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Research article

Multifactorial Considerations for the Neurocognitive Aspects of Military Operations in Space

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Abstract

Addressing the physical and psychological realities of the operational theatre and arming those serving in mission command and control roles with sound tenets of national and international security, have always been essential to military professionalism. As humanity ventures further into space for productive endeavors, the ethical considerations surrounding military space operations will become increasingly complex, and ever more necessary. We propose and argue that military space ethics would commendably pursue ambitious programs that jointly target global security, international stability, and space habitability. The unique environment of space demands a cogent and prudent ethical framework prepared for the expeditionary nature of all missions, civilian and military, aiming at cultivating the vast rewards of space investment. Integrating principles of military ethics and cosmopolitan ethics within a structural-functional framework would permit responsible strategies that safeguard national security together with global well-being.

Space Force: Military Mission and Ethical Considerations

Gen. Chance Saltzman, commanding the United States Space Force, recently reinforced how this service is indeed a military branch tasked with securing United States (US) dominance and ensuring theatre control. That mission includes the achievement of "space superiority," which must "think of space as a warfighting domain" in a manner that encompasses both kinetic and non-kinetic capabilities to disrupt, degrade, and, if necessary, destroy adversaries' military systems in space. Toward these ends, Gen. Saltzman urged Space Force guardians to "embrace their role as warfighters" consistent with the "warfighting ethos" as advocated by Secretary of War Pete Hegseth. Gen. Saltzman emphasized that Space Force personnel must consider and enact their role as frontline units and take all steps necessary to foster and sustain military readiness [1]. The ethical aspects of such operations are important to define and better understand collective and individual factors that can contribute to ethically sound performance of deployed personnel in military space operations. A common theme of good governance is already emerging, from the ministration of personnel performance in a challenging environment to the management of a regulated space jurisdiction and the reinforcement of multi-national security imperatives.

The militarization of space is a clear and present reality. Space-based assets play a pivotal role in communication, navigation, surveillance, and missile defense systems; several nations have developed military doctrines explicitly focused on securing their interests beyond Earth [2]. Szocik has referred to space as a "new moral ecology" given the challenges of that environment and the exigencies and contingencies of human interactions and conduct [3]. There are ample grounds to substantiate this assertion (for example, vide infra) which next raise questions about how military forces should responsibly conduct operations in space. There has never been a necessary incompatibility between theater superiority and ethical superiority. What principles should guide the sound operations of military personnel and govern space-based technologies for national security purposes? Military ethics, grounded in Just War Theory (viz.- justification for warfare, jus ad bellum) and just conduct in war (jus in bello), emphasizes precepts of legitimate authority, just cause, proportionality, and discrimination [4]. Principles of military professionalism and ethics provide an extendible framework for evaluating the morality of military activity in space.

New factors are surely at work given the novelty of that space environment. In the space theatre of operations, determining legitimate authority is complicated by the lack of centralized governance. While somewhat older treaties, such as the 1967 Outer Space Treaty [5] claim that space is the "province of all mankind," the issue of what constitutes justifiable defensive enforcement conducted in such an open domain remains ambiguous. It is clear that military operations in space must be justified by national defense prerogatives, as well as by international agreements intended to preserve peace in space. But the supposition of space as a non-bellicose domain is at least anachronistic, surely myopic, if not wholly moot. Many nations' eyes have turned skywards. Gen. Saltzman's direction and directives to the Space Force acknowledge and engage its role as a military cadre, so preparations for discourse and debate about military space operations both preventative and defensive, as well as offensive should weaponized engagements commence. With national military doctrine incorporating ethical guidelines specific to the spectrum of deterrent, defensive, and offensive space operations, we recommend that the scope of this ethics should be proportional to the globe-spanning dimensions of space itself. The vastness of just the local cosmos in Earth proximity lends a cosmopolitan perspective to survey its wide-open potential. Broadening horizons that beckon human expansions throughout history have provoked internation cooperations and creative reconsidering and/or reconstructing of ethical regulations. Thus, it was that needed principles of national and international law were drawn up centuries ago during that early modern "age of exploration" by ship, caravan, and settlement. Principles still prove their utility through adaptability to novel circumstances. Humans are now looking around and down from a higher vantage point in the cosmos. Ethics can be similarly expeditionary and exploratory no less than space operations and mission objectives. Established military ethics in conjunction with ethical cosmopolitanism-here mentioned in

its basic ethical sense of world-spanning and nation-joining-broadens the effective range for the national influence of space superiority in more ways than just the projection of force. The projection of compelling missions that further common objectives of humanity allows military operations in space-those of any nation pursuing peace and prosperity-to comport with planetary progress.

In light of this conjunction of military and cosmopolitan ethics, there is a timely opportunity to advance ambitious programs for global security, international stability, and space habitability. The militarization of space would have never been a justifiable end in itself, merely for the sake of demonstratable threat posturing. Protecting legitimate space interests and vulnerable ground assets assumes the ethical high ground as well as the superior vantage point. The military mission for space can navigate the delicate balance of maintaining space as a domain of stable global security and international cooperation. There will regrettably be nations willing to risk the destabilization of that security by incurring asset and capabilities escalation that undermine stable cooperation, in attempt(s) to achieve dimensional leverage, if not openly hegemonic power. The healthier alternative that looks to attaining and sustaining a balanced posture favorable to all nations takes a view that entails finding space to be a place for investment in protective deterrence and productive deployments, in the hopes of lowering the necessity for confrontational options.

Space Force Missions: Meriting Healthy Responsibility for Those Maintaining the Peace

The world is already familiar with terrestrial military deployments providing security for trade routes, shipping lanes, sensitive regions, and vulnerable populations, often with international consultation and coordination. Ethical frameworks for deterrence operations in space should similarly prioritize diplomatic measures, confidence-building initiatives, and international agreements that deter escalation of kinetic engagement. An enterprise of deterrence must also entail parameters and processes of governance and retributive response. Space must be a lawful and law-abiding place to the benefit of all sharing interests and investments there. Principles of good governance and just proportionality mandate that military responsiveness stays commensurate with the threat faced and/or damage incurred, and should minimize harm to civilian populations and resources. It is true to say that the dual-use nature of orbital lanes and space infrastructures, where civilian and military assets and functions overlap, complicates any calculus [6]. Yet that very fact of shared opportunity and risk only elevates the justification for appropriate governance measures favorable to all peaceful endeavors.

Space is truly vast, but just the local Earth-Moon sphere can get crowded in its own way at hyper-velocity speeds. For example, disabling space-based hardware such as a satellite for purportedly military reasons could disrupt civilian communication, navigation, and/or other electronic services, which in turn incur significant economic impact. The habitability and usability of low-earth orbits and higher orbits can be rapidly degraded, an impact viewable as a non-kinetic or quasi-kinetic engagement, as well as an issue of grave ethico-legal and political concerns and reaction(s). Swift retribution could be just as unhealthy, unwise, and counter-productive. Given the planet's large dependency on space now and into the future, concerns become even more delicate, and complications multiply should any such actions harm more than just finances and properties to the point of endangering human health and life either in space or on Earth. Building national and multi-national consensus on what constitutes viable deterrence operations in space requires the development of norms that reflect prudent exercise of the military mission, and appreciation of cosmopolitan ideals, values, and stances.

Relative global transparency in the scope and tenor of military-and civilian-space operations can help to mitigate risks of misunderstandings, tension, and potential conflicts. Regular communication, data-sharing agreements, and pre-mission notifications can foster trust among spacefaring nations, aligning with both the Just War military ethical construct of jus contra bellum (i.e., justified use of military engagement to prevent warfare, viz.- deterrence operations), and a cosmopolitan ethical aim of global stability and cooperation [7]. Toward such goals, the United Nations Committee on the Peaceful Uses of Outer Space [8] provides an important step toward establishing a forum wherein states can negotiate guidelines for responsible conduct of space operations. This is surely necessary, yet we believe that an even more proactive stance is presently prudent, with an enormous productive payoff.

Military operations and the technologies employed in their articulation, as the tradition of military diplomacy knows well, can simultaneously be secretly classified and yet overtly impressive, and those deployed in space are no different. That workable deterrence requires the establishment of consensus oversight protocols that explicitly define the nature, extent and constraints of military operations, and the technologies and techniques that can be responsibly employed in space**.** Here, consideration of both the military ethos and cosmopolitan ethics comes to the fore in reciprocal partnership in the service of good governance. That just governance reinforces a perspective on space as a global common worth peaceably defending, where the military actions of one state can have profound implications for all. From this standpoint, military operations in space should be defined both by national security concerns and planetary investment interests. (A parallel to the deterrence of nuclear weapons regulated by treaties could not go unnoticed by a grateful planet.)

The Space Force Guardian as Responsible Agent: Idiosyncratic Influences upon Collective Capability

Space Force guardians who are extra-terrestrially deployed will serve as the responsible military agents for the execution of manned operations in theatre. We have pointed out in the preceding section how ambitious programs for global security, international stability, and space habitability will lend the military presence in space enormous credibility and good will. Habitability should not be an afterthought to corps effectiveness as space becomes second home temporarily or semi-permanently for next generations. Military space medicine has a value intrinsic to military preparedness and an immense worth for translational knowledge benefiting health for everyone. It is increasingly important to understand the effects that missions in theatre, no matter how short-term they are plotted on paper, may have on personnel who are journeying there. Physical and cognitive well-being are foundational to missional capabilities. Idiosyncratic factors and effects, especially those of unanticipated origins, can impact decisions and behaviors that are essential to the appropriate conduct of military space operations. The extra-terrestrial theatre entails several factors that can affect personnel performance, inclusive of environmental variables (e.g.- reduced gravity, radiation), compromised communication with command hierarchies, unit isolation. The burdens of responsibility borne by the conduct of "a few" (viz.- those engaged in space) that can significantly affect the many (e.g.- other forces in space, as well as terrestrial assets, and populations).

Thus, we opine that a critical component of any such discourse must be consideration of how aspects inherent to the environs of space create conditions, settings, circumstances, and contingencies able to influence individual and collective decision and behaviors of ethical leadership along with sound command and control of military operations. Of focal concern are the adaptability of human physiology and cognition. [9,10] Human physiologic functioning under the conditions of space has been the subject of considerable investigation since 1960s. [11] More recently, medical and psychological research conducted aboard the International Space Station (ISS) has been especially helpful for furthering understanding of how human capabilities-and limitations-can be affected in the environment and circumstances of protracted space operations. The currently planned Artemis missions (as successor to the Apollo missions) involve collaboration between NASA and other nation's space agencies. Larger crews aboard Lunar Gateway and lunar surface stations will afford ample opportunities to more granularly study the factors influencing successful human performance in space (inclusive of extraterrestrial mission capabilities).

Recognized conditions such as microgravity and weightlessness, air composition and pressure, noise distraction, temperature flux, and ambient radiation, are inherent factors that require protective and mitigating. [12] These factors impact known vulnerabilities of the human cardiovascular, neurological, musculo-skeletal, and immunological systems to extended periods in the space environment. [13-15] Among these environmental factor's attendant with space travel, radiation is viewed as a pressing issue. Space radiation differs from that at the Earth's surface, having a prevalence of high-energy protons and nuclei components that originate from solar particle events or galactic cosmic rays. Solar particle events have an energy spectrum and power able to disrupt cellular and genetic mechanisms, increasing risks of carcinogenesis [16], and lead to acute radiation syndromes, which can impair physiology and impair neuro-cognitive function [17].

Microgravity can negatively impact blood flow, and blood pooling can occur both peripherally and centrally, whereby vasostatic effects can cause changes to visual and auditory processing [18]. As well, circulatory changes in the central nervous system can contribute to changes in cognitive function and emotional states [19]. As demonstrated by astronautic experience aboard the International Space Station, cognitive changes include decremented dexterity, coordination, motion tracking, dual tasking, short term memory, and precision task performance [20,21]. Alterations to diurnal rhythms have produced prolonged sleep cycle disruptions [22,23]. which further exacerbate measurable deficiencies in cognitive and neurobehavioral functioning [24,25].

Cognitive Capacities: Space Psychology and Neuroscience

Space operations involve unavoidable conditions shown to affect the brain in numerous ways [26-28]. Neurological and neurocognitive assessment(s) and interventions must become ever more important. Space neuropsychology has been a fast growing, interdisciplinary research domain for decades [29]. Studies have focused upon those ways that prolonged space operations can affect neural and psychological aspects of human function to impact mission performance [30]. As de la Torre and Lopez-Rios have stated, there will likely be heretofore unencountered variables and effects, which may need to be regarded as "new normals" of human neuro-cognitive function in defined space environments [31].

One of the more pressing concerns is focused upon those ways that the unique isolation of space can influence physiological and mental health [32]. Known neuropsychological impacts of isolation include heightened sensitivity to (other) stressors, reduced emotive control, alterations in patterns of decision-making, and general cognitive decline [33-35]. which have been correlated to observed changes in the formation of synaptic connectivity as well as hippocampal volume and function [36]. And while it is imprudent to imply directional (neural-to-cognitive/emotive; or cognitive/emotive-to-neural) causality of such observed changes, an enhanced focus upon neuropsycho-behavioral health and resilience is being regarded as essential to ensuring operational capability and missional success [37,38].

Toward such goals, space medicine studies have relied on investigations of terrestrial environments that are similar to space travel, such as those ecologies present on submarines, Antarctic research stations [39] and simulated space habitats [40-42]. In this latter regard, recent experiments such as the Crew Health and Performance Exploration Analog (CHAPEA)-1 mission and the Biosphere 2 project have revealed a number of social-psychological factors that can affect human performance in space. The CHAPEA-1 mission, begun in 2023, is the first of a series of year-long Mars surface analog missions conducted in the 1,700-square-foot habitat located in Houston, Texas. By replicating conditions of living and working on Mars, a small crew (i.e., of four) are iteratively assessed for responses to physical, psychological, and operational challenges representative of a long-term space/extra-terrestrial planetary mission.

Simulated objectives include habitat maintenance, resource utilization, and extravehicular activities using VR and physical mock-ups. Data are collected on crew health and performance metrics, including reported stress levels, sleep patterns, diet and exercise regimens, and physiological measures and behavioral evaluations of group dynamics, conflict resolution, and individual coping strategies under prolonged isolation and resource-constrained conditions are performed. Similarly, since 2019, the Human Exploration Research Analog (HERA) project operates a controlled habitat designed for four-person crew simulations involving isolation and confinement, typically lasting 45 days. Physiological and psychological effects of confinement and isolation are evaluated on the Spaceflight Multitasking Cognitive and Crew Performance protocol; weekly questionnaires are administered to assess emotional and mental well-being; and biweekly blood samples are taken to analyze serum cortisol levels (a valid biomarker of neuroendocrine responses to stress).

Leadership, Morale, and Socio-Moral Dimensions of Space Missions

As a current RAND report notes, the iterative and multinational reliance on space will incur a more congested, competitive, contested, and potentially combative environment, which will be "increasingly susceptible to a variety of risks"[43] inclusive of those physical and cognitive aspects of military/combat settings that have heretofore not been encountered, or investigated, in space. Future Space Force missions, like NASA missions prior, inevitably entail rigorous selection and training for those personnel chosen to crew space missions. Consistent with that sound preparedness, the paucity of studies addressing factors affecting individual cognitive functions should be remedied. Personnel must maintain peak abilities with perceiving, processing, and responding to socio-moral command and control dimensions of military space operations. Good morale and good morality are mentally connected. Studies have consistently shown that individuals in isolated and confined environments, such as those experienced during space missions or analog simulations, report a gradual decline in their perception of their social support. This is significant because perceived support is a critical factor in maintaining psychological integrity and behavioral resilience of deployed force personnel. Evidence highlights that strong, positive relationships among crew members contribute to support, shared problem-solving, and maintaining morale. However, tension or conflicts within the crew could exacerbate feelings of isolation and disrupt effective communication and teamwork. Support from the mission organization or management will be playing a crucial role. A decline in perceived support from these sources, due to limited communication, inadequate resources, or perceived detachment, may erode trust and undermine the crew's confidence in their ability to resolve mission-critical issues. This emphasizes the need for organizations to maintain proactive, transparent, and responsive engagement with the crew, ensuring they feel supported throughout as many phases and aspects of the mission/operation as possible. This latter consideration is essential, as extended space missions, particularly those with significant communication delays (e.g. multi-month or year missions), could foster command disconnection, and may prompt feelings of alienation, particularly during critical or emotionally challenging phases of operations. Human socio-moral capacity-namely, the multifaceted ability to interact socially and make moral decisions-won't be a factor untethered to human health and mission capabilities in space. It is not merely rhetorical to postulate how a combination of personal characteristics and interpersonal tensions might affect psychological responses to stress, and to what extent the uniquity of the space environment (under defense-focal space operational mission settings and exigencies) may foster cognitive and behavioral patterns that influence team structure, leadership, and mission priorities [43-45]. Considerable discussion of the bioethical issues inherent to space missions have focused upon whether, and to what extent space personnel can, and/or should be offered/provided particular biological modifications (i.e., enablements, enhancements) to either (1) protect against negative effects of the aforementioned environmental factors that affect physiological/cognitive capabilities, and/or (2) optimize performance on key tasks. Recent studies of the bioethics of space exploration explicitly addresses these possibilities for civilian/non-military space personnel, and they often compare ethical aspects to certain military contexts, but only rarely are there explicit concerns for armed forces' personnel in military space operations. Nevertheless, discussion of bio-modifications for space inhabitants will remain a worthwhile and realistic exercise, as such interventions are also being considered for terrestrial military personnel. A few scholars such as Konrad Szocik have entertained the notion of moral bioenhancement for those in space, yet neuroscientific practicalities [46] cannot be encouraging, given 1) the absence of a targetable "cerebral network of moral cognition" for such interventions;2) the heterogeneity of neuro-cognitive processes involved in what would be considered to be moral decision-making; and3) the way that morality has more to do with group dynamics and social contexts than personal perspectives [47,48]. That social dimension for healthy morale and morality re-targets preventative and interventional measures towards the overall institutional oversight of proper and professional conduct, such as the military ethos. Practical forms of moral enhancement, such as measures to enhance mental resilience and reinforce group commitment, need not be neurologically invasive. We do acknowledge and advocate the importance of deepened understanding-and the utility and merit of engaging-individual and group neurocognitive processes in learning, decision-making, and performance in education, and training of personnel to appreciate and act in accordance with ethical precepts. We have said already that ethics can be exploratory in pace with the experimental nature of space habitation. New neurotechnologies enabling personalized monitoring and early detection of psychological issues prior to any behavioral disruption can be anticipated. Obviously, crew members will not experience space missions and the effect(s) of prolonged habitation in the same way to the same degrees. Individual neurobiological, cognitive-psychological, and psycho-social differences in leadership and conduct styles-and in interpersonal relationships-can evidence considerable variability. Therefore, tailoring personnel evaluation/assessment, crew selection, training, and ongoing monitoring will thus be neuroethical in importance to support military missions, in any/all theatres of operation and especially the expanding frontier of space. Neuroscientific and technological tools and methods will prove to be of value in these endeavors, and their worth and applications should be further explored, for both physiological health and mental healthiness. Military missions conducted in concert with medical advances for the whole human and for human groups would prove exemplary for all those similarly journeying into space hoping to make it more hospitable and habitable.

Conclusion

As humanity ventures further into space for productive endeavors, the ethical considerations surrounding military space operations will become increasingly complex, and ever more necessary. Integrating principles of military ethics and cosmopolitan ethics within a structural-functional framework would permit responsible strategies that safeguard national security together with global well-being. The unique environment of space demands a cogent and prudent ethical framework prepared for the expeditionary nature of all missions, civilian and military, aiming at cultivating the vast rewards of space investment. Space knows no natural barriers or permanent fences; what occurs anywhere soon affects most anything anywhere, including a reach down to the ground. That spaciousness and interrelatedness transcends terrestrial boundaries while unifying commonalities among all peoples. Commercial enterprises, for their part, will be looking for technoscientific partnerships and translational technologies among whoever proves to be more capable and peaceable in space. To that end, military space operations would

commendably pursue ambitious programs targeting global security, international stability, and space habitability together in a unified agenda on behalf of all humanity. A commitment to ethical stewardship, and ethically responsible consideration of the factors that affect neurocognitive and physiological aspects of ethical command and control decisions and behaviors of those deployed in the space environment must guide military activities in this emerging domain.

Disclaimer

The views and opinions expressed in this essay are those of the authors, and do not necessarily represent those of the United States government, Department of Defense, the National Defense University, or those institutions and organizations that support the authors' work.

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