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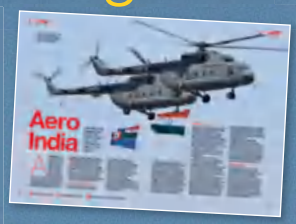

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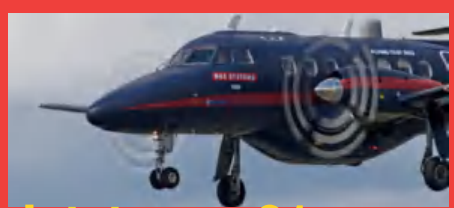

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• CONCEPT • INNOVATION • OPERATION

NEW!

BOEING 747




Produced by the industry-renowned team behind *Airliner World*, **Boeing 747** charts the development of the first widebody, an aircraft that brought air travel to the masses. With superbly illustrated articles paying tribute to the Queen of the Skies, this 100-page publication tells the story of one of the world's most iconic commercial airliners from the inside, through the people who fly it and the passengers it carries.

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LM-100J Rolls Out

The Lockheed Martin LM-100J, the civil version of the C-130J Hercules transport, was recently rolled out at the Marietta, Georgia, factory. After completion of its flight test programme, Lockheed Martin intends to have the LM-100J certified for commercial operation by the US Federal Aviation Administration. The LM-100J is a follow on to the L-100 civil Hercules, 115 of which were built between 1964 and 1992. To enhance exportability and reduce weight and cost, all military mission-specific features have been removed from the LM-100J. These include the lower cockpit windows (used for aligning on drop zones) and provisions for military electronics or air evacuation stretchers. Lockheed Martin has said these changes could reduce the unit cost of an LM-100J to $60–70 million from some $100 million for a military C-130J. China is considered a possible market for the LM-100J, including oil spill dispersion and environmental monitoring missions. However, despite changes in US export regulations under the Obama administration, it remains uncertain whether an LM-100J export licence to China would be granted. *David C Isby*

S-Plane to Make EG-15 Pilot-Optional

The German Stemme AG Ecaryrs EG-15, a single-engine aircraft with an 18m (59ft) wingspan intended for high altitude civil sector survey and surveillance missions, will receive an optionally piloted capability. This will be developed through a joint programme with South Africa-based S-Plane Automation, it was announced at the IDEX defence exhibition in Abu Dhabi in February. The capability will be based on the current S-Plane x-Kit system, intended to provide an optionally piloted capability for existing light aircraft. *David C Isby*

UPS Truck-Launched UAV

The United Parcel Service (UPS) announced on February 23 the experimental launch and recovery of a parcel-delivery unmanned air vehicle from the roof of an unmanned and electric-powered version of one of its familiar chocolate-brown delivery trucks. The test took place in Tampa, Florida.

The Ohio-based Workhorse Group built the HouseFly UAV and the delivery truck as an integrated unit using electric/hybrid power. The HouseFly is an octocopter design, capable of 30 minutes' endurance and delivering 10lb (4.5kg) packages in an underslung basket. On recovery, the basket extends inside the truck, allowing it to be reloaded for the next delivery. *David C Isby*

MAX Milestones

The first Boeing 737 MAX 9 N7379E (c/n 42987) at Renton on the day of roll-out. *Marian Lockheart/Boeing*

Boeing rolled out the initial 737 MAX 9, N7379E (c/n 42987), at Renton on March 7. This is the largest MAX variant to be developed to date. Its first flight was due to take place a few weeks later, after the completion of ground tests and engine runs. The first delivery is due in 2018 following certification testing.

This isn't the only recent milestone in the MAX programme. Two days after the MAX 9's roll-out the 737 MAX 8 received US Federal Aviation Administration Type Certification. Separately, Boeing confirmed during the ISTAT Americas conference in San Diego that it is working a proposed new addition to the family, the 737 MAX 10X. A Boeing statement to AIR International said: "Boeing is studying a new stretched variant. It would offer customers increased capacity [and] the lowest seat costs ever for a single-aisle aircraft. Boeing is actively engaged in discussions with customers about the 737 MAX 10X and has extended business offers in some cases."

A presentation during ISTAT by Boeing Commercial Airplanes Vice-President Marketing Randy Tinseth claimed the 737 MAX 10X would have 5% lower trip costs and 5% lower costs per seat than the Airbus A321neo, its direct competitor. If Boeing's board approves the variant a formal launch could happen later this year. Should it be developed, the MAX 10X would follow the MAX 200 and MAX 7 in the development pipeline with service entry around 2020, Tinseth said. *Mark Broadbent*

COVER CREDITS *MAIN IMAGE: Piotr Butowski LEFT INSET: Roberto Yanez MIDDLE INSET: Derek Pedley RIGHT INSET: Chinese internet*

E195-E2 Emerges

Early March saw Embraer present the first E195-E2, which at 41.5m long is the longest E-Jet E2. *Embraer*

Embraer presented the first E195-E2 at its Sao José dos Campos factory near Rio de Janeiro on March 7. The E195-E2 is the largest E-Jet variant and is scheduled for its first flight "in the coming months", the company said, ahead of service entry in the first half of 2019.

Embraer says the E195-E2 will have a 20% lower trip cost and a comparable seat cost to similar-sized aircraft. Having three additional seat rows from the current E195 the E2 will be able to seat 120 passengers in a two-class layout or 146 in single-class. Its range will be 2,450 nautical miles (4,537km), 450 nautical miles (833km) more than the current generation aircraft. It will burn 24% less fuel and have 20% lower maintenance costs than the current jet, Embraer says.

The E195-E2 rolled out is the first of two examples that will be used for certification testing. The first prototype will undertake aerodynamic and performance tests and the second, which will fly by the end of 2017, will be used to validate maintenance tasks and the interior. *Mark Broadbent*

Mwari

Paramount Group is putting its advanced high-performance reconnaissance light aircraft (Ahrlac) into production at a new facility at Wonderboom airport, South Africa in April this year. The 15,000m^2 facility will produce the unarmed Ahrlac, which will be outfitted with mission systems at a separate facility for conversion to the militarised Mwari. Paramount's Wonderboom facility has capacity to manufacture two aircraft a month, and up to four if necessary. Paramount promoted the Mwari at the recent IDEX defence exhibition in Abu Dhabi, where it attracted interest from delegations from Abu Dhabi, Colombia, Greece and others. Paramount hopes to expand its presence in the Middle East, particularly with the Mwari, offered as a cheaper option than a helicopter and with greater speed and range.

The first prototype, registration ZU-XDM, has accumulated over 250 hours of flight testing since its first flight on July 26, 2014, including deployments to locations along South Africa's borders, and in Botswana, where remote operations and hot and high flying were tested. ZU-XDM is fitted with an electro-optical turret, an Avni thermal imager and other sensors, while the second prototype ZU-ADM, which is nearly complete, will have a full mission system, conformal fuel tanks and weapons, including Mokopa missiles. Under a partnership announced in 2016, Boeing is supplying the mission system. *Guy Martin*

Paramount is keen for collaborative production of the Mwari in the UAE and other countries in the region. Although not confirmed, Paramount is believed to have at least one launch customer for the Mwari. Paramount

Goodyear Blimp Retires

An era in Goodyear Airship operations recently ended with the retirement of GZ-20A Spirit of Innovation at the company's blimp base in Carson, California. The public was invited to get up close and personal with the airship, a rare occurrence. The Spirit of Innovation, N4A, was named in June 2006 and is the last of its type. Innovation's last flight was for the Academy Awards/Oscars in Hollywood on February 25. At the time of writing, it was still being finalised where the decommissioning would happen. The sight of the GZ-20 over southern California will be missed, but a second new semi-rigid model, the Wingfoot Two, is due to arrive at the end of 2017. Ground has been broken for a new landing pad and hangar with a unique inflatable design. No final decision has been made on what will happen to the GZ-20A's gondola, but it could be loaned to a local aviation museum. *Damon Duran*

Dash 10's De

The 787-10's length compared to the other Dreamliners is apparent in this photo. The variant is 18ft (5.4m) longer than the 787-9 and nearly 60ft (18m) longer than the 787-8. All photos Boeing

Nearly a decade after the Boeing 787's public bow, the first 787-10, N528ZC (c/n 60256), was rolled out at the Boeing South Carolina plant in North Charleston on February 17.

It was a big day for the factory. Although the facility produces the 787-8 and 787-9 alongside the other Dreamliner assembly site at Everett in Washington, the new Dreamliner variant will be produced exclusively in North Charleston.

The jet's roll-out was therefore a moment in the spotlight for Boeing South Carolina, a feeling only reinforced by the attendance of Donald Trump. For the new US President, the 787-10's public debut was a good opportunity to highlight one of his key messages, boosting American jobs – even if the interconnectedness of the aerospace industry means the 787-10 is far from a solely American-produced aircraft, with extensive involvement of overseas suppliers.

The 787-10's first flight was due to occur a few weeks after roll-out. Following flight testing and certification, the variant is scheduled to enter service with launch operator Singapore Airlines in 2018.

Development

The 787-10, a stretch of the 787-9, was launched by Boeing at the Paris Air Show in 2013 following two years of conceptual studies and consultations with customers. Firm configuration was completed in April 2014 and detailed design in December 2015.

Boeing partner Kawasaki Heavy Industries at Nagoya in Japan installed the first circular frames into Section 43 (the mid-forward fuselage section) for N528ZC two weeks ahead of schedule in March 2016. Kawasaki also produces the aircraft's wing box.

These subassemblies and Sections 44 and 46 (respectively the mid-centre fuselage sections fore and aft of the wings, which are made by Leonardo in Italy) were transported by Boeing 747-400LCF Dreamlifter to North Charleston. Other parts that arrived at the plant from supplier factories were Section 41 (the nose, from Spirit AeroSystems in Wichita) and the horizontal stabilisers (from Leonardo in Foggia and Boeing Fabrication in Salt Lake City, Utah). Sections 47 and 48, the centre-rear and aft fuselage sections, were produced at North Charleston by Boeing South Carolina.

All About Capacity

Boeing orders and deliveries data shows that at the time of the 787-10's roll-out there were 512 Dreamliners in service. The type is now used on 530 routes and 140 million people have flown on it.

How does the 787-10 fit into the Dreamliner family? Boeing classifies the 787-10 as a medium widebody (a category it defines as 300 to 450 seats); the 787-8 and 787-9 are classed as small widebodies (a category covering 200 to 300 seats).

Broadly speaking, the concept is that while the 787-8 is intended for initial route development and the 787-9 for adding new connections with its longer range, the 787-10 is optimised to maximise capacity on established routes: for example, network airlines' services between Europe and Asia, Europe and North America and within Asia.

The 787-10 will be able to seat up to 330 passengers in a typical two-class layout, nearly 14% more than the 787-9's 290 passengers and 36% more than the 787-8's 242 passengers. The variant's 6,200ft^3 (175m^3) total cargo volume is 41% bigger than the 787-8's and 15% more than the 787-9's.

Longest 787

The 787-10 is the longest Dreamliner. At 224ft (68.27m), it is 18ft (5.4m) longer than the 787-9, which is 206ft 1in (62.81m) long, and nearly 60ft (18m) longer than the 165ft-long (56.72m) 787-8. The extra length comes from two extra fuselage plugs.

With the 787-10 configured for capacity, it can't fly quite as far as its stablemates. Its 6,430-nautical mile (11,910km) range is 925 nautical miles (1,713km) less than the 7,355 nautical miles (13,623km) the 787-8 can fly and 1,205nm (2,231km) less than the 7,635 nautical miles (14,140km) capability of the 787-9. Despite that, Boeing says the 787-10 will still be capable of flying more than 90% of the long-haul routes today served by twin-aisle aircraft.

ebut

Longer and with more capacity – the third, and largest, Boeing 787 variant has recently been unveiled. Mark Broadbent reports

In addition, Boeing claims the 787-10 will burn 25% less fuel than previous-generation twin-aisle widebodies and offer per-seat fuel burn reductions of 10% from the Airbus A350-1000, its principal competitor, and 30% from the legacy A330.

Commonality

Bob Whittington, Chief Engineer for the 787, told AIR International in 2015 the 787-10's longer fuselage had led to small changes to the landing gear and tailfin, and the addition of more air conditioning packs to cater for the extra passengers aboard.

However, he added: "It's a very common aircraft, and operators who use the 787-8 and 787-9 will see no difference." The 787-10's wingspan and height is the same as the other variants and it will have the same 560,000lb (254,000kg) maximum take-off weight as the 787-9.

BOEING 787-10 ORDERS AND COMMITMENTS

Air France-KLM Group: *7*
Air Lease Corporation: *25*
All Nippon Airways: *3*
British Airways: *12*
Etihad Airways: *30*
EVA Airways: *18*
GECAS: *10*
Singapore Airlines: *49 (30 firm, 19 purchase commitment)*
United Airlines: *14*
Total: *168*

Data correct to February 2017

Boeing says there is 95% commonality between the 787-10 and the 787-9, which for customers operating both variants should produce savings in operations, spares, maintenance and training. The big manufacturers – Airbus as well as Boeing – try to maximise commonality between the variants in each of their aircraft families and also between different models in their product ranges.

What the 787-10 brings to the Dreamliner product range in seating, range and payload is designed to complement the capabilities of the 787-8 and 787-9 and the larger 777 and 777X. The intention is to give customers different options across the entire widebody aircraft market.

Market

Many large airlines have embraced this concept of having multiple aircraft types that have complementary capabilities. All the customers in the 787-10 order book already operate other 787 variants or 777s or, in most cases, both Dreamliners and Triple Sevens.

Is a backlog of 149 firm orders in the four years since launch all that impressive, though? Despite the recent boost of Singapore Airlines signing a purchase commitment for 19 787-10s on top of the 30 it has on firm order, the sales pace for the 'Dash Ten' has clearly been sedate. There weren't any orders or commitments at all in 2016.

However, aircraft ordering is cyclical due to wider factors. Falling oil prices have meant orders for the new generation of more fuel-efficient widebody airliners have slowed over the past couple of years. (There are only 211 aircraft in the backlog of the 787-10's rival, the A350-1000.)

Boeing nevertheless remains confident about the 787-10's potential. Its latest annual Current Market Outlook, released in July 2016, unsurprisingly paints a positive long-term forecast. It predicts a market for 3,470 new medium widebodies from now to 2034. (Not all those aircraft will be 787-10s because Boeing also puts the 777 into this classification.)

The company believes the greatest demand for medium widebodies lies in the Asia-Pacific region, estimating requirements for 1,490 such aircraft there, followed by the Middle East (850 aircraft). Emirates is a major potential buyer. The Dubai airline has been evaluating the 787-10 and A350 for some time in advance of a major fleet replacement decision.

It's this area, fleet replacement, where the 787-10 could score in the long term. Its seating and payload/range configuration position it for the 777-200, 777-200ER, 777-300 and older A330-300 replacement markets. At the time of the variant's launch four years ago Steven Udvar-Hazy, the Chief Executive of Air Lease Corporation, predicted the 787-10 would be one of the best-selling commercial jetliners "for decades ahead".

Time will tell, but for now the Dreamliner family has another member.

BOEING 787-10 CHARACTERISTICS

Wingspan: *197ft (60m)*
Length: *224ft (68m)*
Height: *56ft (17m)*
Cross-section: *18.8ft (5.7m)*
Max take-off weight: *560,000lb (254,000kg)*
Seating: *330 passengers*
Cargo volume: *6,200ft³ (175m³)*
Cruise speed: *Mach 0.85*
Range: *6,430 nautical miles (11,910km)*
Data: *Boeing*

Below: ***Service entry of the 787-10 is due with Singapore Airlines in 2018.***

All In

Roberto Yáñez and Alex Rodriguez tell the story of the first Ejército del Aire Typhoon transatlantic deployment to Exercise Red Flag

After an eight-year absence, this past August the Ejército del Aire once again participated in Exercise Red Flag, when it sent eight EF-18Ms and two KC-130H Hercules tankers to Nellis Air Force Base.

Six months later and while the results of the previous deployment were still being studied, eight Eurofighter Typhoons departed Morón Air Base near Seville on February 18 bound for Red Flag 17-2, the first time Spanish Typhoons have participated in the US Air Force's premier air exercise. The Typhoon entered Ejército del Aire service back in 2004.

Despite speculation that Spanish Typhoons would participate last year, the decision was made to attend this year, because the aircraft has now reached a sufficient maturity with both operating units, Ala 11 based at Morón and Ala 14 based at Albacete, to gain an optimal level of training in both air-to-air and air-to-ground missions.

Execution and evaluation of the Typhoon's air-to-ground capabilities during Red Flag 17-2 is the principal reason for the debut attendance.

In preparation for the exercise one month before flying to the United States, both units dropped live air-to-ground weapons at the Bardenas Range, near Zaragoza. Aircraft from both Morón and Albacete undertook inflight refuelling missions with an Aeronautica Militare Italiana KC-767A while the tanker was detached to Albacete to support course 17-1 of the NATO Tactical Leadership Programme.

Spain's Mando Aéreo de Combate (MACOM or Air Combat Command) had responsibility for planning, directing and executing the deployment and participation of the units involved in the air exercise. (Red Flag 17-2 took place at Nellis between February 27 and March 10.) MACOM's objective was to improve advanced training for both Typhoon units and is responsible for conducting post-exercise analysis.

Dubbed Agrupación Aérea Expedicionaria Red Flag 17-2 (AA-EXP RF 17-2), this Air Expeditionary Task Force was formed to operate outside of Spanish

Top Right: ***Two Ala 11 Typhoons in formation near Morón Air Base, Seville.***
Below: ***Albacete-based Ala 14 flew 40 sorties, all air-to-air missions.***
Right: ***111 Escuadrón, one of two Typhoon units assigned to Ala 11, participated in Red Flag 17-2 with five aircraft and conducted mostly air-to-ground missions.*** *All photos Roberto Yáñez unless otherwise stated*

national airspace in a complex theatre of operations with a high threat laydown as part of an international coalition.

Red Flag also served to train MACOM's General Staff in planning and administering multiple operational, logistical, command and control tasks needed to operate the Expeditionary Task Force.

The operation was divided into four phases.

Phase 1 commenced on February 15 with activation of the Air Expeditionary Task Force and staging of the participating Typhoons, spare and support aircraft, and the general briefing for the exercise.

A day later, Phase 2 began with the deployment of 22 personnel to Nellis charged with receiving the task force and prepositioning three KC-130H Hercules at Lajes Air Base in the Azores. At the same time, two Aeronautica Militare Italiana KC-767A tankers arrived at Morón to accompany the Typhoons on the various stages of the trip to Nellis. On February 18, one of the three Hercules pre-positioned at Lajes left for Bangor, Maine; the other two remained there with the support team awaiting the arrival of

Before taking part in Red Flag 17-2 Spanish Typhoon pilots from Ala 11 and Ala 14 undertook air refuelling training with an Italian KC-767A. *Below:* ***Tranche 3 Typhoon serial number C.16-63 - 10048/11-28 was only recently delivered to the Ejército del Aire.*** *Bottom:* ***An Italian KC-767A in formation with three Ala 11 Typhoons over the United States on the way to Nellis.*** *Ejército del Aire*

10 Typhoons (two of which were spare jets) and the accompanying KC-767As.

Providing search and rescue (SAR) coverage for the Atlantic crossing to Bangor on February 19 were a Grupo 22 P-3 Orion and two CN235 VIGMA aircraft. Two groups of aircraft, a KC-767 and four Typhoons, arrived at Bangor for a refuelling stop before heading south to Naval Air Station Norfolk, Virginia. All three KC-130s also arrived at Norfolk via different refuelling stop destinations.

All three SAR aircraft returned home on February 20 after completing their mission without incident, the P-3 from Bangor and both CN235s from Lajes. That day,

all eight Typhoons, both KC-767s and the three Hercules arrived at Nellis after direct flights from Norfolk. Further support aircraft involved an Armée de l'Air A400M and a 45 Grupo Airbus A310.

Between February 21 and 26, Typhoon and Hercules pilots conducted 24 familiarisation and integration flights with other participants.

Phase 3 was the live exercise and Phase 4 the redeployment that started on March 10 and concluded four days later when the entire task force arrived back in Spain.

EJÉRCITO DEL AIRE PARTICIPANTS

Unit	*Pilots*	*Maintenance and support personnel*	*Aircraft*
Ala 11	16	110	5
Ala 14	9	37	3
Ala 31	12	17	2

For the first time, Ejercito del Aire Typhoons overflew Naval Base Norfolk on their way to nearby Naval Air Station Norfolk. *Ejército del Aire*
Bottom: ***The Aeronautica Militare supported the Ejército del Aire's Red Flag operation with two KC-767A tankers for the deployment and redeployment phases. Retirement of 47 Grupo's Boeing 707TT has seriously hampered the Ejercito del Aire's strategic projection capability, so it's common to enter into agreements with other countries for tanker support.***

An additional 28 military personnel drawn from the Escuadrón de Apoyo Operativo a la Guerra Electrónica (Electronic Warfare Operational Support Squadron) based at Torrejon Air Base, Ala 15 at Zaragoza, Ala 46 at Gando, the Segundo Escuadrón de Apoyo al Despliegue Aéreo (2nd Aerial Deployment Support Squadron) from Zaragoza, Grupo 22 from Morón, Mando de Apoyo Logístico (Logistics Support Command) and MACOM undertook support duties in exercise Red Flag 17-2.

Thirty individuals formed the exercise control group responsible for tracking and analysing results of the exercise and evaluating the missions against the planned training objectives.

Ejército del Aire aircraft and personnel took part in two daily flying periods, one daylight (from 11:00hrs to 02:00hrs the next day) and a night-time period (from 18:00hrs to 08:00hrs the next day). Daily operations spanning 21 hours necessitated a two-shift manning system for the exercise centre, from where Spanish personnel were able to track in real time the 124 sorties planned for Ejército del Aire aircraft during two-week exercise. Sorties comprised 54 air-to-air, 60 air-to-ground, eight air refuelling and two tactical airlift.

As Spain's most experienced Typhoon unit, Ala 11 was tasked with flying the greater number of sorties, undertaking 80% of its missions in the air-to-ground role, while the remaining were air-to-air missions. Albacete-based Ala 14 dedicated all of its 40 sorties to the air-to-air role, because its air-to-ground capabilities are still being implemented.

Above: ***Ejército del Aire pilots walk to their aircraft for the first leg between Morón and Lajes.***

Oregon Snow Birds

Oregon Air National Guard's 173rd Fighter Wing based at Kingsley Field in Klamath Falls has painted F-15C 79-0041 in a bright colour scheme to mark the 75th anniversary of the Oregon Air National Guard. The jet was one of five Kingsley Field-based Eagles deployed to Luke Air Force Base, Arizona in late February to take advantage of the mild winter climate. Fighters that deploy to Arizona from bases in the northern United States for training during the winter months are colloquially referred to as snow birds. Kees van der Mark

All in the Numbers

The Singapore Government will order 16 Airbus Helicopters H225M Caracals and 10 Boeing CH-47F Chinooks, all of which will be delivered from 2020. Although the Ministry of Defence announced the order last November, numbers were not specified and were only revealed in the latest Stockholm International Peace Research Institute arms transfer database, released in late February 2017. The same report also revealed that the two additional Sikorsky S-70B Seahawks ordered in 2013 have been delivered.

The CH-47F Chinooks will eventually replace six CH-47Ds based at Dallas-Redmond Taylor Army Helicopter Port in Texas for the Peace Prairie detachment, while the four additional CH-47Fs might be based at Oakey in Australia where the Republic of Singapore Air Force operates a training detachment for its AS332 and AS532 Super Pumas. The 16 H225M Caracals will eventually replace two squadrons of 32 Super Pumas.

Triton Conversion

At a cost estimated at $116 million, the US Navy is to convert a Northrop Grumman MQ-4C Triton UAV developmental test aircraft to LRIP Lot 2 configuration.

Once reconfigured, the aircraft will take part in the MQ-4C initial operational test and evaluation, which is expected to start in FY2021 using Integrated Function Capability (IFC-4) software that enables multiple-intelligence capability and the use of a signals intelligence package designed as a replacement system of the US Navy's EP-3E Aries II. Flight testing of the modified IFC-3 software, the version to be used by a two-vehicle force with early operational capability in FY2018 should start this year. Previous flight testing and an operational assessment in December 2015 used IFC-2 software. *David C Isby*

A-10 Retirement Decision Postponed

The US Air Force will not decide on the future replacement of its force of Fairchild A-10 Thunderbolt II attack aircraft until FY2021, the date put forward for a replacement decision since 2015. Previous plans for a near-term A-10 retirement encountered congressional opposition. With the first divestments on hold until 2021, at least some A-10 units are likely to remain operational through the 2020s.

Speaking in Washington DC on February 7, Air Force Chief of Staff General David Goldfein said the US Air Force will consult with the Department of Defense and the other services before deciding on what the way forward will be for capabilities required to carry out the close air support (CAS) mission: "Air Force thinking has moved away from a single A-10 replacement. We'll get this right if we can move from a platform discussion to a family of systems discussion."

General Goldfein identified a family of systems approach not as being limited to a specialised CAS platform or multimission fighters (Lockheed Martin F-35 Lightning II), but rather as including terrestrial weapons (long-range rocket launchers), helicopters (AH-64 Apache), unmanned combat air vehicles (General Atomics MQ-9 Reaper) and bombers (Rockwell B-1B).

Currently, A-10s are carrying out a high operational tempo. In early 2017, the A-10 had the highest mission-capable rate – 74% – of any US Air Force tactical aircraft. In its FY2017 budget request, the US Air Force put the cost of retaining the A-10 through 2021 at $3.4 billion. All operational A-10s now have the helmet-mounted integrated targeting modification, reducing target-acquisition time. A-10 cockpits are currently being modified with a high-resolution centre display. This allows pilots to view high-definition imagery generated by targeting pods. It remains uncertain how the FY2021 date will affect existing plans for Indiana Air National Guards' 122nd Fighter Wing to convert from A-10s to the F-16 in 2018. *David C Isby*

Tiger Style

Fighter Composite Squadron 13 (VFC-13) 'Saints' based at Naval Air Station Fallon, Nevada operate a fleet of F-5N Tiger IIs in a variety of aggressor colour schemes. The squadron provides adversary support to the Naval Air Forces. F-5N BuNo 761544/AF05 painted in a two-tone grey tiger-style colour scheme seen at Fallon in mid-February. Dan Stijovich

HH-60W Test Aircraft

The US Air Force will build five test versions of the Sikorsky HH-60W Combat Rescue Helicopter (CRH) before building the first of its $9.8 billion 112-aircraft production order. On January 31, Sikorsky announced the five new helicopters were added to the programme under a $200 million option added to the current engineering, manufacturing and development contract awarded to Sikorsky in June 2014.

Work on the test helicopters is due to start this year, with deliveries starting in 2018 and flight testing in 2019. The five helicopters will also be used for initial operational test and evaluation. A CRH programme critical design review will take place this year; first production aircraft is to be delivered in 2021, with full-rate production being achieved in 2023. *David C Isby*

KC-46 Lot 3

Fifteen more KC-46A Pegasus tankers have been ordered under a $2.1 billion contract as low-rate initial production (LRIP) Lot 3, Boeing announced on January 27. These aircraft are expected to be delivered by 2019. The KC-46A programme, along with the Lockheed Martin F-35A Lightning II and the Northrop Grumman B-21 Raider bomber, is among the Air Force's top procurement priorities, and has been specifically authorised to increase production rates, despite the current continuing resolution that would normally be capped at previous levels.

This order follows contracts for two previous LRIP lots announced in August 2016. At that time, following the completion of its second operational assessment, the KC-46A passed its Milestone C review, clearing the way for transition to full-rate production.

Challenges in the KC-46A's development have forced Boeing to absorb an anticipated total of $2 billion to $3 billion in costs under the terms of the $4.9 billion fixed-price development contract signed in 2011. The cost to Boeing increased by some $300 million in January and is still increasing.

Boeing is obligated under the 2011 contract to have 18 KC-46As (configured for boom refuelling only) delivered to the US Air Force by August 2017. Boeing has said the last of these aircraft would be delivered five months late, in January 2018. Four flight test aircraft have currently logged some 1,500 flight hours. The next upcoming hurdle for the KC-46A is the start of initial operational testing and evaluation (IOT&E). Originally scheduled for April 2017, IOT&E may have to be postponed, due to earlier setbacks in development. Testing of KC-46A vulnerability for electromagnetic pulse has been scheduled for April 2017. *David C Isby*

Japanese F-35As at Luke

Japan Air Self Defense Force F-35As 79-8703 (c/n AX-03, FMS 14-5116) and 79-8704 (c/n AX-04, FMS 14-5117) on approach to Luke Air Force Base, Arizona, during a joint mission on February 24. Four Japanese F-35As were built by Lockheed Martin in Fort Worth, Texas, and have all been delivered to Luke, with AX-03 joining the 944th Fighter Wing in late January and AX-04 in mid-February. Aircraft AX-04 is the last Lightning II built in low-rate initial production Lot 8. The remaining 38 Japanese F-35As (c/n AX-05 to AX-42) will be assembled at the Mitsubishi Heavy Industries Final Assembly and Check-Out facility in Nagoya, Japan. *Kees van der Mark*

AGM-88E Setback

The US Department of Defense's Director, Operational Test and Evaluation (DOT&E) determined the US Navy's Raytheon AGM-88E Advanced Anti-Radiation Guided Missile (AARGM) was neither operationally suitable nor effective after Block 1 operational testing (OT) was prematurely terminated by DOT&E in 2016. This information was published in the DOT&E Annual Report released in January.

The AARGM is a follow-on to the AGM-88B/C High-Speed Anti-Radiation Missile, designed to hit switched-off radars, using digital anti-radiation homing, a GPS, millimetre wave guidance and a weapon impact assessment transmitter. The AGM-88E AARGM is employed by Boeing F/A-18 Hornet and Super Hornet and EA-18G Growler aircraft.

Following the decision to halt OT in 2016, the Naval Air Systems Command (NAVAIR) reviewed the programme and directed that developmental testing continue. NAVAIR will release the Block 1 Upgrade software to the fleet in 2017 without completing OT and according to the DOT&E Annual Report, "without adequately addressing the numerous performance reliability, and software stability problems discovered during Block 1 Upgrade testing". The DOT&E also noted in its report, the upcoming AARGM Extended Range version, "is currently based on the Block 1 Upgrade weapon and will require extensive work to correct the accuracy, reliability and software deficiencies discovered during Block 1 testing."

Disputes between the DOT&E and service programme offices responsible for developing aircraft and weapon systems have been commonplace. From the language in the annual report, this one seems to have been particularly heated. Whether the AARGM Block 1 will prove operationally effective in fleet service remains to be seen. *David C Isby*

Singapore CH-47

Republic of Singapore Air Force 127 Squadron 'Stallion' is celebrating 20 years of CH-47 Chinook operations this year and has painted commemorative markings on an upgraded CH-47SD featuring a glass cockpit, radar warning receivers and a radome housing a secure datalink. The ten CH-47SDs based in Singapore will be upgraded to lengthen their service life, the first having been seen in May 2016. Six older CH-47Ds assigned to the Peace Prairie detachment based at Dallas-Redmond Taylor Army Helicopter Port in Texas will be replaced by an unspecified number of CH-47F Chinooks. *Republic of Singapore Air Force*

Airpower, Politi
Turbulence in V

by David C Isby

For an aircraft to fly, it requires three things: lift, thrust and money. Lift and thrust can be designed in – they're what wings and engines are for – but for any military aircraft, money has to come from the government. The government, in turn, has to get the money from taxpayers.

It's easy to talk about getting money for airpower. It's hard to actually get money. Congress decides how much to spend and where it will be spent, even though the Department of Defense submits a detailed annual request, which this year is yet to appear. It is harder still to turn money into airpower represented by aircraft on flight lines, proficient aircrew and combat-capable squadrons. Even the United States, with the world's largest economy and most capable armed forces, finds it difficult to create and sustain effective airpower.

Money Matters

No one in Washington knows what the recent administration change is going to mean for airpower. It may mean more money, President Trump has called for "an historic increase in defence spending". He announced he would ask for a $54 billion increase in defence spending in his FY2018 budget, bringing the defence budget top line to a whopping $604 billion.

In all probability, defence spending was going to go up regardless of who was in the White House. In its last budget request, the previous Obama administration said it would increase spending by $33 billion; but even in Washington, $54 billion still represents serious money and would bring the top

cs and Money: Vashington

line to a level still considerably less than it would have been under the provisions of the FY2012 presidential budget (the last before imposition of the current budget caps imposed by the Budget Control Act, the dreaded sequestration). The Trump top line is also less than Senator John McCain, chair of the Senate Armed Services Committee, has proposed. On February 27, the senator himself pointed out: "With a world on fire, America cannot secure peace through strength with just 3% more than President Obama's budget. We can and must do better."

Of course, there is no guarantee that $604 billion will be the amount made available to fund US national security for FY2018 starting on October 1, 2017. It would be unwise to bet your own money on this being the case. Trump's top line is more than 10% over the $549 billion budget cap imposed by the Budget Control Act (on pain of sequestration of funds). It will require at least 60 senators to agree to change this. One way around it would be to use overseas contingency operations funding to meet the higher top line, which is not subject to the budget cap.

This is a possible – indeed, likely – outcome, but is likely to encounter extensive political opposition in the Congress from both senators and representatives on both the left (those opposed to higher defence spending) and the right (those opposed to increasing budget deficits). With the Trump administration proposing spending cuts in other government departments – including the US Coast Guard, whose airpower has to sustain a high operational tempo – the Congress is likely to want to spread some of the pain around and include the defence budget.

Political processes involved would be complex even at the best of times. The dysfunctional nature of US politics in recent years, however, suggests that this year will be far from the best for defence spending, as well as for larger issues. "In terms of near-term readiness, there is a significant challenge in meeting not only the current operational tempo with training ready forces, but having sufficient forces ready

Fourteen KC-135 Stratotankers lined up during a simulated alert call to demonstrate rapid mobility capabilities within minutes of being notified of a mission at McConnell Air Force Base, Kansas. *Airman 1st Class Christopher Thornbury/US Air Force*

A crew chief, pulls a maintenance platform up to a C-5 Galaxy at Ramstein Air Base, Germany. Airmen assigned to the 721st Aircraft Maintenance Squadron marshal aircraft to parking, chock the wheels, hook-up generators, check tyre pressures, refill oil, and refuel the aircraft. *Senior Airman Tryphena Mayhugh/US Air Force*

A weapons load crew assigned to the 34th Aircraft Maintenance Unit based at Hill Air Force Base, Utah, loads a GBU-12 into an F-35A Lightning II. *Nial Bradshaw/US Air Force*

A KC-135 Strantotanker assigned to the 100th Air Refueling Wing refuels a B-2 Spirit from the 509th Bomb Wing during a mission that targeted Islamic State training camps in Libya. SSgt Kate Thornton/US Air Force

to deploy in the event of an unforeseen contingency," US Army's Vice Chief of Staff, General Daniel Allyn, told the Senate Armed Service Committee (SASC) on February 8. He said the US Army needs "sustained, long-term, and predictable funding". Right now, neither Allyn, nor the other service leaders, has that.

Dysfunction has many costs, and money may be the least of these. US Air Force Chief of Staff General David Goldfein said in Washington on February 23 that if Congress fails to pass a FY2018 budget meaning the US Air Force has to operate under a year-long continuing resolution (CR) instead, it will cost the service over $1.3 billion. Operating under a CR will also prevent new capabilities being deployed, aircraft being sustained and flight hours being funded. "There is no enemy on the planet that can do more damage to the US Air Force than us not getting a budget," he said.

Similarly, Vice-Chief of Naval Operations, Admiral Bill Moran, told the Senate Armed Services Committee on February 7: "We are going to have to shut down two air wings," and experience further deterioration in the shortfall of aircraft availability and aircrew flight hours if the US Navy has to continue until October 1 without a new budget or a supplemental FY2017 spending bill.

The supplemental budget request for FY2017, anticipated to be some $18 billion and come before the Congress in March–April, could not be acted on until the bill it is supplementing – the FY2017 Defense Appropriations Bill – is actually signed into law. In the absence of a signed appropriations bill, the US Department of Defense is funded by a CR that expires in April, so that, too, becomes uncertain.

US airpower may be short on pilots (particularly in the US Air Force) and spare parts for US Navy and US Marine Corps F/A-18 Hornets, but it is not short of uncertainty in defence spending.

Turning Money into Airpower

The uncertainty as to how much money is actually going to be available for the services to turn into airpower, starting on October 1, makes it hard for the services to set priorities. Do they buy new aircraft? More munitions for a potentially more intense conflict in Syria and Iraq? More spare parts to increase aircraft availability? Bonus payments to retain trained pilots?

US Marine Corps General Joe Dunford, Chairman of the Joint Chiefs of Staff, said in Washington on February 23: "At the end of the day, we cannot be paralysed by tough choices. We have to frame those choices to the president and articulate the consequences of those choices and give him the chance to select one of those."

In a press interview on February 8, John Lehman, who was Secretary of the Navy in the 1980s, said: "The priority is to achieve balance. Readiness and sustainability must be dealt with simultaneously embarking on procuring the necessary new ships and

Airmen assigned to the 56th Equipment Maintenance Squadron phase shop perform an inspection on an F-16D Fighting Falcon at Luke Air Force Base, Arizona. Airman 1st Class Pedro Mota/US Air Force

aircraft." However, getting the balance right without knowing how much money is going to be available is difficult, but some of the ways to reduce spending to free resources to accomplish this goal have the potential to be counterproductive.

One way the Trump administration has chosen to save money and make it available for defence spending is by imposing a hiring freeze on federal civilian employees, but this is already on course to have a negative impact on US airpower. On February 13, General Goldfein said: "Unless the freeze is lifted soon, I'm not going to have the flying hours to be able to get those things airborne, and I'm not going to be able to invest in the training, and I'm not going to have any relief."

Making Choices among Priorities

Whether what seems like a good idea for investing any additional money in an increased defence top line is going to prove counterproductive rather than enhancing airpower is difficult to determine, even among high-ranking professionals. For example, one choice that should not be made, if there is additional money available, is to boost procurement of Lockheed Martin F-35A Lightning IIs for the US Air Force.

Vice Commander, Air Combat Command, Major General Jerry Harris, told the House Armed Services Committee (HASC) on February 16: "Additional F-35As would be delivered in the current configuration and will have to go through an extensive retrofit programme once the upcoming Block 4 upgrade and software is ready. There are currently 108 US Air Force F-35As waiting for retrofit."

A Block 4 F-35A will have greater capabilities. However, Congress likes to see more aircraft built, so may be more inclined to increase production, even if this means more money will be required to be spent on them in the future.

Other US Air Force leaders want any additional funds to pay for more people rather than more aircraft. General Goldfein said: "The state of our Air Force, in terms of readiness, is that we've got serious challenges."

Commenting on priorities, in January Goldfein said he would rather have more personnel than aircraft, some 25,000-30,000 to meet current shortages and increase capabilities for flight line maintenance, cyber warfare and space operations. On February 23, Goldfein said the Air Force personnel strength is "the smallest we've ever been".

Not everyone agrees. Commander of Air Combat Command, General Hawk Carlisle wants deliveries of the long-delayed F-35As accelerated to 60 a year from the current level of 40 as soon as possible.

New Requirements

No one knows how much money and what resources will be available to sustain – let alone enhance – US airpower in the near future. Still to be determined is what the US Government is going to ask American airpower to do. The Trump administration may put in place policies or actions that will quickly hoover up any additional funding.

The administration's rhetoric suggests other areas where more may be asked and hence more airpower resources expended. The conflict in Somalia may require additional US airpower involvement, where currently it is limited to a relatively few aircraft from Special Operations Command. The situation in Afghanistan, with new Taliban attacks expected in the spring, may call for US aircraft with a range of missions: close air support, casualty evacuation and air transport. US and NATO missions in Iraq are unlikely to end once the Iraqi Government regains control of Mosul. The new administration's often repeated concern about border security suggests this is an area where more resources may have to be allocated. Dunford said: "[There is] a full range of options on the table for US actions in the conflict in Syria and Iraq." Trump's administration ordered a 30-day review of the conflict in January. As the administration said in initiating the review, the result may, accelerate US involvement. If this is the case, it is likely to mean more aircraft, more munitions, more resources and more funding will have to be allocated to combat.

On January 27, the president signed an executive order for a Nuclear Posture Review of the priorities Trump's administration inherited from his predecessor. Under the Obama administration, it appeared the need to modernise nuclear deterrent forces would be a priority for research and development (R&D) and procurement funding in future years. Obama left office before the bills for the expensive parts of the requirement became due. Donald Trump's statement, during a press interview on February 24, that he means to ensure US strategic forces remain "top of the pack" suggest this will remain one of his top concerns. If this is the case, it may be allocated additional funding.

Where will the resources required for such emerging priorities come from? R&D may become a bill-payer. On February 7, US Air Force Vice Chief of Staff General Stephen Wilson told the HASC: "Right now, our R&D is about two percent [of total defence spending]. We need to keep it at that [level] or even grow that because otherwise, our adversaries will outpace us."

If the government cuts back R&D, its potential high-end competitors are unlikely to do so. Speaking in Washington DC on February 17, Senator McCain said: "For 20 years, our adversaries have gone to school on the American way of war. We can no longer take victory for granted. America could lose the next war we fight."

Four B-1B Lancers assigned to the 9th Expeditionary Bomb Squadron, at Andersen Air Force Base, Guam on February 6, 2017, in support of US Pacific Command's continuous bomber presence. *TSgt Richard Ebensberger/US Air Force*

Sea Dragon Bows Out

The Japanese Maritime Self Defense Force retired the Sikorsky MH-53E Sea Dragon (export designation S-80M-1) on March 3, 2017. On February 20, 111 Kokutai carried out its last training flight on aircraft serial number 8625 from Marine Corps Air Station Iwakuni. Japan is the sole export customer for the Sea Dragon, operating 11 airframes since 1989. In May 2015, the US Navy signed a contract to purchase two decommissioned MH-53Es from Japan for parts, including 12 engines and two tow booms. AgustaWestland MCM-101 Merlins now conduct the duties once performed by the Sea Dragon using the AQS-24A airborne mine hunting system: the AES-1 airborne laser mine detection system and the Mk104 acoustic minesweeping device. Chen Chuanren

Russian Airpower Modernisation

Russia's military took delivery of 166 modern aircraft in 2016, Defence Minister, Sergei Shoigu told the State Duma on February 22. He said modern aircraft now represent two-thirds of Russian military aircraft, over half of those under the command of the country's military district headquarters (and hence intended to have an operational mission) and 58% of those in combat units. President Vladimir Putin has previously announced a target of 70% of Russia's major military equipment being modern types by the end of 2020.

Shoigu said Russia's armed forces are now operating over 600 unmanned air systems with over 2,000 unmanned air vehicles, organised in 38 units. This year, Russia's military is expected to receive 170 new and upgraded aircraft, including one Tupolev Tu-160 *Blackjack* and four Tupolev Tu-95MS *Bear-H* bombers. Elsewhere, delivery details reported include Mil Mi-8AMTSh-VA Arctic transport and attack helicopters, designed to operate at -60°C. They will go to the Pacific Fleet.

The day before Shoigu's speech, Deputy Defence Minister Yuriy Borisov said 2017's state defence order would include replenishment of munitions expended during Russian combat operations in Syria. A new air defence division will be established in 2018 to cover the eastern Arctic region. It will be responsible for the area from Novaya Zemlya (56°E) east to the Chukotka peninsula (177°E), opposite Alaska. The existing 1st Air Defense Division will cover the area west of this, to the Finnish and Norwegian borders. *David C Isby*

Light Attack Funding Request

The US Air Force is requesting funding in the FY2017 supplemental budget request for a test and evaluation programme for its A-X (attack-experimental) light attack aircraft programme. The evaluation will aim to identify the potential of off-the-shelf designs that can provide an A-X capability and build on experience gained in a limited objective experiment dubbed Combat Dragon II programme.

In 2013, Combat Dragon II operated two 1960s-era Rockwell OV-10G+ Bronco aircraft; modified to be able to deliver current precision-guided munitions, with US Special Operations Command at Naval Air Station Fallon and Nellis Air Force Base in Nevada. In 2016, these aircraft were used on combat operations in the US Central Command area of operations as part of Operation Inherent Resolve.

Speaking in Washington DC on February 23, Air Force Chief of Staff, General David Goldfein said: "The next step of the process is to go to industry and say, OK, here are the operational outcomes of the Combat Dragon II. Show me what you've got. I'm looking for something we can get right now, commercial off the shelf, low cost, that can operate in an uncontested environment; deliver the capabilities we need that can also be something for, perhaps, our allies and partners."

The A-X evaluation is planned to start in the current year as soon as funding can be appropriated. *David C Isby*

Wing Loong II Maiden Flight

After its debut at the Zhuhai Airshow in November 2016, Chengdu Aircraft Industry Group's latest unmanned aerial vehicle (UAV), the Wing Loong II (or Pterodactyl II) made its maiden flight on February 27. The test flight lasted for 31 minutes at an undisclosed airfield in northwest China.

AVIC Vice President of Aircraft Design, Li Yidong, revealed the UAV has already secured China's largest export unmanned aerial vehicle sale to an unspecified client even prior to the test flight.

Wing Loong II has a 480kg (1,058lb) external payload capacity carried on six under wing pylons. The aircraft displayed at Zhuhai had numerous air-to-ground munitions, including the CM-502KG missile and LS-6 precision-guided bomb. Its predecessor, the Wing Loong I, has reportedly been sold to at least six nations, including the UAE, Kazakhstan and Saudi Arabia, the latter having used the type in combat over Yemen. *Chen Chuanren*

Romanian Vipers on the Boom

A Forțele Aeriene Române (Romanian Air Force) F-16A assigned to Baza Aeriana 86 (86th Air Base) Borcea-Fetești approaches the boom of a US Air Force KC-135R Stratotanker on February 28, during air refuelling training over Bucharest, Romania. When the US Air Force and Forțele Aeriene Române made their first air refuelling contact on the February 28 mission, history was made. Fourteen members of the 100th Air Refueling Wing based at RAF Mildenhall, England, deployed to Borcea-Fetești on KC-135R 60-0321 to train and certify Forțele Aeriene Române F-16 pilots on air refuelling with a US tanker. SSgt Kate Thornton/US Air Force

Holloman's first QF-16 Sortie

The 82nd Aerial Targets Squadron Det.1 based at Holloman Air Force Base flew its first manned sortie with a QF-16 full-scale aerial target on February 10, 2017. The flight was described by Det.1 Commander, Lt Col Ron King as "significant because it is the first step in standing up the QF-16 programme. Compared to its predecessor, the QF-4 which was retired in December, Lt Col King said the QF-16 offers more realistic threat replication in performance, manoeuvrability and capabilities. *Photo Jim Haseltine*

Herons Operational in Mali

Germany announced its Heron I UAVs reached full operational capability in Mali on February 1, serving with the United Nations Multidimensional Integrated Stabilization Mission in Mali (MINUSMA). The declaration was made six months after the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support was tasked with getting the aircraft operational. The contract was signed in July 2016 when the Bundeswehr assumed responsibility for the intelligence unit in Mali from the Netherlands. Over 120 containers of equipment were sent to Mali from September, after which the first Mali-based Heron mission was flown in October, followed by the first operational mission from Gao airport on November 1. Germany's Heron I deployment in Mali is due to continue until at least February 2018 and involves Airbus Defence and Space Airborne Solutions, which is responsible for the provision, maintenance and overhaul of the system in Mali. Germany's Heron 1 aircraft are leased from Israel Aerospace Industries under an arrangement similar to that in Afghanistan where the Heron I flew over 2,300 missions and 30,000 flight hours. The Bundeswehr said the Heron deployment to Mali has allowed the potential reconnaissance radius of the German MINUSMA force to increase from 80–900km (43–485nm). *Guy Martin*

Netra Introduced

In addition to Netra aircraft KW3556 on static display at Aero India, a second aircraft, KW3555, took part in the flying display. *Piotr Butowski*

On the inaugural day of the 2017 edition of the Aero India air show, the Indian Defence Research and Development Organisation (DRDO) ceremonially handed over the first Netra, serial number KW3556, in initial operational configuration to the Indian Air Force.

Netra is an AEW&C aircraft based on the Embraer EMB145 regional jet, fitted with Indian mission systems, including two electronically scanned early warning radars (primary and auxiliary, one integrated into another), an electronic warfare system, command and control systems, electronic and signal intelligence equipment, and satellite communication equipment. System integration is coordinated by the DRDO at Bangalore and its subdivision, the Centre for Airborne Systems.

In July 2008, India ordered three EMB145i aircraft from Embraer, modified to its needs; the first aircraft arrived at DRDO's Bangalore facility on August 22, 2012. Embraer had already built AEW&C aircraft based on the EMB145 for Brazil, Mexico and Greece.

India's platform differs from earlier versions, having additional systems fitted that include an air refuelling probe, more powerful electric generators and more efficient cooling devices.

Netra is the latest AEW&C aircraft in Indian Air Force service, after three Russian-built Il-76MD-90s with an Israeli ELW-2090 mission system were delivered between 2009 and 2011. A contract for two further Il-76 aircraft has been under negotiation for several years, and two Il-76 airframes have been waiting for the conversion at Beriev's facility in Taganrog, Russia, for several years. In the future, the Indian Air Force intends to purchase six (possibly ten) large AEW&C aircraft based on the Airbus A330 platform fitted with an Indian mission system and a 10m (32ft 10in) radar dome mounted above the fuselage. *Piotr Butowski*

Victor

David C. Isby follows the upgrade programme for the US Army's UH-60 Black Hawk and the first flight of the UH-60V

The US Army's upgraded Sikorsky UH-60V Black Hawk successfully made its first flight on January 19 in Meridianville, Alabama following a 29-month engineering and manufacturing development (EMD) programme that made use of mature technologies. The UH-60V – formerly designated UH-60L digitization – will recapitalise 760 UH-60Ls in service with the US Army. The upgrade includes installation of a new all-digital cockpit incorporating multifunction displays and advanced avionics. With a high level of standardisation and commonality in terms of training, components and capabilities with the UH-60M Black Hawk, the UH-60V is expected to remain in service until the post-2050 timeframe; its cockpit will look, feel and function like that of an UH-60M.

UH-60V Programme

The UH-60V's design, development and systems integration is being carried out by the US Army (as was the case with previous helicopter programmes such as the cancelled cockpit and sensor upgrade programme for the OH-58D Kiowa) with industry support. Three UH-60V Engineering Development Models (EDM) were modified by Redstone Defense Systems at its Meridianville facility for the US Army Aviation and Missile Research, Development, and Engineering Center's Prototype Integration Facility (PIF) at Redstone Arsenal, Alabama. The PIF is a new organisation, set up to meet army rapid prototype requirements.

Northrop Grumman was selected as the designer and producer of the integrated avionics suite in a 2014 competition, and is providing full, unlimited government purpose rights to technical data and software.

After acceptance testing, the UH-60V will begin its flight test programme, which will run through FY2017. Limited testing by the US Army will take place in FY2018. A decision on full rate production (FRP) will be made after initial operational testing and evaluation, using five UH-60V EDM aircraft in FY2019. Following low rate initial production (LRIP), planned to start in FY2018, and follow-on operational test and evaluation in FY2020, FRP is due to start in FY2021 and work up to a rate of 48 UH-60Vs per year, ending in 2033. Follow on research, development testing and evaluation is planned to incorporate future upgrades – such as systems currently under development to prevent brownout – once the UH-60V is in production.

The Corpus Christi Army Depot (CCAD) in Texas, which handles overhauls and recapitalisation for US Army helicopters, will house the UH-60V production line.

Upgrade kits for the first three EDM UH-60Vs were prepared by the CCAD and the depot will also upgrade the remaining two EDM aircraft. The UH-60V programme may be expanded, as international Black Hawk operators may also participate through Foreign Military Sales (FMS), gaining economies of scale from the large US order. UH-60Vs will be delivered from the CCAD with 10 or more years of service life.

Cockpit and Avionics

The central element of the UH-60V upgrade is a new cockpit and its associated integrated avionics system, designed by Northrop Grumman. Intended to maintain a high level of commonality with the UH-60M while reducing weight, electrical power requirements and operating costs while increasing reliability, it is based on systems developed for the US Marine Corps' Bell UH-1Y.

Below Left, Opposite Page: ***UH-60V 90-26242 made the type's first flight on January 19, 2017.*** *Northrop Grumman*
Above: ***The first of five engineering development model UH-60Vs, 90-26242, is a former UH-60L model.*** *Northrop Grumman*
Below Left: ***Northrop Grumman's UH-60V integrated cockpit avionics system.*** *Northrop Grumman*
Below Right: ***Four US Army UH-60Ls over Tarin Kot, Afghanistan. All the UH-60Ls remaining in US Army service will be upgraded to UH-60V configuration.*** *US Army*

The avionics system uses an Intel Wind River VxWorks 653 platform for the centralised processor and Northrop Grumman FlightPro Gen III mission computers using a Thales i-FMS200 interactive flight management system. It provides improved communications (including joint variable message format messaging) and identification (Mark XIIA IFF) capabilities, improved navigation, an interface for enhanced aircraft survivability equipment and a digital moving map capability for the MFDs. Provision is included for state-of-the-art video input (which can be displayed in-cockpit on the MFDs) and output.

The cockpit and avionics have been designed to provide commonality and an open architecture capability, with future changes accommodated by new software using Future Airborne Capability Environment technical standards (developed by Naval Air Systems Command) and integrated modular avionics ARINC specification 653 standards; both intended to provide avionics interoperability and software portability using multiplatform off-the-shelf components and common software.

The UH-60V cockpit and avionics are compliant with Federal Aviation Administration global air traffic management requirements, important for US Army Reserve and National Guard helicopters that routinely operate in civil controlled airspace. The design was extensively flight-tested on a modified UH-60L before the UH-60V programme started.

Role of the UH-60V

US Army UH-60As have been retired or converted to UH-60Ls; an upgrade carried out at the CCAD that resulted in increased performance, 15 to 18 years of additional service life and up to a 37% reduction in annual maintenance costs. The V-model's configuration will build on the UH-60 programme's earlier investment in airframe, engine and power train life, and will make a future all-digital cockpit Black Hawk force viable through keeping up numbers to meet needs and preventing the larger fleet of UH-60Ms being over-used.

While the US Army's Future Vertical Lift programme is intended to select and procure a Black Hawk replacement, the US Army will continue to invest in upgrades. An initiative dubbed the Improved Turbine Engine Program will lead to retrofits starting in FY2026. UH-60Ms are to be recapitalised, starting in FY2032, as they approach the end of their 25-year design service life, enabling US Army operation until post-2050.

Air Wing Shut Dow and Readiness Sh

by Rick Burgess

The US Navy is in the process of shutting down its tenth Carrier Air Wing (CVW) and three carrier-based aviation squadrons. The moves come even as political momentum builds to grow the size of the US fleet, that includes increasing the aircraft carrier fleet back to 12.

According to Cdr Jeannie Groeneveld, spokeswoman for Commander, Naval Air Forces, the US Navy deactivated Carrier Air Wing 14 (CVW-14) effective from March 31. CVW-14 has been just a shadow of its former self since 2012, when initial plans were made to deactivate the wing that were later reversed.

Based at Naval Air Station Lemoore, California, CVW-14 has been under strength in squadrons and has not deployed since 2011. The deactivation was authorised by the FY2017 National Defense Authorization Act, which allowed the US Navy to reduce the number of CVWs to nine until the number of deployable carriers can fully support a tenth or until October 1, 2025, whichever comes first, at which time the Navy will return to a strength of ten CVWs.

Also deactivated on March 31 was MH-60S-equipped Helicopter Sea Combat Squadron 15 (HSC-15) 'Red Lions' based at Naval Air Station North Island, California Cdr Groeneveld said HSC-15 was identified as the best squadron based on time in the training cycle.

One of two more units scheduled for deactivation on May 31 is F/A-18C-equipped Strike Fighter Squadron 15 (VFA-15) 'Valions' based at Naval Air Station Oceana, Virginia, although its farewell ceremonies were held on March 31. The squadron gave up its last aircraft in December. Groeneveld said: "This removes the requirement to move a squadron from Oceana to Lemoore in 2017 as was originally planned."

Carrier Airborne Early Warning Squadron 112 (VAW-112) 'Golden Hawks', an E-2C squadron based at Naval Air Station Point Mugu, California, will also be deactivated on May 31. Once again, Cdr Groeneveld cited timing as the reason for the selection of VAW-112, saying: "VAW-112 was identified as the best squadron based on time in the training cycle and proposed transition to E-2D."

VAW-112's loss to Point Mugu will be alleviated by the transfer there in June of VAW-115 'Liberty Belles' from Naval Air Facility Atsugi, Japan. The squadron has been replaced at Atsugi and in CVW-5 by E-2D Advanced Hawkeye-equipped VAW-125 'Tiger Tails' previously based at Naval Air Station Norfolk, Virginia.

F-35B Shuffle

The US Marine Corps has pulled an AV-8B Harrier II attack squadron from its place in the F-35B transition schedule and replaced it with an F/A-18 Hornet fighter-attack squadron, because of the better health of the Harrier force.

Marine Attack Squadron 311 (VMA-311) 'Tomcats' based at Marine Corps Air Station Yuma, Arizona, was next in line to make the transition in 2018, following the transitions of Marine Fighter-Attack Squadron 121 (VMFA-121) 'Green Knights', now based at Marine Corps Air Station Iwakuni, Japan, and VMFA-211 'Wake Island Avengers' at Yuma.

During a February 8 roundtable with reporters at the Pentagon, Lt Gen Jon Davis, Deputy Commandant for Aviation, said VMFA-122, an F/A-18C Hornet unit based at Marine Corps Air Station Beaufort, South Carolina, will take VMA-311's transition slot and will change its home base from Beaufort to Yuma.

He said the Independent Readiness Review of the Harrier fleet showed a more robust posture than anticipated. The Harrier force has seen a 23% increase in ready base aircraft, the service's metric for aircraft ready to fly. The Harrier force is scheduled to serve until 2026.

Davis said he would prefer an F-35B procurement rate of 37 aircraft per year, compared with an approximate 20 aircraft per year scheduled for FY2018 through 2021. He said an increase to 37 aircraft per year would enable the Marine Corps to accelerate squadron transitions and retire both its F/A-18 Hornet and AV-8B fleets by 2026.

F/A-18C Hornet BuNo 164671/NJ300 was the final CAG-bird assigned to VFA-15 before the squadron's Spring 2017 deactivation. The aircraft is shown at low-level in a Californian canyon when operated by Air Test and Evaluation Squadron 9 (VX-9) 'Vampires' based at Naval Air Weapons Station China Lake. Dan Stijovich

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nortfall Recovery

One of three units to be deactivated as a result of CVW-14's shut down was MH-60S Seahawk-equipped Helicopter Sea Combat Squadron 15 (HSC-15) based at Naval Air Station North Island, California. Named the Red Lions, HSC-15 operated MH-60S BuNo 168530/NA610 in this themed paint scheme featuring fearsome red lion artwork in 2012. Dan Stijovich

Davis also said the fourth operational F-35B squadron will be VMFA-225, redesignated from VMFA(AW)-225, an all-weather F/A-18D Hornet squadron currently based at Marine Corps Air Station Miramar, California. Another Miramar-based F/A-18 Hornet squadron, VMFA-314 'Black Knights', will be the first Marine squadron to make the transition to the carrier-based F-35C.

The US Marine Corps currently has about 50 F-35Bs in inventory, including training and test aircraft. On January 18, VMFA-121 arrived at to Iwakuni, Japan, where it formed part of Marine Aircraft Group 12, beginning the first deployment of the F-35. VMFA-121 will deploy a detachment on board the amphibious assault ship *USS Wasp* (LHD 1) beginning in 2018, the same year that VMFA-211 will deploy a detachment on board the amphibious assault ship *USS America* (LHA 6).

E-2D Forward-Deployed

The newest radar warning aircraft has arrived in Japan to equip the US Navy's forward-deployed CVW. Carrier Airborne Early Warning Squadron 125 (VAW-125) 'Tiger Tails' arrived at Marine Corps Air Station Iwakuni, Japan, on February 2017. The squadron moved from Naval Air Station Norfolk, Virginia, with five E-2D Advanced Hawkeye aircraft to join CVW-5, the air wing assigned to the aircraft carrier forward deployed to Japan, *USS Ronald Reagan* (CVN 76).

Assignment of the E-2D to CVW-5 accords with the US Navy's strategic plan to forward deploy its most modern capabilities in the Western Pacific. The E-2D, built by Northrop Grumman, is equipped with the Lockheed Martin APY-9 active electronically scanned array search radar, an upgraded mission computer and data link, a digital cockpit and the ability for the co-pilot to serve as an extra mission controller.

VAW-125 is replacing VAW-115, which flies the older E-2C Hawkeye at Naval Air Facility Atsugi, Japan, along with the rest of the air wing's squadrons. CVW-5's four F/A-18 Super Hornet strike fighter squadrons and its EA-18G electronic attack squadron will move from Atsugi to Iwakuni beginning late this year as part of a planned shift of the air wing.

Marine Attack Squadron 311 (VMA-311) AV-8B Harrier II BuNo 165573/WL02 on the taxiway at its home base of Marine Corps Air Station Yuma, Arizona prior to a four-ship training mission. The squadron's F-35B transition slot has been taken by F/A-18C-equipped VMFA-122 because of the better health of the Harrier force. Mark Ayton

Marine Fighter Attack Squadron 122 (VMFA-122) 'Werewolves', an F/A-18C Hornet unit based at Marine Corps Air Station Beaufort, South Carolina, will take Marine Attack Squadron 311's (VMA-311) slot for transition to the F-35B and will change its home base from Beaufort to Yuma, Arizona. In 2012 VMFA-122 marked its 70th anniversary with a commemorative colour scheme applied to F/A-18C BuNo 164247/ DC00 with the legend '70 Years of Steel on Target' applied to the aft fuselage below the vertical stabiliser. The unit's original 1942 name 'Candystripers' was carried on the underwing drop tanks. Dan Stijovich.

VAW-125 was the US Navy's first E-2D fleet squadron and has already completed one deployment on the *USS Theodore Roosevelt* (CVN 71) in support of Operation Inherent Resolve. Two other Norfolk-based squadrons, VAW-121 'Bluetails' and VAW-126 'Seahawks' have also completed transition to the E-2D. VAW-124 'Bear Aces' is scheduled to begin transition in March 2018.

VAW-115 has been forward deployed to Japan since the early 1970s, rotating with CVW-5 to the forward-deployed carrier, beginning with *USS Midway* (CV 41) and through its successors *USS Independence* (CV 62), *USS Kitty Hawk* (CV 63), *USS George Washington* (CVN 73) and now *USS Ronald Reagan*. The squadron will move during the summer to the West Coast E-2 base at Naval Air Station Point Mugu, part of Naval Base Ventura County, California, and will eventually transition to the E-2D.

MV-22 Took No Enemy Fire

A US Marine Corps MV-22B Osprey tiltrotor aircraft lost during a special ops forces raid in Yemen on January 29 did not crash as a result of hostile action, US Central Command said in a January 31 statement. A spokesman said the MV-22 experienced a hard landing at a staging area in Yemen's Al Bayda Governorate, injuring three personnel: "The aircraft did not take enemy fire and did not go down because of hostile action against it. The aircraft was determined to be unflyable and was destroyed in place by US forces."

Strike Fighter Squadron 147 (VFA-147) 'Argonauts' based at Naval Air Station Lemoore, California celebrates its 50th anniversary this year. The squadron has painted F/A-18E BuNo 166821/NH200 with the legend '1967 ARGONAUTS 2017' along the top of the fuselage. Kevin Whitehead

Elements of Carrier Air Wing 11 deployed to Naval Air Station Fallon, Nevada in February for a training detachment. Strike Fighter Squadron 146 (VFA-146) 'Blue Diamonds' deployed its latest CAG-bird F/A-18E Super Hornet BuNo 165783/NH300. Dan Stijovich

According to unofficial records, no US Marine Corps or US Air Force Ospreys have been lost to enemy fire in nearly ten years of operations, although at least two, including one US Air Force CV-22, crashed while supporting combat operations. Three CV-22s were hit by small arms fire in December 2013 during a mission to evacuate American civilians from South Sudan.

Readiness Shortfall Recovery

US Marine Corps aviation forces are still under water with regard to readiness, but recovering as the percentage of aircraft ready for flight steadily increases, said its Deputy Commandant for Aviation.

During a February 8, 2017, roundtable with reporters at the Pentagon, Lt Gen Jon Davis said the Marine Corps is doing better now and that by 2019 readiness of aviation forces should be restored. "That's when we come out of the water," he said.

Davis said the need for spare parts has been the main driver in aircraft being unavailable for flight: "We still don't have what we need," he said, noting the parts shortage affects old and new aircraft alike.

Davis presented some metrics that showed the improving readiness level. Of the Marine Corps' 1,065 aircraft (approximately), only 378 were RBA — ready base aircraft in Marine Corps terminology, meaning ready to fly that day — in December 2014. Two years later, the RBA total was up to 439 aircraft. The target RBA is 589.

The Marine Corps has 171 F/A-18 Hornet strike fighters in a reporting status — including in the fleet replacement and reserve squadrons — but only 72 are RBA, below the service's goal by about 20 aircraft.

Davis said the depot facilities had brought 43 F/A-18s back into reporting status for the Marine Corps, only one short of the goal for 2016.

Davis also addressed the spate of mishaps in 2016: "We're not seeing material problems with the mishap rate." The lack of RBA aircraft is resulting in "unexecuted flight hours," meaning "We're flying safe airplanes; we're not flying safe airplanes enough."

The US Marine Corps, and its aviation

To complete a quartet of CVW-11 aircraft in this section, EA-18G BuNo 168381/NH500 is the first Growler CAG-bird operated by Electronic Attack Squadron 142 (VAQ-142) 'Gray Wolves' which transitioned to the type during 2015 and continued work-up training throughout 2016. The squadron is set to make its first Growler deployment on board the USS Nimitz (CVN 68) during 2017. Dan Stijovich

forces in particular, he said, have been "very deployed and very busy" since 9/11, and actually since Operation Desert Storm in 1991, and that the US Marine Corps flies the oldest jets in the Department of Defense.

Davis praised the F-35B Lightning II and noted the first operational squadron, VMFA-121, has maintained high readiness metrics — between 70 and 90% — since it deployed to Japan last month.

"All the jets stayed up the entire time [during their transit to Japan via Alaska]. I'm very confident of the [F-35's] ability to provide close air support," he said, noting the aircraft's radar's capability to see through the clouds, along with the coming of streaming video and the GBU-39 Small Diameter Bomb II, of which the F-35B will carry eight when the Block 4.1 software is installed.

Davis also praised the MV-22B Osprey tiltrotor aircraft, noting the high demand for it among combatant commanders, saying: "We have flown the paint off that aircraft."

Among the US Marine Corps' fleet of MV-22Bs and the Air Force's fleet of CV-22s are 77 different configurations, he said. Most of the differences are minor and affect maintenance personnel, rather than the flight crew. The mix of configurations was created because modifications were made as the aircraft came off the production line.

A consequence of this situation is that the Marine Corps has to transfer Ospreys between squadrons frequently to keep a common configuration within a deploying unit. Davis said there had been 650 transfers between 2011 and 2016. "A common configuration will alleviate the need to transfer airplanes," he said, noting "At the end of the day I'm going to be the one to approve transfers."

The Marine Corps is implementing the Common Configuration Reliability and Maintainability (CCRAM) initiative to bring 130 Ospreys to a common configuration. The first two will be delivered this year. The goal is to modify 24 per year. One modification is a redesigned engine nacelle.

As part of the CCRAM effort, the US Marine Corps will install an electro-optical/infrared sensor with a laser designator as a replacement of the existing sensor. The new sensor is needed for the crew to see the landing zone from medium altitudes well in advance of arrival, and will need to be able to stream and share video with GPS-quality coordinates.

The sensor will also enable future weapons employment from the Osprey. Testing has been conducted with the Switchblade munition free-falling from an Osprey, which Davis said "worked phenomenally well".

A competition between the sensor proposals of three companies will be held with a fly-off this spring at Yuma, Arizona. Davis declined to name the three companies.

Mayport and the Triton

The US Navy has selected Naval Station Mayport, Florida, as the East Coast Forward Operating Base (FOB) for the MQ-4C Triton unmanned aircraft system, according to US Fleet Forces Command. As the East Coast FOB, Mayport will be the launch-and-recovery site for four forward-based MQ-4C Tritons and consolidated maintenance hub for up to four additional aircraft. Nearby Naval Air Station Jacksonville is the home of the Navy's first MQ-4C squadron, Unmanned Patrol Squadron 19 (VUP-19) 'Big Red', which will control the Tritons from Jacksonville.

Another element from CVW-11 present at Fallon in February was Carrier Airborne Early Warning Squadron 121 (VAW-121) 'Bluetails' making its debut Fallon detachment with the E-2D Advanced Hawkeye including aircraft BuNo 168600/NH604. Dan Stijovich

Predator Retirement

The US Air Force will retire the last of its General Atomics MQ-1 Predator series unmanned aerial vehicles (UAV) in early 2018 as the more capable General Atomics MQ-9 Reaper replaces them. This will enable the US Air Force to stop Predator-specific training, operations and maintenance activities.

MQ-9 service life is also of concern to the US Air Force because of the ongoing around-the-clock UAV operations.

Block 1 MQ-9s were built with a design service life of 20,000 hours, which was increased to 40,000 hours for Block 5 MQ-9s. Static testing on MQ-9s to identify potential structural problems is currently underway and will be completed in FY2019. *David C Isby*

Paragon

On March 2, Lockheed Martin announced its Dual Mode Plus laser-guided bomb will be named Paragon. The weapon uses an inertial navigation system and all-weather moving-target capability with increased standoff range, and maintains the same physical dimensions, mass properties and outer mould line as Lockheed Martin's combat-proven laser-guided bomb.

According to Lockheed Martin, the Paragon weapon has been successfully integrated on the F/A-18 Hornet, although flight testing continues and flight tests on the F-16 are planned for the second quarter of 2017.

Ouadi Doum

On March 2, the Armée de l'Air unveiled Mirage 2000D 652/3-XN assigned to EC 03.003 'Ardennes' based at BA133 Nancy-Ochey in a colour scheme with associated markings to commemorate the 30th anniversary of an air raid carried out by the unit in 1987 on a Libyan Air Base at Ouadi Doum in Northern Chad. In 1987, the then EC 3/3 'Ardennes' was equipped with the Jaguar A. *Michael Balter*

Empire's H125s

Defence company QinetiQ has signed a £15 million contract covering four Airbus H125 helicopters for the Empire Test Pilots' School (ETPS) as part of the school's modernisation. Based at Oxford-Kidlington Airport, Airbus Helicopters UK will undertake a modification programme for each of the new helicopters involving installation of a three-axis autopilot, dedicated communications equipment, traffic awareness systems, and a suite of flight test instrumentation.

In December 2016, QinetiQ and the UK Ministry of Defence signed an agreement valued at a whopping £1 billion to modernise the UK's test aircrew training and air range capabilities.

According to QinetiQ, the company will invest £85 million in the ETPS to "reduce operating costs, enhance capabilities and drive future growth, including purchase of eight new aircraft to comprehensively update the ETPS fleet."

The H125s are expected to enter service in early 2019.

Complete Renewal

Russia's military has considered its options for replacing the ageing fleet of Tupolev Tu-134 and Tu-154s used for passenger and VIP transport in the foreseeable future.

Likely candidate types to fill the niche role are the An-148 and Tu-214, manufactured at the Voronezh and Kazan aviation plants respectively. Both are controlled by the United Aircraft Corporation.

Driving the recently launched initiative to replace the entire fleet of passenger and VIP-outfitted jets operated by the Russian Air and Space Force is the crash of a Tu-154B-2 near Sochi on December 25, 2016, which killed all 92 people on board.

According to deputy defence minister for procurement Yury Borisov, the Sukhoi Superjet SSJ100 has been rejected as a Tu-134 replacement, because its engines, mounted low to the ground, are deemed unsuitable for landings on military airfields with runways in a poor condition and the risk of foreign object damage. In addition, the SSJ100 features a high proportion of parts and assemblies supplied by Western companies, which is not acceptable to the Russian Ministry of Defence. *Alexander Mladenov*

Wingman UAV Tests

On February 23, the US Navy announced recent simulated flight tests of a wingman UAV concept in a beyond-visual-range combat scenario. Coordination between UAVs, acting as wingman to a manned aircraft, was handled by Tactical Battle Manager software, which communicated between manned and unmanned platforms during the flight tests. Collaboration for the flight tests involved Naval Air Systems Command, the Navy Center for Applied Research in Artificial Intelligence and the Air Force Research Laboratory (AFRL).

The AFRL Loyal Wingman programme is working on similar concepts and is aiming for technology demonstrations by 2023. *David C Isby*

Mi-8MTV-5-1s at Kamensk

In February, Russian Air and Space Force's 48th Army Aviation Base (AAB) at Kamensk-Uralsky in the central military district accepted a batch of 16 new Mi-8MTV-5-1 tactical transport helicopters to re-equip fully one of its squadrons.

In addition to the typical Army Aviation roles, the 16 Mi-8MTV-5-1s will also be used for search and rescue in support of Russia's space programme.

Located in the central part of Russia, traditionally helicopters assigned to the 48th AAB have been deployed on an as-needed basis to various locations in the country and neighbouring Kazakhstan to secure the landing sites of re-entry space vehicles returning to earth. *Alexander Mladenov*

Fourth A-50U

On March 6, Taganrog-based TANTK Beriev reported it delivered the fourth major upgraded A-50U airborne early warning and control aircraft to the Russian Air and Space Force. The long-running A-50U upgrade and life extension programme is being undertaken jointly by Beriev and Vega, the radar system manufacturer. The fourth aircraft, wearing side number Red 41 and Russian military registration RF-94268, was manufactured in 1988 and first displayed to the public in October 2016, and its first post-upgrade test flight took place on December 7, 2016. Upgrade was carried out under an April 2014 contract. According to Russian sources, by early 2017 the 144th Airborne Early Warning Aviation Regiment based at Ivanovo-North had a fleet of 17 A-50s. Of these, nine A-50s and three A-50Us were in active service, and at least two more A-50s were in long-term storage. In 2014, a Vega representative publicly revealed the Russian Air and Space Force has an inventory of 22 A-50s, including the examples kept in reserve. Alexander Mladenov photo TANTK Beriev

Mi-171A2 Production

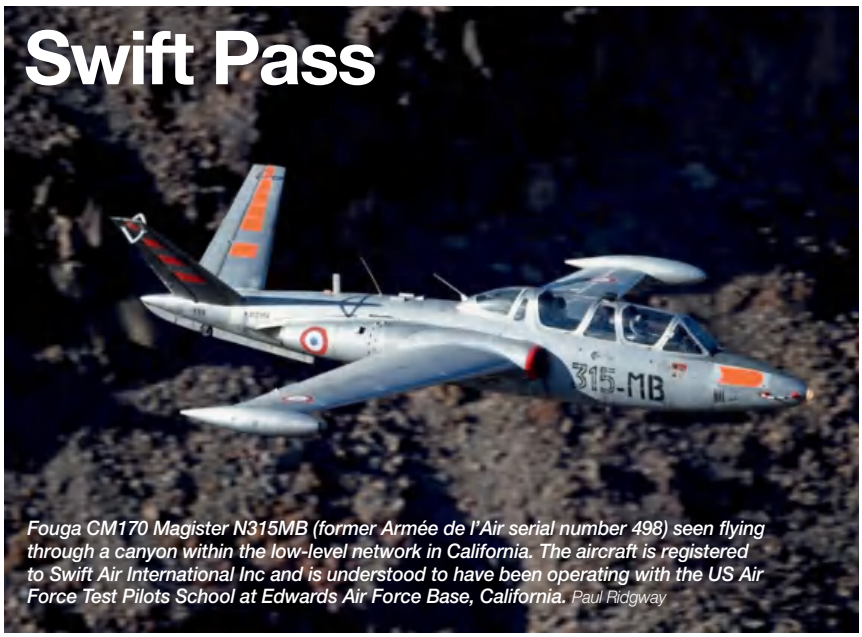
Russian Helicopters launched series production of the Mi-171A2 in early 2017, according to the company's new director general, Andrey Boginsky, who said four machines are planned for roll-out this year. The Mi-171A2's production line is at the Ulan-Ude Aviation Plant in Eastern Siberia.

Boginsky did not reveal the name of the launch customer for the Mi-171A2, which remains in its certification testing phase and is expected to obtain its type certificate from Rosaviatsia (the new Russian aircraft certification authority) by late 2017.

The 14-tonne Mi-171A2 is an upgrade of the Mi-8 with improved performance, optimised for commercial passenger and cargo transport, SAR missions and VIP transport. It features a new rotor system with composite blades, the KBO-17 digital avionics suite, two FADEC-equipped Klimov VK-2500PS-03 turboshaft engines and a Safir auxiliary power unit.

The first Mi-171A2 prototype, dubbed OP-1, made its maiden flight on November 25, 2014, followed by OP-2 on November 9, 2015. Russian Helicopters' original plan was to complete certification in 2016. That never happened. The delay may eventually amount to less than a year. *Alexander Mladenov*

Swift Pass



Fouga CM170 Magister N315MB (former Armée de l'Air serial number 498) seen flying through a canyon within the low-level network in California. The aircraft is registered to Swift Air International Inc and is understood to have been operating with the US Air Force Test Pilots School at Edwards Air Force Base, California. Paul Ridgway

Tu-160M2 Deliveries

According to information released by Tupolev's director general, Alexander Konyukhov, first deliveries of new Tu-160M2 *Blackjack* strategic bombers to the Russian Air and Space Force are planned for 2021.

Tupolev is currently designing new systems for the Tu-160. Digitalisation of design documentation was completed at the end of 2016, and production of the first parts and assemblies has been already begun. Russia's deputy defence minister for procurement, Yuriy Borisov, revealed in October 2016 the Russian Ministry of Defence is considering an order for as many as 50 new Tu-160s. Production will be launched at the Kazan-based KAPO plant, now a subsidiary of Tupolev.

According to Borisov, the maiden flight of the Tu-160M2 is tentatively planned for 2018, while the series production is to be launched in 2020. *Alexander Mladenov*

UAE Completes Predator Order

The UAE has received all of the unspecified number of unarmed General Atomics RQ-1E Predator XP unmanned air vehicles ordered as part of a $200 million contract in February 2015, according to an announcement made at the IDEX defence exhibition in Abu Dhabi during February. Predator XP can be differentiated from previous versions by its winglets. Other countries in the Middle East are reportedly currently evaluating the system. *David C Isby*

This year's edition of the Avalon air show included debuts by five RAAF types. Two of the first four EA-18G Growlers delivered to RAAF Base Amberley the week before, including aircraft A46-306, were at the show. Nigel Pittaway

Killer Drones, Ta and Kiwi Sword

by Nigel Pittaway

The 2017 Australian International Air Show, held at Avalon near Melbourne between February 28 and March 6, was one of the largest ever. Several important announcements were made over the three trade days of the show, including the final operational capability milestone for the Royal Australian Air Force's (RAAF) Airbus KC-30A multi-role tanker transport (MRTT) and industry teaming arrangements for the Commonwealth's armed UAS requirement.

In other news, details of an interim communications gateway capability for the Australian Defence Force (ADF) emerged and industry was keen to talk about New Zealand's Future Air Surveillance Capability (FASC) programme.

Predator versus Heron

Both of the primary contenders for Australia's armed medium-altitude long-endurance UAS requirement, the General Atomics MQ-9 Predator/Reaper and Israel Aircraft Industries Heron TP, were displayed at Avalon, separated only by the width of the taxiway.

Between 2017 and 2026, Australia is looking to acquire an armed UAS under Project Air 7003, and the government's Defence Integrated Investment Programme has allocated between one and two billion dollars for the programme.

General Atomics Aeronautical Systems Inc (GA-ASI) used the opening day of Avalon 2017 to formally launch Team Reaper Australia, an industry consortium which includes Cobham, CAE Australia, Flight Data Systems and Raytheon Australia.

Cobham will be the lead team member for GA-ASI in Australia; Flight Data Systems for the flight data recorder; CAE will provide simulators and a training package based upon the zero-time simulator currently used by the Aeronautica Militare for its Predators; and Raytheon Australia will furnish the DAS-1 Multi-Spectral Targeting System.

Team Reaper Chief Executive Officer Linden Blue said: "We recognise the importance of working with Australian established partners. We have been working closely with the ADF to understand the operational needs of Air 7003 and we are confident that our RPA System solution will provide mature, persistent, interoperable support to Australia's warfighters."

Team Reaper Australia's bid will likely be based upon the Certifiable Predator B system, recently ordered by the United Kingdom.

Israel Aircraft Industries Executive Vice President and General Manager of the Military Aircraft Group, Shaul Shahar said the Heron TP being offered to Australia will benefit from the extensive experience the ADF has gained from operating the Heron 1 system, both in Afghanistan and in Australia, since 2010. "We believe the Heron TP brings a significant advantage to our Australian customers, since it is operated with the same operational concepts as the Heron 1, allowing a virtually seamless transition between it and the much larger and more capable Heron TP," he said.

Two PC-21s in full RAAF markings, still owned by Pilatus and displayed with their Swiss civil registrations, were at Avalon. Both aircraft are due to be delivered in mid-2017. Nigel Pittaway

nker Milestones
lfish

More MRTT Milestones

Australia's Minister for Defence, Senator Marise Payne announced on March 2 the RAAF's KC-30A tanker had achieved final operational capability. In a statement from Canberra, Marise Payne said: "The KC-30A has been an outstanding asset over Iraq on Operation Okra, having offloaded over 74 million pounds of fuel to coalition aircraft, including Australia's F/A-18A Hornet and E-7A Wedgetail aircraft. Just one KC-30A can support the deployment of four fighter aircraft over 2,700 nautical miles [5,000km], with 50 personnel and 12 tonnes [26,455lb] of equipment. It is an extremely versatile aircraft suited to the long ranges of the Australian continent."

At Avalon on the same day, Chief of Air Force Air Marshal Leo Davies and Airbus Defence and Space Head Fernando Alonso signed a research agreement to further develop the KC-30As capabilities. The initial work will involve joint development of an automatic air-to-air refuelling (A3R) system for the boom.

Alonso also used the opportunity to launch Airbus Defence and Space's SMART tanker which, in addition to A3R, will include development of the MRTT as a command and control (C2) node, Big Data (enhanced use of the MRTT's central maintenance computer to monitor mission systems performance) and Space Data Highway (laser SATCOM).

"The KC-30A offers tremendous combat potential at the heart of the integrated Air Force of the future, including using the platform as a communications node, to maximise air power delivery," he said.

Swordfish Pitched to New Zealand

Responding to reports that the New Zealand Government has requested pricing and availability data on the possible acquisition of two Boeing P-8A Poseidon aircraft, Saab is pitching up to six Bombardier Global 6000 platforms, fitted with its Swordfish maritime patrol mission system.

Saab's Head of Marketing and Sales, Airborne ISR, Richard Hjelmberg said: "We have presented our Swordfish solution to New Zealand and we've had a lot of positive feedback. We are aiming at two thirds of the direct unit cost of a P-8A and 50% of the lifecycle cost."

A Boeing spokesman at Avalon would not comment on reports that New Zealand has requested details of Poseidon cost and availability due to concerns that production will soon end. Boeing has recently delivered the 50th P-8A to the US Navy and more than 70 are still to be built. In addition, Boeing is building aircraft against export orders from Australia, India, Norway and the United Kingdom.

New Platforms and King Air Communications

Avalon 2017 was remarkable in that there were no fewer than five RAAF platforms making their debut at the show. This line up included two Australian F-35A Lightning IIs, which had been flown in from the United States specifically for the show and two of the first four Boeing EA-18G Growlers delivered to Amberley the week before. Also on display was a Leonardo C-27J Spartan, the first P-8A for the RAAF and the first two Pilatus PC-21s.

The PC-21s are still owned by Pilatus and carried their Swiss civil registrations, but were in full RAAF markings and are due to be delivered in mid-2017. Air Marshal Leo Davies commented: "Air Force is planning to commence PC-21-based training of undergraduate students in pilots' course and flying instructors' course in early 2019."

In other news from the show, the RAAF will trial Northrop Grumman's Airborne Gateway communications relay and gateway system aboard a Beech King Air 350 platform under an Air Force Minor Programme this year. Funded under Plan Jericho, the interim capability will be used to define the best way to digitally link existing air, ground and sea platforms and other capabilities across the ADF in a two-year trial.

The ADF previously tested the Airborne Gateway system, installed aboard a Northrop Grumman-owned Gulfstream II during Exercise Jericho Dawn last year.

Mi-17s carrying the flags of India and the Indian Air Force led the flypast during the opening ceremony of Aero India 2017.
All pictures by Piotr Butowski

Aero India

Piotr Butowski brings us the latest news from this year's Aero India, held between February 14 and 18

Aero India, like every big air show is driven by money. After the conclusion of the Medium Multi-Role Combat Aircraft (MMRCA) fighter tender and several other procurement programmes for the Indian Ministry of Defence, a brief respite. Only 549 companies took part in this year's 11th exhibition at Yelahanka Air Base near Bangalore (there were 623 in 2015 and 650 in 2013). The exhibition was opened by Minister of Defence Manohar Parrikar, followed by an air parade headed by three Mi-17 helicopters, suspending the flags of India, the Indian Air Force and Aero India. 'Made in India' was the theme of the formation which featured a group of Dhruv, Rudra, LCH and LUH helicopters and then a group of Tejas, Su-30MKI, Do-228, Hawk-i and HTT-40 aircraft. Aero India focuses exclusively on military aircraft and there were no token civilian aircraft present this year.

New Show, Old Tale

The author has reported from Aero India since 2005. His reports usually contain details of aspirations of the Indian Air Force including its objective to have 42 fighter squadrons operational by 2022; how the MiG-21 fighter fleet is close to the end of its service life; and how the expected deliveries of new Light Combat Aircraft (LCA) Tejas and MMRCA Rafale fighters have yet to begin.

There are currently 33 fighter squadrons in the Indian Air Force order of battle comprising about 700 aircraft; a squadron complement is 18 aircraft plus a few more for maintenance reserve and strike off wastage.

Current squadron count includes 11 squadrons of MiG-21s and MiG-27s, soon to be deactivated, which means India must purchase 400 fighters to equip 20 squadrons by 2022. Since the introduction of the MiG-29 and Mirage 2000 fighters 30 years ago, India has only introduced the one type of fighter, the Su-30MKI *Flanker*, albeit in large numbers. Despite its urgent need for 126 MMRCA fighters, the procurement programme was cancelled and India ordered just 36 expensive Rafale fighters instead; the first batch should arrive in India in 2019. Three Rafales took part in Aero India 2017, two flying and one on static display.

Fighter Mania

In early October 2016, the Indian Ministry of Defence issued a Request for Information (RFI) about a new fighter with just two conditions: the aircraft is to be a single-engine design (thus cheaper than the Rafale) and production is to be undertaken in India. Consequently, the list of contenders is short, just two types qualify as single-engine designs: Lockheed Martin's Block 70 F-16 and SAAB's JAS 39E Gripen.

SAAB had a significant presence at Bangalore, displaying a mock-up of the Gripen E and three JAS 39C Gripens on the flight line.

Lockheed Martin, was as usual supported by the US Air Force with two F-16C Fighting Falcons on the flight line.

Assessing the chances of both candidates is difficult. Most observers lean toward the Gripen, but Lockheed Martin can play a trump card: an offer to produce an export version of the F-35 Lightning II in India in the more distant future.

Since December 31, Chief of the Air Staff Air Chief Marshal Birender Singh Dhanoa stated selection of the new fighter would not only be a choice of the aircraft, but also the choice of a strategic partner that will launch a production line in India, provide transfer of technology and, in the more distant future, help India with the development of a next generation of indigenous fighter aircraft.

India's Ministry of Defence has not included the number of single-seat fighters required in the Request for Information. Dhanoa has simply said the Indian Air Force will maintain an optimum ratio of light, medium and heavy class combat aircraft.

Minister Manohar Parrikar quite unexpectedly mentioned at Bangalore that India was considering a further fighter competition (presumably for a twin-engine type) that will only be addressed once the tender for the first competition is concluded. Because India has already placed orders for two squadrons of Rafales, six LCA Tejas squadrons and two Su-30MKI squadrons; tenders for a single, and perhaps a twin-engine fighter, may involve 200 aircraft.

Naval MRCBFs

At a press conference on December 2, 2016 (Navy Day), Chief of Naval Staff Admiral Sunil Lanba caused a storm stating the Indian Navy is not considering the indigenous Naval LCA as the aircraft for India's new aircraft carriers, but would look overseas for a new ship-borne fighter type. In reality, Admiral Lanba said nothing new – a decision that the first variant of the Naval LCA would not be used operationally was made as early as December 2009. At that time six Mk1 aircraft, built for evaluation and pilot training, were ordered and development of the highly revised Mk2 began.

Single-seat Naval LCA 3002 (c/n NP-2) is one of two prototypes and was on static display at Bangalore.

During Aero India 2017, Parrikar softened the Admiral's statements, thanking the team of the Aeronautical Development Agency (ADA) for its good work and emphasised that the Indian Government will still fund the Navy LCA programme. Nevertheless, the Mk2 Navy LCA will not be ready soon; the ADA is aiming for the Mk2's first flight in the 2020-2021 timeframe. At Bangalore, single-seat NP-2 (Naval Prototype) 3002 (one of two existing Navy LCA aircraft) was on static display.

In January, the Indian Navy issued an RFI for 57 Multi-Role Carrier Borne Fighters, dubbed MRCBF. The detailed document poses many questions, but does not specify a launch configuration; catapult assisted take-off but arrested recovery (CATOBAR), or ski-jump assisted short take-off but arrested recovery (STOBAR). Time is an important criterion: Admiral Lanba set a five to six-year timeline for the MRCBF's introduction into service. This deadline limits candidates to two: Boeing's F/A-18 Super Hornet and Dassault's Rafale M; a naval Gripen M or Lockheed Martin's F-35C Lightning II Carrier Variant are less probable, and Russia's MiG-29K is not being considered. The fact that the Indian Navy is insisting on a new tender rather than further MiG-29K purchases may indicate the service is not satisfied with the type; complaints from the Indian Navy concern poor maintenance and limited payload and endurance.

Indigenous Tejas

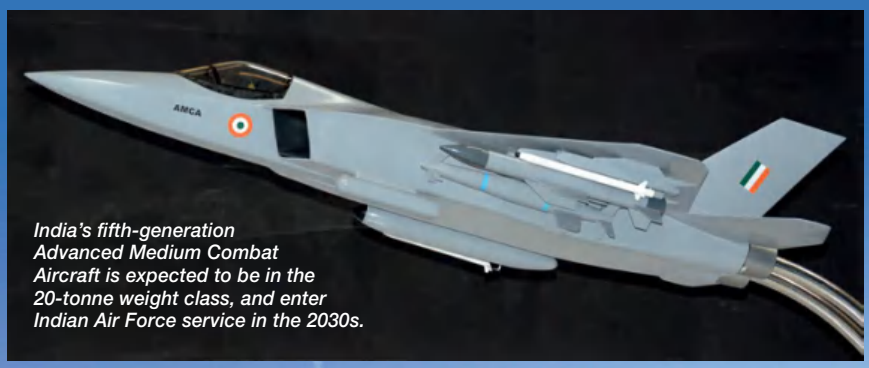
Progress of the Tejas LCA programme is much slower than announced. Two years ago, the then chairman of Hindustan Aeronautics Limited, R.K Tyagi said the company would manufacture six Tejas aircraft in FY2015-2016 (ended in March 2016) and eight more in FY2016-2017. Only three were built.

On July 1, 2016, the initial two series production aircraft (c/n SP-1 and SP-2) were delivered to the first operational unit, No.45 Squadron 'Flying Daggers', temporarily based at Bangalore.

Aircraft LA-5001 (SP-1) was on static display at Aero India 2017, other aircraft made demonstration and customer flights during the show.

Two orders currently exist: the first from 2006 for 20 Mk1 aircraft compliant with the requirements of the initial operational clearance standard, and a second from 2010 for 20 aircraft compliant with the final operational clearance configuration. According to current plans, No.45 Squadron is to be fully equipped with 20 aircraft in 2018 and the other 20 will be completed in FY2019-2020, that is by March 2020.

A further four squadrons were to be equipped with the new LCA Mk2 version with the more powerful GE-F414-INS6 engine, slightly enlarged airframe and more advanced systems. However, the plan recently changed; the Mk2 configuration was shifted to the more distant future and instead a new, interim Mk1A configuration appeared, featuring the existing airframe and engine, but the new systems planned for the Mk2. The Mk1A will feature an active electronically scanned array (AESA) radar; an electronic warfare suite with an internal radar warning receiver and podded self-protection jammer; an aerial refuelling capability; and carry beyond-visual range air-to-air missiles.



India's fifth-generation Advanced Medium Combat Aircraft is expected to be in the 20-tonne weight class, and enter Indian Air Force service in the 2030s.

The Naval LCA is reportedly underpowered, so the Indian Navy intends to use it for evaluation and pilot training purposes only. For operational tasks, 57 carrier-borne fighters will be acquired instead.

HAL's Light Utility Helicopter (LUH) prototype ZG-4620 (c/n PT-1) made its debut at Aero India this year. The LUH is expected to achieve certification by December 2017 and subsequently enter production at Tumkur.

Maintenance improvements include easier access to equipment and interchangeable modules. In December 2016, RFIs were sent to equipment manufacturers. During Aero India 2017, all manufacturers from everywhere, including Sweden and Russia, declared a readiness to supply an AESA radar system for the Mk1A. There is also an indigenous radar option, called the Uttam made by the Electronics and Radar Development Establishment (LRDE), part of DRDO.

In November 2016, the Defence Acquisition Council cleared procurement of 83 Mk1A aircraft, production of which, according to HAL Chairman and Managing Director T Suvarna Raju, will begin in 2019 and be complete by 2027-2028. To meet this plan, according to Raju, HAL is setting up a second Tejas assembly line, allowing for an increase in the production rate from eight to 16 per year with an increased level of outsourcing.

Another Reincarnation

India's Aeronautical Development Agency (ADA), which builds the Tejas LCA, is also working on the fifth-generation Advanced Medium Combat Aircraft (AMCA). In the initial configuration, shown in pictures from more than ten years ago, the design featured a tailless configuration of the Tejas with two engines.

A model of the AMCA in a more traditional configuration featuring an empennage was displayed at Aero India 2009. This year's exhibition included a model of the fourth AMCA variant featuring changed wing and empennage shapes. One model featured an open internal weapons bay.

The AMCA design includes characteristics typical of new generation fighters; low observability (including internal weapons carriage); supercruise capability; the latest sensors and weaponry and network-centric warfare capability and it's classed as a medium-weight fighter with a 20,000kg (44,000lb) take-off weight.

The AMCA programme continues at a general research stage.

Reportedly the ADA is currently building a full-scale AMCA mock-up primarily intended for testing the stealth characteristics of the airframe. Once the problems of the Tejas programme have been corrected, the AMCA programme may be speeded up, although the type's maiden flight cannot realistically be expected in less than ten years.

Where fifth-generation fighters are concerned, the Indian-Russian Prospective Multirole Fighter (PMF) based on the Russian T-50 PAK FA programme continues to shift further and further back in time. Remarkably, HAL's exhibition hall displayed nothing about the PMF. At the 2013 and 2015 editions, HAL displayed a model of the PMF in Indian Air Force markings. Both parties, India and Russia, conceded there are some problems and said talks are in progress. An Indian Government committee, established to thoroughly evaluate the PMF programme, is soon expected to deliver its results.

Helicopters

India purchased so many Russian Mi-17 transport helicopters that HAL eventually proposed an indigenous helicopter in this niche. If the Indian Multi Role Helicopter (IMRH) comes into being, it will be the heaviest indigenous helicopter ever developed. A full-scale mock-up of the IMRH debuted this year at show central in HAL's exhibition hall; the type was ceremonially unveiled by Indian Minister of Defence Manohar Parrikar on the first day of the show.

Powered by two engines, the type is yet to be unspecified, the IMRH mock-up featured a five-blade composite main rotor and four-blade tail rotor; a tall fuselage that allows passengers to stand upright inside the cabin; retractable landing gear; state-of-the-art mission equipment and avionics with a glass cockpit. Although the IMRH mock-up was displayed in a leather-upholstered VVIP configuration, its design is primarily geared for the military market configured for a wide range of missions from transport of 24 troops, through combat search and rescue (CSAR), to anti-submarine warfare in carrier-based version with folding rotor blades. This latter version would replace Indian Navy Sea King helicopters.

Back in 2009, HAL displayed a poster of the IMRH project with the same specification but the design featured aft-mounted engines, driving the main gearbox mounted in front of them. Engines on the latest

Two, two-seat Tejas fighters flew customer orientation and familiarisation flights during the show. Note the Israeli Litening targeting pod carried on the under-fuselage hard point.

Above: ***By February all four of HAL's Light Combat Helicopters had accumulated 850 flights. Sensors and weapons integrated on the LCH are systems already fitted to the Rudra.*** *Below:* ***Weighing 12.5 tonnes, the Indian Multi Role Helicopter is the heaviest helicopter ever developed in India. A full-scale mock-up was placed in the middle of HAL's exhibition hall for its Aero India debut.***

IMRH CHARACTERISTICS

Main rotor diameter: *18.0m (59ft 1in)*
Tail rotor diameter: *3.7m (12ft 2in)*
Fuselage length: *17.5m (57ft 5in)*
Fuselage width: *2.6m (8ft 6in)*
Height without rotor: *5.6m (18ft 4in)*
Cabin length: *5.7m (18ft 8in)*
Cabin width: *2.1m (6ft 11in)*
Cabin height: *1.9m (6ft 3in)*
Max take-off weight: *12,500kg (27,558lb)*
Payload: *3,500kg (7,716lb)*
Never-exceed speed: *148kts (275km/h)*
Max speed: *124kts (230km/h)*
Service ceiling: *21,325ft (6,500m)*
Range: *500km (270nm)*
Range with additional tanks: *800km (430nm)*

mock-up are mounted in front of the main gearbox. It is not known why this change has been made; a configuration featuring aft-mounted engines is generally considered better because it reduces aerodynamic drag and cabin noise, and is safer in the event of an emergency landing. All-in-all, the current design looks very old-fashioned.

Russian Helicopters announced at Bangalore they were expecting another order from India for 48 Mi-17V5s by the end of the year. To date, India has received 151 Mi-17V5s under two contracts placed in 2008 and 2012, not to mention about 400 examples of older Mi-8 versions.

Light Utility Helicopter

Making its flying debut at the show was the first Light Utility Helicopter prototype (PT-1) serial number ZG-4620. It lifted off for the first time on September 6, 2016 and made its first full-flight on October 28. The LUH programme is a priority for HAL faced with an urgent need to replace old Cheetah and Chetak helicopters. The company plans to achieve LUH certification by December 2017 and to start production at a new facility in Tumkur, 75km (45 miles) from Bangalore.

However, like the Russian Mi-17 being a rival to the IMRH, the Ka-226T (originally developed for an Indian programme for 197 reconnaissance and surveillance helicopters) is a rival to the LUH. Forty Ka-226Ts built in Russia are due to be delivered to India and a further 160 will be produced at Bangalore by an Indian-Russian joint venture. Since the Indian armed forces estimate a demand for about 485 light helicopters, there is a place for both the Ka-226 and LUH.

Light Combat Helicopter

During Aero India all four existing examples of the Light Combat Helicopter (LCH) appeared; the newest, technology demonstrator (c/n TD-4), serial number ZF-4604, completed its first flight on December 1, 2015. By February 2017 the four LCH helicopters had accumulated 850 flights since the maiden flight of TD-1 on March 29, 2010. Current testing involves weapons and the fire control system.

In 2016, the Defence Acquisition Council cleared procurement of ten limited series production helicopters. According to an earlier letter of intent, HAL expects an Indian Army order for 114 and one from the Indian Air Force for 65.

The Light Combat Helicopter uses the engine, transmission and rotors of the Dhruv Advanced Light Helicopter, but has a new, narrow fuselage with a crew of two seated in tandem. Armament and targeting

Top Left: ***HAL's Weapon System Integrated Advanced Light Helicopter (WSI ALH) MkIV Rudra, the combat version of the Dhruv, received its initial operational clearance in February 2013 and is now in production.*** *Top Right:* ***Dhruv ZD-4146, is a rare example of an Indian Air Force Dhruv configured with a wheeled retractable tricycle landing gear. Most are equipped with skids; wheels are typical for the Navy's variant. This variant is equipped with a self-protection suite similar to the system fitted to the Rudra.***

systems were taken from the ALH MkIV, called the Rudra, in production and service since February 2013.

HAL's helicopter complex in Bangalore currently builds 22 to 24 ALH Dhruv/Rudra helicopters per year. By February 2017, the production plant had delivered 136 of the 159 ALH helicopters ordered (105 by the Indian Army and 54 by the Indian Air Force) in various versions, and awaits orders for a further 73. After launch of full-scale series production of the LUH and LCH helicopters, India will produce a combined total of 85 to 90 ALH, LCH and LUH helicopters per year.

Trainers

India's 100th Hawk Mk132 built by HAL's Aircraft Division in Bangalore, named Hawk-i and painted blue and white, was on display at Aero India 2017. The Hawk-i aircraft, which took part in the flying display, is an upgraded Indian version of the Hawk with an indigenous mission computer; a digital map generator to improve situational awareness; a new embedded virtual training system; data link and secured voice communication.

A more advanced Hawk upgrade was presented in the static display by BAE Systems using company demonstrator aircraft ZJ100. The Advanced Hawk has greater ordnance carrying capability on seven hard points for a total payload of 3,000kg (6,614lb) and can serve as a lead-in fighter trainer or light combat aircraft. The demonstrator was converted at HAL's facility in Yelahanka. The aircraft was displayed with a Paveway IV precision-guide munition; a Brimstone air-to-surface missile; ASRAAM air-to-air missile; and an Israeli Litening targeting pod. The wing was retrofitted with combat flaps and adaptive leading-edge slats to improve turn rate and landing performance; the aircraft has reinforced landing gear and a refuelling probe. New Rolls-Royce Adour 951 engines provide 14% more thrust than the previous Adour 871. The cockpit has a large-area multifunction display and a new head-up display.

HAL previously made 99 Hawk aircraft for the Indian Ministry of Defence; the first contract in March 2004 for 42 and another contract in July 2010 for 57 aircraft (40 for the Indian Air Force and 17 for the Indian Navy). Prior to that, India purchased 24 aircraft built by BAE Systems in the UK. India's fleet of Hawks has accumulated more than 100,000 flight hours. During Aero India 2017, the Surya Kiran aerobatic team gave its first performance with Hawks.

The HTT-40 turboprop basic trainer (Hindustan Turboprop Trainer) made by HAL from its own funding without an order also debuted at Bangalore this year. The first aircraft (c/n PT-1), serial number TSR001 (flying since May 31, 2016) took part in the flight display, while the yet-to-fly TSR002 (c/n PT-2), stood on static display. HAL's HTT-40 has a strong rival in India: the Pilatus PC-7 MkII, 75 of which were ordered by the Indian Air Force, and one – P-143 – took part in the flying display.

LIGHT UTILITY HELICOPTER CHARACTERISTICS

Main rotor diameter: *11.6m (38ft 1in)*
Tail rotor diameter: *1.8m (5ft 11in)*
Fuselage length: *11.5m (37ft 9in)*
Fuselage width: *1.6m (5ft 3in)*
Height without rotor: *3.4m (11ft 2in)*
Max take-off weight: *3,117kg (6,872lb)*
Empty weight: *1,910kg (4,211lb)*
Payload: *500kg (1,102lb)*
Cruise speed: *127kts (235km/h)*
Service ceiling: *21,325ft (6,500m)*
Range: *350km (190nm)*
Range with additional tanks: *800km (430nm)*

Below: ***The one hundredth Hawk assembled and upgraded by HAL, was presented as the Hawk-i, seen in formation with an example of the indigenous HTT-40 turboprop basic trainer.***

Supersonic X-Plane Tests

Lockheed Martin's Quiet Supersonic Technology (QueSST) X-plane preliminary design is undergoing high-speed wind tunnel tests at NASA's Glenn Research Center in Cleveland, Ohio as work continues to research new supersonic passenger airliners.

Two months of tests using a 9% scale model of the design began in February in the 8 x 6ft (2.4 x 1.8m) Supersonic Wind Tunnel at the facility. The model is being exposed to wind speeds ranging from 150mph (241km/h) all the way up to Mach 1.6 to understand the lift, drag and side forces on the model at different angles of attack, and to ensure air flows smoothly into the engine under all operating conditions.

Dave Richwine, NASA's QueSST preliminary design project manager, said: "This test is an important step along the path to the development of an X-plane that will be a key capability for the collection of community response data required to change the rules for supersonic overland flight."

Lockheed Martin says its research indicates it's possible for a supersonic aircraft to be shaped in such a way that the shock waves formed when flying faster than the speed of sound can be reduced to a quieter 'heartbeat' sound rather than the traditional sonic boom.

Wind tunnel testing and analysis is expected to continue until mid-2017. NASA awarded Lockheed Martin a contract in February 2016 for the preliminary design of a supersonic X-plane flight demonstrator. The agency's plan is for a low-boom flight demonstration aircraft to start flight testing in 2020. The QueSST design is part of NASA's New Aviation Horizons initiative, which aims to reduce fuel use, emissions and noise through researching innovations in aircraft design that depart from the conventional tube-and-wing aircraft shape. *Mark Broadbent*

Mechanical technician Dan Pitts prepares the 9% scale model of Lockheed Martin's Quiet Supersonic Technology X-plane preliminary design for its first high-speed wind tunnel tests at NASA's Glenn Research Center. *NASA*

Air Canada Goes Retro

Air Canada Boeing 787-8 C-GHPQ (c/n 35257) departing Toronto Pearson International Airport as AC407 to Montreal on its first revenue flight wearing the new livery. *Andrew H Cline*

Air Canada has unveiled its first major rebrand for more than a decade by introducing a fresh identity that includes several touches from previous liveries carried by the Canadian flag carrier.

The new scheme was simultaneously unveiled in three separate cities (Toronto, on a Boeing 787-8, and Vancouver and Montreal on Airbus A321s). The livery restores the airline's red maple leaf 'rondelle' logo to the tail and revives the black tail that featured on the carrier's aircraft from 1993 until the most recent rebrand in 2004. The new look was created by design firm Winkreative, previously responsible for rebrands at Porter Airlines and Swiss.

The rebrand coincides with Air Canada completing the reconfiguration of the cabins in its 25 Boeing 777s to provide commonality with those in its 787s, and a network expansion which includes new services from Toronto and Montreal to destinations including Mumbai, Berlin, Reykjavik, Algiers, Taipei and London Gatwick. The airline has also confirmed it expects to receive its first 737 MAX 8 at the end of this year.

Mark Broadbent

Boeing's UK Factory

Boeing will manufacture parts for 737NGs, 737 MAXs and 777s in the UK after it unveiled plans to open a factory in Sheffield – its first in Europe. Boeing Sheffield will produce actuation systems for wing trailing edges as part of a broader plan to increase in-house manufacturing of key components and systems, which the company says will improve efficiency and reduce costs.

Subject to planning permission being granted, the proposed 25,000ft² (2,300m²) Boeing Sheffield building will be located next to the Advanced Manufacturing Research Centre (AMRC), in which Boeing has been involved since its opening in 2001.

Boeing Sheffield will work closely with Boeing Portland, which produces complex machining, gear systems and flight controls and has also been awarded new work on the 737 and 777. The company said Boeing Sheffield will open new opportunities for UK suppliers to bid for work.

The AMRC is part of the Advanced Manufacturing Park, a high-tech research, development and manufacturing cluster outside Sheffield, located on the site of the former Orgreave colliery. In addition to the AMRC and the new Boeing factory, the AMP also includes a Rolls-Royce factory that produces fan blade castings. *Mark Broadbent*

Emirates' Options

Emirates A380 A6-EEI (msn 123), marked with the United for Wildlife livery, departs Paris CDG. The type has been a major part of Emirates' growth, but large widebodies like this are just one option for the Gulf carrier as it considers its next fleet purchase. *Philippe Noret/AirTeamImages*

Emirates is assessing three options for its next fleet requirements, says its President Sir Tim Clark. The Gulf airline is studying whether to continue buying more twin-aisle widebody aircraft, acquire single-aisle narrowbody types such as the Airbus A320 or Boeing 737, or order both smaller twin-aisles and single-aisles. A decision on new aircraft will be made over the next 18 months. Clark said: "When the time is right we will decide. We are just biding our time to see which way it all pans out."

Clark's comments, made in a CNN interview, appear to again delay a decision from Emirates about whether it will buy A350s or 787s, or both. Reports in some media outlets in mid-2016 that Emirates was close to a decision on these types proved unfounded, as no announcements have been made. The carrier cancelled an order for 70 A350s in 2014 and more recently deferred the deliveries of six A380s by a year to 2019.

Any purchase of single-aisles would mark a major strategic shift for the airline. Emirates exclusively operates twin-aisles, which feed passengers through its Dubai hub from its extensive global network. It has been the leading airline advocate of the A380 – it is the largest single operator of the type (93 as of early March) and Clark has been vocal in recent years in urging Airbus to re-engine the type. Emirates is also the largest single Boeing 777 operator, with 150. The airline has not operated narrowbodies since flying Boeing 727s in its earliest years of operation in the 1980s. *Mark Broadbent*

Bryza for the Civil Market

The PZL Mielec M28 Bryza short take-off and landing light twin turboprop is being marketed internationally by Lockheed Martin for civil applications. It is being offered as a 19-seat airliner and cargo aircraft with a maximum load of 2,300kg (5,000lb). The aircraft's capability for airlift and special operations missions has been demonstrated by its use by the US Air Force. It can operate from unimproved airfields as short as 1,500ft (548m). Its high-lift wing and thrust-reversing propellers on two 1,100shp (820kW) Pratt & Whitney Canada PT6-65B turboprop engines provide hot-and-high capabilities. Lockheed Martin obtained marketing rights to the M28 through its acquisition of PZL's US parent, Sikorsky, in November 2015.

An M28 left Poland in February for a sales tour of South and Central America that will run through to May. It crossed the Atlantic by the northern route and started its tour in Port of Spain, Trinidad & Tobago, on March 17. The aircraft will attend the biennial LAAD Defence and Security Exhibition in Rio de Janeiro in April. Its military use by countries in the region including Colombia and Venezuela is considered a selling point. Lockheed Martin is aiming to achieve annual sales of 10-15 M28s in what it sees as a world market for some 150 aircraft in its class.

Lockheed Martin is offering the M28 as a 19-seat airliner, with this aircraft currently undertaking a sales tour of South and Central America. *Lockheed Martin*

The M28 has been certified for commercial operations by the US Federal Aviation Administration, European Aviation Safety Agency and the Brazilian ANAC (National Civil Aviation Agency). *David C Isby*

Aurora and the A350

The Northern Lights above A350-1000 F-WWXL (msn 71) at Iqaluit, Canada, during extreme cold weather testing in temperatures as low as -37°C (-34°F). S Ramadier/Airbus

Kung Fu Panda 787

Hainan Airlines' Boeing 787-9 Dreamliner B-6998 (c/n 62718), pictured in Toronto, has been painted in this distinctive livery featuring characters from the Kung Fu Panda animated film. Andrew H Cline

MRJ Icing Tests

The Mitsubishi Regional Jet (MRJ) recently conducted icing tests at Chicago-Rockford International Airport, Illinois. Flight test aircraft 4 (FTA4, JA24MJ) collected data on the MRJ's performance in natural icing conditions. This was the first test on the MRJ undertaken away from the Moses Lake Flight Test Centre at Grant County International Airport in Washington. The MRJ will now undergo extreme hot and cold weather testing at the McKinley Climatic Laboratory at Eglin AFB in Florida. *Mark Broadbent*

LEAP with the A321neo

The Airbus A321neo powered by the CFM International LEAP-1A engine has received joint Type Certification from the European Aviation Safety Agency and US Federal Aviation Administration. The approval followed a certification programme involving over 400 flight hours amassed in more than 160 flights.

This is the fourth A320neo Family member to be certified. The A320neo has been certified with both the Pratt & Whitney PurePower PW1100G and the LEAP-1A, the two engine options, and the PW1100G-powered A321neo was certified in December 2016. *Mark Broadbent*

Eurowings A319

Airbus A319-119 D-ASTX (msn 3202), pictured at Manchester, is one of the first aircraft to transfer to Eurowings under the Lufthansa Group's restructuring of Air Berlin. Thirty-three A320 family jets will move to Eurowings and three to Austrian Airlines. Ashley French

IN NUMBERS


NHV

10,000

HOURS FOR NHV H175s

Airbus Helicopters H175 launch operator NHV Group has passed its first 10,000 hours since the super-medium-sized helicopter entered service in December 2014. The company's eight H175s are used to supply offshore oil and gas platforms in the North Sea and Ghana. Separately, Airbus Helicopters has announced a payload and range improvement adding 300kg (661lb) to the type's maximum take-off weight or an extra 40 nautical miles (74km). Mark Broadbent

20

MORE AEROFLOT SSJ-100s?

Aeroflot is in negotiations for 20 further Sukhoi SSJ-100 Superjets. Under a fixed-price follow-on order from the United Aircraft Corporation, 12 aircraft would be delivered in 2017 and eight in 2018. Aeroflot currently operates 30 SSJ-100s. Meanwhile, Russian energy minister Aleksandr Novak has said an unidentified Iranian airline is interested in 12 SSJ-100s. David C Isby

Boeing

Customer	Aircraft	Number	Date
Business jet/VIP	737	1	February 14
Juneyao Airlines	787-9	5	February 16
Singapore Airlines	777-9	20, purchase commitment	February 9
	787-10	19, purchase commitment	February 9
Unidentified customer(s)	737	3	February 14
Unidentified customer(s)	737	26	February 21
Unidentified customer(s)	787	5	February 21

Data covers orders announced February 4-March 6. Compiled by Mark Broadbent

9,032

MILES ON LONGEST ROUTE

Qatar Airways now claims to be flying the world's longest commercial air route. Its new service between Doha and Auckland is 9,032 miles (14,535km), the furthest distance between any two cities linked by direct flights. The record for the longest route was previously held by Emirates with its 8,823-mile (14,199km) Dubai-Dallas-Fort Worth service. Mark Broadbent

2

G600s NOW FLYING

Two Gulfstream G600 flight test aircraft are now flying. The second jet undertook its first flight from Savannah, Georgia, on February 24. The aircraft will be used for flight-loads testing. The first G600, which flew on December 17, 2016, is conducting flutter and flight envelope trials. It has achieved more than 150 flight hours. Additionally, Gulfstream recently completed ultimate load testing of the G600 structural test article. Certification of the new long-range business jet is expected in 2018. Mark Broadbent

IN BRIEF

Air Botswana Privatisation

Botswana is attempting to privatise struggling national carrier Air Botswana, and has invited expressions of interest from the market. A five-year turnaround strategy has seen the carrier cut unprofitable routes to Harare and Lusaka and laying off staff, reducing losses to $8 million in 2016. Another 100 staff are due to be cut this year. South Africa's Comair indicated it would make a submission, with its CEO Erik Venter saying the company wants equity in and control over the airline and would explore a management contract. If successful, Comair may move some of the airline's services to South Africa. Previous attempts at privatising Air Botswana came to nothing, but Comair has capital available to invest in the airline, having posted a ZAR 199 million profit for the second half of 2016 and in February it was awarded ZAR 1 billion by a court in an anti-competitive behaviour dispute with South African Airways. *Guy Martin*

Arik Air Takeover

The Asset Management Corporation of Nigeria (AMCON) has taken over Arik Air. The takeover was implemented to prevent the collapse of Nigeria's airline sector and the loss of 3,000 jobs; Arik Air accounts for over half of Nigerian passenger traffic. Crippling debt had left the carrier unable to pay salaries and aircraft leases and the financial woes have seen thousands of flights delayed and cancelled. Arik Air owes the International Air Transport Association $78 million, for example, and AMCON says the airline has $940 million of debt. AMCON said that of Arik's fleet of two A330-200s, nine 737-700s, four 737-800s, four CRJ900s, one CRJ-1000, and four Dash 8 Q400s, only ten are commercially serviceable. It indicated it does not want to liquidate the airline but hopes to turn it around and add five aircraft to the fleet. *Guy Martin*

Winglets for the A380?

Airbus is reportedly considering adding winglets and between 40 and 50 more seats to the A380. Reuters cited unnamed sources saying the potential changes, dubbed 'A380 Plus', could improve the type's fuel efficiency by 2%. The modernisation could lead to the replacement of the A380's grand staircase in the forward fuselage by a more compact staircase, the report said. Airbus declined to comment on the detail of the report. Its latest figures say the global fleet of A380s (208 aircraft as of early March) now undertake 2,000 flights a week to 55 destinations. *Mark Broadbent*

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Su-35C 02 Red, one of the first batch of 12 delivered to the Russian Air Force in February 2014 and now operational at Dzyomgi Air Base.
Artyom Anikeev/AirTeamImages

Flanker

For more than three decades Sukhoi's Su-27 Flanker has been Russia's primary fighter and a symbol of the nation's prowess for building highly capable fighters and securing export contracts from around the world. Piotr Butowski presents the missile-totting Flanker

In December 1969, the US Air Force selected the McDonnell Douglas F-15 design for its future air superiority fighter. In the same year, the USSR launched the Perspektivnyi Frontovoy Istrebityel (PFI or future tactical fighter) with the following requirements: a max speed of Mach 2.0-Mach 2.2 (2,500–2,700km/h); Mach 1.14-Mach 1.22 (1,400–1,500km/h) at sea level; a climb rate of 300–350m/sec (985–1,150ft/sec); a range of 2,500km (1,350nm) or 1,000km (540nm) at sea level, without auxiliary tanks. Taking part in the competition were Sukhoi with the Su-27, Mikoyan with MiG-29 and Yakovlev with the Yak-45 and Yak-47. Before a decision was made, the designers at Mikoyan felt their MiG-29 was losing to the Su-27 and proposed development of two new fighters like the United States: the heavy Su-27 (to match the F-15) and the lightweight MiG-29 (to match the F-16) and scaled down the MiG-29 design, which was originally a heavy fighter. The proposal was accepted in 1971 and both fighters, MiG-29 and Su-27, were ordered.

The first Su-27, which had the design bureau T-10 designation, featured a wing with an ogival leading edge and a deformed shape to achieve a maximum lift-to-drag ratio: the amount of lift generated by a wing, divided by the aerodynamic drag created by the wing when moving through the air. Models of the T-10 used in wind tunnel tests showed a lift-to-drag ration of 12.6 at Mach 0.85.

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The original T-10 design stipulated a bicycle (tandem) landing gear configuration to achieve an aerodynamically clean aircraft: a requirement to which all other aspects of the design had to be subordinate. As a result of the stringent design approach, aerodynamically the T-10's design was being spoiled, but the manufacture process was becoming simpler.

Double curves in its planform were replaced by a sequence of single curves and the troublesome bicycle landing gear was replaced by a conventional tricycle configuration.

The first prototype T10-1, built by the design bureau's workshops at 23a Polikarpov Street in Moscow, was first flown by Sukhoi's chief test pilot Vladimir Ilyushin at Zhukovsky airfield on May 20, 1977.

Details of the Su-27's existence were first published by the US Department of Defense in March 1979.

Once the new T-10 was spotted at a Soviet research and test facility, the US Department of Defense assigned the T-10 the preliminary name Ram-K, Ram being the designator for Ramenskoye in Moscow. Subsequently, the Air Standards Coordinating Committee (comprising representatives from Australia, Canada, New Zealand, the United Kingdom and the United States) gave the T-10 the NATO reporting name *Flanker-A*.

In November 1983, the US Department of Defense published the first photograph of the T-10 prototype, a very poor quality image captured by satellite. Better T-10 images appeared in a documentary film about Pavel Sukhoi, first screened by Soviet TV on July 21, 1985, featuring a ten-second take of T10-1's first flight. Shortly after its first TV appearance, prototype T10-1 was retired to the Soviet Air Force Museum at Monino near Moscow.

2

Radical Redesign

In January 1976, management of the Su-27 programme was assumed by Mikhail Simonov, the future designer general of the Sukhoi design bureau. Simonov had not previously dealt with the Su-27 and was convinced the type required a major redesign. Design characteristics of the T-10 were not attained, because the equipment designed for the new fighter was much heavier than anticipated and the engines consumed more fuel than required.

Even before the first flight of T10-1, design of an entirely modified T-10S version was developed. The first objective was to reduce the aerodynamic drag coefficient and for this purpose the designers reduced the wing camber. Drag decreased, but so did lift at high angles of attack, thus leading edge flaps had to be introduced, so the leading edge had to be straightened, which on the T-10 was S-shaped. Conventional ailerons and flaps on the trailing edge were replaced by flaperons.

Another improvement was reducing the area of the mid-ship section by 20%, which involved a redesign of the main landing gear, relocating the engine gearboxes to the top

1 Su-27UB trainer 74 assigned to the 831st Tactical Aviation Brigade of the Ukrainian Air Force. *Piotr Butowski* **2** The first T-10 prototype T10-1 was first flown on May 20, 1977, by Sukhoi's chief test pilot Vladimir Ilyushin. *Sukhoi* **3** Lyulka-Saturn's AL-31F turbofan engine is the powerplant of all Su-27 and Su-30 versions. *Piotr Butowski* **4** The conventional Cassegrain-antenna N001 radar is fitted to standard Su-27, Su-33 and Komsomolsk-made Su-30 fighters. *Sukhoi* **5** T10-17 was the first production Su-27 in T-10S configuration that first flew at Komsomolsk on June 2, 1982. *Sukhoi*

of the engines and many local aerodynamic changes. Moving the gearboxes required the tailfins to be relocated; on the T-10, the tail fins stood on the engine nacelles.

Eventually, the tailfins on the T-10S were repositioned lower, on the outrigger on each side, which in turn reduced the effective fin area so ventral fins were added to compensate.

After redesigning the landing gear, a new solution for airbrakes had to be found. Previously, the landing gear doors served as airbrakes; in the T-10S, the airbrake was mounted atop the fuselage, similar to the F-15 Eagle.

Nine T-10 prototypes were built before the first modified aircraft made by Sukhoi in Moscow, dubbed the T10S-1, flew for the first time on April 20, 1981 with Vladimir Ilyushin at the controls. The aircraft crashed on September 3.

The Yuri Gagarin Production Plant at Komsomolsk-on-Amur had been participating in the work on the T-10 programme from the start, and was ready to launch production of the aircraft quickly.

The first production Su-27 configured as a T-10S (NATO reporting name *Flanker-B*) flew at Komsomolsk on June 2, 1982.

On March 7, 1985 the first two-seat Su-27UB *Flanker-C* (UB for Uchebno-Boyevoy or combat trainer) built at Komsomolsk flew for the first time.

After five Su-27UBs were built at Komsomolsk, production of the combat trainer version was relocated to the plant at Irkutsk, which had just finished production of the MiG-27 *Flogger* fighter-bomber. The first Su-27UB built at Irkutsk flew on September 10, 1986. In contrast to other two-seat combat aircraft, a good example is the MiG-29, the Su-27UB retained its full fire-control system. With no change to the dimensions of the Su-27, the two-seat tandem cockpit was fitted at the cost of a fuel tank. To compensate for its higher forward fuselage, the tailfins were heightened and the dorsal airbrake enlarged. These changes made the Su-27UB heavier with lower performance than the single-seat Su-27.

Everything New

Designers responsible for the Su-27's design made two important decisions on the aircraft's shape. First was the use of a blended-body aerodynamic configuration (known in Russia as an integral configuration), with the aircraft having a continuous, smooth wing-fuselage junction. This configuration offers two distinct advantages: a high lift-to-drag ratio and capacity to house plenty of fuel and equipment.

Second was use of a configuration with longitudinal static instability, bringing the advantage of higher agility. However, this objective was not fully achieved, because the equipment installed in the forward fuselage, mainly the radar, proved to be heavier than anticipated, so the Su-27 has a longitudinal stability rating close too neutral. Since a statically unstable aircraft cannot be controlled by a mechanical flight control system, a fly-by-wire flight control system was developed for the Su-27. Fly-by-wire was only employed in the longitudinal channel where the benefit is greatest. The Su-27 was the first aircraft produced in the Union of Soviet Socialist Republics with a fly-by-wire control system.

Airframe characteristics were not the only new features in the Su-27; there were also engines, the fire-control system and weapons.

In 1975, the design team at engine manufacturer Arkhip Lyulka (now Saturn) began development of the AL-31F turbofan engine. Specification for the AL-31F required a thrust of 122.58kN (27,558lb) with afterburner, an 8:1 thrust-to-weight ratio and a rate of fuel consumption in cruise of 0.60lb/h-lbf (pounds of fuel per hour-pound of thrust) or 61g/h-N (grams of fuel per hour-Newton of thrust).

Specifications for thrust and weight were attained, but the minimum fuel consumption increased by more than 10% to 0.67lb/h-lbf (or 0.78 at maximum dry, or 1.96 with afterburner). Developing a new engine usually takes more time than the development of a new aircraft and the first T-10 prototypes were fitted with AL-21F3 engines, power

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plant of the Su-17 and Su-24. The AL-31F engine underwent state evaluation as late as 1985, along with the T-10S aircraft.

A team led by Viktor Grishin at the Tikhomirov NIIP institute at Zhukovsky developed a new radar with vertical plane electronic scanning and horizontal plane mechanical scanning. Previously, NIIP had developed and produced the first electronically scanned radar, named the Zaslon, for the MiG-31. However, development of the new radar for the Su-27 failed, because it was too heavy for a fighter. In 1982, the electronic scanning capability was abandoned and the new N001 radar, unified with the N019 radar developed at the time by the rival Phazotron-NIIR institute based in Moscow, was ordered for the Su-27. The N001 radar uses the same Cassegrain antenna as the N019, but has a larger diameter and a more powerful transmitter. Many other components in both radars are the same.

The Su-27 has: an S-27 (izdeliye Sh101) fire-control system operated by two Ts100 computers, including the RLPK-27 (Radiolokatsyonnyi Pritselnyi Kompleks) N001 Myech radar system coupled with an OEPS-27 electro-optical sight system; an SEI-31-10 Nartsiss-M data indication system; a Parol IFF interrogator; and the SUO-27 weapons management system.

The RLPK-27 is a coherent pulse-Doppler look-down, shoot-down radar with a search range of 85–100km (45-54nm) for a fighter-size target with a 3m^2 radar cross-section head-on, and 30-40km (16-21nm) tail-on. The radar system can track while scanning up to 10 targets simultaneously engaging two of them.

The OEPS-27 (Optiko-Elektronnaya Pritselnaya Sistema, izdeliye 31Ye) electro-optical sighting system comprises an OLS-27

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(Optiko-Lokatsyonnaya Stantsya, izdeliye 36Sh) infrared search and track (IRST) system coupled with a laser rangefinder (with a tracking range of 50km (27nm) tail-on and 15km (8nm) head-on) and the Shchel-3U helmet-mounted target designator. The SEI-31-10 Nartsiss data indication system (with its own Orbita-20 computer) includes an ILS-31 (Indikator na Lobovom Stekle) head-up display and IPV (Indikator Priamogo Videniya) tactical display.

Integration of the Su-27's radar, IRST system and a helmet-mounted cueing system was the most innovative and tactically beneficial feature of the fire-control system. For example, if a target tracked by the IRST enters cloud, it can be further tracked by the radar.

A considerable part of the Su-27's in close-air combat capability is due to the Shchel-3U helmet-mounted sight, the first Soviet helmet-mounted target designator, designed and manufactured by Arsenal in Kiev, Ukraine. The sight uses a cross hair for aiming, a function aided by automatic tracking of the pilot's head movement, and displays the aiming information in the pilot's visor and a display in the cockpit. In addition, the seeker of an R-73 missile tracks the pilot's head movement, so launch can be achieved whatever the position of the aircraft and without the need for the pilot to pursue and maintain alignment with the target.

The Su-27 is equipped with a PNK-10-02 flight navigation system comprising of a suite of subsystems: the SAU-10-01 autopilot and 911-01 navigation subsystem with two RV-21 altimeters; ARK-22 radio direction finder; MRP-76 beacon receiver; Kvitok-1 LORAN; TACAN; and SO-72 transponder.

Two datalinks are also fitted: a TKS-2-27 (Tipovyi Kompleks Svyazi) secure datalink, which enables group operations involving up to 16 Su-27s; and the Spektr-1, which receives target information from land-based radars.

1 Su-27 RF-92407 from the 790th IAP based at Khotilovo Air Base during an intercept by an RAF Typhoon over the Baltic Sea in 2014. *Ministry of Defence* **2** The R-27R semi-active radar-guided long-range air-to-air missile is one type of a family developed especially for the Su-27 and MiG-29 fighters. *Piotr Butowski* **3** The R-27T differs from the R-27R with the passive infrared Geophisica 36T seeker in that it has no mid-course path correction and tracks only after the target is locked on by the seeker. *Piotr Butowski* **4** Short-range R-73s and long-range R-27s on a Su-27 at the Lipetsk evaluation centre. *Piotr Butowski* **5** Thanks to a combination of gas and aerodynamic controls, the R-73 is one of the world's best short-range air-to-air missiles. The laser fuse of the R-73L is recognisable by rectangular windows positioned aft of the front fins. *Piotr Butowski*

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Missiles

The Soviets developed two new air-to-air missiles dedicated to the Su-27 and MiG-29 fighters: the medium to long-range R-27 and the short-range R-73.

R-27 Medium to Long Range Air-to-Air Missile

A Vympel R-27 missile was first launched in 1979 from a MiG-23ML *Flogger-G* and remains as Russia's primary medium-range air-to-air missile. Since 1983, Artem's factory in Kiev, Ukraine has undertaken series production of all R-27 versions; there is no production in Russia.

The R-27 (AA-10 *Alamo*) is modular in construction comprising a common mid-body section with control fins, autopilot, power supply, warhead and fuse, and two replaceable rear sections with motors and wings, and a variety of different forward seekers.

Butterfly fins (wider at the tip than the root) are a novelty of the missile's aerodynamic configuration and provide reduced drag and enhanced manoeuvrability during the terminal phase of flight. The first two versions (officially accepted in 1987, although in production since 1983) were the semi-active radar-guided R-27R (R for Radiynaya or radio) and the passive infrared-guided R-27T (T for Teplovaya or heat). A third variant, the passive radar-guided R-27P (P for Passivnaya or passive) has also been integrated on the Su-27.

The R-27E (E for Energeticheskaya or energy) missile variant (officially accepted in 1990) has a more powerful dual-pulse engine (a standard R-27 has a single-pulse engine) with an increase in range and average speed of the missile. Three extended range R-27E sub-variants are the semi-active radar-guided R-27ER, infrared-guided R-27ET and passive radar-guided R-27EP.

The maximum ballistic range of an R-27R is 60km (32nm) and the extended range R-27ER 95km (51nm). However, these ranges are not achieved in real combat. Much depends on the altitude: the lower the altitude, the shorter the range of the missile. Another factor is speed of the Su-27 and the target: the higher the approach speed, the longer the firing distance on a head-on course and the shorter the distance in a tail-chase. For example, the R-27ER missile, with a

SU-27 DESIGNATIONS AND NATO REPORTING NAMES

Designation	*Reporting Name*	*Details*
T-10	Flanker-A	Initial prototype configuration.
Su-27 (T-10S)	Flanker-B	Initial production single-seat variant which includes the Chinese Su-27SK and indigenous J-11, and the Su-27P interceptor without an air-to-ground weapons control system and wiring.
Su-27UB	Flanker-C	Two-seat combat trainer. Also includes Su-27UBK variant.
Su-33	Flanker-D	Carrier-based versions, originally designated the Su-27K (T-10K).
Su-27M (T-10M)	Flanker-E	Advanced single-seat multi-role derivative designated the Su-35 in export configuration. Also includes the Su-37 (T10M-11) demonstrator with thrust vectoring.
Su-30 (T-10PU)	Flanker-F	Two-seat version of the Su-27P interceptor. Also includes the Su-30K for the export market, and the upgraded multi-role Su-30KN.
Su-30MK	Flanker-G	Two-seat strike version for the export market designated Su-30MKK, Su-30MK2 and the Russian Su-30M2.
Su-30MK	Flanker-H	Two-seat strike version for the export market designated Su-30MKI, Su-30MKM, Su-30MK(A) and the Russian Su-30SM.
Su-34	Fullback	Two-seat tactical bomber variant with side-by-side seating; originally designated Su-27IB (T-10IB); the export version is designated Su-32.
Su-35		Single-seat multirole version currently in production; also includes the Russian Su-35S.

1 Su-27SKM TS-2705 is one of three such aircraft unique to the Tentara Nasional Indonesia-Angkatan Udara; all were delivered in 2010. *Royal Australian Air Force* **2** Upgraded Russian Air Force Su-27SM(3) fighters assigned to the Lipetsk evaluation centre. *Piotr Butowski* **3** 30mm rounds being loaded in to the Su-27's Gryazev-Shipunov GSh-301 cannon fitted in the starboard leading-edge root extension. *Piotr Butowski* **4** Central to the Su-27's cockpit is the ILS-31 head-up display; on the right is the IPV tactical situation display, with the navigation device required for international flights above. *Piotr Butowski* **5** A Su-27 with its airbrake deployed atop the fuselage. *Piotr Butowski*

maximum range of 95km (51nm), can in reality hit a target from up to 60km (32nm) in a head-on course or 30km (16nm) in a tail-chase at an altitude of 33,000ft (10,000m) and with the Su-27 and target flying at a speed of 485kts (900km/h); at an altitude of 16,000ft (4,877m) these ranges are 40km (21nm) and 18km (10nm) respectively, and at an altitude of 3,000ft (915m) 26km (14nm) and 10km (5nm) respectively. Moreover, the limitations of the missile's seeker must be considered. For example, the R-27T and R-27ET variants have to lock on to the target before launch, which means the missile's range cannot exceed the seeker range. Target manoeuvring and jamming decrease the true range of a missile even further.

R-73 Short-Range Air-to-Air Missile

The R-73 (AA-11 *Archer*) was designed to be the smallest possible missile fitted with an all-aspect infrared seeker. Initial design started at the Molniya (lightning) design team in Moscow during 1976. After Molniya was assigned the Buran space shuttle development in April 1982, 300 missile experts moved to Vympel to complete R-73 development. The R-73 entered production in 1982 and was officially commissioned on November 5, 1983. During Soviet time, the R-73 missile was manufactured at two plants, Duks in Moscow and TASA in Tbilisi, Georgia. Production continued at Duks after the dissolution of the Soviet Union. Total R-73 production in the USSR is unknown; TASA says it produced 6,000 missiles a year until the early 1990s. After 1992, over 10,000 examples were produced for export, but there was virtually no production for the Russian Air Force.

The R-73 missile has a canard aerodynamic configuration with four cruciform triangular fins in the front and four trapezoidal wings installed around the engine.

The R-73's excellent tactical characteristics have been achieved mainly by virtue of combined gas-aerodynamic control, enabling the missile to make a sharp turn towards the target at an angle-of-attack of up to 40° just after being launched. Two twin interceptors are arranged around the engine's exhaust nozzle for pitch and course control during the active phase of flight assisted by aerodynamic controls. Four mechanically

R-27 MISSILE CHARACTERISTICS

	R-27R	*R-27T*	*R-27ER*	*R-27ET*	*R-27P*	*R-27EP*
Terminal guidance	Semi-active radar	Infrared	Semi-active radar	Infrared	Passive radar	Passive radar
Mid-course correction	Yes	No	Yes	No	No	No
Max range	60km (32nm)	50km (27nm)	95km (51nm)	90km (48nm)	72km (39nm)	110km (59nm)
Min launch distance	500m (1,640ft)	500m (1,640ft)	500m (1,640ft)	500m (1,640ft)	2,000-3,000m (6,562-9,843ft)	2,000-3,000m (6,562-9,843ft)
Max target altitude	82,000ft (25,000m)	79,000ft (24,000m)	89,000ft (27,000m)	98,500ft (30,000m)	66,000ft (20,000m)	66,000ft (20,000m)
Max target g-load	8	8	8	8	5.5	5.5
Launch weight	253kg (558lb)	245kg (540lb)	354kg (780lb)	347kg (765lb)	248kg (547lb)	346kg (763lb)
Warhead weight	39kg (86lb)	39kg (86lb)	39kg (86lb)	39kg (86lb)	39kg (86lb)	39kg (86lb)
Length	4.08m (13ft 5in)	3.79m (12ft 5in)	4.78m (15ft 8in)	4.49m (14ft 9in)	4.00m (13ft 1in)	4.70m (15ft 5in)
Body diameter	230mm (9.1in)	230mm (9.1in)	260mm (10.2in)	260mm (10.2in)	230mm (9.1in)	260mm (10.2in)
Wingspan	772mm (30.4in)	772mm (30.4in)	800mm (31.5in)	804mm (31.7in)	772mm (30.4in)	804mm (31.7in)
Fin span	972mm (38.3in)	972mm (38.3in)	972mm (38.3in)	972mm (38.3in)	972mm (38.3in)	972mm (38.3in)

interconnected ailerons secure stabilisation to the longitudinal axis. Once the missile's rocket motor fuel is exhausted, the missile is aerodynamically controlled only.

Two versions of the R-73 are in use: the original R-73K (R-73E export version) fitted with a Krechet (merlin) radar proximity fuse; and the later R-73L (R-73LE export version) with a Yantar (amber) laser fuse; rectangular windows for the laser fuse positioned just behind the front fins make the R-73L easily recognisable.

The R-73 uses inertial mid-course guidance with a terminal infrared Mayak-80 seeker designed and manufactured by Kiev-based Arsenal. The seeker is capable of tracing targets in any direction, not just from the rear like a thermal seeker, thanks to high sensitivity of a nitrogen-cooled, indium antimonite-based photo element. The R-73 can be launched from any position under any g-load caused by manoeuvring of the Su-27 with no limitation.

R-73 CHARACTERISTICS

Length: *2.90m (9ft 6in)*
Wingspan: *510mm (20.1in)*
Fin span: *385mm (15.2in)*
Body diameter: *170mm (6.7in)*
Launch weight: *105kg (231lb)*
Warhead weight: *7.4kg (16lb)*
Max range head-on: *30km (16nm)*
Max range tail-on: *14km (7.5nm)*
Max seeker range: *10–12km (5–6nm)*
Min launch distance head-on: *650m (2,133ft)*
Min launch distance tail-on: *300m (984ft)*
Target altitude: *20–22,000m (66–72,000ft)*
Max target G-load: *12g*

In Service

The first operational Soviet Air Force unit to receive the Su-27 Flanker was the 60th IAP (Istrebitelnyi Aviatsionnyi Polk, Fighter Aviation Regiment) based at Dzyomgi Air Base near Komsomolsk-on-Amur, where the production plant is located. The objective was to facilitate maintenance of the new aircraft during its initial period of service. The 60th IAP started Su-27 flight operations on June 22, 1985, followed in the autumn by the 941st

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CURRENT RUSSIAN SU-27 UNITS

Russian Air Force	
Belbek	38th IAP
Besovets	159th IAP
Dzyomgi	23rd IAP
Khotilovo	790th IAP
Krymsk	3rd SAP (Composite Aviation Regiment)
Kubinka	237th Air Technology Demonstration Centre
Kushchevskaya	195th UAB (Training Air Base)
Lipetsk	4th TsPAPiVI (Air Personnel Preparation and Military Evaluation Centre)
Tsentralnaya Uglovaya	22nd IAP
Russian Naval Aviation	
Chernyakhovsk	72nd Air Base

IAP based at Kilp Yavr Air Base on the Kola Peninsula. When the Su-27 entered Soviet Air Force service in 1985, America's F-15 Eagle was already 11 years into its US Air Force career. Today, Dzyomgi is home to the 23rd IAP equipped with Su-35S fighters.

According to official information from Sukhoi, 645 single-seat Su-27 fighters were manufactured by 1999. After then, five aircraft were manufactured for Indonesia and 12 Su-27SM(3)s for Russia. The Irkutsk plant built over 200 two-seat Su-27UBs and Su-27UBKs.

Other former Soviet Su-27 operators comprise Armenia (second-hand aircraft acquired in Russia in 2005), Kazakhstan (14 aircraft were received between 1999 and 2001 in exchange for Tu-95MS *Bear* strategic bombers handed over to Russia), Ukraine and Uzbekistan. Belarus retired its Su-27s in December 2012.

SU-27 FLANKER-B CHARACTERISTICS

Wingspan: *14.7m (48ft 3in)*

Wingspan: *with two wingtip R-73 missiles 14.95m (49ft 0.5in)*

Length (without probe): *21.93m (72ft)*

Height: *5.93m (19ft 6in)*

Height: *6.35m (20ft 10in)*

Wing area: *62m² (667.8ft²)*

Tail plane span: *9.88m (32ft 5in)*

Wheelbase: *5.88m (19ft 4in)*

Wheel track: *4.34m (14ft 3in)*

Empty operating weight: *16,380kg (36,112lb)*

Take-off weight with nominal fuel; two R-27 and two R-73 missiles: *23,430kg (51,654lb)*

Max take-off: *28,300kg (62,391lb)*

Max permitted take-off weight: *30,450kg (67,130lb)*

Max permitted take-off weight with upgraded landing gear: *33,000kg (72,752lb)*

Max landing weight: *21,000kg (46,297lb)*

Max permitted landing weight: *23,000kg (50,706lb)*

Max Mach number clean: *2.35*

Max speed: *Mach 1.96 (2,400km/h)*

Max speed at sea level, clean: *Mach 1.14 (1,400km/h)*

Ceiling (clean): *60,000ft (18,500m)*

G limit: *+9g*

Take-off distance: *450–700m (1,476–2,297ft)*

Landing distance: *620–700m (2,034–2,297ft)*

Max range with two R-27s and two R-73s (low altitude): *1,340km (725nm)*

Max range with two R-27s and two R-73s (high altitude): *3,530km (1,905nm)*

Max range at high altitude (clean): *3,720km (2,000nm)*

Operational radius at high altitude: *1,090km (589nm)*

Operational radius at low altitude: *420km (227nm)*

Engines: *Two Lyulka-Saturn AL-31F turbofans, each rated at 75.2kN (16,909lb) dry and 122.6kN (27,558lb) with afterburner*

Internal fuel: *Up to 9,400kg (20,723lb)*

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1 Upgraded Belarussian Air Force Su-27UBM1 side number 63. This aircraft crashed during a demonstration at Radom Air Base, Poland, in August 2009. *Piotr Butowski* **2** Sukhoi development Su-27SKM, side number 305, drops two 500kg (1,100lb) KAB-500Kr TV-guided bombs. *Sukhoi*

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China purchased 46 Su-27s (36 single-seat Su-27SKs and 10 two-seat Su-27UBKs) delivered in two batches in 1992 and 1996, the first nation outside the former Soviet Union to buy the type.

China acquired an additional 28 Su-27UBKs between 2000 and 2002.

On December 6, 1996, Moscow and Beijing reached an agreement for China to start licensed production of 200 Su-27s in Shenyang under the J-11 designation.

The first two license-built aircraft assembled from parts delivered from Komsomolsk-on-Amur flew in December 1998. Despite the original agreement for 200-aircraft, production ended after 105 Su-27s had been built. Instead China introduced the indigenous J-11B derivative.

Vietnam received five Su-27SKs and one Su-27UBK between March and May 1995, followed by six more (including four trainers) during 1997 and 1998. Indonesia received two Su-27SKs in 2003, followed by three upgraded Su-27SKMs in 2010. Indonesia is the only operator of the Su-27SKM version. Several countries have acquired Su-27s from stocks of former Soviet operators, including Angola (one Su-27 and one Su-27UB), Eritrea (one Su-27 and one Su-27UB) and Ethiopia (14 Su-27s and at least eight Su-27UBs).

Mid-life Upgrades

The importance of the Su-27 to the Russian Air Force is illustrated by the fact that even in times of financial defence cuts between 1990 and 2000 all Su-27s remained in service, while lots of similar generation fighters, MiG-29s and MiG-31s, were withdrawn and preserved. Moreover, in the 1990s, the Russian Air Force started a thorough upgrade of its Su-27 fleet.

Irkut, working with Russkaya Avionika (Russian Avionics), proposed the single-seat Su-27KN based on the prototype Su-30KN, side number 302, first flown in April 1999, and two-seat Su-27UBM based on prototype Su-27UBM, side number 20, developed in early 2001.

Irkut's proposal was a relatively simple upgrade featuring an improved radar and new air-to-surface weapons, similar to the MiG-29SM upgrade by Russkaya Avionika a few years earlier.

The improved radar featured a computer that enable ground mapping and tracking moving targets without intervening with existing software and hardware. New air-to-surface weapons included TV-guided Kh-29T missiles, Kh-59M TV-guided extended-range missiles, Kh-31A anti-ship and Kh-31P anti-radar missiles and KAB-500Kr bombs.

Other than an MFI-55 colour liquid-crystal display replacing the original IPV TV display, the cockpit remained unchanged.

Prototype Su-30KN successfully completed state trials on November 9, 2001, and the company was preparing serial upgrades, but after a change in leadership of the Russian Air Force in 2002 to one less well-disposed to Russkaya Avionika, the Su-27KN/Su-27UBM proposal was rejected. Instead, the upgrade packages were introduced outside Russia. Belarussia's 558th ARZ repair plant at Baranovichi upgraded four Su-27UBM1s for the Belarussian Air Force between 2001 and 2005, and four Kazakhstan Air Force Su-27UBM2s between 2008 and 2010. Kazakhstan's Su-27UBM2s also had Israeli Litening III pods integrated for designating laser-guided weapons, and Belarussian Satellit electronic countermeasure pods for self-defence.

SU-27UB CHARACTERISTICS

***Max speed:** Mach 1.73 (2,125km/h)*

***Max speed (sea level):** Mach 1.06 (1,300km/h)*

***Approach speed:** 124kts (230km/h)*

***G limit:** +8.5g*

***Ceiling:** 57,400ft (17,500m)*

***Max range (clean):** 3,000km (1,620nm)*

***Max range (clean s.l):** 1,200km (648nm)*

FIRST CONTACTS

On February 7, 1987, a pair of Su-27s were encountered by a Western aircraft, two Royal Norwegian Air Force F-16s over the Barents Sea, for the first time. On September 13, 1987, a mid-air collision occurred between a Soviet Air Force Su-27 and a Royal Norwegian Air Force P-3 Orion patrol aircraft.

The P-3 was intercepted at 10.39hrs by the Su-27, flown by Vasily Tsimbal assigned to the 941st IAP, over international waters, 90km (48nm) from the coast of the USSR during a patrol in an area where Soviet warships were on exercise. To block out the Orion's reconnaissance equipment the Soviet Su-27 flew beneath its belly. The propeller of the Orion's outer starboard engine hit the Su-27's fin. Fortunately, both aircraft returned to their bases. The Norwegian committee investigating the collision blamed the Su-27 pilot concluding the accident resulted from his errors. The Soviet claim that the Orion pilot made dangerous manoeuvres was rejected. The Orion's repair cost was estimated at $130,000.

Three photos of the Su-27 taken by the Royal Norwegian Air Force P-3 Orion on September 13, 1987.

RUSSKIYE VITYAZI

Russkiye Vityazi (Russian Knights), the Su-27-equipped Russian Air Force aerobatic team is popular in Russia and abroad. Based at Kubinka Air Base as part of the 237th Air Technology Demonstration Centre, the team made its first international tour with a series of displays in the UK during September 1991, which began at RAF Scampton, Lincolnshire, home of the Red Arrows. No other aerobatic team fly aircraft as large and powerful as the Su-27. In addition to its performance and manoeuvrability, the Su-27's fighter pedigree affords carriage of flares that provide an additional attraction when launched during a display.
Aircraft assigned to the Russkiye Vityazi are painted in Russia's national colours: noses are white with a red and blue arrow painted on the upper surface; the lower surface is blue.
Tail fins feature large Russian Air Force flags, the nose carries the logo of the Sukhoi design bureau and the legend Russkiye Vityazi. In October and November 2016, the Russkiye Vityazi received eight new Su-30SM fighters (side number 30 through 37). The first performance by the Russkiye Vityazi using the Su-30SM is planned for the LIMA airshow in Malaysia in March 2017.

The NIIP N011M Bars electronically scanned array radar features three rows of small T-shaped antennas in the centre for the IFF.
Piotr Butowski

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Back in Russia, the air force selected the Su-27SM offered by the Sukhoi design bureau featuring systems previously developed for two-seat multirole Su-30MK2s produced for the Chinese order, and thus most of the research and development work was financed by China.

The Su-30MK2 configuration features the SUV-VEP fire control system, the baseline standard that was developed to SUV-P-R standard for the Su-27SM and features the RLPK-27P Myech-M radar system coupled with the OEPS-27MK electro-optical targeting system, SILS-27M data display system and IFF interrogator. A separate computing channel with the BTsVM-900 computer enables terrain mapping with synthetic aperture, detection of surface targets with the ability to feed target information to Kh-31A anti-ship missiles. It also enables use of RVV-AE active radar-guided air-to-air missiles. The OEPS-27MK targeting system includes a more powerful OLS-27M IRST sensor and a Sura helmet-mounted system. The SILS-27M data display system comprises an ILS-31 head-up display, two MFI-10-6M 152 x 203mm (6 x 8in) multifunction displays and a single MFPI-6 data input panel. Additionally, the Su-27SM has a separate SUV-P1 channel to enable use of laser-guided and TV-guided munitions. The L-150-27.2 Pastel radar warning receiver had been fitted instead of the old Beryoza, enabling target indication for Kh-31P missiles. The Su-27SM also incorporates a new S-107 communication suite and an A737 GPS receiver.

The upgraded fire-control system supports guided air-to-ground weapons, including: up to four Kh-31A anti-ship or Kh-31P anti-radar missiles; up to four Kh-29L/T/TD laser-guided and TV-guided missiles; two S-25LD laser-guided rockets; four KAB-500Kr; and one KAB-1500Kr guided bomb. Air-to-air weapon options include the RVV-AE medium-range missile.

Modernised Su-27SM prototype, side number 56, made its maiden flight on December 27, 2002, at Komsomolsk-on-Amur, with Yevgeniy Frolov at the controls, followed in 2003 by export demonstrator side number 305. The first five upgraded Su-27SMs were handed over to the evaluation centre at Lipetsk in December 2003. The initial operational unit, the 23rd IAP based at Dzyomgi Air Base, received its first Su-27SMs on December 23, 2004. By 2009, the regiments based at Dzyomgi and Tsentralnaya Uglovaya both had 24 Su-27SMs assigned. Su-27SMs based at Tsentralnaya Uglovaya were also fitted with

AUXILIARY FUEL TANK

Nobody has ever seen a Su-27 with external fuel tanks.
Use of a blended-body aerodynamic configuration for the Su-27 resulted in plenty of space inside the fuselage providing the required combat ranges with the internal fuel tanks only partly full and not to maximum capacity. A Su-27 requires 5,270kg (11,618lb) of fuel to meet its combat range requirement yet the airframe has space capacity for 9,400kg (20,723lb). An impressive capability statistic perhaps? Not so. According to strength norms the design team had to guarantee an operational 8g capability with the fuel tanks 80% full, so the airframe's strength was adapted for a lighter load of fuel. Airframe strengthening would be required to enable the aircraft to carry 9,400kg thereby increasing the airframe weight. Eventually an agreement was reached between the design team and the Soviet Air Force to limit fuel capacity to 5,270kg (11,618lb) and the remaining 4,130kg (9,400 minus 5,270) if required can be carried in an internal auxiliary tank: a tank never seen.
As a consequence of the agreement, the design team was able to keep the Su-27 light compared to its size. Typically, a Su-27 carries fuel in three tanks, two in the wing centre section and one in the tail boom. A tank in each of the outer wings remain empty.

Series 42 AL-31F engines each rated at 80.9kN (18,188lb) and 132.4kN (29,762lb) with full afterburner. When the units based at Dzyomgi and Tsentralnaya Uglovaya received the Su-35S, the Su-27SMs were transferred to Belbek (in the Crimea) and Besovets Air Bases. Three Su-27SKMs were sold to Indonesia in 2010, the only operator of this version.

Production of the Su-27 for the Russian Air Force resumed in August 2009 when 12 new Su-27SM(3)s were manufactured using subassemblies made in expectation of an order from China that were never delivered. The first were delivered to Krymsk Air Base in February 2011; some are also at Lipetsk. Upgrades of operational Su-27s to Su-27SM(3) standard are underway, with the first two examples delivered to Krymsk in May 2014; the next aircraft will go to Besovets. Compared to the Su-27SM, the Su-27SM(3) has the SUV-P-RM fire-control system; the L-265M10 Khibiny-M electronic countermeasures suite; and introduces new R-77-1 medium-range air-to-air missiles.

Bestseller

The most commercially successful member of the Flanker family is the two-seat multirole Su-30MK and it's little wonder. From the outset, the Su-30MK was made for the export market and only ordered by the Russian Air Force after many years. Because the two-seat Su-27UB *Flanker-C*, manufactured at Irkutsk, retained the entire fire-control system of the single-seat Su-27, the decision was taken to use the configuration as the baseline design for a long-range interceptor, capable of commanding other aircraft. As part of the conversion, the aft cockpit had a tactical situation display installed for use by a weapon systems officer and an air refuelling probe fitted to enable air refuelling and thereby extend endurance. Initially the new configuration was designated as the Su-27PU and later the Su-30.

In 1987, test pilots Nikolay Sadovnikov, Igor Votintsev and Viktor Pugachev made several long-distance flights with Su-30

RECORDS

On October and November 15, 1986, Viktor Pugachev flying the third Su-27 T10S-3 prototype aircraft dubbed P-42 established absolute world records for time to climb to 9,800ft (3,000m) in 25.373 seconds, 2.2 seconds less than former record held by the American F-15 Eagle; to 19,685ft (6,000m) in 37.05 seconds; to 29,525ft (9,000m) in 47.028 seconds; and to 39,370ft (12,000m) in 58.102 seconds. Nikolay Sadovnikov set another series of records in between March and June 1987 climbing to 9,000m in 44.176 seconds, 2.8 second less than Pugachev; Sadovnikov also held a record altitude of 63,435-63,740ft (19,335-19,429m) for the statutory 90 seconds. In total, 41 world records were set by P-42.
To reduce weight for the record setting flights aircraft P-42 was stripped of some equipment, the entire armament system and braking parachute. Nose flaps were locked and paint removed from the airframe surface. Fuel reserve was reduced to the absolute minimum and the engines were uprated to 128.4kN (28,865lb).
Another T10-20R had its radar removed to free up space for a fuel tank. Additional fuel was held in a tank housed in an enlarged sting between the engines. Ogival ends were attached to the wings. The objective was to use T10-20R to set a speed record over a closed distance of 500km (270nm). However, sometime later, the interest with records weakened and eventually, the T10-20R was abandoned.

1 Russian Air Force Su-27SM RF-92211 was upgraded in 2002-2003 and now serves at Lipetsk with the evaluation and crew conversion centre. *Piotr Butowski* **2** Aircraft T10S-3 (P-42) was stripped of most of its equipment and paint to reduce weight for its record-breaking flights. *Piotr Butowski* **3** Aircraft T10-20R was prepared for a range of record flights with fuel tanks fitted in the nose and tail beam, and ogive ends attached to the wings. The record-breaking flights were eventually abandoned. *Piotr Butowski*

1 Su-30 502 is a Sukhoi test aircraft based at Komsomolsk used for the development of versions of the Su-30MK. *Piotr Butowski*
2 As of January 2017, the Indian Air Force had received 233 Su-30MKI fighters, including 50 delivered in flyaway condition from Irkutsk in Russia. *Piotr Butowski* **3** Twelve Su-27M fighters, side numbers 701 to 712, were built between 1988 and 1994, and assigned to trials. Aircraft 709 was displayed at air shows with the Su-35 export designation. *Piotr Butowski* **4** One of 18 Su-30MKMs delivered to Malaysia in 2007–2009 feature French and Russian-made systems instead of Israeli ones as used in Indian Su-30MKIs. *Piotr Butowski*

3D FROM 2D

Nozzles fitted to AL-31FP engines installed in the Su-30MKI move by 15° up and down. So how is three-dimensional thrust vectoring achieved with engine nozzles that only move in one plane? Nozzle movement planes in both engines need to be deflected sideways. On the Su-30MKI the vertical central plane of each nozzle is deflected by 32° (the right-hand nozzle to the right and the left-hand nozzle to the left) so the nozzles move within a V-like volume intersecting the planes to give three-dimensional control. Symmetrical deflection of both nozzles allows pitch control by diverse deflection, roll and yaw control.

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prototype aircraft. The longest, on June 23, 1987, from Moscow to Komsomolsk-on-Amur and back, was flown in 15 hours and 31 minutes. The aircraft flew 13,404km (7,237nm) with four trips to the tanker for air refuelling. After several prototypes were built, at least six Su-30s were manufactured between 1994 and 1996; five aircraft (side numbers 50 through 54) were allocated to an evaluation squadron based at Savasleyka.

The Irkutsk plant had considerable experience in working with Indian authorities and companies for the licence production of MiG-27ML fighter-bombers at HAL Nasik between 1986 and 1994. Alexey Fyodorov, the manager of the Irkutsk plant at the time, had good working relationships with his counterparts in India. Therefore, in the early 1990s when India began to consider purchase of a two-seat multirole fighter, the Su-30 produced at Irkutsk was the basis for talks with Russia.

With India in mind, the Russians displayed the Su-30MK (Mnogofunktsionalnyi, Kommercheskiy or multifunction, commercial) demonstrator loaded with dummy Kh-29, Kh-31 and Kh-59M air-to-surface missiles and KAB-500 guided bombs at the 1993 Paris air show held at Le Bourget that June.

In July 1995, the Indian parliament approved the purchase of a batch of Su-30MKs. Sixteen months later, India signed a contract for the development and delivery of 40 Su-30MKIs (the first batch) at Irkutsk Russia on November 30, 1996. Sukhoi designated the custom-built Su-30MKI using the letter I to denote India. Good news for the Russians, but not without its challenges: India's Su-30MKI is an advanced aircraft featuring a new fire control system, avionics sourced from international suppliers and thrust-vectoring engines which were non-existent at the time even in prototype form.

A clause within the November 1996 contract stipulated the first eight aircraft would be delivered in an interim Su-30K configuration, one that differs little from the Su-30 interceptor variant but without air-to-ground capability, and later upgraded to the full Su-30MKI configuration. The eight aircraft were delivered during April and May 1997 with a plan to deliver the remaining 32 between 1998 and 2000, but the Su-30MKI programme suffered from delays, so India ordered an additional 10 Su-30Ks on December 18, 1998.

All 18 Indian Su-30Ks, serial numbers SB001 through SB018, were assigned to No.24 Squadron 'Hunting Hawks' at Air Force Station Lohegaon near Pune to replace the venerable MiG-21bis.

The story of India's Su-30Ks neared completion in April 2007 when India signed a contract with Russia to exchange all 18 Su-30Ks for new Su-30MKIs on a one-for-one basis. In July 2011, India's Su-30Ks were transferred to the 558th ARZ repair facility at Baranovichi in Belarussia to await a new customer. In October 2013, Angola ordered 12 of the former Indian aircraft; the first of which flew after its overhaul at Baranovichi in January 2017.

The story of the Su-30MKI is incomplete without going back to the days of the USSR. On December 29, 1983 the Soviet Government took a resolution to launch work on the Su-27M (T-10M, M for Modernizirovannyi) featuring all of the

PUGACHEV'S COBRA

In May 1989, the Su-27 was displayed up close for an international audience for the first time when single-seat Su-27 388 and two-seat Su-27UB 389 arrived at the Paris air show.
Sukhoi design bureau test pilot Viktor Pugachev demonstrated an aerobatic manoeuvre dubbed the cobra for the first time, more technically referred to as dynamic deceleration (though the first pilot to execute the cobra manoeuvre on the Su-27 was Igor Volk on September 29, 1987).
The cobra manoeuvre starts in high-speed level flight when the pilot rapidly increases the angle-of-attack to 120° practically lying on its back and flies tail-first forward for a few seconds, before lowering the nose and returning to level flight without losing altitude. The manoeuvre was named the cobra because of a loose similarity between the aircraft's motion and the movement of a cobra snake's head when stood-up while feeling threatened.
To execute the manoeuvre, the pilot must accelerate to 205 to 228 knots (380-420km/h) between 1,650 and 3,300ft (500 and 1,000m) altitude and rapidly pull on the stick. Having reached the maximum angle-of-attack the pilot must rapidly return the control stick to neutral position and accelerate while carefully preventing the aircraft from entering a negative angle-of-attack flight regime. The flight control system limiter must be inactive during a flight routine involving the cobra manoeuvre.

SU-30MKI, SU-30MKM AND SU-30SM CHARACTERISTICS

Wingspan: *14.7m (48ft 2in)*

Length (without probe): *21.93m (71ft 11in)*

Height: *6.4m (20ft 11in)*

Nominal take-off weight: *26,090kg (57,519lb)*

Max take-off weight: *34,000kg (74,957lb)*

Max permissible take-off weight: *38,800kg (85,539lb)*

Max speed: *Mach 1.9*

Max speed (sea level): *Mach 1.1 (1,350km/h)*

G limit: *9g*

Service ceiling (clean): *56,758ft (17,300m)*

Max range: *3,000km (1,620nm)*

Max range (at sea level, with maximum fuel and two R-27s and two R-73s): *1,270km (685nm)*

Take-off run (normal take-off weight): *550m (1,804ft)*

Landing run: *750m (2,461ft)*

Engines: *Two AL-31FP thrust-vectoring turbofans each rated at 122.6kN (27,562lb) thrust with max afterburner*

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technology and systems later introduced on the Su-30MKI.

Under the supervision of Tamerlan Bekirbayev, the N011 radar featuring a slotted aerial was developed for the Su-27M by the NIIP institute. Later the N011M version featuring electronic scanning was developed and tested on Su-27 side number 712.

Improvements in the new N011M included the ability to simultaneously guide between four and six missiles (the Su-27's N001 radar was limited to two missile), and detect and engage ground targets. The N011's forward-looking search capability was complemented by the aft-looking search capability of the N012 radar installed in the sting between the engines. The N012 operates in the decimetre band so has a warning capability only: missiles cannot be guided.

Canards

The development of the carrier-borne Su-27K saw the Soviets adding small fore planes (canards) to the airframe to help reduce the angle-of-attack during carrier approaches. In May 1985, Viktor Pugachev made the maiden flight of experimental aircraft T10-24 fitted with canards (the aircraft crashed on January 20, 1987).

Once the new, heavier N011 and then the N011M radar was installed on the Su-27M the aircraft's centre of gravity moved forward, which degraded agility: a condition compensated for by either redesigning the airframe or by adding a small lift surface on the front of the fuselage. The latter, simpler solution was chosen. Fore planes were added to the forward fuselage to shift the centre of pressure forward and restore the aircraft's static instability (on the Su-27 it was neutral, on the Su-27M it was negative 5 to 6%).

Tests showed canards also have other benefits. Two powerful vortexes generated by their tips blow out a thick boundary layer on the wing near the flaperons. This improves lateral stability at high angles of attack, prevents the loss of lift during violent manoeuvring, and eliminates vibrations induced in this area of the flight envelope, which disturbs pilot control and weapon aiming. Canards also act as vibration dampers during low-altitude flight when powerful turbulence is normal.

Because of the benefits, canards were installed on several versions of the *Flanker* including the Su-27M, Su-27K (Su-33), Su-27IB (Su-34 *Fullback*) and the Su-30MKI. The Su-30MKI's all-moving swept canards are

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5 The front cockpit of a Su-30MKK with two 150 x 200mm (6 x 8 inch) MFI-10-5 multifunction displays, an ILS-31 head-up display and a set of conventional standby instruments. *Piotr Butowski* **6** The Su-30MKI and its derivatives, like this Su-30MKM, are the most successful Russian fighter types of the post-Soviet period. By February 2017, Irkut had delivered 390 aircraft from an order book for 475. *Piotr Butowski* **7** Aircraft T10-24, the first Flanker with canards made its maiden flight in May 1985. *Piotr Butowski collection*

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deflected symmetrically only from +7° to -70° at their leading edge.

Great importance was given to the Su-27M programme, which attests to the fact that as many as 12 aircraft were assigned to trials involving aircraft T10M-1 through T10M-12, side numbers 701 through 712; the first, side number 701, flew for the first time on June 28, 1988; while aircraft 712 was built in 1994. During its international debut at the Farnborough air show in September 1992, Su-27M side number 703 was presented as the Su-35 export version. Possibly the most familiar aircraft, side number 711, was fitted with thrust-vectoring engines in 1996 and was displayed at various air shows starting with Farnborough in September 1996. During its flight demonstration, aircraft 711 undertook a new aerobatic manoeuvre known as the summersault (the kulbit in Russian) – a roll over the back performed with almost no forward movement. Aircraft 711 crashed on December 19, 2002 due to flight control system failure; the pilot ejected successfully. Another, aircraft 708, until recently was used for elements of the flight testing of the flight control system of the T-50 PAK FA: aircraft 710 continues to support the PAK FA flight test programme as a test bed for the PAK FA's engine.

As a result of the economic crisis in Russia during the 1990s, Su-27M production did not gather pace. After 12 prototype aircraft were built, in 1995 the plant at Komsomolsk made three production aircraft, side numbers 86, 87 and 88. In 2003, all three production Su-27Ms and prototypes 703 and 712 were handed to the Russkiye Vityazi aerobatic team at Kubinka and painted in the team's livery. The team never used the aircraft for a display routine.

No further Su-27Ms were built, but many elements of its design were subsequently used in the development of the Indian Su-30MKI. Vyacheslav Averyanov flew demonstrator Su-30MK-1 fitted with canard fore planes and thrust-vector engines for the first time but not new avionics. The aircraft later crashed at Le Bourget on June 12, 1999.

International Equipment

The edge of the Su-30MKI's combat potential lies with its avionics, especially the RLSU-30MKI (Radiolokatsionnaya Sistema Upravlenia or radar control system) Bars radar system, based around the PESA (passive electronically scanned array) N011M radar made by the NIIP institute at Zhukovsky, and controlled by RC1 and RC2 computers manufactured by the Hyderabad Division of the Hindustan Aeronautics Limited. The first experimental N011M was made in 1991; flight tests began in 1996 with Su-27M side number 712. Electronic scanning allows the radar beam to be moved to other points in space in milliseconds thus enabling true multi-target engagement. The main shortcoming of the PESA are small angles of observation – only 45° to each side – which is poor for a manoeuvrable fighter. Hence the Bars electronically scanned array is installed on a hydraulic drive, rotating to the left and the right by 25°.

Due to its electronic scan mode, the array's mechanical sweep can be less dynamic than a typical mechanically scanned array radar. Typically, the array functions in the electronic scanning mode, and the mechanical sweep is only performed when a tactical situation requires it. The array weighs 110kg (243lb).

Other fire control sensors integrated on the Su-30MKI include the Russian OLS-30 (35Sh-01) infrared search-and-track system; the Ukrainian-built Sura-K helmet-mounted sight; Israeli Elop SU967 head-up display and Rafael Litening targeting and navigation pod.

The self-protection suite comprises an Indian-made IFF 1410A; Tranquil (Tarang Mk2) radar warning receiver; Israeli Elta EL/L-8222 podded jammer and seven 14-round 50mm (1.9in) UV-30MKI chaff and flare dispensers housed in the tail sting.

2

1 Once all contracts are fulfilled, Russia will have ten Su-30SM squadrons making it the most numerous fighter in the Russian Air Force fleet. *Piotr Butowski* **2** Since September 2015, four Su-30SM fighters are deployed to Syria to provide air cover to the Russian Air Group. *Russian Ministry of Defence*

3

3 Su-30M2s serve as combat trainers in units equipped with upgraded Su-27SMs. Russian Air Force Su-30M2 RF-96521, 10 Red is assigned to the 3rd Composite Aviation Regiment at Krymsk. *Piotr Butowski*
4 Su-30MK2V 1168 of the Aviación Militar Bolivariana. *Ivan Nesbit/AirTeamImages*

4

The Su-30MKI has a strengthened airframe to increase the munitions payload to 8,000kg (17,637lb) with 12 hard points which can carry a variety of air-to-air missiles; up to eight semi-active radar-guided R-27R or R-27ERs and two IR-guided R-27T or R-27ETs; or up to ten active radar-guided RVV-AEs; or six R-73s. Russia's Su-30SM is modified to carry the R-77-1.

Air-to-surface missile loads include two Kh-59M or Kh-59MEs (with an APK-9 targeting pod); up to six Kh-31A anti-shipping or Kh-31P anti-radar missiles; up to six Kh-29s (the laser-guided version requires a targeting pod) or up to three 1,500kg (3,307lb) or six 500kg (1,102lb) guided bombs; up to 32 250kg (551lb) free-fall bombs; or S-8, S-13 and S-25 rockets. Like all *Flankers*, the Su-30MKI is fitted with a 30mm GSh-301 cannon with 150 rounds.

Customers

A four-year delay in delivering the Su-30MKI to India was caused by implementing a new aerodynamic configuration and thrust-vectoring engines controlled by a new flight control system, and integrating a suite of avionics and systems supplied by a mix of overseas suppliers. The first fully-equipped Su-30MKI, side number 05, did not fly from Irkutsk before November 26, 2000. An An-124 delivered the first two Su-30MKIs from Irkutsk to India on June 22, 2002; a ceremony to commission the first ten aircraft was held at Air Force Station Lohegaon on September 27, 2002.

India signed a series of subsequent contracts, the biggest on December 28, 2000, licensed the production of 140 Su-30MKIs and a suitable number of AL-31FP engines in India; total orders for the Indian Air Force amount to 272 Su-30MKIs. The most recent Indian contract, covering 40 more aircraft, was initiated at the beginning of 2016. By early 2017, the Indian Air Force had received 233 aircraft; 50 delivered in flyaway condition from Irkutsk and 183 assembled by Hindustan Aeronautics Limited at its Nasik facility.

Malaysia ordered 18 customised Su-30MKMs which were delivered between 2007 and 2009. Malaysia took delivery of slightly modified Bars-M radar units and replaced Israeli subsystems with French equipment including the Thales Damocles targeting and navigation pod, a NAVFLIR (navigation forward-looking infrared) system to complement the Damocles pod, and the Thales CTH3022 HUD and IFF systems. New on the Su-30MKM is the self-defence system comprising the Russian L-150-30 radar warning receiver and South African Saab Avitronics MAW-300 ultraviolet missile approach warning system and LWS-310 laser illumination warning system. Malaysian Su-30MKMs carry Russian SAP-518 self-protection jammer pods and SAP-14 escort jammer pods instead of Israeli systems used on the Su-30MKI.

Algerian Su-30MKI(A)s retain the same configuration of systems as the Indian Su-30MKI with the exception of the Russian

N011M BARS RADAR CHARACTERISTICS

Frequency	X- and L-band (IFF) channels
Antenna	N11-01M phased array with hydraulic drive in azimuth
Search angle in azimuth	+/-70°
Search angle in elevation	+/-45°
Pulse power	4 to 5kW
Air-to-air mode	
Number of simultaneously traced targets	15
Number of simultaneously engaged targets	4 to 6
Search range, fighter size target, head-on position	120-140km (65-75nm)
Search range, fighter size target, tail-on position	60km (32nm)
Air-to-ground mode	
Search range, railway bridge	80-120km (43-65nm)
Search range, group of tanks	40-50km (21-27nm)
Search range, destroyer	120-150km (65-81nm)

L-150-20 Pastel radar warning receiver instead of the Indian-made Tarang Mk2 radar warning receiver and no podded jammer.

Between 2007 and 2012, 44 Su-30MKI(A) aircraft were delivered to the north African nation which ordered another 14 in April 2015; the first eight were delivered in December 2016.

Su-30SM

After years of production for export customers, the Russian Ministry of Defence ordered its own version of the proven Su-30 with six contracts placed between March 2012 and April 2016 covering 116 Su-30SMs: 88 for the Russian Air Force and 28 for Russian Naval Aviation.

The first Su-30SM flew at Irkutsk on September 21, 2012 and was subsequently delivered to Akhtubinsk for trials. Domna Air Base near to the city of Chita near the Chinese border is home to the first Russian Air Force Su-30SM unit; the 120th SAP (Smeshannyi Aviatsionyi Polk or Composite Aviation Regiment), which received its first aircraft in November 2013. A second regiment, the 31st IAP based at Millerovo Air Base near the Ukrainian border, took delivery of its first Su-30SMs in October 2015.

Meanwhile Russian Naval Aviation's 43rd ShAP (Shturmovoi Aviatsionnyi Polk or Attack Aviation Squadron) based at Saki in the Crimea started Su-30SM operations in December 2014. Today, a full squadron of Su-30SMs operate from the base. Follow-on deliveries to Russian Naval Aviation went to the 72nd Aviation Base at Chernyakhovsk Air Base (part of the Baltic Fleet) followed by the 279th OKIAP (Shipborne Fighter Aviation Regiment) at Severomorsk-3 Air Base (part of the Northern Fleet).

By January 2017, the Russian Ministry of Defence had reportedly received 81 Su-30SMs. Once all 116 aircraft covered by the six existing contracts are delivered nine, or possibly ten, Russian Air Force and Russian Naval Aviation squadrons will operate Su-30SMs making it the most numerous type in service with the Russian Ministry of Defence. A surprising reversal of situation; originally the Su-30 was made for export and for ten years was only produced for foreign customers.

In September 2015, four Su-30SMs from Domna deployed to Syria to provide fighter cover for the Russian Air Group flying with a typical air-to-air missile payload comprising four medium-to-long-range R-27Rs and two short-range R-73s.

Kazakhstan ordered 11 Su-30SMs in two contracts signed in 2014 and 2015. The first four were delivered to Taldy-Kurgan Air Base in April 2015 with a further two in December 2016.

1 Su-30MK test aircraft, side number 504, fires a supersonic Kh-31 air-to-surface missile. *Sukhoi*
2 Su-33s on the flight deck of the carrier *Admiral Kuznetsov*. *Sukhoi*

Import Substitution

Configuration of the Russian Su-30SM is close to India's Su-30MKI. The modified RLSU-30MK-R Bars-R (N011M-R) radar retained Indian-made computers but has additional operating modes and the Russian-made IFF and L-150 Pastel radar warning receiver suite are installed. French equipment including the Sagem Sigma 95NAA inertial navigation system, and Thales SMD-55 and SMD-66 multifunction displays, CTH 3022 head-up display, and TLS 2020 and NC 12 tactical navigation receivers remained, as did the Sura-K helmet mounted sight designed and manufactured by Arsenal in Kiev, Ukraine.

As a result of sanctions imposed by the West after the Russian intervention in Ukraine, Russia has no access to the systems and is replacing each system with a Russian equivalent. These include the BINS-SP-2

3 Su-30MK2V 5812, assigned to Grupo Aéreo de Caza 13 of the Aviación Militar Bolivariana, is one of 24 received by Venezuela between 2006 and 2008. *Ivan Nesbit/AirTeamImages* **4** Su-27K T10K-1, side number 37, was the first one built and made its maiden flight on August 17, 1987. *Sukhoi* **5** The UPAZ-1K refuelling pod fitted under a Su-33 enables fuel transfer to another aircraft at a rate of 2,300 litres per minute. *Piotr Butowski* **6** The UPAZ-1K refuelling pod features three coloured lights for signalling to the pilot of the receiver aircraft. *Piotr Butowski*

inertial navigation system (used on the Su-35); MFI-66 displays; IKSh-1KI-1 head-up display; VIM-95 and VND-94 TACAN receivers; and the NSTs-T-03 helmet-mounted sight.

In early 2016, Russia started marketing the Su-30SME version independently of the Indian Su-30MKI version; the export derivative of the Su-30SM without equipment supplied from overseas nations.

Further Improvements

Russian authorities intend to further improve the Su-30SM's capabilities in a research and development programme started in 2016 which is expected to last until 2019.

The improved version will be fitted with a new computing system and carry a series of new types of weapons; most likely the R-77-1 and R-74M air-to-air missile; Kh-31M, Kh-35U and Kh-38M air-to-surface missiles. Others are planned.

Two stages of a radar upgrade are planned: the first replaces the Indian computers with indigenous examples, and the second enhances performance (longer range, higher jamming resistance and new operating modes). Replacement of the passive array with an active array unified with the N036 radar's antenna from the T-50 PAK FA was considered, but has fallen out of favour.

In 2013, the Russian Ministry of Defence placed an order with the KNIRTI institute at Kaluga to supply the new L-420 Khibiny-U (U probably stands for Unifitsirovannyi or unified) self-defence suite for various fighter types; the Su-30SM will be equipped first.

The new S-107-2 communication suite will also be installed.

Also set for a major upgrade programme is the Indian Su-30MKI, unofficially known as the Super Sukhoi or Super 30, the upgrade has remained in negotiations between Russia and India for a long time without a conclusion. Extent of this upgrade would be similar to the Russian programme, but involves the use of foreign components, including the planned use of an Israeli computer.

India wants to adapt the Su-30MKI to carry indigenous weapons including Astra air-to-air missiles. An Astra missile was launched from a Su-30MKI for the first time on May 4, 2014.

On June 25, 2016 the first, long-awaited flight of a Su-30MKI loaded with an Indo-Russian Brahmos-A missile carried on its belly hardpoint took place from HAL's airfield at Nasik. The first unpowered release of a Brahmos-A missile took place in December 2016. In February 2017 BrahMos Aerospace Chief Executive Officer Sudhir Mishra told AIR International the missile's launch against a ship target would be conducted within two to three months.

Su-30MKK

The common Su-30MK designation covers two separate families of two-seat multirole fighters; the *Flanker-H* built at Irkutsk and

BUDDY-BUDDY TANKER

The Su-33 has the ability to conduct buddy-buddy air refuelling when fitted with a UPAZ-1K (Unifitsirovannyi Podvesnoy Agregat Zapravki) refuelling pod carried beneath the fuselage. The UPAZ-1K pod houses a 52mm (2in) internal diameter 26m (85ft) long hose and functions with a fuel transfer pump rated at 2,300 litres (607 gallons) per minute. Powered by a ram air turbine, extension and retraction of the hose and the fuel transfer pump operation is autonomous, without the need for external power from the aircraft.

Air refuelling is an important capability, because the Admiral Kuznetsov has a ski-jump rather than steam catapults, which limits an aircraft's maximum permitted take-off weight.

If needed, a Su-33 can launch with the required weapons payload without full fuel tanks; refuelling takes place in the air. Maximum take-off weight from the carrier deck is reportedly 26,000kg (57,200lb), which means with a nominal (not full) fuel load a Su-33 can only carry four air-to-air missiles.

SU-30MK2 AND SU-30M2 CHARACTERISTICS

Wingspan: *14.7m (48ft 3in)*

Length without probe: *21.93m (71ft 11in)*

Height: *6.4m (21ft)*

Wing area: *62.03m² (668ft²)*

Tail plane span: *9.88m (32ft 5in)*

Wheelbase: *5.8m (19ft)*

Wheel track: *4.34m (14ft 3in)*

Max take-off weight: *34,500kg (76,059lb)*

Max permissible take-off weight (no more than 20 take-offs): *38,000kg (83,776lb)*

Max landing weight: *23,600kg (52,029lb)*

Max permissible landing weight: *30,000kg (66,139lb)*

Max speed (high altitude): *Mach 2.0*

Max speed (sea level): *Mach 1.1 (1,350km/h)*

G limit: *+8.5/-2g*

Service ceiling (clean): *56,760ft (17,300m)*

Max range: *3,000km (1,620nm)*

Max range (sea level, maximum fuel and two R-27 and two R-73 missiles: *1,270km (685nm)*

Take-off run (normal take-off weight): *550m (1,804ft)*

Landing run (brake chute deployed): *750m (2,461ft)*

Engines: *Two AL-31F series 23 turbofans, each rated at 122.6kN (27,562lb) with maximum afterburner*

the *Flanker-G* built at Komsomolsk-on-Amur. A third family, which started with the Su-30MKK developed for China, is based on the standard Su-27UB airframe with the Su-27's conventional fire-control system, and features minor upgrades but is less advanced.

The early Su-30MKK version (K for Kitay, Russian for China) has an N001VE radar; a standard Su-27 N001 radar with a Cassegrain antenna, upgraded with a new computer and software to enable use of RVV-AE air-to-air missiles.

Additionally, the Su-30MKK has a separate SUV-P1I fire control subsystem enabling use of laser- and TV-guided air-to-surface munitions.

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KH-31 MISSILE CHARACTERISTICS

	Kh-31P	*Kh-31A*	*Kh-31PD (PM)*	*Kh-31AD (AM)*
Max range	110km (59nm)	50km (27nm)	180-250km (97-135nm)	120-160km (65-86nm)
Min launch distance	15km (8nm)	7.5km (4nm)	15km (8nm)	
Release altitude	330-49,000ft (100-15,000m)	330-33,000ft (100-10,000m)	330-49,000ft (100-15,000m)	330-49,000ft (100-15,000m)
Release speed	Mach 0.65-1.5	Mach 0.65-1.5	Mach 0.65-1.5	Mach 0.65-1.5
Max speed	Mach 2.93	Mach 2.93		
Cruise speed	Mach 1.76-2.05	Mach 1.76-2.05		
Launch weight	600kg (1,323lb)	610kg (1,345lb)	715kg (1,576lb)	715kg (1,576lb)
Warhead weight	87kg (192lb)	94kg (207lb)	110kg (243lb)	110kg (243lb)
Length	4.70m (15ft 5in)	4.70m (15ft 5in)	5.34m (17ft 6in)	5.34m (17ft 6in)
Body diameter	360mm (14.2in)	360mm (14.2in)	360mm (14.2in)	360mm (14.2in)
Wing span	914mm (36in)	914mm (36in)	954mm (37.6in)	954mm (37.6in)

Originally designed for Chinese Naval Aviation service, the Su-30MK2 uses the N001VEP radar with a separate computing channel to enable ground mapping in synthetic aperture radar mode, detection of surface targets and designation for Kh-31A anti-ship missiles.

Su-30MKs built at Komsomolsk use entirely Russian equipment and are therefore not subject to export limitations and can be sold to countries subjected to sanctions.

China purchased 76 Su-30MKKs between 2000 and 2003 and 24 Su-30MK2s in 2004, but later stopped ordering aircraft from Russia and started development of its own J-16 fighter, an indigenous version of the Su-30MK2.

Other orders for Su-30MK-series aircraft are: Indonesia two Su-30MKKs (2003) and nine Su-30MK2s (2008 to 2013); Vietnam 24 Su-30MK2Vs (2004 to 2012) and another 12 (2014 to 2016); Venezuela 24 Su-30MK2Vs (2006 to 2008); and Uganda six Su-30MK2s (2011 and 2012).

Russia's Ministry of Defence ordered Su-30M2s (a version of the Su-30MK2 adapted for Russian requirements) with new software modes, national IFF, and datalink; four ordered in August 2009 (delivered in 2010 and 2011), and 16 ordered on December 29, 2012 (delivered between 2013 and 2016). These aircraft are being used as combat trainers and assigned to units operating single-seat Su-27SM and Su-35S fighters. It remains unlikely that the Komsomolsk plant will produce any more Su-30MKs because its production is now focussed on the Su-35S.

Strike Capabilities

The Su-30 is a multi-role version of the *Flanker*, capable of carrying air-to-surface weapons, unavailable to the classic Su-27 version. Although weapons integrated on the Su-30MKI and Su-30MK2 are virtually identical, in reality India's Su-30MKI serves primarily as an air superiority fighter while China's Su-30MK2 is more focussed on strike missions. The most potent weapon is the supersonic Kh-31 (AS-17 *Krypton*) missile.

The Kh-31 has rocket-ramjet propulsion with a solid rocket propellant booster and a ramjet which accelerates the missile to Mach 3.5 at 52,500ft (16,000m), or Mach 1.8 at sea level: high-speed is the Kh-31's big advantage. The first and most widespread version is the anti-radar Kh-31P with a passive radar seeker. The Kh-31A is an anti-shipping derivative with the RGS-31 active radar seeker with a lock-on range of 30km (16nm) and lock-on before and lock-on after launch operating modes.

Initial flight tests with a Kh-31 were made in May 1982. Series production of the missile started in 1987 at a plant in Korolev. Production stopped after collapse of the Soviet Union and resumed in 1997 for export sales to India, China, Vietnam and Yemen, and later for the Russian Air Force.

Against an order placed in 1994, the Russians designed the KR-1 (Kitay-Rossiya or China-Russia) version of the Kh-31P, later manufactured in China as the Ying Ji YJ-91. At a later date, a batch of standard Kh-31P and Kh-31A missiles was sold to China together with Su-30MKK and Su-30MK2s.

Production of the modernised Kh-31PM (Kh-31PD for export) started in 2012. The Kh-31PM features a longer body (5.34m/17.5ft versus 4.70m/15.4ft); an increased fuel load; and a new seeker. Maximum range, when launched from 49,000ft (15,000m) at Mach 1.5, increased to 180-250km (97-135nm). The Kh-31AM active-radar version is under development.

1 In 2002, thrust-vectoring AL-31FP engines were fitted on the Su-27KUB. *Piotr Butowski*
2 A rare weapon configuration under the folded wing of a Su-33 comprising two S-25OFM unguided rockets on a twin pylon and an R-73 air-to-air missile and Sorbtsiya electronic counter-measures pod above. *Piotr Butowski*
3 The first Su-35S for the Russian Air Force during tests with Kh-31 air-to-surface and R-73 air-to-air missiles. Note the freefall bombs loaded on pylons between the engines. *Piotr Butowski*

The Sailor

The Su-33 is not a lucky aircraft. In the 1980s, the Su-33 (or Su-27K) carrier-based fighter was important for the Soviets, when they were planning to construct a large fleet of aircraft carriers. At the end of the USSR, there was one aircraft carrier in service, now known as Admiral of the Fleet of the Soviet Union Kuznetsov. Two other ships, *Varyag* and *Ulyanovsk* were under construction at the Mykolaiv shipyard in Ukraine. Russia ceased funding for the ships' continued construction after collapse of the USSR and Ukraine did not need the ships. The *Varyag* was sold to China, where she currently serves as *Liaoning* and the *Ulyanovsk* was dismantled in the dock. Russia has no current aircraft carrier construction programme and it's doubtful a new ship of this class will be built within the foreseeable future given Russia's difficult economic situation.

According to the original plan from the early 1980s, the primary aircraft to be deployed on board the *Admiral Kuznetsov* was the Yak-41 short take-off, vertical landing fighter. However, because the fourth-generation MiG-29 and Su-27 each offered a high thrust-to-weight ratio, they were applicable to horizontal take-off carrier operations using a ski-jump. When later trials at Nitka (see below) confirmed the applicability of the MiG-29K and the Su-27K to carrier operations, development of the Yak-41 was stopped.

To support its carrier aviation plan, in 1982 the Soviets built the Nitka ground test facility imitating the deck of a future carrier commonly called Nitka (Naziemnyi Ispytatelno-Trenirowochyi Kompleks or ground research and training complex) at Naval Air Base Novofyodorovka near the town of Saki in Crimea.

The first ski-jump built at the Nitka facility, dubbed T-1, was 5.0m high with a slope of 8.5°.

Su-27 prototype T10-3, side number 310, flown by Nikolai Sadovnikov took off from T-1 for the first time on August 28, 1982 (MiG-29, side number 18, completed its first take-off from T-1 on August 21). The trials showed the ski jump needed extensive modifications which resulted in construction of a modified ski-jump, dubbed T-2, completed in 1984.

T-2 was 5.6m high, 53.5m long, 17.5m wide, with a slope of 14.3°: identical to the flight deck of the *Admiral Kuznetsov*.

Su-27 prototype T10-25 began trials using T-2 and the use of an arrester hook on September 1, 1984.

Sukhoi and TsAGI developed a new aerodynamic configuration featuring canards to decrease the aircraft's angle-of-attack during take-off and landing specifically for the Su-33. Compared to the standard Su-27, the Su-33 also has an arrester hook (no drag chute) and strengthened landing gear with long-stroke shock absorbers and twin nose wheels. A large flaperon occupies the full trailing edge of the wing (about 60% on the Su-27) to decrease landing speed; two-section single-slotted flaps are built into the flaperon. Full-span slats are also included.

Reduction of the Su-33's footprint size was paramount for stowage in the carrier's hangar deck, so the outer wing sections, tail planes, nose radome (hinged upwards) and tail boom can all be folded. Competition with the smaller MiG-29K forced Sukhoi's designers to seek every possible way to reduce the Su-33's footprint size for parking.

SU-33 CHARACTERISTICS

Wing span: *14.70 m (48ft 3in)*
Length (without probe): *21.18m (69ft 6in)*
Max height: *5.72m (18ft 9in)*
Width for stowage (wings and tail plane folded): *7.40m (24ft 3in)*
Length for stowage (nose and tail folded): *19.2m (62ft 11in)*
Wing area: *67.84m² (730.2ft²)*
Tail plane span: *9.80m (32ft 2in)*
Wheelbase: *5.87m (19ft 3in)*
Wheel track: *4.44m (14ft 6in)*
Nominal take-off weight: *25,000kg (55,116lb)*
Max take-off weight: *33,000kg (72,752lb)*
Max landing weight: *24,500kg (54,013lb)*
Max speed: *Mach 2.17*
Max speed (at sea level): *Mach 1.96 (1,300km/h)*
Approach speed: *240km/h (149mph)*
G limit: *+8/-2g*
Service ceiling: *56,000ft (17,000m)*
Max range (without flight refuelling at sea level): *1,000km (540nm)*
Max range (without flight refuelling at altitude): *3,000km (1,620nm)*
Engines: *Two modified AL-31F series 3 turbofans, each rated at 75.2kN (16,909lb) dry; 122.5kN (27,558lbf) with afterburner and 125.5kN (28,219lb) emergency thrust.*

NEW AIR-TO-AIR MISSILE CHARACTERISTICS

	R-74M (RVV-MD)	*R-77-1 (RVV-SD*	*R-37M (RVV-BD)*
Max range	40km (21nm)	110km (59nm)	200km (108nm)
Max range of the seeker	15-20km (8-11nm)	-	40km (21)
Min launch distance	300m (984ft)	300m (984ft)	
Target altitude	66–65,617ft (20–20,000m)	66–82,021ft (20–25,000m)	49–82,021ft (15–25,000m)
Max target g-load	12g		8g
Missile weight	106kg (234lb)	190kg (419lb)	510kg (1,124lb)
Warhead weight	8kg (17.6lb)	22.5kg (50lb)	60kg (132lb)
Missile length	2.92m (9ft 7in)	3.71m (12ft 2in)	4.06m (13ft 4in)
Body diameter	170mm (6.7in)	200mm (7.9in)	380mm (15in)
Wing span	510mm (20.1in)	420mm (16.5in)	720mm (28.3in)
Fin span	385mm (15.2in)	680mm (26.8in)	1.02m (40.2in)

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The Su-27K's fire-control system is slightly modified when compared with the Su-27's S-27 (mostly software) and combines the RLPK-27K (N001K) radar and OEPS-27K electro-optical targeting system with increased-range and the OLS-27K infrared search and track sensor. The navigation system was augmented with the Rezistor-K42-Bort system that allows fully automatic or manual approach to the aircraft carrier. Up to 6,500kg (14,330lb) of weapons and stores can be carried on 12 hard points.

Weapon options are generally similar to those of the Su-27 and include air-to-air missiles; R-27 and R-27Es (medium-to-long-range/extended-range) and R-73s (short-range).

The K-27EM (Morskaya or sea) air-to-air missile was specifically developed for the Su-33 with the RGS-31 semi-active radar seeker, intended for use against targets flying at low altitude just above the sea surface (Tomahawk and Harpoon cruise missiles).

Development work was aborted in 1991 before trials began. The single GSh-301 fixed cannon is retained. As a pure fleet defence and air-superiority fighter; the Su-33 has no capability to carry air-to-surface guided weapons.

The first Su-27K T10K-1, side number 37, flew for the first time on August 17, 1987 piloted by Viktor Pugachev.

Viktor Pugachev landed a Su-27K aboard the *Admiral Kuznetsov*, under way in the Black Sea, on November 1, 1989; the first time a conventional Russian aircraft landed aboard a ship (followed by a MiG-29K and a Su-25UTG the same day).

Two Su-27K prototypes, T10K-1 and T10K-2, were built by the Sukhoi works in Moscow and seven pre-production aircraft, T10K-3 to T10K-9, were built at Komsomolsk-on-Amur between 1990 and 1991 were all used for tests. A further 26 aircraft were delivered to Russian Naval Aviation between 1993 and 1996.

Sukhoi's design bureau has used the designations Su-27K and Su-33 since the early 1990s. After many years of testing and improvement, the Su-27K officially entered Russian Naval Aviation service on August 31, 1998 when it was officially designated as the Su-33 for the first time.

Export Customers

When Sukhoi's management realised further production of the Su-33 was unlikely and therefore would not generate much profit they lost interest in the aircraft. Sukhoi only refreshed the Su-33 programme for a brief time when India and China were seeking a fighter for their respective carriers; *INS Vikramaditya* (the former *Gorshkov*) and the future *Liaoning* (the former *Varyag*).

In 1999, Sukhoi prepared a proposal for the upgraded Su-33KM (Kommercheskiy Modernizirovannyi or commercially modernised), which in addition to the original weapons arsenal could carry up to six RVV-AE air-to-air missiles; up to six Kh-31 air-to-surface missiles (Kh-31A anti-ship and Kh-31P anti-radar); two TV-guided Kh-59M extended-range missiles; short-range electro-optical guided Kh-29 missiles; and KAB-500 and KAB-1500 guided bombs. The N001K radar was to be upgraded to a standard similar to the system fitted in Su-30MK2; and a glass featuring two large multifunction displays were to be integrated in the cockpit.

While the Su-33KM was only a concept, the Su-27KUB (Uchebno-Boyevoy, combat trainer or Su-33UB) reached prototype status. A prototype Su-27KUB was converted from the Su-33 T10K-4 which made its first post-conversion flight on April 29, 1999. On September 6, the aircraft took off from the Nitka ski jump and landed aboard the *Admiral Kuznetsov* for the first time on October 6. In September 1999 an Indian pilot flew a familiarisation flight in the Su-27KUB at Saki; the aircraft was also presented to Chinese authorities.

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1 The AL-41F1S engine powers the latest Su-35. *Piotr Butowski* **2** The most modern member of the *Flanker* family is the Su-35S, intended as a low-cost complementary fighter to the T-50 PAK FA, along with its Su-30SM and Su-30M2 fleets. *Piotr Butowski* **3** The first Su-35 prototype, side number 901, was used for initial testing and lacks a fire-control system. *Piotr Butowski* **4** All three types of new air-to-air missiles under development for the *Flanker*: the short-range R-74M; long-range R-77-1; and very long-range R-37M. *Piotr Butowski* **5** The upper forward fuselage of the Su-35 houses sensors for the OLS-35 IRST (left); the SOER missile approach warning system (middle); and the air refuelling probe (right), all mounted forward of the cockpit canopy. *Piotr Butowski*

Changes introduced to the Su-27KUB airframe compared to the Su-33 were significant enough to consider it a new aircraft; the cockpit has side-by-side seating; the wing span of 16.36m is 1.66m more than the Su-33; and the tail- and foreplanes were enlarged.

Despite its designation, the Su-27KUB is a combat aircraft rather than a trainer. In 2001, the Su-27KUB was fitted with a Phazotron-NIIR N010 Zhuk radar (from the MiG-29K) and two years later an experimental Sokol N031 Zhuk-MSF passive electronically scanned array radar. In 2002 AL-31FP engines with thrust vectoring were retrofitted to the Su-27KUB. However, in 2004, India eventually selected the MiG-29K and China decided to develop the indigenous J-15 carrier-borne fighter using as a pattern, Su-33 prototype T10K-7, acquired by China from Ukraine in 2004. Consequently, Sukhoi lost interest in carrier-based fighters, and voluntarily gave way to the MiG-29K.

Syrian Deployment

Of the 26 operational Su-33s delivered, five were lost in service (aircraft side number 65 in 1996, 73 in 2000, 70 in 2001, 82 in 2005 and 67 in 2016); another production aircraft crashed in 1994 before delivered; and two prototypes crashed, T10K-1 in 1988 and T10K-8 in 1991.

Russian Naval Aviation reportedly has 14 airworthy Su-33s currently assigned to the 279th OKIAP (Otdelnyi Korabelnyi Istrebitelnyi Aviatsionnyi Polk, Independent Shipborne Fighter Aviation Regiment) based at Severomorsk-3 Air Base and part of the Northern Fleet.

Aircraft with side numbers 60 through 76 have an eagle emblem on their tailfins denoting assignment to the first squadron, and side numbers 77 through 88 have a tiger emblem for the second squadron. The unit's full name is the 279th Smolensk OKIAP, which was awarded the Order of the Red Banner and named after World War Two ace Boris Safonov.

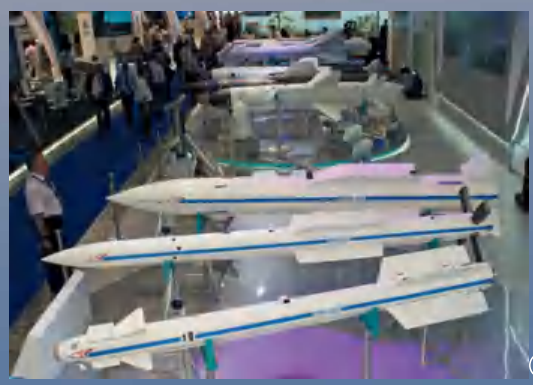
Admiral Kuznetsov left Murmansk on October 15, 2016, bound for the Mediterranean Sea and accompanied by the nuclear battlecruiser *Pyotr Velikiy* and other smaller ships to participate in Russian military operations in Syria. It was Kuznetsov's sixth deployment to the Mediterranean and its combat debut. On October 26, the battle group passed through the Strait of Gibraltar, entered the Mediterranean Sea and reached its operating area off the Syrian coast on November 8.

Prior to the deployment, the Su-33s underwent an upgrade that had been planned for years, but not implemented due to indecision. Included were partial replacement of the original navigation system by the low-cost SVP-24-33 (Spetsializirovannaya Vychislitelnaya Podsistema, special computing subsystem), a device that enhances navigation accuracy, thanks to a new computer and radio navigation system coupled to a satellite receiver.

The SVP-24 was originally developed for the Su-24M *Fencer* tactical bomber by Gefest & T based at Zhukovsky, which claims navigation accuracy is increased by a factor of two to three. Being equipped with the SVP-24 enables the Su-33 to employ unguided weapons during complex manoeuvring; previously the fighter could only employ unguided weapons in straight and level flight.

Installation took place during the summer of 2016 on at least eight Su-33s (side numbers 60, 67, 71, 77, 78, 84, 85 and 88) at Gefest & T workshops at Zhukovsky. Despite the upgrade, the Su-33 primarily remains an air-superiority fighter tasked to provide carrier defence.

In keeping with usual Russian Naval Aviation standards, the air group embarked on the *Admiral Kuznetsov* included at least nine Su-33s: side numbers 62, 66, 67, 71, 76, 78, 84, 85 and 88 were observed. Reportedly, four of these aircraft took part in a strike mission against targets in Syria for the first time on November 15, 2016, each loaded with two 500kg free-fall unguided bombs. The November 16 mission was the first combat use of the Su-33 from *Admiral Kuznetsov*, though it's hard to class the strikes as being of great operational significance.



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Russian Naval Aviation lost three aircraft during the cruise; one Su-33 and two MiG-29s.

Su-33 side number 67 sank in the Mediterranean Sea on December 3, 2016. When an arresting wire broke on landing, the aircraft failed to stop, overran the deck and fell into the sea, but, thankfully, the pilot ejected safely. Russian media, referring to sources in the Russian Navy's staff and the

aerospace industry, claim the Su-33 was lost because the pilot exceeded the landing axis limit, inducing excessive load into the arresting wire, which tore off. The measured landing axis for the December 3 accident was 4.7m (15.4ft), while the limit is 4.2m (13.8ft).

Cause of the wire break was initially alleged to be a production defect, though this was rejected by Proletarsky Zavod in St Petersburg, the manufacturer of the arresting wires. Russian Naval Aviation lost another Su-33 in the Atlantic Ocean on September 5, 2005, due to the arresting wire breaking.

Everything New, the Su-35

Although the Su-35 looks similar to the Su-27, it differs from the classic version more than any of the later variants of the *Flanker*.

Launched as an export-only programme and funded solely by Sukhoi and its partners, the Su-35 was unveiled at the Dubai air show in December 2003. Initially, the project was designated the Su-35BM (Bolshaya Modernizatsiya, major modernisation) to distinguish it from the previous Su-35 (Su-27M), but the BM letters were soon abandoned.

No Canards

Launched 30 years after the original Su-27, many of the original design features were revised; new lighter materials were adopted for the internal structure and the canard fore planes were removed for a couple of reasons. Canards impeded the design team's ability to improve manoeuvrability, a function performed on the Su-35 by movable jet nozzles; and a deflected engine thrust vector generates additional super circulation airflow around the wing to increase significantly the lifting force at high angles-of-attack. Consequently, the original advantages of fitting canard fore planes to the *Flanker* were lost leaving just disadvantages of additional weight and drag. Thus, after years of the tandem triplane configuration, Sukhoi's hallmark, the Su-35 returned to a configuration similar to the classic Su-27. The most significant aerodynamic configuration change is the lack of a large aerodynamic brake on the spine of the Su-35. Instead, air braking is effected by differential deflection of the rudders. The Su-35 features one entirely new feature: a quadruple-redundant digital fly-by-wire system.

Uprated Engine

Flankers have always been powered by two AL-31F engines each rated at 122.5kN (27,558lb) of thrust with upgrades introduced primarily to improve handling characteristics and extend the service life; with few exceptions, engine thrust has remained unchanged. For the Su-35, Sukhoi designers opted to install a new engine with much greater thrust. When the Su-35 was under development, Sukhoi was simultaneously designing the T-50 PAK FA new-generation fighter powered by the AL-41F1 (izdeliye 117) engine. Its subvariant, the AL-41F1S (izdeliye 117S) with its own control system was adopted for the Su-35. Control of the AL-41F1 used on the PAK FA is via the aircraft's flight control system. The AL-41F1S is an upgraded version of the AL-31FP featuring a larger 932mm (36.7in) diameter fan (compared to the original 902mm/35.5in) and greater thrust rated at 142.2kN (31,967lb) in emergency mode. On March 5, 2004 Su-27M experimental aircraft, side number 710, commenced test flights powered by a prototype version of the AL-41F1S engine installed in the starboard nacelle.

The Su-35's key capability is full integration of all systems and sensors within the KPrNO-35 (Kompleks Pritselno-Navigatsionnogo Oborudowaniya, targeting-navigation equipment system) controlled by a central computing system incorporating two Baget-53 computers. Sukhoi's design bureau is responsible for the systems integration; in the past, fire-control and flight-navigation systems were usually integrated on Sukhoi fighters by RPKB of Ramenskoye. Similar architecture used for the Su-35 has also been integrated by Sukhoi on the PAK FA.

Irbis Radar

The Sh135 Irbis (Snow Leopard, or Irbis-E for export) radiolocation system comprises an N135 radar and a Khibiny-M electronic countermeasures suite. The N135 developed by the Tikhomirov NIIP institute and produced by the GRPZ facility in Ryazan is an evolution of the N011M Bars radar fitted to the Su-30MKI. The radar system employs a passive electronically scanned array and two Solo-35.01 (initial signal processing) and Solo-35.02 (data processing and radar control) computers. A Type 4283MP IFF interrogator is integrated within the Sh135 radar system. Advantages of the Irbis system compared to the Bars include a wider range of operational frequencies, a greater angular search zone in azimuth of up to +/-125° (due to an improved antenna and double-step drive), increased range (due to a more powerful transmitter) and improved resistance to jamming, as well as finer resolution. The radar has an aperture sufficient to specify the number of targets in a group: from a distance of 50km (27nm), the Irbis-E can reportedly distinguish targets located 50–100m (160-320ft) from each other.

The Irbis-E is capable of tracking-while-scanning up to 30 air targets, eight of which can be quasi-continually tracked with an accuracy sufficient for simultaneous engagement by medium-range radar-guided air-to-air missiles. Two targets can be

1 Russian Air Force Su-35S RF-95477, Red 54 lands at Kubinka Air Base. *Piotr Butowski* **2** In 2004, a Su-30MK2 dropped a Kh-59M2A anti-ship missile that reached a range of 285km. *Sukhoi* **3** The Su-35 cockpit features two 380 x 380mm (15 x 15in) MFI-35 displays, a wide angle IKSh-1M head-up display and data input panels. *Sukhoi* **4** An Irbis radar during tests on a Su-30. *Piotr Butowski collection* **5** An N135 Irbis radar for the Su-35 during tests on Su-30MK, side number 503 test aircraft in 2007. *Piotr Butowski collection*

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engaged simultaneously with semi-active radar-guided missiles (requiring target illumination). In air-to-ground mode, the Irbis-E can simultaneously engage four surface targets.

Operating in so-called long-range detection mode at a peak power output of 20kW (standard power is 5kW), limited to a narrow sector, the Irbis-E can detect a fighter-sized target from 350–400km (189–216nm) head-on or 150km (81nm) tail-on. Ranges are half the specified distances in normal search mode.

Made by KNIRTI at Zhukov near Kaluga, the L-265M10R Khibiny-M electronic countermeasures suite comprises a reconnaissance and a countermeasures section. Part of the Khibiny-M suite, operating in the most common HF waveband (H-J), is built in to the airframe. When required, two pods can be mounted on the wingtips to enhance the system's capability via the medium waveband (E-G).

Typically for a Russian fighter, the OLS-35 infrared search-and-track sensor, made by the NPK SPP (Scientific and Production Corporation Precision Instrument Systems) company in Moscow, is mounted forward of the cockpit. The sensor comprises mid-range infrared (3–5µm wavelength) and electro-optical cameras using a common optical module, and a laser rangefinder and target designator. The reflector scans a sweep of +/-90° in azimuth and -15/+60° in elevation. A target of the size of a Su-30 can be detected from 90km (49nm) tail-on, or 35km (19nm) head-on; four airborne targets can be simultaneously tracked. The laser rangefinder acquires the distance to the air target within a range from 200m to 20km (650ft to 11nm), or 30km (16nm) against a ground target. The pilot uses a Sura-M helmet-mounted sight made by Ukrainian company Arsenal, but these are currently being replaced with Russian-made NSTs-T devices.

Self-protection Sensors

NPK SPP produces the SOER (Sistema Optiko-Elektronnoi Razvedki, electro-optical reconnaissance system) missile launch and approach warning system that includes six infrared sensors: one forward-looking mounted near the IRST; one aft-looking, mounted on the fuselage spine behind the cockpit; two on the sides of the forward fuselage; and two sensors, one forward-looking and one aft-looking, mounted in a small pod underneath the nose. The infrared sensors work in the 3–5µm waveband range and (data for export version) recognise launch of a man-portable anti-aircraft missile from 10km (5nm), an air-to-air missile from 30km (16nm) and a large surface-to-air missile from 50km (27nm). A laser subsystem has two laser warning sensors mounted on the sides of the forward fuselage that can detect laser rangefinders tracking the aircraft from 30km (16nm). According to NPK SPP the SOER system determines the position of a detected aircraft and missiles with an accuracy up to 1° and a laser radiation source up to 5°.

The Su-35's radar warning receiver is the L150-35 Pastel made by TsKBA in Omsk that features an extended working frequency range (for the Su-35) from 1.2 to 40 GHz (typically up to 18 GHz); its direction finding resolution is 3–5°, and also indicates targets for anti-radar missiles. The Su-35 has six 14–round UV-50 decoy dispensers mounted in the sting positioned between the engine nozzles. All six were launched upwards on early aircraft, but in current production aircraft the two outer cassettes are launched downwards.

New Missiles

A Su-35 can carry a weapon and stores payload of up to 8,000kg (17,637lb) carried on 12 hard points managed by an RSUO-


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35PS stores management system. All types of tactical air-to-air missile currently in the Russian inventory are cleared for carriage on the Su-35 and will be joined by new missiles released for service in the coming years. On July 27, 2012, a guided missile, probably an R-73, was fired by a Su-35S for the first time.

Air-to-surface weapons cleared for the Su-35 include: the Kh-31PM and Kh-58USh anti-radar missiles; Kh-31AM, Kh-35U and Kh-59MK anti-ship missiles; universal Kh-38M air-to-ground missiles with various seekers; and 250kg (551lb), 500kg (1,102lb) and 1,500kg (3,307lb) guided bombs.

Sukhoi has presented advertisements for the Su-35 featuring other weapons, for example the heavy Yakhont and Kalibr-A anti-ship missiles.

A new interim generation of Russian air-to-air missiles intended for the Su-35 and other fighters are the short-range R-74M, medium-range R-77-1 and long-range R-37M missiles, are all being developed by Vympel based in Moscow. All three types are currently in production, while the next short-range K-74M2, medium-range K-77M and long-range 810 are being tested.

The K-74M short-range air-to-air missile is a further development of the R-73 with a new more sensitive two-band infrared Impuls-90 seeker with increased off-bore sight angles and digital signal processing. Except for the seeker, the missile's external appearance has not changed. On October 3, 2012, the K-74M completed state evaluation and was officially commissioned for service with the Russian Air Force and given the military designation R-74M (K denotes the development phase and once in service it adopts the R designation). There are two subvariants; the R-74MK with a radar proximity fuse and the R-74ML with a laser fuse. The R-74 is offered for export as the RVV-MD (Raketa Vozdukh-Vozdukh Maloy Dalnosti, short-range air-to-air missile). Series production of the R-74M, due to start in 2013 at the Duks Company facility in Moscow, remains at a standstill, because of lack of Impuls-90 seekers, which are produced in Ukraine. Despite efforts, the Russians have not managed to replace the Ukrainian seeker with an indigenous alternative.

The R-77-1 (AA-12B *Adder*) or for export the RVV-SD (where S denotes Sredney, medium) medium-range air-to-air missile is an upgraded version of the R-77 (RVV-AE for export), which was launched for the first time by a Su-27SM(3) in September 2010. In comparison to the basic RVV-AE, the R-77-1 features refined aerodynamics with a streamlined nose cone, hidden control fin fittings and rounded under-fuselage. Software for the missile's control system has been updated and the upgraded seeker has a more powerful transmitter, a more sensitive receiver and improved resistance to jamming.

The R-37M (AA-13 *Axehead*) or for export the RVV-BD (where B means Bolshoy, big) is a new long-range air-to-air missile that was launched for the first time by a MiG-31 in 2011. The R-37M completed state acceptance evaluation in early 2014 and remains in series production at the KTRV factory in Korolev.

Powered by a dual-mode solid-propellant rocket motor, the R-37M flies to the target on a lofted trajectory profile controlled by a dual X and Ku-band active radar seeker in the terminal stage. The seeker can lock on to a target with a 5m² (54ft²) radar cross-section from at least 40km (21nm) distance. Currently, the MiG-31BM interceptor is the main Russian Air Force type to carry the R-37M missile, but is fielded as a universal weapon for various MiG and Sukhoi fighters. The Su-35 carries four R-37Ms, two loaded in tandem between engines and two on inner underwing pylons.

SU-35 CHARACTERISTICS

Wingspan: *14.7m (48ft 2in)*

Wingspan with wingtip pods: *15.3m (50ft 2in)*

Length: *21.9m (71ft 10in)*

Height: *5.9m (19ft 4in)*

Nominal take-off weight (with four air-to-air missiles): *25,300kg (55,777lb)*

Max take-off weight: *34,500kg (76,059lb)*

Max speed (at 36,000ft/11,000m): *Mach 2.25*

Max speed (at sea level): *Mach 1.14 (1,400km/h)*

Service ceiling: *59,000ft (18,000m)*

Acceleration (at 1,000m/3,281ft with 50% nominal fuel): *13.8 seconds from Mach 0.48 to 0.89 (600 to 1,100km/h) and 8 seconds from Mach 0.89 to 1.06 (1,100 to 1,300km/h)*

Max rate of climb (at 1,000m/3,281ft with 50% nominal fuel): *280m/s (55,118ft/min)*

G limit: *9g*

Max range (with full internal fuel at sea level and Mach 0.7): *1,580km (855nm)*

Max range (with full internal fuel at high altitude): *3,600km (1,945nm)*

Max range (with two 2,000-litre/440 gallon external tanks): *4,500km (2,430nm)*

Take-off run (nominal take-off weight, with full thrust): *400–450m (1,312–1,476ft)*

Landing run (nominal landing weight with brake chute deployed): *650–700m (2,133–2,297ft)*

Engines: *Two thrust-vectoring AL-41F1S turbofans with a maximum dry thrust of 86.3kN (19,401lb); afterburning thrust of 137.3kN (30,865lb); and emergency thrust of 142.2kN (31,967lb) each. A TA14-130-35 auxiliary power unit is provided.*

Operators

The Su-35 has replaced Su-27SM(3)s and two-seat Su-30MK2s on the production line at Komsomolsk-on-Amur. The first Su-35, side number 901, in export configuration flew on February 19, 2008, with Sergei Bogdan at the controls. The second, side number 902, commenced tests on October 2, 2008, and should have been followed by the third, side number 904 which burned out on the runway on April 26, 2009, before its first flight (903 was built for static testing). Aircraft 904 was the first in full configuration and its loss delayed testing by many months.

Initially, the Su-35 was positioned as an interim fighter until the launch of the T-50 PAK FA fifth-generation fighter. However, the position of the Su-35 has radically changed, because the Russian Ministry of Defence concluded that converting ten fighter regiments each equipped with 36

aircraft (currently the Russian Air Force has as many *Flanker* and *Fulcrum* operational units) solely with expensive PAK FA fighters was too costly. Another fighter type, simpler and cheaper than the PAK FA, is need, but one that meets basic Russian Air Force requirements including a range of at least 3,000km (1,620nm), which rules out any type of lightweight fighter. Consequently, the Su-35 (along with the Su-30SM) will complement the PAK FA in the ranks of the Russian Air Force.

In accordance with this concept, the Russian Air Force ordered 48 Su-35S fighters to be delivered by 2015 during the MAKS air show at Zhukovsky near Moscow in August 2009. On May 3, 2011, Su-35S-1 (the third Su-35 to fly) made its first flight at Komsomolsk-on-Amur, the first Su-35S to do so. On May 28, 2011, Su-35S-1 arrived at Akhtubinsk, the military evaluation centre, to commence qualification trials. The second aircraft, Su-35S-2, flew for the first time on December 2, 2011, the third Su-35S-3 followed on January 17, 2012, and the fourth Su-35S-4 on February 19, 2012. All four of the initial Su-35S aircraft, side numbers 01 to 04, are used for testing, which progressed very slowly because of serious problems with avionics integration.

The first batch of 12 Su-35S fighters was delivered to the Russian Air Force on February 12, 2014; their home was the 23rd IAP at Dzyomgi Air Base (Komsomolsk-on-Amur). Further deliveries followed to the 22nd IAP at Tsentralnaya Uglovaya Air Base (Vladivostok) in July 2015, and then to the 159th IAP at Besovets Air Base in Karelia near the Finnish border, where four aircraft arrived on December 6, 2016.

Like the Su-30SM, the Russian Air Force deployed four Su-35S fighters to its base in Syria to provide fighter cover for the strike group. In addition to R-27 and R-73 missiles, the Su-35S fighters have been seen operating with the new R-77-1 medium-range air-to-air missile that recently entered service.

In December 2015, the Su-35S successfully completed all trials (the so-called second stage of state evaluation), the month that the Russian Ministry of Defence ordered 50 more increasing its total to 98. By the end of 2016, the Russian Air Force had received 58 Su-35S aircraft, which includes 12 delivered in 2006.

Because of the Su-35, new Sukhoi fighters were delivered to China for the first time in ten years. China signed a contract for 24 Su-35 aircraft in November 2015 and the first four arrived in country in December 2016. The aircraft are delivered in a baseline configuration and then adapted for integration of Chinese equipment and weapons.

1 Su-30MK2, side number 503, launches a Kh-29L laser-guided missile. *Sukhoi* **2** Ukrainian Air Force Su-27, side number 100, received a digital colour scheme in 2012. *Piotr Butowski*

Blazing its O

Southwest Airlines is continuing to prosper despite various challenges – and, as David Armstrong explains, it continues to do things in its own way

Boeing 737-7H4 N778SW (c/n 27883) photographed at Denver International Airport. Southwest Airlines introduced a revised colour scheme in 2014. *Angelo Bufalino/AirTeamImages*

Own Trail

In the topsy-turvy world of civil aviation, there are few things more predictable than this: the pioneering US low-cost carrier Southwest Airlines (SWA) will make money. It happened again in 2016, as the carrier earned a profit of $2.24 billion on record-high $20.5 billion revenues, buoyed by a strong fourth quarter during which the Dallas-based company rode robust holiday passenger numbers into the black.

Southwest achieved all this despite widespread anxiety in global aviation, an industry shaken by terrorist attacks, the uncertain impact of Brexit and wobbly national economies in many nations, including normally fast-growing China and the 46-year-old carrier's home, the USA.

Southwest's Chairman and Chief Executive Officer is 61-year-old Gary C Kelly, a 30-year veteran of the company who assumed

the top job in 2008. He acknowledges civil aviation faces headwinds in the near-term, but insists that prudent management will continue to pay off for his company, which launched services in 1971 with three aircraft, serving only the state of Texas.

Southwest's senior leaders stress the underlying financial fundamentals of Southwest Airlines, which helped create the low-cost carrier business model, are solid.

Last year Tammy Romo, Chief Financial Officer and Executive Vice President, said: "With $3.6 billion in cash and short-term investments, our cash flow from operations has been strong, and capital spending was at manageable levels." (At the end of 2016, cash reserves dropped slightly to $3.4 billion.) Southwest also has a $1 billion available line of credit, she noted.

Continued Profitability

Southwest Airlines, which has LUV as its stock market ID on the New York Stock Exchange, has been in the black for 44 consecutive years and returned dividends to stockholders for 162 consecutive quarters. Lifted in part by low fuel prices, it reported a profit of $2.4 billion back in 2015 (up from $1.2 billion in 2014), on then record-high operating revenues of $119.6 billion, before recording modest gains in 2016. Although 2016 was a profitable year for major US carriers, for many profitability is novel. Not so, for Southwest.

SWA is the fourth largest US carrier. As measured by passenger traffic, it is the largest airline in the US domestic market and the world's largest (transporting 145 million passengers in 2015). It flies the world's largest fleet of all-Boeing jetliners – 724 Boeing 737s in several iterations. In peak travel season, it operates some 3,900 daily departures to 98 US cities and seven Latin American countries.

All told, 97% of Southwest's passengers fly on domestic routes; its fledgling international service, launched in 2014, accounts for the remaining 3%. Kelly says that number will grow, chiefly in Mexico and sun-bleached Caribbean leisure travel markets – including Cuba, where Southwest began service late last year. In the near term, SWA's small international footprint limits its exposure to global turbulence.

One of the first Southwest 737 MAX aircraft, N8705Q (c/n 42558), at Boeing's Renton facility in January. Norwegian will be first to put the 737 MAX 8 into service, but with 200 737 MAX 8s on order, Southwest will be one of the major operators of the updated 737. *Joe Walker*

In good times and bad, Southwest deliberately sets itself apart from other carriers. It is not a member of the International Air Transport Association. It charges no fees for changing flights. It features open seating. It has long resisted calls by stock analysts and others to charge lucrative fees for all checked luggage, instead allowing two free checked bags and building its customer-focused brand with humorous, high-profile 'Bags Fly Free' television adverts.

Although SWA's fares have risen in recent years, its ticket prices are lower than those of all but bare-bones competitors such as Spirit Airlines and Frontier Airlines on many routes. It follows a shrewd strategy that positions Southwest as the traveller's friend, attracts loyal repeat customers and generates steady

Southwest flies the world's largest all-Boeing 737 fleet – 724 aircraft in several iterations, including 737-8H4 N8643A (c/n 42524) pictured at Seattle-Tacoma. *Dipankar Bhakta/AirTeamImages*

A number of Southwest's aircraft wear distinctive special liveries, including 737-7H4 N918WN (c/n 29843), pictured here at Las Vegas, which has a livery called Illinois One. *Adrian Jack/AirTeamImages*

revenues and profits. Southwest is an unusual example of 'American exceptionalism' in that it is exceptional even in America.

As outlined by senior Southwest executives last summer in an investor day briefing and questions and answer session at the New York Stock Exchange, the airline said it plans to move forward with deliberate speed on a variety of fronts in 2017.

One Res

One of SWA's most important and costly initiatives, dubbed One Res, is the modernisation of its outdated reservation system. "We're estimating the capital spend on our reservation system will be about $500 million," said Tammy Romo. "The corresponding benefits of our new system are significant, and we will be able to recoup our $500 million investments by 2020." With initial stages of One Res rolled out in December 2016, Southwest has set a target date of May 9, 2017 for complete implementation.

For many travellers, technological upgrades to SWA's outdated, overburdened reservation system can't come soon enough. That was illustrated last July, when Southwest's computers crashed, stranding tens of thousands of travellers and causing cancellation of 2,300 flights. The crisis, caused by a faulty data centre router, lasted from July 20 to 23. Smartphone videos of grounded flyers slumped in airport terminals, comforting squalling children, dolefully picking at tepid fast-food and queuing at customer help desks flooded social media – ever alert to moments of drama and trauma.

Business-travel specialist Joe Brancatelli cast a cold eye on the carrier. "Boy, this has been a lousy week for Southwest Airlines," commented the New York-based Brancetelli, a sometimes-caustic critic of the airline industry. "A computer meltdown on Wednesday continues to mess up its flyers something awful. The airline was just 45% on-time Wednesday with 571 cancellations, a dreadful 14.4% of its schedule. Yesterday was even worse: just 35% on-time and 22.6% of its flight schedule. Today is terrible, too. As of 11:00, according to Flightstats.com, it had cancelled more than 275 flights and there are already more than 700 delays. As usual, Southwest is closed-mouthed and tells passengers and journalists virtually nothing about its problems."

It wasn't closed-mouthed for long. Southwest spun into full crisis-control mode, apologising profusely and allowing stranded passengers to rebook at their original fares. Nevertheless, it was a big black eye for an airline that is usually praised for having one of the US airline industry's best on-time records (85%) and unfailingly cheery, peppy customer service. One Res is designed to prevent a major computer crisis from happening again.

Arrival of the MAX

Many of Southwest's technological and operational challenges have been exacerbated by rapid growth, especially in the six years since SWA bought rival AirTran Airways and expanded its fleet by 25% by incorporating AirTran's aircraft. Gary Kelly says expansion will slow briefly this year to consolidate growth; retire older, slower 737-300 and 737-500 Classics; and allow employees with what he terms "change fatigue" to catch their breath.

Southwest has delayed delivery of 67 Boeing 737 MAX 8s to slow capital expenditure (capex), explains Romo. "The impact of our capex from the changes was to defer $1.9 billion of aircraft capex beyond 2020," she said last July. The first of a total of 200 Boeing 737 MAX 8s Southwest has on order are expected to start arriving in July 2017.

That is two months after Norwegian Air is scheduled to take delivery of the very first 737 MAX. Southwest, which has a long-standing business relationship with Chicago's Boeing, is the designated launch customer for the 737 MAX, a single-aisle jetliner that can fly 400 nautical miles (740km) farther than vintage 737s, offers greater fuel efficiencies and needs less-frequent maintenance.

Although the Norwegian low-cost carrier has stolen the march on SWA by taking delivery of the first 737 MAX before Southwest, Kelly insisted to Bloomberg News: "We're the launch customer, regardless of when we take the first delivery." Southwest's Chief Operating Officer and Executive Vice President Mike Van de Ven adds: "We're the ones that have done the service-ready operational validation for Boeing. We're the ones working very closely with Boeing to make sure it's operating as everyone intended."

Underserved Markets

Even as Southwest has throttled back spending and the pace of fleet expansion, it continues to launch services to what it regards as underserved domestic and international markets. In 2016, Southwest began services at California's Long Beach International Airport, strengthening its hand in the Los Angeles Basin, where it claims 30% of the USA's second-largest market. Elsewhere in California, Southwest has added new flights at Oakland International Airport and Mineta San Jose International Airport.

Andrew Watterson, Southwest's Senior Vice President, Network and Revenue, notes: "As GDP grows, it generates demand for air travel, and as air travel grows on your routes, it eventually gets to the point we need new frequency, you plot one in and it works. One of those is San Jose. San Jose to BWI [Baltimore-Washington International], unserved. Who would have known that the Silicon Valley was not connected to Washington, DC?" Launched late last year, Southwest's daily non-stop flight connects the American high-tech capital of creative disruption to its tumultuous capital of political gridlock.

Like all American carriers of size, Southwest recently began flying from the US state of Florida to Cuba. Washington banned direct flights to Cuba in the 1960s. When last year then-President Barrack Obama gave the go-ahead to resume direct flights, Southwest launched services to Cuba's premier airport, Havana's Jose Marti International, and several provincial airports. SWA also flies from Fort Lauderdale, Florida, where it has 18% overall market share, to Havana twice daily, and operates a daily flight between Havana and Tampa, Florida, where it has 38% share.

SWA is one of eight US carriers approved to serve Cuba, so the Cuban market is fragmented. In any case, the resumption of aviation and travel ties between the two neighbouring nations may have more symbolic and emotional resonance than financial importance.

Australia's CAPA Centre for Aviation notes potentially troublesome infrastructure at Cuban airports, including, "prolonged time for security screening [and] the lack of amenities such as kiosks and e-boarding". The Sydney consultancy also warns: "Many of the secondary airports US airlines plan to serve are leisure destinations that cater to tourists from other global regions."

The new administration of President Donald Trump is another wildcard, as Cuba is a flashpoint in American politics, especially among the conservative core of Trump's supporters. Even so, Southwest wasted no time in attempting to get the new president's support for its Latin America expansion plans. In January, Southwest asked the US Department of Transportation to grant the airline landing rights at Mexico City's Benito Juarez International Airport, as part of Trump's self-proclaimed 'America First' commercial and political agenda.

Domestic Expansion

Southwest is on firmer ground with ambitious expansion at airports and other facilities at home. In 2014, it finished extensive expansion at Dallas's Love Field (the inspiration for the airline's LUV stock market ID), where it claims 90% of passenger traffic. Also in 2014, Southwest opened a training and operational support building there housing its three-year-old network operations centre.

In 2015, Southwest opened an international concourse at Houston Hobby International. It's building a new concourse at Fort Lauderdale International and modernising terminal 1 at Los Angeles

Another colourful Southwest special is 737-7H4 N280WN (c/n 32533), seen at Fort Lauderdale Hollywood International, wearing its Missouri One livery. *HAMFive/AirTeamImages*

Southwest 737s on stand at Los Angeles International. The airline claims 30% of the Los Angeles Basin, the USA's second-largest market, and is currently modernising its facilities at the airport in a project scheduled to be completed in the second quarter of 2018. *Simon Willson/AirTeamImages*

International (LAX). The Los Angeles project, scheduled to be completed in the second quarter of 2018, is budgeted at $500 million, according to Van de Ven.

Also under construction is a new office building at Dallas Love Field that Southwest calls Wings. The company expects to open the Wings building in the first quarter of 2018. Wings will eventually be home to 18 flight simulators, according to the airline.

While all this is unfolding on the ground, Southwest is upgrading its customer experience in the air, rolling out Heart, a programme that features a new logo, a fresh aircraft livery, a new interior aircraft design festooned with vivid colours, cabin crew uniforms designed in part by Southwest cabin crews, and seats made with reclaimed leather salvaged from cabin interior makeovers. It plans little imminent change for its in-flight entertainment system, which highlights free, live television.

Most Southwest passengers take short-haul flights averaging two hours and two minutes to domestic destinations. Basic Wi-Fi connectivity and uninspiring snacks such as bagged pretzels and peanuts are fine with them, so long as flight schedules are timely and fares are reasonably priced. At times the cabin experience, though always friendly, evokes Southwest's roots as a no-frills budget carrier.

Critiques

Despite all SWA's success, gimlet-eyed Wall Street aviation industry analysts are convinced that profitable, popular Southwest is leaving money on the table. The first change they'd like to see is jettisoning the 'Bags Fly Free' policy. In a 2014 interview with TheStreet.com, Standard & Poor Global Market Intelligence analyst Jim Corridore described initiating checked-baggage fees for Southwest flights as a no-brainer, terming subsequent ancillary revenues "low-hanging fruit".

Southwest management begs to differ. Loyal Southwest flyers don't want to be squeezed by "bespoke" add-on fees, they say, and could lose trust in the airline that's taken decades to build.

The company's stance has at times led to acrid critiques by Wall Street insiders, eyes firmly fixed on the bottom line. In an earnings call with industry analysts in July 2016, things got personal between an outspoken analyst and CEO Gary Kelly. JPMorgan Securities analyst Jamie Baker, directing a barb at Kelly, declared: "The impression investors have is that your priorities at the moment might be somewhat out of order. The impression is that passengers come first, then labour unions, then shareholders."

Kelly promptly defended the carrier's business acumen and its corporate culture. "We want to protect our brand," he said. "It's a really good brand. We don't want to begin to pull threads that could cause the whole thing to unravel. We'll want to be careful about that."

Inside the company, Southwest presents itself as one big, happy family, made up of all 53,000 employees. But that doesn't always work for workers. Contentious contract negotiations this decade with pilots, flight attendants and mechanics dragged on for more than four years, sometimes spilling over into public view. In May 2016, fuming members of the Southwest Airlines Pilots' Association were barred by the city of Chicago from renting space on a billboard at city-owned Midway Airport – a major SWA hub – to complain about their stagnant wages. The billboard message was to read: "Shareholder returns: $3.1 billion. Pilot raises: $0." Pilots said they had not had a pay rise since 2011.

That changed late last year, when Southwest signed wage-boosting contracts with major employee groups, including pilots. Management maintains that prudent spending is needed to make Southwest's business model work; low costs make low fares possible.

Such conflicts notwithstanding, Southwest distributed $586 million through its long-standing employee profit-sharing scheme for 2016. The 2016 payment averaged about $13,000 per employee, according to the company.

As it has grown from a quirky, entrepreneurial start-up into an established player, Southwest has become somewhat more conventional. SWA has raised fares but they remain competitive. It has squeezed 9-12% more seats into aircraft to accommodate high load factors (84% in 2016). It has introduced Business Select with upgraded seats and amenities, inaugurated a branded credit card and, since 2011, operated profit-spinning points programme Rapid Rewards.

Even so, Southwest remains proudly different from US legacy carriers and many newer low-cost carriers. Always a maverick, the Texas airline blazes its own trail.

More than two years after the completion of Operation Herrick in Afghanistan, Joint Helicopter Command (JHC) and its subordinate rotary and fixed-wing units are as busy as ever training hard for future conflict.

During the years of the campaign in Afghanistan, JHC knew who its main opponents were, understood the broad profile of its missions and could plan logistics and training requirements with some certainty. The situation has changed markedly and militaries around the world are now operating within an operational climate which requires a different approach and mindset. JHC and its subordinate units are therefore preparing for future operations in a much broader range of environments working alongside allies.

Following more than ten years of operations in Iraq and Afghanistan, JHC has learned a lot about the capabilities of its structure, and the qualities of its aircrew, engineers, medical and numerous tactical support teams who performed admirably throughout these challenging campaigns.

Combat Impact

Major General Richard Felton CBE, Commander JHC, outlined to AIR International how the operational lessons learned from campaigning throughout Operation Herrick are being used to good effect to prepare for the global contingent environment.

He said: "We grew up tremendously as a force in terms of professionalism and dealing with very high levels of combat and risk. Our people did an amazing job supporting troops in many guises on the battlefield. The rescue of approximately 13,500 battlefield casualties and the award of 24 DFCs [Distinguished Flying Cross] says it all.

"From an air mobility perspective, we understand better the contribution of rotary wing ISTAR [intelligence, surveillance, target acquisition and reconnaissance] as part of Core FIND [one of the three roles for JHC's battlefield helicopters, the others being LIFT and ATTACK]. We will never forget the

Commando Helicopter Force Merlin HC3s will all be upgraded to HC4 standard under the Merlin Life Sustainment Programme, the first of which is expected to be delivered by the end of 2017.
All photos Ian Harding

How is the UK's Joint Helicopter Command adapting to contingent operations? Ian Harding spoke with its Commander to find out

A New E

hugely successful development of MERT [Medical Emergency Response Team] and the wider germination of our model; also the relationship we made with allies, especially working closely with the US Marine Corps out of Camp Bastion, Helmand and Leatherneck. These will continue through the Lead Commando Group and their affiliations. There are many other aspects we'll take forward into our doctrine which include mission execution check lists and go/no-go lists for example. Afghanistan hasn't been forgotten but contingency is much different."

This final point is critical. In this new era, JHC's challenge is helping future aircrew understand what to expect, how to conduct themselves, deal with operational risk and mental issues and ultimately to succeed safely within a more uncertain operational environment. Maj Gen Felton said: "Much of this comes from realistic training which helps generate trust, understanding of colleagues, the capability of your aircraft, understanding the logistics and command and control chain. You can have the best kit in the world but if you haven't got the best people to fly them, you don't have capability. We are blessed at JHC with having a fantastic set of people. Being 'Joint' and exercising together is good."

Reflecting upon a campaign like Operation Herrick in Afghanistan in the broader sense can never be straightforward because it evokes so many difficult memories. One's thoughts always naturally focus on those personnel who made the ultimate sacrifice, those injured and scarred, lives saved by the MERT and the honours bestowed on individuals for acts of bravery.

1 The Chinook is the now the only heavy-lift helicopter in service with the Royal Air Force. All 14 of the new HC6 variant, seen here, have been delivered to RAF Odiham whilst the legacy fleet has also been upgraded.

From a purely operational perspective, statistics provided to AIR International confirm the sheer scale of the campaign effort made by JHC and its subordinate units during Operation Herrick. The total amount of flying completed by its five main battlefield support helicopters amounted to approximately 140,800 hours. This breaks down to: Chinook 41,000 hours, Apache 49,800; Lynx 19,500; Merlin 18,000; and Sea King 12,500. Their combined efforts transported approximately 720,000 personnel and 54.67 million pounds of cargo (24.8 million kilos). Over 27.69 million gallons of fuel (125.9 million litres) were used during the operation as well as those undertaken by the MERT.

Post-Herrick Challenges

The UK's Ministry of Defence and JHC are resetting future plans, accounting for the objectives and spending review contained within the UK MoD's 2016 Strategic Guidance initiative which aims to map out a broad range of strategies to ensure objectives are aligned and coherent across the MoD.

Maj Gen Felton explained: "Context is really important here. In a similar way following our campaign efforts, it was clear when I took command that generating contingent force was pervasive amongst everything we did. The challenges I therefore face as commander are broadly four-fold. The first is managing structural change. For example, command of 16 Air Assault Brigade [British Army Rapid Reaction Force] transferred to the Commander Field Army in November 2015 but I took command of the Watchkeeper force from August 2016. Secondly, the ten-year recapitalisation and modernisation of our fleet which has impacted almost every aircraft type in some way. Thirdly, the reset of contingency training and operations and, finally, ensuring we are manned sufficiently to meet our tasks with suitably qualified and experienced people.

"This final point is important to me personally, coming from a background of frontline operations. We are totally inclusive and wedded to talent management within an engaging environment. I watch my forces with awe as they move forward and I give them clear markers as to what I want them to do and the standards required. Our aim is to provide personnel with the opportunity to succeed. Building trust is vital and the key is giving people the opportunity to make decisions and learn from failure within safe boundaries during training and exercises."

Training Requirements

What are the implications of training to meet operational requirements in this new era of global uncertainty? Context is again important. In the current climate, JHC and its subordinate units are conducting operations and training forces at a high tempo in concert with other components of the UK's high readiness forces, and with its primary NATO allies. It is business as usual in some respects, although closer analysis confirms the tempo and diversity of training has increased, as have the component elements operating within the structure of the exercises and deployments undertaken.

This is partly due to the nature of perceived threats but also to ensure that JHC has sufficient numbers of skilled air and

ground crew to meet future demands. As one might expect, some experienced personnel (especially in terms of aircrew; those with 1,500+ flight hours) sought new career opportunities away from the armed forces post-Afghanistan and JHC is addressing this as a priority. Maj Gen Felton confirmed that average cockpit experience across the rotary force has reduced by approximately 40% during the last six years.

He said: "The key challenge for our aircrew now is having the capacity to multi-task; managing all the information they face inside the aircraft, disseminating data effectively, having good judgement and making the right decisions. The challenge for me as the commander is how to 'turbocharge' this experience in the right way, reflecting the current operational environment and the type of aircraft we now operate. My view is this is best done by providing the very best training programmes available backed up with short and intense detachments to many different countries where junior commanders get the opportunity to command, make decisions and take responsibility.

"I always drive my force commanders hard in this respect because I believe in productivity [and] value for money, plus helicopters aren't cheap. If I don't do this, how can I expect my air and ground commanders to make the right decisions on operations when they haven't considered it in training? We are now training how we think we'll fight in the future. I want people to have responsibility and the confidence to do their job. We therefore work hard to establish the right atmosphere which includes them telling me when it's getting too tough.

"Ultimately, I have to generate capability but this will never be at the expense of safety in the air and on the ground especially during training when there is no need. We therefore have to temper our aspirations to meet what the forces can deliver."

MAA Regulation

The role of the Military Aviation Authority (MAA) has been questioned from an operational perspective in some quarters, with suggestions that increased regulation can stifle capability. Maj Gen Felton doesn't share this view: "I feel the MAA has done a tremendous job in establishing a regulation structure for defence and now we've matured to understand where flight safety sits, I'm absolutely convinced that flight safety is enhancing operational capability.

"I have four rules about flight safety that I tell my pilots, which are as follows. Don't make it too much a science, don't let it stifle mission command, don't allow the flight safety management system to become a safety risk in itself, and most important, if it doesn't enhance operational capability you've got it wrong. With that understanding we can use flight safety to enhance operational capability, and it has done because our flight safety record has improved tremendously. We've had some tragic accidents: Puma [in 2015] and Lynx before that, but aviation is a dangerous business and I can put my hand on my heart as the aviation duty holder to say we do everything we can to understand where the risks are and to mitigate them both through training and our equipment programmes."

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New Paradigm

Defining contingency in a military sense is not easy. The reality is the operational crystal ball is quite cloudy in terms of providing clear insight. JHC and its allies must prepare as best they can for every eventuality. Despite being a widely used term within defence circles, contingency has no formal definition. The definitions seek to explain what the future character of conflict will look like and, within this, defence policy makers including JHC must clarify what form their response will take. The public may expect clarity but one should not expect this because opponents unfortunately do not follow any rules; anything goes.

Does a contingency plan exist that meets every eventuality? The truth is it cannot because generating capability is costly and difficult and, ultimately, perfect foresight does not exist. Nobody can predict what future events will look like but at some point, UK policymakers responsible for defence must decide how good they want the military to be and allocate funds accordingly. It might be possible to maintain a high state of readiness 24/7 with assets to meet every potential eventuality, but this carries a high cost.

2 Captured completing a confined area landing, the Puma HC2 reached a new milestone in early 2017 completing 15,000 flying hours. In that time the Puma force has continually supported Operation Toral in Afghanistan and numerous training exercises in the UK and around the world as well as holding national standby commitment. **3** Tactical Supply Wing based at RAF Stafford play a key role supporting the deployment of helicopter operations from forward operating bases. They specialise in rotors-turning refuelling using their Oshkosh Tactical Aircraft Refuellers seen here.

3

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One definition of contingency is: "Military activity, including but not restricted to the application of force, undertaken in response to crisis arising out of circumstances that cannot be fully anticipated, planned or trained for with respect to environment, scale, timing or nature of adversary or partners."

Maj Gen Felton said: "We basically have to consider how we conduct operations against a belligerent we don't know, with an unknown threat level, in an unknown environment and with 'friends' we don't know either. In addition, the future character of conflict will be congested, cluttered, contested, connected and constrained. We will work alongside allies or partners when we can but this backdrop could be different. The most likely area for our future operations based on current events will be the Middle East and North Africa but these will likely be for short periods of time rather than campaigning. This will require our forces to be comfortable with uncertainty, conceptually agile and physically flexible to deal with complex environments and unclear outcomes."

Comparing contingent operations with those in Afghanistan and Iraq is difficult. There, rotary units mainly operated from a single base, enabling logistics to be centralised, and worked alongside allies with relatively clear standard operating procedures. Combat levels were high, units generally knew their opponents, and the level of threat was unsophisticated. Training was considered relatively easy in some respects. The environment was harsh (hot and high with degraded vision) but everyone understood its demands and could plan accordingly.

Maj Gen Felton said: "The training for campaigning was laid out for people. We had an excellent pre-deployment package with mission-specific training which turned people into a very effective fighting force in Afghanistan. The situation for contingency is very different. I could tell you what a profile for an Apache or Chinook sortie looked like in Afghanistan but for a contingent sortie profile, I'll say it depends on the threat level as there isn't a standard answer. Our mission commanders and aircrew at all levels therefore need the mindset, mentality, confidence, understanding and judgement to take decisions in this situation.

"As a force we try to install comfort with uncertainty and that takes trust and training. When we buy equipment, it must be highly deployable and able to operate and be maintained in austere environments. We need to be able to understand and operate in a range of threat environments, which means our platforms need ballistic protection, comprehensive defensive aids systems against both RF [radio frequency] and IR [infrared] threats. There was little RF threat in Afghanistan and we have some catching up to do."

Training Environments

JHC's aviation assets will need to lift troops, conduct medical evacuation and support ground forces with attack helicopters. They will also need to carry out manned aerial surveillance at home and abroad, data link with other complex systems including unmanned aerial vehicles, and provide forward air controller (airborne) capability, co-ordinating fast jet operations alongside ground forces. They will need greater operational dexterity and the ability to change roles quickly across a diverse range of operational environments – most notably from the sea to the land and back again.

Recent examples of major exercises completed which tested the force's capabilities to respond and meet future demands have included Exercise Trident Juncture 2015 (NATO's largest exercise for 20 years), Exercise Griffin Strike 2016 (Anglo-French interoperability), Exercise Clockwork 2016 (cold weather and UK-Royal Norwegian Air Force interoperability), and Exercise Voijek Valour (UK-US interoperability).

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Maj Gen Felton explained: "Our personnel at all levels will have to embrace new technology and apply a different operational mentality, adjusting within environments. Future missions may be more complex. Having become used to desert operations, the land environment may also include Arctic and temperate conditions, hence the breadth of training we've conducted since returning from Afghanistan.

"We have to ensure we train to the right environments and our logistics personnel can deal with the concurrency of different locations at the same time. We have to prioritise based on perceived threat levels but consider the needs of each environment; we can't put all our eggs in one basket. This will never happen because contingency means lots of deployments which require an increasing amount of resource to sustain them including deployable spares packs, engineers' toolkits, and transport kits.

"We aim to produce the maximum outputs from the minimum inputs and therefore, design a system with flexible training programmes that provide the skills people need. This addresses both the quantity and quality of the capability we produce. The test of how good we are is ultimately determined by our ability to provide a force which understands the risks and can operate in any part of the world against a belligerent in their environment, when the UK MoD demands."

Applied Pragmatism

It is an applied science working out what does and does not work from an operational perspective. The current range of training is very dynamic. This is a conscious decision considered necessary to practise skills and refocus minds on training which was not required in Afghanistan. Training for future contested missions means learning how to counter a kinetic threat within an environment degraded in terms of jamming, electronic warfare and communications. "This could apply in all theatres and countries of instability around the world," Maj Gen Felton said.

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The structure of deployments has been changed in line with policy, as he outlined: "Our deployments are more frequent, less intense and the average person is probably visiting three continents per year. Nights deployed seldom exceed around 120-150. The opportunity for air and ground crew to do interesting, challenging training in completely different environments and locations is up for grabs."

A good example of this came in 2016 when the Chinook force operated in the US (from two locations), in Cyprus and aboard ships. Apaches went to the Middle East and United States and Wildcats to the United States, completing environmental training in Arizona and California, and Canada. There was various concurrent UK training and Arctic training in Norway for the Merlin force.

Re-equipment Programme

Undertaking the largest ever UK rotary re-equipment programme alongside intense, high-tempo training is helping reshape operational mentality and the scope of permissive operations undertaken by JHC and its subordinate units. Allied with technological advances, these assets provide new opportunities previously unavailable, which is exciting for the command leadership.

Maj Gen Felton said: "My squadrons understand why we need to do this and what they need to do to produce a credible capability, and they are simply getting on with the job. Generating capability is extremely challenging in the current climate. When people ask, 'is there an endgame?' my response is simply, 'how good do you want us to be?' That is a question for the MoD.

"In the meantime, we will move forward positively and proactively and re-set ourselves constantly. Change is the new norm and I think that is right. There is a commonly used quote which says, 'if you don't like change, you are going to like irrelevance even less'. We should embrace change with the opportunity it provides rather than the threats. There are so many unsung heroes within JHC which includes engineers and Tactical Supply Wing [TSW]. Air and rear crew tend to get all the attention. TSW have so many people at high readiness doing remarkable things in all parts of the world at short notice. Ultimately, we are only ever as good as the weakest link."

4

1 The Commando Helicopter Force's transition from the Sea King HC4 to the Merlin HC3 and HC3A was completed in June 2016 when 845 Naval Air Squadron returned home to RNAS Yeovilton in Somerset joining 845 NAS aircrew seen here. CHF's primary role is supporting 3 Commando Brigade, Royal Marines.
2 Captured departing a forward refuelling point on Salisbury Plain is an Apache AH1 with a 230-gallon extended refuelling tank attached. The MoD will replace its legacy fleet with 50 Apache AH-64Es from 2020. **3** Dust landing training represents a vital part of the environmental training undertaken by many types within JHC. Here an upgraded Chinook HC4 based at RAF Odiham, home to the UK Chinook force, departs one such area having completed its sortie.
4 A classic sunset scene as an Army Air Corps Apache AH1 based at Wattisham descends to refuel from a forward refuelling point during a mission rehearsal exercise. JHC's aspiration is its fleet of 50 AH-64E Apaches will be operational before the AH1's scheduled 2025-2026 out of service date.

Although aesthetically not as striking as the J-20, the Xi'an Y-20 is – at least for a military transport – quite a handsome design; it is nicknamed the 'chubby girl'. Following its maiden flight on January 26, 2013, the Y-20 accomplished its flight testing in an astonishingly short time (for a Chinese aircraft) and entered service within the People's Liberation Army Air Force (PLAAF) in June 2016.

Officially, the Y-20 is named the Kunpeng after a giant mythological bird. Not only is it by far the largest indigenous Chinese aircraft, but it is also China's first domestically developed heavy transport aircraft. As such, and similar to the J-20, the Y-20 represents both a giant leap in China's goal of building true strategic airpower and an important milestone for the Chinese aviation industry.

History

The initiation of the Y-20's development was closely connected with China's acquisition of Ilyushin Il-76MD transports in the early 1990s. Between 1991 and 1996, 14 Il-76MDs were delivered by the Chkalov Tashkent Aircraft Production Company to China and in parallel the first studies were initiated into developing an indigenous strategic military transport. Several more Il-76MDs were planned to be purchased, as well as Il-78 tankers, but this deal never materialised due to political issues, and consequently the design of an indigenous 200-tonne military aircraft became a high-priority project.

Naturally, the development of such a complex aircraft was a demanding effort for the Chinese aviation industry. The full background is not entirely public. However, in early April 2006, Chinese representatives approached the Ukrainian company ANTK

Andreas Rupprecht profiles China's new military transport aircraft, the Xi'an Y-20

Antonov – by then involved as a consultant in the development of the Y-9 transport and ARJ-21 airliner – to assist in the development. The true extent of Antonov's involvement in what became the Y-20 was much more than consultation. It contributed to the aircraft's development, reportedly with a jet-powered derivative of its An-70. On the Chinese side, the Xi'an Aircraft Company (XAC) was given responsibility for the project and the design team was led by Chief Designer Tang Changhong at XAC's design Institute 603.

According to reports, in the following three years the design was revised due to adjusted requirements from the PLAAF for an increased maximum take-off weight and dramatically higher payload. The whole project switched to a substantially larger and heavier proposal with a take-off weight of 230,000kg (507,063lb) and a maximum payload of 60,000kg (132,277lb). In this form, the design received its Y-20 designation in late 2009.

At around the same time the first concept drawings appeared on the Chinese internet, stating the prototypes and early serial aircraft were planned to be powered by Russian D-30KP-2 engines, with later production versions using a new indigenous high-bypass turbofan called the WS-20 Huanghe. A maiden flight at around the turn of the year from 2012 to 2013 was mentioned. In the meantime, China acquired a few more used Il-76MD and Il-76TDs as a stopgap measure until the Y-20 entered service.

Development Progress

A first full-scale metal mock-up of the aircraft's front section had been built by 2008 and by mid-2009 construction of the rear fuselage for the first prototype had begun. A full-scale mock-up was completed in early 2010 and by early 2012 rumours popped up on internet forums stating the first prototype had been finished.

On Christmas Eve 2012, a small, grainy image appeared on the Chinese internet of the first prototype, s/n 20001,

Russian D-30KP-2 engines power the Y-20s flying so far. Later production versions will use a new indigenous high-bypass turbofan, the WS-20 Huanghe. *All photos Chinese internet*

China's Giant Bird

1

1 One of the first Y-20s delivered to the PLAAF. Reports suggest the four aircraft in service are the final prototype and three LRIP aircraft. **2** Y-20 serial number 783, pictured flying at Airshow China in 2014, was the second example to fly. **3** This year is expected to see the maiden flight of a Y-20 fitted with the WS-20 engine, pictured on the inner port pylon on this Il-76LL testbed. **4** The first operational Y-20 unit is the 12th Regiment of the 4th Transport Division at Chengdu-Qionglai. **5** Reports say during the design process the Y-20's maximum take-off weight was increased to 230,000kg (507,063lb) and its maximum payload to 60,000kg (132,277lb).

2

undertaking taxi tests (which began on December 21, 2012) at the Chinese Flight Test Establishment (CFTE) airfield at Xi'an-Yanliang. The long-awaited first flight was successfully completed on January 26, 2013, marking a major achievement for the Chinese aviation industry.

A lot happened in the three-and-a-half years between the Y-20's maiden flight and its service entry in June 2016. Aircraft 20001 was soon renumbered 781 and received a dark charcoal colour scheme. In December 2013, the second prototype, 783, flew for the first time, followed by additional aircraft (785 and 788) during 2015. The final prototype, 789, already close to low-rate initial production (LRIP) standard, flew in February 2016.

Before then, in autumn 2015, press releases reported that a pulse assembly line had been established at XAC and the factory was ready for production. Late in 2015 XAC's parent company, AVIC, officially announced the research and development (R&D) phase of the Y-20 programme was complete, prompting the members of web forums about Chinese aviation to begin discussing whether the type would soon enter service. Between March and May 2016, several reports in the Chinese media were surprisingly open in their discussion of the Y-20 and the project's progress. Some experts stated the Y-20 would be put into military service in mid-2016, openly admitting the transport would use imported engines – D-30KP2s – as an interim measure.

There were no significant hold-ups during development, manufacturing and testing. As such, the R&D phase was completed and the type received its certification. The Chinese media even openly discussed the PLAAF's requirement for the airlifter, erroneously reported in some Western media as 1,000 aircraft. According to a military expert interviewed by the People's Daily Online, no more than 100 Y-20s will be deployed by the PLAAF in the future. These statements were a prelude to the official service introduction, which began with a handover on June 15, 2016.

A first aircraft, serial number11051, was delivered in a ceremony at XAC's facility at Xi'an-Yanliang and later transferred to Chengdu-Qionglai. A second aircraft, 11052, was spotted a day later. The first operational unit is the 12th Regiment of the 4th Transport Division at Chengdu-Qionglai, previously a Xi'an Y-7 operator. On July 7, the two Kunpengs were officially introduced to the PLAAF; in service this type is officially designated Y-20A. Two more as yet

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unnumbered aircraft made an appearance prior to Airshow China at Zhuhai in November 2016 and were handed over soon after the show. The latest reports say these four aircraft are in fact the final prototype, 789, and three LRIP aircraft.

What is 'In Service'?

It may come as a surprise that the Y-20 reached series production after only three years of testing, especially as the Chinese lack any prior experience in the development, testing and certification of an aircraft of this size. Comparable modern transports, such as the Boeing C-17, the Airbus Defence and Space A400M and the Kawasaki C-2, have generally required three to five years of testing.

However, the Chinese understanding of 'in service' is in no way comparable to a Western initial operating capability. By Chinese standards, an aircraft is considered in use when it has obtained its approval/certification and the first examples have been handed over. Therefore, the milestone event on June 15, 2016 was above all a signal, perhaps more important in a political context. True operational testing will continue for some time longer.

Operational use of the first Y-20s will be quite limited, but will likely include testing in different scenarios and mission profiles to gain further experience. This will certainly involve setbacks and maybe even delays, but this is standard Chinese practice.

Ultimately, the Y-20B with the WS-20 Huanghe engines will emerge. A first glimpse of how this definitive version will look was presented at Airshow China in 2014, with the showing of a civil version called the Y-20-F100. In contrast to the current Y-20, this version features a slightly stretched fuselage.

Progress on the WS-20 engine is reported to be proceeding well and the maiden flight of a Y-20 with this engine is expected this year. Testing of the WS-20 has continued at the CFTE using a converted Il-76LL engine testbed in parallel to the Y-20's service introduction and LRIP.

The WS-20 is China's first modern high-bypass turbofan. It is based on the core of the military WS-10A, as used for some time in the Shenyang J-11B fighter. With a projected thrust range of 120-140kN (26,977-31,473lb), the WS-20 entered testing in 2014.

Probably only with the WS-20 engine will the Y-20 finally fulfil its projected performance. Consequently, China's giant bird has a long, bumpy and surely interesting road ahead of it.

Both of HMS Endurance's Lynx HAS2ICE helicopters over Mare Harbour in the Falkland Islands during February 2007. *LA(Phot) Whybrow/Royal Navy*

Ian Harding covers retirement of the Lynx helicopter from the Fleet Air Arm after 41 years of service

Lynx Farewell

Everyone associated with the Westland Lynx helicopter describe it as agile, dynamic, fast and highly manoeuvrable. It is considered the sports car of its generation, but sadly, in Royal Navy service, the Lynx will race no more following the decision to withdraw the final seven aircraft from service on March 31, just three weeks after the final embarked Lynx Flight returned to its home base at Royal Naval Air Station Yeovilton in Somerset. The Lynx has served the Fleet Air Arm for 41 years at sea in some of the toughest environments on earth. It was no challenge to find Royal Navy personnel willing to talk about its service history and operations.

All at Sea

Commanding Officer 815 Naval Air Squadron (NAS), Commander Philip Richardson, first flew the Lynx in 2003 and continued to do so until its withdrawal. He is now in the process of transitioning the squadron to the Wildcat HMA2, which started in April 2016 when 815 received its first four aircraft.

When asked why the Lynx was so capable, Cdr Richardson replied: “One of its most impressive qualities is its performance and excellent handling ability in the roughest sea conditions. Westland’s ground-breaking and innovative designs made it ideally suited to the maritime environment. The features which allowed it to operate safely and successfully at sea in a dynamic environment, during the day and night, whilst being immersed in salt water conditions are testament to the work of the design engineers in the 1970s, and the development of the aircraft ever since.

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Service History

The first maritime Westland Lynx (WG-13) flew from Westland Helicopter's Yeovil site on the March 21, 1971. The Lynx was intended to replace the diminutive Westland Wasp in a similar embarked role.

Royal Naval Air Station Yeovilton was the first base to operate the Lynx and 700L NAS, known as the Intensive Flying Training Unit for Lynx commissioned on September 1, 1976, was the first squadron to receive the Lynx HAS2. In 1978, 700L became 702 NAS, the Fleet Air Arm's Lynx training unit, which continued in that role for 36 years until its disbandment on August 1, 2014.

In 1981, 815 NAS received its first Lynx as a front-line squadron and headquarters for all Lynx Flights, a role still retained today but with the Wildcat HMA2.

"Reasons why the Lynx successfully operated in this harsh environment include the aircraft's harpoon system, which is a hydraulic deck lock system in which a ram is inserted into a grid which quickly secures the aircraft on to a moving deck. Secondly, the Lynx was designed with a very low centre of gravity, thus ensuring it has greater stability when the flight deck moves. It also has a fixed titanium main rotor head which allows a highly responsive and agile movement around the deck for the pilot. Also, the ability to use negative pitch on the main rotors to blow the aircraft down once on deck makes landings at sea safer."

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Royal Naval Air Station Portland in Dorset became the home of 702 and 815 NAS from July 1982 until both squadrons returned to Yeovilton in 1999. In 1986, 829 NAS was activated as a second frontline squadron and shared responsibility for embarked Lynx Flights (with 815 NAS) until it disbanded in March 1993; today 829 operates the Merlin HM2.

Between 1976 and 1982 the Fleet Air Arm received 60 Lynx HAS2s from Westland, followed by 30 Lynx HAS3s (delivered from 1982 through to 1988) which supported 40 Ship Flights, the last of which was 208 Flight.

Lynx HMA8SRU ZF557/PD426 wearing commemorative markings and the legend 'Lynx Flights 1981-2017' returned to Yeovilton on March 10, 2017, following a nine-month deployment to the Arabian Gulf and South Atlantic aboard Type 23 frigate *HMS Portland*.

Upgrades

During their service lives, Royal Navy Lynx helicopters underwent upgrade and modification, the most important of which being the conversion of Lynx HAS2 aircraft to HAS3 standard with uprated Gem 42 engines, a new floatation system and an upgraded electronic support measures.

In 1993, the Fleet Air Arm introduced the Lynx HMA8 variant featuring new British Experimental Rotor Programme rotor blades, a new tail rotor, a forward looking infrared radar and the ability to carry torpedoes and Sea Skua missiles. All-up weight of the Lynx HMA8 was 11,750lb (5,330kg). The final modification to the HMA8, dubbed the Saturn Radio Upgrade (designated HMA8SRU), added an improved communication systems and a defensive aids suite.

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1 Lynx HAS2ICE XZ241/EE435 of 212 Flight assigned to *HMS Endurance* (A171) parked on the beach at Possession Bay in South Georgia. *Lt Weston/Royal Navy*
2 Lynx HMA8SRU ZF557/PD426 had commemorative markings and the legend 'Lynx Flights 1981-2017' applied to mark the final Lynx ship flight deployment to the Arabian Gulf and South Atlantic aboard Type 23 frigate *HMS Portland* (F79). *Ian Harding*
3 A Lynx HMA8 assigned to 702 NAS undertakes familiarisation training at Okehampton Camp. *LA(Phot) Bunting/Royal Navy* **4** A Lynx HMA8 in the hover loaded with two Sea Skua missiles. *Royal Navy* **5** Sea boats and the ship flight's Lynx from *HMS Chatham* (F87) in the Northern Arabian Gulf while assigned to Combined Task Force 158 tasked with protecting Iraqi oil terminals in 2008. *LA(Phot) Winter/Royal Navy*

1 A Royal Marine descends the rope suspended from a Lynx HMA8 during fast roping training on board *HMS Dragon* (D35) in the Arabian Gulf. *LA(Phot) Jenkins/Royal Navy*
2 Weapon loading drills on the flight deck of *HMS Montrose* (F236) during Operation Kipion in the Arabian Gulf. *LA(Phot) Knott/Royal Navy*
3 Members of 815 NAS prepare to load a dummy Stingray torpedo to a Lynx HMA8 on board *HMS Edinburgh* (D97) in the Caribbean. The drill loading was undertaken as part of a routine flying exercise. *LA(Phot) Rosenbaum/Royal Navy*
4 A Lynx HMA8 is moved into the hangar bay on board *HMS Manchester* (D95). *LA(Phot) Rosenbaum/Royal Navy*
5 Tight for space, *HMS Manchester's* Lynx HMA8 stowed in the hangar bay. *LA(Phot) Rosenbaum/Royal Navy*

Conflict

Royal Navy Lynx have taken part in numerous conflicts since Operation Corporate during the Falkland Islands war in 1982 when *HMS Ardent* (F184), *HMS Coventry* (D118) and the MV Atlantic Conveyor were lost to enemy action resulting in the loss of three embarked ship flights.

Fleet Air Arm Lynx deployed to the Persian Gulf as part of the Armilla Patrol following the Iran-Iraq war and regularly before, during and after both Gulf Wars in 1991 and 2003.

More recently, 815 NAS undertook maritime counterterrorism operations in support of the international Combined Task Force 150 in an area spanning two million square miles (5.18 million km^2), covering the Red Sea, the Gulf of Aden, the Gulf of Oman and the Indian Ocean. Back home in the UK, 815 NAS Lynx conducted 24/7 security operations during the 2012 Olympic Games held in London operating from *HMS Ocean* (R11) moored in the Thames.

Nuances

Few people understand the Lynx better than Lieutenant Commander Alun 'Lucky Al' Read, a qualified helicopter instructor and one of five Lynx pilots assigned to 815 NAS at the squadron's retirement. Alun's 38-year naval flying career started in 1979 and ended when the Lynx retired from service.

Reflecting on 4,000 flying hours in the Lynx while standing beside helicopter XZ689/314, one of the oldest still flying, Lt Cdr Read said: "This aircraft first flew in 1978, one year before I joined the Royal Navy. I started flying Lynx in 1989 having flown the Sea King as a pinger [a colloquial term used for anti-submarine warfare] from 1982. I've always loved this aircraft. Stepping from the Sea King to the Lynx was like moving from a Transit van into a supercharged Ford Focus. When the aircraft first arrived, everyone was expecting a replacement Wasp with two engines. The radar was a real bonus and made the aircraft a lot more useful than we

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all originally thought. In the air, our aim was to get the Lynx into the right places, so it could be used when needed. We certainly did that. However, when it got very hot and humid the camera just didn't work, so we had to get closer! What we used to do in the old days was to sneak up on our targets at very low level. It's very different now with Wildcat and the new systems available."

Control of airframe vibration has hugely improved thanks to the introduction of Health and Usage Management Systems on the Wildcat, on which Lt Cdr Read reflected: "With the Lynx you can feel if the aircraft isn't quite right on start-up. I used to lean my hand on the instrument console and could tell which direction the vibration was going in; if it was four times the speed of the rotational head or 12 times it would either be the gauge or the pressure, the temperature transducer on the gear box or the engine. I'd then debate with the engineers what the problem was. If it was vibrating fast, it was probably electric!"

So why 'Lucky Al'? Lt Cdr Read explained why: "Landing the Lynx at sea was relatively easy due to the aircraft's fixed titanium head, which gave the aircraft a lot of quick dynamic movement around the deck. The tough part was taking off with a full fuel load. At full weight, this aircraft uses a lot of its available power to take off. At night we always take off in the direction the ship is facing, but we can turn into the wind during the day. We slid off the side of a Type 23 backwards in a Mark 3 in the dark at maximum weight in very rough sea conditions. There is a four-inch metal edge on the flight deck which we thought would stop us but sadly not. The aircraft went below the flight deck and down between the troughs of two waves, ending up approximately a quarter of a mile behind the ship before we were able to climb above the level of the waves and recovered. The good news: we were able to fly it home."

Maintenance

With 36 years' experience of maintaining the grey Lynx, nobody understands the aircraft better than Chief Petty Officer Andy Wardle who first set sight on a Lynx two years after joining the Royal Navy in 1979. CPO Wardle started on the HAS2 before progressing on to HAS3, HAS3S (fitted with a more secure radio system) through to the HMA8 and finally HMA8SRU. He said: "Maintenance was very hands on and generally straight forward with few issues we hadn't come across and couldn't fix. Having prepared the aircraft, start-up was always an issue due to the battery, which was never really up to the job. Generally, we tried to avoid doing these. There was always a power issue with the avionics, but other than that nothing else, really. With the introduction of modern gyros, start-up became instantaneous."

Having performed many roles during his Lynx career, including flight test, vibration control and as Programme Manager for the Saturn radio communication upgrade (SRU), CPO Wardle is well aware of the aircraft's durability, especially it seems when the aircraft was deployed: "The aircraft's build life was 7,000 flight hours, but this was increased to 8,000 hours following a life extension programme which added 1,000 hours. We had a couple [of

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1 *HMS Daring's* Lynx HMA8 operated by 200 Flight delivers aid to the village of Hagden on the Philippines island of Guintacan in the wake of Hurricane Haiyan in November 2013. *LA(Phot) A'Barrow/Royal Navy* **2** A Lynx HMA8 from *RFA Fort Victoria* on scene of a Royal Marine boarding operation on a dhow with Somali pirates on board. *LA(Phot) Heller/Royal Navy*

helicopters] at this level, but most have around 5,000–6,000 hours. Generally, we operated the latest aircraft at around 5,300kg [11,680lb], but interestingly, the aircraft lost 80kg [175lb] with the SRU avionics. The later DAS upgrade added weight back though. From a maintenance perspective, I rate the Lynx highly. They are still very serviceable. Scheduled maintenance on the Lynx was always the biggest area, but fault rectification was all avionics. The whole maintenance approach has changed completely compared with Wildcat.

"My best Lynx memory was during a West Indies deployment aboard *HMS Brave* [F94] on counter-piracy and drug operations lasting from dawn to dusk. In a little over six months we flew just under 360 hours, which was huge for a Mark 3. The aircraft remained serviceable the whole time bar a few minor issues. If you completed 30 hours per month now, that would be pushing the airframe quite hard. I shall miss her when she finishes."

Aircraft Engineering Officer with 815 NAS, Lieutenant Commander Kirsty Marlor spoke of the enjoyment gained from being hands-on with a Lynx during maintenance: "What's so nice with Lynx is the level of engineering experience we have. There haven't been many issues we've not come across before, so fault fixing is straightforward."

Final Observer

Lieutenant Max Cosby was the last person to collect his wings, as an observer, on the Lynx in February 2015. Lt Cosby transitioned to Wildcat in June 2016, but has fond memories of his brief experience on the Lynx: "My Lynx career started with 702 NAS in January 2014 and lasted one year. Having gained experience, I was fortunate to be deployed to the Caribbean for six months aboard the auxiliary landing ship *RFA Lyme Bay*. Our work was extremely varied involving disaster relief operations, counter-narcotics and defence engagement. Flying the Lynx under the conditions of the Caribbean was a fantastic opportunity to make a difference in this helicopter. Converting to Wildcat is easier in some respects, although the differences are huge, especially for the observer. Operating in a Lynx was like having your mobile phone strapped to your computer strapped to your digital camera. In a Wildcat, everything is integrated into one system and based around how we want to operate it."

Lynx and Wildcat

Commanding Officer of the Lynx Wildcat Maritime Force, Commander Gus Carnie has the honour of being the final Lynx Commander. Reflecting on a 15-year period spent flying the Lynx and transitioning to Wildcat, Cdr Carnie said: "Wildcat's capability is so far ahead of the Lynx, but the Lynx remains a very impressive machine and will not be forgotten in the Fleet given its extensive operational service and the [world] speed records set: it's a genuine piece of UK rotary-wing history.

"I undertook evacuations of personnel in Lebanon as the flight pilot aboard *HMS Gloucester* [D96]. This involved collecting personnel and replacing them with specialist operators. Other operations of note included a

hostage rescue in Eritrea and a merchantman retake off the coast of Somalia in 2006 with American forces, which to my knowledge was the first, and maybe the last, Royal Navy action allowed inside Somalian territorial waters."

The Fleet Air Arm flies the Lynx and Wildcat with two aircrew, a pilot and an observer, plus crewman, depending on the mission, which Cdr Carnie explained: "In the Lynx we sit close together, and the reality is we could go through a whole sortie not talking, yet we know exactly what each other is thinking. From a pilot's perspective, the Lynx is [like] a sports car; you can really throw it around. On occasion, I've lost an engine in the Lynx and the helicopter has always brought me home safely, and I always felt safe in it. For a rotary-wing aviator, it's quite a sensation dropping a heavy-weight missile like a Sea Skua from a Lynx."

Sea Skua

Lynx armed with Sea Skua missiles are credited with helping to destroy the core strike capability of the Iraqi Navy during both Gulf Wars. During the first Gulf War, the United States had no type of helicopter capable of destroying Iraqi surface ships, so Fleet Air Arm Lynx were given the task.

During one mission, a Lynx HAS3 deployed aboard *HMS Manchester* (D95) was tasked to take out an Iraqi patrol boat that had fired at a US helicopter. At a position ten miles (16km) from the Iraqi boat's last reported position, the observer flashed up the radar and found the enemy craft; a Kuwaiti vessel commandeered by Iraqis. The observer set the missile to skim the waters of the Gulf and hit the craft close to the waterline, punching through its thin skin, before the warhead detonated destroying the target.

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During the 1982 Falklands War, Fleet Air Arm Lynx armed with Sea Skua missiles proved effective in disabling Argentine vessels. The final launch of a Sea Skua missile from a Fleet Air Arm Lynx took place in the mid-Atlantic during the final deployment by 208 Flight embarked on *HMS Portland* (F79), which returned home on March 10, 2017, after a nine-month deployment.

Cdr Carnie said valuable experience with the Lynx has been passed on to the Wildcat operators: "The Lynx served us all so well in theatres as diverse as Antarctica, the Middle East and the Caribbean and will not be forgotten."

From April 1, 815 NAS will be equipped with the Wildcat HMA2 as the frontline squadron responsible for ship flights while 825 NAS will continue as the Wildcat training unit.

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3 Return from deployment. The pilot of Lynx HMA8 ZF557/PD426, assigned to Flight 208, hovers the helicopter to a parking spot at Royal Naval Air Station Yeovilton on March 10, 2017, marking the end of the type's final deployment and 41 years of operational service. *LA(Phot) Rosenbaum/Royal Navy*
4 *HMS Dragon's* Lynx HMA8 fires a salvo of flares at sunset at the end of a day-into-night training sortie. *LA(Phot) Jenkins/Royal Navy*

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Special

The 1st Special Operations Wing (1st SOW) is based at Hurlburt Field in Florida. The wing's flying unit is the 1st Special Operations Group (SOG). Five of its assigned squadrons operate aircraft. In the November issue of AIR International, we covered the AC-130U-equipped 4th Special Operations Squadron (SOS) and the MC-130H-equipped 15th SOS. Now we look at the Bell-Boeing CV-22B Osprey-equipped 8th SOS and the U-28A-equipped 34th and 319th SOS.

The 8th SOS operates the CV-22 Osprey, the version of the famous tilt-rotor aircraft designed for special operations. The mission of this machine, which mainly replaced the MH-53, is long-range infiltration and exfiltration of troops and materials, usually at night. The CV-22 can land on simple spots as a helicopter, but can also deliver personnel by airdrops or fast-rope.

Osprey's Origins

The CV-22's origins date back to Operation Eagle Claw in April 1980, the failed US Special Forces mission to rescue American hostages from the US Embassy in Tehran involving US Air Force EC-130Es and MC-130E Combat Talons and US Navy RH-53D Sea Stallion helicopters.

The mission's failure led to the Joint-service Vertical take-off/landing Experimental (JVX) programme, whose contract was assigned in 1983 to Bell-Boeing. The first of 51 CV-22s for the US Air Force entered service with the 58th SOW at Kirtland Air Force Base, New Mexico in March 2006, and the type was officially accepted at Hurlburt Field the following November. The 8th SOS was the first front-line squadron to be declared operational, reaching its IOC in March 2009. Today, the 8th SOS operates 14

Ops

Riccardo Niccoli visited the 1st Special Operations Wing and reviews the CV-22 Osprey and the U-28

A CV-22 Osprey approaches a drogue on the end of the hose extended from a MC-130H Combat Talon II during a training mission. *Senior Airman Christopher Callaway/US Air Force*

Ospreys. The CV-22 is still in production and deliveries are expected to be completed by 2019.

Captain Jon Lohse, a CV-22 pilot, told AIR International: "The famous rescue mission of hostages in the US Embassy in Tehran in 1980 took about 36 hours. Today, with the Osprey, it would need only one night and eight hours. The Osprey flies twice the speed of a helicopter and has twice its endurance, and can fly at higher altitude."

Complementing the Talon

The Osprey is a necessary complement to the 1st SOW's MC-130H Combat Talon II, as it can take off and land in small areas, like a helicopter can. A CV-22 can also perform automatic approaches and, thanks to its hoist, conduct rescue operations.

Pilots assigned to the Osprey come from helicopter or C-130 fleets. The initial qualification training is carried out with Marine Medium Tiltrotor Training Squadron 204 (VMMT-204), the US Marine Corps' Osprey training unit based at Marine Corps Air Station New River, North Carolina. The course is about four months long and includes 50–60 missions in the simulator, and 25–30 flying hours, covering basic flight operations.

Further training is carried out at the 58th SOW, where new pilots learn how to employ the CV-22 in an operational environment, mostly at night. The course at Kirtland is six to nine months long (depending on the training opportunities) after which pilots are assigned to an operational squadron.

A new pilot arrives at Hurlburt qualified as a Mission Pilot, but still has a lot to learn. Operational training includes a deck landing qualification, free fall personnel airdrops and night hoists at sea. It's easy to understand the difficulties Osprey pilots have to face – for example, they must learn and qualify to carry out in-flight refuelling at an altitude of 500ft and 115kts (213km/h) – at night! This

phase of their operational training lasts about another nine months and must be achieved before a pilot can be assigned to their first operational deployment.

Special Forces Modifications

The CV-22 includes a series of modifications necessary to perform Special Forces operations. It boasts extra wing fuel tanks, which increase the fuel capacity by 588 US gallons (2,230 litres). In addition, the cargo cabin can accommodate up to three auxiliary tanks of 200 or 430 US gallons (757 or 1,627 litres) capacity.

The Raytheon APQ-186 multimode radar has terrain following/terrain avoidance capability for safe flight down to 100ft (30m) at night, in adverse weather and in a high-threat environment. It also boasts ground mapping, air-to-ground ranging, weather detection, beacon interrogation and cross-scan modes.

Other systems fitted to the CV-22 are Raytheon's AAQ-27 electro-optical/infrared sensor; an ALQ-211(V)2 integrated radio frequency countermeasures system designed to counter advanced threats with a radar warning receiver, radar jammer, and airborne radio frequency expendables. The ALQ-211 also manages two defensive systems; the AAQ-24 DIRCM (directional infrared countermeasures) and ALE-47 airborne countermeasues dispensation system for chaff and flares.

The CV-22 is equipped with a glass cockpit featuring four large multifunction displays and one central display unit. A cockpit management system fully couples autopilot functions, including an automatic mode to switch from forward flight to 50ft (15m) hover, with no pilot intervention. This, coupled with a head-down display and hover symbology helps to overcome brown-out situations.

Crew and Armament

A CV-22 crew comprises two pilots and two flight engineers. One engineer has a crew station located just behind the flightdeck, managing navigation and aircraft systems, the other is in the cargo area as a loadmaster and gunner. The two can change position on-board; they have the same qualifications. During a sortie, the aircraft commander manages the mission and communications, while the second pilot acts only as pilot. The cargo cabin can accommodate 24 troops seated or 32 troops on the floor, or 10,000lb (4,540kg) of cargo.

The CV-22 has a collapsible mount fitted on the aft ramp for either a M240 0.3-inch (7.62mm) or M2 0.5-inch (12.7mm) machine gun. Trials have been conducted for fitting a forward-firing weapon. However, this would introduce more weight and could affect the general performance of the aircraft.

Initially, the CV-22 was deployed without armour floor panels, but these were introduced after December 2013, when three aircraft deployed in South Sudan suffered heavy damage during a rescue mission flown to evacuate American civilians. Operations are classified, but Air Force Special Operations Command CV-22s are used for missions in Africa and the Middle East against IS forces.

Capt Lohse said: "The CV-22 receives regular upgrades, especially avionics and software; other recent improvements include a new fuel dump system and a new head-up display used in conjunction with night vision goggles [NVGs]. There is also a new colour helmet-mounted display in two versions, one for the use of NVGs and the other for daylight operations, but at present, only the first has been assigned."

Maintaining the Osprey

Maintenance is performed by personnel from the squadron and the wing, supported by Bell-

1 The cockpit of the CV-22 Osprey is dominated by five colour multifunction displays. **2** A CV-22 on the 8th SOS ramp at Hurlburt Field. **3** The only weapon currently employed by the CV-22 Osprey, an M2 0.5-inch machine gun mounted on the rear ramp. **4** Two squadrons operate the U-28A, for utility and ISR missions. *All photos Riccardo Niccoli unless stated*

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Boeing field service contractors, necessary when some complex or new technical problems appear. They also check the data feedbacks downloaded from the aircraft after every flight.

The Osprey requires a lot of extra maintenance compared to other aircraft due to the number of systems and new technologies used on the aircraft. For example, the rotor washplates must be changed every 420 hours. Major inspections are scheduled every 210 flying hours (A phase); 420 hours (B phase); 630 hours (C phase) and 860 hours (D phase).

Thanks to feedback from operational use, in the future the A phase will probably be increased to 350 hours. Depot-level overhaul is scheduled to take place at every second D phase inspections (1,720 hours), and is performed at Hurlburt, where the other AFSOC Osprey units also send their aircraft for depot maintenance. The oldest CV-22 had logged 2,500 hours by March 2017. According to Capt Lohse: "Reliability is improving a lot, thanks to the efforts of the industries involved."

AFSOC first deployed the CV-22 Osprey in November 2008 for Exercise Flintlock in Mali, flying non-stop from Hurlburt to Africa, thanks to in-flight refuelling. In August 2009, the 8th SOS was deployed for the first time in Iraq. Since then, the squadron has also served in the Horn of Africa, Afghanistan and the Middle East.

U-28A

Two other squadrons are part of the 1st SOW: the 34th and 319th SOS, both fly the U-28A, the US Air Force version of the Pilatus PC-12 turboprop utility aircraft. The 319th SOS was formed in October 2005 just to operate the type, initially receiving six aircraft. In April 2010 it was followed by the 34th SOS, with a similar number of aircraft. Today, 28 U-28As are in service, with the type also assigned to the 318th SOS at Cannon Air Force Base, New Mexico.

The U-28A was purchased with funds from Special Operations Command (not the US Air Force) for Operations Enduring Freedom and Iraqi Freedom. As appears from its designation, the U-28A is mainly a utility aircraft, able to carry nine people (plus three or four crew) and cargo, and fly from short and unpaved strips. The U-28 is fitted with military communication equipment (including datalink, video, data and voice), aircraft survivability and advanced navigation systems. Some U-28s also have electro-optical sensors installed for intelligence, surveillance and reconnaissance missions.

Not much is known about missions assigned to the U-28 fleet, though they usually support operations in Africa and the Middle East. Part of the fleet received a military camouflage colour scheme, but other examples operate in civilian style liveries.

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Building In

Integrating unmanned aircraft into civil airspace is a big challenge. As Mark Broadbent discovers, research into this area continues in the UK with a Jetstream J31

When in the late 2000s the UK aviation industry started researching how unmanned air vehicles (UAVs) could be successfully integrated into civil airspace, the issues of transparency and equivalence were identified as key areas to address.

Transparency refers to ensuring a UAV performs in non-segregated airspace in the same way as a manned aircraft, and equivalence refers to ensuring a UAV is at least as safe as a conventional aircraft in that environment.

The issue was how to achieve these things. Maureen McCue, Head of Research and Technology for Military Air and Information at BAE Systems, said: "That's what ASTRAEA set out to solve."

The Autonomous Systems Technology Related Airborne Evaluation and Assessment (ASTRAEA) project involved a consortium of companies researching technologies to allow the routine operation of UAVs in the UK's commercial airspace. The organisations involved included Airbus, AOS, BAE Systems, Cobham, QinetiQ, Rolls-Royce and Thales.

ASTRAEA Research

ASTRAEA's starting point was that unmanned aircraft fundamentally changed the key regulations affecting commercial aviation, because they remove the pilot from the aircraft and move human supervision to the ground. A first phase researched the requirements that would be needed to ensure safe and reliable autonomous operations, while phase two researched how new technologies – sense-and-avoid, autonomy, communications, operations and human/system interaction – would achieve that all-important transparency and equivalence.

McCue said: "There was increased regulatory engagement, all the way up to working some draft regulations, and working hand-in-hand with the regulator developing and testing those systems."

BAE Systems provided its stalwart Jetstream J31 Flying Test Bed (G-BWWW) as a platform to test the new technologies. The culmination of the work came in April 2013 when G-BWWW flew from BAE Systems Warton to Inverness Airport, completing the first flight in civil UK airspace by an unmanned aircraft – technically, a 'surrogate' aircraft, as there were pilots aboard – in non-segregated airspace.

McCue said: "The aim was that the research and the regulations would converge in ASTRAEA 3, and then ASTRAEA 3 would give a body of evidence to give confidence that transparency and equivalence could be achieved and regulated."

That was not to be. The UK Government, which since 2006 had provided funding for ASTRAEA through increments from the Department of Business, Innovation and Skills, in September 2015 rejected a further request from the ASTRAEA consortium for a £26 million grant.

Continued Research

Despite the halt to the ASTRAEA programme after nearly ten years' work the funding cut caused, BAE Systems nevertheless decided to build on ASTRAEA by continuing research and development on technologies designed to prove the safe operation of unmanned aircraft in UK airspace – specifically, new sense-and-avoid, weather avoidance and satellite-based communications systems.

The latest phase of work, funded by BAE Systems' own internal funding to the tune of £400,000, initially involved ground and rig testing, then in late 2016 the research moved into the air with a flight test campaign using the Jetstream. McCue said BAE Systems' decision to continue with the research came from a desire, "to start to gather some of that body of evidence to give us confidence that the regulations that are emerging are sufficient to prove transparency and equivalence in operation".

BAE Systems' Jetstream J31 Flying Test Bed G-BWWW has been used for a series of company-funded test flights trialling new sense-and-avoid, weather avoidance and satellite-based communications systems. *All photos BAE Systems unless stated*

Sense-and-Avoid

The sense-and-avoid and weather detection technologies are both based on camera systems that record live video imagery. There are seven optical cameras and an infrared camera mounted around the Jetstream.

Algorithms interpret the imagery captured by the cameras and determine whether there's an incoming hazard, such as an intruding aircraft or a cloud that contains icing conditions. McCue explains: "The algorithms are looking for objects that are approaching, the size of the object [and] the rate of the object. The algorithms are designed to filter out the things that naturally appear in the environment.

"It's non-cooperative sense-and-avoid. In a cooperative system you would have a transponder and that would transmit and you'd know there was another aircraft there, [but] smaller aircraft don't necessarily have a transponder, or there may be a system failure or malicious intent, [so] the [sense-and-avoid] system is designed to identify and deal with it.

"On weather avoidance, [the algorithms are] looking at the type, range and the pattern of the cloud, and to determine whether the cloud is likely to present a hazard, such as icing."

The infrared camera is being evaluated to test its utility to support emergency landing situations. The system compares the picture captured by the infrared camera with an on-board database to find the safest place to land the aircraft. "What the infrared camera does in that situation is to do a confidence check to ensure there are no people or animals on the ground," McCue said.

The purpose of these camera systems and algorithms is to enable a UAV to recognise hazards automatically and enable it to plot a course autonomously that allows evasive action, just as a human pilot would in a manned aircraft. In other words, replicating the routine of human pilots and achieving those goals of transparency and equivalence to manned operations.

McCue said: "The human trusting the algorithm to make the decision is why the tests we're doing at the moment – where we're gathering the evidence, increasing the competence and gradually building from a narrow operation to a wider operation – are really important. That's part of building the trust in the decision-making, that the human decides what [decisions] the algorithm can make on our behalf."

While radar systems could also be used to detect weather and/or intruders, McCue said: "The problem with radar is it's expensive. From a military perspective, it occupies prime sensor real estate. The aim of this system is to give that open access, so for smaller aircraft that couldn't necessarily afford or fit a system there's now a system that's capable. From a military perspective, you've got the added benefit of not having to put a radar in prime sensor real estate."

Voice/Satellite Communications

Another aspect of the latest trials using Jetstream G-BWWW concerns voice communications. Mccue explains: "One of the things we did in [ASTRAEA] test flights was to fly through controlled airspace where NATS [the UK's air navigation services provider] gave command to the aircraft. Obviously, to keep things transparent and equivalent NATS want to keep things exactly as they would with a manned aircraft, and get the response back in the same way and the same time."

ntelligence

To achieve this, the ASTRAEA programme developed a digital voice to enable a UAV to communicate with NATS and then trialled those technologies in flight using the Jetstream. The voice communications were transmitted between NATS, the ground pilot and the Jetstream using satellite comms links. McCue said. "One of the observations from those flight trials was that the system worked fine, but there was an increased latency. The solution we've looked at in this phase of trials is whether we can use secure internet protocol to do that first stage of communications, so at the moment you'll go from a ground control station to a local earth satellite, up to the satellite. Can we use secure internet protocol to go directly to the satellite? That's the concept we're testing at the moment."

Test Flights

BAE Systems evaluated all these systems in a series of 17 test flights, which started late in 2016 and continued into the early part of this year. Each flight lasted around 90 minutes, with the aircraft flying through a corridor of non-congested airspace on a route from Warton to Inverness (around 300 miles/482km) and normally flying at 15,000ft (4,572m).

1 BAE Systems says using the J31 is a concept the Civil Aviation Authority likes because it allows experiments to be conducted in a safe way. *Derek Pedley/AirTeamImages* **2** Each flight lasted around 90 minutes, with the aircraft flying through a corridor of non-congested airspace on a route from Warton to Inverness **3** In addition to a flight test observer and a vehicle commander on the ground, two engineers were aboard the Jetstream in the cabin workstations.

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Speaking of Jetstream G-BWWW itself, Martin Rowe-Willcocks, Head of Sales for Future Programmes and Services for BAE Systems Military Air and Information, told AIR International: "It's a pretty versatile airframe. It's got a set of benches for computers and workstations and a couple of places where the guys can actually operate the vehicle."

A pilot and co-pilot were in control for take-off and landing, but once airborne and in controlled airspace the Jetstream flew itself. Two engineers were aboard the Jetstream in the cabin workstations. Together with NATS controllers, they continually assessed the performance of the systems on the testbed. On the ground, a flight test observer and UAV commander monitored the flights via satellite communications.

Rowe-Willcocks said: "At the front of the aeroplane it's still a normal cockpit. It's still got a pilot and a co-pilot and they're there as a check pilot when you actually flick the aircraft into its surrogate UAV mode."

Results

With the latest flight trials now concluded, BAE Systems engineers will evaluate the findings to determine the scope of further research. AIR International asked McCue about the initial feedback from the latest test flights. She said "some degree of competence and greater evidence" has been gathered, but further work is required.

She continued: "Initial evidence suggests we'll need to do some further work around the subtleties of cloud detection, for example its ability to deal with different light levels. It has that ability built in, but some minor modifications are needed there." The test flights also suggest improvements are needed to make digital voice commands "more slick and effective".

Moving Forward

With further work needed into all these technologies, it appears likely research using the Jetstream will continue in the future. Rowe-Willcocks said using G-BWWW is, "certainly a concept we like and it's a concept the Civil Aviation Authority likes because it allows us to explore and experiment but in a safe way".

The continuance of research using the Jetstream is also boosted by the bigger developmental picture at BAE Systems. The company is looking to mature technologies that could go not just into unmanned platforms, but also manned aircraft. Rowe-Willcocks said: "We've got a broad research programme, and this is just one example of what's going on. We have a basket of technologies that we're trying to develop across airframes, mission systems, the control environment, the human-machine interface and the level of automation that you're comfortable to put inside these systems. That forms our overarching research programme. This is just one of the technology threads we've got running at the moment."

Replicating the Human Brain

The underlying focus is about developing intelligence. Rowe-Willcocks said: "When we talk about this particular trial activity we do tend to focus on the sensor head side of it.

"The really clever part of this demo is the signal and data processing that sits behind it. Effectively what you're trying to do is not just replace the detection side of the human eye, but also the intelligence of the human brain – having seen something, deciding what to do about it.

"In our language, it's about the level of intelligence automation within the system, so you inform the people on the ground who are in command of the vehicle with the best information you possibly can so that, collectively, the human and the machine respond in a timeframe.

"The unmanned aircraft has to respond as if there was a pilot in the cockpit, looking out the window, spotting something and making a decision against a set of rules and flying norms to either ignore it or avoid it. That's the process we're trying to build up and it's as important as the man on the ground in control of this platform.

"When you move that forward into other environments, intelligent decision-making is a technology translatable into other spaces as well."

Announcing the Schools Aerospace Challenge 2017

Schools Aerospace Challenge is a competition for 16-18 year olds, challenged to submit design solutions to a fictitious, but realistic, RAF Operational Requirement.

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So, what are you waiting for?
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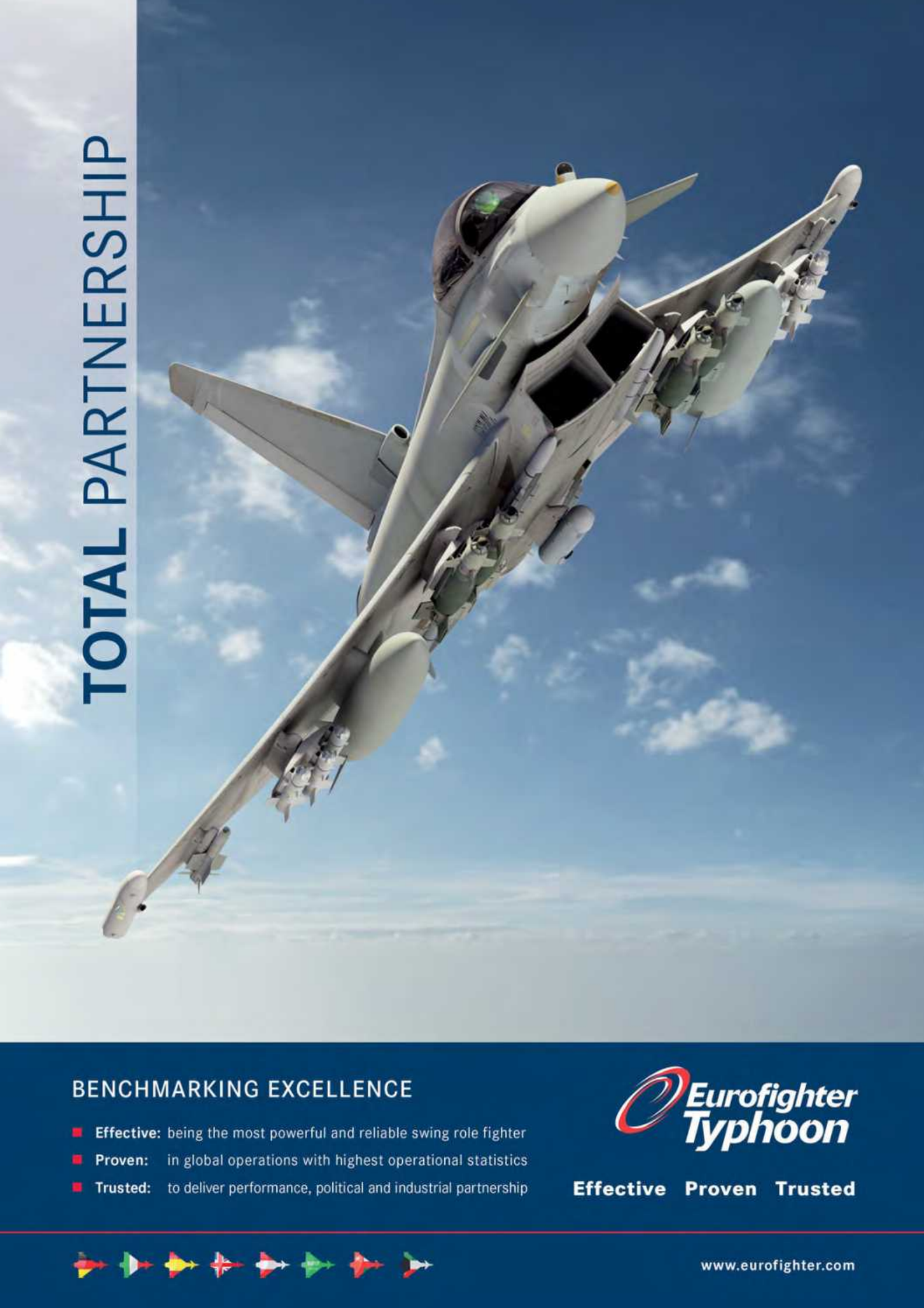

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