The Calculus of Future Vertical Lift

With outside-government help, the US Army figures out how to make fast-tracked combat rotorcraft transformational and affordable.

By Frank Colucci

Future Vertical Lift (FVL) is moving from technology maturation to programs of record. US Army internal calculus defined the family of systems using streamlined contracting tools to prototype promising technologies. It also drew on the outside-government insights of the Vertical Lift Consortium (VLC), the consortium of large and small businesses, academic institutions and non-profit entities, including the Vertical Flight Society (which helped start up the VLC in 2009). The Army considered FVL research plans, aircraft designs and capability sets, and leveraged other transaction authority (OTA) to connect government and industry players quickly.

VLC vice chairman, retired Army Maj. Gen. Rudy Ostovich, explained, “The Army needed a way... to expedite the process by which we could bring these emerging new and capable technologies into the hands of our soldiers quickly, more effectively than we have in the past and hopefully more successfully than we have in the past.” The VLC today shares leadership with the National Armaments Consortium (NAC) in the broader Aviation & Missile Technology Consortium (AMTC), to more broadly support the Army Combat Capabilities Development Command (DEVCOM) Aviation and Missile Center (AvMC) at Redstone Arsenal, Alabama. The VLC has also held talks with the Air Force on electric vertical takeoff and landing (eVTOL) aircraft and with the Navy considering FVL-Maritime Strike.

Army Futures Command built its FVL cross-functional team (CFT) to fast-track four signature vertical lift modernization efforts with reach, speed and standoff lethality to dominate multi-domain operations by 2035. CFT operations and integration officer Col. Matthew Isaacson told the VFS Forum in May, “When we think of a near-peer competitor, range and standoff are really important.” He explained, “We’re focused on high TRLs [Technology Readiness Levels].” TRL realism means some FVL wishes, such as optionally manned cockpits, will come in increments. “We imagine all the wonderful benefits you get from optionally manned, but optionally manned is just something we’re looking at for future increments,” said Isaacson. “Optionally piloted has not shown maturity for Increment One.”

The Army expects Bell and Sikorsky to fly competitive prototypes of the Future Attack Reconnaissance Aircraft (FARA) in fiscal year 2023 and to deliver preliminary designs of their Invictus and Raider X weapon systems. One contender will be selected for engineering and manufacturing development (EMD) to start FARA low-rate initial production (LRIP) around 2028.

A finalized request for proposals on the bigger, faster Future Long Range Assault Aircraft (FLRAA) is due this summer aimed at a FLRAA first unit equipped (FUE) in fiscal 2030. Competitive demonstration and risk reduction (CD&RR) pits the Bell Valor
against the Sikorsky-Boeing Defiant X while the bidders finish preliminary subsystems design. One annex of the FLRAA request for proposals will define the Modular Open System Approach (MOSA) ultimately shared by FLRAA, FARA and the Future Unmanned Aircraft System (FUAS).

FUAS includes unmanned Air Launched Effects (ALE) flown from the manned FARA and FLRAA, as well as some runway-independent Future Tactical UAS (FTUAS) to replace today’s catapult-launched, runway-recovered Textron Systems RQ-7B Shadow. The Army UAS program manager in April 2020 released a request for enhanced white papers from ALE prototype systems integrators. Under a Futures Command OTA, industry is competitive-prototyping ALE air vehicles, mission systems and payloads. In May 2021, contenders were finishing final design technical interchange meetings for ALE test, evaluation and final selection by the end of the year. The prototyping exercise serves to inform and refine requirements for a future program of record that will put large and small ALE on FARA with MOSA and a scalable control interface.

The ground-launched FTUAS is also supposed to interoperate with FARA and FLRAA. A successful FTUAS “rodeo” at Fort Benning, Georgia, last March aimed to help the FVL CFT and Army leadership accelerate an interim capability pending an FTUAS program of record. According to Futures Command, the Army plans to replace the Shadow with a more expeditionary system capable of taking off in confined areas with minimal support equipment, first in brigade combat teams and then in aviation brigades.

The FARA and FLRAA are pieces of the fast-tracked FVL Initiative. Here, the Sikorsky Raider X and Sikorsky Defiant X show features of the compound helicopter solution to FVL requirements. (Lockheed Martin)

Shapes and Sizes

Congressional action — spurred by VFS and its members (see www.vtol.org/FVL) — and well-documented capability gaps in the US military helicopter fleet inspired first-phase studies of faster, longer-ranged Joint Multi-Role (JMR) technologies at Fort Rucker in 2009 and the Army soon involved the Vertical Lift Consortium (VLC). VLC chairman Nick Lappos said, “Frankly, we were formed for the purposes of contracting with the government and not necessarily pointed at FVL.” The OTAs enabled government and industry to communicate more freely than permitted by Federal Acquisition Regulations (FAR) and provided ways to prototype technologies quickly, without protests. “FVL was the big, important game in the room, so for the last decade or so, we’ve done a lot of the work towards helping to form the concepts for FVL, including written recommendations and informal meetings with the government.”

Whatever their recommendations, VLC white papers and reviews included all member inputs to add balance and credibility. Lappos recalled, “Our first document that we produced was an 80-page written summary based on industry comments on the research plans that the Army was putting in at that time... Then we also made some comments on aspects of the designs.” An early meeting at the University of Maryland, which included Navy/Marine Corps participation, began turning scalable JMR technology into FVL capability sets (CapSets) from light, unmanned systems to heavy cargo lifters. “One of the balances for useful load was the sizing and the horsepower required. That became background information. From that, the Army came back with the CapSet definitions.”

Mid-sized CapSet 3 encompassed a squad carrier big enough to replace the 22,000-lb (10-metric-ton) Black Hawk and a notional attack version to replace the 20,000-lb (9-t) Apache. “In the absence of strong requirements definition, it would grow enormously,” observed Lappos. “We saw some CapSet 3 early discussions that were up in the 60,000-lb [27-t] neighborhood with what I’ll call ‘unconstrained requirements.’” More realistic analyses described a JMR vehicle with a cruising speed around 230 kt (425 km/h) and a radius around 229 nm (368 km) to span a divisional area of operations twice as fast as helicopters to double the number of troop lifts possible under the cover of night.

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flight test a JMR technology demonstrator (JMR-TDs) sized around 30,000 lb (13.6 t) gross weight. All four TIA holders funneled flight test and/or wind tunnel data to the Army’s Aviation Development Directorate (ADD) — now Futures Command’s Technology Development Directorate (TDD) — to support informed decisions on FVL. AVX has since completed all JMR work on its coaxial compound helicopters, but Karem continues full-scale tests of its optimum speed tiltrotor technology.

The Bell V-280 Valor advanced tiltrotor and Sikorsky-Boeing SB>1 Defiant compound helicopter were contractor-owned aircraft flown with experimental certificates from the US Federal Aviation Administration (FAA). The size of the demonstrators drove the choice of thirsty current-technology engines — twin T64s for the tiltrotor Valor and two T55s for the coaxial Defiant with its integrated tail thruster. The Bell Valor ultimately logged 215 flight hours by April 2021 and exceeded 300 kt (555 km/h). As of early May, the Sikorsky-Boeing Defiant had accumulated 26 flight hours plus 148 hours running time on the propulsion system testbed, backed by flight tests of the smaller, company-funded S-97 Raider.

CD&RR Phase I transitioned the JMR-TDs to FLRAA weapons systems in a digital engineering environment. Feedback from Phase I and government research shaped FLRAA operational requirements for CD&RR Phase II now underway. Phase II has the OTA project agreement holders working through preliminary design and further refines FLRAA requirements. It lays the foundation for a contract award next year under FAR rules for a single vendor to build true FLRAA prototypes. The number of test vehicles is to be determined, but the FVL CFT says CD&RR enables Army leaders to make early, informed decisions on requirements for affordability and helps align strategies, requirements and technology for fiscal 2030.

**Speedy Scouts**

FVL CapSet 1 described notional unmanned aircraft systems and manned scouts. The VLC’s Lappos said, “I can’t say we defined FARA, but we certainly helped define a CapSet 1 aircraft, defining what size it might be.” Retirement of the 5,500-lb (2.5-t) OH-58D Kiowa Warrior and failure to field the ARH-70 and OH-58F replacement helicopters left combat aviation brigades in need of a Future Attack Reconnaissance Aircraft. The new scout had
to be big enough for weapons and mission systems yet small enough to fight in cities. Urban canyons capped rotor diameter and overall aircraft width around 40 ft (12.2 m), effectively ruling out a tiltrotor. The Army wanted the agile scout powered by the 3,000-shp improved turbine engine (ITE) and armed with a 20 mm turreted cannon and integrated munitions/ALE launcher — all government-furnished equipment. The same aircraft needed ALE stand-off survivability and MOSA connectivity to lead a team breeching integrated air defenses.

The Army specified a FARA minimum cruise speed not less than 180 kt (333 km/h) and a combat radius greater than 155 nm (285 km) with a 1,400-2,000-lb (640–900-kg) payload. CapSet 1 could have encompassed an aircraft weighing more than 20,000 lb (9 t), but the Army capped FARA gross weight at 14,000 lb (6.35 t). “Part of it too had to do with how much power you had in the vehicle,” observed Lappos. “The government wisely roped in power requirements and put that stake in the ground.” Significantly, expensive JMR requirements for hover-out-of-ground-effect at 6,000 ft and 95°F (1,840 m and 35°C) relaxed to 4,000 ft and 95°F (1,230 m and 35°C) for the scout. Also significant, the Army pegged FARA fly-away cost at no higher than $30M and cost-per-flight-hour no greater than $4,200 (in fiscal 2018 dollars).

John Stough, VLC-AMTC board representative and chief architect officer for engineering firm JHNA, added, “It’s not so much about the size of the aircraft but the mission, and the size of the aircraft that was appropriate for that mission.... That’s an important distinction, because if you have the right understanding of how those things interact with each other — the physics of the problem versus the mission that you’re trying to solve — I think it makes the government’s job choosing the things that industry offers that much easier.” Stough added, “The aircraft size is largely determined by physics. What you do with that aircraft is determined by the mission. The FARA is a mission-focused response.”

The FARA strategy buys competitive prototypes under OTAs with industry cost-sharing. The tandem-seat Bell Model 360 Invictus helicopter is being assembled in Amarillo, Texas, while the side-by-side Sikorsky Raider X coaxial compound helicopter is coming together in West Palm Beach, Florida. Each FARA competitor will deliver one air vehicle prototype to fly in fiscal 2023, and will also provide initial preliminary design efforts toward the full weapons system to be tested and qualified during EMD. FARA competitors will be evaluated by an objective Army source selection board, and the winner will be awarded a FAR-based EMD contract. The FVL CFT expects the FARA winner to produce six EMD test articles prior to LRIP.

**Approach to Architecture**

Key to the FVL family of systems is the modular open system approach to avionics architectures, with standardized rules and interfaces. The Army aims to integrate new capabilities into FVL platforms quickly to keep pace with changing threats, and it wants to do so unencumbered by expensive, proprietary hardware and software. Stough explained, “The MOSA aspect really said, ‘I’m not going to have just one vendor who builds everything, I’m going to have a whole ecosystem of vendors. How do I get a clear voice from industry on the appropriate severability points, with multiple different-sized platforms, between the air vehicle and the mission systems that go on the air vehicle?’” The VLC developed an air vehicle mission systems interface definition adopted for the FVL model-based systems engineering (MBSE) framework.

The JMR mission system architecture demonstrations (MSAD) and reports are complete. The Army is funding the integrated mission equipment (IME) science and technology effort to mature and advance MSAD concepts. The service continues to use cooperative research and development agreements (CRADAs) with different vendors to further explore MOSA by inserting software applications into computing environments developed by other vendors. According to the FVL CFT, the experiments show that modular, open design principles can reduce integration risks and effort, and enable applications from different vendors to operate seamlessly. Though there is no MOSA request for proposals describing a specific testbed or demonstration, the Army will continue to utilize the IME, CRADAs, government-managed computing environments and industry demonstrations to further advance MOSA principles.

Full MOSA architectures are not expected on early FVL aircraft. Col. Isaacson told the VFS Forum, “We cannot wait. The technology that’s available now is what we envision being fielded in our first increment of FARA, FLRAA and MOSA.” However, the Army Program Executive Office (PEO) Aviation now includes a MOSA transformation office that issued a MOSA implementation guide and a reference architecture description document. In the near term, the office is focused on defining major system components, leveraging near-term MOSA opportunities, and building bridges to the enduring fleet.

The enduring Army fleet introduces open system functionality in the recapitalized UH-60V Black Hawk. The Victor cockpit replaces analog gauges with digital displays and complies with future airborne capability environment (FACE) standards. “We like to say it’s hardware-defined and software-enabled,” said Northrop Grumman Vice President of Electronic Warfare and Targeting Jim Conroy. “The system itself is a combination of some systems that Northrop Grumman has evolved, some systems that are COTS [commercial off-the-shelf], as well as systems that are developed by suppliers. What makes it open is that the government has all the data rights and they can go and see it... We are not holding the government hostage. We’re enabling them, and they own this architecture.”

UH-60V software load version 3 with instrument flight rules (IFR) functionality is now in certification testing, and future releases will be developed using MBSE standardized across FVL. The new Black Hawk cockpit preceded the FVL MSAD demonstration, but the complete system has already demonstrated the ability to add new features quickly. Conroy said, “An example of that is the forward looking infrared [FLIR], something that others might have taken months or years to do. We did it in a factor of weeks.” The -60V also gives the Army significant growth margins. “To our knowledge, this is the first system that uses a multi-core processor in a DO-178-certified system. So it has plenty of growth capacity to continue extending and scaling to meet their requirements.” (DO-178 is the primary document by which the FAA and other civil certification authorities approve commercial software-based aerospace systems.)

AMTC is pursuing a range of programs outside vertical lift, but VLC expertise remains on call for all Army aviation needs, even after FVL enters production. Consortium members, for example, saw potential FVL savings in common systems. Lappos offered, “What we proposed was a serious consideration of commonality in such things as cockpits, flight controls, the fundamentals of electrical systems, hydraulic systems and so on... It might be fun to see in the future, when these vehicles begin to gel, if commonality is found again.”