Bargain hunt: Air forces move to embrace low-cost UCAVs

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Unmanned systems have become increasingly sophisticated and consequently expensive. *Richard Scott* and *Huw Williams* examine the emerging requirement for low-cost unmanned combat air vehicles and how this can be delivered

Unmanned aircraft systems (UAS) have evolved rapidly over the last two decades or so, transitioning from platforms largely centred on the provision of limited reconnaissance and battle-damage assessment (BDA), to assets that even at the lower end of the tactical level are able to provide persistent, high-fidelity intelligence, surveillance, and reconnaissance (ISR) capabilities.

Their development has in no small part been driven by the conflicts in Iraq and Afghanistan, which have spurred significant investment in platforms and payloads, and seen the widespread use of UAS in strike roles.

Display board showing the manned/unmanned teaming of an F-35 aircraft with a number of UTAP-22 UCAS vehicles. Kratos has characterised UTAP-22 as an 'unmanned wingman', and believes it offers an inexpensive force multiplier. (Richard Scott/NAVYPIX)

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UAS are often entrusted with critical missions and in many cases are equipped with some of the most sophisticated payloads in militaries' inventories; combined with increasing platform performance, and in some instances even 'stealthy' characteristics, the cost of UAS has risen steeply, and they are increasingly no longer being viewed as expendable as they once were.

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Low-cost asset

At the forefront of efforts in this area is the US Air Force Research Laboratory's (AFRL's) Low-Cost Attritable Aircraft Technology (LCAAT) effort, one element of which is the Low-Cost Attritable Strike UAS Demonstration (LCASD) programme.

"The motivation for this initiative is driven by the fact that when you look at the cost of exquisite weapon systems and air vehicles, and you look at the trajectory of their cost, there really is nothing in place to inhibit that cost to continue to grow," explained William Baron, the programme manager for LCAAT.

Baron told *Jane's* that in all likelihood in the future the air force will have fewer high-end aircraft, and that LCASD is exploring the potential to change the force mix and concept of operations for the service, "Cost is the fundamental focus of this initiative and it is exploring whether or not there is an air vehicle concept, in particular a UAS, that could be disruptive in the sense that it would be a very-low-cost asset that ultimately could be used in very different ways."

Baron said that the AFRL has traditionally looked into the development of low-cost aircraft technologies and that the LCASD effort would attack the cost problem, noting that one challenge is in balancing cost, performance, and how attritable a platform should be, and that the lab is targeting "An air vehicle asset that is at a price point that is low enough that we can afford to lose it, but with an intent to re-use the asset."

Baron said that the development of a low-cost asset will likely require a change in mindset and approach towards how aircraft technology is developed. "[This is] very unlike a traditional aircraft development concept, where we design to very tight specifications and guidelines to ensure that we have an aircraft that offers very high levels of safety and reliability.

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On the other hand, however, Baron noted that the design approach should also not follow that for systems developed for single missions, such as cruise and other missile types. "We're looking at the opportunity space that exists between those two book ends, the design space between the exquisite and the expendable, if you will."

Baron said that this is not a new approach, pointing to the Firebee aircraft developed by Teledyne-Ryan, which variously served in reconnaissance roles and as targets.

Technological developments in a number of areas, such as engines, composite materials, and flight control systems, are enabling this design principle to be re-examined, "to take advantage of these technologies and in effect bring forward a new class of attritable aircraft solutions", Baron said.

Baron noted that the LCASD is primarily a research and development challenge that is centred on understanding what platforms could be developed now, if industry was pressed hard to look at cost versus performance in meeting the mission requirements outlined.

The AFRL's objective with the LCASD is to establish a benchmark, culminating in a flight demonstration, for the 'art of the possible' with regard to a baseline system costed against a notional set of strike vehicle requirements. Alongside this, the programme will also identify key enabling technologies and provide the AFRL with a vehicle for future capability and technology demonstrations.

In July 2016, the AFRL selected Kratos to deliver the LCASD programme. Under a cost share arrangement with the AFRL, the company is contributing USD33.5 million of its own funds over the 30-month period of performance, while the government is committing USD7.3 million: the pay-off for Kratos is that it will retain the intellectual property rights on the XQ-222 Valkyrie air vehicle design under development for the programme.

LCASD cost and capability goals set down by the AFRL include a unit acquisition cost of not more than USD3 million for the first unit up to 99 units, and USD2 million or less for 100 or greater volume purchases; a 1,500 n mile mission radius with a 500 lb (230 kg) payload; and an internal weapons bay sized to carry and deliver at least two GBU-39 Small Diameter Bombs.

An XQ-222 operational concept drawing. (Kratos)

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Other objectives include a capability for runway-independent take-off and recovery, and the maximum use of commercial off-the-shelf (COTS) materials, subsystems, manufacturing processes, and open mission system architecture concepts.

Baron said that Kratos is uniquely suited to LCASD, because of its expertise in the high-end target business; however, he noted that the programme goes beyond the technical aspects and requires an examination of the operational context for such systems.

In order to exploit the "attritable space", Baron said that airworthiness considerations need to be addressed and how and where these aircraft will be operated. As they would likely be used only in controlled airspace and times of war, the same strict specifications required for flight in the national airspace might not be applicable, Baron said, pointing to the military's use of target drones at controlled test ranges.

The AFRL is placing an emphasis on leveraging COTS and military off-the-shelf (MOTS) systems and components, and understanding what the impact might be.

Baron said that tremendous cost savings could be made by taking advantage of COTS and MOTS technology, but caveated that in some instances designs might not be optimised for this approach, with the potential for a parasitic impact on an aircraft's weight or performance.

The platform under development for LCASD is using a Williams turbofan engine - the J33 - that is typically used in business jets. "[However, that is] not to say that there won't be an opportunity at some point in the future to try and improve engine efficiencies and bring costs down by considering the engine and other subsystems as attritable and rethinking how we address the reliability of some of the subsystems," Baron noted.

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Among the operational issues to be understood are the introduction of sense-and-avoid technology and greater levels of autonomy.

The lab is using modelling and simulation to identify and understand the "sweet spots" for where this type of aircraft should be used. Baron said, "In the LCAS programme we are very clear to express the fact that these aircraft are not going to replace the need for high-end platforms in the air force," rather they will augment these aircraft and hopefully act as force multipliers.

The AFRL is also looking at the development of new cost models, as traditional approaches do not apply for attritable aircraft, and will need to determine the necessary performance for these assets, the possibility of making savings in the manufacturing process - for example, replacing touch labour with automation - and where best in the design to reach out to the non-aerospace sector, such as drawing expertise from the automotive industry.

Baron also said that they would like to have flexible manufacturing capacity. "We would like a vehicle concept that allows us to surge in the event that they are needed. So we don't necessarily have to go and build 10,000 of these aircraft and keep them stored in crates."

Significant challenges present themselves in the areas of survivability and payloads, with both mission aspects potentially driving up costs.

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Likewise, if a mission will require a high-end, very-expensive payload, then attritable aircraft will not likely be the best assets to use. "From the get go that has been one of the considerations … if you've got a 15 million-dollar payload you're not going to want to put it on a 2 million-dollar aircraft," Baron explained, adding, "We're not going to do a lot of the missions that require an exquisite payload. That being said, we are working very closely with our sensor directorate to start exploring what sensor constructs can be brought forward."

The general trend for improvements in cost versus performance in the field of sensors is beneficial to attritable aircraft, Baron said, adding that they have been conducting analysis into the suitability of sensors that are available now as well as projecting what will be available as payload costs come down.

The Unmanned Systems Division of Kratos Defense and Security Solutions - incorporating the activities of Composite Engineering, Inc (CEi) - is involved in attritable aircraft developments outside of the LCASD effort, and has put high-performance tactical UCAVs at the heart of its strategy for growth.

Keeping in tune with the principles of the Third Offset Strategy, the company has argued that downward budget pressure, and continuing advances in adversary anti-access/area denial (A2/AD) capabilities, demands a move towards low-cost/high-performance UCAVs able to operate in contested airspace against near-peer adversaries; leveraging CEi's heritage in high-speed aerial targets, the business has invested significant amounts of capital over the last few years to position itself in this still embryonic market segment.

Jeff Herro, CEi's senior vice-president of business development, told *Jane's* that the company - acquired by Kratos in 2012 - had demonstrated its ability to manufacture high-performance, attritable unmanned aircraft at very low cost. "Target vehicles are inherently survivable because they are designed to mimic enemy aircraft or missiles and employ complex high- *g* manoeuvres to evade enemy defences," he said. "What we have been able to do is bring the costs of production right down.

"A large part of that is the vertically integrated nature of the company. We build the airframe tip to tail, and the avionics that go into our targets come from other Kratos companies. It is only the powerplant and recovery parachutes that we buy in from third parties."

Value engineering is another differentiator. "We don't design our targets like regular manned aircraft," Herro said. "For example, the structure of a regular aircraft build requires a lot of component parts, but we build using unibody construction which drives both the labour and parts costs down. Also, we're not putting multiple layers of redundancy into these vehicles."

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UTAP-22 Mako

The internally funded development and demonstration of the UTAP-22 has provided tangible evidence of Kratos's ambitions. An advanced derivative of the company's BQM-167A target drone, the UTAP-22 - later given the name Mako - has been introduced to the market to fill a gap for an off-the-shelf 'force multiplier and unmanned wingman' available to meet near-term tactical needs in A2/AD environments.

According to Kratos, the system has been designed to combine "fighter-like tactical speeds and manoeuvrability with a capability for collaborative manned/unmanned teaming operations". Figures released by the company state that the UTAP-22 Mako is able to operate at a maximum speed of Mach 0.91, fly at altitudes between 320 and 50,000 ft, and achieve a maximum range of 1,400 n miles.

With the support of the US Navy, the company ran three flight demonstrations on the China Lake range in California during the last quarter of 2015. The first, flown in October that year, lasted just over 90 minutes and successfully achieved several test objectives: command and control (C2) from a tactical datalink network; execution of semi-autonomous tasks through the tactical datalink network, including formation flight; and the ability to transfer control between different operators in the network.

Kratos performed three flight tests of its UTAP-22 unmanned combat platform in late 2015. Testing was performed at the US Navy's China Lake range; the navy identified key performance and capability features to inform the demonstration objectives. (Kratos)

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The second test, to demonstrate tactically representative manned/unmanned teaming, was performed on 23 November in conjunction with a US Marine Corps AV-8B Harrier II. This proved collaborative airborne operations with a manned tactical aircraft; C2 through the tactical datalink; execution of semi-autonomous tasks; execution of autonomous flight in formation with the AV-8B; transfer of UTAP-22 control between non-line-of-sight (over the horizon) operators in the tactical network; and transfer of control (hand-off) from the tactical network to an independent dedicated control link.

A third and final demonstration, conducted on 11 December, saw two UTAP-22 aircraft executing continuous collaborative airborne operations through the tactical datalink while flying formation with one another, flying formation with a third UTAP (simulated) as the lead aircraft, lead-follow in semi-autonomous/autonomous modes, lead-follow in manual/autonomous modes, and multiple autonomous joins from several pre-join scenarios. Additionally, the UTAP-22 successfully co-ordinated semi-autonomous payload deployment, breaking formation to perform independently with a subsequent rejoin, and 'loyal/trusted wingman' flight with one UTAP-22 being flown as if it were a manned aircraft and the second UTAP-22 joining and sustaining autonomous formation. The full mission was flown under the control of a single operator.

According to Kratos, the results of the demonstration flight series "validated the concept and technical readiness of [unmanned aircraft] with fighter-like performance operating collaboratively with each other, and collaboratively with manned aircraft".

In October 2016, Kratos announced a USD12.6 million single award prime contract from the Pentagon's Defense Innovation Unit Experimental (DIUx), in co-ordination with US Strategic Command and the Strategic Capabilities Office, to explore the use of high-speed drones in either fully autonomous or semi-autonomous roles to support fourth- and fifth-generation fighter aircraft. Under this effort, the DIUx has contracted Kratos to perform the integration of certain sensors into the UTAP-22 Mako, flight services, and for several Mako vehicles to fly in a large, complex exercise to run in the second half of 2017.

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A model of the XQ-222 tactical unmanned aircraft. (IHS Markit/Beatrice Bernardi)

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Although the LCASD stresses low cost, Kratos has taken measures to reduce radar cross-section (RCS) through the incorporation of V-tails, a high-mounted engine inlet duct, and twin internal weapon bays (the option also exists to mount weaponry on wing stations albeit accepting an increased RCS). Furthermore, while the company's BQM-167 and BGM-177 target drones use Microturbo TR 60-5 turbojet engines, the Valkyrie will be powered by an internally fitted Williams International WJ-33 turbofan.

According to data released by Kratos, the XQ-222 will be able to achieve a maximum speed of Mach 0.85 and a ceiling of 45,000 ft. The fuel-efficient WJ-33 engine is intended to enable the Valkyrie to deliver a range of up to 1,850 n miles.

Kratos in May 2017 stated that it was on schedule for an estimated second quarter 2018 maiden flight.

Lockheed Martin's Skunk Works division is also developing attritable aircraft technologies, again with a focus on driving down costs and not just with regards to the aircraft. "The number that is thrown out quite often is the cost of the airframe, but what we've been focusing on is the affordability of the end-to-end solution," explained Joe Pokora, Attritable Aircraft programme manager at Skunk Works, adding, "It does you no good to buy a USD2 million airframe if it costs you more than an F-16 to operate."

Pokora said that Lockheed Martin has been working to understand where operational, maintenance, and sustainment cost savings can be made for attritable aircraft, which by their very nature will be refreshed at a fairly high rate.

Pokora believes that there are a number of potential solutions to delivering the attritable aircraft capability, and points to the importance of developing concepts of operations (CONOPS) for these platforms. "What we see as important is understanding how this class of vehicles works in the manned-unmanned teaming space. How do we take these low-cost UCAVs and pair them with tactical and even strategic assets to get an enhanced capability …. I think the air force, as well as Lockheed Martin, don't believe this is a single platform, there are a variety of technologies that we are pursuing that are applicable to clean sheet designs and other platforms moving forward."

Lockheed Martin's Skunk Works' Low Cost Attritable Aircraft Concept. (Lockheed Martin)

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Pokora noted that Skunk Works has been looking at low-cost platforms for more than 20 years and is leveraging this expertise. "JASSM [Joint Air-to-Surface Standoff Missile] was one of the earlier examples and since then we had the Polecat demonstrator several years ago," he explained. "It is a challenge to balance cost with the payload, with survivability, and all of the different attributes that you'd like with this technology, but that's where we are really trying to engage in this mission space to understand what can we do to maximise utility at the most affordable system."

The CONOPS, and in particular the introduction of greater levels of autonomy and teaming with manned and other unmanned aircraft, will have a significant impact on the effectiveness of attritable aircraft. Pokora believes, "The interaction with other tactical assets is essential for both the way it operates and as an enabler to lowering the cost, so we don't have to carry all of the systems you need to operate in these very challenging environments."

"We see that in the future battlespace there's going to be increased teaming between manned and unmanned assets," explained Shawn Whitcomb, Loyal Wingman programme manager at Skunk Works.

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Lockheed Martin has placed a significant focus on systems architecture. Whitcomb said, "We invested a lot in open systems architecture, in particular on our own instantiation of the air force's open mission systems architecture standard, we call it our enterprise open systems architecture, so we've developed a compliant software and hardware suite, and that software suite continues to increase in complexity and breadth. What we are working on here is being able to take a common core software environment and capability, and transition it across that spectrum of potential unmanned assets."

Skunk Works has been furthering its manned-unmanned teaming capabilities through the Have Raider programme with the AFRL. In the Have Raider 1 tests the company employed two F-16 aircraft, one of which operated as a surrogate UCAV, and investigated autonomous vehicle control, autonomous formation flying through a series of tactical scenarios, as well as 'autonomous rejoin', automatic route following, simulated weapons deployment, and BDA.

The Have Raider 2 trials took place in March of this year at Edwards Air Force Base in California.

"We started to marry autonomous vehicle control with autonomous battle management," Whitcomb explained. "Here's where you start to get that idea of loosely tethered operations, whether that is a [UAS linked to a] C2 node on the ground or to a manned asset in the air, so you get more autonomous mission execution capability. Instead of a series of tasks we gave desired end goals for a ground attack mission and we let the onboard software determine the best way to go about routing the aircraft through a simulated battlespace and achieving the end state. We also did things like put a series of simulated contingencies in there, we added pop-up threats, ground-to-air threats, had the system recognise there was a pop-up threat and either change the routing, change the prioritisation, or accept a certain level of risk to undertake the mission as it was defined. We also looked at things like loss of communications and how do we want the autonomous system to behave in those situations."

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