Flying Around Noise

NASA and the US Army develop tools to predict noise and the acoustic footprint of maneuvering rotorcraft

By Frank Colucci

Noise threatens helicopter operations, both civil and military. In July, the New York City Council banned sightseeing flights from all city heliports to satisfy community noise protests. Forty-five years after Hughes Helicopters flew a Vietnam OH-6A Loach with Quiet One technologies, internet video shows modern insurgents alerted to Apaches by the noise of the attack helicopters. Researchers from NASA and the US Army are collaborating on tools to predict the source-noise of maneuvering rotorcraft and its ground footprint. "We're just starting to understand the maneuver acoustics," explains Susan Gorton, project manager for the NASA Revolutionary Vertical Lift Technology (RVLT) initiative at NASA Langley Research Center in Hampton, Virginia. "We're not talking about violent maneuvers. We're talking about the turns and maneuvers helicopters do every day in their jobs." One far future application of the research may be a cockpit flight director that maps the ground noise footprint in current conditions and shows a route to minimize the disturbance. "The pilot knows he's making noise. He doesn't know what direction to take to correct it. We're trying to get to that point where you have that information and give it in a very compact way to the pilot."

The Flight Acoustics Group within the NASA Langley Aeroacoustics Branch teams researchers from NASA and the Army Aviation and Missile Research, Development and Engineering Center (AMRDEC). A paper presented by NASA research engineer Dr. Eric Greenwood at the AHS Forum in Virginia Beach this May explained how FRAME – Fundamental Rotorcraft Acoustics Modeling from Experiments – uses collected flight data to predict the acoustic impact of helicopter operations. "It's the first time we've been able to show good correlation between the predictive maneuver noise and flight test data," says Ms. Gorton. FRAME computer code generalizes steady-state acoustic data to various maneuvers, density-altitudes, temperatures and aircraft configurations.

The RVLT work falls under NASA'S broader Advanced Air Vehicle program and pursues rotary-wing investigations separate from fixed-wing noise studies. Civilian investigators and the Army share in the fundamental research looking for common analytical tools. Also at the AHS Forum, Army researcher Dr. James Stephenson described a wavelet extraction computer code to isolate helicopter Blade Vortex Interaction (BVI) noise from other source-noise. FRAME and the BVI extraction codes

AHS Community Noise Initiative

This article is the sixth in an ongoing series on helicopter noise since 2013. In recognition of the increasing community noise complaints and successful efforts to restrict helicopter usage, AHS International initiated an effort with HAI to help the technical and regulatory community better understand and address helicopter noise and noise complaints. Go to **www.vtol.org/noise** to learn more or to download past articles and technical reports.

AHS has been convening community noise workshops at each Annual Forum, and has held presentations and discussions with FAA to educate the headquarters staff on the technical underpinnings and the dramatic, immediate noise reductions possible through Fly Neighborly procedures. AHS is also working to support helicopter noise research of the FAA's Aviation Sustainability Center (ASCENT) and other organizations, and encouraging dialogue between the different constituencies.

The Bell 525 uses rotor blade refinements to meet current and anticipated FAA noise standards. These increasingly stringent requirements to lower peak noise nevertheless do little to reduce flyover noise or community complaints. (Bell Helicopter)

Commercial helicopters like the S-92 operating over noisy Manhattan must still adhere to Fly Neighborly procedures including defined noise avoidance routes. Current noise models do not take into account 'urban canyon' acoustics. (Sikorsky Aircraft)

may help develop low-noise operations. Dr. Oliver Wong, Army Aviation Development Directorate experimental aeromechanics lead at Langley explains, "The acoustic issues are the same for the Army and NASA – the generation of the source-noise, the propagation of the source-noise to the ground. What you do with the noise when it gets there is where it splits . . . . The characteristics you look for are different."

Army noise data and its users are largely classified, but one possible military application is ROSAS or Route Optimization for Survivability Against Sensors. At the Helicopter Association International (HAI) HeliExpo in March, NASA plans to present some lessons learned from recent flight tests that will highlight the noise differences and reductions that can be obtained through executing maneuvers with alternative control inputs – this information can be applied to the Fly Neighborly noise abatement guidelines. As part of its research plans, NASA is working to develop a noise tool that can predict the noise impact along a flight path. A long-term, stretch goal for NASA is to develop real-time acoustic cockpit displays that help direct pilots how to fly the aircraft quietly, safely and avoid noise-sensitive areas. HAI president and CEO Matt Zuccaro routinely enters helicopter noise disputes and says, "What we're finding is data has been absent in most cases when we're dealing with legislators and regulatory agencies. None have the data to prove the problem exists." HAI member operators routinely practice noise abatement procedures and follow noise avoidance routes, he says. "Where we've had data, we've found out there's an extremely high level of compliance with the routing."

NASA researchers also make their plans and findings available to regulators. "We do coordinate with the FAA noise division," adds Ms. Gorton. "They in the past several years particularly have become extremely interested in helicopter noise because there's been an explosion of helicopter noise complaints."

AHS has also played an important role with its Community Noise Initiative, says Ms. Gorton. "The AHS International noise meetings at the recent Annual Forums have provided insights into noise problems and have fostered interaction among many different pieces of the community, including manufacturers, operators, and government agencies."

AHS also lobbied Congress for additional funding for NASA rotorcraft research – some of which is now being applied to the noise problem – and is working to educate the manufacturers, regulators and operators, in concert with HAI.

Ms. Gorton notes, "As NASA moves forward with planning our research to address rotor noise issues, the AHS International focus on noise has been very helpful by highlighting issues, providing information from many parts of the community, fostering and encouraging interaction and promoting awareness of the issues."

Complicated Noisemakers

Helicopter noise comes from multiple sources and varies dramatically with aircraft type, weight and maneuvers. Main rotor impulsive noise in high-speed forward flight comes from air compressed by the advancing blade. BVI from successive blades generates distinctive slapping or chopping shock waves at lower speeds. Tail rotor blades make their own impulsive contribution, and complex rotor noise mixes with engine and transmission noise. "We don't completely understand all the source-noise mechanisms and how they interact," acknowledges Susan Gorton. "In the past, we did a lot of studies, particularly on Blade Vortex Interaction in approach. With the noise complaints now, we're looking at Blade Vortex Interaction in level flight en route and hovering – those are different kinds of noise. We've also concentrated a lot on main rotor noise. The tail rotor, the engine, depending on where the observer is, those noises can also be very significant."

Helicopter noise also varies with ambient conditions. "We have to be able to model the atmospheric effects," says Ms. Gorton. "How do you do that in the daily, varying environment when a front comes through or an atmospheric inversion occurs?" She adds, "We don't have good models for things like reflections in what some people call an 'urban canyon' with tall buildings." The same uncertainty applies to reflections off bodies of water such as Long Island Sound where noise complaints around the Hamptons became national news, and resulted in drastic flight restrictions.

The Langley Aeroacoustics Branch deploys a Mobile Acoustic Facility (MAF) for noise measurements in different environments. The MAF links up to 32 wireless microphones to control and instrumentation trailers and includes tethered weather balloon and ground-based LIDAR (Light Detection and Ranging) systems that measure wind speed, direction and other

Acoustic measurements were made with a light civil AS350B (shown at Salton Sea) and a medium military EH-60L helicopter at three different elevations with the same pilots flying identical profiles. (NASA photo)

parameters. An Aircraft Navigation and Tracking System (ANTS) documents the position of flight test vehicles. MAF noise measurements are used to conduct fundamental research into rotor noise mechanisms and gauge the detectability or annoyance potential of rotorcraft.

Just why helicopter noise is especially annoying is another area of investigation. Helicopters are singled out for complaints in notably noisy Manhattan. "It doesn't appear to me to be exactly loudness," says Ms. Gorton. "In some communities, loudness would be acceptable, some not . . . . The noise metrics we have do not take into account the tonal nature of helicopter noise – not enough to predict the impact on the community." NASA Langley has an Exterior Effects Room to measure observer noise response in a laboratory environment. "It's got an amazing sound system in there," explains Ms. Gorton. "We can take human subjects and have them listen to real sounds – recordings from the field played back to them – or sounds generated by analysis and simulation."

The Transportation Research Board of the National Academies of Science, Engineering and Medicine is meanwhile halfway through a real-world survey to assess tools that measure community annoyance with helicopter noise. The study conducted by airport consultants Landrum & Brown will document acoustic and non-acoustic factors that drive community reaction. Researcher Vincent Mestre explains, "For 40 years, social survey data has been done around airports asking people to rate their annoyance with fixed-wing noise. Very little similar work has been done for helicopters." The Schultz Curve that matches noise dose with annoyance factor around runways and railroads may or may not apply to helicopters. Researchers will measure noise around heliports before and during neighborhood surveys and expect to have results by June 2016. "The end game is to find out if there is a way to recreate the fixed-wing noise survey for helicopter noise."

Ironically, as noise sensitivity and complaints increase, helicopters are growing quieter. According to Albert Brand, Bell Helicopter director of Flight Technology, Research and Simulation, all Bell helicopters in production today meet Federal Aviation Administration Stage 3 noise limits for takeoff, flyover and approach. The five-bladed Model 525 Relentless first flown in July has a "significantly quieter rotor system" than previous models. Dr. Brand says, "It is anticipated that the Relentless will be quiet enough to meet the next stage of FAA noise regulations expected to be adopted in the next 10 years."

The Airbus Bluecopter demonstrator with Blue Edge main rotor blades and acoustically refined Fenestron aims to reduce further conventional helicopter noise. Meanwhile, the AgustaWestland AW609 tilt rotor and Sikorsky S-97 Raider coaxial compound helicopter exploit innovative configurations to cut noise. AgustaWestland claims the AW609 in flyover does not have the high-amplitude, low-frequency noise associated with a helicopter. The eight-bladed Sikorsky Raider leverages low rotor tip speed and the ability to de-clutch the tail propeller at lower speeds to reduce noise. "The manufacturers are working that issue," acknowledges Matt Zuccaro. "However, we can show those [improvements] on statistical charts, but the average person out there on the street has trouble discerning the difference even though an aircraft is quieter . . . . It's still perceived as a helicopter making noise."

Bell and HAI launched the Fly Neighborly initiative in 1982. General Fly Neighborly guidance advises pilots to plan routes that avoid noise-sensitive areas, fly as high as safely possible enroute, avoid noisier flight conditions and descend using the quietest safe approach for the specific aircraft. Sikorsky acoustics technical fellow Eric Jacobs notes: "Altitude guidance is based on the physical benefits of increasing source-receiver distance, although in some cases that must be balanced against directivity effects; i.e., increased altitude in some situations can expose a greater proportion of the community to higher source-noise levels emitted beneath or near beneath the helicopter."

More specific Fly Neighborly procedures are tied to individual aircraft. While pilots of Russian Mil and French-designed Airbus Helicopters should put noise-sensitive areas on the right, pilots of most other helicopters must keep them on the left. Mr. Jacobs explains, "Noise abatement guidance for the S-76 and S-92 helicopters were defined through flight testing performed by Sikorsky Aircraft. Turn direction primarily impacts tail rotor anti-torque requirements and, in some cases, blade vortex interaction effects." Understanding the interactions has special relevance to Sikorsky efforts to build helicopter autonomy. "Flight guidance technology is an enabling technology for automated low-noise flight procedures that would minimize noise footprints."

Fly, Listen and Predict

NASA noise footprint studies have typically characterized rotorcraft noise in steady-state flight over a linear microphone array perpendicular to the flight track. The technique measures lower hemisphere noise as a function of airspeed and glideslope. A straight-and-level flyover defines a rectangular footprint. Flight tests with a Bell-supplied Model 430 over the NASA Mobile Acoustic Facility at Eglin Air Force Base in 2011 marked the first time NASA tried to measure noise with a maneuvering helicopter. The collaborative tests collected noise measurements in transient pitch-ups, pushovers, longitudinal and rolling maneuvers, and velocity changes. Other measurements were taken in steady-state 80 and 130 kt (148 and 241 km/h) level flight and descending at 70 kt (130 km/h) with a flight path angled 9°. FRAME code predicted some 500 acoustic spheres covering airspeeds from 40 to 130 kt (74 to 241 km/h) in climb and descent with various load factors.

The investigation showed the refined FRAME-QS model accurately estimated the near-horizon noise radiated in transient helicopter maneuvers and demonstrated an approach that can generate a source noise modeling database for different flight conditions. "With our old predictions, we were missing the noise by twice the level of loudness," summarizes Susan Gorton. Accurate models could be used to generate low-noise mission profiles. "In a perfect world, where we could have information coming to the pilot, I would like to have a flight director cueing system that shows it knows where you want to go and here's the low-noise path to get there. In order to do that and do it safely, you're going to have to have some terrain information … some atmospheric information, and real-time aircraft trim state."

Any quiet flight path would also have to take into account safe handling. A steep, 12° glideslope, for example, reduces noise on the ground. "It's safe, but it's not something the pilots like, and it may not be something with which the passengers are comfortable."

Follow-on acoustic maneuvering tests in 2013 and 2014 flew very different aircraft at different weights. The MAF at Eglin collected noise data on the AH-64 Apache, the wide-bladed HH-60M Black Hawk, and tilt rotor CV-22 Osprey in a wider experimental envelope, according to Ms. Gorton. "You can put them through maneuvers you might not necessarily do with a civil configuration – higher G-loading maneuvers."

Other recent tests flown in California with AS350B light civil and EH-60L medium military helicopters were replicated by the same pilots flying identical profiles: at Salton Sea just below sea level, at Sierra Army Depot at 4,000 ft (1.2 km) and at Sweetwater, part of the US Marine Corps' Mountain Warfare Training Center along the Nevada border at 7,000 ft (2.1 km). "What we saw a hint of and decided to explore was the actual acoustic data changes with altitude," says Ms. Gorton. "It's non-linear, so you can't just make an extrapolation from sea level to altitude."

The wealth of experimental data is still being digested, and NASA and the Army are still formulating future acoustic test plans. "If we could boil it down to a few parameters, that would be wonderful," says Ms. Gorton. "It's a very complex, interactive system. We're trying to get our arms around the best way to proceed in that arena."

With proprotors in airplane mode, the AW609 tilt rotor avoids the high-amplitude, low-frequency noise associated with a helicopter. Helicopter-like landings nevertheless put the revolutionary rotorcraft back in noise-sensitive environments. (AgustaWestland)

Forum 71 Best Papers

The prestigious Alfred Gessow Award for the best technical paper at the 71st Annual Forum was awarded to Troy Schank and Kynn Schulte, Bell Helicopter, for their paper, "A Smart Position Sensor for Articulated Rotors," part of the Condition Based Maintenance (CBM)/Health and Usage Monitoring Systems (HUMS) sessions.

The summary reads: "A novel rotor blade position sensor for articulated rotors was developed at Bell Helicopter. The device has been successfully demonstrated to measure the coupled flap, lag and pitch displacements of a spherical joint as realized through an elastomeric bearing. The device will be used in flight tests of the 525 Relentless, where accuracy of the flap and lag measurements is anticipated to be within ±0.26° flap, ±0.21° lead-lag, and ±0.95° degrees in feathering."

The winning Gessow paper will be presented at the European Rotorcraft Forum (ERF), held September 1-4 this year in Munich, Germany. The award is named after Alfred Gessow, a helicopter pioneer, researcher, author, professor and founder of the rotorcraft center at the University of Maryland. Find this and the 18 other best papers at: **www.vtol.org/Gessow-Forum-71**