WHY THE EXISTING ASTRONAUT IN-SUIT MAXIMUM ABSORBENCY GARMENT (MAG) CREATES A MISSION RISK FOR FUTURE MARS MISSIONS

HOW THE SUCCESS OF FUTURE SPACE TRAVEL AND MARS MISSIONS IS DEPENDENT IN AVOIDING THE SOCIAL MISTAKES MADE DURING THE APOLLO MISSIONS

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Tomas E. De Oliveira

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Catherine D. Baritaud and Bryn Seabrook, Department of Engineering and Society

Space travel has become more paramount to modern society than former generations could have ever predicted it to be. The last 60 years of space exploration have brought with it virtually every piece of technology deemed necessary and at times indispensable to contemporary society as we now know it. From Kiger and Spoon's article in HowStuffWorks (2021), we are reminded that memory foam such as that likely found in your mattress, cochlear hearing implants and scratch resistant eyeglass lenses are all innovations common today due to space explorations from yesterday; furthermore, there is something even more commonly beneficial to all rich and poor, man or woman, and perhaps most relevant to this paper, the water filtration system (Top 10 NASA Inventions). These technologies are all modern and mundane iterations of revolutionary developments created for the space program a very long time ago (Kiger & Spoon, 2021). It is imperative then, to dissect how technologies that have served us well in the past sixty years worth of space exploration that spans manned and unmanned trips to the depths of space, the International Space Station (ISS), and the culmination of brave exploratory missions that saw man land on the moon will soon be proven to be insufficient technologies for future exploration and in dire need of revamping. Though fruitful as the evolution of space technology has been, some of these amazing discoveries may be reaching their limit.

As an engineering student, one should hold a logical and primordial practical approach to space exploration and interplanetary travel: take humans out of the equation. If we could only be motivated to experience Mars, at least for a short while longer, from afar and by proxy of unmanned semi-autonomous machines, it could be expected that the initial settling of the planet - that is laying down of infrastructure, raising buildings, erecting labs, and the like - could be accomplished with minimal to virtually non-existent injury to a human crew or loss of life directly attributed to the venture. However, we, humanity, are explorers and exploring must be done by experiencing new frontiers first-hand. This explorer mindset and way of life, presents unique challenges when the exploration pushes us millions of miles from Earth, and for hundreds of days at a time. The primary issue of a manned mission to Mars being time is better understood when considering the three different mission types that astronauts must embark on aboard a spacecraft for as brief as 400 days with as little as 30 days on the surface of the planet, to potentially as long as 600+ days on the surface and a trip total of 900+ days (Williams & Shaw, 2015). The development of new technologies needed for this type of mission are on a scale never before seen, and dwarf the technological leap that was required for the initial space race. Broadly speaking, the topics of this paper will revolve around the waste management systems required for a 6 person mission to Mars, one that could potentially last 900 days, to be successful and survivable. In particular, we will firstly analyze the inadequacies of the current in-suit waste management system, the Maximum Absorbency Garment (MAG) and examine a proposed state-of-the-art substitute that may prevent serious astronaut comfort, and health issues, as well as safeguard mission accomplishment. The MAG is bulky and has been described as uncomfortable to wear by most US astronauts who have performed Extravehicular Activities (EVA) (Belobrajdic et al., 2021). This also adds the issue of wearing an unsanitary device if the astronauts are forced to urinate or defecate while in an EVA which is expected to significantly increase for future Mars missions:

> Shorter EVA durations partly solve the need for waste management systems, but as operational requirements dictate longer EVAs, this will not be an option…. Future long-duration missions to the Moon or Mars will require astronauts to perform up to 24 h of

EVA per week, which is significantly greater than the typical three to four EVAs astronauts perform during a 6-month ISS stay. (Belobrajdic et al., 2021)

Secondly, we will look at the history of the space program to identify the relationship between the technological development necessary to effectively renovate our spacefaring equipment, such as the MAG, and the perspectives and support needed for space exploration to be successful. This perspective will be a comparative analysis of scholarly articles, as well as paper media publications and the opinions of the general public in support or opposition of different approaches to space and future Mars missions - specifically, can any effort made by governments or public industry survive a well-informed public and the scrutiny of the court of public opinion about the merit of capital investments in technology necessary for space exploration when the argument can be made for a refocusing of resources here on Earth. Space exploration was a novel thing 60 years ago and yet remained mostly unpopular as outlined by Konicki and Pethokoukis in their New Atlantis publication as "most of the available polls show that a solid plurality–and sometimes a majority–of Americans actually *opposed* the space program in its heyday," but today forms a much more comprehensive layer of common knowledge for the general public, and information as well as education is easier to find than ever before (The New Atlantis, Spring, p.92). This new normal begs the question, if a society no longer possesses the curiosity to explore as it once did, a curiosity that can now be otherwise fulfilled by science fiction and media, is support for technological development aimed at space exploration doomed?

Hughes' theory of technological momentum might offer a glimmer of hope for future exploration of space and other remote planets–interplanetary civilization, the stuff of science fiction, may afterall find its residence amongst the stars guaranteed–secured under the umbrella of a technological innovation machine that can, once set in motion by societal construction, and indeed must operate independently from the court of public opinion (Vermaas et al., 2011, p.88). In the case of space exploration, the spark that ignited the development of new technologies for the conquest of space was the social motivations or pressures for political, technological, and militaristic supremacy over the Soviet Union during the Cold War–where shortly after winning the race to the Moon in 1969, Americans largely lost interest in the remaining space program. Despite this reality, the space program continues to this day carried by the inertia of its now technological determinism as a different system than its original purpose, after several self-sustained technological iterations that gave society countless modern day conveniences as were mentioned earlier (Konicki & Pethokoukis, p.91). Concurrent with Hughes' theory, it seems the current space race is carried on by its self-sustaining technological momentum.

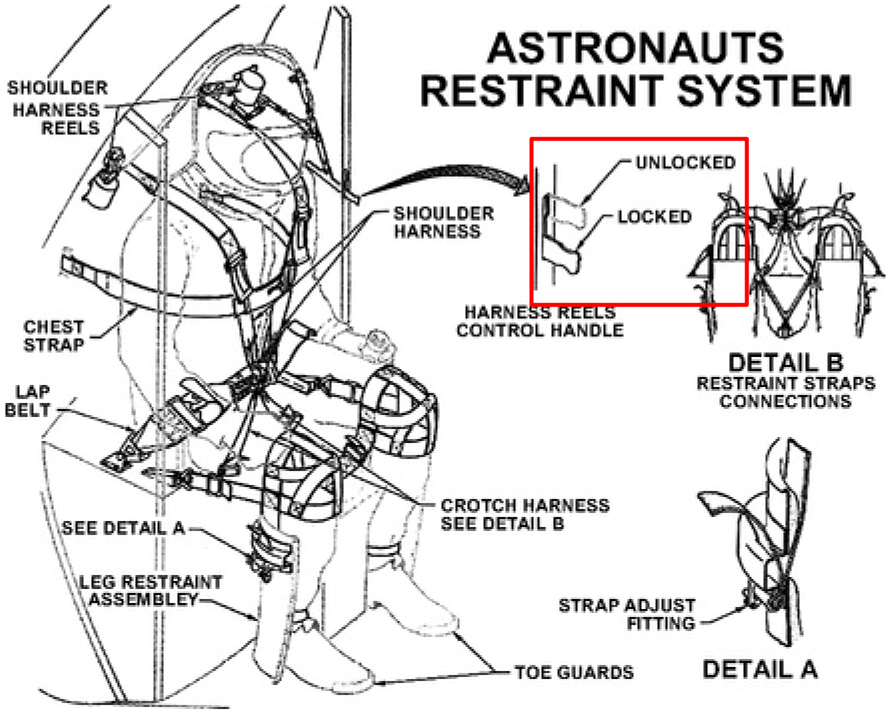
WHY THE EXISTING ASTRONAUT IN-SUIT MAXIMUM ABSORBENCY GARMENT (MAG) CREATES A MISSION RISK FOR FUTURE MARS MISSIONS

The current solution to waste management in space has worked for the past 60 years and served astronauts from a multitude of different nations adequately to this day. Pomeroy (2013) recounts that before the MAG, early attempts to the waste management problem consisted of a threatted catheter harvested from the archives of the U-2 spy-plane program, a system that was adopted for the program due to its long duration flight mission, and a cramped cockpit which closely mirrored the parameters of a space faring manned mission; as you might imagine, the procedure was uncomfortable for the first astronauts to be subjected to it, and quickly fell out of practice being replaced by the MAG (RealClear Science, para. 3).

Missions also suffer from delays, Pomeroy (2013) explains, which can turn disastrous as it was for Alan Shepard when, despite having relieved himself before boarding the spaceship, he was unable to keep his pants dry after waiting nearly 8 hours on the launch pad, subsequently short-circuiting the electronics onboard due to the safety harnesses needing to be in the "LOCKED" position during takeoff as seen in Figure 1 (RealClear Science, para. 2).

Figure 1.

Image of astronauts restraint system comprised of six separate assemblies



Note. Adapted from RealClear Science, 2013.

(http://www.realclearscience.com/blog/F2.medium.jpg)

Since operations enroute to and on the surface of Mars will exceed the operating conditions seen on the ISS and previous programs, with increased duration and requiring a greater range of movement than ever seen before, comfort will be of the utmost important for the astronaut wearing it; furthermore, a MAG substitute also has an increased need of sanitation and reliability that would easily overwhelm current waste management systems (Belobrajdic et al., 2021). The MAG creates an environment where astronauts feel the need to circumvent natural biological processes during extravehicular activities and other EVAs; this creates health and biological complications by way of urinary tract infections, kidney stones, erectile dysfunction, incontinence, and much more both in space and upon returning to Earth (Belobrajdic et al., 2021; Castiello, 2021; Johnson, 2021; Sauer & Jorgensen, Ch. 2, n.d.; The Guardian, n.d.). The most mission critical issue that arises from this is the treatment of set complications while in space or on the surface of Mars which can have detrimental impact to the success of a mission if the astronauts health hinges on it; not to mention the risk to astronauts as additional complications to the matter are the lack of medical equipment or medical professionals needed to adequately diagnose and treat any of the above-mentioned medical problems (Belobrajdic et al., 2021; Castiello, 2021; Sauer & Jorgensen, Ch. 2, n.d.).

This technical research project aims to develop and provide proof of concept for an improved in suit undergarment which has urinary devices better suited to each astronaut therefore encouraging or facilitating the ease of use during space walks and other Mars surface missions, hopefully solving any mission critical health problems that might arise from the current practice of astronauts abstaining from biological processes. With the information provided in an exploratory publication on Urologic Innovation in a Spaceflight Environment, device prototyping has been comprehensively guided with a data focused approach (Kahlenberg et al., 2021). A crewman specific fitted garment and anatomically correct urinary device that will replace the one size fits all approach of the unpopular MAG. The replacement system will would make it more comfortable to urinate by eliminating the shared airspace between the waste produced and the air breathed by the crewman, as well as separate the urine from contact with the skin in the hope of minimizing crew discomfort associated with skin contact dermatitis from prolonged exposure to a soiled diaper. Expectation for the project is the full development of a device prototype, with components seen in Figure 2, and complete integration into NASA's and private spaceflight companies in preparation for the planned ventures to the moon, future space stations, and the eventual colonization of Mars.

Figure 2.

Note. Prototype components are non-specific generic stand-ins to be assembled from left to right.

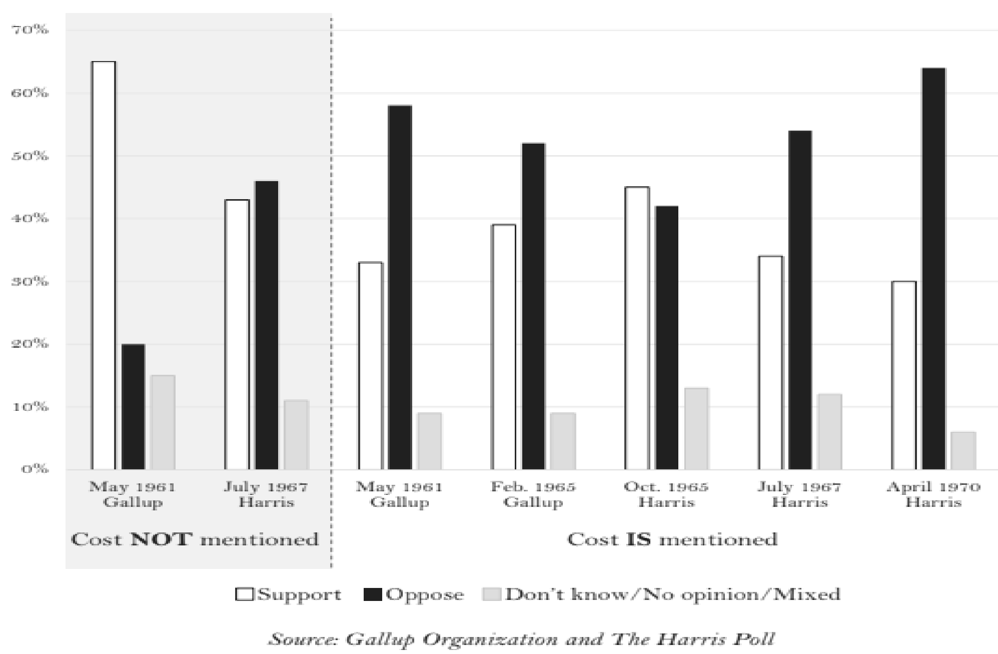
As this project is being embarked upon well ahead of securing funding, advising, and contractual agreements with any potential investors, all research to its merit is being funded, tested, and assembled by the author in an individual capacity. Initial interviews with potential research partners in the fields of biomedical engineering and entrepreneurship have been conducted and the project manager is currently awaiting partnership agreements to be completed.

HOW THE SUCCESS OF FUTURE SPACE TRAVEL AND MARS MISSIONS IS DEPENDENT IN AVOIDING THE SOCIAL MISTAKES MADE DURING THE APOLLO MISSIONS

The space program in the United States came from humble beginnings and was solely motivated by the international security need to show absolute technical supremacy over our Soviet counterparts, and with NASA's budget peaking at $6 billion in 1966, the space program was not free from critique (Brownell, 2021). We revel in the advancement of our days whilst forgetting that the national funding of the space program was not free of controversy of perceived misallocation of funding that many of the day, and even today, would argue could have been better spent to provide more students in poor neighborhoods with better resources to improve on minority education and provide for low income neighborhoods (Born, 1966; Brownell, 2021; DeGroot, 2007; Urey, 1967). The privatization of future space travel may have the effect of creating silos of technological development into international corporations' safekeeping, effectively removing US government agencies such as NASA from the technological development information loop, but as private industry takes the lead in space exploration, we must be careful to avoid losing public support for government involvement in space exploration as was the case in the 60's (Figure 3) or we may find ourselves outside the sphere of benefit from innovations made by private industry which will hold all rights to intellectual property (Konicki & Pethokoukis, 2022; Musser, 2019).

Figure 3.

U.S. support for the space program, 1961-1970.



Despite the receipt of government subsidies and contributions in the way of contracts, the U.S. government and its technology development agencies are largely blind to the futuristic and state-of-the-art technological developments being made by private space travel and exploration corporations. This creates a technology innovation trough to which the general public may not have access for a period that is antithetical to the days of past space exploration, when under the funding and development of the government, the technology was largely publicized to US manufacturers that later invested in technologies that benefited society by military developments and trickle down technology which eventually found its way to the public, even altering the course of science and technology education today (Grubbs, 2014; Weeks & Faiyetole, 2014).

What societal impacts might this new private information access moratorium on technology bring upon the evolution and innovation of new tech? If private industry can keep all their developments “private”, how will society benefit without its own modern-day NASA-like discovery of world changing technology innovations? It may be possible that technology developments do find their way to the general public by virtue of profitability, but the answer to avoiding an innovation availability drought may lie in the parallel continuous funding of our own government’s race to Mars. Perhaps a government against private industry space race, one such as where in the past we aimed to beat the Soviet Union to the moon as a way to show our superiority, today we need to set our sights on private companies as the new challenger. The Apollo program once employed over 400,000 technicians, engineers, contractors, and more–today there are more than nine major companies (Figure 4) that pose a very real threat when it comes to outperforming the current U.S. government’s efforts in the field–but today, our involvement in space exploration is heavily dependent on contractors from the very companies we should be competing with (Chandler, 2007).

Figure 4.

Private spaceflight: The different approaches–or as they should be viewed: the U.S. Government’s competition

Company	Project	Launch type	Fuel/oxidizer	Seats	Notable for
Armadillo Aerospace	Pixel (prototype)	Vertical take-off and landing	Ethanol/ liquid oxygen	2	Entry in NASA Lunar Lander challenge
Blue Origin	New Shepard	Vertical take-off and landing	High-test peroxide	4	Preliminary test flights
Benson Space Company	X-1	Vertical take-off, horizontal landing	Hybrid (rubber/ nitrous oxide)	6	Designed to produce lower g-forces than other systems
Interorbital Systems	Neptune	Vertical take-off, straight to orbit	Unspecified hypergolic hydrocarbons	6	Fuel mix does not require ignition system
Rocketplane Kistler	K-1	Vertical take-off, straight to orbit	Kerosene/ liquid oxygen	5	Fully reusable orbital system
	XP	Horizontal take-off and landing	Kerosene/ liquid oxygen	4	Jet engines for take-off, then rocket to reach space
SpaceX	Falcon/Dragon	Vertical take-off, straight to orbit	Kerosene/ liquid oxygen	7	Test flight in March highest ever for private craft
Virgin Galactic/ Scaled Composites	SpaceShipTwo	Horizontal take-off and landing	Hybrid (rubber/ nitrous oxide)	8	SpaceShipTwo's predecessor, SpaceShipOne, was first civilian spacecraft
EADS Astrium	Astrium spaceplane	Horizontal take-off and landing	Methane/ liquid oxygen	5	Jet engines for take-off, then rocket to reach space
Xcor Aerospace	Xerus	Horizontal take-off and landing	Kerosene/liquid oxygen	2	Rocket motors for take-off and to reach space

When addressing the uphill battle the U.S. government has ahead of itself, Senior Lecturer with the department of Science, Technology, Society, Professor Catherine Baritaud accurately expressed that the real problem that NASA had, and may continue to have in its search for support–read funding–is that the agency may not have the greatest luck in marketing its successes or for that matter the relevance and importance of its work (C. Baritaud, personal communication, August 5, 2022). Although, Professor Baritaud’s comment could be dismissed as anecdotal or lacking in scientific data to back up its merit, it nevertheless is pointed to the public opinions of the general public’s opinions of where they thought their money or government’s time would be better spent as its shown in Figure 5, not too mention that Figure 6 shows that the general public believes that private companies are almost, if not equally qualified to take over space exploration efforts (Konicki & Pethokoukis, 2022).

Figure 5.

Which three of these national problems would you like to see the government devote most of its attention to in the next year or two?

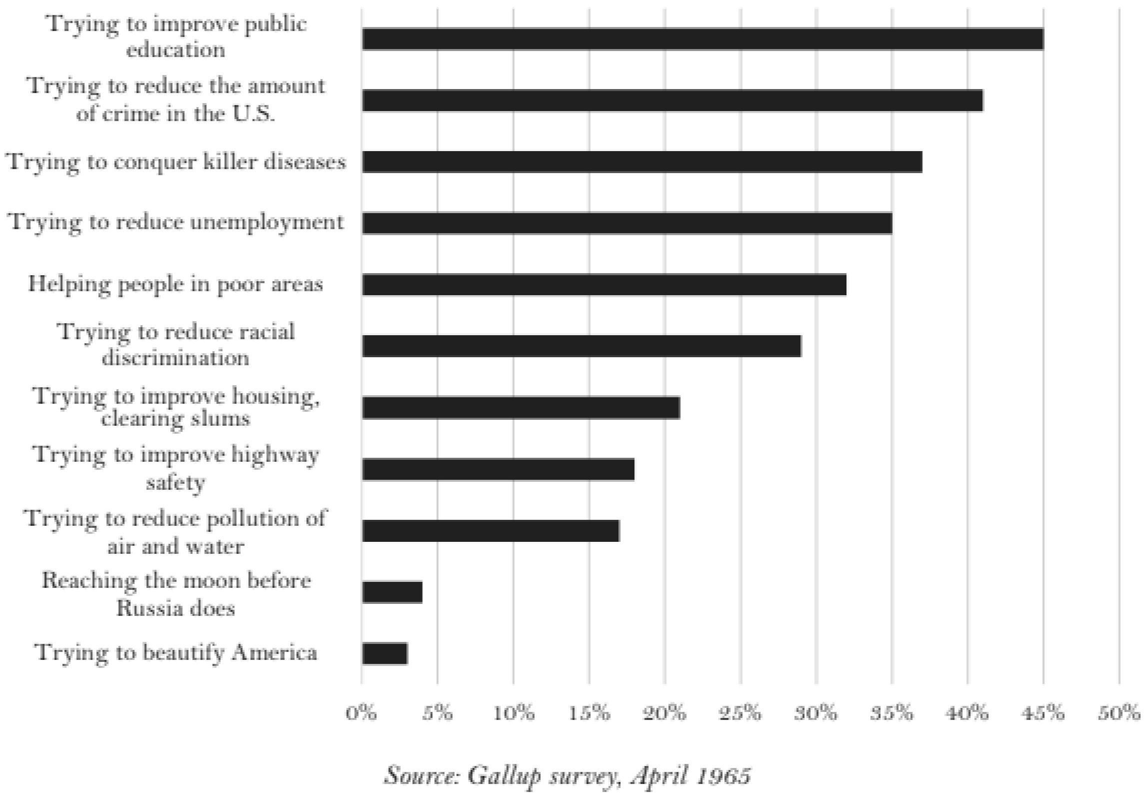
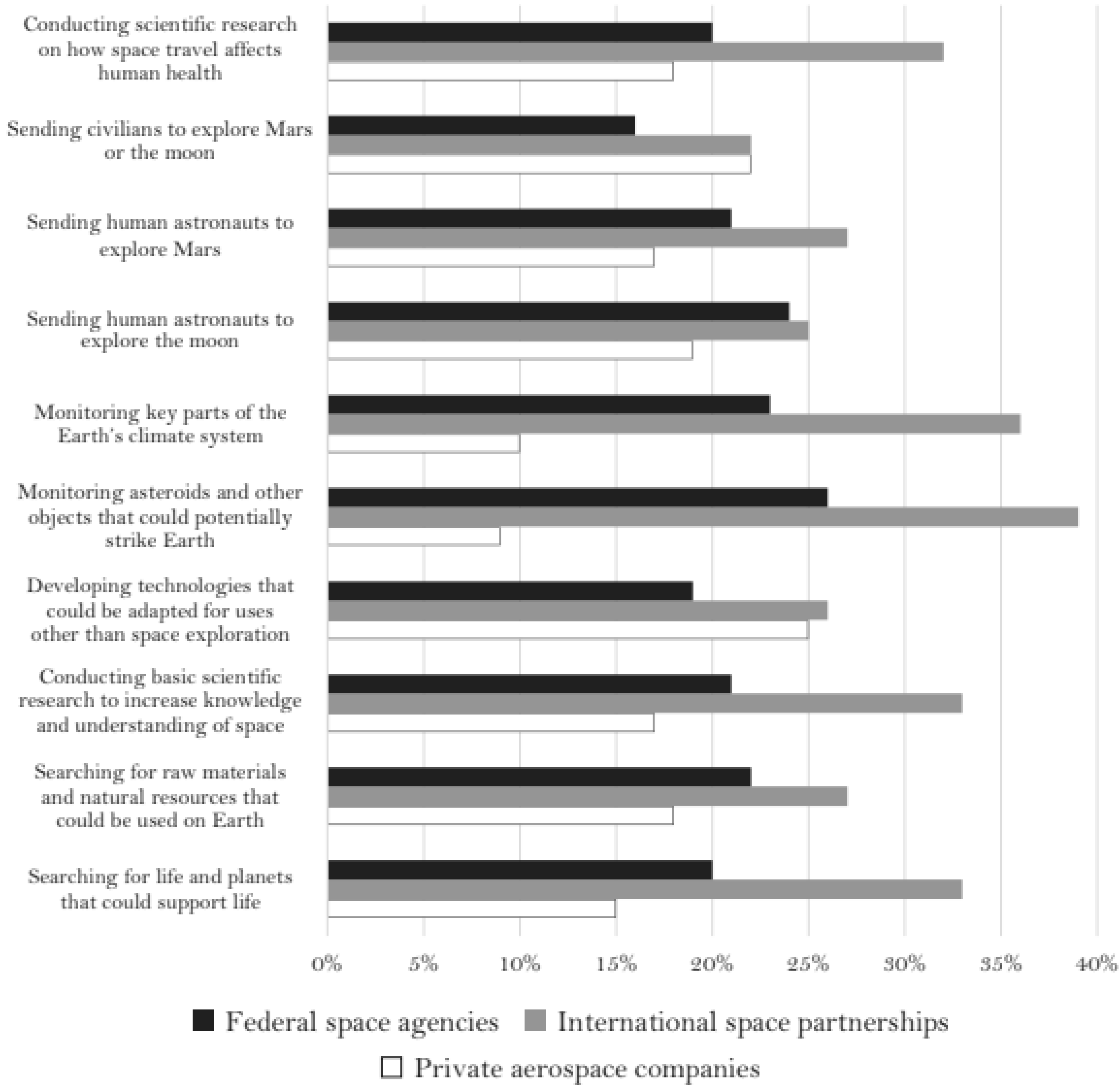


Figure 6.

Which is best prepared to handle each of the following?



Source: Morning Consult survey, February 2021

A DIAPER REPLACEMENT AS THE SAFEGUARD FOR AN IMPROVED FUTURE FOR HUMANITY

It has been said that humanity must prepare to leave this planet and that our very survival within this universe depends on it. We started this arduous fight over 60 years ago, discovering how to escape our planet's unavoidable gravitational pull. Outside the realm of science fiction, today we aim to go farther than many could have ever imagined we would be able to all that time ago, and technologies developed in the past 60 years benefit our civilization today. It is with this lesson learned in mind that we look into the future of space exploration and the technological research and innovation that goes along with it in the hope that this new Mars race of government funded agencies versus rich entrepreneurs will continue to benefit humanity for generations to come. The absolute goal of space travel should never fail to include the prosperity and advancement of the transitional generations that will never be free of Earth's gravitational prison. Therefore, we must have a vested interest in the posterity of humanity and that the technological momentum of space exploration should continue freed from barricades of public opinion that would otherwise strip bare the funding needed for lack of vision or regard for the magnitude of quality of life change that can and will continue to arise from innovations in matters that they, the public, have so poorly understood as disconnected from their comfortable lives. As mundane to the common observer as a urinary device may seem in the scheme of safeguarding humanity’s future, a device that reduces infection, reduces mission risk, and increases mission success; furthermore, mission accomplishment leads to further space exploration and greater trust and investment into research that may someday feed the hungry as we learn to grow crops in Mars, or cure cancer as we learn to keep astronauts safe from the sun’s deadly radiation on longer missions. Mission success is therefore not insignificantly connected to the triumph of humanity, all stemming from funding a mundane replacement to a diaper.

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