Groundbreaking flight control system undergoes third round of testing

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Illinois professor Naira Hovakimyan's and her team have been working on the L1 adaptive control system since 2005. Its goal to control aircraft in the presence of extreme failure. Credit: University of Illinois Department of Mechanical Science and Engineering

Illinois Professor Naira Hovakimyan is poised to enter into an unprecedented third round of flight tests using her L1 adaptive control system.

Hovakimyan's L1 adaptive control is a novel theory she and her research team have been developing since 2005 for the design of robust adaptive control architectures using fast adaptation schemes. The goal of the pioneering L1 system is to maintain aircraft performance and maneuverability even in the presence of severe failures—ultimately increasing aircraft safety, resilience to critical failures, and ease of operation for human pilots, as well as autopilots, in extreme conditions.

Flight control systems on today's aircraft have been tested and matured for decades and are considered extremely safe for their redundancy. Despite their safety, however, there is still great need for new technologies that could prevent more accidents. Hovakimyan and her control engineers, graduate students Javier Puig-Navarro and Kasey Ackerman, said the goal is for aircraft manufacturers to explore control architectures that can prevent aircraft accidents under the most extreme situations. This third round of testing pushes the L1 technology ever closer towards commercialization.

In early 2015, the team began testing at Edwards Air Force Base in California. Flown by students at the Air Force Test Pilot School (TPS), flight tests were completed successfully for the first time on a manned aircraft, a Learjet 25 equipped with a variable stability system. One year later, tests were performed on a VISTA-F16, a fighter aircraft with faster and more challenging dynamics. Throughout these flight tests, artificial failures were injected with and without L1 to evaluate its efficacy. On both aircrafts, when L1 was engaged, desired handling and flying qualities were recovered consistently across all failure configurations—proving that the L1 control architecture is predictable, reliable, repeatable, and safe, a remarkable achievement for a flight control system.

In early March, L1 will undergo more advanced testing in a project called Advanced L1 Airborne Superiority (ALIAS). Flight tests will take

place at Edwards Air Force Base and will be performed by TPS and Illinois students flying a Learjet 25. Recovery of strict military requirements regarding safety and performance of flight control systems in the presence of failures will be the primary focus. Ground checks and simulation rehearsals are scheduled for the first week of March, with manned tests taking place in the second and third weeks of March.

"We've improved a lot with respect to previous flights with the Learjet," said Puig-Navarro. "One thing we have worked on is leveraging L1 to further decouple the lateral and directional dynamics of the aircraft."

Coupling occurs, for instance, when a pilot inputs a pedal command to induce a change in the heading angle (horizontal movement of the nose) and simultaneously experiences a roll (movement of the wings). Often, this movement is unsolicited, and perceived by the pilot as undesired. Hovakimyan and her team have worked to combine L1 with traditional decoupling mechanisms, so pilots no longer have to compensate for that effect, making their job safer and easier.

"L1 adaptive control has overcome some of the major limitations of conventional adaptive control systems, by providing predictable robustness guarantees in the presence of a large class of uncertainties. Its features have been validated in a variety of applications and challenging flight tests, leading to commercialization opportunities across a few industries. The flight tests at Edwards AFB gave us an opportunity to demonstrate first-of-its-kind manned flight with an adaptive controller on board. It is commendable that the entire software was written and developed by my students at Illinois," said Hovakimyan.

In addition to the system's decoupling abilities, ALIAS will demonstrate its adherence to Level 1 military specifications—the strictest requirements for a flight control system of this type—as well as pilot feedback and suggestions.

L1 has the potential to revolutionize aircraft safety by greatly diminishing the possibility of pilot error during high workload maneuvers. However, its effects transcend the dynamics of flight. Its applications are diverse, and the technology has earned interest from various industries.

"We've proven that L1 works mathematically and we're showing that it also works in application," said Puig-Navarro. "Its biggest contribution to society and the world of engineering is ensuring that time-critical systems like those in aircraft have performance and robustness guarantees."

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