ACRP 11-08: Future of Aviation Insight Event

Summary of Literature Review

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ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

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1 Introduction

The global growth in the middle class, increasing urbanization and a demand for global high-speed travel and on demand services is contributing to a growing aviation industry. According to a forecast by the International Air Transportation Association (IATA) conducted prior to the current COVID-19 crisis, global passenger traffic is expected to double by 2037 to over 8 billion.[1] Although the aviation industry has experienced an unprecedented contraction due to the pandemic, expectations are that passenger traffic will eventually rebound to similar levels by 2024.[2]

Planning for the growth in demand and preparing for changes brought by future technologies is challenging for an industry with a long planning horizon like aviation. Decisions made today will have lasting impacts for the next 20 to 30 years and beyond, due to the extensive investment required and average useful lifespan of airport infrastructure and aircraft fleets. This creates a conflict with the often-rapid pace of technological development, changes in consumer preferences and behavior, and disruptive events. Just as deregulation changed the industry dramatically in the 1970s, recently implemented technologies and trends such as unmanned aerial vehicles (UAVs or drones), on-demand ground transportation and aviation services, urban air mobility (UAM), connected devices and the electrification of vehicle fleets to highlight a few, are currently transforming the aviation industry today. The recent COVID-19 crisis has also highlighted the importance of coordinated and effective public health planning and preparedness. Airport industry practitioners need to consider how these types of developments will impact the planning, design, and operations of airports and passenger needs in the future. It is increasingly important for the airport industry to understand, prepare for, and adapt to these trends, as the economic costs of failing to do so may be significant.

To address this need, the Airport Cooperative Research Program (ACRP) is planning a "Future of Aviation" Insight Event (ACRP project 11-08), designed to bring together industry practitioners, subject matter experts (SMEs), regulators, researchers and other interested stakeholders to "promote communication and collaboration, foster innovation, and help identify areas of future interest and research".[3]

Task 2 of ACRP Project 11-08 consisted of a literature review and preliminary stakeholder interviews to identify the major themes or trends shaping the future of the aviation industry. Sources reviewed include federal agency research and strategic plans, specifically from the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA), trade association publications (from airlines, airports and manufacturers), news articles, corporate press releases, research roadmaps and academic articles. An annotated bibliography containing sources reviewed and summaries of each are included in Section 5. This document summarizes the research team's key findings from the literature reviewed and discussions with stakeholders.

There is an almost limitless number of topics could be considered for an event titled "Future of Aviation". For many subjects, particularly those that involve new and exciting technologies, such as urban air mobility (UAM), unmanned aerial vehicles (UAVs), electric vertical takeoff and landing aircraft (eVTOL), supersonic aircraft, commercial space and cyber-security, there are already active industry groups and a variety of conferences in existence that provide the opportunity for industry practitioners and subject matter experts to engage in detailed discussion on those specific topics and technologies. Consequently, the primary focus of this Insight Event is to envision how the major themes or trends will interact, converge and/or conflict to shape the aviation industry in the long term. Since the Insight Event cannot reasonably cover every topic that is related to the future of aviation, this literature review

[1] International Air Transport Association (IATA). "IATA Forecast Predicts 8.2 Billion Air Travelers by 2037". Press Release No. 62, October 24, 2018.
[2] IATA. "Recovery Delayed as international Travel Remains Locked Down". Press Release No. 63, July 28, 2020.
[3] ACRP Insight Event webpage, accessed at: http://www.trb.org/ACRP/ACRP-Insight-Events.aspx

attempts to narrow the focus of the Event to a few, high-level themes and consider how they intersect to affect the evolution of the industry.

The three key themes identified during the literature review conduced in Task 2 and discussed in this document are: 1) Technology and Data, 2) Sustainability and Climate change, and 3) Human Factors and Workforce. The fourth theme, "Black Swans", or planning for the unknown, is discussed in this document but not summarized as a separate topic because by definition, these future events are unforeseen. The Insight Event Committee, to be comprised of subject matter experts and industry practitioners, will further define the scope of the event. This document is intended to serve as a starting point for the Committee's consideration. Possible topics and questions to explore during the event are included in each section for Committee consideration.

For the purposes of this document and discussion with the Event Committee, the research team has identified two time periods of interest for the Insight Event, Mid-term (2025-2035) and Long-term (2035 and beyond). These time periods align with the approach NASA takes in the Aeronautics Research Mission Directorate (ARMD) Strategic Implementation Plan, in which they are defined as[4]:

- "Mid-term (2025-2035) – Outcomes are often in a transitional stage, aimed at a combination of new concepts and applications within the current system. They reflect applications of emerging technologies, initially within the paradigm of the existing aviation system, but often leading to transformative innovations responsive to future needs.
- Far-term (beyond 2035) Outcomes are more exploratory in nature, focusing on concept exploration and technology research."

[4] National Aeronautical and Space Administration (NASA). 2019. NASA Aeronautics Strategic Implementation Plan: 2019 Update. https://flight.nasa.gov/pdf/armd-strategic-implementation-plan.pdf

2 Key Themes

Each of the first three themes are discussed in this section at a high-level, with subtopics identified and questions to consider included as the Event Committee shapes the agenda. As previously discussed, many of the topics included in this summary are interrelated and multidimensional. The Insight Event will consider how these themes will interact and affect airports, airlines, mobility service providers, passengers, and communities in the future. Although the topics are discussed in this document by theme, they should not be considered independently.

2.1 Technology and Data

The introduction of new technologies can facilitate growth and act as a disruptive force that changes the landscape of industry trends. The ability to integrate new technologies into existing physical and virtual infrastructure requires flexibility and adaptive planning from airports and airlines. To maintain viability and competitiveness, airports will need to be resilient to avoid disruptive impacts and flexible to accommodate technological advancements. The industry will also need to find ways to use, process, store and protect the massive amounts of data generated from internet connected devices, particularly customer and passenger data.

2.1.1 Evolving Air Service Trends and Technological Democratization

As global population grows more rapidly in developing nations and populations centralize in metropolitan areas, these patterns are impacting how, when, and where airports are built, modified, modernized, and used. The general trend of populations moving toward metropolitan areas and away from smaller, more rural areas is expected to continue globally, reaching 68 percent of the global population living in urban areas by 2050, with much of this growth occurring in Africa and Asia.[5] Population growth in developing nations in general is expected to outpace developed nations and as wealth increases across all populations, anticipated air travel demand in Africa, India, and other regions is expected to increase. These expected population shifts from rural to urban and from west to east will have an impact on where the growth in air travel occurs, and where new airports and aviation services are needed. In addition, other major trends such as the emergence of UAM will affect the types of air services in demand, how populations in large urban centers move around and how passengers and cargo get to and from airports (and whether traditional airports are needed for certain short haul routes).

In addition, the democratization of technology, or the increasing access to internet connected devices like smart phones, gives consumers around the world greater access to on-demand services, including ground and air transportation. Current access to air travel is primarily determined by access to financial resources, but as the middle class grows globally, demand for air travel and consumer goods delivery will also grow. Demand for aviation services (passenger or cargo) will become more varied and distributed, which will require more advanced technologies and interoperability to maintain high levels of safety, and more sustainable use of materials to meet growing demand without negative environmental impacts.

Growth in demand for high-speed transportation services for both long-haul and short trips, and cargo delivery, is a result both of changing population and demographic trends and the development and availability of new technologies and services. These trends have driven the development of UAM, UAV, eVTOL, and supersonic aircraft. Improved processing capacity and cloud computing will enable autonomous operation of vehicles and unmanned air traffic services, which can improve safety and the efficiency of the NAS. The development and deployment of

[5] United Nations Department of Economic and Social Affairs. World Urbanization Prospects. 2018 Revision. May 16, 2018.

UAM services and supersonic aircraft are underway, and these types of services and vehicles are expected to be in operation in the near to mid-term.

While the market penetration of UAM, UAVs (for cargo for example), and supersonics will be limited in the near to mid-term, there is great potential for disruption in regional air service models, on-demand mobility and consumer services, business travel, and the aviation workforce. The demand for mobility services extends beyond aviation, and it is important to also consider the connections needed for seamless travel experiences such as highspeed rail, transit, and autonomous vehicles.

2.1.2 Data Privacy, Safety, and Security

In handling consumer data or 'big data', the ability to implement technology is no longer the major hurdle. Rather, the legal and contractual issues and privacy concerns are challenges that limit the ability of entities to share data across organizational boundaries (for example those between airlines and airports). As a result, airports have started to collect their own data but the challenges with and limits on how this data can be shared across organizations affects how this data can be used, for example for security, revenue generation, customer service and facilitation and public health.

The boundary between the consumer and airports, airlines, and other stakeholders presents a challenge as data ownership and privacy concerns remain prevalent in discussions of biometrics, connected devices (i.e. the internet of things, or IoT), and consumer data mining. In addition to data analytics, technologies like biometrics and blockchain present opportunities for increasing safety and security.

TSA is currently leveraging biometrics technologies to modernize and streamline identity verification, improve security, and increase efficiency. Strategic drivers for using facial recognition to improve TSA security capability includes the changing operational landscape, technological advancement of biometric matching algorithms and data (including facial images), consumer cultural shifts towards use of biometrics in everyday life, rising travel volumes and staff shortages, and the emerging business case for collaborative partnerships between TSA and industry. Although technologies are currently available, system capacity, consistency, and interoperability are required to improve safety in the future.6 Interoperability describes the need for different biometric systems to interact with one another so that multiple stakeholders have access to exchange the information.

The advancements in biometrics, improvement in cloud computing, automation and the increase in the use of and reliability on internet-connected devices, (including consumer devices and components integrated into buildings, facilities and vehicles) can increase safety and security but also raises cyber-security concerns.7 The industry will need to transition to an automatic, proactive approach to detecting and defending against cyber threats to ensure safety and security of the system in the future.

2.1.3 Commercial Space

Recent developments in commercial space and partnerships are proving to be successful investments. NASA currently has a Commercial Crew Program (CCP) focused on partnerships with commercial space partners such as The Boeing Company, Sierra Nevada Corp. and SpaceX.[8] In the future, commercial space leisure travel and

[6] Transportation Security Administration. September 2018. TSA Biometrics Roadmap for Aviation Security & the Passenger Experience. https://www.tsa.gov/sites/default/files/tsa_biometrics_roadmap.pdf
[7] AIA. What's Next for Aerospace and Defense: A Vision for 2050. March 2019. https://www.aia-aerospace.org/wp-content/uploads/2019/04/Whats-Next-for-Aerospace-and-Defense.pdf
[8] https://www.nasa.gov/sites/default/files/files/CCP-Apr-14.pdf

commercial research activity will increase as technology continues to prove to be safe and effective.[9] To date, there have been 351 licensed launches, 22 licensed reentries, and 12 spaceport operator licenses granted by the FAA's Office of Commercial Space Transportation.[10] This commercial space activity is expected to increase over the mid and long term, including the development of a greater variety of vehicles operating from more locations. Additionally, some of these vehicles will be able to operate both space flight and within the National Airspace System (NAS).[11] These launch and reentry operations will have to be safely and efficiently integrated into the NAS by the FAA Air Traffic Organization (ATO) in the coming years which will require advances in technology and policy in how air navigation service providers operate.

2.1.4 Artificial Intelligence

Artificial intelligence (AI) algorithms rely on big data to develop useful tools that reflect reality. Currently, aviation data is fragmented across stakeholders and data sharing is not uniform or regulated, resulting in inconsistencies and data availability gaps. Sharing data between public and private organizations results in legal and contractual challenges, as well as data privacy and cybersecurity concerns that require agreements between data owners.[12,13] Roles of stakeholders such as airports, airlines, and governments need to be defined so that AI can be better leveraged for the benefit of the industry.

Applications of AI to the aviation industry include using machine learning to facilitate customization of services, enabling automation and autonomy, and improving safety and security. One example of a current application is Delta Air Lines' (Delta) development of a full-scale digital simulation environment for its global operation that analyzes millions of operational data points and creates hypothetical outcomes based on historical Delta operations data. The data will assist Delta in making decisions before, during, and after large-scale disruptions, and will also serve as a post-mortem tool to explore where improvements to decisions and the decision-making process could be made. Delta planned to implement the machine learning platform in 2020.[14] Similar efforts could be made by other airports and airlines as decision-making tools, especially relevant in a post COVID-19 world in which operations are changing on a month-by-month basis and previous forecasts are likely no longer applicable.

2.1.5 Technology and Data Topics and Questions

Some topics for consideration within the Technology and Data theme are listed below.

Mid-term (2025-2035):

- Integration of new entrants (UAM, UAVs, commercial space) into the NAS, including changes needed to technologies, automation, and policies to facilitate integration

[9] International Air Transport Association (IATA). 2011. Vision 2050. Accessed at: https://www.iata.org/contentassets/bccae1c5a24e43759607a5fd8f44770b/vision-2050.pdf
[10] https://www.faa.gov/space/
[11] FAA. Commercial Space Integration into the National Airspace System Concept of Operations. May 2019. https://www.faa.gov/space/airspace_integration/media/Final_CSINAS_ConOps.pdf
[12] EuroControl. European Aviation Artificial Intelligence High Level Group: The Fly AI Report 2020. March 5, 2020. https://www.eurocontrol.int/sites/default/files/2020-03/eurocontrol-fly-ai-report-032020.pdf
[13] Aerospace Industries Association. "What's Next for Aerospace and Defense: A Vision for 2050". March 2019.
[14] Delta News Hub. 2020. Nothing artificial about this intelligence: Delta's industry-first machine learning platform minimizes customer inconvenience during tough operations. https://news.delta.com/nothing-artificial-about-intelligence-deltas-industry-first-machine-learning-platform-minimizes

- Integration and availability of UAM services to consumers, and connection between UAM service providers and airports, other modes of transportation, and the impacts on small and rural airports, business and general aviation, and urban airports
- Proliferation and integration of UAVs, delivery drones and impacts to cargo aviation and airports
- Impact of new entrants on communities, community acceptance or rejection of new entrants, impacts to quality of life, new or different communities affected (compared to those directly adjacent to airports, for example)
- Cyber-security risks of distributed technology
- How airports can/will utilize big data and data analytics to increase operational efficiency and improve customer service and facilitation at airports, i.e. "smart airports"
- Legal and contractual hurdles for collection and sharing of customer/passenger data
- Collaboration between regulators, manufacturers, and end users to increase interoperability of technology and connectivity/communication between aircraft types and systems (this is also a long-term consideration)
- Vertical integration trends in cargo (i.e. Amazon fleet of aircraft)

Long-term (2035+):

- Integration of new entrants (UAM, UAVs, commercial space) into the National Airspace (NAS)
- Impacts of new entrants like supersonic/hypersonic aircraft or other aircraft advancements on global travel patterns
- Changes to airline service models
- Integration of aviation with other modes of transportation, multimodal considerations
- Community/ public reaction considerations: Will states' use of data for surveillance, security, and predictive analytics cause public backlash?
- Impacts of automation/ AI on safety, and on aviation workforce (pilots, security, maintenance, etc.)

2.2 Sustainability and Climate Change

Airports, airlines, and manufacturers in the aviation industry have faced consistent pressure from regulators and the public to manage their environmental impacts, operate more sustainably, and address their impacts to climate change. The industry has worked for decades to limit its environmental footprint and develop an approach to sustainability. For example, in 2008, airports in the U.S. and Canada in coordination with airline partners worked through industry trade associations to develop the Sustainable Airport Guidance Alliance (SAGA), a database comprising several hundred sustainability practices and related information.[15,16] Airport sustainability planning became more widespread with the launch of the FAA's Sustainable Master Plan Pilot Project in 2010, which funded the development of 44 sustainable master or management plans (SMPs) at U.S. airports.[17]

[15] Airport Cooperative Research Program Project 02-30, *Enhancing the Airport Industry SAGA Website*. 2011-2017. Project website. Retrieved from: https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3031 .
[16] SAGA website http://airportsustainability.org/
[17] Federal Aviation Administration. *Report on the Sustainable Master Plan Pilot Program and Lessons Learned*. December 17, 2012. Retrieved from:

Since that time, the airport industry's understanding of what sustainability encompasses has evolved and expanded to include consideration of frameworks like the United Nation's (UN) Sustainable Development Goals (SDGs), and consideration of advanced sustainability rating systems like the Airport Carbon Accreditation program and the Institute for Sustainable Infrastructure's Envision rating system, among others.[18, 19, 20] Sustainability initiatives within the industry continue to expand to include social aspects, such as public health considerations, diversity and inclusion, and consideration of community quality of life. As the effects of the COVID-19 pandemic continue to unfold, there is an emerging opportunity for airports to take a holistic look at their impacts on and role in local communities. Maintaining airport longevity and gaining public confidence will be dependent on unconventional outreach efforts that continue to evolve in a temporarily virtual setting.

Best practices will develop in the mid- and long-term as new technologies, processes, materials, and policies enable the aviation industry to operate in a more sustainable manner, address climate change, improve resiliency, and achieve deep decarbonization.

2.2.1 Climate Change

Climate change is a global threat and one that requires action from governments, industry, corporations, and organizations to limit warming to avoid the most severe consequences. According to the Air Transport Action Group (ATAG), aviation currently accounts for approximately 2 – 3 percent of global carbon emissions, but global growth in emissions from aviation could increase by 300 – 500 percent by 2050.[21] Due to growth projections, the aviation industry is under growing scrutiny from governments and the public regarding its contributions to climate change and has been taking steps to reduce its impact. The International Civil Aviation Organization (ICAO) recently adopted the Carbon Offset and Reduction Scheme for International Aviation (CORSIA), which is designed to limit growth in GHG emissions from international aviation.[22] The industry has also set its own ambitious goal to cut CO_2 emissions in half by 2050, based on 2005 levels.[23] In addition, based on work completed at ICAO's Committee on Aviation Environmental Protection (CAEP), member States including the U.S. have adopted CO_2 standards for new aircraft engines.

Public pressure on the aviation industry to address its contribution to climate change has increased recently and will continue to do so post-COVID recovery. Climate activists have urged the traveling public to take other forms of transportation and supported the "Flygskam", or "flight shame" movement, which while more widespread in Europe than the U.S. has led to measurable impacts on air traffic in some countries.[24] Climate change has also been used to

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https://www.faa.gov/airports/environmental/sustainability/media/SustainableMasterPlanPilotProgramLessonsLearned.pdf

[18] International Civil Aviation Organization (ICAO). ICAO and the United Nations Sustainable Development Goals. Retrieved from: https://www.icao.int/about-icao/aviation-development/pages/sdg.aspx

[19] Air Transport Action Group (ATAG). *Flying in Formation: Air Transport and the UN Sustainable Development Goals*. February 2017. Retrieved from: https://aviationbenefits.org/media/166149/inside_abbb2017_atag_web_fv.pdf

[20] Shannon, Carly. *Airports Increasing Interest in Envision*. June 22, 2017. Retrieved from: https://sustainableinfrastructure.org/airports-increasing-interest-in-envision/

[21] ATAG Facts and Figures, accessed December 23, 2019 at https://www.atag.org/facts-figures.html

[22] ICAO. Resolution A40-19: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Carbon Offsetting and Reduction Scheme for International Aviation. 2019. https://www.icao.int/environmental-protection/Documents/Assembly/Resolution_A40-19_CORSIA.pdf

[23] ATAG. Commitment to Action on Climate Change. https://www.atag.org/our-activities/climate-change.html

[24] Wilkes, William, Richard Weiss. "German Air Travel Slump Points to Spread of Flight Shame". *Bloomberg News*. December 19, 2019. At: https://www.bloomberg.com/news/articles/2019-12-19/german-air-travel-slump-points-to-spread-of-flight-shame?sref=61mHmpU4

halt airport development, as evidenced in a recent United Kingdom Court of Appeals determination rejecting Heathrow's plans for a third runway, citing that the project did not take account of the county's commitment to tackle climate change under the Paris Agreement.[25, 26] "Eco-taxes" are another measure in place to address aviation's impact on climate change, such as those imposed by France and Germany.[27] Pressure for the aviation industry to continue to cut emissions and address its climate impacts is expected to continue from both the public and the regulatory community in the future, particularly as many international goals for carbon reductions focus on the 2035 and 2050 timeframes.

2.2.2 Resiliency

Resiliency is a broad concept that encompasses many factors relating to an airport's ability to recover from shocks and continue operations regardless of the circumstances. System disruptions can include natural and human-made disasters, as well as short-term disruptions. Recent examples include the 2017 power outage at Atlanta Hartsfield Jackson International Airport, active shooter situations at both Los Angeles (LAX) in 2013 and Ft. Lauderdale (FLL) in 2017, hurricane damage in Houston, Florida, and Puerto Rico from the 2017 season, airfield flooding at LaGuardia Airport (LGA) following Superstorm Sandy in 2012, and terminal flooding at JFK in 2018.[28] Resiliency can refer to infrastructure and physical assets as well as to business processes, supply chains, management, cybersecurity and human resources.

Airports on both coasts must consider the risks to their infrastructure posed by climate change such as sea level rise and storm surges, increased frequency and intensity of precipitation, greater temperature swings, droughts, flooding, and other extreme weather. Infrastructure that was designed to withstand a 100-year storm using historical data may now be exposed a similar level of extreme weather more frequently, and as a result, may not be equipped to withstand changing conditions and stressors. Airports need to assess their resiliency and develop plans to ensure their operations, infrastructure, and organizations are resilient to many types of challenges.

2.2.3 Alternative Fuels and Decarbonization

As the impacts of climate change continue to become more visible to society-at-large, airports and airlines will likely feel increased pressure to decarbonize. This is evidenced today as the number of airlines and airports that have made public commitments or set ambitious targets regarding carbon emissions reductions continues to grow. For example, there are 313 airports worldwide that participate in the Airport Carbon Accreditation program (ACA), which is a carbon management and reduction program originally developed by Airports Council International – Europe.[29] Airlines are also taking steps to reduce their emissions, both individually and through trade associations such as IATA. In the U.S., airlines have partnered with the FAA, the Aerospace Industry Association (AIA) and the Airports

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Peske, Nicole. "How Greta Thunberg and 'flygskam' are shaking the global airline industry". *MarketWatch*. December 2019. At: https://www.marketwatch.com/story/flygskam-is-the-swedish-travel-trend-that-could-shake-the-global-airline-industry-2019-06-20

[25] Carrington, Damian. "Heathrow third runway ruled illegal over climate change". *The Guardian.* February 27, 2020. At: https://www.theguardian.com/environment/2020/feb/27/heathrow-third-runway-ruled-illegal-over-climate-change

[26] The Paris Agreement is an international climate agreement made within the United Nations Framework Convention on Climate Change (UNFCCC), with the objective of limiting global warming to 2 degrees C, and addresses greenhouse-gas-emissions mitigation, adaptation, and finance, signed in 2016.

[27] Chappell, Bill. "France plans to put an "Ecotax" on nearly all air travel". *NPR.* July 9, 2019. At: https://www.npr.org/2019/07/09/739981243/france-plans-to-put-an-ecotax-on-most-air-travel-out-of-the-country

[28] ACRP Thought Leaders Forum. Enhancing Resiliency of Airports and Interrelated Systems. 2018. http://www.trb.org/acrp/emergingissues.aspx

[29] ACA participation figures available at: https://airportco2.org/

Council International – N. America to advocate for the development of sustainable aviation fuels (SAF) through the Commercial Aviation Alternative Fuels Initiative (CAAFI). Globally, the industry is investing significantly in the development, certification, and deployment of SAF. These fuels are expected to increase in market availability as the economics improve (attributable to a combination of regulatory intervention, volatility in the oil market, technological advancements, increased fuel production and certification pathways, etc).[30] Widespread availability and use of SAF is required for the industry to meet its carbon reduction goals, and research into new fuel feedstocks and development pathways will continue in both the mid- and long-term.

Additionally, technology continues to evolve to address climate change. Examples include more efficient aircraft and engines, improved operational efficiency, electric aircraft, ground fleet electrification, alternative fuels, renewable energy, sustainable building, and advanced materials

2.2.4 Sustainability and Climate Change Topics and Questions

Some topics for consideration within the Sustainability and Climate Change theme are listed below.

Mid-term (2025-2035):

- How will airports and airlines redefine sustainability and resiliency post-COVID (to address economic and public health threats)?
- Progress on the development and commercialization of alternative fuels
- The success of CORSIA in curbing carbon emissions from aviation, impacts to carbon offset market
- Proliferation of domestic climate/ emissions regulatory schemes
- How will UAV/UAS be used to enhance resiliency and disaster response
- Public sentiment regarding flying and climate change, consumer behavior changes
- Availability of electric vehicle charging infrastructure and integration with the larger grid
- Integration of resiliency planning with airports and communities, how to model future operational disruptions
- Growth of distributed energy resources and microgrids

Long-term (2035+):

- Development of electric aircraft
- Growth in electric vehicles
- Deep decarbonation of buildings, facilities (zero emissions, net zero energy/ carbon)
- Zero emissions transport (hydrogen, hyperloops)
- Changing travel patterns due to climate impacts
- Use of electric vehicles as power storage

[30] Commercial Aviation Alternative Fuels Initiative (CAAFI). 2020 Goals and Priorities, Building on Industry Accomplishments and Addressing Remaining Challenges. 2020. http://www.caafi.org/files/2020_Goals_and_Priorities.pdf

2.3 Human Factors and Workforce

Technological advancements, changing industry trends, and a myriad of unforeseen factors contribute to the reality that the most in-demand and critical airport jobs 20 or more years into the future likely do not currently exist, nor can they be fully anticipated. Additionally, until the COVID-19 crisis, the industry was facing a pilot shortage. Although the immediate need for additional pilots has been temporarily removed, this may become an issue depending on the speed of economic recovery. In the mid- to long-term, as automation and AI technologies are implemented and integrated, single pilot or pilot-less aircraft (at least for cargo operations) are very feasible, although public acceptance will be a challenge.

2.3.1 Retirement Boom

As the baby boomer generation (born 1944-1964) ages out of the work force, replenishing the knowledge base to maintain continuity of operation is critical to airport success. The industry faces a retirement wave in all segments including airports, airlines, manufacturing, maintenance, and more. This effect may be accelerated because of COVID-19 with staff layoffs and buyouts as recent research shows 3 million U.S. workers over the age of 55 have left the workforce since March 2020.[31] Facing the retirement of the baby boomer workforce, as well as general demands to attract new talent for the airport workforce, the industry will need to increase visibility and awareness of career opportunities, invest in development of new talent and talent pipelines, invest in knowledge transfer from the outgoing experts, and work creatively to increase retention.

It is likely that the airport and airline industries will look very different post COVID-19 recovery. It is possible that future aviation careers are far more information-technology (IT) focused than existing careers. The workforce will need to understand how to manage and develop AI and information security. There may be a need for more public health professionals in the industry to prepare for disaster response and resiliency efforts, such as those of global pandemics. The industry will need to determine what specific skills are needed to address the challenges and trends described in Sections 2.1 and 2.2

2.3.2 Virtual Work

It is unknown what percentage of the workforce will permanently remain virtual (or virtual on at least a part-time basis) following COVID-19. This will not only affect the aviation workforce, but it will also affect the financial recovery of the industry if business travel does not return to pre-pandemic levels. As businesses learn which employees and positions can maintain a high level of productivity without going into an office, business travel may recover slowly if at all. In-person conferences and meetings are also being held virtually, contributing to the low level of business travel. Until it is safe to hold in-person meetings with large groups of people, this trend is expected to continue in the short-term. It is yet to be determined how the current economic conditions affect the future of aviation in in the mid- to long-term.

2.3.3 Community Engagement

Communities adjacent to airports are traditionally viewed as aviation stakeholders. However as new types of air service and new entrants emerge, “affected communities” will become geographically more diverse. Communities that historically have never experienced impacts from aviation (those not under a flight path for example) may perceive they are newly affected by aircraft or UAVs. While airports, the FAA, and to a lesser extent the airlines, have

[31] Ghilarducci, Teresa. The COVID-19 Recession is Forcing a Wave of Early Retirements, Time to Boost Social Security. August 5, 2020. Forbes. https://www.forbes.com/sites/teresaghilarducci/2020/08/05/boost-social-security-since-the-covid-19-recession-is-forcing-early-retirements/#74714f0c2142

communicated and engaged with their communities with varying degrees of success for decades, new entrants have not had the benefit of this experience.

Airports track and communicate their environmental (noise, air quality, water quality, etc.) impacts on surrounding areas, and they measure their economic impact on the local and regional economies (jobs created, businesses supported, cities connected, etc). They often have long-standing community advisory committees or other mechanisms in place to communicate with communities about airport projects, changes in air traffic, and construction projects, for example. These groups are intended to improve communication with stakeholders and mitigate problems. Noise is a constant challenge for the aviation industry. Although aircraft have gotten quieter over the past several decades and there is promise of even less noise from future aircraft (i.e. electric aircraft, "boomless" supersonics, quieter conventional aircraft), community annoyance and opposition remain a problem. Increasingly savvy communities are politically active and, in some cases, have taken legal action against airports, the FAA, and/or operators to challenge what they view as unacceptable harm. Non-acoustic factors of annoyance (concerns over safety, altitude, the visual presence of aircraft, etc.) are difficult to address even for experienced organizations.

As UAM, UAVs, supersonics, and commercial space operations proliferate, community engagement will be critical to gaining public acceptance of these technologies. If meaningful engagement does not happen or happens poorly, the long-term growth of these new market segments may be jeopardized.

2.3.4 Human Factors and Workforce Topics and Questions

Some topics for consideration within the Human Factors and Workforce theme are listed below.

Mid-term (2025-2035):

- Post-COVID virtual work trends: does business travel recover if remote work permanently expands?
- How airports/ aviation will attract the next generation of workers in a post-COVID environment
- How to maintain knowledge and operational continuity following the upcoming retirement boom
- How to bridge skills for current workforce regarding emerging technologies
- Pilot shortage reemergence post-COVID recovery
- Reduction in need for pilots due to automation
- Skills needed from outside of traditional aviation field (programming, data scientists, pilots/operators for UAV/UAM)
- Aviation university programs need to be realigned to future skill gaps
- Revenue model disruptions
- Shifting community expectations for stakeholder engagement post-COVID and in relation to new entrants

Long-term (2035+):

- How should airports think long-term about organizational structure and culture to effectively manage changing demographics, technologies, and unforeseen factors to workforce/labor needs?
- Automation impacts on workforce (reduction in need for human staff or shifting humans to other responsibilities)
- How will community engagement change with new entrants and service models? Affected communities will become more geographically distant and diverse, how should the industry define stakeholders?

- Will non-acoustical factors (annoyance) inhibit growth of the industry? Will new vehicle noise profiles affect complaints and community annoyance? Who will resolve these future noise issues?
- Economic trends (rising or reduction in inequality, growth or stagnation of middle class) and the relationship to community/ public acceptance of aviation, new entrants, service.

3 Stakeholder Outreach

Review of relevant literature was supplemented with discussions with multiple stakeholders representing a range of perspectives. Representatives from national trade associations representing airports, airlines (both passenger and cargo), consultants, and aerospace manufacturers were primarily chosen for these preliminary conversations due to their national and, in some cases, international perspectives and understanding of their members' priorities, in addition to stakeholders who have participated in ACRP or associations at the leadership level in the past, and the FAA. Anonymized stakeholder affiliations are listed in Table 1 along with the key takeaways from each discussion.

Table 1 Stakeholder Outreach

Affiliation/Organization	Key Topics Identified
Airport / Airline Industry Consultant (former Airline and Airport executive)	• possibilities for AI integration into aviation and related challenges; consider how to integrate more complex data gathering into big data sets • Applications for AI and machine learning to aviation, what is the macro vision for the industry? What role will airports/airlines/government etc. have? • Integration of UAS/UAM into airspace safely, replacing ground transportation, need to coordinate/ integrate with city planners • New skills needed from workforce to manage/deploy AI and new technology • Sustainability expansion to be broader, more ongoing community engagement
Aerospace Industry Trade Association representative	• Advanced air mobility, supersonics • Cybersecurity and interconnectivity • UAS communications integration, integration of all aircraft types into airspace • Lower altitude communications systems • Changes to certification processes/regulations as technology advances
Airport Trade Association representative	• Workforce changes due to looming retirement wave and new technology requiring new skills • Airports looking to structure more like corporations • Big data vs. privacy concerns, data sharing between entities, airports gathering their own data on passengers instead of getting from airlines • Monetizing data • AI – significant topic with profound impacts for aviation, suggests that ACRP should have a separate event on AI • UAM impacts in airspace, disrupt airport ground operations, ground transportation options
Airline Trade Association representative	• Workforce issues, pilot shortage is no longer a problem in short-medium term • Diversity of workforce will be a focus • Large fleet retirements in short term, delay in developing new aircraft because of depressed demand • Some noise and air quality pressures resolved in short-term • Changes to travel patterns, business travel because of COVID • COVID results in more technology integration, automation, fewer touch points • Climate policy and regulations to shape industry • Alternative fuels • Improved data sharing

Affiliation/Organization	Key Topics Identified
	• Better planning for disasters
Airport Consultants Trade Association representative	• Better customer data and technological integration • IT integration is a significant issue, how to develop infrastructure to accept new tech and facilitate passenger movement • Biometrics • Data and privacy concerns • Changing workforce needs (ex. will airports need medical officers?)
Cargo Airline Trade Association representatives	• Single pilot cargo aircraft or automated aircraft • Proliferation of drones and impacts on urban areas • Pilot shortage will come back once demand returns • Climate policy and environmental pressures will continue, development of biofuels • New revenue models
Airport Executives Trade Association representative	• Urban air mobility will continue to be a focus • Drone security and integration • IT integration and interoperability • Changing regional transportation models • Space tourism, commercial space
Former FAA official	• Changes in how we manage public health, take the CASC safety model to develop partnerships between aviation industry and government • Changes in aviation depend on economics and length of COVID recovery • Evolution in service for small airports, continue to see consolidation of service to larger airports away from smaller and rural airports • Culture change internationally to prioritize safety outcomes rather than punitive which discourages information sharing • Data and privacy concerns • Workforce needs – pilot shortage that was looming is delayed because of pandemic. Will it have shortages in the future, more automation, fewer people? • Noise, community acceptance, annoyance • Alternative fuels necessary for decarbonization • New entrants, drones, UAM, supersonics, autonomous vehicles, and aircraft • Risk mitigation and planning, redundancy and resiliency, network or networks • Hydrogen technology • Civil space tourism
Transportation Network Company (TNC)	• UAM will be significant factor in future of aviation • Changing business models and technology to address public health • Continued investment in new entrants, eVTOL, electric aircraft, supersonics • Low altitude airspace • Continued progress and investment in low carbon technologies
Airport Development Executive	• Evolving financial models so airports are not so dependent on passenger revenue • Flexible infrastructure

Affiliation/Organization	Key Topics Identified
	• Air traffic systems managing new entrants, space travel, and current aircraft, how can air traffic be used to reduce carbon • Better use of IoT

4 Annotated Bibliography

This section lists the primary documents and sources reviewed for this document along with a short summary of the contents of each source.

Airlines for America (A4A). 2020. A4A Applauds Approval of New Sustainable Aviation Fuel Pathway. https://www.airlines.org/news/a4a-applauds-approval-of-new-sustainable-aviation-fuel-pathway/

An Airlines for America (A4A) press release regarding the approval and publication of a new sustainable aviation fuel (SAF) specification that will further enable the use of SAFs by US airlines.

A4A. 2019. Deployment of Sustainable Aviation Fuel in the United States: A Primer. https://airlines.org/wp-content/uploads/2019/08/A4A-Sustainable-Fuel-Report_FINAL.pdf

An A4A primer that serves as a reference on SAF development and deployment in the US, as well as the challenges for commercial viability of SAF. It includes a tool for airlines, airports, and other stakeholders to work together to overcome obstacles, promote common understandings, and provide resources for information exchange and best practices. It outlines the environmental benefits of SAF implementation, the need for supply diversification and operational reliability, pathways to ensuring the safety and effectiveness of SAF, methods for ensuring lifecycle GHG emissions benefits, and a general outline the pathway to commercial viability. Additionally, several resources are provided for information of SAF implementation.

Aerospace Industries Association (AIA). 2016. Unmanned Aircraft Systems: Evolution and Opportunity, Regulatory Adaptation in a New Era of Flight. https://www.aia-aerospace.org/report/unmanned-aircraft-systems-evolution-and-opportunity/

An Aerospace Industries Association (AIA) report that offers perspectives for government and industry to collaborate on development of regulations, policies, and procedures for integrating unmanned systems into US airspace. Generally new rules or policies should: promote emerging technologies while maintaining aviation safety; achieve routine access for unmanned aircraft systems to all classes of airspace; harmonize with international regulations; and reform U.S. export policies.

AIA. 2019. What's next for Aerospace and Defense: A Vision for 2050. https://www.aia-aerospace.org/wp-content/uploads/2019/03/Vision-2050.pdf

AIA outlines the trends influencing the future of aviation through 2050, including technology and innovation, economic and societal trends, A&D policy and regulation, and industry dynamics. Major themes include universal connectivity and artificial intelligence, unmanned air traffic and new entrants, uncertainty around liability and intellectual property standards, pressure on public resources, intense competition for talent, and AI/pervasive cloud computing.

AIA. 2019. Blockchain in Aerospace and Defense: Establishing an industry approach to blockchain governance, standards, and participation. https://www.aia-aerospace.org/report/blockchain-in-aerospace/

An AIA white paper that describes the benefits of implementing blockchain for security, recordkeeping, and operational efficiency in the aviation and defense industry.

Airport Cooperative Research Program (ACRP). Emerging Issues for ACRP website. Accessed July 1, 2020: http://www.trb.org/ACRP/EmergingIssues.aspx

This website provides information on seven emerging issues identified by the ACRP Oversight Committee (AOC). Each of the seven issues has a separate link that provides background information, related research and future

research ideas. The seven topics include: 1) total customer experience; 2) challenges and opportunities for the airport business model; 3) impacts of innovating and emerging technologies; 4) airport sustainability; 5) enhancing resiliency of airports and interrelated systems; 6) airport workforce development; and 7) enhancing the aviation ecosystem.

Bastian, E. 2020. Consumer Electronics Show 2020 Opening Keynote. Delta. https://news.delta.com/video-delta-ceo-ed-bastian-ces-2020-opening-keynote-full-length

Delta Air Lines' CEO gives the keynote address at the 2020 Consumer Electronics Show, discussing airline innovations and how technology will influence the future of flight.

CAAFI. 2019. Current State of Alternative Jet Fuel Deployment. http://www.caafi.org/focus_areas/docs/Alternative_Jet_Fuel_Deployment_Status_July%202019.pdf

Commercial Aviation Alternative Fuels Initiative (CAAFI) presentation summarizes the state of SAF implementation in the US. It includes updates on SAF production, production facilities, commercial agreements, and other updates.

CAAFI. 2020. 2020 Goals and Priorities: Building on Industry Accomplishments and Addressing Remaining Challenges. http://www.caafi.org/files/2020_Goals_and_Priorities.pdf

The document includes a summary of CAAFI 2019 activities and accomplishments, including those related to a new ASTM fuel pathway qualification, successful SAF operational demonstrations by the business community (including airports and commercial airlines), advances in SAF production, use, and partnerships along with additional industry initiatives and commitments to sustainability. It also includes a statement and prioritization of the organizations' 2020 priorities.

Delta News Hub. 2020. Delta partners with IBM to explore quantum computing – an airline industry first. https://news.delta.com/delta-partners-ibm-explore-quantum-computing-airline-industry-first

The Delta News Hub article describes how Delta partnered with IBM to explore the first use of quantum computing in the airline industry. The two companies created a partnership to build practical quantum computing business cases. IBM will utilize Delta data to inform airline technology strategy and solve existing challenges.

Delta News Hub. 2020. Nothing artificial about this intelligence: Delta's industry-first machine learning platform minimizes customer inconvenience during tough operations. https://news.delta.com/nothing-artificial-about-intelligence-deltas-industry-first-machine-learning-platform-minimizes

The Delta News Hub article discusses how Delta has developed a full-scale digital simulation environment for its global operation that analyzes millions of operational data points and creates hypothetical outcomes based on historical data of Delta operations. The data will assist Delta in making decisions before, during, and after large-scale disruptions and will also serve as a post-mortem tool to explore where improvements to decisions and the decision-making process could be made. Delta planned to implement the machine learning platform in the Spring of 2020.

Domone, J. 2018. The challenges and benefits of the electrification of aircraft. Atkins Global. https://www.atkinsglobal.com/~/media/Files/A/Atkins-Corporate/Electrification%20White%20Paper%20-%20digital.pdf

The white paper dives into the history of electric and hybrid aircraft development, driven by the need for decarbonization of the aviation industry. It presents design specifications under consideration for the electrification of aircraft, including longer, thinner wings and reduced airframe mass. It also explores funding mechanisms for research and design. The white paper concludes with potential infrastructure needs and changes to operational trends that may result from electrification.

Dowling, S. 2018. "Norway's plan for a fleet of electric planes" BBC. https://www.bbc.com/future/article/20180814-norways-plan-for-a-fleet-of-electric-planes

The article discusses Norway's plan to transition all short-haul flights to electric aircraft by 2040. Though the current market of electric aircraft consists primarily of small, training aircraft, Pipistrel (a Slovenian aircraft manufacturer) intends to have built a 19-passenger hybrid commuter aircraft by 2025, and Zunum Aero (a subsidiary of Boeing) intends to have a 100-seat, 1500-mile aircraft viable by the late 2020s, with a 12-seat by 2022 and a 50-seater with a range of 1,000 miles by 2027. Avinor, which runs 46 airports throughout Norway, stated that one benefit of electric aircraft is that they are smaller and take up less space. Additionally, they will be much quieter, due to the lack of combustion needed to power the engine and the size of the aircraft, which will allow them to fly later at night and earlier in the morning, increasing operational efficiency.

Eagan, M. 2019. Proposed Supersonic Aircraft and Related Noise Issues. HMMH.

The paper explores the noise considerations and standards associated with development of supersonic aircraft for commercial operation. For supersonic aircraft under development, it will be difficult for aircraft manufacturers to meet Chapter 14 (Stage 5) noise standards. This paper explores the potential for FAA/ICAO to develop a supersonic-specific noise standard for emerging aircraft. The primary concern for supersonic aircraft will likely be issues related to the unique characteristics of the noise that they generate. Historically, there are strong community reaction to "new noise" in an environment. Airports will need to prepare for the introduction of new noise and related community expectations.

Etherington, D. 2020. SpaceX cautions on launch regulation that outpaces innovation. Tech Crunch. https://techcrunch.com/2020/01/30/spacex-cautions-on-launch-regulation-that-outpaces-innovation/

The article discusses the future of FAA regulations on commercial space launches and the associated challenges as innovation continues to build in the industry. There are similarities between the air transportation industry and space launch sector but also many differences which must be considered when making any new regulations.

ENAC Alumni. 2020. The Future of Airports: A Vision of 2040 and 2070. https://www.alumni.enac.fr/global/gene/link.php?doc_id=653&fg=1

The white paper provides an in-depth analysis of the future of aviation both 20 years out and 50 years out (2040 and 2070, respectively). It explores themes and drivers for 10 different industry influence areas, including sustainable business models and funding, smart airports/IT, security threats, safety, airside/airspace compatibility, passenger terminals and customer experience, operational performance and resilience, mobility and communities, sustainability and airport citizens, and human resources and education.

European Aviation Artificial Intelligence High Level Group. The FLY AI Report: Demystifying and Accelerating AI in Aviation/ATM". March 5, 2020. At. https://www.eurocontrol.int/publication/fly-ai-report

The FLY AI Report was produced by a consortium of government, industry, and academic partners. It provides an overview of artificial intelligence (AI), and the applications for aviation and air traffic management. The report focuses on Europe but conclusions can be applied globally. It provides examples and case studies of AI use in aviation, and the current regulatory framework that applies to AI (in Europe). The report provides recommended actions to accelerate the development and deployment of AI in European aviation and ATM, culminating in an action plan.

Federal Aviation Administration (FAA). 2019. 2017/2018 National Aviation Research Plan (NARP). FAA. June 2019. https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/2017_2018NARP.pdf

The NARP is a submission to Congress from FAA to describe how the agency implements its Research and Develop plans to address the Department of Transportation's three strategic goals: 1) Safety: reduce transportation-related

fatalities and serious injuries across the transportation system; 2) Infrastructure: invest in infrastructure to ensure safety, mobility and accessibility to stimulate economic growth, productivity and competitiveness for American workers and businesses, and 3) Innovation: lead in the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's transportation system. This document includes information about the planned R&D budget for programs in the FAA's research portfolio and provides the reader with information on the agency's priorities for the next 5 years. This in turn provides a snapshot of the technologies under development which is relevant for understanding the near and mid-term developments in the aviation industry.

Federal Aviation Administration (FAA). 2019. FAA Strategic Plan 2019-2022. FAA. 2019. https://www.faa.gov/about/plans_reports/media/FAA_Strategic_Plan_Final_FY2019-2022.pdf

The FAA Strategic Plan outlines the agency's strategic goals and objectives for fiscal years (FY) 2019 - 2022. It aligns with the U.S. Department of Transportation's (DOT) Strategic Plan and describes four-year goals the agency will pursue and the initiatives and activities undertaken to achieve the goals (goals include Safety, Infrastructure, Innovation and Accountability). Annual priorities are outlined as well as near term forecasts /trend for the commercial aviation industry: growth in passengers and cargo operations, growth in unmanned aircraft systems and commercial space operations, increase in data use and automation, increase in international competition

Federal Aviation Administration (FAA). 2020. FAA Aerospace Forecast: Fiscal Years 2020-2040. FAA. https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2020-40_FAA_Aerospace_Forecast.pdf

The FAA Aerospace Forecast provides information on anticipated trends in global commercial aviation industry, with a focus on economic indicators such as passenger traffic, revenue, general aviation, cargo and commercial space forecasts. The report also covers impacts to FAA workforce and facilities, air traffic, The report was issued in early 2020 just as COVID-19 impacts were beginning to be felt within the industry, and it therefore does not account for the short, medium or long term impacts of the pandemic.

Federal Aviation Administration (FAA). 2020. Commercial Space Integration into the National Airspace System, Concept of Operations. FAA. May 2020. https://www.faa.gov/space/airspace_integration/media/Final_CSINAS_ConOps.pdf

This Concept of Operations (ConOps) document is an update to the 2014 Space Vehicle Operations ConOps and describes the concepts for managing the NAS for commercial space launch and reentry vehicles. The concepts outlined in this document would reduce inefficiencies for current airspace users (14 operational shortfalls are described in this report), including reduction of delays, reduced route deviation, reduced fuel burn and emissions, and for commercial space operators, the benefits are mainly from increased availability of launch and reentry sites.

Ferrier, L. 2016. Electric Airports. MIT. https://cmsw.mit.edu/wp/wp-content/uploads/2016/05/Lochie-Ferrier-Electric-Airports.pdf

The paper explores the potential overhauls to airport infrastructure needed to support electric aircraft and vertical take-off and land (VTOL) operations. It explores how space required on the airport may drastically change to support emerging aircraft operations, as a transition to VTOL would decrease the capacity necessary for runways for lateral landings. The implementation of electric aircraft and VTOL are a possible a solution for reducing taxiway queuing, delays, and increasing the safety of take-off and landing.

Fisch, J., Elliot D., and Tarantino, W. 2019. Electrification in aviation: Identifying opportunities and challenges. Thomson Reuters. https://media2.mofo.com/documents/190619-electrification-aviation-opportunities-challenges.pdf

The white paper explores the challenges and opportunities related to integrating electric aircraft, including infrastructure, environmental impact, and regulatory considerations. Specifically, it raises considerations for airlines and airports in terms of the role of airports, including the potential for airports to become energy storage facilities

for local utilities and the grid at-large, providing a potential new source of revenue for airports. As onsite charging infrastructure is developed, airports should consider potential financial opportunity. The paper also discusses the potential reduction in noise impacts due to smaller, lighter aircraft without combustion engines. It is expected that reduction in noise would allow for longer hours of operation into the night and early morning, and potentially new flight paths that are currently off-limits due to land use compatibility issues. From this perspective, electrification has the potential to drive growth in the aviation industry as noise impacts are one of the primary limiting factors for airport/aviation growth. Additionally, the paper calls for the development and implementation of common standards, regulatory frameworks, and infrastructure across states, municipalities, and continents related to electrification in aviation.

Future Travel Experience. 2020. 12 technology trends for airlines and airports to focus on in 2020. https://www.futuretravelexperience.com/2020/01/12-technology-trends-for-airlines-and-airports-to-focus-on-in-2020/

The article provides an overview of aviation technology application trends expected to continue to make headway in 2020. This includes covering the latest industry innovations: robotics, autonomous vehicles, airport digital twins, artificial intelligence (AI), machine learning, virtual reality (VR), immersive experiences, 5G, expanded inflight WiFi, biometrics, sustainability, assistive technology for increased accessibility, hearable/wearable voice technology integration, eVTOL and autonomous travel, increased airline and airport collaboration with technology startups and businesses.

Future Travel Experience. 2020. Top tech, disruptors and the next decade of aviation, according to air transport leaders – Part 1. https://www.futuretravelexperience.com/2020/01/top-tech-disruptors-and-the-next-decade-of-aviation-according-to-air-transport-leaders-part-1/

The article provides insight from three aviation industry experts who provide opinions on emerging short-term technology trends and their viability, along with general industry advice. Experts include representatives of Southwest Airlines, Vantage Airport Group, and Bangalore International Airport Limited (BIAL).

Future Travel Experience. 2020. Top tech, disruptors and the next decade of aviation, according to air transport leaders – Part 2. https://www.futuretravelexperience.com/2020/02/top-tech-disruptors-and-the-next-decade-of-aviation-according-to-air-transport-leaders-part-2/

The article provides insight from five aviation industry experts who give their opinion on emerging short-term technology trends and their viability, along with general industry advice. Experts include representatives of Los Angeles World Airports, American Airlines, Hamad International Airport (Qatar), Vancouver Airport Authority, and Japan Airlines.

Graver, B. Zhang, K., and Rutherford, D. 2019. "CO2 emissions from commercial aviation, 2018" International Council on Clean Transportation (ICCT). https://theicct.org/sites/default/files/publications/ICCT_CO2-commercl-aviation-2018_20190918.pdf

The ICCT working paper describes a methodology for determining a global commercial aviation carbon emissions inventory for 2018 using historical flight data from national and international agencies in combination with "Piano aircraft emissions modelling software." Carbon emissions from passenger aircraft, belly freight, and dedicated freight are all accounted for, totaling 918 million metric tons (MMT) of CO2, representing 2.4% of global CO2 emissions. The paper provides additional details related to methodology, data analysis, and industry CO2 emissions statistics.

International Air Transport Association (IATA). 2011. Vision 2050. Accessed at: https://www.iata.org/contentassets/bccae1c5a24e43759607a5fd8f44770b/vision-2050.pdf

The International Air Transport Association (IATA) report provides a vision for the airline industry into 2050, focused on the industry's ability to maintain profitability, meet the needs of a changing consumer base, while adjusting to changes in infrastructure and technology. It addresses that efforts are needed to break down the silos that dominate the industry's value chain. It describes a desire to challenge governments to make a shift toward commercial freedoms and shifting the industry's center of gravity away from the west and toward Asia-Pacific.

International Air Transport Association and School of International Futures. 2018. Future of the Airline Industry 2035. https://www.iata.org/contentassets/690df4ddf39b47b5a075bb5dff30e1d8/iata-future-airline-industry-pdf.pdf

IATA's Industry Affairs Committee (IAC) commissioned a study by the School of International Futures (SOIF) to envision the future of the airline industry into 2035. The study is intended to identify opportunities and challenges that will face the airline industry, facilitate dialogue for airlines and airline alliances to address these opportunities and challenges, and create partnerships between governments to facilitate sustainable air travel and global connectivity. It seeks to identify actions that can be taken in the near term to be better prepared for the future of aviation.

International Air Transport Association, "IATA Forecast Predicts 8.2 Billion Air Travelers by 2037," Press Release No. 62, October 24, 2018. Accessed at: https://www.iata.org/en/pressroom/pr/2020-07-28-02/

This press release summarizes IATA's global forecast for passenger growth in the aviation industry to 8.2 billion passengers by 2037. The forecast is based on an anticipated compound annual growth rate of 3.5 percent. The forecast also highlights a shift in traffic growth from the west to the east.

International Air Transport Association, "Recovery Delayed as International Travel Remains Locked Down", Press Release No. 63, July 28, 2020. Accessed at: https://www.iata.org/en/pressroom/pr/2020-07-28-02/

The press release updates prior forecasts of aviation industry recovery from COVID-19, predicting a return to pre-COVID traffic levels in 2024. The growth will start with short-haul, domestic traffic before the international markets rebound. The delayed recovery is attributed to poor performance of the U.S. in containing the virus, lack of consumer confidence and reduced corporate / business travel. The traffic rate in 2020 is anticipated to be 55 percent of 2019 levels, rising to just over 60 percent in 2021.

Kennedy, Catherine. 2020. Future of Airports: Change is Coming. New Civil Engineer. May 11, 2020. https://www.newcivilengineer.com/the-future-of/future-of-airports-change-is-coming-11-05-2020/

In this article the author discusses trends that may accelerate due to COVID-19, such as increases in point-to-point travel and a move away from hub and spoke operations; thriving large hub and international airports and less service to smaller airports; increase in multi-modal transportation networks and planning (air to rail); touchless technology and increased personal space needs; environmental and sustainability challenges.

Klauber, A. 2020. Delta and The World Need Carbon Offsets To Stop Global Warming. Forbes. https://www.forbes.com/sites/adamklauber/2020/02/17/delta-air-lines-carbon-neutral-offsets-global-warming/#53e1d84f61ed

The article describes how carbon offsets are an economically viable option for airlines to reduce their environmental impact. The author argues that carbon offsets are a short-term measure to begin to remove CO2 from the atmosphere as the industry works to replace conventional fuel with SAF. Many existing GHG accounting schemes do not recognize offsets as an emissions reduction measure but airlines should consider them especially since current SAF supplies are limited and additional feedstocks are needed for it to be a more viable global aviation carbon reduction measure.

Lang, Catherine. 2020. "Statement of Catherine Land, Senior Advisory, Federal Aviation Administration Before the Committee on Transportation and Infrastructure, Subcommittee on Aviation, United States House of

Representatives, Looking Forward: The Future of America's Aviation Maintenance and Manufacturing Workforce". (02/11/2020). https://cms7.dot.gov/testimony/looking-forward-future-america%E2%80%99s-aviation-maintenance-and-manufacturing-workforce

The testimony of Catherine Lang, Senior Advisor to the FAA Administrator on Aviation Workforce Outreach before the House T&I Aviation Subcommittee describes the FAA's efforts to identify workforce needs, recruit and train future workforce to maintain the safety and integrity of the National Airspace System (NAS). Trends such as pilot and aircraft maintenance worker shortages are discussed, along with emerging trends in aviation careers (for example commercial drone pilots). Lang describes her role leading the Aviation Workforce Steering Committee and industry partnerships to address workforce needs. FAA educational and training initiatives discussed including STEM and AVSED, and USAF collaboration.

National Air Transportation Association (NATA). 2019. Urban Air Mobility: Considerations for Vertiport Operation. https://www.nata.aero/assets/Site_18/files/GIA/NATA%20UAM%20White%20Paper%20-%20FINAL%20cb.pdf

The National Air Transportation Association (NATA) white paper provides a gap analysis and literature review of UAM. It is intended to serve as a resource for UAM stakeholders to facilitate collaborative dialogue as the industry evolves. It addresses the current regulatory gap and FAA oversight authority for 'vertiports.' It explores the lack of standardized regulation as both a hindrance for investment but also an opportunity to shape regulation for this emerging market. NATA explores UAS considerations related to safety, security, passengers, signage, marking, lighting, emergency response, and provides summaries of where current regulation would be applicable to UAM.

National Academies of Sciences, Engineering, and Medicine 2016. Identifying and Evaluating Airport Workforce Requirements. Washington, DC: The National Academies Press. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_webdoc_028.pdf

The ACRP Guidebook identifies and evaluates workforce requirements for airports. It provides workforce planning and development strategies to prepare airports for emerging challenges. It is based on research completed for ACRP Web-Only Document 28 which identified changes occurring in the airport industry that will impact airport workforce needs such as: new technologies, financial and commercial pressures, political pressures, regulatory pressures, and impending retirements. The chapters give frameworks and suggestions for each workforce capacity need identified, which fall into 3 major categories: attracting new talent, building internal staff capacity, and planning for future workforce needs. It provides best practices and effective strategies to help airports build and sustain a talent pipeline equipped to meet emerging capacity and technology requirements.

National Academies of Sciences, Engineering, and Medicine 2015. Guidebook on Best Practices for Airport Cybersecurity. Washington, DC: The National Academies Press. https://doi.org/10.17226/22116.

This ACRP Guidebook provides background information on cybersecurity and cyber threats for airport practitioners, as well as guidelines on how to address these vulnerabilities in a multi-layered approach. Best practices from other industries such as health care and financial services are provided.

National Academies of Sciences, Engineering, and Medicine 2018. Guidebook on Building Airport Workforce Capacity. Washington, DC: The National Academies Press. https://doi.org/10.17226/25263.

This ACRP Guidebook identifies and evaluates workforce requirements for airports. It provides workforce planning and development strategies to prepare airports for emerging challenges. It is based on research completed for ACRP Web-Only Document 28 which identified changes occurring in the airport industry that will impact airport workforce needs such as: new technologies, financial and commercial pressures, political pressures, regulatory pressures, and impending retirements. The chapters give frameworks and suggestions for each workforce capacity need identified, which fall into 3 major categories: attracting new talent, building internal staff capacity, and planning for future workforce needs. It provides best practices and effective strategies to help airports build and sustain a talent pipeline equipped to meet emerging capacity and technology requirements.

National Aeronautical and Space Administration (NASA). 2019. NASA Aeronautics Strategic Implementation Plan: 2019 Update. https://flight.nasa.gov/pdf/armd-strategic-implementation-plan.pdf

This document outlines NASA's Aeronautics Research Mission Directorate (ARMD) strategy and six strategic thrusts (building off the first ARMD strategic plan published in 2015): 1) safe, efficient growth in global operations; 2) innovation in commercial supersonic aircraft; 3) ultra-efficient subsonic transports; 4) safe, quiet and affordable vertical lift air vehicles; 5) In-time system-wide safety assurance; 6) assured autonomy for aviation transportation. The 2015 plan included low carbon propulsion as a strategic thrust as well. The plan identifies the aviation community's vision for each of the six areas and ARMD's role over three time periods, near term (2015-2025), mid-term (2025-2035) and far term (2035+). The mega trends that are shaping NASA's research in these areas are: 1) global growth in demand for high-speed mobility, 2) global climate change, sustainability and energy use, which present sever challenges to affordability and sustainability, and 3) technology convergence (specifically, convergence in industry sectors such as materials, manufacturing, energy and comms technologies that have the ability to transform the aviation industry.

O'Neil, S. and Sumers, B. 2019. The Rise of Smart Airports: A Skift Deep Dive. https://skift.com/2019/11/20/the-rise-of-smart-airports-a-skift-deep-dive/

The article explores the challenges and creative solutions airports are using to implement smart airport technologies, from facial recognition in Daxing Airport in Beijing to iris scanning at Dubai Airport. The authors suggest that airport planning, design, and construction for the future should consider integration of smart technology and design public spaces accordingly. Many airlines and airports are focusing on improving the passenger experience as high-expense travelers are more likely to choose airlines where layovers occur at airports at which they have good experiences. Ultimately, the authors express a call for 'digital master-planning' in airports to address growing demand for improved passenger experience, especially in the US, where airports and US Customs and Border Control have fallen behind in integrating smart tech, resulting in delays and queues.

Shieber, J. 2020. Playing traffic cop for drones in cities and towns nets Airspace Link $4 million. TechCrunch.com. https://techcrunch.com/2020/01/23/playing-traffic-cop-for-drones-in-cities-and-towns-nets-airspace-link-4-million/

The article presents a profile on the startup company, Airspace Link, that has been launched to help manage airspace congestion due to the use of drones. The technology integrates with mapping tools used by municipal governments, including ESRI, which allows it to pair government mapping capabilities and services. It allows the FAA to create approved air routes for drones, connects drone operators with local governments, collects fees for registering drones, provides a service for permitting drone operators, and allows people to opt-in or out of drone deliveries.

Transportation Security Administration. September 2018. TSA Biometrics Roadmap for Aviation Security & the Passenger Experience. https://www.tsa.gov/sites/default/files/tsa_biometrics_roadmap.pdf

The roadmap document presents TSA's comprehensive vision for the future, leveraging biometrics technologies to modernize and streamline identity verification, improve security, and increase efficiency. Strategic drivers for using facial recognition to improve TSA security capability includes the changing operational landscape, technological advancement of biometric matching algorithms and data (including facial images), consumer cultural shifts towards use of biometrics in everyday life, rising travel volumes and staff shortages, and the emerging business case for collaborative partnerships between TSA and industry. The roadmap includes the following four goals for TSA's biometrics vision: "partner with CBOP on biometrics for international travelers, operationalize biometrics for *TSA PreCheck*™ travelers, expand biometrics to additional domestic travelers, and develop supporting infrastructure for biometric solutions."

U.S. Department of Transportation. 2020. Our New Mobility Future: A U.S. DOT Volpe Center Thought Leadership Series. https://www.volpe.dot.gov/sites/volpe.dot.gov/files/docs/events/64101/mobilityseriesreport508.pdf

The report includes proceedings from the U.S. DOT Volpe Center thought leadership series, "Our New Mobility Future," held in 2019 which convened leaders in the transportation industry to collaborate on emerging transportation challenges and envision innovative solutions. Discussion and presentations focused on addressing U.S. DOT strategic priorities: safety, infrastructure, innovation, and accountability.

Unmanned Airspace. 2019. Drone delivery services growing at extraordinary rate – new Unmanned Airspace survey. https://www.unmannedairspace.info/uncategorized/drone-delivery-services-growing-at-extraordinary-rate-new-unmanned-airspace-survey/

The article summarizes the growth of the drone delivery market in 2019, with 45 countries implementing or planning to implement drone delivery services. This includes long-range transportation of freight overseas. Currently, China is leading the way in terms of scale, number, and complexity of drone operations while Canada and US are increasing services, though primarily in experimental phases.