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Certification Process for Intra-Vehicular Activity (IVA) Spaceflight Suits for Suborbital Flights

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Abstract: As commercial suborbital spaceflight becomes more accessible through companies like Blue Origin and Virgin Galactic, the need for reliable and rigorously tested intra-vehicular activity (IVA) spaceflight suits has become increasingly important. Unlike extravehicular activity (EVA) suits, designed for prolonged exposure to the vacuum of space, IVA suits are worn inside the spacecraft to provide safety and life support in emergencies such as cabin depressurization. Suborbital flights, like those on Blue Origin's New Shepard, expose passengers to high acceleration forces, rapid altitude changes, and brief periods of microgravity. While these flights are designed for safety and automation, IVA suits serve as a critical backup system, ensuring astronaut survivability in worst-case scenarios. Additionally, these suits must offer sufficient mobility, thermal regulation, and ease of use, as passengers may need to react quickly in emergencies. As space agencies and private companies push further into space, we cannot afford for astronauts to be grounded—or worse, put at risk—because of something as basic as a suit that does not fit (Clark & McBarron, 2015). This proposal calls for a Global Adaptability Review (GAR) for all certified IVA spaceflight suits to ensure every astronaut, regardless of size, nationality, or mission, has access to a properly fitting suit (National Aeronautics and Space Administration [NASA] Office of Inspector General, 2019). A Global IVA Suit Standardization Working Group (GISWG) will create an internationally recognized sizing system, ensuring all astronauts have properly fitting suits, regardless of their agency (Ross et al., 2017).

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1. Introduction

A structured certification process is required to ensure IVA suits meet the demands of suborbital spaceflight. This process verifies that the suits can:

- Maintain pressure integrity in the event of a decompression emergency.
- Provide sufficient mobility and dexterity for astronauts to operate spacecraft controls and perform critical tasks.
- Regulate temperature and manage comfort in the highly variable thermal environments experienced during a flight.
- Enable rapid suit donning and emergency egresses to support astronaut safety during unexpected situations.

By certifying IVA suits against these four critical criteria, space agencies, private companies, and regulatory bodies can ensure that passengers and crew members are adequately protected throughout the flight. The following sections outline each certification's specific tests and rationale, ensuring that suborbital spaceflight prioritizes astronaut safety and mission success. To eliminate suit-related mission risks, we propose a Global Adaptability

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Review (GAR) for all IVA suits after certification. This will ensure that every suit meets the highest safety and usability standards, no matter who wears it.

2. Pressure Integrity & Leak Test Certification

Ensure the suit maintains structural integrity and provides adequate pressurization in case of cabin depressurization event.

Figure-1 Final Frontier IVA is being pressurized to check for leaks. (J. Fox, 2023)

A pressure leak test and a decompression test should be conducted. The suit is pressurized inside a vacuum chamber in a pressure leak test to simulate space-like conditions. Sensors monitor leakage rates over time to ensure they remain within safe limits. [As shown in Figure-1 above.] However, during the rapid decompression test, the suit is exposed to a sudden decrease in ambient pressure (e.g., from 1 atm to near-vacuum) to verify that it can maintain pressure and does not experience catastrophic failure (NASA, 1975). In the unlikely event of a depressurization emergency, astronauts rely on their IVA suit to maintain life-supporting conditions.

Unlike extravehicular activity (EVA) suits, which are designed for continuous vacuum exposure, IVA suits need to protect astronauts only in short-duration emergencies. However, even brief exposure to near-vacuum conditions can be fatal if the suit fails. During the test, we are looking for leak rate control; small leaks could lead to a dangerous loss of oxygen over time, compromising astronaut safety. A rigorous pressure leak test ensures the suit material, seams, and connectors prevent excessive gas escape. Structural integrity under decompression is also monitored; this simulates a rapid depressurization test and mimics an emergency scenario, such as a hatch failure. If the suit fails to maintain pressure quickly, astronauts could suffer decompression sickness or hypoxia (International Organization for Standardization, 2011).

3. Mobility & Dexterity Certification

Ensure astronauts can move comfortably and perform critical tasks while wearing suits, including operating vehicle controls and emergency systems. Astronauts perform standardized movements (e.g., reaching, bending, securing harnesses) while being suited and pressurized to verify flexibility. IVA gloves, while more flexible than EVA gloves, still reduce dexterity. Fine motor skill assessments, such as flipping switches, pressing buttons, and using a touchscreen, are also conducted while wearing pressurized gloves. Microgravity-simulated movement testing is conducted in a parabolic flight or underwater to assess movement efficiency in low-gravity conditions. Even in a controlled intra-vehicular environment, a spacesuit must not hinder an astronaut's ability to respond to emergencies or operate spacecraft controls. Gross motor skills refer to large muscle movements used for activities such as walking, reaching, bending, and maintaining balance. Figure-2 below shows the challenges faced with playing soccer in a pressurized IVA.

Figure-2 IIAS Chris Lundeen and Jenee' Fox while performing gross motor skills in pressurized IVA. (P. Mhatre)

Pressurization often stiffens the suit, making movement more difficult. It is critical to ensure astronauts can still reach control panels, fasten restraints, and use safety equipment. Many spacecraft systems require precise hand movements. If the gloves are too rigid or bulky, astronauts may struggle to operate essential controls, potentially leading to mission failure or safety risks (NASA, 1973). During a suborbital flight, astronauts experience brief microgravity. An improperly designed suit could restrict movement, making it challenging to adopt safe body positions or return to a seat in an emergency (Ross, 2017). While IVA suits are designed for flexibility and comfort inside a spacecraft, they still impose physical limitations that astronauts must adapt to. The weight and bulk of the suit shift the astronaut's center of gravity, making sudden movements more difficult.

4. Thermal & Comfort Certification

Ensure that the suit maintains a safe and comfortable temperature throughout all phases of flight, preventing overheating or excessive cooling.

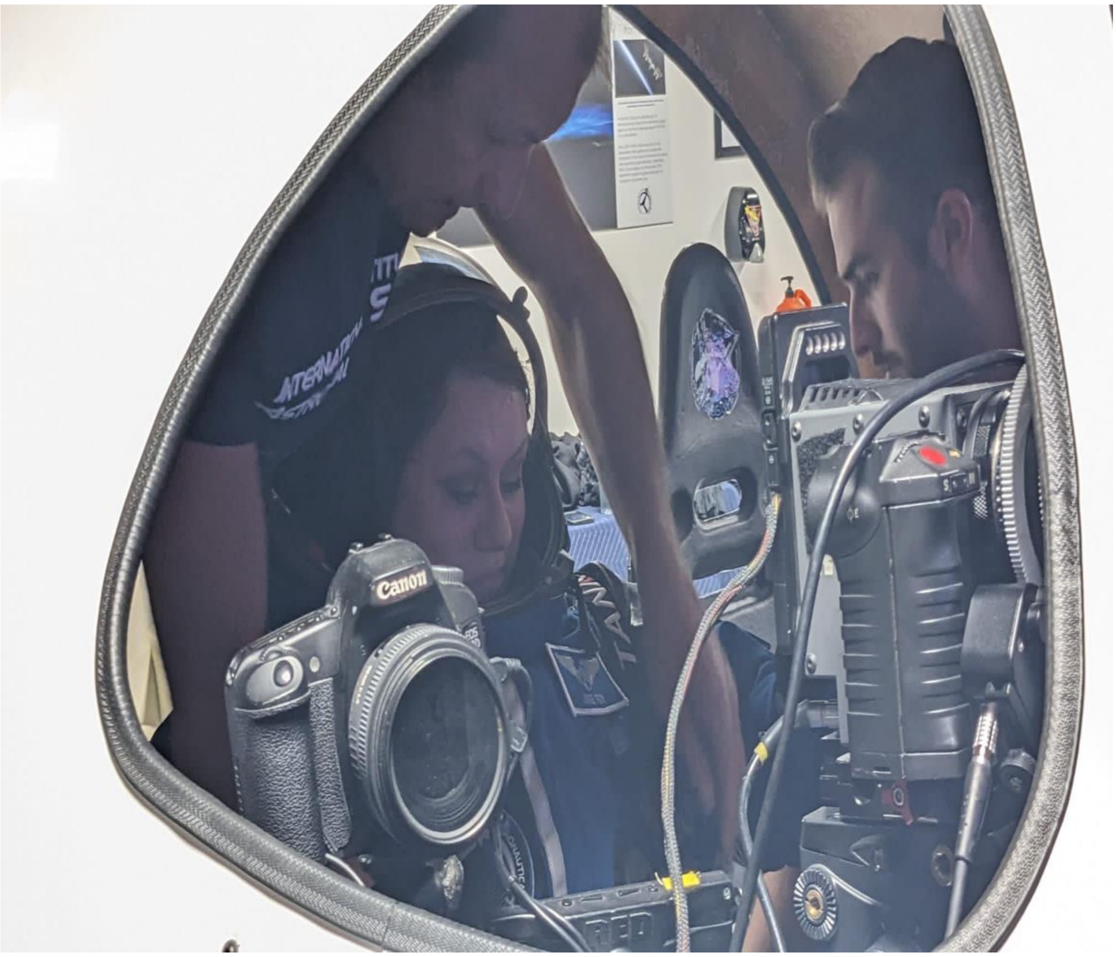

Figure-3 Chris Lundeen assisting Jenee’ Fox in the flight simulator to take images and samples. (P. Mhatre)

Astronauts wear suits for an extended period under realistic conditions (including heat exposure) to measure moisture buildup and ventilation effectiveness. Figure 3 above shows Jenee’ Fox in a flight simulator wearing a pressurized IVA with forced cooling. The suit is tested under simulated environmental conditions, including the high temperatures of a launch pad and the cold temperatures of the upper atmosphere and space (NASA, 1975). Suborbital flights involve rapid transitions between different temperature extremes. Without proper thermal regulation, astronauts could suffer from heat stress or hypothermia (Chiou & Jao, 2009). On the launch pad, astronauts may be suited up for an extended period under warm conditions. The suit must allow for sufficient cooling to prevent heat exhaustion. The temperature drops significantly as the spacecraft ascends to higher altitudes and enters space. Without insulation, astronauts could experience cold stress. However, excessive sweating can lead to dehydration and discomfort, while condensation inside the suit could fog visors or interfere with electronic components. A well-ventilated design prevents these issues. (NASA, 1965).

5. Emergency Egress & Suit Donning Certification

Ensure astronauts can quickly put on the suit and exit the spacecraft safely in case of an emergency, including post-landing scenarios.

Figure-4 Chris Lundeen assisting Jenee' Fox with glove mobility in pressured IVA. (P. Mhatre)

During the emergency donning test, astronauts must be able to put on and secure the suit within a strict time limit (e.g., under 90 seconds) to simulate a rapid emergency response. A full-scale mock-up of the spacecraft tests astronaut mobility during emergency exits while suited, simulating a rapid egress. If applicable, the suit is tested for buoyancy and compatibility with flotation devices in the event of an ocean landing. A suborbital spaceflight like New Shepard involves high acceleration forces and an unpowered descent. While the standard landing is controlled, emergency scenarios could require astronauts to exit quickly.

In case of a sudden decompression or other in-flight emergency, astronauts must don their suits quickly. Survival rates could decrease if the process takes too long or is overly complex. While standard procedures involve ground crew assistance post-landing, astronauts must be able to exit independently in case of a delay or emergency. A bulky or restrictive suit could make evacuation difficult. Figure 4 above shows Jenee' Fox getting assistance to put on her gloves. Even though New Shepard lands on solid ground, contingency planning for water landings is necessary. The suit must allow astronauts to stay afloat and move effectively in water if needed (NASA Office of Inspector General, 2019).

6. A Lesson from Space

In 2019, NASA astronauts Anne McClain and Christina Koch were set to make history with the first all-female spacewalk. However, a critical issue forced a last-minute change: the right-sized spacesuit was unavailable (NASA Office of Inspector General, 2019). This meant McClain had to stay behind while another astronaut took her place—an avoidable problem that underscored a more prominent issue in spaceflight. Missions today involve NASA, ESA, Roscosmos, CNSA, private companies, and others. Spacecraft, technology, and personnel are shared spacesuits (International Organization for Standardization, 2011). The ISS only had one medium-sized Hard

Upper Torso (HUT) component of the NASA Extravehicular Mobility Unit (EMU) spacesuit ready for use. McClain had trained in both medium and large torso sizes on Earth, but in space, she found that the medium size allowed better mobility in microgravity. Since Koch also needed a medium-sized suit, there was only one available, forcing NASA to reassign McClain's spacewalk to another astronaut with a different suit size (NASA Office of Inspector General, 2019).

Future space stations, like the ISS, Artemis Gateway, and private stations, will keep a reserve of universally adjustable suits for contingencies (NASA Office of Inspector General, 2019). The solution is simple: no astronaut should ever be left behind because of a suit that does not fit. By implementing the Global Adaptability Review (GAR), we are future-proofing human spaceflight, ensuring that every certified IVA suit is

- Safe in emergencies
- Interchangeable across agencies
- Designed for real astronauts—not just a specific body type
- Standardized for a new era of global space travel

7. Conclusion

The certification process for intra-vehicular activity (IVA) spaceflight suits in suborbital missions is essential to ensuring astronaut safety and mission success. As the commercial space industry expands, the reliability of these suits becomes increasingly critical—not only for professional astronauts but also for space tourists and researchers who may have little to no prior spaceflight experience. Each of the four certifications—Pressure Integrity and Leak Testing, Mobility and Dexterity, Thermal and Comfort Regulation, and Emergency Egress and Suit Donning—plays a vital role in mitigating risks associated with suborbital flight. Pressure integrity testing ensures the suit can provide life support during cabin depressurization, preventing fatal exposure to near-vacuum conditions. Mobility and dexterity certification guarantees that the suit does not hinder an astronaut's ability to interact with spacecraft controls or perform emergency procedures. Thermal and comfort regulation is crucial to maintaining astronaut well-being throughout the mission, as temperature extremes can impact performance and survival. Finally, the ability to quickly don the suit and exit the vehicle in an emergency ensures that astronauts can respond effectively to unexpected situations, including rapid vehicle evacuation or post-landing contingencies. See Attachment 1 for an example of a passing IVA certification. The structured and rigorous approach to IVA suit certification aligns with industry best practices from organizations such as NASA, FAA, and ASTM, ensuring that these suits are held to high safety and performance standards. As suborbital travel continues to evolve, further refinements to IVA suit testing may be needed to accommodate new vehicle designs, mission profiles, and passenger requirements. By implementing a thorough certification process, spaceflight providers can enhance crew and passenger safety, instill confidence in space tourism, and lay the foundation for future advancements in commercial spaceflight. As humanity moves toward more frequent and accessible space travel, the importance of well-tested, reliable IVA spaceflight suits will continue to grow. The future of space travel includes astronauts of all body types. We must design suits that reflect the diversity of those who wear them (Chiou & Jao, 2009). We can achieve new horizons through IVA certification and GAR; this is not just a recommendation but a necessity. Every space-faring nation, every company investing in human spaceflight, and every astronaut, depending on their suit, deserves a system that works for all (Federal Aviation Administration, 2024).

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