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AAM:
A PHILOSOPHICAL GUIDE FOR EARLY OPERATIONS

"Revolutions in aerospace must intersect with the evolution of air operations."

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ADVANCED AIR MOBILITY

Photo Credit: Volocopter

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- AAM commercial operations will be required to be conducted by licensed air carriers and, particularly in the early stage, those experienced in vertical lift safety management will be most efficient at doing so.
- Early-stage AAM operations are best conducted by companies experienced in purchasing and configuring aircraft for their intended uses, and AAM manufacturers would be advised to work with experienced commercial operators during product development processes to ensure a successful early adoption of AAM by the publicand in the marketplace.
- Early AAM operations should be conducted by air carriers with existing infrastructure that have the capability and desire to collaborate and share certain data to enable AAM to scale globally.
- Air carriers involved in AAM flight operations should have appropriate equipment, programs, and personnel in place to manage health and flight data in a manner consistent with aviation industry best practices.

INTRODUCTIONS AND OBSERVATIONS

This philosophical guide is not intended to be a “how to,” nor meant as an exercise to debate the broad technical, regulatory, and funding challenges that must be addressed for the future of advanced air mobility (AAM) flight. I have not focused on the complexities of developing the scaled ecosystem necessary for a transformational change of transportation. Rather, I intend for this paper to serve as a general review of AAM, my current observations and interim conclusions on the nascent industry, and a proposal for how a successful, and more importantly safe, introduction to these new-technology aircraft, enabling scale from an air carrier’s point of view, might come about. This paper is not written for industry experts and others already operating in the AAM ecosystem, though I do hope it sparks ideas and debate for those in the industry. The ideas set out in the following pages are for the growing number of organizations and individuals who are interested in, or will be part of, this ecosystem, and have minimal or no experience working in AAM or the commercial air transportation industry.

My introduction to AAM was about fifteen years ago when I ran into a friend during a trade show who was working on an electric vertical takeoff and landing (eVTOL) aircraft. We didn’t use terms like AAM or eVTOL then, but the design and possibilities excited me. The friend is Dr. James Wang. He had just designed and successfully tested the Project Zero demonstrator, which is the world’s first all-electric tiltrotor VTOL aircraft, while working as the Vice President of Research and Technologies for Leonardo. James’ excitement was contagious. I was hooked, and little did I know in the decade to come I would have the opportunity to see this technology advance to the point where it is commercially viable. As Bristow Group Inc. started its journey to investigate AAM almost four years ago, James was the first person I contacted. I asked him about the technology, where we should focus and its potential uses. James had some very wise words, “If it can be dreamt, it can be built.”

Over the last few years, I have had the opportunity to attend, participate in, and speak at various conferences and industry events focused on AAM and future mobility. I have met with manufacturers, investors, infrastructure companies, various regulators, government officials (at all levels) and politicians from the United States, Europe, the United Kingdom, and the Middle East to discuss their thoughts on AAM. It has been an enlightening learning opportunity. Their collective excitement about AAM is truly energizing. However, what is clear to me, across the board, is that expectations are perhaps unrealistic for what AAM can deliver at launch. During these discussions, I observed certain assumptions and perceptions that I believe we need to address as AAM prepares for its introduction in the marketplace.

FIRST OBSERVATION

While AAM aircraft offer redundant electric propulsion systems (i.e., no single main rotor) and simplified human interaction from the advancement of digital flight control systems, there is a prevalent assumption that these aircraft are so advanced as air vehicles that the hard lessons learned from the evolution of safe commercial operations may not have to be considered. I believe that inattention to how current air operations have become the safest mode of transportation around the world would endanger the implementation of a viable, safe urban mobility business model.

It is important for us to look back at the dawn of the aerospace industry, apply lessons learned, and be pragmatic and realistic in our general approach to initial concepts of AAM operations. This reflection on the past does not mean we must have a similar timeline for the development of a safe AAM operational model. In fact, I believe the technological advancements we enjoy today will enable faster-to-market AAM services and justify the technical and financial investments made thus far. However, for an AAM industry that can scale to its promise, we still must test, certify, regulate, gain public acceptance, and continuously improve air and ground safety, which requires robust processes and, necessarily, time.

Photo Credit: BETA Technologies

SECOND OBSERVATION

Industry, supported by a willing general media, has helped create a widely held expectation by the public of a futuristic mass transportation system solution in the near term.

The developers and manufacturers that I have spoken with understand there is more to safety than type-certification.

For example,I know that beautiful renderings of vertiports and "air taxi" services build excitement for the industry, and hopefully someday we will have an AAM system that resembles these designs. However, particularly as the industry evolves to a market-facing position, we must reinforce a reality to the businesses and consumers who will be the early customers and influencers of this new technology that existing aviation infrastructure will be utilized during the initial phase of AAM operations. Further, early AAM services are not likely to be futuristic, on demand, point-to-point transportation.

It is important to note that early adopters are generally forgiving about early teething problems, have the resilience to work with the manufacturer and understand not all expectations will be met immediately. To be successful commercially, we need the early adaptors to adjust some of the perceptions in an effective and meaningful way.

Photo Credit: Lilium

THIRD OBSERVATION

There appears to be a general perception among those in government and the general business community closely following the industry that, upon initial type-certification of AAM aircraft, we will then have a viable business model. Again, this is a general perception, the developers and manufacturers that I have spoken with understand there is more to safety than type-certification. I will discuss an approach for introducing AAM aircraft to commercial operations safely and pragmatically. I believe that the promise of AAM can only be realized through an economically viable, scalable industry, which new, proven technology does not, in and of itself, guarantee.

We are blessed to live in an age with brilliant engineers with years of education and experience in the aerospace and other applicable industries who have started companies to design and bring to market revolutionary new aircraft types. Technological advancements in aerospace, a desire to make aviation much more sustainable from a climate standpoint, and the financial and private market's willingness to fund advanced air transportation have intersected to power the development of AAM aircraft. I doubt we have even begun to grasp the impact of this novel air system's many applications for the world's future.

From my research and work in this industry, I see advantages well beyond the critical need to support sustainability by transitioning from carbon powered aircraft to electric propulsion. These include greater connectivity/access and different transportation choices the public will enjoy, whether they want to move within their municipality or beyond. And AAM's lower cost structure estimates compared to traditional aircraft will support transportation networks in general. These benefits will not be limited to urban mobility networks. AAM, with a broader product scale and an advantaged cost structure, should also improve the distribution and availability of products and transportation services in less populated and remote locations throughout the globe.

In the following pages, I will review what AAM is, why experience matters when introducing a new, advanced aviation system and argue that we should start by harnessing the rigor of the regulatory process, the intellectual property of experienced air operators and smart business modeling to the exciting technology of the aircraft in development to evolve this revolutionary point in aerospace into a promised fulfilled by AAM.

AAM

WHAT ARE AAM AIRCRAFT?

WHEN YOU QUERY CHATGPT, “WHAT IS AAM?”, YOU WILL RECEIVE THIS RESULT:

“AAM (AAM) refers to the rapidly developing ecosystem of aerial transportation that includes electric vertical takeoff and landing (eVTOL) aircraft, urban air mobility (UAM) services, and other emerging aviation technologies. AAM aims to revolutionize transportation by enabling on-demand, point-to-point aerial mobility in urban, suburban, and rural areas. It encompasses a wide range of activities, including the development of electric aircraft, infrastructure for vertiports, air traffic management systems, and regulations to support safe and sustainable aerial transportation. AAM has the potential to transform industries such as logistics, emergency services, tourism, and commuter travel by providing efficient, environmentally friendly, and innovative aerial transportation solutions.”

Advanced air mobility (AAM) aircraft as I define them for this philosophical guide, are aircraft utilizing electric or hybrid-electric distributed propulsion systems, advanced digital control systems and with a vehicle configuration that is likely to be different from standard airplanes and helicopters with which we are currently familiar. AAM designs and concepts have a broad range of types and applications, most of which focus on (i) the use of vertical takeoff and landing (VTOL) or (ii) the use of short takeoff and landing (STOL) in small areas effectively the size of a soccer or football field, depending on where you live. VTOL and STOL capability will allow for the elimination of the large runways we use today, and AAM aircraft could operate directly from city centers. Most AAM aircraft designs proposed in recent years are solely electric powered, hence the name electric vertical takeoff and landing (eVTOL, eSTOL) aircraft. Advances in energy sources, microprocessors, material science, aerodynamics, powertrain, communication, navigation, and general avionics systems have enabled engineers and designers to think beyond and outside the constraints of 100% carbon powered aircraft.

Nearly all the AAM aircraft designs currently in concept and testing employ fixed pitch or variable pitch propeller/rotor(s) and their control methodologies are different from a traditional helicopter. These AAM aircraft can be sub-categorized in the following types:

- Lift plus Cruise;
- Tiltrotor;
- Tiltwing;
- Multi-Rotor;
- Blown-lift (including Sea Gliders);
- Tail sitter; and
- Vectored Thrust.

The energy source and propulsion types in concept and testing includes:

- Fully electric with rechargeable battery;
- Hybrid-Electric (carbon powered engine driving a generator (serial hybrid) or an engine in parallel with the electric motor (parallel hybrid);
- Hydrogen combustion;
- Hydrogen fuel cell;
- Direct drive electric motors; and
- Geared variable speed electric motors.

Control technologies and methodologies include:

- Multi-rotor type control (by varying rotor RPMs and/or thrust for different rotors);
- Vector thrust (by tilting the rotor);
- Blown flap (controlling the thrust direction with control surfaces);
- Fly-By-Wire control systems;
- Dual/Single pilot controls;
- Single pilot augmented with digital advanced control systems;
- Remotely piloted; and
- Fully autonomous.

Except for the tiltrotor, blown-lift, and multi-rotor designs, to my knowledge none of the above concepts are in production or operation today; none have carried passengers for commercial uses. The tiltrotor is only in operation for military use (example V-22 Osprey). Blown-lift is a proven design for short field takeoff and landings for past general aviation use and some previous military applications. Of course, there are a multitude of multi-rotor designs employed in small drone (FAA Part 107 type) operations. I do not intend to argue the pros and cons of design type or propulsion and control systems. It is merely to outline the changes in aircraft type and how they may be used properly.

SIMPLE FIRST
AIRCRAFT

To me, the most beautiful and efficient designs are the simplest. Relying on the curves of nature, simplifying the power and control systems, and designing sleek airframes, all make for an elegant and successful aviation product.

I have had the privilege of spending 40 years in the helicopter industry. Helicopters are unique in their ability to take off and land vertically, but they certainly are not simple or efficient, machines compared to fixed-winged aircraft. I worked at Sikorsky Aircraft for the first 20 years of my career. There are many quotes attributed to Mr. Igor Sikorsky, one of which he specifically used to highlight the unique attributes of vertical (direct) lift: “If a man is in need of rescue, an airplane can come in and throw flowers on him, and that’s just about all. But a direct lift aircraft could come in and save his life.” [1]

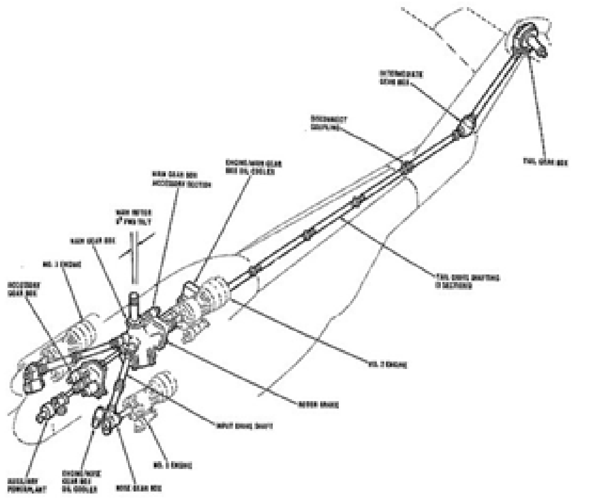
Over the years since 1939 and their first flight, we have found so many interesting and unique applications for the helicopter. It has enabled industries, supported the exploration and production of offshore energy, fought fires, delivered lifesaving supplies during catastrophes, and saved countless lives in air ambulance and search and rescue applications, just to name a few. But one application that never materialized, which I know that Mr. Sikorsky had in mind, was transportation for significant numbers of people as a part of their daily life. There is an old black-and-white video from 1943 available on YouTube (Society, 2013) that shows a household using a helicopter to run errands that ends with Igor Sikorsky commenting on the unlimited uses of helicopters. The video even shows the person forgetting to pick up butter and returning to the store to pick it up. Yes, the content is a bit old fashioned, but the message is clear. Transportation by rotorcraft for the larger population was on Mr. Sikorsky’s mind as well as quite a few other innovators in the helicopter world.

What has held helicopters back from a mass transportation system is the complex nature of their design, notably powertrain and flight control systems. They are complex, thereby costly to build and costly to operate. Many of the components rotate, which means you need gears, and bearings in various transmissions (gearboxes), to transfer power from the engines to the rotor system.

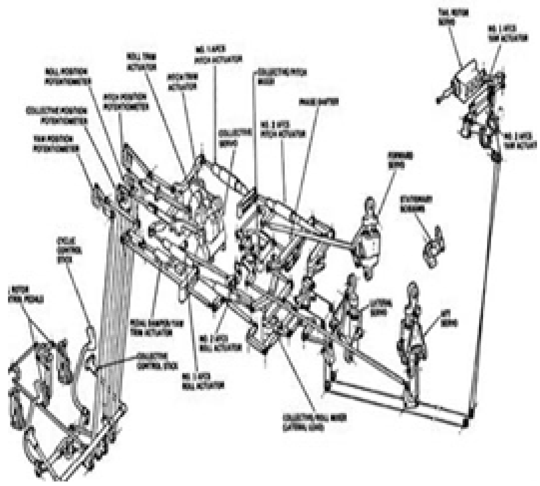
In addition, transport category helicopters are generally powered by turbine engines, in most case dual-engine configurations. These engines are expensive and rotate at very high speeds, therefore, generating significant vibration and heat in the rotation and exhaust gases. Control of the rotor head must be organized through a complex series of rods, bell cranks, mixing units, bearings, and a swashplate for mechanical flight controls. Engines and gearboxes, including air and liquid cooling systems, must, at significant cost, be overhauled or replaced at defined life-cycle points because the dynamics of the power, drive and control systems naturally cause wear and tear, while at the same time, suffering challenging weight constraints. A recent development in helicopter technology has introduced “fly by wire.” While offering benefits enabling stability and safety these too require complex, expensive mechanical actuation devices, which also must be maintained. All this complexity to produce an aircraft that can do the unique things a helicopter can do lead to a hefty penalty to its payload and range.

[1] Sikorsky, Igor (1996). Retrived from https://www.azquotes.com/author/19661-Igor_Sikorsky,%20n.d.

BELOW IS ONE OF THE MOST COMPLEX EXAMPLES OF A HELICOPTER POWER, DRIVE (FIGURE 1) AND CONTROL SYSTEM (FIGURE 2). THERE CERTAINLY ARE SIMPLER SCALED VERSIONS BUT THIS ILLUSTRATES THE UNIQUE REQUIREMENTS FOR VERTICAL LIFT.

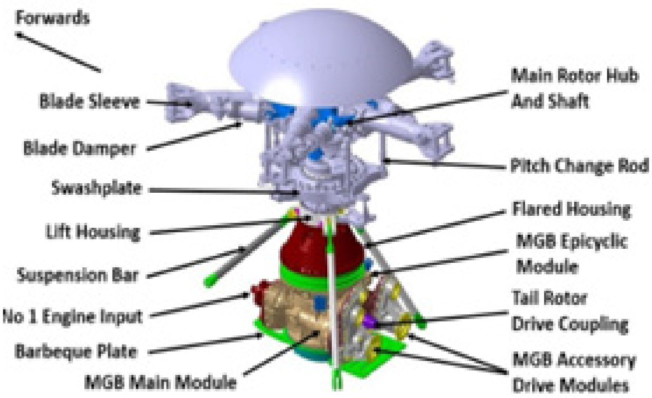


(Young 2020) Figure 1

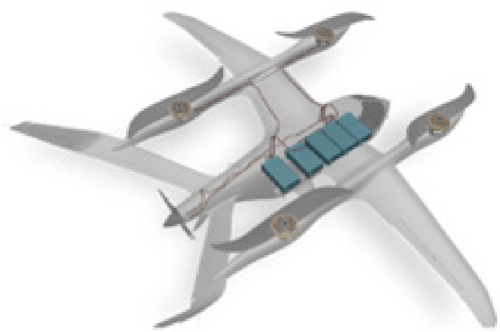


(Magno 2014) Figure 2

Figure 3 is an example of a helicopter rotor head and its control system. As you can see, it is mechanically complex and contains many parts. Only in the last 10 or so years, engineers and entrepreneurs have started to dive into electric propulsion, disruptive aircraft configurations and advanced flight control systems. The result is a reduction in part count, and the distributed electric propulsion capability helps allow refreshing new aircraft configurations. Figure 4 is a simple diagram of a fully electric rechargeable battery powertrain system.



(Aerossurance, 2018) Figure 3



(Courtesy of BETA Technologies) Figure 4

The elimination of complex mechanical systems illustrated earlier in traditional helicopters enables designers and engineers to experiment with new forms of design without the constraints of traditional control and propulsion systems. Furthermore, the elimination of most of the mechanical systems reduces parts count, production, and operating costs. Fewer parts not only contribute to reduced cost; operational reliability may be improved simply because there are fewer components to fail. Utilizing these new technologies, companies have begun test and certification phases of these aircraft with some of the attributes of a helicopter and some from an airplane, but with a simpler systems technology as the backbone for propulsion and control.

However, there is a negative side to these new electric aircraft. Though you remove complex mechanical systems, cost, and weight, you add back weight in the form of energy sources, notably the rechargeable batteries. First, the specific energy (Watt-hour/kg) of even the best technology battery is still 1/20th that of fossil fuel. Second, the weight of a battery does not get lighter as you use its energy, unlike fossil fuel that is consumed by the engines. Therefore, today's pure electric aircraft will not be able to replace the range, payload, or operational capabilities of a helicopter as it is used today for longer range or heavy utility type operations. The helicopter will remain unique in this category until alternative energy sources are available and/or other efficiencies are gained in aerodynamics, electric motors, rotor systems, software, and hardware systems. This means future efficiencies are not limited to improvements in battery specific energy alone.

There are a few eVTOL aircraft designs that are close to certification in Europe and in the U.S. These designs are the multi-rotor design, effectively a helicopter that uses multiple electric motors and small rotors instead of a single large main rotor to provide lift and control. This design is relatively straightforward and, from the regulatory standpoint, has the benefit of multiple redundancies in the rotor system, but is limited in its range and payload capabilities due to large drag in forward flight.

Lift plus cruise type aircraft are likely one of the next versions to be certified. Some of these aircraft are flying today with government agencies in test and evaluation programs. Lift plus cruise aircraft utilize multiple lifting motors and rotors, like a multi-rotor, for hovering. The difference is they have a wing to provide lift during cruise and a separate thrust motor and propeller to provide forward propulsion during cruise. The lifting motors will shut off and stow in a streamlined position once positive lift is generated from the wing. These aircraft tend to have higher range and payload than multi-rotor aircraft because they do not have to rely on using lift rotors during cruise, thus saving battery energy. Lift plus cruise designs benefit from not having any complex tilting mechanisms, but they do require separate large motors dedicated for forward flight use only. The drawback is having to carry two sets of motor systems: one set for hovering only and one set for cruising only.

Photo Credit: Elroy Air

Tiltrotor aircraft are quite popular designs as they use the same motors and rotors for hovering and for cruising. This usually provides a cleaner aerodynamic configuration during cruise and there is no requirement to carry two sets of motors and rotors for hovering and cruising. An additional benefit is the tilting rotor couple provide additional degrees of freedom for flight control. These tiltrotors are likely to be some of the early certified designs for operations simply because some of the first movers in eVTOL aircraft manufacturers have selected the tiltrotor configuration. On the other hand, the transition of flight on a single rotor adds significant stability and control challenges, however, the development of digital control systems means this is much easier to manage than in the past, and as parts count increases, therefore adding cost for the components that move the motors and rotors.

Air carriers will have the ability to utilize each of these designs in their fleet depending on the mission requirements as well as the transportation and logistics networks they build out. Each of these designs has unique attributes of cost and performance (payload and range) capabilities. Each share the simplification and potential cost savings as compared to helicopters. As mentioned previously, fewer dynamic components, removal of turbine engines, no complex hydraulic systems, no mechanical flight control system and reduction of heat and vibration means that AAM designs should be capable of higher reliability compared to current helicopters.

AAM aircraft designs are not limited to aircraft that can take off and land vertically (VTOL). Some AAM manufacturers are designing electric short-field takeoff and landing (eSTOL) aircraft with blown-lift technology. This is also a simpler design, and unlike other designs mentioned earlier, blown-lift technology has been proven in the last few decades. Additionally, these designs will likely be certified as an airplane, potentially streamlining the certification process. AAM blown-lift designs utilize the greater power to weight capabilities of electric motors coupled with efficient rotor (propeller) designs made possible by advanced composite manufacturing processes, to blow large amounts of air over the wing and flaps thereby creating lift normally associated with higher forward speed takeoffs. Compared to AAM aircraft that can take off and land vertically, these aircraft will require very short length areas to take off and land coupled with the ability to execute steep approaches and departures to clear obstructions in higher density regions.They should provide higher payloads and range compared to vertical AAM aircraft and offer a greater number of places to operate compared to traditional fixed-wing aircraft.

Photo Credit: Electra.aero


Photo Credit: Lilium

AAM AIRCRAFT

"Blown-lift eSTOL AAM designs provide higher payloads and extended range compared to vertical takeoff models, and can access a greater number of operating locations than traditional fixed-wing aircraft."

SIMPLE FIRST
OPERATIONS

While AAM technology is not changing the physics or fundamentals of flight, new designs, with new technologies to support these designs, are being introduced. It is important to recognize this shift and understand the dynamics of this change as it relates to commercial operations. As we view AAM, we must look through the lens of transport-category aircraft, and not general aviation, private-use aircraft or (based on some public expectations) "flying cars and taxis." The intended uses of these new aircraft and future business plans rely on a fee-for-service model, with passengers paying for transportation services and logistics operations paying for cargo movement. Other potential paid services include, without limitation, coastal and forest surveillance, and medical transport services. Any company offering these services using AAM aircraft would, therefore, be functioning as an air carrier in the traditional sense and must have the qualifications, licenses, and certifications necessary to do so.

WHAT DOES THE ECOSYSTEM OF AN AAM AIR CARRIER REQUIRE?

What does the ecosystem of an AAM air carrier require? In addition to the type certification, manufacturers must design an aircraft robust enough to support thousands of hours of flight per year and thousands of takeoffs and landings. When operating as an air carrier (no matter how revolutionary and new the technology involved), a thorough life-cycle plan must be in place that includes all aspects of training, technical and flight support, environmental protection, documentation, maintenance repair and overhaul systems, and data collection, aggregation, and distribution.

Photo Credit: Eve Air Mobility

Beyond aircraft and operational fundamentals, investors, manufacturers, and operators must also consider inherent risk factors. The adage "just because you can does not mean you should," certainly comes into play in these early days of AAM, especially when considering that the barriers to entry for new air carriers are low relative to traditional commercial air operations, and the funding sources available for "green" technologies may be more readily available than for traditional air transportation. Additionally, there are market and other pressures at work to be first in type, first in region and to be an early system adopter. We will see these pressures in play in certain cities or countries that are eager to solve mobility concerns, including in densely populated environments, or locations that just want to be "first," even without a robust AAM ecosystem in place. Companies in the AAM space are also likely to face investor pressure for quicker returns on their early-stage investments, which have now taken longer to realize.

Photo Credit: Electra.aero

Photo Credit: Lilium

Photo Credit: BETA Technologies

As we progress toward the introduction of AAM operations focused on business and consumer models, it is vital that we take pragmatic, critically important steps that will result in safe operations. Manufacturers will go through their respective flight tests, type certification and production certification for their aircraft. Regulators charged with type certification in their respective jurisdictions will proceed under their governing regulations to ensure that each manufacturer meets the standards necessary for type certificate and production certification. Once a manufacturer receives the required certifications, they effectively have a license to sell the aircraft to commercial air carriers, government entities, private companies, and individuals. This is the point when the aircraft type enters the operating ecosystem.

For an AAM vehicle to find commercial success, an operator, or air carrier, must put it into service. To that end, it is critical to understand that, first and foremost, an air carrier's duty is to operate its aircraft safely, efficiently, and reliably. How can these critical responsibilities be successfully undertaken utilizing a nascent technology? To do so, an AAM air carrier must understand the entire operating ecosystem, which requires collaboration not just between departments within the air carriers, but also across the industry. These companies must employ appropriate business practices and systems operations, leverage the intellectual property and experience of established, traditional air operators and institute, and continuously improve a culture of safety within their organizations. Each component of the ecosystem is essential and dependent on the others.

Successful air carriers have evolved the traditional aviation ecosystem well beyond the minimum certifications and licenses required by law and regulation. To maximize the chances for success, the AAM industry should look to traditional air carriers and utilize their collective safety management systems (SMS), business and operational processes and procedures so that AAM's revolutionary technologies can be successfully operationalized to enhance future mobility.

Air operations are highly complex in nature. Adding to this complexity, the AAM industry is introducing new types of aircraft with novel propulsion, control systems and airframe architecture. Most companies involved in the development of AAM are producing their first aircraft. Moreover, additional complexity comes with new businesses and operating models, such as "air taxi" service in densely populated areas, known as urban air mobility. Starting a new transportation system with new and novel technology, infrastructure and service is a daunting task.

Before we bring mass transportation using this technology to the public and begin operations in densely populated regions, it is incumbent upon the air carriers to first build a simple operating network that reduces safety risk and operational concerns and provides for business continuity.

Deploying aircraft using vertical takeoff and landings as a primary means of operations and flying in low-altitude airspace in either populated areas or remote regions introduce hazards and risks not necessarily associated with fixed-wing operations from airports. Understanding these fundamentals is necessary to build out an early AAM adoption model that is safe, efficient, and reliable. Therefore, it makes sense that initial AAM operations should begin with companies that have vertical lift operations experience and an evolved safety culture with a clear understanding of the unique risks associated with vertical takeoff and landings. Otherwise, we could easily launch operations with unnecessary complexity that do not fully recognize these hazards and risks. Even experienced air carriers with vertical lift operations should begin at least twelve to eighteen months prior to delivery of their first type-certified AAM aircraft to conduct training, write operating manuals, engage in maintenance, and supply chain planning, and work with the applicable regulator to obtain approval to add new type aircraft to their operations specifications. (Operations specifications form an agreement between the regulator and air carrier on what aircraft the carrier will use and how the carrier will operate it.) Additionally, it is likely that global airlines will not be able to support regional and urban air mobility in more than their home country's jurisdiction due to ownership and regional regulatory restrictions.

My First Thesis: Early-stage AAM operations should focus on a business-to-business model supporting a logistics network in an industrial area within a 20km-60km range.

An example of a realistic early operations environment: A low-populated industrial zone with low-density air traffic, utilizing existing logistics bases, warehouse locations and distribution centers within the range of current regional aerodromes for point-to-point transportation. This model would serve several purposes:

1. Prove the commercial viability of the AAM aircraft:
    a. Higher daily flight hours compared to initial flight test and certification programs;
    b. Multiple takeoff and landings per day with various weights;
    c. Varying weather and environmental conditions;
    d. Maintenance programs in place;
    e. Pilot workload management; and
    f. Ground handling in action.
2. Prove to the regulators the efficacy of the safety cases outlined in an initial concept of operations.
3. Prove the commercial viability of AAM to those investing in infrastructure.
4. Demonstrate to the public that AAM aircraft are safe, efficient, and reliable.
5. Create the conditions to encourage market expansion to passenger and cargo intra-regional (60km - 400km) service.
6. Provide the data and use cases necessary to build out urban air mobility (intra-city) operations.
7. Provide data and use cases for investments required to build out regional air mobility (400km to 1,200km).

Photo Credit: Elroy Air

AVIATION AND INDUSTRIAL SAFETY MANAGEMENT— LEVERAGING EVOLUTIONARY EXPERIENCE TO SUPPORT THE AAM REVOLUTION

Another famous quote from Mr. Sikorsky related to the early days of aviation and the need for development of safety systems and technologies: "At that time [1909] the chief engineer was almost always the chief test pilot as well. That had the fortunate result of eliminating poor engineering early in aviation." [1]

The safety we enjoy today in our aviation system is built on 120 years of aviation experience. Testing, experimentation, analysis, manufacturing processes and procedures, design regulations and certification basis, operational regulations, training, and intellectual property developed by manufacturers and air carriers over the last century have each contributed to building the safest mode of transportation available today for the traveling public.

Safety is not static. In my opinion, an air carrier cannot say, "I have the latest technology with the highest safety standards for design and certification available, and so my employees and customers are safe." In addition, it is not accurate to conclude that a company that has a license to operate as an air carrier and meets the regulatory requirements is, therefore, sustainably operating in the safest manner or with the appropriate equipment. It is important to understand how safety must necessarily evolve. Air carriers especially must continuously improve their safety culture and procedures with the introduction of new technologies, changes in human resources and training processes, and through new operating models that fit within the challenges of financial constraints and dynamic, sometimes adverse business climates. It is vital that a culture of safety be part of the DNA of any air carrier and the aviation ecosystem of investors, executive leadership, employees, and the community.

Typical air carriers manage safety through a process called Safety Management System or SMS. An aviation SMS consists of four pillars: Safety Policy; Safety Risk Management; Safety Assurance; and Safety Promotion. Below is the Federal Aviation Administration's (FAA) outline of a safety management system: [2]

- **Safety Policy** — Establishes senior management's commitment to continually improve safety; defines the methods, processes, and organizational structure needed to meet safety goals
  - Establishes management commitment to safety performance through SMS
  - Establishes clear safety objectives and commitment to manage to those objectives
  - Defines methods, processes, and organizational structure needed to meet safety goals
  - Establishes transparency in management of safety
    - Fully documented policy and processes
    - Employee reporting and resolution system
    - Accountability of management and employees
  - Builds upon the processes and procedures that already exist
  - Facilitates cross-organizational communication and cooperation

[1] https://www.azquotes.com/quote/745518, n.d.)

[2] Safety Management System | Federal Aviation Administration (faa.gov)

- **Safety Risk Management (SRM)** — Determines the need for, and adequacy of, new or revised risk controls based on the assessment of acceptable risk
  - A formal process within the SMS is composed of:
    - Describing the system
    - Identifying the hazards
    - Assessing the risk
    - Analyzing the risk
    - Controlling the risk
  - The SRM process may be embedded in the processes used to provide the product/service
- **Safety Assurance (SA)** — Evaluates the continued effectiveness of implemented risk control strategies; supports the identification of new hazards
  - SMS process management functions that systematically provide confidence that organizational outputs meet or exceed safety requirements
  - AVS (FAA definition of AVS: Aviation Safety) SMS has a dual safety assurance focus:
    - AVS organizations
    - Product/service providers
  - Ensures compliance with SMS requirements and FAA orders, standards, policies, and directives
    - Information acquisition
      - Audits and evaluations
      - Employee reporting
    - Data analysis
    - System assessment
  - Provides insight and analysis regarding methods/opportunities for improving safety and minimizing risk
  - Existing assurance functions will continue to evaluate and improve service

SAFETY PROMOTION

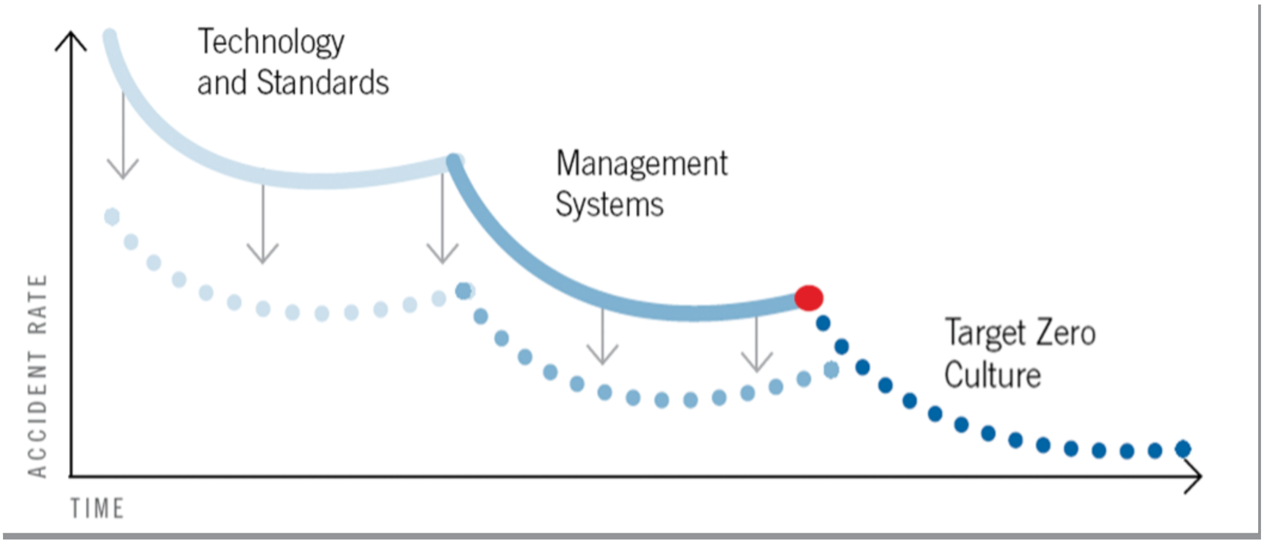
— Includes training, communication, and other actions to create a positive safety culture within all levels of the workforce

- Safety promotion activities within the SMS framework include:
  - Providing SMS training
  - Advocating/strengthening a positive safety culture
  - System and safety communication and awareness
  - Matching competency requirements to system requirements
  - Disseminating safety lessons learned
- Everyone has a role in promoting safety

Photo Credit: BETA Technologies

Regulators around the world will have similar requirements for an SMS. Licensed air carriers in most jurisdictions are required to have SMS manuals written for their operations. I would argue that companies, no matter how dedicated to the concept and core mission of safety, cannot set policies and fully understand and manage the risks and assurance of running air operations without the experience that comes from being an air carrier. Even with the requisite experience to effectively promote safety, it takes an unwavering commitment from company leadership to ensure that the entire organization lives and continually improves its safety culture. It requires constant and consistent attention, emphasizing integrity as critical to this mission, in the various communication methods used to reinforce this priority. A successful safety culture is predicated on an evolved and empathetic company leadership team and organization that has the resilience to withstand the challenges all businesses face.

Below is a simple chart outlining the importance of an evolving safety management system. It is derived from Dr. Patrick Hudson's model "Getting to Zero." [1]



CHANGING THINKING = CHANGING BEHAVIOUR = CHANGING PERFORMANCE

1. **Technology and Standards: Established ... Continuously upgrading**
2. **Safety Management Systems: In place ... Refining KPIs and Processes**
3. **Safety Culture Improvement: Measure Conversations and Actions for Improvement**

My Second Thesis: AAM commercial operations will be required to be conducted by licensed air carriers and, particularly in the early stage, those experienced in vertical lift safety management will be most efficient at doing so. For AAM services to be successfully introduced into the marketplace, and for these services to be able to be scaled, early operations should be conducted by companies that understand the risks and hazards and have the financial strength to manage through technical and regulatory issues inherent in an air carrier ecosystem that involves vertical lift. How will companies that have not operated as an air carrier before or have not operated aircraft of a similar type, with vertical takeoff and landings, off airport operations, in low altitude and low airspeed environments, know the risks they must assess? This analysis cannot be based on theories or models alone.

Additionally, I would argue that air carriers who initially operate AAM networks have a duty to share safety and certain non-commercial operational data with the other companies operating in this new system. How air carriers share such data also requires experience, but this critical collaboration can and will contribute to a higher level of safety across the industry. This is a lesson the helicopter industry has learned over decades of operations around the world, especially by companies supporting the offshore energy industry. HeliOffshore is the global safety-focused association for the offshore helicopter industry. It was founded for the purpose of sharing non-commercial best practices and safety data among a group of vertical lift industry members.

[1] Hudson, Dr. Patrick, (2001) "Getting to Zero"

Photo Credit: Eve Air Mobility

Bristow Group Inc.,

a founder of HeliOffshore, has begun the formal process of establishing an AAM operators' safety consortium for the purpose of sharing safety data and discussing operational issues with other air carriers interested in AAM. To date, there is a core membership, and a small board has been formed, bylaws are in draft format and organizational processes are in the works. The potential scale of AAM justifies the establishment of an industry group to foster collaboration on safety. Consider that there is a potential market for 60,000 passenger-carrying AAM aircraft to be flying by the mid-2030s.

What the AAM industry should conclude is that current, experienced vertical lift air carriers are best placed to operate the newest aircraft during initial AAM operations.

AIRCRAFT TYPE CERTIFICATION IS ONLY THE BEGINNING OF SAFETY

There are three certification processes that must be completed before an aircraft type can be placed into service without specific or extensive restrictions and are available for hire or compensation (i.e., commercial operations). They are:

1. Type Certificate
2. Production Certificate
3. Airworthiness Certificate

Type certificate or “getting your aircraft certified” is discussed most actively today as it relates to AAM. Obtaining a type certificate is a risky, extended, and expensive endeavor. For transport category aircraft the expenditure of over USD$1 billion is not uncommon to complete initial type certification for this category of aircraft. The type certification process includes the approval of the design of the aircraft and all component parts (e.g., propellers, engines, control stations). Approval signifies that an aircraft design is in compliance with applicable airworthiness, noise, fuel venting and exhaust emissions standards. The applicable regulations are complex and robust, and the means of compliance require flight test and demonstration, destructive and nondestructive testing, finite element analysis, failure modes, effects and criticality analyses, and data collection and analysis. The type certification process is designed to ensure that aircraft meet the minimum safety and design standards for their class of aircraft. Safety and design standards that have evolved over the years to effectively enhance safety and operational capabilities.

A production certificate is much as it sounds and allows a company to produce and reproduce a type-certified aircraft. Generally, the company that designs an aircraft and receives the type certificate also produces the aircraft, but not necessarily. Production is also a very complex operation under a production certificate, a manufacturer must demonstrate that it has the ability through its personnel, facilities, and a quality system to produce components and assemble an aircraft in a manner consistent with the type certificate.

The airworthiness certificate is a three-part process:

1. Owner registers the aircraft;
2. An application is made to the local regulatory office; and
3. The local regulator ensures the aircraft by serial number is eligible and in a condition for safe operations.

With the airworthiness certificate, a manufacturer can sell the aircraft, or if also operating, transfer the aircraft to their air operations. But far more common is that the aircraft is sold to a licensed air carrier because a manufacturer typically does not operate the aircraft it produces.

Photo Credit: Vertical Aerospace

In this paper, I have tried to argue that experience matters in fully understanding the risks associated with the intended use of aircraft. While regulators ensure that aircraft designs meet safety standards, they are not responsible for certifying that fundamental safety-related operational processes and procedures can be economically carried out by air carriers, or that certain equipment that experienced air carriers may utilize to enhance safety and operational reliability are included in the design and certification of the aircraft. Operators of aircraft may require certain enhancements to either operational performance or aircraft systems based on their experience on what optimizes operational safety. Although regulators must approve such procedures and enhancements, they are not necessary for purposes of the type certificate or baseline certification required to sell and take delivery of aircraft. (There is a good reason for this: not all operations, missions and environmental conditions are the same.)

In traditional helicopter operations, several added enhancements are in place by industry standard to mitigate risk but are not required for an aircraft type certification. These enhancements are generally installed through a supplemental type certificate process or STC. They may include Enhanced Ground Proximity Warning Systems (EGPWS), Terminal Collison Avoidance Systems (TCAS), various weather radar systems, data collections systems (including health monitoring of components and flight data), wire strike protection, de-icing systems, high-intensity external strobe lights and high-intensity interior exit lights.

First and foremost, in an air carrier's decision-making process when analyzing the potential purchase of an aircraft and choice of configuration are weight, cost and complexity. These commercial decisions directly inform performance, reliability, and decisions on operational and safety enhancements.

If an air carrier already has a "certified" aircraft, what would lead it to modify or add additional systems? This can be a very difficult question to answer but is critically important to the safety of operations. Understanding and analyzing operational data and safety cases for intended operational uses will provide most of the data required. To properly conduct this analysis, air carriers must be able to recognize and identify hazards and risks for each one of its operational uses and build a case of safety mitigation for the associated risks. And they must have the discipline, based on experience, to make the difficult financial decisions necessary to ensure that their certified aircraft are optimally equipped from a safety standpoint for the mission, and in the market, in which they will operate.

The concern, therefore, is that potential new air carriers, though well intended, may not be able to identify the risks they are confronted with or understand the best way to mitigate them. They may unintentionally but incorrectly believe that their aircraft (and their systems), which meet the minimum required standards and certifications, are in fact optimized for safety. The highly competitive/low-margin nature of the commercial air transportation business would not encourage inexperienced air operators to make additional expenditures on enhancements beyond those undertaken for certification. New air operators, with new leadership teams (and their investors), entering new markets with new missions (intra-city and low-altitude regional), and eager to solve future mobility issues with groundbreaking modes of transportation, may not be best placed to execute this exciting vision.

Photo Credit: Lilium

Photo Credit: BETA Technologies

Photo Credit: BETA Technologies - Bristow's Bryan Willows coming in for a landing

My Third Thesis: Early-stage AAM operations are best conducted by companies experienced in purchasing and configuring aircraft for their intended uses, and AAM manufacturers should work with experienced commercial operators during product development processes to ensure a successful early adoption of AAM by the public and in the marketplace.

I have come to believe the second part of my third thesis from my experience selling, purchasing, and configuring helicopters over the last four decades. I stated above that new types of aircraft entering the market may not have the features necessary to operate in specific missions at initial type certification. Therefore, air operators are compelled to make the modifications themselves or have a third-party service center perform the modifications. These modifications often occur post-delivery, delaying placing the aircraft into service, meaning capital investment is idle during the modification period, which may range from a few weeks to several months.
Over time and various production cycles, manufacturers have added some, but not all, product enhancements to their aircraft that have been shown by industry to be needed. However, manufacturers are market driven, and many of these production decisions have occurred when manufacturers do not yet fully understand their customers varied commercial missions.

GAINING OPERATIONAL AND REGULATORY CONFIDENCE

So far, I have discussed AAM type(s) selection, devised a simple operational business model to start initial operations, built our safety cases and espoused our safety culture to the newly trained technical staff, ground support personnel and flight crews. I discussed why it is so important to work with manufacturers to build out a product support structure to enable reliable operations. I also outlined how we will work with our local regulator to grant an airworthiness certificate on the aircraft and then place the AAM aircraft on our operations specifications. Remember safe, reliable, and efficient operations are our goal. We now have an AAM aircraft in our fleet. An aircraft that has received a type certificate from the applicable regulator's aircraft certification office, but it has never entered or operated in a commercial business. The flight test and certification process, as robust as it is, does not replicate the operational strains and stresses the AAM aircraft will see in commercial operations. Considering the intended uses of AAM aircraft, it is likely to be operated on short segment routes multiple times per day. This will result in a high number of takeoffs and landings, potentially five to six per hour. To yield a financially successful and viable business, the aircraft will likely be operated eight to ten hours per day. This could be 40 to 60 takeoffs and landings per day for each AAM aircraft. Contrast this to large transport aircraft for the airline industry; for example, an international class aircraft might experience 60 takeoffs and landings per month.

During these operations, there will be passengers frequently embarking and disembarking, seat belts and interior upholsteries in constant use, aircraft doors opened and closed dozens of times per day, baggage loaded and unloaded, and ground handling regularly relocating aircraft, just to name only a few of the "moving parts" that will take place. Combine these occurrences with changing weather and environmental conditions, which include rain, lightning, sleet, wind, dust, sand, and salt air, and you begin to understand just a few of the challenges air operations face that the certification process considers but does not replicate. Today's current, traditionally powered commercial aircraft have been put through most of these paces. System enhancements and product improvements have been made to accommodate lessons learned. Written practices and procedures regarding ground handling, flight operations and maintenance are continually refined from operational experience to ensure safe, reliable, and efficient transportation.

Every early operator of AAM aircraft will almost certainly be a "launch customer" for this breakthrough technology and will necessarily go through an even more intense and comprehensive learning process than is usually the case with new model types of traditionally powered aircraft. Air carriers who have worked with manufacturers and regulators to introduce new aircraft types possess valuable institutional knowledge and experience that will smooth this critical transition and marketplace introduction. While these aircraft represent technology that is revolutionary, what customers will expect in AAM transportation can only be delivered by carriers who have lived and perfected complicated ground/baggage/cargo handling and maintenance processes, managed high-paced/short-duration flight operations and operated thousands of passenger movements.

Behind the scenes in an AAM operations launch will be the regulator who oversees the air carrier's certificate. The air carrier must demonstrate to the regulator the ability to operate planned or example routes, depending on a multitude of factors. These routes could be relatively short or quite long and involve complex flight demonstrations. These proving operations are crucial to a successful launch, but once again they do not replicate the high-density tempo of regular commercial flight operations. The experienced air carrier, however, will enter this phase of the launch leveraging institutional knowledge gained over the years of its operations, and the regulator having worked with the air carrier will have some level of confidence in the carrier's ability to operationally launch this new technology.Once the proving phase with the regulator is completed, commercial operations can begin.

Above, I mentioned the importance of a pragmatic approach to initial AAM operations. The amount of capital invested in the program at this point will have been substantial, and the public's interest in AAM is also likely to be very high. That interest will be positive or negative based in part on the quality of community and political engagement undertaken. Some regions will be competing for AAM operations, while others will view the prospect with potentially great skepticism or worse. Air carriers, as the market-facing representatives of this new technology, must manage their launch of AAM services with input from government (at all levels), investors, customers and, perhaps most importantly, the communities where they operate. Initial commercial operations require a disciplined and experienced approach and response to the inevitable technical, public relations and financial challenges during the early, crucial phases of commercial flight operations.

An experienced air carrier with high-tempo vertical lift operations will know to begin AAM operations in a temperate region, with a customer and regulator with whom there has been previous collaboration. For the first series of commercial AAM operations, it will also be important to utilize a short supply chain, and leverage an experienced workforce and existing infrastructure, each present in existing air carriers' operations. The world will be watching as the industry begins these operations, and technical failure or safety incidents could prove fatal to the future success of the sector. Because of this and as discussed above, early-stage AAM air carriers must be willing to share non-commercial operational data and technical lessons learned for the industry to succeed and scale.

Photo Credit: Electra.aero

My Fourth Thesis: Early AAM operations should be conducted by air carriers with existing infrastructure that have the capability and desire to collaborate and share certain data to enable AAM to scale globally.

DATA: VEHICLE HEALTH MANAGEMENT AND FLIGHT OPERATIONAL DATA

VEHICLE HEALTH DATA

About forty years ago, a few vertical lift companies started experimenting with monitoring the health (i.e., wear and tear) of rotating components of helicopters, including tracking and balancing the rotor systems. Accelerometers to measure vibration of components, temperature sensors to measure heat and potential degradation of gears and bearings, and cameras to track the rotor path became popular systems added to existing helicopters. By the 2000s, some manufacturers incorporated these systems, known as Health Usage Monitoring Systems (HUMS), into their production aircraft either as an option or as incorporated to their type certificate. HUMS truly has been an advancement in aircraft life-cycle management and safety. If utilized properly, HUMS has the potential to detect failures before damage or inflight issues appear, and the system can extend component lives. An effective HUMS program offers improved flight assurance safety by predicting potential failures and, as an economic benefit, provides data to establish longer service life of components. This is possible through the progression of the algorithms used to analyze raw data to detect anomalies.

Effective analysis of HUMS data is much more than just measuring the information received. Helicopters, by virtue of the many dynamic components and the torque applied to the airframe from the main and tail rotor system, vibrate. So, for example, when measuring vibration, what is the threshold past which a safety problem is potentially indicated? If there is a vibration that may be a precursor to failure, at what rate does it degrade? Once baselines have been established, how and when should a vertical lift operator measure, analyze and take appropriate maintenance actions? How should the operator work with the original manufacturer of the aircraft or component if there is an issue? What are the operator's responsibilities to the regulator and industry at large once the data is in hand?

To my knowledge, there is no regulatory requirement that mandates the installation of a HUMS system on a type-certified aircraft. If an air carrier chooses to install the system or the manufacturer provides the system in a baseline configuration, there are guidelines regarding best practices for HUMS systems provided through advisory circulars from regulatory agencies and industry groups. (In fact, there may be some regulatory requirements in certain jurisdictions or for specific type of operations where it is necessary to have a HUMS system installed, such as offshore helicopter operations and air medical operations.)

One of the benefits of a "clean-sheet"-designed AAM aircraft is that it is highly likely that manufacturers will include a system to monitor the health of the components and airframe in its standard production. There may even be some major advancements as these systems are developed and integrated, which could include the capability to monitor in real time and download remotely. The systems may also come to offer higher reliability of predictive failures and perhaps extensive airframe monitoring. All the AAM manufacturers with whom I have engaged have plans to include a HUMS system, which is very encouraging.

Air carriers starting a new AAM business or existing air carriers adding AAM aircraft to their fleet should develop a HUMS program to download, process, analyze and action health data. Appropriate personnel must be in place to develop the processes and procedures to govern their specific-type health data. Air carriers with the system in place should (as much as possible) utilize published regulatory advisory circulars and HUMS best practices. Additionally, they are well advised to work with aircraft and component manufacturers to establish protocols for detection of anomalies and develop actions to take if anomalies are found. These protocols and actions should be communicated through an appropriate system to other air carriers operating similar AAM aircraft to ensure that they are aware of the issues that arise and the measures to address those issues. Airworthiness issues will be addressed by the appropriate regulators through airworthiness directives; however, much of the data that can be helpful to air carriers may not be at the level required to be reported to the regulators. This makes collaboration by the AAM air carriers on safety-related and other operational data even more important.

FLIGHT OPERATIONS DATA

For this section of the paper, I will use the term Flight Data Monitoring (FDM) (also known as Flight Operations and Quality Assurance (FOQA)) as synonymous with flight operations monitoring. FDM in most regulatory jurisdictions is mandatory for air carriers that operate aircraft over a certain size, generally 27 metric tons. The FAA has not yet made it mandatory, but it is my understanding that all major U.S. airlines have a FDM system in place. Many of the regulatory agencies publish guidelines and best practices for FDM. Helicopter operators began using FDM in the 2000s by basing their systems, processes, and procedures on those used in the airline industry. (Some operations in the U.S., such as supporting the offshore energy business and air medical operations, require a FDM system.)

What is the purpose of FDM?

An FDM system allows an operator to compare their Standard Operating Procedures (SOPs) with those achieved in everyday line flights. A feedback loop, preferably part of an SMS, will allow timely corrective action to be taken where safety may be compromised by significant deviation from SOPs.

From the UK CAA CAP 793, the FDM system should be constructed to [1]:

- Identify areas of operational risk and quantify current safety margins. Initially an FDM system will be used as part of an operator's System Safety Assessment to identify deviations from SOPs or areas of risk and measure current safety margins. This will establish a baseline operational measure against which to detect and measure any change. Example: Current rates of rejected takeoffs, hard landings, unstable approaches.
- Identify and quantify changing operational risks by highlighting when non-standard, unusual, or unsafe circumstances occur. In addition to highlighting changes from the baseline, the system should enable the user to determine when non-standard, unusual, or basically unsafe circumstances occur in operations. Example: Increases in above rates, new events, new locations.

Photo Credit: Lilium

What is the purpose of FDM?

[1] Civil Aviation Authority, [PDF document]. Retrieved from http://www.caa.co.uk/docs/33/CAP739.PDF

- To use the FDM information on the frequency of occurrence, combined with an estimation of the level of severity, to assess the risks and to determine which may become unacceptable if the discovered trend continues. Information on the frequency of occurrence, along with estimations of the level of risk present, is then used to determine if the individual or fleet risk level is acceptable. Primarily the system should be used to deduce whether there is a trend towards unacceptable risk prior to it reaching risk levels that would indicate the SMS process has failed. Example: A new procedure has introduced high rates of descent that are approaching the threshold for triggering GPWS warnings. The SMS process should have predicted this.
- To put in place appropriate risk mitigation techniques to provide remedial action once an unacceptable risk, either present or predicted by trending, has been identified. Once an unacceptable risk, either present or predicted by trending, has been identified, then appropriate risk mitigation techniques must be used to put in place remedial actions. This should be accomplished while bearing in mind that the risk must not simply be transferred elsewhere in the system.

I do not intend to debate some of the controversies surrounding FDM, such as the charge that it is a "big brother watching" system solely utilized to punish aircrew. FDM processes and procedures, if used effectively and in a non-punitive manner, promote less egregious unsafe behavior. Where data collected is anonymous and aggregated separately from senior management, FDM can be an effective safety and quality tool. FDM produces better safety outcomes and assists in the development of air crews through interaction with mentors and improved training curriculums. The system can even provide economic benefits, though not designed for it. Considering the potential scale of AAM and the likelihood that many of the aircraft will be flown either with a single pilot or in some cases piloted remotely, it is my opinion that a robust FDM program must be in place for AAM air carriers. In the case of AAM, FDM is likely to be voluntary, with applicable regulatory guidelines and best practices available should an air carrier wisely choose to institute a program. The lack of an FDM regulatory mandate does not excuse AAM operators from not having one in place. AAM air carriers should consider it as a requirement even if regulators do not.

Thesis Number Five: Air carriers involved in AAM flight operations should have appropriate equipment, programs, and personnel in place to manage health and flight data in a manner consistent with aviation industry best practices.

Photo Credit: BETA Technologies

GAINING MARKETPLACE CONFIDENCE BY MANAGING THE HYPE AND CONCERNS TO ALLOW THE INDUSTRY TO SCALE

As a child of the 1960s and 70s, I would love to live in the world of the Jetsons. Some early AAM marketing, use cases and even investment prospectuses, though not blatantly promoting flying vehicles for personal use, have offered a Jetsons-type outlook for the AAM sector. Slick renderings describe vertiports with aircraft flying through congested cities whisking passenger's point-to-point on demand. Materials offered for public consumption outlining similar operating and business models that are an immediate solution for mass transportation in congested cities or promote a ride hailing system in the sky available at the tip of your finger, should be worrying to anyone interested in a disciplined, effective launch of AAM services into the marketplace. Highlighting a use case that may be achievable in the future but is not feasible in the near term may cause the public and government at all levels to have an unrealistic perception of AAM and cause long-term damage to public confidence.

Thesis Number Six: Five theses are enough. If we, as an industry, want to scale AAM to solve transportation problems; improve the delivery of goods safely, efficiently, and reliably; reduce transportation costs; reduce pollution; increase transportation accessibility; reduce congestion; and launch a product that could lead to future aerospace technological advancements, review Theses One through Five.

We must be pragmatic throughout the entire AAM ecosystem. Let's first have the companies designing, building, testing, and certifying an electric aircraft, produce a machine that can take off and land vertically. As a part of this process, the regulatory and associated government agencies will adopt rules and regulations for AAM aircraft. While this process goes forward, let's make sure we explain to the public what these aircraft realistically can do in the form of plans that reflect use cases based on the known performance of AAM aircraft today. I often hear from aviation industry colleagues that AAM will not work for the following reasons: the batteries are too heavy, so let's move to hydrogen now; there are not enough heliports or it costs too much to build out infrastructure necessary to support urban air mobility; air traffic management systems will not be able to handle the sheer number of aircraft; and AAM will only work once we get to autonomous flight.

I do understand these concerns and the resulting skepticism. But I would advise that the nascent AAM industry proceed step by step and not get out ahead of itself.

1. Build a type-certified AAM aircraft.
2. Produce a quality AAM aircraft.
3. Develop a simple commercial use case for AAM aircraft to be implemented in a way that makes use of all available and relevant experience.
4. Evolve this revolutionary technology and solve the micro and macro problems the industry will face to scale it.

Photo Credit: Volocopter

I began to evaluate AAM as a pure thought experiment. As I considered the promise of AAM, I kept looking back to the early revolutions in aviation both for inspiration and a reality check. I do not think the Wright brothers and other early pioneers thought we would have mass air transportation systems in the first few years after they mastered control of powered flight. A few years after he flew the VS300, I doubt Igor Sikorsky thought we would fly helicopters 200 miles out in the ocean and deliver nineteen passengers to an oil rig located in ten thousand feet of water. If the end goal of these early pioneers had focused on the mass transportation services that we enjoy today, they may never have gotten off the ground. (Excuse the pun.)

Whether it's an industrial company, a logistics provider or perhaps an airport network, we need to discuss with our potential customers and the public what is possible with AAM today. To customer X, I could say that AAM can move your goods and products from one defined point to another defined point carrying a maximum of 500 pounds of payload 50 miles in distance. To airport or airline management, I could say that AAM can move your passengers two to three at a time from existing aerodromes to your airport, and AAM can do it in certain defined conditions twice per hour until operational experience permits expanded services.

As we gain experience from early operations, we can prove to the regulatory agencies that we can operate in a safe, efficient, and reliable manner. This will allow the industry to expand its service offerings and provide time for the public to gain confidence in AAM transportation. We can demonstrate that AAM is quiet and less intrusive in their environment and provide data for municipalities that may be apprehensive about this revolutionary new transportation network. We can demonstrate that AAM is not just a cool way to get places, but also a mode of transport that is cost effective and sustainable. We can also provide data to the investment community to confirm the cost modeling that justifies the substantial capital investments required to grow AAM beyond simple remote operations supporting logistics.

What I hope this paper has conveyed is that we should not overhype AAM before a successful launch. We should keep initial operations simple, be transparent with the marketplace so as to set early, realistic expectations for AAM operations, and we should not assume that the revolutionary technology of AAM aircraft equates to safe, efficient and reliable commercial operations. To achieve that, we would be well advised to look to vertical lift air carriers with a track record of safe operations and the experience to launch AAM successfully on its way to the phenomenal future we all believe is its destiny.

Photo Credit: BETA Technologies

ABOUT THE AUTHOR

David F. Stepanek became Bristow's Executive Vice President, Chief Transformation Officer in March 2021. In this role, David is leading the transformation of Bristow by introducing the next generation of Advanced Air Mobility (AAM) aircraft and expanding Bristow's core business in new regions. Through David's efforts, Bristow has forged strategic relationships with multiple AAM manufacturers, leveraging Bristow's 75 years of safety management and vertical lift operations. He participates in a variety of public speaking engagements related to AAM operationalization and overcoming the hype of AAM to bring it to reality.

David previously served as Bristow's Executive Vice President, Chief Operating Officer, responsible for Bristow's global operations, supply chain and IT. Prior to joining Bristow, David held positions within PHI, Inc., including President of PHI's Energy business and PHI Americas. David started new air carrier businesses for PHI in Australia, Cyprus, Ghana, Saudi Arabia, and Trinidad; he also led PHI's acquisition of Helicopters New Zealand in 2017. He has held board positions with Cougar Helicopters and HeliOffshore, the global, safety-focused association for the offshore helicopter industry. David spent twenty years at Sikorsky Aircraft in a variety of leadership positions, including technical support, customer service, and commercial sales. During his time with Sikorsky, David sold and delivered the first commercial S-92 model helicopter and booked over USD$1 billion in commercial helicopter sales. David is a veteran of the United States Marine Corps and a Fellow of the Royal Aeronautical Society.

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