MEDICAL SUPPORT FOR MANNED MILITARY SPACE MISSIONS:

A ROLE FOR AN EXISTING MEDICAL SERVICE, OR A NEW APPROACH FOR THE FINAL FRONTIER?

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WRIGHT FLYER PAPERS

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Foreword

It is my great pleasure to present another issue of The Wright Flyer Papers. Through this series, Air Command and Staff College presents a sampling of exemplary research produced by our resident and distance-learning students. This series has long showcased the kind of visionary thinking that drove the aspirations and activities of the earliest aviation pioneers. This year's selection of essays admirably extends that tradition. As the series title indicates, these papers aim to present cutting-edge, actionable knowledge—research that addresses some of the most complex security and defense challenges facing us today.

Recently, The Wright Flyer Papers transitioned to an exclusively electronic publication format. It is our hope that our migration from print editions to an electronic-only format will foster even greater intellectual debate among Airmen and fellow members of the profession of arms as the series reaches a growing global audience. By publishing these papers via the Air University Press website, ACSC hopes not only to reach more readers, but also to support Air Force–wide efforts to conserve resources. In this spirit, we invite you to peruse past and current issues of The Wright Flyer Papers at https://www.airuniversity.af.edu/AUPress/Wright-Flyers/.

Thank you for supporting The Wright Flyer Papers and our efforts to disseminate outstanding ACSC student research for the benefit of our Air Force and war fighters everywhere. We trust that what follows will stimulate thinking, invite debate, and further encourage today's air, space, and cyber war fighters in their continuing search for innovative and improved ways to defend our nation and way of life.

EVAN L. PETTUS
Brigadier General, USAF
Commandant

Preface

This research project is of particular importance to me as I am an emergency medicine (EM) physician. I expect there to be incredible changes in medicine as humans travel more frequently and with greater numbers into space. My medical specialty has the highest rate of use in operational missions and is flexible enough to allow for extensive utility in future space missions. EM physicians have served in medical support roles for space missions both as astronauts and on the ground as flight surgeons for the National Aeronautics and Space Administration (NASA). I hope this research project provides some semblance of a way forward regarding military manned missions. Scenario development pivots primarily on whether a separate branch for space will come to fruition, and how that branch will be organized. Future questions are more of a beacon for excitement about space instead of consternation. I look forward to seeing how the issues of medical support for manned military space missions will work out in the near future and hope that this research will contribute meaningfully to these changes.

I would like to thank those in high levels of space medicine administration of the USAF and NASA. They provided great sources and contributed to this project extensively, providing validity for my research. Some have chosen to remain anonymous as they do not want to appear to express official viewpoints on behalf of their respective administrations. I would also like to thank my classmates, Majors Jennifer Duhon and Kenneth De Feo, as well as our instructor, Dr. Raj "Buck" Agrawal. Their collective insight and guidance have been essential in this project's success. Finally, I would like to thank my family for their unremitting support and encouragement in all aspects of our lives together.

Abstract

America's success in space and the continuation of escalating military missions in this security domain necessitates a perpetual and potent medical support apparatus both in space and on land. This research sought to answer the question: How will medical support for manned military space missions need to be organized, trained, and equipped to meet the National Security Strategy (NSS) objective of advancing space as a security domain? The hypothesis was that a dedicated medical support structure specifically for DOD space operations would be necessary. The scenario planning research methodology was used, and four scenarios were compared. The four models included use of the current Air Force Medical Service, current NASA medical support, a hybrid of the two, and an entirely separate medical service. The key findings were that these scenarios are based heavily on how the DOD chooses to organize its space assets. Whether the Space Force, Space Corps, or some other variation of organization is used will drastically change the feasibility of a particular medical support structure. Also, a collaboration with NASA, especially in the early stages of DOD manned space operations, will be essential. Additionally, a sustainable training pipeline is lacking in the DOD for space medicine specialists. Recommendations include: developing a training pipeline at USAF School of Aerospace Medicine (USAFSAM) in collaboration with the University of Texas Medical Branch (UTMB), utilizing NASA medical support for early manned DOD missions, including physicians in manned space missions to provide medical support in-mission when possible, and maintaining flexibility and adaptability regarding medical support for space.

Introduction

The United States's armed forces stand at the precipice of dramatic change regarding its approach to superiority in space. Just as the US has sought superiority in the land, sea, and air domains, it is important that they seek to minimize hindrances to operations in space due to adversarial opposition. Operations in this relatively new security domain began with the formation of NASA in 1958, and American missions in space commenced when astronaut Alan Shepard manned the nation's first space flight on 5 May 1961.[1] Subsequently, the US has advanced technology and increased operations in this newest security domain. The future holds the promise of a continued increase in a national presence in space for the US. The proposal of establishing an independent branch of the US armed forces dedicated to space will only see military operations in space advance in complexity and increase in frequency.[2] Regardless of whether the US Space Force will come to fruition, the national climate appears to lean toward the importance of maintaining a robust presence in space. The question looms: how will medical support for manned military space missions need to be organized, trained, and equipped to meet the National Security Strategy objective of advancing space as a security domain?[3]

Increased operations in space also require a robust support apparatus for anticipated manned operations. The environmental constraints placed upon operators in space necessitate a fully dedicated medical support structure to ensure astronauts are properly vetted for selection and supported during missions in space and have adequate support once they complete operational duty. To that end, a problem must be solved regarding how best to train, equip, and organize such a specialized medical support element. This research sought to provide answers to this problem. Like special operations forces (SOF), many of which have dedicated special operations medical teams (i.e., forward surgical teams [FST] and special operations surgical teams [SOST]), operators in space require a medical support structure that is specifically qualified to address the medical threats posed by the space environment. Additionally, by simply operating in space, astronauts subject themselves to possible medical conditions even after their time in space is complete. Those operators require lifelong medical care and deserve a medical system dedicated to that mission.

Scenario Planning Methodology

This project sought to discover how to best organize, train, and equip medical support for manned space missions using a scenario planning structure. This method, outlined by Peter Schwartz in his work, *The Art of the Long View,*

assumes "certain socio-economic driving factors will continue" and impact future events.[4] In an attempt to predict the outcome of these driving factors, scenarios are developed to explore several possibilities. This methodology requires that a focal issue be identified, key factors assigned, and driving forces influencing these key factors derived based on their level of importance and uncertainty regarding the development of proposed "alternate futures." When comparing the explored scenarios, the key factors and driving forces were ranked and used as points for weighing each scenario against the others to conceive an optimal recommendation. The key factors used in this comparison include: (1) efficacious care for manned space missions, (2) presumed cost of scenario, (3) ease of transition from current model to a new structure, and (4) availability and ease of training personnel to fit the new model. The key driving forces include: (1) future organizational structure of a DOD space element, (2) military-civilian collaboration in space operations, and (3) adversarial military operations in space. The aforementioned key factors and forces provide a good foundation for comparison and qualification of all proposed scenarios. Additionally, "predetermined elements" and "critical uncertainties" were identified to provide structural confines for the scenario development, as directed by Schwartz's book. [5] For the purposes of this research, the predetermined element was that DOD involvement in space would continue to increase. Primary uncertainties involved the organization of DOD space assets and thus how it would be supported medically.

In support of the research methodology, four separate scenarios were proposed and investigated, allowing for a reasonable recommendation to arise from the analysis. Research in this field is relatively lacking considering the current absence of manned space missions directed by the DOD. Structures for medical support are in place to support astronauts within NASA; however, if the military intends to increase its operations in space with the aim to project military power into the domain, then NASA's mission as outlined by the National Aeronautics and Space Act is in opposition to what would be the military's mission in the domain.[6] Therefore, it became imperative to research the appropriate structure of medical support that will provide adequate medical coverage for military astronauts when the DOD begins projecting human assets into space.

The four scenarios include: (1) the current NASA structure of medical support; (2) expanding the Air Force Medical Service's (AFMS) responsibilities to include manned space missions; (3) the development of a medical service separate from Army, Air Force, and Navy services; (4) establishing a hybrid medical support structure solely dedicated to space missions. The feasibility of these four scenarios is dependent upon how the DOD structures its space

assets, earlier mentioned as a key driving force. Currently, DOD space assets are being organized under a newly activated subunified command, United States Space Command (USSPACECOM) directly under United States Strategic Command (USSTRATCOM), slated to become an independent unified combatant command. However, medical support will largely depend upon whether a Space Force is established as a branch equal to the Air Force or structured to fall under its administrative control (ADCON). The latter would resemble the Marine Corps, as it falls under the Department of the Navy, and is the current proposition based on the president's recent space policy directive.[7] There is a strong possibility that a separate Space Force or Space Corps is not established at all, choosing instead to remain as a major command (MAJCOM) only. The scenarios used in this project were built using the overarching organizational framework for DOD space forces to derive the best medical support apparatus for each framework. For instance, the scenario establishing a separate medical service for space operations includes the assumption that a separate Space Force is established, independent from the other branches of the US armed forces. It is important that medical support be decided upon prior to any new shifts in the administrative organization for military space missions because training and equipping of medical assets are dependent upon that administrative structure.

This research acknowledges the importance and effectiveness of NASA's current medical structure but also outlines the need to investigate how medical support will be structured and perpetuated in an age where military space missions continue to become more frequent and robust. As operations in space continue to increase, the operations tempo will depend upon a strong medical apparatus to ensure operations are conducted safely in order to maximize mission effectiveness. To that end, it becomes essential to investigate different possibilities to provide for an optimal model for medical support as the DOD presses toward increasingly complex manned space operations.

Background

"Space . . . the final frontier," as in the television show *Star Trek,* is no longer just a catchphrase to a phenomenal science fiction series but rather a motto that is quickly becoming a reality.[8] As technology evolves to allow for more consistent and safe space travel, it becomes more and more likely that the United States's physical presence in space will evolve as well. That evolution will undoubtedly include manned travel in both short- and long-duration missions. Until now, the US military involvement in space has been limited to projecting and operating satellites that primarily provide resources to mili-

tary branches in other domains such as land, sea, air, and cyberspace. Additionally, US military personnel have been recruited and utilized as astronauts under NASA to further research our collective understanding of this relatively new area of operations. The expansion of US military involvement in space is certain, and as such, it is important to plan for all necessary support structures for this inevitable expansion.

The background section provides insight into the medical complexities inherent in space and enhances an understanding of the current medical support structures that may be adapted for use in military manned missions in space. The Military Health System (MHS), specifically the Air Force Medical Service, and NASA will be the specific organizations highlighted, as they comprise the majority of medical support for current space operations.

Medical Complexities of Space

The space environment requires many medical considerations when planning manned missions. These considerations have been defined, redefined, researched, and planned for through the six decades humans have been traveling into the domain. The engineering feats required to propel humans into space and support them during their mission are astounding and continue to progress. Consequently, medical planning must take into account factors such as the implications of microgravity, radiation exposure, and psychological effects, as well as the spacecraft environment to allow for this continued success in space.[9]

In orbit, astronauts attain a perpetual free-fall state, having been released from the confines of gravity grounding humans on earth. This free-fall state is often referred to as microgravity and can play a pivotal role in medical support. Imagine, for instance, that an astronaut goes into cardiac arrest while on a mission. Now visualize trying to perform chest compressions on that crew member without the aid of gravity. This feat can be mitigated with some forethought but illustrates an imaginable scenario in which microgravity can play a role in providing medical care in space. Additionally, demands on the astronauts' bodies in this state are much less, meaning that they will experience muscle atrophy and skeletal demineralization at much accelerated rates. Although this may seem a minor issue while in the space environment, it has far-reaching implications both during missions and postmission.

Radiation exposure is another important factor in space flight. Ordinarily, while on Earth, humans are largely shielded from excessive cosmic radiation by Earth's geomagnetosphere. However, as humans travel farther into space, the less that geomagnetosphere protects them from the ionizing radiation,

pervasive throughout space. A chronic increase in radiation exposure increases the risk of gene alterations, increases cell aging, and increases the risk of cancer due to chromosomal alteration. Although NASA uses several regulatory measures to reduce astronauts' exposure to cosmic radiation, it remains a significant risk to space travel and will only worsen with longer duration and farther-reaching missions. Again, while such conditions as cancer in otherwise healthy, rigorously screened individuals arising in missions may not be at the forefront of the planners' minds, it exemplifies the importance of dedicated medical support and preparation. Furthermore, strategic level mission planners owe it to those performing the mission to properly prepare and reduce risk to further US objectives and improve mission success.

Psychological effects of space are multifactorial; a large contributor is the isolation inherent in space missions. Astronauts live in close quarters with few crewmates in a dangerous environment with elements much different from life on Earth. One can imagine the difficulties that can arise from such conditions: being far from home and family, stuck in a confined area, and literally floating around with only a few other people to interact. In addition, interpersonal relationships with limited human contact may become strained during the mission, causing yet more psychological difficulty to an already overburdened psyche. These stressors cause emotional and psychological strife on the sufferer as well as prove a significant challenge to human performance during space exploration and potentially detract from mission success.

Finally, because of the deadly nature of the space environment, astronauts are completely dependent on a self-contained reproduction of the earth environment. Space Medicine, *Auerbach's Wilderness Medicine*, states that this environment requires several systems to provide "a breathable atmosphere; water and food supply, [and] hygiene methods, [among] other critical elements."[10] A malfunction of any of these systems could mean catastrophe for any mission. Additionally, the decreased ability to resupply or repair such systems in a timely manner makes them all more critical, with mortal implications should they fail. Though the ship design and its systems are the realm of other specialists, it is important to account medically for system failure because many of these failures could lead to medical complications that must be accounted for prior to mission launch.

The above issues are a small accounting of the important medical complexities in the space environment but provide a background for highlighting the importance of adequate medical support. The overall complex nature of manned missions to space requires a multidisciplinary approach, and although medicine is but one of those disciplines, it is nonetheless very important and requires careful planning for effective mission execution.

Air Force Medical Service Origins and Structure

Origins. Air Force medicine can draw its roots back to the very beginnings of aviation; however, organized aerospace medicine did not formalize until a few years later. After identifying the need for dedicated medical support for aviation, "the US Army appointed Lt Col (Dr.) Theodore C. Lyster as the first chief surgeon, aviation section, of the signal Corps."[11] Dr. Lyster's appointment was in response to unacceptably high rates of flying personnel loss. His initiatives sought to remedy these high losses. Additionally, under his leadership, the flight medicine specialty was born and continues to be an integral part of Air Force medicine. Aerospace medicine continued to develop through World War I and World War II (WWII) as a contingent of the Army Air Corps. Following WWII, with the passing of the National Security Act of 1947, the US Air Force was established.[12] Shortly thereafter, the need for an independent medical service was realized and remedied.

The AFMS was established in 1949 with the issuing of Air Force General Order no. 35 after Maj Gen Malcom Grow, the USAF's Air Surgeon, convinced the US Army and President Truman that the Air Force required a dedicated medical service.[13] The establishment of an independent medical service was to allow for better overall medical care for the newly established Air Force conducting warfare operations in a newer, unique domain. The AFMS has evolved, overseeing medical support missions across the Air Force, to include high altitude flight, high altitude low open parachute jumps, and care for those pilots operating in aircraft with perpetually increasing capabilities. Additionally, members of the AFMS have been called upon to provide medical support for space operations as flight surgeons assigned to NASA.

Structure. The AFMS's leadership chain of command, similar to its Army and Navy counterparts, is unique when compared to other military hierarchies. There exist hierarchies of classic military rank structure and clinical hierarchy when referencing patient care.

For instance, a nurse of higher rank than a physician could never, aside from blatant physician negligence, dictate patient care to that physician regardless of rank. In the same sentiment, a physician cannot disregard orders outside the clinical environment merely because they are given by a nurse or Medical Service Corps officer. This hierarchical dichotomy is important to consider when digesting the AFMS structure.

The Air Force Surgeon General heads the AFMS and is currently the highest-ranking figure in Air Force medicine. The hierarchy descends from there to include a deputy, the ranking enlisted member of the AFMS, and down through the MAJCOM and combatant command (COCOM). Each

MAJCOM and COCOM has several military treatment facilities (MTF) under their command. MTF commanders oversee and direct all clinical and administrative functions within their medical group. The MTF is the primary operating unit within the AFMS, the size and capabilities of which can range anywhere from a small outpatient clinic to a fully functional trauma center. To illustrate this point, a small MTF would have capabilities limited to outpatient clinics such as family medicine, pediatrics, dental, and flight medicine, with no inpatient services. In contrast, Brooke Army Medical Center, the MHS's largest facility with only a level I trauma center, has a complete range of medical specialties, has 483 inpatient beds, sees 80,000 emergency room visits annually, and serves a population of around 240,000 military beneficiaries.[14]

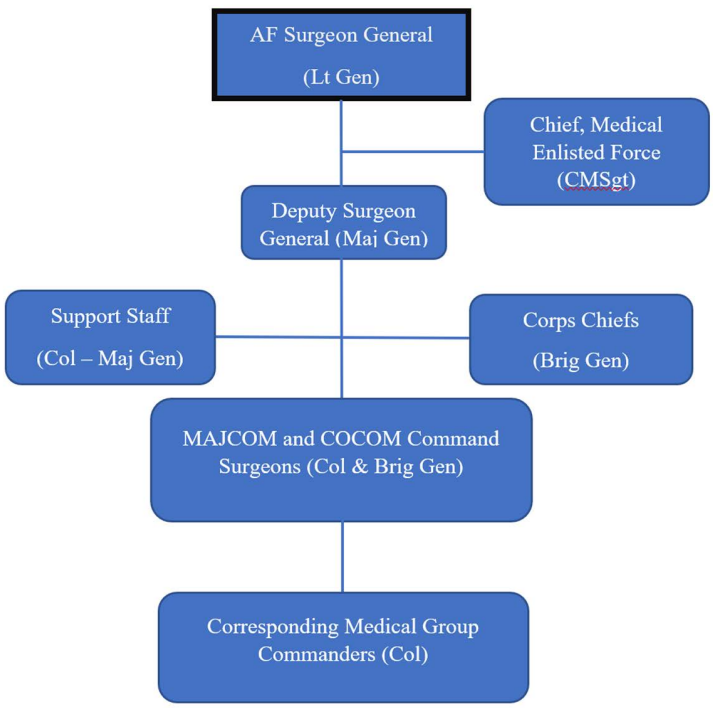

Figure 1. Simplified AFMS leadership structure

The organization amongst the separate branches of the US military has, however, been less than perfectly collaborative. Until recently, Air Force, Army, and Navy medical services have operated somewhat independently of one another with some exceptions found in joint hospitals (i.e., Walter Reed National Military Medical Center, Bethesda, MD, and San Antonio Military Medical

Center). However, the DOD will soon see a shift in oversight when the Defense Health Agency (DHA) takes control of DOD medical assets and policies.[15] The DHA, as outlined in section 702 of the National Defense Authorization Act of 2017, will take charge of enacting "policies, procedures, and [standardizing] clinical and business processes" across all military MTFs. The reorganization of medical services under the DHA will roll out incrementally, having begun in October 2018, and is scheduled to be completed in the fall of 2021. The vision of this transition is to streamline and improve medical care across the Military Health System, while prioritizing medical readiness to improve combat support and ensure operational effectiveness.[16] This transition will become important should the DOD develop a medical service specific to an independent Space Force, as this medical service will also fall under the DHA.

National Aeronautics and Space Agency Medical System Origins and Structure

Origins. NASA's development of its medical systems provides a useful construct for the future US Space Force. NASA medical systems have their origins in medical monitoring during Project Mercury, when Dr. Stanley White, Space Task Group, identified the need for enhanced medical support for manned space missions. Dr. White reasoned that manned space missions would have "fairly considerable requirements for additional medical support in monitoring recovery, and post-flight research and support."[17] Once identified, actions were developed to fulfill the necessity for specialized medical support. Ultimately, the solution for medical support of Project Mercury was to use medical personnel primarily from the DOD medical services. These personnel would support NASA missions with the understanding that they would operate at their normal duty stations but be assigned temporary duty for training and actual operations.

On 30 October 1959, the details of the plan for medical support were proposed and given to the project manager of Project Mercury. This plan outlined the purpose for medical monitors, which would be to preserve the health of the pilot by providing remedial advice during the flight, evaluate the current medical status of the pilot, and correlate spacecraft and physiological data with the mission profile. The monitors would provide medical advice to flight and station directors, and recovery commanders, as appropriate; provide preventive medical care for personnel at remote sites; gather research information in space medicine; and train personnel for support of future space projects. Project Mercury was just the beginning but proved that "man could survive and function as a pilot-engineer-experimenter in the space en-

vironment without undesirable reactions or detriment to normal body functions for periods of as long as 34 hours."[18] From that point on, NASA continued to ensure medical support was hardy enough to support operations in space while maintaining medically sound practices with a robust medical support element.

Structure. Today, medical support at NASA is managed and organized under the Office of the Chief Health and Medical Officer (OCHMO). The current chief health and medical officer (CHMO) is Dr. J. D. Polk, and he is "responsible for the oversight of all health and medical activities at NASA, including medical aspects of all national and international NASA missions involving humans."[19] The CHMO's authority over medical policy is derived from the Health and Medical Technical Authority (HMTA). The technical authority originates from the administrator and is delegated to the CHMO to allow for appropriate direction of the health and medical support for manned missions.[20] The responsibility implemented by the HMTA "provides independent oversight of all health, medical, and space crew/personnel performance matters that either arise in association with the execution of NASA programs or projects or are embedded in NASA programs or projects." The CHMO has a deputy chief health and medical officer to assist in the administrative duties of the OCHMO.[21] The OCHMO is further divided into two divisions: Health and Medical Systems and Medical Policy and Ethics.

The Health and Medical Systems Division is subdivided into the Aerospace Medicine and Occupational Health sections. The Aerospace Medicine Section has primary responsibility "for the organization, planning and development of headquarters oversight for all activities supporting space medicine, from research requirements to deliverables."[22] Specifically, these responsibilities include: "ground-based analogs for space missions, development of vehicles for human and animal access to space, International Space Station activities, planning for future space missions and supporting the execution of the [HMTA]." Oriented under the aerospace section is the cadre of aerospace medicine and space medicine specialists. They are responsible for providing direct care and support before, during, and after NASA's manned space missions. NASA's Occupational Health section supports the NASA "policy to promote and maintain the physical and mental well-being of agency employees in the workplace" and ensures adherence to national standards regarding occupational health and safety. The importance of this insight into the organizational structure of NASA's medical apparatus is that it provides an understanding of how medical support will be oriented in scenarios with specified NASA medical support. It also allows for a basis of comparison with the military medical structures present in the scenarios studied.

The Medical Policy and Ethics Division develops "policies related to the health and medical care of spaceflight and aviation crews" and provides "regulatory oversight of the use of animal and human research subjects in NASA sponsored biomedical research."[23] This oversight is important because of the unique operational environment of space. Medical policy is continuously changing as further research becomes available; the standard of medical care can change based on the results of said research. Since medical research in space is constrained relative to other medical research and because of its unique nature and limited accessibility, it is important that this division implement changes to medical policy based on ethically and medically sound research. Medical support for military manned missions must also seek to expand professional knowledge and implement changes based on best medical practices.

Scenarios

Air Force Medical Service Support (AFMS+)

In this scenario, future military space operations fall under the direction of the Space Corps and are administratively oriented under the US Air Force. Medical support would most likely fall under the direction of the MHS, specifically the AFMS in a scenario where a Space Corps is established. The USAF would have to flex its medical capability to include appropriate support for the operations tempo of manned space missions. They would have to account for medical support during premission, during the mission, and during postmission/recovery phases. Astronauts would also require lifelong medical care following their operations to address long-term medical issues that may have resulted from their mission(s).

Organization. This scenario assumes that manned space missions in the military will be directed by a new branch of the military with ADCON held by the USAF. Organization of the medical support element therefore will be incorporated into the AFMS chain of command. The best way to accomplish this would be to assign an additional Deputy Surgeon General with the sole responsibility of oversight of space medicine assets and personnel. This Deputy Surgeon General for space would oversee all organization training as well as logistical support for a USAF space medicine element. Under the deputy, there would be various support personnel, but MTF commanders would continue to fall under the direction of the USAF Surgeon General. This orientation is similar to the Marine Corps organization with relation to their Navy counterparts. The Navy Bureau of Medicine and Surgery oversees medical care and provision for all Navy and Marine personnel as well as their depen-

dents and other MHS beneficiaries.[24] This structure would be the orientation of the medical support for space under this scenario.

Personnel performing space missions would be assigned to a USAF MTF for their regular care and care for their dependents. However, the mission necessitates dedicated space medicine specialists and support staff. The model most likely to be used would be one like that seen in flight medicine, where a space medicine specialist would be assigned to operational units instead of an MTF. This organization would allow those specialists to maintain consistent oversight in military astronaut medical care and would be present for all phases of the space mission for medical response. Medical care during the mission would also require space medicine physicians to participate in manned missions as astronaut physicians. This would allow for real-time medical response to potential injuries or illness incurred during the mission. The inclusion of a space medicine specialist would be of increased importance during long duration missions. Additionally, to enhance the ability of the space medicine specialist to provide adequate care for space operations, a consultation service would be available to provide expertise for specific disease conditions outside the expertise of the space medicine specialist. The operational medical element for space units could use the Aerospace Medicine Consultation Division, housed at the US Air Force School of Aerospace Medicine, to provide additional input.[25] During missions, these specialists would be required to provide real-time medical consultation to facilitate expeditious treatment of the specific conditions requiring consultative services. This practice of consultation from afar is commonly referred to as telemedicine and is a staple within the medical community.

Training. The training of personnel for this scenario of medical support will require the development of a sustainable collaboration with NASA. As it stands, NASA has the most training and experience in providing medical support for manned space missions. Starting with the missions of Project Mercury and extending to today's international space missions, they have addressed both the ground portion of astronaut care, real-time engagement of in-flight medical scenarios, and postmission medical care.[26] As such, the Space Corps medical contingent can learn a great deal from that experience and expertise.

A good way of streamlining and formalizing this training would be to include the development of a specific space medicine track for aspiring space medicine specialists. Currently, the USAF hosts a residency in aerospace medicine at the US Air Force School of Aerospace Medicine (USAFSAM) at Wright-Patterson Air Force Base.[27] An initiative exists that includes a curriculum as part of that program that directly concentrates on space medicine.[28]

This initiative would be a phenomenal initial push toward developing a formalized pipeline training program for space medicine specialists, which can then serve as the backbone for medical support in this scenario for manned military missions.

A training pipeline will also be necessary to train nurses, medical technicians, and Medical Service Corps personnel so that they are better able to address the specific requirements of the space mission. Particular attention will need to be given to these personnel regarding progression in their respective fields. It would not suffice to have them trained specifically for this unique job only to retain them for a short time. Considering the uniqueness of the space environment for operators, it is important that the USAF develop a sustainable training platform and cadre of medical personnel available to meet the needs of those involved in the manned missions to space.

Equipping. Equipping such a medical support apparatus in this scenario would not be unlike the logistical support for other USAF units. The Space Corps would be a separate organization under the USAF but will acquire funding dedicated to them separate from the USAF. Appropriations would be allotted by Congress on a regular basis and outlined as available to the branch. The funds would further be categorized and allotted by the branch to include medical support among its other responsibilities. The defense budget for FY 2019 includes a request for $50.6 billion, which accounts for several facets that contribute to the health care benefit for around 9.5 million beneficiaries. The defense budget outlines a total monetary amount for the Unified Medical Budget (UMB), which is spread throughout the MHS to cover funding for personnel as well as equipment.[29] Specific allocation of said funding is the responsibility of the director of the Defense Health Agency per the National Defense Authorization Act of 2019.[30] In this scenario, the assumption is that funding for medical programs will continue to proceed in this manner.

NASA Medical Support (NASAmed)

This scenario is akin to the status quo regarding medical support for missions and assumes that an independent military branch for space is not established. Currently, NASA provides the personnel and expertise needed to support manned missions. The idea behind this scenario provides that the use of the NASA medical support structure also allows support for manned missions of purely military objectives. Manned operations into space are currently directed by NASA and they use their medical support structure. Since the retirement of the space shuttle fleet, NASA manned missions have depended upon collaboration with Russia for manned lift capabilities.[31] As such,

it is conceivable that NASA may be able to provide the same support to the DOD should manned missions to space begin for military ends.

Organization. The organization of medical support would look similar to the current medical support supplied by NASA. The CHMO would continue to oversee the medical structure and implementation of medical policy. Military personnel slated for space missions would be vetted for medical acceptability by NASA medical personnel, and NASA would provide their in-mission care. Additionally, medical care for personnel having accomplished missions in space would be provided by medical specialists approved for use by NASA and appropriately trained to support those with experience in space. As in the previous scenario, telemedicine with access to numerous medical specialties would continue to be necessary to provide for a number of possible medical situations that may arise in flight and on extended missions.

There would be reason to expand the Aerospace Medicine Section of the NASA medical structure to provide for an eventual increase in manned missions. Scientific and purely exploratory missions will still be carried out by NASA while those focused on military objectives will be the aims of manned military missions. Additionally, the authority for NASA support of space missions would require modification to allow support for purely military missions in addition to scientific missions. Currently, NASA's mission is aimed at purely peaceful ends, therefore Title 51 (National and Commercial Space Programs) must be modified or replaced to allow support for military missions.[32]

Training. Medical support training by NASA will follow the same structure currently available. NASA uses military and civilian flight surgeons for medical support of missions on the ground and in space. There is a space medicine residency program at the University of Texas Medical Branch (UTMB), which is funded by NASA and could be expanded to suit the needs of additional space medicine specialists. [33] The Residency of Aerospace Medicine at USAFSAM could also be expanded to add additional space medicine specialists for medical support of manned military missions. This new dichotomy of NASA's medical support for both peaceful and military missions would be more easily accomplished if NASA split the medical support into those supporting military missions and those supporting traditional NASA missions. In this structure, knowledge would be shared amongst medical personnel supporting both missions, but military personnel would take responsibility for military missions and civilian personnel for civilian missions. In this structure, the stark contrasts between civilian and military aims would be insulated by the separation of medical support missions.

Equipping. Procurement of medical support supplies and personnel in this scenario would follow along these lines; NASA would continue support

monetarily by appropriations from the federal government and supplemented by a portion of the DOD budget allotted for space mission. NASA has a robust medical structure, which will be the easiest way to transition support of military missions. As the funding for military space operations expands, the budget should provide for additional medical support needed to safely sustain military space missions.

Hybrid Medical Support

This scenario considers a blending of current medical support functions with proposed structures. DOD and NASA medical organizations would be combined to provide medical support for both military and civilian space missions. In military space missions, NASA and DOD medical personnel would be combined into one medical service to support civilian and military missions. The USAF would establish a separate medical service specific to space and incorporate NASA medical personnel in the same hybrid structure. The USAF would assume primary responsibility for both civilian and military space mission medical support with both active duty and reserve medical personnel. Added to this structure would be civilian general schedule (GS) medical personnel who provide medical support for manned space missions. Furthermore, as commercial space companies continue to pursue increased involvement in space, it is likely that they will require and develop their own medical support. This civilian medical capability can also be utilized to provide support for military missions.

Organization. The organization of this hybrid structure would reorient the medical structure for both DOD and NASA space missions under a single authority. If USSPACECOM becomes the primary organization directing operations in space for the DOD, this particular structure may develop to be the primary medical support structure. Under this framework, the hybrid structure would be organized under the DHA; however, it would be independent from any particular service's medical hierarchy. The hybrid structure would fall under a separate directorate for space medicine developed within the DHA structure. As a subsidiary under the DHA, the hybrid scenario would be subject to the authority of the director of the DHA and would pull personnel from all branches of the military to support the mission in space. Just as USSPACECOM includes space assets from the USAF, Army, and Navy, so would medical support draw from those same pools.

In this potential option, the cadre providing medical support would be organized in a specialized group specifically designated to meet the medical needs of the space mission. This structure would combine the medical assets

of NASA and the DOD. NASA would continue its manned missions of exploration and research, while the DOD would perform missions aimed at military objectives. However, the medical support ADCON for both mission sets would fall under a unified focus within the DOD. To allow for oversight and to ensure medical support for one mission set is not unfairly prioritized over another, a civilian medical representative from NASA will be assigned to the DHA. This administrator will function as the NASA CHMO and ensure that NASA's concerns are met to minimize degradation of their mission. The divisions currently under the administration of the CHMO would be combined within the DOD medical support structure for space operations. Hierarchies within those divisions will need to be closely controlled such that GS personnel from NASA and military personnel drawn from the services will be on equal footing.

Training. NASA personnel have traditionally held supremacy in this field thus would provide most of the training for medical personnel. The DOD would best utilize its available assets by drawing from historical precedents and forming a space medicine residency program built around the experience drawn from NASA's exposure to missions in space. The DOD would be remiss to allow so much historical experience to go untapped. This proposed space medicine residency would best be localized in one place, such as USAFSAM, to provide a centralized training platform and pipeline. This pipeline would provide manning of medical support for space operations. The aerospace medicine residency program out of UTMB would also continue its invaluable support with provision from the DHA instead of NASA alone, as has been in the past. In addition to purely didactic training, the residency programs would also include extensive clinical training. As manned missions increase and operational demands for astronauts expand, there will be a more consistent need for medical personnel to address medical issues surrounding space flight. The demand for trained medical personnel and providers will only continue to grow, which will require an expansion of these residency programs. The additional funding can be garnered from commercial space companies provided they are allowed the use of the trained space medicine specialists to further their interests in space.

Equipping. Funding for equipment and personnel for this system would be included in the annual defense budget. Like the rest of those under the control of the DHA, the UMB would be requested and designated.[34] Following passage of the bill, monetary allotment would be doled out based on the needs of each service component, including this proposed medical element. Medical personnel would have access to the use of any DOD or NASA medical facility to provide care to those involved in space missions. Commercial

space companies would have to provide their own facilities; if contracted to support a military mission, they would be required to provide their own facilities and materials.

Funding for the graduate medical education (GME) platforms at UTMB and USAFSAM would also be included in the UMB of the federal budget. Other GME programs fall under education and training within each specific service. Since this scenario includes medical personnel from all three services, the GME availability will be extended to all three services to fill the needs for space medicine. Additionally, a medical education program for nurses and medical technicians will be required. The most likely site for that training is at USAFSAM as they already possess the aeromedical evacuation training pipeline and have experience in training enlisted and officer medical personnel alike. Modification will be required to provide adequate space medicine training appropriate for each level of expertise, but these changes are easily accomplished. Faculty will be drawn from all three services to provide the specialized training and will also continue to provide a clinical function as needed to support manned missions on an as-needed basis. Since this training platform will be tri-service, funding will be decided upon and maintained by DHA.

United States Space Force Is Established (USSFmed)

This final scenario foresees the establishment of a separate branch of the US armed services dedicated to space. The United States Space Force would be equivalent to the Army, Navy, and Air Force and comprise an independent medical service. Space Force MTFs would be established and serve all DOD beneficiaries. The service's medical component would prioritize space missions and the perpetuation of the space medicine specialty but would also provide medical care to dependents and retirees identical to other DOD medical services. USSF medical assets would have sole responsibility for support of space missions in addition to traditional domestic outpatient and inpatient clinical responsibilities, like those present in sister services.

Organization. The USSF Medical Service would be organized just as its sister services are, in that they will fall under a surgeon general for readiness and operational support functions. They would also be responsible to the DHA regarding MTF operations and clinical responsibilities to beneficiaries.[35] An anonymous Air Force Space Command (AFSPC) administrator opined that if the USSF was established, NASA would be included in the new structure.[36] However, this opinion is directly contested by Dr. Polk. He contends that even with the establishment of the USSF, "NASA would not cease

to exist nor would it ever fall under the military command structure." His reasoning for this statement is that the missions for NASA and the DOD in space would be completely different. He further illustrated his point by saying that he "sincerely doubts that a military Space Command would care about water ice on Io or Europa."[37] For the sake of the scenario, a compromise between these two competing professional opinions will be struck. The USSF will indeed absorb NASA assets and missions and continue to perpetuate NASA-oriented exploration and research missions. What was previously NASA would now become a division for research and exploration. This would satisfy the continuation of NASA mission sets while simultaneously providing for military space missions under a consolidated administrative structure. In this scenario, NASA missions would benefit from the increased relative budget while also assisting DOD operations with valuable research and exploratory findings.

Training. USSFmed would follow the same lines in training as GME programs do in its sister services. Using the USAF example as a model, USSF would establish the projected needs for specialties in the service and would publish a list of available GME training slots. Medical students from the Uniformed Services University of the Health Sciences (USUHS) and those training under the Health Professions Scholarship Program (HPSP) at civilian institutions would apply for residency training spots according to their preference. As opposed to the hybrid scenario, more than just Space Medicine GME training will be available. These specialties include everything from family medicine to surgical subspecialties. Once applications are submitted, residency program directors decide on their desired candidates and meet at a Joint Service GME Selection Board (JSGMESB).[38] The JSGMESB will then notify individual applicants of their selection or deferral for training. The only difference between the USSF and other services is that USSF will have a monopoly on GME for space medicine. Since the Space Force will be the only service involved in space operations, it goes without saying that the USSF would possess the only training slots for aspiring space medicine specialists. The active duty training site would continue to be USAFSAM, but civilian deferred training would also be available at UTMB or any other location with a space medicine residency program. Space medicine residency graduates would then be used to staff clinical sites specifically designated for space medicine. They would also be eligible to apply for the DOD astronaut program to become mission specialists able to provide medical care during manned missions.

Equipping. Funding for the USSFmed scenario would follow similar lines to those seen in previous DOD-oriented scenarios. The fiscal year government budget would outline the UMB, which would then be parceled to each of the

armed services for use in medical services. DHA personnel would assign funding based on the needs of each service and the overall beneficiary population. Immediate construction of separate medical facilities would be curtailed by providing facilities for the USSF from existing sister service MTFs. For instance, AFSPC is currently based out of Peterson Air Force Base, Colorado, and that region already includes MTFs at Peterson, Fort Carson, and the USAF Academy. One of these sites could be designated as a USSF MTF and assets allocated for the new service to reappropriate the facility and its capabilities. MTF staffing would be consistent with previous staffing with the exception that the USSF would provide the medical personnel from its own ranks.

The DHA also uses a market system to shore up shortfalls in specific MTFs by using the capabilities of other military MTFs in the area. These "multiservice markets are geographic areas where at least two medical hospitals or clinics from different services have overlapping service areas."[39] Multiservice markets will be a huge boon to the USSF Medical Service in the fledgling period of its establishment. They will ensure that all USSF beneficiaries obtain optimal medical care using the established medical support structures of other services. Eventually these multiservice markets will likely be consolidated to improve cost efficiency, but they will be an important mitigator of access to care issues as the new service is established.

Scenario Comparison

With the four scenarios developed and explained, it now becomes important to compare those scenarios and make projections about the future of space medicine. The scenarios were developed in an attempt to predict how medical support will be structured considering uncertain future developments in the DOD orientation of space assets. This uncertainty is the reason that organizational structure is used as the primary driving force. The remaining two identified drivers of civil-military collaboration and adversarial operations in space will contribute to the evolution of US military posture and its ability to operate in space. This evolution will not occur immediately but rather will proceed with time, tempered by advances in technology and a dynamic geopolitical environment. For this reason, the scenarios will be compared in two phases: (1) near term (1–10 years), and (2) a more distant future (50+ years). Transposing scenarios in these situations will improve the validity of the anticipated medical support sight picture. During the comparison discussion the AFMS+, NASAmed, Hybrid, and USSFmed scenarios will be assessed for feasibility based on the key factors of effective medical care, presumed cost, ease of establishment, and training availability.

Near Term (1–10 Years)

The near-term outlook will be dependent on how the US Congress decides to handle the proposed formation of an independent military branch for space. In a memo issued to the Secretary of Defense on 18 December 2018, President Trump directed the formation of the USSPACECOM. This combatant command will act to unify joint space operations under one directorate.[40] However, this is likely only the first step in the president's desire to push toward the creation of an independent Space Force.[41] The development of an independent force, for the time being, does not look promising considering bipartisan congressional concerns regarding the cost of establishing a new service.[42] In response, the president has shifted from his original stance and is now supporting a space-specific sixth branch of the military under the USAF.[43]

It is most likely that the USSPACECOM will continue to be the primary command under which DOD space operations will proceed. This is not an unreasonable organization for the US currently, as the military's primary foray into space involves projection and management of unmanned DOD assets in the domain. As soon as manned military missions are proposed they will require a strong medical support component. In this phase, the most probable applicable scenarios include the NASAmed and Hybrid models. The NASAmed scenario would be the easiest to implement considering it is nearest to current practices. With NASA filling its traditional role in medical support, their assets would be able to fulfill the needs of early manned DOD space missions quite readily. A more robust training track for space medicine specialists would be ideal as this would provide for a larger pool of qualified medical support. With an increase in medical personnel trained by active duty DOD medical providers, NASA could easily flex its medical coverage for the increase in mission burden. Additionally, the financial burden for support would fall on the DOD, saving the much smaller NASA budget to support its other missions. As their medical support is already proven efficacious and adequate, that primary key factor is fulfilled by this scenario in this near-term phase.

The Hybrid scenario, although comprising many similar components, would be an increasingly more difficult proposition, organizationally and administratively. This scenario would see a combination of the current NASA medical support organization and a newly vitalized DOD Space Medicine contingency. Adequate and efficacious care would be maintained, as NASA medical personnel will be available to provide their insights into the best medical practices for astronauts. The cost burden could, however, be significantly more than the NASAmed scenario. Hybrid would require reorganization of NASA medical support under DHA; thereby the DOD would assume

the responsibility of budgetary support for those personnel and their equipment. Additionally, the DOD would assume the burden of funding a more robust space medicine pipeline to include increased availability and access to residency training for aspiring physicians. All that aside, this scenario would be the more transformative of the two. Also, if contingency planners project a progressive increase in DOD manned missions, this scenario would pave the road to a support structure that can be modified to fit future needs of the military. The initiation of this scenario would also have some issues in integrating NASA medical personnel into the DOD organization. This may be seamless, but a potential exists for NASA to harbor some consternation due to the drastic change.

Distant Future (50+ years)

US military involvement in space will continue to expand. Eventually, assuming manned missions become normal operations, the need for medical support for those operations will likewise grow. In this environment, the AFMS+ and USSFmed scenarios are the most likely options for medical support. Eventually, as with the USAF after WWII, a need for a separate service will be realized and established. As with the NASAmed scenario in the near-term phase, AFMS+ will prove easiest to implement in the event that a Space Force under the USAF is established. There is no doubt that effective medical care could be provided in this model, as in the distant future, additional research and refinement of space medicine will be available. With a cadre of space medicine specialists and other support personnel, AFMS+ would see efficacious medical care provided to manned space operations at a decreased cost when compared to USSFmed. The ease of transition to this model also favors AFMS+ over the USSFmed option as the AFMS is an established entity and would require only few modifications.

The USSFmed scenario would assume that an independent and separate service is created. This organization overall would increase costs, not to mention the cost of establishing a completely separate medical service. Where USSFmed has an advantage over AFMS+ is that it would encourage growth in the domain as opposed to stifling expansion. The concern in establishing a space service that is a subsidiary of the USAF is that USAF's determined needs will perhaps take precedence over those of a Space Force. If the US Space Force and affiliated medical service are established, then that service is limited in scope only by their own administration and budget. This is not to say that stifled growth and siphoned budgets are assured consequences of organizing under the USAF, but rather to identify that there will be competing interests.

Results

Results of the scenario comparison are largely based on a litany of contributing factors, all of which would be impossible to account for without knowing the future of DOD objectives and capabilities in space. For the purposes of this project, four key factors were presented for comparison of these scenarios in their temporal phases. As garnered from the above comparisons section, these key factors and their implications can place one scenario more likely than another. Below is a chart outlining the results of these comparisons.

Table 1. Scenario comparison results

		Factors			
Phase	Scenario	Cost	Training	Ease of Establishment	Growth Potential
Near	NASAmed	↔	↑	↑↑	↔
	Hybrid	↑	↑↑	↓	↑
Far	AFMS+	↑	↑	↑	↔
	USSFmed	↑↑	↑↑	↓	↑↑

The near future phases are represented with scenario comparisons shown by the arrows for each scenario and each contributing factor; for example, cost, training, ease of establishment, and growth potential. As represented, the Hybrid and USSFmed scenarios are primarily hindered by these factors. However, their potential for growth and therefore adaptability outshines their competitors. True preference of one scenario over another purely based on this chart is not feasible. Although, it appears that NASAmed and AFMS+ enjoy a healthy lead in preference on their counterparts, this chart does not take into account the weight assigned to the contributing factors. Assigning weights in this project would be outside the scope of its applicability, but knowing to anticipate weighted factors deems each scenario possible. Therefore, the results of this report act to provide a foray into the discussion of medical support for space missions as opposed to determining a clearly superior scenario.

Each of these scenarios possesses merits that would contribute to superior medical care for military operators in space. Preference of one scenario over the others will most certainly depend on the status of military capabilities and objectives in space. As such, these scenarios, though important to consider now, will likely evolve to fit the needs of whatever platform is used to project US military might into this new area of responsibility.

Conclusion

This research sought to answer the question of how best to organize, train, and equip medical support to meet the NSS objective of advancing space as a security domain.[44] To answer this question, four scenarios were developed using the scenario planning methodology outlined by Peter Schwartz.[45] Key driving forces and factors were derived to help develop appropriate scenarios for comparison. The four scenarios that resulted (AFMS+, NASAmed, Hybrid, and USSFmed) were then compared based on two temporal phases (near term and far future). It was important to note that early on in the research, it became evident that the medical support structures best suited for DOD space missions would depend on how DOD space assets and personnel will be organized. Therefore, a scenario such as the USSFmed would be much less feasible without also having established a US Space Force. Additionally, upon reaching the comparison phase of this research, it was all too evident that the four scenarios were less feasible without a given timeline or temporal reference for application. Once these parameters were realized and introduced, comparisons amongst scenarios became much more plausible.

The four scenarios, within the confines of their temporal parameters, were compared based on the criteria of cost, training requirements, ease of establishment, and growth potential. This project realizes the ambiguity of using a qualitative means to compare the scenarios (as seen in table 1), but with this project being a future projection, hard numbers were impossible to derive. Presumption was required in order to establish appropriate comparisons amongst the scenarios. Assumptions were required to mitigate the uncertain variable of how the larger military space forces will be organized.

The recommendations to follow will not point to a single superior scenario but rather to elements of the scenarios that are required for growth and eventual realization of an effective and robust medical support apparatus for manned space missions. It is important that this structure be flexible to account for technological advancements that are rapidly seeing the possibility of more complex and frequent missions to space. Unfortunately, no one can predict the future with absolute certainty. However, by planning contingencies and using scenarios to project and account for future changes the DOD can investigate courses of action to prepare for coming developments. By using this method of administrative war gaming, this research successfully illustrates several important points to consider when planning for medical support of DOD space operations.

Recommendation

First and foremost, there is a definitive need to develop a formalized pipeline within the DOD for space medicine specialists. As mentioned in all scenarios, training medical personnel to meet the needs of manned space missions is essential to ensure perpetual and reliable medical support for a foreseeable escalation in said missions. An important step for the USAF to take toward that end would be to develop a residency program dedicated to space medicine. The current residency in aerospace medicine would be an adequate starting platform to develop this program. As DOD-directed manned space mission are initiated, a greater number of qualified medical personnel will be required, and thus by having a pipeline established the DOD can ensure that operations are not hindered or delayed due to the lack of medical support personnel. The program at UTMB is also a good resource for personnel training. A proposed program at USAFSAM would benefit greatly from a collaboration with the current program at UTMB to develop an appropriate curriculum and program structure. A partnership with NASA will also be essential to provide clinical experience for aspiring space medicine specialists.

Second, in the short term of DOD space missions, NASA is best suited to provide medical support. It possesses the experience and training necessary to be immediately applicable to DOD space missions. Since Project Mercury, NASA has been providing medical care for astronauts and compiling and applying medical research to improve the care for astronauts before, during, and after space missions. It is properly equipped to meet the need of early DOD space missions and will provide a solid foundation for military medical support going forward.

Third, manned missions, especially long duration missions, are best supported from a medical standpoint with a medical specialist as a part of the crew. Telemedicine from the ground will provide little if no crew member can reliably act on the advice provided. Telemedicine will remain an important asset but is of little utility without a medical specialist on board if more advanced medical interventions are required. By having a physician as a crew member, the astronauts will have better access to medical care during missions and will likely feel safer and more comfortable performing their duties knowing that they have direct medical support. Should the DOD and NASA develop a moon base to help project missions to Mars and elsewhere, medical personnel and equipment will be required to maintain a presence on the base. The specific medical complexities and implications impacting the level of support required on such a base are outside the scope of this research. The

research and testing necessary are substantial and will take several years to refine following this publication.

Finally, organizational flexibility and adaptability will be paramount in the early and sustainment phases of medical support of space missions. Although NASA provides a fantastic foundation upon which to build future support structures, as expeditions into space progress, changes in medical support will require adaptation to meet arising needs. It would be inappropriate to develop a medical support structure for DOD space operations that is incapable of the degree of malleability necessary to effectively support the dynamic nature of these operations. After all, America's Soldiers, Sailors, Airmen, and Marines are courageous, selfless, and sacrificing and therefore deserving of the highest level of support possible. This must also extend to America's spacefaring forces, so that we can "boldly go where no man has gone before."[46]

Notes

(All notes appear in shortened form. For full details, see the appropriate entry in the bibliography.)

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Abbreviations

ADCON	administrative control
AFMS	Air Force Medical Service
AFSPC	Air Force Space Command
CHMO	chief health and medical officer
COCOM	combatant command
DHA	Defense Health Agency
DOD	Department of Defense
EM	emergency medicine
FST	forward surgical team
GME	graduate medical education
GS	general schedule
HMTA	Health and Medical Technical Authority
HPSP	Health Professions Scholarship Program
JSGMESB	Joint Service Graduate Medical Education Selection Board
MAJCOM	major command
MHS	Military Health System
MTF	military treatment facility
NASA	National Aeronautics and Space Administration
OCHMO	Office of the Chief Health and Medical Officer
SOF	special operations force
SOST	special operations surgical team
UMB	Unified Medical Budget
USAFSAM	USAF School of Aerospace Medicine
USSF	United States Space Force
USSPACECOM	United States Space Command
USSTRATCOM	United States Strategic Command
USUHS	Uniformed Services University of the Health Science
UTMB	University of Texas Medical Branch
WWII	World War II

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