U.S. Department
of Transportation
**Federal Aviation
Administration**

Office of the Administrator

[redacted]

February 11, 2022

Dr. R. John Hansman, Ph.D.
Chair, Research, Engineering and
Development Advisory Committee
Massachusetts Institute of Technology
[redacted]

Dear Dr. Hansman:

Thank you and the Federal Aviation Administration's (FAA) Research, Engineering, and Development Advisory Committee (REDAC) for your November 23, 2021, letter providing recommendations for the Fiscal Year (FY) 2024 Research and Development (R&D) Portfolio. The awareness and knowledge of the dynamic aviation, aerospace and related industry community subject matter professionals of REDAC promote excellent insight contributing to the successful implementation of various R&D programs within the FAA. The important guidance generated during the REDAC Summer-Fall 2021 virtual meeting held on October 20, 2021, is much appreciated.

The broad range of topics discussed during the meeting addressed critical elements, diverse strategies and roadmaps needed to fulfill technical requirements essential for continued safety within the National Airspace System (NAS). This includes the important discourse concerning the awareness of the significant impact and demands, near-term and long-range, on the aviation spectrum. It is essential that the Agency evaluate current and anticipated usage to maintain the bandwidth needed for aviation and non-aviation related endeavors.

The Committee's assessment of FAA's R&D portfolio promotes positive guidance and direction yielding informed leadership that supports the sustaining of effective aviation program policies. Experts with proficiencies covering the spans of NAS Operations, Aircraft Safety, Human Factors, Airports and Environment and Energy contributed to this important assessment on research program areas. Including the acknowledgement that the FAA continues to accomplish many tasks successfully in spite of the delays or interruptions presented by less than optimal conditions due to impacts of the pandemic.

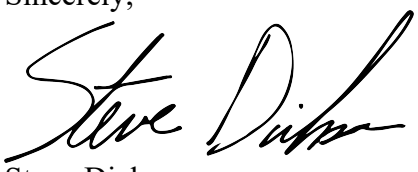
Notable examples of successful achievements within the last year included several environmental programs. The FAA continues to provide key influence in this area and we appreciate your awareness of the efforts. The steadfast advice of REDAC supports the research

endeavors of the many technical advisors, scientists, directors and teams in the Environment and Energy programs.

I have reviewed the 22 recommendations submitted by the REDAC. The enclosed FAA Response Report reflects our Agency replies to these recommendations. The FAA Response Report includes our dispositions for the total of 22 recommendations made by the five Subcommittees and authorized by the parent REDAC Committee as follows: Environment and Energy (4); NAS Operations (6); Airports (2); Human Factors (2); and Aircraft Safety (8). The FAA fully concurs with 20 twenty of 22 items, and partially concurs with noted exception, the two remaining recommendations submitted in the report. The FAA has identified efforts to address the partial concurrences and provided justifications for those suggestions that are unable to be fully completed at this time.

We will continue to address all of the Committee's recommendations and incorporate those items as applicable to maintain our R&D portfolio that addresses the safety, efficiency, and capacity of the air transportation system in an environmentally responsible manner.

Sincerely,



Steve Dickson
Administrator

Enclosure

Research, Engineering, and Development Advisory Committee (REDAC)
Guidance on the FY 2024 Research and Development Portfolio

Subcommittee on Environment and Energy

General Observations: The Environment and Energy (E&E) Subcommittee of the Federal Aviation Administration (FAA) Research, Engineering and Development Advisory Committee (REDAC) focused on reviewing the RE&D Portfolio for the Office of Environment and Energy that was developed based on the RE&D budget for Fiscal Year (FY) 2021 that was enacted on December 27, 2020 (RE&D received $198M). We were advised that the FY 22 budget had a request for $258.5M for RE&D. During the meeting, the staff from the Office of Environment and Energy (AEE) provided updates on all of the major research projects within the portfolio. Work on programs such as the Aviation Sustainability Center of Excellence (ASCENT), Continuous Lower Energy, Emissions and Noise (CLEEN), Commercial Aviation Alternative Fuels Initiative (CAAFI), and the Aviation Environmental Design Tool (AEDT) have been progressing. The updates highlighted accomplishments, since our last meeting that have been realized both locally and on the international front directly linked to the ongoing research. Listing the individual accomplishments and their impacts on many of the different facets of aviation is not realistic during this presentation, but these accomplishments further validate the need for sound research when developing regulations, policies, and procedures.

Despite the ongoing COVID-19 pandemic impacts, the Subcommittee continues to be very impressed with the job the leadership and staff of AEE have been doing. The presentations outlined a high level of communication between AEE staff and their partners to continue these necessary research efforts, but they also showed the challenges associated with COVID-19 restrictions and how they have impacted some projects.

As was highlighted in our March 21 briefing, there is a heightened awareness about the environmental impacts associated with the aviation industry. The current administration has made a commitment to climate change and has issued an Executive Order 14008 that outlines its goals. It has a commitment towards "reducing the aviation sector's emissions in a manner consistent with the goal of net-zero emissions for our economy by 2050". The government has announced its intention to advance the development and deployment of sustainable aviation fuels and to maintain a leadership position at the world level with organizations such as the International Civil Aviation Organization (ICAO). The establishment and funding of the new Sustainable Aviation Fuel Grand Challenge aimed at dramatically increasing the production of sustainable aviation fuels are initiatives that demonstrate U.S Leadership. We know that partnerships with other governments, other federal agencies, our Centers of Excellence, and Private Corporations who are involved in the research portfolios that AEE has in place provide results and are a very effective vehicle to conduct and coordinate future research and maximize limited resources.

The Subcommittee believes that AEE is doing a good job and has once again presented a balanced portfolio. We believe that AEE has added research projects that address the priorities that the Subcommittee has previously identified. The Subcommittee believes that additional research will probably be needed within CLEEN and ASCENT to support the government's

initiatives. The Subcommittee members realize that there is still additional research required to address ongoing areas of concern.

The Subcommittee is comfortable that AEE, the ASCENT Center of Excellence, CLEEN Program, CAAFI, and others efforts, as well as their partners, including National Aeronautics and Space Administration (NASA), are working together to realistically address the impacts that the COVID-19 pandemic has had on continued research efforts. The long-term impacts of this pandemic on the citizens of the world and the aviation industry are still not known, but we believe that AEE has a proven blueprint that can be used to address future research needs. Guided by the updates and presentations, the Subcommittee has proceeded with the following "Findings and Recommendations." The recommendations offered are all for inclusion in the REDAC report.

Finding: Sustainable Aviation Fuels (SAFs) - We know that the Sustainable Aviation Fuel (SAF) Program, including efforts in the Commercial Aviation Alternative Fuels Initiative (CAAFI), Continuous Lower Energy, Emissions and Noise (CLEEN), and Aviation Sustainability Center of Excellence (ASCENT) are a critical component of the industry's global emission reduction strategy. In order to meet the federal goals of increasing the production of SAFs to at least 3 billion gallons per year by 2030; demonstrate new technologies that can achieve at least a 30% improvement in aircraft fuel efficiency, there will need to be an increase in the research projects within the ASCENT portfolio. The same can be said if we hope to develop fuels that can be blended above 50% in today's fleet of aircraft. The current research has helped with the creation of a number of companies that have the potential to benefit the rural economies of several states and the U.S. Aviation industry. In 2020, 4.6M gallons of was used by the U.S. Aviation Industry, a 190% increase over 2019, and 2021 were on pace to exceed 2020 levels. The establishment of the Sustainable Aviation Fuel Grand Challenge will ensure that the U.S. Government and the private sector are working together to address aviation sector emissions. The creation of the SAF MOU between the DOE, DOT, and USDA will initiate and commit resources to the necessary research, development, and deployment. There are ongoing efforts to ensure that alternative jet fuels are in CORSIA through ICAO CAEP. The FAA must also use their research to address the challenges from other countries/companies that are proposing other alternative fuels as realistic or long-term solutions.

Recommendation 1: The Subcommittee agrees with the mandate proposed by the current administration that the work on Sustainable Aviation Fuels (SAF) is a critical component for the reduction of aviation sector emissions and supports the SAF Grand Challenge. Since the maturation of the Sustainable Aviation Fuel program will be a major environmental benefit for the public, will create a new industry within the U.S. that benefits rural America, and will benefit the U.S. aviation industry, we strongly recommend that the FAA AEE continues to allocate funds for the continuation of research on SAFs. We also strongly recommend that any additional funding that AEE receives should be used to accelerate this program in order to accomplish the goal of being able to supply 100% of the aviation fuel needed in 2050. The FAA must maintain a leadership role in the development of SAFs to ensure that the rules to be considered at a global level (ICAO) will be beneficial to the U.S. industry.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address it – The U.S. government and industry both understand the importance of SAF to reducing the greenhouse gas emissions of aviation, both in

the near term and in the long term. This has been captured by the commitments of both the U.S. government in the SAF Grand Challenge as well as from domestic airlines who have committed to using 3 billion gallons of SAF by 2030. We in the FAA are working with DOE and USDA, as well as stakeholders from across government, academia, and industry, to develop a roadmap for SAF research, development, and deployment as required under the SAF Grand Challenge Memorandum of Understanding. While this roadmap is being developed, we are also continuing our long-standing efforts in ASCENT, CAAFI, and CLEEN to support SAF development through testing, analysis, and coordination activities. Aspects of this work have taken on expanded importance in the last year as Congress is developing a SAF Blenders Tax Credit that would leverage the life cycle greenhouse gas accounting methods of the ICAO Carbon Offsetting and Reduction System for International Aviation (CORSIA), which were developed under the leadership of the FAA AEE. We are also looking to expand our efforts on SAF. Once the FY22 budget is enacted, we intend to fund testing to support the certification and qualification of 100% SAF for use with today's fleet of aircraft, as well as to conduct research on the full SAF supply chain to identify opportunities to both reduce the production cost of SAF while also reducing life cycle greenhouse gas emissions. We also intend to conduct measurements to understand the benefits of using SAF to reduce the impacts of aviation-induced cloudiness on the climate. To reach our goal of net zero greenhouse gas emissions from the aviation sector by 2050, we will need to be able to use 100% SAF in our existing fleet of aircraft and this SAF will need to provide a maximum reduction in climate impacts, at minimum economic cost.

Finding: Public Private Partnerships - The Subcommittee continues to acknowledge and support the fact that the Office of Environment and Energy (AEE) have proven over decades to be very good stewards of taxpayer money. The leadership team at AEE has used their budgeted amounts to conduct and coordinate the research necessary to produce informed, data driven policies, facilitate technological advances in the aviation industry, and produced models and data that have positioned the U.S. as both a State leader at ICAO CAEP and on the global aviation stage. The execution of this research portfolio has been accomplished by working collaboratively with private industry, major universities through the ASCENT Center of Excellence, other Federal Departments and Foreign Governments. Three quarters of Environment and Energy research funds generate 100% plus cost matching from non-federal partners (CLEEN, CAAFI, and ASCENT). This leverages scarce FAA R&D funds to accomplish significant advances and improvements. In addition, we believe that government funding has been used and executed effectively to lower the risk of new and emerging technologies such that they can be adopted by industry. The benefits of these partnerships has clearly been proven over time and is very apparent in most of the current projects. The maturation of new technologies has delivered improved environmental performance and has enabled aviation system growth and associated positive economic impacts. In order to comply with Executive Order 14008 on Tackling the Climate Crisis, there will be an increased reliance on these Public Private Partnerships.

Recommendation 2: Whereas the Subcommittee continues to endorse Public Private Partnerships like the CLEEN, CAAFI and ASCENT programs to leverage resources, we believe that the FAA will not be able to accomplish any of the priorities set forth by the current administration without allocating robust funding for these programs. AEE should be given the flexibility to utilize any additional funding that it receives in FY22, FY23 and FY24 on projects

within its portfolio that will enhance and accelerate existing research to best address the current federal mandates.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address it - The FAA understands the importance of maximizing the impact of taxpayer dollars. By partnering with industry, academia, federal agencies, and foreign governments, we are making our research investments go further by leveraging our collective resources. By having universities in ASCENT work directly with industry partners, it increases the likelihood that the industry will use the research product to reduce noise and emissions. By requiring cost share within CLEEN, we increase the likelihood that the industry partner will use the new technology to reduce noise and emissions. CLEEN, CAAFI, and ASCENT have all been successful because of their strong engagement with the industry. Each of these programs has had strong partnerships with and support from the industry for over a decade. The FAA recently awarded the contracts for the third phase of CLEEN, which ensures the continuation of this model of public-private partnership on aircraft technology development. We are also talking to our industry partners about how CAAFI could best help us meet our 2030 SAF production goals. We intend to use the enacted FY22 budget to expand our efforts in CLEEN, CAAFI, and ASCENT, and we will consider this recommendation as we develop the FY23 and FY24 budgets.

Finding: Global Leadership - It is evident that the FAA AEE currently maintains a leadership role in ICAO CAEP and has been the driving force behind the push for data-driven rulemaking. Based on the commitments made by the current administration on Climate Change, the Subcommittee firmly believes that maintaining the U.S. global leadership position at ICAO CAEP is essential and advantageous to the U.S. aviation industry and will allow the U.S. government to defend its positions based on scientific research. Previous work that has been done with ASCENT and the Volpe Center has clearly allowed the FAA to maintain a scientifically supported position at ICAO CAEP. The close collaboration with NASA at ICAO CAEP is also clearly supporting global leadership. Anything that jeopardizes ongoing research at AEE will impact the FAA/U.S. global leadership position at ICAO CAEP.

Recommendation 3: The Subcommittee recommends the continuing strong support of all research efforts/programs that will allow the FAA and the U.S. to maintain its current global leadership position at ICAO CAEP. It is the belief of the Subcommittee that if the FAA/U.S. does not maintain its leadership position at ICAO CAEP, it will not be able to influence policy/rulemaking, and this could have a significant negative impact on the U.S. aviation industry.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address it - The FAA appreciates the support of the Subcommittee for our ICAO CAEP activities and the importance of continued U.S. leadership therein. We have made considerable investments over the years to support the work of ICAO CAEP, and that continues today, as FAA leadership is critical to securing U.S. objectives at ICAO. ICAO relies on FAA-funded research and analyses to inform its environmental work. Research efforts led by FAA AEE will be central to the deliberations that will be taking place leading up to and through the ICAO Assembly on a long-term aspirational goal for international aviation CO_2 emissions. Much of this analytical work was done by ASCENT COE universities and the Volpe Center, under the direction of FAA, in close collaboration with NASA and industry. We are in the

process of standing up two new ASCENT projects to support CAEP standard-setting efforts. These projects will help us understand the opportunities to reduce aircraft noise and carbon dioxide emissions through the standard-setting process as well as explore metric systems that could be used to control full-flight nitrogen oxide emissions. These new projects will enable us to provide intellectual leadership to the international community as we seek means to reduce noise and emissions from aircraft. We are also continuing to fund research to support the development of noise standards for supersonic aircraft and are examining how our ongoing research could support work on noise standards for drones and advanced air mobility vehicles.

Finding: Noise Research - Aviation noise is and will continue to be one of the biggest environmental impacts related to the aviation industry, and it requires ongoing research in order to address the concerns of the citizens. The Subcommittee realizes that there is much research that is still necessary to address the ongoing topic of aviation noise. Whether there are new technologies or new procedures that can be implemented to help reduce the impacts of noise as the aviation industry rebuilds needs to be evaluated. Historically, advances in aircraft technology have been the major factor in reducing aviation's environmental impacts. But the Subcommittee understands that there is about a seven-year lag between flight testing technology and its appearing in the fleet. Therefore if we want to consider any new technology being introduced into the fleet in early 2030, we need to invest in the research now. The use of government resources during the initial research stages helps mitigate technology risk and incentivize private companies to invest and develop cleaner, quieter technology. AEE has seen a number of research projects that have contributed to more fuel-efficient and quieter aircraft. They have also developed new operational procedures that have reduced the noise impacts in communities in and around airports. There are a number of new research projects that have been added to address issues related to new entrants into the aviation system. There also have been significant upgrades made to the Aviation Environmental Design Tool (AEDT). AEE has established an AEDT User Review Group for ideas and feedback in order to ensure that the tool is beneficial to the actual users. FAA has also launched an initiative to partner with airports to gather more noise data resulting from noise complaints. Finally, AEE is working with the industry to accelerate the development of technologies that reduce noise through the CLEEN Program.

Recommendation 4: The Subcommittee strongly supports the prioritization of the noise research that will support informed decision-making, the introduction of new entrants to the national air space, and enable Next Generation Air Transportation System (NextGen) deployment.

FAA Response: The FAA concurs with the Committee's findings and recommendations and is undertaking the following actions to address them. The FAA is committed to developing meaningful and equitable solutions to address the complex and nuanced issue of aviation noise. On January 13, 2021, we published an Overview of FAA Aviation Noise Policy and Research Efforts on the Federal Register that contained a comprehensive overview of FAA R&D efforts on noise. We will continue to support the R&D portfolio outlined in the notice while also looking for opportunities to expand our work. We are also conducting a policy review that builds on our work to advance the scientific understanding of noise impacts, as well as the development of analytical tools and technologies.

In addition to our long-standing efforts to address noise from the existing commercial fleet of aircraft and helicopters, as was captured in the finding, we are also using our research portfolio

to address noise from unmanned aircraft (UA) and advanced air mobility (AAM) vehicles. Through ASCENT, work is ongoing to explore concepts to model noise from UA and AAM, including with the Georgia Institute of Technology to integrate new computational techniques specific to UA and AAM. Existing work with Pennsylvania State University on high fidelity helicopter noise modeling is being extended to consider UA and AAM noise. Additionally, we intend to use the FY22 appropriation to start new ASCENT projects to account for UA and AAM flight configuration within noise modeling and to explore how UA and AAM flight data could be used for visualization and noise modeling. The FAA also maintains a close relationship with NASA on UA and AAM research, including through the development of a new Space Act annex agreement on AAM community response research. Through this collaboration, FAA is helping NASA to develop new community response studies to better understand the potential for community annoyance from AAM noise. FAA and NASA are also continuing collaborations to improve UA and AAM noise modeling capabilities, including fostering researcher partnerships and data sharing. In addition to core research activities, the FAA is also working to develop tailored noise assessment methodologies to inform a regulatory decision on proposed federal actions. Assessments to inform the Title 14 *Code of Federal Regulations* (CFR) Part 107 rulemaking, as well as actions to approve commercial use of UA for package deliveries under Title 14 (CFR) Part 135, have been developed. To aid both the research and regulatory consideration of UA and AAM, FAA has also actively sought opportunities to collect acoustical information on these vehicles. Through a partnership with the Volpe center, the FAA has sponsored noise data collection campaigns, where UA manufacturers and operators have been invited to bring their vehicles and have noise measurements collected.

Subcommittee on Aircraft Safety

Finding: Transfer of NAS Related Technology from NASA to FAA - The REDAC Subcommittee on Aircraft Safety (SAS) maintains awareness that NASA periodically transfers NAS-related technology to the FAA for further maturation and deployment. The SAS notes that NASA may not have matured some of these technologies to a NASA Technology Readiness Level (TRL) 6, where it has been tested in a relevant environment. The SAS finds that some of these technologies have been placed in FAA projects funded by F&E rather than RE&D funds and, therefore, not presented to the SAS for review. In addition, NASA transfers to FAA can also have forms of other technology such as data, concepts of operations, technical manuals, etc., which helps inform future FAA decisions and technology roadmap definitions.

Recommendation 1: The SAS recommends that all NASA technology transfers to FAA that have not reached a NASA TRL 6 maturity level be included in future briefings to the SAS such that the Subcommittee will have adequate information upon which to base its advice on RE&D funding and prioritization to the FAA. This will further ensure sufficient relevant environment evaluation exists for successful implementation decisions.

Recommendation 2: It is also recommended that the SAS receive briefings on low-TRL work in progress on the non-technology knowledge transfers from NASA, such as data and documentation, which are used to help inform FAA decisions. This will provide SAS members with a better understanding of the long-term RED portfolio and direction.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address its recommendations - NASA transfers data and technologies to FAA at various Technology Readiness Level (TRL) increments, and not all are planned for direct implementation by FAA. Some data and technologies are meant only to inform future FAA investment, implementation, standards, and certification decisions, while others are algorithms or Concepts of Operations which are to be integrated into FAA systems, and yet others are to be deployed as parts of FAA automation systems. FAA will catalog research transfers from NASA, which are below TRL6, and provide the next steps of how the research informs FAA's investment, standards, and certification decisions. NASA and FAA Research Transition Team (RTT) Convening Authority holds semi-annual progress update meetings on the RTTs. FAA and NASA will provide a copy of the RTT status briefs to the sub-committee. FAA will coordinate with NASA on providing briefings to the subcommittee on the long-term R&D plan and coordinate for FAA's 2035 Info-Centric NAS Vision and NASA's longer-term Sky For All 2045 Vision.

Recommendation 3: To address the broader level of other ongoing NASA research, the SAS recommends that NASA provide periodic briefings to the SAS on those topics of research that may be applicable to our scope of oversight. It is further recommended that this be addressed as a recurring agenda item at future SAS meetings with rotating topics of interest.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address its recommendations - NASA and FAA collaborate extensively on research and development on Air Traffic Management (ATM) operations, safety, and vehicle technologies for both current generation and future aviation systems such as commercial electric transports, supersonics, Advanced Air Mobility, Unmanned Aircraft Systems (UAS), and High-Altitude Long-Endurance (HALE). FAA will coordinate with NASA and the sub-committee on providing briefings on topics of interest to the sub-committee. NASA has representative members on the REDAC SAS, NAS Ops, Human Factors, and E&E subcommittees, who will also help facilitate and coordinate the briefing requests.

Finding: Electric Aircraft Research - The SAS notes that the research in the A11L Unmanned Aircraft Systems landscape is timely and appropriate. However, as technology advances, a new Budget Line Item should be added for solely electric-powered aircraft. Further in-depth research can aid the industry in addressing this new and emerging technology appropriately.

Recommendation 4: The FAA should conduct research exclusively on electrically powered aircraft, including flight planning requirements and a correlation of battery level to an emergency or minimum fuel equivalent. This research should apply to small UAS, large UAS, advanced air mobility (AAM) vehicles, and other applications of electric propulsion systems. Any inability of aircraft to not have adequate power supply and reserves can impact the users of the NAS. Included in the F&R, specific addressing of battery standards, tolerances, capabilities, crashworthiness, effects on battery performance by the range of anticipated temperatures and altitudes, and fire hazards (including suppression) should be researched.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address its recommendations - The FAA recognizes the technology advancements and industry plans in the area of electric vehicles for UAS and Advanced Air

Mobility (AAM). The accurate indication of energy available from the battery in an electrically powered aircraft is essential for pre-flight planning and inflight awareness of the current electrical energy state. Current FAA research includes efforts to determine the information necessary in the cockpit to operate electric aircraft safely, and additional research focused on the characteristics of propeller speed control systems on electric aircraft. The FAA has already completed research in assessing the propagation of battery testing and fault mitigation for UAS, which informed standards, including Radio Technical Commission for Aeronautics (RTCA) Special Committee 225 Rechargeable Lithium Battery and Battery System Standards, and SAE-7B Power Management, Distribution, and Storage Standards. In addition, the FAA has begun working with NASA to define specifics for drop testing and other battery crashworthiness research. Some of this work has included a look at automotive crash standards to assess applicability to our aerospace environment. The FAA will continue to work with standards-developing organizations and their industry partners to consider the recommended UAS/AAM electric vehicle research areas as UAS/AAM integration stakeholders build upon the active and completed research in the FAA's Aviation Safety R&D portfolio.

Finding: UAS Radio Frequency Spectrum - In the opinion of the SAS, the research in the A11L Unmanned Aircraft Systems landscape is excellent. An additional observation of the committee is that various segments of the radio frequency spectrum have recently been allocated and assigned for auction. There can be safety and interference hazards with reassigned frequencies that may be adjacent to those required by manned aviation. In certain cases, shielding may not be an appropriate measure of mitigation, nor a protective "guard band" may be enough to protect critical, often the safety of life systems on manned aviation.

Recommendation 5: The FAA should research and test the radio frequencies that are used by low altitude UAS including those that operate Unmanned Traffic Management (UTM) systems and or Beyond Visual Line of Sight (BVLOS). Additionally, the research should examine the appropriateness of the utilization of non-aviation networks by small UAS, as well as overall latency and integrity issues in communications.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address its recommendations - The FAA recognizes the importance of radio frequency spectrum to support command and control (C2) capabilities for UAS. Spectrum and C2 requirements are dependent on the criticality of the link, which is dictated by the design of the overall UAS. Latency, integrity, and contingency planning requirements are a core part of any certification project and are integral to any operational approval. The FAA has a long history of C2 and spectrum research that has served critical needs in informing industry consensus standards such as RTCA SC-228 C2 standards. The FAA continues to identify and plan research that will support this area, including Evaluating C2 Link Compatibility and Evaluating UAS Air-to-Ground NAS Communications Latency and Voice Intelligibility.

Furthermore, the FAA partnered with NASA, industry, and UAS Test Sites to evaluate Unmanned Traffic Management (UTM) capabilities, including data exchange and communications, and support Beyond Visual Line of Sight (BVLOS) operations. These results and lessons learned will be used to inform near-term activities and coordination between

government and industry stakeholders to further enable BVLOS operations and operations in low-altitude airspace. The FAA continues to collaborate with external stakeholders, including NASA and industry partners, to identify and address specific research needs.

Finding: Airframe Icing on Non-Standard Aircraft Configurations - The SAS agrees that the FAA research in the A11D budget line item for Aircraft Icing is appropriate. However, a research gap exists. For example, UAS airframe icing is lacking for study. As these present unique designs are vastly different from traditional transport aircraft, potential testing methods may also differ.

Recommendation 6: The FAA should expand the Research Landscape to include the non-standard configurations. This research will cover all types of UAS from small to large, as well as Advanced Air Mobility (AAM) type aircraft. Icing studies should include airframe, engine, and rotor icing. Without adequate research, ice accretion could cause a catastrophic condition affecting users of the NAS, both in the air and on the ground.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address its recommendations - The FAA recognizes the need for airframe icing research for non-standard aircraft. The FAA has plans to initiate research in this area within the UAS Research portfolio beginning no later than FY23, including a research project for Icing, Snow, and Rain Means of Compliance. In addition to the work defined in the UAS Research portfolio, the FAA plans to develop aircraft regulatory icing requirements and guidance for Urban Air Mobility (UAM)/Advanced Air Mobility (AAM) operations in icing environments. Under the Aircraft Icing Budget Line, the FAA is currently testing a UAM/AAM rotor/propeller, blade materials that may reduce ice accretion, cooling inlets for electric engine and battery installations, and an innovative ice detection system to assess the effects of icing on these non-standard designs. A UAM/AAM rotor design has been procured, and a test plan is being developed and coordinated with a leading UAM/AAM manufacturer to assure relevancy to these configurations. This will form part of the inflight aircraft icing program under the Aircraft Icing Budget Line: Aircraft Icing. Inflight aircraft icing includes both super-cooled droplet icing conditions, which affect aircraft, rotorcraft, and engines, as well as Ice Crystal Icing (ICI), which affects turbine engine operations and aircraft flight data probe functionality. The ground icing program forms the other part of the Aircraft Icing Budget Line. The ground icing program conducts research to maintain safe winter ground operations, evaluate the effects of changing ground operations, and develop testing and analysis methods to support these changes. It is also intended to address the effects of innovative aircraft design, such as folding wing aircraft, and new formulations of fluids and innovative methods used in deicing and anti-icing procedures. As these projects yield results, the FAA will continue to incorporate future phases of UAS/AAM icing research as needed in our Aviation Safety R&D portfolio planning process. The FAA will also continue to collaborate with UAS/AAM research partners to identify areas where we may leverage research.

Finding: UAS Safety and Security Technologies - For the research being conducted in the A11L Unmanned Aircraft Systems landscape, it is critical that UAS enter the market with the appropriate safety and security technologies that include standardized operational protocols that are expected by those in manned aviation. Certain technologies that may be labeled with a safety function should be researched as a check and balance to the overall safety system.

Recommendation 7: The FAA should research the capabilities of all "turn-key" technologies that allow mission completion right out of the box where most often, no pilot input is involved. This includes evaluation of all technologies that would permit this capability and evaluating risks that would be posed. Additionally, safety and security features, such as "geo-fencing," "return to base," "lost link," and other safety risk mitigation technologies should be evaluated, and a basis for standardization established from the data. The standardized performance of these features is needed to ensure that the safety and security protocols protect all members of the NAS.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address its recommendations - The FAA recognizes the need for research into evaluating risks with the use of UAS safety and security technologies. Specifically, the FAA's focus is on identifying and defining performance levels to achieve an acceptable level of safety in the National Airspace System, regardless of specific technology. This is supported through research that has aided the FAA's evaluation of hazards and risks via FAA Safety Risk Management processes. There is growing research in this area as technology incorporates more features that require "no pilot input" and perform automated or even autonomous functions. The FAA will continue to research the impact of technology that supports the safe integration of UAS in the NAS, including autonomous systems, right-of-way rules, collision avoidance equipage, and UTM. For specific technologies, such as those referenced in the recommendation, the FAA relies on industry standards organizations to lead the development of standards to support the rapid integration into policies and rules and evaluate how specific technologies meet the standards in alignment with FAA.

Finding: Role of Landscapes in Prioritizing BLIs - The Subcommittee on Aircraft Safety (SAS) makes note that both industry and FAA place much effort in developing the Research Landscape for the National Airspace System 2020 - 2030 that was last updated on February 14, 2020. This Landscape document identified important areas of "research drivers" that would provide an external force or motivation that may stimulate R&D investment. From the SAS members' perspective, it has become unclear how the research landscape effort is currently being used in the prioritization process when developing BLI items for the research portfolio.

Recommendation 8: It is recommended that the FAA provide a briefing to the SAS on how the research landscape document that was developed with both industry and FAA input is being used to identify both gaps in the current R&D portfolio as well as in the prioritization of future BLI items for research.

FAA Response: The FAA concurs with the Committee's recommendation and is undertaking the following actions to address its recommendations - The FAA will provide a briefing as requested on the next SAS meeting in March 2022.

Subcommittee on Human Factors

Finding: Training Air Traffic Controllers for Increased Automation Use - Current training for air traffic operators tend to be developed for individual capabilities, with a "knobology" (user interface) scope, and typically does not focus on operational use, nor the cognitive skills needed

for increased use of automation (e.g., decision support tools) when compared to traditional "manual" skills. We acknowledge some current research is starting to be more operationally focused [(e.g., on Trajectory Based Operations (TBO)], but this research does not address skill degradation (e.g., from automation or long periods away from work) nor the subtleties of cognitive skills for the full-spectrum proficiency of Controllers, Supervisors, and Traffic Flow Managers. Further, proficiency in cognitive skills is currently assessed mostly by the subjective judgment of instructors/examiners, whose assessments are very difficult to standardize. Likewise, the development and incorporation of post-automation proficiency in off-nominal conditions do not appear to be accounted for in the plans for automation introduction.

Recommendation 1: The FAA should conduct research to identify ways to effectively train air traffic personnel and assess their proficiency in using tools and systems that are increasingly automated. The research should identify the associated cognitive skills and knowledge Air Traffic personnel need to use automation effectively across operational contexts, as well as methods to assess proficiency**.** For example, training should:

- Address knowledge and skills associated with tasks requiring psychomotor, perceptual, and cognitive skills, as well as the ability to participate effectively as a member of a team.
- Extend learning that only deals with how to accomplish specific tasks while using a tool, to include additional understanding and application of the full capability of the tool in the context of other systems during operation.
- Address the skills that a Front Line Manager should have to assess and address proficiency and skill degradation for controllers.
- Develop and maintain proficiency in the knowledge and skills necessary when operations transition from an automated environment to a potentially degraded automation environment.

These new training aspects should also consider:

- The needs for initial training as well as the needs for recurrent training.
- Address issues associated with potential skill dependency due to long-term use of automation.
- Training to deal with anomalous situations.

There is an assumption that necessary skills are developed today as a result of an experience in the operational environment; however, these skills may not be developed due to reliance on automation during routine operations.

Without identifying required knowledge and skills and providing appropriate training, operational personnel may not have the skills and knowledge needed to manage degraded system states. As the operational landscape increases in complexity with TBO, training content will need to keep pace with operational change to ensure the workforce remains proficient across all states of operations to maintain the safety of the system.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address its recommendation - As the HF Subcommittee identified, current research is addressing training on Trajectory Based Operations. Additionally, recent research explored human performance during degraded NextGen operations.

Furthermore, current flight deck HF research is addressing cognitive skills for flight operations, including effects from the use of automated systems. Similar research for air traffic personnel will be considered, in which cognitive skills and proficiency assessments are explored for tasks with and without automation (typically decision support tools) and in nominal and off-nominal conditions. The FAA will brief the HF Subcommittee on progress towards new research on this topic at the FY22 Winter/Spring meeting and the FY22 Summer/Fall meeting.

Finding: Update Alerting Systems Standards - The current flight deck designs and regulatory framework for flight deck alerting systems were based primarily on research that was conducted by aircraft manufacturers in the late 1970s and early 1980s. The last major collaborative efforts in improving and standardizing aircraft alerting systems by U.S. commercial transport aircraft manufacturers were from 40 years ago. The results of these studies were used as a foundation for the current aircraft certification regulation on Flight Deck Alerting 25.1322 and FAA Advisory Circular 25.1322-1 for the design approval of flight crew-alerting functions. Since then, technology has advanced significantly, and new capabilities have been implemented in modern alerting systems such as prioritization of alerts within the categories of warnings, increased categories of alerts, the grouping of alerts under "umbrella" messages, intelligent alerting based on information integration from multiple sources, etc.

Today the level of aircraft systems integration has grown exponentially, resulting in significant increases in the complexity of failure and non-normal conditions. At the same time, the proliferation of automated systems has changed some flight crew tasks to increase monitoring and assessing the outputs of automated information integration. This shift has led flight crews to place more reliance on alerting automation and has increased the need for pilots to have a comprehensive understanding of aircraft systems to effectively understand the operational behaviors and outputs of the alerting systems. The combination of these factors has directly impacted human-machine interaction by exposing flight crews to conditions that may not have been identified in previous guidance. These conditions may include increased susceptibility to startle effect, which may directly impact cognitive performance, sensory overloading, prioritization of complex information under high workload, and swift transitions from passive monitoring to manual control tasks.

Recommendation 2: The FAA should conduct research that provides a current scientific and engineering basis to update alerting system standards for the design and implementation of modern flight deck alerting systems. The research should focus on human performance considerations to inform the design of alerting systems and updates to the associated regulation to enable a harmonized interpretation.

For example, the research should address:

- Cognitive performance and alerting such as the effective use of human senses according to the tasks.
- The effectiveness of current alerting methods and systems, and identify effective means to mitigate identified human performance issues such as startle, sensory overloading, prioritization of complex information, and swift transfer of control.
- Temporal characteristics of the actions the alerts trigger and improved ways to effectively delineate between categories of alerts such as advisories versus cautions.

- Ways to represent and present alerts to flight crews to effectively guide response to and understanding of the failure. The complexity of the automated systems that also hide their automated processes can be difficult to understand without extensive knowledge of the systems, and they may result in increased reliance on automated alerting.
- Increased system integration that processes information and outputs it to the flight crew with no transparency into its processing. Flight crews must monitor and assess automated system outputs, which creates new tasks and adds workload.

Technology and system integration has advanced significantly, and new capabilities have been implemented in modern alerting systems. Without updated research and assessment of the effectiveness of alerting methods on modern and future flight decks, the industry may continue using outdated knowledge, approach, and methods, which do not reflect the current and future task demands of the flight crew and their operational environments. Additionally, the lack of common ground on human performance related to alerting systems contributes to divergent interpretations of the regulations.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address its recommendation - Two research projects related to this recommendation have been identified. One project will analyze pilot responses to system malfunctions, which includes alerting, procedures, and training. The other project will directly analyze current flight deck alerting systems. The FAA will brief the HF Subcommittee on the progress of these two projects at the FY22 Winter/Spring meeting and the FY22 Summer/Fall meeting.

Subcommittee on NAS Operations

General observations: Weather RE&D Funding - In the prior Winter/Spring 2021 meeting, the NAS Ops Subcommittee noted concern over significant reductions in weather-related RE&D funding and recommended that the FAA aggressively increase visibility into the importance of this line of research. At its Summer/Fall 2021 meeting, the Subcommittee was pleased to learn that FY22 weather-related RE&D funding is slated to be restored to more robust levels similar to earlier years that are more appropriate to the national need to conduct this research. The Subcommittee also appreciated receiving the presentations from the Weather RE&D and NextGen Weather Technology in the Cockpit BLIs that reviewed the broad extent of ongoing research contributing to aviation safety and efficiency.

Finding: Environmental Impact Mitigation Through Advanced NAS Operations - The Subcommittee noted the significant increase in planned FY22 RE&D funding allocated towards environment and energy considerations. We observe that beyond the development of core technologies such as advanced fuels and reduced-emissions propulsion systems, new air traffic management procedures may enable lower-noise lower-fuel-burn operations with earlier implementation timelines. Some of these new procedures may be implemented in the near term without requiring new technologies. In the longer term, it will be important for the FAA to research and develop effective decision support systems for more complex procedural concepts to enhance NAS domestic and International efficiencies. In addition, future vehicles may have

different optimum performance profiles than current generation vehicles. The air traffic management system will need to seamlessly integrate these vehicles and provide them with trajectories tailored for optimum energy performance. Adding to the complexity of these problems is the requirement to balance changes across multiple stakeholders, including the FAA, adjacent Air Navigation Service Providers (ANSPs), airspace users (airlines, general aviation, small and large UAS operators, Advanced Air Mobility operators, and commercial space operators), and outside communities and neighborhoods, involving both technical and non-technical (policy) issues.

Recommendation 1: The Subcommittee recommends that the FAA continue to foster and strengthen linkages between new initiatives in AEE, ANG, and ATO (in particular, AJV-S) related to environmental impact mitigation through new technologies for NAS operations. Regular coordination between these organizations will help ensure that RE&D efforts are initiated in time and in a coordinated manner to support the introduction of new procedures and technologies that reduce the environmental impact of the nation's aviation system.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address its recommendation(s) - There has been regular cross-organizational engagement and collaboration related to the environmental impact mitigation of RE&D efforts. Examples include:

- AEE, ATO, and ANG regularly coordinate on cross-cutting noise issues via the Executive Noise Steering Group and the Noise Working Group.
- AEE and AJV are having ongoing discussions on capturing operational fuel/CO2 savings and identifying additional operational opportunities for environmental impact mitigation. AJV's Community Engagement Strategist is analyzing local operational fuel/CO2 savings (e.g., utilization of OPDs) with input from AEE on methods and metrics. AEE and AJV-P have also had discussions around additional opportunities for research. As a result of these talks, AEE will engage with ATO SysOps to discuss examining NAS operational data for potential targets of opportunity for reducing aviation's climate impact.
- ANG-B7 is evaluating the environmental benefits of NAS modernization (e.g., TBO), and socialized some of their analysis approach with AEE.
- AEE and ATO International have coordinated on operational opportunities for reduced climate impact in oceanic airspace. We have discussed the fuel burn reduction benefit pool and messaging related to the Future of the Ocean 2035 project. AEE has also participated in Pacific Technical Interchange Meetings to understand ongoing efforts to reduce fuel burn through increased user-preferred routing in oceanic airspace.
- AEE is initiating research in the ASCENT Center of Excellence to develop decision-support tools to cost-effectively reduce aviation climate impacts through mitigation of contrails and aviation-induced cloudiness. As this project develops, ANG and ATO engagement will be needed to understand the implications to trajectory management and additional constraints.

Recommendation 2: Three example RE&D topics at the intersection of environment and NAS operations include (1) development of new ATC tools and procedures to enable adaptive low-workload efficient and safe, systematic dispersion of departures; (2) exploring enhancements to

the Terminal Sequencing and Spacing (TSAS) system that may be needed to efficiently accommodate a mix of aircraft types performing delayed deceleration approaches; and (3) integration of future reduced-emissions vehicles for optimum trajectory profiles. A roadmap for RE&D activities to support the introduction of these and other aspects of environmental impact reduction while ensuring safe and efficient NAS operations should be developed and executed.

FAA Response: The FAA concurs with the Committee's recommendation(s) and with the noted exceptions and clarifications intends to undertake the following actions to address its recommendation(s) - With respect to the topic (1), under the Massport Memorandum of Understanding, AEE has worked with MIT to explore various options for achieving systematic dispersion and to develop modeling methods/metrics for communicating impacts to support community understanding and decision-making. These methods can be applicable to other settings and roundtable discussions.

With respect to the topic (2), AEE continues to work with MIT to evaluate and validate the impact of Delayed Deceleration Approaches and identify barriers to implementation. We plan to explore TSAS as a potential enabler as part of this research, but this element of the work has not yet begun. AEE plans to engage with other parts of FAA to understand the TSAS system and whether it can be utilized or enhanced to enable lower energy approaches that reduce noise and emissions.

With respect to topic (3), as future reduced-emissions vehicles mature and we learn more about their performance characteristics, we will consider implications and opportunities for optimized trajectory profiles (including en route). We do not yet know enough about these vehicles at this time to define an RE&D roadmap.

Finding: Human Factors - The Subcommittee received a briefing on the RE&D Enterprise Human Factors research activities, which highlighted a growing volume and variety of human factors research and development work compared to recent past years. The Subcommittee was particularly pleased that research activities in this budget line are introducing activities related to addressing Human Factors needs and challenges associated with strategic air traffic management concepts, including traffic flow management. This research has broadened to include a focus on the Human Factors associated with the operational integration of complex Traffic Flow Management (TFM) concepts and decision support capabilities. Examples of research focus areas include:

- The impact of Trajectory-Based Operations (TBO) on the Traffic Flow Management Unit (TMU)
- TMU regional coordination and decision making
- Effective methods for TBO training.

While the Subcommittee is encouraged by the important focus of these activities on TBO-related considerations, the Subcommittee is aware that emerging Traffic Flow Management concepts that build upon the foundation of TBO must also be examined. These emerging traffic flow management concepts will require the introduction of new decision support capabilities, new training needs, and potentially changes to the decision-making process in the strategic management of traffic. It will be important to define and pursue additional research into systems and procedures for ensuring effective multi-stakeholder collaborative decision-making using

uncertain forecast information. Future concepts also depend on the use of advanced capabilities, such as machine learning/artificial intelligence, which present unique Human Factors challenges beyond those studied through TBO.

The Subcommittee considers the following focus areas as particularly urgent due to the complexity of these future concepts and the challenges associated with the operational integration of new traffic flow management capabilities:

- Future Flow Management
- Performance-Based Flow Management

These concepts, and their maturation plans, are in development but are not considered focal areas for the Enterprise Human Factors research and development until Fiscal Year 2024. The complexity of these research needs will warrant continued investment in Human Factors.

Recommendation 3: The Subcommittee recommends that the FAA continue to grow strategic enterprise Human Factors Research and Development funding and activities associated with longer-term strategic traffic flow management and collaborative decision making.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address its recommendation(s) - The NextGen Enterprise HF Portfolio plans to continue to emphasize traffic flow management research. Currently, there are multiple projects being conducted that are related to strategic Traffic Flow Management (TFM) and Collaborative Decisions Making (CDM), as well as FY21 research plans that include four projects related to TFM and CDM. A detailed and updated state of research and planning on these topics will be briefed to the REDAC HF Subcommittee at the FY22 Winter/Spring meeting.

Recommendation 4: The Subcommittee also recommends accelerating the focus on Human Factors considerations associated with the FAA's info-centric vision for the NAS generally and the Future Flow Management and Performance-Based Flow Management concepts and plans specifically.

FAA Response: FAA concurs with the Committee's recommendation(s) and, with the noted exceptions and clarifications, intends to undertake the following actions to address its recommendation(s) - Future Flow Management is still in early concept, but HF will be considered as the project matures. The Enterprise HF Portfolio provides HF guidance at the enterprise level for use by multiple programs, so any future research related to the Info-Centric NAS, Future Flow Management, or Performance-Based Flow Management would address HF aspects that are common across concepts. The state of research planning on these topics will be briefed to the REDAC HF Subcommittee at the FY22 Winter/Spring meeting.

Recommendation 5: In addition, given the progression to highly automated systems of the future, the Subcommittee also recommends focusing on human/machine teaming and graceful degradation of automated systems for handoffs in off-nominal conditions from automation to human.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address its recommendation(s) - The FAA agrees that

graceful degradation of automated systems is important, and notes that past and current projects have addressed human operator aspects of degraded operations, including risks and mitigations. Examples include current flight deck research on Manual Flight Operations and recent Enterprise HF research on human-automation teaming and degraded operations. Additionally, the FAA and NASA Human Factors communities are coordinating Advanced Air Mobility HF research concerns to identify potential research opportunities for consideration by each agency. These research opportunities include human/machine teaming and the graceful degradation of automated systems. As air traffic and aircraft automation capabilities mature towards functions that have been traditionally performed by human operators, FAA will consider new HF research to support safe human-system operations in nominal and off-nominal conditions. Any new research related to these topics will be identified within the standard FAA HF portfolio briefings to the HF Subcommittee at the FY22 Winter/Spring meeting and the FY22 Summer/Fall meeting.

Finding: Flight Dynamics Research Related to Advanced Air Mobility - New flight vehicle concepts, such as Electric Vertical Takeoff and Landing (eVTOL) aircraft for Advanced Air Mobility (AAM), may require new technologies to enable safe and effective manual or automated flight control. The flight dynamics and physics of these new vehicles are different from prior aircraft because of the difference in electric powertrain response time constants, in particular. The outcomes from this domain of R&D are vital for understanding the effect of eVTOL flight path control capabilities on airspace procedures design and management.

At its Fall meeting, the NAS Operations Subcommittee received a briefing describing a study underway to explore issues related to flight control of eVTOL vehicles using NASA's Vertical Motion Simulator (VMS). The Subcommittee observed that the current FAA R&D activities using the VMS seem mismatched to the potentially very different flight dynamics of future vehicles. The specific research requirements and objectives that led to the decision to use the VMS were also not clear to the Subcommittee.

Recommendation 6: The Subcommittee recommends that the FAA (with NASA) articulate and evaluate the requirements for using piloted motion-based simulators (such as the NASA Ames VMS or NASA Langley Cockpit Motion Facility (CMF)) for R&D of eVTOL aircraft entering the AAM markets. If the use of a motion-based flight simulator is determined to be necessary, the FAA and NASA should ensure that the selected simulator has been appropriately modified to provide a high-fidelity emulation of the flight dynamics of these new aircraft types as well as the Human-Machine-Interfaces (HMI) of these new aircraft types.

FAA Response: The FAA concurs with the Committee's finding and recommendation and is undertaking the following actions to address its recommendation(s) - FAA and NASA previously determined that NASA's existing Vertical Motion Simulator (VMS) provides the required high-fidelity flight dynamics necessary to emulate the flight dynamics of new aircraft types. More specifically, the VMS can emulate AAM flight dynamics and Human-Machine-Interfaces (HMI) of new eVTOL aircraft types, and its use was required to accomplish research leading to improvements of (1) the regulatory processes and guidance for aircraft certification and operational approvals, especially for new technologies and operations, and (2) consideration of human performance and operational consequences in the following areas: Changes to existing flight deck design through Supplemental Type Certificates (STCs), Technical Standard Orders

(TSOs), or field approvals, and Introduction of new operations or changes to operations, to include implications for training, flight crew procedures, and operational risk management.

FAA & NASA's Phase I work resulted in a novel prototype V/STOL aircraft-pilot interface integrated into a Flight Deck Z Simulation Program run on the VMS, test maneuvers for interface concepts for pilot testing, and a refined V/STOL aircraft pilot interface test matrix for pilot usability testing in the VMS.

Ongoing FAA/NASA work includes further software development towards a novel V/STOL aircraft pilot interface in NASA's VMS (representing an industry eVTOL aircraft simulator) and performing a Human-In-The-Loop (HITL) study utilizing the VMS's enhanced capability. The anticipated project completion date is December 2022.

Subcommittee on Airports

Observations and Commendations: We appreciate FAA's continuing focus on time-critical research projects. These include evaluation of Alternative Aircraft Firefighting agents and assessment of Uncrewed Aircraft System (UAS) detection and mitigation systems, both of which are associated with legislative requirements in the 2018 FAA Reauthorization Act.

We are also pleased to see the results of research into other areas involving new airspace entrants, including continuing work on beneficial uses of UAS at airports, the impacts of climate change on airport operational and infrastructure needs, sustainable airfield pavement research, and Vertiport design standards.

The Subcommittee was also pleased to see the alignment of the Program's research portfolio with current Administration priorities. The Subcommittee was particularly interested in how much of the Program's airport planning and pavement research is helping to enhance airport sustainability and resiliency.

The Subcommittee also remains pleased regarding the Program's efforts to modernize and enhance FAA pavement design and management tools, evaluate airfield pavement design, and assess airport resiliency.

With respect to firefighting research, the Subcommittee expressed its concern and disappointment that the FAA's evaluations of PFAS-free firefighting foams had not identified agents capable of meeting current FAA and Department of Defense (DoD) performance standards.[1] We expressed these concerns in a letter to the FAA Office of Airports that we sent in August, preceding the meeting. In the letter, included as Attachment A, the Subcommittee expressed our support for synchronizing FAA and DoD firefighting agent research efforts and statutory deadlines to provide an achievable pathway to transition to fluorine-free agents. We discussed the synchronization of these research efforts at length during the meeting.

[1] Current DoD performance specifications necessitate use of firefighting foams that contain per- and polyfluoroalkyl substances (PFAS), a class of chemical compounds that is bio-accumulative, persistent, and have been linked to adverse health impacts in humans and animals.

Finding: Alternative Firefighting Agent Research - As noted in our last two Subcommittee reports, the Program's Alternative Firefighting Agent Research project has been of concern to the Subcommittee because:

- The Project's findings were needed to support FAA action regarding Section 332 of the FAA Reauthorization Act of 2018. Section 332 included a three-year deadline—ending on October 4, 2020—for FAA to "not require the use of fluorinated chemicals to meet the performance standards referenced in chapter 6 of AC No: 150/5210-6D and acceptable under 139.319(l) of title 14, Code of Federal Regulations."
- Airport operators are under considerable pressure from state and local governments and local communities to reduce or eliminate the use of PFAS at airports.
- There are significant and growing concerns about the human health impacts and associated liability associated with PFAS contamination on and near airports.

Per our Spring 2021 recommendations, the Subcommittee submitted a letter on August 18, 2021, supporting FAA's request to Congress to extend the Section 332 deadline. The U.S. Congress declined to approve this extension in late September. Without the extension, U.S. airports have been left in a challenging situation with fluorinated foams being the only firefighting agents that meet current FAA and DoD requirements, but under legislative provisions that do not allow FAA to require the use of such foams.

The current pathway to approval of non-fluorinated firefighting foams for use at U.S. airports relies on DoD's introduction of a new performance standard for non-fluorinated/PFAS-free foams, which the U.S. Congress has mandated by January 31, 2023.

Recommendation 1: Consistent with our Spring 2021 report, the Subcommittee recommends that the FAA prioritize assistance and support for DoDs research efforts regarding a new performance standard for non-fluorinated/PFAS-free foams. We also reiterate our recommendation from Spring 2021 that the FAA prioritize research associated with ARFF training, equipment requirements (including equipment cleaning), tactics, and other supporting guidance that will be needed to facilitate the transition from fluorinated to non-fluorinated foams.

FAA Response: The FAA concurs with the Committee's findings and recommendations and is taking the following actions to address it - The FAA will continue to work closely with the DoD on the development of a new performance standard for non-fluorinated/PFAS-free foams. The FAA has established a roadmap that lays out a timeline for research efforts conducted by both the DoD and the FAA, as well as a transition phase from fluorinated to non-fluorinated foams. As a new performance standard emerges, the FAA will ensure that necessary research associated with the application of that new standard is conducted. As appropriate, this might include ARFF training, equipment requirements, tactics, and supporting guidance.

Finding: Airport Sustainability and Resiliency - As noted previously, the Subcommittee appreciated the categorization of several of the Program's projects in terms of airport sustainability and resiliency. U.S. airport operators are extremely interested in ways they can enhance both sustainability and resiliency through appropriate capital investment and changes in operating and maintenance practices.

Recommendation 2: The Subcommittee recommends that the FAA continue to prioritize research projects that enhance airport sustainability and resiliency, particularly within the advanced pavement materials, extended pavement life, airport planning & design, and environmental tools & guidance Research Program Areas (RPAs).

FAA Response: The FAA concurs with the Committee's findings and recommendations and is taking the following actions to address it - The FAA will conduct a review of the Airport Technology Research Portfolio and will ensure that research projects that enhance airport sustainability and resiliency are incorporated in the portfolio. The FAA concurs that a number of research program areas related to pavement longevity, physical infrastructure resilience, energy supplies, climate preparedness which includes planning and design, are well-suited for an enhanced focus in airport sustainability and resiliency.