Pillars to Products

Sikorsky Innovations broadens its technology investment pillars and looks to better integrate them into unspecified flying demonstrators.

By Frank Colucci

Cancellation of the US Army's fast Future Attack Reconnaissance Aircraft (FARA) in February 2024 (see "FARA Falls," pg. 18) denied Sikorsky Aircraft its near-term chance to turn the company's first "technology pillar" into a paying product. However, compound helicopter speed was only one pillar demonstrated by the company's Innovations rapid prototyping shop. Autonomous flight controls guided an uncrewed Black Hawk through tactical courses in 2022, and helicopter prognostic and diagnostic intelligence today underpins Sikorsky's Global Customer Center overseeing commercial fleet operations.

As Sikorsky Innovations refines its first three technology pillars, it aims to integrate new investigations of aircraft systems electrification and more reliable and effective uncrewed aircraft systems (UAS). Innovations Director Igor Cherepinsky observed, "Because of the digital engineering thread, it's very neat how we can tie a lot of these pillars together and show them off on a demonstrator or a vehicle aimed at a particular set of markets."

Sikorsky has not yet disclosed the shape or size of its announced HEX hybrid-electric demonstrator aircraft. HEX recently passed its preliminary design review, and company engineering labs have proprietary electric motors and power distribution systems running. Innovations also plans a HEX propulsion system testbed to support development. Meanwhile, UAS certification talks are underway with the US Federal Aviation Administration (FAA) to put the company's Matrix autonomous flight controls on an unidentified fixed-wing platform. The new UAS pillar aims at military and commercial customers. Cherepinsky said, "We don't want to dictate whether a particular mission should be 100% autonomous or should have a human on the loop… That's for our customers to figure out. We want to provide the tools. That's where Matrix coupled with things like electric flight and this new UAS pillar can revolutionize how we look at aircraft design holistically."

Within the Sikorsky engineering organization, the small, agile Innovations organization was formally announced in 2009 to address difficult aviation challenges and present solutions to relevant parts of the company. Cherepinsky acknowledged, "We've had a lot of business folks help us and work with us, but once we've incubated some of these pillars, they get launched into the bigger Sikorsky." Innovations work on the helicopter intelligence pillar, for example, was commercialized by Sikorsky Global Sustainment. The US Department of Defense (DoD) Future Vertical Lift (FVL) initiative was big enough to justify its own organization to apply high-speed technology to FARA and the Future Long Range Assault Aircraft (FLRAA).

Sikorsky's X2 demonstrator integrated a coaxial lift-offset rotor, a pusher propeller and other new technologies for the first Sikorsky Innovations pillar — speed.

The Innovations speed pillar and the X2 flight test program grew out of work begun in 2005 (see "ABC Revisited," *Vertiflite*, Fall 2009). Cherepinsky explained, "The original challenge from our executive team was, "Let's see what we can do to increase the speed of the helicopter — double or more — while retaining all the typical helicopter properties — efficient hover, handling qualities, everything we know and love about the aircraft but twice as fast.'" The team studied a range of high-speed configurations and the technologies to support them. It first flew the X2 coaxial compound helicopter demonstrator in August 2008; in 2010, it achieved cruise speeds greater than 250 kt (463 km/h) with exceptional handling and hover efficiency.

Sikorsky senior manager for advanced concepts Bill Eadie worked on the single-seat X2 to integrate coaxial rigid rotor aerodynamics, integrated auxiliary propulsion, fly-by-wire flight controls, weight-saving composite materials and advanced vibration suppression. He explained, "That synergy of technologies is what made the X2 demonstrator viable and the technology viable."

The high-speed trade studies spawned more demonstrators in different sizes for different missions. Eadie served as chief engineer on the 11,000-lb (5,000-kg) S-97 Raider first flown in 2015. The company-funded risk-reduction vehicle exceeded 200 kt (370 km/h) in October 2018, and was subsequently evaluated

Matrix autonomy enabled unskilled pilots to fly the Sikorsky Autonomy Research Aircraft (SARA).

DARPA-sponsored autonomy development enabled an uncrewed Black Hawk to fly tactical missions.

by potential customers, including US Army experimental test pilots. The 30,000-lb (13,600-kg) class S-100 — the Sikorsky-Boeing SB>1 Defiant Joint Multi-Role (JMR) Technology Demonstrator — first flew in March 2019. It helped inform the US Army's Future Vertical Lift (FVL) initiative about X2 technologies but lost the competition for a squad-carrying FLRAA to the Bell Valor tiltrotor.

Eadie noted, "The three demonstrators showed that X2 co-axial architecture works best in the design space between conventional helicopters and higher-speed winged designs." The 14,000-lb (6,350-kg) S-102 Raider-X competitive prototype re-scaled X2 technologies for the FARA scout-attack helicopter (see "The Moving Parts of Future Vertical Lift," *Vertiflite*, Sept/Oct 2019) now abandoned by the Army. Where X2 technologies can find commercial customers is to be determined. Eadie said, "We have to look at the business cases going forward." The Sikorsky-Boeing Team ceased flying and ground runs of the SB>1 Defiant after the FLRAA downselect. The S-97 has accumulated 147 flight hours and continues to generate data. The Raider recently validated load-reducing control laws for future high-speed technology applications. "The aircraft today is still risk-reducing all of the technologies that we're feeding into our products."

Rapid prototyping imposed different rules on Innovations engineers. Eadie explained, "A key part of any of the Innovations rapid prototypes was to minimize KPPs — Key Performance Parameters. That allows the execution to focus on what's most important. Everything else was tradeable, besides safety, on our X2 and S-97 demonstrator programs. For the '97 we had speed. We had high/hot hover performance. We had endurance or time-on-station and a payload which led to the six-passenger cabin. One more kind of nuanced one was a weight-empty fraction." He noted, "There are tradeoffs in every configuration you design for every customer mission. Clearly, it's going to take more fuel to go faster, whatever configuration you're using."

Autonomy, Intelligence

The Innovations autonomy pillar evolved from helicopter pilotage work. Cherepinsky explained, "It was really aimed at solving degraded visual environments [DVE] as a safety problem and from there extended to help human beings operate these complex aircraft in an ever-changing world — flying EMS [emergency medical service] missions, landing on an oil rig on a dark night in the North Sea, or the DoD mission, which only gets harder and harder."

Matrix autonomy has evolved since its implementation on the Sikorsky Autonomous Research Aircraft (SARA) first flown in 2013. The fly-by-wire S-76 enabled untrained pilots to fly the helicopter through a tablet computer during the Aircrew Labor In-Cockpit Automation System (ALIAS) initiative funded by the Defense Advanced Research Projects Agency (DARPA). It was also integrated into a Cessna 208 Caravan fixed-wing turboprop airplane using the same pilot interface and, in June 2019, into a Sikorsky-owned UH-60A Black Hawk helicopter. In 2022, Matrix enabled the uncrewed ALIAS Black Hawk to fly tactical courses and deliver cargo.

Matrix is today at a technology readiness level (TRL) 7 — near an operational system. Cherepinsky reflected, "When SARA first flew with the initial version of Matrix, it had basic autonomy capability — motion planning, etc. Over the years we added functionality to allow operation in complex airspace — the system is capable of uncooperative see-and-avoid; it can pick landing zones and perform both normal and emergency landings, including full autorotations." The current system integrates different light detection and ranging (lidar) scanners, cameras and other sensors to perform full landings in most DVE situations, and it creates a protective zone around the aircraft to mitigate controlled flight into terrain.

Cherepinsky said, "Matrix exists as a software library that goes on things like FVL and Black Hawk." Sikorsky is now in discussions on how autonomy might be applied to the US Army's Enduring Fleet helicopters, and the company is exploring how to put Matrix on its commercial platforms with additional functionality. "Now we can look at what Matrix has accomplished. On the UH-60, you have seen us fly the Black Hawk in its optionally piloted configuration where you can have great handling qualities with human beings on board and the next second land, have those human beings depart, and execute the

Technology Pillars of Sikorsky Innovations

Speed

Twice the speed of conventional helicopters

- S-94 X2 — first flight 2008
- S-94 X2 — 250 kt flight 2010
- S-97 Raider — first flight 2015
- S-100 Defiant — first flight 2019
- S-102 Raider X — first flight 2024?

Autonomy

Offload pilots for safety, productivity

- Matrix S-76 SARA — first flight 2013
- ALIAS UH-60A — first flight 2019
- Matrix Caravan — flight tests 2016
- Expanded crewed/uncrewed control functions

Intelligence/Self-Awareness

Aircraft diagnostics/prognostics

- Commercial Customer Care Center opened 2016

Electrification

Distributed propulsion/reliable actuation

- HEX demonstrator initiated 2023

UAS

Reliable, efficient uncrewed flight

- Integrated autonomy, intelligence, electrification

mission without anybody on board." Sikorsky plans to announce more autonomy demonstrators. "It really is a continuation," said Cherepinsky. "We are not going to do one grand demonstrator. Matrix is designed to do multiple missions."

The Innovations helicopter intelligence or self-awareness pillar grew out of health and usage monitoring systems (HUMS) on the commercial S-92 and S-76. Director for Global Sustainment Simon Gharibian explained, "One aspect of the pillar was collecting all the disparate elements of HUMS, pulling it together and reducing it to practice in a meaningful production environment in the total life-cycle cost of the aircraft." He continued, "The intelligence pillar really culminated in the Customer Care Center in Trumbull, Connecticut, primarily dedicated to the commercial rotorcraft fleet."

The Center treats aircraft as capital equipment. "They are only making money when they're flying," said Gharibian. "It was [created] to drive down aircraft-on-ground issues and to drive up availability while simultaneously reducing the overall cost in inventory to support that fleet." The payoff was first realized in the S-92 fleet with its Collins Aerospace integrated mechanical diagnostic/integrated vehicle health management system (see "Positive Prognosis," *Vertiflite*, May/June 2012). "We're talking about a legacy platform with a relatively limited HUMS sensor suite focused on the dynamic systems of the aircraft. Where Intelligence really shone in that situation was all of the amazing, unique ways we could take advantage of that data set, things we had never expected to do at the outset."

The first part of HUMS draws data from sensors and aircraft systems. The second part converts data into actionable information. Gharibian noted, "It is in this second part — the interpretation of the data — where Sikorsky adds intelligence and the most value. Where Sikorsky really differentiates is in our ability to aggregate and analyze data from the entire fleet of aircraft over millions of flight hours, couple that with the inspection and maintenance history over the same time period, and then add in the fundamental design knowledge of the part in question."

S-92 operators were saddled with costly inspections as tail rotor pitch change bearings overheated. According to Gharibian, "We were mature enough from an Intelligence standpoint to ask, 'Is there data — telltale signals in the data coming off the aircraft from existing sensors — that could actually help us detect the degradation of the bearings ahead of time with enough fidelity to have confidence we didn't need a physical inspection." Gharibian added, "The thought behind that was, 'Let's make our aircraft more intelligent from a prognostics and diagnostics perspective, drive toward reduction of maintenance, start applying artificial intelligence and other ways of doing things we were used to doing by inspection and other really labor-intensive things.'"

Sikorsky analytics are able to reduce fleet operator inspections efficiently despite sensors located far from degraded bearings. Gharibian concluded, "You can definitely quantify a need for removal or replacement better than a physical inspection. The other aspect of it is that we can use HUMS data to also determine if operational aspects are driving increased degradation… We found that certain pedal inputs over certain durations would actually exacerbate that tail rotor pitch shaft bearing degradation. There was an operational advisement that went along with a change in inspection protocols." Safety and reliability is still based on robust design and established maintenance methodologies. "However as regulatory authorities, both civilian and military, gather enough evidence to support expansion of condition-based maintenance methodologies, we believe we have world-class expertise."

Sikorsky's intelligent analytic tools leverage HUMS data from different vendors. "We're the OEM" — the original equipment manufacturer — noted Gharibian, "so we can develop sensor-based algorithms that are coupled with our knowledge of the physics of the items we're trying to prognose. If we're the ones designing the gearboxes, we can put sensor-based algorithms around exactly the resonant frequencies and determine what bearing and which location is driving that response because we know all the ins and outs of the design. Nobody else would be able to do that." Aircraft intelligence enables the Customer Care Center to develop new algorithms in response to inspections, incidents and telemetered data.

Electric and Uncrewed

With a new pillar in electric flight, Innovations director Cherepinsky observed, "Electrification opens the aperture in some configurations — electrified X2s can be really neat things, so can other configurations." The electrification pillar nevertheless goes beyond distributed electric propulsion. "We are after bigger vehicles. Sikorsky doesn't necessarily want to play in 30-, 40-nm [55- or 75-km] range vehicles and missions that are purely electric, but we are looking at hybrid-electric aircraft where we are doing the right things for our planet — less fuel burn — as well as doing the right things for our customers in terms of economics… in general reducing the cost of vertical takeoff and landing flight in whatever form or shape it might take."

The electrification pillar applies technology to a range of vehicles. Cherepinsky observed, "It's more about electrification of the systems. For example, we are looking at organic actuation, things like individual blade control [IBC], pure electric actuation. Removing working fluids and replacing them with electrons is always a good thing." Hybrid-electric drivetrains will dramatically reduce direct operating and acquisition costs by reducing the number of mechanical driveshafts, gearboxes, etc. "Additionally, since the amount of electric power goes up, we can shift from hydraulic actuation to electric actuation — again reducing acquisition and operating costs."

In contrast to the once-stovepiped pillars of Sikorsky Innovations, the new UAS focus integrates electrification, intelligence and expanded autonomy. Cherepinsky said, "We want to bring UAS away from how it began — a small R/C [radio controlled] airplane vintage. As we talk about UAS doing more and more things… we want to bring these UASs to be more in line with what we think of as a manned aircraft without the expense and complexity." The new UAS technology pillar consequently embraces intelligence, autonomy and electrification. Cherepinsky concluded, "We're looking at how these three things meet to produce some really revolutionary products."

Helicopter intelligence is the foundation of the Sikorsky Customer Care Center.

About the Author
Senior contributing editor Frank Colucci has written for *Vertiflite* for 30 years on a range of subjects, including rotorcraft design, civil and military operations, testing, advanced materials, and systems integration. He can be reached at **rotorfrank@aol.com.**