NASA Advisory Council Aeronautics Committee Meeting
July 24-25, 2019
Glenn Research Center, Cleveland

Welcome

Mr. John Borghese, Committee chairman, called the meeting to order and welcomed everyone. He asked everyone present in the room to introduce themselves with name and affiliation, noting the new committee members present – Lisa Ellman, Eric Fanning, and Michael Hirschberg.

Ms. Irma Rodriguez, the Committee executive secretary, reviewed meeting logistics, procedures and policies. Dr. Jaiwon Shin, NASA associate administrator for the Aeronautics Research Mission Directorate (ARMD), added his welcome to what was his final meeting as NASA Aeronautics Associate Administrator prior to his retirement in August 2019.

Mr. Borghese reviewed committee meeting plans for the rest of the calendar year and the topics that will be discussed. For the benefit of the new members, he then led a brief discussion on the differences between the committee making a recommendation to NASA or citing a finding.

Ms. Marla Perez Davis, Deputy Director of the Glenn Research Center, briefed committee members on the research capabilities available at Glenn both to the agency’s aeronautics activities, and its space-related programs.

Dr. Shin then provided an overview of ARMD’s research portfolio so that new committee members could have a better understanding of what is driving the directorate’s research thrusts, and how those activities are meant to directly support the U.S. aviation industry and maintain our aeronautical leadership in the world. Dr. Shin noted that our ability to clearly articulate our research strategy – as presented in the continually evolving Strategic Implementation Plan – has been well received by Congress. He also noted the importance of maintaining a healthy balance in research between wind tunnels, computer simulations, and actual flight tests.

NASA Electrified Propulsion Research Summary

Mr. Jay Dryer, ARMD Deputy Associate Administrator for Programs, presented the overall strategy on electrified propulsion research at NASA. At its highest levels, the work NASA is doing in the area of electric propulsion can lead to benefits such as improvements to highly optimized aircraft such as single-aisle transports, help open up a robust Urban Air Mobility market, and revitalize the economic case for small, short-range aircraft services such as those in support of regional connectivity.

Whether it's small Unmanned Aircraft Systems (UAS), small aircraft associated with Urban Air Mobility, regional jets, single-aisle airliners, or large passenger or cargo transports, when it comes to integrating electrified aviation propulsion (EAP) into future designs, seven primary challenge areas exist. These include safety standards, certification standards, design tools, architectures, testing and evaluation, subsystems and components, and energy storage. Of these, industry still needs help in solving most of them – although the small UAS market is farthest along.

Mr. Dryer summarized NASA's research strategy and highlights as it relates to advancing transport-class aircraft technical and integration readiness, noting that a key element will be improving small core turbomachinery to enable efficient, compact power generation and improved overall propulsion system performance.

He also reviewed challenges associated with small vehicle EAP and discussed the importance of flight tests to solve them. Related to this, the committee was reminded that the X-57 is an opportunity to demonstrate the nation's ability to design, test, and certify electric aircraft, and to transfer that knowledge to industry.

Mr. Dryer highlighted several fundamental EAP challenges still at play, including finding new lightweight materials that can safely be used with electrified aircraft, as well as realizing better ways to leverage advances in energy storage found in other industries – namely automotive – for use in aviation applications. A key opportunity to solve some of these fundamental challenges may be found within the academic community as facilitated via NASA's University Leadership Initiative effort.

Mr. Dryer concluded his presentation with these summary statements:

- More electric systems will impact aviation ranging from small all-electric vehicles to larger aircraft with hybrid or turbo-electric propulsion.

- U.S. industry collaboration interest is high and international competition fierce with increasing R&D budgets in pursuit of more electrified vehicles.

- NASA has developed a strategy that provides leadership and a vision for this more electric future and addresses key areas where industry needs assistance.

Discussion

A lengthy discussion took place both during Mr. Dryer's presentation and after. The most relevant portions of this discussion resulted in a formal recommendation, which is stated here and includes the substance of the discussion as part of the major reasons for the recommendation section.

Throughout the discussion, a common theme revolved around the question of: what level of research should NASA be doing when it comes to battery cells (i.e., at the cell chemistry level or more of a systems level in which NASA uses battery cells already developed and made available from industry). Along these lines, different opinions were expressed as to the applicability of the automotive industry's experience with batteries to the aviation community.

Recommendation

The Committee applauds NASA's research in Electrified Aviation Propulsion. Research is being performed in many relevant areas: aero efficiencies, compliance and certification, tools for better design trades and new materials such as insulators. The Committee recommends that NASA consider developing and maintaining a database of battery and cell test results to share with industry. The idea is to have an energy power storage (e.g., cells, batteries, etc.) laboratory within the current NASA infrastructure dedicated to testing specific electric aircraft propulsion. This lab would test against standardized protocols and make the results available to industry to accelerate the adoption of electrified powertrains. This approach could be expanded to other system components, such as power electronics in the future.

The Committee further recommends that NASA explore other promising aircraft electric propulsion technology alternatives, such as fuel cell variants currently in use in automobile and bus transport vehicles. There are potential applications to the Mars mission so it will benefit not only ARMD but also NASA as a whole.

Major Reasons for the Recommendation

Both large and small innovative companies in the emerging electric aircraft industry are struggling to solve the energy storage problem. While significant progress is being made in the electric motors and lift systems, battery capacity with safe and efficient integration into air vehicles remains the critical component for success. Significant research is being performed at the University level. However, the immense challenge of transitioning these battery technologies is accomplished at very few manufacturing companies due to the difficulty of achieving large-scale consistent manufacturing processes at scale.

These manufacturing companies do not readily reveal their latest cell capability to small companies. Other electric propulsion alternatives suitable for aircraft applications (i.e. lightweight, high power/energy density) are in early stage development. NASA can fill this critical gap by providing a responsible, credible, and consistent testing methodology that industry can access. Other electric propulsion alternatives suitable for aircraft applications (i.e. lightweight, high power/energy density) are in early stage development. NASA could provide a test bed capability for these emerging technology capabilities, providing significant value to the emerging US electric aircraft marketplace. The country wants to lead in this technology area and the value to the US economy is tremendous.

Consequences of No Action on the Recommendation

The lack of extensive testing on new battery cell and other emerging electric propulsion technologies, along with the lack of supporting data will impede the small electric aircraft industry from developing the most efficient vehicles for this emerging market.

Autonomous Systems Research Strategy

Dr. John Cavolowsky began the second day of the meeting with an overview of NASA Aeronautics autonomous systems research strategy, noting at the very outset that ARMD is in the midst of concluding an extensive planning effort to coordinate budgets and activity related to autonomy across all programs and projects.

Dr. Cavolowsky described NASA Aeronautics' role is to act as a catalyst to accelerate the advancement of autonomous aviation systems and ensure the U.S. remains competitive. The idea is to lead the creation of national-level, large-scale systems enabled by autonomy; resolve critical technical bottlenecks with targeted research and development; build paths to implementation; identify and validate approaches to certification and operational approval; speed processes to achieving compatible systems operating procedures and minimal viable products; lead and coordinate the aviation stakeholder community; define realizable long-term objectives and track community progress; and develop system-wide industry consensus standards to enable markets to flourish.

Current activities to achieve these goals draw from NASA's extensive experience conducting research and development in automating aircraft and airspace operations, including technologies related to Unmanned Aircraft Systems such as detect and avoid, traffic management, and adaptive re-planning in response to real time changes in air traffic and weather.

These goals are informed by a number of operational objectives that have been suggested by the aviation community and/or are reflected in government policy documents including from NASA and the FAA. The objectives as summarized during Dr. Cavolowsky's presentation include:

- Enable aircraft without an on-board pilot to routinely operate in the National Airspace System.
- Remove the need for the current regulatory paradigm that requires a pilot for every passenger aircraft.
- Achieve an order of magnitude of more vehicles than operators.
- Enable order of magnitude increases to airspace system capacity, unconstrained by human workload limitations.
- Enable air transports to be piloted safely by a single operator.

- Enable new emerging market pilots to receive certification with order of magnitude reductions in training.
- Enable aircraft to auto-land anywhere and under nearly any conditions.

Dr. Cavolowsky wrapped up his presentation by leading a discussion of the markets that will need autonomy to thrive and what the status of various technologies related to autonomy are as they relate to those various market opportunities. He noted that NASA is expanding its research portfolio related to autonomy with a focus on working with its government, industry, and academic partners in the areas of vehicle autonomy, airspace operations, and certification approaches to enable autonomous missions.

Discussion

The discussion that took place during and after the formal presentation covered a wide range of topics and sharing of experiences. As they did following the electric propulsion topic presentation during the first day, committee members took time after the meeting to draft several findings that in stating those findings also summarized the major discussion points.

Findings

The Committee finds that NASA has developed a reasonable strategy for advancing this important area of contemporary aeronautics research and development. The strategic focus on national level, large scale applications such as future air traffic management, unmanned air systems, and emerging urban air mobility provides both motivation for NASA involvement and rationale for specific targeted programs. In addition, the plan to develop assurance methods for complex, machine learning-based systems recognizes the need to address future aviation autonomy capabilities beyond the reach of industry investment timelines. The importance of the human operator-intelligent machine relationship is also recognized as a major challenge relevant to the broadest class of aviation systems. Additional areas that require long term NASA attention include cyber-security and -resiliency, especially in the case of networked multi-platform systems-of systems. A companion NASA technology roadmap focused on stimulating fundamental advances would also be helpful. To facilitate those advances most germane to the aviation enterprise, NASA should continue its collaboration with the universities to increase interest and motivation in autonomous systems, while involving the students since they are the next generation of NASA engineers.

Other suggestions on where NASA can provide significant value in autonomy include:

- *Certification of Autonomous Systems* – Current approaches to hardware and/or software system verification and validation are ill-suited to today’s complex and highly automated systems, often resulting in prohibitively expensive (… in time or money) test and certification programs.. These methods are fundamentally incompatible with emerging autonomous capabilities that incorporate machine learning as part of their design. The ability to establish trust in and the requisite level of safety for these systems is a critical challenge for all applications that expect to exploit high levels of autonomy as a key feature of their management and operations. Certification methods that are compatible with learning systems and which focus on assessing operational safety are essential to the continued evolution of all the applications mentioned above. NASA, along with its industry and university partners, can play a key role in leading the development of these methods and motivating their adoption by federal regulatory organizations, especially the FAA.

- *Datasets for testing of autonomy under all relevant flight conditions* – The FAA currently has methods and test cases for the certification of aircraft subsystems. For example, there are 34 test cases that support Terrain Aware Warning System certification. There are no current datasets or test approaches to certify autonomous capabilities at the aircraft level. This class of data sets with supporting simulation capability can help catalyze the industry toward developing more robust autonomous systems. NASA has already amassed significant datasets that would be useful to this end. Publication of these datasets would be beneficial.
- *Continuation of the UTM construct* – NASA's Unmanned Air Traffic Management (UTM) initiative has captured the attention of the commercial unmanned air vehicle (UAV) industry and served as an initial catalyst to enable more widespread airspace operations, including high density air traffic, at lower altitudes. The UTM effort over the last 4 years on TCL-1 through TCL-4 has demonstrated NASA's role in providing global leadership in air traffic management for this new operational arena. Given the anticipated expansion in low altitude operations from UAM and larger UAS platforms, more needs to be done to grow the capabilities of UTM for these emerging applications, as well as to enable the effective transition of UTM to the FAA. The role of increasingly autonomous capabilities in coping with the demanding timelines and added complexity of the airspace can be anticipated. The Committee therefore believes that this program should continue with an expanded operational scope. Ideas to consider include adopting an "X Plane" approach (e.g. UTM-X?) to excite the public and motivate the industry for this important technology. A follow on to UTM could involve the assignment of special case airspace such as TRACON to provide a more realistic environment for UTM maturation.

Lastly, while the NASA strategy for autonomy has matured since the introduction of the "Assured Autonomy" Strategic Thrust over 4 years ago, detailed program level plans demonstrating an integrated, comprehensive approach to advance the autonomy agenda have been elusive. The Committee urges that ARMD formulate a long term, integrated Program Plan to address the challenges embodied in the Autonomy strategy, including the allocation of adequate financial investment and suitable personnel resources that demonstrate NASA's commitment to this important area for 21st century aeronautics.

List of Attendees

Committee Members

Dr. John Borghese
Mr. Scott Drennan
Dr. Eric Allison
Dr. Mike Francis
Mr. Anil Nanduri (via Webex)
Dr. Tom Shih
Ms. Lisa Ellman
Mr. Eric Fanning
Mr. Michael Hirschberg
Mr. Andrew Cebula

NASA

Dr. Jaiwon Shin
Mr. Robert Pearce
Mr. Jon Montgomery
Mr. Jay Dryer
Ms. Irma Rodriguez
Dr. John Cavolowsky
Mr. Akbar Sultan
Ms. Barbara Esker
Ms. Lee Olson
Mr. Eric Cooper
Mr. Neil O'Connor
Ms. Jennifer Kibbler
Ms. Vanessa Aubuchon
Mr. Chris Teubert
Mr. Nelson Brown
Dr. Marla Perez Davis
Dr. Ruben Del Rosario
Mr. Greg Follen

Fed Writers

Ms. Abigail Casas

Via Webex

NASA
Mr. Nateri Madavan
Dr. Ed Waggoner
Mr. Shawn Engelland
Mr. Dana Gould
Mr. Jim Banke
Mr. Richard Barhydt
Mr. Daniel Williams
Mr. Andrew Carnell
Mr. Matt Murray

Other

B. Harvey
J. Kleifgen
Jerold Stratton