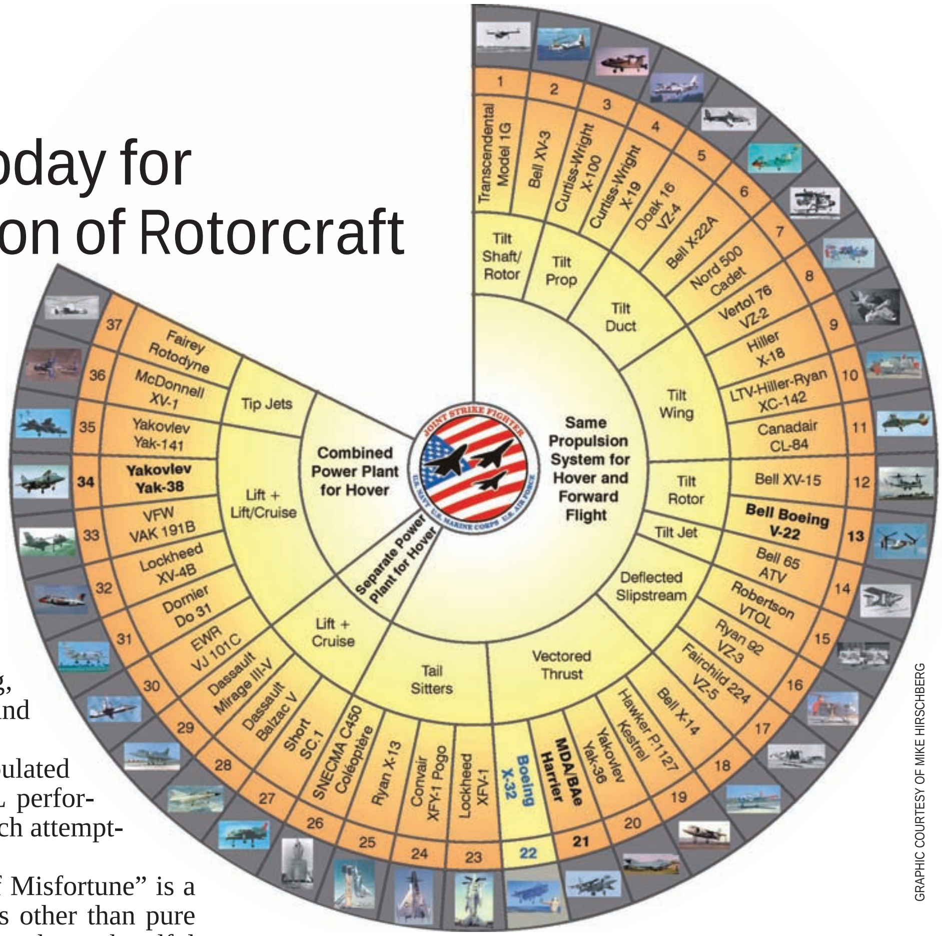
DARPA:

Planting Seeds Today for the Next Generation of Rotorcraft

By Donald Woodbury and
Daniel Newman

SPECIAL FOCUS

THE FUTURE OF ARMY AVIATION TECHNOLOGIES



GRAPHIC COURTESY OF MIKE HIRSCHBERG

This vertical or short range take-off and landing (V/STOL) wheel of research and development aircraft is still incomplete, but has yielded several aircraft to make it into military service.

To have a vertical takeoff and landing (VTOL) capability incurs a price in weight, power loading, cruise performance (speed, efficiency) and complexity.

The history of aviation has been populated with many approaches that trade VTOL performance for improved cruise capability, each attempting to provide an improved balance.

The well-known "V/STOL* Wheel of Misfortune" is a compendium of dozens of such attempts other than pure helicopters taken to flight test – with less than a handful reaching production.

A system with both excellent VTOL performance and cruise performance has always been the "Holy Grail," but today's technology offers at best moderate performance when compared separately to either conventional rotary wing or fixed wing aircraft.

Even minimal improvements in one aspect of performance are costly to the other.

Few technological advances have fundamentally affected this trade, but the Defense Advanced Research Projects Agency (DARPA) in Arlington, Va., is making investments to develop and demonstrate technologies that could provide dramatically enhanced speed, range and endurance without the historical penalties.

The operation of VTOL aircraft at slow speeds and near to the ground, in close proximity to the conflict, increases exposure to threats and intensifies the need for survivable designs – making VTOL aircraft survivable is an area of interest for several DARPA program managers.

Though rotorcraft do not require extensive infrastructure for launch and recovery operations, there is a significant deployed logistics tail associated with the complexity of the aircraft and their limited range and endurance.

Improvements in range, endurance and speed offer not only improvements in aircraft capability, but also benefits for the balance of the force structure.

This article outlines a number of the current rotorcraft investments by DARPA. It is also a call for the services to capitalize on the technological advancements made possible by these investments to enable the development and fielding of a new generation of VTOL systems.

**vertical or short range take-off and landing*

Speed

The challenge is to double or triple the speed and range performance of rotorcraft, while minimizing the impacts on VTOL and hover performance, and still provide the capability to operate from unimproved terrain with a high payload fraction and reasonable fuel efficiency.

Past programs have explored approaches to achieving substantial increases in the cruise speed of rotorcraft – potentially approaching that of fixed wing turboprops – with reduced impacts on low speed and hover performance.

DARPA remains interested in approaches to blend the best features of helicopters and fixed wing aircraft to change the way that the military moves people and materiel on the battlefield.

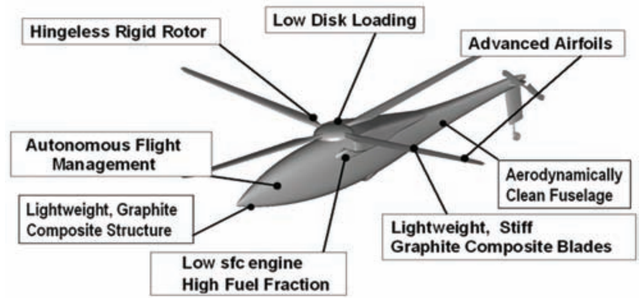
Endurance

Our warfighters must not only get to a combat area fast, but they must also sustain our military presence and superiority there indefinitely.

We need persistent platforms that enable the consistent surveillance and targetable information necessary to act quickly and precisely.

BOEING COMPANY PHOTO

DARPA is working with the Boeing Company on the development of the A160T Hummingbird unmanned rotorcraft, here following a high-altitude hover-out-of-ground-effect flight demonstration May 9 at the Army's Yuma Proving Ground, Ariz.



Turbo-shaft A160 Variant	Demonstration/ Validation	Result
Endurance 20 hours (Objective), 300 lbs 18 hours (Threshold), 300 lbs	Flight test	18.7 hrs
Range >1160 nm @ best endurance speed (1866 km)	Flight test	1813 km
>2200nm @ best range speed	Analysis of test data	Complete
140 kts	Flight test	146 kts
15K ft (HOGE),	Flight test	15,631 ft MSL
30K ft operating ceiling	Analysis of test data	Complete
1000 lbs to a radius of 500 km	Fight test	962 km
1,000 hrs between aircraft losses	Analysis of test data (Engineering improvements impact reliability)	1,418 hrs

DARPA GRAPHIC

This chart depicts both the characteristics of the A160 Hummingbird and performance milestones.

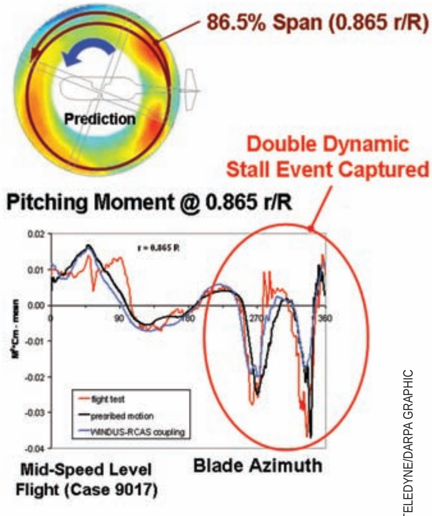
Past fixed wing aircraft created from DARPA investments, including the Global Hawk and the Predator, can loiter above a target for dozens of hours.

DARPA is working to obtain similar endurance from rotorcraft.

The A160 Hummingbird unmanned aircraft has shattered our expectations for rotorcraft with a recent demonstration in May of 18.7 hours of endurance with a 300 pound payload – a record for the longest unrefueled flight by any rotorcraft – and is planning to demonstrate even greater endurance.

The A160 achieves its endurance through a range of performance enhancements including the use of an optimum speed rotor – which enables the Hummingbird to adjust rotor RPM (revolutions per minute) at different altitudes and cruise speeds to improve overall fuel efficiency – and a lightweight, low drag fuselage.

Here is a representation of a Falcon View display with predicted acoustic detection footprints using high-fidelity models of atmospheric propagation and human perception.
SONALYSTS/DARPA GRAPHIC



TELEDYNE/DARPA GRAPHIC

DARPA has developed high-fidelity, physics-based tools to enable accurate computational predictions of rotor performance, loads and aero-acoustics. This chart accurately captures previously un-modeled normal force dynamic stall events for conventional rotor systems.

DARPA's "Sandblaster" program uses several situational awareness technologies to help pilots land safely during "brown-out" conditions. A 94-GHz radar is able to "see" through dust clouds to help pilots control the aircraft to safe touchdown.
SIKORSKY/DARPA GRAPHIC

The Hummingbird is designed to fly 2,500 nautical miles at an estimated top speed of 140 knots and altitudes up to 30,000 feet. It can hover out of ground effect at over 15,000 feet, making it suitable as a platform for a range of intelligence, surveillance and reconnaissance (ISR) sensors.

Future missions envisioned for the A160 include target acquisition, communications relay, precision re-supply, or as a weapons platform.

The Naval Air Systems Command is purchasing several Hummingbirds, and the Army is currently planning additional flight envelope exploration.

Survivability

An overarching goal for military rotorcraft is the capability to fly with impunity against all existing and emerging threats.

The fixed-wing community has made great strides towards this goal, focusing substantial investment and innovation on reduced susceptibility to detection, sensors providing advanced "see first" warning, physical and electronic countermeasures, reduced vulnerability, and advanced standoff "shoot-first" weapons capability.

The rotorcraft community has not had the resources to invest to enable comparable strides in survivability.

DARPA has invested in analytical tools to support design and operation of survivable systems.

In the Helicopter Quieting Program, DARPA has developed high-fidelity, physics-based tools to enable accurate computational predictions of rotor performance, loads and aero-acoustics. The tools have demonstrated orders of magnitude improvements in the ability to computationally predict the range at which a rotor can be perceived acoustically. Companion tools provide high-fidelity modeling of acoustic propagation and perception to provide a robust suite of tools supporting the design and operation of survivable aircraft.

VTOL aircraft offer the flexibility to hover in close proximity to complex terrain, and to land at austere, unprepared sites. A challenge with operating from austere sites is the lack of visibility associated with "brown-out" conditions.

The DARPA Sandblaster Program is developing the technology to reduce pilot workload and enable safe landings under degraded visual environment conditions by providing a real-time "see-through-the-dust" visualization of the outside scene to the multi-function cockpit display.

A 94-GHz radar is able to see through dust clouds, allowing the synthetic scene to be continuously updated even after the helicopter has entered the dust cloud.

Flight testing is currently in progress on the joint NASA/Army JUH-60A Black Hawk Rotorcraft Advanced Systems and Controls Airborne Laboratory research helicopter, known as "RASCAL."

The services need to initiate new programs that integrate the advanced safety and survivability technologies that have been developed by DARPA and others to produce a VTOL system with the capability to operate with impunity.

Other Developments

DARPA continues to invest in breakthrough payloads that could capitalize on extended loiter capabilities.

New sensor systems– including the foliage penetration reconnaissance, surveillance, tracking and engagement radar (FORESTER), the "Jigsaw" active laser radar, and the multifunction electro-optics for defense of U.S. aircraft (MEDUSA) programs – are demonstrating dramatic new capability to find and fix challenging targets in complex environments previously incapable by conventional aircraft and sensors.

The A160's high hover altitude combined with these new payloads could enable a persistent stare capability to detect slow moving targets, or targets under the canopy, and provide stand-off detection of potential threats.

DARPA has also developed, demonstrated and successfully transitioned ducted fan technology.

The RQ-16A Tarantula Hawk, a micro air vehicle or MAV, now deployed with the Army and Navy, is a small autonomous VTOL system providing a backpack size portable airborne ISR capability for small combat units.

The technology provides safe VTOL operation with hover/stare capability in close proximity to Soldiers, sailors, air-

ARMY PHOTO BY PFC KYNDAL BREWER

DARPA and the Army have tested the micro air vehicle system as a backpack portable reconnaissance and surveillance system to provide useful real-time combat information to platoon size tactical units.

men and Marines, with relatively low hardware complexity.

Summary

We have described several of DARPA's efforts to develop and

COURTESY PHOTO

The RQ-16A Tarantula Hawk MAV is now being fielded to Army and Navy units.

demonstrate dramatic capability improvements to VTOL aircraft – specifically significant advancements in speed, endurance, safety and survivability – for the next generation of military rotorcraft.

It is imperative that our service partners move forward to integrate these technologies and capabilities into VTOL aircraft that offer the speed, range, and endurance of fixed-wing aircraft, the situational awareness that is necessary to find and identify targets at stand-off ranges, the safety to operate these systems in complex environments, and the survivability that enables our systems to operate with impunity.

Such a capability must be developed and matured to a sufficient technology readiness level to present a viable alternate for the next service acquisition program.

Without investments to mature the technologies that DARPA and others are developing, our future acquisition programs will be left with no viable alternatives to the continued cycle of incremental upgrades to our existing rotorcraft platforms.

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Don Woodbury and Dan Newman are both program managers in the Tactical Technology Office of the Defense Advanced Research Projects Agency in Arlington, Va.