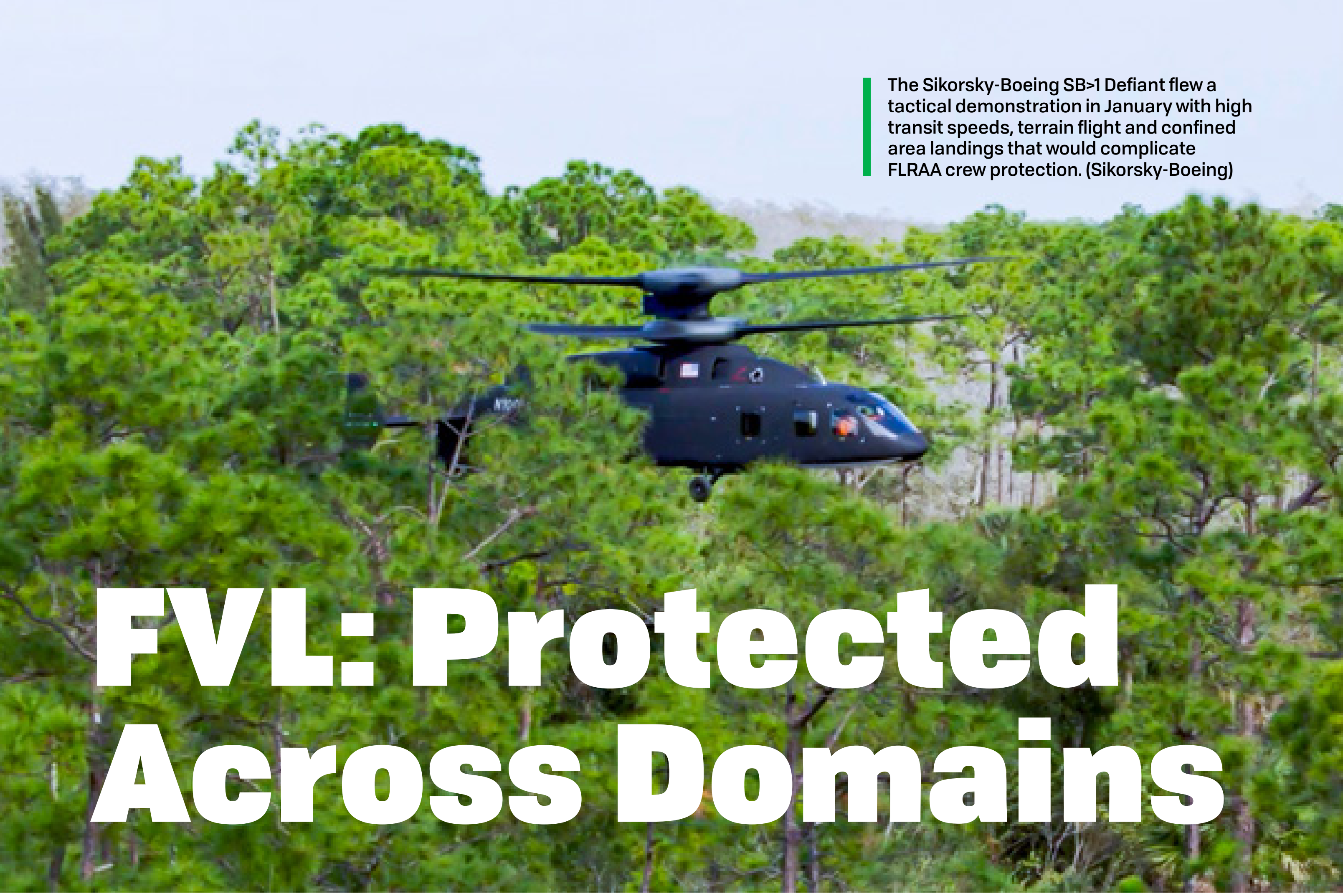

The Sikorsky-Boeing SB>1 Defiant flew a tactical demonstration in January with high transit speeds, terrain flight and confined area landings that would complicate FLRAA crew protection. (Sikorsky-Boeing)

FVL: Protected Across Domains

Flying fast over water in the lower-tier air domain complicates crashworthiness and crew protection for Future Vertical Lift.

By Frank Colucci

Whatever their configurations, the fast, long-range rotorcraft of Future Vertical Lift (FVL) will have to protect aviators from crash hazards more complex than those that shaped Black Hawks and Apaches. The US Army's existing assault and attack helicopters were designed to protect against largely vertical impact at low speed on land. Twice as fast as legacy helicopters, FVL is tailored to multi-domain operations (MDO) in the Indo-Pacific Command region surrounded by water. According to deputy FVL Cross-Functional Team (CFT) leader Dan Bailey, "Crashworthiness and crew protection are an important part of the overall design of the FVL aircraft, as they have been with the current fleet of aircraft. The expanded operational usage spectrum, such as speed, is taken into account within the design of the aircraft, as well as anticipated future threats."

Threats push the Future Long Range Assault Aircraft (FLRAA) and Future Attack Reconnaissance Aircraft (FARA) down into the lower tier of the battlefield air domain under 300 ft (91 m) to evade radar and visual acquisition. Enroute speeds of at least 230 kt (426 km/h) for FLRAA and 180 kt (333 km/h) for FARA are meant to increase air assault productivity and survivability. They also decrease reaction times and increase impact energies amid tree limbs and battlefield drones. Hybrid composite structures have to harden FVL without excessive weight (see "Making FVL," *Vertiflite*, Sept/Oct 2021). FLRAA and FARA also promise greater agility and more dynamic crash conditions than today's helicopters.

Civil air regulations put crash-resistant seats and structures in modern commercial helicopters, and North Sea union rules specify helicopters float in Sea State 6. Bailey noted, "Military rotorcraft typically fly lower and faster than commercial rotorcraft. Payloads tend to also be a higher fraction of empty weight, which drives loads into the structure for high mass retention challenges in crash events." He added, "These crash events for military rotorcraft have a high probability of occurring in austere and remote conditions."

In January, the Sikorsky-Boeing Defiant Joint Multi-Role Technology Demonstrator (JMR TD) dashed at 236 kt (437 km/h), hovered in defilade, and dropped near-vertically into a Black Hawk-sized landing zone near Sikorsky's Florida development flight center. The coaxial rigid rotor helicopter with its tail thruster decelerated rapidly and landed level without the usual Black Hawk flare. It also exercised fly-bywire (FBW) agility with its propulsor and active rudders and elevators. Defiant chief flight test pilot Bill Fell explained, "…we were focused on continuing to expand the bank angle and roll rate envelope at a range of speeds that provide the basis for terrain flight maneuvering." Forward speeds and lateral maneuvers complicate crash events (see "Instrumental Impact," *Vertiflite*, Nov/Dec 2013). The Sikorsky-Boeing team acknowledges their SB>1 Defiant X design for FLRAA leverages composite work from the Marine Corps CH-53K heavy-lift helicopter.

During its flight test program, Bell's FBW Valor JMR TD previously achieved 305 kt (565 km/h) in airplane mode and used proprotor tilt and differential cyclic to decelerate and mimic helicopter agility. A production Valor would have to provide crashworthiness in either mode of flight. Bell acknowledges its V-280 Valor inherits V-22 crashworthiness features — the big Osprey has an anti-plowing bulkhead and dual keel beams to keep the cabin from digging in and deforming with horizontal crash energy. Heavy dynamic components and fuel located outside the fuselage separate crash hazards from occupants, and Bell calculates the tiltrotor wing reduces the tendency of its FLRAA to roll over on land or water impact.

FLRAA competitive demonstration and risk reduction (CDRR) runs through May 2022 to choose a new Army squad carrier. In addition to their FLRAA efforts, Bell and Sikorsky are building FARA competitive prototypes (CPs), both about 75% complete in January 2022 and aiming for an armed scout down-select in fiscal 2024. The Bell Model 360 Invictus CP is an articulated-rotor helicopter with lifting wings that program manager Lee Anderson noted reduce the chances of rollover and rotor strike during an adverse event. The Sikorsky S-103 Raider X is a coaxial rigid-rotor helicopter with side-by-side seats and a tail propulsor like that of the bigger Defiant X to provide large angular rates and precision attitude control.

More FLRAA and FARA crew protection details are hidden in competition, but the Army expects both fourth-generation rotorcraft to blend model-based systems engineering and high-fidelity modeling tools with a new design specification for holistic crashworthiness. Bailey noted, "That clean-sheet design is like going from a 1970s automobile to a 2022 automobile with the inherent survivability aspects to protect the occupants for a broader operational usage and MDO environment."

Navy and Marine helicopters with Army origins operate over water routinely, but shipboard or island-hopping scenarios add to FVL crew protection concerns. Retired Apache pilot Warren Aylworth developed littoral warfare tactics for the AH-64D in the Asia/Pacific region and gave a user's view of crashworthiness in the littoral environment at the VFS Rotorcraft Structures and Survivability Technical Meeting in October (see "Modeling, Manufacturing and Materials," *Vertiflite*, Jan/Feb 2022).

Aylworth noted historical crashworthiness criteria fail to account for FVL performance and MDO. "The most glaring example of the crash survivability shortfall is the most ridiculous little Smart Car has to pass the 35 mph [55 km/h] solid barrier crash test. Our current spec for rotorcraft is 20 ft/s [6 m/s], so we're talking something like 12 knots [22 km/h]." Even Black Hawk autorotation speeds dictate water impact with 40-to-80 kt [74-to-148 km/h] horizontal speed and a vertical descent rate around 1,000 fpm [5 m/s]. "There is no scenario where you can crash slow enough to be survivable."

Designed for multi-domain operations, a FLRAA such as the Sikorsky-Boeing Defiant X has to integrate crashworthiness and crew protection feature for overwater scenarios. (Sikorsky-Boeing)

The Bell V-280 Valor JMR Technology Demonstrator demonstrated the high-speed, long-range performance expected of FLRAA for the Indo-Pacific region. (Bell)

Land crashes may still be more forgiving than ditching at sea. "Trees become the airbag," observed Aylworth. "They absorb some of the energy, but if you're still breathing when all the pieces stop, you can climb out or someone can pull you out. That's what's different from the overwater environment. Water will come crashing in. That's a whole different damage mechanism they don't have in the terrestrial environment, and that's even before you sink. I think that's an area of concern that's in want of technological advancement."

Holistic Protection

The Apache and Black Hawk were designed to absorb hard landings on solid ground. The landing gear and fuselage structure help absorb the impact, while crashworthy seats can further help reduce injuries.

In one likely scenario for the FARA, an AH-64E Apache operates from USS Essex. Overwater operations pose special challenges for helicopter crews. (US Department of Defense)

Bailey on the FVL CFT offered, “One [single] domain is not necessarily more or less difficult to protect against. It is more of a challenge to be able to adapt to, or provide occupant protection across, these multiple domains.” Helicopter landing gear that attenuates energy from hard landings or impact on solid ground is less effective on water, snow or soft swamp surfaces. Losing the protection of stroking gear lets the fuselage hit the surface faster and could lead to other failure mechanisms such as a hydrodynamic impulse that bursts fuselage skins in a water impact.

FLRAA and FARA Abbreviated Capabilities Development Documents (A-CDD) and system specifications have been updated with lessons from the JMR TD science and technology (S&T) program, the FLRAA CDRR and FARA competitive prototyping. The FVL team draws on the S&T community, the Army Aeromedical Research Lab at Fort Rucker, warfighting labs, and industry expertise for aircrew protection ideas. A Full-Spectrum Crashworthiness (FSC) effort led by the Army Combat Capabilities Development Command (DEVCOM) Aviation & Missile Center (AvMC) built on a mishap analysis by SAFE, Inc., and a technology and requirements review led by the Center for Rotorcraft Innovation (now the Vertical Lift Consortium). The report leverages existing MIL-STD-1290, ADS-33 and ADS-36 standards, the Crash Survival Design Guides, and applicable specifications.

The FSC report is not a new crashworthiness standard, but it does tell industry how technologies, such as cockpit ergonomics and airbags, advanced crew seats, adaptive flight controls and external airbags, can achieve holistic crashworthiness for MDO. The Combat Tempered Platform Demonstration (CTPD) led by AvMC, for example, redesigned Black Hawk structures to improve crashworthiness, ballistic protection and availability without reducing payload-range performance. The ongoing Aircraft and Aircrew Protection (A&AP) effort applies lessons learned to a clean-sheet, FVL-relevant rotorcraft.

Industry provides more crash protection options. Boeing developed the Rotorcraft Active Crash Protection System to provide data about imminent crash conditions and engage damage mitigation steps. The Sikorsky Platform Situational Awareness effort aims to warn of impending hazards and take control via a digital copilot to avert the danger. According to AvMC, FARA and FLRAA requirements do not prescribe specific solutions, and any technology has to earn its way on Army rotorcraft. A cockpit air bag system (CABS) fielded on UH-60A/L Black Hawks was discontinued for the UH-60M. However, CABS technology has since evolved and research continues.

Crash and Carry

US Army helicopters have long operated over water. Armed MH-6s and OH-58s flew from Navy ships in the Persian Gulf during operation Earnest Will in 1987. The latest AH-64E Apaches conducted deck landing qualifications off Bahrain in 2020. Crew survival in aircraft not designed for ditching or equipped for escape and rescue raises concerns for FVL. “Water impact is a thing,” acknowledged Aylworth. “We still do dunker training. It’s important and necessary, and confidence-building, but the importance of dunker training is they drop you vertically into the water. You’re in a bucket that rolls you upside down, but it’s not representative of forward impact. You can’t write-in a scenario where you’d touch down that slowly.”

Even modest water impact speeds impose catastrophic loads on today’s helicopters. In 2006, a Canadian Cormorant struck the water at 30–50 kt (55–90 km/h) with 18 degree nose-down attitude and broke cleanly aft of the cockpit before it capsized and sank. Without flotation gear, top-heavy helicopters roll over in water, making escape more difficult. Ideally, a survivable FVL would skip off the surface rather than plunge in, and once down would float upright long enough for crew to escape. The Navy Seahawk derived from the Army Black Hawk originally supplemented its sealed, buoyant tailcone with stabilizing floats on landing gear sponsons. The floats were abandoned for fear they would obstruct cockpit doors when inflated, even though the doors could be jettisoned for speedy exit.

Jettisoning Apache side windows with explosive cutters is hazardous under water and increases sink rate. Escape tests on an Apache airframe revealed water pressure implodes canopy side plastic about 10 ft (3 m) below the surface. Increasing depth increases pressure, and life vest inflators are soon negated. “There’s a point at which there ain’t enough floatation to pull you up,” summarized Aylworth. Helicopter Emergency Egress Devices (HEEDS) typically provide only enough breathable air to escape from a submerged aircraft, and their duration varies with depth.

Once on the surface, helicopter crews face another survival challenge. In 1989, a Kiowa Warrior crew in life vests spent 45 minutes floating in the Persian Gulf until rescued by a Navy helicopter. In other theaters, cold water adds urgency. Early Wildcat fighters in World War II stowed a pilot’s life raft in a compartment behind the cockpit. Today’s helicopters have no built-in raft provisions, leaving crews to stow and deploy personal rafts or contend with bulky exposure suits. Aylworth explained, "That's critical because anywhere you go in the water, you're going to die within 35 minutes if your core temperature goes below 35°C [95°F]. You've got to get out of the water. You've got to get into a life raft."

The Bell 360 Invictus FARA competitive prototype (75% complete in January) will have wings that may keep the helicopter upright in a water landing. (Bell)

Special Operations helicopter crews train routinely to rescue other aviators with their own aircraft. Without special training and equipment, regular Army crews in multi-domain operations may be at risk. "The country doesn't own enough dedicated rescue assets," said Aylworth. "Everything gets worse if you can't get them out now." Air assault Black Hawks have no rescue hoist, and Apache rescue gear has been ad-hoc. The Spur Ride system on Apaches ties the rescued to hand-holds never certified to carry a fully equipped aviator. "If you're in a -D or -E model Apache with EFABs [Enhanced Forward Avionics Bays], you cannot see below you." A fresh FARA solution would ideally be easy to use. "It might be as simple as an automotive backup camera on the belly beneath you to drag rescue ladders."

Finding downed FARA and FLRAA aircrew rapidly and understanding what happened may justify automatic deployable flight data recorders like those on NATO maritime helicopters. "All of this speaks to, I think, we should take this seriously. If we're going to fight peer competitors, everywhere we go, there's going to be an overwater component to it."