J-UCAS: Inventing a Weapon System for the Information Age

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Sometime in the future, in an unknown part of the world, the US and its allies are threatened by a hostile nation armed with long-range missiles and protected by an integrated air defense system (IADS). Far from a host nation, coalition air forces must traverse long distances, only to face advanced surface-to-air missiles (SAMs), in order to destroy the adversary's offensive weapons. Unmanned aircraft take off from a forward-operating base, rendezvous with other unmanned aircraft from an aircraft carrier and co-operatively locate and attack each element of the IADS, without risking the lives of pilots. Able to interoperate with heterogeneous groups, these unmanned aircraft, progeny of today's Joint Unmanned Combat Air Systems (J–UCAS) programme, are able to infiltrate deep into hostile airspace without being detected, jam the enemy's most advanced radars and systematically destroy the network of SAMs, clearing the way for the manned strike forces.

During the conflict, the unmanned aircraft exploit their long endurance and sizeable bomb load, continuing to locate and eliminate time-critical and high-value targets. After the successful conclusion of hostilities, the unmanned aircraft patrol the skies to enforce no-fly-zone restrictions, using in-flight refuelling to extend each aircraft's patrol time to days, without suffering the limitations of a human pilot.

Although this may sound like science fiction, the underlying technologies and operational capabilities are being developed today. A joint effort between the Defense Advanced Research Projects Agency (DARPA), the US Air Force and the US Navy, the J–UCAS programme is charged with exploring the potential that a networked system of high-performance, weaponised unmanned aircraft could bring to the battlefields of the future, where the ability to penetrate and persist deep within denied enemy territory will be essential to achieving success.

Fully Exploiting the Information Age

The genesis of the J–UCAS programme occurred in the mid-1990s at DARPA. Through several generations, projected missions and design concepts have evolved, leading to the system and the air vehicles being pursued in the current joint programme. When flight testing begins in 2007, Boeing's X–45C and Northrop Grumman's X–47B will be the most advanced aircraft ever built. Designed for affordable stealth to the next level, the tailless demonstrators will feature advanced systems such as all-electric infrastructure, advanced electronic support measures (ESM), synthetic aperture radar (SAR), robust secure communications and vehicle health management systems. With a mission radius well in excess of 1000nm and a payload of over 4500lb, these are the largest unmanned aircraft yet developed, with gross weights in the 35,000 – 50,000lb range.

These aircraft are planned to expand the 'operational envelope' of potential missions in which a J–UCAS derivative might excel. Future operational aircraft could end up being 'productionised' versions of these X-plane demonstrators, or they may be larger or smaller, or totally different in appearance. The results of an operational assessment, to be conducted by the US Air Force and the US Navy beginning in late 2007, will shape the character of the system that will eventually be fielded.

Whatever the form that these future air vehicles take, one constant that will remain is the revolutionary software system designed to integrate the J–UCAS system elements – bridging the gap between the industrial age platforms and the network-centric architectures expected to dominate 21st century combat operations.

In a departure from aerospace tradition, the J–UCAS program is developing a Common Operating System (COS) – an all-software, 'connect-the-dots' package that prescribes and enables the interactions of the various system components, including air vehicles, control stations, and other 'nodes in the network'. Not only will the development of a single COS realise cost savings, but the common system architecture will allow for intra-operability between the individual aircraft and other components of J–UCAS, and interoperability with external elements, such as manned aircraft, command and control centres, and space assets. Decoupling the air vehicle development from the mission software development allows them to progress independently, adding unprecedented flexibility to future system upgrades and modifications.
The COS will enable interoperability among multiple types of air vehicles and mission control elements and will facilitate the integration of other subsystems such as sensors, weapons and communications. The COS will encompass the software architecture, algorithms, applications and services that provide command and control, communications management, mission planning, much of the interactive autonomy, the human systems interface and the many other qualities associated with the J–UCAS system. The ability COS will provide in inter-vehicle collaboration will improve both system performance and survivability in the most challenging missions J–UCAS is expected to undertake.

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The COS is being developed by Boeing, Northrop Grumman, Johns Hopkins University's Applied Physics Laboratory (APL) and other technology contributors working collaboratively under a consortium-like business arrangement. APL was competitively selected to serve as an 'Integrator/Broker', charged with facilitating, co-ordinating, and, if necessary, completing the development of the J–UCAS enterprise architecture and integration of the COS. It was also tasked with developing and maintaining an executable J–UCAS architectural model, providing infrastructure (equipment and services) to support technology identification and evaluation, and maintaining configuration control of interface control documents and COS software releases. From their lead, the consortium will evaluate the widest possible range of capabilities and functionality, selecting solutions that provide the best value to make J–UCAS as capable as it can be. The consortium makes decisions about the COS in a collaborative manner, resolves conflicts and selects other technology contributors as needed to attract 'best of breed' algorithms and functionality.

Programme Accomplishments to Date

The J–UCAS programme has conducted a

number of demonstrations of potential combat capabilities that rank as 'first-of-a-kind' in aviation history. Using two X–45A air vehicles built by Boeing to demonstrate technologies during the precursor effort, the J–UCAS programme has continued to evolve capabilities relevant to the anticipated mission set.
Since they began flying in May 2002, the two X–45As have demonstrated numerous capabilities including loss of communications behaviour, autonomous targeting capability by dropping an inert precision guided weapon (following human consent), and hand-off of vehicle control from the test site in California to Boeing's engineering centre in Seattle, as well as the simultaneous hand-off of control of two vehicles from one control station at the flight test centre to another. A reactive suppression of enemy air defences (SEAD) mission demonstration has also been conducted. Future demonstrations will continue to explore potential concepts applicable to J–UCAS.

The J–UCAS X–47 team has also successfully demonstrated key functionality needed for future aircraft carrier operations. Using its self-funded X–47A demonstrator, Northrop demonstrated a simulated aircraft carrier-type landing. Other experiments proved that an unmanned aircraft is capable of receiving digital messages from an aircraft carrier, processing them and responding to shipboard air traffic control commands.
The development of the larger X–45C and X–47B designs has also progressed significantly. Construction of the first X–45C has begun, while the first mission control element has already been delivered. The X–45C full scale antenna model has begun testing and the full-scale pole model is nearing completion. The fabrication of a second X–45C demonstrator will begin later this year. Meanwhile, the Northrop Grumman team completed the X–47B

preliminary design in early 2005 and will conduct the critical design review later this year. The X–47B full-scale pole model will also soon be complete.

The COS development is moving forward as well, with a distributed simulation demonstration having been conducted in December 2004. Requirements for the first test version (Build 0) are complete and a demonstration is planned for the end of 2005. By the time of this article's publication, work on Build 1 will also have begun in earnest.

The Challenges Ahead

UAVs have generally been developed for dull, dirty and dangerous missions and J–UCAS has been designed to penetrate and persist deep within enemy territory. The high levels of autonomy planned for J–UCAS are crucial for operating the aircraft from anywhere in the world. Its communications system design assumes imperfect conditions as the norm – always latent, sometimes intermittent and occasionally not there at all. Whether caused by sunspots or jamming, degraded communications must not impair aircraft functionality or the system's ability to conduct its missions within the assigned rules of engagement (e.g. the use of lethal force only authorised by the human operator).

Furthermore, instead of today's norm involving multiple operators controlling a single UAV, J–UCAS will demonstrate a new crewing paradigm, with multiple aircraft being controlled by a relatively small number of operators, their tasking optimised for workload and mission-critical needs. J–UCAS aircraft will collaborate with each other and other assets to enhance overall situational awareness and improve the speed and precision with which to geo-locate, identify, track, attack and assess targets.

This autonomy of the aircraft also brings with it a number of challenges. For instance, J–UCAS will operate at the speed and altitude of typical commercial air traffic. A 'sense and avoid' capability will be necessary to allow these large unmanned aircraft to operate routinely in the global air traffic management system. In order to have true global reach, the J–UCAS aircraft will also sport an automated aerial refuelling capability. Both of these challenges are planned for demonstration under parallel efforts.

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The ability to work with other assets includes other manned and unmanned platforms anywhere in the world. Space assets are expected to provide the infrastructure of the network-centric future. Global reach means global communications, bringing with it 'reach back and reach forward' capabilities for surveillance and reconnaissance data. Space assets will support global navigation through the global positioning system (GPS). Other satellites are envisioned to provide collaborative sensing, sensor cueing and, potentially, even missile launch warnings and bi-static radar operations.

Beyond the technical issues lie other longer-term challenges, including the building of user trust and public confidence through demonstrated reliability and safety. The removal of regulatory barriers is a long-term endeavour necessary to permit routine airspace control accommodation, eventually enabling commercialisation of derivative unmanned transport capabilities. Integration into the existing military infrastructure, including operations and basing, logistics and maintenance, is an obvious essential prerequisite to fielding the system. Perhaps of greatest importance is the programme's need to meet its expectations of affordability. Although a highly sophisticated system necessitated by the nature of its mission set, J–UCAS must ultimately satisfy the need for it to be an affordable solution in the context of its important combat role.

United Kingdom Participation

After several years of information exchanges, DARPA and the UK Ministry of Defense (MoD) initiated a collaborative programme in 2004 to determine the military benefits of, and interoperability prescription for, unmanned combat aircraft in future coalition operations. Through this relationship, the J–UCAS programme will conduct experimentation in a real-time, distributed simulation environment using a trans-oceanic network and simulation facilities in both the US and the UK. With this capability, the programme will support the development of coalition concepts of operation, assessing interoperability issues and risks.

The international collaborative effort is expected to culminate in an effectiveness demonstration involving live and virtual manned and unmanned assets from both countries, operating in a networked coalition warfare scenario. The information generated by this unique collaboration will aid both nations in evaluating the cost-effectiveness of these vehicles as components of a future coalition offensive air capability.

Summary

The long odyssey leading up to the development of a versatile, capable unmanned combat air system finally appears to be nearing its conclusion. Boeing and Northrop Grumman are both well into the development of X-plane demonstrators, which will enable a comprehensive operational assessment to begin in 2007. That assessment, conducted jointly by the US Air Force and Navy, will provide key demonstrations and insights on the expected performance, versatility and vulnerabilities of the J–UCAS concept. The Common Operating System development, although in its infancy, promises to provide the levels of intelligence, intra-operability and interoperability necessary for success in the future integrated warfighting environment. The UK's committed involvement assures even greater progress in those areas relevant to effective coalition operations. The J–UCAS programme is now well on its way to transforming the battlespace of the 21st century. ■