EMBRY-RIDDLE Aeronautical University SCHOLARLY COMMONS

International Journal of Aviation, Aeronautics, and Aerospace

Volume 9 | Issue 2 Article 6

2022

The Necessity of Global Standardization Guidelines for Space Travel

Joshua Larson
joshua.larson100@gmail.com
Mallory K. Casebolt
Oklahoma State University, Mallory.Casebolt@okstate.edu

Follow this and additional works at: https://commons.erau.edu/ijaaa

Scholarly Commons Citation

Larson, J., & Casebolt, M. K. (2022). The Necessity of Global Standardization Guidelines for Space Travel. *International Journal of Aviation, Aeronautics, and Aerospace, 9*(2). https://doi.org/10.15394/ijaaa.2022.1696

This Article is brought to you for free and open access by the Journals at Scholarly Commons. It has been accepted for inclusion in International Journal of Aviation, Aeronautics, and Aerospace by an authorized administrator of Scholarly Commons. For more information, please contact commons@erau.edu.

Currently, national space agencies and private commercial space entities in the world function independently. Their independence and the lack of any global standards and guidelines pose a potential problem for the future of commercial human space transportation. This study sought to conceptualize the necessity and idea of a global agency that can create safety standards grounded in evidence-based best practices for commercial and personal space travel.

When referencing the significant number of existing worldwide national space agencies and corporate space entities, the need for order, direction, and governing policy to ensure that safety standards are being met for civilian consumers trying to access space travel would seem reasonable. To date, the United Nations (UN) has—through separate entities like the International Civil Aviation Organization (ICAO), the UN Office for Outer Space Affairs (UNOOSA), and the Committee on the Peaceful Uses of Outer Space (COPUOS)—served as the international organization for the development of international space treaties and regulations. This research sought to explore the need and feasibility of an international entity that would serve as a clearinghouse for all matters regarding space law, policy and procedures, operations, interagency relations, licensing, monitoring, enforcement, interdiction, training, testing/evaluation, and certification. The benefits of such guidance could enhance the efficacy of space safety integration and interoperability that controls Earth's private citizens while utilizing a universal Space Traffic Management (STM) system that is governed and regulated by one policy and single controlling agency. By having a well-defined and established single set of regulated policies and procedures that govern doctrine and set universal perpetual expectations, the spaceflight industry can capitalize on safety from the lessons learned over the last 118 years from the aviation industry. These policies could be like organizations such as ICAO that have created a set of unified safety recommendations for the global aviation industry. The benefits of establishing one global/universal commercial space transportation guideline and governing policy would benefit all nations with standardized emergency procedures and protocols on Earth, during spaceflight, and at every possible destination in space as a contingency.

Statement of the Problem

Although society has come a long way since the beginning of the Space Race in the 60s, there are still things to consider as we advance and establish a permanent presence in space. Whether public or commercial, continued space travel poses complex medical and mechanical challenges (Sielaff et al., 2019). Many problems can occur for the human body in spacecraft due to the lack of atmosphere and exposure to various space radiations, microbes, and biofilms (Durante & Cucinotta, 2011). In addition to medical challenges in space, mechanical failures and existential threats are ever-present, which could result in fires or collisions with micrometeoroids or debris, causing loss of spacecraft

pressure, spills, or collisions (NASA, 2007). According to Sielaff et al. (2019), mechanical failures and existential threats pose a constant danger due to the need for in-flight maintenance and regulated control. Despite these risks regarding health and mechanical dangers, NASA has initiated a public-private partnership to continue deep space capabilities (Vuolo et al., 2017). These are all important issues to consider as society continues to advance in space travel. According to Reddy (2018), because of the launch of society into space, we have entered a new era of transportation with commercial space travel. Durkee (2019) suggests that because of the development of space travel that it will lead to a space commerce industry, including space mining, space tourism, space defense, and much more. Vanian (2015) implies that future space travel will be processed by the power of quantum computing and the integration of more artificial intelligent (AI) robots. In addition to (AI) robots some scholars have suggested that the internet of things (IoT) might provide opportunities for digitally enhanced space living (Kua et al., 2021), while others have explored the role of design when planning human-occupied spacecraft or colonies (Dominoni, 2021). Due to the lack of global international standards and commercialized space travel guidelines, this study sought to explore the development of a single global agency. Potential guidelines include, but are not limited to, standardized safety integration and interoperability protocols, spacecraft, design, and certification requirements, as well as personnel training and certification requirements. Such an agency could establish guidelines and act as a clearinghouse for the certifications, requirements, and ethical standards for space travel and colonization by both government and private entities on a global scale.

Research Objectives

The purpose of this study was to investigate international experts' thoughts regarding the need to establish and prioritize guidelines for developing an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for commercialized space travel and colonization between global governments and private entities. Due to the lack of global international standards and commercialized human space travel guidelines, this research sought to explore the need for a single global agency's development that would establish guidelines and act as a clearinghouse for the certifications, requirements, and ethical standards for space travel and colonization by both government and private entities. This study included questions concerning the prioritization of issues relevant to establishing guidelines to regulate commercialized human space travel and colonization.

Global governance theory and public space governance theory were utilized to guide this study. As deep space is a public space not owned by any single government or entity, it can be considered an international public space in which global governance applies. This study included results from 28 global experts from 10 different nations. The participants included international experts that possessed

in depth knowledge and experience in aerospace and space through their experience in the space profession. The following research questions guided this study:

1. What are the priorities for the development of guidelines for space travel and/or colonization as expressed by public (government) and private entities?
2. What is the feasibility of the development of an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for space travel and colonization between governments and private entities?
3. What are practical solutions to the development of an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for space travel and colonization between governments and private entities?

Governance of Outer Space

Although international agencies exist, the current "space race" involves both commercial and political representatives that are interacting in the international space law regime. The need for outer space governance is essential given the increase in outer space travel both by public and commercial entities: "developments in outer space have exploded in complexity, ambition, and commercial promise" (Netea et al., 2020). Currently, space governance is guided by international agencies and national governments that have implemented their own space laws and regulations for their own individual nation. Existing space treaties reflect the international desire to prevent space's militarization (Netea et al., 2020). There are agencies for outer space and several policies and laws in place for various nations, but no central, universal global agency that oversees commercial or personal spaceflight exists.

The current international agencies for outer space include the United Nations Office for Outer Space (UNOOSA), which supports countries in developing their own national space laws and policies, and the Committee on the Peaceful Uses of Outer Space (COPUOS), which governs the use and exploration of space for humanity's benefit. Other agencies include the Inter-Agency Space Debris Coordination Committee (IADC), which was developed to govern the issue of space debris (Inter-Agency Space Debris Coordination Committee, n.d.) and the Committee on Space Research (COSPAR), which is an international agency responsible for space research. In addition to these different agencies, there are also several treaties governing the exploration and use of outer space. Most of these treaties, such as the United Nations Outer Space Treaty of 1967, are related to the peaceful exploration of space and the prohibition of claiming sovereignty over any part of space. Crucially, the United States developed the Commercial Space Act of 1998 in response to the increase in commercial space development. The Act was developed "[t]o encourage the development of a commercial space industry in the United States and for other purposes" (Commercial Space Act of 1998, 1998). The

Commercial Space Act includes the commercialization of the space station and space launches and the acquisition of commercial space transportation services; however, its scope is limited to the United States rather than the international commercialization of space. It is, therefore, limited in terms of application to international commercial space entities.

Methods

According to Okoli and Pawlowshi (2004) and Sekayi and Kennedy (2017), a Delphi research approach was utilized in this study to identify and prioritize issues for decision-making through consensus among study participants. In the Delphi method, iterations of data collection from participants were utilized to identify key issues, prioritize these issues, and develop a concept or framework based on issues that are prioritized through consensus (Okoli & Pawlowshi, 2004).

In the first round of the Delphi method, participants were asked to provide their inputs about the most critical issues related to the topic of interest, using a qualitative approach. The Delphi method's first phase is referred to as "brainstorming" that generates ideas and allows participants complete freedom in their responses. According to Gibson (1998) this helps identify issues which would be addressed in subsequent rounds. The goal of Round 2 was to develop consensus among participants to narrow down the list through a selection process. After the initial brainstorming phase, the participants ranked the factors on the pared-down list. Rounds 1 and 2 are described in greater detail below.

In Round 1, a questionnaire consisting of open-ended questions was developed to engage the expert panel in open-ended brainstorming on the topic for the purpose of developing a list of factors meriting further consideration in Round 2. In Round 2, a list of statements developed from Round 1 findings was presented to all participants. Qualitative in nature, Round 2 had participants rate their level of agreement with statements on a series of 45 five-level Likert-like items. When the mean response to the questionnaire item across all participants was 3.5 out of 5 (70%) or greater, this indicated that consensus in agreement with the statement was reached, which aligns with the recommendations of Okoli and Pawlowski (2004). A mean response of 1.5 or less out of 5 indicated consensus in disagreement with the statement. When a consensus was reached in relation to a statement on the questionnaire, the statement was considered endorsed by participants.

Target Population and Participant Selection

The survey population included international aerospace and space professionals in both the government and commercial/private sectors. The qualifications of the aerospace and space professionals that participated was that they had some form of extensive training, work experience, or background in the aerospace or space community throughout the globe with a minimum of 8 years of experience. Participants were recruited through a purposeful sampling strategy, screened for eligibility, and contacted through LinkedIn. Participants of the study

had a minimum of at least 8 years of expertise in areas such as aerospace engineering, aerospace defense, the airline industry, commercial and military piloting, space medicine, space journalism, and space operations. Participants were contacted via LinkedIn and provided with Oklahoma State University (OSU) Institutional Review Board (IRB) documentation explaining the study and requesting their consent to participate.

Description of the Research Questionnaire

The research questionnaire was developed by first asking participants to provide three priorities for developing guidelines for space travel in an open text box. All survey questions were tailored explicitly to revolve around the safety of human space travelers within the commercialized space industry. To ensure the reliability of the survey questions, multiple aerospace and space industry professionals reviewed the survey questions and provided feedback. The survey questions were refined for clarity based on any ambiguities revealed. The participants that reviewed the questions did not participate in the study and were not a part of the study sample. In Round 1, participants were asked to write their responses regarding the following:

- The development of guidelines for space travel and/or colonization;
- Implications for the development of an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for space travel and/or colonization; and
- Practical solutions for the development of an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for space travel and/or colonization.

In Round 2, a consensus of 70% from participants was reached in 28 of the 45 statements (62%). Data from Round 2 were divided into two participant categories: academics/regulators/policymakers and end-user/operators such as pilots, engineers, and missile operators. In Round 2, the participants were asked to rank each question in terms of importance using a quantitative Likert scale from the participants' perspective. This data allowed researchers to reach consensus by asking participants to determine which of the identified items, from participants' perspective, was essential regarding the feasibility of establishing and prioritizing a guideline for developing an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for commercialized human space travel and colonization between global governments and private entities.

Results

Round 1 Results

The questionnaire provided to participants in Round 1 consisted of 21 open-ended items. Responses under each item were analyzed thematically to cluster similar responses into thematic categories. Table 1 indicates the themes identified under each item and the number of participants who agreed to the question.

Table 1
Results from Round 1

Question	Participants in Agreement	Themes
From your perspective, what are the priorities for the development of guidelines for space travel and/or colonization as expressed by public (government) and private entities?	28 of 28 respondents (100%) 10 of 28 respondents (34%)	Safety should be a priority Safety should be balanced against innovation, profit, and development Prioritize environmental impacts
What is the feasibility of the development of an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for space travel and colonization between governments and private entities?	20 of 28 respondents (71%) 9 of 28 respondents (32%)	Developing a global agency for standardization of requirements is feasible Developing such an agency is not feasible, and regional agencies are more feasible
What are practical solutions to the development of an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for space travel and colonization between governments and private entities?	9 of 27 respondents (33%) 9 of 27 respondents (33%) 9 of 27 respondents (33%)	A united agency to regulate space travel is unfeasible and undesirable and regarded it as not worth pursuing Collaboration could be increased through transparent research, international summits, and the establishment of a board of representatives Existing international law already provides a template for the needed consensus
Does having multiple	14 of 28 respondents	Multiple, independently

Question	Participants in Agreement	Themes
independently functioning worldwide national space agencies and private commercial space entities, with various undefined governing laws, policies, and procedures, pose a problem for future space exploration and colonization?	(50%) 14 of 28 respondents (50%)	functioning worldwide, national, and private space entities would pose a problem Standardization under a single agency or clearinghouse was undesirable because it would impose a level of uniformity in practice that would stifle meritocratic competition and innovation
Is there a need to investigate the requirement for a single entity for global space safety?	13 of 28 respondents (46%) 10 of 28 respondents (36%) 9 of 28 respondents (32%)	There is no need to investigate the requirement because bodies already exist to regulate space activities There was no need to investigate the requirement because all parties would trust no single entity It is too early to investigate requirements because the United Nations, a model for any such effort, had not sufficiently standardized its own approach
What are the needs in developing one global/universal commercial space transportation guideline and governing policy	13 of 28 respondents (46%)	There is no need to develop one global/universal commercial space transportation guideline and governing policy

Question	Participants in Agreement	Themes
with well-defined, established emergency procedures and protocols on Earth, during spaceflight, and in space to preserve and protect life and property?		because current guidelines are sufficient
Is there a need to investigate the requirement for infrastructure to develop a universal Emergency Space Response Management System (ESRMS)?	20 of 28 respondents (71%) 6 of 28 respondents (21%)	Yes, the need exists establishing the infrastructure necessary to protect life and property in space would be highly costly and require an international effort No investigation was needed because a universal ESRMS was neither feasible nor necessary
Is there a need to explore the feasibility of establishing and prioritizing a guideline for developing an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for commercialized space travel and colonization between global governments and private entities?	17 of 27 respondents (63%) 10 of 27 respondents (37%)	Yes, the priority of protecting life is an urgent reason to move toward establishing international standards related to all aspects of safety The need for a single agency or clearinghouse was far from established and too remote in the future to merit serious consideration in the present
How do commercialized vessels manage inflight and off-Earth mechanical	25 of 28 respondents (89%)	Suggestions from participants (with each recommendation made

Question	Participants in Agreement	Themes
failures?		by a different participant, and each made by only one participant) included having repair capabilities onboard, having hubs or space stations where repairs could be performed, and making commercial entities responsible for their own collection and repairs
How do commercialized vessels manage inflight and off-Earth collisions with micrometeoroid and orbital debris (MMOD), leading to a major loss of cabin pressurization?	8 of 21 respondents (38%) 13 of 21 respondents (62%)	The response was verbatim from the previous question Diverging responses included training crews to respond to collisions, having patch kits onboard, deploying shields, and segmenting ships to contain depressurization
How do commercialized vessels manage inflight and off-Earth collision with a visiting vehicle?	9 of 22 respondents (41%) 13 of 22 respondents (59%)	The response was verbatim from the previous question The focus should be on preventing inflight and off-Earth collisions with visiting vehicles rather than managing such collisions after they occurred.
How do commercialized vessels manage inflight and off-Earth toxic spills that endanger the people onboard or off-Earth?	9 of 22 respondents (41%) 13 of 22 respondents (59%)	The response was verbatim from the previous question No consensus -

Question	Participants in Agreement	Themes
		Participants' recommendations included containment of the spill by isolating the area, donning of HAZMAT suits or other PPE, vacuuming up the spilled material and triple-bagging it to prevent off-gassing, and having redundant emergency systems in the craft
What safety equipment should be required on all spacecraft for inflight/spaceflight operations, and what governing guidelines doctrine and agency should have the oversight to ensure that there is a universal minimum standard level of safety equipment onboard?	6 of 25 respondents (24%) 5 of 25 respondents (20%) 3 of 25 respondents (12%) 2 of 25 respondents (8%)	Spacesuits, pressurized oxygen, and oxygen masks should be required Fire suppression equipment should be required All crafts should have a transponder or locator beacon Escape capsules should be required
Should there be a universal minimum standard for screening, selection, training, and certification for all commercialized humans before space travel?	18 of 25 respondents (72%) 7 of 25 respondents (28%)	Yes, there should be a universal minimum standard that addresses medical, psychiatric, and training requirements No, standards should be set by individual national agencies according to craft capabilities and risk tolerance
Should there be different	18 of 25 respondents	Yes, there should be

Question	Participants in Agreement	Themes
screening, selection, training, and certification criteria based on the person's function in space, i.e., tourist, flight crew, employee, colonist, etc.?	(72%) 7 of 25 respondents (28%)	different criteria depending on the person's function in space. No, differentiated criteria should not exist
Should space entry for all commercialized travelers be specifically categorized, i.e., tourist, an employee with defined role and responsibility, flight crew, colonist (Lunar or Deep Space, i.e., Mars "longevity trip"), etc.?	20 of 26 respondents (77%) 6 of 26 respondents (23%)	Yes, because passengers' specific category of space entry would determine the nature of the responsibilities for which they would need to be prepared No, because consideration of traveler classification was premature at present
Should all spacecraft greater than X number of passengers onboard be required to carry an onboard medical officer? If so, what should that X number be?	12 of 22 respondents (55%) 8 of 22 respondents (36%) 2 of 22 respondents (9%)	Yes, a medical officer should be mandated in all or most cases; no specific number was agreed upon Whether a medical officer should be required cannot be determined without further information and should instead be assessed on a case-by-case basis No medical officer should be required
Is there a need to investigate better long-endurance (greater than one day in space)	16 of 24 respondents (67%) 8 of 24 respondents (33%)	Yes, space travel can be highly stressful, both physically and psychologically, and that

Question	Participants in Agreement	Themes
passenger and crew requirements, crew rest and seating accommodations, and amenities onboard commercialized spacecraft?		the mental and physical demands on passengers are to some extent proportional to flight duration No, further information about other factors, such as the nature of flights and the effects of zero gravity on the general population, is needed
What are the top three things that may lead to an onboard accident in spacecraft resulting in death and/or property loss?	28 of 28 respondents (100%) 15 of 28 respondents (54%)	No convergence on a common theme; factors identified included human error, depressurization, and structural failure Human error will be one of the top three causes of accidents
What are the top three things that will lead to an off-Earth, i.e., on another planetary body accident (not including a spacecraft accident) resulting in death and or loss of property?	10 of 28 respondents (35%) 3 of 28 respondents (11%)	Mechanical failure will be one of the top three causes of accidents Other causes of error were mentioned, such as terrorism, crash landing, and medical emergencies

Round 2 Results

In Round 2, the goal was to develop consensus among experts to narrow down the list through a selection process. In Round 2, a list of statements developed from the Round 1 findings was presented to all participants. Based on the findings from Round 1, 45 five-level Likert-like items were developed for Round 2. Perspective questions were offered as Likert-like items in an ordinal measurement pattern that offered respondents the options: Strongly Agree, Agree, Disagree, or Strongly Disagree. For this study, the authors used a 0-5 forced response. A total of 28 participants completed the questionnaire who identified as either an end-

user/operator or someone in the academic/regulator/policymaker fields. For each of the 45 questionnaire items, a mean was calculated across all 28 participants ("*N* value" for total sample size). A mean of 3.5 or higher was the standard for consensus in agreement with the item. A mean of 1.5 or lower was the standard for consensus in disagreement with the item. No items yielded a consensus of disagreement. Round 2 was expanded after an initial brainstorming of Round 1 results to include several additional items. Table 2 indicates the means for each of the 45 Likert-like items.

Table 2

Mean Round 2 Reponses Across all Participants

Item #	Item text	Mean (*N*=28)	Consensus reached?
Q1	The development of universal global guidelines for space travel and colonization is desirable at the present time.	4.0	Yes
Q2	Substantial development of universal global guidelines for space travel and colonization is feasible at the present time.	3.3	No
Q3	The development of an agency or clearinghouse for the standardization of certifications and technical requirements for space travel and colonization is desirable at the present time.	4.1	Yes
Q4	The development of an agency or clearinghouse for the standardization of ethical standards for space travel and colonization is desirable at the present time.	3.9	Yes
Q5	The development of an agency or clearinghouse for the global standardization of certifications and technical requirements for space travel and colonization is feasible at the present time.	3.4	No
Q6	I do not believe that the development of an agency or clearinghouse for the global standardization of certifications and technical requirements for space travel and colonization is feasible at present. However, I believe that developing a regional agency of allied nations for standardizations of certifications and technical requirements is feasible.	3.9	Yes
Q7	Substantial development or defining of a global agency or clearinghouse for the standardization of ethical standards for space travel and colonization is feasible at the present time.	3.3	No

Item #	Item text	Mean (*N*=28)	Consensus reached?
Q8	I do not believe that the development of an agency or clearinghouse for the global standardization of ethical standards for space travel and colonization is feasible at the present time. However, I believe that the development of a regional agency of allied nations for standardizations of ethical standards is feasible.	3.0	No
Q9	Regardless of feasibility or desirability, the safety of persons and preservation of life should be the highest priority in developing universal guidelines for space travel or colonization.	4.2	Yes
Q10	Regardless of the desirability of developing a global agency or clearinghouse for the standardization of certifications and technical requirements, organizations such as the United Nations and/or ICAO provide a sufficient template for doing so.	3.4	No
Q11	Regardless of the desirability of developing universal guidelines for space travel and/or colonization as expressed by public (government) and private entities, existing guidelines from agencies such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), the Commercial Spaceflight Federation (CSF), and the International Association for the Advancement of Space Safety (IAASS), would provide the baseline for further guidelines to be developed.	4.0	Yes
Q12	Multiple, independently functioning, worldwide national space agencies and private commercial space entities, each with their own governing laws, policies, and procedures, would be more effective in promoting the advancement of space travel and colonization than a single, global agency or clearinghouse.	2.8	No
Q13	Further investigation is needed to determine whether a single entity for global space safety would be optimal for promoting the advancement of space travel and colonization.	3.8	Yes
Q14	If an infrastructure to develop a universal Emergency Space Response Management System (ESRMS) is developed through international collaboration and investment, the	3.6	Yes

Item #	Item text	Mean (*N*=28)	Consensus reached?
	influence of individual governments over decision-making related to the project (e.g., number of votes) should be proportional to each government's investment in the project.		
Q15	If a guideline for developing an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for commercialized space travel and colonization between global governments and private entities is developed, participation should be optional—that is, sovereign states should be able to opt-in or opt-out.	3.6	Yes
Q16	There should be a universal minimum medical standard for screening, selection, training, and certification for all commercialized humans before space travel.	3.6	Yes
Q17	There should be a universal minimum training standard for screening, selection, training, and certification for all humans before commercialized space travel.	3.6	Yes
Q18	At least while space travel is still in an early stage, there should be different screening, selection, training, and certification criteria based on the person's function in space, i.e., tourist, flight crew, employee, colonist, etc., and one of the primary purposes of such classification should be to assign individual responsibilities and/or assess fitness to fulfill them.	4.5	Yes
Q19	There should be different screening, selection, training, and certification criteria based on an individual's function in space, i.e., tourist, flight crew, employee, colonist, etc., even if the criteria are to some extent dependent on mission variables such as duration, distance, and the nature of the craft.	4.6	Yes
Q20	Space entry for all commercialized travelers should be specifically categorized (e.g., flight crew, tourist, or colonist), and one of the purposes of such categorization should be to assess the individual's fitness for fulfilling any associated responsibilities.	4.1	Yes
Q21	Space entry for all commercialized travelers should be specifically categorized (e.g., flight crew, tourist, or colonist), and one of the purposes of such classification	3.1	No

Item #	Item text	Mean (*N*=28)	Consensus reached?
	should be to determine the individual's rights and/or their ability to waive their rights.		
Q22	At least while space travel is still in its early stages (i.e., before it is developed to a level akin to commercial air travel), all spacecraft with 10 or more passengers onboard should be required to carry an onboard medical officer.	3.2	No
Q23	Spacecraft with human passengers should be required to carry an onboard medical officer when a planned space travel duration exceeds a defined time.	3.6	Yes
Q24	All spacecraft with any number of human passengers should only be required to carry a first aid kit as the minimum medical equipment needed for spaceflight certification.	3.3	No
Q25	All spacecraft with any number of passengers onboard should be at minimum required to have automatic fire suppression system(s).	4.1	Yes
Q26	Whenever feasible, all spacecraft should be segmented to allow containment of events such as fires, depressurization due to meteorite or debris collisions, or toxic spills.	4.0	Yes
Q27	Human error will be among the top three causes of onboard accidents in spacecraft and off-Earth accidents resulting in death and/or property loss.	4.0	Yes
Q28	Mechanical or systems failures will be among the top three causes of onboard accidents in spacecraft and off-Earth accidents resulting in death and/or property loss.	4.3	Yes
Q29	Depressurization will be among the top three causes of onboard accidents in spacecraft and off-Earth accidents resulting in death and/or property loss.	3.8	Yes
Q30	Universal guidelines for passenger and crew requirements associated with long-endurance spaceflight (greater than thirty days in space) should be developed and accepted globally as a standard.	4.0	Yes
Q31	Guidelines for passenger and crew requirements for long-endurance spaceflight (greater than thirty days in space) should only be developed and accepted as a standard at the national or regional level.	2.9	No
Q32	Additional data about the effects of physical and psychological stressors on the general population are	3.7	Yes

Item #	Item text	Mean (*N*=28)	Consensus reached?
	needed to determine whether and to what extent guidelines for passenger and crew requirements for long-endurance spaceflight should be developed.		
Q33	One of the most significant disadvantages to developing a single agency or clearinghouse for the standardization of certifications, technical requirements, and ethical standards is that one-size-fits-all regulation would hamper meritocratic competition to an extent detrimental to the overall advancement of space travel and colonization.	3.4	No
Q34	One of the greatest barriers to the development of a single agency or clearinghouse for the standardization of certifications, technical requirements, and ethical standards is that nations will not be willing to relinquish sovereignty in their pursuit of space travel and colonization goals.	4.1	Yes
Q35	With the recent launch of Virgin Galactic and Blue Origin reaching different altitudes during their space flights, the argument of which crews actually or theoretically reached space presents more need to define the globally recognized requirement boundary for a defined entry into space?	3.4	No
Q36	It is feasible to define the space flight boundaries as quantified series of three zones instead of a singular line with separate governing rules, regulations, and requirements, which could ease the restrictions on suborbital and low Earth orbital flights.	3.9	Yes
Q37	Space regulation and policy governance should continue solely under the United Nations and be perpetually known as the single regulatory entity responsible for Earth's space policy regulations and legislation matters?	2.5	No
Q38	It is ideal for keeping the global space governing regulation policymaking under the United Nations (UN) and expand global operational authority and responsibility under the International Civil Aviation Organization (ICAO) for all future space operations as it has done for global aviation. However, ICAO should remain unbiased and apolitical.	2.6	No
Q39	As a result of international space regulations, the International Civil Aviation Organization (IACO) name should be amended to the International Civil Aerospace	3.1	No

Item #	Item text	Mean (*N*=28)	Consensus reached?
	Organization (ICAO) better to describe a possible overarching industry/community inclusion.		
Q40	There should be a space tourism tax as part of space tourism, which all spacefaring nations within the United Nations pay to fund the ICAO commercial space office to develop, support, and sustain the infrastructure of commercialized human space safety.	3.0	No
Q41	The Artemis Accords should serve as the vessel that operationalizes the Outer Space Treaty (OST) of 1967 and allows space policy regulation to evolve and mature in today's modern era. This allows for universal cooperation from all participant nations to agree to work together for the better good of the peaceful use of space.	3.7	Yes
Q42	There is a need to create an International Space Academy to develop and train our next generation to ensure the highest level of success before any off-Earth colonization and/or longevity endurance space travel commences in the Cosmos.	3.6	Yes
Q43	A single universal entity infrastructure with overarching responsibility for all space emergencies and rescues should be developed to ensure the highest probability of survival to human life and recovery of property is assured.	3.1	No
Q44	There is a need for a unified global space safety regulation that the global community uses as the universal standard regarding commercial crews, passengers, and vessels. This list would include but is not limited to the designated maximum allowable space flight times for awake duty cycles for crewmembers and non-crewmembers, sleeping accommodation requirements, spacecraft minimum equipment lists, radiation exposure monitoring standards, onboard medical care requirements, and emergency procedures/protocol for flight crews and ground support crews/staff.	3.8	Yes
Q45	If life support cannot be maintained and/or space flight cannot continue, there should be an escape craft capable of sustaining all onboard passengers' and their life support	3.6	Yes

Item #	Item text	Mean (*N*=28)	Consensus reached?
	requirements to the intended point of destination, with maneuvering capabilities.		
	n of items on which a consensus was reached (*N*=45):		28

Based on the responses across all 28 participants, a consensus was reached in over half (62%) of the items. However, a different pattern emerged when separate means were calculated for the responses of end-users/operators and academicians/policymakers/regulators. When viewing the breakdown of responses between the end-users/operators (end-users) and the academic/regulator/policymakers (policymakers), the end-users reached a consensus on 78% of the items, while the policymakers reached a consensus on 51% of the items.

Discussion

Overall, the participants of this survey reached a consensus of the need of a global standardization for the safety of human passengers in space, emphasizing health, safety, precaution measures, training/selection, and the overall well-being of individuals and countries regarding pursuit of space flight. Question 19 demonstrated the highest consensus on the necessity for different screening, selection, training, and certification criteria based on an individual's function in space, illustrating the importance that experts surveyed placed on these issues. While the participants of this study were advocates of global standardization for screening, training, and certification they do not think this should be accomplished under the United Nations. Question 37, which focused on space regulation and policy governance under the United Nations, had the lowest consensus. This discrepancy in results reflects the values participants of this study place on training, but also the necessity for international distinctions and heterogeneous training to impact how training is implemented and regulated. Participants highly valued safety factors that influenced loss of life or property with respect to safety. For example, a high level of consensus was found regarding the likelihood of mechanical systems failures being among the top three causes of accidents.

Additionally, there was a high level of agreement regarding human error and depressurization causing loss of lives and onboard accidents. Question 26 and Question 29 demonstrated a high level of agreement concerning matters of depressurization. Safety was the most common theme throughout the entire study. Safety was the only theme that significant consensus emerged at a rate of 100%. Only two other themes, development and profit, and environmental impacts

received support from more than 33% of participants. While this study's results emphasized safety. It is important to note that it is a common concern across the aerospace sector because safety is also a theme mentioned by ICAO in its strategic objectives (ICAO, 2021). These themes existed along with capacity and efficiency, security and facilitation, economic development, and environmental protection. These themes align with previous research.

Two themes emerged when similar responses to the second question pertaining to the development of an agency or clearinghouse were grouped. Twenty out of 28 participants (71%) strongly agreed or agreed that the development of an agency or clearinghouse was needed. Nine out of 28 participants (32%) strongly disagreed or disagreed, expressing the perception that the development of such an agency was not feasible. It is interesting to note that although there were disagreements in responses considering it not feasible that some nations are implementing what some could interpret as a step in that direction. For example, within the United States, lawmakers have mandated that the DOT—through the FAA, via the commercial space transportation entity, and at the discretion of the passenger willing to travel into space—sign a space flight participant waiver of claims against the U.S. government (Sagath et al., 2018). Therefore, the Artemis Accords, which describe a vision for a safe and transparent environment that facilitates exploration, science, and commercial activities for all of humanity to enjoy, are essential in understanding the potential regulation of human spaceflight in the future. Existing space policies and agencies are reflective of the interest to prevent the misuse of space in terms of militarization and colonization. According to The United Nations Office for Outer Space Affairs (2021) agencies such as COPUOS exist to maintain peace within outer space, and their success relies on national space agencies' membership and coordination.

Steer (2019) points out that the problem with existing agencies and policies for outer space is that the race to space, including space travel and colonization, includes both government and commercial actors In addition, according to Powell (2019), there is also a lack of a central agency that governs both commercial and government actors on an international level. This study illustrates current concerns associated with the feasibility of establishing and prioritizing a guideline for developing an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for commercialized human space travel and colonization between global governments and private entities. The participants in this study were evenly divided between those who considered independent functioning of multiple national space agencies worldwide as likely to be problematic and those who did not believe that it would be problematic because the alternative of a single agency would be less desirable. For instance, the creation of NASA was geared toward helping the country explore space and compete effectively with the Soviet Union. According to Mieczkowski (2013), the creation

of this space agency was the product of successful cooperation and planning between the administration of President Eisenhower and eminent scientists. Jakhu (2006) and Vasilieve (2008) remarked that despite multiple international agencies, treaties, and agreements, there remains a lack of clarity in space governance. As evident thus far, many of the existing policies pertaining to outer space focus on maintaining peace by preventing weaponization and militarization. Other factors, such as protecting individuals from the negative health impacts and the dangers of space, have received less scholarly attention.

Recommendations

The findings of this study illustrate the level of consensus regarding the necessity for standardized certifications and guidelines related to space travel. Based on the results of the research, the researcher recommends the following:

1. A standardized global Space Safety Risk-Based Management System should be developed to preserve life, which all nations could choose to adopt.
2. Spacecraft design and certification should improve lifesaving standards to include escape craft in case of emergencies.
3. As part of the spacecraft design and certification process, whenever feasible, all spacecraft should be segmented to allow containment of events such as fires, depressurization due to meteorite or debris collisions, or toxic spills.
4. Environmental impacts should be prioritized, particularly regarding debris mitigation and planetary protection standards.
5. There is a need to develop a clearinghouse to standardize certifications, requirements, and ethical standards for space travel and colonization between governments and private entities.
6. A clearinghouse should prioritize the protection of life and move toward establishing international standards related to all aspects of safety. These aspects include but are not limited to the following: space law, policy, and procedures, operations, interagency relations, licensing, monitoring, enforcement, interdiction, training, testing/evaluation, and certification. Other issues that should be considered include detection of space accidents, space rescues, insurance and bond requirements, space traffic management, security to avoid hostile utilization of space, standardized testing, and intellectual property protection.

Conclusion

The importance of this research study lies in the identification of areas that future scholars can use for topics of discussion to investigate international experts' thoughts regarding the need to establish and prioritize guidelines for the development of an agency or clearinghouse for the standardization of certifications, requirements, and ethical standards for commercialized space travel and

colonization between global governments and private entities. Additionally, the findings captured a global consensus on many space safety concerns regarding human passengers, interoperability, integration, and globalism in space theory for future policy doctrine application. This study can potentially serve as a minimum reference baseline for an international study regarding the integration and interoperability for commercialized human space safety programmatic and/or policy standardization at national and/or international levels.

References

Commercial Space Act of 1998, 42 USC § 14701. https://www.govinfo.gov/content/pkg/BILLS-105hr1702enr/pdf/BILLS-105hr1702enr.pdf

Dominoni, A. (2021). Living in space by the lens of design. In *Design of Supporting Systems for Life in Outer Space*, 41–62. Springer.

Durante, M., & Cucinotta, F. A. (2011). Physical basis of radiation protection in space travel. *Reviews of Modern Physics, 83*, 1245. https://doi.org/10.1103/RevModPhys.83.1245

Durkee, M. J. (2019). The future of space governance. *Georgia Journal of International & Comparative Law, 48,* 711.

Gibson, J. M. E. (1998). Using the Delphi to identify the content and context of nurses continuing professional development needs. *Journal of Clinical Nursing, 7,* 451-459.

International Civil Aviation Organization. (2020). *About ICAO.* https://www.icao.int/about-icao/Pages/default.aspx

Inter-Agency Space Debris Coordination Committee. (n.d.). *Home.* http://www.iadc-online.org/

Jakhu, R. (2006). Legal issues relating to the global public interest in outer space. *Journal of Space Law, 32*, 31–110.

Kua, J., C. Arora, C., Loke, S. W., Fernando, N., & Ranaweera, C. (2021). Internet of things in space: A review of opportunities and challenges from satellite-aided computing to digitally-enhanced space living. *Sensors, 21*. https://doi.org/10.3390/s21238117.

Mieczkowski, Y. (2013). *Eisenhower's Sputnik moment: The race for space and world prestige*. Cornell University.

National Aeronautics and Space Administration. (2007). *Final report of the International Space Station independent safety task force*. https://www.nasa.gov/pdf/170368main_IIST_%20Final%20Report.pdf

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information & Management, 42*, 15–29. https://doi.org/10.1016/j.im.2003.11.002

Powell, C. S. (2019). These new technologies could make interstellar travel real. *Discover Magazine.* https://www.discovermagazine.com/the-sciences/these-new-technologies-could-make-interstellar-travel-real

Reddy, V. S. (2018). The SpaceX effect. *New Space, 6*, 125–134. https://doi.org/10.1089/space.2017.0032.

Sagath, D., Papadimitriou, A., Adriaensen, M., & Giannopapa, C. (2018). Space strategy and governance of ESA small member States. *Acta Astronaut, 142*, 112–120. https://doi.org/10.1016/j.actaastro.2017.09.029.

Sekayi, D., & Kennedy, A. (2017). Qualitative Delphi method: A four round process with a worked example. *Qualitative Report, 22*(10), 2755–2763.

Sielaff, A. C., Urbaniak, C., Mohan, G. M. M., Stepanov, V. G., Tran, Q., Wood, T. M., Minich, J., McDonald, D., Mayer, T., Knight, R., Karouia, F., Fox, G. E., & Venkateswaran, K. (2019). Characterization of the total and viable bacterial and fungal communities associated with the International Space Station surfaces. *Microbiome, 7*(50). https://doi.org/10.1186/s40168-019-0666-x

Steer, C. (2019). Who has the power? A critical perspective on space governance and new entrants to the space sector. *Georgia Journal of International & Comparative Law*, *48*, 751.

United Nations Office for Outer Space Affairs. (n.d.). *Status of international agreements relating to activities in outer space*. http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/status/index.html

Vanian, D. (2015). How NASA uses quantum computing for space travel and robotics, GIGAOM. https://gigaom.com/2015/02/13/how-nasa-uses-quantum-computing-for-space-travel-and-robotics/

Vasiliev, V. (2008). The draft treaty on the prevention of the placement of weapons in outer space, the threat or use of force against outer space objects. *Security in Space: The Next Generation: Conference Reports*.

Vuolo, M., Baiocco, G., Barbieri, S., Bocchini, L., Giraudo, M., Gheysens, T., Lobascio, C. & Ottolenghi, A. (2017). Exploring innovative radiation shielding approaches in space: A material and design study for a wearable radiation protection spacesuit. *Life Sciences in Space Research, 5*, 69–78. https://doi.org/10.1016/j.lssr.2017.08.003