ABSTRACT
Ensuring Safety of Government Personnel During Suborbital Spaceflight

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The NASA Suborbital Crew (SubC) project is focused on enabling flights by NASA civil servants, such as scientists and engineers conducting research, on suborbital vehicles. A broader goal is ensuring that commercial human spaceflight is both viable and safe. Within the Commercial Crew Program (CCP), the SubC project is exploring game-changing methods to perform safety assessments to enable NASA personnel to fly on suborbital missions. Commercial suborbital space flight capabilities are anticipated to be more accessible, affordable, and available than missions to the International Space Station and could provide additional opportunities for testing and qualification of space flight hardware, human-tended microgravity research, and further cutting-edge research enabled by the space environment. Although NASA currently permits human tended suborbital payloads for non-civil servants under auspices of NASA's Flight Opportunities Program, the SubC effort will enable civil servant scientists, researchers, and even engineers to accompany their experiments and tests into the space microgravity environment. Figure 1 illustrates how the SubC program complements other microgravity experimental platforms. The targeted scope for SubC includes end-to-end suborbital capabilities reaching ~80km with several minutes of sustained microgravity (Table 1).

The NASA SubC project office is working with the Federal Aviation Administration's Office of Commercial Space Transportation (FAA-AST) and the commercial suborbital space transportation industry to develop an efficient and holistic approach to a safety review and eventual government participation in suborbital flight. The current FAA certification process for suborbital launches is congressionally mandated to only consider public safety. NASA is responsible for understanding the risks to its employees should they fly on a commercially available suborbital flight. The SubC project is employing a Safety Case approach, applied to commercial suborbital providers, which is not a traditional certification process as was used for the SpaceX Dragon and Boeing Starliner vehicles. Rather, it is an assessment using elements of NASA's Risk-Informed Safety Case and the Armstrong Flight Research Center's Airworthiness Assessment process.

The Safety Case is predicated on each suborbital provider having their own certification plan and demonstrating compliance to that plan. For each suborbital provider, SubC has created a multi-pronged plan that includes:

- A comparison of vehicle standards against applicable NASA/industry standards
- Deep Dives into the systems and subsystems of top risk
- A quality and safety assessment

The Deep Dives and quality and safety assessment are conducted by a NASA team of disciplinary specialists to assess the functional area's readiness for flight, categorization of hazards, likelihood of mission success, and flight/ground/range safety procedures.

Deep Dives utilize a multi-faceted engagement format to interact in-person with the private launch providers, performed in months rather than years using a small team of appropriate NASA subject matter experts. In parallel, SubC determined that traditional and existing program risk matrices were not built for the above constraints. Therefore, NASA subject matter experts must identify inherent system risks and the company's maturity to mitigate them. The SubC project is employing the Safety Case methodology because each provider has already designed, built, tested, and is flying their own vehicle – all of which was done independently of NASA. This Safety Case approach went through a pathfinder and is currently being communicated through NASA technical, program, and agency level forums.

A NASA Flight Readiness Review Board at the Armstrong Flight Research Center is an independent team of disciplinary specialists chartered to assess a project's overall readiness for flight, categorization of hazards, probability of mission success, and flight/ground/range safety procedures. The findings are provided to the Airworthiness and Flight Safety Review Board. This expertise is being applied to assess flight- and space-worthiness and associated hazards of candidate suborbital flight vehicles being evaluated by the SubC team.

Secondary objectives are met by an assessment of corporate process, design, build, and operational products in each functional area with a comparison to NASA's experience base. Here, NASA functional managers consider if the provider's approach is in-family with their experience or have a clearly identifiable risk that needs to be assessed. NASA's insight is focusing on four primary areas:

1. Design is capable of handling mission extremes and contingencies;
2. Manufacturing, integration, test, and checkout are sufficient to ensure build reliability;
3. Operational plans, support, training, and post-flight review ensure mission is maintained within the vehicle design limits, and anomalies are identified and resolved; and
4. Organization's engineering and safety culture supports decision making through all elements of the life cycle

Voluntary Consensus Standards are another element being addressed. Two key international committees developing consensus standards addressing human spaceflight safety are (1) the International Organization for Standardization (ISO) Technical Committee 20 on Aircraft and Space Vehicles, and (2) ASTM International Committee F47 on Commercial Spaceflight.

Example standards that have been issued by ISO TC20 include:

- ISO 14620-3:2021 – Space systems – Safety requirements – Part 3: Flight safety systems, 08/04/2021
- ISO 17763:2018 – Space systems – Human-life activity support systems and equipment integration in space flight – main document, 08/28/2018
- ISO 16157:2018 – Space systems – Human-life activity support systems and equipment integration in space flight – Techno-medical requirements for space vehicle human habitation environments, 06/25/2018
- ISO 16126:2018 – Space systems – Human-life activity support systems and equipment integration in space flight – Techno-medical requirements for space vehicle human

habitation environments – Requirements for the air quality affected by harmful chemical contaminants, 04/26/2018

ASTM International's Committee F47 on Commercial Spaceflight, formed in 2016, is developing and maintaining voluntary consensus standards and recommended practices for the commercial spaceflight industry. The voluntary consensus standards are being developed by groups of subject matter experts through a formal drafting and review process. Technical subcommittees develop and maintain these standards and recommended practices. Specific areas addressed include design, manufacturing, and operational use of vehicles used for spaceflight as well as human spaceflight safety. Stakeholders represented include vehicle operators and parts manufacturers, the Commercial Spaceflight Federation (CSF), regulators including the FAA Office of Commercial Space Transportation, US Government users including NASA Centers and Headquarters, National Air Space (NAS) users, spaceport operators, medical professionals, the AIAA, academia, and other interested stakeholders.

Example standards that have been issued by ASTM Committee F47 include:

- F3479-20 Standard Specification for Failure Tolerance for Occupant Safety of Suborbital Vehicles
- F3520-21 Standard Guide for Training and Qualification of Safety-Critical Space Operations Personnel
- F3610-23 Standard Classification for Descriptions of Spaceport Capabilities
- F3550-22 Standard Guide for Classifying Safety-Related Events

NASA's Safety Case Assessment approach is tailored from the above Risk-Informed Safety Case. NASA will continue to work with industry providers and international initiatives to find the most effective methods of ensuring success. NASA's approach seeks to provide value, not just as a risk-assessment activity, but to expand the possibilities for how government and industry can work together for a common goal.

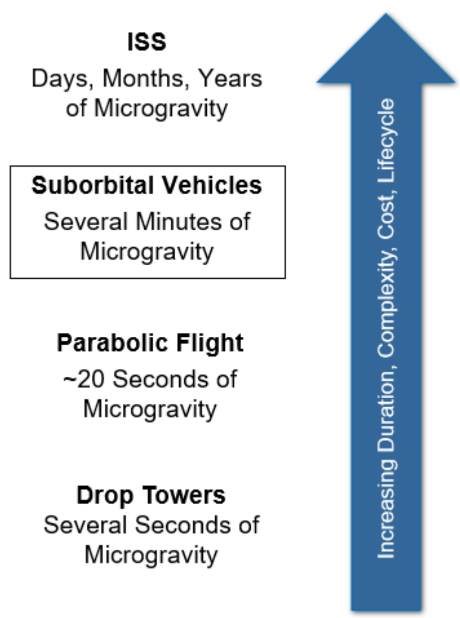

Figure 1. Why SubC?

Table 1. Potential SubC Applications

- **Human-Tended Microgravity Research**
  - **Materials processing**
  - **Life sciences experiments**
  - **Research payloads**
  - **Experiments for planetary sciences, and more**

- **Testing and Qualification of Spaceflight Hardware**
  - **In-flight testing of hardware (equipment, tools, etc.)**
  - **Provide confidence in new systems & components to support qualification**