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Flying high, flying safe:

AFF mitigates risk and safely exceeds mission goals

By Jay Levine
X-Press Editor

Two Dryden F/A-18 research aircraft fly an Autonomous Formation Flight (AFF) mission.
NASA Photo / Carla Thomas

Two Dryden research aircraft are showing they can save fuel and reduce drag by flying like birds do - in formation.

Autonomous Formation Flight (AFF) missions flown by F/A-18 aircraft have shown in about 40 research flights substantial fuel savings of up to 20 percent, high accuracy during autopilot-controlled formation flight and excellence in identifying and mitigating risks to fly the missions safely.

"It is very important to take the time at the very beginning of the project and structure the project in such a fashion so that you can identify and mitigate all the risks the project has in terms of not just safety, but also technical and programmatic risks," Project Manager Gerard Schkolnik said.

"It follows in the philosophy of design it out. Design out the risks. Don't show up in the end game when every-thing is all built, designed and ready to go fly and say 'whoops, here is something we just completely overlooked.' I think one of the real successes of the AFF Project is the way that the team got together at the very beginning and laid out the project and structured it to identify the key risks. We structured the project to systematically mitigate those risks," he said.

Two Dryden F/A-18 research aircraft fly an Autonomous Formation Flight (AFF). AFF

The two main risks identified early in the project were the potential for a mid-air collision when the planes are flown as close as 20 feet apart at high speeds. The second risk is the possibility of overstressing the aircraft structure should the research autopilot command large deflections of the control surfaces, explained Brent Cobleigh, AFF chief engineer. Those hazards were identified the way most projects begin assessing risks - a brainstorming session.

Three approaches are used to mitigate risk. First, the potential hazard is assessed to see if it can be designed out of the system. For example, more stringent tests were conducted on the hardware systems that constitute the AFF autopilot to avoid potential issues in flight.

Formation Flight (AFF). AFF research flights have verified a fuel savings up to 19 percent for the trailing aircraft.
NASA Photo / Carla Thomas

flight.

A second way of mitigating risk is through automated warning and caution systems. This type of system automatically disengages the AFF systems if the distance between the two aircraft closes to within 56 feet from the nose of the trail aircraft to the tail of the lead aircraft.

The third level of mitigating risk is by procedures and training in the sky and in simulators. The control room also plays a critical role in safety by monitoring a number of factors such as the trailing aircraft's airspeed or severe oscillations. In cases like those, the pilot could be instructed to disengage the autopilot.

Multiple layers are built in to protect the pilots and project. For example, electronics monitor the "heart beat" from all the autopilot computers 20 times a second. If the system detects a change, it automatically disengages.

Another layer of safety is a pilot in the cockpit. They have visual information about the nose to tail distance and the pilot in the trailing aircraft can either push a button to manually disengage systems, or move the stick more than a half inch, which automatically disengages the system so that the pilot can regain control of the aircraft.

Risk reduction has been a big part of project preparations. AFF relative position sensor systems were first researched on cars at El Mirage, Calif., in July 2000. UCLA prototype sensors were used on cars driving along close together to confirm the precision of the data, Schkolnik said.

The Formation Flight Information System (FFIS) is an advanced GPS system capable of computing the relative distance and velocity between two moving aircraft to an accuracy of 1 foot. Dryden's standard GPS receivers were tested in 2000 on antennas attached to the NASA King Air. The tests confirmed recent changes concerning GPS signals had yielded accuracy that was 10 times greater than before.

"We took the concept of a build-up approach and applied it to each aspect of the program before going into a hazardous situation," Schkolnik said.

This 32 second video clip shows two F-18s in NASA's Autonomous Formation Flight (AFF) program. The aircraft use smoke contrails to gather data on wingtip vortices. Flight research attempts to utilize the energy in the vortices for more efficient flight. [320x240] QuickTime [160x120] QuickTime
NASA Video

The aircraft initially were kept at distances of 100 feet to 200 feet to avoid any potential risks in the early stages of the program. The project also used what is called a Class B envelope - an airspeed of no more than 250 knots - to mitigate any potential danger to the aircraft from any errant autopilot inputs.

"Overstress of an aircraft is always a possibility if research software sends an errant command to the flight control box. That is a hazard Dryden has a lot of experience mitigating," Schkolnik said.

Steven Jacobson, lead controls engineer, said the AFF software also provided many challenges.

"The most unique aspect of the design was developing technology to design a control system that operates in the vortex. The system is able to keep itself in the correct position while counteracting the effects of the vortex," Jacobson said.

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Mapping the vortex, or the swirling air that comes from the lead aircraft, is what researchers concluded in December research flights. One find was that the vortex energy does not dissipate quickly. However, while the best area in the vortex can provide fuel savings, drag reduction and fewer emissions, other areas of the vortex create turbulence.

When a project is confident that it is ready to fly, Dryden's Chief Engineer Marta Bohn-Meyer selects a group of experts from each discipline for the first flight readiness review board known as the Dryden Independent Review. The group looks at all elements of the project, asks questions and makes recommendations, Cobleigh said.

That peer team then goes to Dryden's Airworthiness and Flight Safety Review Board with recommendations to fly or not, and any requirements or questions that need to be resolved before the project can move on to the next steps to flight.

The airworthiness board issues a letter containing any conditions on the flight, or items to be resolved before a flight is permitted. A tech brief, which identifies what the project will do and how it will operate on the research missions, is the last step. A tech brief can cover one flight or a block of similar flights. An anomaly or hardware problem requires another tech brief on what occurred and what will be changed for the next flight. A mini tech brief is required if minor modifications or test point changes are needed between flights. The whole process takes about a month, or more depending on the project's complexity.

If there are major changes, the project must re-enter the flight readiness process. Small changes or fixes don't require more than a tech brief or mini tech brief. Some times tech briefs only approve one or two flights to see how it is going before allowing a block of flights, Cobleigh said.

Dryden had many partners in the AFF research. Langley Research Center, Hampton, Va., assisted in quantifying fuel savings and emissions reductions, UCLA's Autonomous Technology Instrumentation Lab developed sensor software and prototype sensor hardware.

Boeing St. Louis researchers worked on flight control computer software development. And the Formation Flight Control System autopilot box was developed by UCLA and repackaged by The Boeing Company to fly on the research F/A-18s.

Responsible NASA Official: Steve Lighthill
For questions, contact: Jenny Baer-Riedhart
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