COMSTAC Safety Working Group Report
May 2022

Introduction

The commercial human spaceflight industry has achieved a number of historic milestones over the last few years, from return of the capability to launch astronauts from American soil to suborbital and orbital flights of commercial astronauts, to space tourism flights to the International Space Station (ISS). Even more are in sight as several companies are involved in development of commercial space habitats including modules to the ISS and independent private space stations. Considering the significant progress and rapid growth of the industry, coupled with the upcoming scheduled expiration of the Learning Period in 2023, the FAA tasked the COMSTAC with the following:

- Provide recommendations on the top 5 high priority areas for future regulation of Human Spaceflight, referencing the 2014 *Recommended Practices for Human Spaceflight Occupant Safety* as a starting point for areas to consider
- Offer advice on expanding the Recommended Practices document scope to include:
    - Flights longer than 2 weeks
    - Flights beyond LEO
    - Rendezvous and docking
    - Radiation hazards
    - Planetary protection
    - Government astronauts
    - Spaceflight Participants (SFPs) flying on-board autonomous vehicles
- Offer advice on if there should be different Recommended Practices that may apply to suborbital versus orbital flights and if so, initial recommendations as to what those topics should include

Top Five Priorities for Human Spaceflight Regulation

After consultation with industry leaders and with careful consideration of the current state of industry as well as future growth, the COMSTAC offers the following top five high priority areas for future regulation of Human Spaceflight:

1. Establish a permanent regulatory environment that specifies the scope of informed consent and to the maximum extent incorporates performance-based requirements.
    - Industry has operated under an informed consent regime since initial implementation of human spaceflight regulations in 2007. Informed consent can largely be credited for the rapid growth of and great demand for commercial human spaceflight, enabling operators to engage in commercial operations without the tremendous impact of prescriptive certification requirements. Compared to commercial aircraft certification, certification of space vehicles (as opposed to licensing) would present an outsized financial burden on industry, as space companies operate only one to a handful of vehicles at an extremely low tempo. Despite the extraordinary progress of industry so far, commercial human spaceflight remains a nascent and fragile industry. Until flights are routine and numerous, continued use of informed consent is imperative to industry survival. This point is echoed by lessons of aviation history--despite tens of thousands of passengers flying in the first decade of commercial aviation, none of the commercial airlines survived until the government provided economic certainty through air mail

contracts. While informed consent is quite different from government contracts, its impact on business risk and industry survival is similar. It is with these points in mind that the COMSTAC strongly advocates for continued use of informed consent as a foundation for the future human spaceflight regulatory framework.

- Expanding upon the intent of Streamlined Launch and Reentry Licensing Requirements, performance-based human spaceflight regulations would provide a flexible regulatory framework that not only ensures safety, but also enables continued innovation. From vertically launched rockets to air launched spaceplanes, from stratospheric balloons to reentry capsules, system diversity within the commercial human spaceflight industry is immense. As a result, it would be extremely challenging to leverage design commonalities as a basis for a comprehensive set of regulations. Rather than prescriptive requirements that assume particular vehicle and mission design characteristics, or even multiple sets of requirements to capture specific vehicle and mission types, both government and industry are best served by performance-based regulations focused on design principles that apply across a wide array of designs.

2. Consider the current and anticipated body of voluntary industry consensus standards to inform future regulations and serve as means of compliance.
    - Performance based regulations provide latitude for compliance, but should be supported with guidelines and best practices. In addition to FAA guidance documents already in development, human spaceflight industry standards such as those published and planned by ASTM International provide best practices that can serve as means of compliance to future regulations. Specific examples include: medical qualifications for SFPs, safety and emergency training, seat restraints, and cabin environment. Adoption of industry standards could provide the starting point for specific requirements.

3. Utilize industry provided input including the COMSTAC November 2021 Recommendations for Human Spaceflight (HSF) Regulation as well as seeking industry feedback on the 2014 Recommended Practices for Human Spaceflight Occupant Safety.

    - The COMSTAC document recommends key focus areas based on industry feedback after years of experience under the existing regulatory regime. Accompanying comments to the Human Spaceflight Checklist outline specific topics applicable to future rulemaking, recognizing that current regulations are focused on requirements relevant to public safety and liability and only minimally address safety of those onboard.
    - Since publication of the FAA Recommended Practices document in 2014, several companies have used these guidelines in development of human spaceflight systems, whether for strictly commercial use, or through compliance with NASA Commercial Crew requirements from which the document was derived (though revised multiple times since). While many in industry have assessed these requirements for applicability to new guidance documents and regulations, a formal review is advised to provide comprehensive comments.

4. Address integration of occupant and public safety including priorities when conflicts arise.

- This topic was intentionally excluded from the Recommended Practices document, yet has been a critical issue in development of contingency procedures, flight rules, and abort systems, as well as selection of contingency landing locations. This is of particular note in relation to Commercial Crew providers, as NASA astronauts were previously delegated public safety responsibility under the Space Shuttle Program, but this authority cannot be extended to commercial operators.

5. Build a regulatory framework that considers applicability to/dovetailing with future orbital transportation/orbiting platform requirements at the point regulatory authority (by whatever agency) is established for on-orbit activities.
    - FAA should work with other government agencies and industry to establish a roadmap for future on-orbit regulatory authority. This would not expand the scope of new human spaceflight regulations, but would be an exercise in identifying human launch and reentry requirements that could be part of a streamlined future regulatory framework when on-orbit activities are regulated.

The COMSTAC believes these priorities will be useful to inform future rulemaking and set ground rules for the Human Spaceflight Aerospace Rulemaking Committee. The foundation and structure of a future regulatory framework is critical not only to public and occupant safety, but also to the continued health of the commercial human spaceflight industry.

Recommended Practices Scope Expansion

The COMSTAC considered the seven topics presented for possible scope expansion, with specific attention on the regulatory landscape and value to industry. While all of the topics are of interest to industry, the COMSTAC advises against FAA undertaking efforts unique to on-orbit operations, including flights longer than 2 weeks, flights beyond LEO, rendezvous and docking, and planetary protection. Though commercial industry is expanding its reach from launch and reentry into development of commercial space stations, on-orbit activities clearly lie outside the current regulatory authority of the DoT/FAA. If FAA wishes to pursue these topics, they should seek guidance from the White House and Congress.

Even so, at this point the COMSTAC advises keeping guidance documents focused on launch and reentry, recognizing the extensive resources required for the huge undertaking of HSF rulemaking and associated guidance document development, and with appreciation of FAA's focus on this extremely important effort. Until commercial on-orbit regulatory authority is established, the COMSTAC suggests that guidance on such activities is appropriately addressed by industry consensus standards.

- Government Astronauts

  The COMSTAC finds the topic of government astronauts to be of great interest to industry. In terms of safety, there should be no distinction between U.S. Government, foreign government, and private crewmembers. Instead, requirements and practices specific to government astronauts are levied by NASA or equivalent foreign government agencies. From a liability standpoint, this topic will be addressed by the upcoming Part 440 Space Rulemaking Committee. Therefore, the COMSTAC

recommends deferring development of recommended practices on this topic, whether in the Recommended Practices document or elsewhere, until the ARC issues its recommendations.

- Radiation Hazards

  Though the COMSTAC recommends against pursuing efforts exclusively related to on-orbit activities, guidance on this topic would be helpful for launch and reentry of human spaceflight vehicles. Space weather constraints are commonly used for evaluating launch readiness for spacecraft, and just as solar storms can impact avionics, communications, and aerodynamic forces; strong solar activity is a risk to occupant safety, even on short duration flights. The COMSTAC supports FAA efforts to examine public and occupational health limits on short-term and lifetime radiation exposure and develop guidance on space weather constraints and design mitigations to ensure human safety during launch and reentry.

- SFPs Flying On-board Autonomous Vehicles

  The COMSTAC agrees that this is a valuable topic for FAA to address, particularly since autonomous vehicles are already in commercial operation with more in development.

  While not explicitly stated, some parts of the current human spaceflight regulations and the Recommended Practices document imply the presence of at least one flight crew member onboard. Recommended crewmember responsibilities include decision authority for the vehicle and occupant safety, communications with ground controllers, executing safety-critical actions, and using onboard medical equipment. Per regulation, SFP training requirements are limited to responding to emergencies, including smoke, fire, loss of cabin pressure, and emergency egress. While automated functions are discussed in recommended practices regarding manual intervention, neither fully autonomous vehicles nor the presence of SFPs without a crewmember have been addressed.

  The COMSTAC notes that autonomous human spaceflight systems are currently operating under FAA licenses which do not require onboard crew for the safety of SFPs or the uninvolved public. Similarly, the presence of crew onboard some vehicles does not necessarily imply a need for them to perform safety-critical functions.

  Depending on the extent of vehicle autonomy and remote command capability, a pilot may not be required onboard to control flight. However, that doesn't necessarily imply an absence of safety-critical operations requiring a crewmember. On some vehicles a non-pilot crewmember may still be necessary to provide safety-critical communications with ground control, ensure safety of occupants, or provide SFP direction for nominal operations (such as when seat restraints may be removed and must be re-attached), off nominal, and emergency actions (such as when to don oxygen masks). Based on system design and operations, on some vehicles neither a pilot nor a crew member may be required.

  If a pilot is not required but the system dictates the need for a non-pilot crew member, it could be supplied by the operator, a contractor, or a customer. A highly qualified SFP (one or more) could also assume this role, given enhanced training to execute safety responsibility and perform the functions required over and above those of a standard SFP— analogous to how aircraft passengers

seated in the emergency row are tasked with understanding and being capable of operating the aircraft door if called upon. Many of these practices may already be included in flight training for autonomous vehicles currently carrying SFPs. Learning from these operational systems should inform best practices and any future regulations.

In order to determine if a non-pilot crew member is required, the extent of vehicle autonomy as well as human factors should be integrated into a comprehensive system safety analysis, as is currently required for public safety and recommended for occupant safety.

- If SFP error or behavior under duress could jeopardize the safety of others (such as in the case of opening a hatch in flight or interacting with safety or life support systems), a crewmember might be prudent to ensure public and/or occupant safety.
- If there are no safety-critical communications or actions in flight AND analysis shows that an SFP could not defeat vehicle hazard controls that ensure acceptable public risk and baseline occupant risk, a crewmember may not be necessary.

The COMSTAC recognizes that FAA does not take lightly the decision to authorize autonomous vehicle operations without crewmembers, rather carefully considers system-specific design and safety analysis in its evaluation. The COMSTAC advises that FAA guidance on this topic consider variations in system architecture, operations concepts, mission lengths, and flight environments. FAA should also leverage existing processes and products required under Part 450 in preparation for a similar performance-based structure in future human spaceflight regulations.

Suborbital vs. Orbital Recommended Practices

The COMSTAC acknowledges both differences and commonalities between suborbital and orbital human spaceflight systems and missions, and notes that a vehicle may be capable of performing both suborbital and orbital flights. Given the vehicle diversity discussed earlier in this report, as well as the various launch and landing methods, differences in best practices may be as much attributable to vehicle category as to suborbital vs. orbital mission profile.

While some industry standards address only one or the other, much of that is due to the separate, parallel evolution of suborbital and orbital systems. Commercial suborbital human spaceflight systems were primarily developed independently with private funding, as opposed to the majority of orbital systems which were developed under NASA contracts with detailed system and mission design requirements. This resulted in different needs and focus areas between suborbital and orbital vehicle operators developing best practices. Industry collaboration has substantially increased over the last few years, with suborbital and orbital vehicle operators now contributing towards development of common commercial standards. In fact, the ASTM International Committee F47 on Commercial Spaceflight recently merged their suborbital and orbital subcommittees on occupant safety, streamlining efforts while giving a nod to similarities between the two.

In defining commercial best practices, the extent of applicability, efficiency, and maintainability should drive determination of whether standards are common or distinct to each flight realm. In cases where practices are largely applicable to both suborbital and orbital missions, the COMSTAC advises

streamlining practices into a single document with exceptions noted; this leverages commonality and reduces document maintenance. The same applies when suborbital practices are a subset of orbital practices, in which case it's effective to list common elements in one section, followed by additional scope relevant to orbital missions. Examples of recent COMSTAC recommendations corresponding to these cases include *Guidance on Informing Crew and Space Flight Participants of Risk* in which practices were primarily common, and *Guidance for Medical Screening of Commercial Aerospace Passengers* in which suborbital screening criteria were a subset of orbital criteria. In addition, significant commonality could be, or has already been, leveraged in standards for the following system-level topics:

- Human Factors
- Failure Tolerance
- Environmental Control and Life Support Systems
- Emergency Equipment and Supplies
- Safety and Emergency Training
- Communications

When practices differ significantly between orbital and suborbital missions, or only apply to one, separate documents are advised. Topics in this category could include:

- Health Stabilization
- Consumables
- Pressure Suits
- Ionizing Radiation Protection
- Micrometeoroid and Orbital Debris (MMOD) Protection
- Bio-waste Management

Conclusion

The COMSTAC appreciates the opportunity to provide recommendations on the structure and focus of future human spaceflight regulations, an imperative first step towards future rulemaking and providing guidance for a Human Spaceflight Aerospace Rulemaking Committee. In addition, the COMSTAC is pleased to advise on commercial best practices and anticipates productive collaboration between FAA and industry in the development of guidance documents and incorporation into the human spaceflight safety regulatory framework. We welcome the opportunity to provide clarification or further feedback wherever needed.