status are dynamic processes, especially in space flight, and subject to rapid fluctuations. Evolving medical risks over time should be taken into consideration, incorporated into the planning phase of each mission, and health and medical care resources allocated accordingly using the maximization approach (Figure 8).
In some instances, it will be impossible or unwise to use all the medical supplies of the expedition to administer care to a seriously ill or injured crew if re-supply or rescue is not possible. Alleviation of suffering based on a triage principle—a sorting of individuals according to need or likelihood to survive, or deciding that some severely injured people should not receive care because they are unlikely to survive—might be indicated in such situations. Triage and amelioration of the suffering decisions as feasible and appropriate will require real time participation of physicians and bioethicists. Stakeholders, policy makers, explorers, and their families should be made aware of the extent and availability of health and medical care capabilities prior to each exploration mission to promote realistic expectations.

The GMU research team believes that over time and with the development of new technologies and knowledge, the process leading to the resource allocation of health and medical care in exploration missions will require periodic re-evaluations. Additional insights into the insertion of novel, space untested, health care technologies into the exploration missions should be periodically subjected to ethical reviews. Such a review is more important if the use of such technologies is not associated with specific research protocols. In summary, ethical considerations should be an integral part of the health and medical policy generating process, especially when dealing with poorly understood or poorly researched risks.
References


18. *ESA Portal - Life in Space - The ethics of outer space*. ESA and UNESCO have prepared a joint report on the ethics of space, [http://www.esa.int/esaCP/GGGFHPPH7CC_Life_0.html](http://www.esa.int/esaCP/GGGFHPPH7CC_Life_0.html)


40. International maritime laws: http://members.aol.com/dangelaw/admir2.html

41. The House Science and Technology Committee eventually folded most of the language of the Act into the NASA Authorization Bill of 1988, which was signed into law (P.L. 100-685) by President Ronald Reagan. In essence, the law declares that Congress believes space settlement to be the ultimate result of human space flight and that human expansion into space will enhance the common good.


44. FASEB FY 1997 Report: NASA FASEB Report, Sustaining the Commitment: 
   http://www.faseb.org/opa/consensus97/nasa97.html


Attachment I

Participants List for the July 29 and September 15, 2005 Workshops

John Allen, Ph.D.
Program Executive, CH&S
Office of Space Operations Mission Directorate
NASA Headquarters

Steven J. Allen, J.D.
National Center for Biodefense

Catherine Angotti, RD, LD
Director, Occupational Health
Office of the Chief Health and Medical Officer
NASA Headquarters

Kira Bacal, M.D., Ph.D., MPH
Robert Wood Johnson Foundation
Institute of Medicine
Health Policy Fellow,
Office of Senator Orrin Hatch

Virginia Brown, MA
Howard University

Kenneth Button, Ph.D.
Professor
Director, Center for Transportation Policy, Operations and Logistics
George Mason School of Public Policy

Faith Chandler
Office of Safety and Mission Assurance
NASA Headquarters

Roger Crouch, Ph.D.
Senior Scientist
NASA Headquarters

Clifford Goodman, Ph.D.
Senior Scientist

Edmund (Randy) G. Howe, M.D., J.D.
Chair of the Committee of Ethics Consultants to the Surgeons General,
Human Use Institutional Review Board, USUHS,
and the Ethics Subcommittee,
Society of Medical Consultants to the Armed Forces

James Kirkpatrick, MA
Executive Director
AAS

Roger Launius, Ph.D.
Director, Division of Space History
National Air and Space Museum

David Liskowsky, Ph.D.
Director, Bioethics and Transition to Practice
Office of the Chief Health and Medical Officer
NASA Headquarters

David Longnecker, M.D.
Director, Division of Health Affairs
Association of American Medical Colleges

Desmond Lugg, M.D., FAFOM, FACRRM
Distinguished Research Professor
School of Public Policy
George Mason University
AM/Office of Chief Health and Medical Officer
NASA Headquarters

Michael Manyak, M.D., FACS
Senior Vice President, Medical Affairs
Cytogen Corporation

Ronald Merrill, M.D., FACS
Professor, Division of General Surgery and Director MEDITAC,
Virginia Commonwealth University

Danielle Mutone-Smith, MA
PhD Student/Graduate Research Assistant
School of Public Policy
George Mason University

Arnauld Nicogossian
Distinguished Research Professor
Director, Office of International Medical Policy
George Mason School of Public Policy

Bryan O’Connor
Chief Safety and Mission Assurance Officer
NASA Headquarters
Edmund Pelligrino, M.D., MACP  
Professor Emeritus of Medicine and Medical Ethics  
Georgetown University Medical Center

Polly Penhale, Ph.D.  
Biology & Medicine Program Manager  
Office of Polar Programs  
National Science Foundation

Russell B. Rayman, M.D., M.P.H.  
Executive Director Aerospace Medical Association

Victor Schneider, MD  
Program Scientist  
Human System Research & Technology Office  
Exploration Systems Mission Directorate  
NASA Headquarters

Franceska O. Schroeder, Esq.  
Partner, Pillsbury Winthrop LLP

Marc Shepanek, PhD  
Deputy Chief of Medicine of Extreme Environments  
NASA Headquarters

Carlos Sluzki, M.D.  
Research Professor, GMU  
Clinical Professor of Psychiatry and Behavioral Sciences, GWU  
Editor of the American Journal of Orthopsychiatry

David Solomon, M.D., PhD  
Assistant Professor  
Department of Neurology  
School of Medicine  
Johns Hopkins University

Maxwell Stearns, JD  
Professor of Law  
School of Law  
George Mason University

Frederick Tilton, M.D.  
Deputy Federal Air Surgeon  
FAA

Susan Tolchin, PhD  
Professor  
George Mason School of Public Policy

Richard S. Williams, M.D., FACS  
NASA Chief Health and Medical Officer  
NASA Headquarters

Rosann Wise, MA  
PhD Student/Graduate Research Assistant  
School of Public Policy  
George Mason University

Paul Root Wolpe, Ph.D.  
Chief, Bioethics and Human Subjects Protections, NASA, and Assistant Professor of Sociology and Psychiatry Center for Bioethics  
University of Pennsylvania

Melvin Worth, M.D., FACS  
Senior Advisor, Institute of Medicine National Academies

Tom Zimmerman, PhD  
Research Professor  
Office of International Medical Policy  
School of Public Policy  
George Mason University

Guest

Bonnie Stabile  
PhD Candidate  
George Mason University
## Attachment II
Questions from the NASA and GMU Discussion Papers

<table>
<thead>
<tr>
<th>QUESTIONS</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISSUE 1</td>
<td></td>
</tr>
<tr>
<td>All space travelers and future settlers be entitled to the same rights as people on Earth.</td>
<td>[Strongly Disagree  Disagree  Undecided  Agree  Strongly Agree]</td>
</tr>
<tr>
<td>Space travelers should be subjected to different rights and protection guidelines and laws from environmental and technological hazards than those that are guaranteed by most governments to their citizens on Earth.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>In the process of resource allocation for the design of space vehicles and habitat(s), the highest priority should be given to life support, capable to ensure the survival of the space explorers.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Since survival cannot be guaranteed in exploration/space missions, explorers should be required to execute a living will addressing end of life issues.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Preservation of human life NASA’s highest principle and is the first criterion of mission success.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>The preservation of the health and well-being of the crew, to the degree prudently possible given the limitations of the CEV, is among NASA’s highest priorities.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Human habitation of the CEV must be central to the design and development of the craft.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>To the degree possible, the CEV environment should not itself induce predictable permanent negative health condition or significantly increased susceptibility or likelihood of disease or disability.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Health maintenance must be directed at maintaining sufficient capability to adequately handle all critical operations and emergent situations on the CEV.</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

| ISSUE 2   |       |
| NASA should focus its scarce resources toward resolving unique problems focused on NASA missions such as life support, food preservation, radiation protection, countermeasures to physiological deconditioning and robotic technologies to | [Strongly Disagree  Disagree  Undecided  Agree  Strongly Agree] |

40
<table>
<thead>
<tr>
<th><strong>deliver medical care.</strong></th>
<th><strong>NASA should continue to rely on other federal health agencies to provide timely information on health issues through their research activities.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Given the Presidential Vision, other health agencies should assign a high priority to space medicine related projects.</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>Because of the constraints imposed by the availability of resources, professional skills and technological capabilities, NASA should concentrate on preventive health programs rather than medical care.</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>NASA should be exempt from terrestrial ethics and use genetic testing in their preventive programs for crew selection (HR 1227/S 306, 109 Congressional Non-discrimination Act 2005).</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>Policies must be configured for such eventualities as major crew member disease or injury, crew member death, loss of mission, and family tragedy (information and counseling policies).</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>As a general policy, a trained health care professional, preferably a physician, should be a member of the crew on every ECM.</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>Within the limitations of the craft environment, research and medical development efforts should be directed towards the capacity to diagnose and treat disease with standards as close to terrestrial professional medical standards as possible.</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>Permissible exposure limits will be determined for radiation and not exceeded. Other exposure and outcome limits will be set based on principles of maintenance of crew health and will not be exceeded except in extraordinary circumstances.</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>Specific standards should be set for crew health based on all available data.</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
<tr>
<td><strong>Bioethical input should be integrated into NASA decision-making at all levels of medical and psychosocial care of the astronauts.</strong></td>
<td><strong>1 2 3 4 5</strong></td>
</tr>
</tbody>
</table>
In order to justify hazardous ECM mission and to set reasonable standards, NASA must pursue a coordinated comprehensive research program on basic physiology/science, preventive measures (e.g., medical, psychiatric), and countermeasures.

Astronauts should be included as active participants in the planning of life sciences research to the degree possible, in order to maximize astronaut buy-in.

Competition for limited space on the craft will be fierce. If NASA assumes the responsibility of sending human beings into a hostile environment and isolating them millions of miles from Earth, it must prioritize health maintenance and medical resources.

Allocation of medical resources must be sufficient to allow achievability of level-of-care policies.

Countermeasure procedures and equipment should appropriate, available, and operational.

Resources should be allocated in such a way as to maximize health-in-flight and assure return to health scenarios post-flight.

Allocation of medical resources in-flight should be done by an authorized agent, most likely the medical professional, and will follow clear guidelines for allocation when and if resources run low.

Amelioration of human suffering should be prioritized. Adequate pain mitigation resources should be supplied.

**Issue 3**

Engineer ethics should be an integral part of every space project and incorporated with the biomedical ethics, in the resource allocation process and spacecraft/habitat design.
<table>
<thead>
<tr>
<th><strong>Environmental health</strong>, which includes food, atmosphere, toxicology, radiation protection and <strong>physical countermeasures</strong> to space flight deconditioning, should be considered as the top two priorities when allocating resources.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Is it reasonable to accept the fact that medical care in space, until larger crews, capable of establishing outposts and settlements, will be limited.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strongly Disagree</strong>  <strong>Disagree</strong>  <strong>Undecided</strong>  <strong>Agree</strong>  <strong>Strongly Agree</strong></td>
</tr>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>It is ethical to accept the notion that serious injury and diseases (to be defined) will be not treatable in space in the foreseeable future or during the early phases of exploration.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The development of a “space ambulance” should be a high priority for the Moon/Mars exploration missions (experience gained from Apollo 13).</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NASA should publicly plan for medical contingencies and inform all stakeholders of the needed resources in the presidential/congressional budgeting cycles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crews and their families should be thoroughly briefed in all policies pertaining to crew health and well-being.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lines of medical authority should be clearly demarcated. Decisions affecting personal health status should be made, to the degree possible, by the flight surgeon and other relevant NASA medical and support persons in consultation with the crew member.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crew should understand in advance policies of uploading potentially disturbing information (familial, social).</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
Attachment III

NASA Chief Health and Medical Officer Requirements Guidance

Excerpts from the December 20, 2004 document issued by the NASA Chief Health and Medical Officer, containing guidance on “Human Health and Medical Direction for Space Exploration.” This document addressed the health and medical requirements for the development of vehicle design, operations, and research to ensure that the human system is successfully incorporated into all space exploration planning. The intent of the guidance was to maximize preservation of the health of the crew members involved, within mission constraints. The following guidance was included in this document:

“… Environmental health systems designs shall address:

Crew exposure to radiation sources from within and external to the spacecraft regardless of the location of the crew (intra-vehicular activity, extra-vehicular activity, or planetary surfaces).

Crew exposure to toxicological and microbial contamination of internal air, water, and habitat surfaces

Crew exposure to vibration and noise

Human habitability issues should be incorporated in designing space exploration missions and systems. The following human factor design considerations shall be incorporated in spacecraft design and mission operations:

Adequate and ergonomically correct work and living volume

Adequate lighting to assure maximum performance

Adequate areas that allow for restful sleep, and personal physical space

Capacity for exterior views

Environmental controls for temperature, humidity, noise, and odors

Work schedules that are not excessively demanding, and that incorporate sufficient rest and recreation periods

Scheduling that allows for private time

Time and resources for personal hygiene

Nutritionally healthy and palatable varieties of food and beverage, with attention being given to individual crew member (crew member has been used on preceding pages and in text below) preference and other human factor issues
Health Maintenance Criteria

The health status of crew members must be maintained in order to insure their ability to function and perform all assigned duties over the duration of their career as an astronaut. This includes the ability to conduct planned and contingency activities during launch, space flight, de-orbit, entry, and landing on Earth or other planetary surfaces, and the ability to execute a contingency egress from spacecraft after all space missions. Crew members shall have the ability to maintain health capabilities to allow performance of all required duties during the phases of a mission, including those involving transitions to altered gravitational conditions. Such capabilities include maintaining orthostatic tolerance, sufficient neurosensory function, and physical fitness. Post-mission persistent ill health effects from space flight in low-Earth orbit and exploration missions should be kept as low as reasonably achievable. It is expected that life span and quality of life will not be compromised.

Crew Medical Evaluation, Monitoring, and Certification

Crew members for exploration missions shall be medically screened, evaluated, and certified using evidence based medical selection and retention.

Clinical evaluation and monitoring of astronaut health shall be conducted at regular intervals to determine medical status during ground based training and space flight. While on space missions, crews will undergo regular, full evaluation of their physical and behavioral health status. Adjustments to their health maintenance program will be made, as necessary, to maintain an acceptable health status during flight, planetary surface deployment, and re-integration to life on Earth. Medical monitoring during unique or potentially hazardous activities, including EVA and planetary surface exploration, is also required. These evaluations, in conjunction with the physical health evaluations prior to each mission, will establish a baseline normative database against which post-flight recovery will be implemented and evaluated.

In cases where medical intervention is required, medical status will be monitored, outcome recorded, and effectiveness of the intervention assessed.

In order to assist in the medical evaluation and care of space crews, data to establish astronaut population health norms in the terrestrial environment will be collected.

Level of Medical Intervention and Care Criteria in Space Exploration Operations

Medical care to maintain the ability to perform assigned duties is required before, during, and after space flight. The level of medical care for a given mission shall be established through a health risk identification, prioritization, and management process that balances ethical constraints, knowledge, and optimal medical care possibilities against mission and program constraints.

Ultimately, the level of medical care should maximize the chances for mission completion and minimize the impact of a crew member’s illness or injury to any other crew member. Post-flight health rehabilitation shall also be provided to assist the astronaut for a return to functional baselines in the areas of physical fitness, and physiological and behavioral health. The capability to successfully treat crew members
for a wide range of illness, injury, or behavioral health problems, and return them to effective duty during the mission shall be developed and maintained.

Medical care capability shall include the following:

Appropriate diagnostic and treatment systems which are commensurate with the level of medical care established for specific mission scenarios; appropriate medical hardware, procedures, and protocols to support cardiopulmonary and trauma life support shall be available, within mission constraints.

Crew member treatment with respect to decompression sickness will be provided at a level comparable to Earth-based standards, within mission constraints.

Emergency life support capabilities, cleanup, and decontamination systems will be provided for hazardous (chemical or bacteriologic) exposures. There will be plans for crew member protection and treatment, and module control, in the event the environment becomes contaminated.

Palliative treatment and comfort measures will be provided for crew members in the event of irremediable injury or the development of fatal disease, within mission constraints.

Medical Management and Training

Provisions for emergency medical services in support of all phases of a mission shall be made available. Adequate medical communications, consistent with the Privacy Act, shall be provided.

Medical and behavioral health training shall be provided for crew members consistent with mission demands and limitations (e.g., communication delays). This will consist of each crew member receiving appropriate baseline medical training and certification, including proficiency training prior to flight, continuing medical education, imaging, telemedicine, and training in flight. To facilitate in-flight training and maintenance of skills, appropriate portable trainers/simulators to perform routine procedures will be available to crews.

Depending on the size of the crew and mission constraints, human exploration missions shall include a physician who has additional training in space medicine, surgery, internal medicine, otolaryngology, critical care medicine, urology, behavior, psychiatry, gynecology, and gastroenterology. These physicians are specially trained to provide medical care on exploration missions. An important aspect of exploration missions is that crew members may not be in continuous contact with the Earth because of delays in communications over such long distances; therefore, the physician must be trained for independent duty without immediate support from the Flight Surgeons assigned to the mission. Another member of the crew will be given special training in order to assist the physician and provide a level of backup.
**Preventive Medicine and Countermeasures**

A program of preventive medicine shall be established, and updated, based on research findings, lessons learned, and current standards of medical practice, risk management data, and expert recommendations. This program shall address all mission phases and target human physiologic and behavioral health factors, and required performance capabilities, at risk, as well as interventions, protocols, or systems (i.e. countermeasures) to reduce that risk. Pre-flight countermeasures should include crew selection, behavioral health training, physical fitness and exercise, physiological adaptive training, and health stabilization programs. In-flight countermeasures should include those activities necessary to maintain physiological health, mental and behavioral health, nutritional health, physical fitness, and mission performance. Post-flight countermeasures should include those activities necessary to assist the crew members in a return to preflight physical, physiological, and behavioral health baselines.

In order to guide and focus this program, medical standards for the development of countermeasures, interventions, and procedures to ameliorate and prevent the deleterious health and performance effects of space flight will be established. Standards will consist of fitness for duty criteria, and other criteria and limits as appropriate. Where appropriate, Permissible Exposure Limits that are consistent with physiological and behavioral health changes, which are environmentally adaptive, reversible, and without sequelae affecting quality of life and life expectancy, will be determined. The following medical standards shall be established:

- A Permissible Exposure Limit for bone atrophy related to altered gravity
- A Permissible Exposure Limit for muscle mass and strength loss
- A Permissible Exposure Limit for space flight radiation exposure
- Fitness for duty criteria for cardiovascular fitness that will allow crew members to perform all required duties during all phases of a mission
- Fitness for duty criteria for neurosensory and motor functioning that will allow crew members to perform all required duties during all phases of a mission
- Individual and group, behavioral health criteria for crew selection, composition, and performance …….”

Obviously the above can be considered as a guide for resource allocation within NASA spacecraft development projects. This guidance is also consistent with the earlier description of the critical technologies required to maintain crew health and well-being during and after the long duration exploration missions.
Attachment IV
Summary of Results from the Individual Survey

Issue 1- Mission Planning Strategies and Resource Allocation Priorities

- Executing of a Living Will Prior to Space Missions
- Health Maintenance for Emergencies
- Highest priority to life support to ensure survival
- Highest principle is preservation of life
- As much as possible no health impact from habitat design
- Habitation of Crew Exp. Vehicle
- Preservation of Health & Well being

Issue 2: Formulating medical policies and practices

- NASA exempt from terrestrial ethics
- NASA concentrate on preventive medicine
- Other Federal Health Agencies give Priority to President Vision
- Support from Other Health Fed. Organizations
- Research directed at medical care similar to Earth standards
- Set permissible, not to be exceeded standards
- Resources focused on NASA Unique Needs
- Comprehensive outcome directed research
- Astronaut Inputs into the Biomedical Research
- Allocation of resources to achieve a level of care policy
- Trained health care professional on all Exp. Missions
- Bioethics part of Policy
- Allocations designed to maximize health pre & post mission
- Health standards based on available data
- Guidelines and health professional for in-flight medical allocations
- Prioritize Medical Resources
- Countermeasures available
- Amelioration of suffering prioritized
- Develop Medical Policies for Loss of Life
Issue 3: Specific Ethical Considerations

- Priority to rescue and "space ambulance"
- Allocating resources to environmental and physical health
- Injury and illnesses might not be treatable
- Medical care will be limited
- Integrating engineering and medical ethics
- Public openly informed of health risks
- Clear medical line of authority
- Families to receive disturbing news
- Crew and family risk briefings
The individual responses were rated on a scale of 1 to 5.