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On the advantages of the disabled in space.

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Abstract

Since the start of the astronaut program in the 1960s, candidates have had to prove to be in prime physical shape before being granted clearance to fly, whereas those with physical disabilities such as blindness or deafness are automatically disqualified. The stigma that disabled persons are less qualified to succeed in a physically alien environment has persisted, though little research exists in revisiting the difficulties posed by allowing this group into the space program. This paper aims to reconsider the advantages and disadvantages of a disability-friendly space program, to include cost considerations, potential challenges, and the unique benefits posed by allowing this minority group into the astronaut program. Such advantages include unique health and mental advantages disabled persons acquire as a result of their disability. Suggestions to reconfigure the current space program into a disability-friendly one are introduced for consideration.

Keywords: Space program, disability accommodations, hard of hearing, deaf, blindness, paraplegic accommodations, International Space Station, NASA, spaceflight, spaceflight accommodations

On the Advantages of the Disabled in Space

Throughout the National Aeronautics and Space Administration's (NASA) 61-year history, only one astronaut with any physical impairment has made it to space. Most often recognized by his official NASA portrait where he is featured posing with his two dogs, Leland Melvin—a former professional football player and the thirteenth African American in space—was completing an underwater spacewalk simulation for his training when an accident left him deaf in one ear, leaving him medically disqualified from further space preparation until after the Columbia shuttle disaster in 2003. Lucky circumstances and self-declared stubbornness enabled him to earn a medical waiver and serve as Mission Specialist for two missions, in 2008 and 2009, taking ten years to reach space, compared to the average astronaut's two (Melvin, 2018).

Since then, the possibility of disabled participants in the space program has returned to an impossibility. Medical waivers, as outlined on NASA's website, are no longer issued for any medical disqualification (National Aeronautics and Space Administration, n.d.). In an unforgiving work environment, having to provide extra accommodations in an uncomfortably small spacecraft for a deaf or blind astronaut seems unnecessary, costly, and dangerous. If disabled persons are already barred from military service, space programs are no more likely to expect them to be able to perform under similarly dangerous and stressful conditions, 200 miles up in space. This perspective, however, comes from a majority group of non-disabled persons who have not experienced a need to incorporate disabled colleagues since the beginning of the Apollo missions.

Indeed, in preparation for the first human spaceflights of the Space Race, NASA placed a heavy emphasis on the study of recruited deaf students from Gallaudet University to study their peculiar talent to not experience motion sickness, an enviable quality for any astronaut (Hotovy, 2017). As motion sickness comes from conflicting signals from the inner ear, eyes, skin receptors, and muscle and joint sensors, deaf subjects without a functioning inner ear are often immune to motion-related nausea and sickness, giving them a potential advantage over hearing astronaut candidates, who may be distracted in the first several days of spaceflight due to motion-related space sickness. Such space motion sickness can "significantly jeopardize their [astronauts'] operational preparedness" and is a chronic issue even today to ensure that astronauts are alert enough to respond to issues at the beginning of missions (Russomano, da Rosa, & A dos Santos, 2019). Despite this obvious advantage in deaf candidates' eligibility for spaceflight, NASA ultimately deemed the Gallaudet 11 unfit for space travel.

Only recently has the topic of disabled astronauts cropped up again with the publication of Sheri Wells-Jensen's Scientific American article "The Case for Disabled Astronauts," and only recently has the question been asked on whether disabled people are more qualified to be astronauts than those qualified under the normal standard for fitness ascribed to today (Eveleth, 2019). If the deaf were allowed to participate in the space program, then not only would they likely not have to worry about the motion sickness that takes over most astronauts, they would not have to worry about the potential for hearing loss that often comes with living in such a constantly loud environment for an extended period of time. If blind scientists were on board, they would not be as distracted in times of crisis where the lights are often the first to go out (Wells-Jensen, 2018). Although the thought of incorporating physically disabled candidates into the space program would mean considering new design problems in spacecraft and its operations, it would also mean enabling a uniquely qualified group of individuals to tackle a hostile work environment they already have experience coping with. After all, disabled persons already spend every day on a planet designed for a population that is not like them, giving them valuable experience in dealing with less-than-easy conditions. It is these considerations that form the basis of this research, and will be explored in-depth throughout this article.

There is, however, a lack of in-depth thought and research into what exactly a space program with disabled people would have to look like. Wells-Jensen, Miele, & Bohney (2019) discuss the inherent advantages of allowing deaf and blind individuals into the space program, particularly considering the growing global interest in longer-duration space travel, where the physical toll on a human body gets more severe with time. However, other than offering the suggestion of a universal design system—that is, simply designing spacecraft to be user-friendly for all—there is no collective work on what would have to be considered in identifying redesigns to the space program to allow for disabled scientists to be included. Further, there exists no quantitative research on the actual benefit of allowing disabled scientists into the space program. Without the medications and training to abate motion sickness, how much money and time is saved, for instance, by allowing a deaf researcher into the program? And specifically how much extra time and money must be spent to incorporate sign language or a screen language system for the entire crew? Although plenty of articles appear to support the idea of a disabled astronaut and the possible advantages, there is a lack of cost and design studies regarding such an undertaking.

Utilizing NASA's publicly available designs (in particular, the design of the International Space Station, or ISS), along with publicly available training curricula, this research project examines the potential challenges and advantages of three primary physically disabled groups—deafness/hard-of-hearing, blindness, and paraplegics and amputees from the waist-down—in a spaceflight environment and offers low-cost suggestions for adaptation of NASA's current program to accommodate these groups. The implementation of disabled persons in space, a minority group yet to be addressed by NASA in a decade of milestones for women, members of color, and LGBT members, would obviously be another landmark achievement in the quest for social equality, but there are additional benefits for space programs themselves for implementing this untapped resource. Firstly, there would be access to an additional group of knowledge; by not automatically disqualifying these people, academic and personality merits can be given additional weight over physical readiness. Secondly, the skills acquired by these individuals living as a minority with unique requirements—such as attention to detail, critical thinking, and adaptability to name a few—are key survival skills in space, and these individuals are already forced to develop these traits each day. Finally, the unique biological conditions of a disabled person (lack of motion sickness due to deafness, for instance) can be creatively utilized in space to reduce training and costs. Current literature spanning biological and psychological patterns in disabled persons, as well as studying NASA space stations and operations today, are studied to address these issues. Scientific reports on how the human body is affected in space, such as studies on the operation of cochleae in a zero-gravity environment, are used to identify potential advantages and shortfalls to a disabled astronaut. This project draws on open source research into the physiology and psychology of disabled versus non-disabled persons, and publicly available records on NASA operations; hopefully, further research would include the actual construction of the theoretical ideas put forth in this article to be tested further.

In this case, "disabled" will focus on those with hearing, visual, and physical impairments from the waist down. Although there are several other groups deserving of consideration for such a program, these three groups are some of the most prominent groups in the disability community and will be used as a starting point for what hopefully becomes a serious discussion in the spaceflight community. Additionally, learning disabilities, such as dyslexia or dysgraphia, are outside the scope of physical disabilities in this research and are not discussed in this instance.

First, consideration is given to the commonly held disadvantages of these groups, with an analysis on how severe these are compared to the potential advantages—how are these individuals forced to operate on earth that can be helpful in the space program, compared to their more abled peers? Ultimately, these advantages and disadvantages of each group will contribute towards creating ideas for key design changes on the ISS to be conducive towards an effective living environment for disabled astronauts. The report ends with a final discussion on what a space crew with multiple disability representations may look like.

1. Current Duties and Routines of Astronauts on the ISS

After years of training in Russian, robotics engineering, emergency medicine, flight routines, winter survival (in case an emergency landing causes a crew to end up in northern Russia), stress resilience, and general worst-case scenarios, daily life on the ISS can seem like a rigorous yet standard routine (Bond, 2002). An astronaut's primary three tasks on the ISS are to maintain research projects, conduct research on themselves to distinguish effects of long-term spaceflight, and maintain the general upkeep of the ISS, where mitigating mold spores, dust, and performing equipment repairs and replacements can take up a significant part of the day (Kelly, 2017). Sleeping, eating, and physical activity are closely monitored and not retrenched in favor of research or maintenance—each astronaut exercises at least 2.5 hours a day to counteract the effects of bone and muscle loss due to the zero gravity environment. Tables 1-3 show examples of typical daily routines for a flight commander, pilot, and engineer of a given crew.

Table 1. Example of Daily Schedule for Flight Commander (CDR)[1]

Time (GMT)	Activity
06:00-06:10	Morning Inspection
06:10-06:40	Personal Hygiene (post-sleep)
06:40-06:50	HEMATOCRIT: measurement of hematocrit value
06:50-07:40	Breakfast
07:40-07:55	REFLEX-N: equipment setup
07:55-08:10	REFLEX-N: setup and activation of PC
08:45-09:00	Daily planning conference
09:00-09:10	Work prep
09:10-09:30	Daily status check of US payloads
09:30-09:55	SAMS filter cleaning
09:55-10:25	SAMS ICU: drawer 1 relocation
10:25-10:40	SAMS ICU activation
10:40-11:10	SSC Router relocation
11:10-12:10	Physical Exercise (RED)
12:10-12:48	CDR Lunch
12:48-12:53	Prep for ISS ham radio session
12:53-13:03	ISS ham radio session
13:13-13:35	ISS3/ISS4 crew conference (S-band)
13:35-14:35	UF-1 Timeline review
14:35-14:55	UF-1 Timeline A/G tagup (S-band)
14:55-15:25	UF-1 Timeline review
15:25-15:55	Maintenance
16:00-16:30	REFLEX N: CDR subject
16:30-16:45	REFLEX N: equipment stowage
16:45-18:15	Physical Exercise (TVIS)
18:15-18:30	Review of plan for upcoming day
18:30-18:55	Report prep
18:55-19:10	Daily planning conference
19:10-19:30	Report prep
19:30-20:00	Dinner
20:00-20:30	Daily food ration prep
20:30-21:30	Personal Hygiene (pre-sleep)
21:30-06:00	Sleep

[1] Table adapted from Table 7.1 in *The Continuing Story of the International Space Station*, Peter Bond, 2002.

Table 2. Example of Daily Schedule for Pilot (PLT)[2]

Time (GMT)	Activity
06:50-07:00	Morning Inspection
07:00-07:10	HEMATOCRIT: measurement of hematocrit value
07:10-07:35	Prep for SPRUT experiment
07:35-08:15	SPRUT experiment
08:15 - 09:10	Breakfast
09:10-09:40	Collect FMK monitors
09:40-10:40	Dismantling SSC network. Conference with ground specialist (S-Band)
10:40-11:10	REFLEX-N: PLT Subject
11:10-12:10	Physical Exercise (cycle)
12:10-13:10	Lunch
13:13-13:35	ISS3/ISS4 crew conference (S-band)
13:35-14:35	UF-1 Timeline review
14:35-14:55	UF-1 Timeline A/G tagup (S-band)
14:55-15:25	UF-1 Timeline review
15:40-17:10	Physical Exercise (TVIS + RED)
17:15-18:15	Connecting SmartSwitch Router. Conference with ground specialist (S-Band)
18:15-18:30	Review of plan for upcoming day
18:30-18:55	Report prep
18:55-19:10	Daily planning conference
19:10-19:30	Report prep
19:30-20:00	Dinner
20:00-20:30	Daily food ration prep
20:30-21:30	Personal Hygiene (pre-sleep)
21:30-06:00	Sleep

[2] Table adapted from Table 7.1 in *The Continuing Story of the International Space Station,* Peter Bond, 2002.

Table 3. Example of Daily Schedule for Flight Engineer (FE-1)[3]

Time (GMT)	Activity
06:50-07:00	Morning Inspection
07:00-07:10	HEMATOCRIT: measurement of hematocrit value
07:10-07:35	Prep for SPRUT experiment
07:35-08:15	SPRUT experiment
08:15-09:10	Breakfast
09:10-09:40	REFLEX-N: FE-1 Subject
09:40-10:40	Dismantling SSC network. Conference with ground specialist (S-Band)
10:40-12:10	Physical Exercise (TVIS + RED)
12:10-13:10	Lunch
13:13-13:35	ISS3/ISS4 crew conference (S-band)
13:35-14:35	UF-1 Timeline review
14:35-14:55	UF-1 Timeline A/G tagup (S-band)
14:55-15:25	UF-1 Timeline review
15:40-16:40	Physical Exercise (cycle)
16:40-17:15	Delta file downlink prep
17:15-18:15	Connecting SmartSwitch Router. Conference with ground specialist (S-Band)
18:15-18:30	Review of plan for upcoming day
18:30-18:55	Report prep
18:55-19:10	Daily planning conference
19:10-19:30	Report prep
19:30-20:00	Dinner
20:00-20:30	Daily food ration prep
20:30-21:30	Personal Hygiene (pre-sleep)
21:30-06:00	Sleep

Primarily, however, astronauts are simply full-time lab assistants in a uniquely strict environment. Astronauts can generally expect to be busied with conference calls, filter changes, and scientific experiments that are typical of a lab on Earth. The following recommendations for

[3] Table adapted from Table 7.1 in *The Continuing Story of the International Space Station,* Peter Bond, 2002.

disability accommodations, then, are discussed based on what is actually required to perform daily duties on the ISS. Assuming that an initial flight crew would not consist solely of disabled persons (though what a thought!), it is assumed that the position of piloting a disability-friendly crew to and from the ISS would still lie with a traditionally medically qualified candidate. However, accommodating disabilities once on the ISS and other long-term spacecraft is generally doable, and even beneficial, to the long-term success of the space program.

2. **Deaf and Hard-of-Hearing Considerations**

Although deaf and hard-of-hearing individuals are often grouped together, their circumstances are quite different in terms of accommodation on Earth. Deaf individuals are generally dependent on sign language as their primary means of communication, while hard-of-hearing individuals can generally function well in either deaf or hearing society; they usually wear hearing aids as a supplemental hearing device, while deaf individuals are typically only able to distinguish loud noises with the aid of cochlear implants, which do not serve the same function as hearing aids. Deaf individuals can and are likely to still be reliant on sign language even if they do wear implants.

Thus, deaf and hard-of-hearing individuals pose their own unique challenges when considering their integration in the space program, though both will have a heavy reliance on visual cues as a mode of communication. This ultimately means that some form of sign language would likely have to be implemented into the already-lengthy astronaut training program, where some 1600 hours of NASA's program is already devoted to Russian language instruction (Bond, 2002). At least another 800 would have to be devoted to learning either American or Russian sign language, based on current estimates of how long it takes to become intermediate at a non-native language (Center for Applied Second Language Studies (CASLS), University of Oregon, 2010). Without access to an itemized budget for NASA's candidate training program, it is difficult to exactly estimate the cost of a sign-language program into training. However, assuming the salaries of a crew of approximately 20 extended by six months, along with the cost of language instructors, the total cost would likely come out to be in the hundreds of thousands of dollars, but out of a yearly budget of $19,653.3 million as of 2017, this ultimately equates to less than 0.6% of NASA's budget allocated for human spaceflight (NASA).

However, signing is not the most practical means of communication on the ISS, and other modes reliant on visual cues would have to be implemented. For deaf candidates, one has to be willing to forgo hearing and sound cues as a necessity on the ISS. Communications between the ISS and Mission Control are managed via the Tracking and Data Relay Satellite (TDRS) system, which is a fleet of nine satellites managing telecommunications between orbit and ground mission control centers (NASA, 2019). Audio communications—the current primary mode of communication used on the ISS—are controlled through the TDRS's S-band system, whereas larger data dumps such as television shows and video conferences are managed through the fleet's Ku-band and Ka-bands (Barrett, 2015). After a 2013 upgrade, the Ku-band system gained significant quality improvements despite a 10-minute exclusion zone approximately every 90 minutes, and further improvements and additional satellite replacements have made access to streaming and video conferencing commonplace on the ISS (NASA, 2017). Utilizing the TDRS system to switch from an audio-focused communications system to a visual-focused communications system, through fairly simple technological implementations such as typing screen messages onto a spacecraft-wide instant-messaging service, would be one such way to effectively deliver messages throughout the ISS. Deaf individuals are typically more prone to notice visual cues, making it unlikely for them to miss such messages (Marschark & Spencer, 2003).

For hard-of-hearing individuals, a space crew could still utilize hearing and speech as a primary means of communication, but with technological adjustments that filter sounds to better focus on a current speaker. 21st century technology has already provided such a solution, and the use of an FM-like system (See Figure 1) among a crew to utilize a specific low-bandwidth radio channel that streams speech from a microphone into a hearing aid would potentially prove useful on the ISS (American Speech-Language-Hearing Association, n.d.). Not only would such a system enable clear communication around the space station, but it would help eliminate the constant background noise of the ISS machinery as a major hearing impediment.

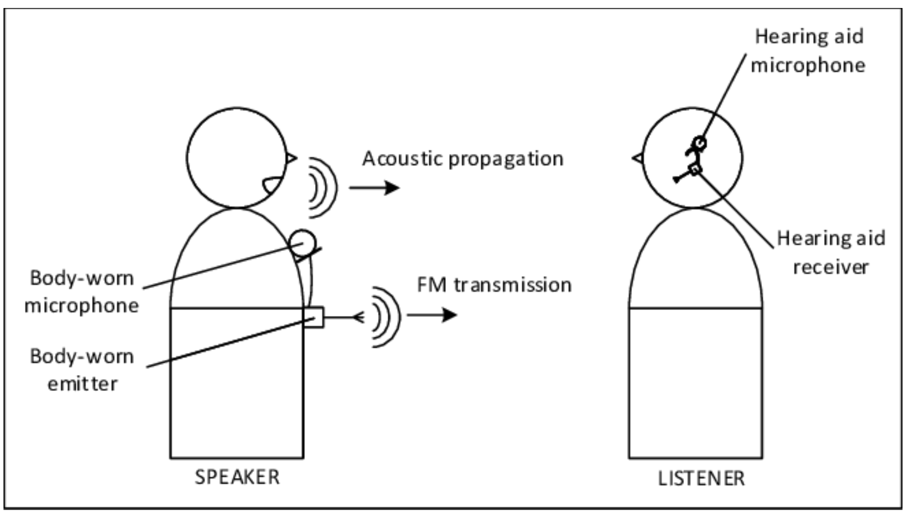

Figure 1. Simple diagram demonstrating how an FM system on Earth is utilized to stream sounds into a hearing aid receiver using a specific FM radio channel. Source: Courtois et. al, 2014.

Both of these proposed alternate modes of communication on the ISS may initially seem to be unnecessary in terms of time and expense in design and training, but these methods also address a critical issue facing astronauts as they advance towards long-term space travel—hearing loss due to extended exposure to ISS machinery noise (Clark, 2001). Multiple cases of partial hearing loss have been reported as a result of long-term exposure to noise on the ISS, and with increasing pressure to send a manned mission to Mars before the end of the century, hearing degradation is an increasing inevitability for even a hearing crew (Roller & Clark, 2003). Not only will methods such as these bypass such complications that may arise from an extended spaceflight, but implementing deaf and hard-of-hearing individuals would help prepare researchers and other crew members for how to handle this change in physiology, once it appears. By doing so, stress on hearing crew members could be lessened, and methods would already be implemented to alleviate mission-related issues caused by hearing loss (via communication mishaps).

3. Blind and Visually Impaired Considerations

Blindness requires one to think from an auditory and tactile viewpoint rather than a visual one. Blind and severely visually impaired individuals rely primarily on these senses to navigate the world, whether it involves a colleague reading notes aloud to them or using touch to maneuver around a house. In this instance, relying on S-band audio communications is not an issue, but navigating the ISS and completing laboratory tests would require some schedule modifications. Braille labels would need to be implemented on all technical equipment and handbooks, and as blind astronauts would already have ample ground training on a mock-up ISS to become familiar with the technology and space barriers, they likely would not need much more than first few days already allotted for missions on the ISS to become acclimated using tactile methods to memorize their surroundings.

Although there is generally enough space on the ISS for it to not generally be an issue for visually impaired astronauts to move from place to place, learning to handle and clean new equipment may prove to be an initial challenge. Blind persons have varying capabilities of sensing vague shapes around them, and what the ISS lacks in people to navigate around it makes up for in wires and complicated equipment (Friedel, 2011). This clearly indicates a learning curve that needs to be addressed during training, but ultimately, scientists who have previous experience in handling lab equipment are likely able to adapt to such an environment with relative ease. Blind chemists, doctors, and athletes are not unheard of, and they generally have their own preferred methods for handling equipment and interpreting data that are not obtrusive to their seeing colleagues. Braille keyboards and speech output systems on computers are basic and cost-effective ways to bridge communication gaps between the ISS and Mission Control, and blind engineers and scientists are well experienced dealing with unfamiliar and new equipment. A persistent and self-aware personality more than physical ability in this case would be more important in determining how easily one could adapt to spaces on the ISS (Willoughby, 2012).

One of the unique advantages of having blind scientists on a research team stems from their inability to visually interpret graphs and figures, such that they generally have to resort to mathematically rendered versions to interpret research properly. From a scientific vantage, this has the benefit of identifying patterns that may have been unrecognizable from a visual perspective (Brazil, 2017). Computer programs and web extensions such as the SAS Graphics Accelerator offer automatic ways to convert data and tables into forms that visually-impaired researchers are able to interpret, which can take several different forms. Sonification, for instance, is a process used that “plays” a graphic to the reader, with rising tones for higher values and lower tones for lower values (Holton, 2018). Alternatively, SAS is able to convert data that a blind researcher inputs into visual graphics useful for other seeing researchers to interpret, ensuring a method for two-way communication of data in research.

In addition, relating to a long-term spaceflight to the Moon or Mars, blind and visually impaired individuals may be able to better cope with and react faster to common technological mishaps such as light malfunctions (Wells-Jensen, Miele, & Bohney, An alternate vision for colonization, 2019). Further, blind candidates would not have to worry about the eyesight decline that constantly plagues astronauts today. Poor eyesight as a result of long-term spaceflight is considered a mission-critical issue, and astronauts who initially board the ISS with regular eyesight have a difficult time adjusting to instances of visual decline as a result of spaceflight. The was initially the reason that Scott Kelly, who gained international attention in 2016 for spending a year doing research on the ISS, was medically disqualified from going back to the ISS in 2015 (Kelly, 2017). After several shorter-term stints, he had noticed a considerable decline in vision, which NASA medical officials worried would become permanent if he spent longer than six months back in a zero-gravity environment. However, the logic used here was faulty; when the intention of studying long-term physiological effects of spaceflight is contingent on a candidate not suffering any damage due to previous spaceflight, this causes a scientific bias and prevents researchers the opportunity to study how to adapt to such changes, which was ultimately the argument Kelly proposed that allowed him back on the program.

4. Paralyzed & Amputee Candidate Considerations, and what a multi-disabled crew might look like. Paraplegics, amputees, and partially paralyzed candidates are likely the easiest out of the three main groups discussed here to assimilate into the space program, partially because they were almost included in the past: John Hockenberry, an American journalist who became paralyzed from the chest down after a car accident in the 1970's, became a semi-finalist in the top 40 of NASA's Journalist in Space program (which was ultimately cancelled as a result of the 1989 *Challenger* disaster.) In an applicant pool that averages in the tens of thousands today, Hockenberry was clear about his paraplegic status, and yet this was not viewed as an inhibition to performing well in space. The weightlessness of space removes the need for legs; though it would be important for paraplegics who still have their legs to regularly exercise them to prevent osteoporosis, there is no reason that they could not go about as a regularly functioning astronaut as long as they retain full mobility of their arms (Ramachandran, et al., 2018). Amputees would arguably be in an even better position, having to not worry about exercising their legs at all and be able to dedicate more time to research and other mission critical activities. These arguments were enough to convince the hiring committee at NASA in the 1980's, and they remain valid today.

The primary consideration that would have to be accounted for in this group are modifications to the exercise machines utilized on the ISS to preserve bone mass and muscle function (Canright, 2009). Figures 2 and 3 display the current design of the Advanced Resistive Exercise Device (ARED), the primary device used to act as a free weight system in a microgravity environment on the ISS:

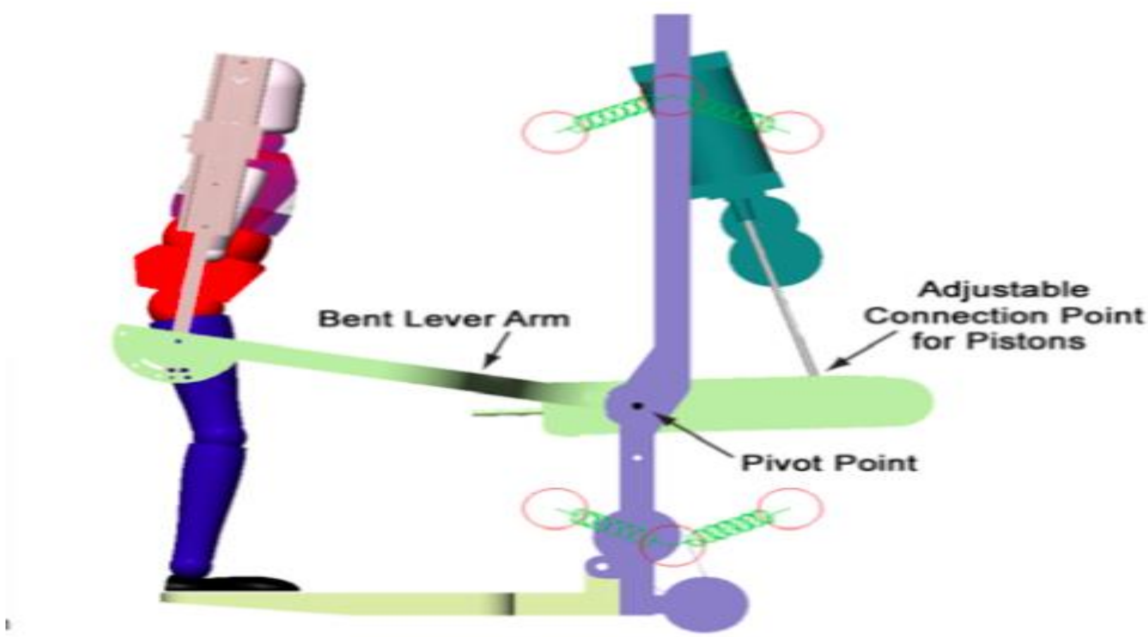

Figure 2. Side view of the ARED at work. Source: NASA

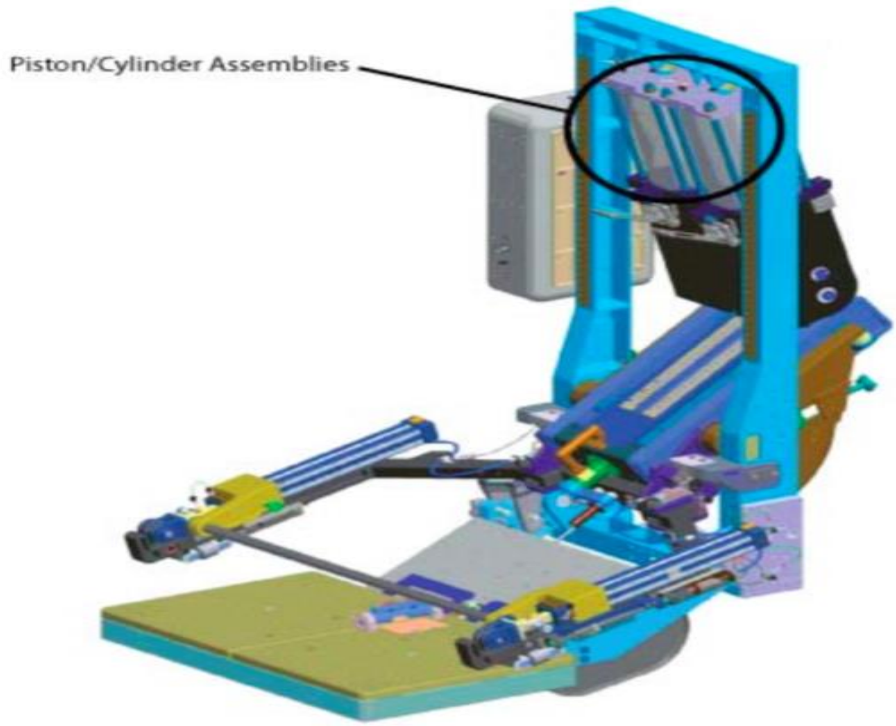

Figure 3. Front graphic view of the ARED. Source: NASA

Because the ARED relies on the use of legs to simulate the feeling of free weights in microgravity, paraplegics and amputees unable to use their legs would either need an additional device designed just for arm and core resistance, or modifications would have to be made to the current ARED that allows the astronaut to be strapped into the device and push on the lever arms without the use of legs (Miller, 2004). Either idea would be simple and cost-effective enough to produce, and would help to inhibit the early onset of bone loss in spaceflight (Ashe, Craven, Eng, & Krassioukov, 2007).

So far, each case of disability has been discussed without factoring in the challenges of combining a crew made up of multiple disabilities. How, for instance, would a crew with both blind and deaf astronauts communicate effectively? Paraplegics have no real issues with communication as much as they do mobility, which is arguably made easier in a weightless environment; but deaf and blind individuals rely on different senses entirely to communicate with the rest of the world, and it is difficult to design an already compact ISS to accommodate Braille, sign language, hearing assistive devices, and audio controls into one program (American Association of the Deaf Blind, 2009). The primary outcome of this research is to acknowledge that it is not necessary, and even harmful, to restrict astronaut selection to a small selection of physically standard candidates. It is also advantageous to consider a paraplegic and deaf astronaut working together on the ISS, or to have a blind engineer and amputee on the same crew.

5. Concluding Remarks

Such suggestions for implementing a disability-friendly astronaut crew would have been largely unthinkable forty years ago, when spacecraft design was new enough that limitations posed by audio communications and engineering design were not able to be easily modified. Although NASA was willing to utilize disabled individuals such as the Gallaudet 11 to study how their disability prevents them from typical spaceflight ailments such as motion sickness, NASA was unwilling to focus a spacecraft design around such a minority to trust them in the then-new environment of outer space. However, the current advancements and goals of NASA show a much different environment than the one of the Space Race; technology is vastly improved, and the focus on shifting astronaut crews from short-term to long-term flights to eventually accommodate a mission to Mars means that focusing on the human physiology in space is much more critical than it was for three- or four-day missions in the 1960’s.

Further development on this research would include additional outreach to current designers and engineers at NASA to inquire into the latest ISS designs, training regimens, budgets, and physical research needs out of their astronaut cohort today. Detailed itemized budgets specifically for the astronaut training program are unavailable to the public, but knowing such specifics would allow for an accurate estimate on the fiscal cost of additional language training and technology upgrades suggested in this paper. Although it can generally be assumed that such costs would be negligible in the context of NASA's human-spaceflight budget, which has also been increasing by a significant percentage in recent years, it is necessary to see how specific costs can affect certain regular programs. Additionally, testing on the consistent reliability of FM systems, other hearing assistive devices, and the Ku- and Ka-bands, given recent upgrades to the TDRS system, is necessary to view these technologies as viable communication methods on a long-term spaceflight.

Ultimately, the question of whether physically disabled persons are capable enough to participate in the space program has already been answered in the form of previous achievements—if a paraplegic made it to the top forty for consideration for the program in the past, and if a hard-of-hearing astronaut made it to and from orbit without error, then it stands to reason that a large percentage of the disabled community today is just as prepared, if not more so, to join the astronaut community, so long as some measure of creativity and flexibility is accommodated by participating space programs. Rather than having to adapt to an environment with strict physical requirements from a group that has never had issues with such concerns on Earth, disabled candidates have had to adapt to such an environment since the onset of their disability. Rather than viewing this as a disadvantage, researchers would do well to view this group as an untapped resource for flexible, creative individuals who interpret the world in a way that makes them well-abled for space travel.

Perspective is the paramount necessity in implementing a disability-accommodating space program. "To deal with the tragedy of not being able to live underwater or in the air," Hockenberry argues in the case of allowing disabled persons into space, "humans invent a less humiliating way of thinking about it. It is not we who are flawed… it is they who are underwater creatures, it is they who are winged—their physical assets redefined as rungs of evolution's ladder... But when we are not slaughtering them with rifles, jet engines, and nets, birds and fish must view us as the slow group" (Hockenberry, 1995). Simply because a spacecraft is designed with hearing or seeing individuals in mind should not automatically imply that it is the only, or even the best, way to design a spacecraft. Ultimately, when it comes to moving forward to manned missions to Mars, engineers would do well to look at those they previously disqualified as prime examples of candidates who can cope with the unforgiving nature of spaceflight.

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