NASA Advisory Council (NAC)
Aeronautics Committee

July 26, 2016
Ohio Aerospace Institute
NASA Glenn Research Center Cleveland, OH

Summary of Meeting Minutes

Participants:

First	Last	Organization	Role
Marion	Blakey	Rolls Royce North America	Chair
John	Borghese	Rockwell Collins	Vice Chair
Dr. John Paul	Clarke	Georgia Tech	Member
Dr. Michael	Francis	United Technologies RCenter	Member [PHONE]
Dr. Lui	Sha	University of Illinois	Member
Dr. Greg	Hyslop	The Boeing Company	Member
Dr. David	Vos	Google X	Member
Dr. Karen	Thole	Penn State University	Member [ABSENT]
Dr. Jaiwon	Shin	NASA	Deputy Administrator
Robert	Pearce	ARMD OAA	DAA / Strategy
Jon	Montgomery	ARMD OAA	DAA / Management
Dr. Woodrow	Whitlow	Cleveland State Univer.	NRC Low Carbon Study
Dr. Edgar	Waggonner	ARMD IAS Program	Director
Jay	Dryer	ARMD AAV Program	Director
Dr. John	Cavolowsky	ARMD AOS Program	Director
Doug	Rohn	ARMD TAC Program	Director
Irma	Rodriquez	Aeronautics Committee	Exec. Secretary
Lester	Lyles	AESB	Ex Officio
Ralph	Jansen	NASA Glenn	Tech Integration Manager
Angela	Surgenor	NASA Glenn	Subproject Technical Lead

Tuesday, July 26, 2016
The meeting was called to order at 10:19 a.m.

Introductions and Reflections

Chair Ms. Marion Blakey asked Irma Rodriguez, Executive Secretary to go over administrative details at the beginning of the meeting. Ms. Blakey thanked Ms. Rodriguez for her hard work in making the Committee meetings possible. The Committee appreciates the contributions made by former members, Steven Morford and Tom Wood, during the time that they served the Committee. Their terms have expired and a search for new members is in work.

Ms. Blakey said that we are in an interesting period of Presidential transition. There should be smooth continuity moving forward. Ms Blakey indicated that the NAC Interim Chair asked the committees to reflect on past discussions, in addition to regular business, to develop a list of general observations and concerns that the Committee has discussed over time for presentation at the next Council meeting. He asked that the committee limit the list to no more than five items and observations that can be presented on one slide, including positive comments that are important to present as consensus items that the Committee members are worried about or encouraged to see. The thought is that these lists will give a feel for discussion in the Committee and will be a useful way of conveying key issues to the next administration's transition team.

During a presidential election year, both major political parties form transition teams to help the presidential candidates formulate views on subjects with which they may not be immediately familiar. Ms. Blakey would be interested in the Aeronautics Research Mission Directorate's (ARMD) perspective on what the teams have said or the interest they have expressed.

Dr. Jaiwon Shin indicated that his year could be different: the two transition teams could be reaching out to agencies and departments well before the election. It could happen to the more influential or prominent departments. NASA may or may not be included. NASA's Associate Administrator for Strategy and Plans, Thomas Cremins, has been named as the point of contact for the transition teams. NASA's senior leaders are working to build a coherent NASA story, from aeronautics to space. Agency leadership is 100% behind the New Aviation Horizons (NAH) initiative.

NASA's Environmentally Responsible Aviation (ERA) Project had its genesis before the 2008 presidential election. Perhaps ARMD could use the presidential transition period to explain and promote NAH. Mr. Jon Montgomery is preparing materials for ARMD for inclusion in the reports to the transition teams. Gen. Lester Lyles referred to the congressional mandate to prepare materials to be submitted to the transition team. There isn't much clarity as of yet on a common format.

Commercial Aircraft Propulsion and Energy Systems Research: Reducing Global Carbon Emissions by Dr. Woodrow Whitlow, Jr. and Dr. Karen Thole

This paper will be presented during a special session during a propulsion conference in Salt Lake City, Utah at the same time as this committee meeting in July 2016. The recommendations will involve all sectors, public and private. Mr. John Borghese said that he thought there would have been another challenge. Industry is absolutely aligned with

alternative fuels, cost being a major factor. Is there a challenge for original equipment engine manufacturers to embrace these approaches? Dr. Woodrow Whitlow, Jr. replied that there will be a discussion about who should do what. Not everybody is recommended to do everything. Historically, what NASA realizes is that industry tends to look at the next quarter; federal labs can look out to several years. Dr. Greg Hyslop said he would push back against that [assertion]. He indicated that when Boeing puts a bet on a new airplane, it's a long-term bet. New aircraft designs are far more integrated than ever before.

Dr. David Vos asked if climate change agreements are important in this case. Dr. Whitlow replied that the paper addresses 2% of carbon dioxide emissions into the atmosphere. Even though it's a relatively small amount, the paper's authors anticipate the emissions will be more tightly regulated.

Dr. Lui Sha said that carbon reduction costs are increasing. He indicated that the automobiles and the trucks are the biggest problem. He added that the most important thing is to get the technology ready and highlighted the DARPA (Defense Advanced Research Projects Agency)-like grand challenge as an example. Fuel efficiency is a primary driver for aircraft and engine manufacturers alike. Dr. Whitlow replied that a carbon tax isn't under consideration. A grand challenge is something Dr. Shin would have to take up within ARMD. The paper's authors were specifically tasked to develop a research agenda, which intrinsically limits some of the things that might otherwise be recommended. There is at present no recommendation for a grand challenge rather one for 12 research thrusts.

Mr. Borghese said that, in terms of energy efficiency, any company will want to keep it to themselves and expressed concern about how the research gets incorporated system wide. Dr. Sha cited solar cells and hydrogen cars, some of which has already being tried by the government. The question is whether a small study of the policy issues might help. Dr. Whitlow said it would be a question for Dr. Shin. When the authors received the ARMD instructions, they were explicitly told to exclude policy.

Dr. Vos mentioned the differences between aircraft size and carbon footprint. He asked where are the most inefficiencies occurring. Trajectory management helps size the nature of the problem. A hybrid system is more realistic short-term. Power generation ideally would come from sustainable sources. The analysis should occur at a system level. Dr. Whitlow said Dr. Vos made great points and added that a change in operations would be needed. Also mentioned was that China remains the largest emitter of carbon per capita in terms of gross tonnage. Dr. Vos added that the United States is the largest in terms of net emissions. Ms. Blakey cautioned that the discussion was ranging well beyond the scope of the paper under discussion.

Mr. Borghese asked if the paper authors considered using a different propulsion mechanism for taxi, cruise and descent: that is, to modify propulsion based on the phase of the flight. Dr. Whitlow replied by saying the authors were tasked to look at power requirements and that affected some of the recommendations, but not to look at how things operate. Dr. Sha said he was puzzled why the operational profile wasn't included to get data available for research as part of it. Ms. Blakey said there already is a huge amount of operational data available.

Dr. Shin said that all the comments on the operational side are valid. There were reasons this study committee was focused on low carbon from the vehicle side. A

higher level of integration is absolutely needed, and ARMD is going to work on that. That is a great recommendation, and ARMD is thinking along the same lines. This study will be very valuable.

Mr. Pearce said that ARMD needed a number of components. Now that ARMD has seen what is possible, the next step is a deeper look at the global systems analysis and more integration across these various areas. ARMD has done studies on the vehicle and operations levels, so over the next year all of those can be compiled.

Dr. Vos said the urgency is what worries him. To have the United States assume leadership in global carbon reduction is very important. There are a multitude of studies out there. What's at stake is the future of the country. What's critical are line items that say, in the next month, this is what needs to be done. He added that he feels a tremendous sense of urgency to move forward and not just do another study. Mr. Pearce replied that ARMD isn't waiting, but moving out. Dr. Vos said the sentiment should be more on the strategic level, with simple goals that are aeronautics-focused. There should also be an unassailable visionary statement that contextualizes everything.

Ms. Blakey said the Committee would have an opportunity in the afternoon to make recommendations. Dr. Hyslop said the Chinese will get this problem solved, but that the United States should solve it first. Dr. Vos agreed that the U.S. should solve it first. He indicated that the US knows how to do it better than anybody and it's the country's responsibility.

Ms. Blakey asked about trend lines regarding biofuels. She added that there was a huge momentum behind alternative, sustainable fuels and expressed curiosity about the pace of progress. Dr. Whitlow said that there have been up to six pathways approved to make alternative fuels, and there's a lot of activity. But that activity is going up against established industry and the sheer volume of what's required.

Dr. Vos asked if, when the authors discussed developing technologies for each of these areas, were they talking modeling or actual construction. Dr. Whitlow replied that they meant components, lighter-weight materials, aerodynamic issues, manufacturing processes: methods that can be used to build larger nacelles. It's not necessarily analysis or computer models, but things that one could manufacture at scale. Mr. Borghese asked about the art of the possible. Mr. Dryer responded by citing NASA's open-rotor research that involved industry. It's necessary to understand the trade space. It's a combination of all the relevant factors. Mr. Borghese mentioned computational fluid dynamics as a groundbreaking NASA achievement. Mr. Dryer said that ARMD uses that as a driver to point the Directorate where it needs to be.

In terms of turboelectric propulsion research, Dr. Hyslop thought that industry could provide enough research in that area. Mr. Borghese said that, considering all the relevant technologies, some companies have matured them, but they're not the original equipment engine manufacturers. Dr. Francis said that work on megawatt-class systems will resonate with the folks in the defense arena, although it's costly. A brief discussion ensued about the cost of technology development and its application, especially as regards to defense.

Dr. Vos said that there have been a ton of studies and efficiency penalties that hit hard. Dr. Whitlow said the authors didn't come across anything that actually has been demonstrated. Mr. Borghese said he assumed the reason ARMD thought the work was feasible was because there would be many motors driving many propellers. Mr. Ralph Jansen indicated that the research would be different than that conducted two decades ago. There is now better propulsion integration, although the electric system is the downside. There are weight issues as well. A discussion then followed about efficiency and the need for ongoing research. Loads and operating speed may affect overall gains.

Dr. Vos asked if the transportation load redistribution was considered, how much does it change the carbon footprint depending on altitude, vehicle class, range, etc. Dr. Whitlow said he didn't know the answer. Considering the environmental impact of aviation, about 80% of emissions in aviation come from trips of 1,500 kilometers (932 miles) or more. Dr. Vos said he envisioned a future where short-range aviation accounts for the majority of travel. It would be feasible and affordable.

ARMD Strategic Thrust 4: Transition to Low-Carbon Propulsion by Jay Dryer

In terms of ground-based aerospace infrastructure, Mr. Borghese asked if ARMD will use existing or new. Mr. Dryer said he didn't know the answer specifically. Dr. John-Paul Clarke said that, going forward, the Directorate may have to make huge changes. Mr. Dryer said that where ARMD is today, he couldn't say where the state of the art is.

Mr. Borghese wondered if the transition to low-carbon propulsion is more of a thrust feeder to Thrust 3, ultra-efficient commercial vehicles. Mr. Dryer said it's more in parallel, and is helping ARMD to highlight that the Directorate isn't just focused on advancing the next generation of turbine engines. Thrust 3 and Thrust 4 are in the same project; ARMD is trying to advance both going forward. Mr. Pearce said that ARMD was trying to create an integrated story, hopefully communicating the creation of emphasis in these areas. Mr. Borghese praised the coordination, but cautioned that the Directorate shouldn't engage in duplicate efforts.

Mr. Dryer said that ARMD is considering the research from an integrated and systems perspective. There may be different paths to getting to the overall goal. There's a drive from the military side and a general trend in more electric aircraft. Mr. Pearce said Mr. Dryer is accurately representing the thrust plan ARMD has devised but there remains some built-in competition. ARMD has the ability to create challenges and award prizes. It makes everybody healthier. The Directorate wants people thinking and bringing new ideas. Mr. Dryer said ARMD is welcoming Convergent Aeronautical Solutions Project proposals that challenge current thinking. But those potential shortcuts are high risk. Even though ARMD efforts do feed upon each other, he didn't think there's much duplication.

Electrified Aircraft Propulsion by Ralph Jansen

In terms of electrified aircraft propulsion, Mr. Borghese observed that ARMD hasn't yet looked at hybrid wing aircraft, which could have many benefits. Mr. Jansen said it was an important area, and that concepts also exist for vertical lift. In terms of reduced carbon, fuel burn and emissions, Mr. Borghese said that while such strategic goals are laudable, any potential future airplane that individually cut emissions by 20% would

equate to just 1% annually over the life of that one airplane. Mr. Jansen agreed, saying it takes a long time to get the technology on the aircraft and the aircraft into the fleet. There are a couple of areas where one could get fleet-wide benefits fairly quickly: "When you build an airplane, you lock those things in. It behooves us to look as far ahead as we can. It's a tough problem."

Dr. Francis said that, recognizing that economics drives change, how much has inexpensive fuel affected carbon impacts? Mr. Pearce replied that, in the end, the two big drivers are the cost of fuel and what that does to the cost of transportation. Fuel cost remains a big issue. It will probably come down to policy. Dr. Francis said that, taking a systems perspective, there is an economic forcing function. Dr. Vos said it would be advisable to reduce carbon in order to move a kilogram (2.2 pounds) of material around the planet. Right now there are no traffic jams. Looking at it from that point of view, there are opportunities to trade [carbon emissions]. Mr. Jansen said it was a good point and was the overall goal.

Dr. Vos wondered if multi-optimization tools were useful. Mr. Jansen said no, but Mr. Dryer said the tools were driving some of ARMD's efforts. Dr. Vos added that, in 30 years of use, only a small number of things can be optimized. Mr. Dryer cited bird strikes as one example of something that can't be optimized, but can drastically affect performance overall.

Further discussion then ensued concerning optimization approaches and techniques. They could be quite useful in regards to battery power during flight. There are economies of scale when discussing millions of unmanned aerial vehicles (UAVs) in operation, at all trajectories and altitudes. The smaller the aircraft, the more flexibility. Dr. Vos: "There are phenomenally exciting things to be done if we just allow ourselves to go there." Dr. Clarke said that cruise glide would require an entirely new architecture. Mr. Jansen said in terms of fuels, there are batteries, fuel cells, and other options. Mr. Borghese said that efforts needed to optimize for drag. Dr. Vos urged widening the trade space, since so much is going to happen, and indeed is happening now.

ARMD Strategic Thrust 4a by Angela Surgenor

In terms of transition to low-carbon propulsion, Mr. Borghese asked what Ms. Angela Surgenor meant by alternative architectures. She replied the definition is those things made outside of natural resources: something humans would have to create. In terms of alternative fuels, Dr. Clarke said he knew of one company actually building a plant. Is ARMD sitting on the sidelines waiting for it to fail? Ms. Surgenor replied that ARMD attempts to look at every effort and then use anything that can be pulled into the research. Mr. Dryer said there is no one-size solution, but multiple steps are needed to arrive at a solution. A brief discussion ensued about U.S. and Chinese efforts to work with alternative fuels.

In terms of technical advancements for fuel flexibility in low-carbon performance, Dr. Clarke wondered how one would parameterize. There are things one needs to know to chart performance characteristics. Mr. Dryer said that is something "on our radar screen." Dr. Vos asked if octane ratings really mattered: "In a turbine there's a continuous burn, so it doesn't nearly matter as much. Small diesel engines are really growing." He cited flame burn that matters greatly with autos but that doesn't pertain much here [to aviation].

Mr. Borghese asked why more progress hasn't been made, and what was stopping widespread adoption of alternative fuels. Ms. Surgenor replied that, while the architecture and infrastructure is already in place, in switching over to alternative fuels, there must be assurance that jet engine seals don't swell. Mr. Dryer said that production can't yet compete with low-cost petroleum-based fuels. It's getting close, but it's not there yet. Mr. Borghese: "Given that there are significant problems, would it be better to invest that money in more efficient turbines?" Mr. Dryer: "We're just not there yet. We're proportionally invested." Dr. Vos asserted that the reason was two-fold: legislation isn't there to mandate it, and there are market forces in play. Ms. Blakey said that it was critical NASA continued its alternative fuel research, even if only as a defensive measure. Mr. Dryer said that ARMD alternative fuel research was evolving as progress in the field continued. The Directorate wants to stay coordinated, ready from an aircraft standpoint, and doesn't want to be the holdout. Mr. Borghese said that no one knows what is going to be successful. ARMD is placing a lot of bets in a lot of different areas.

A discussion then ensued about where to put research dollars, and making current combustion as efficient as possible. Hybrid electric may be the most feasible, near-term approach. It is likely decades out before a long-range all-electric plane is put in service, but it is a solution for short-range plane. Batteries are not the solution for long range, at least not yet, even though it does sharpen the story. Fuel with zero emissions will get one there faster than a single-plane concept that would take 30 years to develop. Progress is being made in lowering alternative fuels cost, from $40 to $10 per gallon.

Regarding the transition to low-carbon propulsion and alternative jet fuels, Mr. Borghese asked whether, as ARMD is working on new designs for injectors and combustors, a whole-engine change be required. Ms. Surgenor said researchers have to make sure the components work with the whole engine.

New Aviation Horizons Overview by Dr. Edgar Waggoner

Considering the proposed series of X-planes, Dr. Francis said there are five very different ideas. How do you decide to do what next? Dr. Edgar Waggoner said that ARMD is looking at ones that are the most mature, ones that have the most benefit for the community. The Directorate won't know the design space until ARMD obtains a definitive budget. Hybrid wind body and truss-based wing designs are the most mature. Dr. Francis: "Will this be an annual decision based on the budget every year? What's the strategic perspective?" Dr. Waggoner replied that ARMD has laid out a plan for each concept and is going to a preliminary design for each one. The NASA budget will be a marker, and a detailed plan will be devised: "But since [the NASA budget is] an annual process, we have to be flexible, we have to be agile. We will be ready to adjust." Dr. Waggoner added that ARMD intends for the New Aviation Horizons (NAH) initiative to truly be a partnership, and will institute a gating process to make sure that we make wise budget decisions

Dr. Francis said that if NAH had occurred 30 years ago, there would have been a somewhat diverse group of primes building these aircraft. Now there is only one. The military will piggyback on anything done here. He urged ARMD to look at the key suppliers and what they would offer in this space.

Dr. Clarke asked if the program had an idea of what the outcome should be in terms of specific capabilities. He urged the program to have an idea before down selecting to be able to find out what set of technologies people would want and could use and to be able to demonstrate capabilities down the road. Dr. Waggoner agreed. ARMD is considering requirements and benefits, particularly for the subsonic demonstrators. Dr. Clarke said that, considering the inherent risk, ARMD needs to buy down that risk.

A discussion then ensued about looking at everything together holistically, how NAH fits into the entire system and into the entire design space. The program's benefits must be communicated. Inspiring the next-generation workforce is vitally important. Dr. Shin asserted that NAH must be a truly 21st century X-plane program, not one from the 1950s and 1960s. Dr. Clarke added that is also important to define and let people know how the results will be applied going forward.

In terms of the fiscal year 2017 President's Budget Request, Dr. Clarke suggested picking one demonstrator and down selecting for the second. Dr. Waggoner said the point was well-taken. Dr. Sha said that, since NAH is an integrator program, like the F-22 and F-35 fighter aircraft, software could be a huge problem. Fail-safe autopilot is the default and it is a major risk factor in an integrated system. There is no established procedure to use more than one computer core [in supposedly multicore systems]. Current multicore chipsets cannot be used.

Dr. Vos said that the technology shouldn't be declared unusable before actually using it. Cables and connectors can be problems; one must deal with the whole thing. Ms. Blakey said she assumed ARMD's Integrated Aviation Systems Program (IASP) was looking at software integration issues. Dr. Waggoner agreed, but that IASP would not be creating new software, but rather relying on software that has been tested and validated. Mr. Pearce said that if there are key issues that need to be brought to light and ARMD would examine the whole range. For these particular vehicles, the goal is to have the right software so they can actually be flown. Dr. Hyslop agreed and recommended to only use what's needed and to use proven systems.

Dr. Vos said he wouldn't cry wolf on any one technology domain. He doesn't believe that any of these [proposed NAH] airplanes would need to be certified. Mr. Borghese said the biggest issue would be some of the aircraft would be unstable. Dr. Francis said that for any X-plane, certification will be needed for more intelligent vehicles. If software is the primary means of focus, related issues need to be examined more closely. Mr. Pearce said ARMD would agree, even though, for this proposed X-plane group, the issues may not apply as intensely.

Dr. Vos would strongly encourage a whole domain space for flying smaller-scale vehicles. Mr. Pearce said ARMD is examining that. Onboard experiments would be directly related to the ARMD Strategic Plan. Dr. Vos said the best engineers to hire are the ones who touch on the whole domain space: theory and experiments. Dr. Francis said that any X-plane is a long-term proposition that comes with an often unpredictable flight test period. One needs to understand the strategic partnerships being set up. Such a strategy will be useful over time. Dr. Vos wondered about involvement of small business. Dr. Waggoner said that would be part of any large contract to be awarded. ARMD's ultimate goal would enable air travelers to eventually fly anywhere in the world in six hours. Dr. Clarke observed that ARMD should consider how to get a university through the design review.

A discussion then followed about how fundamental research feeds into such efforts. A feedback loop has resulted in these ARMD programs and projects. The pace of supersonic work has dramatically accelerated. Tools transfer to industry has also become a priority. Kickback on thinking process and rationale behind research priorities from ARMD to the Committee would be extremely helpful.

Committee Deliberations and Findings

In soliciting findings and recommendations, Ms. Blakey asked if any Committee member has any specific input. Dr. Vos expressed: “First of all, I loved that there’s a very clear beacon and vision driving where everything’s going. There needs to be a cross-research domain. There should be cross-pollination of ideas. I would strongly encourage complete fearlessness going into these domains. Be intrepid and don’t be afraid of anything.” Dr. Clarke: “Don’t be constrained by conventional boundaries. Think bigger across the programs and projects.”

Mr. Borghese said that the National Research Council study of traditional engines and propulsion didn’t include potential invention of a game-changing battery. In aeronautics, one should look out 50 years. Energy storage needs to be considered, as does getting rid of carbon emissions. Dr. Clarke said that engineers jump to solutions because they’re engineers. But perhaps first go to the second solution: how does it drive the trade space? Dr. Vos said the trade space should include the balance of cost and value, terrestrial and space. He said he really wanted to compliment ARMD on its vision statement. Dr. Sha said he was very impressed by what he heard. Lessons learned from the Department of Defense should be seriously considered, especially software.

Dr. Francis asked that, referring to the August 2 autonomy roundtable, what are the expectations? Mr. Pearce said ARMD invited members of the autonomy study to convene and share how ARMD folks are creating a more detailed autonomy roadmap. The goal is to see how well the bases are being covered. ARMD is trying to do as much as possible to get feedback, and see how the roadmap jibes with the autonomy report. Dr. Sha said that autonomy and machine learning pull a lot of decisions from the domain of pilots. Behavioral constraints for software are essential.

Ms. Blakey asked the Committee members if they wished to convey any specific recommendations regarding the material presented. Mr. Borghese said that, in previous sessions, there have been differences of opinion in other areas of NASA, but not in aeronautics. There was a desire to get into autonomy, be he hasn’t heard anything about it. Dr. Vos said that the United States needs to step up to maintain its aerospace leadership for the world. How does the U.S. keep its aerospace industry a vigorous world leader?

Dr. Clarke said it may be obvious to the Committee that X-planes are a series of experiments, but to many people, it’s a nice demo. It needs to be thought of as an opportunity to drive investment decisions, and not just cool stuff aerospace engineers like to be doing. Dr. Hyslop said he thought it’s more of an issue of expectations management for certain people in government. Smaller demos at universities is a very good suggestion.

Dr. Vos said that democratizing access to a fourth dimension [of time] opens up 25% of world gross domestic product not accessible at present: “This is an incredible, explosive opportunity.” Dr. Hyslop said that competitive pressures will lead certain ways, but will not lead to the kind of breakthroughs described [in the briefing]. Opening up the aperture here is very important for the nation. Dr. Clarke said that development of [a new class of] X-planes will bring excitement from the public. Dr. Hyslop asserted that tube-and-wing [designs are] still a growing industry.

Ms. Blakey wondered if the Committee should ask if the aperture should be opened. Mr. Borghese said don’t treat too many things as constraints. Dr. Shin said that ARMD understands about opening the trade space, opening the aperture. One thing that would be helpful is how ARMD figures in the Committee’s current thinking. He would suggest that the Committee clearly articulate that. Ms. Blakey said she didn’t want the Committee “to open aeronautics to criticism. I think frankly the X-planes have sold themselves with concrete, real benefits.” Dr. Vos said there are different degrees of optimality. Ms. Blakey said that bringing in industry is something the Committee should call out and encourage.

Dr. Clarke suggested iterating what constraints, if relaxed, would give ARMD the biggest bang for the buck. He added to start from the current position and then define the trade costs. Mr. Borghese pointed out one such example in ARMD: research on how to make the national airspace more efficient. Dr. Shin mentioned a pending ARMD leadership team meeting offsite at NASA’s Glenn Research Center in the next two days. He cited the Federal Aviation Administration’s Next Generation Air Transportation System (NextGen). Many air traffic management experts are following the NextGen vision. What is next? A lot of people are talking about trajectory-based operations (TBO). Unmanned aerial systems traffic management (UTM) came along as a wedge into NextGen that five years ago no one anticipated. Now, fundamental questions about TBO have to be asked.

In mentioning UAVs and UTM, Dr. Clarke said there’s now the ability to test with air traffic management and how good TBO will prove to be. ARMD should seize it. Dr. Shin said that, even though TBO might be the right goal, ARMD still has to question it. Mr. Borghese said one may call TBO the same thing, but the way it ultimately will be done will be totally different. Dr. Shin said this was the time to shift and change regarding 20 years out. He added that the meeting was really interesting, and that there doesn’t seem to be lingering disagreement among the Committee. Ms. Blakey said that the Committee was a very good group to surface [such issues].

A discussion then followed about early efforts with UAVs integrating into the national airspace system. Google X doesn’t want to generate standards and requirements that waste months and years. Define the application program interface (the set of routines, protocols, and tools for building software applications) and communicate with one another. Safety and security comes with identity, said Dr. Vos. But the Federal Aviation Administration still has responsibility for the airspace, from blades of grass up to thousands of feet.

Dr. Francis said he resonated with a comment made earlier by Dr. Vos regarding integration among the ARMD research thrusts that would lead to a larger systems solution. Mr. Borghese suggested that if ARMD retooled the thrusts, perhaps it would be wise to keep all six rather than pare back to five.

Gen. Lyles said there is a groundswell spurred by Department of Defense Secretary Ash Carter to start experimentation across all the U.S Air Force mission areas and the entire Defense Department. He cited air superiority as one example. Looking across the whole spectrum, Gen. Lyles didn't think that any of it has been exposed to ARMD. He hoped there's a way to bring all these activities together.

Public Comments:

None.

MEETING ADJOURNED at 5:01 p.m.