PARASTRONAUT FEASIBILITY FOUNDATIONAL RESEARCH STUDY

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Potomac Institute for Policy Studies
901 N. Stuart Street, Suite 1200
Arlington, VA 22203
www.potomacinstitute.org
Telephone: 703.525.0770; Fax: 703.525.0299

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EXECUTIVE SUMMARY

National Aeronautics and Space Administration's (NASA) Office of the Chief Health Medical Officer (OCHMO) engaged the Potomac Institute for Policy Studies to conduct a study on the feasibility of sending parastronauts (i.e., an individual with a lower leg deficiency, short stature, and/or leg length difference) to space. This research included documentation of relevant US Department of Defense (DoD) case studies, assessment of policy issues related to parastronauts, and identification of potential hurdles and considerations (i.e., technical, operational, medical) for parastronaut inclusion.

In the past decade, advances in technology and medical care have dramatically improved access for those with disabilities. Primarily, technology has shifted societal approaches toward valuing diversity and inclusivity regarding individuals with disabilities. While no individual with a known physical disability has flown in space to date, feasibility is becoming less of a factor. Already commercial space ventures are beginning to lessen disqualification criteria to ensure broad access to their space missions.

This necessitates a forward-thinking mentality regarding astronaut medical standards and criteria that should evolve with growing technological capabilities and medical advances. Expanding astronaut selection to include parastronauts could lead to new innovations and benefits to the safety and performance of future crews. These innovations might also translate to improvements for terrestrial health and medical care. For NASA and international space agencies to maintain their cutting-edge technological status, the feasibility of parastronaut inclusion and relevant policy implications must be investigated. This must include a comprehensive understanding of the overall mission risk, which is comprised of both human systems risks and engineering risks.

This report reflects the Potomac Institute's efforts toward identifying relevant policy issues and considerations regarding parastronauts, investigating the measures that must be taken to enable otherwise qualified professionals to serve as crew members on a safe and beneficial space mission.

From Potomac Institute research, informational interviews with key subject matter experts and stakeholders, literature review, the following two overarching findings were identified regarding parastronaut feasibility:

1. **NASA's current medical standards disqualify parastronauts.**
    a. The US DoD currently has more inclusive policies regarding amputees than NASA's Astronaut Corp that vary across the branches of services.
    b. Increasing human access to space is being pursued in private industry and non-profit organizations. Commercial space flight policies currently envision greater inclusivity using baseline standards for crew members to meet (rather than more rigorous medical disqualification criteria) and leveraging technological advances.
2. **Inclusion of parastronauts, while considered technologically feasible, will require additional research and development (R&D) and alignment of human systems and engineering risk assessment.**
    a. Successful inclusion warrants a comprehensive understanding of overall mission risk comprised of both engineering and human systems risks, particularly in the areas of emergency procedures and spacesuit and spacecraft design.
    b. Some of the proposed solutions will require explicit experiments in space to validate safety and performance.
    c. Shifting societal views and policies have led to an emergence in research, and development of technological and medical advances, related to individuals with disabilities.

From these findings, the Potomac Institute study team identified two corresponding recommendations regarding the inclusion of parastronauts into the Astronaut Corps:

1. **Revise medical standards and baseline fitness qualifications to reflect recent advances in science.**
    a. Evaluate current medical standards and astronaut selection criteria at the Agency level to ensure they are appropriate and modernized.
    b. Consider disabilities beyond the three physical disabilities (i.e., lower leg deficiency, short stature, and/or leg length difference) explored in this study.
2. **Employ experimental design utilizing technological and medical advances and relevant partnerships to inform overall parastronaut risk assessment and develop risk reduction pathways.**
    a. Determine the true costs (i.e., time, funding, resources) associated with parastronaut inclusion.
    b. Utilize parabolic flights to demonstrate parastronaut proof-of-principle.
    c. Leverage partnerships with industry to connect government with commercial and non-government organizations already pursuing research, development, technology, and engineering advances related to flying individuals with disabilities.

INTRODUCTION

Since its inception in 1958, the National Aeronautics and Space Administration (NASA) has pushed the boundaries of human space exploration. NASA's current mission is to "drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality and stewardship of Earth," which focuses on five core values – safety, integrity, teamwork, excellence, and inclusion.[1] To successfully achieve these mission objectives, NASA recognizes that it must create a diverse[2] and inclusive[3] environment that brings together the best and brightest minds.[4] As such, NASA must attract, utilize, and retain the best talent to develop creative and innovative solutions to address the unique challenges of spaceflight and exploration.

The Astronaut Selection Process outlines astronaut selection criteria to include education, work experience, and medical qualifications that must be met to apply to the Astronaut Candidate Program. Due to current space hardware limitations and the inherent risks of human spaceflight (i.e., radiation, isolation and confinement, distance from Earth, reduced gravity, and a hostile/closed environment)[5], astronaut selection adheres to stringent physical, psychological, cognitive, and technical requirements. Among these current requirements is the ability to pass the NASA long-duration space flight astronaut physical.[6] This physical includes specific medical, physical, and mental requirements designed within space hardware parameters and current operational procedures of human spaceflight to ensure the health and safety of the crew and the success of the mission. In addition, astronaut candidates must meet current anthropometric requirements of both the spacecraft and the spacesuit.[7]

NASA's Astronaut Corps is cultivating an astronaut selection pool that pulls candidates from a wide array of backgrounds; however, all astronaut candidates must meet these above physical and mental health requirements. Only applicants deemed "medically qualified" by the Astronaut Selection Committee are referred to final evaluation and possible astronaut selection.[8] These current requirements exclude certain categories of individuals with disabilities.[9]

In line with ongoing inclusivity efforts, NASA is exploring the prospect of allowing "parastronauts," individuals with certain physical disabilities (i.e., lower leg deficiencies, short stature, or leg length differences), to apply for astronaut selection, marking progress toward increased inclusion for human spaceflight. NASA recognizes the importance and added benefits of "[opening] doors to talent previously left untapped," as recently remarked by NASA Administrator Bill Nelson.[10] Greater inclusivity is tied to increased innovation, more effective decision-making, and in fostering creativity and problem solving.[11] Integrating parastronauts into human spaceflight programs could initiate advances in the development of novel technology and medicine (for both space and terrestrial application) and enhance safety measures.

Re-assessment of the current requirements for astronauts will be required to ensure safety and continued performance of all crew members – with or without disabilities. Advancements in terrestrial technology and medical care are providing capabilities previously thought impossible, such as enabling individuals following an injury or condition resulting in disability to physically perform at an equivalent level prior to injury (in some cases, even better). These advances should be taken into consideration when developing standards and quantifying risk for the Astronaut Corps to allow the best and most qualified individuals to contribute to and advance human space exploration. However, to allow individuals with disabilities into the Astronaut Corps while maintaining the health and performance of the crew, the feasibility of such a task must be investigated.

NASA CONSIDERATIONS

NASA's Office of the Chief Health Medical Officer (OCHMO) is responsible for ensuring the policy and oversight of all health and medical activities at NASA. With this comes development of Agency-level health and medical policy, procedural requirements, and human spaceflight standards for use by programs and projects across the Agency.[12]

Currently, OCHMO is identifying and evaluating technical, medical, operational, and policy considerations regarding the integration of parastronauts into NASA's human spaceflight program. These considerations are vital to understanding the possibility of parastronauts and ensuring the health and safety of both the parastronaut(s) and the crew.

Recently, NASA announced a new effort, *Mission Equity*, to assess programs, procurements, grants, and policies across the Agency, and to explore the barriers and challenges that underrepresented and underserved communities face in Agency procurement, contract, and grant opportunities.[13] While not tied to astronaut selection, *Mission Equity* highlight's the Agency's drive for increased inclusion and diversity. OCHMO can help aid this mission through assessing increased astronaut inclusivity.

EUROPEAN SPACE AGENCY ASTRONAUT SELECTION CHANGE

In February 2021, the European Space Agency (ESA) launched a pilot project, the Parastronaut Feasibility Project, to open its Astronaut Selection Process to include individuals with certain physical disabilities.[14] As such, ESA is beginning to assess the inclusion of an individual with a physical disability while still ensuring that the mission is safe and productive. Astronauts must still qualify based on psychological, cognitive, technical, and professional requirements, but might have a physical disability that would normally prevent them from being selected due to current criteria. These requirements might be imposed by current space hardware but would otherwise not preclude them from the application and selection process.

The ESA assessed each type of disability using knowledge of the prerequisites to the tasks of a safe and beneficial space mission, and assigned each to one of three categories:

1. Green: the kind and degree of disability can be compatible with the task.

2. Yellow: the kind and degree of disability could become fully compatible with the task with some adjustments, modifications, or innovations.

3. Red: the kind and degree of disability was not or not safely compatible with the task.

PARASTRONAUT CRITERIA

The following disabilities have been identified by the ESA and are being considered in the Parastronaut Feasibility Project:

a. persons who have a lower-limb deficiency (e.g., due to amputation or congenital limb deficiency) including single- or double-foot deficiency through ankle, or single- or double-leg deficiency below the knee (BK);

b. persons who have a leg length difference (missing or shortened limbs at birth or as a result of trauma); or

c. persons of short stature (<130 cm; 4’ 3”).

DEFINING A PARASTRONAUT

In line with ESA’s Parastronaut Feasibility Study, this report focuses on parastronauts defined as an individual with one or more of three specific physical disabilities (i.e., lower leg deficiency, leg length difference, or short stature). Each physical disability is described in further detailed in this section.

Lower Leg Deficiency

A lower leg deficiency occurs when part or all of the limb are not present, resulting in asymmetry of the limbs.[15] The ESA specifically notes their scope as loss below the knee or below the ankle.[16] The two types of limb deficiencies are congenital (limb discrepancies present at birth) and acquired (limb discrepancies acquired after a major injury or health crisis).[17] More than two million Americans are currently living with limb loss in the US.[18] By 2050, it is estimated that over 3.5 million Americans will be living with amputations, with roughly 40% of those individuals being under the age of 65.[19]

This term can also be used to define loss of function in the lower limb such as drop foot gait which is a disability common after traumatic injury or in elderly populations.[20] This definition may be explored in future studies, but the current definition and scope will limit to anatomical loss.

Leg Length Difference

Leg length differences occur when the length of both legs differs, which can vary depending on severity. Studies on leg length differences have estimated that up to 40 – 70% of the population has some form of leg length difference, though cases of significant enough length discrepancy to warrant classification as a physical disability are much less common – the American Association of Orthopaedic Surgeons suggests that this occurs when the difference in leg lengths is greater than or equal to 3.5–4% (usually 4 cm or 1 2/3 in) or significant enough to cause a limp.[21]

Short Stature

Short stature is commonly defined as a condition in which an individual's height is two standard deviations below average for their age and sex.[22] In medical terminology, this is known as dwarfism.[23] Short stature could be idiopathic (i.e., with no known cause), an inherited/genetic trait, or a symptom of an underlying disorder (e.g., hormone deficiency, malabsorption disorders like celiac disease, Cushing's disease).[24] Little People of America (LPA) defines dwarfism as a condition usually resulting in an adult height of 4′ 10″ or shorter; typical heights range from 2′ 8″ to 4′ 8″ with the average height being 4′ 0″.[25] An estimated 30,000 individuals in the US have some form of dwarfism.[26] About 1 in 15,000 to 1 in 40,000 individuals in the US has achondroplasia, the most common form of dwarfism causing short stature.[27]

NASA's existing height requirement requires astronauts to stand between 5′ 2″ and 6′ 3″.[28] As such, an individual of short stature as defined by this report and ESA parastronaut guidelines would currently be disqualified from NASA's astronaut selection.

STUDY APPROACH

The Potomac Institute conducted a Parastronaut Feasibility Study to better understand the policy and relevant considerations (e.g., technical, operational, and medical) associated with parastronauts.

Policy Survey

The Institute surveyed relevant policies set by organizations including the US government (USG), the US military, and commercial companies regarding the three specific physical disabilities. These policies were documented through robust internal research and discussions with subject matter experts (SMEs) and leaders in the field.

Case Studies

Twenty-three case studies were documented through research and discussions with SMEs and leaders in the field. Specifically, case studies pertaining to the physical disabilities outlined in the ESA Selection Change were explored; however, the scope was also expanded to those examples that significantly challenged the status quo, achieved exceptional accomplishments, and/or directly related to the mission of NASA and Human Space Flight (e.g., commercial spaceflight). The case studies documented herein are not an exhaustive list of service members with the listed physical disabilities but represent exemplar cases to better inform and benchmark parastronaut policies.

Considerations and Hurdles

Technical, operational, and medical considerations were identified including potential hurdles to parastronaut inclusion. It is imperative that integration of parastronauts into the Astronaut Corps maintains the continued safety and usefulness of the mission. Therefore, understanding these outlined components will inform the feasibility and overall cost (e.g., time, funding, resources) required to realistically integrate parastronauts into a spaceflight mission. The study team identified relevant hurdles that might present significant challenges or barriers for integration of parastronauts, such as technological roadblocks (e.g., alterations or redesign of spacesuits), operational practices and procedures (e.g., training), emergency protocols, functional testing, and astronaut qualification (e.g., flight certification).

Relevant policies across government (federal and DoD), commercial (including private space flight entities), and other organizations are detailed to provide context and benchmarking related to potential parastronaut policies.

US FEDERAL POLICIES

US federal policy has increased diversity and inclusion of underrepresented groups over the past decades, particularly for individuals with disabilities. Section 504 of the Rehabilitation Act of 1973 (Rehab Act), as amended, states "No otherwise qualified individual with a disability in the United States, as defined in Section 705(20) of this title, shall, solely by reason of her or his disability, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program[29] or activity receiving Federal financial assistance or under any program or activity conducted by any Executive agency or by the United States Postal Service."[30]

In accordance with the Rehab Act,[31] the 1992 amendments to the Rehab Act,[32] the Americans with Disabilities Act of 1990 (ADA),[33] the Americans with Disabilities Act Amendments Act of 2008 (ADAAA),[34] and the Equal Employment Opportunity Commission's (EEOC) Enforcement Guidance on "Reasonable Accommodation and Undue Hardship Under the Americans with Disabilities Act," federally-funded agencies are required to provide "reasonable accommodation" for known physical and/or mental limitations of otherwise qualified employees unless it can be demonstrated that such accommodation(s) would impose an undue hardship on the organization.[35]

A "reasonable accommodation"is a change in the work environment and/or operating procedures that enables a qualified individual with a known disability to have equal employment opportunities. However, employers are not required to make accommodations that would result in "undue hardship," that is, accommodations that would result in significant difficulty and/or expense. Undue hardship can be unduly costly, extensive, substantial, and/or disruptive.[36] It considers the nature and net cost of the accommodation; overall financial resources of the employer; number of employees; number, type, and location of the employer's facilities; and the employer's operation.[37] In a situation where accommodations would fundamentally alter the nature of a program, service, or activity, the ADA does not require changes.[38]

Historically, undue hardship defenses in court have focused on the impact the accommodation would have on the employer at a particular time. This has translated to a multi-faceted inquiry into "(1) financial cost; (2) additional administrative burdens; (3) complexity of implementation; and (4) any negative impact that the accommodation may have on the operation of the business, including the effect of the accommodation on the employer's workforce," with the court ultimately ruling on if the accommodation constitutes undue hardship.[39]

Further executive orders have stressed the importance of federal employment and representation of individuals with disabilities, including Executive Order 13548 of July 26, 2010: "Increasing Federal Employment of Individuals with Disabilities."[40] This order specifically required each federal agency to "designate a senior-level agency official to be accountable for enhancing employment opportunities for individuals with disabilities and individuals with targeted disabilities within the agency" and allowed certain funds to be used for reasonable accommodations.[41]

Disability Protections and the Department of Defense

While discrimination in DoD civilian positions is governed by the Rehab Act and ADA, this policy does not apply to "uniformed members of the military departments."[42] As such, the US Armed Forces are exempt from the ADA, as is NASA regarding astronaut selection. However, the DoD considers diversity to be a strategic imperative, both critical to mission readiness and accomplishment as well as a leadership requirement.[43] The DoD recognizes that as the demographics of the US continue to evolve, the DoD must position itself to capitalize on the broad range of talent across the country by attracting, recruiting, developing, and retaining the best and brightest. For the DoD, greater inclusivity of diverse backgrounds translates to greater connection to the citizens it serves.

GENERAL DEPARTMENT OF DEFENSE STANDARDS

The DoD has published "Medical Standards for Appointment, Enlistment, or Induction into the Military Service" and "Medical Standards for Military Service; Retention" (DoD-I 6130.03-V1 and -V2 respectively), which give information about disqualifying disabilities. Each branch of the DoD currently restricts anyone with the three physical disabilities the ESA is currently considering in their feasibility study from joining in an active military duty role. While individuals with missing limbs may not enlist in the military, those who experience amputations while serving have the option to remain in a combat or non-combat role depending on their degree of injury and the imposed functional limitations. Each branch has specific standards by which it evaluates a limb loss injury and the individual's subsequent "fitness for duty" as detailed in subsequent sections. Below are specific policies for return to active or active reserve duty for representative branches of the military. While disqualification policies are specific for each branch, no person may return to service without passing required medical and fitness tests.

Medical Evaluation Processing Station

The USG has set up a standardized location for all recruits to be medically evaluated prior to service. The Medical Evaluation Processing Station (MEPS) conducts all these screenings and is run by the United States Military Entrance Processing Command (USMEPCOM) Medical Qualification Program.[44] USMEPCOM Regulation 40-1 provides guidance on this process. Every individual is to complete a detailed pre-screening form before attending their MEPS physical.[45] This form determines whether the individual has a simple pre-screen or complex pre-screen. Complex pre-screens require closer evaluation and additional approvals as detailed below.

Relevant items to this study considered disqualifying that indicate a complex pre-screen include:[46, 47]

- Bone, joint, or other orthopedic deformity
- Loss of finger or toe, or extra finger or toe
- Loss of the ability to fully flex (bend) or fully extend a finger, toe, or other joint
- Impaired use of arms, hands, legs, or feet (any reason)
- Any swollen joint(s)
- Surgery on any joint/bone (including arthroscopy)
- Plate(s), screw(s), rod(s), or pin(s) in any bone
- Any need to use corrective devices such as prosthetic devices, knee brace(s), back support(s), lifts, or orthotics
- Paralysis
- Artificial or replacement body part (eye, bone, palate, hip, knee, joint, leg, arm, etc.)

Other relevant items to this study considered disqualifying in the physical examination by a MEPS practitioner include:[48]

- Heights not listed on Service-specific height/weight chart
- A Body Mass Index (BMI) below 17.5
- Inability to perform any maneuver in the orthopedic/neurological examination (ONE) including range of motion measurements
- Disturbance in balance, pain, or apprehension with any movement required for the ONE
- Deformities of the extremities
- Missing digits, incomplete digits, extra digits, or digit deformities

After examination, the practitioner will determine whether the individual is "qualified or disqualified" for service.[49] Individuals who do not meet standard guidelines typically will be given disqualified status; however, disqualification does not necessarily mean the individual may not serve. There are two types of disqualification: Temporary Disqualification (TD) or Permanent Disqualification (PD).[50] A TD is a condition that "might cause a delay in admission yet doesn't qualify as a permanent decision," while a PD is one "that requires surgery, or will never go away... [and] cannot get undone" but could be corrected or improved.[51] All PD will require a waiver to serve, but TD often do not depending on the service branch. The waive process is detailed later, under *DoD Waiver Process and Return to Combat*.

Lower Leg Deficiencies

According to DoD-I 6130.03-V1, the "current absence of a foot [or hand] or any portion thereof" is disqualifying. There are no explicit references to protheses in the DoD-I 6130.03, as individuals with a prosthesis cannot enlist in military services.[52] Per DoD-I 6130.03-V2, however, individuals who incur limb loss during service may be able to continue to serve. These individuals may not reenlist if their "condition [persists] despite appropriate treatment and [impairs] function to preclude satisfactory performance of required military duties of the Service member's office, grade, rank, or rating," or the individual is not able to safely perform the activities of the service-specific physical fitness testing.[53]

While beyond the scope of this policy survey, it is worth mentioning general DoD policy concerning paraplegia, or the motor and or sensory deficiency in the lower limbs of an individual. This type of paralysis can affect all or portion of the person's torso, legs, feet, urinary, and sexual organs. Etiology of this condition can originate from developmental disorders, vascular, tumor, infectious conditions, or mechanical injury. The American Spinal Injury Association classification describes a "complete" or "incomplete" paraplegia meaning complete loss of function of partial loss of function, respectfully.[54] The DoD disqualifies individuals with paraplegia under Spinal Cord Injuries as individuals with "postural deformities or limitations in motion."[55]

Short Stature

For most military services, the general height requirements are between 58 and 80 inches (4' 10" and 6' 8"). Generally, the military does not accept individuals below 4' 10" into active-duty/combat situations due to operational restrictions (e.g., ejection seat limitations, lack of individually customized equipment). An exception can be seen in the Air Force with their recent changes to their height restrictions as detailed in the below *US Air Force* section.[56]

Leg Length Differences

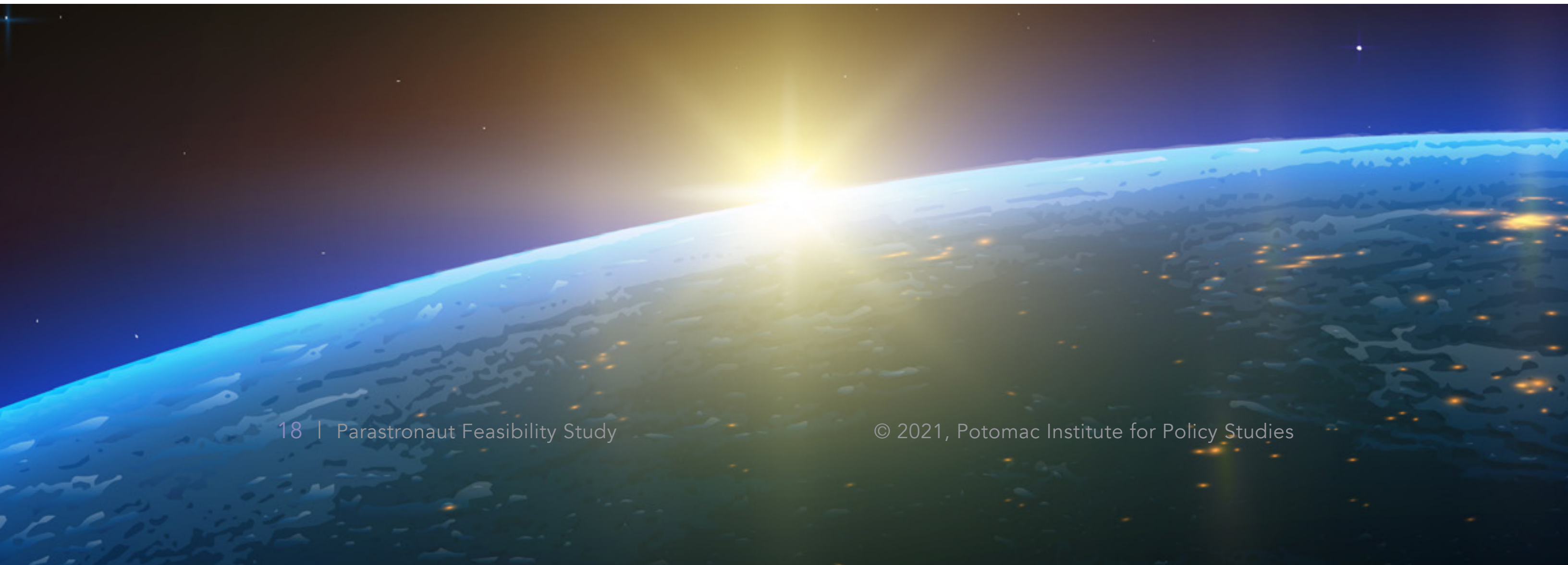
Currently, the military generally does not accept a difference in leg length large enough to cause a limp.[57] The American Association of Orthopaedic Surgeons suggests that this occurs when the difference in leg lengths is greater than or equal to 3.5–4% (usually 4 cm or 1 2/3 in).[58] A 2006 study found that 11.5% of military cadets measured had a leg length difference of >0.5 cm and had no higher rate of injury than other cadets.[59]

SPECIFIC MILITARY POLICIES

Each branch of the US military follows their individual, specific guidelines dictating the policies and regulations concerning physical disabilities and service. These are summarized in Table 1. Each cell indicates the specific service's guidelines for service and is shaded to indicate if an individual with a physical disability as outlined above would qualify for service. Of the three physical disabilities assessed for this study, in general, the US military only allows amputees that have experienced amputation while serving in the military to continue to serve.

Table 1. Summary of specific policies for each branch of the US military for lower leg deficiencies, short stature, and leg length differences. Shading indicates green = parastronaut would qualify for service; yellow = parastronaut would qualify in certain situations/with medical waiver; red = parastronaut would be disqualified based on medical guidelines and not be eligible for a medical waiver.

Service	Short Stature	Lower Leg Deficiencies		Leg Length Differences		
Air Force	58–80 in (non-pilot/enlisted)	Condition incurred prior to serving	Condition incurred during service in the line of duty or during an authorized absence	Difference <3 cm that does not cause a limp or affect the spinal column	Difference >3 cm that does not affect gait or the spinal column	Difference that causes gait alteration or significantly affects the spinal column
	Standing height 64–77 in Sitting height 33–40 in (pilot/enlisted)					
	No minimum requirement (pilot/officer)					
Army	60–80 in (men) 58–80 in (women)					
Navy	57–80 in					
Marines	56–82 in (unofficial)					
Coast Guard	62–77 in (pilots/class 1)					
	60–78 in (non-pilots/classes 2–3)					



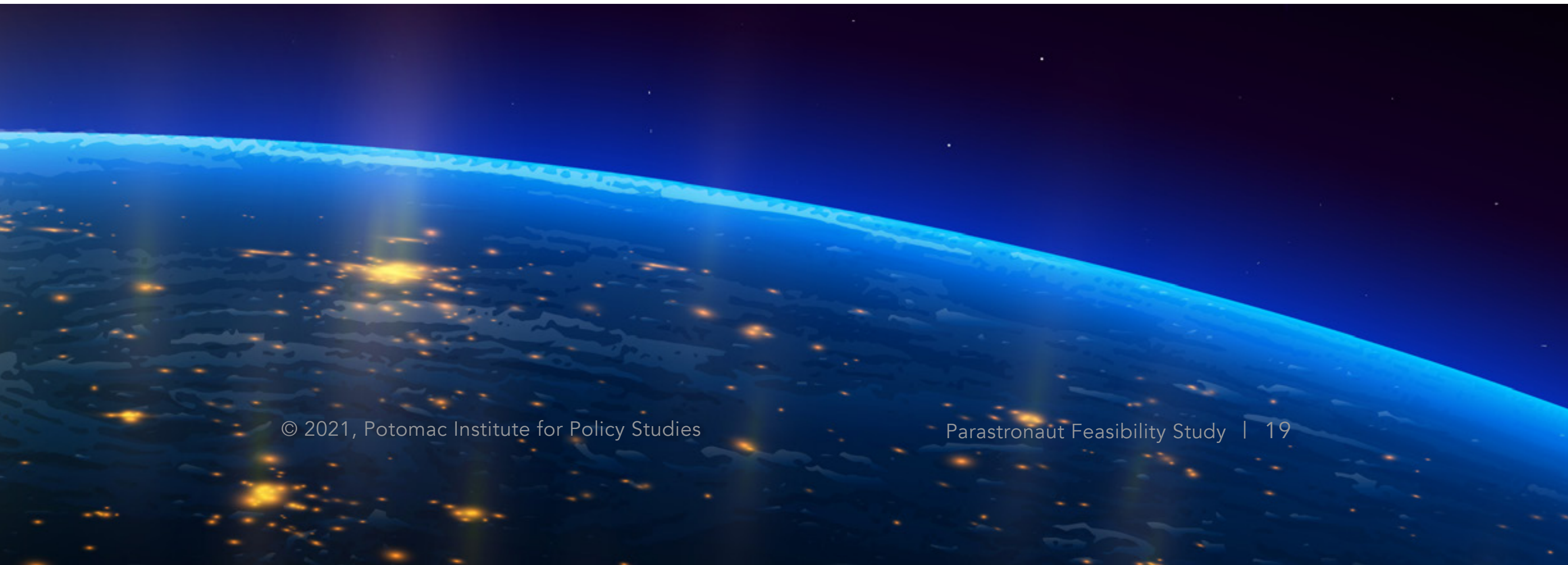
US Army

The US Army adheres to the Continuation on Active/Continuation on Active Reserve (COAD/COAR) Program for guidance on disabilities.[60] The following general requirements must be met for return to active or reserve duty following injury:

- The disability was not caused by misconduct, willful negligence, or unauthorized absence
- The disability is basically stable or of a slow progression
- The soldier is able to work in a military environment without adversely affecting their health, posing a risk to other soldiers, or requiring undue loss of time from duty for medical treatment to remain in the Army
  - Must satisfactorily perform Primary Military Occupational Specialties and Advanced Operations Course as well as activities on Department of the Army Form 3349[61]
- Is not within 12 months of mandatory retirement or retention control point (RCP)
- Is not a retiree recall
- Holds general officer rank

Lower Leg Deficiencies

Currently, only service members who incurred the lower-limb deficiency while serving may remain in service. Individuals with a pre-existing condition have historically been disqualified without waiver opportunity. However, the Army State Reserves in California has enlisted a congenital amputee of the upper limb.[62]



Short Stature

For the Army, height requirements are between 60 and 80 inches (5' and 6' 8") for men and between 58 and 80 inches (4' 10" and 6' 8") for women.[63] There is a possibility to submit a waiver if an individual does not fit these criteria. Waiver denials are, however, final.[64]

Leg Length Differences

The US Army follows the same criteria as the DoD regarding leg length differences.

US Air Force

The US Air Force adheres to Air Force Instruction (AFI) 48-123 standards to inform medical standards and eligibility to serve in the Air Force.[65] Generally, standards are not adjusted for amputees. AFI 36-3212 outlines general provisions for physical conditions, stating "the mere presence of a physical defect or condition does not qualify a member for disability retirement or discharge. The physical defect or conditions must render the member unfit for duty."[66]

According to the AFI 48-123, the following are reasons for disqualification:

- "The individual is precluded from a reasonable fulfillment of the purpose of his or her employment in the military service.
- The individual's health or well-being would be compromised if he or she were to remain in the military service. This includes but is not limited to: dependence on medications or other treatments requiring frequent clinical monitoring, special handling, or severe dietary restrictions.
- The individual's retention in the military service would prejudice the best interests of the government.
- Limitation of mobility or assignment or requiring exemption from any portion of the fitness test for >1 year."[67]

As such, to be considered "waiverable," any disqualifying condition a service member has must meet the following criteria as outlined in Section 6.2 of AFI 48-123:

- "Not pose a risk of sudden incapacitation;
- Pose minimal potential for subtle performance decrement, particularly with regard to the higher senses;

- Be resolved or stable, and expected to remain so under the stresses of the aviation environment;
- If the possibility of progression or recurrence exists, the first symptoms or signs must be easily detectable and not pose a risk to the individual or the safety of others;
- Cannot require exotic tests, regular invasive procedures, or frequent absences to monitor for stability or progression; and
- Must be compatible with the performance of sustained flying operations."[68]

Lower Leg Deficiencies

In the Air Force, lower leg deficiencies are governed by DoD criteria as detailed above. Currently, only service members who incurred the lower-limb deficiency while serving may remain in service.

Short Stature

In the Air Force, general height requirements for service members and Air Force Academy Cadets are between 58 and 80 inches (4′ 10″ and 6′ 8″).[69] For pilots and aircrew, height specifications are more stringent and do vary based on the aircraft. Historically, height restrictions have served as an operational limitation rather than medical; however, the majority of aircraft in the Air Force today can be adjusted to accommodate a wider degree of heights. The Air Force uses anthropometric measurement of specific body parts to determine eligibility for specific aircraft.

Enlisted pilot candidates are required to be between 5′ 4″ and 6′ 5″ standing with a sitting height of 34″ to 40″.[70] As of March 2020, the Air Force removed height requirements for officer pilot candidates. Previously the requirements were the same for both enlisted service members and officers, and any pilot outside the stated range would require a waiver to serve.[71] Maj. Gen. Craig Wills (19th Air Force Commander) noted that the majority of service members below 5′ 4″ had received approval if they had submitted waivers, citing a 95% approval rate if between 5′ 2″ and 5′ 4″.[72] Heights down to 4′ 11″ had been approved in certain circumstances, but the Air Force found that just having the process in place created an unnecessary barrier, especially for female pilots.[73]

Leg Length Differences

The US Air Force follows the same criteria as the DoD regarding leg length differences, though the service member's lower limb must meet the anthropometric measurement requirements of the craft they will utilize.[74]

US Coast Guard

The US Coast Guard explicitly disqualifies "any neurologic disorder or nerve problems including numbness and/or paralysis … amputation, prosthesis, or use of ambulatory devices… [and] injuries, fractures, or recurrent dislocations causing impairment or limitation of motion of any joint," without a medical waiver.[75] Requirements to receive a waiver are determined by desired position.[76] In general, to pass the physical assessment to obtain a waiver, the individual must prove that one:

- "Has no disturbance in the sense of balance;
- Is able, without assistance, to climb up and down vertical ladders and inclined stairs;
- Is able, without assistance, to step over a door sill or coaming;
- Is able to move through a restricted opening of 24-by-24 inches (61-by-61 centimeters);
- Is able to grasp, lift, and manipulate various common shipboard tools, move hands and arms to open and close valve wheels in vertical and horizontal directions, and rotate wrists to turn handles;
- Does not have any impairment or disease that could prevent normal movement and physical activities;
- Is able to stand and walk for extended periods of time;
- Does not have any impairment or disease that could prevent response to a visual or audible alarm; and
- Is capable of normal conversation."[77]

The exam conclusions are valid for 12 months. The Coast Guard may require continued testing and/or restrict duty options even with an accepted waiver. Regardless of waiver status, all individuals must complete the fitness test requirements detailed in Appendix II, Table 4.

Lower Leg Deficiencies

An individual missing a lower limb or any portion thereof would need to proceed through the waiver process. Amputation and the use of prosthetics or ambulatory devices are an automatic disqualifier without a waiver.[78]

Short Stature

Height requirements are between 58 and 80 inches (4′ 10″ and 6′ 8″).[79] Due to operational restrictions (i.e., ejection seat limitations), pilots must be between 62 inches and 77 inches tall.[80] Each aircraft has specific requirements additionally for anthropomorphic measurements (Appendix II, Table 3).

Leg Length Differences

Similar to short stature, the individual's anthropomorphic measurements would need to fall within those outlined in Appendix II, Table 3. They would also need to prove the condition does not cause any disturbance in balance, restrict movement, or make it difficult to walk or stand for long periods of time as outlined in the waiver process.[81]

US Navy

The Navy adheres to the Officer Special Assignments – Reassignment of Disabled Officer (2003) policy for guidelines on disability.[82] The following requirements must be met for reinstatement if they possess a disability qualifying them as traditionally "unfit" for service:

- Amputees
  - Must have prosthetic
  - May not fly
- Other Disability
  - Will be reevaluated
  - Navy Personnel Command will consider each case individually
  - No minimum year requirement

Additionally, the Navy states "medical conditions such as contagious diseases, conditions that limit mobility, geographic placements, or performance [or that are aggravated by required performance] may disqualify you from service."[83] Their Physical Readiness Test includes timed sit-ups, timed push-ups, and a 1.5-mile run.

Lower Leg Deficiencies

Amputees may be reinstated but must use a prosthesis and are restricted from flying. Currently only those service members who experienced limb loss while already serving may continue to serve.

Short Stature

The Navy lists acceptable heights of 57 to 80 inches.[84]

Leg Length Differences

The Navy follows the same criteria as the DoD regarding leg length differences.

US Marine Corps

As part of the Department of the Navy, the Marine Corps follows Navy Policy in accordance with the Rehab Act and ADAAA to provide reasonable accommodation to qualified individuals including "reassignment of a qualified employee with a disability to a vacant position within the agency if the employee is able to perform the essential functions of the identified position, with or without accommodation," as long as the accommodation does not put undue hardship on the Marine Crops.[85] All Marines must complete both the Physical Fitness Test and the Combat Fitness Test requirements outlined in Appendix II, Table 5.

Lower Leg Deficiencies

The US Marine Corps follows the same criteria as the DoD regarding lower leg deficiencies. Currently, only service members who incurred the lower-limb deficiency while serving may remain in service.

Short Stature

The US Marine Corps lists no official height requirements for potential service members, but rather suggests that the requirements are "different for each recruit" and that the individual contact a recruiter to discuss.[86] However, unofficial sources list height requirements of at least 56[87] to 58 inches[88] and at most 80[89] to 82 inches.[90]

Leg Length Differences

The Marine Corps follows the same criteria as the DoD regarding leg length differences.

US Space Force

The US Space Force (USSF) is an important branch of the US military services and a valuable partner for NASA. Currently, however, individuals are unable to directly enlist into USSF; the potential candidate must transfer from active duty in another branch.[91] Therefore, all USSF service members must meet the requirements of another branch. Medical direction and delegation for the USSF is housed within the US Air Force command hierarchy.[92]

To avoid redundancy, the study team will not detail USSF requirements in the same manner as the other branches. It can be assumed that a USSF service member must adhere to one of the sets of requirements listed.

DEPARTMENT OF DEFENSE WAIVER PROCESS AND RETURN TO COMBAT

Every branch has a process by which individuals who are disqualified by the traditional standards can apply for a Medical Waiver exception. There are nuances between every branch's process; however, generally, the individual will apply for the waiver, go through a physical exam conducted by a physician, and then have his or her file reviewed by the branch's medical board for approval or denial. All disqualifications and conditions that require a waiver are determined by the DoD and therefore, are the same for every branch. The ability to approve or deny, however, lies within the branch and is dependent on the needs and requirements of that branch. If the individual is going through this process because of an injury sustained in the line of duty, the evaluation is based on the Integrated Disability Evaluation System (IDES).[93]

Integrated Disability Evaluation System

When a service member develops a condition that may make them "Unfit for Duty," they are referred to the IDES.[94] The IDES was developed in 2009 in an effort to bridge the gap between the DoD Disability Process and the Veteran Affairs (VA) Disability Process.

There are three phases to the IDES: the Medical Evaluation Board Phase (MEB), the Physical Evaluation Board Phase (PEB), and Transition (Figure 1). If the service member is discharged, then there is a fourth phase, Reintegration, which is when the VA finalizes the now-veteran's status. The phases are the same for all branches, although each branch develops its own boards and uses its own reporting authorities. The process can only begin once injury has healed and been rehabilitated and can take an estimated 180-210 days.[95]

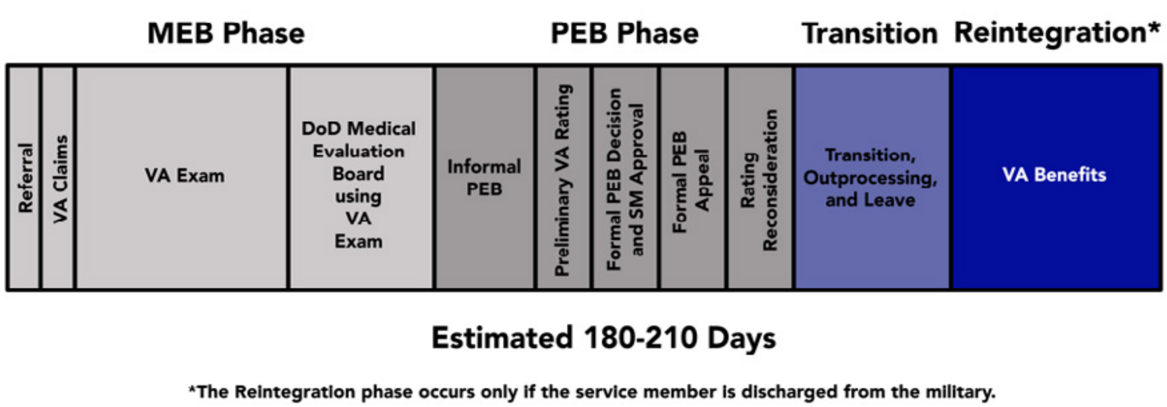


Figure 1. IDES Timeline.[96]

Medical Evaluation Board

The Medical Evaluation Board (MEB) phase of IDES begins when the treating physician determines the service member is unfit for duty due to a condition or does not meet the retention requirements listed in DoD-I 6130.03-V2[97] and will not be fit or will not meet the requirements in one year.[98] This phase mostly consists of evaluation of the condition and gathering information from expert opinions by a board of three physicians, sometimes to include a psychiatrist.[99] The evaluation template for amputees can be found in Appendix III. An evaluation template for General Medical Conditions which would pertain to Leg Length Difference and Short Stature can also be found in Appendix III; however, it is likely that these conditions would exist prior to service and therefore, would not go through this process unless the condition had significantly deteriorated.

This phase is also when Veterans Affairs (VA) is notified of the case and a claim is started. The MEB creates a report on the disability and their evaluation of its condition and effects then submits it to the PEB. Their report and this phase are considered "informal" as there is not decision-making power (regarding reinstatement or discharge) held within either.[100]

Physical Evaluation Board

The Physical Evaluation Board (PEB) phase has two parts: formal and informal. In the informal stage, a PEB reviews the report of the MEB. They will list the condition that they believe to make you unfit and make a recommendation on 1) ability to continue service, and 2) eligibility for disability payment based on the nature of the condition.[101] There are five categories for the recommendation: Return to Service, Limited Assignment Status, Temporary Disability Retirement, Discharge With Severance Pay, or Permanent Retirement.[102] This evaluation is referred to the VA to rate the condition, which determines the commensurate disability pay or severance if applicable. The file is then turned over to the service member and their case manager to review. If the service member agrees with the evaluation, he or she may end the phase, foregoing the formal PEB (FPEB).[103] If the service member disagrees with either the PEB's or the VA's evaluation, a formal hearing is conducted with another PEB.[104] In a court-style hearing the FPEB will either uphold the initial recommendation or amend it.[105] The service member then again has a choice: 1) to accept all recommendations and evaluations, 2) to accept the FPEB evaluation but to contest the VA disability rating, or 3) to contest the decision entirely and send the case to that branch's highest personnel officer.[106] As stated previously, each branch composes their own boards familiar with service requirements for that branch's service members. In all cases each board consists of three experienced officials from the branch.

Transition

In this phase, the decision made by in the PEB phase is enacted. This process can be different in each case but may consist of discharge/separation, reassignment, and/or compensation.

Reintegration

Only individuals that have been discharged from military duty move into Reintegration. In this phase, the VA finalizes the now-veteran's status and disability benefits.

Additional Approval Processes and Accommodations

Anthropomorphic Measurement

The Air Force Academy has a specialized measuring device, utilized across the Air Force in their waiver program and special situations, that measures all limb dimensions and ratios of a candidate including "sitting eye height, buttocks to knee length, and arm span" to determine his or her viability for service or academy admission. Measurements taken by a specially trained team are compared to a master list of vessels in service to see if the individual could safely operate the vessel adequately. It is the only approved device of its kind in the nation.[107] The US Coast Guard and US Army also utilize anthropometric measurement for service member eligibility.[108] However, they do not use the same specialized machine as the US Air Force.

Body Composition Measurements

When an individual is missing a portion of his or her body or is significantly shorter than the average human, traditional measures of body composition may not be accurate – specifically BMI, a ratio of height to weight. Traditionally, requirements are listed by BMI; however, all branches now also list body fat percentages (BF%) as an alternative. This measurement is taken by using skin fold calipers to determine density at standard locations on the body. The Marine Corps also allows individuals to skip this measurement if they achieve a high score on their fitness tests.[109] The Navy uses BMI to determine whether individuals need further screening such as BF% or additional psychological screening for an eating disorder.[110]

On-Duty Accommodations

In general, the soldiers with disabilities are held to the exact same standards as any other soldiers, and are not granted any accommodations. However, the Army allows soldiers requiring prosthetics to bring more luggage weight on deployment.[111]

It is important to note as well that alternate or limited duty may be assigned to individuals with the aforementioned disabilities. This is not accommodation, however, as the individual is serving in a different role rather than serving differently in a role.

Financial Responsibility

The VA provides medically prescribed prosthetic devices to eligible veterans. Loss of limb falls under TRICARE coverage, which includes costs incurred from emergency amputation surgery, hospital stays and care, rehabilitation, psychological and mental well-being, and prosthetic devices.[112] SMEs estimate the average cost of developing a prosthesis can range upwards of $40,000 per device (exclusive of the R&D funding needed to design, develop, and test the device).[113]

In the case of a parastronaut, it is likely the individual would have already recovered from an amputation prior to astronaut selection; however, the question remains if NASA would be financially responsible for providing medical care as well as prosthetic devices should an astronaut experience a traumatic amputation while on mission.

COMMERCIAL AIR AND FLIGHT POLICY

As commercial spaceflight endeavors increase, the standards and policies dictating astronaut requirements will inevitably change. More and more companies are expanding human spaceflight capabilities, including Virgin Galactic, SpaceX, Blue Origin, and Boeing.[114] With an increasing number of private spacegoers and commercial space companies, commercial astronaut requirements are changing rapidly.[115] However, as private astronauts are likely less "hands-on"[116] than those sent on behalf of their country/government and there are added financial incentives of customers willing to pay to fly, requirements are less stringent. Detailed herein are commercial air and flight polices set by the Federal Aviation Administration (FAA) as well as individual private space company policies.

Federal Aviation Administration

The FAA primary focus since its establishment in 1958 is civilian safety of the airways. Due to the burgeoning growth of commercial space flight, the United States forged ahead to organize an agency to include all aspects of space safety for civilians. In 1984, The Office of Commercial Space Transportation was assigned as an agency under the FAA and tasked with regulating private enterprise launches.

The FAA has made its own strides to develop a medical certification process that must be passed for student flyers to be permitted to fly solo.[117] In order to allow qualified applicants the opportunity to train, a limited medical certificate can be issued. This permits training until the applicant is ready to take a medical flight test. For any medical condition, the condition or limitation must not:

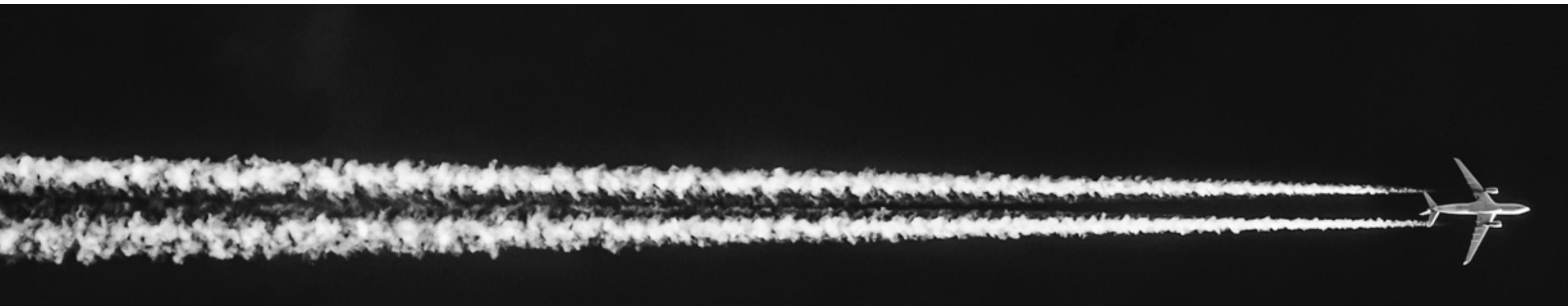
1. "Make the person unable to safely perform the duties or exercise the privileges of the airman certificate applied for or held; or

2. May reasonably be expected, for the maximum duration of the airman medical certificate applied for or held, to make the person unable to perform those duties or exercise those privileges."[118]

Federal Aviation Regulation (FAR) 61.53 focuses on the legality of pilot privileges being exercised when there is a known medical condition that could be disqualifying (including but not limited to the medical conditions listed in Part 67 of the FAR 61.53).[119] It is up to the discretion of the Federal Air Surgeon to issue either an Authorization or Statement of Demonstrated Ability (SODA) with varying conditions for those who would otherwise not meet the standard medical certificate requirements.[120]

Lower Leg Deficiencies

Amputations are considered medical conditions of aeromedical significance.[121] Aeromedical assessments of musculoskeletal functions in persons with an amputation include the five following principles: mobility, strength, dexterity, tendency for sudden change in function, and pain. However, the regulations outlining the assessment process[122] do not consider situations such as "emergency egress."[123]



The FAA Conditions and Course of Action for amputees requires an individual "submit a current status report to include functional status (degree of impairment as measured by strength, range of motion, pain), medications with side effects and all pertinent medical reports" for review.[124] If the applicant has a SODA already issued on the basis of the amputation, a medical certification will be issued. If otherwise, the applicant must await further review of all medical data, in which case the FAA may authorize a special medical flight test.

The protocol for a medical flight test dictates that "When prostheses are used or additional control devices are installed in an aircraft to assist the amputee, those found qualified by special certification procedures will have their certificates limited to require that the device(s) (and, if necessary, even the specific aircraft) must always be used when exercising the privileges of the airman certificate."[125] Additionally, an applicant with a history of musculoskeletal conditions must submit the following if a medical certification is desired: current status report, functional status report, and degree of impairment as measured by strength, range of motion, pain.[126]

Short Stature

According to the FAA Aviation Medical Examiners Guide, "Although there are no medical standards for height, exceptionally short individuals may not be able to effectively reach all flight controls and must fly specially modified aircraft. If required, the FAA will place operational limitations on the pilot certificate."[127]

Leg Length Difference

While the FAA does not have outlined medical requirements for leg length differences in an individual, the Medical Examiners Guide notes that any upper and lower extremity "deformities, either congenital or acquired, or limitation of motion of a major joint, that are sufficient to interfere with the performance of airman duties" require FAA decision following submission of a current status report to include functional status (i.e., degree of impairment as measured by strength, range of motion, and pain).[128]

FAA and Commercial Spaceflight

The FAA has developed recommended medical guidelines for human spaceflight. The FAA recommends that flight crew members undergo a medical evaluation 12 months prior to flight. The Administration notes that "a flight crew member should not fly if they have a medical condition or physiological change (acute or chronic) that would make them unable to perform safety-critical operations," although the FAA leaves this designation up to an examination by a licensed physician board certified in aerospace medicine.[129] The frequency of medical examinations recommended by the FAA is based on the necessity for crew safety as opposed to mission success in the case of NASA.[130]

The FAA recognizes that flying members of the public outside the relatively healthy government astronaut population is new. As such, the FAA recommends space flight participants seek medical consultation prior to flight; however, the FAA has declined to provide performance standards or medical criteria that might limit private space flight participants beyond those required for FAA pilot certification (if applicable).[131]

Commercial Spaceflight Companies

Astronaut requirements of four commercial spaceflight companies are summarized in Table 2. Each company's policies are detailed more below. While the previous sections have depicted relevant policies for each of the three parastronaut cases (i.e., lower leg deficiency, short stature, and leg length differences), the following sections generally summarizes available health and medical policies for each company.

Table 2. Commercial spaceflight requirements by private organization.

Organization	Age (yrs.)	Height and Weight	Other Relevant Requirements
Blue Origin	18	5'10"–6'4" 110–223 lbs.	• Crew must be able to climb the *New Shepard* Launch Tower (equivalent to seven flights of stairs) in under ninety (90) seconds and walk quickly across uneven surfaces
Space X	18	No taller than 6' 6" No greater than 250 lbs.	• Crew must be "physically and psychologically fit for training and Spaceflight" • Goal of crew being FAA certified
Virgin Galactic	• Virgin Galactic has not publicly announced any requirements for potential passengers to meet, but note "[although passengers] will not need to meet the incredibly rigorous levels of fitness required of government space agency astronauts, our in-house Medical Team conducted specially designed Medical Consultations with each Future Astronaut" • Virgin Galactic believes "the majority of individuals with well-controlled medical conditions" will be able to take part		
Boeing	• To date, Boeing plans to use NASA astronauts for crewed missions making their requirements the same as NASA's		
Zero-G	8	• Children under 14 years of age must be accompanied by an adult • All potential passengers must disclose any medical conditions from a list identified by Zero-G and provide a doctor's note if they have any of the listed conditions (full list provided below)	

Blue Origin

Founded in 2000, Blue Origin's main objectives include increasing access to space and finding new energy and material resources. Blue Origin designs and manufactures reusable launch vehicles, propulsion systems, and rocket engines for commercial, civil, national security, and human spaceflight.[132] Another part of Blue Origin's vision encompasses building space colonies with artificial gravity for thousands of humans to one day reside. Blue Origin now boasts having taken the oldest astronaut into space – Ms. Wally Funk. Blue Origin has approximately 3,390 employees and an estimated net worth of $48.7 million.

Individuals wishing to fly on a Blue Origin spacecraft must be "at least either (a) eighteen years of age or (b) the age of majority in their country of residence, whichever is older."[133] Individuals from all over the world are welcome to join the Blue Origin corps as long as they have a valid passport and are able to legally remain in the US for the duration of the flight.[134] Blue Origin lists the following relevant functional requirements for potential astronauts in their Terms and Conditions:

- Be within the following height and weight range: 5′ 0″–6′ 4″and 110–223 lbs;
- Dress themselves in a one-piece, zip-up flight suit;
- Climb the *New Shepard* Launch Tower (equivalent to seven flights of stairs) in under ninety (90) seconds;
- Walk quickly across uneven surfaces, such as a ramp or a deck with occasional steps;
- Fasten and unfasten their own seat harness in under 15 seconds (about as difficult as fastening the seatbelt in an unfamiliar car in the dark);
- Sit strapped into the CC's reclined seat for forty to ninety minutes without getting up, and without access to a bathroom;
- Experience up to three times normal weight (3gs) pushing them into their seat for up to two minutes during powered ascent;
- Experience up to five-and-a-half times their normal weight (5.5gs) pushing the Astronaut into their seat for a few seconds during descent into the atmosphere; and

- Lowering down from the CC's hatch opening to the ground after landing, (equivalent to lowering down to the floor from a dining-room table; Blue Origin expects to provide the use of stairs within a few minutes of landing).[135]

SpaceX

Headquartered in Hawthorne, California, The Space Exploration Technologies Corporation, now known as SpaceX, has approximately 9,500 employees, and an estimated net worth of $90 billion.[136,137] Founded in 2002 by Elon Musk, SpaceX focuses on efficiency (in cost and mission operations) as well as innovation in technology for reusability, sustainability, landing, and launching.[138] SpaceX is the first private company to have both successfully launched and returned a spacecraft from Earth orbit in addition to being the first company to launch a crewed spacecraft and dock with the International Space Station (ISS).[139]

To fly on one of SpaceX's crewed spacecraft, Dragon or Falcon 9, a passenger must be at least 18 years old and a US resident.[140] Physical requirements include being no taller than 6'6" and weighing no more that 250 lbs.[141] Musk has said of the requirements to fly that, "If you can go on a roller coaster ride, like an intense roller coaster ride, you should be fine for flying on Dragon."[142] One specific SpaceX astronaut that meets these requirements but not NASA's current requirements is Ms. Hayley Arceneaux (detailed further in the *Case Studies* section).[143]

Virgin Galactic

Branded as the world's first commercial spaceline, Virgin Galactic is a subsidiary of Virgin Group Ltd. and is headquartered in Las Cruces, New Mexico with approximately 823 employees.[144] Its purpose is to expand the future of sustainable life and human ingenuity and capability.[145] They aim to achieve this by "operating a variety of vehicles from multiple locations... transporting passengers to Earth orbiting hotels and science laboratories, or providing a world-shrinking, transcontinental service."[146]

Virgin Galactic's initial operations will fly large numbers of non-professional astronauts in both high acceleration and microgravity environments.[147] The company has 90-minute tourism flights planned for as early as 2022. Virgin Galactic has begun training over 400 future passengers for these tourism flights. The training includes, "talking about the safety system, how to buckle yourself in, and get out of your seat... and to mentally prepare for the journey what's going to happen so that when they are in the microgravity time..." according to the Vice President of Government Affairs, Sirsha Bandla.[148]

Virgin Galactic has not released any specific restrictions on or requirements for their passengers. However, they do note that "[although passengers] will not need to meet the incredibly rigorous levels of fitness required of government space agency astronauts, our in-house Medical Team conducted specially designed Medical Consultations with each Future Astronaut"[149] and that they've turned away two potential passengers so far.[150] One source interviewed for this study noted that their current trained space flight passenger corps does include one or more amputees.[151]

Based on testing conducted in the National Aerospace Training and Research Center in Southampton, Pennsylvania including "pre- and post-spin blood pressure, continuous heart rate, and oxygen saturation in the blood" and questionnaires "regarding motion sickness, disorientation, grayout and nervousness, among other symptoms," the corporation believes that "the majority of individuals with well-controlled medical conditions" will be able to take part in this experience.[152] The cost of the ticket is approximately $250,000.[153] Currently, there are no Virgin Galactic missions slated that would include extravehicular activity (EVA).

Boeing

Boeing has long been a manufacturer for government agencies, and their Space Exploration Division produced space shuttle technology and systems since the very beginning of US space exploration. Overall, the corporation has over 15,000 employees and an estimated net worth of $150 billion USD. The Space division employs 3,500 employees in Texas, California, Alabama, and Florida, which bolster the Boeing Defense, Space & Security's Network and Space Systems business.

Boeing's most recent development for NASA is the CST-100 Starliner which is in mission testing at Johnson Space Center and Cape Canaveral for an eventual crewed mission to the International Space Station.[154] The mission will utilize NASA astronauts. Therefore, Boeing's astronaut requirements are classified that same as NASA's, a difference from the other commercial space flight corporations.[155]

Zero-G

The Zero Gravity Corporation, or Zero-G, is a commercial parabolic flight company founded in 2004 by Dr. Peter Diamandis, a former astronaut, and a NASA engineer. They offer the public the opportunity to purchase a 5-hour weightless experience on a modified Boeing 727. Notable individuals they have flown include Stephen Hawking, Martha Stewart, and Buzz Aldrin. In addition to their commercial and chartered flights, Zero-G also notes that they offer "research and educational flights."[156]

To fly with Zero-G, individuals must complete a medical waiver and disclose any of the following conditions:

- "Frequent or severe headaches or head injury in the last five years
- Weakened limbs or joints or broken bones within the past year
- Eye trouble (except glasses), ear disease, hearing loss or balance disorders
- Behavioral health issues, such as anxiety or panic attacks, fear of heights, fear of flying or fear of closed spaces
- Neck, back or other spinal problems
- Currently pregnant
- Diabetes
- Brain or neurological disorders: epilepsy, seizures, stroke, paralysis, multiple sclerosis, or others
- History of GERD or other blood disorders
- Dizziness, blackouts, fainting spells, or loss of consciousness for any reason
- High or low blood pressure
- Recent severe illness, surgery, or admission to hospital
- Heart or vascular trouble, stroke, history of angina or chest pain
- Medical rejection, medical discharge from military or other disabilities
- Stomach, liver, esophageal or intestinal trouble
- Lung disease, breathing problems, asthma or others"[157]

Potential passengers with any of the above conditions must have a note from a physician for approval to fly.[158]

OTHER RELEVANT ORGANIZATIONS' POLICIES

Beyond the US military and commercial space ventures, there are other organizations helping to develop relevant policies concerning individuals with limb losses, short stature, and/or leg length differences, as well as to promote astronauts with disabilities.

AstroAccess

AstroAcess is a non-profit organization working to advance disability inclusion in space. Their partners include Zero-G, Gallaudet University, Space for Humanity, Disabled for Accessibility in Space, and SciAccess, among others.

AstroAcess is set to launch a crew of disabled scientists, veterans, students, athletes, and artists (dubbed AstroAccess Ambassadors) on a parabolic flight with Zero-G.[159] Slated for October 17, 2021, the flight is noted as the "first step in a progression toward flying a diverse range of people to space."[160] These parabolic flights will include lunar, Martian, and zero-gravity observations and experiments that will investigate how the physical environment aboard spacecraft should be modified to enable all astronauts, regardless of disability, to successfully operate in the space flight environment. The first flight will focus on basic operational tasks to (1) demonstrate the abilities of crew members with disabilities to work effectively in a microgravity environment and (2) investigate minor changes that could make the environment more accommodating for future flights.[161]

Project PoSSUM (Polar Suborbital Science in the Upper Mesosphere)

Project PoSSUM is a 501(c)(3) non-profit organization focusing on research and education. They offer a variety of programs including a Scientist-Astronaut Training Program and conduct a variety of research projects including intravehicular activity and EVA spacesuit evaluations.[162]

The Scientist-Astronaut Training Program is a 5-day active learning experience that includes educational lectures and webinars, flight condition simulations, and operational training. The program costs $5,000, and participants must have a FAA Class III Flight Physical, Self-Contained Underwater Breathing Apparatus (SCUBA) Certification, and a Bachelor's degree in a science, technology, engineering, and mathematics (STEM) field.[163] As detailed above, for amputees to be medically cleared for a FAA Class III Certification, their condition must not render them "unable to safely perform the duties or exercise the privileges of the airman certificate applied for or held at the time of certification or for the maximum duration of the airman medical certificate applied for or held" and must not be dependent on any medications with side effects.[164] After completing this training, Scientist-Astronaut candidates are eligible for the OTTER (Orbital Technologies and Tools for Extravehicular Research) certification course.[165]

Regarding spacesuit studies, Project PoSSUM partners with Final Frontier Designs and Integrated Spaceflight Services to design and evaluate spacesuits respectively utilizing Bioastronautics which they define as "the study associated with the support of life in space, including the design of payloads, space habitats, and life support systems."[166]

US Paralympics

Since its 2001 inception, the United States Paralympics unites people living with disabilities (including physical disabilities and visual impairments) to compete in the national and international level sports.[167] It is recognized by the International Paralympic Committee (IPC) and has the responsibility of sending the US Paralympic Team to the summer and winter Paralympic Games.

Classification

The IPC classification process is an important part of the Paralympics, helping ensure level competition in each sport.[168] The classification process helps determines which athletes are eligible to compete in a sport and how athletes are grouped together for competition (that is, by the degree of activity limitation resulting from the impairment).

There are ten eligible impairment classifications for parasports: Impaired muscle power, impaired passive range of movement, limb deficiency, leg length difference, short stature, hypertonia, ataxia, athetosis, vision impairment, and intellectual impairment.[169] Each sport has a list of eligible impairments as well as various classification levels. For example, in track and field (T/F), athletes with short stature compete in either sport class T/F40 or T/F41, depending on their body height and proportionality of their arms. Athletes with a leg deficiency who compete with a prosthesis compete in classes T/F61-64. Athletes with legs affected by an impairment would compete in T/F42-44.

It should be noted, however, that IPC policies surrounding athletes with physical disabilities are developed to ensure fair competition and a level playing field, in comparison to DoD policies (and likewise, NASA policies) designed to ensure the safety, health, and performance of the individual.

Dwarf Athletic Association of America

The Dwarf Athletic Association of America (DAAA) is a non-profit organization committed to increasing sports participation by individuals with dwarfism.[170] DAAA strives to encourage "true sportsmanship and fair play, to gain a lifting of self-esteem, a sense of achievement and a feeling of self-worth."[171]

DAAA follows the 2013 International Dwarf Athletic Federation (IDAF) rule book.[172] DAAA athletes compete in sports such as track and field, basketball, powerlifting, swimming, table tennis, volleyball, and soccer. To be considered eligible for participation, persons with a disproportionate dysplasia shall be less than 5' 0", or less than 4' 10" for those with proportionate short stature. Similar to IPC policies governing athlete participation, DAAA and IDAF guidelines are designed to ensure a level playing field and fair competition.

The Institute identified and detailed exemplar DoD case studies to help benchmark parastronaut policies, including individuals who have overcome the challenges of physical disability and/or policy put in place restricting participation in the US Armed Forces. The US military seeks out a similar demographic as NASA does for its Astronaut Corps, holds their service members to similar medical and health standards, and is bound by similar US government policy. Further, most astronauts come from military backgrounds. In 2016, roughly two thirds of current and former astronauts also served in the US Armed Forces (219 of 330 astronauts).[173] Of the current 44 active astronauts, about one third are military detailers and two thirds have military backgrounds.

DEPARTMENT OF DEFENSE CASE STUDIES

While discrimination in DoD civilian positions is governed by the Rehab Act, this policy does not apply to "uniformed members of the military departments."[174] As such, the US Armed Forces is exempt from the ADA, as is NASA in regard to astronaut selection. However, the DoD considers diversity to be a leadership requirement and a strategic imperative – both critical to mission readiness and accomplishment.[175] DoD recognizes that as the US demographics continue to evolve, DoD must position itself to capitalize on the broad range of talent across the country by attracting, recruiting, developing, and retaining the best and brightest. For DoD, greater inclusivity of diverse backgrounds translates to greater connection to the citizens it serves.

Through technological and medical advancements and policy revisions, service members that experience traumatic amputations can return to duty, and in some cases, return to active combat roles. In the two decades since 9/11, the DoD has treated more than 1,500 service members with major limb amputations resulting from injuries while on deployment.[176] During the 1980s, roughly 2.3% of all US amputee soldiers returned to active duty (11 out of 469 soldiers).[177] Today, however, returning to service after amputation is not a rare occurrence. Between 2001 and 2006, 16.5% of amputee soldiers returned to combat – Figure 2 depicts the incidence of return based on location of amputation.[178] The majority of amputees that were able to return to duty experienced lower leg amputations. In 2012, roughly 40 soldiers were serving in combat zones with state-of-the-art prostheses.[179] A 2013 retrospective study found that Army Infantry, the Marine Corps Infantry, and the Army Armor accounted for more than 57% of all amputees from October 1, 2001 to July 30, 2011 – approximately 89% of service members with amputations in that study separated from military service following injury.[180] The US Army estimated at least 167 soldiers who have had a major limb amputation have remained on active duty since the start of the Afghanistan and Iraq wars, with some returning to combat duty (through 2012).[181]

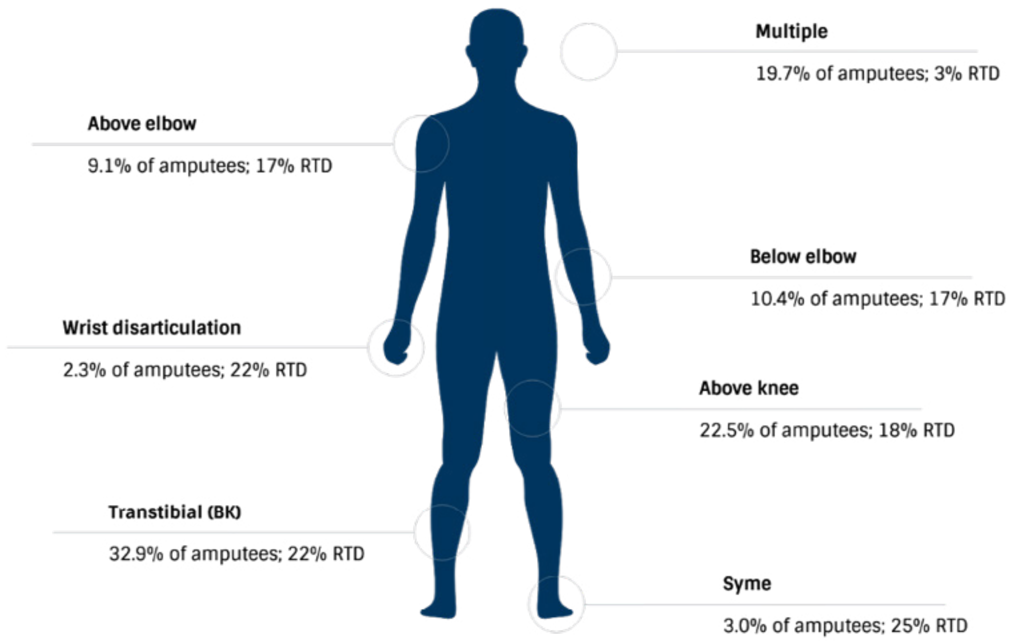


Figure 2. Distribution of amputees and return to duty (RTD) rates of amputee soldiers between 2001 and 2006 in Afghanistan and Iraq conflicts. Of the amputees analyzed, 16.5% remained on active-duty service. Amputation categories are: multiple (includes more than one extremity), above elbow (including shoulder disarticulation and elbow disarticulation), below elbow, wrist disarticulation (including hand proximal to metacarpals), above knee (includes hip disarticulation and knee disarticulation), transtibial (below knee, BK), and Syme (including foot proximal to metatarsals).[182]

The severity of the injury (including associated injuries, e.g., brain trauma, and the nature of the injury, e.g., bomb blast) have a significant impact on the individual's ability to return to active military duty. Factors that can negatively impact the timeline and one's ability to return to active duty include psychological adjustment to limb loss,[183] comorbidities such as traumatic brain injury, and complications associated with the healing limb, among others.[184] While largely anecdotal, positive characteristics of amputees who have sought to remain on active duty have been cited, including "strong individual motivation for continued military service, anticipated ability to meet the performance standards of their military occupational specialty, solid support from close family members and friends, and possession of highly valued military-specific skills."[185]

Here, select exemplar service members that have experienced an amputation (either traumatic or congenital) from across the US military are presented. It is worth nothing that of the three physical disabilities currently being considered by ESA, most of the case studies focus on amputees (with the exception of two short stature examples), as the DoD currently disqualifies individuals of short stature and significant leg length differences from entering the military.[186] Case studies documented include individuals who were injured during their military services and returned to duty/deployment, individuals who were injured during military service and went to an alternative duty/activity (e.g., transitioned to the police force), and one example of a congenital amputee that joined the US reserve services.

Injured During Service, Returned to Active Duty/Deployment

Select individuals who were injured during their military services and returned to active duty and/or deployment are detailed herein.

Navy Master Diver Carl Brashear

Master Diver Carl Brashear was both the first amputee Naval diver and the first Black Master Diver. He lost his left leg below the knee in an on-deck accident in 1966 while attempting to recover a hydrogen bomb on the ocean floor with his crew. He was told by doctors that it would take him three years to walk again, but he was up on his own prosthetic in less than one year. The medical board recommended retirement, but Master Diver Brashear refused to accept it and continued to train himself on land and in the water. He re-qualified, passing the standard evaluation without mistake in 1970 and served the next nine years on submarines and salvage ships before retiring. Master Diver Brashear passed away in 2006 and had a ship commissioned in his honor in 2008.[187]

Army Sergeant First Class Dana Bowman

A member of both a Special Forces and the Golden Knights Parachute Team, Sergeant First Class Dana Bowman is the first double amputee to ever reenlist in the Army. In February of 1994, he lost both legs, one above the knee and one below the knee, during the annual Golden Knights sky diving training. Nine months later he reenlisted in the Army, parachuting into his commissioning ceremony.[188] He went on to become the US Parachute Team's recruiting commander and lead speaker as well as the founder of the HALO for Freedom Warrior Foundation – most recently, he was awarded a Distinguished Service Award from the Military Officers Association of America in 2019.[189] After retirement from the Air Force, Bowman received his commercial aviation certification and is a certified helicopter flight instructor.[190]

Army Major David M. Rozelle

Major David Rozelle is the first Army officer to experience limb loss in Iraq and return to a combat zone. His right leg was amputated below the knee after being wounded by an anti-tank mine blast in 2003.[191] He completed two tours abroad post-amputation (three in total) and participated in running and skiing recreationally; and in 2011, retired from active duty to be commanding officer of the University of Colorado Boulder's Army Reserve Officer Training Corps program.[192]

Army Sergeant First Class John "Mike" Fairfax

Sergeant First Class John "Mike" Fairfax is the first amputee to complete the Jumpmaster Course, a course for expert paratroopers who train other soldiers in jump techniques.[193] An Army Special Forces intelligence non-commissioned officer (NCO), he suffered injuries to his right leg, right eye, and left lung. He spent over a year fighting to save his leg before eventually made the decision with his medical team to amputate it above the knee. One year post-amputation, he completed the Jumpmaster Course. Soldiers must pass with 70% proficiency in all events and inspect three rigged jumpers (which requires the soldier to bend, kneel, and/or go into a deep squat multiple times) in just five minutes. Fairfax said, "I knew I would be paving the way for other amputees to go through the course, and I didn't want this to be something they couldn't do."[194]

Marine Staff Sergeant Brian Beem

Staff Sergeant Brian Beem lost his right leg below the knee in an improvised explosive device (IED) explosion in Afghanistan in 2006.[195] With the support and assistance of his commander Colonel Todd Wood and COAD/COAR Program, he deployed to Iraq with his squadron less than a year post-amputation serving in battle staff operations rather than his previous patrol post. He said "It was really gratifying to be able to deploy. It's possible, but it's not easy. The process is there for those who have the perseverance." He also noted, "Disability is a technical term. It doesn't mean I'm less able."[196] Staff Sergeant Beem went on to enlist in a second tour and earn a Purple Heart for his service.[197]

Air Force Captain Ryan McGuire

Captain Ryan McGuire lost his right leg in a boating accident in 2009 during training at Laughlin Airforce Base following graduation from the US Air Force Academy in 2008. [198] Within a year post-amputation, Captain McGuire competed in the Warrior Games in Colorado, completed the Air Force Marathon in Ohio, and was named the Air Education and Training Command Male Athlete of the Year.[199] The following year he completed his pilot training, qualified as a C-17 Globemaster III, and was awarded the Daedalian Award for the 11-09 Air Force Specialized Undergraduate Pilot graduation class.[200]

Marine Corporal Garrett Jones

Corporal Garrett Jones was the first combat amputee to deploy to Afghanistan. His left leg was amputated above the knee after a traumatic IED explosion on deployment in Iraq in July of 2007. He also lost both eardrums to the blast and suffered a concussion and multiple shrapnel wounds. [201] In November of the same year, he was up and walking on one of his six specially made prosthetics (one of which was made specifically for snowboarding, which he began again in December). He began training again to rejoin his squadron in February 2008. Of the training, which included "close quarters combat drills, 'Humvee' scenarios, survival training, machine gun packages, combat life saver courses, and several other pre-deployment courses," he said, "it wasn't just a hookup; I had to do all the training all other Marines do."[202] He completed all requirements and served as an intelligence analyst with his battalion and as a hospital liaison from 2008-2009. During this time, he went into the field twice assisting with resupply missions.[203]

Army Captain Daniel Luckett

Captain Daniel Luckett is a double amputee who returned to active-duty patrol in Afghanistan two years after his injury, following an interim 8-month rehabilitation. While on duty, Luckett lost his left leg below the knee as well as part of his right foot, including loss of his five toes. Upon returning to active duty in 2010, Luckett took four new custom-made sockets and three different legs on deployment.[204] Following his injury, Captain Luckett attained the Expert Infantryman's Badge, requiring a 12-mile run in under three hours with a 35-pound backpack – the success rate of which is generally between 20 and 50%.[205]

Marine Staff Sergeant Jason Pacheco

Staff Sergeant Pacheco is the first amputee to return to a combat zone in an infantry military occupation specialty. He returned to combat in 2011, 15 months following his injury – a right leg amputation below the knee, soft tissue damage to his left leg, and amputation of his right pinky finger.[206] Part of his return to active duty required successful completion of the Combat Fitness Test, which requires Marines "in battle dress uniform to sprint a timed 880 yards, lift a 30-pound ammunition can overhead from shoulder height repeatedly for two minutes, and perform a maneuver-under-fire event, which is a timed 300-yard shuttle run in which Marines are paired up by size and perform a series of combat-related tasks."[207]

Army Lieutenant Joshua Pitcher

First Lieutenant Pitcher lost his left leg below the knee in a combat explosion in 2012. Once he received his prosthetic, he learned to walk on it in one week and ran the Army 10-Miler on it three months later. He was recertified for active duty in January of 2013, passing the fitness test in the top 10% of all active-duty soldiers. First Lieutenant Pitcher went on to also recertify as an airborne paratrooper and eventually lead a platoon of 21 other paratroopers in Northern Afghanistan. On active duty, he wears "a prosthetic that includes a curved blade at the bottom, which allows him to dig into the mud and snow for balance."[208]

Army Green Beret Sergeant Nicholas Lavery

Sergeant Lavery is the first Special Operations Force operator to return to combat in 2015 following an above the knee amputation in 2013. Sergeant Lavery is the first amputee to obtain the following certifications: Special Forces Warrant Officer Technical and Tactical Certification, the Special Operations Combative Program Instructor, and the Combat Diver Qualification.[209]

Air Force Major Christy Wise

Major Wise, who lost her right leg above the knee in a boating accident, returned to flight in 2016 following eight months of rehabilitation and recertifications, including passing the same physical fitness tests, flight checks, and emergency procedure drills (proving she "can get out of the aircraft quickly on the ground if there's a fire or something"[210]) that all other pilots undergo. She is the 6th pilot (HC-130) and first female to return to flight with her most recent deployment to Iraq in 2019.

Injured During Service, Returned to Alternate Duty or Activity

Select individuals who were injured during their military services and returned to an alternative duty or activity (e.g., joined the police force) highlighting their physical capabilities after injury are detailed herein.

Marine Corporal Zach Briseno

Corporal Zach Briseno is a US Marine Corps Veteran and the second double amputee to become a police officer. During his second tour to Iraq in 2007, he lost both his legs below the knee to an IED explosion. He returned state-side, retired from active duty, received his prosthetics, and began coaching his son's little league team and training to enter the police academy in Fort Worth, TX eventually graduating in 2020 and passing all tests without accommodation.[211] Prior to receiving prosthetics, he stood 5', 7"; with his titanium prosthetics, he stands 6', 1" tall. Corporal Briseno has been awarded a Purple Heart by President Bush and the Most Dedicated and Determined Recruit award for his police academy class by his commanding officers.[212, 213]

Marine Lance Corporal Matias Ferreria

Lance Corporal Matias Ferreria is a US Marine Corps Veteran and the first double amputee to become a police officer. Born in Uruguay, he moved to Atlanta, GA at the age of 6 (1997), and became a US citizen and enlisted in the Marines at 19 (2010). In January of 2011, he lost both his legs below the knee to a detonated IED during his first tour in Afghanistan. He was medically retired from the Marines in 2012. He graduated from the Suffolk County Police Academy in New York in March of 2017 and runs half marathons in his free time.[214]

Marine Sergeant Kristie Ennis

Sergeant Kristie Ennis served in the Marine Corps as a helicopter door gunner and airframe mechanic until 2012 when she lost her left leg above the knee to a gun wound during her second deployment in Afghanistan. In addition to the amputation, she also suffered "full-thickness facial trauma, [a] traumatic brain injury, cervical and lumbar spine trauma, and bilateral shoulder damage."[215] Sergeant Ennis competed on the 2018 Paralympic Snowboarding Team, summitted Mt. Kilimanjaro, started a non-profit that supports veterans, and was the first Veteran on the cover of *ESPN magazine*.[216] Of disability, Sergeant Ennis said, "One of the things people misunderstand about veterans going through recovery is that they want pity — but all they want is opportunity."[217]

Marine Staff Sergeant Charlie Linville

Staff Sergeant Charlie Linville was the first combat amputee to reach the summit of Mt. Everest, the world's tallest peak, in 2016 as part of the Hero's Project Expedition. Three years earlier, his right leg was injured in an IED blast during deployment in Afghanistan where he served as a member of a bomb disposal unit.[218] His medical team spent 18 months trying to save the leg, but ultimately made the decision to amputate it below the knee. He completed a triathlon within the first two months post-amputation and summited Mt. Everest just over a year later.

Congenital Disability, Entered Service

While the military bars individuals with missing extremities from entering active-duty services, it is possible for congenital amputees to join reserve services or state militia following a medical waiver.

Green Beret Captain Richard J. Flaherty

Captain Richard Flaherty is the shortest man known to have served in the US military. He was commissioned in August of 1967 at 4' 9" and 103 pounds (gaining 6 pounds the prior weekend to meet the 100 lb. requirement) after receiving a height waiver from his congressman. During training, Captain Flaherty received no special accommodations and parachuted with full gear that weighed 80-100 lbs. In the next five years, he served two tours – one in Vietnam and the other in Thailand. After being decommissioned in 1971 due to budget restructuring and force drawback, he served the CIA briefly then reenlisted in 1986 as a Green Beret and Special Forces Undercover Operative. In almost a decade of service, Captain Flaherty was awarded over 13 honors including Silver and Bronze Stars, Purple Hearts, the Army Commendation Medal, and the National Defense Service Medal. He died in a fatal hit-and-run accident on May 9, 2015.[219]

Army Reserve Sergeant Zachary Foster

Sergeant Zachary Foster is one of the very few soldiers granted reserve enlistment with a pre-existing condition. He is missing his right arm due to a congenital deficiency, but joined the California State Military Reserves in 2008. This required special approval directly from Brigadier General Jack Hagan. He served in active-duty medical training activities, with the Civil Air patrol, and in a variety of administrative and "desk" roles.[220]

Air Force First Lieutenant Andrea Barry

First Lieutenant Andrea Barry was the second shortest pilot in the Air Force as of April 2013. Although a height of 5′ 1″ is not often considered a disability, the height requirement to become a pilot at the time was 5′ 4″. After attending the Air Force Academy, Barry joined the 1st Helicopter Squadron at Andrews Air Force Base. She doesn't use any special accommodation in flight (i.e., booster seat, seat cushion) but occasionally does find it "embarrassingly hard to reach things" on base. First Lieutenant Barry continues to serve today.[221]

OTHER RELEVANT CASE STUDIES

As commercial ventures turn to private spaceflight and space tourism, there will be a rise of individuals with conditions that have disqualified them from traditional astronaut requirements. While outside of the scope of DoD case studies, it is worthwhile to track and document emerging cases from private spaceflight that deviate from current NASA astronaut medical standards. We also present one NASA astronaut that developed a physical disability (deafness) after joining the Corps. Additionally, amputees have participated in and demonstrated success in weightless parabolic flights.[222]

Hayley Arceneaux

Hayley Arceneaux is a childhood osteosarcoma (bone cancer) survivor. On September 16, 2021, she was one of the four members of SpaceX's *Inspiration4* mission—the world's first all-civilian spaceflight. Ms. Arceneaux has a titanium prosthesis in her left leg as a result of osteosarcoma in her femur as a child. Before the mission, she completed astronaut training with the goal to become FAA-certified commercial astronauts.[223] Ms. Arceneaux served as the medical officer for the flight. Her internal prosthesis handled up to 8 Gs during flight training and a month later, withstood the rigors of actual space flight.[224]

Wally Funk

On a space flight with Blue Origin on July 20, 2021, Wally Funk became the oldest person to enter space at 82 years old, beating John Glenn's previous set record by five years. From 1961 to 1962, Ms. Funk trained to be an astronaut in a privately funded project eventually known as the "Mercury 13" organized by Dr. Randy Lovelace who hypothesized "that women might fare just as well, or even better, [because] women are, on average, lighter and smaller, and would require less food and oxygen."[225] She excelled at a variety of strenuous tests including spending over ten hours in an isolation tank. However, she never made it into the Corps – even after applying four more times – at first because of her gender, then because she lacked an engineering degree. She instead spent her career in the FAA, becoming the first female safety inspector, and flying planes in her free time.[226]

Philippe Croizon

Philippe Croizon is a French quadruple amputee, having lost both his legs and arms after an electrical accident at the age of 26.[227] Mr. Croizon is the first quadruple amputee to swim across the English Channel and to run the Dakar Rally (an 8,000+ kilometer off-road rally race). In early 2021, Elon Musk, CEO of SpaceX, announced that he would make plans to allow Mr. Croizon to travel into space. If accurate and Mr. Croizon is selected for a Spaceship mission, he would become the first amputee in space.

Leland Melvin

Leland Melvin is a former NASA astronaut. Following an underwater training accident, he went deaf in his left ear and became medically disqualified; however, he was medically cleared to fly following a medical waiver given by Rich Williams, the chief flight surgeon at the time, who "felt if [Melvin] could effectively clear [his] ears, then there'd be no reason why [he] shouldn't be able to fly in space."[228] Mr. Melvin successfully participated on two missions (12 and 10 days) to the ISS in 2008 and 2009, respectively, logging 565 hours in space.[229] Aboard the ISS, Mr. Melvin's main job was to operate a robotic arm to help install new modules to the station.

PARASTRONAUT CONSIDERATIONS

A variety of technical and operational considerations will need to be evaluated, and possibly redesigned and recertified for flight of parastronauts. Considerations for parastronaut feasibility herein include: technical (e.g., spacesuits/EVAs, human-centered spacecraft design), operational (e.g., emergency ingress/egress, safety procedures), medical/health (e.g., health concerns associated with traumatic amputation, common comorbidities), and potential benefits. The following sections explore considerations broadly as well as highlight considerations for one or more of the three disabilities. If a disability is not noted, it does not mean that there are not related considerations, but rather they are not substantial at this time. Although not considered in the scope of this study, financial costs should be explored concurrently to understand the full feasibility of parastronaut implementation.

TECHNICAL CONSIDERATIONS

Technical components associated with spaceflight will need to be assessed and potentially redesigned or altered and reevaluated in zero gravity, such as cockpit seats, spacesuits/EVAs, and spacecraft design.

Launch, Entry, and Abort and Extravehicular Activity Suits

Currently, NASA offers medium, large, and X-large EVA suit sizes. A size "small" was attempted (designed to accommodate astronauts around 5 feet tall) but scrapped due to the additional challenges to make it operational.[230] Engineering and design obstacles relating to attachment of the arm and leg units, as well as the devices to provide oxygen, remove carbon dioxide, and maintain pressure precluded further development of the smaller suit. These challenges did not necessarily arise directly from the height of the suit, but rather from the decreased distance between the astronaut's armpits, determining how much gear could be carried on the back of the suit. As such, a parastronaut's spacesuit would need to be modified for the parastronaut to account for either (a) the presence and/or absence of a prosthesis or (b) a person below 5′ 2″.

Lower Leg Deficiencies and Leg Length Differences

Minor accommodation will likely be required for launch, abort, and entry (LEA); however, more significant accommodation will be required for EVA (including evaluating the material of the prosthesis and integration with suit).[231] A modular spacesuit design could address this, by designing leg attachments or components of the suit to be adapted to different individuals, or even placing the prosthetic device outside of the suit.[232] SMEs suggest the prosthetic device could be incorporated into the suit rather than freely attached to the individual.[233]

Short Stature

There are potential challenges to EVA and LEA suit design for short stature individuals due to design parameter challenges as outlined above. Further, there is concern regarding decreased load the individual could bear in a reduced gravity environment, including less oxygen and other equipment.[234]

Seats and Ejection

NASA's existing height requirement requires astronauts to stand between 5′ 2″ and 6′ 3″.[235] In order to maintain the safety of a parastronaut who falls outside of this height range, adjustments/alterations to the cockpit seats on the launch vehicle will likely be necessary.

Short Stature

According to LPA, the average height of an adult with dwarfism is 4 feet, although typical heights range from 2′ 8″ to 4′ 8″.[236] People with dwarfism or other forms of short stature can successfully drive and operate vehicles with certain adaptations, including pedal extenders, custom hand controls, or seat cushions (although seat cushions would likely not work in the context of launch).[237] To accommodate individuals of short stature, a redesign of the seat with a larger adjustable range and/or development of a custom seat will be required. This comes with a range of human performance and engineering restraints that need to be explored in further detail.

Interior Spacecraft Design

Interior spacecraft design will need to be adapted and/or redesigned for parastronauts. Legacy systems will need to be adapted and retrofitted for increased accessibility. SMEs noted that new space vehicle and equipment designs should focus on human-centered design principles.[238] This could include additional handholds or grip bars throughout the cabin to reduce gap distances and modifications to exercise equipment to accommodate a wider range of individuals. One SME highlighted the advantage of applying a universal design within the space vehicle such that individuals with varying degrees of disabilities can safely operate inside the spacecraft.[239] This approach would not only allow the specified parastronauts to function inside the spacecraft environment but could also expand the possibility of allowing individuals with physical disabilities not explored in this study to operate within the spacecraft safely and productively. In general, SMEs believe it is feasible to adapt or redesign internal spacecraft design for parastronauts; however, further research would be necessary to identify appropriate design modifications as well as associated cost.

Stabilization During Activity

The primary method of astronaut stabilization during an active task (e.g., vehicle maintenance, bolt tightening) in current spacecraft is the utilization of footholds.[240] For individuals with leg length differences or lower-limb deficiency, these conditions may not provide a safe, accessible, or stable platform. Alternative stabilization methods will likely need to be considered.

Onboard Equipment

Onboard equipment and tools include a variety of uses, applications, and ways of human interaction. From sleeping bags to toilet facilities to the equipment used for eating and drinking, redesign and/or adaptations will be required depending on a parastronauts level of ability to safely and effectively use the equipment for its intended purposes. SMEs noted that equipment accommodations should focus on human-centered design principles.[241] For example, fitness equipment may need modification and/or extra equipment to accommodate parastronauts and ensure they can receive necessary fitness maintenance.[242] Physical fitness activity maintenance procedures are discussed in a later section.

Short Stature

Terrestrially, individuals of short stature utilize stepstools and lower height counters, tables, etc. similar to those used by individuals in wheelchairs[243] to improve access. In a microgravity environment, the same limitations would not be in effect negating the need for these accommodations. However, in the presence of gravity in a landing or simulated gravitational environment, these additions to onboard equipment should be considered.

Prosthetic Devices

A parastronaut with a lower leg deficiency would likely make use of a prosthesis. Terrestrially, prostheses, and leg prostheses in particular, function to provide support to the body due to gravity, among other capabilities. In a zero-gravity environment, this aspect of a prosthetic is unnecessary. As such, the design of prosthetics for use aboard spacecraft will likely be different than those traditionally used on Earth. However, lunar and Martian landings as well as return to Earth might necessitate multiple designs and prosthetics brought with the parastronaut. Additionally, NASA must consider if wearing a prosthesis during launch conditions poses a risk to the parastronaut (e.g., injuring the residual limb due to high G forces[244]).

For example, Captain Luckett (referenced above) utilizes different prosthetic legs depending on the task, each attaching to his thigh via a carbon fiber socket: 1) one fitted with a tennis shoe for running, 2) one fitted with a boot, 3) one made of aluminum so it will not rust, fitted with a waterproof black Croc for showering, and

4) one high-tech leg reserved for patrols that has a high-tech axle that allows him to move smoothly over uneven terrain.

Materials

Prosthetic devices today can be composed of polymers (e.g., poly vinyl chloride/PVC, polyethylene), carbon fiber composites, and/or metals (often, titanium, but can also include aluminum, copper, steel, or others).[245] Supporting materials that can also be used in prosthetics can include Spenco (perforated EVA foam insole with nylon support), Poron (fine pitch open cell urethane foam), Nylon-reinforced silicone, or Nickelplast (high-strength expanded polyethene composite). Materials can also vary depending on the individual's activity level and the task(s) they are hoping to accomplish with the prosthetic. One SME noted that hand-built monocarbon devices are likely to hold up best for spaceflight purposes.[246]

Definitive prostheses are not designed to last forever – they are not permanent as any mechanical device will eventually wear out, particularly depending on activity level, the individual's weight, etc. The average life span for a definitive prosthesis is from three to five years, though zero gravity will likely increase the lifespan of the device.[247] It is possible prosthetics could be 3D printed aboard the spacecraft and/or modulated as needed, though SMEs estimate that a 3D printed prosthesis using today's technology would only last around three months.[248]

Some prosthetic devices on the market today are motorized, using primarily lithium-ion batteries to power the device (others can leverage solar power).[249] SMEs note that service members deployed in an active-duty environment traditionally use simple prostheses, rather than devices that use microprocessors to mitigate potential challenges associated with batteries (e.g., relying on charging the battery).[250]

Sockets and Securing Mechanisms

Prosthetic devices are traditionally held onto the individual's limb (i.e., stump) by gravity. In a reduced or zero-gravity environment, additional securing mechanism will likely be necessary to ensure the prosthesis stays connected to the parastronaut.[251] There may be need for adjustable sockets if volume changes occur or for supplemental socket suspension.[252]

There is also the possibility of osseointegration, wherein a metal implant is surgically inserted into the bone of the residual limb that then attaches directly to the prosthesis.[253] This can eliminate socket-related issues in addition to other commonly experienced prosthetic issues like excessive sweating, pain, pressure, chafing, and skin sores (discussed further in *Medical Considerations*);

however, further experimentation might be necessary to determine the safety of flying an astronaut with a metal implant.[254]

Maintenance

In the US military, deployed amputees are taught how to fix their own prothesis and are given a toolkit to repair their device as needed.[255] NASA would need to consider what additional equipment would be necessary to ensure continued maintenance of the prosthesis in the event of damage or wear/degradation.

Emerging Technology

NASA could leverage emerging prosthetic capabilities. For example, new devices are being developed that utilize an energy storing device, wherein the kinetic energy generated by using the prosthesis powers the device.[256] SMEs also noted that NASA has vast experience developing and utilizing robotic systems in space exploration – this knowledge could be a source of information for new prosthesis design and capabilities.[257]

OPERATIONAL PROTOCOLS AND PROCEDURES

Current operational protocols and procedures are designed to ensure the safety and performance of the crew. While an initial look into relevant DoD policies concerning individuals with physical disabilities indicates that alterations to certification processes/requirements are not currently given (e.g., pilots must pass flight certification drills regardless of physical disability), the uniqueness of the spaceflight environment might warrant further investigation of NASA's policies and procedures. Initial operational considerations include:

Mission Requirements

NASA will need to consider individual parastronaut performance and capabilities with the mission's requirements. It is possible that parastronauts might only be "qualified" for certain missions, e.g., not qualified for EVA. The duration of time spent in space on each mission will need to be balanced with maintaining the health and safety of the parastronaut, which might "disqualify" a parastronaut from the first Mars mission or upcoming lunar missions until the technology and procedures are in place to do so safely.[258]

Lower Leg Deficiencies and Leg Length Differences

Prosthetic gait requires more energy. For example, individuals with a unilateral transtibial amputation usually require 20-25% more energy exertion and walk slower compared to able-bodied individuals.[259] In a reduced gravity environment, functional testing would be needed to inform parameters surrounding surface missions (e.g., acceptable duration, distance) and determine the feasibility of such aspects.

Short Stature

Shorter limbs can lead to quicker fatigue and less strength in comparison to able-bodied individuals.[260] This might lead to restrictions on the potential missions these individuals can fly.

Onboard Safety Training and Protocol

Onboard training and procedures may need to be altered and/or adapted to allow parastronaut integration; these will need to be considered for each type of physical disability. Possible safety benefits are discussed in the "*Parastronaut Benefits*" section below.

Emergency Ingress and Egress

Terrestrial evacuation from the capsule on the launch pad and/or after landing are of concern for parastronauts. New and/or updated training and drills for emergency ingress and egress will possibly be necessary. Upper body strength to lift/maneuver the safety latch and safely egress will be important to ensure.[261] Functional testing should be carried out for each type of parastronaut; SMEs suggest that NASA give potential parastronauts the opportunity to prove they can safely egress.[262]

Lower Leg Deficiencies and Leg Length Differences

Similar to FAA certification requiring amputee pilots to demonstrate they can safely operate a plane using a prosthetic device, parastronaut amputees should be able to demonstrate they can safely operate emergency equipment and follow egress procedures. An individual should be able to demonstrate they can efficiently and safely egress, and that the prosthetic device will not cause added safety risk.

Short Stature

SMEs highlight similarities to terrestrial egress procedures, such as building fire drills and use of the "buddy system." In case of fire evacuation, individuals of short stature can have a designated buddy that will help them evacuate in the event evacuation requires egress capabilities the individual cannot perform. While this could bring increased risk to the able-bodied individual, functional testing should be conducted.[263]

Onboard Physical Training and Maintenance Procedures

Onboard physical fitness regimes and maintenance procedures will need to be adapted to the parastronauts to ensure continued fitness throughout mission. Of concern will be ensuring that individual physical fitness regimens help maintain the cardiovascular system and musculature and reduce loss of bone density.[264]

Lower Leg Deficiencies and Leg Length Differences

SMEs do not see limitation with daily rehabilitation or fitness activities given appropriate accommodations.[265] SMEs highlight the importance of maintaining stump fit while in zero-gravity environments and recognize an adjustable socket might be required.[266] This could be accomplished through careful fitness regimes to maintain fit and/or use of an adaptive prosthesis while transitioning from zero gravity to reduced gravity environments. Additionally, there could be a benefit to these individuals as the lack of gravity may reduce the complexities associated with traditional exercise machines such as balance.[267]

Short Stature

Shorter limbs can lead to quicker fatigue and less strength in comparison to able-bodied individuals.[268] This might warrant different fitness regime standards for short stature parastronauts to achieve desired fitness outcomes.

MEDICAL CONSIDERATIONS

The medical considerations here provide a broad overview of the medical imperatives of lower-limb loss, leg length differences, and short stature and concludes with reflections on safely engineering humans into the severe system that is space. The austere environments of space and interplanetary exploration include physical adversities such as microgravity and radiation. At the same time, the distance from Earth, cramped quarters of habitation, and isolation are social and psychological stressors. SMEs suggested that although parastronauts would face the same physical challenges associated with space exploration, the psychological hardships may be less difficult for those who have already overcome the challenges of their disabilities, as they can possess above-average mental resiliency and motivation.

The goal of medical certification of parastronauts should be to meet the standards necessary to ensure safe and reliable mission performance. Current medical countermeasures have been developed over many years to protect astronauts from the inherent physiological risks associated with space flight. As space flight increases in duration and distance from Earth, these countermeasures must be continually reevaluated and modified.[269] The medical conditions deemed most likely to occur during space exploration have been compiled in the Space Medicine Exploration Medical Condition List, which also provides recommendations to ensure that appropriate medical capabilities are available for missions. A similar procedure, including strenuous training to prepare for such scenarios, should apply to parastronaut examination processes. [270, 271] To date, there are no set criteria to determine whether those with lower-limb deficiencies and differences and short stature are medically capable of space flight. Standardized objective outcome measures can serve as assessment tools for the medical examiner to establish medical readiness of the parastronaut.[272] Similar to cardiovascular risk assessment tools (e.g., Framingham, Reynolds Scoring System, ACC/AHA ASCVD Risk Calculator) that help cardiologists evaluate an individual's risk for heart disease, assessment tools for lower-limb deficiency and differences and short stature will be instrumental for specialists to understand each individual's medical fitness for their specific role and missions as a parastronaut. Future research will have to concentrate on prioritization of the redesigning and inclusion of disabilities in all aspects of research studies. A revamped or specialized parastronaut medical advisory board, which will collaborate with risk strategists, engineers, and other personnel to space flight will be beneficial.

Lower-Limb Deficiency

Lower-Limb deficiency, for the scope of this study, is described as unilateral or bilateral foot (below ankle) or leg (below-knee) loss. The level of the limb loss greatly influences mobility outcomes. The energy expenditure needed to move about increases with higher levels of amputation, and thus preservation of the greatest possible length of the limb leads to increased functionality.[273] Parastronauts with lower-limb deficiency subjected to zero-gravity or microgravity environments would mean fewer total weight and lower-limb bone mass loss concerns due to the loss of proportion of body weight.[274]

Any potential astronaut with limb loss selected for space will likely be otherwise as physically fit as any other astronaut. As a result, the loss of limb will not be related to dysvascular causes or tumors that are usually associated with other comorbidities.[275] Limb loss related to trauma typically does not impose additional medical comorbidities with the exception of trauma related comorbidities such as fractures, muscle loss, organ damage, and traumatic brain injuries. The assumption is that general medical challenges would be no different than those associated with any other healthy person.

SMEs highlight the utility of the comprehensive high-activity mobility predictor (CHAMP) test to determine differences in lower-limb coordination and agility prior to and after space flight in astronauts, both with and without limb loss.[276] CHAMP is designed to determine lower-limb stability in addition to agility, speed, power, and reaction time.

Etiology of Injury or Condition

The etiology of lower-limb deficiency helps in shaping the full health picture of the parastronaut. Persons who have traumatic amputations, as described in most of the case studies above, are likely to be more physically able compared to persons whose lower-limb deficiency is due to dysvascular etiology.[277] Yet complications stemming from a trauma may exist, as one SME noted that those with lower-limb deficiency caused by a blast injury may have additional adverse effects from the blast, including damage to the urinary, gastrointestinal, and cardiovascular systems, traumatic brain injury, and mental health problems (such as post-traumatic stress disorder). [278, 279]

Fatigue Rates

Increased fatigue rates with lower-limb deficiency stem from an increase in oxygen consumption by 9% in the amputated leg compared to those with an intact limb. Higher levels of amputation increase severity, with approximately 49% and 280% increased energy expenditure in above-knee and bilateral above-knee amputees, respectively.[280] SMEs reported that shortened limbs result in decreased muscle mass, and this leads to quicker fatigue and less strength.[281] This has the potential to impact a spaceflight mission. Higher oxygen consumption means that estimates may not fully capture crew oxygen requirements, and parastronauts might require higher caloric intake if they are exerting more energy moving around.

Although amputation of a limb results in loss of the muscles that would normally help move that limb, prosthetics are often lighter than the tissue they replace, and therefore may reduce the energy costs of moving that limb. Adequate fitness and rehabilitation after limb loss can help minimize gait deviations and energy expenditure.[282]

Range of Motion

Adequate joint mobility is required for maneuvering both inside and outside of a space vessel. The range of motions can be restricted in those who have developed symptomatic joint inflammation (osteoarthritis) and contractures (permanent tightening of the muscles, tendons, skin, and nearby tissues due to inactivity and scarring), which both cause restricted joint movement and discomfort.[283]

Residual Limb Volume

Residual Limb Volume that changes during the day in a mature stump is primarily due to an excess of fluid in the interstitial space.[284] SMEs suggests that limb volume fluctuates dramatically within the 18 months post-op and will likely fluctuate in varying gravity environments. During that time post-op, specialty socks in which the residual limb is "trained" to fit its prosthetic are utilized.[285] These could be considered during surface landings or upon return to Earth to acclimatize the amputee back to an appropriate fit.

Perspiration and Temperature

SMEs noted that in general those with an amputation had higher than average temperatures due to the increase in energy consumption and the lack of ventilation between the prosthetic limb and the residual limb.[286] However, increases in perspiration may not be problematic, as one SME pointed to the ISS being temperature controlled. [287] Special techniques and equipment lining changes (e.g., using phase-change materials) can help in temperature control as well.[288]

Infection and Dermal Complications

The tight fitting-prosthetic may result in a hot and damp skin interface environment, which can cause friction wounds and infections. Repetitive skin discomfort and pressure will also be prone to calluses, blisters, and local swelling.[289]

Short Stature

The height of a person taken from the ground to the vertex when the head is positioned in the Frankfort horizontal plane (F-H) is known as the height vertex and is commonly called stature. Short stature is defined as height that is two standard deviations below the corresponding mean height of a given age, sex, and population group.[290] There are two types of short stature: proportionate short stature (PSS) and disproportionate short stature (DSS). PSS has short height with the usual proportional trunk and limbs whereas DSS has different sizes of arms, legs, trunk, and/or head. DSS has various subcategories in which anthropometric measurements help in the differential diagnosis process. The normal variant causes of short stature are usually non-syndromic conditions resulting from multiple genes, as opposed to syndromic conditions resulting from a defect in a single gene that cause short stature with pathological disorders.[291]

Individuals with normal variant short stature generally do not need restrictions in activity.[292] However, our research has found that people with short stature often have impaired health status due to comorbidities (including weak muscle tone, dental problems, bowed legs, sleep apnea, and spinal stenosis) that influence their daily living, with greater than average declining health status with increasing age.[293, 294]

Leg Length Difference

Leg length difference is described as an individual's lower limbs being unequal in length.[295] Approximately 23% of the general population has leg inequality of at least 1 cm or more.[296] There are two types of leg length difference – anatomical and functional. The former is described as a true or structural limb length inequality in the femur and ankle joint. Functional leg length difference is the appearance of a shorter limb due to issues with muscle, ligament, or soft tissue rather than bone.[297]

The extent of the discrepancy is not the sole determining factor for the mode of treatment. Management of this condition is mostly based on the functioning ability of the person. Research shows that those with leg length differences use compensatory strategies to minimize the displacement of their body center of mass, which then reduces their energy expenditure.[298] There are many differing opinions in the medical community surrounding the effects of leg length difference, and there are no national or international guidelines on this common condition. There are no definitive connections between leg length differences and other medical conditions; however, it is commonly associated with back pain, osteoarthritis, functional scoliosis (temporary curvature of the spine), inefficient gait, and lack of ankle flexibility.[299]

Each person with a leg length difference has a unique physical capacity to compensate for their limb disparity and therefore, a tailored approach to medical screening should be applied.

Health Data Gaps for Individuals with Disabilities

Mainstream studies within the research community, including aerospace medicine research, severely lack inclusion of persons with disabilities. NASA can help close this gap by incorporating inclusivity in their research study designs. Evidence exists to support that aerospace physicians and researchers with disabilities in leadership roles (both within research or not) are a valuable resource as they offer perspectives and innovations that could otherwise be missed.[300] Remarkably, translational research on common chronic ailments is overwhelmingly in those without disabilities despite similarly afflicting disabled individuals. This disparity leads to a deficit in proper medical treatment for this large demographic.[301] Human spaceflight continues to defy physical norms and influence advancements in every industry, including health. NASA's name is synonymous with innovative and forward thinking. This thinking has successfully retrofitted the human being into the volatile conditions that are par for the course for space exploration. Maintaining a leading presence in aerospace requires an invested and energized reshaping of studies, preparations, as well as mission surveillance that influences future missions. The data produced from the combination of humans with and without disabilities can bolster past and future discoveries. A small number of studies and events suggested that persons with well-controlled chronic conditions can safely withstand actual and analogous space flight conditions.[302] These efforts were possible through several labs simulations that closely replicate extreme space environments.

As it stands, human spaceflight already defies the physical norm. For parastronauts, this will mean using the science we have now and applying it to all astronauts in pioneering space missions for research and design from terrestrial analogs to the flight itself.

Laboratory Space Simulations

Laboratory simulations host a range of space environmental stressors for subjects to use in training such as human centrifuges, underwater training facilities, and altitude chambers. These simulations themselves are typically dangerous and come with numerous advance warnings for participants. The assumption remains that relatively fit and healthy parastronaut will be undertaking the challenges of these training scenarios and should be capable of being suitably assessed on the tasks that their missions require of them. The high accelerating forces, pressure extremes, and the performance measures displayed in standard and emergency assessment trails are opportunities to design space vessels, equipment, and protocols that can be adaptable for most (i.e., human centric). Those with numerous organ system maladies or severe conditions could have their conditions exacerbated beyond repair. With this is mind, future risk assessment and medical preparedness studies should include those with disabilities to establish baselines in medical, technical, and operational parameters that will advance for humans of all abilities – terrestrially and beyond.

POTENTIAL BENEFITS

Beyond the stated challenges and hurdles to parastronaut inclusion, there are added benefits ranging from increased safety to innovation and enhanced crew performance.

Regarding each of the three physical disabilities, SMEs note some practical benefits. For example, individuals of short stature weigh less and take up less space, which could be an added benefit in an environment where each additional pound of payload costs thousands of dollars.[303] Amputees also weigh less on average – prosthetic devices are very light in comparison to the human leg, and in some cases, can lighten the weight of the human body by a third depending on the prosthesis material and degree of amputation.[304] On average, a below-knee prosthetic device weighs between 0.5 and 2 kg, whereas the limb that it is replacing is closer to 4 kg (assuming a 70 kg man).[305]

Several SMEs and academics have noted that updates to onboard training and procedures to accommodate parastronauts could, in fact, lead to an overall increase in safety and performance.[306] Not only does universal design facilitate inclusion, but it also inherently results in system redundancies and functionalities that could increase safety measures for the entire crew. For example, accessible instrumentation that has been adapted for a blind or visually impaired astronaut could be utilized by a sighted astronaut in the dark, or a temporarily blinded astronaut, as in the case of Canadian astronaut Chris Hadfield during a 2001 spacewalk.[307] Similarly, during the 1997 fire aboard the Russian Mir space station, the crew's vision was obstructed by smoke. A blind astronaut would not be impacted by the sudden lack of vision and would be able to locate the fire extinguisher based on their awareness of the cabin.[308] In the event of sudden temporary (or even permanent) hearing loss, a deaf astronaut knowledgeable in American Sign Language could continue non-verbal communication with their crew if properly trained.[309] Additionally, due to differences in the vestibular system, some deaf individuals are immune or resistant to motion sickness – during the famous Gallaudet 11 studies in the 1950s, NASA demonstrated that deaf individuals might be more adaptable to foreign gravitational environments.[310]

There is strong consensus among SMEs that allowing differently abled people in space will benefit NASA by demonstrating the capabilities of individuals with disabilities.[311] Further, individuals with disabilities can bring many desirable skillsets and unique perspectives to NASA's astronaut pool. Improved inclusivity can positively impact a team by increasing innovation, motivation, and a sense of individual value.[312]

SMEs have highlighted positive characteristics of individuals with disabilities that would likely be considered for parastronaut selection, including being highly motivated,[313] less risk adverse,[314] adaptable and perseverant,[315] resilient,[316] and possessing strong mental fortitude.[317] Many individuals with disabilities have high problem-solving skills, due to having to adapt daily to a world not always designed for them.[318] Further, individuals who have experienced a traumatic amputation could be calmer in emergency situations, as they have likely demonstrated this ability upon experiencing the traumatic amputation.[319]

DISCUSSION AND CONCLUSION

DISCUSSION

For NASA and the international space agencies to keep pace with societal and commercial advances, understanding the feasibility of inclusion of parastronauts in space is warranted. In the past decade, societal attitudes toward diversity and inclusivity have shifted along with a shift in technological capabilities and accommodations. While no individual with a known, disqualifying physical and/or mental disability has yet flown in space, commercial space ventures are already beginning to lessen restrictions of who qualifies for human spaceflight. The likelihood of an individual with an amputation or other physical disability traveling to space will increase in the upcoming decades with increased space flight participation from commercial entities. The technology and health/medical standards necessary to fly them safely must also increase and evolve with changing astronaut medical standards and policies.

Parastronaut inclusion may require redesign of current and future systems, but challenges our notions of human spaceflight as they stand today. NASA's perspective should transition from "what can parastronauts do or not do?" to "what role do we want parastronauts to fill?" For example, all NASA crewmembers are currently expected to fly aboard the spacecraft and perform space walks.[321] As such, astronauts must meet the anthropometric requirements for both the spacecraft and EVA suits. NASA could consider having different roles or responsibilities for parastronauts; that is, an individual could be qualified for the space flight, but not qualified for space walks.[322] This would still allow the parastronaut to take part in a space mission, and the added costs and potentially significant technological challenges of parastronaut EVA suit development would be obviated. However, the trade-off of an astronaut not being able to participate in EVA in the event of emergency should be weighed.

Continued human space exploration, in term of length of time and distance traveled, increases the chance that those individuals might experience an adverse medical condition or traumatic injury resulting in a temporary or permanent physical state similar to that of a parastronaut. Regardless of the amount of terrestrially testing and training, the space environment and subsequent planetary gravity systems is different, which will lead to unanticipated challenges.[323] Implementing human-centered, inclusive design approaches on the front end could help alleviate some of these unknown hurdles.

Investment in technology and capabilities to enable parastronauts could translate beyond human space exploration to terrestrial medicine and health care. For example, low Earth orbit could lend applicable for "Space Rehab," that is, leveraging microgravity to conduct more effective physical therapy and rehabilitation. One expert noted that low Earth orbit-based rehabilitation could be beneficial to new amputees, enabling them to manage re-loading and weight bearing rehabilitation possibly more effectively than on Earth.[324] Further, technological innovations realized through parastronaut inclusion could be utilized in terrestrial care. Much like the DoD has been a driver for prosthetic device technology in recent decades,[325] NASA could see dual use in innovations for individuals with disabilities beyond parastronauts. The DoD advances have benefited not only veterans, but the greater disabled community. NASA has the opportunity to make a similar impact.

Understanding the feasibility of parastronauts is not only about shifting the work environment to view disability beyond the medical lens, but also understanding that disability is part of an individual's larger identity. Disability can add value to an individual's experiences and brings new perspectives to the table. While only three disabilities were studied for this report, it is likely that after the success of an initial parastronaut program, further physical conditions will be removed from the disqualification list. NASA will need to consider the degree to which they are willing to accommodate and continue to monitor the feasibility of a wider range of physical disabilities.

There are many unknown risks related to parastronauts, but this does not imply they are inherently "riskier." Rather, parastronauts face different, unique types of risk that must be comprehensively assessed. On the question of parastronaut feasibility, SMEs consulted by the Potomac Institute indicated there is likely no question: instead, the question revolves on whether there is significant motivation, allocation of resources (i.e., time and funding), and a thorough understanding of the overall mission risk (both human and engineering systems) to change and evolve astronaut selection criteria for the modern era of human space flight. Parastronauts will not fly until these factors are considered and in alignment.

In order to shed light on the overall mission risk, OCHMO and NASA could first envision a series of small parabolic flights to understand moving from operational safety demonstrations to conducting real space research or demonstrating technology. This could move into an intermediate step – suborbital flights – wherein individuals with disabilities could carry out research on actual space flights. Finally, this could transition to an eventual ISS or shuttle mission assignment if data collected in earlier steps demonstrates satisfactory safety and performance thresholds. However, an additional consideration for NASA is the degree to which some mission delay is acceptable, particularly in light of upcoming timelines for Artemis missions.

NASA's Flight Opportunity Program also offers individuals who have not met the astronaut requirements the opportunity to enter space and fly with NASA. These researchers are able to conduct human-tended studies in austere environments including zero gravity, extreme radiation, and extreme temperatures through this program.[326] While policy alterations to the Astronaut Corps selection requirements would be required to allow individuals with physical disabilities to fly, the Flight Opportunity Program does not pose the same hurdles. Therefore, it could be an avenue to explore this possibility.

CONCLUSIONS

The possibility of increasing access to space is inspiring and aligns with NASA's overarching vision to "reach for new heights and reveal the unknown for the benefit of humankind."[320] However, integrating parastronauts into NASA's Astronaut Corps requires a thorough understanding of the technical, operational, and medical hurdles, relevant policy implications, and effective alignment between the human systems needs and engineering systems requirements.

Policy Assessment

NASA's Astronaut Corps is fostering an astronaut candidate pool that pulls individuals from a wide array of backgrounds. All astronaut candidates, however, must meet the stringent physical and mental health requirements of the Astronaut Corps. Only applicants deemed "medically qualified" by the Astronaut Selection Committee are referred to final evaluation and possible astronaut selection, which currently excludes certain categories of individuals with disabilities.

US federal policy has increased diversity and inclusion of underrepresented groups over the past decades, particularly for individuals with disabilities, with the Rehab Act, ADA, ADAAA, and various other federal policies and executive orders. As such, federally funded agencies are required to provide "reasonable accommodation" for known physical and/or mental limitations of otherwise qualified employees. However, in the case that it can be demonstrated that such accommodation(s) would impose an undue hardship on the organization or accommodations would fundamentally alter the nature of a program, service, or activity, the ADA does not require changes.

The DoD currently disqualifies individuals for military service if they have lower-limb deficiencies, short stature (below approximately 4' 10"), and/or leg length differences significant enough to cause a limp, as outlined above. Each branch of the US military has specific standards for disqualification as detailed, but generally follows the aforementioned standards.

While individuals with missing limbs may not enlist in active military roles, those who experience amputations while serving have the option to remain in a combat or non-combat role depending on their degree of injury and the imposed functional limitations. Each branch has specific standards by which it evaluates a limb loss injury and the individual's subsequent fitness for duty.

Across the DoD, an individual that experiences a limb loss while serving on active military duty must demonstrate they can perform at the same physical level and meet the same physical standards as individuals with no limb loss to return to active duty. The DoD does not offer alternative accommodations or adaptations to the certification/recertification of its service members following a traumatic limb injury and/or loss; however, the DoD has revised its policies in recent decades to allow individuals the opportunity to re-qualify for duty.

As commercial spaceflight ventures increase, policies concerning private astronauts and space flight participants are being developed through the FAA and private entities. In some cases, these policies are less rigorous than those required by NASA. Commercial entities view private spaceflight as less demanding compared to governmental space agencies aided by purview of different technological capabilities, and see the role of their astronauts and space participants differently than NASA.

Case Studies

Twenty-three case studies (nineteen DoD; four other) were identified to document individuals that have experienced limb loss (either traumatic or congenital amputation) or are of short stature, and highlight their experiences in returning to military duty and/or alternative activities.

Understanding previous cases of service members who have sustained physical disabilities can improve situational awareness and provide a benchmark to inform decision-making surrounding the integration of parastronauts into the Astronaut Corps. Commercial space flight ventures include individuals who would not qualify under NASA's current medical standards but are able to fly successfully under commercial qualification criteria.

Considerations and Hurdles

It is imperative that inclusion of parastronauts into the Astronaut Corps maintains the continued safety and usefulness of the mission. Therefore, understanding these outlined considerations helps inform the feasibility and overall cost (e.g., time, funding, resources) required to realistically integrate parastronauts into a spaceflight mission.

Technical and operational considerations surrounding parastronauts highlights the importance of employing human-centered design approaches to spacecraft and equipment development. However, there are potential benefits to inclusion of parastronauts – from more universal-design approaches to human system risk mitigation and increased diversity.

Significant hurdles including technical, operational, and medical challenges are related to parastronaut inclusion. These include spacesuit design considerations, functional testing of emergency ingress and egress procedures, and interior space craft design modifications or adaptations. Short stature will likely require the most technological and operational developments, especially for emergency ingress/egress. Depending on the degree of impairment, leg length differences present the least difficultly for space flight.

OCHMO requested the Potomac Institute develop a parastronaut feasibility study to include documentation of relevant DoD case studies, a policy assessment of policy issues related to parastronauts, and identification of potential hurdles and considerations (i.e., technical, operational, medical) for parastronaut inclusion. The body of this study has included findings for each of the specified components related to individuals with a lower leg deficiency, short stature, and/or leg length difference. Stakeholders with varying backgrounds and perspectives were identified across

industry, non-profits, medical providers, government and military, and academia. Based on a comprehensive review of all the findings, which are largely based on interviews and understandings gleaned from SMEs in addition to robust, internal research, we conclude that the feasibility of parastronaut inclusion in NASA's astronaut pool is high; however, there are insufficient resources to safely and effectively fly parastronauts of the sort studied in this report in the near future while restrictive medical standards prohibit the possibility of parastronauts. Restructuring and reframing approaches to medical standards, the astronaut selection process, and risk studies practiced can be adapted for parastronauts inclusion to modernize the Corps and the future of human space exploration.

Findings

Accordingly, we present the following findings integrated from the individual findings throughout this report:

1. **NASA's current medical standards disqualify parastronauts.**
   a. The US DoD currently has more inclusive policies regarding amputees than NASA's Astronaut Corp that vary across the branches of services.
   b. Increasing human access to space is being pursued in private industry and non-profit organizations. Commercial space flight policies currently envision greater inclusivity using baseline standards for crew members to meet (rather than more rigorous medical disqualification criteria) and leveraging technological advances.

2. **Inclusion of parastronauts, while considered technologically feasible, will require additional research and development (R&D) and alignment of human systems and engineering risk assessment.**
   a. Successful inclusion warrants a comprehensive understanding of overall mission risk comprised of both engineering and human systems risks, particularly in the areas of emergency procedures and spacesuit and spacecraft design.
   b. Some of the proposed solutions will require explicit experiments in space to validate safety and performance.
   c. Shifting societal views and policies have led to an emergence in research, and development of technological and medical advances, related to individuals with disabilities.

Recommendations

From these findings, the Potomac Institute study team identified two corresponding recommendations regarding the inclusion of parastronauts into the Astronaut Corps:

1. **Revise medical standards and baseline fitness qualifications to reflect recent advances in science.**
    a. Evaluate current medical standards and astronaut selection criteria at the Agency level to ensure they are appropriate and modernized.
    b. Consider disabilities beyond the three physical disabilities (i.e., lower leg deficiency, short stature, and/or leg length difference) explored in this study.
2. **Employ experimental design utilizing technological and medical advances and relevant partnerships to inform overall parastronaut risk assessment and develop risk reduction pathways.**
    a. Determine the true costs (i.e., time, funding, resources) associated with parastronaut inclusion.
    b. Utilize parabolic flights to demonstrate parastronaut proof-of-principle.
    c. Leverage partnerships with industry to connect government with commercial and non-government organizations already pursuing research, development, technology, and engineering advances related to flying individuals with disabilities.

APPENDIX I. ACRONYMS AND ABBREVIATIONS

ADA	Americans with Disabilities Act of 1990
ADAAA	Americans with Disabilities Act Amendments Act of 2008
AFI	Air Force Instruction
ASL	American Sign Language
BF%	Body Fat Percentage
BK	Below the Knee; also referred to as transtibial
BMI	Body Mass Index
CHAMP	Comprehensive High-activity Mobility Predictor
CHMO	Chief Health Medical Officer
COAD	Continuation on Active Duty
COAR	Continuation on Active Reserve
DAAA	Dwarf Athletic Association of America
DoD	Department of Defense
DSS	Disproportionate Short Stature
EEOC	Equal Employment Opportunity Commission
ESA	European Space Agency
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
F-H	Frankfort Horizontal Plane
FPEB	Formal Physical Evaluation Board
FY	Fiscal Year
IDAF	International Dwarf Athletic Federation
IDES	Integrated Disability Evaluation System
IED	Improvised Explosive Device
IPC	International Paralympic Committee
ISS	International Space Station
LEA	Launch, Entry, and Abort
LPA	Little People of America
MEB	Medical Evaluation Board
MEPS	Medical Evaluation Processing Station

NASA	National Aeronautics and Space Administration
NCO	Non-commissioned Officer
NL	No Limit
OCHMO	Office of the Chief Health Medical Office
ONE	Orthopedic/neurological Examination
OTTER	Orbital Technologies and Tools for Extravehicular Research
PD	Permanent Disqualification
PEB	Physical Evaluation Board
PoSSUM	Polar Suborbital Science in the Upper Mesosphere
PSS	Proportionate Short Stature
RCP	Retirement or Retention Control Point
RTD	Return to Duty
R&D	Research and Development
SCUBA	Self-Contained Underwater Breathing Apparatus
SME	Subject Matter Experts
SODA	Statement of Demonstrated Ability
S&T	Science and Technology
STEM	Science, Technology, Engineering, and Mathematics
TD	Temporary Disqualification
T/F	Track and Field
USG	United States Government
USMEPCOM	United States Military Entrance Processing Command
USSF	US Space Force
VA	Veteran Affairs

APPENDIX II. SUPPLEMENTAL REQUIREMENTS

Table 3. List of anthropomorphic measurements by aircraft.[327]

Aircraft	Sitting Height (in)	Thumb Tip Reach (in)	Sitting Eye Height (in)
HU-25	33.0-40.9	27.0 or greater	28.5 or greater
MH-65	33.0-40.9	28.5 or greater	28.5 or greater
MH-60	33.0-40.9	29.0 or greater	28.5 or greater
HC-130	33.0-40.9	26.5 or greater	28.5 or greater

Table 4. US Coast Guard Physical Fitness Requirements.

Activity	Time Allowed	Requirement for Women	Requirement for Men
Push-Ups	1 minute	15 reps	29 reps
Sit-Ups	1 minute	32 reps	38 reps
1.5-Mile Run	X	15 mins 26 secs	12 mins 51 secs
Swim Circuit	No Restriction	Jump off a 1.5 meter platform into the pool, swim 100 meters unassisted	

Table 5. Required physical ability demonstrations to enter the US Marine Corps by task and gender. Where there were discrepancies in requirements, the lowest was listed for the minimum and the highest was listed for the maximum. [328]

	Activity	Requirement for Men	Requirement for Women
Initial Strength Test	Push-Ups OR	34 reps	15 reps
	Pull-Ups	3 reps	1 rep
	Crunches OR	44 in 2 mins	
	Plank Pose	40 seconds	
	1.5-Mile Run	13:30* or less	15:00* or less

	Activity	Requirement for Men		Requirement for Women	
		Min	Max	Min	Max
Physical Fitness Test	Push-Ups OR	39-42 reps	82-87 reps	18-19 reps	42-50 reps
	Pull-Ups	4-5 reps	20-23 reps	1-4 reps	7-12 reps
	Crunches OR	70 reps	105-115 reps	50-60 reps	100-110 reps
	Plank Pose	NL**	5 mins	NL	5 mins
	3-Mile Run	31 minutes or less		28 minutes or less	

	Activity	Description	Requirement for Men		Requirement for Women	
			Min	Max	Min	Max
Combat Fitness Test	Movement to Contact	880-yard sprint that mimics the stresses of running under pressure in battle	3:45- 3:48*	2:38-2:40*	4:36-4:45*	3:10-3:19*
	Ammunition Can Lift	Lift a 30-pound ammunition can overhead until elbows lock out as many times as possible in 2 minutes	2-67 reps	106-116 reps	30 reps	66-75 reps
	Maneuver Under Fire	300-yard course that combines a variety of battle-related challenges, including crawls, ammunition resupply, grenade throwing, agility running, and the dragging and carrying of another Marine	3:17-3:22*	2:07-2:45*	4:40-4:53*	2:42-2:55*

** Minutes: seconds   ** No Limit (NL)*

APPENDIX III. MEDICAL EVALUATION BOARD: EVALUATION TEMPLATES

Evaluation Template for Amputees[329]

Residuals of Amputations Examination

Name: SSN:

Date of Exam: C-number:

Place of Exam:

A. Review of Medical Records:

B. Medical History (Subjective Complaints):
Comment on:

1. The location of the amputation site.
2. If symptoms exist, describe precipitating factors, aggravating factors, alleviating factors, alleviating medications, frequency, severity, and duration.
3. If there are periods of flare-up of condition:

   State their severity, frequency, and duration.

   Name the precipitating and alleviating factors.

   Estimate to what extent, if any, *per veteran*, they affect functional impairment during the flare-up.

C. Physical Examination (Objective Findings):
Address each of the following and fully describe current findings:

1. Swelling, deformity, tenderness of stump.
2. Skin, including scar.
3. Circulation.
4. Muscles.
5. Describe any limited motion or instability in the joint above the amputation site.
6. **A detailed assessment of each affected joint is required**.

a. Using a goniometer, measure the *passive* and *active* range of motion, including movement against gravity and against strong resistance.
b. If the joint is painful on motion, state at what point in the range of motion pain begins and ends.
c. Describe presence or absence of: pain (including pain on repeated use); fatigue; weakness; lack of endurance; and incoordination.

7. Bones.
8. Length of stump.
9. Neuroma, if present.
10. Is amputation of lower extremity improvable by prosthesis controlled by natural knee action?

Measurement of the Stump:

The stump of an amputated **thigh** will be measured from the perineum, at the origin of the adductor tendons, to the bony end of the stump, with the claimant recumbent and the stump lying parallel with the other lower limb. It is to be kept in mind that if the limb is abducted, flexed, rotated or adducted, its length will be altered. The effective length of a thigh stump is governed by its inside dimension. Measure length of normal thigh if present and indicate whether amputation is in upper, middle, or lower third. When amputation is bilateral, estimate the same for a person of similar height.

The stump of an amputated **leg below the knee** must be measured from the insertion of the internal hamstring muscles to the bony end of the stump with the patient recumbent and the leg flexed at 90 degrees.

The stump of an amputated **arm** should be measured from the anterior axillary fold to the bony end of the stump, with the stump hanging parallel to the chest wall. Indicate whether the amputation site is above or below the insertion of the deltoid muscle. A statement of the remaining function is the best indicator of a disability's severity.

The stump of an amputated **forearm** should be measured from the insertion of the biceps tendon to the bony end, with the elbow flexed at 90 degrees. Indicate if the amputation site is above or below the attachment of the pronator teres.

Amputations of **fingers** should be described as through the distal, middle, or proximal phalanx or as disarticulations through the distal interphalangeal, proximal interphalangeal, or metacarpophalangeal joint. Resection of the head of the metacarpal will always be reported if shown. Complete or partial loss or resection of bones of the hand will described in terms of the fraction of each remaining. If surgery has altered the usefulness of remaining or transplanted digits, this will be described.

Complete or partial loss of **toes** or **metatarsal or tarsal bones** should be described as in the subparagraph above. Always report loss of metatarsal head or other defects. Indicate if amputation is through the tarsal-metatarsal joint and if any other portions of the bones of the foot remain.

D. Diagnostic and Clinical Tests:

1. X-ray if exact amputation level is not of record.
2. Include results of all diagnostic and clinical tests conducted in the examination report.

E. Diagnosis:

Amputations must be described in accordance with the following levels:

1. ARM:

   a. Disarticulation.
   b. Amputation above insertion of deltoid muscle.
   c. Amputation below insertion of deltoid muscle.

2. FOREARM:

   a. Above radial insertion of pronator teres (function is best indicator of disability).
   b. Below insertion of pronator teres.
   c.

3. THIGH:

   a. Disarticulation, with loss of extrinsic pelvic girdle muscles.
   b. Amputation of upper, middle or lower third, always measured from perineum to the bony end of the stump with the claimant recumbent and stump lying parallel with the other lower limb.
   c. State whether this level permits satisfactory prosthesis.

4. LEG:

   a. Give level of amputation and condition of stump.
   b. State whether this level permits a satisfactory prosthesis.

c. Describe any stump defects (e.g., painful neuroma or circulatory disturbance).

F. Additional Limitation of Joint Function:

Impairment of joint function is determined by actual range of joint motion as reported in the physical examination and additional limitation of joint function caused by the following factors:

1. Pain, including pain on repeated use
2. Fatigue
3. Weakness
4. Lack of endurance
5. Incoordination

Do any of the above factors additionally limit joint function? If so, express the additional limitation in degrees.

Indicate if you cannot determine, without resort to mere speculation, whether any of these factors cause additional functional loss. For example, indicate if you would need to resort to mere speculation in order to express additional limitation due to repetitive use.

Signature: Date:

Version: Pre-2006

EVALUATION TEMPLATE FOR GENERAL MEDICAL CONDITIONS
(which likely pertain to Leg Length Discrepancy and Short Stature)[330]

General Medical Examination

Name:	SSN:
Date of Exam:	C-number:
Place of Exam:	

Narrative: This is a comprehensive base-line or screening examination for all body systems, not just specific conditions claimed by the veteran. It is often the initial post-discharge examination of a veteran requested by the Compensation and Pension Service for disability compensation purposes. As a screening examination, it is not meant to elicit the detailed information about specific conditions that is necessary for rating purposes. **Therefore, all claimed conditions, and any found or suspected conditions that were not claimed, should be addressed by referring to and following all appropriate worksheets, in addition to this one, to assure that the examination for each condition provides information adequate for rating purposes**. This does not require that a medical specialist conduct examinations based on other worksheets, except in the case of vision and hearing problems, mental disorders, or especially complex or unusual problems. **Vision, hearing, and mental disorder examinations must be conducted by a specialist**.

The examiner may request any additional studies or examinations needed for proper diagnosis and evaluation (see other worksheets for guidance). All important negatives should be reported. The regional office may also request a general medical examination as evidence for nonservice-connected disability pension claims or for claimed entitlement to individual unemployability benefits in service-connected disability compensation claims. Barring unusual problems, examinations for pension should generally be adequate if only this general worksheet is followed.

A. Review of Medical Records: Indicate whether the C-file was reviewed.

B. Medical History (Subjective Complaints):

1. Discuss: Whether an injury or disease that is found occurred during active service, before active service, or after active service. To the extent possible, describe the circumstances, dates, specific injury or disease that occurred, treatment, follow-up, and residuals. If the injury or disease occurred before active service, describe any worsening of residuals due to being in military service. Describe current symptoms,
2. If there are flareups of any joint (including of spine, hands, and feet) or muscle disease, state the frequency, duration, precipitating factors, alleviating factors, and the extent, if any, per veteran, they result in additional limitation of motion or other functional impairment during the flareup.
3. Describe details of current treatment, conditions being treated, and side effects of treatment.

4. Describe all surgery and hospitalizations in and after service with approximate

dates.

5. If a neoplasm is or was present, state whether benign or malignant and provide:
   a. Exact diagnosis and date of confirmed diagnosis.
   b. Location of neoplasm
   c. Types and dates of treatment
   d. For malignant neoplasm, also state exact date of the last surgical, X-ray, antineoplastic chemotherapy, radiation, or other therapeutic procedure.
   e. If treatment is already completed, provide date of last treatment and fully describe residuals. If not completed, state expected date of completion.

C. Physical Examination (Objective Findings):

Address each of the following and fully describe current findings: The examiner should incorporate results of all ancillary studies into the final diagnoses.

1. **VS:** Heart rate, blood pressure (see #13 below), respirations, height, weight, maximum weight in past year, weight change in past year, body build, and state of nutrition.

2. **Dominant hand:** Indicate the dominant hand and how this was determined, e.g., writes, eats, combs hair with that hand.

3. **Posture and gait:** Describe abnormality and reason for it. Describe any ambulatory aids and name the condition requiring the ambulatory aid(s).

4. **Skin, including appendages:** If abnormal, describe appearance, location, extent of lesions. If there are laceration or burn scars, describe the location, exact measurements (cm. x cm.), shape, depression, type of tissue loss, adherence, and tenderness. See the Scars worksheet for further guidance. Describe any limitation of activity or limitation of motion due to scarring or other skin lesions. **NOTE:** If there are disfiguring scars (of face, head, or neck), obtain color photographs of the affected area(s) to submit with the examination report.

5. **Hemic and Lymphatic:** Describe adenopathy, tenderness, suppuration, edema, pallor, etc.

6. **Head and face:** Describe scars, skin lesions, deformities, etc., as discussed under Skin.

7. **Eyes:** Describe external eye, pupil reaction, eye movements. State corrected visual acuity and gross visual field assessment.

8. **Ears:** Describe canals, drums, perforations, discharge. State whether hearing is grossly normal or abnormal. Is there a current complaint of tinnitus? If so, do you believe it is related to a current medical or psychological

problem, or is the etiology unknown without further information?

9. **Nose, sinuses, mouth and throat:** Include gross dental findings. For sinusitis, describe headaches, pain, incapacitating (meaning an episode of sinusitis that requires bed rest and treatment by a physician with 4-6 weeks of antibiotic treatment), and non-incapacitating episodes of sinusitis during the past 12-month period frequency and duration of antibiotic treatment.

10. **Neck:** Describe lymph nodes, thyroid, etc.

11. **Chest:** Inspection, palpation, percussion, auscultation. Describe respiratory symptoms and effect on daily activities, e.g., how far the veteran can walk, how many flights of stairs veterans can climb. If a respiratory condition is claimed or suspected, refer to appropriate worksheet(s). Most respiratory conditions will require PFT's, including post-bronchodilation studies.

12. **Breast:** Describe masses, scars, nipple discharge, skin abnormalities. Give date of last mammogram, if any. Describe any breast surgery (with approximate date) and residuals.

13. **Cardiovascular:** NOTE: If there is evidence of a cardiovascular disease, or one is claimed, refer to appropriate worksheet(s).

    a. Record pulse, quality of heart sounds, abnormal heart sounds, arrhythmias. Describe symptoms and treatment for any cardiovascular condition, including peripheral arterial and venous disease. Give NYHA classification of heart disease. A determination of METs by exercise testing may be required for certain cardiovascular conditions, and an estimation of METS may be required if exercise testing cannot be conducted for medical reasons. Report heart size and how determined. (See the cardiovascular worksheets for further guidance.)
    b. Describe the status of peripheral vessels and pulses. Describe edema, stasis pigmentation or eczema, ulcers, or other skin or nail abnormalities. Describe varicose veins, including extent to which any resulting edema is relieved by elevation of extremity. Examine for evidence of residuals of cold injury when indicated. See and follow special cold injury examination worksheet if there is a history of cold exposure in service and the special cold injury examination has not been previously done.
    c. **Blood Pressure:** (Per the rating schedule, hypertension means that the diastolic blood pressure is predominantly 90mm. or greater, and isolated systolic hypertension means that the systolic blood pressure is predominantly 160mm. or greater with a diastolic blood pressure of less than 90mm.)

        i. If the diagnosis of hypertension has not been previously established, and it is a claimed issue, B.P. readings must be taken two or more times on each of at least three different days.
        ii. If hypertension has been previously diagnosed and is claimed, but the

claimant is not on treatment, B.P. readings must be taken two or more times on at least three different days.

iii. If hypertension has been previously diagnosed, and the claimant is on treatment, take three blood pressure readings on the day of the examination.

iv. If hypertension has not been claimed, take three blood pressure readings on the day of the examination. If they are suggestive of hypertension or are borderline, readings must be taken two or more times on at least two additional days to rule hypertension in or out.

v. In the diagnostic summary, state whether hypertension is ruled in or out after completing these B.P. measurements. If hypertensive heart disease is suspected or found, follow worksheet for Heart.

14. **Abdomen:** Inspection, auscultation, palpation, percussion. Describe any organ enlargement, ventral hernia, mass, tenderness, etc.

15. **Genital/rectal (male):** Inspection and palpation of penis, testicles, epididymis, and spermatic cord. If there is a hernia, describe type, location, size, whether complete, reducible, recurrent, supported by truss or belt, and whether or not operable. Describe anal fissures, hemorrhoids, ulcerations, etc. Include digital exam of rectal walls and prostate.

16. **Genital/rectal (female):** Pelvic exam, including inspection of introitus, vagina, and cervix, palpation of labia, vagina, cervix, uterus, adnexa, and ovaries, rectal exam. Do Pap smear if none within past year. If unable to conduct an examination and Pap smear, or if there is a severe or complex problem, refer to a specialist.

17. **Musculoskeletal:**

    a. For all joint or muscle disorders, state each muscle and joint affected.
    b. Separately examine and describe in detail each affected joint. Measure active range of motion in degrees using a goniometer. State whether there is objective evidence of pain on motion. After 3 repetitions of the range of motion, state whether there are additional limitations of range of motion and whether there is objective evidence of pain on motion. Also state the most important factor (pain, weakness, fatigue, lack of endurance, incoordination) for any additional loss of motion after repetitive motion. Report the range of motion after 3 repetitions. (See the appropriate musculoskeletal worksheet for more details.)
    c. Describe swelling, effusion, tenderness, muscle spasm, joint laxity, muscle atrophy, fibrous or bony residual of fracture. If joint is ankylosed, describe the position and angle of fixation.
    d. If foot problems exist, also describe objective evidence of pain at rest and on manipulation, rigidity, spasm, circulatory disturbance, swelling, callus, loss of strength, and whether condition is acquired or congenital.
    e. If there is amputation of a part, see the appropriate worksheet.

f. With disc disease, also describe any abnormal neurological findings and total duration in days or weeks of incapacitating episodes (an incapacitating episode is a period of acute signs and symptoms due to intervertebral disc syndrome that requires bed rest prescribed by a physician and treatment by a physician).

18. **Endocrine:** Describe signs and symptoms of any endocrine disease, effects on other body systems. See endocrine worksheets for further guidance.

19. **Neurological:** Assess orientation and memory, gait, stance, and coordination, cranial nerve functions. Assess deep tendon reflexes, pain, touch, temperature, vibration, and position, motor and sensory status of peripheral nerves. If neurological abnormalities are found on examination, or there is a history of seizures, refer to appropriate worksheet.

20. **Psychiatric:** Describe affect, mood, judgment, behavior, comprehension of commands, hallucinations or delusions, and intelligence (This is meant to be a brief screening examination. If a mental disorder is claimed, or suspected based on the screening, an examination for diagnosis and assessment should be conducted by a psychiatrist or psychologist.)

D. Diagnostic and Clinical Tests:

1. Include results of all diagnostic and clinical tests conducted in the examination report.
2. Review all test results before providing the summary and diagnosis.
3. Follow additional worksheets, as appropriate.
4. The diagnosis of degenerative or traumatic arthritis of any joint requires X-ray confirmation, but once confirmed by X-ray, either in service or after service, no further X-rays of that joint are required for disability evaluation purposes.

E. Diagnosis:

1. Provide a summary list of all disabilities diagnosed. Include an interpretation of the results of all diagnostic and other tests conducted in the final summary and diagnosis.
2. For each condition diagnosed, describe its effect on the veteran's usual occupation and daily activities.
3. **Capacity to Manage Financial Affairs:** Mental competency, for VA benefits purposes, refers only to the ability of the veteran to manage VA benefit payments in his or her own best interest, and not to any other subject. Mental incompetency, for VA benefits purposes, means that the veteran, because of injury or disease, is not capable of managing benefit payments in his or her best interest. In order to assist raters in making a legal determination as to competency, please address the following:

What is the impact of injury or disease on the veteran's ability to manage his or her financial affairs, including consideration of such things as knowing the amount of his or her VA benefit payment, knowing the amounts and types of bills owed monthly, and handling the payment prudently? Does the veteran handle the money and pay the bills himself or herself?

Based on your examination, do you believe that the veteran is capable of managing his or her financial affairs? Please provide examples to support your conclusion.

If you believe a Social Work Service assessment is needed before you can give your opinion on the veteran's ability to manage his or her financial affairs, please explain why.

Signature: Date:

Version: 2-25-2010

ENDNOTES

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901 N. Stuart St. Suite 1200
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