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Next Generation Aerostructures

Throughout its history, aviation has always been driven by those men and women brave enough to rise up and prove their dreams. One hundred years after the Wright Brothers' historic first powered flight at Kitty Hawk, the field of aviation remains a place still rich in new approaches, in dreams to be fulfilled.

In the past year, Steve Fossett became the first human to complete a solo flight around the world aboard Virgin Atlantic's Global Flyer. Reminiscent of the 1920s and 30s Schneider Cup competition, Burt Rutan led a private sector team that successfully launched a human into the fringes of low earth orbit and returned him safely to the ground. Each effort involved advances in aerostructures research and development. In the case of the Global Flyer, engineers were able to achieve an aircraft fuel mass fraction of 82 percent; the Spaceship One team was able to use composite structures technology to build a lightweight vehicle

Wright Brothers' flight at Kitty Hawk

that could support aerodynamic loads while being propelled by a hybrid rocket into space.

DARPA, in its efforts to provide better capability to our Services has, since its inception, fueled its quest for revolutionary change by empowering its managers to draw on the stuff of "blue sky" to use their imagination to inspire the next reality. Nowhere is this more apparent in the field of aviation than in the development of revolutionary advances in structures technology.

These revolutionary advances include the development of advanced short take-off and vertical landing (A/STOVL), advanced subsonic, supersonic, and, most recently, hypersonic aircraft, and numerous manned and unmanned X-planes. Some of these, such as the unmanned Global Hawk and Predator (the last with its ability to fire Hellfire missiles), have proven their worth in the ongoing conflicts in Afghanistan and Iraq.

There are those who are inclined to conclude, all too casually, that the field of aviation is fully mature. They are mistaken. It has not "all been done before" and, rising to the continuing challenge, DARPA's aviation activity is not soporific.

We seek to bring breakthrough aviation capabilities to our military. That means being able to fly aircraft as big as an aircraft carrier and as small as an insect, aircraft that change shape in flight, aircraft that have long endurance, and those that can land without a runway.

To meet and overcome the many technical challenges, we are supported by you, our great national aviation community, whose tradition is firmly rooted and inspired by the events of that December day in the dunes in 1903. So, in the field of aerostructures, how may DARPA contribute to the further revolution in aviation technology?

Today's large aircraft are based on tube and wing designs. For such aircraft, performance improvements of lift-to-drag ratio, fuel consumption, and payload fraction have largely stalled at the incremental level for the past half century. Eccentrically, the 50-year-old B-52 lift-to-drag ratio appears as a high watermark of design. DARPA's Tactical Technology Office (TTO) is investigating new modular aircraft concepts that will strive to improve significantly the performance of future large military aircraft.

Modular aircraft assume a common structure that can be configured to perform in multiple roles while minimizing particular mission redundancy. They seamlessly integrate aerodynamic wing-propulsion systems with fuselage-payload systems.

Fairy Rotodyne

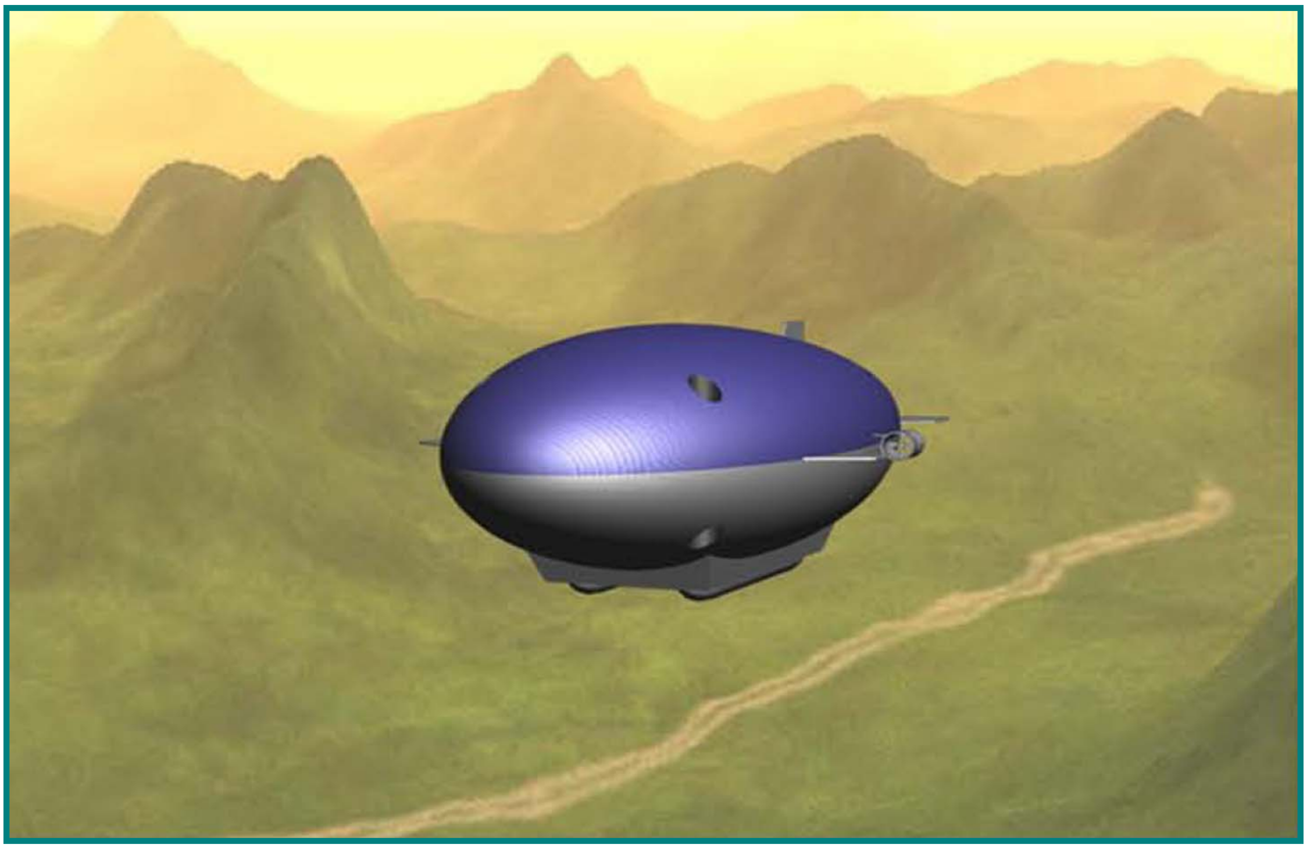
This can lead to reduced drag, increased lift, and reduced empty weight. For example, imagine an aircraft operating as a tanker that can be reconfigured with a structurally integrated and environmentally controlled weapons bay module for strike missions.

How do we design such a modular aircraft that can perform multiple roles? The answer requires overcoming many technical challenges and dispensing with old design shibboleths: we must make better use of composite materials and structure. Make the engines or payload bay modules part of the load-bearing fuselage structure. Consider variable aspect ratio and dispense with see-through canopies. Our development of the B-2 bomber offers some insights, but the key challenge is to remove redundant weight, and modularity provides a promising path to achieve these design efficiencies.

The military requires high-value cargo and personnel to be transported to remote regions—to places where runways do not exist, and to support isolated forces in the field. To satisfy this need, we seek the full capability of a helicopter to take off, land, and hover with a relatively benign downwash and the cruise capability of a fixed wing aircraft.

Used on the 1950s Fairy Rotodyne, one key concept that DARPA is considering is the use of tip jets to power large-diameter rotors to achieve lift. The technologies have come of age to make an older idea viable**.** New approaches will meet challenges such as noise levels, rotor speed and retreating blade stall, lightweight primary structure, efficient engines, low drag, active vibration control, integration, and so on. This initiative is complementary to other compound helicopter ideas and has value ranging from the combat search and rescue to the heavy-lift rotorcraft missions of the future.

Imagine an aircraft that is really, really, really big. Suppose we want a capability to deploy all the elements of an entire brigade over global distances,



Artist's concept of Walrus

from fort to fight in under 7 days. That would be Walrus, or likely a pod of Walruses! Consider such a capability in the form of a futuristic aircraft that generates lift from an integrated suite of technologies including various types of dynamic, aerostatic, and direct lift. The principal goal for Walrus is to control lift in all stages of air or ground operations. This will include off-loading of payload without taking on external ballast.

Walrus is distinct from the earlier airship era vehicles. It will operate heavier-than-air and will seek to achieve the operating utility of modern military transport aircraft. It will carry greater payload, have unimproved landing site capability, and will provide better transport efficiency. Walrus will be largest single aircraft ever developed. As you might imagine, there are numerous challenges to turning this vision into reality. How will we construct such an aircraft? What materials and structures will we use to build it? At over 800 feet long, how will we control this behemoth?

Consider next, futuristic aircraft that can radically change their geometric shape to perform multiple missions. Imagine how a low-speed reconnaissance aircraft could convert itself from a high-aspect ratio configuration to a lower aspect ratio, high-speed configuration to conduct strike missions. Developing wings that can radically change shape will expand the roles and functions of military reconnaissance and high performance aircraft. There are numerous aero-servo-elastic challenges in morphing the shape of a wing of an aircraft in flight. Not the least of these is aerodynamic performance and structural integrity throughout the flight envelope, as well as power and cost. These devices are being developed at the component level now and we are very interested in system-level applications for the future.

While most of the future systems I have described involve larger manned or unmanned aircraft, at DARPA we seek to develop vehicles and technologies at the very smallest scale, vehicles that can enhance situational awareness in the urban environment. Imagine a vehicle that can navigate autonomously in urban terrain, enter a building, and provide timely reconnaissance data to the warfighter on the outside.

We are not too far from this dream becoming reality, but as you can imagine there are many challenges to manufacturing a vehicle at the micro- or nanoscale of flight. How will we power these vehicles for sustained operation? How small can we build such a system? How far can they fly? Under what weather conditions can they operate? Can they be affordable? What missions will they perform? We are looking for clever system ideas in this area.

These are just some key breakthrough aircraft concepts DARPA is working on and what's clear is that it has not all been done before. Completely new aviation domains lay waiting to be demonstrated. For example, can we achieve the state where vertical take-off and landing, for faster cruising aircraft, is as natural a component of operations as the use of conventional runways? Radical new approaches are becoming possible as enabling technologies emerge at both the biggest and smallest scales imaginable.

Abraham Lincoln said, "Towering genius disdains a beaten path. It seeks regions hitherto unexplored." We seek revolutionary change in aerostructures; we seek the next generations in aviation. The story of innovative developments is not over at DARPA. Engineering has the power to make a bad idea work. Great engineering takes a good idea and produces a supremely elegant and harmonious solution. If you have new ideas that can rise to this challenge, that push the limits, please come and speak to us. We should work together.