Research, Engineering and Development Advisory Committee

Subcommittee Report – NAS Operations

October 2014

FAA Research Issues and Opportunities

Input from REDAC NASOPS Subcommittee

Research Issues that the FAA should "get ahead of"

Issue: <u>Integration of UAS into the NAS</u>

There has been an unprecedented demand by the UAS community for access to the NAS. While the FAA has devoted significant effort to this issue over the past few years, it is clearly not ahead of it. Small UAS operations represent the majority of the user community demand in the relatively near term, principally because of their low cost of operation and significant economic potential. While some progress has been made in the integration of small UAS operating within line-of-sight of the operator, the concepts for broader integration of small UAS are not well understood and research is urgently needed to define and validate these concepts. This research must be well-focused and oriented to ensure that timely solutions can be introduced that are safe, while minimizing impact to current NAS operations.

It is clear that in the near term, small UAS will operate in airspace that is largely segregated from manned aircraft. However, the demand will likely drive the UAS operational density to levels much higher than can be managed using manual ATC methods, particularly as small UAS operations extend beyond operator line-of-sight and become more autonomous. The proposed FAA rule for small UAS, while helpful, will satisfy only a fraction of proposed small UAS operations. The more general FAA UAS concept of operations specifies IFR operation, which is not a good fit for small UAS due to a lack of pilot training to operate IFR, difficulty of compliance with IFR visual operations, and the sheer volume of expected operations.

NASA is developing new concepts for autonomous airspace operations and there is an opportunity for FAA to collaborate with NASA and use the small UAS flight regime as a first step toward a more autonomous airspace system (see the associated research opportunity below). Because these lower altitude airspace regimes are likely to initially be segregated, they offer an opportunity for the FAA to be more agile in the development and implementation of new concepts.

An overall research strategy for UAS is needed that captures the range of operations and timeframes for UAS operations. This strategy needs to capture the role of both FAA and other organizations (NASA, DoD, academia, etc) in solving key challenges to safe and efficient UAS operations in the NAS.

Issue: <u>General Aviation Safety</u>

The Administrator has designated the improvement of General Aviation safety as one of FAA's top priorities. However, the FAA is not "getting ahead" of this problem. GA accounts for 96% of all aviation accidents and 97% of all fatal aviation accidents.[1] It has been estimated that the average annual cost of GA accidents in the United States is $1.64B.[2] While the accident rate of Part 135 and corporate aviation has improved over the past decade, the accident rate of personal aircraft has not.

The FAA should focus its GA safety initiative on developing a fundamental understanding the underlying sources of the GA safety problem, and based on this understanding, develop and validate the system-level approach most likely to produce a significant impact on GA safety. To the extent that improved access to information is a factor in GA decision-making, the subcommittee notes that there are many new sources of information and decision support applications available to GA pilots. While there appears to be some penetration of these applications into modern GA cockpits, it will be important for the FAA's research to determine why they have not yet had a significant impact on overall GA safety statistics.

Issue: <u>Data Integrity</u>

There has been an exponential growth in the volume of data associated with aviation operations. This data is generated, processed, and stored in highly distributed systems which include air traffic management automation, airline automation, aircraft avionics, and a variety of commercial vendors. These distributed systems are interconnected via a variety of air and ground networks. Ensuring the integrity of this diverse data set from unintentional errors, accidental corruption, and deliberate spoofing is important to ensure the reliability of aviation operations. At the same this data represents a significant resource to the broader R&D and operational community and the data must be made available to the maximum extent possible while maintaining appropriate levels of privacy and security. The FAA must "get ahead" of this issue by establishing appropriate policies for data collection, processing, storage, protection, and dissemination that keep pace with the exponential growth of data generation and increasing demand for the data to support operations, research, and development. A clear approach for developing and implementing robust cyber-security practices, in particular, is needed to address the increasing threats to US systems. These policies must appropriately balance the cost of collection and maintenance of the data with its utility to the broader aviation community.

Issue: <u>Verification and Validation of Complex NAS Systems</u>

The NAS is a very complex system as are the current and future systems that manage it. We require that these complex systems be extremely reliable and that they deliver their promised benefits. The Verification and Validation (V&V) of future NAS systems is an issue that will pace the FAA's NAS modernization progress and therefore the FAA should "get ahead" of it. In anticipation of the

[1] National Transportation Safety Board Review of US Civil Aviation Accidents (NTSB/ARA-12/01) October 2012.
[2] Sobieralski, J.B., The Cost of General Aviation Accidents in the United States, Transportation Research Part A: Policy and Practice, Volume 47, January (2013).

implementation of increasing levels of autonomy and system complexity in NAS operations, FAA should focus on developing V&V techniques that handle both deterministic and non-deterministic system behavior (see related research opportunity below). The FAA should leverage research in other government agencies and V&V activities in other industries, particularly where there are likely to be overlaps in the physical and cyber-security components of the V&V process. This research should include not only the techniques for V&V; it should also address ways to introduce change into current institutional processes. Significant innovation is occurring in sectors that are not traditionally aviation-focused; there is a need to balance the disruptive approaches from "innovation" culture versus the traditional aviation safety culture. Software integrity and robustness is not only a concern for the end of a capability lifecycle. In addition to performing research specifically targeted to V&V techniques, the FAA should ensure that its research projects to develop new NAS capabilities address any unique V&V requirements for the new capability early in its development. Further, this research should be integrated into a broader evaluation of NAS robustness, addressing the various ways that efficient NAS operations can be disrupted.

Research Opportunities for the FAA

Research Opportunity: <u>Increasingly Autonomous Systems in the NAS</u>

This research opportunity is articulately summarized in the following excerpt from a National Research Council report[3]:

> "The development and application of increasingly autonomous (IA) systems for civil aviation is proceeding at an accelerating pace, driven by the expectation that such systems will return significant benefits in terms of safety, reliability, efficiency, affordability, and/or previously unattainable mission capabilities. IA systems range from current automatic systems such as autopilots and remotely piloted unmanned aircraft to more highly sophisticated systems that are needed to enable a fully autonomous aircraft that does not require a pilot or human air traffic controllers. These systems, characterized by their ability to perform more complex mission-related tasks with substantially less human intervention for more extended periods of time, sometimes at remote distances, are being envisioned for aircraft and for air traffic management and other ground-based elements of the national airspace system. Civil aviation is on the threshold of potentially revolutionary improvements in aviation capabilities and operations associated with IA systems. These systems, however, face substantial barriers to integration into the national airspace system without degrading its safety or efficiency."

[3] National Research Council. "Autonomy Research for Civil Aviation: Toward a New Era of Flight". Washington, DC: The National Academies Press, 2014.

Increasingly autonomous systems have the potential to significantly improve NAS safety and performance, particularly as applied to the planning, negotiation, and real-time monitoring of aircraft trajectories that satisfy user preferences in the presence of dynamic and stochastic airspace constraints. However, significant research and development is required to achieve these benefits.

While the FAA has the opportunity to leverage autonomy research at NASA and in the commercial world there is a need for a focused FAA effort to ensure that these sophisticated non-deterministic and adaptive software systems can be trusted and remain resilient in the NAS. There is a need to adapt current certification mechanisms and policies to ensure that they scale to the complexity of evolving automation technologies. The FAA research should address revisions to certification processes as well as new techniques for verification, validation, test and evaluation that can generate the data necessary for a safety determination. It should also address the new software and system architectures that ensures that increasingly autonomous operations have the level of robustness necessary for NAS operations.

Research Opportunity: Big Data/ Measuring the NAS

As described in its Strategic Plan, the FAA is committed to a consistent, data-driven approach when making system-level decisions. Given the complexity of the NAS and the exponential growth of data available (see related issue above), there is a need for a systematic approach to the collection and analysis of NAS performance data. There are many measures of NAS performance – some of them reflect the satisfaction of user demand and others reflect more technical aspects of system performance that enable optimization and problem diagnosis. The FAA should leverage industry and research community "big data" practices to guide its research on the collection and analysis of NAS data in order to inform its decision-making. Related to this is the challenge of defining new data sources, especially with the introduction of new entrants such as UAS or commercial space. This research opportunity is related to, but distinct from the data integrity issue described above in that the research here would be focused on the algorithms used to organize and analyze the data and the means to present that analysis to support decision making.

Aviation supplies excellent data for measuring system performance, compared to other modes of transportation, but aviation performance measurement lags other modes. Now that delay is coming to be understood as a feature of a healthy transportation network, it is time to research additional measures for evaluating the impact of real-time decisions. Large-scale transformations of the NAS need large-scale measures of performance. Research is needed to understand the NAS in its proper context: supplying high-price, high-value connections to parts of the economy that could not function at longer time scales.

Research Opportunity: Modeling and Simulation

Modeling and Simulation (M&S) are the principal tools that enable the FAA and the broader aviation community to understand how the NAS could operate in the future. A robust M&S capability allows researchers to design and test new concepts early in the development cycle, before proceeding to more costly field trials. Both fast time and human-in-the-loop simulations enable new concept validation and risk reduction that is essential to successful transition to operations. While it is important to perform M&S studies at an appropriate level of fidelity to ensure the validity of results, in general, the M&S capability can be matched to the specific research and development question being answered, thus reducing development cost.

The subcommittee has observed that the FAA has recently significantly scaled back its M&S efforts for operational concept validation. While this may be due to funding limitations, the subcommittee is concerned that a de-emphasis on M&S will simply pass on risk to the deployment phase of new capabilities, resulting in implementation delays and further funding shortfalls. FAA should invest in and utilize M&S to the maximum extent possible when exploring new concepts and continue its use of M&S throughout the development cycle. As part of this investment, FAA needs to ensure that M&S tools incorporate new entrants to the NAS such as the wide range of UAS operations and performance , commercial space operators, and other emerging users. The FAA should maintain a portfolio of simulation capabilities for concept development and risk reduction. The portfolio should be made broadly available to the FAA research community along with guidelines for its use. This will help ensure that results are equally valid across the research domains. Because there will be a continuing need for high fidelity, distributed, human-in-the-loop simulation that reflects the operational diversity of the future NAS, and because these large scale simulations are expensive to develop, the FAA should leverage the significant investment that DoD has made in live virtual simulation technology.

Research, Engineering and Development Advisory Committee

Subcommittee Report – Aircraft Safety

October 2014

Research, Engineering Development Advisory Committee (REDAC)
Subcommittee for Aircraft Safety (SAS)

Emerging Issues and Future Opportunities Tasking Report

The sub-committee for Aircraft Safety met on Sept 10 - 12 in Atlantic City, NJ for its routine fall meeting. In advance of the meeting the sub-committee received a special, non-routine tasking, which requested guidance on identification of emerging and future issues that the FAA should consider in its research plan. In support of this tasking the sub-committee engaged in pre-planning and requested that each member prepare and present their thoughts on what the emerging and future issues were. Additionally, presentations from seven of the FAA's Chief Scientist and Technical Advisors were also reviewed. All told the committee reviewed 18 presentations detailing different strategic imperative perspectives including topics such as aeromedical, airline operations, engine design and certification, general aviation technology and crashworthiness and structures.

Aviation safety is a complex and integrated subject covering a range of disciplines including material technologies, design, system integration, certification, aerospace medicine, software engineering, operations, and maintaining continued airworthiness. The presentations the sub-committee reviewed highlighted the diversity and interconnectedness of these topics. After much deliberation and discussion the sub-committee narrowed down the emerging issues for additional research to four which are presented in more detail in the report:

1. Real Time System-Wide Safety Assurance
2. Dependability of Increasingly Complex Systems
3. Certification of Advanced Materials and Structural Technologies
4. High Density Energy Storage, Management and Use

It was recognized that the FAA is already heavily engaged in UAV-related research and as such we did not specifically address that area in our deliberations. The committee has also identified four areas it believes the FAA should keep ahead of in its work plan. These areas are also worthy of future research consideration.

1. Commercial Space Integration with the National Airspace System
2. General Aviation's Role in Safety Systems Development
3. Identification and Funding of Strategic Research and Development
4. Effects of Breakthrough Medical Technologies on FAA Medical Certification Standards

The sub-committee would like to thank you for the opportunity to provide input into these important deliberations.

Respectfully Submitted,

Ken Hylander

RECAC Sub-Committee for Aviation Safety Chairman

Research, Engineering Development Advisory Committee (REDAC)
Subcommittee for Aircraft Safety (SAS)

Emerging Issue: Real-Time System-Wide Safety Assurance

Why this issue is important. Commercial aviation is the safest mode of transportation. This enviable record is the result of decades of continuous improvement in reaction to known hazards, incidents, and accidents. As aviation exploits technology advances to enhance the capacity, efficiency, and uses of the National Airspace System (NAS), it will be vital to recognize and quickly mitigate emerging safety issues in real time before they become hazards.

The focus of this strategic research effort is to enable development of a real-time, system-wide safety assurance system. The ongoing advances in sensor and networking technology, computation, communications, and integration can be combined with advanced data analytics to accelerate access and protection of sensitive data. This will enable discovery, alerting, and mitigation of anomalous events at a progressively more rapid pace, and will enable unprecedented insight into system operations, health, and safety. An additional component of this future real-time information system will be the integrated monitoring of the human operator state, providing human performance data to the automated system. These advances applied broadly within the aviation system and combined with system-of-systems modeling and prognostics, offer a new vision of real-time, system-wide safety assurance. Strategic research in this area will deliver a progression of capabilities that accelerate the detection, prognosis, and resolution of systemwide threats.

Research Needs. Continued development of advanced safety analysis and assurance tools such as data mining and analysis, automated prognostics, and safety risk modeling will substantially improve the ability to gain insights and develop mitigations from the growing amount of available aviation system data. These developments will dramatically improve safety assurance by reducing the time to analyze, identify, and mitigate safety risks.

Research is needed to enable the integration of advanced tools into a more highly automated safety assurance system that will enable continuous systemwide safety assessment. This advance can lead to rapid identification of safety issues and corrective actions before the issues become hazards. Such an automated system will evolve to be near-real-time as confidence increases in continuously validated system judgments. Biomedical research is also needed to develop the psychological and physiological measures from the human operator that will inform the automation system.

As the automated safety assurance system becomes integrated with real-time operations to help create an aviation system that exhibits the autonomic properties of self-protection and self-healing. In this future, research to determine how human operators and autonomous systems will collaborate to ensure an optimal mix of actions – from immediate operational adjustments to far-term system and infrastructure changes – will minimize safety risks.

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<u>Emerging Issue</u>: Dependability of Increasingly Complex Systems

As we move towards increasingly complex system-of-system architectures in aviation which consist of both airborne and ground-based interconnected components, the following issues becoming increasingly important as we pursue an enterprise systems engineering approach:

Software, Automation and Autonomy

<u>Why this issue is important</u>. Software for onboard systems is increasing in complexity, sophistication, and size as previously independent mechanical, pneumatic, and hydraulic functions are replaced by highly integrated electrics and electronics. Advances in computer processing, sensors, networking, and other technologies are also enabling the aviation system to continue to augment the human decision-makers with sophisticated automation both on-board the aircraft and in ground systems including air traffic control. Within the foreseeable future we expect humans will maintain the role as the final authority for safe operations.

As technology evolves, these automation systems will become increasingly interconnected and increasingly move towards autonomy where the machine is intelligent, perceiving, deciding, learning, and acting, often without human direct engagement. Such advanced automation systems also integrate the real-time human operator state, which will help inform the level of automation implemented by the system. Ensuring that these sophisticated, adaptive, interconnected, and non-deterministic automation systems remain resilient to a range of expected and unanticipated circumstances, and environments, is a concern.

<u>Research Needs</u>. Our current mechanisms and policies for oversight and certification of these systems to ensure they operate robustly in safety-critical situations are not keeping pace with technology advancements. These software-intensive automation systems must be resilient to design defects, missing or corrupt data, and deliberate attacks. Revisions to certification processes as well as new analytical techniques for verification, validation, test, and evaluation that can generate the data necessary for a safety determination are required.

Analytical Means of Compliance (MoCs) for software are also necessary. Fundamental research is needed to develop methodologies, frameworks, and algorithms enabling streamlined software architectures, testability, and certifiability.

Research and Development will be needed to ensure that automation on the flight deck and other safety critical applications is designed and implemented in a way to complement the strengths and weaknesses of the human operator. Biomedical research is also needed to develop the psychological and physiological measures from the human that will inform the automation system.

Data Integrity

<u>Why this issue is important</u>. There has been an exponential growth in the volume and distribution of electronic data associated with real-time operations. There is also increased advocacy for more frequent — or continuous — inflight aircraft-to-ground communication. Safety and operational value of expanded uses for engine and aircraft health monitoring systems are growing. Such ubiquitous data communication and sharing can provide safety and operational benefits - depending on available bandwidth and cost. These systems of systems typically use a mix of certified and uncertified automation and data distribution

systems. As an example, aircraft and engine data which is governed by various certification requirements may be delivered to the ground and processed by several largely uncertified systems using Commercial off the Shelf (COTS) software and hardware. The FAA has does not have an efficient method to evaluate COTS hardware and software that is available today.

Research Needs. Ensuring the integrity of this diverse data set from unintentional errors, accidental corruption, and deliberate spoofing is important to ensure the reliability of aviation operations.

Consideration of the regulations and Means of Compliance (MOCs) for use of COTS software and hardware in airborne and ground-based applications for safety-significant functions is required.

Updated Federal Aviation Regulations (FARs) and Means of Compliance

Why this issue is important. The pace of innovation has accelerated with the advent of new architectures and the expanded use of structural composites and advanced metallics, among other factors. Aspects of existing engine and aircraft FARs were developed long ago and should be examined for modernization in light of the latest design, development, and testing technologies. Some prescriptive certification Means of Compliance (MoCs) may no longer be producing the desired result when applied, for example, to current high and ultra-high bypass engines.

Sophisticated high-fidelity subsystem tests are increasingly employed by Original Equipment Manufacturers (OEMs) in early development to reduce risks in full-up engine or aircraft testing. In some cases these subsystems enable testing that cannot be reliably or repeatedly performed in an engine ground test or in flight.

As aircraft systems inevitably become more integrated in the drive for improved safety and efficiency, the lines between engine and aircraft certification responsibility become blurred, and, even today, substantial overlap exists. This can create duplicative work or lead to unacceptable gaps. Examples include, but are not limited to, electronic integration and pneumatic systems integration. Current and future large transport aircraft don't, and won't, split neatly down FAR 33 / FAR 25 lines.

Research Needs*.* Research should begin to ensure a proactive framework for timely and flexible requirements and that means of compliance are in place to handle near-term engine and aircraft architectural advancements without undue burden.

Research into validation technologies should be conducted, and approved methods for use of all adequate techniques and technologies as acceptable Means of Compliance (MoCs) should be developed.

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Emerging Issue: Certification of Advanced Materials and Structural Technologies

Why this issue is important. As aircraft and engine designs drive towards advanced performance, new material systems and structural concepts will continue to be introduced that are significantly different from the current ways of designing, building, and maintaining airframes and engines. The FAA needs to stay abreast of these changes to make certification decisions and build its knowledge to support regulations, standards, guidance materials, and training that maintain safety.

Other changes are developing will begin to accelerate in the future, such as use of additive manufacturing. Given that this is an emerging technology, issues of standardization, variation in process, resulting properties, and uncertainties in failure modes need to be understood.

Research Needs. The FAA needs to focus on technical methods to stay abreast of these changes to make performance-based certification decisions and evolve processes and inspection techniques to support regulations, standards, guidance materials, and training that maintain safety. An example of this is non-destructive inspection (NDI) where these new materials and structures are used. For many existing material systems and structural designs, the traditional inspection processes fall short of being reliably able to catch flaws, thus driving the need for more modeling and analysis. Research also needs to focus on the application of computational material methods to streamline the certification process.

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Emerging Issue: High-Density Energy Storage, Management, and Use

Why this issue is important. Aircraft manufacturers are always trying to optimize performance while decreasing operating and maintenance costs, and reducing environmental impacts. This optimization has pushed the aircraft industry to break away from traditional systems and install more efficient electrical powered systems onboard their aircraft.

The general trend in aircraft manufacturing has been a steady increase of electrical components and more integrated systems and avionics (i.e., “The More Electric Aircraft”). Future aircraft will continue to expand the use of electrical energy technologies and capabilities. This requires the development and application of new high energy density storage, management and distribution technologies and systems which can present new potential hazards to aircraft and operations.

Research Needs. Research is needed to understand and assess the characteristics of various high energy generation, and storage technologies with applications that are expected to increase in aviation products. The research should provide data for the appropriate standards and safeguards for the design, implementation, certification, maintenance and operation of these new systems, with emphasis on developing safe power technology, to ensure the successful use.

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Future Opportunity: Commercial Space Integration with the National Airspace System

Why this issue is important. Commercial space activities continue to expand worldwide with a growing industry based in the US. Commercial Space Vehicle Operations (SVO) include both human and cargo space flight missions. The FAA has the responsibility to license spaceports and space vehicle operations, including commercial space transportation operations conducted under Government contract (e.g., NASA commercial crew program, DoD payloads). The current mechanisms for ensuring the safety of legacy National Airspace System (NAS) users mainly focus on setting up restricted areas to enable launch and recovery during space vehicle operations. These mechanisms will not likely scale to the operational tempo anticipated by the industry. The FAA's efforts to provide guidelines to this emerging industry have focused on protecting SVO occupants (i.e., crew and passengers) and not necessarily on public safety (i.e., other aircraft or persons/property on the ground) or on minimizing the operational disruption of commercial launches.

Research Needs. Continued research is needed in establishing the necessary guidelines, operational procedures, policies, and potential regulations necessary to both protect the safety of SVO participants, the public, and other aviation operations, and maintain operational efficiency of the NAS. Increased research emphasis is recommended in the areas of medical certification standards for passengers and crew of commercial SVO, as well as standards for cabin safety and emergency procedures/egress/survival.

Research, Engineering Development Advisory Committee (REDAC)
Subcommittee for Aircraft Safety (SAS)

Future Opportunity: General Aviation's Role in Safety Systems Development

Why this issue is important. The sub-committee supports R&D initiatives in the portfolio that target improvements in General Aviation (GA). GA is an important part of the US air transportation system and a pipeline for highly qualified pilots and mechanics that are vital to the continued safe growth of aviation. In addition, GA serves as a unique incubator for the validation of safety equipment and interventions and it offers opportunity for safety systems development in a timely and streamlined manner.

Research Needs. A strategic R&D program is needed to evaluate safety enhancements through the application of technologies, taking advantage of the safety opportunities in GA, that improve situational awareness, aircraft operational protections, automation, and autonomy that make it safer and easier to fly in the National Airspace System (NAS).

The objective of this R&D initiative is to coordinate with other R&D initiatives and identify safety applications within GA aircraft using safety-risk continuum principles to ensure an appropriate level of rigor to enable these safety-enhancing technologies to be rapidly installed in both retrofit and new applications.

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<u>Future Opportunity</u>: Identification and Funding of Strategic Research and Development

<u>Why this issue is important</u>. Today's Research, Engineering, and Development (RE&D) identification and prioritization process is not suited to ensure adequate focus on – and allocation for – long-term, emerging needs. The current environment is dominated by known, near-term needs and by reacting to previously unforeseen activities. This severely limits FAA's ability to set aside resources for long-term RE&D. To be successful in the long run, and leverage the resources available today while meeting the FAA's stated strategic goals, the process to identify and prioritize RE&D needs must be rooted in a broad aerospace community view of the FAA's statutory mandate to promote safety. Looking at today's extremely safe aviation industry, many stakeholders agree that the way to maintain, and certainly to improve, requires a cross-cutting, multi-disciplinary approach to addressing the remaining known and emerging new safety risks.

<u>Research Needs</u>. In this vein, the subcommittee recommends FAA conduct the research needed to support the development of a sustainable process to enable:

- The identification of long-term (strategic) R&D needs using risk-based, data-driven principles at the aerospace system level.

- Further, the FAA needs a funding approach – including setting aside funds – that will protect the critical elements of long-term R&D needs

<u>Future Opportunity</u>: Effects of Breakthrough Medical Technologies on FAA Medical Certification Standards

<u>Why this issue is important</u>. Medical science is advancing at an unprecedented rate, as the genetic basis for many diseases is deciphered, novel drug therapies are approved, and revolutionary surgical procedures and medical devices are proven effective. The aviation community deserves the fullest possible benefit from these medical advances. Diseases that have traditionally ended aviation careers may someday be able to be waived; while certain medically-indicated treatments may present unrecognized risks to aviation safety. It is therefore essential that the FAA be aware of the important advances in medical and surgical therapeutics, so that any potential effect on flight safety and aeromedical standards is investigated, and possible changes to medical certification standards enacted.

<u>Research needs</u>. The FAA should support an aerospace medicine program to examine the effects of emerging medical technologies (e.g., practices, pharmaceuticals, devices) on the clinical health and occupational safety of aviation personnel. This program should include surveillance of medical research and practice developments in the United States, examination of the existing FAA medical standards in view of these developments, and research to determine the effects of these developments on aircrew performance, safety, and aeromedical certification.

Research, Engineering and Development Advisory Committee

Subcommittee Report – Human Factors

October 2014

FAA REDAC Subcommittee on Human Factors Summer Meeting Report

The Subcommittee met September 16-18, 2014 in Washington DC and received updates on Human Factors and Engineering, Human Factors Research Processes, ANG Human Factors Action Items and reviewed progress on past Findings, Recommendations, and Action Items.

The primary thrust of this meeting was to "focus on developing a list of emerging issues (things the FAA should get ahead of) and future opportunities (future areas where R&D could benefit the FAA). Each Subcommittee should refine their list of issues and opportunities to their top 4-5 and include an explanation for each as to why it is important the FAA should consider it."

The subcommittee committee chair asked each of its members to provide their view of the top future FAA Human Factors issues and also received viewpoints from Headquarters NASA and Gulfstream Corporation. The subcommittee member representation included DoD, NASA, Industry, Academia, Federally Funded Research and Development Centers, and the Airline Pilots Association. The subcommittee derived a list of 14 topics, which was reduced to a total of six. The topics ran the gamut from near-to-mid-to-far term, such as mixed equipage issues (near term) to highly automated vehicles (far term). The final six topics are listed, and are not in priority order: (1) System Information Management; (2) Automation/Highly Automated Systems Roles and Responsibilities; (3) Integration of UAS/RPAS (Remotely Piloted Aircraft Systems) into the NAS; (4) Dealing with Mixed Equipage Operations in the Design and Evolution of the National Air Space; (5) Human Machine Design, Integration, and Certification; and (6) Workforce Selection, Training, and Proficiency. These topics are summarized below and follow the following format—Issue, Rationale, and suggested Way Forward.

(1) System Information Management

Issue:

Increasing information management demands for pilots, controllers, dispatchers, and traffic managers will create human factors risks and vulnerabilities such as higher workload, distractions, longer task times, and errors.

Rationale:

A variety of circumstances are converging to create, or exacerbate, human factors issues related to information management in NextGen and beyond. There are increases in the amount, diversity, and complexity of information that users must manage because of a proliferation of new information systems. In many cases, new systems and functions are introduced into existing flight decks and controller workstations where the new systems could conflict with the philosophy, information flow, and scan pattern of the flight deck or workstation to which they are added. Greater data communication bandwidth, more distributed systems, and greater processing power on the aircraft, on the ground, and in the cloud can produce even more information (e.g., big data analytics). At the same time, there is more variability in the quality of information that systems produce because pilots and controllers are utilizing a mix of certified, operationally approved, and uncertified/unapproved systems. Further, information requirements and information sharing requirements are changing as more collaboration is occurring, not only between pilots, controllers, and dispatchers, but between human and automated systems. All this is happening while human ability to process and manage information remains constant, or changes in unexpected and subtle ways as the user population demographics change (e.g., as potential generational and cultural differences become more important). The PARC/CAST Flight Deck Automation Working Group report on Operational Use of Flight Path Management Systems provided a recommendation related to information automation and discussed the information management issues described above.

As the demand for users to process and manage information increases, if too much information is provided, if too much human information processing is required to access, filter, understand, interpret, and integrate relevant information, if it is difficult to monitor and verify the quality of information and the integrity of raw data, or if the appropriate information is not shared among collaborators in the same form in a timely fashion, a variety of human factors issues can result. Users will over-trust automated systems because they do not have the capacity to interpret and verify outputs. Performing information management tasks such as organizing, filtering, and prioritizing information will distract from more important tasks. Collaboration will break down because collaborators do not have the same information or do not interpret the information similarly because it is in different forms or formats. Primary tasks will take longer because additional information management tasks are overhead tasks that add task time, but not direct value. The primary tasks for flight crews include aviate, navigate, and communicate; maintain separation, provide expeditious traffic flow, and provide services to users encompass the primary tasks for controllers. If this research priority is not addressed, the significant changes in the information environment related to NextGen and beyond will increase existing human performance issues and introduce new ones that could reduce safety and efficiency.

Way Forward:

1. Near Term – Identify the appropriate guidance materials for use of information automation and management in order to mitigate the risks in current and near-term operations described above. In addition, information requirements for human agents in the overall system for various NextGen scenarios and operations need to be analyzed so that the value of each new information system can be assessed. This needs to include analysis of collaborative tasks and the requirements for shared information. The use of a framework such as the control structure could be very valuable in this activity. It would also be valuable to identify how and why various information systems, such as PED applications, are being used today. This might provide insights in terms of risk-benefit analyses.

2. Far Term – Information management needs to be assessed at a system-of-systems level. Further research on the human performance envelope, in terms of the capacity to process and manage information, is needed. This will address not just capacity in terms of quantity of information that can be managed, but also how diversity, quality, and complexity of information impact that capacity. The ability to train information management skills must be assessed. For example, information management, distraction, performing information triage, collaborative decision making, etc., could be good candidates for CRM training. Procedures for use of mixed information systems (certified, operationally approved, and uncertified/unapproved) need to be explored.

(2) Automation/Autonomy Roles and Responsibilities

Issue:

Understanding the appropriate roles, responsibilities, and authority between humans and automated systems to both enable optimal design of Next Gen as well as adequately certify more automated aircraft systems and flight decks.

Rationale:

1. As identified in the PARC/CAST Flight Deck Automation Working Group report on Operational Use of Flight Path Management Systems, the use of automation, while having demonstrated benefits in the aviation system, continues to also have negative consequences on safety and to some extent efficiency of the system.

2. The development and application of increasingly autonomous systems for civil aviation is proceeding at an accelerating pace, driven by the expectation that such systems will return significant benefits in terms of safety, reliability, efficiency, affordability, and/or previously unattainable mission capabilities (National Research Council. "Autonomy Research for Civil Aviation: Toward a New Era of Flight". Washington, DC: The National Academies Press, 2014).

3. Hence there is an urgent need to address the negative consequences that automation brings to the table and either eliminate the risks or mitigate them.

4. Following are identified gaps that need to be closed in this area:
   a) Gap 1 - Methodologies to effectively design human-automation systems and automation. Automation will introduce new safety risks and vulnerabilities into the system. Effective tools and processes need to be developed to both reduce risks through adequate system design and potential risks need to be identified proactively so that they can be eliminated or mitigated.

b) Gap 2 - Automation can increase the risk of humans not being able to handle situations where the automation fails and the automation often cannot handle situations where the humans have made mistakes. Hence a more resilient and robust system design is needed. There is a gap however in practical methods of ensuring resiliency within the NextGen design.

c) Gap 3 – The appropriate functional allocation of tasks within the human-automation system is key to creating both a safe and efficient system. There is a known gap in the ability of system designers of NextGen to appropriately allocate functions among components of the human-automated system design due to a lack of adequate tools, methods and practical research in this area.

d) Gap 4 – There is a need for effective and efficient methodologies used to certify automated systems to ensure that they are safe, including the assessment of resiliency and robustness needed in more automated systems. If unfilled, this gap results in increased safety risk due to the possible implementation of unsafe automation into vehicles. Unfilled it also brings the risk of not being able to certify automated systems that could introduce enhanced safety and/or efficiencies into the system.

e) Gap 5 - Intelligent and non-deterministic automated and autonomous systems technology is on the horizon and there are gaps in understanding both how to appropriately apply this technology as well as certify it.

f) Gap 6 – As more automated systems have entered the aviation system, a risk to safety has been identified with respect to human trust in automated systems. This has resulted in the inappropriate over- reliance on automation causing safety vulnerabilities. On the other side, mistrust of the automation results in the inefficient use of the automated capability. There is a gap in the methodologies needed to address the appropriate level of trust for automation as Next Gen is implemented as well as in the ability to appropriately assess automation and pilot trust from a certification perspective.

Payoff:

1. A commercial aviation system that can employ automation effectively to enhance system performance while also enhancing safety
2. A more efficient and effective certification approval for more automated aircraft systems that ensures enhanced safety in a cost effective manner

Way Forward:

1. A multi-faceted research program into human-automation system design and certification.

2. Components of this program include:
   a) Developing a framework for the incorporation of automation within complex systems
   b) Developing a tool suite and methodologies for the appropriate functional allocation within the human-automation system
   c) Develop tools and methods for conducting predictive safety analysis of more automated systems
   d) Conduct research to identify the many ways in which human intervention has saved the day when systems fail or unforeseen events occur
   e) Develop better cognitive modeling in order to understand the impacts of automation during early stages of the design
   f) Develop best practices, tools and methodologies to effectively and efficient certify more automated systems
   g) Develop practical ways of ensuring resiliency in the aviation system as well as effective methodologies for assessing the resiliency of systems in support of certification approval for more automated systems
   h) Research methods for ensuring appropriate levels of trust of automated systems as well as to assess safety risks in automated systems for certification approval.

3. While research required to adequately address automation is necessary, ways to employ the research products effectively within the AMS process for ATO components needs to be developed and implemented

<u>(3) Integration of UAS/RPAS into the NAS</u>

Issue:

There has been an unprecedented demand by the UAS/RPAS community for access to the NAS. Demand will likely drive the UAS operational density to levels much higher than can be managed using manual ATC methods, particularly as small UAS operations extend beyond operator line-of-sight and become more autonomous.

Rationale:

While the FAA has devoted significant effort to this issue over the past few years, it is clearly not ahead of it. The small UAS/RPAS operations represent the majority of the user community demand in the relatively near term, principally because of their low cost of operation and significant economic potential. While some progress has been made in the integration of small UAS/RPAS operating within line-of-sight of the operator, the concepts for broader integration of small UAS are not well understood and research is urgently needed to define and validate these concepts. This research must be well-focused and oriented to ensure that timely solutions can be introduced that are safe, while minimizing impact to current NAS operations.

It is clear that in the near term, small UAS/RPAS will operate in airspace that is largely segregated from manned aircraft. However, the demand will likely drive the UAS/RPAS operational density to levels much higher than can be managed using manual ATC methods, particularly as small UAS/RPAS operations extend beyond operator line-of-sight and become more autonomous. The proposed FAA rule for small UAS/RPAS, while helpful, will satisfy only a fraction of proposed small UAS/RPAS operations. The more general FAA UAS/RPAS concept of operations specifies IFR operation, which is not a good fit for small UAS/RPAS due to a lack of pilot training to operate IFR, difficulty of compliance with IFR visual operations, and the sheer volume of expected operations.

NASA and DoD are developing new concepts for autonomous airspace operations and there is an opportunity for FAA to collaborate with NASA/DoD and use the small UAS flight regime as a first step toward a more autonomous airspace system. Because these lower altitude airspace regimes are likely to initially be segregated, they offer an opportunity for the FAA to be more agile in the development and implementation of new concepts.

This new complex addition to the airspace will have a significant human factors impact on the overall system as well with each of the operators (pilots, air traffic control, etc.), which will require more attention to operator selection, training, and proficiency.

The new airspace environment will require regulations, which follow a paradigm of human capable of direct manual control when required RPAS control stations become more highly automated with supervisory control methods and future, intelligent, non-deterministic remotely piloted system technology on the horizon.

An overall research strategy for RPAS human factors research is needed that captures the range of operations and timeframes for all RPAS operations. This strategy needs to capture the role of both the FAA and other organizations (NASA, DoD, academia, etc.) in solving key challenges to safe and efficient RPAS operations in the NAS.

Way Forward:

1. Develop RPAS Research Plan with coordination/leverage of NASA/DoD and other government agencies focusing on sense and avoid, communications, and human system technologies and fund research.

2. To support the certification of RPAS remote control stations and RPAS operators:
    a. Develop flexible and layered human-automation interface methodologies.
    b. Develop research methods for ensuring properly calibrated trust of automated systems.
    c. Develop realistic pilot performance models for required constructive simulations to prove the safety case.
    d. Develop research into effective, fault-tolerant RPAS control station designs/architectures, information displays and intuitive control, attention cueing, contingency management, and mitigation of control loop degradation.

e. Determine the appropriate skills and knowledge required by RPAS operators to support appropriate training requirements

3. Develop realistic pilot performance models for required constructive simulations to prove the safety case.

(4) Dealing with Mixed Equipage Operations in the Design and Evolution of the National Air Space

Issue:

Operational Concern. There are numerous advances planned under NextGen that are likely to be phased in, rather than mandating a change by all of the flight operators at one point in time. The result is that the system will have to deal with a mixed equipage or operational environment in a safe and efficient manner for some extended period of time.

Rationale:

Examples of this issue include the introduction of DataCom and more precise navigation capabilities (RNAV/RNP and ADS-B Out and In equipage) on aircraft. This phased approach has major human factors implications as, until everyone (or almost everyone) has transitioned, there is a potential increase in complexity for a number of different actors, especially controllers.

In the initial stages of such an evolution, when the majority of the aircraft are still unequipped, a strategy is needed that provides sufficient benefit to the equipped aircraft to reward equipage while maintaining high efficiency for the majority of the aircraft. In the mid-term, when there are large numbers of both equipped and unequipped aircraft, cognitive complexity becomes the dominant issue. In the longer term, when all or almost all of the aircraft are equipped, the human factors issue is whether equipage or resultant operations are uniform. An example of the latter arises if, for instance, most aircraft are DataCom capable, but they use a wide range of message sets that differ across flight operators.

The human factors concern is clear: If a controller or some other actor needs to deal with aircraft differently based on their equipage, this introduces additional task load and cognitive complexity depending on the number of equipment packages which must be considered and the procedural differences for each type. If the cognitive complexity or task load is too high the controller will have increased risk of errors or will default to the procedures for the lowest equipage level, thus negating the benefit of the NextGen improvement.

It is important to understand how these factors impact controllers cognitive complexity to determine limits or mixed equipage or procedural strategies to manage the complexity. This issue also has implications regarding the demands on training and job responsibilities. Such complexities in turn can affect efficiency in the NAS (reductions in capacity in order to safely deal with the increased complexities) or safety.

Potential Human Factors Solutions. Depending upon the nature of the new capability, there are a number of different classes of solutions that can be investigated. One is to look for design solutions that reduce the complexity of operating in a mixed equipage environment without losing the desired benefits. A second solution is to consider the implication of human factors considerations for policy making. If the human factors issues indicate that there is no effective way to maintain efficient operations with mixed equipage, then it may be desirable to mandate a transition by all aircraft who wish to operate in high demand airspace at some point in time. The transition to reduced vertical separation standards was an example of this.

A third possible solution (or partial solution) is to modify the tools and displays used so that it is easy to identify and deal with aircraft based on equipage.

Another possible solution is best equipped aircraft get served first by ATC rather than today's first come first served. This could gain significant benefits of NextGen quickly and encourage equipage without mandate by others.

Way Forward:

For specific types of equipage and associated operational concepts, the potential impact of mixed equipage on human and system performance needs to be assessed relative to alternative design, procedural and policy solutions. This is necessary to make informed decisions about how to approach the introduction of the intended operational improvement.

In addition, for the selected solution, it is necessary to determine the training implications.

High Priority Applications:

1. DataComm
2. ADS-B In Applications(e.g. delegated separation)
3. TBFM (Time Based Flow Management)
4. Navigation (RNAV/RNP and ADSB)
    a) Approaches
    b) Departures
    c) Enroute
    d) Surface
5. Others?

(5) Human Machine Design, Integration, and Certification

Issue:

Airspace system complexity will increase dramatically given the number and diversity of aircraft, aircraft equipage levels, airborne and ground-based capabilities as well as operator cultures and proficiencies. Operators in the system, such as controllers and pilots will not be able to keep track of and properly manage this complexity.

Rationale:

Traditional human/machine design approaches try to allocate specific functions to one or the other and generally result in replacing human functions with automated systems. However, these approaches have already proven inappropriate because they introduce new risk, such as human skill degradation, and often make it impossible for humans to predict or understand the automation behavior; this is considered the predominant contributor to automation related incidents and accidents. Moreover, highly complex automated systems are extremely difficult to develop, maintain and certify. We require that these complex systems be extremely reliable and that they deliver their promised benefits. The Verification and Validation (V&V) of future NAS systems is an issue that will pace the FAA's NAS modernization progress and therefore the FAA needs to "get ahead" of it. The proliferation of non-certified devices and decision support aids in cockpits and ATC are already having an impact on aviation operations. The FAA needs to get a handle on regulating these devices to allow their effective utilization in a way that does not pose a new safety risk. To mitigate the substantial safety risks associated with the new ways that humans and machines will interact in NextGen methods for human-machine design, integration, V&V and certification are required. Many of these will have to utilize modeling and simulation, the principal tools that enable the FAA and the broader aviation community to understand how the NAS could operate in the future. Modeling and simulation significantly reduce the risk of costly implementation mistakes, but the effectiveness of human-machine interactions also need to be continuously evaluated in operation. This will mitigate operational risks within the existing systems and design and integration risks for future systems.

Way Forward:

The following research is recommended to help establish a resilient human/machine system that can utilize emerging technologies while coping with the anticipated complexity:

1. Conduct research on containing the overall complexity of aircraft, equipage, capability, training and proficiency levels (for example identify whether clustering the diversity into a few designated categories can get the majority of the benefit).

2. Conduct research on developing a process for design, engineering, integration, training and procedure development that employs human factors design and analysis methods to:
   a) Synergize human and automation capabilities as complimentary components of the overall system.
   b) Maintain human awareness, expertise and performance with increasingly autonomous systems.
   c) Assess human and automated system performance envelopes and avoid situations that confront humans or automated systems with unmanageable problems.
   d) Develop procedures and training that ensure the appropriate use of new functions and help achieve the anticipated benefits.
   e) Evaluate and quantify operational effectiveness and iterate design, procedures and/or training if necessary.

3. Accelerate research into new methods for V&V of complex systems (deterministic and non-deterministic) in coordination with other government agencies (NASA, DOD) and in other industries, particularly where there are likely to be overlaps in the physical and cyber-security components of the V&V process.

4. Invest in and utilize modeling and simulation throughout the development cycle and share these capabilities with research partners. The capabilities need to incorporate new entrants to the NAS such as the wide range of UAS/RPAS operations and performance, commercial space operators, and other emerging users. To reduce overall cost leverage the significant investment that DoD has made in live virtual simulation technology as well as the capabilities in existence and under development at NASA and other partners in the research community.

5. Re-examine the certification methods and conduct research to determine new criteria for certifying emerging technologies and operations and for streamlining the certification process. Determine the function allocation between government, regulated services and commercial applications, and define minimum performance standards, operational boundaries and strict safety and security regulations for commercial systems in aviation applications. Research the feasibility of hybrid systems in which the FAA ensures safety, security, equitability, etc. and commercial products provide the optimization.

High Payoff Areas:

1. Collaborate on non-traditional/emerging efforts, (e.g. NASA's low altitude UAS Traffic Management (UTM)) to pursue new methods for design, procedures, training, V&V and certification.

2. Develop process for upcoming operational improvement that increases complexity: e.g. RECAT if successful, apply to introduction of data comm.

(6) Workforce Selection, Training, and Proficiency

Issue:

Understanding the human factor aspects and required skills, aptitude, and traits for the human components required for NextGen is essential for the optimal design of NextGen and for hiring, training, and maintaining a workforce. This will enable the workforce to continuously adapt to increasing demands of interacting with automated systems while remaining proficient in manual handling operations in order to provide the flexibility and safely handle the variability in the system to mitigate operational and safety risk.

Rationale:

The aviation industry is challenged by a difficult economic context, changing demographics, and new technologies with far-reaching potential. Policy to ensure enough competent personnel with the right skills and aptitude are available to manage and maintain a global air transportation system is crucial to the success of NextGen. In this context, it becomes urgent to understand the human factor issues of this new work force and modify existing policies for the recruitment, education, training and retention of the next generation of aviation professionals (which includes pilots, air traffic controllers, maintenance, dispatchers, etc.). ICAO is already addressing the issue in the Next Generation of Aviation Professional (NGAP) in order to prepare for the continued growth of the air transportation system and to address these challenges.

New capabilities and generational differences can alter the human role in negative ways (less engaging, less vigilant, changing procedures, new habit patterns, new monitoring requirements, handling unforeseen problems, mode confusion, etc.). How do we handle demographic changes in the aviation workforce resulting from the looming mass retirement of older, more experienced workers and influx of younger, less experienced, more technological savvy workers? Evidence is starting to accumulate for both pilots and air traffic controllers showing that reduced opportunities to practice manual handling operations coupled with increasing requirements to use automated systems can erode not only manual skills, but also cognitive skills accomplished by the automated systems. Examples of cognitive skills that may erode could include the ability to do computations, integrate information from several sources, innovate in ways such as developing and executing an emergency plan in order to safely continue operations when automated systems fail, etc. Information management has also become an increasing safety issue because of the large amount of available information (such as EFB's, and computerized MEL) which is being introduced into the workplace. More research to understand the human factors issues across multi-generational workforce for introducing new technology into future airspace operations is needed, and then potential solutions such as training changes and more practice of particular skills during operations need to be developed, implemented, and evaluated.

New technology is being introduced at such a fast rate that current training devices, methodologies, and training footprints are not keeping pace with the required increase in knowledge and skills required by humans in the aviation workforce. Evidence shows current training methodologies, including distance learning, may not be effective for maintaining the required knowledge and skills required for future aviation workers. The recent study completed by the PARC/CAST Flight Deck Automation Working Group titled "Operational Use of Flight path Management Systems" provides a detailed discussion of current and future issues surrounding the changing demographics of the aviation workforce, evolution in the knowledge and skills needed by pilots and air traffic controllers, and exploiting new technology and operational concepts for future airspace operations. These operations will require efficient and safely distributed processes which will require more collaboration and negotiations between actors such as traffic flow managers, controllers, and pilots. Communications will be more detailed and less voice-based, increasing the need to properly deal with changes and negotiations through computer systems.

Introducing current and future technology into all sectors of the airspace system, coupled with changing roles, responsibilities, and human-machine/human-human communications and interfaces will have a major impact on the human factors issues and effects automated systems have on training, maintaining proficiency in required skills, and existing Crew Resource Management (CRM) practices. CRM training will need to continuously evolve in order to maintain safe pilot and crew performance during line operations, as well as safe performance of all workforce members in the system. In addition, as the use of automated systems becomes more integrated, so too will the necessity to develop and train CRM methodologies across workgroups. Operators and FAA oversight personnel will need specific guidance on how to effectively develop and deliver CRM training, and measure human performance for desired training and operational outcomes.

It will be up to the FAA and all stakeholders, including airlines, employee groups, air navigation service providers (ANSP), the research community, as well as training and education providers to define, update, and modify the regulatory and training environment. This must be done in order to improve the effectiveness and efficiency of design, education, training, and methods for maintaining proficiency of required skills and competencies. The FAA can have a direct impact on these challenges by conducting this research into more effective and efficient ways of recruiting, training, and maintaining proficiency, and designing resilience into the system.

Way Forward:

1. Develop methodologies for identifying the skills and aptitudes required for the workforce for NextGen as well as screening techniques for identifying potential candidates with the desired traits.

2. Develop methodologies for maintaining and training resilience in the NAS, especially dealing with non-routine situations (including dealing with "unknown unknowns"), failures unanticipated by designers, partial failures, failures across systems, and startle effects.

3. Research into what the human performance envelope is for flight and air traffic control operations, how to measure human performance (including required data collection), how to conduct training to improve human performance, and how to incorporate new technology to improve human performance while staying within that "envelope."

4. Define human factors issues and criteria for improving pilot and controller performance in line operations in order to develop new/improved training devices, methodologies, and instructor skills for current and future technology, including addressing the effects of automated systems. This includes such things as: improving pilot performance in flight path management; improving controller performance in separation management; monitoring; task/workload management; managing automated systems; dealing with unforeseen or unknown problems; manual handling operations; managing fatigue; and other HF issues surrounding new technology.

5. Training research supporting effective distributed team collaboration strategies, which encompasses changes in information automation and human-machine/human-human interactions resulting from negotiations through computer systems.

6. Research methods for developing and delivering effective distance learning, along with the proper balance of distance learning with classroom style instruction and learning. Providing specific guidance to operators and those providing FAA oversight on how to effectively develop, deliver, and measure human performance for desired training and operational outcomes.
   a) What types of knowledge and skills distance learning can and cannot be used for.
   b) Human factor requirements for developing effective distance learning courseware.
   c) How to measure the effectiveness of distance learning.
   d) How to integrate distance learning with other training delivery methods (e.g., classroom, simulator, etc.) to optimize human performance.
   e) Develop means for system-of-system operations and evaluations, including how to train all aviation professionals for managing integrated systems.

7. Human-automated systems research to best manage increasing information complexity. Define the human factors issues and methodologies associated with development and approval process for properly designing and incorporating Information Automation / EFB into the flight deck so it improves human performance and does not inhibit it. This

guidance should provide specific guidance to operators and those providing FAA oversight on how to effectively develop, deliver, and measure human performance for desired training and operational outcomes, including guidance on SOP development and how to safely introduce and use EFB's in line operations.

8. Provide increased human factors support to air traffic facilities during training and operational implementation of new technologies and procedures. In order to attain the full benefit of new functions and systems, the FAA needs to follow through with human factors monitoring and analysis of how well new functions and procedures are used and utilized in the field and take corrective actions where necessary. There will likely be unforeseen integration issues with other systems and procedures or reasons why new systems and functions cannot be utilized as envisioned. Human factors support during the operational implementation can mitigate substantial risk by improving training and attaining the required proficiency levels for operating new systems and procedure in air traffic facilities.

9. Define the human factors issues and effects current and future automated systems have on existing Crew Resource Management (CRM) practices and training. This needs to include how CRM training should be modified in order to improve pilot and crew performance during line operations. This guidance needs to provide specific guidance to operators and FAA oversight on how to effectively develop and deliver CRM training, and measure pilot performance for desired training and operational outcomes.

10. Review and revamp CRM methods to reflect new realities for functional and cross-functional job performance.

Research, Engineering and Development Advisory Committee

Subcommittee Report – Environment and Energy

October 2014

FAA REDAC Subcommittee on Environment and Energy

Recommendations for Developing Strategic R&D Plan

August 2014

At its summer meeting in Washington, DC, the FAA REDAC Subcommittee on Environment and Energy deliberated in two separate teams to develop recommendations of issues and opportunities for the FAA to consider in defining a strategic R&D plan looking out 10+ years. The following represents recommendations from the E&E Subcommittee regarding research areas the FAA should include in the Strategic R&D Plan that is in addition to the currently established R&D portfolio and focused on the longer term. The subcommittee supports the consideration of longer term needs but is concerned that some of the near- to mid-term programs are not sufficiently funded to be able to achieve their objectives.

1. Low Emissions Aviation Alternative Fuels:

Alternative fuel is a significant component of aviation stakeholders' strategy for environmentally sustainable growth. Research is needed to develop a fuel qualification based on chemical composition related to engine operational figures of merit. This would not only speed up the qualification of new alternative fuels but it also presents the opportunity to tailor fuel composition to reduce emissions (e.g. non-volatile particulate matter). This R&D would lead to alternative fuels with reduced climate and air quality impacts.

2. Advanced Technologies and Configuration Maturation:

The current research portfolio at NASA, FAA and industry for commercial aviation include many technologies and configurations that are significantly different than what we see today. A significant effort will be required to mature these technologies to a higher technology readiness level via demonstration in a relevant system to be a candidate for application to an airplane design. FAA's Continuous Low Emissions Energy and Noise (CLEEN) program has been successful in achieving this for low NOx combustor, Composite Matrix Ceramic (CMC) nozzle and fan blades, advanced wing trailing edge, among others. CLEEN-2 is expected to mature several more technologies in the next 5 years. The advanced technologies being developed now (e.g., hybrid systems, morphing surfaces, manufacturing technologies, etc.) will require a follow on to CLEEN-2 for technology maturation after 5 years

3. Technology Certification Process:

As engine / airplane systems become more complex, demonstrating safety and environmental compliance is becoming more complicated, lengthy and costly. These processes need to be made more efficient. This can be accomplished by using more analysis and less testing for certification. A focused effort that advances and validates analysis procedures is required to accomplish this objective.

4. Incorporation of "Growth / Diversification" Areas into NAS:

The aviation system is rapidly evolving driven by traffic levels, passenger flight preferences, and new vehicle opportunities like Unmanned Air System (UAS), supersonic, Vertical Takeoff and Landing (VTOL), Personal Air Vehicle (PAV), and Commercial Space Transportation (CST). There is a need to establish methods and procedures to integrate these changes into the NAS. UAS operations at low altitudes and in urban environments are a particular area of concern environmentally.

5. Big Data / Information Technology Integration:

Real-time information-based decisions are critical to improving the operational efficiency and environmental impact of air vehicles. To enhance decision making, large datasets from airplane and airspace (e.g., vehicle health, ATC, environmental impact, etc) must be captured and processed. Technology that enables integration of relayed information (e.g., weather, 4D trajectories, etc) with cockpit information is needed. This will enable higher levels of onboard automation and the ability to further reduce the environmental impacts from aviation.

6. Integrated Modeling and Simulation:

The FAA has made significant progress in the development of tools to assess aviation environmental impacts and these tools are being used in both domestic and international policy development. For NextGen applications a pervasive integration of the entire FAA tool chain is desired. The tools also need enhancements in more probabilistic use of modeling and simulation as well as inclusion of future concepts of operations including autonomous operations. These improvements will enable strategic decision making and planning initially but ultimately they will enable informed decision making at a more tactical level (e.g., control of specific flights) for reduced environmental impact.

Research, Engineering and Development Advisory Committee

Subcommittee Report – Airports

October 2014

RESEARCH ISSUES & OPPORTUNITES
FOR REDAC CONSIDERATION

Subcommittee on Airports

FAA Research, Engineering, and Development Advisory Committee

Issue 1: Integration of New Generation Aerospace Vehicles into the NAS

The emergence of commercial space operations and unmanned aerial systems (UASs)/remotely piloted aircraft (RPA) pose significant new challenges for the FAA, vehicle operators, airport/spaceport operators, and local communities. Despite defined research portfolios for both types of vehicles, critical research challenges remain. Perhaps more importantly, given the rapid development and proliferation of these new vehicles—especially UASs/RPA—these research challenges are extremely time critical.

Research can help address many of these concerns and identify how combinations of technology, procedures, and regulations can facilitate access to new generation vehicles without compromising the safety or efficiency of conventional aircraft operations in the air and on the ground

With respect to commercial space operations, additional research is needed regarding how both vertical and horizontal launch concepts can be integrated effectively into the NAS, safely and with minimal operational disruptions to conventional aircraft operations. Additional research is also needed regarding the physical infrastructure that will be required at spaceports to accommodate these space vehicles.

With respect to UAS/RPA operations, additional research is needed in multiple areas including aircraft certification, airspace and airfield operations, human/machine interactions, legal & regulatory frameworks, and safety & security assurance. The research needs to encompass the breadth of existing and likely future UAS/RPA users (military, commercial, and recreational), vehicle types, and vehicle uses.

Issue 2: Effects of Climate Change on Aviation Infrastructure and Operations

The scientific community has reached general consensus that anthropomorphic climate change is occurring, driven by global increases in the use of fossil fuels and other activities that generate greenhouse gases.[4] In the aviation sector, research is needed both to (1) determine best available measures to reduce the aviation's climate change impacts and (2) adapt aviation infrastructure and operations to reflect the impacts that do occur.

Considerable research has been conducted regarding the former area—including significant research and development into more fuel efficient engines and airframe designs. Such research

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[4] See for example *Climate Change 2013, The Physical Science Basics,* published by the Intergovernmental Panel on Climate Change.

should continue. Ongoing research and development regarding NextGen capabilities that improve the management of air traffic congestion both on the ground and in the airspace is also critically important. Such research can be expanded to include improving the energy efficiency and reducing the resource consumption of airport infrastructure—including more efficient airfield lighting systems, less energy intensive paving and construction methods, and more efficient terminal and support building maintenance and operations systems.

In terms of adaptation, significant research is needed regarding the impacts climate change will have on critical infrastructure—including airports and ground-based navigational aids. For coastal airports that may be threatened by forecast sea level rise and/or storm surge, this research includes best practices for hardening airfield and terminal infrastructure, research into saltwater-resistant lighting systems, and in extreme cases, evaluation of alternative airport sites. Adaptation-related research is also needed regarding the performance of airfield pavements and navigational aids when exposed to extremely high temperatures, as well as the impact of such temperatures on construction processes. From a flight operations perspective, research and development efforts that focus on operations in very hot environments may also be needed.

Issue 3: Managing Airport Operations in a NextGen Environment

As NextGen capabilities are introduced over the next five to six years, they are expected to bring substantive improvements to airport capacity, shared situational awareness, and collaborative decision making. Many of these capabilities will directly affect airport surface operations as well as have secondary impacts on airport terminal and landside operations. Research is needed to assess the likely magnitude of these impacts and assess the best ways in which airport operators, the airlines, and other stakeholders can prepare for them.

Areas of research related to this issue include:

- Assessing how NextGen may shift capacity bottlenecks from terminal airspace and runway systems to apron, terminal or ground transportation systems, particularly during irregular operations events and developing planning guidance that accounts for such shifts.

- Improving methods for sharing data regarding airport operations among all key stakeholders, including the FAA Air Traffic Organization, airlines, other aircraft operators, airport operators, and ground service providers.

- Developing decision support technologies/tools that can be utilized to optimize airfield and terminal operations, enhance gate utilization, improve resource allocation, and bolster operational safety.

- Evaluating the potential consequences and mitigation actions that should be taken in the event of NextGen capability disruption (e.g., GPS outage).

Issue 4: NextGen and Noise in the Airport Environs

Not many years ago, the severity of aircraft noise problems on and around many major airports was seriously constraining the growth and expansion of such facilities, casting doubt on the degree to which such airports could be relied on to meet the needs of a growing civil aviation industry. In more recent years, the progression to less-noisy generations of aircraft, coupled with aggressive noise abatement steps such as flight path adjustments, residential and school sound-proofing, and land acquisition programs have established a new balance of interests that is more accommodating to airport growth and expansion. The perils to airport growth which noise problems posed in the past are serious enough to warrant extreme care in anticipating and recognizing the potential of such issues to again arise as NextGen moves in the direction of increasing the density of overflight activity in the airport environs and in altering flight paths to accomplish that end.

The progress which has been made on this issue over the years resulted from a combination of federal and local actions. While the federal actions have concentrated on establishing increasingly stringent limits on aircraft noise output and on financial support for land acquisition and building soundproofing , the local airport operator actions have included proactive work with local land use and zoning authorities, noise monitoring and reporting systems, and a wide array of other community outreach and aviation advocacy efforts. In the course of these many local efforts it has been apparent that while the acoustic aspects of aircraft overflights is indeed, as the name suggests, a major part of the "noise problem", it is not the only ingredient. Community pushback was, and is, also a reflection of discomfort with the potential safety element of low-flying aircraft, with perceived deterioration of property values, and with the strength and vigor of political mobilization of community resistance. All in all, the "noise problem" is more complex than the simple notion of acoustic disturbance.

All of this gives rise to the need for extreme care in fashioning the flight regimes of NextGen and in recognizing that highly localized measures, tailored to deal with the technical and political factors found at specific locations, have been key to diffusing much of the "noise" issues of the past, and need to be understood and respected if the promise of NextGen is to be realized throughout the US aviation system.

Issue 5: Advanced Pavement Materials

Maintenance and reconstruction of airport pavement represents a major financial commitment to airports and the Federal Aviation Administration. Relatively minor improvement to the life of pavements can provide substantial cost savings both in direct repair /replacement costs and user delay costs. Improvement and innovation in paving materials represents the most direct way to extend pavement life. The fundamentals of current paving materials technology evolved in the 1940 and 50's. With the exception of polymers in asphalt and admixtures in concrete, current pavement technologies have not changed significantly. Nanotechnology represents a potential fundamental breakthrough in paving materials technology that has the promise to provide significant improvements in pavement materials.

Materials scientists are studying and experimenting with fundamentals in nanotechnology. More research is needed in applying nanotechnology to paving materials and in studying direct application to nanotechnology to pavements. The FAA’s National Airport Pavement Test Facility is an excellent location to study these applications and bridge the gap between science and implementation by using accelerated testing.

RESEARCH ISSUES/NEEDS
REDAC Subcommittee on Airports
September 24, 2014

LONG-TERM/STRATEGIC ISSUES

Safety Risk Assessment Processes for Airport Design Standards

EMERGING ISSUE: As formalized safety risk assessment processes proliferate in the U.S. aviation industry, increasing tensions are arising between historical airport design standards (e.g., those developed without the use of safety risk assessment techniques, including quantitative assessment of risk) and newer generation standards that take these techniques into consideration. Perhaps more problematically, some “new-generation” standards have been developed without apparent assessment of risk, raising the question regarding the safety justification of these standards.

RESEARCH NEED: Research is needed to develop improved guidance regarding risk assessment methods that can be applied in airfield standards development—particularly when these risks are associated with rare or very-rare events for which limited historical records of occurrence are available.

Airport Data Management

EMERGING ISSUE: Over the past decade, there has been a proliferation of geospatial, operational, and safety databases pertinent to airport operations, maintenance, safety, and planning. These data are spread across a wide variety of “owners”—including airport operators, airlines, the FAA, and private providers—creating a patchwork of data with varying degrees of accuracy, currency, and accessibility. This patchwork has created duplicative and sometimes conflicting aviation data in areas including airspace obstructions, airport surface surveillance, flight status, safety risk assessment, etc.. It has also raised significant questions regarding who “owns” particular types of data and how the accessibility of critical operational and safety data can be provided to those that have a need for it.

RESEARCH NEED: Research is needed regarding how airport operators, the FAA, and airport users can best manage and use the vast array of geospatial, operational, and safety data that are available both within the FAA and commercially to improve the safety and operational efficiency of the airports within the National Airspace System. This research should look beyond the FAA’s ongoing Airport GIS program to future needs for airport data management.

Autonomous Ground Service Equipment at Airports

EMERGING ISSUE: There have been several proposals over the past 5 years regarding the use of autonomous or remotely controlled ground service vehicles at airports. Most of these proposals have focused on aircraft tugs and have included use of these tugs to tow aircraft to locations at or near the ends of departure runways to reduce aircraft fuel consumption.

RESEARCH NEEDED: Research is needed to assess the potential uses of of automated and/or remotely controlled ground service equipment at airports and determine how such equipment can be safely and effectively utilized.

Jet Blast Hazards

EMERGING ISSUE: As the terminal and maneuvering area congestion increases, there is a need to re-baseline whether the typical industry threshold of 35mph contour for personnel exposure remains appropriate or to what it should be. Also for further consideration from a design perspective, is whether additional operational jet blast separation criteria needs to be established for aircraft crossing behind each other.

RESEARCH NEEDED: Research is needed to develop improved guidance regarding jet blast exposure of personnel and aircraft in the apron and maneuvering area.

NEAR-TERM/TACTICAL ISSUES

Improved Pavement Management Approaches

EMERGING ISSUE: Managing pavements requires a reliable pavement performance indicator. Existing pavement management systems are based upon a visually inferred Pavement Condition Index. PCI approach measures some distresses that indirectly relate to structural degradation, such as cracking or rutting, yet no well-defined relationship between structural and functional performance.

RESEARCH NEED: Examine the suitability of using the modulus derived from the falling weight deflectometer method of pavement structural health monitoring. Mechanistically derived pavement condition parameter will provide engineers and improved understanding of pavement distress and lead to the selection of best suited maintenance.

Next Generation Runway Status Light Systems

EMERGING ISSUE: Current Runway Status Lights program will soon be discontinued.

RESEARCH NEED: Examine cost effective solutions that could be deployed at airports to strengthen safety and situational awareness.

Maintenance Technologies/Practices for LED Airfield Lighting

EMERGING ISSUE: Advancements in Light Emitting Diode (LED) technology and their implementation to airfield lighting systems has become commonplace in the aviation world. As opposed to burning out like an incandescent fixture (easy to see with the naked eye), an LED fixture's light output slowly decreases (hard to see with the naked eye). The Illuminating Engineering Society (IES) determined that the usable life of an LED fixture is its L70 value, or point at which the light fixture is at 70% its original light output levels. Due to the slow decrease in light output, an LED fixture may not become noticeably dimmer until it's well past its technical lifespan. This creates a problem in accurately determining the useful life of LED light fixtures.

RESEARCH NEED: Since a single light meter cannot accurately measure the output of an LED airfield light fixture to FAA Advisory Circular standards, one possible solution would be to develop an array of portable light output meters that can be placed over a light fixture to quickly measure the light output of that fixture. The light meter array would be installed on a single frame cylindrical in shape. This would provide a more accurate and repeatable test to quickly determine the light output of the LED light fixture, allowing airport maintenance staff to ensure their lights are operating at FAA and IES standards.

Portland Cement Concrete Paving Trends and Advancements

EMERGING ISSUE: In the last 50 years there have been significant changes in concrete technology as well as concrete pavement construction technology. As construction technology, material suppliers and production techniques change, so does the predictability of the end product, which can significantly impact the 20 year life expectancy and required maintenance of runways .

RESEARCH NEED: The assignment of a historian on construction trends looking at materials, mixtures & pavement construction technology. The historian would also oversee the development of a library of case studies documenting significant success and failures following the industry trends.

Potential Areas to be studied include:

1. Overall changes in design mixes and additives.
2. Consistency and availability of raw material from open-pit mines.
3. Changes in the availability, production and alkaline of Portland used in concrete construction.
4. Historical tracking of success and failures of RWY and TWY construction across the country and their relationship to the materials, equipment and construction techniques used over the last 50-75 years.
5. Examine issues associated with local availability of sub-bases and their effect on constructability and the overall life of the pavement dependent on the area of the county they are constructed.
6. Overall trends in the industry.

Updating Exit Taxiway Location and Design Guidance

EMERGING ISSUE: With the implementation of the FAA's NextGen improvements that provide more consistent and possibly decreased aircraft in-tail separations on final approach (such as ReCat, etc.), there will be increased emphasis on minimizing runway occupancy times for landing aircraft. Guidance on planning and design optimal exit taxiway locations and geometry is dated. For example the primary model for locating exit taxiways -- Runway Exit Interactive Design Model (REDIM) -- was developed under FAA contract by Virginia Tech in the early 1990s. REDIM does not include many of today's aircraft including regional jets, newer, heavier models of 737s and A320s, 777 and 787s.

RESEARCH NEED: Research is needed to update REDIM and or create an improved model that provides practical guidance on optimal exit taxiway locations for new runways or improvements to existing runways. Also, high speed and angled exit taxiway design geometry should be reviewed to ensure efficient layout.

Use of Variable Message Airfield Signing

EMERGING ISSUE: The FAA and airport operators continue to focus on ways to prevent incursions into runways, construction areas, and other closed portions of the airfield. One idea that has been suggested is the use of variable message signing that would supplement conventional airfield signs to enhance "hot spots" and other key areas. These programmable signs (similar to those used for roads) could be relocatable or permanently installed.

RESEARCH NEED: Research is needed to investigate the feasibility of installing and operating variable message signs on the airfield and related technologies and consideration of standards. Technologies may include LED and LCD displays.

Use of ASDE-X or Surface Multilateration System Data in Pavement Management and Evaluation

EMERGING ISSUE: In the effort to reduce the impact on aircraft operations and the significant airport costs for airfield repairs and rehabilitation, there is a need to improve the quality of the input to pavement management systems. The availability of data to better characterize aircraft flow patterns and repetitions provided by FAA's ASDE-X system and/or third-party now being installed at larger airports provide an opportunity to improve the fidelity of the assumptions input into pavement management models such as the FAA's PAVEAIR. These pavement use history assumptions are often hard to estimate accurately.

RESEARCH NEED: Develop an interface that will allow direct or near-direct downloading to PAVEAIR model (or similar models) from data provided from ASDE-X and third-party surface surveillance systems.

Runway/Taxiway Separation Standards Reassessment

EMERGING ISSUE: The steady increase of NLA into the overall commercial aviation fleet is forcing land restricted airports into accepting capacity reductions due to conflicts with runway centerline to taxiway separation standards. As these NLA continue to come on-line and make up a growing proportion of the fleet, these losses in efficiency will dramatically increase.

While much has been done to research taxiway deviations for NLA, a better understanding of runway centerline deviations are needed.

RESEARCH NEED: Research is needed to study runway centerline deviations specifically as they relate to NLA. The number of NLA in the fleet and their operating to multiple facilities worldwide represents a good pool of data. This research should measure a statistically representative number of NLA Runway centerline deviations and the data should be analyzed through a formalized safety risk assessment process. The results of this research should be used to assess existing runway to taxiway and runway width standards for Group VI aircraft and determine the sufficiency of existing requirements.

Obstruction Standards Reassessment in a NextGen Environment

EMERGING ISSUE: Aircraft manufacturers and airlines are showing commitments to equipping their fleets with technology that enables them to use more advanced (accurate) approach procedures at airports (RNAV, GBAS). Airports have invested in these technologies only to find that the airspace needed to protect from an obstructions standpoint spans a much wider area than traditional instrument approach technologies. In order for the efficiencies promised by these advanced systems to be realized, airspace protection needs to be commensurate with the accuracy of the technology providing approach guidance.

RESEARCH NEED: Research is needed to look at the improvement of the protected surfaces for these more advanced approach navigation procedures. Specifically, this research should look at existing procedures (airspace separation, closely-spaced parallel operations, etc) and recommend improvements to standards based on the accuracy of these next-generation systems.

Reassessment of Rationale for Airport Beacons

EMERGING ISSUE: A continued issue for large hub airports is the constant need to relocate or dedicate valuable land to accommodating the airport beacon. The costs and time needed to plan for, design and relocate for beacons is surprisingly significant. For land constrained airports with active tenant communities, this issue continues to present a problem as airport structures are added or demolished.

RESEARCH NEED: Research is needed to determine the utility of airport beacons as they relate to air navigation, specifically at large airports located in sizable metropolitan (brightly-lit) areas.

Improvement in Compaction Testing Protocols for Asphalt Concrete Pavements

EMERGING ISSUE: Density and corresponding air voids are key asphalt concrete mix properties that predict pavement performance. The highway industry uses maximum theoretical density (MTD) as the basis for percent compaction. The airports use laboratory compacted samples as the basis for compaction and only use the MTD test to check air voids. The variability associated with laboratory based density is significantly higher than that where MTD is used as the base. Even though the MTD is more direct and provides a more accurate determination of both density and air voids, FAA has expressed a reluctance to switch to the MTD basis due to the present use of the percent within limits (PWL) specification. PWL is used as a pay factor for determining the statistical consistency of pavement density on a project. The basis of the PWL specification was calculated form actual construction projects records that used laboratory based densities.

RESEARCH NEEDED: Research is needed to confirm or establish a new PWL specification for MTD based compaction. Much of this can be done by re-examining project records and verifying on existing projects.

POLICY ISSUES

Expanding Use of Demonstration Projects to Disseminate Pavement Research

EMERGING ISSUE: Excellent pavement research has been and continues to be produced by FAA. However, the present system of distribution and promoting use of this research has resulted in very slow and limited use of the results and products in the field. The Federal Highway Administration has used a system of demonstration projects and distribution of demonstration project results to make a successful transition to the new technologies. The FAA system does not provide support to project designers and those responsible for specifying new technologies to allow them to take the perceived "risk" of using new procedures and technologies.

RESEARCH NEED: FAA needs to look into new ways to better promote and implement pavement technologies verified in their research projects, possibly through expanded use of demonstration projects.