Getting Smart for FVL

Even before the demonstrators fly, the many moving parts of the Joint Multi-Role Technology Demonstration generate data for decisions on Future Vertical Lift.

By Frank Colucci

With or without flying testbeds, all four contractors in the Joint Multi-Role Technology Demonstration (JMR-TD) are feeding data to the US Army and the other services for an “informed decision” on Future Vertical Lift (FVL). The Bell V-280 Valor advanced tiltrotor demonstrator turned its rotors for the first time on Sept. 20 and should hover this fall. The Sikorsky-Boeing team continues to run its SB>1 Defiant Propulsion System Test Bed and Systems Integration Laboratory, aiming to fly the high-speed compound helicopter in 2018. Karem Aircraft meanwhile continues component- and bench-level tests leading to ground runs of a full-sized Optimum Speed Tiltrotor (OSTR) nacelle in 2019. AVX Aircraft has finished sub-scale wind tunnel tests and piloted simulations for more Coaxial Compound Helicopter work to be determined.

JMR/FVL program director Dan Bailey at the Army’s Aviation Development Directorate (ADD) oversees all the cost-sharing contractors and explained, “Our ultimate goal is to make the government smart on all these configurations. As they learn, we want to learn what Future Vertical Lift looks like.”

FVL Capability Set 3 (CS3) sketches a mid-sized troop carrier using fast, long-range JMR technology to replace today’s Black Hawk helicopter sometime after 2030 (see “No Single Decision,” Vertiflite Nov./Dec. 2014 and www.vtol.org/FVL). The Defiant and Valor demonstrators are each expected to accumulate 120 to 140 flight hours by the end of September 2019. “There is no exact number or exact schedule when you’re talking about a brand-new configuration aircraft,” Bailey acknowledged. “The flight test is more about expanding the envelope of the aircraft. In doing so, you collect data about performance, handling qualities, usage spectrum and so on. ... You’ll collect data and extrapolate it out to certain extremes.”

ADD at Redstone Arsenal, Alabama, manages aviation science and technology (S&T) efforts within the Army’s Aviation and Missile Research, Development and Engineering Center (AMRDEC). The JMR-TD has already given the Army important insights. Bailey offered, “When we chose Bell and Sikorsky-Boeing for the two flight demonstrators in late 2015 and early 2016, they gave us final design and risk review reports. We actually got Model Performance Specifications — updates to their paper designs.” The teams building their flying demonstrators now compare actual components with weight and performance predictions. “They may have to tweak that design; they may not,” said Bailey. “All of those [adjustments] feed back into their paper designs, so that we in turn use that data to update our models. They have their models; we have our models, but we’re using many of the same tools and using the details.”
Our ultimate goal is to make the government smart on all these configurations.

AoA models compare the new-start tiltrotors and compound helicopters with improved UH-60 helicopters — one Black Hawk with the Improved Turbine Engine (ITE) and another baseline upgrade with more power and more fuel. Bentley acknowledged, “We probably know that current aircraft can’t go much faster, but we can design them with bigger tanks to get more range.” The AoA also looks at commercial- and government-off-the-shelf solutions. “What commercial aircraft are available out there that we could develop for military applications; or what aircraft are in the government inventory that could give us this capability?”

The AoA looks at more than aircraft performance. Bentley explained, “Obviously, we’re looking at the technology development — what’s the technical risk of new capability? The manufacturing capability — can we build these aircraft; how producible are they? You look at the APU, Average Price per Unit, and life cycle costs. How affordable is it to buy and how affordable is it to own and operate?” Helios gives the Army and industry a quantifiable model of aircraft life-cycle costs.

Analytical models also pit the different aircraft against future threats. “We work closely with the TRADOC G2 [military intelligence staff] and their Intel Analysis Center,” explained Bentley, “They give us projected threat capabilities. We model those with the AoA in the program of how those threat capabilities would react to FVL capabilities across those five alternatives.”

The AoA final report goes to a study advisory group (SAG) within the Office of the Secretary of Defense (OSD) in the second quarter of 2019. “All the service leaders across DoD are briefed on the analysis and results of the analysis,” said Bentley. “As we talk about building capabilities for the forces, we’re looking at coming out of the AoA with a single joint requirement that we could use across the Army, Marine Corps and SOCOM. We would codify that capability into a draft capability document as we move toward a Milestone A” — a launch decision on the FVL technology maturation phase.

In parallel with the AoA, an operational concept team (OCT) within TCM-FVL flies piloted simulations to provide additional inputs to the AoA. According to Bentley, “We’re using once again the government design and models through the JMR-TD program. We’re going out and using the Vertical Motion Simulator at Moffett Field in California.” Bentley concluded, “We know we’ve got lots more analysis to do.”

According to the Naval Air Systems Command (NAVAIR), the Navy and Marine Corps are not currently pursuing an alternative to FVL. The Marine Corps is working on the FVL Capability Set 3 AoA, and separate Army and Marine Corps teams will lead their respective service analyses for focused recommendations. Upon completion of the service-specific analyses, the FVL teams will conduct an Army-led joint integration analysis looking to meet the needs of both services with a common solution.

Delivering Data

JMR initial design and risk review (IDRR) reports submitted to the Army in 2014 contained paper designs of JMR demonstrator aircraft and performance predictions for FVL model performance specification derivatives. “We gave them a specification that set certain requirements but obviously not final FVL requirements,” said Dan Bailey at ADD. “It was ‘best guess’ at the time.”

The reports led to Sikorsky-Boeing and Bell Helicopter being selected to build the SB>1 Defiant and V-280 Valor, respectively, for flight test. “Their aircraft remain contractor-owned assets,” explained Bailey. “They will not have an Army airworthiness release at all. They are being certified strictly under the [Federal Aviation Administration] ‘Experimental’ certification. To do that, the contractors have to own the assets.”

Under current test plans, neither demonstrator comes to the Army’s Redstone Test Center. Bell will begin flying the Valor at Amarillo, Texas, and migrate the test program to its Arlington, Texas, Flight Research Center with a notional excursion to the tiltrotor-specific RDS-33 handling qualities course at Naval Air Warfare Center Aircraft Division Patuxent River, Maryland. Sikorsky and Boeing will conduct flight testing at the Sikorsky Development Test Center in West Palm Beach, Florida. Bailey
said, “We have no formal requirements for flight test reports, but through our teaming arrangements, we get access to their own internal reports. As flight data is produced, the data comes to the government for our own analysis.”

Flight test plans themselves are developed by the industry players with government input. “It’s pretty set; it’s not a brand-new thing,” noted Bailey. “You take the envelope of the aircraft, and you parse it out with where your high- and low-risk points are and work your way systematically through that process.” The government contributes Army experimental test pilots — two primary and one backup — and two flight test engineers to each team. “They won’t be on every flight,” noted Bailey. “Our objectives for our test pilots’ involvement are pretty specific. It’s relative to pilot feedback on handing qualities — new configurations versus legacy aircraft.”

Bailey said, “We don’t have KPPs [key performance parameters]. That’s a very doctrinal term related to a capabilities document we don’t yet have. What we set were key technical measures: there’s endurance, hover efficiency and forward flight efficiency – L/D [lift/drag] types of things.” He added, “It’s not just about how far you go or how long you can stay in the air. … It’s more about efficiency.”

JMR contractor flight test data will update the FVL model performance specification. “We have government rights to that data,” explained Bailey. “They own it; [and] we own it. We have the right to use it. When you’re talking about sub-component safety-of-flight qualification data, it’s specific to the component. We would not have rights to that data. They share the data but we couldn’t have rights to use it in other ways.”

**Testing Tiltrotors**

Bell Helicopter completed assembly of the V-280 Valor in Amarillo and powered up the restrained demonstrator on the company’s tiltrotor run stand. Keith Flail, Bell vice president of advanced tiltrotor systems and the JMR-TD said soon after, “I’m incredibly proud of the team for the key milestone we achieved today within weeks of the target we set five years ago.” The tiltrotor run stand funded by the Amarillo Economic Development Corp. is designed to test the Valor or V-22 through full tilt from helicopter to airplane mode. Valor test plans advance from restrained and unrestrained ground runs through first hover and vertical flight in helicopter
Acknowledged, "Forward-flight rotor dynamic risks, including throughout the OSTR speed, power and tilt envelope. Tigner and reduce risk associated with integrated subsystems operating rotor dynamics analyses, measure rotor control characteristics turboshaft modified for tilted operation. The test rig will validate a two-speed gearbox and a tilting nacelle containing an off-the-shelf article consists of a variable-speed rotor with electromechanical IBC, speeds. According to Karem president Ben Tigner, the OSTR test regime promises greater efficiency than those with only fixed A tiltrotor that can change rotor speed with the aircraft's flight and CS2 aircraft. (AVX Aircraft) vertiflite, Sept./Oct. 2017.)

Valor test flights will be preceded and paralleled by drivetrain tests in the Bell Drive Systems Center in Grand Prairie, Texas, and piloted simulations in the company's systems integration laboratory (SIL) in Arlington. "We have a lot of off-aircraft testing that is continuing," noted Flail. Drive system rigs measure tooth fatigue with increasing loads on tiltrotor gearboxes. "That testing will continue for quite some time. We're increasing the loads to get a better understanding of the capability and endurance of the gearboxes."

The SIL co-located at the Bell Flight Research Center has a Valor cockpit tied to the full hydraulic system and moving flight controls. "We're able to wring out all of our flight control software, and that work continues," explained Flail. The SIL will also let pilots rehearse test cards and prove out flight control software on the ground, test control laws in the air and validate software changes back in the lab. The Lockheed Martin cockpit in the Valor is an evolution of an existing Future Airborne Capability Environment (FACE)-compliant crewstation. According to NAVAIR, the fixed-wing C-130T Hercules with Lockheed Martin Avionics Obsolescence Upgrade (AOU) is the first operational application of software developed in accordance with the FACE Technical Standard.

The Valor integrates structures and systems from 11 investing team members, and according to Flail, "Throughout the aircraft there is some re-use from other aircraft where it made sense." Flight test instrumentation borrows to some extent from the Bell 525. "It's similar in terms of approach." Flail cautioned, "However, given the helicopter vs the tiltrotor, you're going to instrument things differently. ... It's different in terms of what you have to monitor. You can't do an apples-to-apples comparison."

As Bell Helicopter begins to explore the flight envelope of an advanced tiltrotor, Karem Aircraft is preparing for tests of a full-scale, 36-ft (11-m) diameter OSTR proprotor and nacelle on a ground test stand in Southern California in 2019. According to Dan Bailey at ADD, "We have a full-scale hub complete with Individual Blade Control (IBC) actuators ... and the in-plane power generators in the hub spinning for several thousand hours so far at the Karem facility." A critical design review (CDR) in September will finalize an articulated nacelle able to tilt from horizontal to vertical over the full OSTR rpm and power range. "We have a hold on the Earth; we hope we can move [the planet]," said Bailey.

A tiltrotor that can change rotor speed with the aircraft's flight regime promises greater efficiency than those with only fixed speeds. According to Karem president Ben Tigner, the OSTR test article consists of a variable-speed rotor with electromechanical IBC, a two-speed gearbox and a tilting nacelle containing an off-the-shelf turboshaft modified for tilted operation. The test rig will validate rotor dynamics analyses, measure rotor control characteristics and reduce risk associated with integrated subsystems operating throughout the OSTR speed, power and tilt envelope. Tigner acknowledged, "Forward-flight rotor dynamic risks, including wing-rotor interactional dynamics, can only be assessed through subsequent flight demonstration."

Tigner also noted, "The Army's JMR-TD objective is to mature technologies for application to FVL, but the OSTR has applications in both Army and USMC unmanned platforms as well. The results of the currently funded JMR-TD efforts are supplying data that is being used to calibrate and validate performance and weight projections for FVL, MUX and the FTUAS programs." MUX is the Marine Air-Ground Task Force (MAGTF) Unmanned Expeditionary program to develop a very large, high-end VTOL unmanned aircraft system (UAS). FTUAS is the Army's Future Tactical UAS program for a somewhat smaller VTOL UAS. (See "Unmanned Vertical Wingman," vertiflite, Sept./Oct. 2017.)

Coaxing Compounds

With coaxial rigid rotors, integrated propulsor, fly-by-wire flight controls and active vibration suppression, the Sikorsky-Boeing SB>1 Defiant is the 30,000 lb (13.6 t) iteration of technologies already flown on the 6,000 lb (3 t) X2 demonstrator and the 11,000 lb (5 t) S-97 Raider. The risk-reducing Raider logged about 20 flight hours and 100 hours of total run time before a hard landing on Aug. 2 grounded the first company-funded demonstrator. The Defiant nevertheless continues to draw on a purpose-built Propulsion System Test Bed (PSTB) running to verify drive, control and engine systems before first flight. According to Dan Spoor, Sikorsky vice president, the PSTB"
president for Future Vertical Lift and Mission Systems, the PSTB “is a very important risk-reduction vehicle that Sikorsky uses to gather sufficient data as part of our preliminary flight acceptance testing (PFAT) prior to our first flight. By exercising the systems on the PSTB, Sikorsky minimizes discovery that might interrupt flight testing during envelope expansion.”

As of mid-September, Sikorsky had finished five major ground tests of Defiant dynamic components. All the major parts of the hydraulic, electrical and flight control systems had been fully tested in the Stratford, Connecticut, SIL. The propulsor clutch had been tested on a dynamometer and was slated to run with the rest of the drivetrain on the PSTB. Simulators at Sikorsky in Stratford, Connecticut, and at Boeing in Philadelphia, Pennsylvania, had tested flight controls, handling qualities and the vehicle management system.

The Defiant also benefits from continuing work in the Sikorsky SIL, in piloted simulators, and in wind tunnel and system ground tests. The Defiant composite fuselage made by Swift Engineering in San Clemente, California, arrived at the Sikorsky Development Test Center after successful structural testing at Boeing in Mesa, Arizona. The SB>1 demonstrator now has its landing gear installed and is receiving wiring, hydraulics and some powertrain components.

The center will also host the Defiant’s flight testing and, according to Spoor, “The aircraft is fully instrumented to provide the information needed for FVL. There are several new methods used for specific instrumentation, including examples proven during recent testing of other aircraft, like the CH-53K, CMHP [the CH-148 Cyclone Canadian Maritime Helicopter Program] and the S-97 Raider. The latter contributed to the method for blade proximity measurement.”

AVX also turned to a Coaxial Compound Helicopter (CCH) configuration to satisfy FVL Capability Set 3. The small engineering house used ducted thrusters and lifting canards to attain FVL speed and range. Dan Bailey at ADD explained, “What we had them do is complete their design which led to some wind tunnel testing for a 1/10th scale model that went to a final configuration. We then went to piloted simulation.

“The goal was to fly the aircraft in a realistic but aggressive manner to reduce [rotor] separation from 9% to something less around 7.5%.” Traditional coaxial helicopters have around 9% separation, but AVX hopes to reduce CCH separation and drag with reduced coning. Successful analyses now support follow-on tests for smaller Capability Set 1 and 2 aircraft. According to Bailey, “The majority of the effort is for CS3 and below. … We have always looked at their configuration in terms of scalability across the family.”

**Build a Backbone**

In parallel with ongoing air vehicle investigations, a JMR Mission Systems Architecture Demonstration (MSAD) aims to build an FVL avionics architecture with true plug-and-play capability for rapid upgrades. FVL is expected to have a new digital backbone, a hardware backbone that supports high-speed processing and non-proprietary interfaces to integrate new sensors or countermeasures from different vendors.

Standardized tools and processes and Open System Architecture interfaces will inject new software functions into FVL hardware quickly to counter changing threats. The Army teamed with the Vertical Lift Consortium (VLC) Joint Common Architecture (JCA) demonstrations to model software-intensive systems and exercise the FACE tools and Technical Standard. JCA is ongoing and MSAD is getting underway with multiple VLC member companies involved.
Rockwell Collins (recently acquired by United Technologies Corp., UTC) built some Open System flexibility into the Common Avionics Architecture System (CAAS) flying today in special operations and regular Army Chinooks, and in special operations Black Hawks. Programs manager Brad Neuville explained, “I believe we accomplished a vast majority of the Open System architecture from the hardware point of view. There was less capability to do Open Systems in software.” Neuville noted, “The whole MSAD program is less about a specific architecture or implementation of a system than it is about the engineering processes and tools that would enable the Army and joint team to procure and manage the [FVL] system. … If I can truly model a system up front, I will be able to find and correct deficiencies way before I get to actual implementation when it’s expensive.”

MSAD remains an Army-run S&T effort, but the Navy is the lead service on FACE with its standardized tools and interfaces for new software. NAVAIR is supporting the MSAD demonstration and starting to look at what FVL architecture will work best for Navy and Marine Corps systems. According to NAVAIR, an FVL architecture compatible with rapid upgrades would have to be decomposed to a low-enough logical level to provide open interfaces and necessary data rights. The same rules are already applied to FACE. NAVAIR is now looking at how best to apply the FACE/MSAD philosophy to FVL technical requirements.

The MSAD effort has three phases. The two-part architecture implementation process demonstration is complete. A capstone demonstration awaits a competitive broad agency announcement (BAA) expected in in December 2017 or January 2018. The three-year program would run through late fiscal 2020. The demonstration will define assault and attack missions, and industry teams of traditional competitors will mix different roles and perform prescribed tasks from mission planning to mission debrief. “We jokingly call each other ‘competimates,’” said Neuville. “Right now, we’re trying to have a collaborative effort to explore these things.”