HAPS Alliance

HIGH ALTITUDE PLATFORM STATION

HAPS Operation Using Attended Autonomous Fleet Systems

Collaborative Traffic Management for the Stratosphere

Introduction

The purpose of this paper is to depict the envisioned Collaborative Traffic Management for the Stratosphere (CTMS) operational end-state that enables safe and scalable operations of **High Altitude Platform Systems (HAPS)** operating at altitude as **Attended Autonomous Fleet Systems**. This vision is meant to serve as a guiding light to support safety and regulatory discussions. It also sets out near- and longer-term steps toward achieving this vision. While some aspects of the envisioned state may already be performed presently by some operators, it may take several years for some other aspects or some other operators to reach the described vision.

The HAPS community is global and diverse. The commonalities, however, provide an exclusive opportunity to reshape aviation's future, to design fully collaborative airspace in a new way, using higher levels of automation. Unmanned Traffic Management (UTM) principles, adapted to this airspace, allow regulators and operators to test this approach in a low-density, lower-risk environment and adjust best practices quickly based on lessons learned.

These unmanned and autonomous craft include lighter-than-air and fixed-wing aircraft that are solar powered, as well as an evolving series of craft that do not fall neatly into one of those categories, but combine aspects of both. Their solar-powered nature means that they fly very slowly and have limited agility. They are safe, and environmentally friendly, floating above traditional passenger traffic and above traditional weather.

HAPS vehicles are designed with the best of today's technical capabilities used in traditional and emerging aviation. In addition, they are driven by automation that performs fleet management and provides machine-to-machine communication enabling collaborative conflict detection and resolution, based on commonly agreed "rules of the road" and communication standards. HAPS can be described as **airborne infrastructure**, the operational safety of which will depend on adequate management of fleet-wide interdependencies and systems, akin to power grid management or nuclear power plant management, whose complexity will grow with the number of platforms and different types of technologies being operated.

The HAPS community is collaborating through the HAPS Alliance, and other mechanisms, to provide this cohesive vision. This community is working with key regulators as together they begin to define an achievable concept of operations (CONOPS) that allows for full utility of today's autonomous aviation capabilities. The FAA's ETM CONOPS sets the pace, and through this paper, the HAPS community adds some color to "how" the industry plans to support this CONOPS. The HAPS community is also working through the European consortium developing the European CONOPS, as well as with other key regulators (Australia and others) to promote a shared global vision that could be endorsed by the International Civil Aviation Organization (ICAO) mechanisms.

HAPS Fleet Operation Characteristics

Dynamic fleet systems

While HAPS may be operated as single vehicles, in many cases HAPS will be organized and deployed as a fleet that should be considered as **airborne infrastructure** (e.g., a stratospheric communications platform akin to airborne cell towers). At a global scale, the density of HAPS in the sky may not be very high for several years, but regionally and locally HAPS fleets may create high-density operations.

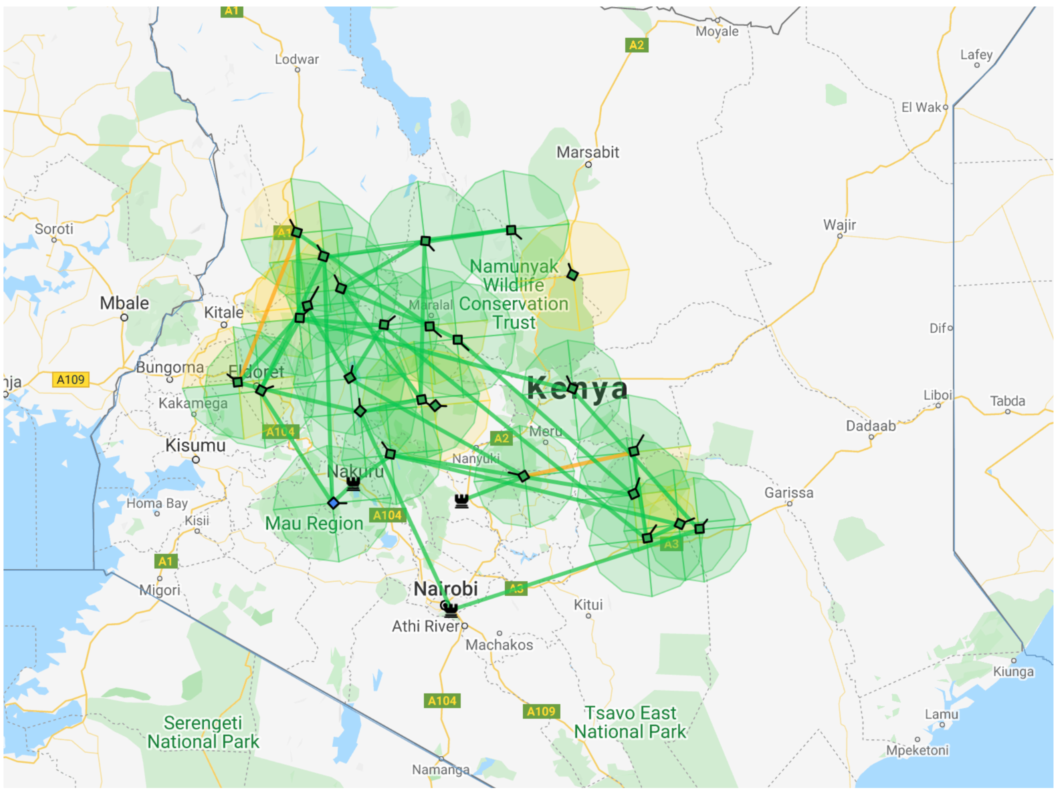

Figure 1– Example of actual HAPS fleet operations for internet connectivity service.

HAPS are sophisticated, interconnected systems where vehicles' behaviors may depend on one another. They rely on sophisticated optimization, power management (which itself depends on many external factors such as weather and service demand) and their behavior may be sensitive to parameters that cannot be forecasted with high accuracy (such as weather). As a result, many HAPS systems will be very dynamic: they constantly replan and adjust (sometimes every minute) to the observed condition and fleet optimization logic.

Operators may be serving multiple missions with a constrained number of airborne vehicles. As a result, fleet management and dispatching automation may also dynamically change and reassign missions to individual vehicles so as to maximize the use of airborne assets. In many systems, the vehicles will mostly be interchangeable (i.e., any vehicle A can substitute for vehicle B); this is unlike traditional passenger transport where a plane loaded to one destination is typically not reassigned to another destination mid-flight for fleet optimization purposes. Some fleet systems may also be composed of mixed vehicle types and performances (e.g., balloons and fixed wings).

Fleet management can be a highly complex and strategic task that needs to account for the current and expected states and environmental conditions of the multiple vehicles. It can be analogous to a game of chess, where each piece is controlled for its specific qualities, performance, and limitations. It will often be performed by sophisticated fleet management and dispatching automation attended by humans.

Fleets of fixed-wing HAPS will fly in circular, elliptical, helicoidal, figure 8 or non-stationary patterns (e.g., search/scanning patterns), exploring an altitude range following a diurnal cycle. They may frequently adjust their “orbit trajectories,” target position and altitude to respond to network management optimization and environmental conditions. Some HAPS platforms may not have sufficient lateral propulsion to overcome the wind. If their station-keeping ability is not sufficient for the desired mission, the fleets may be organized in a large rotational flow such that continuous coverage on the ground is assured despite a constant movement of the vehicles overhead.

All the above implies that the traditional definition of strategic planning as a “pre-flight task” must be reconsidered for HAPS – HAPS strategic planning will continuously happen while the vehicles are airborne (as well as before flight).

When considering the management of such operations, it is important to consider that the control of one vehicle **cannot** be considered independently of other vehicles, as the navigation and decisions made for one vehicle may affect navigational decisions of other platforms (similar to a flock of birds coordinating their movements in the sky). Ensuring safe operations will need to move away from the traditional pilot-vehicle model, and evolve towards a more holistic systems management approach.

International cross-border operations

Because of extended flight durations (sometimes more than a year), the launch and recovery portions (a few hours) of a flight represent a very small fraction of the entire flight (several months). Most HAPS typically (but not necessarily) launch from a limited number of fixed launch facilities (Launch and Recovery Elements, launch sites or stratoports) that often comprise specific infrastructure, and are placed strategically across the world in locations that optimize launch and recovery conditions (optimal weather conditions and remote from population and busy air-traffic centers/routes) and reduce average transit time to the multiple service regions served.

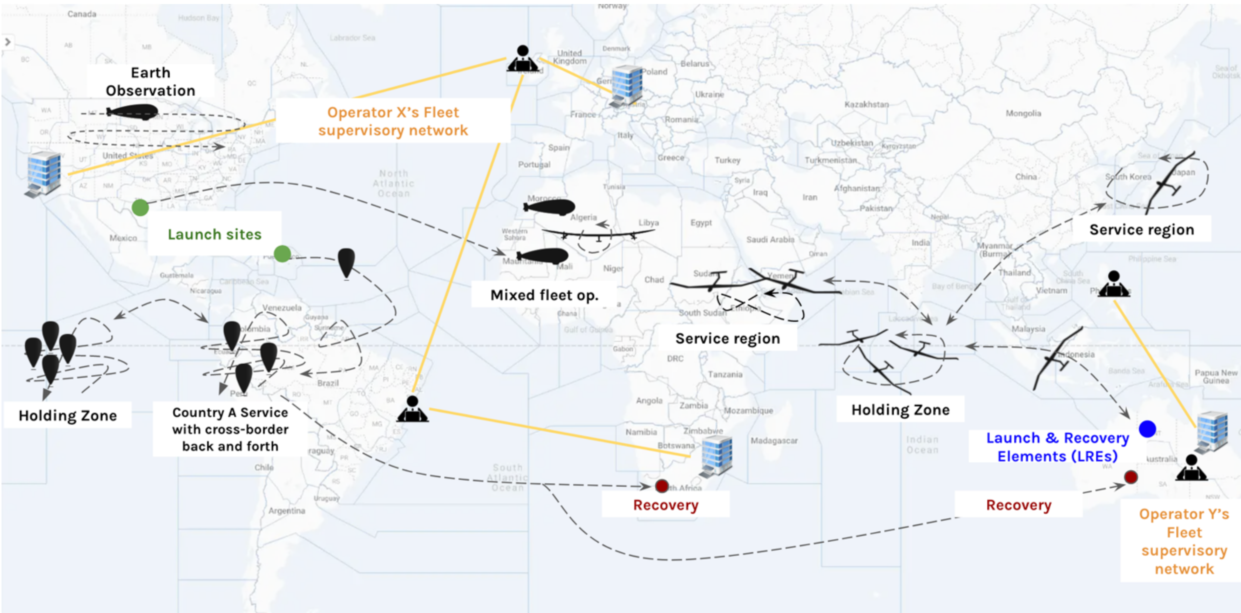

Figure 2 – Notional representation of international operations at altitude involving multiple operators. Each fleet is supervised by the operator's respective fleet supervisory network.

Once at altitude, HAPS may travel from their launch location to their mission destinations, which may be located across the world. Most HAPS will remain airborne between missions: upon completion of a mission (which may be of short or long duration), a vehicle can be assigned to another mission that may be in another region of the world, or the vehicle may be directed to a holding region (analogous to an airborne parking lot) where vehicles are maintained airborne, on hold before being assigned to another mission.

In some cases where the fleets are organized in regional flow rotations, each vehicle may be looping among a series of missions. For example, a fleet can be organized in a superregional cluster that rotates between connectivity missions in Country A > Country B > Country C > Country A. This may be done to exploit dominant wind currents and minimize the power used for navigation purposes so that it can be allocated to mission needs (e.g., communication). This behavior may be frequent for vehicles with limited true air speed capabilities.

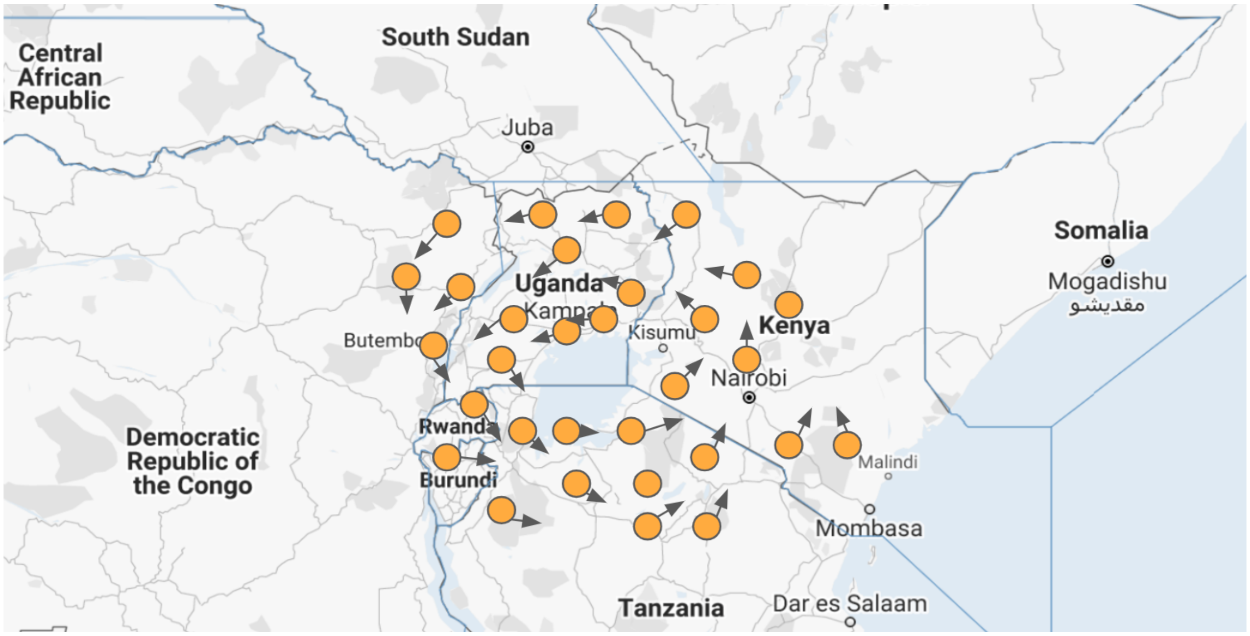

Figure 3 – Notional representation of a regional cluster involving dynamic repositioning and cross-border movement of fleet.

Due to changes in conditions and winds, vehicles may oscillate around a region or airspace boundary with a behavior that is difficult to predict accurately far into the future, making it difficult to communicate airspace transitions too far in advance (or sometimes even further than a few hours), or even to assure that the location of operations will remain above a specific area (e.g., a small country). Collaborative Traffic Management in the Stratosphere (CTMS) will be designed with this constraint in mind.

At the end of a vehicle's life, or when a vehicle needs maintenance, it will be navigated to a recovery location (which may or may not be the same as a launch location). Similar to launch facilities, recovery facilities are, for most operations, comparatively fewer in number than service regions. They are strategically located across the globe to optimize for favorable recovery conditions, and to be most efficient in serving the operational needs. Return and rescue agreements that are analogous to space objects recovery will be established by some operations for emergencies or unplanned landings.

The life cycle of vehicles and the management/dispatching of the fleet are performed by a blend of automated tasks (ground-based) and human tasks, depending on the level of automation in use by an operator. The automated tasks can be running in cloud-based or on-premises hosting facilities, from virtualized, geographically distributed or centralized locations, depending on the reliability needs of the functions they provide. All automated functionality – vehicles, fleet management ground automation, fleet monitoring automation (ground and airborne), etc. – are supervised by human teams who are responsible for monitoring and maintaining the safe and nominal operation of all systems. The human teams and experts responsible for the safe operations of all systems and vehicles are called a **Fleet & Systems Supervisory Network**. The fleet supervisory network team members may be co-located in a single operation center, or may be distributed across multiple locations, depending on the reliability requirements of the autonomous functions they supervise.

We anticipate that most HAPS fleet systems (operations, ground automation and supervisory network functions) will be truly international and cross-border by their very nature.

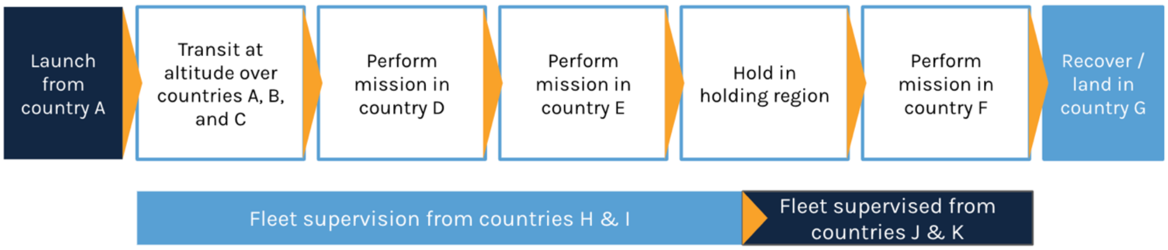

Figure 4 – Example of possible timeline for a single flight journey across multiple countries, performing multiple missions.

Transition into the Collaborative Environment

Fixed-wing HAPS platforms will be remotely piloted through most of class A airspace until they reach the flexible floor altitude (ETM CONOPS) or Deconfliction Flight Level (CTMS CONOPS) – e.g., FL500. Unmanned Free Balloons and other lighter-than-air vehicles will freely ascend under supervision of the operator. During this ascent phase (and transition through commercial air traffic), ATC will provide separation services. Segregation from the rest of traffic (e.g., with TFR or special-use airspace) is likely a viable alternative due to the relatively short ascent duration compared to the time spent at altitude (depending on the ascent location, impact on traffic and frequency).

Once above the flexible floor, there is no more remote pilot assigned to vehicles. The fleet is managed holistically by on-board automation and ground-based fleet management automation. Human interventions will be performed on an exception-centric basis (similar to a satellite fleet). The entire system will be supervised by humans according to the Attended Autonomous Fleet System Management concept described below.

At altitude, traffic management will be collaborative and performed via a set of Community Based Rules (CBR). Operators will exchange intents, constraints and performance to identify conflicts, and exchange preferences and options to negotiate their resolution. Most of these exchanges will be automated and will happen between the operators' respective Fleet Management Systems using accepted standards.

Pilots in Command may be dynamically assigned to handle emergency or planned descents at the end of the vehicle's service life.

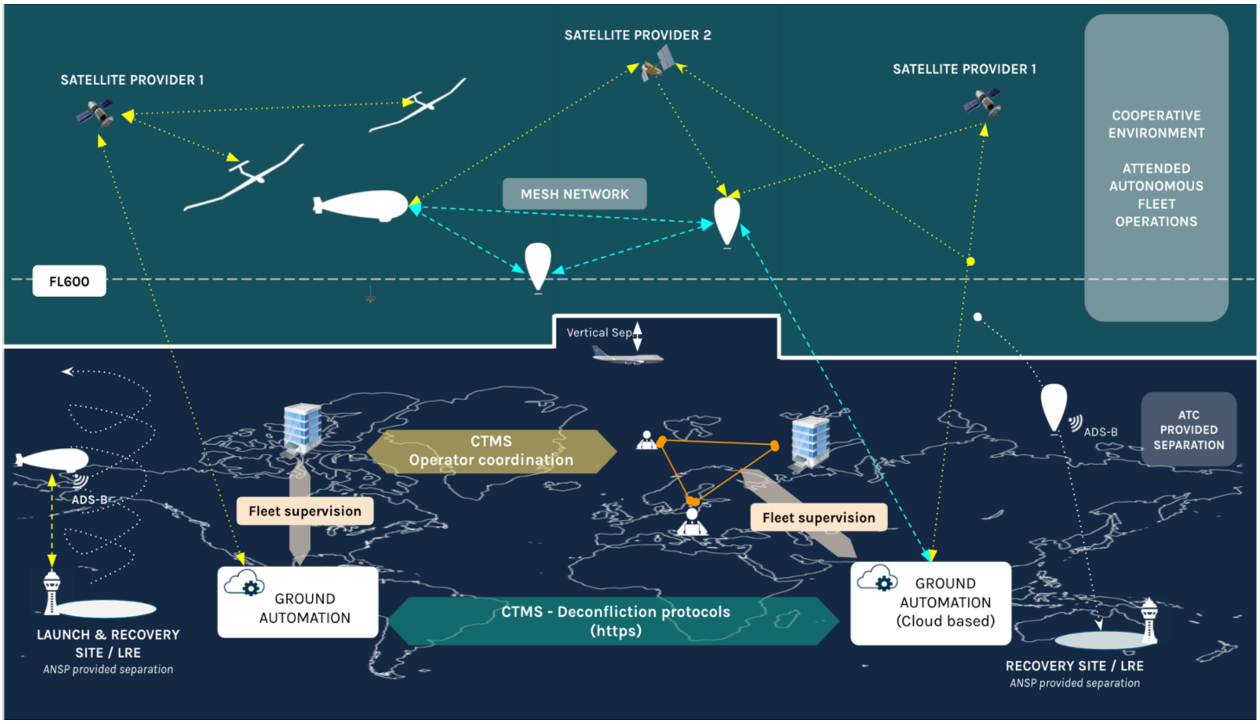

Figure 5 – Above the flexible floor, HAPS will operate according to Attended Autonomous Fleet System Management.

Attended Autonomous Fleet System Management

Overview

The safety of HAPS operations is not strictly tied to individual vehicles. Rather, in order to function nominally, HAPS depend on functionality implemented as a set of interacting systems (vehicles, ground automation, command and control, airspace management, etc.). Anomalies and problems that arise are addressed by built-in automated processes, overseen by Fleet Reliability Engineers, Sub-system Specialists or a combination of them all. This autonomous implementation structure requires that the overall system be *both* vehicle and *fleet* sensitive.

This autonomous system structure represents a necessary and important departure from the traditional, siloed, vehicle-centric approach, which relies on a Remote Pilot in Command to maintain safe operations. Autonomous systems require movement towards a system-wide fleet management approach, one that accounts for the possibility of anomalies arising at fleet system level, and that considers systems and vehicle interdependencies.

Once at altitude, over the span of their entire lives, HAPS will be managed as **Attended Autonomous Fleet Systems**. This is an **exception-centric and system-centric** (rather than vehicle-centric) framework designed to sustain all critical operational systems and ensure the safety of operations. It relies on **exception monitoring and handling services** that monitor the various fleet systems (airborne and on the ground), identify exceptions needing human attention, prioritize exceptions and route them to an appropriate human agent (member of the **supervisory network**), who will be tasked with the resolution of the exception.

The **supervisory network** is composed of system experts (who may be specialized at subsystem levels) and a structured decision chain of command headed by the **Operations Director** (accountable person). At any given time, there is a single decision maker (the Operations Director or a designate) responsible for the safety of the fleet and its operations.

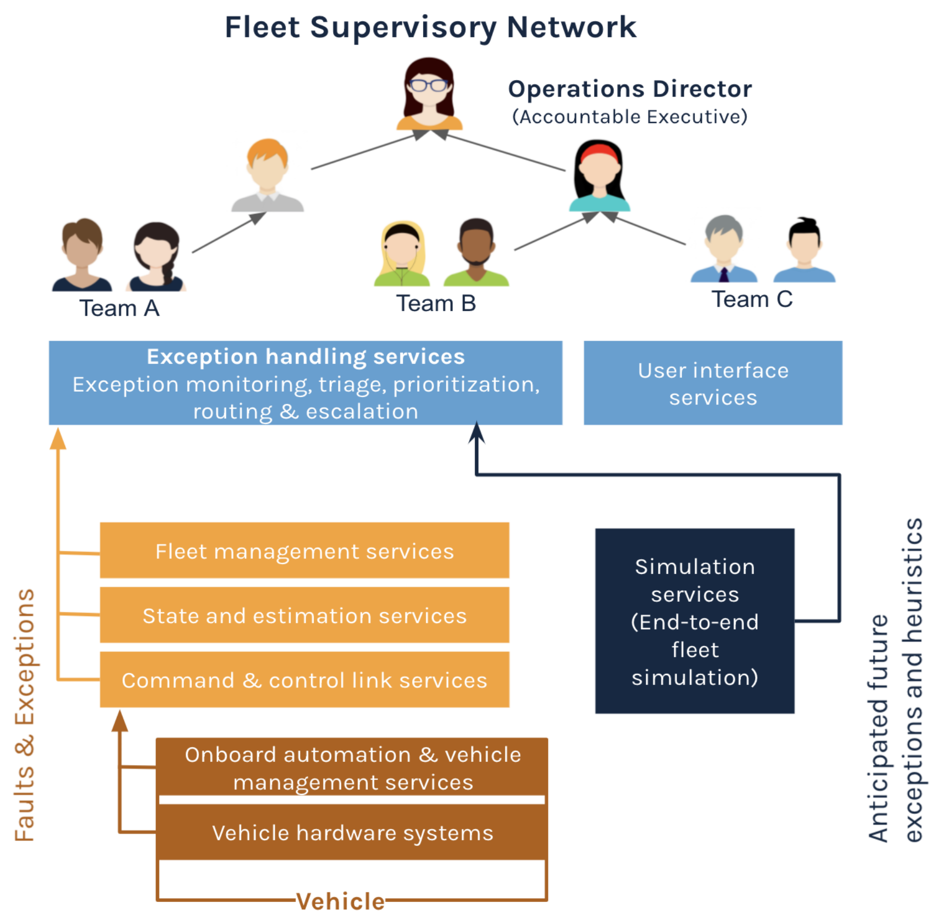

Figure 6 – Attended Autonomous Fleet System Management depicting an exception-centric framework, involving automatically flagged exceptions routed to multiple human teams (on-duty and on-call) depending on the expertise required. A clear chain of command is in place supported by subject matter experts.

System elements description

HAPS are composed of multiple hardware elements (vehicles, communication, servers/data centers, etc.), and multiple interconnected/interdependent **software services** running on the vehicle or in ground automation computing centers. Each service performs a specific function. Not all HAPS operators have identical services: in some systems a particular function may be automated with a software service, while in others it may be performed manually, or not performed at all.

The various systems can be divided into high-level categories:

- **Vehicle systems**
  - The platform hardware systems themselves (propulsion, power, airframe, etc.)
  - **The onboard automation and vehicle management services** are the software services onboard the vehicle in charge of operating the vehicle according to specific configurations or instructions. These include tasks such as low-level navigation tasks (e.g., follow a series of waypoints, pattern, etc.), vehicle health maintenance (thrust control, essential battery management, heater management), command execution and sending telemetry, event logging, fault monitoring, execution of lost communication procedures, etc.
- **Ground systems** – automation systems that run on the ground. They typically include services that operate across multiple vehicles.
  - **Command & Control services** are the collection of services in charge of sending commands and receiving data from vehicles. This includes services such as:
    - data transport services – third-party satellite link and/or proprietary data links
    - authentication services – authenticating commands with digital signatures
    - command sending and routing services – prioritizing, routing and ensuring delivery of commands over multiple redundant communication channels – e.g., multiple satellite links + mesh network
    - telemetry aggregation services (aggregating telemetry received from multiple channels, ensuring data validity and consistency, etc.)
  - **State and Estimation services** are the collection of services in charge of augmenting the telemetry data received from vehicles to build a complete vehicle state picture – e.g., deduce the most likely position from values reported by

multiple sensors, deduce sun elevation based on vehicle location and time, estimate altimetry system error based on GPS altitude, measure barometer and meteorological data, etc.

- **Fleet management services** are the collection of interconnected and interdependent services in charge of managing the fleet while airborne, to achieve a particular objective within specific constraints. These services will assign tasks and configurations to vehicles that will result in configuration commands or instructions being sent to the vehicles. These services include but are not limited to:

  - Dispatching services – assigning vehicles to specific missions or tasks

  - Navigation services – planning the route to achieve a specific task given a set of constraints provided by other services

  - Airspace management services – aware of airspace restrictions, other airspace users, and coordinating with other operators

  - Weather data and avoidance services – informing navigation and health management services on weather restrictions

  - Safety monitoring and management services – managing operational risk, aggregating risk, dynamically configuring lost communications procedure based on airspace, etc.

  - Health and power management services, performing power optimization and vehicle configuration to ensure optimal and healthy operation (e.g., power assignment to various subsystems based on priorities, various system configuration and setpoint setting). It is worth noting that for reliable and safe operation, the vehicles also perform low-level health management functions that are configured by the ground automation, such that they can continue to safely operate in case of a communication loss.

- **Simulation services** are a critical element to operational safety. They perform a continuous fleet predictive assessment through an end-to-end simulation of the fleet systems. They account for all systems interdependencies, and are capable of simulating multiple scenarios based on a distribution of possible inputs. They enable the validation of human interventions for unforeseen consequences. For example, following a manual request for altitude change (which requires power), the simulation services may anticipate that a specific vehicle is likely to run out of power and perform an emergency landing in 48 hours, taking into account latitude, time of day and year, battery state, solar charging models, forecasted cold night temperatures (which will require more heating power) and energy required for anticipated maneuvers. The simulation services will generate an exception that will be routed by the exception handling services to the supervisory network.

- **Exception handling services** monitor the state of systems and the fleet, and they receive exceptions and faults from the various systems and services. Upon receiving an exception, the automated exception handling services will prioritize it, will route it to the appropriate member of the supervisory network to investigate (depending on specialty and availability), and will ensure that exceptions that are not handled in a timely manner (based on priority) are escalated through a series of increasing alerts.

- **User interface services**

    - Provide a display of exceptions, display map and chart the data from various systems and services to allow members of the supervisory network to diagnose exceptions and investigate the best course of resolution

    - Provide an interface to generate simulations of multiple courses of action to assess consequences and interdependencies

    - Provide an interface to interact, configure and override systems and automated services at different levels

Supervisory network roles and modes of operation

The supervisory network is the collection of individuals who are responsible for handling exceptions surfaced by the system. It is important to note that the supervisory network is not expected to monitor the system or identify exceptions the way a pilot monitors the horizon: there is too much information flowing through the system to expect humans to notice exceptions. Rather, it is the role of well-crafted exception-flagging rules within each service to identify any out-of-the-ordinary behavior.

The role of the supervisory network is to investigate each exception, assess the root cause and likely consequences, deep-dive into telemetry data as necessary and determine the best course of action to resolve the exception, applying mitigation or corrective fix. Such resolution may include actions such as: updating a system configuration, adding system constraints, restoring a failed system or service (e.g., software hotfix), overriding the function of a specific service, removing one or more vehicles from the fleet, sending commands (and configurations) to a specific vehicle, etc.

Exceptions that are frequent, with a well-established course of resolution, will tend to be automated over time. As a result, most of the exceptions that the supervisory network handles will be more complex in nature, without predetermined resolution. They will likely require time to investigate (no split-second decision), high skills level and deep system knowledge (possibly requiring a team of experts). Machines are best to execute fast response pre-set procedures, while the supervisory network is best used for critical thinking, problem solving and nuanced decision making.

In some cases, exceptions may critically affect the entire fleet or a large portion of the fleet and difficult decisions with impact much beyond a single vehicle may need to be made. This is where a **well-established chain of command, rolling up to the Operations Director** is necessary. The most difficult decisions will be informed by systems experts but ultimately endorsed and assumed by the Operations Director. Exceptions are typically assigned to one individual who is in charge of the resolution; however, the largest incidents will have a team assigned to the response, typically with a person in charge of coordinating the response and decision making.

Members of the supervisory network may have different expected response times depending on their role and expertise. Some may be on duty (i.e., actively working) while others may be on call (i.e., off duty) with response time requirements that may range from less than a minute to half an hour.

Virtualized and distributed operations

The service-oriented architecture of the Attended Autonomous Fleet Systems framework enables the various systems to run either on premises or in a virtualized cloud-based environment. Web-based user interface services can enable the supervisory network members to perform their function from virtually anywhere.

This can enable a fully distributed and virtualized supervision concept, where the supervisory functions can be performed from multiple locations in the world (simultaneously or successively in a relay around the clock fashion), from any location that meets the adequate working environment and connection security/reliability requirements.

Virtualized and distributed operations offer several important advantages:

- Better management of human factors (e.g., circadian rhythms) to cover 24/7 operations
- Improved system resilience through geographical distribution and redundancy – (i.e., automated services running in multiple datacenters, operation supervision performed from multiple locations)
- Ability to rely on specific subject matter expertise that cannot be replicated across all operating regions

Cloud platforms also offer a robust and reliable development environment with many tools to support the development of a reliable and secure suite of automated services; for example:

automated load balancing and resource allocation, automated code testing and validation, progressive code rollout, code rollback, powerful access control, etc.

Similarities with other applications/industries

The approach described above has many similarities with power grid management, nuclear power plant supervision, airline air operation centers, cloud computing datacenter and infrastructure management, satellite operations, and more.

Human-machine teaming

In the context of Attended Autonomous Fleet System Management, the role of humans, automation and their cooperation (i.e., teaming) takes the following considerations:

Humans will be focused on the things they are interested in and ideally suited for:

- Dealing with novelty and ambiguity
- Interfacing and coordinating with other humans (e.g., dialog)
- Handling hardware and software failures
- Detecting peculiarities

Toil is defined in the Site Reliability Engineering (SRE) framework[1] as: *"the kind of work tied to running a production service that tends to be manual, repetitive, automatable, tactical, devoid of enduring value, and that scales linearly as a service grows."*[2] This definition can be adapted to our purpose as follows:

> *"Toil – the kind of work tied to supervising autonomous fleet systems that tends to be manual, repetitive, automatable, tactical, devoid of enduring value, and that scales linearly as a fleet size grows."*

A goal of the teams supervising the fleet in this framework is to allocate a sufficient portion of their workday to off-duty project work aimed at minimizing toil (essentially automating themselves out of a job). The teams that supervise the fleet have first-hand and best knowledge of common operational issues and repetitive tasks that occupy bandwidth, and are well placed to address them. This dual on-duty vs. off-duty project work has many benefits:

[1] https://sre.google/books/
[2] https://sre.google/sre-book/eliminating-toil/

1. It enables sublinear scalability (human roles and responsibilities should not exceed their physical and mental limitation – e.g., reaction times, cognitive loads, etc.).

2. It increases the job interest and team morale, and enables the hiring and retention of skilled individuals capable of handling complex systems.

3. It promotes a thorough understanding of the system's inner workings, keeping teams busy on improving it (watching automated systems can otherwise be boring), enabling better problem solving on-duty and making it easier to remain current with rapidly evolving systems.

Direction and scope of human job roles:

- Human roles are elevated to more strategic ones that require skills, problem solving and deep system knowledge – system management tasks, troubleshooting (in a longer timeframe), objective configuration, constraint management, etc. In short, people deal primarily with (i.) the larger issues that cannot simply be solved by automation (yet) and (ii.) a more holistic kind of supervision (*not monitoring*) of the entire system, one which engages (or "alerts") the human primarily through an exception-centric framework.

System design direction:

- The roles and system are designed in accordance with human centered principles and the proper functional allocations are conducted as the system evolves.
    - Due to the highly specialized nature of Attended Autonomous Fleet Systems, the appropriate allocation of functions between humans and automation, and the combination of both, must be determined on a system-by-system basis and may also vary throughout a mission.
- Evolution toward distributed systems and automation is necessary to deliver the necessary reliability. The Site Reliability Engineering framework (SRE) is used across the technology industry to operate very-large-scale automation and software (such as cloud platform services) with very high reliability and security objectives. Many of the principles and concepts within the SRE framework are relevant to operating large fleet systems with safety-critical dimensions.

Evolution of systems and roles:

- Evolution of roles: the goal is not to automate human tasks while requiring low-skilled humans to monitor the machine. Rather, it's the creation of new human responsibilities and functions. Humans no longer manage or monitor a vehicle; they manage a system and act primarily on the automation. See more in *Kagan, A 2021, "Whose Flight is it Anyway," The Journal of Air Traffic Control, Summer 2021, vol. 62, No 2, pp 20-27.*

Automated alerting and monitoring are likely to be instrumented to identify symptoms (e.g., response time too slow) rather than potential root cause of a given symptom. This is because we try to cast the widest net possible, since we can't expect the automation rules themselves to be perfect. Humans will be the ones identifying root causes.

Staffing:

- Staffing is exception based, rather than fleet size based. Since we are operating outside the traditional pilot-vehicle paradigm, there is no universal "operator-to-vehicle ratio"; this must be determined on a system-by-system basis. Staffing is based not on fleet size but rather on rate of exceptions, associated workload and the depth of expertise required (division of skills).

Minimize amount and duration of "scaffolding roles":

As a system grows, humans may often have to conduct "boring" work – e.g., repetitive tasks and primitive monitoring responsibilities – until the automation or technology is mature enough to relieve them of these duties. We call these stopgap solutions "scaffolding roles," since they provide *temporary* support in service of more permanent (and reliable) structures.

Apart from the obvious retention issues associated with boring work, there are perennial human risks associated with creating scaffolding roles for humans:

- Maintaining appropriate attention is difficult.
- Situational awareness of large systems becomes unmanageable.
- It is difficult to maintain people effectively trained to solve complex problems that automation cannot solve when 99% of the time humans have nothing to do.
- It is difficult to attract and retain adequately skilled individuals.
- Machines may be able to monitor and react faster than humans (in certain scenarios). Due to convention, however, humans may be pressured to fulfil these roles as well.

These retention issues can be mitigated when the human teams performing the stopgap repetitive and manual tasks are also allocating time to work on projects aimed at eliminating those, making the system more secure and more scalable.

Off-Nominal Situations

An off-nominal situation occurs when one or multiple systems (vehicle(s), ground automation, fleet management, etc.) exhibits an unusual or unexpected system behavior. Depending on the nature of the system component that needs attention, the affected vehicle(s) may be able to remain airborne or be moved to a safe holding area while the off-nominal condition is being investigated and appropriate systems checked. Operating safety or efficiency of the vehicle may not always be impaired and there may not be a need for an immediate forced landing.

In the most sophisticated and large-scale operations, the monitoring of all systems' health is done by automation (on board and on the ground), as there is too much data for humans to process effectively. The system monitoring logic triggers exceptions for any event that requires attention, and associates a priority and severity classification. When an exception is generated, based on the affected system and the exception type, it is routed and assigned to an appropriate and available member of the **supervisory network**, who will investigate, take the necessary risk mitigation measures or corrective actions, consult further experts as needed and escalate critical resolution decisions up the fleet command chain as necessary (possibly all the way to the accountable executive fleet operations director if warranted).

An important notion is that humans are assigned to exceptions, not vehicles. Humans are therefore not pre-assigned to monitor specific vehicles (or systems): they are assigned at the time of the exception, based on their qualification, their availability and the exception.

Should one or more vehicles need to land or if there is an unintentional descent into controlled airspace, a prioritization of actions will occur, and a premade checklist covering essential actions can ensure that no details are omitted and ensure an appropriate response. If an emergency is declared, a human will be assigned to the vehicle to manage the exception. Geographic location, the corresponding Flight Information Region (FIR) and the air traffic Civil Aviation Authority (CAA) are immediately identified, and communication is established with the appropriate Air Traffic Control Center (ATCC). The ATCC will expect immediate verbal coordination and will be the responsible ATCC to serve as the focal point for collecting all information relevant to the status of the emergency vehicle and to support and prepare for the vehicle entering controlled airspace. The ATCC will also conduct coordination with other facilities concerned.

The human assigned to handling the exception will collect a set of data that can be communicated to air traffic, such as which company is originating the emergency message, the nature of the emergency, number of affected vehicle(s), vehicle information (data that would normally be recorded on a flight plan such as type of vehicle, equipment, etc.), the current location or last known position, altitude (or altitude status if descending), probable direction of the vehicle and anything else pertinent to the emergency. The ATCC in return will acknowledge the emergency, request intentions for the vehicle and, as applicable, provide a clearance or block airspace allowing room to maneuver, provide other aircraft in the vicinity information on the emergency and safeguard all concerned air traffic.

Challenges Ahead

Safety Assurance and Community Based Rules (CBR)

While significant progress has been made over the last few years, the HAPS community needs to widen its circle and begin to socialize key concepts in order to continue the momentum and to build advocacy in aviation circles that may perceive HAPS operations as some type of threat.

Different communities will have different concerns, but all will be looking forward to understanding the HAPS community safety approach. Initial feedback has been sought, and this should continue through 2022 to both socialize the concept and take feedback/addressing any specific concerns.

The FAA is expecting the development of the first set of Community Based Rules to be used at CTMS altitude. If this isn't shared during 2022, the community should expect the FAA to pull back resources, which will shift the leadership to a yet unknown European approach, which may well be more limiting, considering geopolitical airspace considerations. Once it is received, the FAA regulatory community will need to establish a cross-agency group to assess and consider the safety approach, fairness, equity and potential legal considerations. No one line of business within the FAA currently exists to review this, and a submission will force the appropriate internal cross consideration. An FAA review and early validation will be a welcome input to the European ECHO project encouraging global harmony.

Allowing industry-based CTMS as airspace density increases

The HAPS community will need to consider the safest and most cost-effective approach to establishing a singular Platform Service Supplier (PSS), or whether a federated approach will best serve the community. There are pros and cons to both approaches and a careful analysis needs to be conducted for a long-term approach. For example:

- If singular, there should be a preliminary identification of mechanism.
- If multiple, there should be some preliminary development and identification of necessary standards.
- An ASTM UTM subgroup has been established to support the development of standards.

International Guidance and Harmonization

The HAPS Alliance needs to begin drafting an ICAO HAPS Circular to facilitate global operations. This document is the simplest (and earliest) type of operational guidance. It references best practices from countries having accepted HAPS operations, which provides some level of instruction for those open to but uninformed about the specific techniques and procedures needed to manage such an operation. It also provides a de-facto ICAO endorsement of expanding HAPS operations in low-density airspace while the familiarity and density increase. This should be done in cooperation with International Coordinating Council of Aerospace Industries Associations and Civil Air Navigation Services Organization to the greatest extent possible, and a draft completed by the end of 2022. The alternative might well have countries referring to the RPAS Manual for guidance, which will impose significant unnecessary and undesirable requirements on the HAPS community.

Other international considerations are:

- Harmonization of Collaborative Traffic Management Concepts and associated flight rules, with particular focus on the mechanisms of a cross-border federated environment, and cross-border discovery and synchronization protocols (DSS)
- International recognition of certification/approvals – e.g., HAPS certified in Country A, flown over Country B, by pilots in Country C
- Liability issues – e.g., person in Country A makes mistakes causing issue in country B.

ICAO involvement is critical for global operations but will take time and effort; regional agreements (and lobbying to get them) will be necessary in the interim.

Human Machine Teaming

- Long-term operations require breaking away from Pilot in Command or Remote Pilot in Command concepts and development of the fleet-wide, system supervision-based approach. This will require some further research, as well as a period of demonstration to validate the approach.
- Further consideration needs to be given to m:N (where N is a vehicle), which still has a pilot approach in mind. A shift to an exception-centric approach (m:E) where E is the workload from exceptions needs to be explored.
- Return of HAPS platforms and payloads similarly to rescue agreement.

Conclusion

Broad HAPS deployment is on the way. We hope this white paper serves as a guide to support safety and regulatory discussions and helps to set out near- and longer-term steps toward achieving safe and effective autonomous aircraft operations. Since the HAPS market is expected to reach $4 billion in value by 2029, according to Northern Sky Research, we hope telecommunications, technology, aviation and aerospace companies, as well as public and educational institutions, will benefit from the paper's information and insights to tap into market opportunity and connect the unconnected.

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 Station (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/.