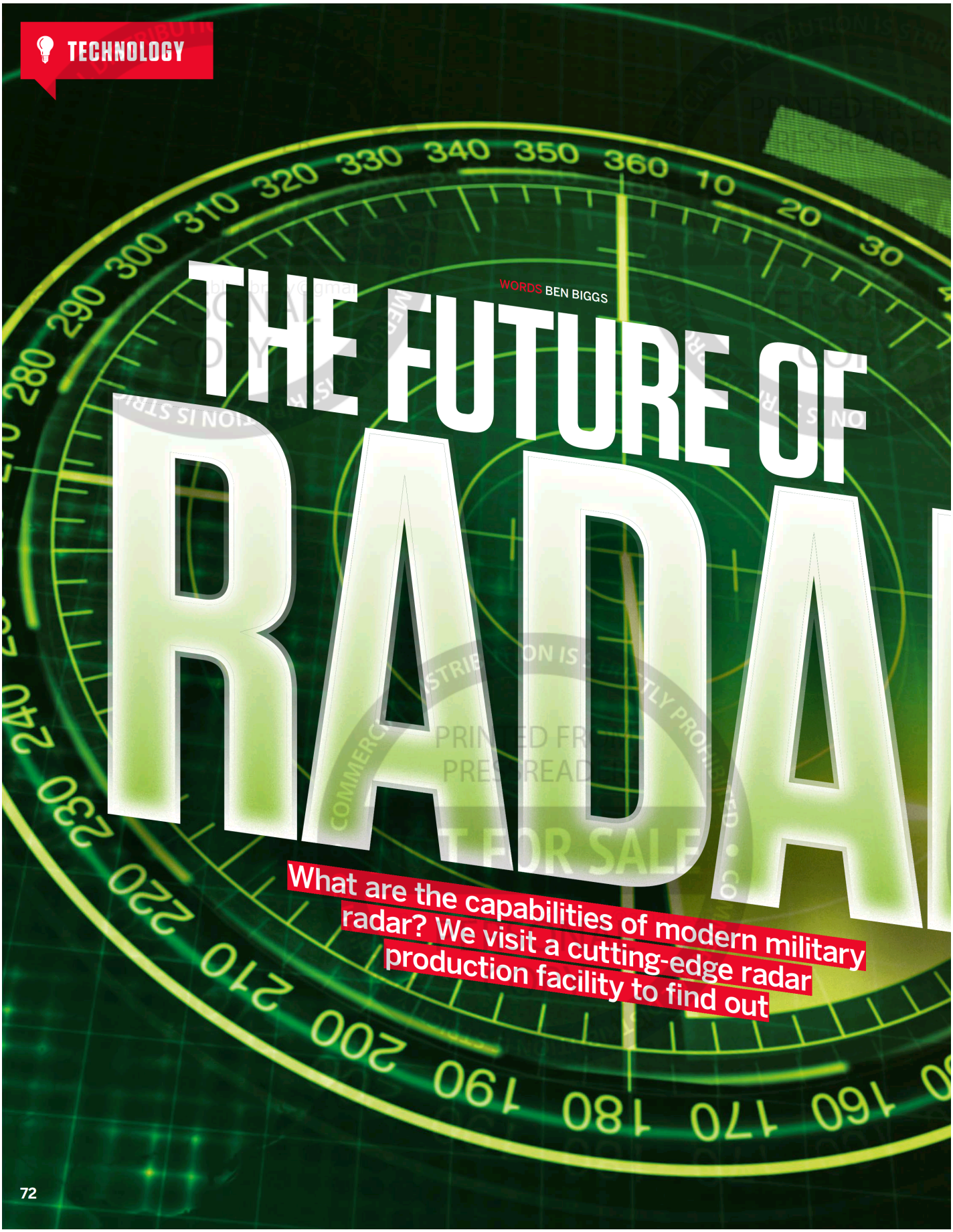
- Radar


TECHNOLOGY
WORDS BEN BIGGS
THE FUTURE OF
RADAR
What are the capabilities of modern military radar? We visit a cutting-edge radar production facility to find out
72

DID YOU KNOW? BAE Systems supplies and maintains radar for every major warship in the Royal Navy



A temporary World War II radar array, called the GCI Intermediate Transportable Aerial System

We're sitting in a conference room in a high-tech facility on the Isle of Wight, as one of Britain's foremost experts in radar technology paints a picture of what BAE Systems does in one of the most advanced radar development and production sites in the world. There's no doubt he knows his craft, but he's got his work cut out for him explaining his way through arrays, TR units and non-cooperative target recognition to a humble journalist who has little more than a few science GCSEs.

Radar architect Martin Widgery slides a large oblong of circuit board set into a wooden frame across the table. It's covered in soldered microchips each as big as a thumb and looks like the motherboard out of a Windows 95-era PC. It's nearly as old as that, too. This 'demonstrator' unit is a proof-of-concept prototype that BAE Systems' enormous Sampson radar system, commonly found atop the Royal Navy's Type 45 Destroyer, is based on. Widgery points at one end of the board, let's call it the 'business end', and tells us that each one of the channels is its own radiating antenna that contributes to thousands of little antennae that can be electronically, rather than mechanically steered. He points to other parts of the test board that are a staple of today's radar systems: individual radio frequency signal generation and reception, a power amplifier, phase and gain control for steering.

We're already more than a little blinded by the science, but it has turned our notion of radar on its head. 80 years ago a series of green blips lighting up a circular display impressed Britain's top brass and changed the course of World War II, though the hardware of these experimental systems amounted to little more than what Widgery describes as an "RF horn and a reflector on a beam that was focused by a bent bit of tin." Not that we're trying to downplay one of the most important inventions of the 20th century, but it's not exactly high-tech next to one of BAE Systems' modern active electronically scanned array (AESA) systems – not to look at and not on paper either. When the Chain Home early warning radar stations were built around the coast of Britain in 1938, it had a range of up to around 100 miles and a precision to within five miles or less. Today's radar can pinpoint a cricket ball flying at that range.

Did you know?
Police use radar to measure the speed of vehicles

That's a really one-dimensional picture of modern radar's capabilities, though. Old-fashioned radar made a rotation every 2 to 15 seconds, depending on its range, and updated everything on the screen in the same way. Modern radar does this in milliseconds, identifying targets with razor precision at much greater ranges, in a much noisier radio airspace and in infinitely more detail than radar technology of generations past. On the workshop floor, the same radar technology is getting cheaper and easier to produce, and the core technology – such as the 30-year-old demonstrator unit we were shown – has already been shrunk down to something that's about the size of a one pence piece, with the benefits of this smaller scale being felt on and off the battlefield.

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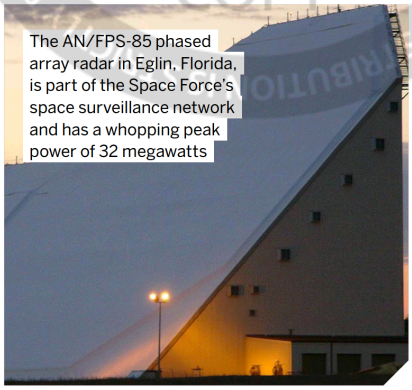
TECHNOLOGY



Aircraft carriers such as HMS Prince of Wales need sophisticated radar systems for air-traffic management, as well as defence



The AN/FPS-85 phased array radar in Eglin, Florida, is part of the Space Force's space surveillance network and has a whopping peak power of 32 megawatts

Did you know?

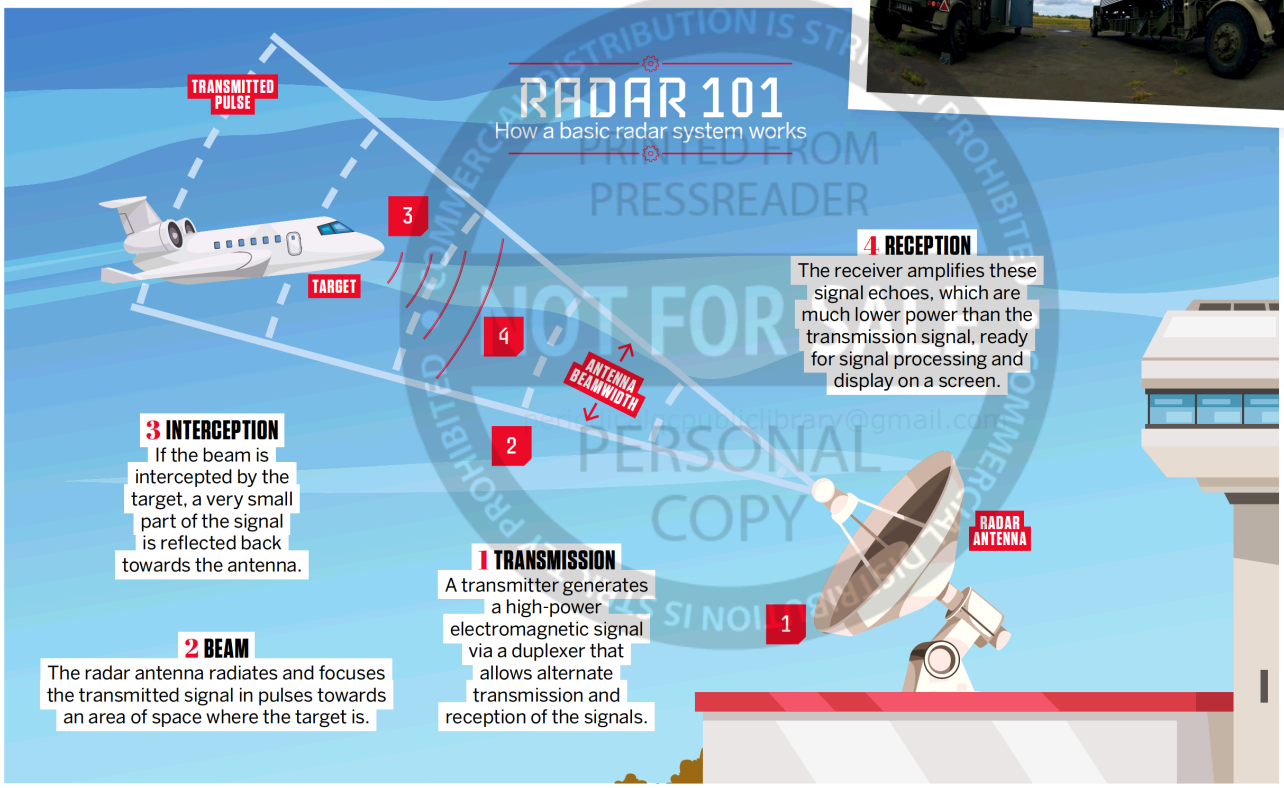
Some radar systems can bounce beams around the Earth

The latest generation of radar can already do some incredible things with microwaves, rather than radio waves, that Robert Watson-Watt and his pioneering colleagues would have been amazed by. Modern military radar can easily discriminate between fixed and rotary wing aircraft – jets or helicopters – for example. Widgery points to a series of fuzzy peaks and troughs on a screengrab from an auxiliary radar display, traces his finger around a busy area that he says is the central body of the aircraft, then two patches that appear to be going around in circles – the main rotor and tail rotor of a helicopter. But a trained operator in front of a live radar display can be even more precise than that. They can ascertain the telltale shape of a target, pick out the number of engines and blades on an aircraft, count the rotors on a helicopter and see how fast they're spinning around. It's the kind of detail that, in the context of a battlefield scenario, will allow the operator to determine the exact type of aircraft that's popped up on their screen long before the target is within visual range.

One of the coolest advances BAE Systems is making inroads in is in what they call 'non-cooperative target recognition', or 'ballistic missile defence discrimination'. This is when a missile has been fired that has separated into multiple pieces, possibly with decoys and multiple warheads, as well as bits of debris. The radar operator needs to easily distinguish between all the little bits that might appear in a tight bunch on the screen, determine what is and isn't a threat, then relay all the vital details to the decision makers. And this has to



Commander radar systems are huge, but can be moved around the battlefield with relative ease and be maintained by army engineers



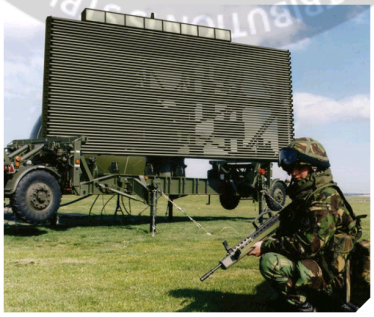
DID YOU KNOW? Routine servicing of the Royal Navy's Sampson radar costs in the region of £500,000 ($633,175) a year

be done fast. Missiles can travel at many times the speed of sound, so they can be on top of you at your position in a matter of seconds. It's only by transmitting with increased power and bandwidth to generate higher resolution radar images that this is possible.

So where do people at the bleeding edge of radar go with the technology next? After the miniaturisation of the hardware, the next logical step isn't to make it even smaller, but to ditch as much of the physical circuitry as possible and digitise it. In other words, turn it into pieces of computer software. Certain parts of radar still need to be a physical component. The power amplifier, for example, might be reduced in size but not digitised. But a lot of the sensitive circuitry could be converted to digital and uploaded to a big computer network. And one major benefit of having large chunks of a modular radar system in a digital format is that if you need to upgrade it, or fix something that isn't working, it's much simpler to change some lines of code in a piece of software, which is then uploaded to wherever it's needed, than it is to change the antenna face on a warship at sea.

"Certain parts of radar still need to be a physical component"

LAND AND SEA DEFENCE



COMMANDER
Land-air defence
This long-range tactical radar system can be deployed and moved quickly around combat zones by a trained army unit. It can also be controlled and monitored remotely. It has been used in Iraq and Afghanistan.



ARTISAN
Naval surveillance
Artisan is used for medium-range target designation on Royal Navy ships, as well as air-traffic management on its big aircraft carriers, like the flagship HMS Queen Elizabeth. It can detect objects as small as a tennis ball travelling at over 2,000 miles per hour from over 15 miles away.

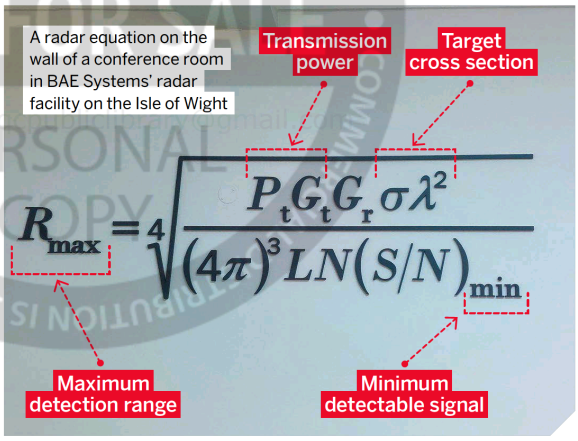


SAMPSON
Multi-function radar
The primary sensor for Type 45 destroyers, this imposing radar system is sometimes referred to as 'the Dalek'. It can track hundreds of targets simultaneously, including objects no bigger than a golf ball as far as the horizon, and provide in-air course correction for homing missiles.

WHY RADAR IS HARD

The word 'radar' is an acronym for 'radio detection and ranging', which makes it sound a lot like the technology used by radio stations to transmit their programmes for reception in home radio systems. But there's one gulf of a difference between these two. Basic radar uses a transmitter to beam microwave signals that are reflected off a target and picked up by a receiver. The energy reflected back to the receiver can be calculated with a radar equation that factors in variables such as transmission wavelength and target cross section – but it all boils down to the same limiting factor: the amount of energy received from the target is a tiny fraction of the energy required for transmission.

If you want to detect a small target at a long range, you'll need to put a huge amount of energy into the transmission. A commercial radio station might use 100 kilowatts of power, whereas a long-range military radar can transmit in pulses that are 20 or 30 times that – easily into the megawatt range.



A radar equation on the wall of a conference room in BAE Systems' radar facility on the Isle of Wight

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TECHNOLOGY



An engineer calibrates the turning unit of an Artisan radar on the workshop floor

A WHISTLE-STOP TOUR

The building that houses BAE Systems' radar facility isn't exactly labyrinthine, but there must be miles of winding corridors and staircases spanning multiple levels – plenty enough to get lost in. Given the company's military contracts, security is unsurprisingly tight, so we weren't able to go anywhere without an escort, not even to the toilet. There's a strict no unauthorised photography regulation in place over most of the interior, and some places were completely off limits to us. Other parts of the building, such as the Test Room, required everyone to place all their electronic devices into a locker before they could enter. Out of an overabundance of caution, some staff did not want to be identified.

Despite these restrictions, we were still given an incredible level of access to the facility, starting with the shop floor. This is effectively a large warehouse with a high roof to allow BAE Systems' big radar to be assembled and worked upon by dozens of mechanical engineers. An imposing Commander array periodically spun on its turning unit at the far end, next to a freshly painted Sampson. Near the gallery where we stood, a man in a white coat and gloves carefully applied something to a large metal radar mount. He could have just been greasing the steel bolts around its circumference, but this seemingly simple job was much more technical than meets the eye.

A short walk around the perimeter of the workshop took us to one of the most fascinating places in the whole facility: the anechoic test chamber. This room is taller than it is wide to accommodate the biggest radar in BAE Systems' armoury for near-field testing. The walls and ceiling are covered with carbon-fibre foam spikes that prevent any electromagnetic echoes reverberating off flat surfaces. That also stopped the sound of our conversation dead, nearly as soon as it had left our mouths. The small adjoining antechamber wasn't much bigger than a garden shed, yet it had more of an echo than this enormous room, which was a very surreal experience.

Did you know?

Artisan radar can cost over £4 million ($5 million)

DEADLY REMNANTS

Although BAE Systems has only been at the Cowes facility for the last few decades, the site has a defence history that dates back to the early 20th century. A civil aerodrome was established in 1915, which was commandeered by the War Office for testing amphibious aircraft in World War II. Towards the end of the war, the Canadian Navy was stationed at the site in preparation for the D-Day landings, and they had a plan in case the Nazis mounted a successful invasion of the island: they booby-trapped the site with pipe mines. When the Canadians left, they destroyed all their sensitive documents, including a plan that showed the location of all the buried bombs. Over the years since the closure of the airfield in the 1950s, most of the pipe mines have been found, defused and removed.



An amphibious aircraft at Cowes aerodrome in 1930

BLIPS ON THE SCREEN

Martin Widgery, future maritime technical lead at BAE Systems' Maritime Services, tells us where radar technology is going next

What can modern radar do that old generations of radar can't?
Modern radar is able to second by second, millisecond by millisecond, decide where they're going to look next, what they're going to do in order to cover the search space they need to cover, but also maintain more information on anything of particular interest or threat. That can quite often mean deciding to spend more time and energy interrogating a target of high priority in order to identify it in detail, determine whether it's a threat and provide high quality track information to support its interception. That's the business we've been in for 30 years – those radar have been gradually surpassing the previous generation.

Why do we need even better radar?
The primary thing that's driving the need to go from the current generation to the future more than anything is the emergence of faster, smaller threats, including ballistic and hypersonic missiles. Their increased approach speeds demand earlier detection at greater range, which in turn demands increases in radar power. In addition, radar must now also address a broader variety of threats, including drones and surface craft, that they did not previously have to deal with, often in highly cluttered environments where such targets can be far more difficult to separate from natural returns, moving or otherwise.

There is now also far greater need to operate in environments that are

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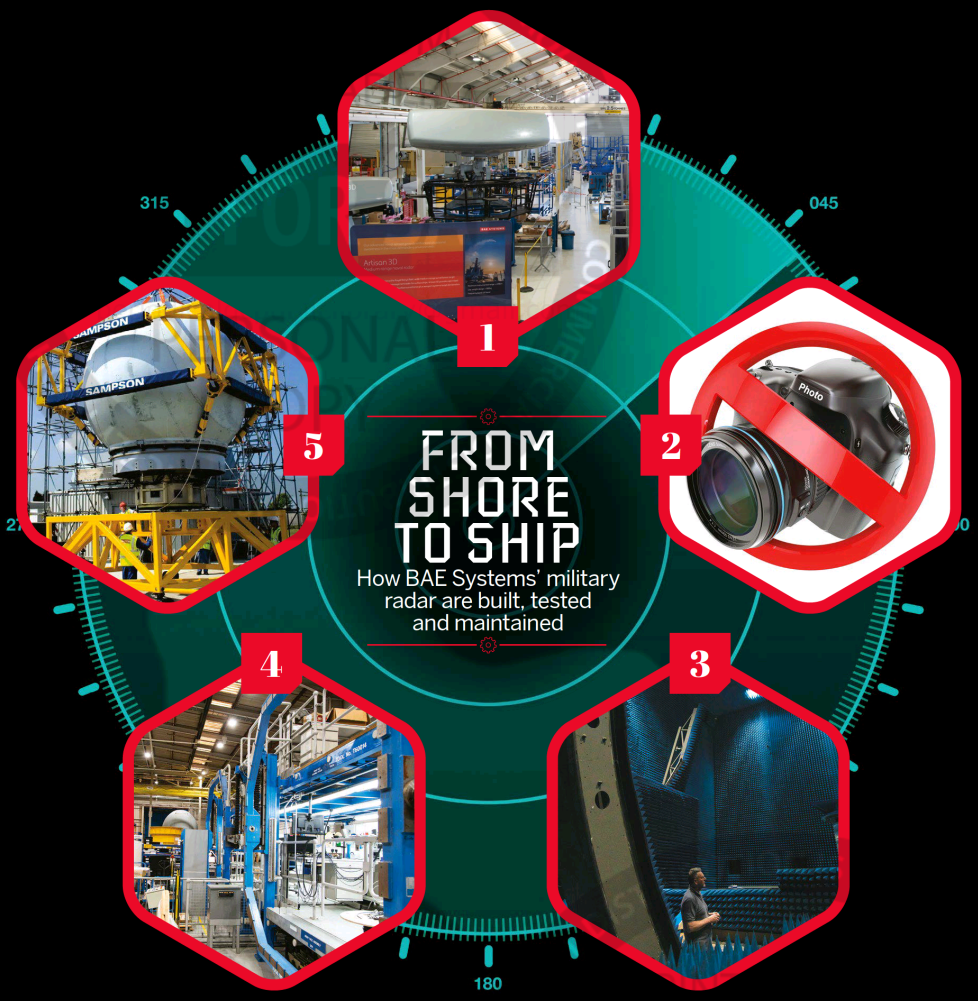
DID YOU KNOW? Artisan can 'see' through noisy radio interference equal to 10,000 mobile phone signals



1 WORKSHOP
Many of the components for a radar system are built off-site, but they are assembled in the Cowes facility. Here, mechanical engineers test the moving parts on stabilised turning units.

2 SAMPSON TEST ROOM
A small room is set up to test the Sampson radar that will eventually be installed on Type 45 destroyers, with computers arranged in similar positions as the stations you'd find in the control room. It's a strict no-photography zone.

3 NEAR-FIELD TEST FACILITY
A large anechoic chamber is used to calibrate big radar, with enormous double-entrance doors to allow access to the six-tonne Sampson. A huge half-circle track allows a probe to run in a 270-degree arc around the radar, which makes the chamber look a lot like the black hole drive from the 1997 sci-fi horror film *Event Horizon*.

4 BUILDING 30
Access to the anechoic chamber is via this building, which is used for building and installing radar array modules, as well as Sampson assembly and maintenance, before they are moved into the near-field test facility on hover pads.

5 RADAR INTEGRATION TEST FACILITY
Prior to mounting on their respective Royal Navy vessels, the radar are lifted onto test towers outside, connected to the computers in the Sampson test room and put through a battery of tests.

ambiguous, with increased potential for confusion with neutral targets demanding increased radar measurement fidelity to assist identification.

What more could radar do in the future?
There is now a lot of drive to take all the platforms we've got in a fleet, and maybe some of the land radar in the area that they happen to be operating in, network all that information and combine it to derive a much improved common picture shared across the wider force. You've got the individual sensors and weapons, you've got the combat system on the ship that joins all that together. And then there's a layer of networking between ships that is shared between nations across NATO generally. It's cross-platform integration, allowing ships in, say, a carrier group to share information at a lower level than they do now. Where we are now is a Typhoon aircraft might detect a threat, pass a warning, the ship will go and look for it, find it and use it.

In the near future, the enhanced networking of sensors and shooters will provide the ability for the aircraft to be able to see something, perhaps even over the horizon from the perspective of the ship, and for the ship to be able to shoot at it based solely on information from the aircraft. That's where we're headed.



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