HAPS Alliance

HIGH ALTITUDE PLATFORM STATION

HAPS Certification Pathways

Introduction

The purpose of this white paper is to identify the key challenges faced by the High Altitude Platform Systems (HAPS) community in getting regulatory approval to start commercial operations and to recommend actions that the HAPS Alliance can take to address these challenges. Operational challenges are covered only from the perspective of the potential impact they have on air vehicle performance.

Obtaining some form of certification (traditional FAA Type Certification being only one possible example) from a major Civil Aviation Authority (CAA) is a key enabler of the large-scale worldwide operation of HAPS. To obtain such a certification, one must show compliance with a set of requirements defined by the CAA using guidelines approved by the CAA. Existing requirements and guidelines were developed for crewed aircraft, and therefore they often carry certain assumptions about the performance and missions of crewed aircraft. Some of those assumptions are not valid for HAPS, which are different from crewed aircraft in the following ways:

1. HAPS are uncrewed, which means there are no occupants of the air vehicle at risk -- all risk is to third parties, which may be sparse or absent depending on the mission and the operational location (e.g., climate monitoring over the high seas).
2. HAPS missions typically require operating for months, as opposed to hours for crewed aircraft.
3. HAPS operate primarily in the stratospheric environment and are exposed to extreme cold, low air density, cosmic and ultraviolet radiation, ozone and other environmental factors not typically seen at lower altitudes.
4. Turbulence levels are expected to be low in the stratosphere when compared to the lower atmosphere where crewed aircraft operate.
5. Air traffic is sparse in the stratosphere.
6. HAPS typically operate from private airfields away from other air traffic, with infrequent takeoff and landing sequences.
7. To minimize energy consumption, HAPS are designed to be slow and lightweight, and they are thus less maneuverable compared to crewed aircraft.

The HAPS community is global and diverse, but there are substantial commonalities. This provides an opportunity to develop consistent regulatory guidelines to enable HAPS operation approval by any CAA. This paper is an attempt to highlight the major areas of concern when developing these guidelines and present some strategies to address them. Two of the primary CAAs that do the Type Certifications are the FAA and the EASA. This paper is primarily focused on challenges related to the FAA Type Certification as it is applied to HAPS, although most, if not all, of these challenges are independent of the certifying agency.

Challenges

Safety Requirements

For existing 14 CFR Part 23 crewed aircraft, safety objectives and the safety assessment process are defined in the FAA guidance material AC 23.1309-1E. Because today's Type Certification frameworks are designed for crewed aviation, a key focus is on preserving the integrity of the Aircraft. Safety objectives in AC 23.1309-1E are tied to aircraft failure conditions and are targeted at managing the risks associated with the effects on aircraft, flight crew and passengers. For example, AC 23.1309 considers any aircraft failure condition that results in hull loss as catastrophic, which implies loss of life for a crewed aircraft.

The absence of people onboard HAPS aircraft creates a fundamentally different risk paradigm from that of a crewed aircraft. Consistent with the 2022 FAA BVLOS ARC for Uncrewed Aircraft, the "focus must be on protecting individuals on the ground and preventing collisions with crewed aircraft, not on preventing a UA crash."

To ensure that the population and other aircraft are not exposed to unacceptable levels of risk, a certification or approval framework must account for:

- The location, population density and airspace density of the operation -- operating above no population and traffic creates very low risk, even if the risk to the HAPS aircraft itself is higher, while operating over people creates more risk.
- The number (or density) of HAPS -- The risk to ground populations and other aircraft depends on the number of HAPS that operate in a region. Larger HAPS systems that require fewer platforms may be safer than smaller systems that require more platforms.
- The time spent over populations -- transient operations typically create shorter risk exposure than loitering.
- System frangibility -- a HAPS designer may design the platform to be frangible, so as to reduce the energy on impact (with ground population or other aircraft).

Existing crewed aircraft safety objectives are intended to assure that an individual aircraft meets certain levels of safety, not accounting for the number of aircraft being operated, population density, other air traffic density or the operating location. This makes the existing crewed aircraft safety objectives, focused on aircraft-level risks, overly conservative for uncrewed aircraft such as HAPS. Attempting to comply with the existing safety objectives for the aircraft will force overdesign, impacting performance and the ability to meet business goals.

The HAPS community needs to advocate for a safety assessment process that is focused on managing the risk of midair collisions with crewed aircraft and with people on the ground. The HAPS Alliance aviation working group is already working on developing such a process. Once developed, the HAPS Alliance should present it to multiple CAAs to obtain visibility. The FAA-established Drone Advisory Committee, in its October 27, 2021 report, has also recommended similar approaches to unmanned aircraft systems (UAS) safety assessment.

An ability for the HAPS industry and regulators to learn and iterate is key to the success of HAPS. The HAPS Alliance should propose a risk-based methodology that could provide a gradual approval framework that would enable commercial operations to start over low-population and low-air-traffic areas and gradually expand to denser regions and more complex airspaces, as the systems mature over time. Some form of internationally recognized certification or approval framework will be required to allow large-scale worldwide commercial operation of HAPS. However, it is beneficial for HAPS operators to start limited commercial service as soon as possible in low-risk areas, build experience and learn while generating revenue to sustain development. Waiting until the certification frameworks are fully developed to start commercial operations may not be viable.

For large aircraft, the current FAA-approved methods of showing compliance with safety objectives rely heavily on design analysis, using tools such as fault trees and functional hazard assessments. Fundamental reliability data with which to perform these analyses is often lacking for HAPS aircraft and their operating environment. As a result, some combination of both analysis and operational reliability data gathered during flight hours flown (using a gradual approval process) should be used for HAPS development. An adaptable and incremental process that allows for the demonstration of required durability and reliability, through analysis using available data and by using additional data from flight hours spent in actual operations, would be beneficial for both the HAPS community and the public that it serves.

Certification for Ground Systems

Existing crewed aircraft certification regulations do not address the certification of ground systems. The complexity of HAPS ground system configuration can vary based on their operational maturity and the scale of operations. HAPS with a single uncrewed vehicle can operate with a single control station. In this case, the control station would likely be considered in the certification. On the other hand, some large HAPS fleets may use a highly complex Fleet Management System built on highly redundant and distributed cloud infrastructures, with web-based interfaces, dynamic configuration control and agile software development techniques. The certification of such systems within traditional certification frameworks may prove particularly challenging.

While there is recognition of the importance of these ground systems on safety, there is currently no internationally harmonized guideline for certifying such diverse systems. The FAA has the concept of associated elements for UAS, which puts all the systems that reside outside the air vehicle, including the control stations, outside the Type Certification boundary. Separating the control station from the Type Certification process is inconsistent with ICAO Annex 8, Amendment 108, which requires that the entire UAS system, including the control station (Remote Pilot Station in ICAO language), be covered in the Type Certification for UAS.

Like the UAS ecosystem, the HAPS ecosystem is expected to be highly diverse. Some players will be fully integrated (HAPS designer, manufacturer, operator, service provider), while others will only produce a vehicle operated by third parties.

Consistent with the 2022 FAA BVLOS ARC for UAS, “regulators should consider eliminating separate airworthiness, operational, airspace, and personnel approval processes. A better approach would be a streamlined, scalable, and holistic application process that accounts for the specific characteristics of different operations and provides flexibility for different operators to seek any subset of approvals at one time.”

International recognition of HAPS Certification will be a key enabler of HAPS operations at scale. Developing a flexible, internationally harmonized process that is consistent with ICAO rules would go a long way toward paving the way for a HAPS Certification or approval framework that is internationally recognized.

Environmental Criteria

To show compliance with performance-based standards, such as the FAA's 14 CFR Part 23 Amendment 64, designers must typically refer to prescriptive consensus standards, such as 14 CFR Part 23 Amendment 63 or ASTM Standards, for their means of compliance. These standards often have implicit assumptions about the aircraft and its characteristics, the acceptable levels of risk to the aircraft, or the aircraft's mission and operating environment. HAPS aircraft and their mission are unique compared to past crewed aircraft and encompass a diverse range of designs. HAPS aircraft need a comprehensive description of the operating environment that does not contain the inherent assumptions derived from legacy crewed aircraft. Whether this description is of turbulence, lightning, temperature or numerous other environmental characteristics, once an official "design environment" and clear acceptable levels of aircraft risk have been defined by the regulators, HAPS designers can design a system and an associated operational approach that can be operated safely and robustly in that environment.

For environmental parameters that vary with time (as almost all of them do), the time variation should also be part of the environmental description, so that designers can design and take advantage of mission planning as a risk mitigation to allow for safe operation while not over-designing the aircraft for use in all possible environmental conditions.

Aviation rules and standards were built over 100 years, yet the stratospheric environment is currently poorly understood, and the science of stratospheric platform development remains relatively nascent, with significant progress being made in recent years. It is therefore critical that regulations remain flexible and capable of rapidly adapting to newly gathered data and newly established "best practices."

Turbulence

Since they are typically slow and lightweight, for many HAPS (particularly fixed-wing) designs the expected levels of atmospheric turbulence are strong drivers for both structural and control system design. One of the Part 23 performance-based structural requirements is to demonstrate, through analysis, that HAPS structures can withstand the expected turbulence encountered during the HAPS mission. The existing prescriptive design guidelines traditionally used as a means of compliance with these requirements are based on aircraft data collected at lower altitudes. These guidelines are not appropriate for the majority of the environments in which HAPS are expected to operate, and the statistical guidelines in the portions of the environment that *are* represented are likely overly conservative, given typical HAPS operational restrictions.

Existing guidance specifies turbulence amplitudes that have implicit assumptions of dynamic similarity to past (e.g., non-span-loaded, higher wing loading) designs, and that also assume a similar mission type. Older criteria—for example, 14 CFR Part 25 Appendix G—attempt to describe the atmospheric turbulence environment as the probability of any given level of turbulence as a function of altitude. This suggested statistical description is at least an attempt to describe the whole environment, rather than imposing specific turbulence amplitudes that are based on assumptions about aircraft and missions. Again however, the statistics are still potentially overly conservative at low altitudes (because HAPS have more operational restrictions than traditional aircraft) and they are lacking in statistically significant data at higher stratospheric altitudes where HAPS intend to operate. Since this statistical description was published in the 1960s, many new measurement and modeling efforts for turbulence at all levels in the atmosphere have been undertaken. Google Loon, for example, has collected over 2 million hours of environmental data at stratospheric altitudes. While many of these new modeling or measurement datasets are available, most have not been distilled down into relevant high-altitude statistical guidance suitable for the aircraft designer. Nor have many of these been recognized and vetted by regulatory agencies to the same extent that existing guidance has been. To the authors' knowledge, no unified collection of all this data has been done with an eye toward improving the knowledge of atmospheric turbulence statistics for use in design.

Given an accurate description of the turbulence environment that HAPS operates in, a mission design approach (such as that suggested in the former 14 CFR Part 25 Appendix G) will allow HAPS structures to be designed to a required structural exceedance rate. These designs can then take advantage of HAPS' primarily high-altitude operations and operational restrictions, such as picking takeoff and landing times or being able to move away from storms.

An approach similar to the above environmental description of turbulence can be used for many other environmental parameters that are needed by HAPS designers. These include, for example, the frequency, location and severity of lightning, wind, rain, icing, ozone, UV radiation, cosmic radiation, temperature and many other environmental characteristics.

Lightning

Designing HAPS air vehicles to survive the lightning environment encountered by crewed aircraft will add significant weight, resulting in a significant reduction in performance. This reduction in performance would likely make HAPS platforms unviable, since the additional weight would likely mean HAPS vehicles could not meet the design case. Existing requirements assume that the aircraft will encounter lightning during operation. However, most HAPS designs assume that the air vehicle will avoid lightning encounters during take-off and landing and that lightning encounters during operations in the stratosphere are very rare. Very little data exists on the frequency or intensity of lightning in the stratosphere to back up this assumption. Therefore, there is a need to collect all available data from HAPS operations and develop a lightning environment definition specifically for HAPS, and demonstrate that risk due to lightning can be strategically avoided via HAPS mission planning.

Environmental Testing

Some of the environmental conditions in which HAPS operates are far different from those seen by typical crewed aircraft. Existing guidelines such as RTCA DO-160 are used to specify test conditions for environmentally qualifying components used in crewed aircraft. The environmental categories specified in these guidelines do not adequately cover the different environmental conditions experienced by HAPS. As an example, the temperature, shock and vibration profiles specified in RTCA DO-160 do not represent the wide temperature range and low vibrations experienced by HAPS operating in the stratosphere. In addition to this, ozone and ultraviolet radiation levels are not addressed in RTCA DO-160.

Developing HAPS-specific environmental test standards would be beneficial to the HAPS community. The HAPS Alliance should work with RTCA and EUROCAE to create a separate category to cover the environments encountered by HAPS. This must include the turbulence environment, temperature profiles, vibration profiles, cosmic radiation, lightning intensities, solar radiation intensity and ozone concentration. The HAPS community should share the operational data collected that is related to these environmental factors.

Detect and Avoid

HAPS air vehicles may be required by existing operating rules to carry onboard Detect and Avoid (DAA) systems to ensure separation while operating in airspaces not covered by current Air Navigation Service Providers (ANSP). Vehicles operating in the stratosphere are expected to have a very wide range of vehicle performance, making the existing DAA standards inadequate. To meet the requirements in the RTCA DO-365B DAA standard, the onboard system would have to detect approaching, faster-moving air traffic from far enough away to allow initiation of an avoidance maneuver. Current commercially available DAA systems are not qualified to operate in the upper airspace, and the weight and power requirements for a DAA system that can provide the detection range needed for a slow-moving HAPS will have a significant effect on performance and hence on HAPS platform viability. To address the challenges related to HAPS operations, the HAPS Alliance should find ways to accelerate the implementation of cooperative traffic management systems (ECHO in Europe and ETM in the United States). The HAPS community should also support the efforts to recognize HAPS as a separate class of air vehicle and ensure that it includes operational guidance for right-of-way rules for large, slow-moving, high-altitude UAS.

Communicating with the ANSPs

The current operating rules may require some HAPS to use onboard radios to communicate with the local Air Navigation Service Providers (ANSPs) and nearby air traffic. The current infrastructure and guidelines allow communication to the ANSPs only via an onboard radio, yet carrying these radios will add significant weight, increase power consumption and reduce reliability, resulting in a significant reduction in mission performance. Onboard radios also require open audio channels that are not conducive to using the low-bandwidth beyond-line-of-sight (BLOS, e.g., satellite) communication required for a commercially viable HAPS fleet.

The complexity of the stratospheric ecosystem and widely varying levels of HAPS vehicle performance capabilities make it impractical and undesirable for ATC separation services to be provided in the stratosphere. For this reason, regulators are developing new concept-of-operation documents (CONOPS), largely based on self-separation enabled by an ecosystem of service suppliers. These CONOPS rely on ground-to-ground data communication over IP instead of voice or onboard radios. In the short term, telephone coordination between the ANSPs and the operator, web-based position reporting portals and the use of minimum altitude floors coordinated over the phone are likely most adequate.

The HAPS Alliance should engage in ETM and ECHO discussions and support the ICAO SASP work that aims to support an informational overview circular for ANSPs on how to handle HAPS.

Component Failure Rate Data

Showing compliance with quantitative safety requirements requires valid component failure rate data. Since HAPS is a new type of air vehicle operating in the stratospheric environment, there are challenges in obtaining valid failure rate data for HAPS components. The data reported in industry databases such as NPRD are not representative of the components used in HAPS, due to the unique operating environment. The long continuous duration of HAPS missions may pose additional challenges and violate some of the key assumptions made in commonly used system safety assessment guidelines such as AC 23.1309-1E. In many cases the service history of identical or similar components is not available to estimate the mature failure rate of critical hardware. Additionally, this data will be specific to a particular HAPS design -- most HAPS components use unique design features tailored to the specific platform design. This also makes the applicability of the failure rate data from industry databases like NPRD and prediction models (MIL-HDBK-217) questionable when they are applied to HAPS items/components.

Establishing a HAPS-specific failure database of typical HAPS components would allow the HAPS community to develop realistic quantitative system safety assessments.

Recommended Actions

Finding solutions to the challenges highlighted in this paper will require significant engagement between the industry and the regulators. Establishing focus groups to develop detailed plans for each of the challenges is the logical next step.

- Safety Focus Group – the primary purpose of this group should be to establish appropriate safety risk metrics, objectives, and risk assessment models with regulating agencies such as the ICAO, the FAA and EASA. The HAPS Alliance Aviation Working Group is developing a white paper documenting the safety risk metrics, objectives, and risk assessment models. Once this document is released, it should be disseminated and discussed with ICAO and all the CAAs worldwide, especially the FAA and the EASA.
- Support and promote the work of the ICAO's SASP, which provides a novel approach for the integration of HAPS in the airspace and produces safety risk assessment guidelines for CAAs. HAPS Alliance members should provide data and feedback to the SASP

(perhaps through a CANSO membership) to ensure that the work accurately represents HAPS characteristics and needs.

- Establish HAPS as a separate category – the purpose of this focus group should be to articulate clearly the differences between HAPS and other aircraft categories. This will be critical in establishing the right-of-way rules and performance requirements appropriate for HAPS. The HAPS Alliance Aviation Working Group is already working on such a document for ICAO.
- Create and socialize a HAPS CONOPS and best practices document for integration of HAPS in the airspace and coordination with ANSPs.
- Related to the above, create and expand a HAPS-specific terminology document that includes explaining key concepts of HAPS CONOPS.
- Establish a self-separation CONOPS and charter agreement to self-separate over the high seas. Support the development by the Alliance of a simple UTM-like technology to enable strategic deconfliction worldwide.
- Establish appropriate environmental description and test criteria for the HAPS operating environment and CONOPS (including turbulence, lightning, wind, radiation and other relevant environmental parameters) – one of the focus groups should review the approximately two million flight hours of data collected by Loon in the stratosphere and any other available stratospheric data, to establish design and testing criteria for operating in the stratosphere. These environmental descriptions will evolve and be expanded as the industry gains additional upper-atmospheric measurements.
- Engage in ETM and ECHO discussions and support the ICAO SASP work that aims to produce an informational overview circular for ANSPs on how to handle HAPS.
- Work with Joint Authorities for Rulemaking on Unmanned Systems (JARUS) and the UAS industry on alternate certification/approval approaches (e.g., SAC). Traditional type certification may not be the appropriate framework for HAPS. A lighter framework that accounts for the lower risk profile and results in some form of system certificate would be preferable. Recommendations from the FAA's Beyond Visual Line-of-Sight (BVLOS) Advisory and Rulemaking Committee (ARC) March 10th, 2022 final report, which are suggested to apply to vehicles with less than 800,000 ft-lbs. of kinetic energy, should be considered for HAPS.

The HAPS Alliance should also look for opportunities to engage representatives from CAAs in their Aviation Working Group meetings. It is vital that the regulators be aware of the challenges faced by the HAPS community and how they can help in removing regulatory roadblocks to enable the large-scale operation of HAPS.

Conclusion

While performance-based, less prescriptive regulatory requirements allow more flexibility, showing compliance with some of the performance-based requirements poses unique challenges for a HAPS installation, due to its unique design, mission and operating environment. The challenges highlighted in this paper must be addressed to enable large-scale worldwide operations of HAPS. The stratosphere is a relatively new operating environment and our knowledge of it is rapidly expanding. Hence, the HAPS community should not be bound by existing guidelines that are created for crewed aircraft at lower altitudes. The HAPS community and its regulators must be able to embrace new lessons learned and datasets as soon as they are available, and they will need to choose data sources that are relevant to their specific application. Industry consensus and dissemination of these datasets and extensive testing at all phases of development will be vital to enabling safe and effective HAPS design and operation. The HAPS Alliance, as the representative of the HAPS community, must proactively influence change in the existing regulatory environment by bringing the HAPS community and the regulators together.

The development of a flexible and internationally recognized performance and risk-based certification or approval process will be a key enabler of HAPS operations at scale. Developing a flexible, internationally harmonized process that is consistent with ICAO rules would go a long way in paving the way for a HAPS Certification that is internationally recognized.

Join Us in Our Work

All companies interested in the HAPS ecosystem are encouraged to become HAPS Alliance members. Alliance membership levels – Principal, General, and Government and Education – are open to organizations in any industry sector. Members have the opportunity to become involved in various membership initiatives, including working groups, member-only meetings, and collaboration with other HAPS Alliance members to work on technology components and use cases for enabling a smarter world.

About the HAPS Alliance

The HAPS Alliance is an industry association of High-Altitude Platform System (HAPS) industry leaders that include telecommunications, technology, aviation and aerospace companies, as well as public and educational institutions. United by a vision to address diverse social issues and create new value through the utilization of high-altitude vehicles in the stratosphere, the Alliance is working to accelerate the development and commercial adoption of HAPS technology by promoting and building industry-wide standards, interoperability guidelines and regulatory policies in both the telecommunication and aviation industries. For more information, please visit https://hapsalliance.org.