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20th Anniversary Issue

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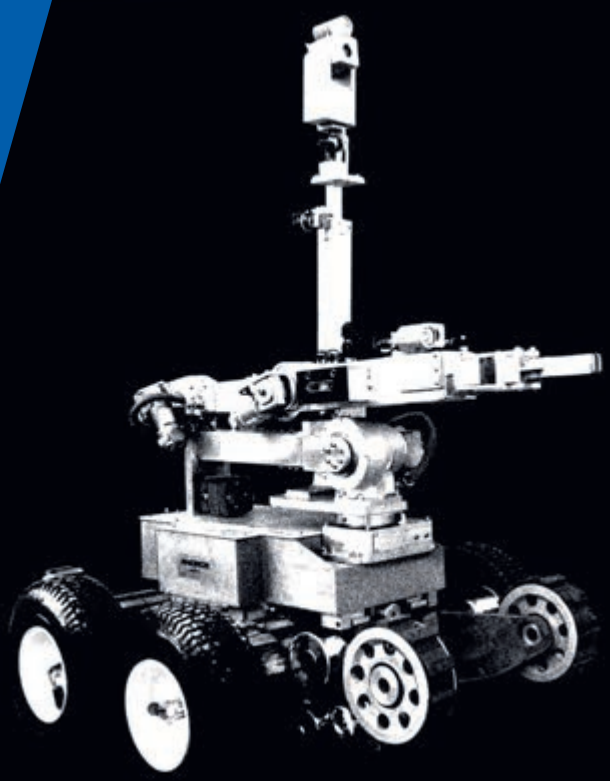

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Front cover: Man has evolved to the next level. *(Image: iStockPhoto/Lorna Francis)*

MQ-9 Reaper

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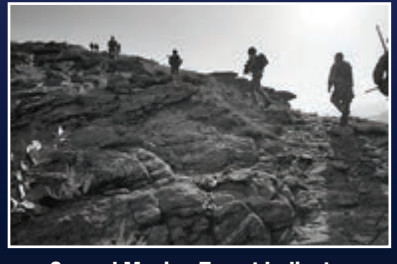
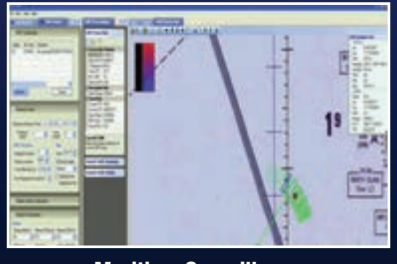


Ground Moving Target Indicator



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The formative years

Welcome to the 20th anniversary edition of *Unmanned Vehicles*. As I'm sure you'll agree, the past two decades have seen many changes in what has proven to be a very formative period in the development of unmanned technology.

From a personal point of view, I have recently returned from another operational tour in Afghanistan as a reservist, where the scale of unmanned support to coalition operations continued to surprise me.

Whether it was visiting Bagram or Kandahar air bases, it was fascinating to see unmanned platforms sharing the hangars and runways with fast jets, other ISTAR assets and troop carriers.

At the tactical level, UAVs continued to support forward-deployed ground forces; UGVs assisted in EOD operations; and VTOL systems conducted cargo drops – all adding to the numerous layers of unmanned support, providing a vital cog in the operational environment.

What struck me most, however – and this differs to my previous visits to the country – was just how comfortable and nonchalant troops appeared to be, operating in close proximity and in conjunction with this technology. The same sadly could not be said of our Afghan partners who still await introduction to such capabilities. This must surely come as ISAF begins to transition combat duties to its Afghan National Security Force counterparts by the end of 2014.

As you will see in the forthcoming pages, much has been achieved in the past 20 years. Our 'Unmanned Milestones' timeline (see p24) highlights just some of the key events witnessed in this period, and I can only apologise to those who have been omitted. As I'm sure you'll agree, there have been too many notable achievements to cater for in one double-page spread.

The list might be criticised for being US-centric, but as the recent arrested carrier landing of the X-47B demonstrated, it is our American counterparts who continue to take unmanned systems to the next level. As UCAS-D wraps up ahead of its evolution into UCLASS, the UK's Taranis UCAV was expected to make its maiden flight as *UV* went to press, and its European equivalent, Neuron, continues with test flights in France and Sweden through 2014.

In this edition, we also take a look at the current state of weaponised UAVs – especially topical in light of US President Barack Obama's comments in May regarding the use of kinetic 'drone' strikes designed to eliminate high-value targets away from the conventional battlefield.

As insurgents and coalition forces alike continue to conduct asymmetric warfare, such a capability must be retained, and critics would do well to note that such operations maintain the 'human touch' in multiple layers.

Elsewhere in the magazine, we take a look at forthcoming trends in mobility for UGVs as users seek capability to operate through snow, mud and water; civil applications for AUVs; the latest methods for recovery of small UAVs; and commonality in data link technology.

Finally, I'd like to express a special thank you to my colleagues at Shephard Media who covered *UV* in my absence. And special congratulations must go to our Staff Reporter Beth Stevenson who won Young Aerospace Journalist of the Year ahead of the Paris Air Show this year.

On behalf of the entire team, we look forward to covering the next 20 years and the inevitable surprises that will be witnessed in this time.

Andrew White, Editor

Beth Stevenson accepting her award for Young Aerospace Journalist of the Year. *(Photo: BillyPix)*

RESPONSE

Unmanned Vehicles' editorial team is always happy to receive comments on its articles and to hear readers' views on the issues raised in the magazine. Contact details can be found on p1.

IN THE NEXT ISSUE

- VTOL UAS
- Data storage
- Middle East market
- Entry-level systems

Europe's UAV developers call for MALE get-together

Key players in Europe's unmanned sector made a show of force at the Paris Air Show in June, reminding spectators that advanced UAS development is fully feasible and that it should top the agendas of politicians for years to come.

In a direct message to governmental decision-makers, Alenia Aermacchi, Cassidian and Dassault Aviation issued a statement on 16 June pushing for joint efforts across the continent in the development of a MALE UAV.

The statement said that such a programme would support the capability needs of European armed forces, while 'optimising the difficult budgetary situation through pooling of research and development funding'.

'European sovereignty and independence in the management of information and intelligence would be guaranteed, while at the same time… a robust system resilient against cyber-attacks [would be delivered],' the release stated.

'I think it's too early for official action,' observed Jean-Marc Nasr, president of Cassidian. However, he argued that the requirement had clearly been stated by the companies, while air forces were 'crying [out] for this'.

'The fact they have a requirement is pretty clear,' Christian Scherer, chief sales officer and head of international operations at Cassidian, added. 'It's a matter of sovereignty and we need to master this technology. The governments' agendas aren't synchronised. With this [report], we're giving politicians a chance… it's not an act of desperation.'

However, other UAV types were not on the agenda for Cassidian, with both representatives saying that the fighter jet sector is strong enough not to warrant UCAV development yet.

This was in spite of the Neuron UCAV, being developed by a consortium of European companies including Cassidian parent EADS, being displayed at the air show for the first time this year.

Meanwhile, following the reported cancellation of Germany's EuroHawk procurement last month, Northrop Grumman, the prime on the programme, was not at the show to provide comment.

Cassidian was a subcontractor on EuroHawk, with Scherer saying that 'momentarily' there was too much focus on the politics of the affair, taking the emphasis away from other important issues such as the MALE UAV requirement.

Elsewhere, it remains unclear whether the British Army's Watchkeeper fleet will ever deploy to Afghanistan. Despite 24 air vehicles having been delivered to the MoD, the design is stuck in a Military Aviation Authority (MAA) certification process.

Programme partners Thales UK and Elbit were confident of the testing effort and gave full support to the MAA process when they spoke to *Unmanned Vehicles* during the show.

Other European stories emerging during the show included the launch of the new German Schweitzer Ingenieur Universal UAV, Sagem's Patroller vehicle passing COMINT flight testing, and Portugal's Tekever extending its range of UAV offerings.

By Beth Stevenson, Paris

Spain selects Skeldar

The Spanish Navy has confirmed that it will be the first customer to operate Saab's Skeldar V-200 VTOL UAV.

Saab announced that it had been awarded a contract, understood to be worth €2.5 million, on 11 July, although it declined to identify the customer.

'It is confirmed that the Spanish Navy has hired the services of Saab to operate its Skeldar V-200 UAV,' a naval spokesperson told *Unmanned Vehicles*. They also added that the length of the contract is still undecided.

The deal will see the platform operationally deployed for the first time, and it is expected to be in service by the end of the year. Skeldar will be the Spanish Navy's first operational UAV.

The navy's Directorate of Supply and Transport said that the system will be offered on a services basis, under an 'Employment Programme On-board Unmanned Aerial System' (PESANTE) arrangement.

The navy launched a tender in 2010 with the aim of equipping its vessels with UAVs as part of its overall contribution to the EU's Operation *Atalanta* counter-piracy campaign, with a budget of €8 million. However, a lack of success here led Spain to launch a UOR some six months ago, which led to the selection of Skeldar.


Photo: Saab

Sources claim that Skeldar beat competition from Insitu's fixed-wing ScanEagle, as well as from Schiebel and local company Sener, offering the Camcopter S-100.

Skeldar is a flexible multi-purpose system designed to meet mission objectives on land or at sea. It is suited to naval operations, where the benefits of a VTOL UAS are most prominent, according to the company.

By Beth Stevenson, London

The X-47B touches down on the flight deck of the *George H W Bush*. *(Photo: USN)*

USN defends X-47B performance

The USN has strongly defended its UCAS-Demonstrator programme, despite both X-47B aircraft managing to land on board a carrier only twice in four attempts during July.

R Adm Mat Winter of the Program Executive Office for Unmanned Aviation and Strike Weapons fought off criticism of the programme, saying that UCAS-D had successfully 'matured' critical technology required for operations in the carrier environment. '[It] has set the stage for naval aviation to blaze the trail for relevant unmanned, carrier-based warfighting capabilities,' he said in a statement.

On 10 July, X-47B 'Salty Dog 502' successfully conducted the first ever UAV arrested carrier landing on board the USS *George H W Bush*. Following a second landing, a third attempt was aborted due to a malfunction with one of the aircraft's precision navigation systems.

MISSION ABORTED

On 15 July, 'Salty Dog 501' was flown to the same carrier to collect additional shipboard landing data. However, during this sortie the aircraft experienced a 'minor test instrumentation issue' and returned to NAS Patuxent River, Virginia. The navy said there were no additional opportunities for testing aboard the carrier, which returned to port on 18 July.

Officially wrapping up the programme, Winter said: 'Completing the first ever arrested landing with an autonomous, unmanned aircraft is truly a revolutionary accomplishment for the US Navy.'

UCAS-D programme manager Capt Jaime Engdahl added: 'We accomplished the vast majority of our carrier demonstration objectives during our 11 days at sea aboard *Bush* last May. The final end-to-end test of the UCAS including multiple arrested landings, flight deck operations, steam catapults, to include hot refuelling procedures was accomplished on 10 July and the procedures, the X-47B aircraft, and the entire carrier system passed with flying colours.'

Looking ahead to the navy's Unmanned Carrier-Launched Surveillance and Strike (UCLASS) programme, Winter described valuable CONOPS gained from the UCAS-D project, including flight deck handling, familiarity of flight deck personnel with unmanned systems, and launch and recovery operating procedures.

'We will leverage off the demonstration all of the technical C2 CONOPS, algorithms and strategies, which will be ported over to the next UCLASS programme of record in order to reduce overheads,' he added.

Meanwhile, the navy confirmed that a draft technology development (TD) phase RfP would be released in August. A final TD phase RfP will be released in the second quarter of FY2014.

In June 2013, the UCLASS air segment provisional design review RfP was released to the four broad agency announcement industry partners (Lockheed Martin, Boeing, Northrop Grumman and General Atomics).

UCLASS will select an air vehicle by the end of FY2014, with the goal of providing two 24/7 orbits from an aircraft carrier. Winter described how the navy would then develop CONOPS for UCLASS, leveraging off what it had learnt from UCAS-D.

'How best to operate the UCLASS system in a 24/7 orbit has yet to be seen,' he said. 'Everything else is work in progress. The ability to bring together technology and the operation of X-47B into the carrier environment is nothing short of amazing.'

By Andrew White, London

On the web

L-3 re-contracted for Predator training system
23 July 2013

German Herons clock up 15,000 hours in Afghanistan
22 July 2013

Raytheon considers UGV solution for C-IED mission
16 July 2013

iRobot announces US Army PackBot FasTac UGV contract
12 July 2013

ReconRobotics reaches delivery milestone
10 July 2013

Camcopter S-100 completes 'DeckFinder' flight tests
3 July 2013

Lockheed Martin controls multiple UAVs with integrated C2
2 July 2013

Aeryon UAVs complete public safety trials
27 June 2013

'Digital' ScanEagle conducts first mission in Dutch service
27 June 2013

Rockwell Collins technologies used in RQ-21A tests
25 June 2013

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Extent of German military UAV losses revealed

The German MoD has published an overview of its UAS 'losses', revealing how a staggering number have been written off on operations over the past decade.

Released on 26 June, the figures illustrate how the German Armed Forces have lost 30 EMT Aladin mini-UAVs – many of them during operations in Afghanistan – while another 290 remain in service.

Four AirRobot AR100 Mikado micro-copters have also been lost, with another 164 still in use with the German Army. The latest variant is the AR100-B, complete with a digital data link, which was introduced into service in 2010. The figures also indicated that another 20 Mikado aircraft have been withdrawn from service. However, the report made no mention of the army's 21 EMT Fancopter systems, which were delivered between 2007 and 2009.

Since 2000, the German Army has also operated nine EMT Luna tactical systems consisting of two GCS and ten air vehicles each. A total of 52 Luna aircraft are now confirmed to have been lost, while 81 remain in service.

Recently, a video emerged of a German Luna UAV almost colliding with a civilian airliner near Kabul International Airport in 2004. The air vehicle subsequently crashed after being hit by turbulent air generated by the A300 jet.

Elsewhere, six Rheinmetall KZO systems are currently in use for artillery target acquisition. Each nominally consists of two GCS and ten air vehicles, but only 43 KZO aircraft remain in service while 17 have been lost.

The German Army's interim MALE capability is delivered by the IAI Heron 1 UAS, which is being supplied by Rheinmetall Airborne Systems, a joint venture between Cassidian and Rheinmetall.

The Heron conducted its first operational mission on behalf of German forces in Afghanistan in March 2010, with two aircraft having been lost on operations since. One air vehicle went 'rogue' after landing and collided with a ground obstacle, while another crashed in late 2010 after control was lost during operations in Regional Command-North.

Three Heron 1s currently remain in service, with the contract to provide airborne reconnaissance to German troops in Afghanistan having been extended until October 2014.

By Pieter Bastiaans, Breda

India deploys VTOL UAS for disaster relief

Search and rescue agencies operating in northern India have successfully used man-portable VTOL UAVs for the first time in humanitarian assistance/disaster relief (HADR) operations.

Industry sources described to *Unmanned Vehicles* how the UAVs were used to find survivors of the flood and landslide disaster in Uttarakhand State in mid-June, conducted by the National Disaster Response Force (NDRF).

Four Netra VTOL UAVs, manufactured by IdeaForge, were deployed to Gauri Kund before being split into two teams with a GCS each. The company was already in talks with the NDRF to supply a demonstration system when it received the call to assist in HADR operations in Uttarakhand.

'They called us up to offer help,' explained chief marketing officer Amardeep Singh. 'No other [manpacked VTOL] UAV was being used there.'

Stationed at the Gauri Kund base camp, a small helipad only a few metres in size was cleared and the NDRF teams operated the UAVs, scanning the mountains and valleys for survivors. 'We could see the other side of the mountain by flying the system and confirming people on the ground,' Singh continued.

Officials said 40,000km^2 of land was affected by flash floods and landslides, with some 95,000 people having been evacuated with a further 10,000 waiting to be rescued.

Agencies operating under the NDRF umbrella, including the Indo-Tibet Border Police, Indian Army and Indian Air Force, tasked the systems, with two of the UAVs airborne at any one time.

Teams deployed on foot towards more inaccessible regions and operated the UAVs to check for survivors in evacuated areas. Para-troopers were then sent in to escort survivors to helicopter landing sites for rescue.

Photo: IdeaForge

'We regret getting the call a little late. The disaster happened three days earlier and we were tracking the news. But we were unsure if we were to be deployed. Response in the first 24 hours of a disaster is most critical,' Singh added. Local media reported that around 190 personnel had been positively identified by the UAVs.

Conditions in Uttarakhand were far from ideal, Singh explained. Netra operated at altitudes up to 8,000ft, with visibility sometimes restricted to a few metres due to thick fog. 'There was not a good GPS signal with the mountains screening the satellites… but [we] did not lose it at any time,' he added.

By Andrew White, London

French Reaper buy imminent

The US Defense Security Cooperation Agency (DSCA) has progressed with plans to sell 16 General Atomics MQ-9 Reaper UAVs to France as the European nation considers deploying them to Mali.

On 27 June, the DSCA notified Congress of a possible $1.5 billion FMS deal which will include associated equipment, spare parts, technical documentation, training and logistical support.

The French government is looking at the fast-track procurement of two Reaper systems which are likely to be delivered directly from a USAF production lot.

On 11 June, French Defence Minister Jean-Yves Le Drian explained: 'We are negotiating with the US for the acquisition of two Reaper UAVs and to have them deployed in the Sahel region. This is an operational necessity due to events in Mali.'

The official DSCA document read: 'France requests these capabilities to provide for the defence of its deployed troops, regional security and interoperability with the US. The proposed sale will improve France's capability to meet current and future threats by providing improved ISR coverage that promotes increased battlefield situational awareness, anticipates enemy intent, augments combat search and rescue, and provides ground troop support.'

According to the latest French white paper on defence and national security, published on 29 April, the MoD is contemplating the purchase of 12 MALE UAVs.

However, it now appears that France is investigating an even larger FMS buy which would encompass 32 spare Honeywell TPE331-10T turboprop engines, 40 General Atomics Lynx radar systems and 40 Raytheon AN/DAS-1 MTS-B Multi-Spectral Targeting Systems. The deal would also include eight GCS and 24 satellite earth terminal substations.

Currently, the French Air Force operates four Cassidian Harfang UAVs as an interim MALE solution. Harfang is based on IAI's Heron 1 and entered service in 2009. It has been used intensively during operations over Afghanistan, Libya and Mali.

Based on the latest white paper, the French Army will also be getting some 30 new tactical UAVs with the Thales/Elbit Watchkeeper being looked at as replacement for the current inventory of Sagem Sperwers.

By Pieter Bastiaans, Breda

BAE Systems exits small UAS market

BAE Systems has sold its Unmanned Aircraft Programs (UAP) unit to former business development director Matthew Pobloske, as the company looks to diversify away from small UAVs.

On 1 July, UAP, now re-branded as Sensintel, announced that a stock purchase agreement had been signed, transferring control of the company to Pobloske for an undisclosed fee.

Based in Tucson, Arizona, Sensintel will operate independently as a provider of UAS, sensors and related services.

A spokesman for BAE Systems told *Unmanned Vehicles*: 'The decision was made to sell the US-based UAP to better align the BAE Systems business portfolio here in the US with our core focus areas.

'This agreement does not affect the company's ongoing UAS work in the UK. BAE Systems remains active in the larger UAS platform market within our UK operations and BAE Systems continues to support the provision and update of electronics for a range of UAS platforms.'

In June 2009, BAE Systems announced the acquisition of Advanced Ceramics Research in a deal worth $14.7 million. At the time, executives said the transaction provided the company with a set of 'mature, operational products within the small/mini and tactical UAS market'.

Referring to his acquisition, Pobloske told *UV*: 'I remain fully invested in unmanned aircraft long term and believe in the future growth of remote sensing in general.'

He said Sensintel is now 'open for business', continuing with the same contract work. He added that all 30 of the former UAP staff would stay at the new company.

Sensintel will continue manufacturing Silver Fox, Manta and Coyote UAS as well as providing ground support equipment, sensors, software and a variety of services including engineering, modifications, flight operations and training.

Looking ahead, Pobloske highlighted 'acquisition, licensing and organic development of sensors, PED and C4ISR hardware and software tools' as areas of interest, alongside complementary tactical platforms.


Photo: Sensintel

'As we move forward, we will continue to look for ways to expand our portfolio of offerings and explore new, emerging platforms and sensors,' he added.

Additionally, he told *UV* he was not currently looking at acquiring any companies but conceded that Sensintel would be 'reaching out' to other industry partners to foster product development efforts.

By Andrew White, London

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The wonder years

Andrew White reflects on two decades of unmanned systems development, and finds a sector that is exceeding expectations and progressing in unexpected ways.

Back in the 1990s, the Teal Group's 'Unmanned Aerial' forecast projected that the UAV market in the US would be worth around $3.9 billion between 1994 and 2004.

Analysts saw the market 'steadily rising to a peak in the year 2000, then dropping again with a rise in 2003' – coincidentally the year in which US and coalition forces entered Iraq for the second time in little over a decade.

Concentrating on just two areas, the report describes the 'target drone' market as 'relatively flat, yet stable' and that the 'reconnaissance drone' market would double in size between 1994 and 2003.

Of course, the term 'drone' has since been dismissed by the industry, although the mainstream media still indulges in its disingenuous use, especially when pinning blame on UAVs for collateral damage caused during precision strike missions.

Fast forward two decades to Teal Group's 2013 'UAV Market Profile and Forecast' – which estimates the same market to be worth approximately $89 billion – and you see a more mature market place.

Target drone development continues, but we have now seen a dramatic increase in the use of ISTAR UAVs, not to mention UGVs, AUVs and USVs. Add to this the introduction of VTOL technology, hydrogen-fuelled aircraft, heavy fuel engines and electric-powered systems – the list goes on and on.

CHANGING TIMES

How the market has changed? In the launch edition of *Unmanned Vehicles*, the news pages covered the planned development of Robug III, a nuclear-powered, robotic spider capable of climbing up the side of a building with a 100kg payload, at a speed of 10m/s. Utilising large suction cups to grip walls, Robug III would be used to retrieve irradiated material or rescue accident victims. Sadly, the closest system we have seen come to fruition is ReconRobotics' magnetic Throwbot, which can scale the side of a ship, and WallRover B that can climb walls.

One just has to look at the news pages of this edition to see how the sector has progressed, with the USN's carrier-capable UCAS-D programme leading onto UCLASS, and VTOL systems assisting in disaster relief operations in India, to name but two.

'Despite near-term US budget cutbacks, UAVs continue as the most dynamic growth sector of the world aerospace industry this decade,' claims the Teal report, which was released at the Paris Air Show in June. Specifically, it describes how UAV spending will more than double over the next decade from a current $5.2 billion to $11.6 billion per annum.

'The UAV market is evolving, it is becoming an increasingly international one as it grows,' Teal Group director of corporate analysis and report co-author Philip Finnegan told *UV*. ➤

The X-47B appears comfortable in the 'carrier environment', following extensive testing in July. *(Photo: USN)*

The number of Predator systems being procured is reportedly to be reduced. *(Photo: US DoD)*

The only prolonged conflict utilising UAVs in the 1990s was in the Balkans, whereas the new millennium has seen extended engagements in Afghanistan, Iraq and more recently Libya.

'UAVs have proved their value in Iraq and Afghanistan and are being sought by a growing number of militaries worldwide. The US will account for 65% of the worldwide RDT&E spending on UAV technology over the next decade, and 51% of the procurement,' Finnegan continued.

'The market has exploded in growth. A decade ago, it was considerably smaller than it is now and we have particularly seen this growth in the US. But this is changing now and the US market is under pressure as the rest of the global market continues to grow.

'The US will see some growth but the market will actually decline year on year. Expenditure on UAVs is not going to exceed current levels of production until 2019,' he added, referring to the past 12 years and again, a focus on operations in Afghanistan and Iraq.

'The number of systems in production is being cut. As an example, you just have to look at air force purchases of the Predator B which are being reduced. Global Hawk is under pressure obviously, and it is expensive, so it is also going to have a strong impact on numbers.

'Looking at smaller systems like Raven in the 2014 Pentagon budget, there is no actual new procurement, but only money being made available for upgrades,' he asserted.

However, Finnegan said that 'diminishing' urgency of UAV operations in Afghanistan and Iraq would turn the focus onto the development of the 'next generation of systems' – namely the UCAV.

'Looking at the long term in the US, we will see an increase in spending and investment on next-generation systems, with greater capabilities in terms of motion and stealth.'

SO EXCITED

Outgoing chairman of the Association of Unmanned Vehicles Systems International, Peter Bale, has been in the industry for 15 years and remains as excited as ever regarding the future of unmanned technology.

'UAVs have proved their value in Iraq and Afghanistan and are being sought by a growing number of militaries worldwide.'

'I was very excited about the prospect [of this sector] years ago and how big and quick this industry was going to grow. It has definitely taken its time to mature in the military sense first, but that was the catalyst for the industry and it really has been [driving] the acceleration over the last ten years as the US has been at war,' he told *UV*.

A company which describes itself as one of the original 'pioneers' in the industry is General Atomics Aeronautical Systems. Its business development director Chris Ames told *UV*: 'When I first joined the navy, men were men and ships were made of wood. There was no conception of unmanned vehicles. That has morphed considerably over the past 20 years into a premier capability. Money, technology and resources are being ever more exploited in this sector.

'Aircraft, surface craft and submersible vessels are all active today, providing some commodity or other. There is no hazard to human life and it has grown less expensive to procure and operate while becoming wildly effective in the domain of persistent situation awareness.'

He continued: 'The company had a vision and had the determination to stick with it. We knew [the unmanned industry] would become incredibly valuable.'

However, it is not only the defence sector which has high hopes of a radical overhaul in the utility of unmanned systems. Concurring with Finnegan over how the recent 'plateau' in military expenditure on unmanned technology has caused a 'reactionary' growth in the commercial and civil sector worldwide, Bale urged: 'Technology is more affordable and achievable and the large primes in the industry are being faced with a conundrum. They have provided a gold-plated solution for the military, but how do they do that for the commercial sector?'

Bale was quick to underline the life-saving capabilities of the unmanned technology available to parapublic agencies today. Recalling the 20 fire-fighters who were killed during forest fires in Arizona at the end of June, he asked: 'Had some robotic ➤

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1999: *AAI's Shadow® Tactical Unmanned Aircraft System is selected by the U.S. Army after a competitive fly-off.*

2003: *Shadow systems begin their first combat deployment in Iraq.*

2006: *The Aerosonde® aircraft sets a world record by remaining in flight for more than 38 hours without refueling.*

2007: *An Aerosonde aircraft makes history by navigating Hurricane Noel's eye and boundary layer for more than 17 hours.*

2011: *AAI's Unmanned Ground Control Station provides command and control for the Shadow, General Atomics Aeronautical Systems' Gray Eagle® and Northrop Grumman's Hunter unmanned aircraft during the Army's Manned Unmanned Systems Integration Capabiity exercise.*

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technology been employed, who knows what the outcome would have been? Embracing this technology is for the good, whether it be for search and rescue or hurricane hunting. I've been part of a lot of those programmes.

'Fish surveys, and wildlife activities like tracking white rhinos and zebras, are now funding UAS operations and putting out RfPs on the street. All the opportunities we dreamed about 15 to 20 years ago are coming to fruition.'

However, unmanned systems continue to receive bad press in the non-specialist media regarding crashes, collisions and collateral damage, but Bale is in no doubt that critics can be won over: 'Naysayers need to investigate the technology being carried [by unmanned systems] before casting aspersions. We have not had the opportunity to showcase ourselves. People have "bashed" killer drones, but from my Aerosonde background – which was a science platform – I have seen that we could get people out of harm's way in a hurricane. Now, we get information that nobody ever got.'

'If integration into the airspace does not happen, this industry will move offshore in many segments.'

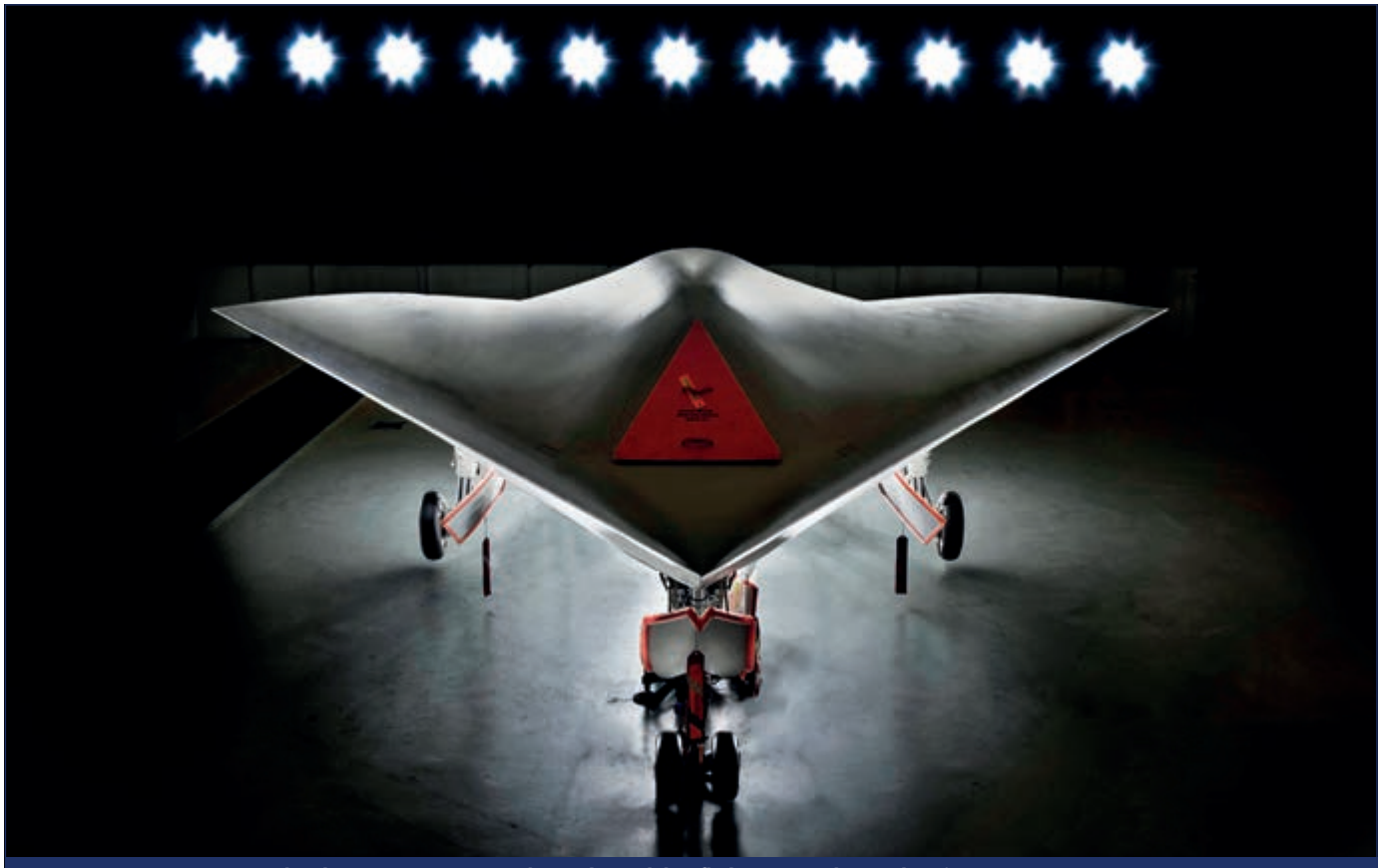
ACHIEVING ACCESS

Finnegan, however, told *UV* that the expansion of unmanned technology into the civil sector was going to take time to develop. 'A lot is going to depend on what the FAA and European agencies decide, how much they want to open airspace,' he warned.

Consequently, a critical element which will affect the future health of the civil and potentially the defence market is certification for flight in non-segregated airspace. Germany's EuroHawk programme has already been halted, reportedly due to a lack of such certification.

Bale remains confident that the FAA will continue to push this matter forward, especially with six designated test sites due to open in the US by the end of the year.

'There is a cautionary note I throw out there,' he warned. 'If integration into the airspace does not happen, this industry will move offshore in many segments. It will move to countries allowing such technologies. The US will still see export opportunities, but it would be a shame to see the industry stagnating over procedural concerns. But I do applaud the FAA for looking at the safety we need.'



Taranis, BAE System's UCAV development, was expected to make its debut flight in Australia in July. *(Photo: BAE Systems)*

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The WallRover B is capable of climbing walls, but falls short of Robug III's aspiration to lug a 100kg payload behind it. *(Photo: WallRover)*

Meanwhile, Ames described a 'growing commitment identified by state governments, the press and FAA commissions', reflecting how UAVs are 'here to stay'.

'We need to adopt requirements and rules to allow their access to national airspace,' he admitted. 'I have really seen a push on this in the last three years. There is funding for it in the US and timelines are developed, but this is not an easy challenge.

'We recognise that these UAVs are not a flight of fancy. They're here for good because of the value they provide and the next step is airspace integration.'

In the UK, the Civil Aviation Authority (CAA) is dealing with integrating unmanned aircraft into the wider airspace. According to Gerry Corbett, head of flight operations policy within the CAA's Safety and Airspace Regulation Group, the full and safe integration of unmanned aviation into the total aviation system is still the main effort.

However, he warned: 'In order to achieve this we need to be satisfied that any particular unmanned aircraft is airworthy and that it can operate safely in airspace shared with manned aircraft.

'Clearly, once these aspects have been addressed, then this will be the point at which the unmanned market can really start to develop, but unfortunately, we don't yet seem to be seeing this eagerly awaited tipping point.

'We're very keen to start seeing the larger UAS flying in the UK, so we can start getting some practical operating experience and also start proving that they can be safely flown for non-military applications, but we are not seeing any tangible progress/products from industry at present. As a result, it is difficult to predict markets over the next five to ten years, but progress is clearly slower than we had hoped for.

Describing how airspace over West Wales had been allocated for UAV use for two years, but was 'sadly underused', he concluded: 'We have always maintained that the airspace is ready, it's just that unmanned systems have not yet demonstrated an equivalent level of capability which will allow them to meet the requirements of the airspace that they wish to operate in.'

Perhaps it is no coincidence that BAE Systems' Taranis UCAV was being transported to Australia in order to complete its maiden flight in July as *UV* went to press.

ENDING SEGREGATION

Acknowledging the unsegregated airspace issue, Martin Rowe-Willcocks, head of business development for future combat air systems at BAE Systems Military Air & Information, described ongoing collaboration between industry and regulators.

Highlighting the company's contribution to the Autonomous Systems Technology Related Airborne Evaluation & Assessment (ASTRAEA) programme as an example, he recalled April's flight of a BAe Jetstream 31 research aircraft adapted to fly unmanned on an 800km journey from Warton, Lancashire, to Inverness, Scotland, under the control of a ground-based pilot and an operator from UK air traffic control provider NATS.

'This was part of a series of flight trials designed to prove the technology needed to allow the safe and routine flying of unmanned aircraft in UK airspace being conducted under the £62 million [$95.5 million] industry-led ASTRAEA programme.

'Until we are able to open up the airspace to the satisfaction of the regulators, we won't truly know exactly what the potential civil uses of this technology will be. We can see some of the practical uses, but others will come about because of the change that we haven't yet considered.'

Looking to the future, Finnegan still sees substantial market growth generally across the unmanned sector: 'You're going to see an expansion of UAS beyond an initial core of ISR to an ever-increasing number of missions. New domains, particularly in maritime UAS, have lagged compared to land systems and are an area of considerable growth.

'Continued development of new mission areas like cargo and an increase in weaponisation, with increasing ranges of miniature systems carried by miniaturised UAVs, is likely,' he predicted.

As Ames concluded: 'The future is very bright. [Unmanned] aircraft are increasing in capabilities and spawning new industries, particularly in the realm of sensors where companies are being set up where nobody would have considered it five years ago.

'Aircraft are proven, reliable and cost-effective and don't endanger humans or aircrew. It bodes well for an expanding horizon for us.' uv

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Raytheon's Pyros has been test-fired from the company's Cobra UAV, and would also be put forward for any armed Shadow requirement. *(Photo: Raytheon)*

Room for improvements

Based on the sheer expense of purchasing a UAV and its subsequent through-life costs, it is no wonder that operators are looking to get the most out of the aircraft they have bought. The payload capacity of such platforms may be pretty fixed, but as technology develops, sensors are becoming smaller, which is leaving room for a different type of payload – a weapon.

In line with this, the concept of operations has developed over recent years, with UAS becoming an ever-present reality on frontline operations, and their role has evolved from a flying sensor to a flying weapon system.

ADDED COMPLICATIONS

However, all of this does not come without complications. As UAVs become more widely utilised, their prevalence in the media escalates, alongside awareness of the systems and the particular operations they carry out.

'Weaponisation of UAVs is increasing in popularity,' a Teal Group spokesperson told *Unmanned Vehicles*. 'Negative publicity will temper the growth, but there is going to be growth in those systems, no doubt about it.'

In particular, the US government's operations using armed UAVs are heavily speculated on, particularly within Yemen and Pakistan as part of counter-insurgency efforts. Many are worried that innocent bystanders are killed by armed UAVs and that the strikes are not controlled by human operators, leading to questions over the legality of such attacks in these countries.

In a 23 May speech on counter-terrorism, US President Barack Obama claimed that UAV strikes were legal. He acknowledged that scepticism over the deployment of these systems was understandable, especially regarding who is targeted and why, as well as the surrounding issues of legality and morality.

'To say a military tactic is legal, or even effective, is not to say it is wise or moral in every instance,' he stressed. 'For the same human progress that gives us the technology to strike half a world away also demands the discipline to constrain that power – or risk abusing it.'

TAKING ACTION

He spoke of 'the backlash among the Pakistani public' regarding territorial encroachment being severe; here the US is trying to rebuild its relationship with the country. It is within this context that the Western nation has taken lethal action against al-Qaeda and associated forces, including through the use of UAVs.

The President also reinforced the fact that beyond Afghanistan, only al-Qaeda and its associates are targeted, and even in these circumstances the application of UAVs 'is heavily constrained', as the US preference is to 'detain, interrogate and prosecute'.

Obama also added that before a strike is carried out, there must be 'near-certainty' that no civilians will be killed. 'Conventional air

The viability of weaponising more unmanned systems is steadily increasing as sensors get smaller and operators look to utilise the full potential of their platforms. **Beth Stevenson** provides an overview of the current market and examines recent developments.

power or missiles are far less precise than drones, and are likely to cause more civilian casualties and more local outrage,' he noted.

Nevertheless, Obama established that this type of warfare is only applicable overseas, as in no circumstance 'should any president deploy armed drones over US soil'.

Regarding the threat to innocent lives, Doug Denneny, VP of business development, government relations and communications at MBDA, told *UV*: 'Actually, in general terms, the use of weapons off RPAs is very tightly controlled, for a variety of reasons. For one, they have the luxury of seeing the entire scene, having great situational awareness and knowing what is going on around them. It's not as if somebody stumbles onto a problem and has to make an incredibly hasty decision.

'Most of these engagements, from what I understand… are made at very high levels as to whether to use weapons.'

BRITISH BOMBS

The UK is also facing problems as a result of armed UAV operations. It was reported in May that the RAF's MQ-9 Reapers were being operated from RAF Waddington in Lincolnshire. The platforms were purchased in 2007 under a UOR in order to carry out ISR operations in Afghanistan, and in 2008 armed missions began. The aircraft currently has the capacity to carry two Raytheon GBU-12 225kg laser-guided bombs (LGBs) and four Lockheed Martin AGM-114 Hellfire missiles, although this number can be changed to suit particular missions, according to the RAF.

In May, it was reported that Philip Dunne, the Minister for Defence Equipment, Support and Technology, said that the MBDA-developed Dual Mode Brimstone (DMB), already operational on the RAF's Panavia Tornado GR4 aircraft, is to be tested on board the Reaper.

The RAF is in the process of increasing its fleet of MQ-9s from five to ten platforms, and the missile testing is expected to be conducted later this year, although the future of the Reapers within the UK's inventory is still to be decided.

As speculation surrounds whether the UOR-procured aircraft will be brought into the core inventory when Afghan operations cease, testing of Brimstone is a sign that the UK will keep the UAVs in the inventory.

MBDA was unable to confirm the potential integration of Brimstone onto the Reapers, deferring comment until the end of the year, supposedly after the testing has taken place.

However, Denneny did praise the performance of the DMB, and explained how it is clearly suited for larger UAVs. 'For the large-sized UAVs or RPAs, I will just say that we believe that the DMB missile is a fantastic weapon… because it is unique and combat-proven off of the Tornado aircraft with the RAF,' he said. 'It is a very precise, low collateral damage weapon that has been proven effective against both high-speed and manoeuvring targets. It is also very effective against stationary targets.'

DUAL APPROACH

This dual capability is due to two main modes: a semi-active laser (SAL) guidance mode to engage static targets with limited or no radar cross-section; and a mode that combines the SAL with millimetric-wave guidance for fast-moving targets in cluttered environments.

'That is a very unique capability unknown from any other weapon in the world, so we believe there is lots of value in offering that for large-sized RPAs that can carry weapons in the 110lb [50kg] class, which is the size of DMB,' added Denneny.

Noting that the RAF already operates the weapon, he said: 'If they decided to do that [deploy the Brimstone on a UAV], there would be synergies with what they are currently doing on platforms.'

Another such system that could be converted for this UAV class is the Lockheed Martin Nemesis, a ground-based system that is being adapted for airborne operations.

It is currently being modified for the C-130 transport aircraft, for which flight testing is due in 2014. This fulfils a US Special Operations ➤

It is expected that the DMB will be trialled on board the RAF's Reapers by the end of 2013. *(Image: MBDA)*

Lockheed Martin is not just concentrating on larger UAV munitions, but is developing the Shadow Hawk for mid-sized aircraft. *(Photo: Lockheed Martin)*

Command (SOCOM) requirement for a Stand-off Precision Guided Munition (SOPGM).

'UAS integration and flight testing would follow testing on C-130s and light fixed-wing aircraft,' Tom Bargnesi, programme manager for the Nemesis at Lockheed Martin, told *UV*.

Nemesis uses the same height-of-burst fusing device as Hellfire, and employs the same semi-active laser detector, seeker and guidance electronics and inertial measurement unit as the company's DAGR weapon.

'The plan is for the Nemesis-class weapons to be integrated onto both small tactical UAS [STUAS] and larger unmanned platforms, such as Predators, Reapers and Gray Eagles,' he continued. 'Modifications to the launch sequence for ejection from a C-130 in the manner of SOPGM will drive the modification for those platforms. This will require a change to the propulsion ignition and wing deployment sequence and the autopilot.'

SEQUENCE TAILORING

Bargnesi said that once these changes have been implemented for larger fixed-wing platforms, straightforward tailoring of the same sequences will be required to adapt to UAV integration, while platform-specific mechanical, electrical and signals interface adaptation will have to accompany each platform integration.

He added that the company is talking with UAV primes about integrating the weapon, but was unable to disclose further details at this time due to 'competition sensitivity'.

Meanwhile, the Small Diameter Bomb II (SDB II) that Raytheon is developing has also been categorised as suitable for Reaper. 'This is a weapon that can get the job done in far less sorties with far fewer engagements,' J R Smith, a senior business development manager at Raytheon Advanced Missile Systems, told *UV*.

He explained that the weapon is being developed for the USAF, under which the service has designated 'threshold platforms' that it will focus on during the current engineering and manufacturing phase. These include the F-15E, F-35B/C and F/A-18 Super Hornet.

'Then there are several objective platforms, and these are ones which the air force, navy and marines fully intend to integrate SDB on, but they are not the first,' continued Smith. 'The MQ-9 Reaper has been established as an objective platform for the SDB II, so that's the plan. When they [the threshold aircraft] come to fruition in early 2015… I think you will see the effort turn to integrate on other platforms like the MQ-9.'

He noted that SDB II provides more stand-off range than Hellfire, so it can be positioned outside traditional ground-based air defence. It can also independently address moving targets in a 'fire and forget' capacity.

> *'Smaller tactical platforms are out there in greater numbers... they can report back, but they can't intervene.'*

Another smaller and more tactical platform that is receiving increased interest in terms of weaponisation is the RQ-7 Shadow used by the US Army and USMC.

'A lot of the smaller tactical platforms are out there in greater numbers and flying more than the Predator or Reaper,' added Smith. 'And when it comes to the smaller military units, they don't necessarily have their own Predator or Reaper in their units, but they do have Shadows, and the marines will one day get Integrator. They are out there every day… and they can report back, but they can't intervene.'

IN THE SHADOWS

Although there have been many chops and changes regarding Shadow's weaponisation – a programme of record is not believed to currently exist – several manufacturers are looking to develop a munition for the platform. It is understood that the USMC wishes to arm its Shadows, although the army has previously been reluctant.

Raytheon is developing the Pyros for a Shadow-sized UAV, a small tactical munition that weighs 5.4kg, including a 2.2kg blast fragmentation warhead, which Smith said is effective against personnel and light vehicles.

'This is specifically designed and tailored for employment on STUAS,' he continued. 'That would include platforms such as the RQ-7 Shadow, the RD-3 TigerShark, and some developmental platforms out there.'

Pyros is currently at TRL 7, and underwent end-to-end warhead and guidance testing in 2012 on board the company's Cobra UAV.

'It was hugely successful testing, and we had the government there watching,' said Smith. 'They are now considering if they want to take us forward and put us through operational evaluation and then eventually production.

'There are also interesting possibilities for MQ-1 and MQ-9 because in the place of one Hellfire, we conceptually have a launch rack that could replace that with six Pyros. What that of course does is increase the number of targets you can address.'

Meanwhile, MBDA also has its eye on the Shadow, for which it is developing the Small Air Bomb Extended Range (SABER).

'SABER is approximately 15lb total weight, and the RQ-7's wingspan is about 20ft, and it weighs about 460lb,' explained Denneny. 'There was a programme started by the USMC for the demonstration of the ability to weaponise Shadow. We believe that is still out there, it's just that there hasn't been any major announcement of any major programme to do it. We know in industry… so at MBDA we plan to lead with our SABER as a candidate.'

He explained that there has been 'an explosion' of UAVs in the medium-range class, so the SABER is suitable for a variety of vehicles. 'SABER has a wing on it so it's highly manoeuvrable, and what's unique is that it has a semi-active laser seeker on board, so it can hit moving targets. SABER has a complete 360°… capability – many UAVs fly orbits, watching ➤

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Nemesis is designed for both STUAS and larger platforms like Predator. *(Photo: Lockheed Martin)*

from ahead, so a classic missile off of a UAV would have to be pointed at the target. With SABER… the wings unfold, and it basically turns and glides with the ability to go in any direction.'

SMALLER INTEGRATION

Lockheed Martin has also realised the potential of this market, and has developed the Shadow Hawk for the RQ-7. In addition to its Hellfire missiles being used on larger unmanned platforms like Predators, Gray Eagles and Reapers, the company is also working to integrate smaller weapons like Shadow Hawk and Nemesis onto STUAS.

The first Shadow Hawk flight test was conducted in 2012 and achieved a direct hit on the target. The munition has since become ready for purchase, should a customer require the system, the manufacturer told *UV*.

'Lockheed Martin, using internal R&D funds, continues to mature the current design to include fusing and warhead variants in anticipation of the identification of customer requirements,' said Lou Karbiener, project manager for Shadow Hawk at the company.

'Shadow Hawk can be integrated on any STUAS employed by the DoD, SOCOM or other government agencies. At 11lb, it adds a precision strike capability with minimal cost to payload or endurance.'

'Weaponisation has come into vogue because of the mindset of "find, fix and finish".'

'The weaponisation has come into vogue because of the mindset of "find, fix and finish",' continued Denneny. 'Generally, these UAVs and RPAs see the problem, like a violent attack that requires retribution… the UAV at 2am is the only one that sees it, and there are no friendly forces in the vicinity, then they need to engage.'

VIPER STRIKE

MBDA's Viper weapon system, meanwhile, has operational experience on UAVs, having been integrated on the RQ-5 Hunter for armed operations by the US Army in Iraq using the Viper Strike. It has undergone an upgrade to take it to the Viper-E configuration, which Denneny said has a new software capability to hit high-speed targets.

The Hunter is currently still in operation, but a decision was made a few years back to de-weaponise it. The weapon is currently flying on operations on the KC-130J Harvest Hawk.

'We as a company are actively marketing Viper-E to US and international customers because it's proven it's ready to go,' added Denneny. 'Commenting on any actual testing would be premature, but we are actively marketing the weapon because it's a low-cost, turnkey solution that comes out of the common launch tube in drop tube configuration.'

The weapon does not have a rocket motor, so it arrives quietly at the target by gliding, using a parachute system with GPS to get close to the aim point using its 'top attack mode'.

'So, the uniqueness of GBU-44/E using this top attack mode, as well as another called "fast attack", these allow it to hit a variety of targets, and the operator can decide which version to use,' explained Denneny. 'Fast attack is used primarily for moving targets, and late last year MBDA did a test with the support of SOCOM to show the ability of Viper-E to hit very high-speed moving targets.

'There are Viper Strikes in canisters ready to go, and there are customers that want them upgraded. We can upgrade them to the "E" variant with some minor modifications that are primarily software,' he added.

PURPOSE-BUILT DESIGNS

Besides adapting ISR platforms to armed mission roles, there is also a category of UAVs that are built specifically for this endeavour.

On the European side, the UCAV effort has seen several programmes develop over recent years, with the aim of replacing or operating alongside fighter jets in combat.

One such programme is the Taranis demonstrator effort commissioned by the UK MoD and led by BAE Systems, the aim of which is to see if a stealthy unmanned aircraft is capable of striking targets with precision at long range, according to the company.

Sources confirmed to *UV* that the Taranis was due to fly in Australia as the magazine went to press. BAE could not comment on the programme, deferring to the UK government, but said that it is progressing with initial trials.

The company is also developing the Mantis UAV, which is intended for ISR, but with the capacity to carry weapons. 'We have previously exhibited a full-scale replica fitted with Brimstone and Paveway LGB for illustrative purposes,' Martin Rowe-Willcocks, head of business development for the Future Combat Air Systems team at BAE Systems' Military Air & Information, told *UV*.

'The final weapons fit is always dictated by the customer. As the Mantis project has been supported by the UK MoD, we are not in a position to confirm exact payload capacity, but there will be provision for a variety of weapons carried on the under-wing pylons.' uv

Unmanned milestones

1993

Self-proclaimed pioneer of modern unmanned aviation and manufacturer of the Predator and Reaper series of UAVs, General Atomics Aeronautical Systems Inc (GA-ASI), was founded.

GENERAL ATOMICS AERONAUTICAL

1994

Designated RQ-1, GA-ASI's Predator UAS launched as an advanced concept technology demonstration. The design was based on the company's Gnat 750 model and the USAF received its first Predator later in the year.

1995

'Jeeves' became the first UGV to perform routine transport tasks and courier trips in the health industry. Operating at a UK hospital, the 5ft-high trackless robot ran pre-programmed routes using IR and ultrasonic sensors to carry medicine, blood samples, packages and food.

1996

The US DoD's RQ-3 DarkStar completed its maiden flight on 29 March

The programme was terminated in January 1999 as the UAV was deemed to lack stability and failed to meet cost and performance objectives.

2004

US-Israeli relations were dealt a blow when the Pentagon criticised Israel for selling UAVs to the People's Republic of China. This was the first time the existence of a deal between the partners had been confirmed. IAI sold Harpy attack UAVs to the country in 1994, which were returned in 2004 for upgrade.

2005

In September, US Customs and Border Protection unveiled its first Predator B UAV at Fort Huachuca, Arizona.

2006

Hizbullah became the first militant group to launch several UAVs armed with explosives into Israel. The aircraft were either intercepted by the Israeli Air Force or crashed into the sea.

2007

The MQ-9 Reaper was deployed to Afghanistan for precision air strike operations. The baseline system carried a multi-spectral targeting system and was armed with munitions including Paveway II, Joint Direct Attack Munition, laser-guided missiles and air-to-ground Hellfire missiles.

2008

Qinetiq's Zephyr UAV broke the world record for the longest duration unmanned mission in August, completing an 82-hour flight and reaching 60,000ft over the Yuma Proving Ground, Arizona. The US DoD funded the joint capability technology demonstration in collaboration with the UK MoD.

2009

The USAF finally confirmed the existence of the Lockheed Martin Skunk Works RQ-170 Sentinel UAV. The stealth platform had been photographed at Kandahar Airfield and became known as the 'Beast of Kandahar'. It was designed to carry out ISR missions in support of forward-deployed combat forces.

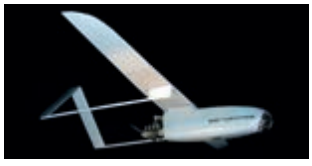
To celebrate the anniversary of *Unmanned Vehicles* magazine, **Andrew White** selects some of the highlights of the past two decades to illustrate how far the sector has come in this time.

1997

Global Hawk was unveiled at Teledyne Ryan Aeronautical's facility in San Diego, California. Multiple upgrades mean the HALE UAS can survey 100,000km^2 a day using high-resolution synthetic aperture radar and long-range EO/IR sensors with long loiter times over areas of interest.

1998

On 21 August, AAI's Aerosonde was the first UAV to fly across the Atlantic Ocean. It also became the smallest aircraft to complete the 3,268km flight between Canada and Scotland, taking 26 hours and 45 minutes.



1999

IAI unveiled the Harpy UAV at the Aero India show. Israel went on to supply various UAVs to India. These were used during the Kargil conflict with Pakistan, thereby starting an unmanned arms race with the country's neighbour.

2000

The world's largest user of unmanned systems, the US DoD, published its 'Unmanned Aerial Vehicles Roadmap 2000-2025'. The document identified missions applicable to unmanned platforms and linked them to emerging capabilities, culminating in a roadmap for current and future UAV projects.

2001

A live Hellfire C missile was successfully launched for the first time from a USAF Predator UAV, signalling a giant step from ISR platform to hunter-killer. Conducted at Indian Springs, near Nellis AFB, Nevada, the test saw the missile hit stationary armoured platforms.

2002

A Predator UAV engaged a civilian vehicle carrying suspected terrorists in Yemen. This was the first known kinetic strike by a UAV outside the 'conventional' battlefield, eliminating six high-value targets. The strike was coordinated from USSOCOM HQ in Tampa, Florida. Later that year, a Predator engaged an Iraqi MiG fighter jet before being destroyed in the first recorded 'dogfight' for a UAV.

2003

The US Army deployed the Shadow 200 in support of Operation *Iraqi Freedom*. The aircraft went on to complete over 500,000 operational flight hours during the campaign, equipped with an EO/IR payload that was utilised for ISTAR missions.

2010

Gray Eagle was deployed to Iraq for the first time with the US Army's 1st Infantry Division, Combat Aviation Brigade. By 2012, the system had been launched and recovered 10,000 times.

2011

The first hydrogen-powered UAV, Global Observer, completed its four-hour maiden flight from Edwards AFB. Manufacturer AeroVironment said the aircraft reached an altitude of 5,000ft. Meanwhile, Iran claimed it had captured a USAF RQ-170 after hacking into the UAV and landing it on home soil.

2012

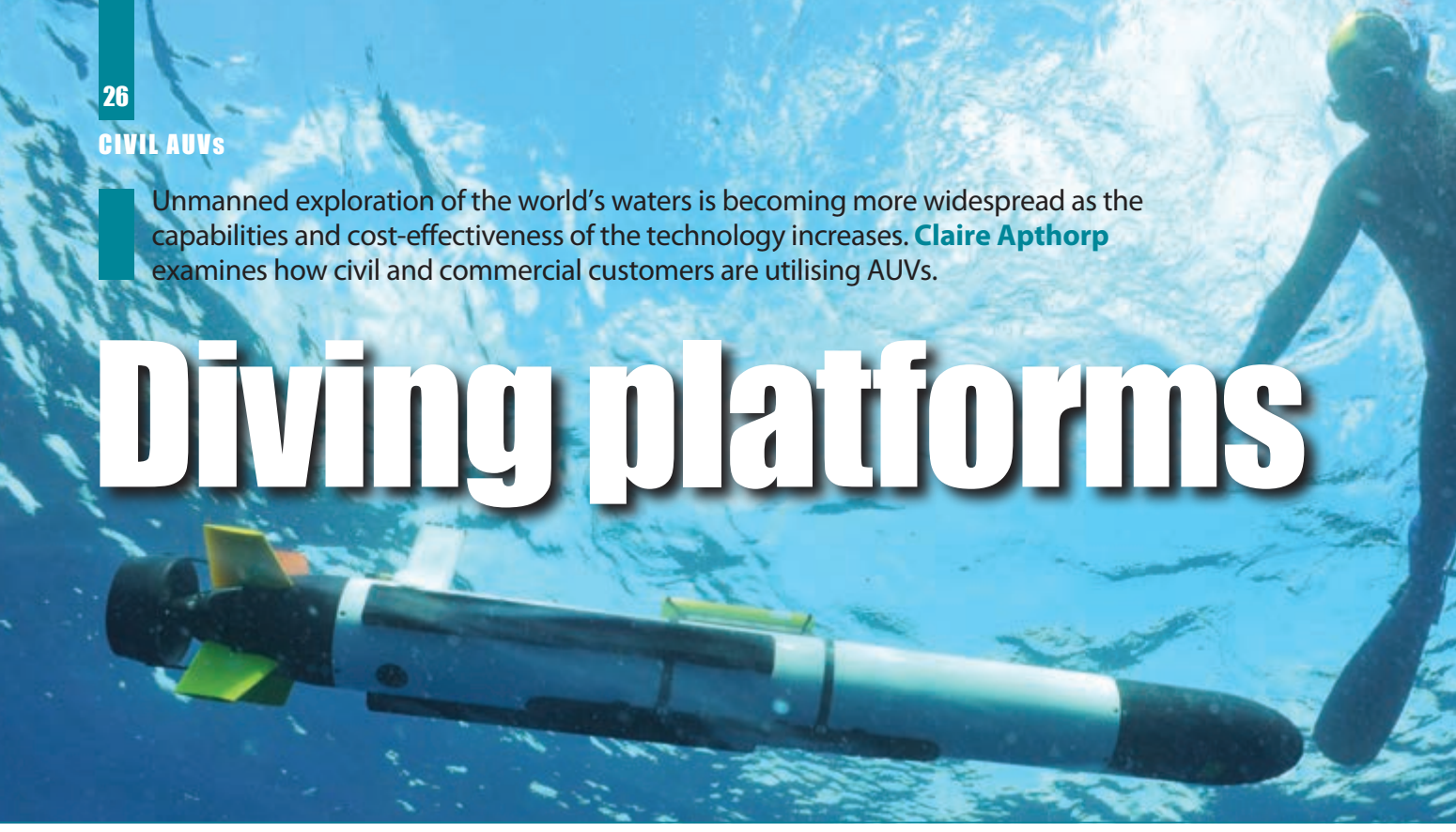
Lockheed Martin's Squad Mission Support System (SMSS) was deployed to Afghanistan for a six-month operational evaluation in January.

2013

The USN and Northrop Grumman completed the first carrier arrested landing of a UAV when the X-47B landed on the USS *George H W Bush*. The demonstration completed the UCAS-D programme and lessons learned will be applied to the forthcoming UCLASS.

Unmanned exploration of the world's waters is becoming more widespread as the capabilities and cost-effectiveness of the technology increases. **Claire Apthorp** examines how civil and commercial customers are utilising AUVs.

Diving platforms



Historically, the sheer magnitude of the ocean has made comprehensive exploration by traditional manned methods unfeasible. As a result, autonomous underwater vehicles (AUVs) are being increasingly deployed to make the impossible possible, fulfilling a range of roles across the world's seas and lakes.

Unmanned technology is a vital tool for organisations wishing to acquire and analyse data and provide information on weather and climate change, ocean topography and marine hazards. There is also an increased focus on understanding the ocean and the processes of global warming, as well as efficiently and responsibly managing maritime resources to preserve them for future generations.

GOVERNMENT FUNDING

The biggest advances in AUV capabilities have occurred in the past decade. This was originally driven by publicised advances through government-funded projects that confirmed the functionality of AUVs and showed how continued improvements in size, cost, operator interface, sensors and deployment methods could yield a practical tool for data collection in research, commercial survey and civil applications.

This has been combined with the demonstration of the advantages AUVs offer in comparison to tethered systems, such as ROVs and towed platforms. Paired with a growing understanding of the fact that AUVs offer a lower logistical footprint, reduced operator workload, increased platform stability for higher quality sensor data, and are overall a more cost-effective method of collecting data, the market for adoption has been steadily growing.

In response to this increasing interest, a number of manufacturers are now meeting this burgeoning demand. One such company is OceanServer, which is working to overcome some of the lingering misconceptions that persist concerning the use of AUVs. Despite the current generation being highly capable and appropriate for use in real-world surveys, historical perception of high cost and complicated operation has hindered the general implementation among commercial and civil operators.

'As early adopters successfully deploy AUVs and publicity improves the understanding of those specifying survey work and those conducting survey work, AUVs will find greater acceptance,' Bob Anderson, president of OceanServer, told *Unmanned Vehicles*.

SOCIAL ACCEPTANCE

Changing attitudes towards unmanned technology are also helping encourage greater deployment of AUVs.

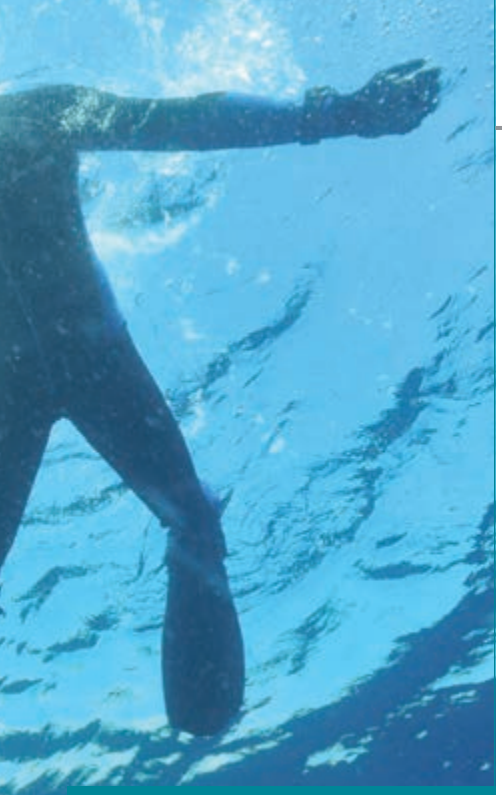
'The idea that automation can provide solutions and improve efficiencies for routine tasks is becoming an accepted aspect of modern society – and the proliferation of UAVs, medical surgical robots, GPS-guided farm tractors, and similar, coupled to tech-savvy younger decision makers, makes the greater adoption of AUVs seem completely logical,' he continued.

'Many critical deep-water missions, such as pipeline inspection, are already using AUVs successfully, and setting a positive example for less demanding applications where an AUV can improve efficiencies and the resolution of collected data, if incorporated into the overall survey operation.'

OceanServer is seeing interest in its Iver2 AUV from a wide range of customers, including university researchers who are attracted to the platform's simple operator interface, open system architecture and relatively low cost. Over time, this group has expanded to include military research and operational users, and increasingly near-coastal survey operators.

The Iver2 AUV is a 15cm carbon-fibre tube with plastic and aluminium components. Lengths vary from 140-200cm, and weights from 22-31kg. The hull is sealed against seawater, with propulsion provided by a brushless DC motor powered by rechargeable Li-ion batteries. Typical operating speeds are 2-3kts.

At a high level, the vehicle is a data-logger that positions a set of sensors in the water column, and accurately tags the results in time and geo-space. The vehicle control software,



OceanServer's Iver2 AUV has attracted interest from university research customers. *(Photo: OceanServer)*

organically developed by OceanServer, provides direction to the motor and four independently controlled tail fins, based on position change data provided by GPS when the AUV is on the surface, and various integrated aids or external acoustic positioning input when sub-surface. The vehicle controller software arbitrates among the various inputs to ensure the vehicle follows a prescribed path.

MISSION SETS

'A typical mission will be an area sonar sweep to either detect objects of interest on the sea floor or develop a bathymetric view of the bottom to aid in making navigation decisions or perhaps calculate water volumes, current etc,' added Anderson. 'When equipped with environmental sensors, the focus becomes water quality attributes, such as temperature, salinity, turbidity and various chemical elements of interest.'

Either case requires the operator to develop a mission plan based on geographical waypoints, as well as vehicle behaviour characteristics – speed, depth, sensor resolution and sensor controls. The vehicle returns from an eight to ten-hour mission with a data set that includes the vehicle performance and the sensor readings at typically 1Hz resolution. This data is then processed by software tools to develop the visual and quantitative information needs that prompted the survey.

'Subject to capabilities, AUVs can operate consistently with little regard for surface sea state, the time of day, temperature, wind, rain or other environmental elements, and they can remain mostly sub-surface for a full working shift or more, and then return to the water after a re-charge or battery swap,' explained Anderson.

'The support required on-site is fairly minimal, and a single operator or small team can operate several AUVs simultaneously. The AUV is especially suited to sonar collection because it can follow the sea floor, remain level and flat, and since it is de-coupled from a towboat, it doesn't imprint any evidence of the surface condition on the data records of high resolution sonar or video.'

FLEXIBLE OPTION

Hydroid's US-based regional sales manager, Rick Morton, is also keen to highlight the benefits of using AUVs like the company's flagship Remus and Hugin systems as a flexible alternative to surface vessels.

'AUVs can glide along the surface, dive to deep depths, explore shallow waters or hover in hazardous areas where navigation is difficult, and Hydroid AUVs have reduced the high costs of ocean exploration and sampling, while increasing the availability, quality and quantity of scientific marine data,' explained Morton.

The Remus AUV is the culmination of 16 years of R&D, and has a proven track record for reliable and consistent field operations. Remus AUVs are offered in three vehicle classes: the man-portable Remus 100 (depth rated to 100m); the modular Remus 600 (600m or 1,500m); and the Remus 6000 (6,000m), a deep-water workhorse.

All Remus AUVs are built on a common technology base incorporating the intuitive vehicle interface program, which keeps vehicle maintenance, mission planning, checkout, data analysis and cross-vehicle training seamless across the model line. The vehicles can be equipped with many different instruments, depending on the model and intended use, and all incorporate embedded software.

According to Morton, Hydroid's R&D efforts have focused on enabling AUVs to operate multiple payload sensors simultaneously, enabling the real advantage such platforms ➤

Hydroid's family of AUVs all rely upon a common technology base.
(Photo: Kongsberg Maritime)

offer. Work has also been conducted to ensure that the timing of sample collection of each instrument (sonars, motion sensors, etc) is synchronised down to the millisecond, enabling comparison of all data at the exact same moment – a vital capability for hydrography, where knowing the exact orientation and position of the vehicle at the time of a sounding leads to better charts of the sea floor.

'Over the past ten years, Hydroid has matured its technology up to a point where reliability and capability now combine to extend a ship's survey capacity – even making the ship itself redundant in some scenarios,' added Morton. 'In traditional offshore surveying, AUVs have a proven track record that has enabled survey companies to increase their profits by lowering cost, increasing production and becoming more competitive, and we continue to strive toward bringing ever greater advances in reliability and autonomy.'

PRE-PROGRAMMING

The issue of autonomy for AUVs is a hot topic, as with all unmanned technologies. Currently, the majority of systems in civil and commercial use require pre-programming, as is the case with Bluefin Robotics' range of systems.

The company has provided vehicles to a variety of institutes, including the Massachusetts Institute of Technology (MIT), the Alfred Wegener Institute, the University of Victoria and commercial survey firms, including Fugro GeoServices, Tesla Offshore and Phoenix International Holdings.

The company spun out of the MIT AUV Laboratory in the late 1990s. The original product has evolved into the Bluefin-21, and when the company branched off, it started producing several of the systems for the domestic scientific and defence markets.

Today, all Bluefin Robotics systems contain one small pressure vessel for the main vehicle electronics; a fully gimballed thruster; communication devices, including antenna, emergency devices and some core vehicle sensors; an energy section reserved for pressure-tolerant batteries, so operators can swap them out on deck quickly, allowing maximum data collection time sub-surface; and a payload section.

The payload section houses the units that determine applications and mission of the system, with typical examples including side-scan sonar, synthetic aperture sonar, multi-beam echosounder sonar, cameras, as well as a nose cone at the end which functions as a recovery device at sea and can include forward-looking sonar for collision avoidance.

The company is continuously adding capabilities to the vehicles in the areas of

autonomy, but currently all the AUVs need to be pre-programmed.

'An operator designs the mission in our planning software, then uploads it to the vehicle, and once all vehicle functionality tests are performed, the vehicle dives and carries out the mission instructions,' David Kelly, CEO and president of Bluefin Robotics, told *UV*.

MISSION PROCESS

During the mission, vehicle status is communicated back up to the topside computers over an acoustic signal so the operator can track the system and its health while it is under way. Once the vehicle completes the mission, it is recovered to the deck, batteries are swapped, data removed and downloaded, and the system is ready to be deployed again.

'Different missions and surveys will require a different concept of operations,' noted Kelly. 'For example, a broad area search for a sunken ship will require the vehicle to comb a large square portion of the sea floor at a particular altitude. Should the ship be found, the system may go back down to depth, fly at a lower altitude and take photos of a smaller, more specific area of the wreck.

'Or, in the case of water sampling in the Arctic, the mission may be designed so that the vehicle can be driven in and out of an ice field taking physical water samples. Or, it dives to depth, turn off its thruster, and while floating to the surface take samples at various altitudes. This provides the scientists with actual water samples in different areas relative to the ice.'

According to Kelly, the main challenge is developing a robust, reliable system with increasingly complex behaviours and more sophisticated autonomy, as well as advanced sensors and payloads to meet the demands of new applications emerging in the market.

'Challenges also include subsea communications, and accurate positioning,' agreed Morton. 'Also, since the AUVs have lithium-based battery cells, battery safety during charging and transportation is an ongoing concern.'

Bluefin Robotics has identified sub-sea communications and accurate positioning as its greatest challenges. *(Photo: Bluefin Robotics)*

LONGER LASTING

There will also be a greater emphasis on endurance and persistence moving into the next decade.

'With advances in battery technology and the use of subsea docking stations, AUVs will be able to stay underwater for a substantially longer time frame,' Morton said. 'Also important is vehicle cooperation, which will see multiple AUVs communicating with each other to complete a task without input from the surface; as is greater autonomy so that AUVs will be able to make more decisions for themselves on the fly.'

GRASPING THE ISSUES

With continuing development, it will not be long until industry has a grasp on these issues, which will in turn affect the growth curve of the market.

'As AUVs increasingly find their way into the survey world, operator expectations and practical experiences will clarify and prioritise industry opportunities for improvements in platform and sensor attributes, applications software and general deployment methods,' added Anderson.

'Hardware will take advantages of improvements in related technologies and financial opportunities will attract capital and new players to address AUV-related challenges. AUVs will be coupled to application-specific sensors, many available today, to create a variety of special-purpose AUVs, all grown from existing or emerging technologies, coupled to new operational concepts to meet an increasing variety of needs.' UV

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NASA's Lockheed Martin S-3 Viking is one of a handful still flying and is an integral part of the joint UAV data link project. *(Photo: NASA)*

Public service broadcasting

As moves are made in the US towards developing a common data link for UAS use in unsegregated airspace, **Tom Withington** assesses the design criteria and maps the progress made in this evolving area of technology.

In early July, NASA performed its latest round of flight testing on a prototype data link radio for UAVs, representing the most recent development in a fast-evolving field.

NASA's work in this area may not only have important consequences as regards improving the integrity and capacity of air-to-ground communications, but herald a step towards the 'holy grail' of achieving everyday unmanned operations in unsegregated airspace.

Data links play an indispensable role in UAV operations. These are the RF conduits via which an aircraft is controlled from the ground, and across which it can transmit the intelligence it has gathered. Consequently, data links have several important design criteria. They must be robust and resistant to jamming and interference; have sufficient bandwidth to handle aircraft commands and transmit intelligence; and possess a sufficient transmission range to enable a UAV to fly at its optimum mission radius and altitude.

BAND SPREAD

For UAVs operating a comparatively short distance from their GCS, data links can use the VHF (30-300MHz) and UHF (300-3,000MHz) segments of the electromagnetic spectrum. The attractions are that both frequency bands can carry a relatively large quantity of data, especially when compared to HF communications in the 3-30MHz range.

That said, both VHF and UHF are limited by LoS considerations, unlike HF. This, however, is not such an obstacle as it can be for ground-to-ground communications, given that aircraft routinely fly at altitudes of thousands of feet. Moreover, VHF is already in widespread use for air traffic control.

Given the comparatively narrow bandwidth of HF, SATCOM offers an alternative for over-the-horizon ranges. It has the attraction that it can handle relatively large quantities of data and has a global reach. The trade-off is that SATCOM, like any RF signal, can be vulnerable to jamming. Therefore, optimising a data link for a UAV begins with ascertaining exactly what tasks the aircraft is to perform and at what ranges.

The Northrop Grumman RQ-4B Global Hawk operated by the USAF makes significant use of SATCOM in the form of its Ku-band (12-18GHz) data link which can routinely handle around 50Mbps of data. This is comparable to a home Wi-Fi system, although the Global Hawk's data link works at ranges of thousands of kilometres, rather than across an area of tens of square metres. ➤

According to José Diez, project manager in the RF and space unit at Spanish communications specialist Erzia Technologies, the key design characteristics for UAV data links include reliability, continuity and stability. 'After that, high telemetry data rates, reduced weight and limited dimensions for the onboard unit [are factors],' he told *Unmanned Vehicles*.

One aspect which UAV data link design has benefited from is the relatively young nature of the technology. 'The technology that enables UAV operations is quite new and UAV data links have benefited from the evolution of digital communications and modulations developed in other areas of telecommunications,' he continued.

NASA joined forces with Rockwell Collins in 2011 to develop its prototype public-use airborne data link, designed to shape the technologies that could eventually be employed in a baseline unit to equip future UAVs operating in unsegregated airspace.

Rockwell Collins has utilised its existing radio products to develop a waveform which could be used as a baseline for UAV operations in non-segregated airspace. *(Photo: Rockwell Collins)*

The company's task includes the development of prototype radios which can be installed in the aircraft to transmit and receive information across the data link and the waveforms it will carry. The intention is for these waveforms to be non-proprietary and available to UAV operators as and when they are available. To date, flight testing, based at the John H Glenn Research Center, Lewis Field, Ohio, has been performed using a modified Lockheed S-3 Viking ASW aircraft, one of the few examples still flying following USN retirement of the type in 2009.

BAND AID

Bandwidth challenges abound as far as UAV data link engineering efforts are concerned. In February 2012, the unmanned community received a fillip when two new segments of radio bandwidth were awarded by the World Radiocommunication Conference organised by the International Telecommunications Union (ITU), a UN branch tasked with coordinating shared global use of the RF spectrum.

This will allow UAV users around the world to utilise parts of the L-band (chiefly 960-1,164Mhz) and C-band (1,530-1,591MHz). The rationale behind using these two bands is because 'each section has different propagation characteristics', according to Jim Griner, lead communications project engineer on the NASA/Rockwell Collins data link initiative.

What this means in practice is that RF signals in these frequency bands behave differently in terms of their performance. What role the L-band and C-band could play in a future civil UAV data link standard is undecided. 'The sections were allocated to be used, but how they will be used has not been cited yet,' noted Griner.

It is possible that one band could act as a reserve for the other to provide safety redundancy. The most important element of the ITU's actions was to get a specific part of the spectrum allocated to UAV operations. 'The idea was to obtain enough spectrum, as there was not enough contiguous spectrum,' said Griner.

'Several UAVs could be linked to a single ground transmitter within a given area.'

Although they are now reserved for UAV use around the world, this does not mean that an operator can jump into either bandwidth and utilise it for day-to-day operations. 'You can't just go out and use those frequencies, but we have authorisation to use them for the purposes of our flight testing,' he said.

The award also only solves part of the wider problem. As UAV operations increase, the more crowded these bandwidths will become. Innovative solutions, therefore, have to be found. The NASA/Rockwell Collins initiative is addressing this by developing a data link architecture in which several UAVs could be linked to a single ground transmitter within a given area. As they fly out of the area, the data link automatically picks up its next nearest ground station and begins transmitting to that.

An analogy to this would be the mobile phone world, where an operator's calls are handled by the nearest tower, until they move out of range, and communications ➤

The USAF's RQ-4B Global Hawk uses a Ku-band SATCOM data link to transmit intelligence across intercontinental ranges. *(Photo: US DoD)*

are picked up by the next tower. This technique could avoid possible spectrum crowding – if each UAV used a point-to-point data link, possibly extending across hundreds of kilometres, bandwidth would rapidly be exhausted, placing a *de facto* limit on the number of unmanned aircraft which could fly over a specific country, for example.

UPWARD SPIRAL

The NASA/Rockwell Collins initiative has been propelled through a series of development spirals. Flight testing of the S-3 equipped with an L-band radio commenced in May 2013. Current flight test activity adds C-band communications to the data link and will see experiments with two ground stations, with the radio using one and then transferring to another as it navigates through the air.

The second spiral will conclude in 2014, with the third following thereafter. This will see the aircraft using both L- and C-band communications for C2 across multiple ground stations, with a ground-based pilot performing *de facto* control of the aircraft while a safety pilot remains on board.

Although known for its airborne communications products, Rockwell Collins is not designing a new radio from scratch for the initiative. Instead, the company is utilising some of its existing airborne software-defined radios (SDRs), which are 'convenient and appropriate'. John Moore, principle investigator for the project, told *UV* that these 'are not being proposed as actual production equipment because, first and foremost, we are trying to validate the waveforms for this project'.

The radios take the form of 'a couple of generic L-band and C-band transceivers and we use these both in the air and on the ground', Moore said. 'These have a relatively small form factor, with each being around the size of a small hardback book, but they are not certified for aviation use.'

Much of the work regarding waveform design has now been concluded, according to Griner, although some tasks remain regarding its 'other attributes for sending data'.

> *'Design the waveform and the prototype radio, and then perform the flight testing.'*

'The intent is to produce a foundation waveform which meets the requirements and which could become an eventual baseline,' Griner noted. This would be utilised for the drafting of regulations by the FAA regarding the use of UAVs in unsegregated airspace.

This baseline waveform, plus the sections of the RF spectrum, which have already been secured, would effectively form a foundation which can be employed when UAV flights in unsegregated airspace become a reality. In this context, significant preparatory work is required to enable the airspace to be opened up to routine UAV operations.

Essentially, the more preparation work carried out now, the less onerous the task of writing regulations will be for the FAA and its counterparts around the world, many of whom will no doubt look towards the US and examine the work carried out there.

THIRD PHASE

As previously noted, the programme is moving towards its third spiral. In the short term, two more flight tests of the first spiral incarnation of the radio are required. Moore said: 'The next version of the radio will be delivered to NASA in September. This will go through laboratory tests and then flight tests which will finish in March next year. [Following this], the third radio will be delivered in 2014, and this will be the final version of the radio and of waveform'. The project is due to conclude in October next year.

In terms of management, funding for this project is being split roughly 50/50 between NASA and Rockwell Collins, with the engineering team similarly split. According to Moore, the project's ultimate aims are 'to design the waveform and the prototype radio, and then perform the flight testing'.

Both Griner and Moore emphasised that the open nature of the project is especially important. 'This isn't just NASA working with Rockwell Collins – it is a community effort. The work that we have performed is fully open and we are getting great feedback from the standards community and the UAV community. Everything that we will deliver concerning this waveform is both open and non-proprietary.' **uv**


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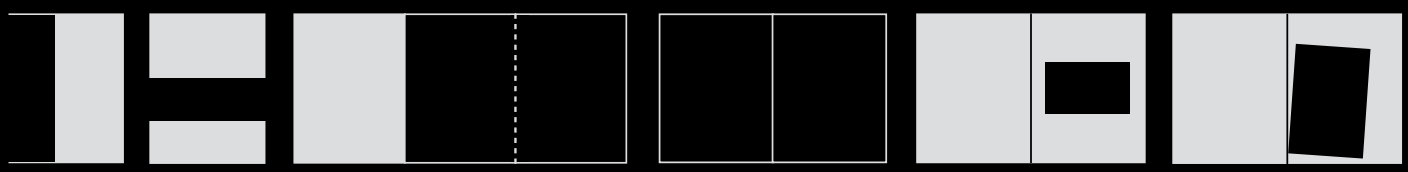

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All-terrain vehicles?

Will future US UGVs operate in the same environments or have the same mobility requirements as those currently used in operational theatres? **Scott R Gourley** canvasses industry opinion.

While the projected end of combat operations in Afghanistan is impacting a broad swath of the materiel programmes that have emerged over the past dozen years, the US military exhibits a continuing commitment to the application of UGVs in a post-*OEF* world.

Recent evidence of this commitment can be seen in a market survey announcement issued by the Project Manager Robotics Systems Joint Project Office (RS JPO), located at US Army TACOM Life Cycle Management Command (LCMC). The announcement identifies interest in a Man Transportable Robotic System Increment II (MTRS Inc II) effort to provide standoff capability for soldiers and marines in future CBRN, EOD and combat engineering missions.

SNOW PATROL

The announcement describes the future system as 'intended to be vehicle-transportable and capable of being carried by two soldiers. The system will be highly mobile and used in mounted and dismounted operations. MTRS Inc II will be a multi-mission modular system that can be reconfigured by adding or removing sensors, manipulator arms and mission module payloads, allowing this capability to operate together with these sensors through the Operator Control Unit [OCU].'

The announcement elaborates on the 'highly mobile' characteristics of the future platform with an extensive set of questions aimed at interested industry responders. These address general mobility issues, ranging from maximum speed on hard surfaces and hard surface climbing angles to stair ascent/descent parameters. Additional factors listed include mobility in snow, movement across unpacked sand, movement through high grass, underwater submersion and movement through mud.

The challenges noted are reflective of the UGV mobility comments identified in the June 2011 'UGV Roadmap' prepared by the RS JPO.

EASTERN PROMISE

'Terrain mobility is a subject of significant R&D within both government and industry,' the document states, pointing to multiple breakthroughs in mobility technology since 2009. ➤

Next-generation UGVs are looking to improve mobility in snow, sand, mud and water. *(Photo: Autonomous Solutions)*

While breakthroughs have been made, the range of future platform mobility questions in the MTRS Inc II solicitation highlights the belief by some that the mobility traits of currently deployed UGV systems might not be the same ones that will be required in the geographic uncertainties of a post-*OEF* environment. It appears that both government and industry participants are working to address some of this uncertainty.

For example, in the Roadmap-cited period since 2009, it is apparent that the US military has been exploring some aspects of a 'Pacific pivot' UGV environment through ongoing regional exercises like *Cobra Gold*. Beginning in 1980 as a bilateral exercise between the US and Thailand, *Cobra Gold* has expanded to include participation by five additional Asian countries with common goals and security commitments in the Asia-Pacific region. It has also provided an excellent venue for the examination of UGVs in regionally unique environments.

REGIONAL ROBOTICS

In February 2009, for example, engineers from the US Army's Tank Automotive Research, Development and Engineering Center (TARDEC) – an element of TACOM LCMC – used the *Cobra Gold 2009* venue as a testing environment to conduct regional robotics experimentation with the iRobot Warrior 700 and Autonomous Solutions Incorporated (ASI) CHAOS platforms. (The first prototype Warrior had participated in the *Cobra Gold 2008* roadshow.) During *Cobra Gold 2009,* US marines operated the platforms through a series of scenarios and provided operational feedback to TARDEC engineers.

The experimentation reflected TARDEC's role in providing science and technology support to the RS JPO.

Along with mobility testing and research by the DoD, industry designers have been working with government agencies and on their own to explore platform mobility issues and potential mobility enhancements.

'iRobot is always investigating ways to enhance robot mobility,' offered company spokesman Charlie Vaida. 'One specific example out of the company's research group is PackBot with Advanced Suspension for Improved Mobility [ASIM]. iRobot developed ASIM with funding from DARPA. ASIM uses a

SMSS was deployed to Afghanistan in 2012 for operational trials. *(Photo: Lockheed Martin)*

bolt-on compliant suspension that allows for climbing of steep slopes and navigation of aggressive rough terrain.'

According to Vaida, when compared to a 'stock iRobot PackBot', an ASIM-equipped model provides up to eight times less energy use and 12% steeper grade climbing over rugged terrain; decreased operator workload driving through rugged terrain; and smoother, more stable mobility.

'While ASIM is not fielded, it serves as an example of the type of work iRobot is conducting around robot mobility.'

There is also the issue of uncertainty – not only in future environments, but in service requirements.

Reflecting on whether the UGV mobility characteristics that have been developed and refined in recent operational environments are optimised for possible future theatres, Myron Mills, manager of the six-wheeled Squad Mission Support System (SMSS) programme at Lockheed Martin Missiles and Fire Control, offered: 'I think the answer to that question is no.'

Moreover, he expressed a belief that many existing platforms are not even optimised for mobility in current operational environments.

Emphasising that he 'could not speak for other folks working in this area', Mills noted that the SMSS platform 'was not specifically optimised for the current battle – the current environment'.

Instead, he pointed to many current designs as reflecting a balance of performance in a wide variety of terrains, as well as cost/affordability, durability, ease of maintenance and transportable packaging.

FUTURE PROOF

'We didn't specifically optimise [SMSS] for Afghanistan or for any other environment,' he said. 'We have tried to come up with a machine that is useful in a wide range of terrain and environments.

'Certainly what we have learned, and what other folks in the industry have learned by their various assessments and evaluations will, no doubt, be used to help refine the ➤

iRobot is tackling future UGV mobility requirements. *(Photo: iRobot)*

vehicle platforms that we're going to use for future UGVs. But I don't think, at this point, that those experiences have resulted in an optimised platform.'

He continued: 'The defence industry is a requirements-driven business. And right now there is something of a dearth of firm requirements in the mid-sized and large-sized UGV area. So, people that are working this area, including us, are talking to the customers, doing field evaluations and thinking about the problem. And people are trying to come up with what they think are going to be useful mobility characteristics for the future UGVs. But when the requirements come down officially one of these days, everybody of course will have to modify their positions somewhat, based on what those requirements end up being.'

AFFORDABILITY ISSUES

Mills said that another issue that factors into new UGV mobility designs is cost: 'We think we know about what kind of a production cost is going to be required for an SMSS-sized UGV. So you have to weigh that into the design of the vehicle and the mobility characteristics, so that we don't produce something that may be hugely capable but is not seen as affordable.'

He observed that today's operational environment includes many UGV platforms based on side-by-side all-terrain utility vehicles. Noting that those platforms are relatively inexpensive and widely available, he offered: 'That certainly makes them good for experimentation but they do have drawbacks from a durability and mobility standpoint, especially when they are loaded to large loads. If you get to 1,200-1,500lb [540-680kg] of load on those vehicles it severely limits their mobility and also wears on the durability and life of a light duty vehicle like that.

'As we go forward into the future, I think you will see that there will be changes to the various competitors' platforms as industry looks at what it takes to meet the requirements, but also to keep an affordable platform.'

Choosing his words carefully, Mills acknowledged that Lockheed Martin's own efforts currently include 'looking at the possibility of changes to our platform that would both improve the performance and reduce the cost'.

THE BIGGER PICTURE

'I can imagine that there are other people in the industry that are also looking at their systems and deciding what they want to do in the long term,' he added.

Not all developers are focused specifically on the UGV mobility challenges that will be found in future operational environments.

'That's one of the beauties of our TerraMax technology,' asserted John Bryant, senior VP of defence programmes at Oshkosh Defense. 'It is really applicable and effective in any environment.'

Reviewing the primary threats experienced by US forces now in-theatre, Bryant said that a large aspect of the response to date has been in armouring solutions across multiple ➤

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vehicle families. Oshkosh's experience with these efforts has extended across both army and marine corps vehicle fleets.

'But the survivability and impacts of our TerraMax technology are a little bit different,' he continued. 'Whereas a lot of the survivability solutions we see in-theatre right now are optimised for that particular theatre, TerraMax is applicable anywhere. It's a system that is scalable and it is a system that can be integrated into any tactical wheeled vehicle – heavy, medium or light.'

Noting that algorithms can be refined for particular types of terrain, and that the company is constantly evolving and improving those algorithms, Bryant stated: 'But our [TerraMax] system is already mature and has been developed, applied and tested in such a variety of environments that it is really "worldwide-deployable" right now.'

'We adapt these systems for the types of vehicles that Oshkosh makes and the types of missions that our customer is looking to conduct,' echoed John Beck, chief engineer of unmanned systems at Oshkosh Defense. 'The mobility really comes down to the platform itself. That's what Oshkosh prides itself in – extreme mobility in any environment. So JLTV, M-ATV, MTVR – all these vehicles – are highly mobile and extremely durable "go-anywhere"-type machines. The real requirement is to make this [TerraMax] kit so that the autonomy can drive the vehicle with full platform mobility.'

Beck said that the ability to control things like driveline locks, central tyre inflation systems and other auxiliary systems beyond traditional throttle, steering and braking is what further enables the company's autonomous system to provide full platform mobility.

Mobility is not just an issue for smaller UGVs – Oshkosh's Terramax technology can be integrated into light, medium or heavy platforms. *(Photo: Oshkosh Defense)*

Asked about Bryant's comment on evolving algorithms for new terrain, Beck described these as 'hard-coded into the "brains" of the TerraMax system', with the algorithms 'written in a way that, if we are in different conditions, make the vehicle dynamics respond in different ways. Knowing that, we can control it.'

LEG UP

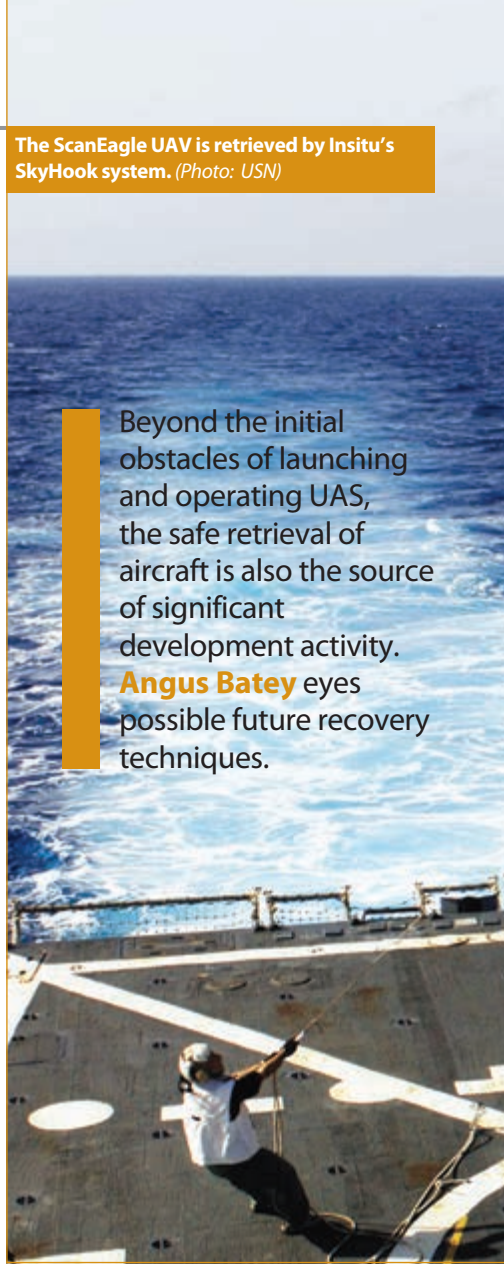
He offered the example of electronic stability control as 'something that manages to keep the vehicle from sliding out. It can control roll and yaw in a manual system, and we can adapt to that within the algorithms of the autonomy system.'

'The way our system is designed and has been tested and proven, it is already smart enough to go anywhere the truck can go,' Bryant echoed. 'We keep working to make it smarter every day.'

Looking towards the future of UGV mobility, the RS JPO 2011 roadmap speculated that tracked and wheeled mobility 'would continue to dominate the robotics trade space for many years'.

It states: 'Legged mobility will likely remain in research for much of the coming decade, but once matured these systems may radically increase mobility in relation to current platforms. Such robots will likely have wide application on future battlefields.'

Along with other future predictions, it remains to be seen whether the mobility trends identified in 2011 will be proven in the coming years. But one factor there seems to be unanimous agreement on is that UGVs have proven their worth in today's military operations and guaranteed their place in the operations of tomorrow. UV



The ScanEagle UAV is retrieved by Insitu's SkyHook system. *(Photo: USN)*

Return to sender

Beyond the initial obstacles of launching and operating UAS, the safe retrieval of aircraft is also the source of significant development activity. **Angus Batey** eyes possible future recovery techniques.

The utility of small UAS has long been proven, but the systems are only cost-effective if the aircraft can be recovered efficiently, safely and without damaging either airframe or payload. For rotary-wing UAS, the problem is relatively straightforward – the aircraft takes off and lands vertically, under control of either a human operator or an autopilot.

Larger fixed-wing systems land and take off like any conventional aircraft, using a runway. However, for users of small fixed-wing systems, with requirements for which a VTOL platform is unsuited and who operate outside the airfields larger aircraft demand, recovery becomes a significant issue.

GOING FORWARD

Small fixed-wing systems are often fielded by militaries in forward operating environments or on board ships, where runways and associated infrastructure are not available. The systems' sensors are often required when operators are under fire or likely to be engaged by an adversary, so accurate recovery becomes critical – the aircraft will have to land in a small and confined space.

UAS developers have therefore taken great pains to carefully examine the options for air vehicle recovery and provide products that offer solutions appropriate to the tactical role the systems fulfil. Recovery solutions do not just shape system effectiveness, they can affect payload integration and airframe performance, influencing aircraft design.

While the recovery systems currently fielded have a considerable degree of maturity, innovation and refinement are ongoing, with improvements to recovery high on many manufacturers' current development agendas.

'When you look at the landing of a small UAS, there are generally about three different primary options,' explained Bill Daly, international business development manager for Lockheed Martin's UAS portfolio, which includes the Desert Hawk system, as used by the British military in Afghanistan. 'They'll either use a deep stall landing, they'll deploy a parachute, or they'll do what Lockheed Martin has done, and go with the third option, a glide landing.'

IAI Malat's Bird Eye utilises a parachute and prongs to protect payloads on landing. *(Photo: IAI Malat)*

SKY DIVE

Daly described the three options as each having benefits and limitations. 'In a deep stall landing, you slowly fly the aircraft to where you want it and just pitch it up abruptly,' he explained. 'The aircraft wings lose lift, and it just drops in place. If you're a good operator, you can tend to have some pretty accurate landings. The disadvantage is that it falls out of the sky, and the payload takes a pretty good beating.

'Another option is to fly the small UAS into close proximity of the landing area, slow it down, then deploy a parachute so it'll drop and float down to the surface,' he continued. 'Some companies have even got, in addition to the

parachute, an inflatable bladder on the bottom of the aircraft that cushions the landing and protects the payload. The advantage is that your payload isn't taking the beating that the deep stall landing would give it, but your accuracy is a little bit degraded, because if there's any sort of breeze or wind the aircraft tends to float off.

He continued: 'So, what Lockheed Martin has done, and what we continue to refine, is the glide landing. We find it provides the most precise landings in the environment that the UK MoD has asked us to provide aircraft to operate in, and our take-offs and landings don't require any additional apparatus. For recoveries, once the mission's complete, the aircraft will navigate itself over to the recovery point and come in for a glide landing.

'The goal of the Royal Artillery [the UK unit responsible for operating Desert Hawk III in-theatre] is to be able to land the aircraft within tight confines surrounded by a high wall, but when you're trying to land in an 80x50m area surrounded by a 5m wall, it's almost like a dog hopping into the back of a moving pickup truck.'

Since its initial development, the Lockheed system has undergone a series of refinements. These first led to the Desert Hawk I+ standard and are now incorporated in the current Desert Hawk III system. During 2011, the Autonomous Trim Landing (ATL) modification was rolled out across the fleet, and has helped increase landing accuracy. 'What ATL allows you to do is to make what were relatively precise landings even more precise with a little manual input,' explained Daly.

GAME CONTROLS

When landing a Desert Hawk III under ATL, many of the previous landing procedures remain the same. The aircraft still flies under GPS guidance to the pre-programmed recovery position and lands primarily under autopilot, but the operator is able to make adjustments during landing. The control pad – an off-the-shelf video game controller – is normally used only to operate the aircraft's sensors, but during ATL-assisted landings, it gives the user the ability to manipulate the control surfaces.

'Prior to the introduction of ATL, if you experienced wind gusts or there were obstacles in the way, you would potentially have some less-than-ideal landings,' admitted Daly. 'ATL provides quick manual inputs for real-time minor deviations, glide-slope corrections or line-up corrections.

'Our own testing shows it has improved accuracy immensely. And, quite frankly, it's saved money, it's saved aircraft, and no doubt it's saved lives, because now you're not having to put soldiers at risk to go out and retrieve ➤

The Desert Hawk III ground control station which aims to conduct 'glide' landings. *(Photo: Lockheed Martin)*

an aircraft that might not have landed as accurately as desired.'

Clues to possible future developments in Desert Hawk recovery were offered in 2012 when Lockheed acquired Procerus Technologies, manufacturer of the Kestrel range of UAS autopilots. These potential refinements could enable a more intuitive and precise landing procedure.

'We've got the option of providing a Kestrel autopilot for Desert Hawk, which provides increased precision when airborne, as well as precision landing capabilities,' Daly said. 'That could be combined with another Lockheed Martin Procerus technology called the Virtual Cockpit, which is a software suite that works alongside the Kestrel autopilot.

'As the aircraft is coming in, you have a situational awareness camera embedded in the wing looking forward – the aircraft uses that to see the landing area, and you can touch the screen and fine-tune exactly where the aircraft is going to be touching down.'

BIRD'S EYE VIEW

Of the small UAS that use the parachute method, arguably the most innovative is IAI Malat's Bird Eye family of aircraft. The parachute is deployed in such a way as to flip the airframe onto its back, ensuring the belly-mounted payload is on top of the vehicle when it hits the ground, protecting it from impact damage.

The top of the aircraft carries three antenna-like prongs, which, in the inverted landing mode, become landing gear, helping minimise damage to the airframe on impact and alleviating the need for additional inflatable cushioning.

The parachute is stowed behind a panel in the airframe, and the fairing remains attached to the parachute after deployment. Immediately on recovery, the parachute can be re-packed inside the fuselage, the fairing replaced and the aircraft readied for another flight.

The Bird Eye family has been in service for almost a decade, during which time there have been 'thousands upon thousands' of landings, according to IAI Malat's marketing manager Danny Bichman, with 'almost no damage to the payload during landing'. The concept, which permits safe and damage-free landings on any surface, was fixed from the outset and has remained a constant as the Bird Eye family of systems has developed.

'Of course, if you have a bigger or heavier aircraft, you need a bigger parachute,' he continued. 'Over time, we improved the parachute, improved the shock absorbers – the landing gear – so they'd be more flexible and better protect the UAV itself. But the concept stayed the same – we like it, the customers like it, it's very simple, very operational. We don't see a problem, so there's no need to change it.'

IAI claims that landing accuracy using its recovery system is comparable to that required in the FOB scenario Daly previously outlined. 'Normally, all you need to do is enter GPS co-ordinates and the landings will be within 50m of that point,' noted Bichman.

Increasing accuracy beyond this level has been considered, but introduces extra complications. Additional onboard equipment would increase the size and weight of the aircraft.

'You'd need to change the parachute, and you'd need to be able to control the parachute,' he added. 'We had ideas for this, but not on those kinds of parachutes and not for those kinds of UAVs. You'd need controls from the autopilot to the parachute, so we are not talking of those systems for mini-UAVs – maybe for bigger aircraft.'

PITCHING IDEAS

The third category of landing, the sudden pitch up, could ultimately be used on any UAS where the operator has control of the aircraft, but the most obvious – if counter-intuitive – way to get an aircraft to stop precisely is to fly it into an object capable of stopping it.

Some developers have used nets to catch small UAS, but one of the most ingenious solutions is that fielded by Insitu, with its ScanEagle and Integrator UAS being recovered by the company's SkyHook system, which involves flying the aircraft wing into a 15m vertical rope.

The rope and the leading edge of the wing tip slide along one another until the rope snags in a hook on the wing; the aircraft, its forward momentum spent, then hangs on the rope where it is retrieved by operators.

According to Ryan Hartman, Insitu's senior VP for Integrator systems: 'When we recover an aircraft using SkyHook, there's a big difference in what happens the heavier or faster the air vehicle is going. We've done a lot of work making sure that the air vehicle is absorbing as little of that energy as possible, which requires us to be more and more creative with the energy absorption with the SkyHook side.'

With ScanEagle, which the company first fielded in 2004, the recovery solution was developed in tandem with the airframe. Insitu began work on what became the SkyHook system after being approached by a group of potential customers in Seattle around 1999 who wanted to investigate the possibilities of using airborne surveillance from on board a fishing vessel to locate schools of tuna.

NET GAINS

'We looked at a lot of different technologies,' explained Hartman. 'Those included putting a small parachute behind the boat to hold a vertical rope, putting a parachute on the aeroplane, using nets and lots of other things. And what became very evident was that the recovery of a ScanEagle into a vertical rope made most sense, for several reasons.

'One is that you could hang a vertical rope off the side of a ship and recover the air vehicle without ever pointing the air vehicle at the ship itself, which automatically meant we were doing something safer than trying to recover an air vehicle onto the deck of a ship. From there, we started to look at how you would hang a rope off the side of a ship, and what became evident was that it needed to be some sort of crane.'

An example of the parachute-enabled landing for UAV retrieval. *(Photo: UAV Factory)*

The eventual solution involved adapting an off-the-shelf design produced by Genie and used as an elevated work platform, which proved to be the best option for combining the requirements of size and strength with limits on weight and cost. SkyHook can be supplied in a portable version attached to a trailer, or fixed permanently in place on board a ship. Through the years of development, the basic system has remained the same.

'We have implemented lots of improvements in how we do things, like the pay-out of rope on the SkyHook,' explained Hartman. 'Then, obviously there's some structural work that has had to be done on the aeroplane itself. We did lots of trade studies to understand what was necessary in maintaining the structural integrity of the air vehicle while suspending flight on the wingtip. Load management and how loads transition and transfer through the airframe was something that we had to gain a keen understanding of.'

ACCURATE RESULTS

What resulted was a recovery system capable of a very high degree of accuracy. The recovery involves flying the aircraft autonomously to a pre-planned location, and Hartman said the margin of error for where the vehicle will hit the rope is plus or minus 3cm.

'That means you can define whether you're going to recover on the left wing or the right wing, and if you're going to recover 1ft or 2ft from the wingtip,' he pointed out. 'The accuracy is maintained, even on board a ship where the SkyHook rope may be moving as the aircraft is on final approach, through software.

'We have a system aboard the ship which provides information to the air vehicle about ship motion,' continued Hartman. 'We can adjust the recovery point in real time. We define the point on the wing where we want the rope to impact, and that's the moving baseline – the air vehicle responds to where the rope is going to be, so as to impact the rope where we want it to.

'Of course, that error margin grows with motion, but the air vehicle still attempts to recover within that plus or minus 3cm location. It's all about closed-loop communication methodologies in the recovery algorithms, and the air vehicle's ability to respond to that.'

The obvious downside to the SkyHook system is the size and weight of the equipment required. While Insitu stress the catapult-launched ScanEagle's deployability, it is an entirely different proposition to Desert Hawk III, which can be carried by one man in a backpack and requires no launch or recovery apparatus. And while maritime customers – now including the Royal Navy – clearly feel the high accuracy and flexibility of recovery is worth the trade-off in additional weight carried on board a ship, Insitu is still working at size and weight reduction.

'I don't think it's as good as it's going to get,' concluded Hartman. 'We're constantly learning and improving our design. We'll be looking to improve both the reliability and the effectivity of the SkyHook methodology, and we'll continue to make it better. There is no better way to recover a UAV, period – we've proven that with 700,000 combat flight hours and many tens of thousands of shipboard hours and recoveries. But we know we can continue to make it better.' UV

Improving initiations

US Army programme managers explain to **Scott R Gourley** how the service is expanding simulator training in order to enhance operator proficiency.

With recent requirements to drawdown assets in-theatre and the pending reduction in live flight operations, US Army UAS planners are committed to maintaining the highest levels of fidelity and crew proficiency.

During the first half of 2013, the army's UAS Medium Altitude and Endurance (MAE) Product Office made a concerted effort to bolster operational support by completing a series of visits to deployed Gray Eagle units on Operation *Enduring Freedom*. In January, key members of staff were deployed to bases in Afghanistan and interacted with a range of personnel to identify the strengths and weaknesses of the system and implement any corrective actions needed.

EXPERIENCE MATTERS

'A recurring theme across the deployed units is the initial low experience level of the average Gray Eagle operator,' acknowledged Jeff Crabb (pictured left), deputy product manager in the UAS MAE Product Office.

'During initial training [at Fort Huachuca, Arizona], operators learn how to plan and analyse flight missions; perform pre-flight, flight, post-flight checks and procedures; payload operations; interpret RSTA data; communicate with ATC; communicate via the Warfighter Information Network – Tactical system; and other critical skills involved in UAS operations. However, due to course length little time is dedicated to preparing operators for manned-unmanned teaming [MUMT] operations.'

He continued: 'Upon graduation from initial individual training, UAS operators are assigned to a unit and receive Gray Eagle System Equipment Fielding and New Equipment Training [NET]. The unit training includes: extensive simulator/simulations work and around 255 flights or 1,000 flight hours, with emphasis on readiness level progression, doctrine and tactics training, including Gunnery Tables I-VI and collective training.

'The PM MAE NET also leverages the UAS – Tactical Trainer [UAS-TT] to help mitigate the lack of crew experience in TTPs. With the continued support through development and strategies, Gray Eagle companies will help establish and implement MUMT training and TTPs that will be used throughout the army.'

According to Maj Voyed Couey (pictured right), assistant product manager in the Ground Maneuver (Shadow) Office, the UAS-TT mission simulation training device 'provides "video game-generation" soldiers with interactive, real-world situations in a familiar setting'.

He told *Unmanned Vehicles:* 'The operators have stated that the UAS-TT provides some of the best training that they receive. They actually have fun training, and the simulation provides a tactical advantage by simulating missions prior to combat deployments.

'With the universal operator concept in mind, PM UAS has also developed a Universal Mission Simulator [UMS] using progressive technologies, creating a simulator with the highest fidelity. These training environments allow commanders a fixed or mobile virtual environment to effectively progress their operators and crews from individual qualifications, to proficiency in MUMT and... the full integration of UAS assets as part of a combined arms team.

'The premise was that the use of a high-fidelity simulator both in the schoolhouse and at the unit would produce a young operator current and capable and also sustain that operator at a unit level, exceeding the limitations of the current training model.'

The UMS trainer facilitates training crew members for operations in GCS and allows a unit to execute realistic operational MUMT mission profiles without restrictive live-fire ranges or airspace constraints in a high-fidelity (form, fit, function) environment.

ADDED REALISM

'UAS simulators accurately represent and correctly display all available manned and unmanned aircraft, data link, payload, weapons, automatic take-off and landing systems and aircraft subsystem responses to failure and emergency conditions,' added Couey, noting that tactical radio communications are simulated 'utilising an appropriate radio simulation that does not limit live radio communications, as well as an army-approved Internet relay chat capability. It also provides a high-resolution visual scene for realistic payload operations.'

With the first fielding to Dugway Proving Ground in support of the Shadow Initial Key Personnel Training, PM UAS is moving forward in its preparation to field over 100 systems to the warfighter.

'The UMS is a success,' said Crabb. 'It is the stepping stone to the new Universal Ground Control Station training for Shadow, Gray Eagle and Hunter. It provides the army with a standalone UAS trainer/simulator for our tactical platforms and is a cost-efficient alternative, ensuring UAS operators remain proficient and prepared in the event of forward deployment.' **UV**

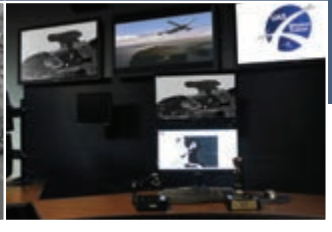
mission ready

It's true… as a global leader in modeling, simulation and training, CAE is applying its expertise and partnering with original equipment manufacturers (OEMs) to support unmanned aerial systems (UAS) mission training.

As UASs take on a growing role, defence and security forces understand the need for more robust and capable mission training solutions. We are focusing on the training required by the mission team – including the pilot, payload specialist and mission commander. We have partnered with OEMs such as General Atomics Aeronautical Systems (GA-ASI) to develop comprehensive training systems for platforms such as the Predator® B/MQ-9/Reaper, Predator C Avenger®, and Predator XP. Our solutions are non-proprietary, flexible, adaptable and interoperable to enable distributed mission operations. Our simulation technology leadership in areas such a sensor simulation, weapons effects, computer-generated forces, artificial intelligence, common databases and true fidelity modeling – combined with our training systems integration expertise – come together to help our customers stay one step ahead and prepare the UAS mission team for mission success.

Come visit CAE's booth (Booth 2526) at AUVSI 2013 to see a demonstration of our UAS Mission Trainer and to learn more about CAE's commercial ISR services using unmanned systems.





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