In May, the Society’s 78th Annual Forum & Technical Display at the Fort Worth Convention Center in Texas brought 1,275 attendees and 79 exhibitors back from two years of pandemic events in cyberspace. VFS Executive Director Mike Hirschberg acknowledged, “Nothing beats face-to-face.” Technical papers, floor exhibits and special sessions again updated the vertical flight community on military Future Vertical Lift (FVL) and civilian advanced air mobility (AAM) developments. Both broad initiatives pose challenges for the rotorcraft workforce and its specialized supply chain. Hirschberg said, “We have a lot of disruptive ideas that can be considered and explored.” He nevertheless cautioned, “There’s a talent crisis growing in vertical flight with an unprecedented demand for experienced engineers.” Forum speakers repeatedly cited a need for 10,000 engineers over the next 10 years to bring AAM and FVL concepts into service.

Equally troubling is the US industrial supply chain unready for transformative flight. Dana Jensen from the US Air Force Office of Commercial and Economic Analysis told a Forum special session that two decades of outsourcing to cheaper global suppliers came at a price. He explained, “What the pandemic has done has held a mirror up to those decisions and made us realize maybe some of the cost savings we’ve been realizing over the years related to supply chain globalization were actually done on credit, and the collateral was potentially the stability of the defense industrial base.” Jensen concluded, “Rehabilitation is really what we need to do to our supply chain, and that’s a long, painful process that takes a lot of discipline and, in this case, is going to be costly.”

The FVL program challenges industry to produce Future Attack Reconnaissance Aircraft (FARA) and Future Long Range Assault Aircraft (FLRAA) that are faster and longer-ranged than today’s helicopters. FVL is also developing Future Unmanned Aircraft Systems (FUAS) — which includes the runway independent Future Tactical Unmanned Aircraft System (FTUAS), unmanned Air Launched Effects (ALE) and the Scalable Control Interface (SCI) — to extend the reach of FARA and FLRAA. All the FVL platforms depend on a Modular Open System Approach (MOSA) to expedite upgrades from competing suppliers.

FVL has already moved traditional design into model-based systems engineering. By the time of the VFS Forum, FARA
competitive prototypes from Bell and Sikorsky were more than 80% complete. Both are to begin ground runs with GE Aviation’s improved turbine engines early next year and support a downselect in 2024. According to US Army Deputy Program Executive Officer for Aviation Pat Mason, “We’ve learned a ton from competitive prototyping even before flying. All of the design work, the modeling, have allowed us to refine our requirements and make design trades, so when we head into Engineering and Manufacturing Development [EMD], we can be where we’ve reduced a lot of that risk already and hopefully our timelines as well.” Mason added, “Flight will be the icing on the cake.”

FVL also changes the way Army aviation fights. Forum keynote speaker UK Army Air Corps Maj. Gen. Michael Keating — currently Deputy Commanding General of the US Army III Armored Corps at Fort Hood, Texas — cited missions flown by III Corps aircraft in the continental US, Europe and elsewhere. He noted, “Vertical flight is a primary example of high-performing teams achieving extraordinary outcomes.”

More than Modernization
Fresh from a warfighter simulation exercise that modeled an FVL-equipped aviation brigade, Gen. Keating offered, “The aviation community needs to do a better job of integrating modern vertical lift capabilities into contemporary combined arms simulation environments.” He added, “Fighting Future Vertical Lift as a family of platforms, and as an expensive kinetic and non-kinetic capability, will dictate success for us as combat aviators, so we need to open the aperture for the entire combined arms team... That team has to include the US allies and partners.”

A collaborative Forum presentation by French aerospace lab ONERA rotorcraft program director Arnaud Le Pape, and the German Aerospace Center (DLR) defense technology program manager Florian Antrack spotlighted current rotorcraft research; this included advanced numerical simulation capabilities, noise experimentation and analysis, manned-unmanned teaming, and sling load stabilization for unmanned cargo aircraft using artificial intelligence. European research on robust rotorcraft structures and

Prof. Marilyn Smith highlighted the role of innovation and partnerships between government, industry and academia in her Nikolsky Lecture.

Dana Jensen highlighted the US Air Force’s concerns about supply chain and the impacts of outsourcing to cheaper global suppliers.
innovative design concepts includes active-twist rotor blades to begin wind tunnel tests in late 2022 or early 2023.

Derek Gowanlock of Canada’s National Research Council (see “Leadership Profile,” pg. 84) told the VFS audience about flight control laws for the CH-148 Cyclone maritime helicopter tested on the NRC’s Bell 412 research helicopter, “We anticipate it should allow us to reduce the cost and time to conduct SHOL [Ship-Helicopter Operating Limits] trials — which is usually about a year long, a hundred flight hours, and a few million dollars to complete — to at least cut that in half and increase safety of the overall approach.”

With FVL expected in the US Army around 2030, NATO allies are looking for new helicopters to bridge the vertical lift gap, pending decisions on compound helicopters or tiltrotors, and confidence in FVL capabilities. UK Defence Equipment and Support senior fellow Pat Collins provided an overview of NATO’s Next Generation Rotorcraft Capability (NGRC), meant to replace around 900 aging helicopters with 600 new manned aircraft plus Unmanned Aircraft Systems (UAS). The current NGRC concept stage sets timelines and attributes for a development stage around 2025 or 2026 with an eye to constrained budgets. “There’s no point making an exquisite piece of technology that’s unaffordable to most,” said Collins.

Airmobile armies will also transition from industrial-era warfare to information-era warfare with artificial intelligence and machine learning. According to Gen. Keating, “It’s still tantalizingly close but annoyingly far away, in my opinion.” MOSA, which must ultimately integrate such advances, was the subject of a dedicated Forum special session. US Army director of MOSA Transformation Matt Sipe told the Fort Worth audience, “There’s not a single MOSA. It’s tailored per platform, per product.”

The MOSA technology office within the Army’s PEO-Aviation provides governance, model-based system engineering and a business environment meant to free the Army from proprietary hardware and software. According to Sipe, it promises to make upgrades faster and cheaper but poses new challenges to suppliers used to long, non-competitive solutions. “How do you have a sustainable business model with no back-end on the contract?”
With prototypes expected in 2024, the ALE sub-set of FUAS starts the first MOSA business test. The Army plans to integrate the unmanned ALE air vehicle, payload and mission system, bought in small competitive lots to minimize risk. According to Army UAS product manager Col. Scott Anderson, “I don’t really care about that air vehicle so much. What I care about is that architecture. What I care about is that mission system. That’s what I want to own as the government. That air vehicle is a truck. That payload, it can be modular. I can get other payloads and integrate those in... What we’re doing with ALE is how we’re going to buy unmanned air systems in the future.”

Deputy PEO Aviation Pat Mason told the VFS audience the component specification model will decompose ALE and FTUAS into functional capabilities common across unmanned systems and tell mission system integrators what they can mix and match. He added, “I can guarantee that we will not get it 100% right. We will be wrong. It’s really in what measure we’re wrong in certain areas.”

Mason told the VFS audience that AMCS gives the enduring fleet an open computing environment to add degraded visual environment solutions or new radios without whole new boxes. “It gives us the ability to collapse infrastructure on the aircraft.” He noted, “Black Hawks will be in the fleet for another generation of pilots, in my view, even when we have FARAs and FLRAAs out there. The same thing for Apache, and certainly on the heavy-lift [Chinook] side of the house.”

Forum program updates outlined targeted modernization plans for the enduring fleet. The Sikorsky UH-60M remains in production through 2026 and the new T901 improved turbine engine, MOSA and multi-core computer upgrades offer the utility helicopter a “capability bump.” With the
Boeing CH-47F Block I production contract concluding this December, the first of the modernized cargo helicopters will hit their 20-year economic service lives in 2026. The CH-47F Block II remains in EMD, and regular Army cargo helicopters can share in work done for the Special Operations MH-47G.

Mason noted, “When a program office doesn’t have money, MOSA becomes a really good idea because someone else pays for it.” The open-system business model simultaneously broadens the supplier base and challenges the old model of proprietary data rights. According to MOSA lead Sipe, “It is not no-rights. It is not all-rights. It’s tailored.”

Naval Air Systems Command (NAVAIR) rotorcraft program managers piped in their video updates for Forum 78. The US Marine Corps declared initial operational capability with the Sikorsky CH-53K heavy-lift helicopter in April and plans a full-rate production decision in 2023 to achieve full operational capability by 2029. With the joint service Bell Boeing V-22 Osprey near the end of its production run, the Navy CMV-22B is filling fleet squadrons for carrier on-board delivery. The Bell H-1 upgrade program ends AH-1Z production for the US Marine Corps this year, but integration work goes on for the Joint Air-to-Ground Missile (JAGM), Intrepid Tiger electronic warfare suite, and potentially ALE on the still-new attack helicopter.

NAVAIR rotorcraft science and technology manager Michael Fallon reminded the Fort Worth audience that the Navy and Marine Corps remain stakeholders in FVL, most notably with the Maritime Strike initiative to replace the Sikorsky Seahawk and Northrop Grumman Fire Scout. He offered, “It may not be a one-for-one replacement. They’ve got certain missions in the 2030s where they want a family of systems — manned/unmanned aircraft, perhaps — that can fit on small ships, the DDG” [guided missile destroyers].

Make What, Where?

VFS now lists more than 670 electric vertical takeoff and landing (eVTOL) concepts in its World eVTOL Aircraft Directory, and several developers count substantial orders for many aircraft yet to fly. A Forum special session on the challenges of eVTOL and advanced air mobility (AAM) addressed the still-formidable engineering, infrastructure and regulatory questions surrounding transformative flight. NASA AAM lead strategist Starr Ginn told the audience, “If anyone has just started in this industry, you have a long way to go.” She recounted how NASA’s own work on the X-57 electric fixed-wing aircraft (see pg. 64) required innovative test techniques and hardware.

Dr. Noah Schiller, associate project manager for NASA’s revolutionary vertical lift technology (RVLT) effort envisions AAM as sustainable, safe, new ways to connect people and cargo in rural and urban operations. The initiative aims to develop and validate tools and technologies for new kinds of vertical lift vehicles, and it focuses on AAM concepts with high economic benefit and hard technical challenges. RVLT researchers model generic concept vehicles sized to carry four to six passengers over 115 to 140 nm (215 to 260 km). Schiller explained, “They’re not meant to be the best vehicle for a given mission. They’re meant to capture the relevant [AAM] vehicle characteristics.” NASA has increased research funding on occupant safety, and handling and ride quality. Validation tests with side-by-side rotor test rigs, for example, characterize the effects of rotor spacing.

eVTOL concepts open new design spaces, acknowledged VerdeGo Aero director of advanced concepts David Eichstedt. However, dreams of clean, quiet, cheap all-electric flight are clouded by the energy density of available batteries. According to Eichstedt, with energy density improving 3–5% a year, eVTOL designers have a long road to all-electric vehicles. “We also have to deal with cycle-life issues, charging infrastructure and recharge time. All of these are things we need to deal with using batteries in electric aircraft.”

Powertrain losses, aging batteries, indirect air traffic routings and energy reserves required by the regulator (the Federal Aviation Administration in the US) further dim the vision of all-electric air taxis. Eichstedt said, “In VerdeGo’s view, sizing
A special session on Agility Prime flight test developments featured four speakers from the Air Force, including Col. Nathan Diller (left), and two speakers from the eVTOL industry.

a [battery] pack for a 20-mile commercial mission is kind of a myth because in order to safely and legally get to that 20 miles, you need to size that pack to deliver theoretically 130 to 140 miles range.” He offered, “For us, hybrids plus sustainable aviation fuels offer a way to get to electrification faster than batteries.”

Hard-to-find battery materials and hard-to-develop manufacturing capabilities in composites, electronics and other specialties pose serious challenges to domestic AAM production. Andy Miller from Benchmark Minerals Intelligence, Ltd., confirmed the disturbing truth. “China is the dominant force across the supply chain. If they don’t produce raw material in China, it has to go to China to be refined.” Miller concluded, “You’re not going to get the cobalt you need for the batteries you need without using [China].”

To circumvent battery shortcomings, Ronda Destout, co-founder and chief engineer of hydrogen fuel-cell developer HyPoint noted current fuel cell technology generates just 600–1,000 Watts per kilogram. More efficient high-temperature proton-exchange-membrane (HTPEM) cells require heavy heat exchangers and cooling loops. HyPoint plans to begin deliveries in 2025 of a turbo air-cooled fuel cell stack capable of 2,000 W/kg. The company’s goal is a single-cell HTPEM generator with 3,000 W/kg energy density. Significantly, the technology requires few special materials other than the company’s proprietary coatings.

Materials and manufacturing capabilities challenge the growth of the AAM industry in the US. Alan Davis, president and CEO of i5 Services observed, “We’ve had, for close to 20 years now, a path to supply that’s been leading us overseas.” However, “the path to supply has not led to US capabilities. It has led to overseas capabilities,” Davis offered, “We can be more resilient. We can do something about it.” Davis talked about his company’s efforts with VFS and the General Aviation Manufacturers Association (GAMA) to illuminate the AAM supply chain and connect suppliers based on what they do, rather than the products they usually make. Original equipment manufacturers looking for machine shops in defense/aerospace, found suppliers in databases from other industry sectors. “It’s a matter of not knowing who our manufacturers are and what they’re capable of doing that keeps us oftentimes from sourcing local first.”

Deloitte Consulting managing director Chad Molter likewise told the VFS audience, “If you can’t see it, you can’t manage it.” He added, “If you think about advanced vertical flight, the supply chain runs six to 10 tiers deep. When that supply chain has that level of depth, you introduce new and different challenges at each level of the supply chain... Any time you look at a particular weapon system or program, by the time you look at Tier 3 or 4, 40–60% of that supply chain is already overseas. Once that supply chain goes overseas, you introduce a whole new set of risks to worry about.” AAM, whether hybrid or all-electric, draws on totally different industrial bases, and Molter noted, “Critical minerals come from places that are not friendly.”

Davis told the Fort Worth audience, “When we solve a supply chain issue, we create a work force issue.” He noted the US nearly matches China’s industrial output with just 10% of the workforce and concluded, “Our innovation actually drives our production. We couldn’t produce that much without innovation.”

Who Makes Them?
The US rotorcraft workforce does not want for innovation. In her Nikolsky Lecture, “Computational Vertical Lift Aeromechanics and Its Future in the Twenty-First Century,” Prof. Marilyn Smith, Director of the Vertical Lift Research Centers of Excellence (VLRCOE) at Georgia Tech, recognized the Ingenuity helicopter exploring Mars. “I believe it’s fair to say that the potential of rotorcraft for planetary exploration is a comparable breakthrough to Igor Sikorsky’s mid-20th century demonstration of the capabilities of helicopters on battlefields and beyond.” She continued, “We need to expand, develop and validate computational tools that are going to consider the impact of different extreme environments,
new designs and operational differences that we’re going to encounter.”

Dr. Smith called for a reboot of the National Rotorcraft Technology Center (NRTC), which funded industry workshops, facilitated technology transfer from academia to industry, and transitioned talented students to industry. She said, “We don’t have the time to wait for five or 10 years while a new graduate becomes a producing engineer.”

Sikorsky Director of Engineering Sciences Dr. Vineet Sahasrabudhe recognized the ongoing contribution of the US Army-led VLRCOEs at Georgia Tech, the University of Maryland and the Pennsylvania State University. More than 15 associate universities are part of the VLRCOEs, providing valuable graduates to the vertical flight industry, academic research and government. “They’re great for us because we don’t have to teach them rotorcraft,” he said. “They come with very solid understanding and background.”

Demand for new engineers in vertical flight needs to open new training paths. Sharon Rossmark of Women And Drones told the VFS audience, “We need to look broader than what we’ve been doing in terms of our traditional processes and we need to look in different places for really creating a pipeline.”

Victoria Natalie, engineering director of the Oklahoma State University Unmanned Systems Research Institute described her school’s efforts to developing an intern and co-op pipeline to industry, supporting student projects with full-time research engineers and faculty. Natalie explained, “If it’s cool and has to do with drones, we’ll take it on.” The institute provides degree programs, business mentorship and networking. USRI is also working with the Tulsa Innovation Lab and the Osage Nation on an AAM “launch pad” research center and testing corridor. “There will be a lot of opportunity for Urban Air Mobility testing out there,” said Natalie.

AAM will need more than engineers. The San Bernadino International Airport Authority made a UAS drone training facility part of the business revitalization of the former Norton Air Force Base. The base closed in 1990, and airport executive director Mike Burrows told the VFS audience, “When you have a military base close overnight, you need a lot of help asking the right questions and getting the right partners at the right time. A little luck doesn’t hurt.” Foundational partners UPS and FEDEX started a renewal that created 14,500 jobs by the end of 2020. “We’re now a full-fledged commercial airport with all the business lines you’d think, including a few large-scale projects.” The UAS Center currently trains pilots for FAA Part 107 certification and will soon school UAS mechanics.

Russell Julian, founder and CEO of Texas UASWERX, now part of the AAM Association, portrayed AAM as the successor to the legacy aerospace industry. He told the Forum workforce session that urban air mobility, regional air mobility and small UAS business segments will need common infrastructure, air traffic control and other supporting technologies. “Everybody knows the aircraft side of it,” noted Julian. “It’s what’s underneath that’s really exciting as well.”

Texas UASWERX is, for example, working with AT&T to develop a unified command and control infrastructure using 5G networks for aviation-grade connectivity. Novel aircraft will also require novel engineering approaches to airspace management and urban planning by civil engineers to interface with multi-modal transportation. “We don’t see any of this as a moonshot,” said Julian. “We see it as an integration exercise. The majority of the technology and systems already exist to implement a first-generation air mobility model.”

Video recordings of all invited sessions and VIP presentations, and the Forum 78 Awards Ceremony, are posted in the VFS Video Library at www.vtol.org/videos. In addition, more than 400 photos from Forum 78 are available on the VFS Photo Gallery at www.vtol.org/gallery.