Decision Time for FARA

By Mike Hirschberg, VFS Executive Director

In July, during the US Army Industry Days at Ft. Rucker, Alabama, the Future Vertical Lift (FVL) Project Manager for the Future Attack Reconnaissance Aircraft (FARA), Col. Greg Fortier, made some remarkable comments. Fortier is in the Army's Program Executive Office for Aviation, PEO(A), which took over leadership of the FARA project from the Army Futures Command (AFC) this year. *Aviation Week*'s Steve Trimble published the story, "Physics-Busting Requirements Challenge U.S. Army FARA Program," on Aug. 3, and also provided VFS with a transcript of the discussion. The article starts by stating, "The US Army's project manager now says the original set of performance requirements for a future rotorcraft that represents the aviation branch's top modernization priority are not compatible with the laws of physics."

This was essentially what several Army engineers and scientists were saying before the launch of the program in 2018. As noted in my Commentary, "What FVL Needs to Succeed" (*Vertiflite*, Nov/Dec 2018):

> With FARA, the Army wants to field a new system in less time that is smaller, faster, longer range, more affordable, more capable, more lethal, more connected, more survivable and more autonomous than current systems. To solve the tension between these conflicting desires, designers need to iterate the design sensitivities with operational analysis to show the pros and cons of each attribute, alone and in concert. In order to fly competitive prototypes (not just demonstrators) four years from [then], the Army must prioritize its metrics and potentially make hard trade-off decisions.

Now the time has come for Army leadership to make those hard decisions.

An Overly Constrained Problem

The six key attributes for the FARA Competitive Prototypes (CP) are:

1. First flight: in fiscal 2023
2. Maximum speed: at least 180 kt (333 km/h)
3. Engine: a single 3,000-shp (2,240-kW) GE T901 being developed in the Improved Turbine Engine Program (ITEP)
4. Rotor: 40 ft (12.2 m) diameter
5. Max gross weight: 14,000 lb (6,350 kg)
6. Mission: range, endurance, capability as specified

The last one — performance — is, of course, the challenge. No, there is nothing incompatible with the laws of physics in the first five requirements, but what performance is achievable with today's technology? Therein lies the rub.

Fortier's comments were profound in their honesty. "There's no version of the world that exists in physics… where the speed at range, endurance at range and payload all exist in a 14,000-lb helicopter — not at what we're asking you to do."

After design study contracts were awarded to five companies in 2019, the Army selected Bell's lift-compound 360 Invictus and Sikorsky's lift-offset thrust-compound Raider X last year, and both companies are now about 50% complete assembling their competitive prototypes (see "Making FVL," pg. 16). The Army intends to select one company in fiscal 2024 to develop its concept for FARA Increment 1 to enter service in 2030. This 11-year development is less than half the time of modern military aircraft development programs.

Fortier explained the basics of the helicopter design problem:

> Speed: It's very counterintuitive, but 180 knots is heavy. Why is it heavy? It's heavy because you've got to retract the gear… It's a drag problem. Maybe you've got to put some lift-share on the wings if you're one of the designs, because you have a single-rotor helicopter [i.e., Bell]. Maybe you put eight rotor blades out because you have extra technology [i.e., Sikorsky]. Maybe those extra rotor blades are pretty big, pretty heavy. And that transmission then becomes very, very heavy to get the speeds and you've got a pusher-prop in the back… It's just physics at the end of the day.
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> So, [we're] learning a ton about speed, learning where the sensitivity is in speed. Learning that 177 to 181 [kt] — what does that cost? Learning 181 to 185 [kt] — what does that cost? What does it mean to the design?
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> Now, ideally, if you're going to design a future helicopter, you're going to want to design the helicopter around the requirement, get the design, and then figure out how much shaft horsepower you need to go from there, right? In our case, we're powered by the ITEP. Again, all for the right reasons: for affordability across the Branch and Army Aviation. Common engine, common engine strategy. So, we have a 3,000 shp engine. So, now we've got a machine that needs to go fast with 3,000 shp, a 40-ft rotor disc, and a target weight of 14,000 lb. The design box just got very, very small for that piece of the puzzle. So, that's why we need to continue to iterate, and get to understand where those trades are, how they trade within the framework of requirements and go from there.

The desire to be able to fly down city streets, like the OH-58D Kiowa Warrior and AH-6 Little Bird, set the rotor diameter at 40 ft and "we don't really want to go higher than that," Fortier said. But "those are decisions that will be made by our senior leaders."

Extension to eVTOL Designs

The military adage, "no plan survives first contact with the enemy" is just as true for aircraft design — for military or civil applications. It is important to define the customer requirements but, as is always the case, aircraft with infinite performance at zero cost are built of "unobtainium."

Those developers with revolutionary concepts such as electric vertical takeoff and landing (eVTOL) concepts for advanced air mobility (AAM) applications also need to heed the lessons emerging from FVL.

Technology advancements are indeed making new designs and approaches possible, but the laws of physics are hard and fast. Eight decades of lessons learned that are the wealth of knowledge of the VFS technical conference papers and peer-reviewed journal articles highlight the limits of physics that these new technologies must still obey (see Commentary: "Stand on the Shoulders of Giants," *Vertiflite*, Jan/Feb 2019). Those with innovative ideas would do well to familiarize themselves with the vast body of work that has come before them.

At the end of the day, design decisions for innovative civil or military aircraft must be made based on the constraints of physics.

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Decision Time

As noted in my 2018 Commentary on FARA, "The challenge is that the Phase 1 contract awards are planned for June 2019 and the first flight is expected by the end of calendar 2022. To meet this deadline, companies must make many major decisions in the October/November 2018 timeframe so that they can submit their proposals by Dec. 18, and then continue with their operational analysis to refine their designs significantly prior to receiving a contract."

Fortier echoed these words: "First flight by 2023 for industry meant that they had to go out with long-lead [orders] in 2019." The FARA CP request for proposal (RFP) demanded that companies come up with their best approach in 2018 and then finalize that design into a prototype, with little room for major changes. As noted in that Commentary, this timeline forced industry to make major decisions early in the development process to meet an aggressive first flight date for CP. Unfortunately, the original requirements that drove these early CP decisions, as Fortier noted, were overly constraining.

Once the Army set a rotor diameter and the engine, the basic performance capabilities of a 2020s-technology rotorcraft were pretty much set. Studying the partial derivatives of speed vs. cost (or weight) from 177 kt to 181 kt might be interesting, but significant improvements are only possible through bigger changes. That is a break point between a conventional helicopter and a compound — 160–175 kt — with a significant impact on power and weight, just as there is between a compound and a tiltrotor above 250 kt.

What other avenues can be explored, besides reducing the speed or increasing rotor diameter by several feet?

- The Army wants FARA to benefit from advanced cockpits with artificial intelligence (AI) and other decision aids — are two pilots necessary or would a single-seat FARA work, with significant weight savings?
- What about the mission equipment package (MEP)? The amount of electronics required has a significant impact on the size and weight of the aircraft. For FARA, the Army is asking for avionics capabilities on par with the 23,000-lb (10.4-metric-ton) AH-64E Apache, with busses for the modular open systems approach (MOSA) as well as legacy systems, which all require space, weight and power (SWAP), including significant amounts of cooling.
- To go fast with a large aircraft, more power is apparently required than available from the 3,000 shp T901. Does the Army develop a growth version of the engine, or dial down on some other requirement for future Increments? Bell announced it had added a Pratt & Whitney PW207D1 turboshaft rated at 610 shp (450 kW) to its Invictus design as a supplemental power unit (SPU); should that approach be extrapolated for more power?
- Like MEP, aircraft survivability equipment (ASE) and survivability requirements adds weight and performance inefficiencies. At what point do the negatives actually make the aircraft less survivable because it is too slow or not maneuverable enough?

Outlook

The Army established its FARA acquisition plan to short-circuit and accelerate the traditional acquisition process. Now, the results of industry's bottom-up designs don't align with the top-down requirements. The Army must continue to be agile and use the information that has emerged from the FARA CP aircraft to update and refine its requirements for Increment 1.

As with all successful aircraft designs, competing engineering teams will come up with their best approach. In the absence of a design solution that meets all requirements, designers need to know the relative importance to their customer of the conflicting requirements, so that they can make the compromises necessary to close on a realizable design.

It is refreshing to see the candor of a government program manager identifying an issue. Having come-up against some hard laws of physics, it is now time for the Army's senior leadership to make the tough choices as to what is essential and what can be traded in the design of FARA Increment 1. This will likely require the Army to put aside some requirements that don't fit within the physics and programmatic limits for FARA. Doing so in an expedient manner will allow industry to continue to make progress towards the FARA 2030 fielding target.

What do you think? Let me know at **director@vtol.org.**