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The X-Plane Imperative

America's military challenges have changed dramatically since the end of the Cold War, but our aircraft force structure has not. We continue to fly a large number of short-range aircraft, but among the new challenges we must prepare for is the need to move quickly to remote locations, and to maintain a long-term presence with few local bases to support operations. This will place difficult demands on the design of future aircraft systems. Range, speed, endurance, survivability, and flexibility will be more essential than ever. Those are the dragons that face future military aircraft designers.

Imagine a single aircraft with unprecedented range and peerless endurance; a supersonic aircraft that could adapt to multiple missions and survive any threat. We don't know how to build that aircraft

today. And learning how will require many leaps in multiple technologies. That's what we're here for. One day, planes like this will surely take flight. And our job at DARPA is to bring that someday a lot closer and make certain that when that technology matures, it is found in American airplanes.

For many years, incremental improvements in aircraft came about in a rapid succession of new aircraft development programs, but while the pace of new aircraft acquisition programs has slowed, we may nonetheless see development times and technology integration challenges that are even more demanding in the future—driven by the need to respond to new and changing threats.

Essential to the success of those programs is a proven technology base, tested in flight and ready



DARPA's X-Planes, clockwise from top left: X-29, X-50, X-36, X-31, and the Falcon Hypersonic Technology Vehicle

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for the next aircraft development cycle. At a time of relatively few new acquisition programs, we believe X-planes provide an attractive way to develop the technologies we'll need.

X-planes have long been used to test and mature technologies that could be demonstrated only in flight, transforming theory into hardware.

- The X-1, which first flew nearly 60 years ago, proved supersonic, controlled flight was possible.
- The X-29 showed how aero-elastically tailored wings and active control could stabilize a forward-swept wing configuration.
- The X-31 demonstrated extreme maneuverability, with coordinated-thrust vectoring and aerodynamic controls.
- The X-36 proved the value of tailless control using thrust vectoring.
- The X-45 and X-47 are exploring the frontiers of unmanned aircraft operations.

In each experiment, the later ones co-sponsored by DARPA, we demonstrated technologies in a way that could only be done in flight. These X-planes were technology demonstrators, not prototypes. We do not see production aircraft resembling the X-29, X-31 or X-36 flying today, but you will find many aircraft using technologies first demonstrated by X-planes.

DARPA continues to sponsor new X-plane concepts, testing the ideas and technologies that will give future American aircraft a decisive edge. The X-45 and X-47 are part of the Joint Unmanned Combat Air Systems program. Led by Dr. Mike Francis, J-UCAS seeks to demonstrate that a network of weaponized, high-performance, unmanned aircraft can survive and succeed in combat missions deep within enemy territory.

Hypersonic aircraft technologies face enormous challenges in materials, propulsion, and aerodynamics. Adding to the physical hurdles is a lack of ground-test facilities, especially for long-

duration testing. Ongoing DARPA programs like Falcon continue to use the atmosphere as a test environment. These programs are helping us develop a rapid global response in a more efficient and affordable air-breathing hypersonic platform.

Whatever new mission requirements might arise, the versatility of platforms will always be an advantage. An example is the X-50 Canard Rotor/Wing, led by Mr. Van Olinger. This design will take off like a helicopter with a tip-driven rotor and transition to fixed-wing flight with the rotor functioning as a wing. There are both structural and aerodynamic control challenges to the X-50 as well as new opportunities for its use. No longer limited by the forward speed limitations of helicopters, the X-50 may open the design space to new rotorcraft with enhanced speed and endurance, impacting search and rescue, special operations, and other capabilities.

All these X-planes pioneered concepts and technologies with dramatic effects on aircraft design. So, what do I see on the horizon? I'd like to suggest just a few ideas for X-plane demonstrations that may open up new and transformational technology areas for future aircraft designs, and that may enable those critical system attributes of enhanced range, endurance, speed, survivability, and flexibility.

The oblique flying wing has been studied for over 50 years, with very limited small-scale demonstrations. The oblique wing could offer a powerful combination of outstanding high-speed and low-speed performance. By varying its sweep with Mach number, this platform can optimize for both wave drag and drag due to lift. Such a capability may allow rapid deployment and long loiter time in, for example, a surveillance or patrol mission.

The oblique flying wing also presents very challenging issues in aerodynamic control, trim, propulsion integration, and aerostructural design. Some of these problems can be solved in ground test or simulations. Other controllability questions,

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however, can be answered only in flight-test demonstration, another excellent role for an X-plane.

Another challenge: maintaining laminar flow, the smooth, nonturbulent flow of air over the wing. Laminar flow has dramatic effects on aircraft drag and heat transfer. If we could achieve laminar flow by simple means on a swept wing, that alone could reduce drag by as much as 25 percent, yielding improvements in range and payload.

Laminar flow control has been tried for many years, but the work was always hindered by problems with distributed suction, weight, cost, power requirements, and integration. Recent work on the passive control of cross-flow instabilities on swept wings, using distributed roughness elements, has renewed interest in laminar flow designs for long-range and long-endurance aircraft, but we do not have ground-test facilities to examine these ideas at full-scale Reynolds numbers in a quiet test environment. Here again, X-planes offer a solution. An X-plane could serve as a flying laboratory, allowing us access to test conditions not easily reproduced on the ground.

Formation flight is an idea we know should work. We see it even in nature, yet while we routinely use formation flight for tactical advantage, it has never been utilized for the full aerodynamic benefit it offers. The aspect ratio benefits of formation flight on induced drag increase with the number of aircraft in formation, offering a means of increasing range with multiple aircraft. Or, if we choose, we could preferentially improve the range of one aircraft in the formation without transferring fuel. This opens a new design space for aircraft conceived and operated as a networked system.

As always, there are challenges to overcome. One challenge is precisely maintaining the relative position of two aircraft, or many aircraft, to take full advantage of the reduction in drag due to lift. Only birds now do this routinely, and they can't explain it to us. Autonomous stationkeeping will require demonstration in flight, building on the

autonomy, networking, and controls demonstrations that DARPA has been conducting for over a decade. It is not simply a matter of placing individually optimized aircraft into a formation. Once we prove that aircraft can maintain an optimum location autonomously, we open the design space to tailoring individual aircraft to optimize the formation itself.

We're always looking for ideas that will lead to transformational capabilities. What other concepts might open up the future design space for aircraft? We can think of many.

- Quiet aircraft with electronic propulsion and aerodynamic innovations may allow discrete operations below the ambient background noise.
- Extremely short take-off and landing aircraft may offer the military the capability of landing on surfaces other than conventional runways for mobility and surprise.
- Micro air vehicles with bird-like agility, and perhaps bird-like characteristics, might be used for sensor emplacement.

Most of us could, and it is my hope that many of you will, add many more ideas to this list.

The critical design challenges in many of these concepts will be difficult. They will require our best design teams, our best modeling and simulation techniques, and our best ground-test capabilities. For many of them, the capstone technology demonstration could be an X-plane. No future aircraft designer will want to take on high-risk technologies that have never been proven in flight. Precisely because they are still unproven, some of these ideas have been around for decades and yet failed to find their way onto an operational aircraft.

That's why we're here. One part of our business is to settle old questions, to put ideas to the test and turn concepts into hardware. Another part of our business is to explore new ideas that have never been tried. I ask you to give these challenges your

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best efforts. With your ideas, with the leadership of DARPA, and with the opportunity of X-plane demonstrations, we will make certain the technologies required to address new threats are available and the finest military aircraft in the world are always flown by the United States of America.