

Issue

1

MONDAY  
18 July 2022

# FLIGHT DAILY NEWS



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The moment  
for reducing  
CO<sub>2</sub> is now



Eve co-chief executive Andre Stein takes the wraps off the cabin mock-up of the in-development electric vertical take-off and landing aircraft at the show yesterday (see P5)

## t for change

Commitment to innovate its way to net zero

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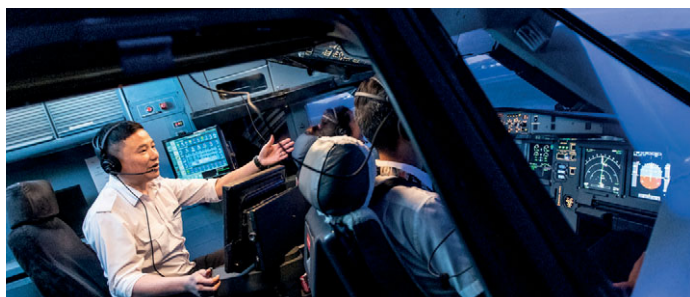
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“We have the global air transportation system modelled here,” says Yutko.

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Meanwhile, Rolls-Royce is to conduct trials of liquid hydrogen combustion (see P7). Airbus reveals that it is studying radical designs for a hydrogen-powered aircraft (see P12). Even supersonic airliner developer Boom is at the show with a sustainability theme.

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## Green light for change

Industry returns to Farnborough with commitment to innovate its way to net zero

Jon Hemmerdinger & Pilar Wolfsteller

Visitors to a scorching hot Farnborough this week will not go far without hearing the 'S' word. Sustainability and aviation's drive to tackle global warming by reducing its emissions are the overarching theme of the show.

With the global aerospace event returning after a four-year absence, the agenda has clearly shifted. While there will be the usual airline orders and updates on traditional aircraft programmes, almost every

announcement over the next four days – from developments in disruptive propulsion and advances in the availability of sustainable aviation fuel (SAF) to electrically-powered air taxis – has an environmental angle.

The show kicks off today with a series of green initiatives. They include Boeing's launch of a digital modelling tool that predicts the degree to which new technologies and the use of SAF will reduce the industry's carbon emissions.

Cascade is a Boeing-designed software tool the airframer says

will "show the best routes to zero carbon". It was developed in partnership with universities and incorporates flight data from sources such as Flightradar24. com, says Brian Yutko, Boeing chief engineer for sustainability and future mobility.

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# Raytheon's big STEP to electrics

Jon Hemmerdinger

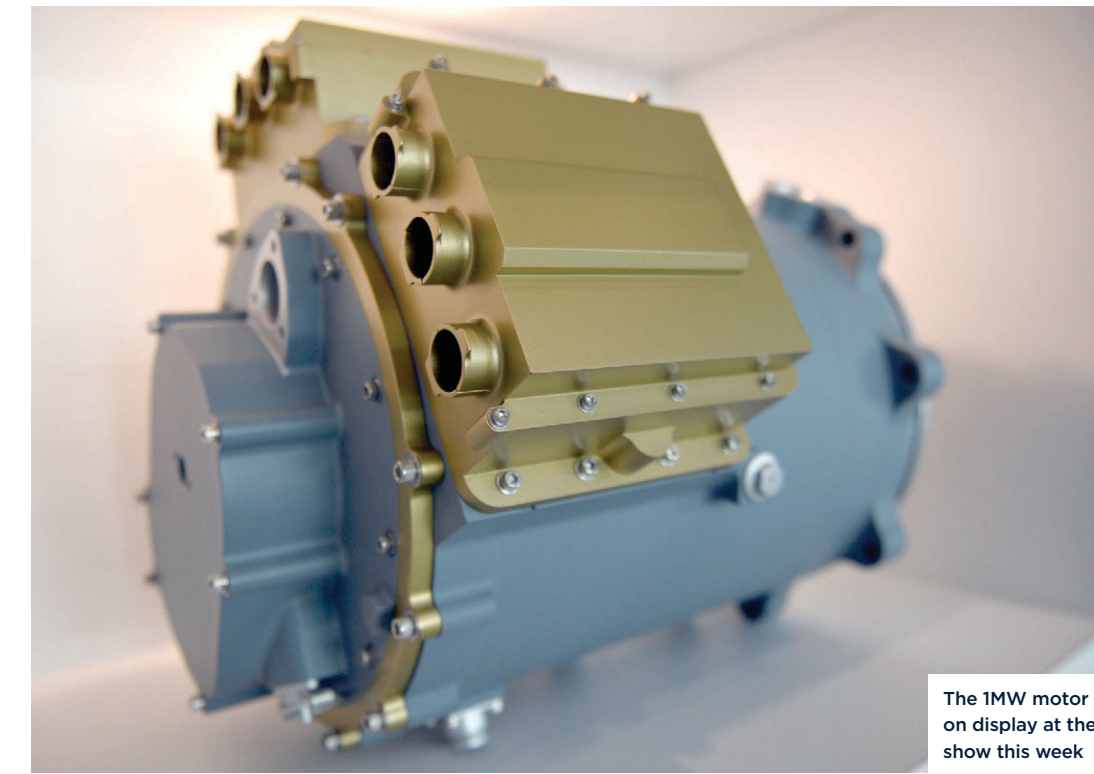
Raytheon Technologies is today announcing the launch of a project to advance hybrid-electric propulsion technologies, while also progressing with development of a 1MW motor to be installed on a modified De Havilland Canada turboprop.

The company's subsidiary Collins Aerospace recently completed a preliminary design review of the 1MW motor, which it is displaying this week at the show.

That project is not new. But the separate hybrid-electric development programme being revealed today – called the Scalable Turboelectric Powertrain Technology (STEP-Tech) demonstrator – is.

Collins and fellow Raytheon subsidiary Pratt & Whitney are leading STEP-Tech from Raytheon's site in East Hartford, Connecticut.

With both projects, Raytheon seeks to reduce the aerospace industry's carbon output. Executives say hybrid propulsion could



The 1MW motor on display at the show this week

first power turboprops and then narrowbody passenger jets. By 2035, Raytheon aims to launch a hybrid-electric version of P&W's geared-turbofan engine – with 25% efficiency gains, it says.

"The STEP-Tech demon-

strator... will focus on developing high-voltage, distributed turbo-electric hybrid-electric propulsion concepts in the 100-500kW-class, with potential to scale to 1MW and beyond", the companies say. "The demon-

strator platform will include full end-to-end system capabilities, including a high-efficiency turbo generator, energy storage, power electronics and modular electrically-driven propulsors."

The demonstrator will

not be an actual aircraft. Instead, it will help mature technology potentially applicable to electric vertical and take-off and landing (eVTOL) aircraft, unmanned air vehicles and "small- to medium-sized commercial air transporters", say Collins and P&W.

The companies this year completed "proof of concept studies" and intend to begin STEP-Tech ground-testing in late 2022.

Separately, Collins has completed the design review of its 1MW motor and a motor controller, and "has tested both systems to full current, voltage and speed".

Collins is developing the motor at its Solihull, UK plant, and testing it at the University of Nottingham's Institute for Aerospace Technology.

The motor will comprise a hybrid-electric system intended to power a Dash 8-100 turboprop. Collins intends this year to ship the motor to Pratt & Whitney Canada (P&WC), which is leading the Dash 8 modification project. Other partners include De Havilland and Swiss battery maker H55.

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Eve interior features four passenger seats

## All about Eve

Air taxi company Eve, the Embraer-backed electric vertical take-off and landing (eVTOL) developer, yesterday unveiled a new vehicle configuration as well as the aircraft's interior at Farnborough.

The Melbourne, Florida-based company, which now has letters of intent for 1,910 of its aircraft, has redesigned the vehicle to have a conventional wing and an empennage. In past design concepts, it had a canard and a wing. The new design still features eight rotors, providing vertical take-off and landing capability, as well as a smooth in-flight experience.

"Our teams have been

working hard to create the best solutions for the global urban air mobility environment, and our aviation experience... not only gives us confidence that we are on the right path but also puts us at the forefront of the market," says Eve co-chief executive Andre Stein.

The interior mock-up shows a single pilot seat up front, with four passenger seats – two forward-facing and two rear-facing. According to the company, Eve will have 54nm (100km) of range.

The company, which went public earlier this year, now expects to have the aircraft in service by 2026.

## London calling for AAM trial

A new consortium led by engineering design consultancy Atkins, and including Vertical Aerospace and Virgin Atlantic Airways, will in 2024 conduct an operational flight test of an advanced air mobility (AAM) vehicle from London Heathrow airport.

Designed to "significantly accelerate the introduction of AAM in the UK", the project has been awarded £9.5 million (\$11.2 million) under the third phase of the government-backed Future Flight Challenge (FFC), with another £5.5 million provided by the consortium

members. Building on work carried out as part of the FFC's phase 2, the trials are designed to create a "blueprint" for AAM operations, says James Richmond, head of future flight at Atkins.

Partner company Skyports will construct an operational vertiport at one of two undisclosed locations north of London, says Richmond.

Ground and passenger operations trials will begin there in mid-2023, eventually leading to a Virgin-operated flight of Vertical's VX4 aircraft from Heathrow to the site.

"We are hoping to demonstrate the commuter use case into London Heathrow," says Richmond, a mission which will be the "capstone" of the project.

"If you can crack that, in terms of how complex Heathrow is, you are well on the way to accelerating the UK and getting it ready for AAM operations."

Prior to the Heathrow tests, the consortium will in early 2024 carry out a flight from Bristol airport in the southwest of England to an undisclosed location around 50km away to demonstrate a "more rural use case".



Virgin will operate VX4 from London Heathrow

## Bristow befriends electric – again



Lillium's launch network will be in Florida

Global helicopter operator Bristow Group has added yet another tentative order for electric-powered aircraft, unveiling a memorandum of understanding (MoU) with Lillium that could lead to the purchase of up to 50 Lillium Jets.

In addition, Bristow will also provide Part 145 maintenance services for the Lillium Jet's launch network in Florida and "other future US and European markets". The German aircraft developer hopes to secure certification for the jet in 2025.

Under the "non-binding" MoU, the pair will develop a maintenance programme to support the operation of the Lillium Jet and will enable Bristow to become an authorised service provider for Lillium. It could also see the operator flying the jets in Florida and the purchase of as many as 50 examples.

Including the pact with Lillium, Bristow has now racked up six separate agreements with developers of full- or hybrid-electric aircraft as it works to become "more sustainable and innovative", says chief transformation officer Dave Stepanek.

He sees advanced air mobility aircraft as complementing rather than replacing its conventional rotorcraft fleet.

"We really see this as

an opportunity to create a parallel path for Bristow and continue operating traditional helicopters for search and rescue and long-range oil transportation.

"We can operate in parallel, because those vehicles will grant us access to markets that we can't work in today because of either cost or noise."

Should Bristow take the maximum number of aircraft covered by the six current agreements it would see the firm operating 400 new-generation air vehicles in addition to its current 213-strong helicopter fleet. Additional orders are also in the pipeline.

But Stepanek denies the operator has over-ordered or is hedging against one of the programmes failing to achieve certification. "We have looked at each of these aircraft OEMs and looked at the applications that we want for early adoption and these are the numbers we think we'll need."

Bristow has so far only made "small" financial commitments as part of its agreements, says Stepanek.

"What we are using is our 'sweat equity' to help this process and thereby secure early delivery positions and help to shape the general operations of these aircraft."



UK will invest £2.35 billion in Eurofighter upgrade

## Big capability jump on radar for Typhoon

Craig Hoyle

The UK has contracted "the single biggest capability jump for [the Eurofighter] Typhoon since its introduction to service", according to the Royal Air Force's (RAF's) most senior officer, as the nation also prepares to power ahead with its Tempest future combat air system initiative at the show.

Describing the £2.35 billion (\$2.8 billion) deal to deliver Leonardo UK-developed ECRS Mk2 active electronically scanned array (AESA) radars as "a transformational upgrade", chief of the air staff Air Chief Marshal Sir Mike Wigston says the activity will equip its 40 Tranche 3 Typhoons by the end of this decade.

Part of a P4E package of enhancements for the Typhoon, the project also

will equip the aircraft with replacement mission computers and a new sensor management and cockpit interface.

Referred to as a 'task-based management' capability, the interface "simplifies the access of information and exploits the radar 2 capability to the fullest extent", Wigston says. The RAF's Tranche 2 jets will also receive this update, and potentially also AESA radars at a later date.

Once equipped with the ECRS Mk2, the Typhoon will be able to perform new roles such as the suppression of enemy air defences and electronic attack. It also will gain new weapons including MBDA's Spear EW surface-to-air missile to perform such tasks.

"These technological enhancements will maintain the cutting-edge capabilities of Eurofighter Typhoon and

help underpin the development path towards the [UK's] Future Combat Air System," minister for defence procurement Jeremy Quin said while announcing the deal at the Royal International Air Tattoo on 15 July.

Leonardo UK will deliver a first flight-test example of the ECRS Mk2 to BAE Systems' Warton site in Lancashire later this year.

The UK will retire its oldest Typhoons later this decade, leaving it with a 107-strong fleet of Tranche 2 and 3 examples for use until the 2040s.

Its Tempest programme should deliver a new manned platform to enter service from 2035. Fresh news about the programme will be announced during the show, including expected closer collaboration with Japan in the combat air sector.



Attractions on show at Leonardo's outside exhibit area include a first glimpse of its M-345A jet trainer in an armed configuration. Currently flown by the Italian air force as the T-345A, the single-engined jet can be equipped with weapons including unguided rockets, bombs, gun pods and air-to-air missiles.

## Global tremors prompt Boeing to trim forecast



Boeing is displaying its 777-9 and 737 Max 10 at the show this week

Jon Hemmerdinger

Boeing has trimmed its 20-year industry-wide delivery forecast by about 2,500 aircraft in response to changing economic and industry circumstances, labour shortages, and Russia's invasion of Ukraine.

Likewise, the company has stripped roughly 2,300 aircraft from its estimate of the size of the global airliner fleet in 20 years, according

to the company's 2022 Commercial Market Outlook, released on the eve of the show.

Boeing now predicts demand will support delivery of 19,575 new freighters, regional jets and single- and twin-aisle aircraft over the next 10 years, and 41,170 aircraft over 20 years.

The 20-year figure is down from last year, when Boeing forecast 43,610 new-aircraft deliveries over two decades.

Reflecting its revised projections, Boeing now expects airlines globally will operate 47,080 aircraft in 2041. Boeing's 2021 market outlook pegged the size of the fleet in 2040 at 49,405 aircraft.

Boeing's latest projections equate to 2.8% annual fleet expansion, between 2019 – the airframer's pre-pandemic baseline – and 2041. The 2019 fleet comprised 25,900 aircraft.

The 2022 report continues a several-year trend of

Boeing revising its estimates downward. By comparison, the airframer's 2019 outlook estimated 44,040 deliveries over 20 years, with the fleet increasing to 50,660 aircraft by 2038.

Boeing vice-president of commercial marketing Darren Hulst attributes the shift to economic factors, including financial market instability and expected slower economic growth.

Hulst says people are clamouring to travel, equating to strong demand. But

supply – meaning flights and seats – remains constrained due to factors including labour shortages.

Hulst also cites geopolitical tensions, including Russia's invasion of Ukraine, as prompting Boeing's downward delivery revisions. That war led Western countries to prohibit the sale of aircraft to Russian companies.

Russian sanctions alone prompted Boeing to remove 1,540 deliveries from its 20-year forecast, says Hulst.

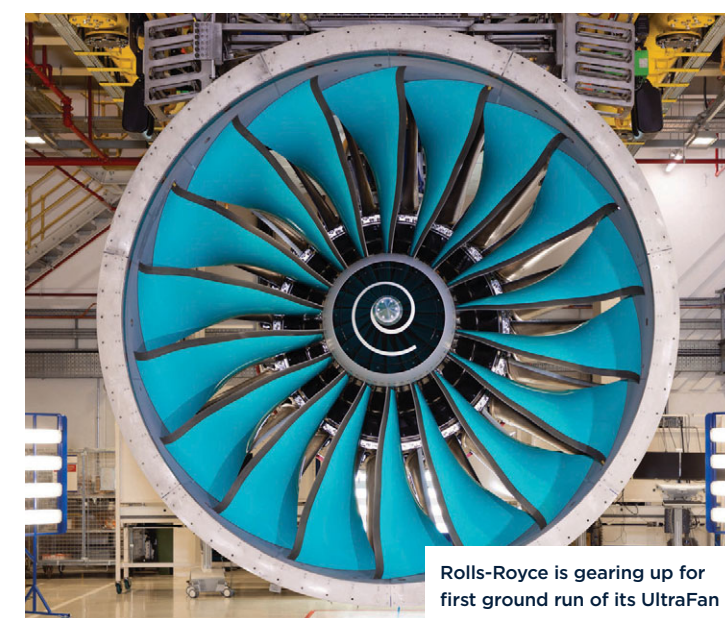
## Rolls-Royce puts liquid hydrogen on trial

Rolls-Royce has become the latest engine manufacturer to launch trials of liquid hydrogen combustion and plans tests using several of its current powerplants in a project that could culminate in flights of a hydrogen-fueled Pearl 15 business jet engine.

As an initial step, ground runs of an AE 2100 turboshaft fueled by liquid hydrogen – the same engine previously used to test its PGS1 turbogenerator system – will commence later this year in the UK.

This "early concept feasibility" phase will provide a "really good early indication of hydrogen combustion", says Alan Newby, director aerospace technology and future programmes at Rolls-Royce.

Previous research suggests that only "a relatively straightforward modification



Rolls-Royce is gearing up for first ground run of its UltraFan

of the fuel injector itself" will be required to allow the engine to run on hydrogen, rather than a complete redesign of the entire combustion

chamber, he adds.

The AE 2100 tests will be followed, at an undisclosed date, by ground runs of a Pearl 15 business jet engine

converted to run on the fuel using a "much more representative system".

"That will give us really good confidence to understand all of the challenges associated with a gas turbine running on liquid hydrogen."

Several locations are under consideration for this part of the programme, including Rolls-Royce's test site at NASA's Stennis Space facility in Mississippi, USA.

Newby says the project could ultimately transition to flight trials of the hydrogen-burning Pearl 15 aboard the company's Boeing 747 flying testbed.

However, the manufacturer has not yet committed to this element of the programme. "We need to understand if there are additional benefits from going and taking a flight test on the engine," says Newby.

Meanwhile, Rolls-Royce is gearing up for the first ground run of its UltraFan demonstrator with the engine build nearing completion at the manufacturer's Derby headquarters.

The engine core, low-pressure system – including the distinctive teal-coloured 140in (355cm)-diameter carbon-titanium fan – and fan case have all been integrated, says Andy Geer, Rolls-Royce chief engineer; the UltraFan team are now working to complete the "massively complex" installation of 2,800 pieces of test instrumentation.

First runs of the 80,000lb-thrust (355kN) powerplant will take place in the second half of 2022 in Rolls-Royce's new £90 million (\$107 million) Testbed 80, says Geer. Initial operations will see the UltraFan powered by 100% sustainable aviation fuel.

# CFM Leaps back to the front

GE- and Safran-owned narrowbody engine supplier is positive about post-Covid recovery

Murdo Morrison

A crisis before the crisis is how CFM International chief executive Gael Meheust describes the withdrawal from service of the Boeing 737 Max in March 2019. As sole engine supplier to the single-aisle programme with its Leap-1B, the GE Aviation/Safran joint venture was dealing with turbulence a full 12 months before the pandemic led to the grounding of almost all other flight activity.

Three years on, Meheust is at Farnborough in upbeat mood. The lifting of the Max ban almost everywhere except China from December 2020, coupled with a strongly recovering airline market, has seen 80% of all CFM-powered aircraft return to operation, he says. Additionally, Max and Airbus A320neo-family aircraft with Leap engines are coming back faster than narrowbodies as a whole.

Leap output hit 1,700 engines in 2019 – as CFM largely continued to supply Boeing at full rate throughout the initial phase of the grounding – but collapsed to just 815 in 2020, with only a minor upturn in 2021, something it attributed to the pressures of ramping back rather than sluggish demand. However, it has said that it expects to be producing 2,000 Leaps a year by 2023.

Continuing production after the Max grounding and through the peak of the pandemic caused undelivered engines to build-up at Boeing's factory. However, Meheust insists this is being rapidly addressed. "We are burning through the inventory of stored aircraft in Seattle pretty quickly," he says. "It's almost like that grounding never happened. We have put it well behind us."

Meheust is also happy about CFM's position on the A320neo range, where it competes with the Pratt & Whitney PW1100G. On 15

June, Airbus flew for the first time the prototype of the latest member of that family, the A321XLR, powered by Leap-1As. He describes it as "an important milestone" that "reinforces CFM leadership on the A320 family".

CFM now has a 60% market share on all A320s in service and ordered, claims Meheust, with commitments for the XLR tracking slightly above that percentage. He says the engine on the A321XLR – which is rated at up to 34,000lb (151kN) of thrust compared with 32,000lb for other Leap-1As – is "performing perfectly and as expected".

In potential contests with Pratt & Whitney this year, there have been a number of notable sales successes, including Air France-KLM this month formally signing off on an order for 200 Leap-1As for its incoming A320neo-family fleet, and UK leisure airline Jet2



Meheust: We are burning through the Max stored inventory

in March committing to the variant for its 75 new A321neos.

As for other engine suppliers, pressures on the global supply chain remain a concern, with shortages of raw materials, partly down to sanctions on Russia, skilled

staff shortages, and some small and medium enterprises financially vulnerable after the pandemic. In February, CFM co-owner Safran warned that suppliers might struggle to meet airframer demand in 2022.

Meheust admits the ramp-up will be far from smooth. "The global supply chain is challenged. This is something every industrial company is facing, and we are not immune," he says. "There are 23,000 parts on an engine. It only needs a few to be missing to prevent delivery, so we are working hard with our supply chain and providing all the help we can."

He says monitoring the supply chain is a priority. Until Covid-19, CFM was preparing for the fastest output increase in its history, aiming to build 2,000 engines in 2020. Meheust says a "network of surveillance" of suppliers put in place ahead of the crisis was "a good way

of preparing ourselves". He adds: "We will do everything we can to support airframer demand. We will get back on track."

Other notable moments for CFM in recent months include the first flight in May of a Comac C919 destined for a customer, powered by another version of the Leap, the -1C. While the Chinese narrowbody represents a more niche opportunity for CFM, Meheust describes says he is "happy to see the programme moving forward".

CFM's two owners are also progressing with the development of the RISE (revolutionary innovation for sustainable engines) open rotor demonstrator, launched in June last year with a view to delivering a 20% fuel efficiency gain over today's narrowbody powerplants. If successful, the technology could be mature enough for a product to be in service in the 2030s.



The Leap-1A powered the first flight of the A321XLR



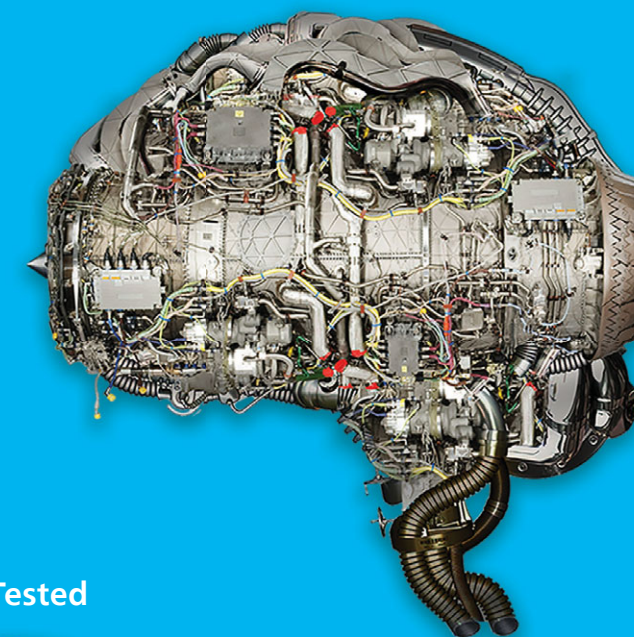
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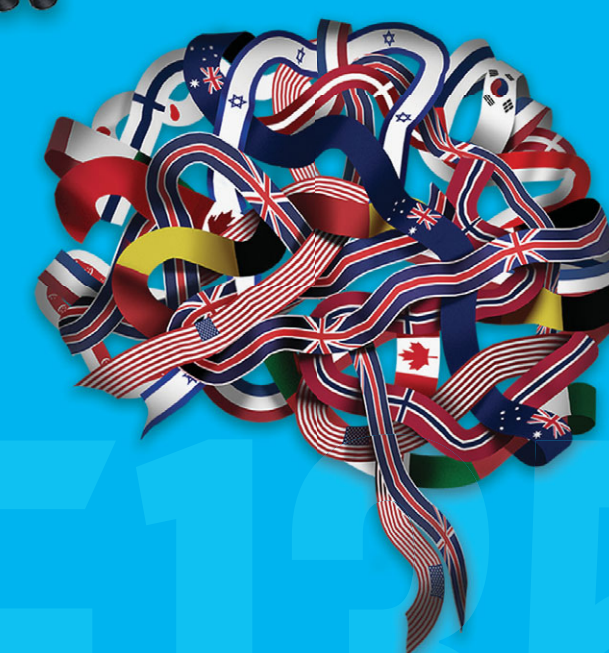
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# Rafael targets missile at light-attack aircraft market

Murdo Morrison

Rafael has unveiled an air-launched version of its recently introduced Sea Breaker precision-guided anti-ship missile, called Ice Breaker, and is displaying it to potential export customers at the show.

The weapon, which has a range of 162nm (300km), weighs 700kg (1,540lb) so is suitable for light-attack aircraft such as the Embraer Super Tucano or Leonardo M-345, as well as helicopters including the Airbus Helicopters H225 Super Puma or Sikorsky SH-60 Seahawk, says the Israeli company.

Although Rafael announced the Sea Breaker a year ago as having sea- or ground-launch capability, the intention was to market it as suitable for air, ground or naval applications, once government clearance was secured, says vice-



Missile can fly at 'high subsonic speed'

president for business development and marketing Ofer Weinberg.

Rafael says the weapon, which is compatible with the company's other missile systems such as Spice and Spyder, has already "attracted attention from prospective customers on three continents".

Although the company will not confirm if it is already in use with the

Israeli military, the country's defence companies rarely market products for export that have not been deployed domestically.

The company describes Ice Breaker as a "fifth-generation, autonomous, precision-guided missile system, enabling significant attack performance against a variety of high-value land and sea targets".

The missile, which is

fitted with an imaging infrared seeker and can fly at "high subsonic speed", is resilient to electronic countermeasures and can operate in GNSS-denied environments, says Rafael.

Datalinks enable operators to abort in mid-flight and receive battle damage assessments. The weapon carries a 113kg penetration, blast and fragmentation warhead.

## FLIGHT DAILYNEWS

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Collins Aerospace

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A blended-wing body is one of the options Airbus is looking at as it mulls its longer-term moves towards a more sustainable future, as chief executive Guillaume Faury explains



Airbus is a few weeks into flight-testing its A321XLR

# Evolution and revolution

David Kaminski-Morrow

Airbus chief Guillaume Faury insists the airframer is studying radical designs for a future hydrogen-powered aircraft, and that even its blended-wing body concept is not simply a headline-stealer but one of the proposals being analysed.

In an interview with FlightGlobal ahead of the show, Faury shrugs off suggestions that Airbus might prefer a conservative approach to a hydrogen design, pointing out that adopting hydrogen power is, in itself, a bold step and that Airbus – having spearheaded fly-by-wire development – has been prepared to take calculated technological risks.

"This will require much more than a small modification of a current-generation aircraft," he says. "The hydrogen [aircraft] will be a completely different platform – that's what we're looking at, working on all parts of what will make a competitive hydrogen aeroplane, for entry into service in 2035."

"Airbus is making major steps forward. Yes, we want to enter into service products that work, that support customers, that deliver the mission."

He points out that hydrogen will demand a "very different" aircraft architecture, to cope with storage and distribution of hydrogen on board. The blended-wing body

is one of the configurations that Airbus is "seriously looking at", he says.

Faury is less concerned about pursuing further evolutionary steps – such as a new wing – for its A321neo, given that Airbus is just a couple of weeks into flight-testing of the latest variant, the long-range A321XLR.

"We're not there yet," he says. "The XLR brings new capacity, the ability to open new routes – thin, long routes to test the versatility [customers] need, and agility because it can be put in a fleet of A321s that you operate in a more seasonal way."

"It's a new tool and customers are starting to play with it. They see a lot of potential, so we're not at the point where we're already starting to think of the next move."

Faury insists the A321neo family is "spot-on where we need it", and Airbus's priority is certification for entry-into-service early in 2024.

"We're not making the A321 obsolete. It's the centre of the market, it's very competitive and that's what the airlines like."

"So we're not in the mood for a 'new wing'. We're in the mood for getting the certification, ramping up the product."

The initial A321XLR flight-test airframe is compliant "to a very large extent" with European Union Aviation Safety Agency requirements, but modifications to

meet recent additional regulatory criteria – which forced a shift in the service-entry date – will be introduced on the other XLR prototypes.

"[The first] prototype will be contributing to the certification campaign but there will be more than one [aircraft] to make sure we [include] all the requirements and modifications," says Faury, adding that Airbus typically ensures that the last prototype to the line is the fully-compliant model.

A321neo models, including the XLR, make up some 60% of the A320neo-family backlog and Airbus is striving to squeeze more production capacity, particularly for its largest variant, out of its industrial system.

Faury is confident the airframer will achieve the ramp-up to its highest-

Faury: Hydrogen will demand a very different aircraft architecture



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Qantas has chosen the A350-1000 for its Project Sunrise initiative

ever single-aisle rate – reaching 75 aircraft monthly in 2025 – even as he acknowledges that supply of engines is lagging current output, an echo of the ‘glider’ situation of 2017-18 when problems sourcing sufficient A320neo-family engines forced Airbus to park dozens of otherwise-complete aircraft.

But he says the issue involves “much smaller numbers” of aircraft than the previous crisis.

“It’s going to peak probably mid-year and then we think we’ll get more engines in the second half,” he says. “That’s what engine-makers are telling us. And it looks like they’re probably going to make it, so we’ll put engines on [aircraft] and deliver [them] at a later stage.”

Returning to a monthly rate of 65 aircraft “isn’t a walk in the park”, says Faury, but he is not fretting over the prospect of hiking to 75 in 2025.

“I spoke to the Airbus people that made the ramp-up from rate 30 to 40, and 40 to 50, and 50 to 60,” he says. “They told me: Don’t be surprised to be challenged all the time on [adding] 10 points of rate. It’s been the history of Airbus, and each time we’ve made it.”

“So I have difficulties understanding, honestly, why we make such a big thing of ‘Will we manage to get to rate-75?’ – of course we’ll manage.”

Faury concedes that the rate increase is “not going to be easy”, but points out that the supply chain has been assessed for preparation and that the airframer has been “listening to their answers, to their requests”.

“We’ve come to the point where [suppliers] have told us, ‘If you have an answer whether you want to go rate-75 or not, [let us know] as soon as you can,’” he says.

“We’ve accelerated sharing, with the supply chain, the fact that we’ve decided to go to rate-75. And now we have time, they have time, to prepare for it.”

While he has “no doubt” that the manufacturer will achieve this output level, Faury says the current recovery course – affected by the tail-end of the pandemic, with continuing difficulties in China, plus the impact of the Ukrainian conflict and the price of energy – is turbulent.

“What we see now is quite classical of going out of a negative

cycle,” he says. “You start to ramp up again, you face that kind of situation. [The pandemic] was a very, very severe crisis. So we see more amplification of this counter-effect.”

“But by mid-2023, I think it’s not stupid to believe we’ll be closer to the end than the beginning of this difficult situation, and then we’ll ramp up from 65 to 75 [aircraft monthly] at a much more prudent pace and slower pace.”

Airbus’s twin-aisle business languished during the pandemic crisis, as international long-haul activity stalled. But just ahead of the Farnborough air show, Airbus recorded its strongest month for twin-aisle business for two-and-a-half years with orders for 22 jets.

Faury argues that the market is still recovering, with only a “very small number of campaigns” open, and believes Boeing’s superior widebody activity over the last 18 months is largely due to the US airframer’s freighter presence – a situation which Airbus is aiming to address with its A350 freighter.

Over 30 freighters have been ordered, from half-a-dozen customers, since the cargo aircraft

secured its first agreements at the Dubai air show last year.

Airbus’s passenger A350 has drawn unwelcome attention through the highly-public legal spat with Qatar Airways’ surface degradation – a dispute yet to be resolved.

Faury attended the recent IATA annual general meeting in Doha, and sat at the same table as Qatar Airways chief Akbar Al Baker, but says: “A settlement is an agreement. It’s like with a commercial agreement – as long as you don’t have an agreement, you have no agreement – that’s where we are.”

But while Airbus has been gradually striking off undelivered A350-1000s from Qatar’s backlog, the -1000 has been given a strong endorsement from Qantas Airways which, in June, firmed its order for a dozen of the twinjets for its ambitious Project Sunrise initiative.

Project Sunrise will realise a long-held vision of connecting London and Sydney with non-stop flights, building on the London-Perth service launched with Boeing 787s in 2018, and showcase the A350-1000’s long-range capabilities as it reduces the ‘kangaroo’ routes to a single hop. ▶



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Airbus and Dassault – partners in the FCAS effort – have been bickering over responsibilities. Guillaume Faury says wider security concerns mean it is essential a compromise is found

Dominic Perry

At the last Paris air show in 2019 there seemed to be a clear sense of direction for the Future Combat Air System (FCAS) being developed by France and Germany, led by their respective military aircraft champions Dassault Aviation and Airbus Defence & Space.

But that relationship has been complicated by the admission in 2019 of Spain to the project, upsetting the delicate balance between the two sometime-rivals. That is particularly true on the New Generation Fighter (NGF), the manned component of the wider programme, on which Dassault is the lead.

Although Indra is Spain's lead on FCAS, Airbus represents Madrid for the NGF development, and its inclusion has forced Dassault to grudgingly cede workshare. But continued wrangling over flight-control system intellectual property rights is holding up the signature of the so-called phase 1B contract which covers the development of a NGF demonstrator aircraft.

The impasse has been characterized by public bickering between the erstwhile partners, with Dassault's outspoken chief executive Eric Trappier offering frequent and pointed criticism of Airbus.

But his Airbus counterpart Guillaume Faury remains confident that a way forward can be found: "I remain completely convinced that there will be an FCAS and there will be an agreement. Why? Because the war in Ukraine calls for more unity, for more cooperation, for more European projects – so the vision we had in 2017 when we started is even reinforced by what's happening. How are we going to get there? By negotiating."

He points out that the FCAS has "come a very long way already",



pointing to the progress made since the project's inception in 2017; accord has been found on six of the programme's seven development pillars – engines, sensors, remote carriers and so on – with the NGF the only outstanding area.

He attributes the tension between Airbus and Dassault – and even between the nations – to the model of co-operation being different from that on previous programmes.

"So we need to bridge that gap on how we are going to make it work. We are very close, but this still needs to be agreed." Political pressure should aid clearing the

logjam, but elections in France and Germany have prevented that from taking place.

It hardly feels like the sign of a healthy programme when so much rancor is being expressed so early on. But Faury thinks there is room for disagreement. "Is it OK to have these difficulties at this moment? I think it's healthy to look into the eyes of the problem and the fact that we come from different cultures when it comes to operating," he says.

Some of the complaints can also be viewed as jostling for position: "It doesn't mean there will be no

agreement moving forward."

Faury says he appreciates Dassault's position "to an extent"; both partners are "trying to defend" the interests of their firms "and we are trying to come together to something that works at the end".

Trappier also recently claimed that delays to signing the Phase 1B agreement will mean that service entry of the NGF is pushed back from 2040 to 2050. However, Faury disagrees: "It's not because we have lost six months that the entry into service is postponed by 10 years." Is Trappier sabre-rattling then? "Ask him", comes the response.

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Faury says progress is being made with the A400M

Airbus, meanwhile, continues its efforts to wrestle the multi-national A400M strategic transport back on track. Faury says the programme is now “on the right trajectory” and “we are ticking the boxes one by one”.

“We have more and more customers who are expressing satisfaction.” He points to the type’s use in the evacuation of Afghanistan which was “super successful” as further evidence of improvement, allied to growing interest from new customers. “We have momentum on exports so the A400M is moving forward at a good pace.”

The problems are “getting fewer” and overall the company is doing a lot to move the programme forward together with its customers, he says, adding: “Which complex [defence] system today at entry into service is perfect?”

Airbus is “putting all its weight” to drive capability improvements forward, and although he accepts there is still work to do to “be better” on availability issues, overall Faury feels the Atlas is moving in the right direction.

“That’s the normal life of a programme at entry into service. The A400M is a very challenging and ambitious programme and that is why we are in that situation. But we are making progress.”

Similar criticisms – teething troubles and low availability rates driven by programme complexity – have been leveled at the NH90 military helicopter that Airbus produces as part of the NH Industries consortium alongside Leonardo Helicopters and GKN/Fokker.

But Faury pushes back against characterisation of the NH90 as a failing programme. “It has been very

successful,” he claims. All complex military programmes experience teething issues, says Faury, adding: “The NH90 is an incredible programme – it has been very successful. How many helicopters have we sold or are in operation?”

He acknowledges that some customers are “not happy” and that “we need to fix the problems”. Although Australia and Norway have been the most outspoken in recent times, the background grumble of complaints runs deeper than just those two operators.

But Faury points to others – New Zealand, for instance – who are “super happy with their NH90s and have a high level of availability”. That positive news story does not receive enough coverage, he claims.

“We need to learn, it’s not perfect, there are difficulties and there have been challenges – when you put many nations together in a programme it’s more complex,” he says. Although all European defence programmes face that challenge through necessity, “I think it’s a model that has proven to work.”

But making sure the challenges of the past are not repeated in the future will be crucial as Airbus and Leonardo contemplate collaboration on a new military helicopter under the NATO Next-Generation Rotorcraft Capability (NGRC) project.

Six nations – France, Germany, Greece, Italy, the Netherlands and the UK – recently committed to launch the concept phase of NGRC, a process that runs until 2025. Between them, Airbus and Leonardo represent, or have a manufacturing presence in, four of the six countries, and are therefore core industrial partners for the effort.

If the NGRC project proceeds to

industrialisation, a new medium-class – 10-17t maximum take-off weight – high-speed helicopter could arrive in the mid-2030s. Faury sees it as “hugely important” for Europe but stresses that it is only a research programme at this stage. “We don’t know where it’s going to go or which countries will be really be interested to be part of [NGRC] when it really becomes a programme

“We will do it as Europeans and I think that’s very good.”

Ultimately, the shape of any future company to build the capability will be led by the end customer, he says. “The customer will trigger the way this has to move forward – who’s going to be involved in the programme, the role that different players will play and how we organize with other ones.”

He sees no danger that European countries will back out of the project in favour of an aircraft from the USA’s Future Vertical Lift programme. “And genuinely speaking, the solution found by the Europeans are different to those put forward by the Americans which are sometimes very, very high-end, specialised and complex; we are more middle of the market, a broader application. That’s what we have seen, at least with vertical lift, in the last decades. And that has been very beneficial, by the way, to the Europeans.”

In the meantime, Airbus Helicopters continues to research and mature new technologies for current and future military and civil rotorcraft applications. “We are improving the product and preparing the technologies for the next generation.” Topics of focus include decarbonisation, safety, reliability and mission capacity, says

Faury, potentially including the use of hydrogen fuel cells as a power source.

Initially that may make an appearance in the urban air mobility (UAM) space, which will be electric-powered from the beginning. “I think by working on electric propulsion on UAM we are preparing the potential use of fuel cells on helicopters, on VTOLs and potentially as well on fixed-wing aircraft.

“We are not going into urban air mobility research only for urban air mobility; it’s a very good playground, a sandbox, to be fast, small, failing quickly and trying something else. It’s a fast and cheap way of experimenting with technologies.”

Hydrogen research is also in future to be conducted at Airbus’s sites in the UK following an announcement earlier this year. Its embrace of the country appears in stark contrast to its position prior to Brexit where the threat was to halt investment if its business model was threatened by the wording of any trade agreement. What changed?

“For us as a European company, really believing in Europe, was the position of the company at that time. We were very worried about the potential for a hard Brexit and the consequences it could have had on our industry. So we worked very hard and we were very vocal on the risks.”

The transition has “been managed reasonably well”, he says, and “has not disrupted us” thanks to both the nature of the deal and the company’s preparedness. “And now it is what it is; it’s behind us. Brexit has happened. We need to move forward. We just work very closely with the British government and they are very supportive.”

It has not been a fast journey so far, but the supersonic jet start-up is exhibiting at Farnborough and edging closer to production of an airliner it remains sure will change the way the world flies

Overture will be a 'jetlag killer' for long-haul travel, says the company

# Boom still feels need for speed

Boom Supersonic

Murdo Morrison

Supersonic aircraft developer Boom is back at Farnborough preparing to break ground for its factory in North Carolina, and still talking up the potential to change long-haul travel of the first faster-than-sound airliner since Concorde.

At the last Farnborough, in 2018, the privately-funded enterprise said it would fly a supersonic demonstrator by the end of the following year. Since then, progress has slowed, although Boom says the XB-1, which rolled out last October, has completed 80% of ground trials and will take to the air this year at the Mojave, California flight test facility.

However, do not expect a public countdown to the momentous event. "We will announce it when it has just happened," founder and chief executive Blake Scholl – who founded Boom in Denver eight years ago – tells FlightGlobal ahead of the show.

As for the 65-seat, Mach 2.2, 4,250nm- (7,870km-) range Overture itself, production in

Greensboro is due to begin in 2024 with Scholl targeting a first flight in 2026, followed by up to four years of flight testing. He acknowledges that the first commercial airliner to fly above Mach 1 for more than 20 years will have to go through the most painstaking certification process.

Many suppliers still have to be confirmed, including, crucially, for the engines. Two years ago,

it announced "an engagement agreement" to "explore the pairing of a Rolls-Royce propulsion system", and particularly whether one of the UK manufacturer's existing engines could be adapted for supersonic flight.

However, Scholl says that while "we are happy with how these talks are going", no decision on a powerplant has been made.

Collins Aerospace is also helping

Boom develop inlet, nacelle, and exhaust system technologies that will help reduce fuel burn and develop "cutting-edge" acoustics, says Scholl, who states that 2022 will be a "big supply chain year – we are approaching a lot of supplier joint development".

The programme also lacks formal orders, although a "purchase agreement" with United Airlines for 15 Overtures, with another 35 options, announced last July, comes close. Scholl describes the deal as "a meaningful cash commitment with serious deposits".

United chief executive Scott Kirby said at the time that "Boom's vision for the future of commercial aviation, combined with the industry's most robust route network in the world, will give business and leisure travellers access to a stellar flight experience".

That followed a December 2017 agreement with Japan Airlines that coupled a \$10 million investment in Boom and a promise to collaborate on the design with an option to order 20 Overtures.

Other notable investors have shown their faith in the programme, including the US Air Force's



Boom says its XB-1 demonstrator will fly this year

Boom Supersonic

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Innovation arm AFWERX, which in January awarded Boom a research contract “worth up to \$60 million”. Last year, American Express division Amex Ventures invested an undisclosed amount in the project.

The thrilling promise of a new supersonic era was dented somewhat last year by the collapse of fellow US start-up Aerion – which had been developing a faster-than-sound business jet for more than 15 years and secured support from several industry big names, including Boeing, Collins and GE Aviation. It had also recently announced a major commitment from fractional operator NetJets.

“We were sad when it didn’t work out for Aerion, as we all want to see more companies developing great ideas,” says Scholl, who insists that his competitor was aiming at a “very different market” and that a supersonic business jet was “a big step in the wrong direction”.

This is because 80% of private flights are over land, where speeds above Mach 1 are banned or difficult, he maintains. Most Overture services, by contrast, will fly the bulk of their time above oceans.

“There are hundreds of city pairs on the planet that have routing that is sufficiently over water,” he says.

The Overture’s main benefit is that it will be a “jetlag killer” on long-haul flights, says Scholl, who cites the example of an executive travelling from San Francisco to Tokyo, who would “save a whole day” on a round



Aerion collapsed last year despite securing big-name backing

trip. Likewise, even on a relatively short flight, such as Hong Kong to Tokyo, a passenger could fulfil a business commitment in a day.

He likens Overture’s ability to transform travel patterns to the transition from propeller aircraft to jets in the 1960s, when the likes of Hawaii became a tourist destination for millions of North Americans. “If the flight is 10-20% faster, it doesn’t really change things. If we double the speed of flight, we can take days off,” he says.

Another difference with Aerion is that Scholl plans to make Mach 2.2 travel “accessible to anyone who flies”. We may not be talking a supersonic Ryanair, but Scholl reckons fares on an Overture could be similar to the price of business class seats today.

He hopes to achieve it sustainably too. This might be a tougher argument to make for a machine that will need sufficient jet fuel to propel it at more than twice the speed of sound, but Scholl is

convinced advanced materials and aerodynamics, combined with the use of 100% sustainable aviation fuel, will help Boom reach its net-zero carbon targets.

Boom’s achievements so far have been impressive. Like Aerion, it has managed to raise funds and support from blue-chip aerospace suppliers, attract high-profile engineering executives and advisers, and secure commitments from big name potential customers. However, it has gone further.

“We are the only non-government entity to have rolled out and tested a supersonic jet,” says Scholl, referring to the millions of dollars of French and British taxpayers’ money poured into the development of the Aerospatiale/British Aerospace Concorde six decades ago.

However, could the opposite argument be made? If there is such a compelling market for a supersonic transport, why have Airbus and Boeing, with their considerably deeper resources, both financial and engineering, not gone down that path?

Scholl is in no doubt. “Airbus and Boeing have higher priorities, and developing a supersonic jet would undermine their cash cow widebody market,” he says. “Boom has all the advantages of existing for a singular purpose.”



Concorde last flew in 2003

## EASA readies supersonic flights framework

David Kaminski-Morrow

European regulators are preparing an initial environmental-protection certification framework aimed at addressing the emergence of new supersonic transport aircraft designs towards the end of this decade.

The measures are being laid out in an advanced notice of proposals by the European Union Aviation Safety Agency (EASA).

EASA states that a new generation of supersonic commercial and business aircraft is expected to be operational from the late 2020s.

Noise and carbon emission requirements for such aircraft are topics that “need to be addressed”, it says, to ensure a “high, uniform level” of environmental protection.

EASA points out that no ICAO standards exist for landing and take-off noise, or emissions, that

would apply to supersonic aircraft – and that it intends to develop detailed requirements, which would apply until ICAO draws up its own.

“Pending ongoing work towards establishing an appropriate [carbon dioxide] limit for [supersonic aircraft], provisions for the standardised measurement and reporting of [carbon] emissions are proposed as an interim step,” it adds.

Its preliminary draft noise requirements would apply to all supersonic aircraft regardless of maximum take-off weight, number of engines, maximum operating Mach or required runway length. ICAO defines maximum limits for subsonic aircraft and EASA is proposing to “apply the same noise limits” to supersonic types.

The effective perceived noise level for subsonic jet aircraft as well as the same noise measurement reference points can be “reused”, it says, as the noise evaluation measure.

“Considering the specifics of [supersonic aircraft] designs, meeting those limits appears to be challenging but technologically feasible, as indicated by results from research studies,” EASA adds.

The regulator says that, without limits in place, the “significantly” increased noise exposure around airports would potentially outweigh the advantages of quieter subsonic models.

Its proposal also outlines the complexities of translating subsonic emissions measurements for certification, based on three reference points, to the supersonic regime, given the specific performance and fuel characteristics of such high-speed designs.

EASA says the proposals “represent a first step” towards environmental protection requirements for supersonic models and will be “further developed” in subsequent steps. It is seeking comments on the measures by 25 July.

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Boeing's fortunes have plunged since the last Farnborough air show in 2018, but the boss of its Commercial Airplanes division says its focus this week is firmly on the future

## Deal maker



Boeing has faced the challenge of bringing its grounded 737 Max aircraft back to service

**Graham Dunn**

When Boeing last arrived in the familiar settings for the Farnborough air show in 2018, few could imagine what the following years would have in store for the manufacturer, its customers and the industry overall.

Back then, Boeing's commercial division was riding high, closing 2018 with a record of more than 800 deliveries, a bursting backlog boosted by almost 900 new orders and an operating profit just shy of \$8 billion. Times have changed.

Since then, Boeing has been

through unprecedented change, as two fatal crashes of its flagship re-engined narrowbody led to the 20-month grounding of the Max, a painful airing of process failings, a renewal of leadership and ongoing overhaul of certification oversight. Such factors continue to complicate its delivery of new products.

That was even before the little matter of a global pandemic, resulting in the most damaging impact on air travel demand ever seen.

Small wonder Boeing Commercial Airplanes chief executive Stan Deal is keen to be back at an event where it can put the focus on products again.

"There is going to be a huge degree of humility going into the show," he says when asked about Boeing's approach, during a 21 June interview. "We are going to let the products do the talking."

There remains, however, no shortage of live issues for Boeing to deal with as it enters the show.

Boeing's last appearance at one of the big summer air shows came at Paris in 2019 in the aftermath of the Max grounding. Even an eye-catching, confidence boosting preliminary deal for the Max from British Airways and Iberia parent IAG – a commitment firming in recent weeks – could do little to take away from the over-riding issue of

what it would take to get the aircraft back in the air.

"Broadly I'm feeling quite good after what we have gone through on the Max and the tragic two accidents and having to make fundamental changes on the aeroplane that we own," says Deal about progress with the Max.

"We got that done. We got through the certification process with the four global regulators. We've got a China approval and we are now working to restore the airplanes in China. Obviously with Covid, that's been intermittent – and you can understand why."

Alongside certification issues, the manufacturer also faced the

■ twin challenges of bringing the 383 aircraft that were flying prior to the March 2019 grounding back into service, as well delivering its own inventory of Max – aircraft assembled but not delivered during the grounding.

“Largely, we have ungrounded all the airplanes around the globe, except the aircraft in China,” says Deal. “We are in the midst of liquidating the inventory we accrued while the Max was grounded. We continue to add resources... to get more of those airplanes liquidated faster.

“That is going well. That is not an easy job,” Deal adds. He notes that assembling new jets takes “almost as much time” as updating previously assembled jets to the Max’s approved post-grounding configuration, which includes a modified flight-control system. “You have to update the standard of the aeroplane to the current production build, plus [make] the changes we committed to on the airplane,” he says.

Boeing, in its most-recent financial results, reported still holding 320 undelivered 737 Max at the end of March.

For customers now flying the type, Deal says the reaction has been positive. “It’s flown almost 1.5 million flight hours. Reliability is at almost 99.5%. Consumer response has been very good. For airlines, fuel burn is better than what they anticipated. It is doing what it’s supposed to be doing,” he says.

But questions remain, including around when crucial certification of its newest 737 member, the Max 10, will come.

Around the time Boeing was preparing to bring the Max back into service, a new delivery headache emerged around the 787 programme. The company halted deliveries of the type in October 2020 because of manufacturing quality issues that included gaps between fuselage sections being larger than specified. Other issues have also surfaced.

Deliveries remain paused and will resume only after the US Federal Aviation Administration (FAA) approves rework being done by



Deal: Throughout its more than three-year crisis Boeing has continued to invest

Boeing. In April, the airframer said it had completed such activity on some undelivered 787s and submitted a “certification plan” to the FAA.

“You’ve heard [Boeing president] David [Calhoun] say it over and over: We are not going to put a timeline on it, because we are not going to pressure on the regulator,” says Deal.

“We have submitted everything to the FAA, the FAA will review that, they will probably ask questions – it’s a give-and-take passing of information – and then we are continuing to rework the airplanes,

anticipating regulatory approval. We are engaging with customers. I am not going to put a date out there yet.”

Boeing has, though, put a new date out there for what was until recently another delivery uncertainty; when its new 777-9 will enter service. Those timings have been complicated by increased scrutiny of the certification process – also a fallout from the Max crisis.

That ultimately led Boeing in April to delay its expected first 777-9 delivery by two years, until 2025, attributing this to “an updated assessment of the time required to meet certification requirements”.

Deal says: “I think that time was absolutely necessary to give our team and the regulators, what is now the normal course of a regulatory process, which is a lot detail around the design assurance of the product. I understand that as a manufacturer, it’s an important criteria. That took time. We are over 2,400 flight hours on the airplane, we’ve done our fuel-burn performance – it’s right on.”

At the same time Boeing has been dealing with the impact of heightened certification processes, airline delivery requirements have been equally fluid, as carriers first sought to delay and defer incoming aircraft as demand evaporated in the pandemic. Then, some customers sought accelerated deliveries as recovery took hold. It has left a number of customers increasingly vocal about the lack of certainty about when they can expect new aircraft.

“We try to keep everyone in sequence to be fair. Some people want to move [deliveries] out – that’s okay. Some want to move [them] in, and we look at those opportunities,” Deal says.

“We have been through those iterations on an ongoing basis. You have to, because they are trying to do fleet plans, we are trying to do production plans, we are trying to decide which airplanes to do the rework first on,” he says. “We are pretty stable on that. The ultimate moment though is when the first aircraft delivers, because that is the moment of certainty, and at that point we will have clarity with every customer on a projection of deliveries.”

Boeing also faces the major complication all manufacturers are challenged with coming out of the pandemic: the extent to which global supply chains can keep pace with demand.

“Our supply chain is going to be a key factor to rate ramp-up, and I think that is an industry view, not just a Boeing view,” Deal says. Boeing has been working on reaching a production rate of 31 737 Max aircraft a month, a point it reached in June.



Delivery of the 777-9 has been delayed until 2025

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“When we set rates, we do an assessment of the supply chain, and see as deep as we can. The one thing that was less predictable in this early phase of the ramp-up was... how fast human capital would come back in, and at what rate the people who were made redundant got back, and it's been slower than anticipated.

“We are in the midst of ramping

up manufacturing, and, ultimately you need every part to build and deliver an airplane. We are running on a notion of driving operational stability. We are not going to move our product through the production line with empty parts. We've played that play; it doesn't end up with high-quality products at the end.

“We will only take the next step in the rate ramp-up as we see the

suppliers' capability,” Deal says.

One of the few upsides from the pandemic for the manufacturer and airlines alike has been the boost to air freight. Both Airbus and Boeing have responded by launching a new dedicated widebody freighter. Boeing unveiling its 777-8 Freighter with a commitment from Qatar Airways at the end January.

“We believe, looking forward,

that cargo demand is a much-more stable growth story,” Deal says, adding that Boeing was quick to adapt to greater freighter demand during the pandemic.

“We dedicated a lot of our 777 demand and rate to the freight market. In fact, we are producing basically all freighters on the 777 classic line – the 200F – and we have been able to take advantage of that opportunity. The 767 sold extremely well [and] the 737 conversion programme has unprecedented orders.

“We have been well positioned in freight and it was just natural to launch now,” he says.

Alongside new products such as the 777-8F, Boeing will be highlighting wider themes of innovation at Farnborough.

“We are going to talk about sustainability and the roadmap there. And under the sustainability umbrella, we are going to highlight some of the investment we have made in non-traditional [technology],” Deal says, highlighting Boeing's electric air taxi initiative Wisk. “That is more than just eVTOL – that's Boeing investment to explore the benefit of electric propulsion in that market and beyond... That product is an autonomous product out of the gate.”

Deal adds: “We are in the airplane business. We are about investing in the future. And during all of the downturn, and all of the things we had to do with the Boeing company, we continued to invest.”

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# Ready for tomorrow



Team Tempest partners include BAE Systems, Leonardo UK, MBDA UK and Rolls-Royce

Craig Hoyle

The launch of Team Tempest and the UK's Combat Air Strategy delivered big defence headlines at the last Farnborough air show – but what impact have factors such as the Covid-19 pandemic had in the four years since then?

Now in its £250 million (\$313 million) concept and assessment phase, the nation's future combat air system (FCAS) effort involves Team Tempest partners BAE Systems, Leonardo UK, MBDA UK and Rolls-Royce, working with the Ministry of Defence (MoD) and Royal Air Force (RAF), and also in partnership with industry champions and defence bodies in Italy and Sweden.

The next major milestone will come in 2024, when the programme partners submit their so-called outline business case 2 (OBC2) proposal, seeking full programme launch the following year and service introduction from 2035.

Their objective is to deliver an operational capability in half the time and at half the cost of previous combat aircraft projects.

"What we are doing through the activities around the Tempest and FCAS programme is very much driven by the future threat landscape, which is that 2040-plus view," says BAE business development director John Stocker. "The solutions and the concepts that we are developing are very much there to meet that long-term threat," he told journalists during a pre-show briefing at the company's Warton site in Lancashire.

"We have continued to iterate concept work around the core platform, and in due course will share information about some of the work that has been going on," Stocker says, standing beside a full-scale mock-up of an early concept for Tempest, which, he stresses, "is not the end solution".

Other programme elements will include unmanned adjunct vehicles; kinetic and non-kinetic "effectors"; command and control/information systems; and digital through-life services.

"In terms of how we develop the evidence over the next couple of years as we go towards the OBC2 gate, we are very much focused on proving the value of the programme

– not just by military capability and cost, but a broader national value assessment," Stocker says. The latter will consider factors such as net economic impact of the major investment, and its ability to support the UK government's so-called levelling up agenda, which seeks to address regional economic inequality.

BAE Systems Air chief operating officer Ian Muldowney notes the major such contribution made today via the company's role in the production, final assembly and export of the Eurofighter Typhoon. BAE says the combat air sector typically accounts for 85% of international defence sales by value from the UK each year, and supports 46,000 high-value jobs – many in the northwest and southwest of England, plus in Scotland.

"The UK is one of the last vestiges of platform whole-system capability around combat air: sensors, propulsion, airframe, flight systems and the ability to integrate all that together. That's not just about BAE Systems – that's a UK endeavour," he says.

Muldowney points to the importance of the Combat Air Strategy in driving investment into

FCAS and Tempest, noting: "2018 saw a statement of intent by the UK government that I had never seen before on any of our future programmes. It was clear about its objectives around the UK wanting sovereign capability around combat air – not just inside the armed forces, but across industry."

BAE did not furlough any of its Warton workforce during the pandemic, and even recruited around 100 staff who were facing redundancy from a Safran site in east Lancashire.

#### Remote working

While the company increased its flexibility for workers during the crisis, including issuing "tens of thousands of laptops" to enable remote working, Muldowney notes: "You can't design and build aircraft from the kitchen table. You've got to be inside the factory to do that." Now, during the recovery, it wants to "shift from a culture of potential presenteeism to one that is about delivering outcomes", he says.

Referring to a goal of moving from full programme launch to initial operational capability (IOC) within 10 years, Muldowney notes: "We

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But FCAS is by no means a UK-only activity – it also involves Italian and Swedish companies – and BAE is separately involved with future fighter projects with industry in Japan and Turkey.

"We are very much targeting an international programme here," Stocker notes. "Everybody is very clear that that is a really important part of how we stand up the next phases of this programme. We're making some fantastic progress on that front, in terms of how the different sets of requirements and military and industrial capabilities come together and form a core element of that future partnership."

Stocker says export control, security and intellectual property considerations are central themes under the programme's multi-national construct. "It is a challenge, and a very different way of doing things. What we are doing is developing a construct that will allow future partners to join in a way that they are not penalised for not having been there at the start."

### Real opportunity

Referring to the strengthened military and industrial relationship between the UK and Japan, Muldowney says their collaboration on advanced fighter technologies represents "a real opportunity".

"There is a real close match on how we are working together to refine that – there is a lot of work going on," he says. Tokyo also is working with Leonardo UK, MBDA UK and R-R, respectively on radar/electronic warfare equipment, weapons, and propulsion.

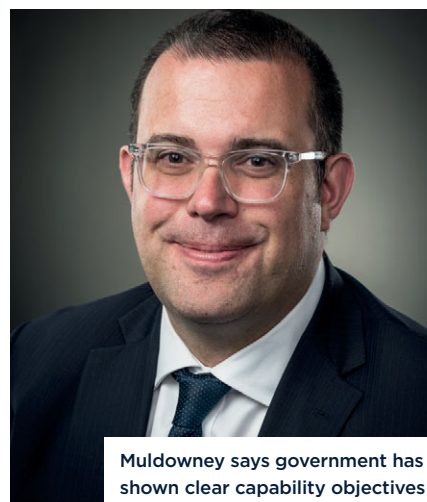
"We have got to work hard collectively as a UK enterprise to make sure that from government through the MoD into industry that we are working at this in the right way, to make sure we are the right partners for Japan, and that they are the right partners for us," he says.

"MHI [Mitsubishi Heavy Industries] are working closely with us in terms of how we evolve things. It is moving in the right direction. They have got great technology, great engineers, have a drive and a similarity in terms of where we see the FCAS system going."

Meanwhile, around 100 BAE personnel are in Turkey supporting Ankara's TF-X future fighter development activity, with around a year left to run on the UK company's current contract. "It is a good



Typhoon is set to be upgraded with Leonardo UK's ECRS Mk2 AESA radar



Muldowney says government has shown clear capability objectives

programme – a very ambitious sovereign capability," Muldowney says. "There are opportunities for us to continue into the next stages of that contract, both with work in Turkey and potentially in the UK. We would like to remain partners on that programme if we can."

Typhoon production has declined over recent years, with BAE currently performing final assembly of jets for Qatar and manufacturing parts for aircraft on order for Germany and Kuwait.

"We would like to have a steady flow of Typhoon final assembly, but we have had a gap before," Muldowney notes of the period

between now and FCAS work ramping up.

A new programme is key to reinvigorating the UK combat air sector, Muldowney says. "Yes, we are on [the Lockheed Martin] F-35 [manufacturing aft fuselages], which is great revenue and great volumes for UK industry, but it doesn't sustain that [whole-system] capability and doesn't allow us to maintain the scale of jobs and skills that pull through the economy that you see on the back of something like Typhoon."

However, the in-service type remains a focus of considerable activity at Warton, regarding both sustainment and capability enhancements.

One of the UK's most important current areas of focus is on preparing the fighter to receive Leonardo UK's ECRS Mk2 active electronically scanned array (AESA) radar.

A first flight-test example of the new sensor will be delivered before year-end, and Tranche 3 aircraft BS116 (ZK355) is already in the flight-test hangar at Warton in preparation to receive it.

Following integration work and ground-based testing, the AESA system is due to undergo flight-testing from late 2023, the MoD says.

Ross Wilson, Leonardo UK's radar chief engineer, says the sensor is now in testing on its roof-top laboratory in Edinburgh, Scotland. "It is real, tested equipment, and we are now testing software," he says. The system re-uses some equipment previously employed during a UK trials campaign named Bright Adder.

For the test phase, a spare radar also will be supplied to Warton, plus around "six additional items" which will support work up to the IOC milestone being declared. At least two flight-test aircraft will be involved, along with personnel and additional assets from the RAF's 41 Sqn test and evaluation unit.

The MoD says service introduction – now targeted for 2030 – will represent the availability of "a robust capability... something that you can rely on and take to war".

The UK will acquire ECRS Mk2 sensors to equip 40 Tranche 3

Typhoons, with integration work expected from 2026. The technology – which also will offer electronic attack functionality – is additionally suitable for incorporation with Tranche 2 examples.

Fresh funding for the ECRS Mk2 effort is due to be approved from late this year, clearing the way for production and equipment delivery.

Separately, BAE is continuing flight testing from Warton of the P3EB capability update package for the Typhoon, along with ground trials in support of a future P3EC modification.

The company also is performing rig and simulator trials of a replacement cockpit display for the Typhoon, developed using internal funds. Featuring a large area display and two back-up high-integrity panels – similar in size to mobile phones – this is being proposed as part of a long-term evolution upgrade for the Eurofighter platform.

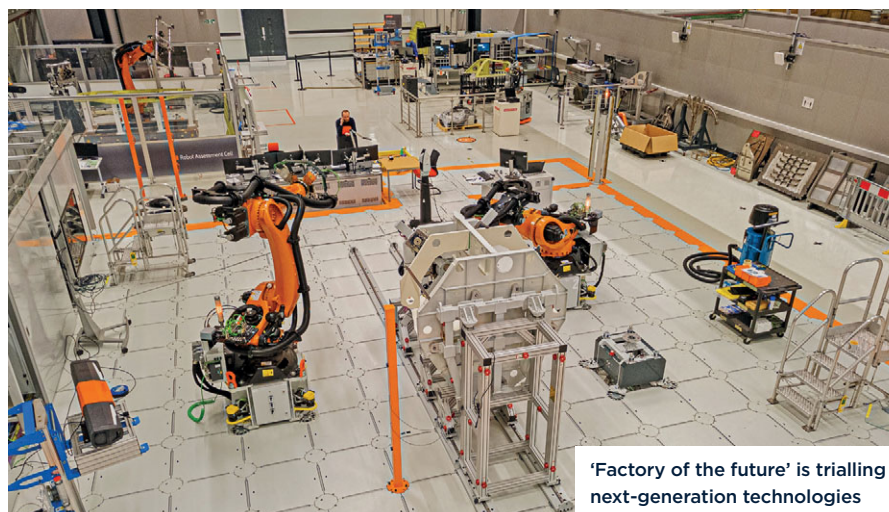
### Manufacturing skills

Among multiple other initiatives BAE is taking now to develop new manufacturing skills is its factory of the future – a hangar at Warton dedicated to trialling next-generation technologies.

This involves partnerships with around 50 organisations, and is trialling the use of equipment ranging from smart machining benches – now employed at BAE's nearby Samlesbury manufacturing site – to a robotic-assisted assembly station. This can be swiftly reconfigured to work on different fuselage sections or aircraft types with tolerances of tenths of a millimetre, BAE says.

Around 30% of a future fighter's airframe could be produced using additive manufacturing, BAE believes, while innovations such as hot isostatic pressing would reduce its reliance on scarce materials by using powdered titanium during parts production.

The company plans to potentially double the size of its factory of the future to continue such research, which will only benefit projects like FCAS and Tempest. ■



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Embraer is a changed company from 2019, when it was preparing for a big merger with Boeing. It is striking out on its own again, with a fresh emphasis on new platforms and disruptive technology

# Going solo



The E-Jet is the only in-production regional jet family

Jon Hemmerdinger

Embraer arrives at Farnborough riding the success of its E-Jet programme while seeking to build momentum behind its executive jets, C-390 military transport and a proposed new passenger turboprop.

The company has also dabbled in higher-risk investments, notable among them being air taxi developer Eve. Also, last year, Embraer revealed a concept to develop a family of electric and hydrogen-powered aircraft.

From the outside, much has changed at Embraer since the last major summer air show – Paris in 2019. Back then, Embraer was preparing to sell 80% of its commercial aircraft business to Boeing for \$4.2 billion.

The combination was widely viewed as mutually beneficial. It would give Embraer a partner that could help the smaller airframer expand globally and support future Embraer development programmes. Boeing, meanwhile, would overnight secure a strong presence in the 70- to roughly 150-seat aircraft

market, letting it better compete with Airbus, which made a similar move when it acquired majority ownership of the A220 programme from Bombardier in 2018.

But the whole Embraer-Boeing deal fell apart in April 2020 when Boeing, struggled under the weight of both the pandemic and its flailing 737 Max programme, backed out.

At the time, the loss appeared a significant setback for Embraer, which again stood alone in an increasingly consolidated industry.

But Embraer might now be counting its blessings. After all, Boeing's position has arguably worsened significantly in the past two years – the 737 Max programme has yet to recover, 787 deliveries have been largely halted since October 2020 and Boeing has again delayed the 777-9's certification, this time until 2025.

Also, Embraer has always had an independent, underdog streak – an asset that might have eroded under Boeing's wing.

Embraer had gone to great lengths in preparing for the Boeing acquisition, undertaking the difficult task of carving its commercial-aircraft business into a distinct unit. It has spent much of the last two

years putting itself back together, a process that caused the company to slow deliveries this year.

"This year we concluded the reintegration of the systems," Embraer chief executive Francisco Gomes Neto said in late May. "It was a painful and expensive project... We have a more-simple organisation. More flexible. We are ready in all respects."

## High inflation

All major airframers suffered handily amid the pandemic, with losses piling up and supply chain troubles hindering production. Now soaring prices of raw materials and components have added to the headaches.

"We are facing the impacts of this high inflation everywhere," Gomes Neto says.

Embraer lost \$732 million in 2020, but pared that figure to a \$45 million loss in 2021. Its deliveries have remained relatively muted. The company handed over 141 civil aircraft last year (including 48 E-Jets and 93 executive aircraft), up from 2020's deliveries of 130 aircraft (44 E-Jets and 86 executive jets). By comparison, pre-pandemic in 2019 Embraer delivered 198 aircraft,

including 89 E-Jets and 109 business aircraft.

The slump persisted in the first quarter of 2022, when Embraer lost \$32 million and delivered only six commercial and eight executive aircraft. The company said the dip resulted from a production halt in January, caused by the work of reintegrating the commercial division following the failed Boeing deal.

More broadly, Embraer has sought to shore up its operation. This year, it sold two aerostructures manufacturing sites in Portugal to Aernnova for \$174 million. Embraer also moved a business-jet seat manufacturing operation from Titusville, Florida to nearby Melbourne, and sold the Titusville land.

Embraer is seeking to squeeze more efficiency from its E-Jet manufacturing plant at Sao Jose dos Campos, with plans to cut production lead times – the duration of a process, start to finish – 40% by 2023, it says. It aims to accelerate production so that each airframe remains at each production station only 2.5 days before moving on. Currently, airframes move from station to station every three days, ▶

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down from four days last year, Embraer says.

The company insists it is getting back on track, with plans to deliver 60-70 commercial and 100-110 executive jets in 2022. It expects to generate \$4.5-5 billion revenue, up from \$4.2 billion in 2021.

Michael Amalfitano, chief executive of Embraer Executive Jets, thinks pandemic-induced travel restrictions and airline cutbacks proved a boon to business aviation, pushing wealthier travellers to private aircraft. Executives at other business jet manufacturers reported the same trend.

"What we saw during the pandemic was this growth from the base of the marketplace," Amalfitano says. "That transformation was historical in nature."

The shift, he adds, particularly benefits Embraer because new customers tend to favour the types of smaller business jets the company produces.

Demand pushed Embraer to record executive-jet sales growth in 2021. "The sales are continuing to grow", Amalfitano says, noting Embraer has no Praetor delivery slots until the second half of 2024.

#### Sales opportunities

Embraer Defense & Security chief executive Jackson Schneider also sees fresh sales opportunities, particularly for Embraer's C-390 military transport. He cites changing geopolitical factors, including Russia's invasion of Ukraine and the hasty 2021 retreat by the USA and its European allies from Afghanistan.

"Many countries in the world... realise that their logistics systems are very old and need to be replaced," Schneider said in May. "They need to replace [those systems] as soon as possible."

The C-390 programme suffered a setback this year when the budget-constrained Brazilian air force – the type's launch customer – cut its orders from 28 to 22.

But Embraer has recently been engaged in "intense" C-390 sales



Embraer released this image of its turboprop concept on 13 August 2021

campaigns, including with countries the airframer had not previously targeted as potential buyers, Schneider says.

Schneider also says such factors bode well for additional sales of Embraer's single-engined Super Tucano – specifically, those examples used for pilot training.

Embraer Commercial Aviation chief executive Arjan Meijer likewise views the pandemic as shifting conditions to the benefit of Embraer.

"We are definitely coming out of Covid in a different form," Meijer said in early June, noting that many people moved from cities to smaller communities during the pandemic. That trend should support strong demand for travel at regional airports, and for E-Jets serving those airports, he says.

"The connectivity across the regions became even more important" post Covid," Meijer says. "Airlines are really leaning into the smaller-capacity aircraft to rebuild their networks."

Embraer's E-Jet programme also stands to gain from the company's March launch of its E-Jet passenger-to-freighter (P2F) conversion programme for E190s and E195s. On 24 June, Embraer revealed having received the first firm P2F orders, with an unnamed customer committing to "up to" 10 conversions.

That builds on a previous agreement – though not a firm order – by Irish lessor Nordic Aviation Capital to convert up to 10 E-Jets. Nordic is the programme's launch customer, with deliveries to start in 2024.

Meijer says freighter-configured E-Jets will fill a currently void market segment – that between freighter turboprops and freighter narrowbodies.

"In the middle, there's a huge gap... There's nothing available there," he says. "The 190 [and] 195 E-Jets offer a great opportunity for cargo operators to connect the fleet between the turboprops and the

bigger narrowbodies."

Embraer sees its P2F programme as a means to capitalise on increasing demand for cargo air shipments due to booming e-commerce.

"We are very bullish and very positive about this new development," Meijer adds.

The E-Jet remains Embraer's flagship, and the programme now holds the distinction of being, essentially, the only remaining in-production regional jet. Embraer took that title after the recent demise of Bombardier's CRJ and Mitsubishi Aircraft's SpaceJet programmes.

#### Challenges

Still, challenges persist. For starters, the Boeing deal collapse left Embraer a relatively small, independent company in an increasingly consolidated aerospace environment. Despite the E-Jet's success, Embraer faces formidable competitive pressure from Airbus's A220. In response, Embraer executives have repeatedly stressed that they are seeking new industrial partners with which to expand.

The viability of Embraer's in-development E175-E2 also remains in doubt. That aircraft could have massive sales potential if not for the little problem of its maximum gross take-off weight (MGTOG) exceeding the limit allowed for most US regional airlines – the exact customers for which Embraer developed the jet.

The problem rests in scope clause provisions within contracts between major US airlines and their pilots. Those clauses generally restrict major carriers' regional partners from operating jets with maximum gross take-off weights exceeding 39,009kg (86,000lb).

Thanks partly to its new and heavy Pratt & Whitney PW1700G turbofans, the E175-E2 exceeds the cap. The type's predecessor, the E175, comes in under the cap and has proved wildly popular among US regionals. Those airlines have some 670 E175s and the smaller E170s in service or storage, according to Cirium data.

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Brazil's air force is the main customer for the C-390

It has been biding its time with the E175-E2, hoping new employment contracts will revise the MGTOW cap. In February, Embraer paused E175-E2 development. It now eyes service entry in 2027 or 2028.

"We do not see that changing in the short term," Embraer's Gomes Neto says of scope clauses.

#### Banner product

Embraer's E-Jets will undoubtedly remain the company's banner product for years, but executives do have their eyes on development of clean-sheet models.

Seemingly most likely of those is a new turboprop – a project company officials have been hinting at for years but that now seems close to getting a green light.

"We hope to launch the programme around mid-2023," Meijer says, adding that the type could enter service "around early 2028."

Embraer anticipates offering 70- and 90-seat variants. Luis Carlos Affonso, Embraer senior vice-president of engineering, technology and corporate strategy, said in May that a 70-seat turboprop could replace 50-seat regional jets – types like CRJ200s and ERJs.

The jet-replacement market is particularly ripe for opportunity in the USA, he notes. Indeed, US regional airlines have more than 600 50-seat jets in service or storage, Cirium shows. Many of those jets are decades old; no viable replacements exist.

Embraer is now maturing its turboprop design, Meijer says. The aircraft will have the same fuselage as the E-Jet, and, in a recent change, Embraer moved the design's engines from being mounted on the wings to being mounted on the aft fuselage. That change will reduce aircraft noise and keep the props far from the eyes of boarding passengers, who, at least in the USA, tend to disfavour propeller aircraft, Embraer has said.

In June, Meijer said Embraer was conducting turboprop wind-tunnel tests, which would be completed by the end of August.

Embraer is also collaborating with industrial partners, including with engine makers. "This year, we want to make a decision on the turboprop engine," Meijer says.

Thanks to modern technology, the turboprop could burn 15% less fuel per seat than an ATR 72, and up to 30% less than a 50-seat jet, Meijer



A Praetor 600, Embraer's super-midsize business jet



A computer rendering of an Embraer 190F and E195F

says. The aircraft, he adds, will be able to burn 100% biofuel from day one. Embraer anticipates airlines will need 2,260 turboprops during the next 20 years.

The company's long-term plan could also include much-more-revolutionary designs. Notably, in 2021, Embraer revealed it is studying a family of electric- and hydrogen-powered aircraft called its Energia family.

Though Embraer has not launched

a formal Energia development programme, the company laid out a vision that first calls for developing a nine-passenger, 500nm (926km)-range hybrid-electric aircraft called E9-HE, for service entry by 2030.

The vision next has Embraer developing two models, each with about 200nm of range and for 2035 service entry: the nine-passenger fully-electric E9-FE, and the 19-passenger hydrogen-fuel-cell-powered E19-H2FC.

#### Conceptual line-up

Rounding out the conceptual line up, with service entry around 2040, would be the E50-H2GT, a 35- to 50-passenger aircraft with twin turbines capable of burning hydrogen.

Speaking in June, Meijer stressed that Embraer's Energia designs remain "concepts", not yet "products".

"We're progressing strong on this concept," Meijer says, noting that the work is putting Embraer on a path to reduce carbon emissions. The company has pledged to be carbon net-zero by 2050.

"This is really an effort by Embraer to show what we believe is achievable on new technology," Meijer says. "We believe the regional segment will lead the technical

revolution."

Embraer's other technological ambitions include making a winner of its Eve air taxi investment. The Brazilian airframer developed Eve in-house during the last several years before spinning off the division as a standalone company in October 2020. Then, in May, Embraer took Eve public on the New York Stock Exchange, generating more than \$300 million in proceeds and leaving Embraer holding a 90% stake in Eve.

Eve – the name of the platform itself as well as the business – is an electric vertical take-off and landing (eVTOL) air taxi that will carry four passengers and have 54nm of range.

#### Vision

The air taxi concept itself remains barely more than a vision, with numerous hurdles yet to overcome. But in June, speaking at Embraer's offices in Sao Jose dos Campos, Eve co-chief executive Andre Stein struck an optimistic tone. He stressed that Eve is pursuing a more-conservative timetable than some competitors by aiming to deliver its first eVTOL around 2026. By comparison, some competitors have promoted 2024 service entry.

Also, Stein says access to Embraer's formidable design and certification resources will help cement Eve's success.

Eve has logged more than 1,800 "launch orders" for its eVTOL, though it notes that the commitments are "non-binding". Aerospace experts generally say such "orders" likely involve little or no money down. They do, however, generate positive press for both parties.

Embraer is also working to increase revenue from its Services & Support business by about 15% annually, says that division's chief executive Johann Bordaïs. That would mean Embraer's service revenue will hit about \$2 billion by 2026, up from \$1.1 billion in 2021, Bordaïs adds.

Prior to the pandemic, Bordaïs had aimed for Embraer's service revenue to reach about \$3 billion by late this decade, but the pandemic pushed that goal "to the right", he says. ▶

# Raytheon Missiles and Defense: Hypersonic air-breathing weapons deliver value and performance

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## The basis of air-breathing weapons

Air-breathing scramjets rely on high speed and accuracy to operate successfully. After being boosted, air and hydrocarbon fuel are burned to produce thrust for sustained flight into the upper reaches of the atmosphere.

In September 2021, RMD, in partnership with the U.S. Defense Advanced Research Projects Agency, U.S. Air Force and Northrop Grumman, successfully completed the first flight test of a scramjet-powered Hypersonic Air-breathing Weapon Concept, or HAWC, missile. The test demonstrated the maturity of an affordable scramjet technology – the basis of air-breathing weapons.

The HAWC flight test also validated RMD's digital design and digital engineering concepts, with the model performance and actual performance mirroring one another. Digital design and

engineering can cut 30 percent or more out of the development and testing timelines.

## Affordable

Digital design must be coupled with additive manufacturing, or 3D printing, to make air-breathing hypersonic weapons affordable. Scramjets can be produced efficiently because they are designed and built to leverage the digital thread and additive manufacturing.

Because thermal management is one of the biggest challenges with developing hypersonic technologies, RMD developed cost-effective solutions to protect the electronics from blazing temperatures without adding extra weight, which can reduce range. For example, air-breathing systems rely on low-cost conventional metals, such as nickel-based alloys, for their airframe. Nickel-based alloys are known for their corrosion resistance and strength, and have superior durability to heat.

## Flexible

Another advantage? Scramjet systems are smaller and can be installed on both fighter jets and bombers. These air-breathing systems use hydrocarbon fuels that have high energy density, and because these systems use air from the atmosphere, they don't need to dedicate space and weight to onboard oxidizers for combustion. Scramjet solutions can also be carried in greater quantities because of their smaller size. This means they can be employed against more targets in a single mission – a huge advantage.

## Survivable

Hypersonic weapons – both air-breathing scramjet and boost-glide – are also survivable. They offer increased survivability against advanced threats compared to legacy systems, allowing them to reach their targets. The altitudes they fly and their range and maneuverability make them difficult to detect and track.



Eve aims to deliver first eVTOL aircraft in 2026

It may be the world's largest aircraft, but developer Hybrid Air Vehicles believes the Airlander 10's small carbon footprint and versatility across aviation markets will be its biggest selling points

Murdo Morrison

Ten years on from when it first took to the skies as part of an aborted US military project, the near-term prospect of the Hybrid Air Vehicles Airlander 10 carrying paying passengers has finally become very real. It comes weeks after the UK-based developer announced a surprise breakthrough deal for 10 examples of the hybrid airship with Spanish regional airline Air Nostrum.

Air Nostrum's "reservation agreement" followed commitments HAV secured last year for three Airlander 10s that will be configured with berths for long-distance sightseeing expeditions over wilderness areas, and a \$200 million funding injection that has allowed the firm to go ahead with plans to open a final assembly plant in South Yorkshire, according to chief executive Tom Grundy.

HAV will confirm the location this year. "We have everything in place for production, but we're not quite ready to announce exactly where or start dates just yet," says Grundy. The factory will have a capacity for 24 aircraft a year by 2027, with Air Nostrum and the customers for the three VIP aircraft "taking a chunk of that" in the first year.

First flight of the Airlander 10 production version is set for 2024 – a now-abandoned prototype made several flights in 2016 and 2017. Certification and first deliveries are expected in 2026. It comes after a nine-year effort by the start-up to raise sufficient funds and establish a market for what will be – thanks to its 91m (300ft)-long helium-filled hull – the world's largest production aircraft.

Bedford-based HAV is exhibiting at Farnborough again after unveiling a VIP cabin concept at the show four years ago as part of a push into the luxury leisure market. Some may be disappointed that the Airlander 10 itself is not making



An artist's impression of Airlander 10 in Air Nostrum livery

an appearance, but Grundy says there is an outside chance the next show in 2024 could see its long-anticipated debut.

Air Nostrum managing director Miguel Falcon will be on the HAV stand on Tuesday to provide more details on how the Valencia-based carrier plans to deploy the Airlander 10 and how it will help Air Nostrum achieve its sustainability targets. The airline plans to introduce the type to its fleet over five years.

Grundy maintains that the operators secured so far illustrate the breadth of the Airlander 10's appeal – the passenger cabin is suspended from the hull, and the Air Nostrum examples will be fitted with 100 seats. Meanwhile, the tourism versions (HAV is not releasing the customers' names beyond saying it is

a "global group of companies") will be equipped for just 16 passengers.

However, Grundy still believes the freight logistics sector represents the biggest opportunity. HAV hopes to develop an Airlander 50, capable of carrying 50t, five times the payload of the Airlander 10. Meanwhile, discussions with potential customers in the military market – for which the aircraft was originally conceived as a long-endurance surveillance platform – remain promising, he insists.

The Airlander 10's sustainability case is the biggest draw for environmentally-minded operators, says Grundy. On the early production examples, a pair of 500KW, UK-built Collins Aerospace electric motors will replace the front two of the prototype's four Continental diesel

engines, with the first all-electric versions ready by 2030.

Because the aircraft's lighter-than-air hull and aerodynamic "flying wing" design provide the bulk of the lift, much smaller engines are required than on an equivalent turbine-powered aircraft. Grundy believes the Airlander 10 can make a serious contribution to the industry's quest for net-zero air travel. "We want to break the link between the growth of aviation and emissions," he says.

Other pluses for passengers include a lower-altitude, smoother and quieter flight and roomier cabin than on an airliner with similar capacity, claims HAV. However, Grundy accepts that the Airlander 10 will remain a niche product in the commercial sector. "We won't directly replace regional jets," he says. "We provide a different set of connections at a different speed point."

Passenger infrastructure is a challenge – operators are unlikely to use conventional airports as one of the Airlander 10's advantages is that it can take off and land vertically, including onto water. HAV is working with consultancy AECOM to find out what ground-based facilities are likely to be needed, although Grundy envisages it being "more like boarding a ferry than going through an airport".

The handful of brief tethered flights over its original Cardington hangar, near Bedford, five or six years ago, gave the industry a glimpse of the Airlander 10's potential. Now HAV must convince potential operators that the giant aircraft is more than an aeronautical novelty, and can provide a serious alternative to flying as we know it. ■



How the VIP version might look



The cabin in 100-seat passenger configuration

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Attention may be shifting towards zero-emission technologies to power a future class of airliners, but the gas turbine remains key to propelling Rolls-Royce's business recovery



## Core values

Engine manufacturer has already validated new composite-titanium fan blades

### Dominic Perry

Rolls-Royce's commercial engines business arrives at this year's Farnborough air show a changed beast – leaner, more agile, heavily focused on decarbonisation – yet with the gas turbine still firmly at the heart of the unit.

The pandemic accelerated a restructuring initiative – the largest in the company's history – that was already in process at the UK-headquartered manufacturer, seeing it slash thousands of jobs and dramatically cut costs (see box).

But while the business itself has been reshaped, its fundamental belief in the primacy of the gas turbine has not, says Alan Newby, director of aerospace technology and future programmes.

"I think sometimes there's a belief that the future is hydrogen and the future is SAF [sustainable aviation fuel] and the future is electricity, therefore the gas turbine has no place," he says.

### Efficiency premium

"We would say quite the opposite – because in a future world, whether you are burning SAF or hydrogen in some form, you are going to need a highly efficient gas turbine. And quite possibly the premium on efficiency will go up because those

new fuels could either be in short supply or more expensive than kerosene today."

That is not to say those other elements have no place, he stresses: in the short term greater SAF use will be the industry's main route to hitting net-zero goals, particularly for long-haul flying. Further out, hydrogen appears to be the future fuel of choice. Additionally, other breakthrough technologies such as full- or hybrid-electric systems will enable even greater levels of performance to be squeezed from

the gas turbine, or can be employed in markets such as those for regional or commuter aircraft.

But the focus is still very much on the gas turbine, and, as Newby points out – only slightly tongue in cheek – "no presentation would be complete without talking about the UltraFan".

UltraFan is a subject that has loomed large in every R-R briefing since the programme was announced in 2014. But with the project now approaching a major milestone – the first engine run – it is

becoming even more prominent.

Newby displays a palpable sense of excitement: "I was part of the team that launched UltraFan a few years back and it's so satisfying to see this coming together: you walk down to the shop and you can see the engine taking shape," he says.

While many of the underpinning technologies – the lean-burn combustor, high-temperature materials, composite-titanium fan blades and advanced low-pressure system – have already been validated in separate tests, the UltraFan engine will see these run in conjunction for the first time. "This is really bringing it all together as a system to make sure it works together and delivers what we expect it to. There's a real buzz around the organisation," he says.

Newby is coy on when the UltraFan will run – it is, he says, a "complex beast", owing to its level of instrumentation – but with a tank of SAF for the powerplant already delivered and the engine complete, that milestone feels imminent.

As currently sized, the UltraFan demonstrator will be the world's largest aero engine, with a fan diameter of 355cm (140in) and a power gearbox that delivered 64MW in early testing. It should achieve a 25% fuel-burn and carbon dioxide improvement against the first generation of Trent engines, or 10% over the newer Trent XWB.



UltraFan demonstrator is being readied for its first run

Rolls-Royce

But the lean-burn combustor will also contribute to lower levels of nitrous oxide emissions and particulates, plus an engine that is 35% quieter too. "This isn't just about carbon [dioxide], it's about the way the whole set of attributes impacts on the environment," Newby says.

No thrust rating for the demonstrator has been disclosed, but R-R says the design is scalable from 25,000lb (110kN) to 100,000lb. Bypass ratio will be an impressive 14:1.

But as Newby is quick to point out, the UltraFan demonstrator is "not the end of the story", because "we will need that architecture which can be developed and can be grown and can be improved".

That means an eventual production engine – whether for single- or twin-aisle applications – which can be used with 100% SAF from the very beginning, has hydrogen compatibility in its roadmap, and could also make use of some form of hybridisation.

"If Airbus, or another manufacturer, is saying the answer for future narrowbodies is hydrogen, then we want to be capable of doing that. We believe the UltraFan architecture is the right solution for that."

#### Eyeing alternatives

In R-R's view, for the vast majority of narrowbody and widebody applications, the most appropriate propulsion system will remain a gas turbine engine. Further down the size range – an area of the market long since abandoned by the manufacturer – are other technologies such as full-, hybrid-electric and fuel cell-based powertrains.

"There are a lot of alternative solutions," says Newby. "We have been in this fortunate world where we've had one size fits all – a gas turbine burning kerosene for all applications – but it may not be like that in the future."

"But if you look at that space – the narrowbodies, widebodies and even some regional aircraft – where the fuel is burned today, or conversely where the CO<sub>2</sub> is produced, those are the solutions that are still going to need a highly efficient



PGS1 demonstrator produced 2MW of power

gas turbine, which is why we are continuing to invest heavily in that."

Potentially supplementing the gas turbine, though, are a whole host of emerging technologies. Take, for example, electric power. The topic poses an interesting conundrum for R-R as a whole: battery limitations mean a large fully electric aircraft is all but ruled out, yet Rolls-Royce Electrical – created earlier this year as its own unit – is actively developing powertrains for the emerging urban air mobility market.

For Rolls-Royce Civil Aerospace, then, the interest centres on hybrid-electric power and is two-fold: first, what can it offer its large-engine portfolio by way of efficiency gains; and, second, can that technology take the company into new, or at least long-relinquished, market segments?

Solutions vary from a "macro-hybrid" architecture – where a significant amount of power is delivered by the electrical system – to a "micro-hybrid", where the electrical system uses "stored

energy to support the gas turbine", whether in flight or on the ground.

Aided by the 2019 acquisition of the Siemens eAircraft business, R-R has been researching both the technology and the attributes of electric systems, allowing it to identify specific applications and tailor the company's approach to specific sectors, says Newby. Activities have included running its PGS1 demonstrator – a pair of generators married to a modified AE 2100 turboshaft – to produce 2MW of power. The PGS1 was originally due to be part of the powertrain on a converted BAe 146 as part of the E-Fan X project the manufacturer was running alongside Airbus.

#### Testing times

Pandemic-driven budget cuts called time on that effort prior to it taking flight, but "we learned a hell of a lot from the ground testing", Newby asserts.

"That was a really successful test – we learned about the electrical machinery, we learned about the

integration with the gas turbine, the control, but also the heat management and the control of the gas turbine itself. So it was a really fascinating one," says Newby. Knowledge from the testing will feed into product studies as R-R looks to the commuter and regional markets.

"It's great doing the experiment, but what really matters is the knowledge you feed back into the system and the lesson you learn to inform the future."

Fuel cells may also feature in future and work is ongoing with R-R's Power Systems business to evaluate "what it would take to make a hydrogen fuel cell competitive for aviation".

Research is also being conducted into the feasibility of using liquid hydrogen as a fuel. "We are of the view that it looks likely there could be a role for hydrogen in the future. And therefore we need to start to understand the challenges of bringing it to market," says Newby. R-R is focusing on the "higher-risk and challenging technologies" required for liquid hydrogen use, chiefly issues around combustion and management.

"That will inform our view on how quickly [liquid hydrogen] could be brought to market and what the major challenges are to be addressed," adds Newby.

A programme to test the feasibility of hydrogen combustion is being embarked upon. This will initially involve ground tests of an AE 2100 turboprop and then a Pearl 15 business jet engine, potentially – if there is value to be gained – culminating in a flight-test campaign.

But with so much spoken about 'disruptive' technologies in aviation, for a company such as R-R, which still has the gas turbine at its core, there seems to be a perception problem. "People think that a gas turbine isn't disruptive, that it's old hat," he says.

As you might expect, Newby takes the opposite view: "You can enhance it with the technologies we have got here for a gas turbine to be a viable and disruptive solution for the future," he says. ■

#### How tough restructuring process has made Rolls-Royce fit for the future

The restructuring undertaken by Rolls-Royce Civil Aerospace cut deep: operational costs were slashed by £1.2 billion (\$1.5 billion), or 35%; footprint was reduced by 27%; and some 8,700 full-time posts, 34% of the workforce, were eliminated, including about one-third of management. Evidence of that exodus can be seen in the number of former R-R staff now occupying senior posts at businesses such as Lilium, Magnix and Vertical Aerospace.

These actions have contributed to making the business "stronger, more efficient, leaner, more simple", R-R civil aerospace president Chris Cholerton said during a pre-Farnborough briefing.

There are no arguments that the restructuring was necessary from a financial; perspective; even before the pandemic hit, R-R had been battling a succession of crises, notably around the Trent 1000 engine for the Boeing 787, on which turbine blade durability forced the grounding of customer aircraft and landed the manufacturer with a bill of about £2.4 billion. Work to address those problems continues.

Then as Covid-19 hit and the aviation industry reeled, R-R found itself hit with a double-blow: not only were deliveries of new aircraft placed

on hold, cutting revenue from sales of new engines, but with the installed fleet also not flying, services revenue also dried up. And, as quickly became apparent, the long-haul market on which R-R relies was going to take substantially longer to recover than the short-haul segment. These factors contributed to underlying operating losses in 2020 and 2021 of £2.57 billion and £172 million, respectively.

As Cholerton points out, there was an "intense focus both before the pandemic and accelerating through the pandemic in driving cost reduction [and] efficiency". However, he asserts that it was not merely about slashing costs but significantly enhancing structure and process to enable the business to "grow from a more efficient base".

"I'm very confident that all the costs we took out through the pandemic, and prior to that, will stay out and we do grow more efficiently through the recovery," he says.

A change in mindset has also taken root throughout the business, Cholerton argues, leading to "a greater belief that ambitious targets can be met and exceeded".

Evidence of the process change can be

seen across the organisation. In the turbine blade manufacturing operation numerous projects have been implemented, ranging from improvements to productivity through the installation of new grinding machines, or reducing the production of what R-R calls "concessions" – or non-conforming parts – at its Rotherham blade casting facility, which has improved by 91% over the last three years.

In its services business, there is increased focus on improving engine time on wing. Projects run from a new in-situ engine wash system to the use of high-power computing and big data to better model engine use.

The return of long-haul flying is also benefiting R-R on the services side, not least that many of its engines power newer, more fuel-efficient aircraft which are being returned to service first. In addition, the manufacturer also sees the market for new widebodies bouncing back.

"We are starting to see airlines think more about their fleet renewals for years to come, and a lot more interest around potential widebody [procurement] campaigns starting again now, some of them active today, looking for orders from 2025 onwards," says Cholerton.

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Four years after its delisting and takeover by Melrose Capital, the UK's biggest tier one supplier believes it can play a key role in transforming the industry

# Agent of change



The company is contributing its wing-design expertise to Airbus's Wing of Tomorrow initiative

**Dominic Perry**

For GKN Aerospace, the past four years have been, well, tumultuous is too strong, so let's just say they have been interesting.

Back at the last Farnborough air show, GKN Plc – as was – had not long been acquired by Melrose Capital, an investment company whose strategy is to buy up underperforming businesses, restructure them, improve their performance, and sell them on.

But restructuring is a notoriously broad term, covering a multitude of tactics from genuine nurturing and improvement on the one hand, to break-up or piecemeal closure on the other. And Melrose, rightly or wrongly, had a reputation for being ruthless with companies in its portfolio.

With the GKN acquisition having only closed on 29 March 2018, it was, by the time the Farnborough air show rolled around in July, still too early to discern what the new owners had in store, save for the fact that a sale was prevented until 2023

thanks to a covenant agreed to as part of the Melrose acquisition.

Some initial restructuring was begun in 2019, putting the business on a slightly firmer footing when the coronavirus outbreak struck early 2020.

But in common with the rest of the industry, GKN Aerospace saw orders dry up – sales fell 27% that year and only returned to growth during the second half of 2021, remaining below pre-pandemic levels. If there was a bright spot, though, it was the robust performance of its defence business which gained 8% in 2020.

Management has also changed since the previous edition of Farnborough: in 2018, GKN Aerospace was led by Hans Buthker who abruptly resigned in September 2020, to be succeeded on an interim basis by Peter Dilot, Melrose's chief operating officer. In turn, he was replaced by David Paja – an executive from outside the aerospace industry – who arrived in August 2021.

Restructuring was already under way prior to Paja's arrival, but that process has accelerated under his leadership, says Melrose in its 2021

annual report. But among the usual cost-cutting (reducing the operational footprint in Europe and the USA, for example) streamlining divisions and management, and portfolio reshaping (non-core businesses Fokker Service and Fokker Techniek were sold off) there are signs of a different business emerging.

Although GKN Aerospace has not abandoned its traditional focus areas (now reorganised into

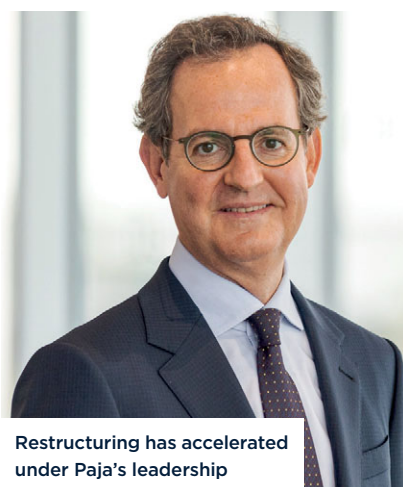
three divisions: civil, engines, and defence) it is positioning itself to take advantage of aviation's pivot towards decarbonisation.

"Over the past few months we have been trying to sharpen our vision, our mission – where we are heading. We look at it as what do we want to be in the industry? Clearly we want to be a relevant player and leading the transformation of the industry from the front," says Paja.

While that is partly related to being seen as a "trusted partner", the real differentiator, says Paja, is on the "sustainability of our products, our technologies, and how they enable the leap to net-zero".

"We are really making substantial investments and gearing our efforts to become a major player in the transformation of the industry."

That has seen investment in facilities – including a portfolio of global technology centres, the latest of which opened in the UK last autumn – and ground-breaking research projects into new technologies including advanced composites, hydrogen power – whether in fuel cells or combustion – and additive manufacturing.



Restructuring has accelerated under Paja's leadership

GKN Aerospace

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Dunn talks up GKN's OEM capabilities

There are key partnerships too: with Airbus on its Wing of Tomorrow programme (see box), and with engine manufacturers Pratt & Whitney and CFM International on their respective future propulsion programmes.

Russ Dunn, chief technology officer, argues that the company's unique "OEM capabilities" on both engines and aircraft – acquired through the purchases of Volvo Aero and Fokker, respectively – allow it to be more than simply a valued supplier.



GKN's latest technology centre opened in the UK last year

### Spar for the course: GKN works on Wing of Tomorrow

Aside from validating improved aerodynamics and wing architectures, the Airbus-led Wing of Tomorrow effort seeks to trial new composite manufacturing techniques that will allow production at the rates required to support a narrowbody programme.

At present, the production techniques used on composite widebody wings are slow and require large and expensive autoclaves to cure the structures. That is fine if you are building say, 12 aircraft per month, but the technology does not scale to support the sort of rates seen on a narrowbody programme.

GKN is producing next-generation composite spars and the fixed trailing edge for the Wing of Tomorrow.

Chief technology officer Russ Dunn compares the maturity of its new production system for these parts with those at the same stage of the Airbus A350 programme, for which GKN produces similar components.

The A350's spar "was nowhere near this level of maturity at the first build. We have already got to the point where we are producing spars of quality on the third shipset that are good enough for entry into service. That's how mature the technology is that's been developed," he says.

GKN is currently in the rate demonstration phase – showing that one production cell can deliver a capacity and cycle time that could then be scaled up.

Dunn says it is targeting "the ability to deliver at rate 100. So we wanted a system that could scale to that type of rate." Aside from the production of several test structures, GKN is also making heavy use of simulation to identify and develop solutions to potential pinch points.

In 2021, GKN delivered to Airbus the first 18m (59ft)-long spar made for the Wing of Tomorrow initiative; two further such components will be shipped this year.

"Our philosophy is that we want to operate one level above our station. That doesn't mean we want to compete with OEMs, but we want to develop OEM capabilities so that we can really understand solutions that are better for the customer."

On an engine, that means GKN can design and analyse the overall engine, as well as the parts

for which it has responsibility, providing feedback or suggesting improvements accordingly.

GKN's whole aircraft design capability has not only helped it attract a new breed of customers – agreements are in place with advanced air mobility start-ups like Eviation, Lilium and Vertical Aerospace – but also enabled the company to better assess which it wants to work with, says Dunn.

"We have done a lot of work to look at the different platforms that are out there, perform our own analysis that says who do we think are credible? Which airframes do we think are good? We have targeted customers we think we can work with."

Ironically, there was in the recent past debate as to whether this level of design expertise was still required, admits Dunn. "If you go back two or three years, we were genuinely having the debate whether our level of airframe and aircraft design capability was more than the industry needed."

"Now suddenly in this space these companies are desperate to

work with people who can provide whole aircraft or airframe design capability," he says.

But if the aerostructures agreements in the AAM segment are playing to GKN's traditional strengths, its research into hydrogen fuel cell powertrains threatens to take the company into an entirely new area. Should the UK government-backed H2GEAR project succeed and deliver a viable system by 2025 – and Dunn thinks such a powertrain could power anything up to a 96-seater – then there could be a clear opportunity to add another business line.

Paja also thinks the investment permitted by Melrose in projects like the network of technology centres and H2GEAR where the returns are many years in the future, is a sure sign of its owner's desire to make GKN a better business.

"Melrose are long-term thinkers in terms of investment," he says. "They have been extremely supportive of investing in the areas that will position the company for a much more sustainable but also successful future."

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In a June management reshuffle at GE Aviation, Russell Stokes was appointed as president and chief executive, Commercial Engines and Services. He has more than 25 years of GE experience, including nine with the Aviation division. He talks to *Flight Daily News* in his new role

# Powering back

**Q** How do you see prospects for recovery in the commercial market this year and next, and, in particular, how quickly is aftermarket business returning to pre-pandemic levels?

**A** We are optimistic about the recent surge that the industry has seen in travel demand, particularly in China where we continue to see positive signs of improvement since the slowdown in February. As of early July, global departures are closing in on 90% recovery worldwide from 2019 numbers. Commercial aviation has navigated through quite possibly the biggest crisis it has ever faced, border restrictions have lifted and travellers are making the most of the opportunity.

We expect narrowbody traffic will recover to 2019 levels by early next year, with widebody traffic to follow by early 2024. Shop visit recovery will follow traffic recovery, but we anticipate legacy engine lines like the CFM56 to hit 2019 levels by 2024.

**Q** What concerns do you have about the supply chain, given the various global economic headwinds?

**A** It's a tough environment for everyone across the industry right now but we are encouraged by the robust demand for our products and are proactively working with supply chain leaders across the company and leadership at key suppliers to identify and mitigate supply chain/sourcing risks.

We're also working closely with our airline and MRO customers to understand their projected demand and provide the right signals to our supply chain.

We've mentioned before we have sufficient hard capacity to meet anticipated demand. Soft capacity has been our focus, and skilled labour hiring has improved. Onboarding and training takes time. We are making excellent progress, along with our suppliers, in that department, which will help stabilize production rates. We are encouraged about turning the corner in

the second half of this year as shop visit demand ramps.

**Q** Over the past decade or so, GE Aviation's business has become very bound to Boeing. How are Boeing's troubles directly impacting GE Aviation, and do you feel you are over the worst?

**A** We work with all major airframers and compete for business across commercial, military and systems daily. We appreciate and are excited about the work we do with Boeing. They have a tremendous portfolio of products that will help them navigate the challenges they are facing.

Our primary focus is on developing and maturing differentiating technologies that separate us from our competitors and make aviation safer and more sustainable. For example, GE Aviation and Safran announced the CFM RISE programme last year without the support of an airframer. We will continue to execute on technology and we'll continue to help build the business case for airframers.

**Q** General Electric is going through a massive restructuring that will leave GE Aviation as its core business. Can you explain the logic behind that and what the implications are for the commercial engines and services business?

**A** I've worked across multiple GE businesses. The talent and passion here is second to none. We are optimistic about an aviation-focused GE, which will form the core of the business. We will be a worldwide industry leader in growing aerospace and defence markets, strongly positioned to support our customers through coming upcycle, with the largest and youngest fleet in the industry.

We're on the cusp of a post-Covid recovery and new engine ramp, accelerating our mission as an independent business to create a smarter and more efficient future of flight. We also have momentum in services and there's a lot we're doing with intense focus on our customers to support them as they continue to meet the challenges of robust demand.

We have a large, young fleet of engines. Our CFM56 product illustrates the growth we can anticipate over the next decade. There are over 19,000 CFM56 engines flying. Over half have not seen a single shop visit, and another quarter have only had one. This represents huge opportunity for the MRO ecosystem. Our widebody engines, like the GE90 and CF6, continue to see strong utilization from operators around the world, also driving significant shop visit volume.

**Q** With entry into service of the Boeing 777-9 delayed a further two years, how is this affecting your progress and production outlook for the GE9X?

**A** We are all excited about the GE9X engine and confident in the long-term success of the programme with the intent to support our customers for decades to come. On the Boeing 777X, the aircraft/engine combination is targeted to deliver a 20% fuel burn improvement that is 55% below current NOx regulatory requirements. Boeing's announcement of the 777-8F programme has also renewed further interest with customers.

This engine has been through the most rigorous testing programme of any of our commercial products, including accumulating 5,000 hours and 8,000 cycles during development and certification testing. We achieved certification in 2019, and we continue to develop and mature the engine as we prepare for entry into service.

Last fall, we completed 1,600 cycles of dust ingestion testing, gaining valuable data of what the engine might experience in the harshest conditions. And we are currently validating the GE9X with EASA [European Union Aviation Safety Agency] and are also working with Boeing on ETOPS [Extended-range Twin-engine Operational Performance Standards] certification. ▶



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Chris Calio is chief operating officer of Raytheon Technologies, the aerospace giant that brings together Pratt & Whitney, Collins Aerospace and the former Raytheon Systems. He describes the challenges involved in joining the businesses, and the opportunities the merger has delivered

# The power of one

**Q** Farnborough will be the first major air show since the creation of Raytheon Technologies in March 2020. Since then, the industry landscape has changed tremendously, with the pandemic decimating air travel for the first 18 months or so after the company came into being, and the situation in Ukraine causing governments in Europe and elsewhere to rethink their defence priorities. There is also now the worrying prospect of accelerating global shortages and inflation impacting wealth and spending. Very broadly, how do you view prospects across the markets you compete in?

**A** The concerns you've identified are real, and we're focused each day on mitigating the impacts of inflation and continued challenges to our supply chain. We're working closely with our suppliers to manage this difficult and complex environment. Through all that, we continue to see clear growth opportunities across our markets.

Commercial air traffic has been resilient – in the USA, the TSA screened more than 11 million passengers over the busy 4 July holiday weekend. That represents about 93% of pre-pandemic traffic, and it indicates how quickly leisure travel is rebounding domestically. And you only need to read the news to see how major European airports are struggling to deal with the crush of international travelers.

And on the defence side, we're seeing long-term increases – especially in western Europe – as our NATO allies respond to increasing threats from Russia. We see those signals continuing for several years.

**Q** Raytheon Technologies is an incredibly diverse company, combining Pratt & Whitney and Collins Aerospace (itself recently expanded through acquisition) with the legacy Raytheon divisions. Can you explain how the new entity is structured and what synergies exist between the four parts? Why did the merger make sense?

**A** The synergies are what makes our company so exciting and interesting. Raytheon Technologies is built on the idea that our businesses – each of them distinct, each with a rich history of innovation – can learn from one another and collaborate in ways that were not possible previously.

Take our cross-company



technology strategy. We are focused on a number of key areas, each of which applies across our businesses. These areas support our efforts to develop discriminators like power and propulsion, and secure, connected ecosystems. Ultimately that drives innovation in the areas our customers care about most – like sustainable aviation, hypersonics and the networking of systems in commercial aviation and defence.

Operationally, our businesses are sharing best practices in key areas, including advanced manufacturing and digital engineering. Those approaches enable us to develop technologies efficiently, in constant collaboration with our customers and at the pace of their needs.

**Q** Is the intention to continue to preserve Pratt & Whitney and

opportunities to collaborate. You'll see our businesses work together to create technology that would not be possible if they went at it alone. And, you'll see us working more closely with our customers at each stage of technology advancement and product development. Partnership occurs throughout development.

**Q** It has often been said that the 2020s will be one of the most innovative decades for aerospace in many years because the push to carbon-neutrality coincides with some dramatic potential breakthroughs in the areas of electric, hydrogen and hypersonic propulsion, as well as in quantum physics, lightweight materials, artificial intelligence and cybersecurity. Which technologies are you most excited about and what sort of timescales do you anticipate for genuinely disruptive advances to emerge?

**A** Some of the greatest advances are happening in sustainable aviation, and in the ways our military customers are using data to change the way they operate in the battlespace. In sustainable aviation, with the industry committed to net zero carbon emissions by 2050, we're pursuing a number of advancements in hybrid electric propulsion. For example, our teams are putting hybrid electric propulsion into a De Havilland Dash 8-100 demonstrator, with support from the governments of Canada and Quebec.

We're also always striving to improve the performance and reduce the emissions of our engines, and we're supporting the use of alternative aviation fuels – including hydrogen in the long term.

In defence, there's the hypersonic work I mentioned previously, and at an even larger scale, there's the concept of multi-domain operations – this idea that networking sensors and platforms around the world will help military commanders and operators make better decisions faster. Artificial intelligence plays an enormous role in that, and our businesses are also using their experience in areas like secure communications, networking and systems integration to deliver the technology our customers need.

And that's what it really comes down to. Our customers are facing some immense challenges, and our ability to deliver the advanced technology solutions for the future is unmatched. ▀

## Collins as independent identities within Raytheon Technologies?

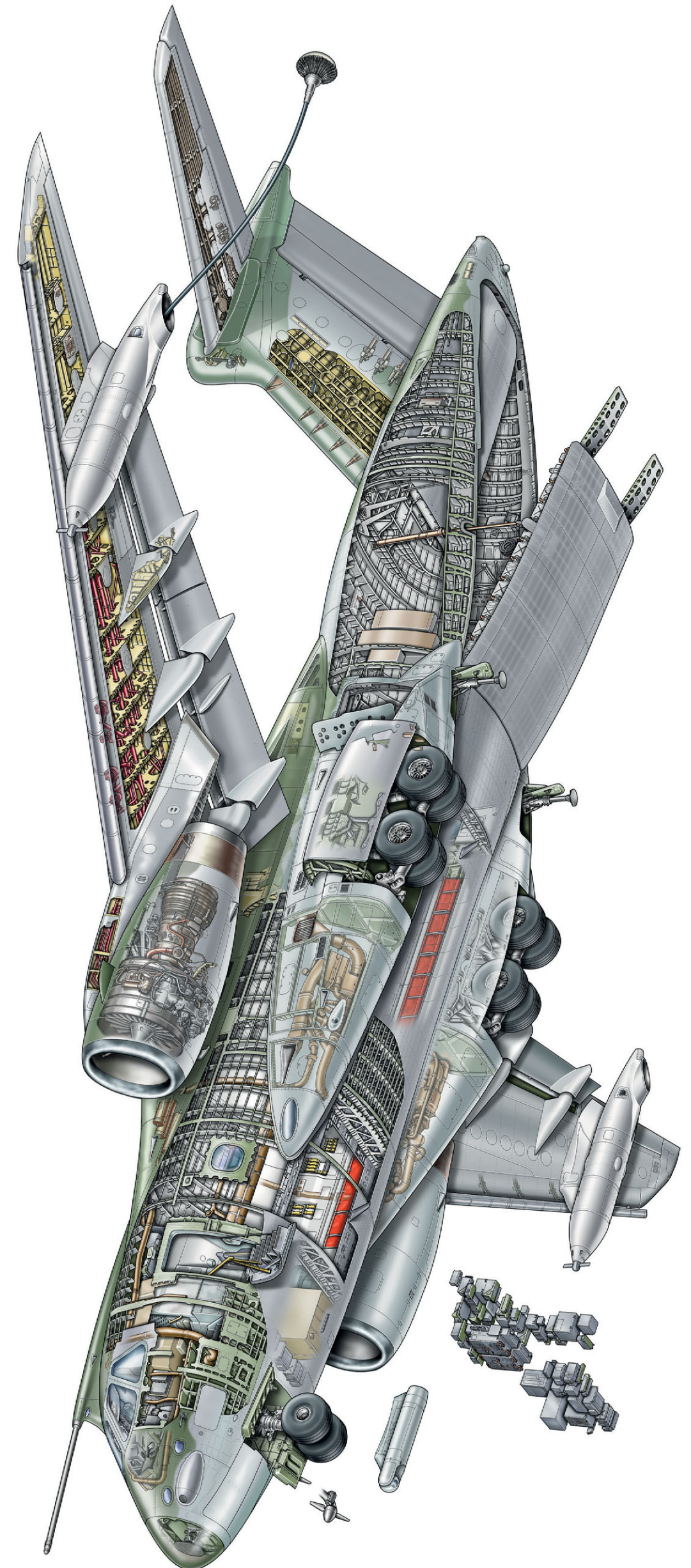
**A** Raytheon Technologies is one company, and we are structured in such a way that each of our businesses can continue to lead within their respective markets. The merger gave each business an accelerant for growth – the opportunity and imperative to share technologies, learn from one another and collaborate to solve highly complex problems.

Let's look at a hypersonics, for example, where we're drawing on cross-domain expertise. That knowledge base includes capabilities in advanced missile design; metamaterials that withstand extreme heat; jet propulsion; command and control; and artificial intelligence. As we evolve, so will those

# Embraer C-390

Originally the KC-390, the C-390 Millennium tactical transport, on display this week, was developed for domestic customer Brazil, which took delivery of its first example in 2019. Embraer has since secured orders for the IAE V2500-powered twinjet from three European NATO nations: Hungary, the Netherlands and Portugal.

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