BE AFRAID OF THE DARK

THE F-15E STRIKE EAGLE STORY

PART 1: 1978-2002

SERIAL:__________

10 PERCENT
TRUE


Spirit of
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0197

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INTRODUCTION

In 2001, I met the commissioning editor of the world's largest aerospace publisher at a sleepy pub somewhere in the English countryside. He was an old school editor and this was the place and the manner in which business was done in those days.

I'd cold called him a few weeks earlier to pitch a book idea, and now it was time for him to properly assess the viability of the project over a Ploughman's lunch and pint or two of IPA.

The pitch was simple: the F-15E Strike Eagle had spent the last decade building a reputation as the world's most capable multi-role fighter, but no one had yet written an in-depth monograph about it. Moreover, people were fascinated by the Strike Eagle and wanted to know more about it.

And so, with the supply-and-demand argument made between mouthfuls of bread, cheese and Branston pickle, the editor seemed satisfied that the title was worth commissioning. We celebrated with another pint of IPA.

Buoyed by getting commissioned, I started my research at Boeing's archives in St. Louis, Missouri. Boeing rolled out the red carpet, lined up unfettered access to their unclassified archives, and brought in a range of retirees for me to interview. At my disposal was one of their historians, and while I gave him a shopping list of source material I wanted, I trawled through catalogues of brochures, press cuttings and images. From this endeavour, the first two chapters of this book were born.

Next, I headed to Seymour Johnson and Mountain Home air force bases, sitting in on briefings, interviewing aircrew who had just come home from the war on terror in Afghanistan, and generally soaking up the experience of being a fly on the wall. At that time, these fighter squadrons were grappling with how to use new tools and develop new tactics to take on a new and asymmetric enemy. I still feel fortunate to have been in the right place and the right time to capture this part of the F-15E's history, and to have seen it unfold in real time.

Finally, I returned home and spent time at RAF Lakenheath, where two squadrons of the dark grey jets sat guard over Europe. There, I did yet more interviews, flew the sim and spent time photographing squadron life.

The result of that year-long research effort was this book.

I never intended to become a writer - I always though that this book was going to be an itch that needed scratching only once. Turns out I was wrong. It should really not have been a surprise, though. I had spent my childhood devouring everything written by the likes of Bill Gunston, Randy Jolly, Ted Carlson, Tony Thornborough, Peter E Davies, Paul Crickmore, William Smallwood, Mark Berent, Stephen Coonts, Robert Wilcox, and many other talented writers besides.

I was fortunate to meet Paul Crickmore and to receive advice and guidance from him early on in my career. Likewise, I was taken under the wing of Paul E. Eden, the most talented aviation editor you've never heard of. I am grateful to them both for helping me so much.

Now, almost 25 years later, this book has become "Part 1" of the Strike Eagle story. At almost 100,000 words, it tells the story of the Strike Eagle up to Suite 3E and approximately 2002. Just bear in mind that the quotes and references in the text are all from that time frame: what people say in this text are the things that were true, or they believed to be true, at that point in time.

So, pour yourself a drink, find somewhere quiet and comfortable, and enjoy reading this tribute to the world's greatest multirole fighter.

Best wishes

Steve Davies
Cambridge, England
June 2025

PS: Don't forget to visit *10percenttrue.com* to grab your copy of Part 2!

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Thank you to each and every one of you for putting your faith in me, trusting me to deliver, and giving me the support I needed to get this book into print. Without you, it would not have been possible.

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OPPOSITE
335th FS Chiefs F-15E over North Carolina. Note the mission markings from its combat exploits over Afghanistan. (Author)

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DEVELOPMENT

Strike Eagle Beginnings: 1978-1980

In 1978, the United States Air Force (USAF) issued a study to evaluate an airframe that would initially supplement, and then replace, the General Dynamics F-111 Aardvark. It was called TAWRS – Tactical All Weather Requirements Study.

The F-111 had been developed initially as a dual role fighter-bomber for both the Air Force and United States Navy, although the Navy eventually left the program when the F-111's weight spiralled beyond the acceptable limits for an aircraft carrier landing.

Featuring a Texas Instruments terrain following radar, variable wing sweep that sequenced according to altitude and speed, a Ford Aerospace AN/AVQ-26 Pave Tack FLIR (Forward Looking Infra Red) pod and two Pratt & Whitney TF-30-P100 afterburning turbofans, the F-111F was perhaps the ultimate incarnation of the design. It was capable of blistering performance at low level, in all weathers, night or day, and of carrying a range of precision guided or tactical nuclear weapons deep into Eastern Europe.

The Soviet Union and the Warsaw Pact had always lagged some ten or more years behind NATO countries in most areas of technological advance. By way of addressing this imbalance, the Soviets concentrated on producing hardware in quantity. Clarence "Lucky" Anderegg, a veteran of 170 combat missions over Vietnam, summarised: "…we faced the spectre of the next war coming in Europe against the Warsaw Pact, which outnumbered us two to one. We called the Soviet and Soviet trained pilots 'Ivan', and sometimes Ivan seemed ten feet tall".

NATO predicted that a conventional attack into Western Europe by the Soviets would be of such size and vigour that there would be little point in attempting to repel it head-on. Instead, planners addressed this by using airpower to target the logistics supply chains of the enemy – POL stations (petrol, oil, lubricants), bridges, motor pools, railway yards etc. This so-called Follow-On Forces Attack (FOFA) was designed to choke the enemy by denying him re-supply. Inevitably, the planners argued, the Soviet attack would grind to a halt, deprived of the oxygen of war – ammunition, fuel, water, food, medical aid – at which point, cut off and without reinforcements, it would be decimated by NATO forces that had quickly deployed to the area from further afield.

The F-111 was an ideal platform to accomplish this. It had extensive range and could carry many tonnes of bombs to even the most distant European choke points. The Pave Tack pod, which offered a combined FLIR tracking system and laser designator, gave the F-111F a fully autonomous precision guided munition capability, allowing it drop highly accurate laser guided bombs (LGBs) within a few feet of the target.

On the downside, USAFE (USAF Europe) had only two Wings of F-111s with which to respond to any attack. Although each was assigned seventy or so aircraft, only one Wing, the 48th TFW, RAF Lakenheath, operated the F model. And that led to the legitimate concern that there were simply not

OPPOSITE

The F-111F was the mainstay of the FOFA attack concept and was a key component in NATO's arsenal. (USAF) enough airframes to get the job done.

To complicate matters, Soviet fighter radars were becoming better able to detect targets amongst ground clutter, which was precisely where the F-111 planned to hide. So, with the Aardvark looking more and more vulnerable to air attack, NATO strategy had to evolve. TAWRS, it was hoped, would provide the answer.

McAir and the F-X Program – the 1960s

Ten or more years before TAWRS, McDonnell Douglas Aircraft Corporation (MDC) had entered a military tender process to replace the F-4 Phantom II – one of their most successful designs. The Phantom had begun to show signs of its age, and the Air Force knew that a replacement would have to be found.

A study, followed by a lengthy tender process had begun in 1965. Called F-X, or Fighter Experimental, it had concluded in December 1969 with McDonnell Douglas being awarded a contract for what would become known as the F-15 Eagle.

The F-15A/B

F-X was influenced heavily by well documented lessons learned during the war in Southeast Asia. It was also procured in accordance with mandates laid down by US Congress. To that end, the Air Force was compelled to purchase a fighter that featured not only good air-to-air characteristics but also a modicum of air-to-ground capability.

Despite staunch resistance to what many saw as unwarranted congressional interference, the F-15 was designed to carry an extensive range of unguided and guided air-to-ground weapons, and provisions were made to equip it with an Electro Optical (EO) or Infra Red (IR) sensor for visually cueing the radar or guiding weapons.

It was also equipped with an advanced fighter radar – the Hughes AN/APG-63 – whose unparalleled air-to-air capabilities were complemented by air-to-ground modes such as the Real Beam Mapping (RBM) mode. RBM would allow the pilot to locate and designate ground targets for attack, day or night, good or bad weather.

An air-to-ground Ranging (AGR) mode was also available and this worked with the Continuously Computed Impact Point (CCIP) air-to-ground attack mode to project a thin bomb fall line onto the pilot's Heads Up Display (HUD). The line represented the path that a bomb released at that moment in time would follow, and a pipper circle at its base represented the point it would impact the ground. Both were continually updated based on speed, altitude, height and range to target and allowed the pilot to visually sight a target, fly the pipper over it and release his bomb(s) with good accuracy.

CCIP contrasted with previous iron sight bombing techniques that used fixed reticules. These typically required the pilot to precisely plan and then execute an attack that offered little room for error or deviation from pre-planned parameters such as height above the ground at the point of release, airspeed, angle of dive or winds aloft. CCIP released the shackles, providing a quick reaction, target of opportunity capability.

The F-15 also ushered in less obvious technological advantages over previous aircraft. It featured redundant hydraulics, fuel and electrical systems as well as engineering improvements that reduced its weight, the number of components, sub-components and access panels. Mean Time Between Failure (MTBF) for many components was dramatically reduced over the F-4 and maintenance times were greatly reduced thanks to the incorporation of 'black box' Line Replaceable Units (LRUs). The design goal for an engine change in the F-15 was twenty minutes, but McAir managed to bring that down to fifteen minutes. By contrast, changing an engine in the Phantom was an all-day affair.

Once the full specification F-15A had been produced in the early 1970s, the Air Force effectively consigned the F-15's 'mud moving' mission the bin. With the notable exception of a few specialised units, most F-15 squadrons only ever operated the F-15 as an air-to-air fighter.

Multi-Role Roots

McDonnell Douglas had a lengthy and proud history for producing multi-mission airframes, starting in 1947 with the strike-, fighter- and reconnaissance-capable F2H Banshee. From there, McAir, as it was known colloquially, continued to develop airframes that could be adapted to suit the secondary needs of their customers.

Of these remarkably adaptable designs, the F-101 Voodoo and F-4 Phantom are instantly familiar. The Voodoo gave the US Air Force an intercept, photo reconnaissance, fighter escort and fighter-bomber capability at minimal cost. The much-vaunted F-4 Phantom was similarly versatile.

Following the F-X contract award of December 1969, McAir engineers continued to evaluate concepts for different F-15 use cases. Of the studies looked at, the most successful and, ultimately, key to the Strike Eagle concept – as yet unborn – was the FAST pack.

ABOVE
McDonnell Douglas' Strike Eagle concept was built on the shoulders of the hugely successful, air-to-air orientated F-15 Eagle. (Author)

Fuel and Sensor Tactical packs were the brainchild of an experienced engineer working in the Advanced F-15 Design engineering team, Frank Laacke. They consisted of aerodynamically shaped fuel tanks that slotted in flush between the lower surface of the wing and the side of the engine intakes.

Laacke explained:

> We started out with the F-15 being a supersonic interceptor. With external fuel tanks on you lose a lot of acceleration capability. Therefore, we needed to come up with another way of carrying fuel. We played around with a number of ideas, but finally settled on the concept of FAST packs.
>
> They provided reduced supersonic drag and a very small amount of subsonic drag. They also had very little effect on stability. As they evolved the Air Force lost interest in extending the range of the jet as an interceptor and we started to look at FAST packs for increasing ferry range and carrying bombs.

Great effort was expended making FAST packs as easy to work with as possible and set times for installation and removal of the system from the jet were worked to and achieved.

It took McAir one year to take the concept from the drawing board to fitting the system to an F-15 airframe, including six months to build the prototype.

The main challenge was to create an effective seal between the aircraft and the pack. A vulcanised rubber seal was chosen, but the system was never perfect and some small gaps between the two were inevitable.

FAST packs started out with a maximum fuel capacity of 4,000lbs, a figure that would swell dramatically to 9,800lbs as the packs increased in size. To achieve this, a more pronounced bulge was built into the pack without changing the basic mould line. The increased bulge was tested to evaluate its effect on performance, and the results were found to be negligible.

The team also evaluated other locations for fuel packs to be attached. One was in the form of a slipper tank beneath the fuselage, but there were too many problems caused by landing gear and missile placement to make the design practical.

The packs were placed fairly close to the F-15's centre of gravity and therefore did not pose a significant problem to the stability of the aircraft. However, to maintain equilibrium, each pack was divided into three fuel cells, each of which would have its own fuel transfer schedule. Governed by float sensors in each cell, a built-in control box would run the schedule, although there was concern as a pump failure could cause an extreme CG condition.

Structurally speaking, FAST packs were strong enough to carry a wide variety of air-to-ground munitions without any additional modification, although structural alterations were required to the mounting points and airframe of the F-15 to cope with the additional weight. The real test that Laacke and the other engineers on the Advanced F-15 Concept team faced, was to keep drag coefficients at a minimum once bulky weapons were loaded:

> Initially, we didn't pay much attention to it [drag] and it was not part of the design evolution. Later, the problem was, 'OK, how do we get them off now that we have got them on?'. They [stores] had a tendency to float as they were released.

'Floating' weapons were a hazard during testing as they sometimes bounced off the pack as they stalled in the highly disruptive airflow around and behind them. There were occasions when munitions were released and would immediately bounce back into the aircraft. Some of these problems were solved by changing the shape and attitude of the pylons on which the stores hung, others could only be solved by placing limitations on the speed, delivery angle and types of weapons which could be released from certain pylons at certain portions of the flight envelope.

Inside each fuel cell were fire retardant slabs that had been extensively analysed through computer simulation and were designed to prevent an explosion if a tank was pierced or damaged. These slabs took some of the energy away from the impact whilst also preventing the build of static electricity by restricting fuel movement. They also raised the ignition temperature of the fuel vapour.

Heat exchanger exits at the back of the airframe interfered with the installation and operation of the packs, and some minor re-design was necessary to allow the two to co-exist. A small duct was installed to get the heat away from the fuel laden packs. Additional redesigns included moving and changing access doors that became inaccessible once the FAST pack was installed.

As the core design of the FAST pack gained momentum, McAir looked to quietly develop the concept further. They proposed a Wild Weasel variant of the F-15 with FAST packs that would carry radar warning sensors, ECM jamming equipment and anti-radiation missiles with which to destroy hostile radar systems. And they offered a reconnaissance version that would see FAST packs crammed with camera and sensor equipment. Other concepts included mounting rockets on them as a form of Rocket Assisted Take-Off, and a Strike Assist combination housing a FLIR or Low light Level TV (LLTV) turret in either pack.

Unsurprisingly, the Air Force lacked interest in all these designs, but they very much liked the FAST pack concept for carrying fuel and so ordered that all production F-15Cs should be capable of carrying them.

Undeterred by the knock back of the alternative Eagle variants, McAir set to work developing the air-to-ground capabilities of the F-15. Meanwhile, the FAST pack would evolve into the Conformal Fuel Tank (CFT).

Creech

General Wilbur Creech was commander of Tactical Air Command from May 1978 to December 1984. This was a difficult period for the command. TAC sat in the shadow of Strategic Air Command and its bomber Generals. Sortie generation rates were at an all-time low. Aircrew regularly falsified flight records to satisfy rules and regulations concerning minimum flight hours, combat efficiency, and bombing accuracy. Intimidation and aggression were the tools of rule and order.

Creech was a visionary leader though. Through incentivisation, high profile dismissals of those not toeing the line, and his own audit of the non-commissioned ranks, he increased morale, introduced the Crew Chief system (whereby a deserving NCO would be given 'ownership' of his own aircraft), reversed an endemic soft drugs problem, and eradicated the slovenliness that permeated many TAC air bases.

A former leader of the Thunderbirds display team and Director of Operations at the Fighter Weapons School, he was a fighter pilot known for his acumen and his attention to detail.

Creech recognised the Air Force needed an advanced fighter bomber that could operate along similar lines to the F-111 – on its own and without the need for an entourage of missionised escorts to accompany it to the target.

His own experience in Vietnam led him to believe that the F-111 was a capable platform in many respects, but he knew it would struggle against the rapidly evolving family of Russian MiG and Sukhoi fighters.

By way of confirmation, "JJ", a former F-111 pilot and later F-15E pilot, explained:

> We could carry two AIM-9 missiles in the F-111, but the radar was really optimised for air-to-ground. We sometimes practised using the Sidewinders, but it was a primitive form of defence to say the least. There was no way we could know who the missile had locked up, and our only indication that it was looking at anything was the [missile's] growl in our headsets!

Creech was familiar with the company-funded, extracurricular work being conducted on the air-to-ground capabilities of the F-15 at McAir. McAir had dubbed this the Strike Eagle, and Creech was very interested in it. Protocol prevented him from approaching the company in any official capacity, so he was vocal in his support of their continued work and unofficially advised them that the Air Force would be receptive to a proposal.

In fact, the Strike Eagle concept was so compelling that it would form the basis of the TAWRS paper.

Requirements

TAWRS would eventually be renamed Enhanced Tactical Fighter, and then Dual Role Fighter in 1982, but the minimum expectation remained unchanged: the winning airframe had to offer an improvement over the F-111F, particularly in inclement weather at night.

The F-111F's AN/AVQ-26 Pave Tack pod would prove its worth in the 1986 raid on Libya (Operation El Dorado Canyon) and would play a major role in elevating the F-111F to the top spot for accuracy and ground kills during Operation Desert Storm in early 1991.

The pod could be tied to the radar or operated independently and gave the WSO (Weapons Systems Officer) a monochrome thermal image of the target. With the target sighted, the WSO could refine the aim point using a small hand controller mounted to his right, then fire the built-in laser to both range the target and guide one or more LGBs onto it.

McAir knew it had a strong offering, but it was not without potential shortcomings. One of these was combat range. TAWRS stipulated a similar range and penetration capability to the F-111 because many of the key choke points in the Warsaw Pact's logistics chain were situated deep inside Eastern Europe. The F-111 could haul a 6,000lb loadout over 1,000nm. This put 30% of NATO's pre-planned targets within its reach.

However, the F-15 was significantly shorter legged than the F-111, and whilst FAST packs gave an additional 9,800lbs (1,446 US Gallons) of fuel, it would still be limited to an effective combat radius of only 680nm: 30% less than required.

Another was concern about the F-15's low wing loading. Wing loading is a term used to describe, in a rough sense, the lift-to-weight ratio per square meter of wing surface area. High wing loading results from a small wing (F-104, for example), while low wing loading indicates a large wing. Each has its own performance characteristics.

The F-15 had been built with a low wing loading to permit sustained high-speed operation with a limited fuel consumption penalty. It meant the aircraft operated well at medium and high altitudes where the air was thinner, but it delivered a bumpy and turbulent ride at low altitudes during high-speed cruise – precisely the domain in which the Strike Eagle was expected to spend much of its time. Conversely, the F-111 had a higher wing loading, which dampened turbulence at low level and gave the crew a very comfortable ride, and a wing sweep system that allowed the jet to hug the ground and accelerate up to 800 Knots without any noticeable change in handling characteristics.

Advanced Fighter Capability Demonstrator: 1980-1982

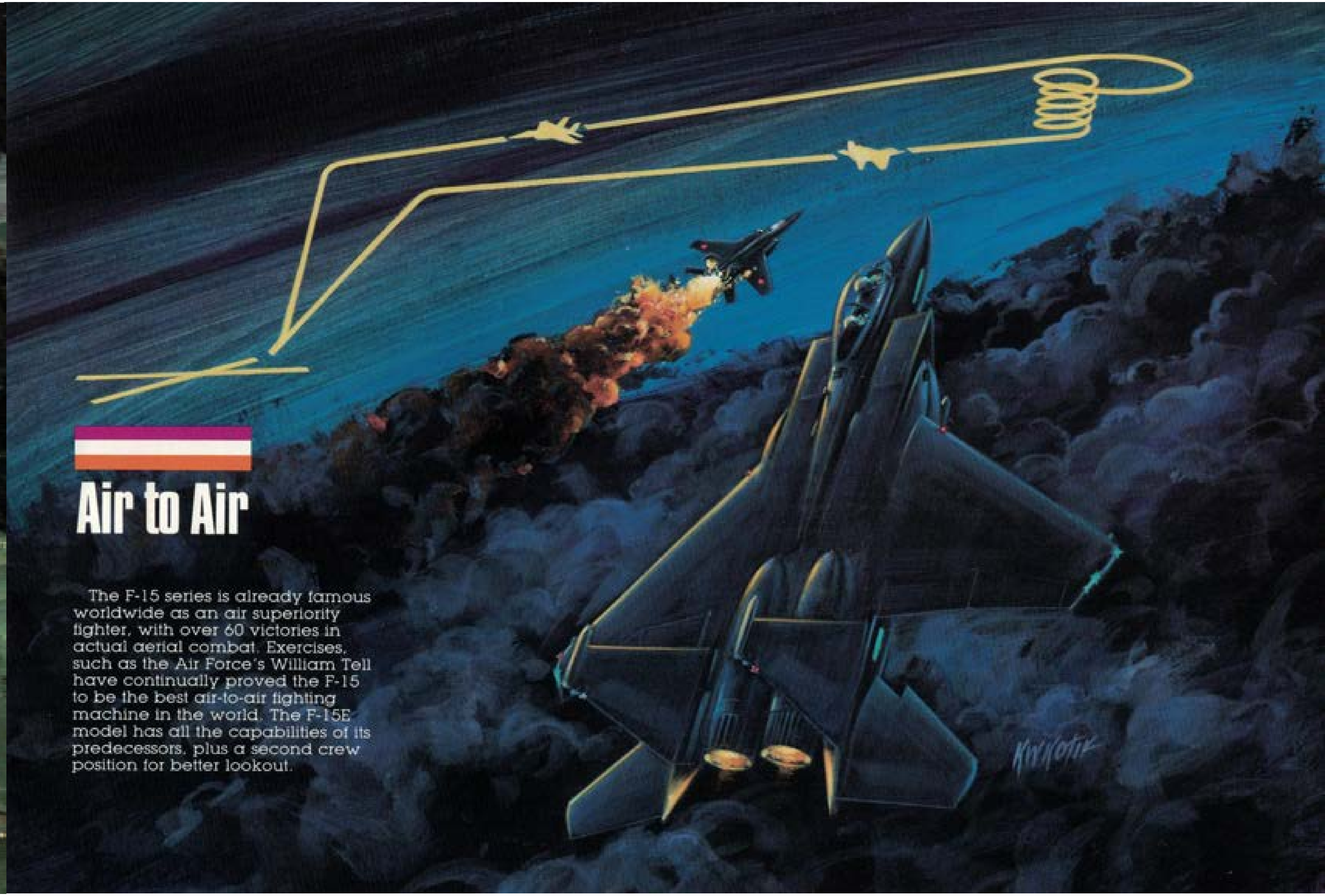
In 1979, McAir had teamed with Hughes, maker of the revolutionary APG-63 radar for the F-15A/B, to produce an Advanced Fighter Capability Demonstrator (AFCD). They used F-15B 71-0291 (formerly designated a TF-15A) for the AFCD platform.

Now, with the Air Force expressing confidence in the Strike Eagle concept, the demonstrator was developed further.

FAST packs with a single hardpoint along the centre were installed onto 291, and it was painted in a European 1 green/grey camouflage scheme; all the better for forming a mental association with both its intended mission and its intended theatre of operation. It first flew on 8 July, 1980, at around the same time Laacke and his colleagues had begun to

Air to Surface

Since the F-15E's primary mission is interdiction, it has outstanding air-to-surface capabilities. First, it can carry a large quantity and wide variety of ordnance. Second, it can navigate at high speeds and low altitudes across any terrain, brushing the nap of the Earth to avoid detection by enemy radars. Third, it can find its targets and hit them with accuracy in any conditions. This requires systems that see through overcast and darkness.



Air to Air

The F-15 series is already famous worldwide as an air superiority fighter, with over 60 victories in actual aerial combat. Exercises, such as the Air Force's William Tell have continually proved the F-15 to be the best air-to-air fighting machine in the world. The F-15E model has all the capabilities of its predecessors, plus a second crew position for better lookout.

refer to FAST packs as CFTs.

The two-seat F-15 offered the ideal platform for the deep strike, precision guided role. With a weapons systems officer occupying the rear cockpit, there would be someone to concentrate exclusively on target acquisition and sensor operation during the attack phase of the flight. And, because the B/D model was almost identical in capabilities to the A /C model, it remained a potent air-to-air fighter.

The Eagle had been built with an advanced mix of avionics. The Heads Up Display (HUD) contained information pertaining to the aircraft's attitude, airspeed, altitude, angle of attack, and a range of similar information. This allowed the pilot to keep his eyes out of the cockpit for longer periods of time as he no longer had to reference dials and displays mounted below his glare shield. During combat the HUD could display weapons launch parameters and missile timings.

Its Hands On Throttle and Stick (HOTAS) came thanks to a McDonnell Douglas engineer who, recognising that the dozen switch selections necessary to launch a missile in the F-4 Phantom was not conducive to dogfighting scenarios, had designed a system that allowed the pilot to make critical selections almost unconsciously. It consisted of a combination of switches and buttons mounted on the control stick and throttle that allowed instant access to weapons and sensors without having to move hands around the cockpit or look inside to locate a switch or dial. Switches were given different shapes, sizes, movements, positions and textures to allow the pilot to manipulate them by feel alone. Learning HOTAS took time, but once mastered it conferred the ability to swiftly target, select a weapon and engage the target.

The Eagle's pilot sat beneath a large bubble canopy that afforded a 360° view in azimuth around the aircraft. His shoulders were sited way above the canopy rail and the bulbous Perspex even allowed some visibility downwards. It was a tremendous change from the heavily framed canopies of previous fighters.

Finally, the APG-63 from Hughes was a high frequency, pulse Doppler attack radar designed primarily for air-to-air combat. Consisting of modular Line Replaceable Units (LRUs), it was rammed with new radar search and track modes with which to find, fix, target and track other aircraft. A passive Sniff mode allowed emission control without having to turn off the radar, and Electronic Counter Counter Measures (ECCM) circuitry that automatically reconfigured the radar to deal with jamming attempts. Once ready to engage, a Flood guidance mode allowed the AIM-7 Sparrow to track and intercept its target.

For close-in combat, a host of Auto Acquisition modes would lock onto the first target detected within 10nm in a dogfight.

To top it all off, the radar featured a non-cooperative target recognition capability and the aircraft was built with a device (ALQ-128) that could spoof the IFFs of threat actors into responding. These once-highly classified capabilities gave the pilot the ability to identify other aircraft autonomously.

OPPOSITE
F-15B '291 first flew in July 1980. She is seen here with early CFTs and light grey colour scheme. (Boeing via Author)

The First Missionised Cockpit

McAir made the decision early on to modify the AFCD's cockpit, which was until then very similar to a production-standard F-15B. They installed four cathode ray tube (5" and 7") displays in the rear cockpit, leaving the front cockpit largely untouched.

The displays were driven by a Multi Purpose Display Processor (MPDP), the first time such a system had been installed in a flying test bed. CRTs could cycle through 'pages' of data, such as configuration, Built in Test, navigation menus, Tactical Situational Display (TSD), radar etc. Later in the program, new pages were added to display target pod imagery, threat warnings, aircraft systems information, and so on.

The pilot's 3" radar display, which was standard equipment in the F-15 front cockpit, was also rigged to take data from the MPDP so that he too could cycle through the pages available to the weapons system officer in the back.

The TSD was an INS-driven moving map like that found in the F-111 and Panavia Tornado strike aircraft. Maps were stored on microfiche and fed into a projector prior to flight, although the technology at the time limited the quality of the maps produced, and they lacked topographical information and were simply composed. Once the INS was aligned, the TSD would overlay a range of data and accurately reflected the aircraft's current position. One observer who flew the aircraft in 1981 commented: "The operator's first reaction is the pleasure of knowing where the aircraft is". Even at this very early stage, the TSD was proving a hit, and in the years to come it would be revised to make it even better.

To make full use of this map and the proposed Synthetic Aperture Radar (SAR), the AFCD also had its Litton LN-31 Inertial Navigation System re-programmed to offer a 500% increase in velocity update rate, although this modification did not make it any more accurate.

A new 1553 multiplex data bus was also installed to allow data to continuously pass between the many new systems without interruption.

To help control the equipment, McAir installed a data input panel in the rear cockpit. This would eventually be called the up front controller (UFC) and while primitive to look at in its early incarnation, it too would receive considerable modification before the aircraft entered service. It was simple in design, featuring a backlit alphanumeric key pad through which data could be entered into very nearly all aircraft systems.

The F-111's tandem seating arrangement offered the advantage of allowing the WSO to visually cross-check the pilot's control and switch settings, but it also featured a radar hood into which the WSO buried his head to view the radar scope or FLIR imagery. While 'heads down', he was thus denied the ability to view the TF scope, or radar warning receiver (RWR) display, the latter of which told the crew if they were being scanned or targeted by radar. By contrast, the new set up allowed the WSO better situational awareness and was geared towards allowing him to glean as much targeting and attack data as possible in a single sweep of the eyes.

McAir mounted an AN/AVQ-26 FLIR turret on the left CFT. By this time, the USAF had started funding its replacement. Pave Tack weighed 1,227lbs and was almost 14' long – too large and heavy for future requirements.

A new radar was also in the works, courtesy of Hughes. Assigned the designation APG-70, it would build on existing technologies from the APG-63 radar set but, crucially, be optimised for the air-to-ground mission. That meant a number of things, but none more important than the development of a SAR mode with which to map and designate targets, as we will see later.

To allow the WSO to operate the systems as efficiently as possible, McAir fitted '291 with left- and right-hand controllers (LHC and RHC, respectively). These joystick-type devices were mounted either side of the ACES II ejection seat and offered the backseater a WSO-optimised HOTAS: switches and buttons to manipulate radar, FLIR and weapons, allowed him to remain focused on the task at hand even during turbulent or high G manoeuvring. The demonstrator featured the LHC mounted outboard of the throttle quadrant, although this was moved inboard of the throttles on production models.

All in all, it was a great setup. Gary Jennings, McDonnell's chief test pilot for the Strike Eagle, recalled:

> It was about the time that we had installed these seven-inch displays in the back when one of our competitors [General Dynamics] released a paper which proclaimed that five inches was the optimal size for CRTs in fighters. It made us laugh. We knew that the only reason they had reached this conclusion was because they didn't have enough space in their cockpit [F-16] to fit anything larger in! The truth was that the larger the display we could fit in the cockpit, the better. Gene Adams, who could put himself into a pilot's shoes better than anyone else I ever knew, was the father of the original F-15 cockpit, the superb F/A-18 cockpit and then the E model cockpit. It was a bit of a tear jerker really. Gene always said that the F-4E could have had the F/A-18 cockpit – I had spent so much time in combat in the F-4E wondering what my back seater was doing and what he was looking at. So, one of the things I wanted to make damned sure of in the F-15E was that both cockpits were mission capable.

Overall, the AFCD cockpit arrangement was a significant improvement on previous designs, although it too would change significantly in the eight years that would elapse before the first production F-15E rolled off the production line.

Farnborough Debut

In 1980, F-15B '291 made its debut appearance at the Farnborough International air show, suitably equipped with twin Multiple Ejection Racks (MERs) and a range of inert weapons.

No stranger to Farnborough, '291 had visited in 1974 when it had demonstrated the utility of FAST packs by flying 3,036nm, unrefuelled, from Loring AFB, Maine, at an average speed of. 86 Mach. Six years later, and in the hands of McAir's chief pilot, Pat Henry, the aircraft flew daily displays that consisted of high G loops, Cuban-eights, and a host of other manoeuvres all designed to demonstrate that the performance impact of FAST packs was negligible. However, despite significant modifications, production standard CFTs were still three years away from development and testing.

Among the weapons on display were the AGM-88 HARM (high-speed anti-radiation missile), AGM-65 Maverick, 30mm gun pod, 500lb BLU-107 Durandal anti-runway bomb, and the Mk 82, -83 and -84 series of general purpose bombs. For good measure, McAir also displayed the Pave Tack pod.

The demonstrator was limited to carriage of MER-200P, VER-200-4 or MAU-12C/A bomb racks on wing pylons and single mounting lugs midway across each CFT. Even so, as McDonnell Douglas' Spirit newspaper later reflected, 24,000lbs of external ordnance could be carried by the Strike Eagle, of which 8,800lbs came courtesy of the packs!.

Perhaps most impressive of all was that all this testing, refinement and development was still being funded straight out of the McDonnell Douglas coffers. It was move that may have been risky in some senses, but it ultimately gave McAir a significant advantage over General Dynamics when the USAF officially announced the Dual Role Fighter (DRF) competition in Autumn 1981.

Volk Field

By the late 1970s, McAir had ramped up flight testing of the Strike Eagle concept and had a development

ABOVE
B-2 first visited Farnborough resplendent in a bicentennial colour scheme. Despite the joviality of the occasion, McAir was putting the foundations in place of what would become one of the world's most successful multi-role aircraft. (Boeing via Author)

centre up and running at Volk Field, Camp Douglas, Wisconsin.

Payday for their CFT development efforts had come when the Air Force ordered CFTs for the F-15C/D as part of the Production Eagle Package (PEP 2000) upgrade, and work now continued to further develop the tanks.

Volk was an Air National Guard training base that lent itself to independent research and development efforts because it was sparsely populated, had limited traffic, was well located and was cheap to use. It was ideal for a contractor such as McDonnell Douglas, which made use of the field, went home and made refinements, then returned to re-test, typically in three-month cycles. Deer season was possibly the only limiting factor for operations out of the base, as local hunters were intolerant of low flying F-15s. McDonnell Douglas consequently planned its testing cycles so that the engineers would be back in St. Louis for the duration of the hunting season.

Tests had also been conducted at Edwards AFB, California, to certify AIM-7 missile carriage on the CFTs, ordered as part of the F-15 Multi Stage Improvement Program II (MSIP). The tests elicited incredulity from the Wing Commander at Edwards: "You're going to launch a missile from a fuel tank?!". This was almost immediately eclipsed by the immortal line: "These two CFTs carry more fuel than an F-16?!".

It was now a natural step for McDonnell Douglas to expand stores release testing to include air-to-ground weapons. Conducted at Volk Field, much of this work was performed as a "risk reduction measure", according to Michael Ludwig, McDonnell Douglas Test Engineer for the DRF competition. In fact, this development phase formed the foundations on which the Air Force would later run validation and testing on the Type III, Type IV and Type V CFT builds, both during and after the Dual Role Fighter competition.

Early proposals centred around using a single hardpoint on the CFT to mount a MER (as depicted at Farnborough), although in truth, this ungainly looking configuration had a detrimental effect on the aerodynamics of the aircraft. Later, following comparative testing between the Strike Eagle and the F-16XL, McAir followed the example set by General Dynamics. GD had developed individual, conformal pylons, onto which a munition could be attached. This approach reduced drag and offered both an improvement in weapons separation characteristics and additional ground clearance.

Volk Field was also home to a concentrated APG-70 radar development effort that predated the CFT. The radar was so immature at this time that Hughes and McAir engineers worked closely in shared laboratories to develop and refine key techniques, such as radar mapping. A small team assembled in a trailer crammed full of telemetry equipment to monitor data, while another trailer at the target complex housed a laser range finder with which they could track '291, flown by Jennings, as it flew past.

BDU-33 practice bombs were first used to test the accuracy of the radar and fire control systems. "We would carry a full load of twelve BDU-33s which would be painted in different colours so that we could identify which bomb had fallen where. We'd go out and dig up the bombs and then stand there, holding a six-foot pole with a reflector on it, while the laser was fired at us to score the accuracy of the bomb fall position. Naturally, we'd face the other way while they fired the laser!"

The development schedule called for extensive testing of the fire control system's automatic weapons release features, across a cross section of delivery profiles and wind conditions. Early tests proved encouraging.

The Air Force stayed in close contact with the team throughout, although had no immediate input into the development cycle as it was still privately funded. McAir was comfortable with their expenditure because they knew that the F-15 already offered a capable, if under-publicised air-to-ground capability. At this time, however, they did not anticipate that they would have to enter into a comparative flight evaluation.

When radar testing was completed, multiple rippled release passes were flown to record weapons separation characteristics and to further demonstrate to the Air Force the tactical utility of real-time, SAR imagery generation. The accuracies achieved were so good that range controllers observing the hits felt it was safe to move closer to the target complexes than had previously been possible.

One of the lead radar engineers paid for his expertise when he lost a bet that the radar was not yet accurate enough to target so precisely that '291 could score a direct hit on a tank turret. The next day, Jennings dropped a single BDU-33 which landed not only on the turret but hit and bent the access handle to the entrance hatch. That evening, he paid his forfeit and ate twelve mussels – a food for which he had an intense dislike – at a local fish restaurant.

McAir always knew that Pave Tack was not

OPPOSITE
The bulky MER and TER hardpoint configuration is evident in this photograph. McAir soon followed General Dynamics and mounted streamlined hardpoints to the CFTs. (Boeing via Author)

going to equip any production Strike Eagle, but they integrated it into the demonstrator to once again prove that the airframe-radar combination was a winner. This integration also reduced costs further down the line and provided an additional layer of risk reduction for the proposal as a whole.

This work was done at Eglin AFB, Florida, and within a short time, the team had matured their new technology enough to allow the radar to hand off a target to the pod with an acceptable degree of accuracy.

Eglin also allowed the crews and engineers, who had by now come to know the lay of the land at Camp Douglas very well, to operate over relatively new and unfamiliar terrain.

A mission systems integration bench was taken to Eglin to allow the team to both make and test software changes to the Pave Tack pod's communication routine in between flights. Ludwig remembered:

> Something that you won't see today was the software engineers we had with us during the de-brief for each flight. We'd talk about the flight and watch the Pave Tack imagery on a TV. Some of the software guys were so cognizant of the software structure that they could say, 'I know what's causing that'. They would walk over to the lab and make a software change there and then, test it on the bench [mission systems integration], and then fly it the next day on the jet. You don't see that kind of thing nowadays, where cycles for that kind of change are in the order of three months.

To add further diversity and challenge to testing, a deal was struck with a small, quiet airport in Andalusia, Alabama. Radar reflectors were placed at certain points on the airport and '291 flew simulated attack sorties against the field, thus avoiding having to pay the USAF for use of their ranges.

All of this testing provided ample opportunity to explore other facets of the demonstrator Eagle, particularly the TSD. Although short of scanned maps in general, range complexes were often scanned in to allow Jennings to stay within their tightly regulated corridors. Initially, range controllers tracking the F-15B would provide directives for turns to keep the jet within these lanes, but as they grew more confident, they stopped issuing instructions altogether. The radar contact representing the F-15B would fly up to the edges of the corridors and then back again, never violating its airspace clearances. '291's crew, of course, were simply flying off their TSD.

By 1980, Jennings had already flown nine weapons release flights at Volk.

The first had involved sixteen Mk 82 LDGP bombs dropped cleanly from a thirty-degree dive in one pass, and the GE 30mm gun pod (GEPOD) being fired in fifteen round bursts and then thirty round bursts.

The second was flown along similar lines, although a dummy Pave Tack pod was carried and the Mk 82 load was reduced from sixteen to twelve.

Subsequent flights followed similar profiles, except for the last flight, where Jennings flew with a Mk 84 2,000lb bomb mounted on each CFT and three 600lb external fuel tanks to simulate the Strike Eagle's deep interdiction capability.

Jennings became the first pilot to ripple twenty-two Mk 82 bombs from an F-15 in the final round of tests at Volk.

The Strike Eagle concept was now more than ready to meet the forthcoming Dual Role Fighter Competition.

Dual Role Fighter Competition: 1982-1984

The DRF competition was announced in October 1981, the same month in which then-president Ronald Regan revived the controversial B-1 project.

The competition started in November 1982 and was headed up by Brig. General Ronald W. Yates, Deputy Director, Tactical Systems, USAF Aeronautical Systems Division. Its purpose was to evaluate airframes for appointment as the USAF's all weather, precision strike fighter. Although foreign aircraft such as the Panavia Tornado were initially considered, significant political considerations made that an impossibility, and the competition centred around just two domestically produced entrants.

General Dynamics had been successful with its small, lightweight fighter aircraft, the F-16 Fighting Falcon. This diminutive jet was part of the Air Force's mix of high- and low-cost fighters, and was designed to do short range, close in dogfighting.

For the DRF competition, GD took the basic F-16A airframe and adapted it to the deep strike role by installing a cranked delta wing and by lengthening the fuselage. Designated the F-16XL (and often referred to as Supersonic Cruise And Manoeuvring Prototype – SCAMP), this radical design showed promise: its aerodynamic qualities were within the realms of those needed to fulfil the role, and its range, payload (15,000lbs) and speed calculations proved to be more than acceptable.

Prototypes in what would have been F-16E and F-16F configurations were produced. These were the single and dual seat airframes, respectively. The single seater first flew on 3 July 1982. Predictably, early flight test reports showed that it handled somewhat differently than the production standard F-16A and provided a much smoother ride at high subsonic speeds.

McDonnell Douglas and Hughes' entry, the Strike Eagle, was headed by Chief Program Engineer, Don Kozlowski, and was almost a finished article by the time the competition was underway, to include the radar. Hughes had delivered an early build of the APG-70 only a few weeks' after 291's debut at Farnborough, although the radar set retained the APG-63 designation at that time.

McDonnell Douglas and General Dynamics both assigned multiple airframes to the competition. McAir chose F-15B AF 71-0291, F-15D AF 80-0055, F-15D AF 81-0063 and F-15C AF 78-0468. The latter three F-15s were flown over a six month period by USAF and McAir test pilots at Edwards AFB, whilst '291 continued to earn her keep as an in-house test bed for McAir and Hughes and was leased back from the Air Force on an indefinite basis. '291 is often referred to as B-2 or TF-2 in the context of the DRF competition.

Air Force Testing

The Air Force selected a cadre of pilots and WSOs who would evaluate the two contenders over a period of around six months. These crews adopted either SCAMP or Strike Eagle as their primary platform for evaluation, but also flew the other entry so that they had at least a little knowledge of both sides of the competition. Even so, data sharing and discussion of test results was strictly forbidden for fear of unduly influencing the competition's outcome.

Dick Banholzer was selected to evaluate the Strike Eagle. A veteran pilot who had already flown the F-4 and F-15A/B/C/D, he was a graduate of the Test Pilots School at Edwards AFB, and had been an Instructor at Fighter Weapons School. He'd also been part of the 422d Test and Evaluation Squadron, which took the Air Force's newest toys and built tactics, techniques and procedures that enabled the warfighter to use them operationally.

"The actual competition was run by the Air Force Operational Test Centre's Col. Dick Tolivar, and in each airframe we had operational pilots and developmental test pilots", Banholzer recalled.

> Perhaps one of the biggest advantages of the F-15E program was that we had some actual hardware with which to evaluate how effective the F-15E might be – we took a D model and hung stores and CFTs on it, we had an almost complete radar etc. – whereas GD had nothing really. No radar, an underpowered engine, and lots of paper study.

The competition was split in two: an air-to-ground evaluation and an air-to-air evaluation. For each, the first evaluation was set out to determine how much ordnance could be carried by each contender; how far they could carry it and what flight characteristics the aircraft exhibited when it was laden with fuel and bombs.

Tactics were also evaluated. For both aircraft, the air-to-air portion of the evaluation was oriented around how much differently they performed when compared to the original airframes, and an even split of sorties between air-to-air and air-to-ground were flown, Banholzer remembered:

> A lot of our sorties were big exercises: we would take off out of Nellis [AFB], engage Aggressors, deliver ordnance on the tactical ranges and egress at high speed. We simulated, as well as we could, how the aircraft would handle a sophisticated IADS and what advantages it had over anything else – what advantages would Synthetic Aperture Radar give us? We also wanted to look at the CFTs to see what aerodynamic penalties we would pay for carrying them. Did they put us at a big disadvantage in the air-to-air arena? So, we flew air-to-air against as many types of adversary as we could. We did what I would call VHNs – Very Heavy Nose – where you have just come off a tanker and are full of gas. We then reduced the weight to a half fighting load and then further reduced it to an ideal fighting weight. We had never flown this heavy before and I wanted to see what would happen when we did".

The Aggressors were experienced pilots who had flown against the air-to-air versions of the F-16 and F-15. The same Aggressors flew against both the Strike Eagle and F-16XL so that, aircrew ability notwithstanding, they could provide an enlightened opinion at the end of the competition as to which airframe was a more difficult opponent to defeat.

The two contenders were also flown against the Air Force's highly classified stash of MiGs, which operated out of both Tonopah Test Range and Groom Lake in the Nellis ranges:

> In terms of air-to-ground and having been an F-4 pilot, this was unbelievable. The tactical capability we had from the radar was incredible. We could find targets fifty or seventy miles out, precisely locate them, freeze that radar picture and memorise it into the computer before dropping down low again. We couldn't be seen again until we popped up right up on the target and dropped the weapons. It was a capability that we had never had before and suited our low altitude tactics back then. We could actively drop high drag general purpose or cluster bomb munitions. The amount of fuel and weapons were incredible, the jet handled well and I was very impressed with it compared to anything I had flown before. When we flew the air-to-air portion of the tests in a VHN condition it did not perform like the C model – it couldn't, it was just too heavy. Once down to a half fuel load though, it would start to fly like a C or D model. However, some of the regimes we flew in surprised us. The CFTs created an interesting drag characteristic which meant that we could, at low speeds, pull the nose of the

ABOVE
F-15B '291 carries the AN/AVQ-26 Pave Tack pod while conducting integration and development work at Eglin and Volk Field prior to the DRF competition. By 1980, Jennings had already rippled sixteen Mk 82 bombs simultaneously from the AFCD. (Boeing via Author)

aircraft up to even higher Angles of Attack than you could in a C model. In a dogfight we could out-nose position the opponent.

This was not the only surprise. Early on in the testing, the aircraft was manoeuvred into a sufficiently high AoA bracket that the horizontal stabilisers were 'blanked out': the large wings blocked airflow from reaching the horizontal stabilators, effectively rendering them useless. An AoA restriction was quickly applied to the testing program until the cause of the problem could be identified (it turned out to be a vortex shed from the nose that created a slow, yawing, out of control flight characteristic). Digital flight controls later ironed out these problems.

Other, less obvious, peculiarities surfaced later. As the competition progressed and the aircraft was pushed further and harder, the ground crews and aircrew soon learned that re-tread tires were not suitable for the high gross weights being tested for the very first time. As the aircraft distended past 70,000lbs gross weight, the re-treads would unravel during taxing.

Both D-model Eagles being used for the competition featured an analogue armament control panel that was archaic in comparison to the computerised system that the E model would receive. On two consecutive sorties Banholzer thought that a bomb had 'hung' – failed to release – whilst at the ranges. On both occasions he returned to Nellis only to find that the 'hung' bomb was nowhere to be seen. The problem was eventually traced back to a fault in the armament control system, which was commanding the release of more bombs than Banholzer had requested.

Short Legs and a Bumpy Ride?

Some of the early concerns about the Strike Eagle were by this time were starting to subside.

Crews were all too aware the F-15 lacked the legs of the F-111, but the clear advantages it had in capability, accuracy and survivability outweighed this.

F-111 crews had practised and pre-visualised their strikes into Eastern Europe on dozens of occasions. Col. John Snider, a former F-111F pilot, admitted that F-111 crews knew they would be able to outrun any MiG-23 Flogger that might try to intercept them as they penetrated Eastern Europe, but the problem was they also knew that by the time they had put their weapons on the target and were running for home, that same Flogger could have landed, refuelled and re-intercepted them head-on. In the ensuing engagement they knew that their chances of winning were not favourable.

So, while the Strike Eagle might not reach the furthest targets, it would certainly be able to fight its way in and out of those which did fall within its reach. The Strike Eagle's formidable air-to-air performance further vindicated any decision the Air Force might make to select it as the winner.

Those who flew it praised the Strike Eagle for its great handling characteristics, even though it flew a lot like the F-4 Phantom when heavy. In mock combat with extremely heavy Strike Eagles, Aggressor F-4s would take their revenge for years of beatings at the hands of A and C model Eagles, although the Strike Eagle could escape the Phantom by diving to low level and accelerating away.

New concerns had arisen, however. For example, the CFTs could jettison their fuel only via the main fuel tanks and then through the dump mast at the trailing edge of the wing – a process that took valuable time. In the event that they were bounced by a hostile fighter while full of fuel, some crews reasoned that the CFTs ought really to have a way of jettisoning fuel directly into the airflow. Laacke, who had observed the effectiveness of the Strike Eagle's low altitude escape manoeuvres, never took this so-called zipper idea seriously.

Ride comfort was a little rougher than that of the F-111, but this was when the jet was light. Loaded up with stores the aircraft would fly "like a Cadillac".

INS problems inherent in other platforms were also addressed at this stage. Whilst the DRF aircraft used normal INS gyros, the F-15E would incorporate Ring Laser Gyros that featured far less drift and were therefore more accurate. In addition, the APG-70 was to be able to perform a PVU – Precision Velocity Update – a scan of eight sectors of terrain in quick succession that either validated or updated the velocities being used by the INS to keep position. Aircrew liked this simple technique, and accurate velocities were in any case essential in making the SAR mapping and targeting process work.

Banholzer therefore planned his evaluative air-to-ground sorties to fly low, pop up and PVU; go back down low; take another PVU and radar map in one final pop up; and then roll into the target. A little INS drift would still occur between the last navigational update and the pop-up attack to target, but this could be countered by good mission planning.

In visual conditions at least, it was possible for the pilot to see the INS drift as the target designation box in the HUD was positioned some way off the target he was seeing with his own eyes. McAir worked to implement a visual designation technique as a result – as the pilot rolled into the target complex, he slewed the misaligned designation box over the target, pressed a button and then received updated weapons release data. The INS could also be cued to take this visual designation as a position update.

Test Duties

F-15D '055 briefly embarked to Eglin AFB, Florida to fly twenty-two weapons separations trials, all of which were concluded without incident by the 3246th Test Wing, Air Force Development Test Centre, Air Force Material Command.

F-15D '063 flew thirty-six operational evaluation sorties – included testing of the radar; long-range sorties to demonstrate endurance; increased payloads; low altitude, high speed sorties; accuracy of weapons computers and cockpit functionality testing.

Up-trimmed F-100-PW-100s were installed in both to simulate the more powerful engines that were slated for the Strike Eagle. These special F-100s ran at 110% and had a service life of only one-hundred hours.

To deal with the additional idle thrust, a parking brake was installed, prompting Banholzer (who was had previously flown Eagle, which had no parking brake) to joke "We had to put the aircraft in afterburner to get it to taxi!".

Cockpit Developments

A lot of time during the competition was spent in St. Louis designing the missionised cockpit.

St. Louis was home to the Manned Air Combat Simulator V building, or MACS V – a dedicated simulator suite used to develop various technologies.

The AFCD had started the ball rolling with the introduction of the hand controllers and CFT outfitted rear cockpit (which had been tested in MACS IV), but it was the operational USAF crews who would have the most influence on the final layout and operation of the crew compartment.

The Air Force had originally requested the front cockpit remain identical to the F-15D, as this would make the transition from Eagle to Strike Eagle easier for front-seaters (and vice versa), but Jennings said that this was not implemented because McAir managed to prove that a glass cockpit was cheaper to install. It was true: mechanical displays were more expensive than CRTs. By way of an example, a single engine gauge, of which the Eagle had ten, was more costly than the Engine Display LCD that was ultimately installed in the F-15E. The LCD showed the same data as all ten analogue instruments combined and was also more reliable.

The DRF crews were effectively given a clean slate to request whatever layout suited them best, and McAir allowed them to select display types and gauges of their choice – touch screen, CRTs, analogue etc.

Larry "Scoop" Cooper, a TAC pilot who flew with Banholzer for the majority of the time; Ray Wilcox, a WSO from AFOTC; and Banholzer, all visited St. Louis together to build a cockpit optimised for the air-to-ground mission. They started by removing the stick and throttles in the rear cockpit to make maximum use of the space available in front of the WSO's knees. Front seat and back seat duties were determined, and magnetic images of displays were then given to the crew to arrange as they felt appropriate (the real displays were installed and tested later). They listed the displays they would most frequently use and specified which format they should take. They also took the CRT page concept a step further by deciding in which order the pages would scroll. It became evident that each operational crew wanted their own sequence, so McAir integrated a software option to allow each display to be programmed before flight to scroll though pages in a custom order. Finally, a simulated LANTIRN system, updated HUD and new hand controllers were installed to allow them to fully explore the functionality of the cockpit.

Banholzer provided input to the design of the mechanism that was used to change from air-to-air mode, air-to-ground mode, Instrument mode and Navigation mode – a simple row of four push-buttons mounted below the UFC.

Touch screens were discarded at an early stage. It had soon become obvious that gloves and high G forces made them impractical because it was difficult to accurately make selections with a finger in such situations, and 'smudging' the buttons was a common occurrence. Additionally, touch screen technology in 1983 was simply too nascent. It would be years before the technology was mature enough for Boeing to implement on the F/A-18E/F's up front controller.

Banholzer and his colleagues also advised on extensive HOTAS modifications, and the front seat stick grip was completely redesigned to incorporate more buttons and control over the displays. Banholzer also requested a panic button on the stick to allow a disoriented pilot to immediately display an Attitude Director Indicator (ADI).

Meanwhile, the up front controller, which was used to enter and view data and was based loosely on that of the F/A-18A/C, was further developed.

One principle underpinning all of this was the importance of building an environment that accommodated a cross section of aircrew. Some would come to the Strike Eagle from single seat fighters like the F-15C and F-16, while others would hail from dual seat fighters like the F-4 and F-111. Invariably, the crews selected to fly the Strike Eagle would be either well versed in crew coordination, or not at all used to sharing tasks in the cockpit. For this latter category of pilots, the cockpit had to make task sharing as easy as possible.

But Banholzer and his colleagues did not have it all their own way. Towards the final stages of the cockpit development, a WSO General from the Pentagon visited the plant to view the progress being made. Upon seeing that the stick and throttles had been

OPPOSITE

The F-15E cockpit configuration in the St Louis simulator in 1983. Minor changes were made to this design prior to the first F-15E being built, but it otherwise it closely resembled the production-standard layout. (Boeing via Author)

F-15E Missionized Cockpits

The front cockpit provides both air-to-surface and air-to-air capability for the pilot. A Wide Field-Of-View Head Up Display (WFOV HUD) and an Up-Front Control (UFC) are centered on the main instrument panel for easy viewing. The pilot can "customize" the instrument panel by selecting the display he wants on each of the three displays. The HUD has the capability to display forward looking infrared video for night terrain following.

The UFC integrates control of communication, navigation, and identification systems. The UFC replaces 13 individual control panels in earlier F-15 aircraft.

An Engine Monitor Display (EMD) presents an integrated display of engine data in one reliable solid-state unit.

The right main instrument panel houses a receptacle for a Data Transfer Module (DTM) by which the pilot can program and retrieve large amounts of digital data, such as the mission plan.

The missionized aft cockpit is also arranged for easy, straight-forward operation of sensors and displays. Each cockpit is independent and each crew member knows what the other has selected. The hand controllers, located one each on the left and right consoles, permit the WSO (Weapons Systems Officer) to select, control, and designate functions on the four multi-purpose display units. The sensor information and menus can be displayed on any of the four display units.

deleted from the back seat, he ordered that they be put back in.

Leadership also overruled the design team on the stick arrangement in the front cockpit, insisting that the sidestick design be replaced by a traditional floor mounted, centrally positioned stick. The side stick had been chosen to allow the panel in front of the pilot's knees to be used for displays and instrumentation, so reverting to the original configuration reduced the amount of information that could be shown to the pilot at any given time.

And while the HUD, now a huge piece of glass far larger than that in the Eagle, was upgraded, the Air Force refused to develop it into a primary flight reference system.

The final cockpit layout, discussed in Chapter 2, would be arrived at three years later. It was never installed in '291.

Outcomes

In all, more than 200 Strike Eagle flights took place in the six-month competition.

Some of the sorties, particularly those where air-to-air capabilities were being evaluated, were several hours long and required two or three aerial refuelling to remain aloft.

Air-to-ground sorties from Edwards AFB often involved the two D models hauling their bombs into the sky for a two hour mission up to the Nellis ranges and back. Handling qualities and radar tests were often completed in the Edwards operating areas, and also often required aerial refuelling.

Some discussion was had between the Air Force and its pilots regarding camouflage. There was a general feeling amongst the aircrew assigned to test the Strike Eagle that the aircraft should retain the two-tone grey colour scheme applied to the A-D models. After all, a threat aircraft that came within visual range would be better aided to identify it as an E model if it were dark grey, meaning that he might treat it differently once he knew it was probably heavy and less manoeuvrable. The Air Force evaluated several schemes on Nellis based Fighter Weapons School F-15Cs, including variations of the Compass Grey F-15 camouflage, and green and dark grey combinations resembling the European 1 scheme. In the end, a simple Gunship Grey was chosen: all the better to hide the jet in the dark and dingy climes of Europe.

At the conclusion of the fly-off, McDonnell Douglas was quick to zero in on the maturity of their offering and the relative ease with which development had taken place: "These tests confirm the designed flexibility of the F-15 and its ability to incorporate state-of-the-art improvements without any major change to basic airframe".

The Air Force, which liked the existing F-15 precisely because it was low risk, must have been thinking much the same thing. In political terms, McAir's proposal combined low risk with low cost to form an attractive package. It was based on a proven design that had already seen vast sums of private capital ploughed into it.

Behind the scenes, and seemingly undocumented, it is almost certain that the USAF placated Congress by making a commitment that Strike Eagle would be used primarily for air-to-ground, leaving the Eagle family, which had already seen hundreds of millions of dollars allocated to it, to remain the primary Air Superiority fighter in the USAF inventory.

In military terms, the Strike Eagle proposal oozed the potential for future upgrades, not only on account of the sheer size of the basic F-15 airframe, but also in terms of weapons carriage, overall performance and supportability criteria.

The DRF competition concluded on April 30, 1982, at which point McAir scaled down their development program and worked closely with AFOTC to provide additional data from their own testing of '291 (they also spent a lot of time further developing the cockpit layout in the simulator).

Then, with assessments and deliberations complete, the Air Force awarded the contract to build their next generation deep strike fighter to McDonnell Douglas on 24 February, 1984. The aircraft would be designated the F-15E.

The Strike Eagle had earned the win in several respects: it had demonstrated 75,000lb take off capability (7,000lbs heavier than previous limits); successfully merged Pave Tack, APG-63 SAR mapping and attack systems together; and had applied these technologies to pass the USAF's visual and radar bombing accuracy requirements (which were flown using Mk 82, Mk 84 and CBU-58).

But for all the Strike Eagle's magnificence, Banholzer could never be lured far from his light grey Eagle roots. At the start of the F-15 programme, the Air Force's F-15 System Programme Office had resolutely pushed back against political pressure to develop the Eagle's air-to-ground capabilities, culminating in the mantra "Not a pound for air-to-ground". Thus, Banholzer's buddies received a series of comedic pictures of him next to one of the F-15Ds at the end of the fly-off. In one, he stands grinning broadly before an aircraft loaded with eighteen Mk 82s, on each of which is spray painted AIM-9. In another, he wears a paper bag over his head to avoid being identified in front of a bomb-laden Eagle.

As for the man himself, there is little doubt that Banholzer's flying skills and gutsy attitude made a difference to McAir's bid to win the competition. His ability and aggressiveness allowed the Air Force to see exactly what the F-15E could achieve, especially at low altitude – as one observer told the Author: "He went low where other guys simply would not go low".

More CFT Development

F-15C '468 was the first ever C model manufactured by McAir and differed little from an A model other than carrying a modified APG-63, enlarged internal fuel tanks and a range of other avionics improvements that left few tell-tale outward signs. It was assigned the job of testing a steady succession of modified CFTs, often flown by John Hoffman and Jim Thomas, both Edwards based test pilots.

From January to April 1982, CFTs had been officially trialled for the DRF competition at Edwards, and ninety one individual sorties were flown under the supervision of Nelda Lee, lead CFT Test Engineer.

Lee, who had arrived at Edwards in August of 1981, recalled:

> We carried out a range of tests on C1 [F-15C '486], including loads testing, fuel systems compatibility testing, fuel migration testing, and CG tests. In December 1981 to early January 1982, we conducted air-to-ground weapons carriage trials, and included in this were tests with external fuel tanks on board. Gun testing looked at how the CFTs dealt with the gases coming out of the M61A1 Vulcan Gatling gun.

The schedule came under the command of the 415th Test Squadron, 412th Test Wing (6510th Test Wing), whose job it was to flight test all F-15s.

The program produced the first production specification of Type III conformal tanks in 1983, the first flight of which saw '468 haul aloft twelve inert Mk 82 GP bombs.

Baffling in the Type III CFT tanks was changed from previous builds, so too was the rear fuel transfer pump. The latter was a key part of the test program as it was critical to maintain equilibrium in the transfer of fuel from the fore, middle and aft fuel cells. Failure of the aft pump could cause CG limits to be drastically exceeded, and an aircraft could be lost as a result.

It was logical, therefore, that once airborne the Strike Eagle would draw its fuel from the CFTs first, allowing a fuel transfer failure to be identified while the aircraft was still in the early stages of flight. To address the issue directly, the aft fuel pump was now scheduled via a CFT mounted black box that turned it off once the fuel cell was empty, thereby preventing it from burning out.

But there was more work to do. Test flights continued through 1983 to fine tune the tanks and gather more data in preparation for the Type IV fuel tanks destined for the F-15E, so two additional F-15Ds were added to the CFT trials force.

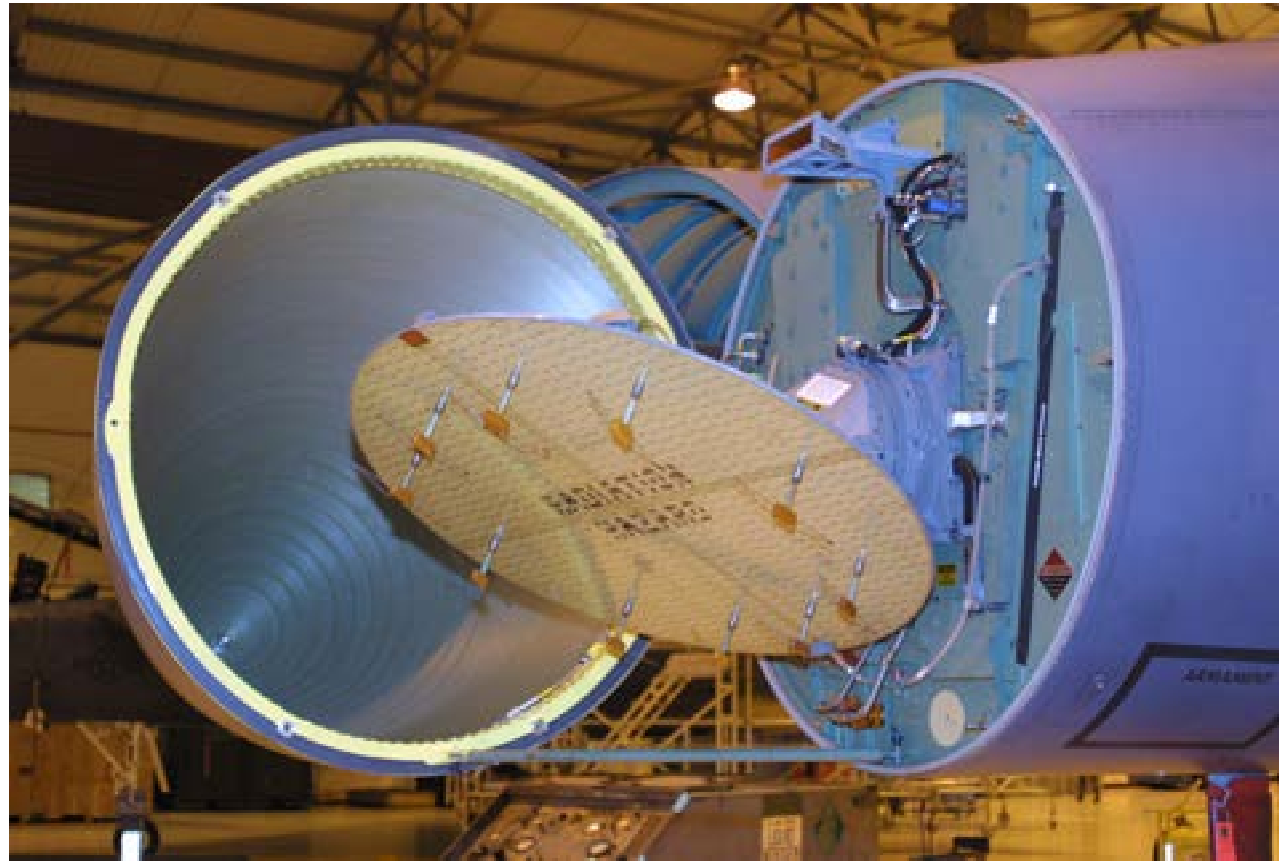
This paid dividends later, allowing the actual Type IV development work to focus more on weapons separation trials.

APG-70

The APG-70 is an I/J band (8-20GHz) radar that weighs 251kg and was designed around the APG-63 and APG-65, the latter of which was installed in the F/A-18 Hornet.

It is a coherent radar, which means the signal

Date	Number of sorties flown	Objective
October 1981 – February 1982	28	Design Load Limit testing: 85% – 92%
September 1981 – October 1981	4	Fuel System compatibility
December 1981 – January 1982 October 1983	17 Air-to-ground 15 Stores 9 Gun 5	Air-to-ground weapons and external fuel tank testing
May 1982 – June 1982 October 1983	26 1	Air-to-air weapons & 20mm testing
August 1982 – September 1982	15	Aft CG testing
July 1982 – October 1982 September 1983	19 2	Performance testing
October 1982 July 1983 – August 1983	2 Nose Wheel Steering	75,000lb weight testing
October 1982 – December 1982 January 1983 – March 1983	12	High AoA testing
May 1983 – July 1983 September 1983	21 4	High AoA characteristics



ABOVE
The APG-70 antenna and ALQ-128 EWWS dipole antennas installed on an operational F-15E. (Author)

source remains running all the time, so the amplifier is turned on and off to transmit the signal out of the antenna.

In development since McAir and Hughes teamed up to build the AFCD, the first flight with a partial APG-70 radar installed occurred on 14 February, 1985. Testing of the radar had been conducted at Volk Field for about a year before Hughes and McDonnell Douglas moved to the more advanced, instrumented ranges at Eglin AFB, Florida.

Hughes took the best features of all their radars and brought them together to form the APG-70, building a radar that could detect targets with more efficiency and with enhanced radar modes.

It was not so much an upgraded APG-63 as many called it, but a new radar that had commonality with the APG-63. The power supply was similar and the antenna was identical to the APG-63 (high gain, low sidelobe planar array), but the other line Replaceable Units (referred to as boxes) were new and incorporated new technology.

Four new boxes replaced five older ones: the Power Supply (PS), Radar Data Processor (RDP), Radar Signal Processor (RSP), Analogue Signal Converter (ASC) and Receiver-Exciter. A new Power Supply was necessary as one of the other boxes, the Receiver-Exciter, required a higher voltage than before.

The RDP is the brain that controls the rest of the radar set. The RSP is another computer that is optimised for data/signal processing. The Receiver-Exciter features thirty-two coherent channels of increased bandwidth, better tracking in ECCM environments, and increased sensitivity and detection capabilities.

Signals received by the antenna are passed to the Receiver, which converts them to a lower frequency and passes them onto the ASC. This turns the signals into digital format, following which they are handed-off to the SP.

The SP then determines the power levels received by the antenna at a speed of over thirty million calculations per second. It is five times faster than the APG-63's SP and has ten times more memory.

Using modular parallel processing via a MIL-STD-1750A central processor unit, the SP passes this information over to the RDP.

The RDP is another computer that operates five times faster, and features ten times more memory, than the APG-63 (1,024k of memory – 220K air-to-air modes, 110k air-to-ground modes, 200k for the Built In Test feature, 64k for the UFC's scratchpad memory, and the rest reserved for future upgrades). The RDP determines whether a signal is a target, and then passes the information on the crew's Radar page.

The APG-70 offers a 33% increase in reliability over the APG-63 and boasts an 80-hour MTBF (Mean Time Between Failure) rate.

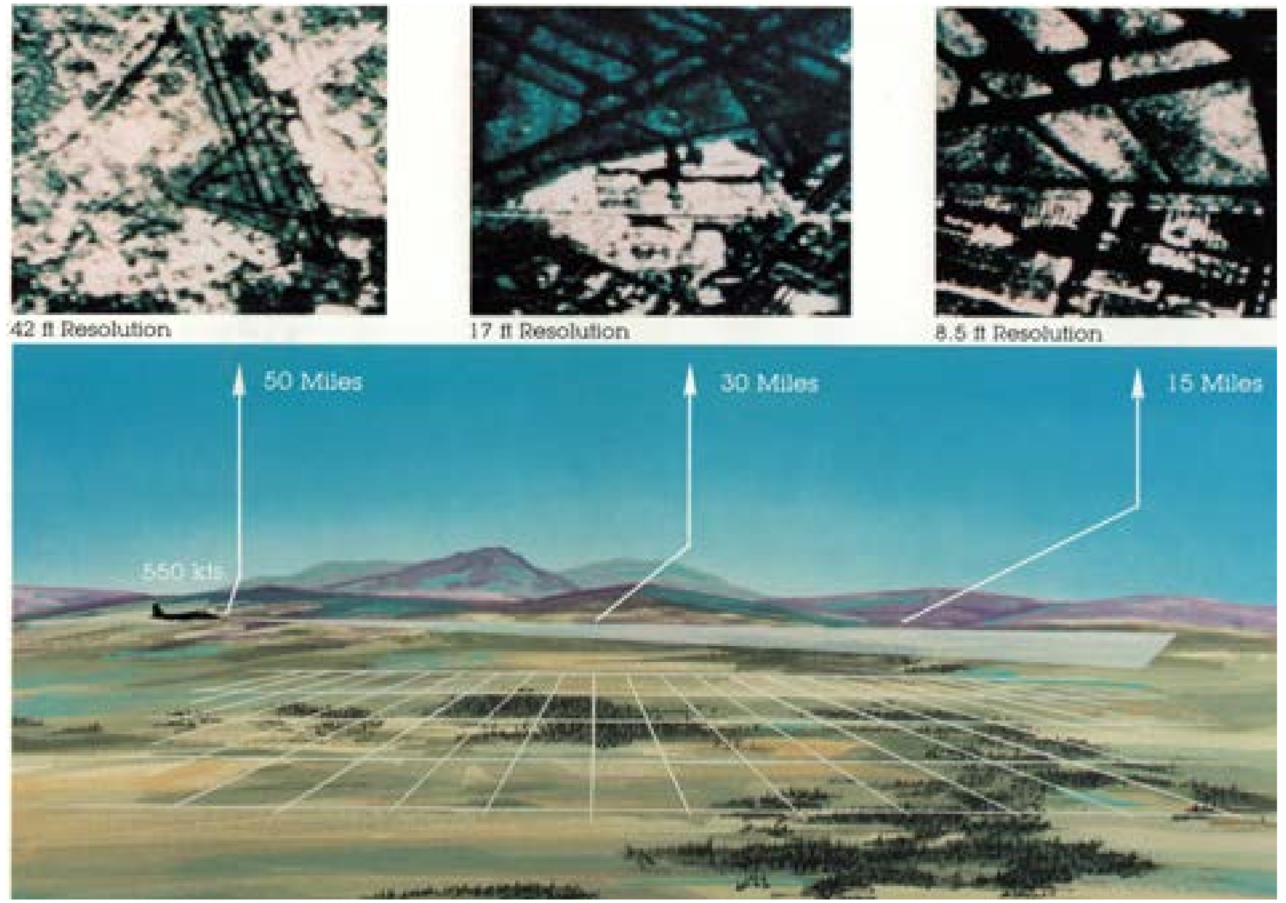
Its BIT check has ten times the memory and six times the number of checks than the APG-63 BIT. These checks are characterised by unambiguous fault detection and isolation. In plain English, the APG-70 can assess what's working and what's not, then narrow down which box has a fault and therefore needs to be replaced.

Synthetic Aperture Radar

Until the arrival of the APG-70, radar acquisition and designation of ground targets had been somewhat primitive. Using the radar was a time consuming and skilled affair: getting the best from the radar had required constant tuning by the operator in the air, and many hours of classroom and practical radar interpretation training on the ground to become proficient.

Like so many components in the F-15E program, Synthetic Aperture Radar – known as the High Resolution Mapping (HRM) mode – would re-shape the way ground targets were detected, identified and designated from a fighter. It was a highly complex technology that centred around mathematical algorithms and was made possible because of new hardware circuitry added to the APG-70.

BELOW
A graphical depiction of the capabilities of a nascent APG-70. Subsequent modifications meant that the production APG-70 was even more capable. (Boeing via Author)



But the most impressive aspect of this SAR capability was that it could be interpreted in real time. SAR allowed almost photographic quality radar pictures to be taken that, when displayed on one of the MPDs, gave the pilot or WSO a bird's eye view of the scanned area.

In simple terms, the radar transmits a pulse and then notes changes in amplitude and phase of the echoes – these changes are be translated into video output to display a picture recognisable to the human eye. To achieve this, the antenna is tilted to direct its energy at the ground and data is collected in a process known as mapping.

As the aircraft moves forward, more and more data is collected as the radar continues to map a designated patch of ground. Once enough data is received, it is computed as a single data file. The algorithms siphon out the radar returns caused by ground features from those caused by the aircraft's own movement over the ground. The resulting image is then displayed to the crew for analysis.

To be effective, the crew have to follow a few guidelines when using HRM mode. Mapping is more effective if the area of interest is put to either side of the nose, as a three dimensional radar picture of the target is much easier to create from one side or the other, and mapping a target directly in front of the aircraft requires excessive amounts of time to create an image (a software limit was implemented to prevent the crew from patch mapping straight ahead of the jet. This zone, referred to as the blind zone, extends

Increased resolutions become possible as the distance to the target area reduces. This means that as the crew get closer, a more detailed picture can be seen. The crew can alter the resolution of the map based on predefined, software controlled tables that automatically rescale the radar display (Range Window), configure the radar, and permit only valid resolution selections:

Range Window (Nautical Miles)	Resolution (Feet)	Min/Max Mapping Range (Nautical Miles)
0.67	8.5	2.7/40
1.3	17	2.7/40
3.3	42	2.7/50
4.7	59	2.8/80
10	127	6/160
20	253	12/160
40	507	24/160
80	1014	48/160

±8° of the aircraft's centreline. The angle either side of the nose is referred to as the squint angle).

A software routine was installed in the radar that predicts how long a patch map will take under current conditions – the radar cursors are placed over the area of interest and a dynamic readout displays the time required in seconds.

Grazing angle restrictions require the vertical angle between the radar beam and the ground to fall within certain constraints. The best patch maps result from mapping at between 2° and 10° grazing angles, as these provide a good mix of horizontal and vertical target returns. High grazing angles (above 20°) result in one-dimensional images being produced as the mapped area lacks contrast. Low grazing angles result in vertical targets dominating the subsequent radar picture and overpowering the image. Antenna elevation is automatically controlled by the radar in HRM mode, requiring only that the pilot climb sufficiently enough to create the desired grazing angle.

Jennings and the small team at Volk Field developed the process for patch mapping through mathematical means prior to flight testing. They flew at a height that gave them their desired grazing angle and once stabilised at that altitude they would start mapping and gradually descended until the picture degraded to the point where it was useless. By this method, Hughes engineers soon developed a feel for the desirable operating parameters detailed above.

The May 1981 issue of Air Force magazine carried what is possibly the first public account of an early APG-70 build in operation. A USAF observer had been treated to a familiarisation flight with McAir's F-15B AF 71-0291 and Pat Henry:

> Pat Henry has the APG-63 [sic] humming now. He has the radar up on the terminal in his front cockpit; then it appears for the observer on the primary right hand terminal in the aft cockpit. The bridge over the river Missouri at Washington is clear; so are the river and the city. The map being painted on the terminal is ten miles square. Pat Henry changes the scale to 4.7nm, and the bridge and town grow in size on the terminal… He moves the cursor over the location of the Winfield Dam on the Mississippi River, then calls up a patch map over the Dam itself. In real time, the right hand primary screen displays the dam area in a ten-mile square image, then enlarges to the 4.7nm image. At a range of twenty-six miles and thirty degrees off the nose, the dam is a clear target, easily found… At about sixty miles from Springfield, the radar map gives the crew a vertical display ten miles square, then enlarges upon command to the 4.7nm picture. The runway patterns at Capital Airport are precisely seen, as is the street pattern of the Illinois capital.

At the time of this flight, the APG-70, which was still being referred to as the APG-63, was limited to a maximum resolution of fifty-nine feet. The design goal of ten feet resolution was exceeded within a few months of the article going to print, and the production APG-70 could map to 8.5 feet resolution (0.67nm HRM picture) by the time it was installed in operational F-15Es.

HRM supplemented the Real Beam Mapping mode (RBM – a low resolution mapping and weather detection mode) already implemented in the APG-63 and carried over to the APG-70. RBM was a fast and simple mode that was drift stabilised up to ±10° in azimuth and scanned at a rate of 95° per second. The APG-70 improved this mode through a 2:1 beam sharpening process that provided a sharper picture.

A GMT (Ground Moving Target) mode was also available, and this detected moving targets on the ground – a key mode for detecting armour or motorised infantry – and one from which the crew could hand-off to an integrated optical/infra-red tracking system (which would eventually turn out to be LANTIRN) for subsequent attack with guided or unguided weapons. The system also featured dedicated support for the AGM-65 Maverick series of standoff guided missiles and allowed for an Interleaved GMT (IGMT) mode, where the GMT image could be merged with that of the RBM.

By the end of the Dual Role Fighter competition, Hughes and McAir had not only proved the APG-70 radar to the USAF but had hammered the point home. By way of illustration, the F-15E's circular error probable (CEP) was significantly smaller than that of the F-111D/F. At night, using radar designation and steering alone, the DRF had achieved a CEP of 10m. This was further reduced to 5m when using Pave Tack. The F-111D/F could only muster a CEP of 24m in the same conditions.

Engine Troubles

Throughout the Dual Role Fighter competition, the question had remained over which powerplant would be selected for installation into the winning contender.

Pratt & Whitney produced the F100-PW-100 engine for the F-15A/B, which was rated at 23,830lbs of thrust in afterburner and represented a leap forward in powerplant technology.

Despite this, it was plagued with problems. It suffered stagnations and compressor stalls on a regular basis – these occurred most often at high altitudes and high Mach numbers and when airflow to the engines was disturbed or interrupted. It also suffered afterburner fires as a result of failure of the reheat to light. When this happened, raw fuel would collect in the afterburner section and then suddenly combust as the hot exhaust gasses heated it (the raw fuel should have combusted immediately). A fire could then burn through the rear of the aircraft unbeknownst to the pilot, and a quick glance in the canopy rail mirrors or a call from a wingman or flight lead would often be the first indication of a problem. The pilot needed simply to come out of afterburner and the fire would subside, although the damage done could sometimes write an airframe off. The first ever F-15 loss occurred for this very reason.

To add to an Eagle driver's woes, subsequent directives forced him to take more care over his manipulation of the throttles as the PW-100 was also beginning to suffer from premature component failures.

Care free handling had temporarily become a distant dream. This was ironic because the Eagle was designed to make flying it so easy the pilot could concentrate on employing it as a weapons system. Previous fighters, such as the F-106, had featured direct mechanical linkages to the fuel flow valves in the engine. By contrast, the F100 had an analogue computer to act as the go-between and facilitate the fastest engine response to throttle requests. Whilst undoubtedly a quantum leap in technology over the previous engines, the analogue unit was simply too slow to keep up with the ever-changing demands for power experienced in air combat.

With the future of the F100 looking bleak as far as the Strike Eagle was concerned, there was much speculation that General Electric might be asked to supply the F110-GE-129 as an alternative powerplant. P&W were therefore under considerable pressure to straighten things out.

They responded by developing and integrating Digital Electric Engine Control (DEEC) technology into a new version of the F100, the F100-PW-220. The PW-220 proved to be a more reliable engine and was less expensive to maintain. It was installed in all F-15Es from October 1986 onwards and was subsequently retrofitted to F-15C and F-15D aircraft. See Chapter 2 for more detail.

LANTIRN – Development & Integration

LANTIRN was originally conceived as a capabilities upgrade program for the General Dynamics F-16 Fighting Falcon that would take the form of a podded system.

It stood for Low Altitude Navigation and Targeting Infrared for Night, and research and development began in September 1980 following the award of a $94m contract to Martin Marietta Corporation by USAF Aeronautical Systems Division.

The Air Force had originally decided that the Fairchild Republic A-10 Thunderbolt II, a dedicated Close Air Support (CAS), twin turbofan aircraft, which carried a range of guided and unguided air-to-ground ordnance in addition to the monstrous GAU-8A Avenger 30mm cannon, would also receive the system. Both aircraft lacked the precise targeting capability required to strike targets near to friendly troops, particularly at night and in poor weather, so LANTIRN would help address this.

Martin Marietta's approach was to modularise key components in two pods, thus allowing both operational flexibility and minimising system support impact. One pod would house navigation and terrain following equipment, the other attack and designation electronics.

Each would operate independently of the other whilst communicating with other aircraft systems via a MIL-STD 1553B data bus. Both pods contained software loads that could be updated and upgraded on an *ad hoc* basis. LRUs were used wherever possible, making repair and maintenance of the system that much easier.

Initial flight testing of LANTIRN commenced in July 1983 when a two seat F-16B fitted with a GEC avionics Wide Field of View HUD (WFOVHUD - onto which FLIR imagery could be projected) carried two fully functioning pods aloft. This first flight followed in-flight calibration of dummy LANTIRN pods in September the same year, when ballast-filled pods had been rigged to measure vibration, flutter and temperature changes across a range of flight regimes. Testing continued for three months before the operational specification of the system was solidified and operational testing got underway in December 1983.

LANTIRN had its critics and was subject to delays, funding suspensions and re-definition throughout this time. In fact, the Armed Services Committee and Congress wavered in their support for the program to such an extent there was real doubt it would receive any FY83 funding.

Congress complicated matters by mandating the evaluation of the Ford Aerospace AN/AAS-38 Nite Hawk FLIR pod used on the Navy's F/A-18 Strike Fighter. Whilst this system provided similar capabilities to LANTIRN's target pod, it lacked a laser designator, Terrain Following Radar and navigation FLIR capabilities. Following twelve months of Development, Test and Evaluation (DT&E) and Initial Operating Capability Test and Evaluation (IOCT&E) by two F-16Bs and two A-10s in Europe's murky and inhospitable climes, LANTIRN was accepted by the Air Force, and an $87m contract was issued to Martin Marietta to begin low-rate initial production of the navigation pod (full rate production go ahead was given in November 1986). Seven months previously, IOCT&E for the targeting pod had reached successful completion following similar trials in a range of weather and lighting conditions. Low rate initial production was subsequently ordered in June 1986.

LANTIRN had been a huge success, so much so that it had been elevated in status from a simple capabilities upgrade program to a fully blown, stand-alone program in its own right. By 1985 it was no longer attached to F-16 funding and was being considered for other airframes in addition to the two already earmarked.

Unfortunately for the F-16 and A-10 community, LANTIRN soon became an integral part of the Dual Role Fighter competition, as a result of which the A-10 was deleted from the list of LANTIRN recipients and the F-16 was demoted to second on the list of priority customers. A cost overrun of about 10% occurred as a result of integration with the DRF competition, although this was a small price to pay for a system that would become a pivotal tool in the Strike Eagle's arsenal, and all without taking up any precious stores pylons on the wings or CFTs.

The two pods are the AN/AAQ-13 navigation pod and the AN/AAQ-14 targeting pod (TP). Each features a contoured pylon designed to fit snugly onto the cheeks of the F-16's air intake. On the F-16, the nav pod is installed on the left side and the TP on the right side.

This is reversed on the F-15E, and new adaptors were designed because the Strike Eagle has flat intakes that the F-16's contoured adaptors do not cleanly connect to. The adapters are designated ADU-577/A for the TP, and ADU-576/A for the nav pod.

It's worth noting that McAir initially proposed a single, nose-mounted fairing to house all the LANTIRN sensors, all the better for reducing aerodynamic drag and increasing the sensors' field of regard (FoR). This idea made sense to the engineers but not to Creech. He had pushed Congress on several occasions for continued LANTIRN funding, so to take the proven podded system and integrate it from scratch would be too risky and might give rise to delays and increased spending – Congress could have pulled the plug on the system altogether. The difference in opinion was resolved when Creech attended a meeting between LANTIRN and McAir engineers: Creech told them that if they wanted to build the F-15E, things would be done his way.

Once the final placement of the two pods was decided, wind tunnel tests were conducted to provide load, aerodynamic and stability data – acoustics and vibration levels would be defined for the E model later. Some modification was necessary to the F-15's countermeasures dispensers due to the proximity and (in the case of the Target Pod, overlap) of the bays and the pods. Limitations were therefore imposed on which dispenser bays could be equipped with flares – the TP would be incinerated if a flare were launched from the two foremost bays.

Securing the pods to the Strike Eagle is a simple affair, as SSgt. Douglas Hunter, a veteran LANTIRN specialist explained:

> Flight line troops take 15 - 30 minutes to fit the adaptor to the aircraft. Once that is on it is just another four bolts, tightened at 180 foot-pounds, to fit the pod to the adaptor. Fixing the pod on with a Jammer [a weapons loader akin to a specialised forklift truck] takes 5 -10 minutes. There are two electrical interface connectors that go to the bottom of the aircraft in addition to the bolts.

OPPOSITE
Early LANTIRN prototype pods (AAQ-13 left, AAQ-14 right) with In-flight imagery from the HUD and MFD of the F-16B testbed. (Boeing via Author)

ABOVE
Placing the TF antenna on the right side of the aircraft reduced TF turn capability to the left. Whilst not normally an issue, this could be problematic when strong crosswinds came in from the left. (Author)

Once attached to the airframe, both pods are mechanically boresighted to account for manufacturing errors on the pod and aircraft hardpoint mounting pads. This is achieved by adjusting the mounting lugs. Yaw, pitch and roll mechanical values, measured in hundredths of a milliradian, are then entered into the aircraft's Central Computer and rounded up to tenths of a milliradian for future reference by the pods.

The boresighting process is an important one not just for reasons of accuracy, but also from a safety of flight perspective – the Terrain Following radar in the Nav Pod draws its biases from the mechanical data values stored in the CC, and up to three feet of altitude can be lost or gained for each mil of error. At speeds of 500 Knots or more, this is a significant margin of error, but it can usually be identified early by the crew as the aircraft exhibits a bias towards flying high or low whilst in terrain following mode.

Differences in the actual mechanical boresight values from those stored in the Central Computer can occur both as a result of long-term wear on the aircraft and as a result of excessive loads being placed on the pods.

AAQ-13 Navigation Pod

The AN/AAQ-13 provides the bulk of LANTIRN's foul weather, night penetration capabilities. It weighs 195kg, has dimensions of 546 x 355 x 1,985mm (H x W x L) and houses both a navigation FLIR (NAV FLIR) that supports HUD video and a terrain following radar (TF).

NAV FLIR optics operate in the 8-12 micron region of the infra-red spectrum and feature a 21°x28° Field of View and a 56°x78° field of regard.

NAV FLIR provides a monochrome green image of the terrain ahead, which it projects onto the WFOVHUD. Originally, the nav pod had been designed to carry only a terrain following radar, but aircrew in the F-16 testing program were keen to add an additional sensor with which to correlate the TF's steering commands with the terrain fast approaching the aircraft: NAV FLIR was subsequently added.

The pilot can manually change NAV FLIR polarity from white hot to black hot as thermal conditions dictate.

Greater boresighting accuracy of the pod is achieved by electronically aligning the IR optics using the UFC and the Target Designator Control switch on the throttle. If the NAV FLIR image generated in the HUD doesn't match the real world image seen by the pilot, he can slew the optics in azimuth and elevation to produce a near 1:1 overlay of the NAV FLIR image with what he is actually seeing though the HUD.

That said, because with the NAV FLIR window is located off boresight from the pilot's direct view forward, some parallax error is to be expected.

The WSO can call up a HUD repeater page on any of his MPDs. Provided that power is being supplied to the pod, NAV FLIR imagery is generated for the repeater regardless of whether the pilot has chosen to turn on the NF.

Banholzer, whose participation in the DRF competition had not included any form FLIR assisted night sorties, was "visibly impressed" upon flying the F-15E with the AAQ-13 for the very first time – following Pentagon tours, he became commander of the 422d Test and Evaluation Squadron at Nellis AFB.

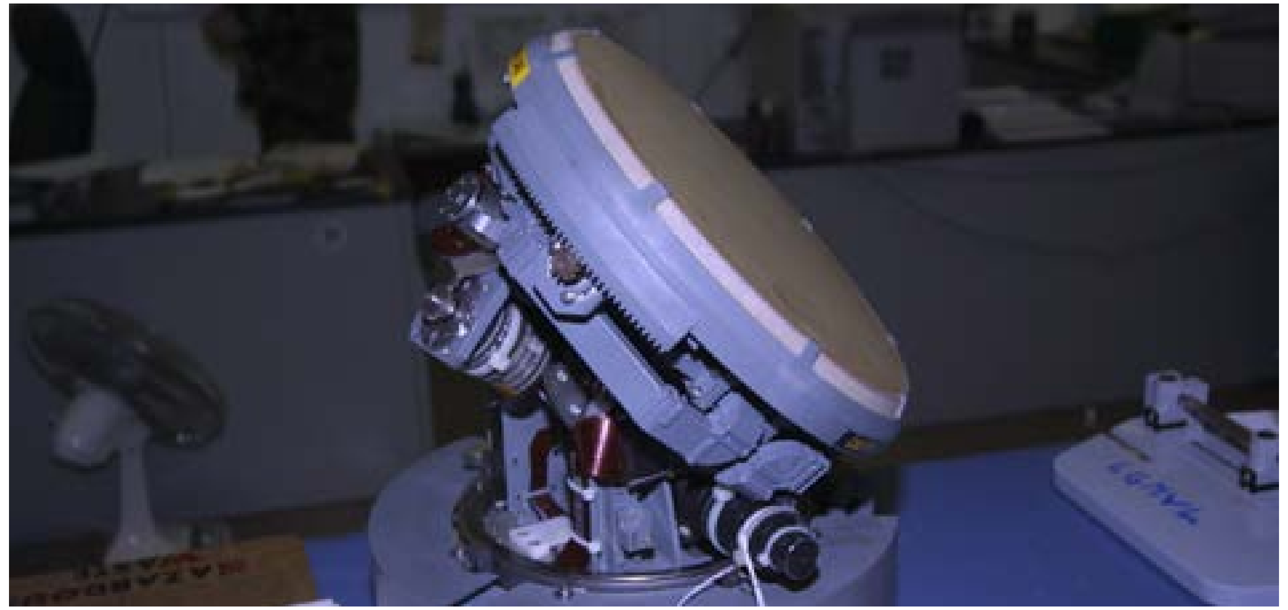
Like many things on the F-15, the AAQ-13 was designed to be maintained on the flightline itself whenever possible. The F-15 had triumphed over the F-4 in the number of man maintenance hours per flight hour (MMHPFH) required to keep it serviceable, and maintenance personnel could swap a broken LRU from one aircraft to another in the space of minutes.

The nav pod is no different and can be almost completely disassembled on the flight line if necessary. This is facilitated by the compartmental design of the pod, which comprises a basic structure around which black boxes can be plugged in using quick connectors and then slotted into their allocated bays. Hunter described the Pod as "completely flight line friendly".

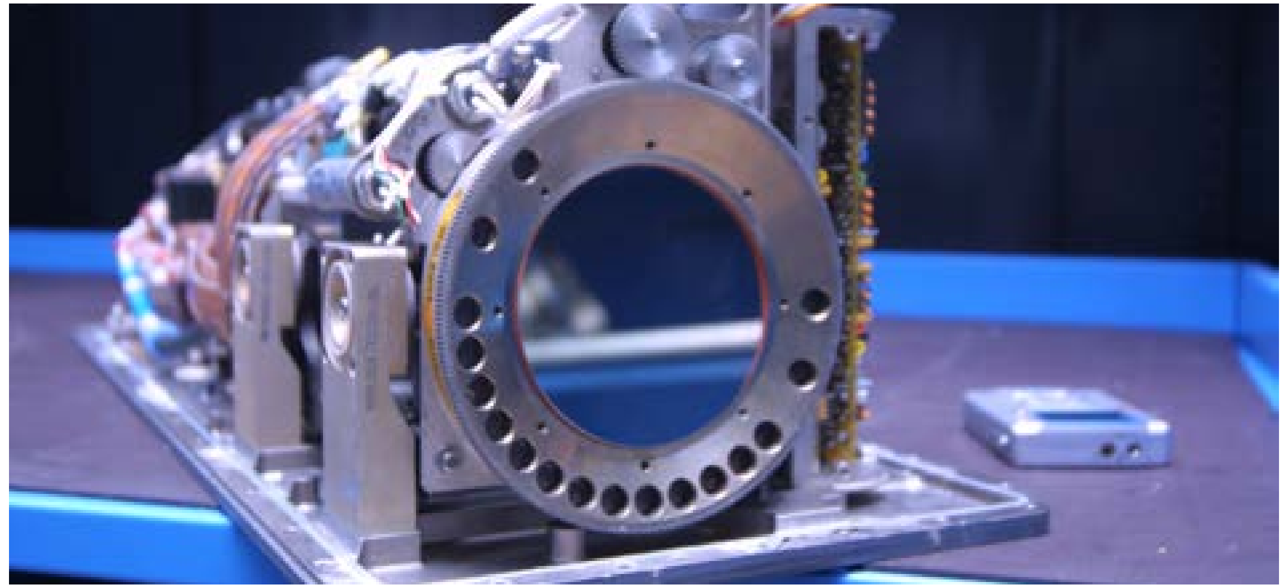
Internally, the AAQ-13 consists of the following LRUs: Environmental Control Unit, Pod Control Computer, Radar Transmitter, Radar Antenna, Radar Interface Unit, Radar power Supply, Terrain Following Radar, Navigation FLIR and Power Supply.

Hunter observed:

> There are many acronyms for the components which made up the pods. Sometimes as many as three for a single part. In the



ABOVE
The business end of the AAQ-13. This flat antenna is the single channel antenna for the terrain following system. (Author)



ABOVE
An AAQ-13 NAV FLIR sensor removed from the pod for routine maintenance. The three small cogs at the perimeter of the window position the sensor for Snap Look and Look Into Turn NAV FLIR functions. See Chapter 2. (Author)

Nav Pod, the FINS is the Forward Infrared Navigation Set [the NAV FLIR section]; the computer is an APCT - Advanced Pod Control Technology – situated on the left side of the pod with the Terrain Following unit next to it. On the other side is a Receiver/Exciter for the TF; a Radar Pressurisation System, which is a Nitrogen bottle for the wave guides [operating at 1,000-3,000 PSI]; a Radar Interface Unit; and below that the Environmental Control Unit. At the very front is the radar gimbal.

The Nav Pod features a different cooling and plumbing system from the target pod. The Nav Pod ECU tends to get quite warm and has a different ECU as safety of flight issue. If something goes wrong in the NAV pod with the ECU, they [the crew] can essentially run that ECU into the ground to continue to get video and TF capability. The ECU in the TP will turn the pod off if conditions deteriorate.

BELOW
The modular make-up of the TP is evident in this image. The space to the far left would have contained the automatic recognition computer, but this feature fell victim to budget cuts and never made it into production. (Author)

In addition to post and pre-flight maintenance, the Nav Pod also features two Built in Test (BIT) routines. A Periodic BIT (P-BIT) routine is enabled automatically upon power being provided from the aircraft's generators to the pod: it operates continuously thereafter and is an non-interruptive system that does not require user selection to operate. I-BIT is a user selectable routine that requires the pod be in standby mode and is a more comprehensive system that can detect and categorise up to fifteen functional failures.

BIT failures are reported via the appropriate MPD page following illumination of an amber AV BIT light on the caution panel. In the case of the I-BIT, failure reports could only be cleared once the pod had been fixed or been removed from the aircraft.

Both pods also feature BIT panels built into their external skin – these small black buttons change to black & white stripes when a failure occurs. A quick glance by the jet's crew chief is often enough to allow immediate identification of a failed LRU.

The TF unit comprises principally of a Texas Instruments KU Band Terrain Following Radar, designated the AN/APN-237A. It was designed to scan a volume of terrain ahead of the aircraft to allow terrain following flight at pre-selected altitudes. Aircrew are be able to use the system either hands-off or manually. Manual TF (MTF) involves the pilot following HUD steering commands from the pod. Auto TF (ATF) allows the AAQ-13 to be coupled to the autopilot for fully autonomous flight, leaving the crew to closely monitor the system while conducting other tasks.

The TF features several modes of operation, but default operation allows:

- Vertical scan of +10° to -20° elevation
- Roll limit of 60°
- 5.5° per second turn rate limit
- 200' – 1000' terrain clearance settings
- Eight-bar radar scan every 2.5 seconds

Like the NAV FLIR system, the TF uses the 1553B mux bus to communicate with the aircraft's Flight Control Computer, and in turn receive data back from the Strike Eagle's Central Computer, Radar Altimeter, INS and FCC.

Terrain detected by the TF is displayed on the TF MPD page. This an E-Scope display shows terrain and shadows out to a maximum range of six nautical miles. Shadows are areas of terrain where the radar is not picking up returns (the back side of a hill or mountain, for example). The TF page also provides an interface that, in conjunction with the UFC, is used to set-up and modify TF flight parameters.

With such a safety critical system come a range of safety features. Critical system status information is presented on the TF, ADI and HUD, and the most important – those requiring immediate aircrew action – are allocated warning lights and aural alerts.

Alerts are generated when systems failures or invalid cockpit switch positions are detected. They can also sound when the aircraft exceeds certain parameters:

- Bank angle exceeding 60° for more than two seconds
- Turn rate greater than 5.5° for more than two seconds
- Turn acceleration more than 2.2° per second for more than two seconds
- Dive angle greater than 3° for three seconds
- Airspeed less than 360 KCAS or greater than 0.97 Mach
- Ground speed less than 360 Knots and drift angle greater than 10°

The crew hear a series of binks – synthesised sounds – to alert them when a potentially lethal deviation from safe flight parameters occurs. In addition, Bitching Betty, a female voice, provides further prompting with the words "TF fail!". A dedicated warning panel is also positioned just below the glare shield in the right side of the pilot's cockpit and repeater lights are installed in the WSO's cockpit just above the MPDs.

Logic control means that when more than one parameter is exceeded simultaneously, only the highest priority warning is displayed.

Sam "Slam" Hendricks described the system as, "A really good piece of kit. It has none of the problems associated with the F-111's TF and is nice a simple to operate". In fact, the AAQ-13 was an improvement over the Texas Instruments AN/APQ-146 TFR of the F-111 not only in terms of capability, but also in terms of reliability.

The nav pod also brought about a better working environment for the crew, Hendricks added:

> There was a very definite way in which we TF'd in the F-111. The radar scope was shielded so that the pilot could not see it. I had to put my head in the scope, look at the ground returns on the radar display, tell him what I saw, and he'd then compare my description visually with what he saw on the E-Scope [mounted below the glare shield in the centre-left of the cockpit]. If I saw terrain at two miles I'd tell him, he'd say 'Yes, I see terrain at two miles', and I'd reply, 'Roger, we should be climbing' at which point we'd get aural tones so that we knew what the command was from the jet. A higher pitch beep would mean the jet should be climbing,

a lower pitch should mean that we're descending. To me it was an aural cue that the jet was interpreting the E-Scope return properly. The F-15E doesn't have the aural beeps, so the cross check now is to take the E-Scope and compare it with the NAV FLIR on my HUD repeater… We went from an audio cross-check to more of a visual one. The comm is now almost gone, no back and forth banter as we can both see the same thing. Generally speaking, we just talk the cross-check through with ourselves.

The AN/AAQ-14 TP was the heaviest and most complex pod. It entered service just prior to Operation Desert Storm, but took some time to reach the operational squadrons. It weighed 245kg and was slightly larger than the nav pod: 381mm wide and 2,500mm long. Providing a high resolution Infrared display in conjunction with an accurate laser designation and ranging system, the pod provided attack capability with LGBs as well as a hand-off capability for AGM-65 Maverick stand-off precision attack missiles.

Like the AAQ-13, the TP was a modular design that made use of LRUs, but it was less flightline friendly because it had a greater number of moving parts. It too featured P-BIT and I-BIT checks, although its list of reportable functional failures had grown to twenty-seven (of which twenty-four could be simultaneously displayed).

Uniquely, the TP featured a Data Logging Module that was installed in the pod and communicated with the Advanced Pod Control Computer to provide real time data recording and logging.

Post flight analysis of this data was accomplished by plugging a portable data terminal into to the pod. The DLM allowed subsequent identification and isolation of low-level faults.

Mechanical boresighting of the TP was supplemented with electrical boresighting. However,

ABOVE
The AAQ-14 Roll & IR Detection Section interface installed (left), and removed (right). This connection system fitted snugly inside the NESA. (Author)

use of the latter resulted in degraded accuracy from the advertised 1.4 mils to, at the very best, 2.5 mils. It was therefore important that gross misalignments were avoided during installation of both the adaptor and pod.

Electrical Boresighting was a simple affair that required the crew to align a distant (+1 mile) target in the HUD while the jet was in flight. The WSO commanded the TP to track the target, which generated a tracking symbol in the HUD. Some careful manipulation of the TDC was then required by the pilot to align two concentric circles in the HUD over the tracking symbol. With this achieved, the commit button could be pressed on the TGT IT MPD page to complete the process.

The TP was divided into Laser Optics, Roll & IR Detector, Electronics and Environmental Control sections.

The WSO or pilot could select from three fields of view on the AAQ-14 target pod:

FoV	Video Dimension	MPD/MPCD magnification
WFOV	5.87° x 5.87°	2.3x /1.9x
NFOV	1.65° x 1.65°	8x / 6.7x
ENFOV	0.825° x 0.825°	16x / 13.4x

The Laser Optics section was housed at the front of the Roll & IR Detector Section and featured a Q-switched neodymium doped yttrium garnet (Nd:YAG) laser and FLIR tracking device. It also contained a humidity detector (desiccant) that changed colour when moisture in this sealed section rose beyond acceptable limits. Once pink in colour, ground crew pulled out the desiccant then purged both it and the Optics section with nitrogen to remove the moisture.

The laser was powered by the Laser High Voltage Power Supply, located within the TP Power Supply unit. It could operate at an eye safe setting of 1.54 microns for training, or a war time setting of 1.06 microns. The former would transmit at 8 millijoules and the latter at 100 millijoules. Selection of training or tactical laser modes was set by a switch mounted externally on the pod.

The laser emitted a beam of light just two inches in diameter which, when using the tactical laser, allowed designation of a target and accurate ranging of a target up to thirteen miles away.

Ranging accuracies of twenty feet were possible in tactical mode. In the eye safe mode, ranging was limited to 3.5 miles.

To avoid conflicting with other aircraft in the area who might also be using lasers for ranging and targeting, and to allow buddy-designation of LGBs, the crew could assign the laser a code to give it a unique pulse signature.

The laser was tied to the FLIR optics, meaning that the FLIR line of sight (LOS) was identical to that of the laser. TP FLIR operated in the same 8-12 micron range as the AAQ-13 NAV FLIR and had an optical aperture of 200mm and a FOR of 150°.

Target FLIR (TGT FLIR), as it was better known, was displayed on an MPD and featured a plethora of data overlaid onto it to provide the crew with precise information as to its modes of operation and operating parameters.

Either crew member could configure it for air-to-ground mode or air-to-air mode at the press of an MPD button. In either mode, various tracking options were available (either ground or aircraft stabilised) to allow target tracking even in conditions of very high and low contrast.

A Field of Regard of 150° was made possible by the NESA – Nose Equipment Support Assembly – the articulated nose section often referred to as the Roll & IR Detection section. NESA's innards rotated continuously by means of a slipring, and it was this incessant spinning that allowed the optics and laser to be rapidly slewed in the direction commanded by the crew.

The slipring provided the electronics with electrical power and coolant throughout the flight.

Built with growth in mind, there were empty avionics bays at the rear of the pod to accommodate future planned upgrades.

Problems with the AAQ-14 began to surface soon after its introduction to service. Flight tests showed that electrical arcing could take place above 25,000' when using the laser, so an automatic lock-out was added to prevent crews from firing the laser above this altitude. Later updates addressed this issue and freed the crew to lase freely up to 40,000'.

The TP also hosted a masking zone data library. When the aircraft manoeuvred, parts of the airframe would obstruct the pod's view of the target, and that could result in loss of guidance for a weapon in flight. Martin Marietta and the Air Force programmed the pod with masking profiles, each of which contained data defining where within the pod's plane of rotation its view might be blocked by a piece of airframe, weapons pylon or store.

The pod would generate a MASK warning over the TGT FLIR MPD imagery when the laser came within 10° of the zone.

During the start up sequence, the Central Computer would automatically select the most suitable masking profile based on the weapons load out the aircrew had tapped into the Programmable Armament Control Set. There were seven profiles for the left hand side of the jet and three for the right. If the stores configuration on the jet did not exactly match a masking profile, additional profiles for each side could be selected.

Because masking while the laser is operating in tactical mode can create reflections strong enough to blind the crew, Martin Marietta installed a switch that would automatically turn the laser off when the pod entered a masked region of the profile.

02

F-15E PRODUCTION & TECHNICAL

F-15E Flight Test Program

Initial estimates had the USAF ordering four-hundred F-15Es, but this was later formally set at three-hundred and ninety-two aircraft.

McDonnell Douglas began manufacture of the Air Force's first F-15Es June 1985, and AF 86-0183 (F-15E #1 – E-1), minus CFTs, took to clear St. Louis skies on 11th December 1986 with the ubiquitous Gary Jennings at the controls.

She wore FS36114 paint, the dark Gunship Grey that would become synonymous with the Strike Eagle, and the stencil E001 on the side of the fuselage.

Configured with air-to-ground munitions on one side, and air-to-air munitions on the other, E-1 was officially rolled out in a ceremony at St. Louis attended by General Robert D. Russ, Commander of Tactical Air Command, and Lt General William Thurman, Commander of Aeronautical Systems Division, Air Force Systems Command.

Amid much pomp and ceremony, E-1's dual configuration provided the public with a vivid show of exactly what she was made of.

She was subsequently ferried to Edwards AFB and designated a mission systems test aircraft in March 1987.

E-2, F-15E AF 86-0184, flew next on 30th May 1987, and joined E-1 at Edwards in August the same year as a loads test aircraft.

Both jets would be operated for the foreseeable future by a joint team of Air Force and McAir test pilots, working under the auspices of the 415th Test Squadron, 412th Test Wing (6510th Test Wing), Air Force Flight Test Centre, Edwards AFB. This organisation was also known as the F-15 Combined Test Wing or Combined Test Force (CTF).

And so began the first of a multi-phased F-15E flight test program.

Phase 1

The F-15E flight test program had actually begun in 1983, before E-1 had even been built. It was planned and managed by McDonnell engineers John Roberts and Kevin Morgan.

Roberts and Morgan split the program into seven phases of testing, many of which ran concurrently to reduce overall timelines, and all of which were characterised by an insatiable quest for both digital and analogue data for analysis.

To make it possible to gather the huge range of data sought, a new instrumentation system was installed – the GFE Airborne Test Instrumentation System. Fitted to the first E models, the system set a precedent for data collection capabilities at that time and echoed McDonnell Douglas' ambition that the FSD (full-scale development) program would be accomplished with as little cost to their customer as possible.

Phase I	Preliminary Development Testing
Phase II	USAF/McAir combined DT&E
Phase III	USAF combined DT&E/OT&E
Phase IV	USAF Follow-on DT&E (Pre-IOC)
Phase V	OT&E

OPPOSITE
The first ever F-15E in the final stages of construction. Its official title was E-1, but it differed somewhat from what would become the production standard Strike Eagle. (Boeing via Author)

Phase VI	Follow-on OT&E
Phase VII	USAF Follow-on OT&E (Post-IOC)

PW-220 Engine

Phase I preliminary testing started in 1983 and acted as a precursor to FSD testing. It utilised ongoing development testing by both the McAir and the Air Force to finalise the final F-15E specification, whilst also reducing risk and costs further down the road to initial operating capability (IOC – the Air Force's way of signalling that a design is ready for combat operations).

The major elements of this phase consisted of the testing and integration of the F100-PW-220, and in the very early stages used an F-15A test-bed as a stand in for the F-15E. The PW-220 was much anticipated and would hopefully provide real improvements in operational maintenance, fuel consumption and overall operating cost.

The new motor actually produced slightly less thrust than the PW-100 (-380lbs), and developed 23,450lbs of augmented thrust.

What made it significantly more attractive, however, was the advantage of full Authority Digital Electronic Engine Control (DEEC). DEEC replaced the PW-100's slower, analogue system, which would often lag behind throttle inputs. It reduced wear and tear on engine components whilst increasing engine performance, fuel consumption and life span. It achieved this through digital control laws that constantly monitored a range of operating parameters and made fine-tuned adjustments to them, accordingly.

Testing of the PW-220 by the CTF commenced in the second quarter of 1985 and ran through until the beginning of the third quarter of 1986.

Subsequently, the PW-220 was installed in F-15Es 86-0183 through 90-0232 and was also fitted to later model F-15Cs and newer F-16C/Ds.

Type IV CFTs

Phase I also comprised of Type IV CFT (also referred to as Dash-4) development, conducted at both Edwards and the Armament Division at Eglin AFB, Florida, from mid-1985.

Production build CFTs were subsequently installed on E-3 (86-0185) for its first flight on 14th September, 1988. Dash-4 modifications primarily consisted of equipping the CFTs for tangential carriage under USAF contract ECP-1652.

The modifications involved installation of six stations on each tank, mounted in two rows of three. The lower pylon is moulded into a single, straight runner that contains three BRU-47/A (Bomb Release Unit) racks. The forward and aft inboard BRU-47s have a combined 2,200lb capacity, while the centre BRU-47 has a 3,300lb capability and is also wired to carry nuclear weapons. All three feature two 30" and two 14" suspension hooks.

The upper three pylons feature the more compact BRU-46/A. These each have a maximum design load of 1,100lbs and are equipped with two 14" suspension hooks.

All the BRUs incorporate swaybrace and pitch valve mechanisms, which would pivot and lock to automatically align the bombs for correct carriage. This had previously been a manual task performed by loading crews. The BRU-47/A also incorporates a reversible in-flight lock (RIFL) that prevents inadvertent release of captive-carry and training stores, and also safeguards against inadvertent release of the B-61 nuclear bomb. In addition, each BRU is ground safed by means of a red arming handle.

The new pylons allowed the nascent F-15E to carry a greater variety of stores, one per station, without the need to load a MER.

McAir also designed the Dash-4 CFT to be interchangeable with earlier CFT types.

An air-to-air configuration was also created to allow installation of two AIM-7 Sparrow or AIM-120 AMRAAM medium range air-to-air missiles per CFT.

The missiles are attached to LAU-106 missile launchers that are installed by sliding the BRU-46/A back into a reserved stowage area within the elongated pylon. Upon reconfiguring the jet for air-to-ground, the LAU is moved into its own stowage area, and the BRU can then be used. To accommodate the smaller diameter of the AIM-120 , forward ejector feet (semi-circular devices used in concert with semi-recessed aft ejection feet to push the missile away from the aircraft during launch) are fitted with pads to ensure a snug fit between missile and pylon.

Contrary to some media reports, CFTs do not impose a manoeuvre or g loading limitation on the Strike Eagle during normal operation. Indeed, they have no impact on the aircraft's G envelope as was demonstrated on 16th November, 1988 when they were flight tested at 9g.

Phase II saw the first Dash-4 CFT weapon release on the 19th January, 1989.

OPPOSITE

The BRU-47/A (top and right) and LAU-106 (bottom left) LAU-106. The two were interchangeable and neatly stowed away inside the pylon when not in use. (Author)

Digital Electronic Flight Control System

The F-15 Eagle features an analogue flight control system comprised of a hydromechanical primary control system over which a Control Augmentation Stability system was placed. The F-15E though, was destined to receive a digital, triple-redundant, Digital Electronic Flight Control System that would provide additional redundancy and better control laws.

Early DRF flight tests had used F-15D CAS matrices in lieu of dedicated F-15E data, and Phase I focused on revamping the flight control system to form custom F-15E control laws. Analogue control laws taken from the D model's two channel CAS were translated into code that the new digital duplex flight control computer could make sense of. It was called the digital electronic flight control system, or DEFCS.

Verifying that the control laws were adequately programmed was a significant and successful portion of the program, and was also critical to the TF evaluation that followed.

The F-15E was fitted with an identical hydromechanical system to previous Eagles, albeit with upgraded components. Collectively, the CAS and hydromechanical components are termed the Automatic Flight Control System.

Dedicated flight and ground tests uncovered issues that were corrected before engineers could complete structural node interaction tests. According to McAir engineer, Michael Ludwig: "We ran ground vibration tests to verify that the structural movement of the aircraft did not provide feedback into the flight control sensors. The airplane has accelerometer packages located in the airframe to sense G loadings in all axis of travel [pitch, roll and yaw]; if those packages are located at a point on the aircraft where the airframe bends or flexes under G, then erroneous feedback into the CAS is experienced".

Extensive strengthening of the Strike Eagle's airframe resulted in it flexing in different places from the F-15D. Accordingly, Ludwig and the team identified new nodes in the F-15E – points "where the amplitude of airframe flexing was natural" – for the placement of the accelerometers that would input into the DEFCS. In lay speak, the nodes were the points in the jet that were not subject to flexing.

The hydromechanical system consisted of rods and pulleys that connected directly to the hydraulic actuators on the aileron, horizontal stabilisers and the rudders. AFCS/CAS (DEFCS is often referred to as AFCS) is a three channel, three axis system that takes electrical signals generated by a stick force sensor mounted at the base of the control stick, and translates these into control surface deflections. CAS does not have any Authority over the ailerons however, and is limited to supplementing only the stabilator and rudder inputs. It offers the advantage of dampening out small stick movements caused by turbulence or other atmospheric phenomena, and also provides better control Authority and stability at high angles of attack. Data for the DEFCS is sourced from the Honeywell AN/ASK–6 Air Data Computer, Teledyne Avionics angle of attack sensors and, until GPS arrived in the late 1990s, a Honeywell AN/ASN-108 Attitude Heading Reference System (AHRS).

Longitudinal stick movements (pilot commands to raise or lower the aircraft's nose) are processed through a ratio of gears that allow CAS to elicit a constant pitch response from the jet for a given movement of the control stick, regardless of the airspeed being flown. CAS will also keep the aircraft trimmed to 1g flight, and will very precisely and rapidly drive the stabilators without the pilot noticing – this is a useful feature that obviates the need to trim the jet when deploying flaps, extending speed brake or releasing stores. If required, mechanical trim can be applied by the pilot or WSO through a small coolie hat switch mounted on the control stick.

A lateral ratio is also installed, and it too compensates for factors such as altitude and airspeed to provide protection from adverse yaw and excessive rates of roll at supersonic speeds. ROLL RATIO and PITCH RATIO switches forward of the throttle quadrant can be independently selected to either AUTO or EMERG positions.

Further AFCS testing continued in Phase II to fully open the flight envelope. And as part of the AFCS evaluation, an Iron Bird, full-scale hydraulics system mock-up was used by McAir to verify new flight control systems component compatibility. Iron Bird was also linked to a manned flight simulator, and this allowed verification of software and hardware changes prior to flight testing.

APG-70 Development

Phase I ran APG-70 testing from 1983 through to 1988 and consumed a large chunk of time and assets. Back-to-back trials of the radar involved testing High Resolution Mapping capabilities until 1984, whereupon its air-to-air capabilities were evaluated. Thereafter, only a limited number of sorties were dedicated to the air-to-ground testing schedule as this

OPPOSITE
The first F-15E readies to launch during Phase II. (Boeing via Author)

was most heavily evaluated in Phase II.

Phase II

Phase II, also known as joint Development Test & Evaluation, was run at the same time as Phase IV in order to minimise budget overlays and provide the United States Air Force with maximum developmental effort. It was a key program hurdle: it would test whether the Strike Eagle could meet the USAF's requirements.

Phase II was managed by the F-15 Systems Program Office (SPO), although the team comprised of a mix of representatives from McAir, USAF, F-15 Systems Program Office (SPO), and the Air Force Flight Test Centre (AFFTC).

This phase concentrated on development, integration and evaluation of mission systems, and on the completion of specification compliance prior to the Air Force's own DT&E and OT&E efforts (Development Test & Evaluation and Operational Test & Evaluation).

Amongst the key areas for analysis were:

1. 9g airframe structure
2. 81,000lb TOGW landing gear
3. DEFCS
4. APG-70 and HRM modes
5. Missionised crew station integration
6. AAQ-13 & AAQ-14 integration and capabilities
7. CARA (Combined Altitude Radar Altimeter)
8. INS
9. Air-to-ground weapons accuracy

E-1 and E-2 were used over a total period of thirty-one months. Two-hundred and eighty-six flights were conducted on a rota of approximately ten flights per aircraft, per month, averaging two hours per flight. These flights also provided the additional benefit of collecting data for basic flight envelope and systems operation, which was subsequently distributed to help validate data collected by other Phases of the test program.

E-1 was used for avionics and weapons systems integration, E-2 for structural, flight control system demonstration and LANTIRN evaluation. Both aircraft were still fitted with the GFE Airborne Test Information System (ATIS) which provided encrypted on-board air-to-ground telemetry and mission measurements. McDonnell Douglas made use of a dedicated laboratory and ground test facilities with which to test modified and new equipment for avionics integration for interference compatibility.

Most sorties were planned so that the crew could explore a range of aircraft features during the course of a single sortie.

AFCS Envelope Expansion

E-1 flew the first envelope expansion sortie as its maiden flight in December 1986. Reaching 40,000' and 0.9 Mach, Jennings noticed no real differences in handling between any other F-15 he had flown – this was no surprise, as it had been a design goal of the team when they had developed the AFCS.

A further eight sorties were conducted from St. Louis to ready the jet for transit to Edwards. On the third flight conformal tanks were carried. Once dummy LANTIRN pods (representing the mass and weight characteristics of the real things) had been flown, three 600 US Gallon external fuel tanks were loaded for the final flight (for the moment, at least) from St. Louis.

By the time the aircraft was ready for shipment to Edwards, it had attained speeds of Mach 1.7 at altitude, and had sustained 600 knots at low altitude. DEFCS was operating well, and no major problems were found with the coding or translation of the digital data. Data from these flight tests, and subsequent Phase II testing, was collected and fed into a DEFCS database. Updates of the database allowed not only fine tuning of flight control laws in the aircraft, but also the flight simulator. E-2 would ultimately take on the role of fully exploring the flight envelope.

Air Force and McAir test crews flew classic manoeuvres within all areas of the flight envelope. When they requested changes, new releases of the FCS software were loaded into the aeroplane for further exploration. Regression tests were subsequently flown to verify the fixes, and they were also compared to the FCS laws used in the F-15C, which had earlier flight tested the CFT.

Of particular interest was the Strike Eagle's spin characteristics: the AFCS featured a Direct Electric Link mode that would replace CAS during a spin. CAS is disengaged and DEL engaged, providing the pilot with full control Authority and redundancy simultaneously. The pilot can also enter his own AoA warning setting. It defaults to 30 units AoA, but can be programmed from 20–45. This tone is two short, 900HZ beeps

OPPOSITE
E-2 fully instrumented and conducting DEFCS envelope expansion work. (Boeing via Author)

followed by a 0.3 second pause and accompanied by flashing of the AoA indicator in the HUD.

A departure Warning system monitors yaw rate. Activating when a rate of 10° per second or more is observed, the system generated the advisory 'YAW RATE, YAW RATE' aural cue as well as a 900HZ beep tone. Beeping increases as yaw rate increases; at its peak, it represents 60° per second. A BIT check can be run on the AFCS via the AFCS MPD page to ensure correct operation of the system.

Twenty-six flights were set-aside for flight control testing, and flights alternated between what McAir referred to as the "E' configuration' (with CFTs) and other, less draggy configurations.

9-g Testing, Structure and Loads

Early in the Strike Eagle program, McAir planned to take advantage of continued research into manufacturing techniques, particularly those involving the use of titanium.

Such changes were necessitated by both the increased empty weight of the F-15E and its massively increased all-up weight (when fully laden with weapons and fuel). The F-15D weighs 28,800lbs empty compared to 31,800lbs for the F-15E.

When fully laden, the F-15D can take-off at a maximum weight of 68,470lb; the F-15E can haul itself into the air weighing a staggering 81,000lbs (24,500lbs of which can be external stores).

The F-15 wing, which is a NACA 64A aerofoil section featuring a torque box with integrally machined skin/ribs made of light alloy and titanium, honeycomb wingtips, flaps and ailerons, was left untouched. McAir anticipated that it was strong enough to maintain structural integrity over its intended 16,000hr fatigue life despite the increased loads associated with heavier ordnance, higher wing loading and buffet of low altitude flight.

McAir instead concentrated on the structure and composition of the forward and the rear fuselage sections. Several factors influenced this, primarily the necessity to increase the F-15E's life cycle to 16,000 flight hours and to allow sustained high-g operations in the denser, turbulent air found at low altitude.

Integrally machined aluminium and titanium had already been used in the production of previous F-15s. McAIr now introduced Superplastic Formed (SPF), Diffusion Bonded (DB) techniques along the rear fuselage keel, main landing gear doors and some fuselage fairings.

SPF/TB was an ingenious system that provided lightweight, high strength structures. Two pieces of titanium would be placed in a jig and sandwiched together. They would then be placed in between two fixtures that were essentially moulds with seals around the outer edges. Once inside the mould, they were superheated until they became pliable, at which time an inert gas was injected between the two sheets. The gas pushed the two skins away from each other, causing them to precisely occupy the curves and lines of the mould.

With this accomplished, hinges and attachment equipment were fitted to the skins. The end product was referred to by McDonnell Douglas as BLATS: Built Up Low Cost Advanced Titanium Structure.

The F-15E shared similar bulkheads to previous F-15s although there were thickness increases that did not change the outer-mould line, and the titanium fairing that usually extends rearwards between the engine exhausts was deleted. When the Air Force discovered that this improved the aircraft's aerodynamics, they ordered all F-15s going through depot level maintenance to be modified as well.

In the course of the rear fuselage redesign, engineers were able to reduce the number of latches and fasteners incorporated into the panels and fittings, saving weight and maintenance costs as a result.

McAir continued to demonstrate good forward thinking when they redesigned the engines bays to accommodate both Pratt & Whitney and General Electric jet engines – plumbing for both was installed, as were fittings and attachments – they were subsequently named common engine bays.

Thirty-one sorties were set aside for loads testing, the first of which were flown to calibrate the loads measuring instrumentation equipment. The testing worked with data obtained from the initial F-15 FSD program many years previously, obviating the requirement to run ground calibrations prior to the first flight.

80% of the design loads limit (DLL) was flight tested following calibration, allowing engineers to establish how accurate their computer predictions had been, and to estimate how accurate computer predictions for the remaining 20% of the envelope would be.

In fact, computer analysis to 150% DLL was completed prior to flight testing to 100% DLL. E-2 reached 800 knots on the 12th November 1987 and then demonstrated a maximum take-off weight of 81,000lbs on the 29th September 1988.

BLATS was also put to test over the course of this time, and the F-15E demonstrated 9g capability for the first time on the 27th June 1988.

Basic Airframe Systems and PW-220 Integration

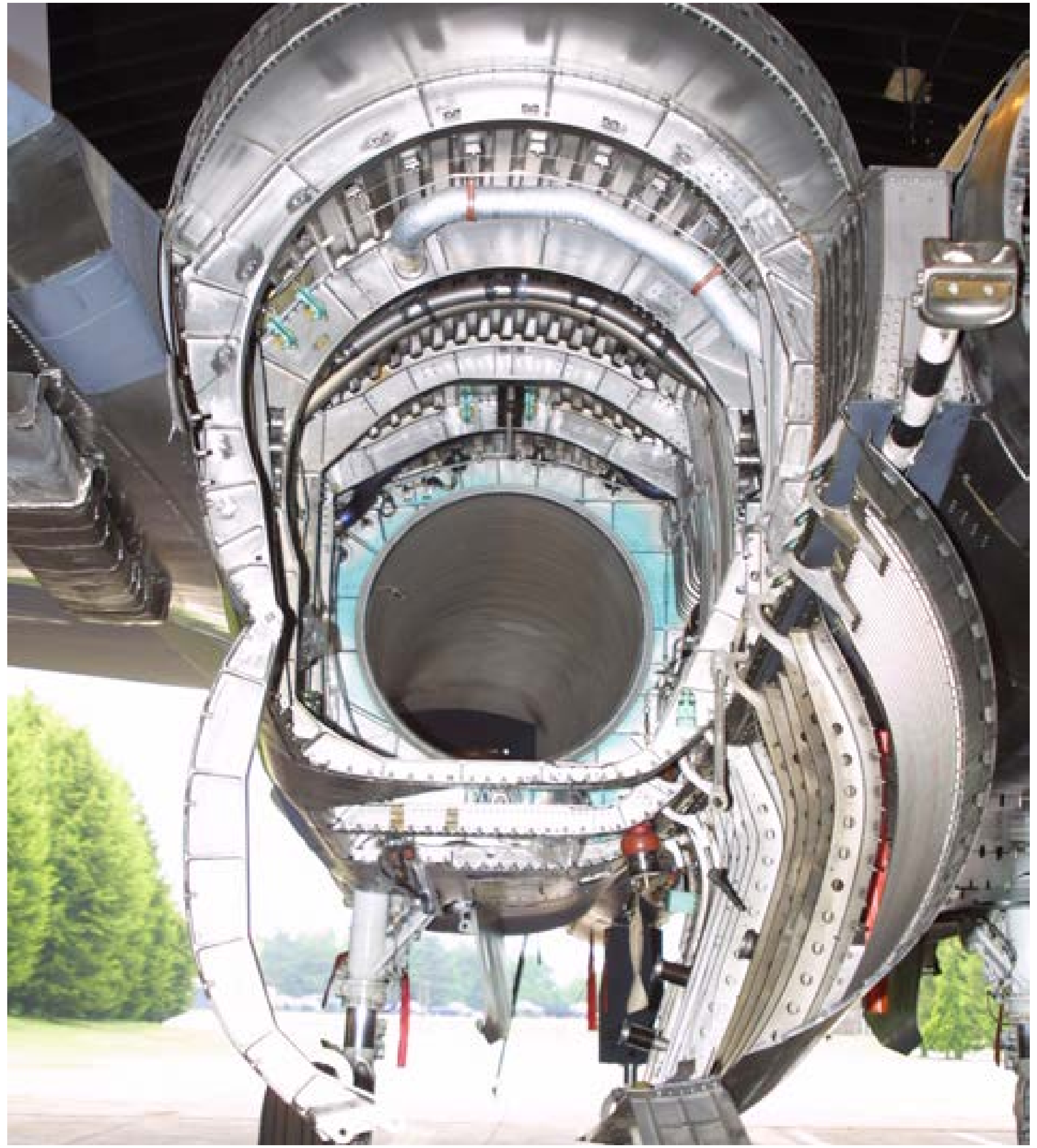
Ground and Flight tests were conducted on E-1 concurrently with systems integration tests in several cases.

The F-15E Engine Inlet System was structurally modified to provide growth potential for the Improved Performance Engines (IPE) that were planned for the future, and the air inlet control system was also evaluated for basic performance data. So, too, was the airstart envelope for the PW-220.

Increased electrical demands from the electronic cockpit and externally mounted sensors (LANTIRN) etc. resulted in the F-15E's electrical system receiving an overhaul. A Lucas Aerospace generating system was installed. This takes an additional transformer-rectifier to complement two uprated, increased-capacity, electrical generators. These each provide enough current to power essential systems should either of the remaining two fail. They are supplemented by engine mounted Hamilton Sundstrand 60/75/90 kVA constant speed drive units.

The generators are linked but work independently of each other to provide power to other aircraft buses, which in turn provide power to specific aircraft systems. They are individually controlled from the front cockpit and function autonomously in most circumstances.

Transformer-rectifiers (TR) provide DC power to the aircraft in a similar fashion, offering redundancy in the event of failure – one TR can power all DC dependent systems. The emergency generator provides both AC



RIGHT
GE and P&W compatible F-15E engine bay. (Author)

and DC current and is a hydraulic, motor driven device that automatically operates when a fault occurs in either AC or DC systems.

Finally, an improved Environmental Control System was installed to cope with increased avionics cooling requirements.

Overload Warning System

OWS was a late innovation developed as part of MSIP and integrated into the Strike Eagle, too. For some time, Eagle pilots had been limited to flying the aircraft at a maximum loading of +7.33 g. Whilst this was an improvement over the venerable F-4, which flew its maximum performance turn at +6 g, it was short of the +9g limit the airframe had been designed for.

OWS was not designed to prevent the pilot from exceeding g limitations and is therefore not a G limiter such as that found in the F-16. Instead, it provides adequate warning that the pilot is fast approaching g limits. In addition to the warnings discussed below, the HUD also provides real-time indications of g allowable and current g loading.

G allowable is affected by a combination of stores carried, gross weight, airspeed and altitude. OWS takes information from the DEFCS and defines a g envelope in which the aircraft can operate safely. It calculates fuel state in real-time and requires the crew to input accurate stores, fuel and weight data following engine start.

Three aural warning tones also provide cues. The single rate beeper sounds at 85% of maximum allowable g; the double rate beeper at 96% and the steady tone at 100%. Exceeding this results in "Over g! Over g!" from Bitching Betty and a severity code is entered into the Central Computer memory.

OWS has its own MPD page that places accumulated severity codes into a matrix. The page carries a line of headings that represent various parts of the airframe , the overload percentage attained, and actual overload g number. Below this is a list of individual overload conditions, ordered by severity. A quick glance at the OWS page allows the crew and maintainers to establish which items have been overstressed and what maintenance checks are required prior to the next flight.

Cockpit

Even though much of the work to finalise the cockpit design for the F-15E had been accomplished at St. Louis during the AFCD and DRF programs, McAir had continued to refine its design.

Extensive use was made of the simulator between 1984 and 1986, and anomalies were ironed out prior to reaching the jet.

E-1 was the testbed for the first full specification F-15E cockpit although, as previously mentioned, it had minor differences to the final layout and design.

Cockpit assessments were added onto sorties whose primary objective was to test some other system or facet. Only once this primary goal had been achieved did the crew turn their attention to the cockpit. McDonnell Douglas records show a total of thirty sorties during which the cockpit design was evaluated.

The final cockpit layout was markedly different from that installed in '291 six years previously. Gone were the two 5" and two 7" monochrome displays from the back seat. Gone too were the old steam driven gauges of earlier generation Eagles. The new cockpit was festooned with display screens surrounded by push buttons, digital displays, data entry panels and controllers with lots of buttons.

The front cockpit was radically different from that of any previous F-15. The HUD had been replaced by a Kaiser IR-2394/A Wide Field of View unit. Squatting above the control panel, it provides a 21° x 28° field of view and can display raster (video) and stroke (symbols) imagery. In a break with previous HUD units, the combining glass and optics are not heavily framed, but rely on curvature and solid base mounting to maintain their strength. A small panel below it contains rotary switches to individually dim or brighten both raster or stroke imagery. A three-way declutter switch was included, and this progressively removes symbology from the HUD should the amount of information displayed become excessive.

Articulating pitch ladders were used for the first time. The pitch ladder is a visual aid to determine the aircraft's attitude, specifically roll and pitch, relative to the horizon. It displayed increments of 5° as solid or dashed lines (above or below the horizon, respectively). The articulation is created by the pitch lines, which angle towards the horizon at half of the angle of pitch the line represented (so, the 40° positive pitch line angles 20° down, the 60° negative pitch line angles 30° upwards).

A 'sky pointer' function was incorporated in the ladder, and this too was a first-time feature – small ticks at the end of each ladder point towards the

OPPOSITE
The production F-15E front cockpit, showing the three displays and wide field of view HUD. (Author)

horizon. Jennings explained that these two features were extremely useful for unusual attitude recoveries without having to place one's head back down in the cockpit to reference more traditional aids such as the artificial horizon.

The new HUD worked extremely well even when front-lit by the sun, although the pilot could always call up a HUD repeater on his MPD if required. For combat, the IR-2394/A was not only capable of displaying a huge amount of flight and navigational data but would also display key pieces of information necessary for air-to-air and air-to-ground engagements.

Directly below and in line with the HUD, McAir added a new Up Front Control panel, or UFC. This provided direct control of the INS, TACAN, Auto Pilot, TF, IFF, AAI, UHF radios, ILS, NAV FLIR, A/G stores delivery bias, and JTIDS. It consists of a row of six Liquid Crystal Display panels, flanked by ten push buttons and two radio channel selection knobs.

The LCD panels are positioned above an alphanumeric keypad through which data is entered into the aircraft's systems. The sixth LCD panel is referred to as the scratch pad because it displays the data being entered from the keyboard, allowing the crew to confirm the entry before committing it to the aircraft's systems.

The F-15E has two UFCs, one in each cockpit, and they run off separate Avionics Interface Units (processors) in order to add a layer of system redundancy. Each has its own BIT.

The controllers allow both crew members to input data into the system at the same time. This can sometimes gave rise to duplication of workload or erroneous entries replacing accurate ones.

Two menus and a series of sub-menus provide access to the avionics, and a MENU button on the key pad allows either crew member to cycle through these. MENU 1 provides flight critical data such as IFF codes, Low Altitude Warning height, navigational data such as TACAN frequencies, TF mode indication, NAV FLIR control, auto pilot control and current steer point.

MENU 2 provides less frequently accessed selections such as ILS frequency and activation, air-to-ground delivery options and setting of a bullseye reference point.

Two DATA menus take the software interface a layer deeper, and provide access to valuable navigational data such as the time, estimated time of arrival, estimated time en route, wind data, ground speed, time over target predictions etc.

A command velocity wiper tied in with route timings is displayed in the HUD to show the pilot whether to increase or decrease speed to reach a steer point on time. The wiper operates based on the INS steer points in the system and assumes that the route is flown as programmed into the INS. When the wiper is at full deflection (too slow or too fast), the ground speed required to arrive at the desired steer point on time is displayed on the attitude director indicator MPD page.

McAir also added two rotary knobs either side of each UFC to either tune the aircraft's two Honeywell AN/ARC-164 UHF Transceiver radios, or to switch them to between pre-set frequencies.

KY-58 HAVE QUICK II, jam resistant auxiliary radios were installed on F-15E 87-0189 and up, and this too was accessed through the UFC.

In the pilot's cockpit, and flanking the UFC below and to the left and right, McAir installed three Honeywell Multi Purpose Displays (MPDs), two monochrome and one colour. The colour display was referred to as the MPCD and was centrally mounted in front of the control stick. MPDs were a direct replacement for traditional cockpit instrumentation such as the Radar Warning Receiver, Radar scope, flight instrumentation, E-Scope etc. Each has twenty push buttons (PBs) numbered anti-clockwise from left to right for ease of use, and crews soon became accustomed to passing on tuition or advice in PB format: 'Press PB9, then hit PB18 and select PB4'.

With the displays turned on, legends align themselves with each button – pressing the button next to the legend activates that feature. The top five PBs on each MPCD are engraved with mnemonic lettering for the aircraft's weapons stations. MPCDs provide colour coded information to further facilitate expeditious interpretation of the displayed data.

PB presses allow additional menus (unrelated to the UFC) to be called up, from which further selections can be made. The MPDs can be programmed prior to flight to scroll through pages, at the touch of a button, in whichever order best suits the operator. Further, each display can be programmed to scroll through three user selected pages upon pressing any of the master mode buttons. This custom programming allowed pilots and WSOs to develop their own habit patterns – they knew that entering air-to-air mode for example, would bring up pages that they most wanted to see. It also allowed them to instinctively reach another page by simply toggling a stick mounted switch a certain number of times

OPPOSITE

The production F-15E rear cockpit. Note the right-hand controller, simplified control stick and "down right controller". (Author) according to the hierarchy they had programmed into the MPDP.

The HUD, MPDs and MPCDs are all powered by the Multi-Purpose Display Processor. The eight channel MPDP produces stroke and raster information, translates the analogue OWS signals into a digital format which can be read by the Central Computer, acts as a back-up MUX controller for the CC, and provides the conduit through which all sensor data is passed prior to display in the cockpit. Whilst the CC controls the MPDs, the MPDP is designed to act as a back-up in case of primary system failure.

In this new Strike Eagle cockpit, a small set of back-up mechanical flight instruments occupied a space below the left MPD, and the engine instruments ordinarily found on the right were replaced by a smaller, monochrome LCD display known as the Engine Monitor Display (EMD).

The EMD provides the same information as the older mechanical gauges, but in a graphical format similar to that found in the F/A-18.

MPD Electronic Attitude Director Indicator (EADI) and Horizontal Situation Indicator (HIS) are display formats that could be called up on any of the MPDs to provide navigational and situational data in lieu of full sized analogue instrumentation. The Horizontal Situation Display provides a plan view of the aircraft relative to navigational aids such as TACAN, and gives steering information such as range and bearing. A compass card dashed at every 5° around the outside of the display rotates so that the aircraft symbol in the centre is always pointing upwards. Range scales of 10, 20, 40, 80 and 160nm can be selected, and these can be used in conjunction with any one of the six individual steering modes available. The EADI, which is often abbreviated to ADI, provides a digital representation of the artificial horizon, slip indicator and turn rate markings. It also features a digital airspeed and altitude readout.

In the event of a CC malfunction, each display reverts to a back-up mode to enable continued instrument aided flight.

Front Cockpit

A newly designed, conventionally mounted control stick and two throttles were installed in the Strike Eagle front cockpit to fully exploit lessons learned in the art of Hands On Throttle And Stick (HOTAS).

The pre-MSIP F-15 had a basic HOTAS, but the F-15E took this several stages further. The stick plays host to no fewer than seven levers or buttons. Three of these are five-way switches, one a two-stage trigger, and the others carry single position detents. Each switch position has its own separate function, and this can change depending on the master mode, radar mode, weapons mode and displays selected.

By way of an example, the castle switch (mounted centrally on the top of the stick) is the primary method of changing displays without having to touch any of the PBs. Pressing the switch down and then in the direction of the MPD of interest causes the switch to take command of that display; pressing it left or right then scrolls through the display pages. Pressing a button on the throttle and simultaneously pressing the castle switch would then drive the NAV FLIR into a Snap Look mode (discussed below). Pressing the master caution light and then simultaneously moving the castle switch left, right or aft will cause the BIT page to appear on the chosen MPD. In air-to-air master mode, pressing the switch forward jumps the system to air-to-ground, causing the displays to reconfigure automatically.

The castle switch is one of the simplest HOTAS element to use. By contrast, the auto acquisition (AUTOACQ) switch can perform more than thirty-five separate functions, depending upon whether it is depressed in conjunction with one of the throttle switches.

This level of sophistication had only ever been dreamed of prior to the Strike Eagle, and it equalled (if not exceeded) the complexity of the oft-fabled F-16 HOTAS set-up. Aircrew quickly developed HOTAS skills through frequent trips to the simulator and time spent flying.

BELOW
The F-15E stick grip provides a myriad of HOTAS functionality. The stick force sensor box, which supplies stick input data to the CAS, is directly below the grip assembly. (Author)

As the F-15E grew even more complicated, time tags were assigned to the HOTAS buttons. In effect, their functionality was uprated 100% by timing the duration of each switch press.

For example, whilst in command of the TGT IR page, placing the AUTOACQ switch aft for less than one second causes the AAQ-13 to return to its original cue, but pressing it forward for greater than one second drives it into snowplow mode.

The split throttles carry their own assortment of HOTAS switches. From left to right are a chaff/flare switch, a rotary dial that controls the elevation of the radar antenna; a single position switch to fire the TP laser, an isometric transducer switch called the target designator control (TDC) with which the TGT IR, HUD target designator box, or radar cursors are slewed to capture a target or reference point; a four-way coolie hat; a three position microphone switch for transmitting on the two UHF radios; a three position speed brake switch; a three position boat switch; and a weapon select switch that accommodates three positions – gun, short range missile and medium range missile.

Some light grey Eagles would eventually be modded with the F-15E stick grip and throttles under the MSIP II program, delivering an identical level of HOTAS wizardry to the air-to-air dedicated variant of the F-15 family.

Rear Cockpit

E-1's rear cockpit featured two MPDs and two MPCDs. These are arranged with the larger monochrome displays in the middle. A back-up set of analogue flight instruments is provided below the four displays.

McAir installed a "sissy bar" above the instrument coaming, allowing the WSO to grab it and twist his torso for a better look behind the aircraft. Below the bar is an elongated annunciator panel and the Master Caution light.

The WSO was provided with a set of simple throttles and control stick identical to that found in previous F-15s, per the General's order. To give the WSO unimpeded control over the weapons system and sensors, McAir had moved the left controller inboard of the throttle quadrant, but other than this remained largely the same as originally installed in B-2.

LHC and RHC HOTAS was even more complex than that found in the front seat, and each controller was dedicated to manipulating the two MPDs on its side of the aircraft – LHC ran the left MPD and MPCD and the RHC controlled those on the right.

Cranked inwards for comfort, the controllers are firmly mounted to fixing plates as all sensor control would be achieved through manipulation of the switches. Each features a three-way, momentary slide switch for chaff/flare or IFF activation; a four-way coolie switch for MPD page scrolling; a five-way castle switch that ran many of the sensor attack functions; a TDC identical to that in the front seat; a two-position trigger; a spring-loaded laser fire button; and a four-way mode reject switch.

The rear cockpit is sparsely instrumented in comparison to the front cockpit, and the side consoles are punctuated by a handful of panels for systems such as the Internal Countermeasures Set, Electronic Warfare Warning Set, Radar Warning Receiver and LANTIRN pods. The WSO's UFC is mounted on the right-side quarter panel.

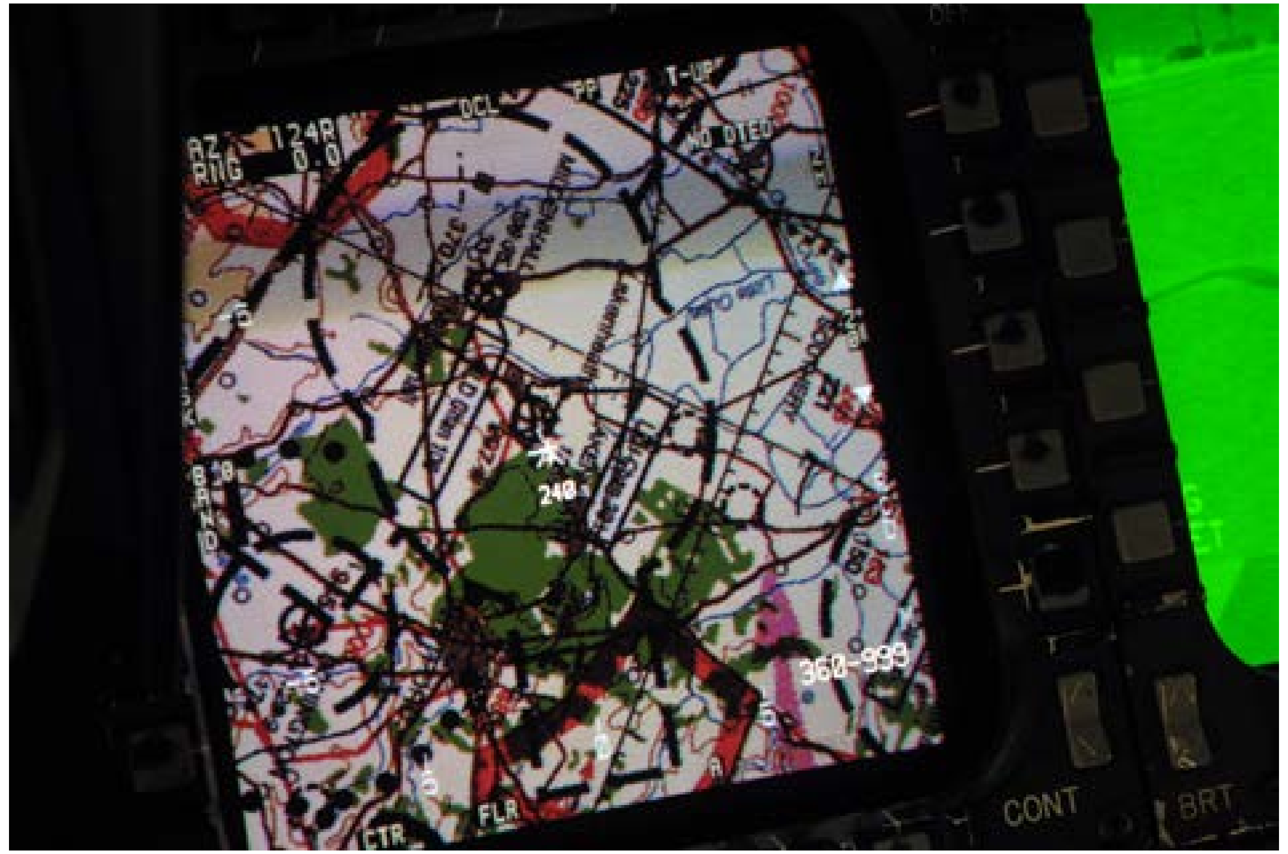
The TSD had also undergone considerable change by the time the crews came to test it during Phase II. The original format – computerised sectional charts – had been replaced with maps converted to cartridge fed 35mm film strip. These are stored in the Honeywell RP-341/A remote map reader (RMR – situated behind and to the right of the WSO).

The fixed map scale had been replaced by four scales that could be loaded into the RMR and selected at will by either crew member. The TSD was evaluated for two primary roles – navigation and sensor cueing. Flying out of Edwards, crews would call it up on an MPCD, taking advantage of the enhanced situational awareness that the colour maps could deliver.

The TSD is fed positional data by the Present Position Keeping Source (PPKS source – INS, AHRS, Mission Navigator and later, GPS) selected by the crew. En-route, the crew can view their targets, steerpoints, ground track, offsets, aim points, bullseye points and a host of other navigational data, all of which are also overlaid onto the map.

With the target area approaching, the radar or TGT IR is cued to point towards the desired location by simply placing the acquisition cursors over the area of interest and pressing a HOTAS switch.

Field of view footprints for each sensor are displayed and can be superimposed on the map. The HRM footprint shows which part of the terrain will be mapped, the TGT IR footprint shows the WSO how much of the terrain will be visible through the pod in its current mode of operation. Changes to the resolution of the patch map or zoom level of the pod are reflected in the size of the footprint displayed. It places an *X* symbol over the HRM footprint when the



ABOVE
The TSD on a rear cockpit MPCD display. Aircrew have described this moving map as one of the F-15E's best features. (Author)

footprint is out of the APG-70's mapping limits.

Both footprints can be displayed simultaneously, thus allowing the WSO or pilot to find and designate one object with the radar, another with the TP and to then compare the positions of the two objects relative to each other. Both footprints also automatically display the range and bearing of their line of sight relative to the aircraft's current heading.

The TSD takes its data from the CC, builds a line drawing of the aircraft's route of flight, then stores it. This functionality meant that Edwards crews were therefore able to step through their upcoming steer points and add, delete, or assign new timings in real-time. When adding new steer points, the TSD automatically calculated the turn radius for any given speed.

Unsurprisingly, it was immediately evident that the TSD would be one of the biggest situational awareness builders available to the crew. Air Force test pilots were also impressed by the flexibility and sheer power of the system. They could define no-fly zones that would help them avoid certain pieces of airspace. They could alter the range scale so that the map area represented 80, 40, 20 or 10nm. And they could further enhance the view with a zoom feature that enlarged the chart by a ratio of 10:7. Multiple routes (three) could be loaded, and the INS could be switched between them at will.

Phase II verification of display formats, software functionality, and interoperability of systems between the two crew members validated the unprecedented level of crew cohesion attainable between the two cockpits. Through a combination of user friendly interfaces, intuitive logic and equipping both cockpits with what was essentially the same tools to get the job done, McAir had made it possible for two crewmen sitting in tandem to task share and sensor share. Fundamental challenges, such as how the radar would be shared between the front and back, had been solved by incorporating simple software routines that informed each crew member when the radar was being used by the other.

RLG INS

The F-15's navigation systems were originally centred around a basic INS. During the AFCD program, Hughes engineers had used an improved, although essentially standard, INS to provide the radar with the velocity updates it needed to make accurate patch maps.

Phase II tested a new form of INS – the Litton LN-94, second generation Ring Laser Giro INS. RLGs are inherently more accurate than previous gyros, and the LN-94 provided better than 0.8nm/hr drift. Housed in the Inertial Sensor Assembly are three rate-integrating gyros, each of which consists of two contra-rotating laser beams. The lasers are housed in a ceramic cavity (the ring laser), which is fitted with mirrors to reflect them. As the aircraft moves, the reflected laser energy changes frequency (when static, both lasers radiate at the same frequency). This shift in frequency is recorded and translated into aircraft velocity in all three axes by the Inertial Navigation Digital Computer. More accurate velocity readings mean improved navigational performance.

Sorties were flown using E-1 to evaluate the integration and accuracy of the LN-94 against pre-defined criteria. The new system included a stored heading, fast alignment mode that used the INS coordinates from the previous flight to align in just forty seconds; a gyro compass (GC) mode that used parking data entered into the UFC and required four minutes of alignment time; and a "nav" mode, which was the in-flight mode selected prior to take-off.

During alignment, all modes provided a HUD prompt as well as a numeric representation of current system accuracy. One clever feature built into GC mode was the ability to taxi after a mere 60 seconds of alignment time, following which the INS would automatically continue to align if the aeroplane stopped mid-taxi.

Acceptable errors were documented for both assisted (in flight updates) and non-assisted operation, and USAF test pilots concluded that the LN-94 exceeded design specification criteria.

The importance of the accuracy of the LN-94 could not overstressed: velocity errors as little as 1-3 knots can easily translate into patch map position errors in excess of 400'.

LANTIRN Integration – AAQ-13 Nav Pod

Following a small amount of work in 1983, full time LANTIRN integration started in July 1985 as part of Phase I. Most of this was conducted on E-2, which had already completed structural loads and DEFCS validation testing.

The F-16 LANTIRN test community provided expertise to the F-15E integration process and Lt. Col. Chuck Kilberg of the F-16 SPO was chosen to work with the F-15E. Kilberg had already accrued four-hundred hours of night flying with LANTIRN in the F-16, and his knowledge of NAV FLIR and TF operations created an extra margin for safety when

BELOW
F-15E 86-0183 with Type IV CFTs and pre-production specification LANTIRN pods. (Boeing via Author)

ABOVE
The NAV FLIR image on the HUD repeater in the rear cockpit shows how well the system transforms night into day. (Author)

the test flying entered the night, bad weather phase.

The first full specification AAQ-13 was flown on the F-15E on 5 May, 1987, paving the way for full flight testing in November.

Kilberg was initially concerned with the NAV FLIR's ability to generate a representative image of the terrain ahead of the aircraft. The F-16's boresight alignment of the pod relative to the fuselage waterline was 4° lower than on the F-15E. Consequently, an F-16 pilot looking through his HUD would see more video of the ground. To exacerbate matters, even with electronic and mechanical boresighting methods, the pod would never exactly line up with the aircraft's waterline – parallax error meant that pilot would always be viewing an image that was slightly at odds with the real world outside. Kilberg found it unsettling to adjust to this change though and asked about the possibility of modifying the HUD optics to bring the imagery into line. This was impossible because the production line at Kaiser had already opened. Instead, he acclimatised himself to this new perspective, much to the amusement of Jennings, who, following a particularly aggressive night sortie over the Sierra mountains with Kilberg at the controls, said "for someone who doesn't like the way our system works, you just impressed the hell out of me!"

LANTIRN was clearly a quantum leap ahead of the now rather primitive looking capabilities of other comparable FLIR systems. During Phase I, the team tested a number of unique features, and solidified the final specification for LANTIRN integration into the operational jet.

The AAQ-13 far exceeded the design specification of being simply a TF/NAV FLIR system. It incorporated some very interesting technology, of which Snap Look and Look Into Turn (LIT), were two examples.

Snap Look provides the pilot with the ability to drive the NAV FLIR 9° up or down, and 25° left or right. FLIR optics in the AAQ-13 pod rotate and the resulting ground-stabilised video image is displayed on the pilot's HUD.

LIT features two modes of operation: one manual, the other automatic. In manual mode, the pilot presses the coolie hat on the stick once he is banked at an angle of +5°. This generates a 6° look-into-turn horizon stabilised image on the HUD. Automatic mode changes the view without input from the pilot as soon as the aircraft is rolled through 33° of bank. In both cases, normal FLIR video resumes once the aircraft returns to pre-defined bank angles (3° and 20°, respectively). With LIT engaged, the pilot can see another 19° into the turn by engaging Snap Look.

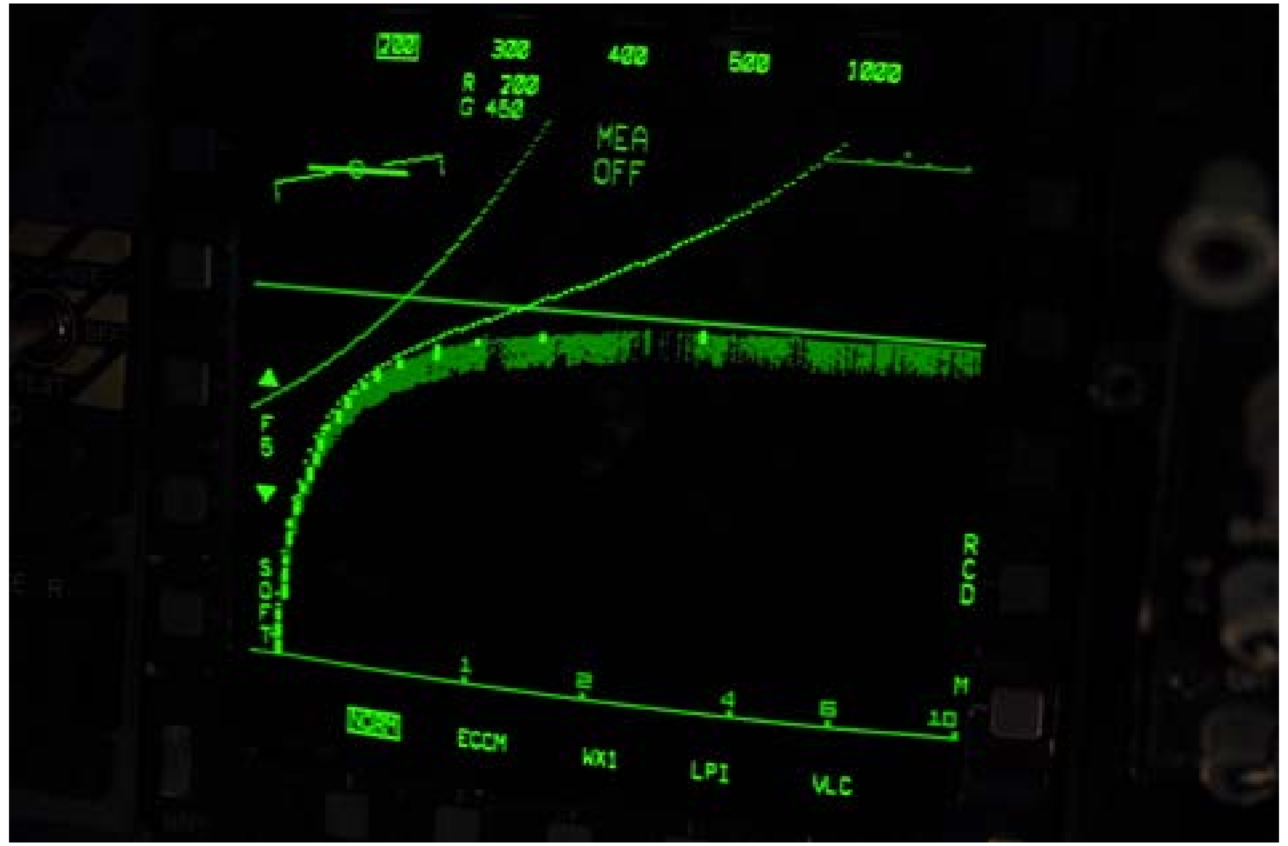
Martin Marietta developed these two systems to allow safer low flying whilst in poor visibility or at night. Upon entering a mountainous area, for example, the pilot could peer into his turn to check for the presence of other aircraft or rocks. Pilots appreciated having the ability to use the system if they needed it, but in practise they often found it a little too disorientating, and neither feature was ever used regularly.

Development also continued for the TF modes. Testing of a variety of terrain following radar modes was complete by May 1987, and the first manual TF flight was flown at Edwards on 28 October

TF was a penetration aid that would allow the F-15E to fly low and fast, underneath the dense thicket of SAM and AAA that would invariably exist in central and eastern Europe. Follow On Forces Attack plans would employ Wild Weasel F-4Gs to neutralise threat emitters at the top of the Electronic Order of Battle, although their small numbers and likely loss rates would mean that the F-15E would remain largely unprotected.

TF synthetic video is displayed on the E-Scope (also called the TF display). The video generated provides the crew with an elevation vs. range format – a cross sectional view of the terrain ahead. The far-right corner of the screen represents the maximum scan distance of the TF radar, and small ticks are positioned incrementally at the bottom of the scope to represent scan range. A dashed, synthetic, video line represents approaching terrain; another less dense line provides Obstacle Warning reference. The zero command line (ZCL) provides an easily interpreted graphical representation of where the aircraft is flying in relation to the SCP. It is a visual version of the F-111's pitch command audio cues.

The AAQ-13 offers the crew a choice of sub-TF modes selectable based on environmental, mission profile, topographical and tactical considerations. Normal mode is a good choice for flight in clear skies and when there is no attempt by hostile forces to jam or degrade the performance of the radar. In all likelihood, there was little chance that this would be the case over the battlefields of Europe. Average European weather statistics were poor (visibility of no



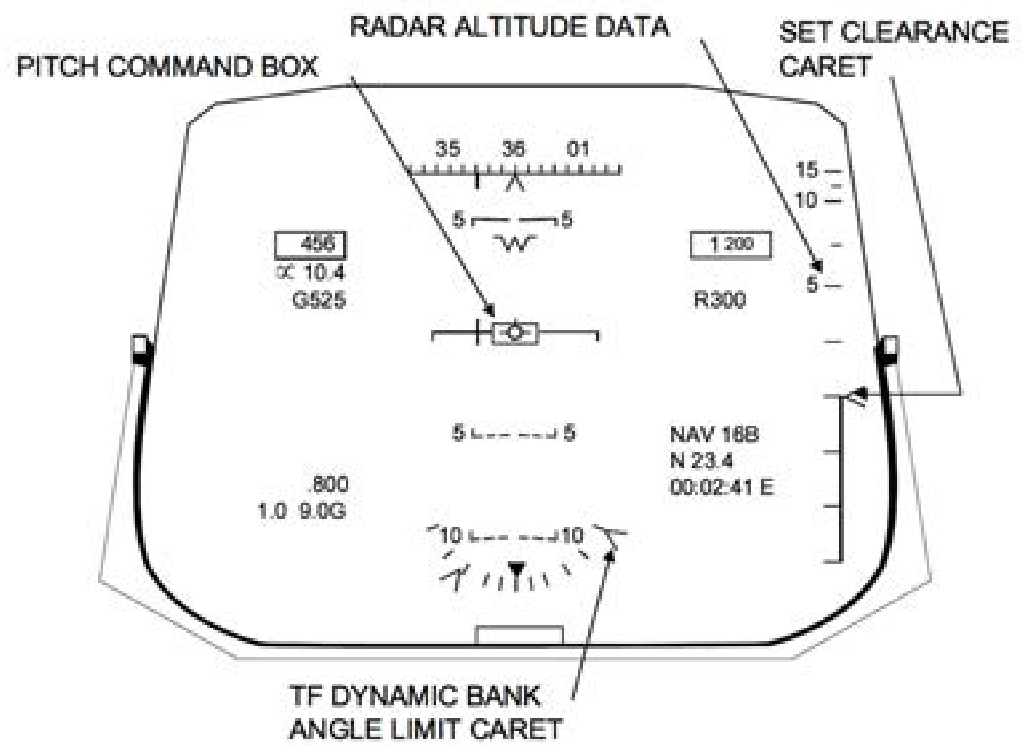
ABOVE
The E-Scope display with mode selection options at the bottom, SCP options at the top and RF channel and ride comfort selection options on the left. The scale at the bottom displays range, whilst the top left corner offers an aircraft pitch and attitude indication. The left-most curved line is the obstacle warning line, the next line is the ZCL, and the fuzzy green is the raw video display of the ground. (Author)

more than 3,000' and rain a likely occurrence) and there would be TF jamming to contend with.

To counter these conditions two weather modes and an Electronic Counter Counter Measures mode can be selected. WX1 (weather 1) is used in light rain up to about 10mm/hour. It slightly desensitises the TF so that echoes from falling raindrops are not mistaken for terrain. WX2 desensitises the radar even further and can be used in moderate to heavy rain fall (although is never for use in peacetime as it is deemed too dangerous).

The sub modes all represent some degree of safety compromise. Because both weather modes de-sensitise the radar, they do not provide the same degree of safety as Normal mode. Instead, the command range – the distance at which the TF radar looks ahead – is reduced from a maximum of 10nm to just 15,000', and vertical scan is reduced to +5° and -20°.

ECCM mode provides protection against radio



ABOVE
The HUD contained a range of TF cues and indicators, including the pitch command box - provided the pilot kept the velocity vector in or above this box, he would remain clear of the terrain. (Author's collection)

frequency jamming and features the same limitations as the WX modes, but makes use of anti-jamming logic.

This can pick out bogus radio signals intended to confuse it from the real echoes returning from the terrain ahead. Having identified that jamming is present, it can then identify the source, display a synthetic line to the crew to let them know that it has picked up on the jamming, and then filter out jamming signals from those it discerned were valid. In addition, the TF can be programmed to ignore chaff bundles that might be launched to further confuse the radar (or be released from strike aircraft ahead).

Ingress towards a target presents unique challenges, of which a key factor is stealth and the element of surprise. Radiating at full power and without a care in the world is a surefire way of letting an adversary know that you are on your way. A low probability of intercept TF mode (LPI) was developed and tested, therefore. LPI limits the size of the TF radar scan volume – instead of completing an 8-bar scan every 2.5 seconds, it completes a one-bar scan and then stows the radar for a brief moment before starting the process over again. ECCM features are also built into LPI mode, and the radar uses automatic power management routines to ensure that emitted RF energy is limited only to that which is necessary to provide TF commands. In all, LPI reduces the likelihood that the adversary will detect the Strike Eagle in enough time to react fully.

To complement LPI, another penetration mode was added and tested during Phase II: VLC – Very Low Clearance.

In all modes, the crew can select the height at which they wish to travel above the ground from a list of pre-set altitudes up to 1,000′ Above Ground Level (AGL). This is known as the Set Clearance Plane. WX2 only allows the pilot to chose from 1,000′AGL and 500′AGL on account of its dramatically reduced margin for error.

All other modes, on the other hand, allow for the full selection of heights to be chosen: 1,000′; 500′; 400′; 300′ and 200′ AGL. VLC reduces this to 100′AGL. Prior to activating VLC, the TF system performs a sanity check to confirm that all associated systems are working properly.

With the development work on these modes completed, the full SCP selection was tested over a variety of flat and undulating terrain from November 1987 onwards. Isolated obstacles were also placed along the flight path to evaluate obstacle avoidance logic.

Phase II dedicated fifty-four sorties to auto TF evaluation, starting on 20th May 1988, and twenty sorties to manual TF evaluation eight months earlier. The AAQ-13 was successfully integrated into the Strike Eagle during the course of these but would be the subject of additional tests during the course of other flight test phases.

ABOVE
The AAQ-14 TGT page, in this instance showing the thermal image of another F-15E parked in front. The central crosshairs and FOV gate are in black. The white mnemonics around the edge show information ranging from FLIR seeker position (azimuth, elevation), LOS coordinates (North, West and Elevation) mode of operation (in this instance, A/G and ATRK), FLIR polarity, and most noteworthy, the north pointer that shows the direction of North relative to the TGT IR image. (Author)

LANTIRN Integration – AAQ-14 Target Pod

The AAQ-14 did not reach the F-15E until 28 October 1987 (almost six months behind the Nav pod) and basic integration with E-1 was only completed in February, 1988, by which time the INS, radar and CC had all already been successfully integrated via the 1553B MUX.

Subsequent tests evaluated target tracking qualities and tracking stability performance in air-to-air and air-to-ground modes. The AAQ-14 operates in ground stabilised or space stabilised modes. In the case of the former, the pod tracks a point on the ground. In the latter, it remains looking at a constant angle and azimuth relative to the aircraft.

LOS drift is experienced when errors exist between the actual ground target elevation and computed aircraft altitude, but this error can be avoided by entering an accurate barometric altitude into the CC.

Four air-to-ground track options are provided by the TGT FLIR, the primary of which are point track (PTRK) and area track (ATRK). Offset track (OTRK) is also an option, albeit somewhat superfluous and rarely used when the jet entered operational service. The same was true of a non-active track mode (CMPT), which uses line of sight rate extrapolation techniques to temporarily track in poor visual conditions.

Cueing the AAQ-14 is easy. The TSD cursor can be alternated between commanding the SAR radar (patch map) or the TP. In the case of the former, the crew member simply places the cursor over the area of interest and designates – the pod will automatically slew in that direction. The pod can also be cued via the RBM or HRM radar page: the cursor is placed over the target and a designation is once again commanded. In

ABOVE

Having put on a few pounds, the F-15E required a new, beefed up undercarriage. Note the enlarged bulge of the undercarriage door (far right). The nose landing gear was revised in the mid 1990s to incorporate an additional brace to counteract the strut experiencing lateral wobble (sometimes referred to as a shimmy) during high speed taxi at high gross weights. (Author)

OPPOSITE

An AGM-65 leaves E-1's launch rails over the Nellis test ranges, marking the Strike Eagle's first Maverick launch. (Boeing via Author)

steerpoint mode, the pod automatically slews to place the INS selected destination point (or any manually selected steerpoint) under the crosshairs. Finally, in HUD mode, the pilot can slave the pod to either a Target Designator diamond or HUD reticle, both of which were manipulated via the TDC.

ATRK uses an area correlation tracker and is most useful in instances where the target IR signature merges with the IR signature of its surroundings. PTRK uses a point contrast tracker that identifies and tracks IR transmissions on each side of the target,. It was found most suitable for vehicles and mobile objects that provide a well defined and "bound" IR signature. Logic in PTRK automatically swaps the mode to ATRK when tracking difficulties are experienced, and when both modes struggle, CMPT is initiated.

Despite these automated tracking features, it is often necessary for the WSO to manually track the target with pressure on the TDC – nudging the track point with pressure on the TDC while the system maintains ATRK. This is routine when guiding precision weapons because ATRK is not able to hold the laser perfectly still.

In manual track mode (i.e. without any of the automated modes engaged) the pod jitters slightly, but once ATRK is selected, it steadies.

OTRK mode provides the crew with the ability to indirectly track a poor IR signature – a readily tracked IR source close to the actual target is designated in PTRK mode, the crew then activate OTRK and slew the crosshairs over the actual target. Provided that the PTRK target remains in sight of the pod, the OTRK target will remain centred in the crosshairs.

It was immediately clear that the AAQ-14 was

ABOVE
Detail of the arrestor hook and deleted aft fuselage empennage. (Author)

an extremely capable sensor. In fact, it has been estimated that the tracking system performs 85% of the work and the WSO the remaining 15%.

The two primary track modes conferred a solution to tracking most types of targets and the two back-up modes were a comforting inclusion in the total package. Even so, it was not yet perfect and software tweaks would be required to smooth out and stabilise tracking solutions and slew rates. At times, these were jerky and lagged behind actual line-of-sight velocities, leading to the crosshairs sliding behind the target as the Strike Eagle overflew it.

INS

Routines for updating the INS were also tested during Phase II.

An INS update was remarkably simple to achieve: the TP is commanded to the nearest steerpoint; as the aircraft nears the steerpoint location the WSO precisely aligns the TP crosshairs with the steerpoint feature (a bridge, road intersection, windmill, building, pylon etc.) and fires the laser to receive accurate ranging information; the update is then committed to the INS.

A similar feature, MARK, was also tested. This allows either crew to visually designate a ground location for future reference, causing the INS to log the lat/long coordinates and target elevation at the moment the MARK button is pressed. Once a mark has been taken, the crew can receive steering to it.

AGM-65 Maverick Shots

On 15 March, 1988, the Strike Eagle's first AGM-65D Maverick missile launch took place.

The Maverick had forged a reputation as a reliable and capable missile, and the Delta variant featured an imaging Infrared sensor designed to overcome the smoke and dust which would no doubt be ever present on the European battlefield.

One of the Strike Eagle design goals was to hand-off targets from the AAQ-14 to the Maverick. Phase II tested this capability, and two days after the first carry, the missile and pod successfully passed data to and from each other, resulting in a successful hand-off and track.

Phase II initially tested single missiles mounted on LAU-117(V)3/A missile rails. Later on, LAU-88A/A three-rail launchers were used on stations 2 and 8, allowing up to six AGM-65s to be carried.

To provide proper physical clearance with AIM-120 or AIM-9 missiles mounted above them, an ADU-578/A missile adapter was installed.

The AGM-65B was carried on 30 March. It had an Electro Optical (TV) camera that provided a scene magnification capability.

AGM-65 hand-off could be completed automatically, and Phase II testing involved refining the process through which the Maverick seeker was passed a point track target via the AAQ-14.

In slave mode, the TP generated commands to the missile seeker and the WSO confirmed the missile had locked the target by comparing one MPD displaying TGT FLIR with another displaying Maverick video. Two slew modes were also developed to allow pre-launch refinement of the seeker tracking solution.

On 11 May an auto hand-off launch of an AGM-65B (inert warhead) was successfully accomplished. The first inert AGM-65D auto hand-off launch took place a few days later, on 17 May.

These sorties were flown as operational sorties and therefore followed a typical attack mission scenario – the crew flew to the target area, took a patch map, cued the TP to the target, gained accurate range data with the laser range finder, and then automatically handed-off the target to the missile.

It was a significant milestone for the Strike Eagle, and Maverick integration testing concluded in the Spring of 1988.

APG-70

In conjunction with weapons, avionics and systems integration, Phase II refined the air-to-air and air-to-ground modes of the APG-70.

The first full up, customer specification APG-70 flew on 8 May, 1987, and was tested by USAF and contractor aircrews. Jennings remembered, "We put corner reflectors on the range to help with radar acquisition and patch mapping. As it turned out, the 3' reflectors being used were too big [reflected too much radar energy] and they essentially caused the radar scope to star – the radar display would bloom with the intensity of the returned radar energy. We told them to change them and replace them with 6" reflectors. Of course, the AF thought we were mad, but that was as big as we needed them to be".

Radar software updates were completed all throughout this time, and the HRM mode of the radar was refined to operational standard.

Undercarriage & 81,000lb Take Off

McAir installed new tires and wheel bases to help cope with the 34,000lb increase in maximum take-off weight originally placarded for the F-15A.

The new tires were Michelin AIR-X radials inflated to 305 PSI (compared to 340 PSI in previous Eagles). The nose wheel measured 22 x 7.75-9 (vs. 22 x 6.6-10), and the main wheels measured 36 x 11-18 (vs. Bendix 34.5 x 9.75 –18). Michelin's so-called chunky tires were mounted to enlarged and strengthened Bendix wheels.

Cleveland Pneumatic Tool Company's oleo pneumatic-shock absorbers remained unchanged, so too did the Honeywell five-rotor carbon disc brakes.

The larger main gear tyres prevented the gear doors from closing fully however, so McAir gently re-sculpted the doors to incorporate a small bulge into which the tyre could nestle.

All F-15s had been built with a retractable arrestor hook located between the engine nacelles at the rear of the airframe – the hook was controlled via a switch in the cockpit and was intended for use during arrested emergency landings using the BAK runway cable system. In anticipation of higher landing weights and speeds, McAir installed a bulkier hook in the Strike Eagle.

The first 81,000lb take-off took place on 29 September, 1988.

IBM CP-1075C VHSIC CC

The Central Computer is the heart of the Strike Eagle. It is a high speed digital computer that crunches data taken from avionics subsystems and is key to the integration of nearly all of the aircraft's avionics. As such, it was the subject of close analysis throughout the test and development cycle. It stores and processes a wide range of data (LANTIRN boresighting values, time of day, navigation data etc.) essential for operational success.

The original CC was the CP1075, although this was later replaced by an upgraded CP1075C on F-15E AF 90-0261 and upwards (a depot level retrofit program modified F-15Es AF 86-0183 through AF 90-0260). It featured 1.5M words of bulk memory and had its own batteries.

The software running on the CC is upgradeable as tweaks are made and new capabilities are added to the jet. This iterative approach is known as the Operational Flight Program (OFP). OFP also allows software upgrades to support new hardware installations, and the version of OFP in use on each jet quickly allows a crew to determine what capabilities the aircraft has.

OFP versions are typically characterised as suites, and because OFP suites are common to the entire F-15 family, an E suffix is added to those upgrades appropriate to the Strike Eagle (i.e. Suite 4E). Additionally, identifiers are added to signify minor upgrades to an existing OFP number (i.e. Suite 4E+).

To save expenditure on operational testing, improvements are tested on an F-15E Weapons Systems Trainer at Hill AFB, Utah. Boeing, which later acquired McDonnell Douglas, continued to provide OFP support and testing in pre-set cycles, although as with Suite 4E+ in the early 00s, out of cycle upgrades sometimes occur. The F-15 SPO at Wright-Patterson AFB, Ohio, is ultimately responsible for prioritising OFP improvements.

Suite Number	Significant Incorporations & Updates
Suite 3 (1998)	EGI, TEWS improvements, SPIN MPD page, DMS
Suite 4 (2001/2)	FDL, TSD improvements, A/A radar improvements
Suite 4+	Out of cycle OFP that allows JSOW, JDAM, and WCMD on two CFT (LC/RC 2) stores via a 1760 MUX

The CC communicates with the rest of the aircraft's systems via multiplex bus (MIL STD 1553B MUX), which provides both the means of data transfer and the scheduling of that transfer to two Aircraft Avionics Interface Units (AIUs).

These AIUs operate as interfaces between aircraft systems and the MUX. The CC also controls the following attack functions:

Air to Air	Air to Ground
Radar Modes	Steering commands and weapons release parameters
Weapons Status	Weapons launch zones
Gunnery computations	Ballistics calculations
Radar target parameters	Sensor cueing
Missile launch zones	Attack symbology
Pre and Post launch missile commands	AGM launch parameters
DTM data capture (similar in air-to-ground)	Automatic weapons release
	Warhead blast fragmentation and ground clearance avoidance

The last Phase II flight was conducted on 13 December,1989, almost a year after the USAF had taken final delivery of F-15E AF 86-0183 (2 August, 1988) & 0184 (22 November, 1988), and following USAF follow-on DT&E.

Phase III

Phase III was an Independent Operational Test & Evaluation run by AFOTEC at Edwards AFB. It ran concurrently with, and combined work from, phases II and IV. It was thus designed to offer an early user evaluation of the F-15E's capabilities.

Phase IV

Phase IV lasted for just over a year, running from Summer 1988 to late Summer 1989.

Four F-15Es were used, two of which were dedicated to developing the communication routines between TEWS components and the radar. The radar warning receiver (RWR), radar and internal counter measures set (ICMS) all shared data.

If the ICMS detected a threat, it would commence the appropriate jamming routine, inform the radar so that radar desensitisation could be initiated if required, and inform the RWR so that it too could factor ownship emissions into its analysis of the electromagnetic spectrum.

Similarly, if the RWR detected a threat before the ICMS did, it could initiate jamming and counter munitions dispensing. Finally, if the RWR or ICMS were slow to detect a threat, the radar could pass detected RF data to either subsystem. An MX-9287 interference blanker system was provided to allow each subcomponent to operate with minimal impact on the other, and Jennings recalled that it was extremely effective.

The Northrop-Grumman ALQ-135(V) ICMS offered active electronic protection to the Strike Eagle in the form of deception and barrage jamming. Limited effective radiated power meant that it was not suited to noise jamming, because this technique used raw power to simply overwhelm the threat receiver. Instead, the ICMS provided a deception jamming capability to trick, confuse and deceive the threat radar.

The ALQ-135(V) differed from the ALQ-135A (early F-15A/C) as it was initially limited to smaller range of frequencies. Ironically, this reduced band coverage meant that the prolific SA-2 SAM fell outside of its jamming envelope. This would have implications when the F-15E went to Desert Storm and flew against defences consisting of a plethora of E, F and G band threats.

Naturally, the ICMS featured reprogramming support capability, allowing software updates to rapidly change pre-flight message (PFM) software in response to changing threat parameters and mission requirements. PFM is a software coded threat library that is uploaded into the ICS LRUs. As new threats emerge or more efficient jamming routines are developed, aircraft are updated to counter or incorporate them. The US DoD's excellent Foreign Technology Acquisition and Exploitation department is key in allowing ongoing updates to be made. The department acquires threat emitters and aircraft and jamming equipment are be flown against them to determine jamming effectiveness.

The ALQ-135 time shares its high band (Band 3) antennas with the RWR. These are mounted at four locations on the airframe: two on the wing tips and two rear-facing at the top of the vertical stabilisers.

A Preamplifier boosted received signals prior to entering the CC/OFP software for analysis, prioritisation and interference analysis. ALQ-135 Control Oscillator boxes and PFM software then create and send jamming signals to an RF Amplifier. These boost jamming signals are then transmitted back towards the threat emitter via two wing root

OPPOSITE
F-15E #1 prior to phase III testing. Note the rudder being automatically blended in with the aileron deflection. (Boeing via Author)

ABOVE

Two DSAs on each side of the jet provided counter munitions dispensing capabilities. In this image, fifteen flare cartridges are loaded in one of the two bays per DSA. Note safety pin and mould line closure panels for unused bays. (Author)

mounted forward antennas, or the rear left tail boom mounted antenna (Band 1.5 integration in 2001 added an additional boom mounted antenna). The PFM then generates primary and secondary responses to a particular emitter.

The ICMS can also be used in a training mode during peace time to avoid interfering with civilian radar systems. User control is extremely limited, and the WSO can only turn the jamming system from STANDBY (a receive only mode) to AUTO, at which point the ICMS radiates whenever a threat exists. In standby mode, the entire jamming process is run (analysis, resources allocated and jamming signal ready to be generated), but stops short of transmitting any RF energy (except for minute calibration pulses every few minutes).

ICMS status indications are provided on the TEWS MPD, and these include indications of jamming, degraded performance, overheating and mode of operation.

An ICS/Radar priority control option is provided for use when the crew wish to manually assign performance priority to the radar or ICMS.

Phase II testing revealed that the ALQ-135(V) was not performing as advertised, and the development program was restructured in 1988 as a result. This brought about a step-by-step testing and development schedule, but also caused delay in getting Band 3 ICS operations ready for the July 1989 deadline. This was significant not only because July was the month targeted for the F-15E's Initial Operating Capability certification, but also because unbeknownst to anyone, the aircraft would be sent to war within two years.

Band 3 was finally deemed to meet minimum requirements for IOC in July 1990 (see Chapter 3), but even at this late stage, many operational F-15Es lacked the ICMS altogether.

The Tracor (now BAe systems) AN/ALR-56C Radar Warning Receiver provides threat emitter location and identification data via the MPD TEWS page. This consists of a centrally positioned cross-hair representing the F-15E, surrounded by a dashed circle at the display perimeter with abbreviated cardinal points interspersed with digits in 30° increments (i.e. N, 3, 6, E, 12, 15, S etc.). Symbology varies depending upon whether the threat is AI, SAM or AAA, and approximate azimuth is indicated by the position of the emitter symbol relative to the crosshairs.

Two audio tones, adjustable in volume, accompany

OPPOSITE

A rare image of an Eglin F-15E carrying an inert warhead, but live rocket motor AGM-88 HARM during Seek Eagle. (Boeing via Author)

the video symbology. A beeping tone is generated when the RWR detects a new threat emitter (thus cueing the crew to look at the TEWS page for visual confirmation), and a higher pitch, constant tone, is generated when a lock-on is detected.

The RWR comprises of a power supply and system computer; a digital signal processor that measured the parameters of incoming signals; and the aforementioned antennas that it shares with the ICMS.

A PFM provides it with a threat library and response logic and a PB selectable sub-mode (missionised PFM) can be used to prioritise the type of threat displayed in high density electronic environments (i.e. surface threats, naval threats, air threats etc.).

Tracor also manufactures the AN/ALE-40/45 Chaff and Flare counter munitions dispensers (CMD) that interface with the RWR.

These CMDs have their own computer that factors ownship velocity and altitude data, afterburner use, and threat information from the RWR before optimising countermeasure dispense rates, patterns and timings, according to its own library of responses. To simplify matters, the RWR will classify threat emitters into eight types based on beam width and pulse characteristics (plus four training mode types), before sending the information to the CMDs.

Feedback is provided to the RWR so that quantities of both expendables can be displayed to the crew on the TEWS page. Caution lights illuminate in the cockpit when chaff and flare fall below a preset quantity remaining.

The CMD consists of a programmer, four dispensing switch assemblies (DSAs) and cockpit controls. Each DSA can receive two magazines of chaff or flare, of which there were four types available: RR-170 or RR-180 chaff, and MJU-7 or MJU-10 flares. The maximum load for each magazine is 30x RR-170 or RR-180 chaff cartridges in two payloads per cartridge, 15x MJU-7 or 6x MJU-10 cartridges. There are therefore many possible combinations of countermeasures, with as many as 240x chaff, 120x MJU-7 flare, or 48x MJU-10 flares allowable.

Ground test and analysis had already determined that the TP would likely be hit with flares launched from the two left DSAs, so McAir implemented logic into the CMD CPU to prevent launch of MJU-10 from the two outboard magazines and the outer row of the left inboard magazines. Meanwhile, MJU-7 was prohibited from use on the two left DSAs.

When chaff and flare are not installed, mould line closure panels are screwed into place to protect the apertures from accidental damage.

The CMD is controlled mainly from the rear cockpit, although the pilot had the ability to dispense chaff and flare, initially via the throttle pinkie switch, but later also using the trim coolie switch on the control stick.

The WSO can place the system into manual, semi-auto and automatic modes. Manual allows individual dispensing of expendables as per the crew's desires; semi-auto allows the computer to make ready an appropriate response, but will only dispense with the consent of pilot or WSO; and auto calculates the best response and automatically dispenses chaff or flare, as appropriate.

In all modes, the ALE-40/45 uses pre-loaded programs designed to produce maximum interference with any of the eight emitter types passed to it from the RWR. These programs vary the dispensed quantity, interval and repetition rate of chaff and flare, and several programs can be initiated simultaneously to deal with multiple threat categories.

Flare dispensing patterns are governed by whether the afterburner was engaged or not, and can be manually entered into the CMD via the crew, if necessary. This includes programming whether the flares burn bright or dim.

Either crew member can command additional countermeasures while the CMD is running one of its programs.

Spoofing the Threat

The Magnavox AN/ALQ-128 Electronic Warning Warfare Set (EWWS) is an outgrowth of the Vietnam-era COMBAT TREE system. It is an IFF spoofing device that interrogates Russian-made SRO-2 and SOD-57 transponder systems.

It consists of a left sector antenna; right sector antenna (both flush mounted, forward and slightly below the cockpit windshield); rear sector antenna (pod mounted on the top of the left vertical stabiliser); fire control radar dipole antennas (attached to the radar dish); a diplexer assembly; receiver/transmitter; and an electronic video switch.

The EWWS displays sector indications on the TEWS page to indicate an IFF response (i.e. it tells the crew that there has been a response in the left, front, right or rear sector). Responses in the front sector are also displayed as symbols on the radar page.

The interrogation codes for the EWWS are provided by intelligence agencies and programmed into the data transfer module during mission planning. Once the aircraft is powered on, the codes are transferred to the classified portion of the central computer.

Operation is accomplished by enabling the system via the guarded EWWS enable switch in the front cockpit, and then transmitting IFF and EWWS interrogations via HOTAS.

Seek Eagle

Phase IV continued at Eglin with the Seek Eagle program: the weapons integration and test phase that the cleared Strike Eagle to employ a full range of munitions.

Ground and flight tests were conducted, including release of inert weapons, from mid-1988 to the end of 1989, and were partially complete by the time the Strike Eagle reached IOC.

Seek Eagle is an ongoing program that has run for the duration of the Strike Eagle's service life, initially under the auspices of Phase VII from late 1989.

The full range of munitions destined for use by the F-15E was extensively evaluated first in wind tunnel tests at the Arnold Engineering Development Centre, and over five-hundred combinations of stores were tested. These included AGM-88 HARM anti-radiation missiles; AGM-84 HARPOON anti-ship missiles; a full complement of unguided LDGP (low drag, general purpose) and AIR (air inflatable retard) weapons; cluster bombs; PGMs; the B-61 nuclear bomb; AIM-7 Sparrow; AIM-9 Sidewinder; and AIM-120 AMRAAM air-to-air missiles.

Seek Eagle tested air-to-ground munitions using radar bombing techniques (patch mapping the target) and the AAQ-14. In each case, the two main delivery options – AUTO and CDIP – were used.

Early weapons bias and wind correction tables were thus formulated and stored in the CC to allow manual entry of weapons release biases closer to, further away and left/right of the target. This was an extremely useful feature in the event that weapons were missing the target even when accurate targeting and delivery had been achieved. Each and every F-15E had its own accuracy quirks, and by noting them and storing them in the jet's logbook, aircrew could alter these biases prior to, or during flight to compensate, accordingly.

Seek Eagle also certified the GBU-15 glide bomb, and the first release from the F-15E took place on 18 May, 1988. Type IV (Dash-4) CFT stores release tests were also flown under Seek Eagle, culminating in the first weapons drop from the new tanks on 19 January, 1989.

Phase IV was completed prior to IOC in 1989. TEWS integration and Seek Eagle programs continued in late 1992 as part of Phase VII.

Phase V

Phase V was an additional AFOTEC independent test that used two F-15Es to evaluate the operational suitability of the aircraft. It provided what amounted to a second opinion to Phase III.

Phases VI & Phase VII

These final phases were follow-on OT&E, flown at Nellis AFB by TAC using the same program elements as Phase IV.

Lt. Col. Larry "Scoop" Cooper, who had earlier flown with Banholzer in the DRF competition, summed up the purpose of the Flight Test Program:

> It is where, for the first time, the actual potential of an airplane is realised. Just sitting in the cockpit of F-15E No.1, I immediately got the impression that there is a lot of potential just waiting to be unleashed. So, my job as a member of the flight test crew is to go out there and fly the airplane to determine its performance and handling characteristics and evaluate the integration of avionic and weapon systems. In a lot of ways, we seem to be the bad guys because we're out there finding things that aren't quite right, as well as what is working as designed… We're flying the jet to evaluate and rate its systems – some of which may be marginal or unacceptable. The low altitude warning system, for example, kept giving us false altitude warnings. Once the problems were identified in flight test, McAir implemented refinements to improve system performance. Upon completion of the flight test program, the F-15E will be able to perform the long-range, all-weather mission plus complement the F-111.

OPERATIONAL SERVICE

Introduction to Service, 1988: 405th TTW, Luke AFB, AZ.

Following almost a decade of both private- and government-funded testing, 18 July 1988 marked the official activation of the first Strike Eagle Wing: 405th Tactical Training Wing (TTW), Luke Air Force Base, Arizona. General Robert D. Russ, TAC Commander, attended the ceremony, and took receipt of F-15E 86-0186 (E-4) and 86-0187 (E-5) from Jim Spehr, McAir Vice President and General Manager of the F-15 program.

'186 and '187 were handed over to the charge of Staff Sergeant Jimmy Ray, the first ever USAF F-15E Crew Chief.

Ray belonged to the Deadly Jesters, officially known as the 461st Tactical Fighter Training Squadron, which had actually been training with the first F-15Es since 12 April. The Deadly Jesters were joined by the 550th TFTS, Silver Eagles, on 12 May 1989. Collectively, the two squadrons made up the RTU (Replacement Training Unit) and were tasked with taking experienced aircrew and training them to fly the new, dark grey Eagle.

Once qualified, the crews were relocated to an operational squadron at the 4th Tactical Fighter Wing, Seymour Johnson AFB, North Carolina, which had received its first F-15Es for ground instructional use in late December 1988.

The Air Force had chosen the Silver Eagles and Deadly Jesters because both had previously operated light grey Eagles and were familiar with F-15 operations and maintenance practices. Despite this, there were some differences between the two F-15 variants that maintainers had to be aware of.

For example, to accommodate the ALQ-135 ICMS black boxes, McAir had made space next to the M61A1 20mm Gatling gun ammunition drum. This used a linear linkless ammunition feed system, rather than the linked rounds in the F-15A/B/C/D. Squeezing the ICS control oscillator LRUs in had necessitated a reduction in the size of the ammunition storage drum, and left the F-15E with a reduced capacity of five-hundred rounds compared to nine-hundred and forty in previous F-15 variants.

Additionally, the proximity of the gun to the comparatively delicate jammer electronics dictated that a maintenance procedure be performed to check for external damage to the boxes after every 10,000 rounds of ammunition expended.

Other avionics bays had been relocated and redesigned to accommodate new LRUs. Fuel tank #1, directly behind and below the crew compartment, was reduced in size to accommodate some of these, resulting in an insignificant fifty-one gallon decrease in fuel capacity.

Triple Nickel

On 1 October 1991, the 405th TTW amalgamated with the 58th Tactical Training Wing to consolidate training assets and bring them under the command of a single training Wing. This brought the F-15E training

OPPOSITE
A Deadly Jesters F-15E carrying twelve live Mk 82 LDGP bombs. (Boeing via Author)

under the Authority of the 19th AF, Air Education and Training Command.

In November, the 555th TFTS, which had continued to operate F-15Cs, became the final 405th TTW squadron to convert to the F-15E.

In reality, this was more an administrative change: the Triple Nickel merged with the 550th TFTS Silver Eagles. As such, the total number of F-15E squadrons at Luke remained at two, although the Air Force had, on paper at least, converted three squadrons.

This was all partly as a result of reduced budgetary support for the number of F-15Es that the Air Force would be permitted to receive. Originally forecast at four-hundred airframes, the actual number would steadily dwindle as Congress retracted funding and forced the Air Force to cancel orders – a process that began a year before the 405th TTW had even received their first jet. The FY1987 order of forty-eight F-15Es had been cut to forty-two (87-0211 through 87-0216 were cancelled). This was repeated in FY1988. Even fewer E models were ordered for FY1989 – thirty-six – all of which were initially cancelled because funds were diverted to other Air Force projects. These funds were subsequently reinstated to the F-15E program and the thirty-six jets were re-ordered.

By March 1989, the Wing still only had sixteen aircraft with which to train. All wore the LA tail code, and Triple Nickel jets featured a green and white stripe at the very top of their vertical stabilisers; the Deadly Jesters an elaborate yellow and black stripe; and the Silver Eagles a black and silver stripe.

With the merging of the 555th and 461st, a new fin stripe was designed that consisted of a green stripe inset with five silver stars. The Wing commander's aircraft carried shadowed tail codes and a collage of squadron patches on the left CFT (these patches included squadrons not flying the F-15E, but still part of the 405th TTW – 310th FS, 311th FS and the 58th Training Squadron). In addition, it wore the colours from each squadron in a segmented tail stripe on both vertical stabilisers.

F-15E production figures year ending 1989:

USAF Tail Numbers
86-183/184
86-185/190
87-169/189
87-190/210
88-1667/1687
88-1688/1708
89-471/488
89-489/506

Rhino and Aardvark Influences

Crews selected to go to the Strike Eagle tended to come from the strike fighter community, although the Air Force intermingled three pilots from Eagle units to add air-to-air expertise. For these individuals, the transition to the F-15E was relatively straightforward, as Anderegg explained:

> Since I was current in the F-15, I went through an abbreviated checkout compared to the one the F-4 and F-111 guys went through. I took ten flights at Luke, which were preceded by about two weeks of academics. Flying the jet was a walk in the park: it was an F-15, and I already had over 1,000 hours in light greys. Learning the avionics took a little time, especially the UFC. In these early days, we did not yet have data transfer modules (DTM) that could rapid-load all the avionics settings, so we had to insert everything manually through the UFC before every mission. Actually, we got pretty good at it. Transitioning to the E was pretty easy: I had many hundreds of hours dropping bombs in the F-4 (two tours of duty as an instructor pilot in the F-4 weapons school at Nellis in the '70s) and I knew weapons and weapons deliveries as well as anyone. I thought the E was a joy to fly: a super-modern F-4 with all the F-4's faults corrected in one package.

Anderegg was in the first group of thirteen pilots and WSOs to go through the training syllabus at Luke (March and April 1989 graduations), but his brief transition was not typical of those who later followed him. F-4 pilots and WSOs spent upwards of four months there.

Most F-4 crews were coming from Seymour Johnson AFB or Clark AB (Philippines), and were invariably well versed in both air-to-air and air-to-ground roles. With the course syllabus being defined and redefined daily, there was a growing feeling amongst the experienced aviators that it was too protracted. In effect, crews were being retaught a job they already knew and had just come from, and many felt it could quite easily have been halved in length. It was, they felt, indicative of an overly conservative approach to the F-15E in its early days.

As the F-4 cadre served out their three-year F-15E tours, the Air Force began to recruit more and more new crews from the F-111 community. Understandably, they applied the tactics and approaches to the F-15E that experience told them worked in the F-111. Anderegg:

> F-111 guys, God love 'em, were not fighter pilots: they were bomber pilots. They were so conservative about the E that it made me want to scream. The initial F-111 guys who came to the E were weak sisters in the squadron, not because they weren't good people, brave and true, but because they had been nurtured in a very conservative environment. They were okay at night, low level if everything went as planned, but when it was time to pop-up, roll in, jink, engage enemy air, etc. they didn't have the background or the attitude to pop out their fangs and go for the throat.

The result was that some aircrew were simply not able to extract the most from the Strike Eagle and struggled with basic weapons delivery profiles. Veteran F-111 aircrew now flying the F-15E refute that the early Aardvark influence was ever so strong, but they do concede that their tactical flying up until that point had been limited.

For many of the F-4 crews coming to the F-15E, there was already some semblance of appreciation for the art of air-to-air engagements, but for the F-111 and A-10 communities (the A-10 was also a significant source of pilots for the F-15E program) this was often a stumbling block. Neither group had ever flown air-to-air as part of their training, and those who were slow or unable to reach an adequate level of competency were re-assigned and sent home.

"Cheese", an F-15E WSO, was selected to attend Luke for F-15E conversion training in 1992:

> Working the mechanics of the radar was not hard to learn, it was fairly straightforward. The problem that most had was tactics – 'What are we trying to achieve and how to we go about doing it?' There is a plethora of tactics you can use to achieve this, and it depends on what you are trying to do – defending yourself; someone else; a no-fly zone; a high value asset target; whatever. It just takes time to get used to it... The F-111 community did have its weaknesses, but we brought a tremendous amount of knowledge to the Strike Eagle too, particularly in the field of laser guided bombs. As I went through Luke, there were instructors who did not have the depth of knowledge that some of us did in this field. When I dropped my first GBU-12 from the F-15E, I gave an instructional brief to my IP [Instructor Pilot]. He turned around and said, 'Wow, I did not know all of that'. So, we did add value. Yes, we had our own way of doing things, and it took us time to change these. Now though, that's dead and buried. The F-111 guys still in the F-15E community are as good as anyone.

Political pressure further inhibited training, as there was overbearing pressure on Strike Eagle pilots not to crash a jet. This resulted in extreme caution in the air-to-air arena and air-to-air training was heavily restricted. ACM (air combat manoeuvring), which typically involves four or more aircraft, was banned outright at Luke for fear of a mid-air collision. On occasions where dogfighting was permitted, it was often conducted under heavy restrictions: Red Air – the F-15Es simulating threat aircraft – had to adopt a defensive posture and vertical/horizontal separations between aircraft were carefully controlled to avoid the possibility of a collision. Combat would never be so simple and rarely would any fighter pilot be afforded the luxury of finding himself right behind an unsuspecting opponent. The adage 'train as you fight, fight as you train' could never have been more distant. Luke's Strike Eagle crews were effectively manacled in their training, despite the emphasis at that time on the dual role capabilities of the F-15E.

Then-Lt Steve "Killer" Kwast reasoned that there was logic in TAC's decision at the time:

> Taking a perspective over ten years, watching the weapon system mature and observing events as they have unfolded, I would be inclined to support their decision. At the time I was so young and inexperienced that I was not in the fray – I never joined the guys saying, 'Hey, why aren't they letting us do this?'. I just sat and observed. It is my opinion that it was a wise choice that they did not allow us to go too fast, too quickly, as there could have been dire consequences. ACM required tremendous skill to get good enough to conduct it safely, especially when you wanted to fly 4 v 10, which the Luke F-15Cs wanted us to do. The F-15E was never going to get into a situation where it went into a visual fight with that many aircraft. We were just bomb droppers, the C models would take care of enemy air. To allow us to have hurled ourselves at that many aircraft would have been irresponsible. We did train to be good at air-to-air, but a risk assessment judgement was made that was right, in my opinion. There was a huge incongruence between what our guys wanted to do and what we would actually do in war. It kept us focused and was a good call.

But Kwast is in the minority in taking this view. Many in the community believe that these limitations had far reaching effects. As the Commander of the 53d WEG (Weapons Evaluation Group), Tyndall AFB, from 1991-1994, Anderegg observed:

> The Seymour Johnson crews would come down for missile shots and evaluation. They were nearly incompetent in anything beyond the very basic air-to-air skills. By 1994 most of the original F-4 cadre had moved on, the F-111 community had taken hold, and the vast majority of them couldn't get out of their own way in a dogfight.

CRM & Crew Coordination

The reaction to the F-15E for the first time was often one of awe. Sam Hendricks, a former RF-4C WSO who attended Luke and converted to the F-15E in 1991, was atypical of those selected for the F-15E early on because he had a reconnaissance background. His experience level, however, was very similar to others picked to fly the jet.

Hendricks' RF-4C squadron in Germany was closing in 1991 when it was contacted and offered a single place in the F-15E program. As an experienced WSO with 1,000 hours in the F-4, he was selected.

> The first time I jumped in the back seat I was just amazed. The cockpit was flat and wide, and I thought, 'this is like a tennis court', it was huge! The TV scopes [MPDs] were the biggest thing though, back then they were just cosmic – this was like Buck Rogers. Air-to-air was a foreign language to me, but there were a lot of similarities to the F-4 that made the job much easier. Our checklist procedures were very similar, so too was the split between responsibilities between front and back seat.

Lessons from the Initial Cadre

In February 1988, Rob "Junior" Suminsby arrived at Luke Air Force Base as one of 32 aircrew chosen to stand up the first F-15E formal training unit. The aircraft was still months away from being delivered, but for the former F-111 WSO, it was an exciting prospect.

The cadre assigned to the 461st Tactical Fighter Training Squadron, known as the "Deadly Jesters," weren't handed a syllabus. They had to write it. They had to learn the jet as it evolved. They had to shape a generation of aircrew who would take the Strike Eagle into battle. "We weren't just teaching a syllabus," Suminsby says. "We were figuring out the airplane".

There were delays from the start. Aircraft deliveries slipped, sometimes comically – a forklift piercing the side of a fuselage on the assembly line, or a bad batch of cable insulation that required miles of wire bundles to be ripped out and replaced. While they waited, the cadre found themselves in a fortunate position. Luke AFB, at the time, was home to nine fighter squadrons, and most jets were two-seaters. Empty back seats on F-15B/Ds and F-16Ds became golden tickets for experience. "You could fly as much as you wanted," Suminsby remembers. He flew 20 or so sorties in legacy F-15s, another dozen in Vipers. "It was great prep for flying a glass cockpit aircraft. I learned a ton just watching how Viper guys operated".

When the jets did start to arrive, the excitement was palpable. "I'll never forget slipping into the back seat of 86-0186," he says of the first Strike Eagle delivered to Luke. "It was like every time you touched a controller, you found a new switch. We were like kids on Christmas morning". That aircraft would fly a blistering 38 sorties in its first month – an extraordinary tempo enabled by the fact that the entire maintenance squadron only had two jets to look after.

Suminsby had been tapped to be the avionics lead. He spent hours studying schematics, working with engineers at McDonnell Douglas, and learning the ins and outs of the aircraft's APG-70 radar, digital buses, and weapon interfaces.

Much of the avionics instruction was based on a document called the Human Engineering Design Approach – a blueprint not of how the systems did work, but how they were supposed to. "It was written by engineers. It wasn't designed for operators. We had to translate it into something you could teach".

While the radar's air-to-air modes had evolved from the F-15C's APG-63, the air-to-ground functionality was revolutionary. The high-resolution mapping mode could produce eight-and-a-half foot resolution images of a two-thirds mile square area from nearly 20 miles away. "The first time you saw an HRM image in the jet, it brought tears to your eyes," Suminsby says. "You could see arresting cables stretched across the runway".

But that capability came with caveats. "We realized quickly that if you mapped a target just 20 degrees off the nose, the INS alignment errors could really throw things off. We started cranking the jet to 45 degrees, mapping fast, designating, then rolling in. The traditional wide base-to-final approach didn't work. We had to rethink it all". This was the Strike Eagle ethos in practice: take nothing for granted, test everything. Tactics development wasn't formalized, but it was constant. "Officially? No. Unofficially? Hell yes. Every time we stepped to fly, we were testing something new".

There was no shortage of strong opinions. Twenty-seven of the 32 cadre members were graduates of the USAF Fighter Weapons School. "The joke was, if you wanted to survive a debrief, get two patch-wearers to argue with each other. Eventually they'd kick the students out and keep going". Debates could go on for hours, about anything from radar modes to INS alignment procedures. "We once had a 45-minute debate during an aircrew meeting about how to align the INS," Suminsby recalls, shaking his head. "It was comical, the passion guys had for getting it right".

Despite the strong personalities, a natural selection process took place. "We didn't try to mandate a single way of doing things," he says. "Eventually the best techniques would rise to the top. Students would say, 'This works for me,' and that became the standard.

Suminsby helped convert raw engineering data into practical instruction. He worked closely with civilian academics and the McDonnell Douglas engineers to understand what the Strike Eagle's radar could and couldn't do.

"I spent hours on the phone to St. Louis. The books didn't always match the jet," he says.

He still remembers a surreal moment during early academics. "I asked an engineer how the bombing computer calculated altitude. He said, 'That's proprietary.' I nearly fell out of my chair. We were like, 'We're paying for this jet – you're going to tell us how it works.'"

Red Flag exercises offered a proving ground. Suminsby's first real test came in a 1v2 against Marine Corps Kfirs. "Most people wait years to do something like that. We did it on checkout ride twelve". Later, the cadre participated in the first night Red Flag in a decade. "The young Eagle drivers flying Red Air had never gone up against a two-seat jet with radar missiles. We surprised a lot of people".

Not every feature of the jet was ready when it arrived. Early models had no radar warning receiver, no LANTIRN pods, and no published Dash-1. "We flew on Xeroxed manuals with handwritten notes in the margins," he says. "There was a line that said 'The HUD is the primary reference for instrument flight,' and someone had scrawled, 'USAF does not agree with this statement.'"

When the first LANTIRN nav pods arrived, but not the targeting pods, the cadre began training low-altitude tactics. "We were flying direct pop-ups at night. Pull up at five miles, roll inverted, pull down through the horizon and try to catch the target in the FLIR. The first time I did that with a lieutenant in the front seat, I thought: I am not getting paid enough for this".

Figuring out night formations took similar ingenuity. "We didn't want to fly eight-mile trail like in the F-111. But you couldn't fly line-abreast either, not without NVGs. So we worked out offset formations that kept your lead in the edge of your FLIR". These ideas filtered back into the syllabus, slowly becoming doctrine.

Throughout, Suminsby emphasized crew coordination. "I used to tell WSOs: if your pilot is staring at the LANTIRN display, you don't need to. Look at something he's not looking at. That's how you add value".

Over time, the squadron grew from a group of test pilots in all but name into a true training enterprise. "We started with guys who were teaching the teachers. But soon we were taking in students who had never seen an Eagle before. We had to systematize what we'd learned".

The syllabus began to solidify. Tactics were shared. Avionics quirks were documented. The cadre became a machine.

BELOW
April 1988: Capt. Rob "Junior" Suminsby in one of the first F-15Es at Luke AFB, Arizona. (Rob Suminsby)

> At Luke we'd be crewed with the same guy so that it made getting to grips with the aircraft a bit easier, but as soon as we reached Seymour Johnson we'd fly with whoever the scheduler put us with. Despite all of the gadgetry to make our lives easier, the F-15E cockpit was actually busier – we had to do far more.
>
> The Strike Eagle computed such things as our Time Over Target (which, in the RF-4, would have had to have been done in our heads); and little gains like this saved us a lot of time. But, by the same token, there was a much wider variety of systems now at our disposal – instead of busying myself checking from clock, to ground, to compass, I was running sensors, updating systems and working the radar.

Cockpit resource management was therefore a key component skill required of all crew members if the Strike Eagle was to be used effectively. Because of the advanced nature of the missionised cockpit, each crewman could run the aircraft's attack systems independently of the other, with only a few exceptions. Logic had been programmed into the sensor suite to provide cues in each cockpit to indicate who was running a particular sensor.

If the WSO was working the air-to-ground radar, the pilot could observe this and even switch his MPD radar display to air-to-air mode, but a 'RADAR IN USE' cue would be superimposed over the centre of the screen until such a time the WSO completed his tasks and relinquished control. This would usually be accompanied with brief communications to confirm who was doing what.

F-15E pilot, Capt. Randall "Hacker" Haskin, explained some of the techniques developed:

> There are really two aspects to flying as a two-person crew in a fighter: one is learning how to get along as a crew, and two is how to divide up duties between the cockpits to most effectively accomplish the mission. Learning how to interact as a crew is called Cockpit Resource Management (just like they teach airliner crews), and dividing up the duties is called Crew Coordination. One of the issues important to a new pilot or WSO is a situation where they're flying with a more experienced or higher ranking person in the other cockpit.
>
> The CRM experts teach us students to cope with feeling like they're unable to point out mistakes or possible dangers to the more experienced or higher ranking person. More dangerous, however, is the tendency for a new guy to be complacent in some situations, thinking, 'that more experienced guy knows what he's doing, so I won't bother him with this or that'.
>
> Crew coordination can be the F-15E's biggest strength as well as its Achilles heel. Since we don't have a mind meld between the cockpits, the community has developed over time and experience a set of crew coordination standards that dictate who's going to be responsible for what during particular phases of a flight.
>
> These divisions of duties vary even between types of flights and may be completely different on an air-to-air sortie compared to a low-level, night, or simple bombing sortie. Interestingly, while there are accepted standard responsibilities and communication, they're rarely written down anywhere officially because they're constantly changing to meet tactical or situational changes.
>
> In fact, it's really up to each individual flight leader to brief how things are going to work between the members of his flight, and it's up to each individual cockpit crew to hammer out their own crew coordination. As such, I sit down with my WSO prior to every flight and we discuss crew coordination, to include comm. between us. Here are a few examples of how duties can be divided up:
>
> For most BVR air-to-air fighting, the WSO traditionally runs the radar (and determines the intercept tactics) on the initial commit and the pilot is keeping the visual with the flight lead or wingman and watching for threats.
>
> This division of duties allows the pilots to maintain that all-so-important visual mutual support between airplanes while not compromising the radar mechanics or the tactics. When it's time to take a missile shot or if we are pressing into the visual fighting arena, roles and responsibilities will swap, with the WSO saying, "your radar," and the pilot replying with something like, "the visual is left 9 o'clock low". Now the front-seater is running the APG-70 and the 'pitter' is keeping tabs on the other flight members.

CRM was a particular challenge for aircrew coming from single seat backgrounds. F-15 pilots had been used to doing everything themselves, and sharing systems, responsibilities and tasks was often uncomfortable, Cheese recalled:

> One of the hardest things was to let the WSO run the radar in air-to-air engagements… I let them learn while I bit my tongue in the front seat. Clearly, the best thing in the long run was to let them learn so the crew could employ the jet the way it was intended, but it was very hard at first watching the scope while the back seater double-dribbled the switches and made a chocolate mess of what was a pretty simple tactical problem.
>
> Good crew coordination allowed the F-15E to complete its mission both accurately and with the added element of survivability. Whilst the pilot flew the jet and maintained a watch for threats, the WSO concentrated on finding the target and killing it – a luxury not afforded to other tactical platforms like the F-16.

Comparisons

Aircrew were introduced to the digital cockpit of the F-15E for the first time at Luke and were required to quickly adapt to the absence of analogue trend

OPPOSITE

Four Luke F-15Es en route to the range. They would be a familiar sight in the Arizona skies until the unit disbanded in 1995. (Boeing via Author)

gauges.

During visual flight rules (VFR) flight, this was less of a challenge, but in weather or at night, a new instrument scan was required as well as closer attention to what the instrumentation in the cockpit was actually indicating to you.

That said, the F-15E was very well received – the HUD, HOTAS, RLG INS, bubble canopy, TSD and excellent DEFCS were all highly praised and appreciated. Dropping bombs in the F-15E was described as a "no-brainer" compared to the F-4 and F-111 – the HUD offered so much information to the pilot that he rarely needed to look down into the cockpit, and the weapon computers were sophisticated and accurate.

Hacker observed:

> The radar in air-to-ground mode was a real eye opener – leaps ahead in technology. We wondered what we might have been able to do with F-15E systems in an F-111.
>
> It was challenging running the F-111 radar; the entire mission revolved around me [WSO]. The Strike Eagle changed this – air-to-ground work became easier and the air-to-air role became equally as important.
>
> We found the LANTIRN picture quality was actually poorer than the PAVE TACK pod, but we could be more dynamic with the F-15E, and that opened up huge windows of opportunity for us.

Pilots and WSOs alike missed the smooth ride down low in the F-111, where the swept wing succumbed less to the turbulent airstream.

But some of the technological wizardry incorporated into the Strike Eagle was less well received. The the way the TEWS scope worked is one such example. Whilst the TEWS' automation was helpful, categorising the threats according to the PFM, some WSOs wanted to see the raw data associated with the RHAW screens, as they had in the F-111 and F-4. This would allow them to make their own interpretation as to what the threat was, and which threat posed the greatest danger. Experience told them that sometimes computers misidentified threat emitters and that the enemy could employ tactics that might confuse an automated RWR, so why would the F-15E be any different?

Pod Shortages and First Luke F-15E Loss

The initial delay in certifying the AAQ-14 target pod was felt at Luke up until 1993.

At the time Anderegg went through the transition course (TX), there was not a single target pod or nav pod available.

Mike Smyth transitioned from the F-4E to the F-15E in August 1990, and recalled:

> In the Deadly Jesters, we only had about three target pods with which to train. All the jets had the nav pod, which had only recently arrived. It was really pot luck if you got to fly and learn to use the TP, and, very early on, guys went through Luke and arrived at Seymour having never used it.
>
> We would turn up for the day or nights flying and look at the schedule board. If your name was next to the tail number of one of the jets with the pod on it, then you'd get to go out to the range and drop bombs with it. If not, you'd bomb with the radar.

On 16 September, 1991, the 461st FS, Deadly Jesters experienced their only F-15E loss. Fortunately, both crew members ejected and were rescued following loss of aircraft control. Reports suggest that the aircraft was lost following aggressive manoeuvring while carrying an asymmetric load, and that the ensuing yaw and roll towards the heavy wing had exceeded even the DEFCS' ability to counter, resulting in a spin.

The accident prompted revisions to the flight manual, which thenceforth prohibited high alpha flight (30+ units) in asymmetric conditions. McAir also revised the DEFCS control laws, thus making the CAS slightly more robust.

Following the crash, it became apparent that the AoA beeper and HUD cues had alerted the pilot to the fact he was approaching the extremes of the flight envelope, but he had continued to manoeuvre the aircraft until control was lost. The mishap therefore did little to support any argument the community might have that they could be trusted to fly the jet aggressively, and privately there was irritation that it was an experienced F-15C pilot who should have known better.

1 April 1994 saw an additional name change to the 56th FW and the disbandment of the Triple Nickel (which moved to Italy and reverted to the F-16).

Later, on 4 August 1994, the Deadly Jesters were also deactivated, leaving one training squadron, the 550th FS Silver Eagles.

A consensus was reached that cost savings and increased efficiency could be accomplished by moving the squadrons onto the same base and under the Authority of a single Wing, and in late 1994 the Silver Eagles begun to pass their assets to the newly formed 333rd FS, 4th FW, at Seymour Johnson. The 550th TFTS graduated its final batch of aircrew in February 1995, and the last F15E left Luke in March that same year.

4th FW, Seymour Johnson AFB, NC.

The F-15E first entered operational service with the 336th TFS Rocketeers, 4th TFW at Seymour Johnson AFB on 29 December, 1988.

Leaving their F-4Es behind, some of the Wing's crews briefly departed to the hotter climes of Arizona and attended the TX course at Luke before returning home and taking delivery of the first dark greys bearing SJ tail codes.

Anderegg was appointed the 4th TFW's Director of Operations (now known as the Operations Group commander) and arrived at Seymour Johnson from Luke on the day the Wing received its first Strike Eagle.

First Operational Sortie

Anderegg flew the first ever operational F-15E sortie in February 1989, following which the Rocketeers worked up their training and flying schedules from scratch. This included training guides, Mission Ready checkouts, simulator courses and IP/IWSO (Instructor Pilot/Instructor WSO) certifications.

Luke had been responsible for taking aircrew and teaching them to fly the jet, but the Rocketeers were now responsible for making them proficient in employing the aircraft.

Anderegg evaluated the first twelve F-15E aircrew, all of whom had arrived at the 336th TFS at the same time as him. Taking each potential IP up for two checkrides to teach them how to land from the back seat, he then went on to check them out as instructors.

The pressure to fly conservatively was never far away:

> When I first met the 9th AF commander, our wing commander's commander, then-Lt Gen Chuck Horner, his very first words to me were, "Don't lose a jet doing air to air". He knew how hard it would be to argue to critics of the E that one had been lost doing a secondary mission, and at that time the E was by far the most expensive fighter the AF had ever procured.
>
> Unsurprisingly therefore, we did only a small amount of air-to-air training. In fact, we were only allowed to do a small amount – up to the 2v2 level only, and within some pretty restricted scenarios, i.e. we were ingressing toward a target and had to defend ourselves. Thus, we worked in an environment where the E was considered a medium bomber, not a fighter.

Frustrated by this, the community worked with what they had to develop tactics, and this was critical if they were going to hit their target IOC date.

This was complicated by the fact the 336th had been forced operate for its first five months without nav pods (December 1988 – May 1989), and it would be without target pods for even longer.

The first nav pods finally began to arrive at Luke in late May 1989, and several crews hastily packed their bags and jetted off to Arizona once again to learn the new system.

Returning to their fellow Rocketeers, they shared what they had learned. As for the target pods, these would not reach Seymour until after Operation Desert Storm!

As tactics were developed, senior leadership within the squadron faced dilemmas brought about by conflicting ideology.

One example was that of the direct pop manoeuvre: an attack where one flew at the target directly at low altitude, pulled into a 30° climb a few miles from the target, rolled inverted, pulled down into a 30° dive, rolled wings-level, acquired the target thought the HUD and then dropped a bomb on it.

The crews returning from Luke had been shown this attack at night and believed it to be a viable tactic against heavily defended targets. The truth was that the direct pop had been around for a long time, it had just never been used at night before.

Anderegg saw the attack as dangerous and unreliable because it required extreme skill and was intrinsically open to pilots getting out of their depth and crashing. There were precious few seconds to find the target through the HUD, identify it and then manoeuvre the aircraft to accurately place the bombs whilst maintaining a valid weapons release solution!

In light of these concerns, he forbade his aircrew from performing the profile, much to the chagrin of those on the squadron who were well aware that Luke's RTU crews were flying the tactic daily.

Asides from the delayed arrival of LANTIRN pods, the Wing was also short of LRUs for the aircraft itself. Innovative solutions were found to keep the aircraft flying, and one in particular stood out. MPDP controllers were in short supply, so when the MPDP in one of the jets failed, enterprising maintenance crews simply took the one from the F-15E simulator and hooked it up to the real jet.

Once the mission was completed, the controller was removed from the aircraft and reinstalled in the sim. This arrangement worked well and was exercised for several weeks before a replacement was found.

On 1 October, 1989, the 336th TFS declared IOC and became the first combat ready F-15E squadron in the world. Boasting a complement of twenty-four shiny new F-15Es, the Rocketeers flew with bright yellow bands at the top of their vertical stabilisers.

They were soon joined by the 335th TFS, Chiefs, which announced IOC one year to the day later (1 October, 1990). They flew with a green stripe on their jets. This now made a total of four F-15E squadrons at Luke and Seymour Johnson.

ABOVE
Pilot and WSO perform the pre-flight walkaround. Crew cohesion and communication is vital in an environment where indecision or misunderstandings can prove fatal. (Author)

Building a Reputation

The direct pop tactic debate was settled once and for all in January 1990, when the Rocketeers attended Red Flag at Nellis AFB, Nevada.

The Strike Eagle crews watched LANTIRN equipped F-16s use the direct pop to attack simulated targets while they flew only level deliveries.

Returning to the mass debrief following the mission, the F-15E crews learned they had achieved exceptionally high scores despite their mundane attack profiles. The F-16 drivers, on the other hand, had missed the majority of their targets and decided to revert to level deliveries forthwith!

In June 1990 the Rocketeers once again stole the limelight when they placed first at the TAC gunnery competition, Long Rifle VI. Second place went to the 405th TTW, who had also travelled to Davis-Monthan AFB, Arizona, to take part.

Both Seymour Johnson squadrons worked hard and flew far more than any minimum regulatory requirement laid down by Air Force. Extensive use was made of the joint USAF/USN Dare County Bombing and Electronic Combat Range (DCBECR), which provided all weather inert ordnance and electronic weapons training facilities.

Night sorties used the Appalachian Mountains to the north west to test the manual and automatic TF features of the nav pod. For many, letting down in the pitch black of night into rolling terrain was the ultimate test of their trust in the Strike Eagle.

OPPOSITE
The 333d FS flagship stands on the ramp at Seymour Johnson. Next to it sits the 4th FW flagship. (Author)

PACS

With the F-15E demonstrating remarkable accuracy in both night and day bombing practise, crews were soon learning to make use of the flexibility and programmability of the PACS – Programmable Armament Control Set.

PACS is the interface via which the crew access their weapons, and was unique in its day. It replaced analogue switches and controls with a digital weapon monitoring and management function via the ARMT (armament) MPD page.

PACS takes digital data and hardwired interface signals from the aircraft's hardpoints to allow the crew to jettison, select, prepare and launch both air-to-ground and air-to-air weaponry. It also provides training modes that emulate carriage of stores without the need to physically load them.

It is used to set the weapons engagement zone (WEZ) of both IR and radar guided weapons, specifically the RMNVR (manoeuvring range) bug – a symbol generated on the WEZ scale in the HUD and radar MPD page.

RMNVR gives an accurate indication of the range at which a missile can be fired at a target and stand a good chance of a kill, even if the target manoeuvres to evade it. For advanced missiles like the AIM-120B/C AMRAAM, PACS also integrates with the CC and radar to automatically give the selected missile an approximate indication of both the physical size of the target and its radar cross section – this can be sent to the missile automatically based on a non-cooperative target recognition routine run by the radar. The RCS setting is important because it determines the point at which the AMRAAM will go active with its own onboard radar.

The PACS also allows the crew to preset the priority in which missiles are readied for launch, saving them from having to cycle though weapons stations in the heat of battle.

The Vulcan cannon is also controlled via the PACS, and a simple press of a push button allows the crew to alternate it between a HIGH rate of fire (6,000 rounds per minute), and a LOW rate (4,000 rounds per minute).

The ARMT page has several sub-menus and provides a graphical depiction of the aircraft from a top down perspective; weapon abbreviations appear relative to the placement of wing and fuselage hardpoints. Cautions appear below the weapon abbreviation to warn, for example, that a missile has failed to launch or is not working properly.

For air-to-ground munitions, the PACS features a library of weapons cleared for release. Fuse timings, ripple quantities, the number of weapons to be released, interval between individual weapons release, release in pairs or singles and a host of other options can be selected from this page.

In addition, when the jet is carrying high-drag devices that deploy upon release (Mk 82 Snakeye or Mk 82 AIR, for example) the crew can disable these features and use the weapon in a low-drag configuration.

When carrying cluster bombs, the PACS provides an array of options to tailor weapon release to the target. For example, height of opening and spin rate, which are factors that change the submunitions' footprint, can be altered from the cockpit.

In those days, PACS allowed the crew to assign two different delivery profiles to each store type, but this was later increased. The advantage of this was that the crew could brief to have a primary and secondary release mode which could be programmed before the aeroplane took off. Once at the range, the pilot or WSO could alternate between these programs as the situation dictated.

This all meant the crew had a lot of flexibility to react to changing conditions if they were not sure of weather or other tactical influences affecting the target until they actually arrived on scene. It also gave them the ability to react quickly to targets of opportunity, as one program could be reserved for just that eventuality.

In all cases, PACS could be changed in flight, but most crews would use the mission planning system in the squadron to choose their release parameters prior to the flight. These were loaded onto a Data Transfer Module and downloaded into the PACS as power was applied to the jet during start-up.

PACS offered another vital function in the form of allowing the crew to select a sensor hierarchy for weapons range and release computations. This allowed the WSO to typically command the CC to use TP laser range finding distance data, APG-70 range calculations and INS range calculations in that order.

Desert Shield & Desert Storm

As the Rocketeers returned from Long Rifle VI, the 4th Wing began to plan for its first Operational Readiness Exercise (ORE), to be held in August.

The ORE would test the F-15E over the course of several days as the Wing acted out a fictitious scenario. The exercise would take the few mission ready (MR) crews from the Chiefs and mix them and their jets in with the Rockets to form a rainbow package (so called because of the mix of tail stripe colours), which would also include F-4s of the 334th TFS, Eagles,

BELOW
Capt. Randall "Hacker" Haskin straps in for another Strike Eagle sortie at Seymour Johnson. (Author)

Forging the Fight: Yogi Alred and the Strike Eagle's Rough Start at Seymour Johnson

When Major Mark "Yogi" Alred reported for duty at Seymour Johnson Air Force Base in the late 1980s, the F-15E Strike Eagle was still more idea than aircraft.

Recently returned from one of the first training classes at Luke AFB, he was stepping into uncharted territory, leading the operational debut of a jet the Air Force wasn't quite sure how to use.

"I was the first weapons officer in the Strike Eagle at Seymour Johnson," he recalls. "I jumped in the back seat with Dick Anderegg when I got back, we flew a mission, did four or five different things, and when we landed, he goes, 'You're an instructor in all phases of the Strike Eagle.' That was my checkout".

There was no syllabus, no training pipeline, no playbook – just a handful of experienced aviators trying to spin up a multirole fighter from a cold start. "That was how we had to do it," he says. "We needed instructors fast, and we didn't have time for anything formal".

But the challenges ran deeper than just manpower. The jets they received were, in Alred's words, "qualified to do absolutely nothing but fly. It was certified to carry slick M82s, and that was basically it".

Despite the Strike Eagle's promise, its operational debut was underwhelming. "We did a lot of low-level training in West Virginia and North Carolina," he says. "But honestly, it was very similar to what we were doing in the F-4".

The limitations weren't just technical. Air-to-air training, one of the Strike Eagle's intended strengths, was effectively banned. General Chuck Horner, then commander of Ninth Air Force, was adamant: no unnecessary risk. "He told us: don't lose one of these $55 million airplanes," Alred recalls. "And the squadron commanders were scared to death".

Alred pushed back. In a now-legendary meeting with Horner and other senior officers, he laid it out: "Sir, the airplane will do 100 times what it did in the F-4, and you're telling us we can't do any air-to-air? That's just stupid. It's going to cost us airplanes in combat".

His protest earned him a compromise: limited intercept training, ending in a 180-degree turn-away at the merge. It wasn't ideal, but it was something. "If you don't do it," he argued, "you can never be good at it".

ABOVE
Air-to-ground PACS page showing settings for a mixed load of GBU-12C and CBU-87. (Author)

which had yet to convert to the F-15E (they would do so and attain IOC roughly one year after the Chiefs).

The objective was to demonstrate the Wing's capability to put lots of iron on target in a small period of time. Amazingly, Wing Intelligence had dreamt up the scenario that the Iraqi dictator, Saddam Hussein, had invaded Kuwait (Virginia, for the purpose of this exercise). The Strike Eagles were tasked to penetrate heavily defended terrain and bring down bridges and other logistics choke points to halt the enemy advance.

They flew for eleven days running, each pilot and WSO often more than twice per day, culminating in the last day (2 August) when twenty-four aircraft made their way north ensemble, and attacked Virginia's finest bridges.

Almost simultaneously, the world watched as the Iraqi dictator aggressively staked his claim to the oil fields in Kuwait and ordered his forces to invade. Then, on 7 August, the Rocketeers ordered to prepare for deployment - the Strike Eagle was going to war. The 335th TFS, of whom only a third were MR, were not expected to deploy.

On 9 August, six-ship flights of F-15Es and forty-eight crewmen began deploying to Seeb AB, Oman – a journey that would require a fifteen hour non-stop flight and which started at Seymour Johnson in atrocious weather.

During the transit one aircraft aborted to Langley AFB, Virginia, as a fuel shut-off valve in the wing hardpoint, which held the auxiliary fuel tanks, failed. Several others experienced similar problems. One aborted to the Azores, one to Spain, and one to Sicily. The fault was probably caused by overpressure inside the tanks during air refuelling. One jet experienced a left engine flame-out only 150 miles from Seymour: the pilot re-lit the engine and then returned home, both crew devastated that such bad luck could befall them.

And for those whose jets lasted the Atlantic crossing and transit down through western Europe, their final destination was changed. Although they were not told over the radio the name of the new location, it eventually turned out to be Thumrait, Oman. See Chapter 4, Combat Records.

After the War

Following Desert Storm, the Chiefs (who had eventually deployed, after all) remained at Al Kharj, Saudi Arabia, while members of the Rockets returned to the US in March 1991.

By this time, the 334th TFS had been stood up and the Air Force was restructuring itself: TAC and SAC

OPPOSITE
The Chiefs - officially, the 335th FS - were the second operational Strike Eagle squadron. The mission markings on this one are from Operation Iraqi Freedom. (Author)

(Strategic Air Command) merged in 1992 to become Air Combat Command.

Consequently, ACC units dropped the T from their nomenclature – hence, the 4th TFW became the 4th Wing, and the 335th TFS, 336th TFS and 334th TFS became FSs.

The 334th FS was initially an operational squadron but adopted the FTU (formal training unit) role in 1996 when the Deadly Jesters at Luke finally closed its doors. By 1994 the case for consolidating all Strike Eagle training to Seymour Johnson was clear. So, the 333rd TFS, Lancers, left their A-10s at Davis-Monthan AFB and relocated to Seymour Johnson to become the F-15E formal training unit. It was expected to declare IOC in July 1991.

With Luke AFB saying goodbye to the mighty F-15E, Seymour Johnson had become 'Home of the Strike Eagle', with almost one-hundred F-15Es occupying its amply proportioned ramps.

Despite the huge task of training all F-15E aircrew, the 4th Wing suffered surprisingly few losses, and only one fatal – at 20:45 on 18 April, 1995.

The Rockets had launched a four-ship night flight to practise 2v2 air intercepts off the east coast of North Carolina. During the course of one of the intercepts, F-15E 89-0504 entered a high-speed dive that resulted in ejection initiated by pilot, Capt. Brad "Noodle" Udell.

Udell had been in a turn at the time of the incident, and although his HUD told him that he had 60° angle of bank, 10° nose down, 400 knots and 24,000' to play with, the growing noise of wind rush had given him cause for concern.

He switched one of his MPDs to the EADI page, which told a different story. He was pointed almost vertically down and was accelerating through 600 knots. Unsure of which instrument was giving the most accurate indication of their plane of travel, Udell pulled back on the stick and noted that the HUD stayed frozen – it had failed.

Calling for a bailout, Udell pulled the ejection handles and catapulted himself and WSO, Captain Dennis M. White, into the night sky. Falling at 1,200 feet per second, White exited the jet at about 4,500 feet and Udell at about 3,000 feet.

Udell landed in the water within seconds of his parachute opening, but had suffered severe trauma to his face, arms and legs, and struggled to find his way into the liferaft, which had deployed below him automatically. Udell was winched to safety within a few hours.

White was killed instantly upon ejection and his body was recovered at noon the next day. He had over 2,200 hours in jets and had flown in the Gulf War. He was a popular and respected WSO.

APG-70 A/A Modes

In the months that followed Operation Desert Storm, the F-4 cadre began to slowly leave the F-15E program as their three-year tours came to an end. In their place, more F-111 crews were rotated into the RTU and FTU at Luke and Seymour Johnson.

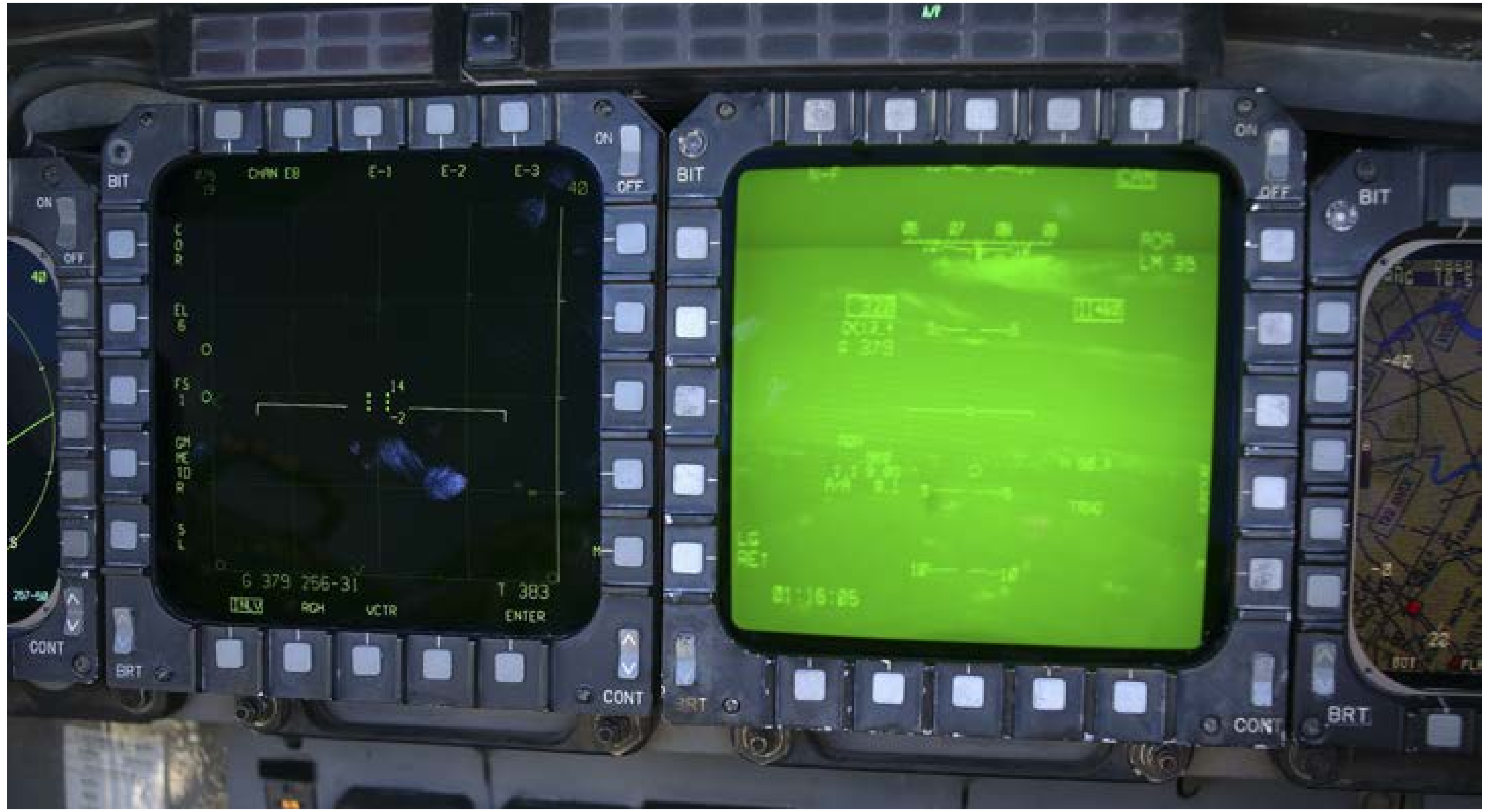
Coming to grips with the tactics employed was their biggest challenge, and although this required hard graft and lots of study in the squadron vaults, the APG-70 radar set itself also required investment of considerable study time. The APG-70 A/A master mode was far more complex than its A/G mode and was alien to many of those coming to it from the F-111.

Operating in medium, high and interleaved pulse repetition frequencies (PRFs), it provided several main modes and sub-modes. All featured a ground moving target rejection (GMTR) algorithm, which, depending upon whether it was in high, medium or low settings, would reject target returns with a velocity component of less than 45 knots, 63 knots and 87 knots, respectively. This was a useful feature for filtering out false returns from ground clutter as well as ECM expendables such as chaff, which slowed as it left the dispensing aircraft, although a separate chaff GMTR setting was also available.

One of five different frequencies could also be selected to avoid mutual interference (MI) between radar sets of nearby F-15Es.

The main search mode was range while search (RWS), which provided a good compromise between scan volume, detection range and data generation. In RWS, the crew could manually change the operating PRFs between HI, MED and INLV, depending upon tactical considerations. High PRFs were good for detecting distant targets with high closing velocities, and Medium PRFs better for medium range targets, those below the radar water line. The interleaved (INLV) option allowed the radar to mix both PRFs, alternating between them as it completed each Bar Scan. Vector Mode (VCTR) was a secondary search mode that made exclusive use of HPRFs and employed a reduced rate of scan (70° per second down to 35° per second) to detect small or stealthy targets at long ranges.

Track While Scan (TWS) was the final search mode. It resembled RWS INVL, but was significantly more flexible and highly useful. The main differences were that TWS could be driven into exclusive HPRF or MPRF formats at any range scale; featured pre-set scan configurations; and provided much more detail



ABOVE
Air-to-air radar page (left) with acqs in the centre displaying altitude coverage in double-digits. The mnemonics surrounding the display relate to radar operating parameters and settings. (Author)

on contacts detected.

TWS scan patterns could configured according to the developing tactical problem. Wide was for tracking co-altitude targets with wide azimuth spacing; Medium for widely spaced contacts in azimuth and elevation; High Data (HD) for manoeuvring co-altitude targets; Three-Bar HD for targets manoeuvring in elevation; and Narrow for targets separated in elevation.

TWS provided much more information than any other search mode and maintained track files on ten targets as well as providing vector sticks for each. Vector sticks (a small line emanating from the contact symbol) gave a graphical indication of both the speed and heading of the contact, and was extremely useful when the crew wished to rapidly visualise the air picture.

TWS also allowed the crew to place their acquisition cursor over a track file (using the TDC) and instantly see pertinent data relating to it – this was only possible in other modes by actually generating a radar lock, which would probably trigger the RWR in the enemy aircraft (see below).

HD scans typically provided more frequent target updates, as the scan pattern collapsed around the acquisition symbol which could be slewed over closely-formated contacts to provide better sorting capabilities. An additional Sort sub-mode was incorporated into TWS to allow even greater target break out, meaning that individual aircraft in close formation would be more likely to show up as separate radar track files.

The three main phases that had to be mastered were target detection, acquisition and tracking. When detecting targets, HPRFs were useful but lacked decent tail-aspect target detection capability. MPRFs were more applicable to most situations and were well suited to look-down scenarios where ground returns could be a problem. MPRFs also had better multi target break out capability. MPRF weaknesses included being range limited to 80 miles (vs.160 miles in HPRF modes). INLV mode was perhaps the better choice therefore: it used both PRFs alternately.

Two other basic modes were provided for the detection phase – range gated high (RGH) and velocity search (VS).

RGH was similar to RWS INVL but allowed the 160-mile radar scope to be selected, giving the crew a very long range search capabilities. The downside was that also meant lots more ground clutter, so this mode could not be selected below 4,000'.

VS was more of a scope format change than a proper radar mode. It changed the MPD from a range/azimuth format into a velocity vs. azimuth one and displayed the fastest closing contacts at the top of the scope and the slowest closing ones at the bottom. It was a useful mode for quickly identify contacts which

ABOVE
Dennis White in front of a uniquely painted Rocketeers F-15E. White was killed during a high-speed ejection. (Author)

might pose the soonest threat, but could suffer from a phenomenon known as JEM (jet engine modulation) – where the fast moving compressor or turbine of a radar contact could trick the radar into thinking that the target was flying faster than it actually was, and that meant erroneous velocity data would then be displayed.

In all, TWS offered the most appropriate observation mode where high confidence sorts of closely formated targets was required, or when tactical considerations necessitated the F-15E not trigger radar warning systems.

In the air, crews needed to remember the implications of changing target aspect and select the mode most appropriate if they wished to secure the fastest detection times and longest detection ranges. Of course, things were not as simple as that, as scan volume and elevation were also key factors in determining which targets would be detected.

The main interface between the radar and the crew were two vertical bars on the display known as acquisition symbol (Acqs, in pilot/WSO vernacular).

The acq symbol was moved via the TDC, and was the primary means of increasing the radar range scale; designating a target; and identifying radar coverage area at any distance. Next to the acqs were two double-digit figures, each representing in thousands of feet the radar's altitude coverage at acq symbol range. Antenna elevation could be altered for example, to ensure that altitude coverage encompassed the

ABOVE
The APG-70 air-to-air modes were designed with the both AIM-7 and AIM-120 AMRAAM missile in mind. Here, munitions specialists at Seymour Johnson load a training AIM-120B onto a LAU-128 launcher pylon. (Author)

altitude of any reported target – confirmation that this had been achieved was simply a matter of placing the acq symbol on the approximate azimuth and range of the reported target, and then checking the top figure (max coverage altitude) and lower figure (min target altitude) bracketed the reported altitude. This technique was known as changing the elevation bar scan, and the radar could be commanded to run at up to six-bars in all search modes. Similarly, the azimuth scan pattern could be widened or narrowed, to either concentrate radar energy on a certain radial or to widely space it to cover the greatest volume of sky. A 120° azimuth scan was usually used, but 60° and 30° scans could be commanded when faster contact updates were required.

With a contact of interest identified and the radar in RWS, VS, VCTR, TWS or RGH search mode, the acqs could be driven over the contact and the TDC depressed and held to command the antenna to run a 3° mini-raster centred on the contact. This provided fast target updates as the radar scan had been effectively collapsed to concentrate exclusively on this target. Releasing the TDC with the acqs still over the contact commanded the radar lock onto that target and placed the radar in single target track (STT) mode.

With the target locked, STT generated data that gave the Strike Eagle crew the altitude, range, closing velocity, heading, aspect angle and true air speed of the target, although all of this was available on up to ten contacts in TWS.

If the radar contact had been locked while in a HPRF mode, the radar would automatically switch to a MPRF at 30 miles, although it would delay this switch if the signal strength proved too weak.

If the pilot had selected an AIM-7 Sparrow from his ARMT page or via the weapon select switch on his throttle, the radar would attempt to revert from MPRF to HPRF when the target came within range of the missile. If the target was small or below the F-15E, ground clutter could interfere with this process. It was necessary to switch to HPRF because the AIM-7 was a semi-active radar homing weapon that relied upon the more frequent radar returns from the APG-70 to guide it into the target, forcing the crew to keep the target locked on radar right up to missile impact. Higher PRFs made for a faster flow of radar returns for the AIM-7 to home in on.

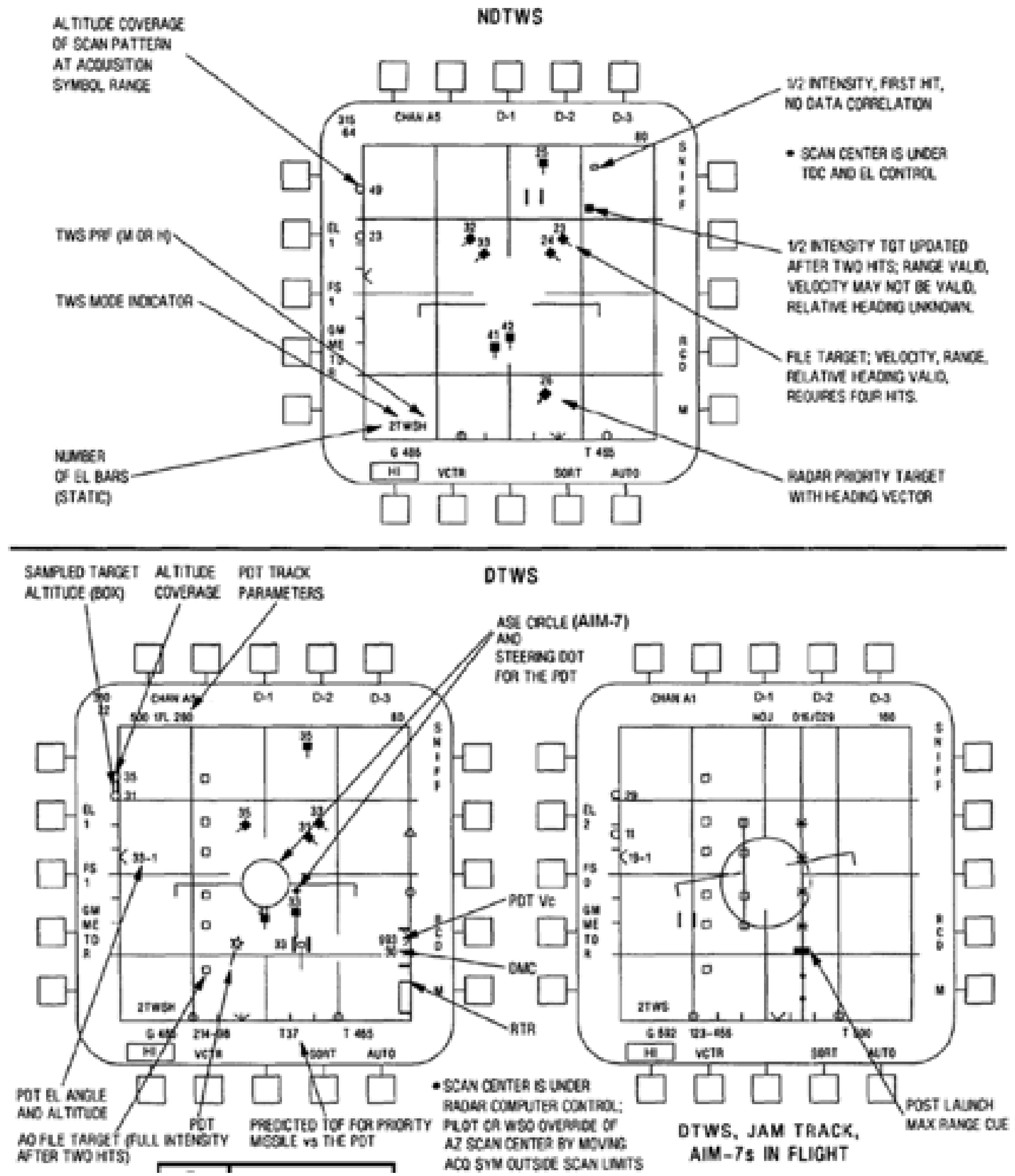
A dual target track mode was also available, and this commanded the radar to lock and track two targets simultaneously for the AIM-120. It did not support AIM-7 launch.

In STT or DTT modes, the radar automatically generated F-pole logic cues that gave a numerical indication of how many degrees of turn were still available to the pilot before radar reached its gimbal limits and broke lock. This logic allowed the pilot to easily execute a turn away from the bandit whilst remaining locked on until the AIM-7 had hit or the AIM-120 had activated its own onboard radar.

In addition to this manual form of target track, the APG-70 offered automatic acquisition options called Auto Acq modes. These were principally used when adversary aircraft were generating contrails and a quick reaction capability was required. Boresight (BST) provided a very fast, visual target lock method, as it concentrated the radar beam into a 4° scan as indicated by synthetic circle generated in the HUD. The pilot simply needed to place any target aircraft inside this circle and the radar would command a lock. A long-range boresight (LR BST) mode served to extend the basic capabilities of BST mode, and was useful when target aircraft were generating contrails whilst beyond what would ordinarily be a visual range. Supersearch (SS) provided a 20° x 20° scan, once again indicated by a circle in the HUD. In this mode, however, the pilot could elevate or depress the scan volume to search sky further above or below him. VS was a vertical scan from +5° to +55° and was a very useful mode that allowed the pilot to lock up targets which were manoeuvring in front of and above him as the scan was not restricted to the HUD FOV area. It was only useful out to about 7 miles. It could also be slewed in the direction of a reported target, although its main application was in the dogfight. GUNS mode was a 60° azimuth and 20° elevation scan which could be positioned according to requirements and would automatically configure the jet for a guns attack.

In all Auto Acq and search and track modes, a track memory capability was provided in case the radar lost its lock on a contact. It worked by extrapolating the data of the last radar return and estimating where the radar contact would next appear. Logic in the radar automatically commanded this mode for a few seconds following loss of lock, following which the radar would revert to the last used search mode in the event that the target was not reacquired.

BELOW
In the early years of operational service, Strike Eagle WSOs would run the radar throughout an intercept and right up until the point of the merge. (Author)



ABOVE
Track While Scan radar page from Suite 3E, with no target designated (NDTWS) and with a primary target designated (DTWS). (Author's collection)

Several special modes were also provided for instances where the radar was experiencing degraded performance. Electronic attack (EA) modes automatically reconfigured the radar to optimise detection and tracking characteristics when enemy ECM jamming was evident, and the APG-70 automatically entered special tracking modes when necessary.

The radar was also equipped with a receive only, sniff mode that ceased transmissions and displayed hits from the RF transmissions of others.

Finally, non-cooperative target recognition (NCTR) could be run on any locked target for identification purposes. NCTR analyses the radar returns from the target's turbine and fan blades. Every engine has its own radar return characteristics, and by studying these and placing them into a table, the radar could to compare actual radar returns with those found in the NCTR library.

NCTR worked best at an aspect angle of greater than 120° and a look down angle of no greater than 5°. It usually displayed an identification on the radar page within 5-7 seconds and somewhat accurate, but required regular library updates.

A/A Training

The key parameters that had to be met before missile launch were 1) positive identification of hostile, 2) lack of friendly indications and 3) clear field of fire to the target.

For BVR engagements, the AAQ-14 was a reasonably good substitute for the IRST (Infrared Search and Track) systems found on threat aircraft such as the MiG-29. The crew could acquire a bandit with the radar, cue the pod to it, break the radar lock to continue the engagement more discretely or to designate additional targets in TWS or DTT, and then fire a volley of AMRAAMs using both pod and radar designations.

During the mid-90s there was a greater emphasis on AIM-7 Sparrow training due to a limited availability of AIM-120 AMRAAM training rounds. By the late 90s, the AIM-120 was far more prolific.

WSOs tended to run the radar for the majority of the fight, although once within visual range, they handed the radar over to the pilot. For the remainder of the engagement they would look for other aircraft or maintain a visual with the target aircraft. This was especially important as there was always a distinct possibility that one or more aircraft from a BVR engagement would succeed in merging with the Strike Eagle. F-16s routinely achieved this in practice engagements with the Strike Eagle, and their standard tactic was called the "exploding cantaloupe" – a manoeuvre that saw a four ship flight of F-16s break dramatically onto different headings and altitudes. This initially made keeping track of them all but impossible for their opponents, and at least one F-16 usually made it to the merge unseen.

The F-15E community countered this tactic before they even left the ground. During the briefing, each crew was assigned a one of four quadrants of sky to monitor, ensuring that if a cantaloupe type manoeuvre were flown there would be calm coordination as the darting Vipers flew their tactic.

This all required a solid understanding of the Air Force's Tactics, Techniques and Procedures 3-1 manual, but generally worked well. On the occasions that it didn't, the F-15E was no match for the more agile fighter.

Light grey aircrew who moved to the F-15E remarked that the two aircraft handled similarly, although the additional basic weight and parasitic drag from the CFTs meant that the F-15E's turn rate was inferior (it lost a few degrees per second of turn rate to the C model) and it bled speed more rapidly in the turn. Unsurprisingly, the Strike Eagle crews' contingency plan was to avoid getting into a rolling dogfight in the first place.

In some senses, this was not unrealistic, they reasoned. There would be few times when the F-15E would go into battle without support assets that would provide either situational awareness input (such as AWACS) or direct support (such as a dedicated escort or sweep fighter package) to keep the threat at arm's length.

F-15E crews appreciated the limitations of their missiles and their radar, but from that appreciation came both strength and tactical acumen – combined, they allowed the Strike Eagle to conduct the fight on its own terms. In the event of a merge, the pilot could extend away from the fight and use superior low level performance to escape.

But the community certainly grew into the air-to-air portion of their multirole capability, growing in confidence as they did. Post Desert Storm, the 4th Wing participated in numerous training exercises, including Red Flag and Roving Sands, the latter of which was an Army sponsored event.

In February 2001 the 336th FS attended Red Flag and were assigned the role normally reserved for the F-15Cs - Defensive Counter Air. DCA required the destruction of Red Air forces attempting to attack their own airfield. In this capacity the squadron excelled themselves: they had come a long way from the early days and were flying a mission that had expressly forbidden ten years previously.

Fighter Data Link

In 2001, following the September 11 terrorist attacks, the Chiefs and Rocketeers were immediately placed on heightened alert and were assigned responsibilities to Operation Noble Eagle – the US homeland defence plan. The squadrons flew nine-hour missions over key US coastal cities.

Meanwhile, the 391st FS, Bold Tigers, Mountain Home AFB, Idaho, deployed to Kuwait and began to strike fixed targets such as caves, bunkers, command and control facilities and terrorist training camps in Afghanistan.

Soon thereafter, the 4th FW received orders to prepare to replace them when they returned in January 2002. The 335th and 336th would deploy six aircraft each to Kyrgyzstan, a nation about the size of South Dakota, which bordered China, Tajikistan, Uzbekistan and Kazakhstan.

During the course of preparations, the squadrons received updates from their 391st FS colleagues to the effect that they had struck almost everything on their list of fixed targets and were spending more of their time flying time sensitive taskings. Accordingly, the 4th FW received top priority to receive Link 16 Fighter Data Link (FDL).

FDL was born from a 1980s program entitled Joint Tactical Information Distribution System (JTIDS). JTIDS used a data link network protocol (Link 16) to allow secure sharing of information between ground and air based command, control & intelligence, surveillance and reconnaissance (C2ISR) platforms.

Despite successful trials, it was installed in a very limited number of F-15s before a shrinking defence budget brought about its cancellation in 1989. The Gulf war prompted Air Combat Command to initiate a fresh look at JTIDS and by 1992 it was once again being tested. In 1996, the US Air Force's Tactical Exploitation of National Capabilities Program (TENCAP) commissioned a series of exercises (Project Strike I & II, and Talon Sword B) and programs to verify the effectiveness of JTIDS for their needs.

Meanwhile, MIDS (Multifunctional Information Distribution system), a joint cooperation between the US, France, Italy, Germany and Spain, was developing the MIDS-Low Volume Terminal. MIDS-LVT provided a cost-effective way of procuring enough sets to install in a significant number of Tornados, F-16s, F/A-18s, F-14s, F-4s etc.

MIDS also spawned the Fighter Data Link, a low voltage LRU that was smaller and lighter weight than the LVT, and destined specifically for installation into F-15C and F-15E aircraft. Link-16 terminals provided a high-capacity, spread-spectrum, frequency-agile, and secure digital communication system that allowed for interoperability between US and NATO forces (the NATO equivalent to Link 16 is TADIL-J).

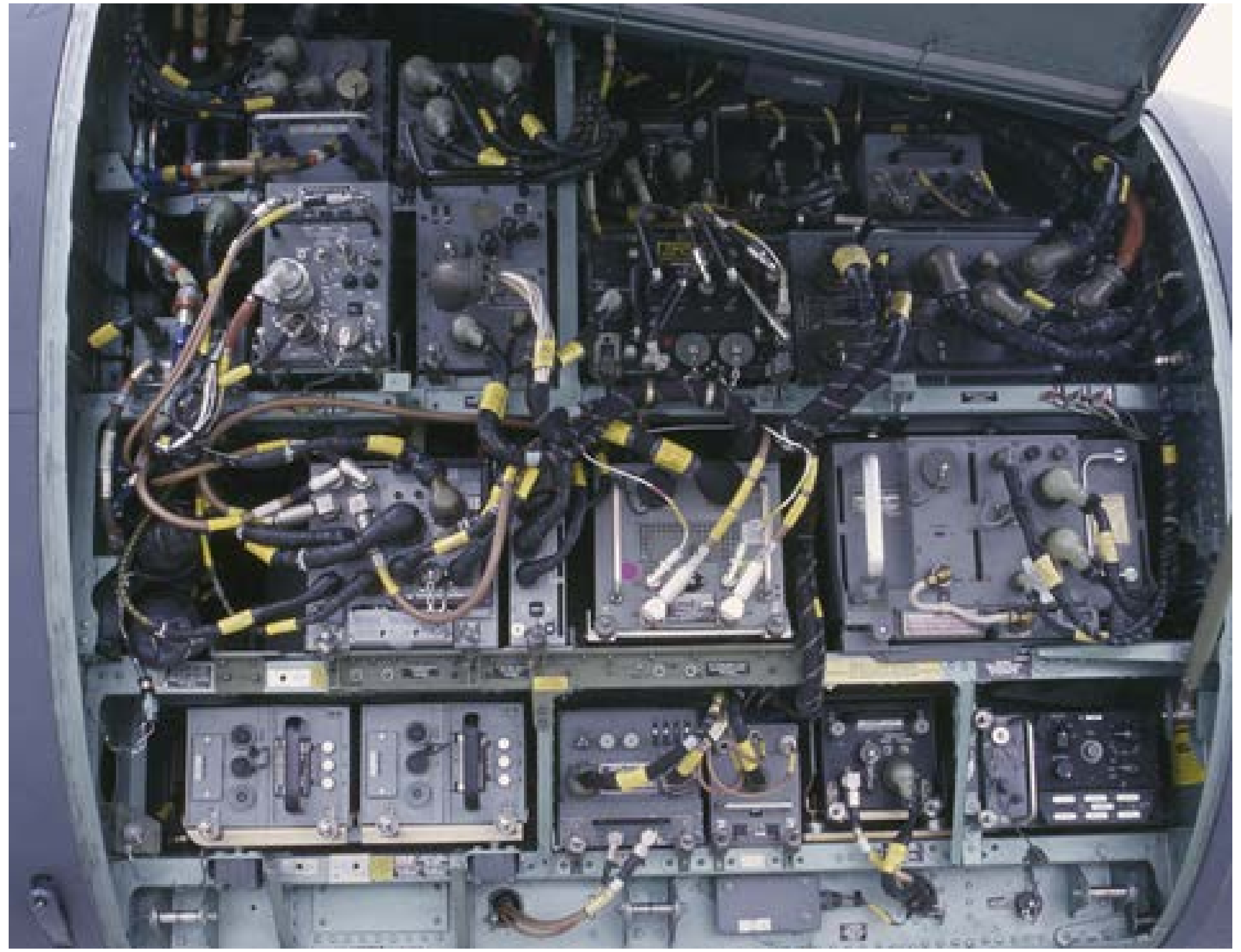
FDL software for Suite 4E was developed concurrently with FDL hardware to allow integration of both into the Strike Eagle, and as the 4th Wing received their first FDL boxes in October 2001, they crammed a 12-month conversion course into the space of six weeks.

The physical installation required the replacement of the TACAN LRU in the right-side nose avionics rack with a LRU containing both TACAN and FDL circuitry (called a dual box).

In basic terms, FDL allowed the F-15E crew to receive data from other sources and sensors and to piece together a top-down picture of the battlespace. E-8 JSTARS, RC-135 Rivet Joint, other strike fighters, and E-3 AWACS reconnaissance/signals intelligence aircraft were all able to pass precise locations of ground targets, threat emitters, hostile aircraft, other friendlies, AAA and other intelligence data to via their own Link 16 terminals to the F-15E in real time.

The Strike Eagle crew could then call up a SIT (SITuation) page and observe these target tracks, even if they were beyond the range of their own sensors. To accomplish this, Link 16 used 128 Time Division Multiple Access time slots per second to exchange information between units at up to 238kb/second.

BELOW
FDL replaced the TACAN LRU with a so-called dual box that contained both TACAN and FDL hardware. It is seen here, with a small purple sticker, in the middle of the avionics racks. (Author)



Collectively, aircraft passing data were referred to as "the network".

To provide immunity from jamming, the system hopped over fifty-one frequencies at the rate of 77,000 hops per second, necessitating that when aircraft joined the network, they synchronised their systems with what was termed a "Net Time Reference" – usually an E-3 or similar command & control asset on station.

When large volumes of network traffic were anticipated, multiple networks could be introduced and stacked, either across a wide frequency spectrum, or through time sharing of a smaller frequency range. Up to 126 network participation groups could be activated, allowing dedicated bandwidth to be assigned to fighter-to-fighter data (F/F); precise participant location and identification data (PPLI); voice data; and surveillance mission management and weapons coordination data etc.

As targets and battlefield information were passed to the crew, controlling Authorities such as Rivet Joint, AWACS or JSTARS could assign actions to the Strike Eagle crew without breaking radio silence. They could have assigned the destruction of a target to a particular element of Strike Eagles for example. In this instance, the symbol representing the target was highlighted to the F-15E crew and an option to accept or decline that tasking appeared next to a PB. For the duration, FDL frequently sent out ownship weapons status (how many and what type), fuel status, radar and sensor status etc. to the rest of the network, and would receive similar information from the other network participants.

In early 2002, a small group of Rocketeers headed out to Nellis to assess the stability and interoperability of FDL. Specifically, they were to evaluate the characteristics of a network comprised of different Link 16 platforms (AWACS, F-16, F-15C, RC-135 etc.). Over the course of their stay, aircraft were able to pass data to each other and significantly enhance situational awareness, and the potential for its use in attacking ground targets in particular was marvelled at.

But there were several problems, mostly due to the immaturity of the system. The first was network stability: the whole thing crashed when more than eighteen aircraft joined. The second was positional errors, which prevented FDL from displaying accurate target positions. And the third was that larger aircraft like the E-3 were having difficulties in efficiently passing data to the fighters, mainly due to inexperience in working with them.

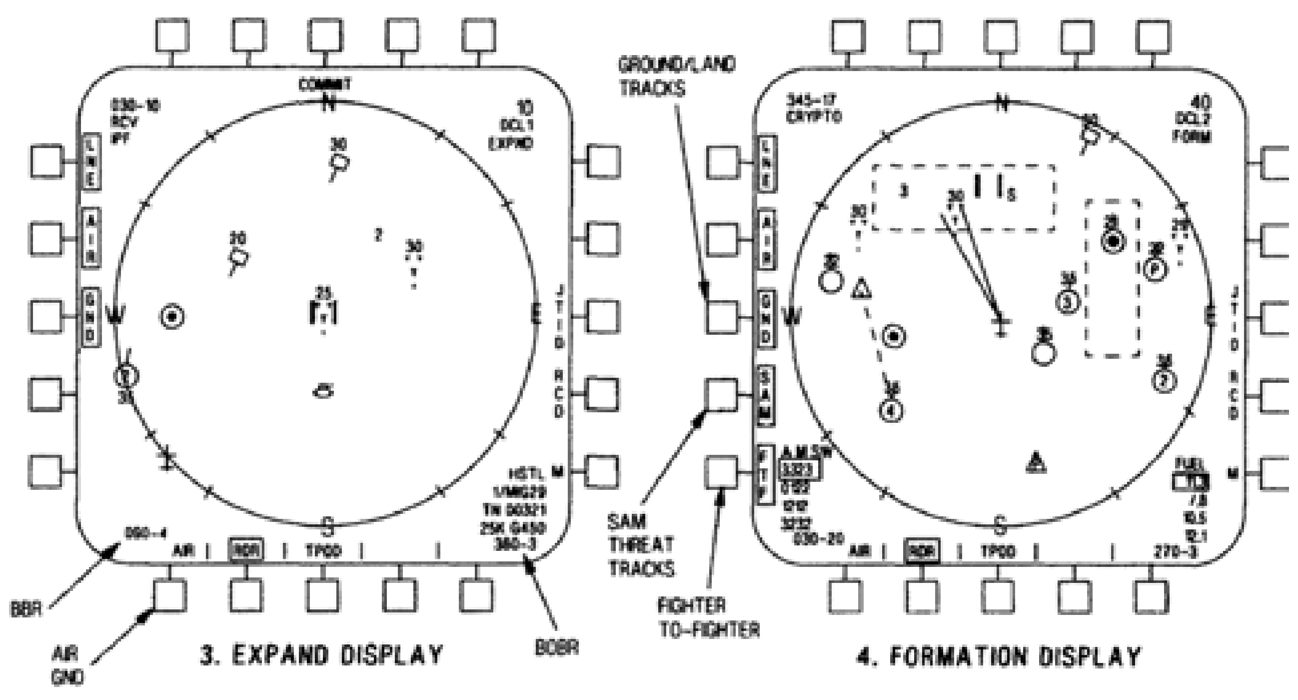
Stability was a real problem as the 336th crews had been kicked off the network as it struggled to cope with an increasing demand for data as more aircraft logged on, although the general feeling was that this could be resolved through additional testing and software tweaks. Navigational errors were equally as frustrating, as the whole concept relied on the relative positions of target tracks remaining accurate. GPS facilitated improvements in this arena, but the tightness of each player's navigational system directly influenced the quality of the information available on the network. The wide-bodies' (AWACS, Rivet Joint, J-Stars) lack of familiarity in working with tactical fighters would naturally improve with practise, but in the meantime, the fast-movers would continue to fall back on traditional radio communications.

On return from Nellis, the crews briefed the remaining Rocketeers on their findings. One impressive feature they had evaluated concerned flight management techniques – flying as a four-ship formation and sharing fuel, stores, targeting and weapons data without a single radio transmission. FDL numbered each aircraft according to the hierarchy of the flight – Lead (labelled '1') could consult his SIT display to see the exact location of his wingmen (2, 3 & 4) relative to him. When they locked ground or air targets up on their radars, FDL sent this information onto the network and small dashed lines connecting the fighters to their targets would appear on all network users SIT displays. Lead could also hook his acqs over other friendly symbols on the display and call up their status (call-sign, fuel status, flight status - refuelling, returning to base, ground attack, intercept etc.). The amount of situational awareness the system provided was worth a thousand words over the radio.

Since 2000, the 336th had been testing PACMAN (also known as Noonan '02 or Super Gooch by those who used it) - a handheld computer with a touch screen and a hard drive loaded with high resolution satellite imagery. Used by the WSO in conjunction with FDL and the F-15E's APG-70 radar, Noonan '02 was expected to allow aircrew to take FDL targets, patch map the target area and then compare the image on the radar screen with that of the satellite imagery on the handset.

Some WSOs, however, felt that another item to clutter the cockpit was not a good idea, and that it might also present a flight safety issue in the event of an ejection. In all, it was seen by many as a lackadaisical solution when what was really needed was dedicated

OPPOSITE
F15E '0229 returns to Seymour Johnson following a FDL evaluation sortie in March 2002. (Author)



ABOVE
The SIT page allowed the crew to rapidly build situational awareness and prosecute their attacks. (Author's collection)

investment in the ZSW-1 Data Link pod, which had yet to enter service.

The 391st FS visited Seymour Johnson on their way home. The Rocketeers deployment to Operation Enduring Freedom had been cancelled in late February 2002, although the Chiefs had deployed in January to replace the Bold Tigers. Disconsolate about the cancelled deployment, the 336th at least had the opportunity to sit down with the Mountain Home crews and learn about new tactics and loadouts. Among these was the propensity to haul aloft a mixed load of weapons, usually Mk 82 500lb and GBU-12 500lb bombs, and to fly TST sorties.

The Bold Tigers used their visit to Seymour Johnson to borrow the Chiefs' now-unguarded squadron mascot – a huge wooden Native American with feather headgear, Chief Hospitality – taking it back to Idaho with them.

48th FW, RAF Lakenheath, Suffolk, England

RAF Lakenheath is host to the 48th FW, USAFE (USAF Europe).

The Strike Eagle arrived in Suffolk on 15 February, 1992, when F-15E 90-0248 landed from its transatlantic ferry flight, becoming the Liberty Wing's flagship in the process.

The F-15E was replacing the F-111F, although of the four resident Aardvark squadrons, only two transitioned to the Strike Eagle – the 492nd FS Bolars and 494th FS Panthers. The 493rd FS Grim Reapers transitioned to the F-15C and the 495th FS was decommissioned.

The first F-111 to leave Lakenheath departed on 10 August, 1991, and the last roared into the sky on 16 December, 1992. By this time, there were thirty-one Strike Eagles in place, and from 9 March, 1992 onwards, both squadrons began working up to IOC.

Lakenheath aircrew slated to transition to the F-15E were divided into small groups and given slots at Luke. However, given that it took upwards of four months to put a WSO and pilot through training, many of the 140+ Lakenheath pilots and WSOs had either left the Air Force or had been reassigned to other posts before they ever got to Luke. "Cheese" estimated that less than half actually reached the jet.

Meanwhile, maintainers were plucked from sunny Seymour Johnson and relocated to Lakenheath to re-train existing F-111F maintenance personnel onsite.

The 492nd FS achieved IOC on 1 July, 1993, with the 494th FS following suit on 1 October. The Bolars achieved full strength (twenty-four jets) by January 1993, although the Panthers hovered at between twelve and nineteen jets until May 1994, at which time they too grew to twenty-four.

In February 1994, the first F-15C/Ds arrived, and by the end of that year the base was flush with the most potent military hardware anywhere in the world – each F-15E squadron had twenty-six birds, and there were twenty-one light greys to keep them company! Generally speaking, the 48th FW received the newest airframes in the Eagle family. All of the E models that arrived in 1992 were less than two years old, and most had been manufactured in 1991 (the 494th's jets were all '91 builds with the exception of one '92 build).

The first jet to arrive, AF 90-0248 was a Block 50 airframe, but the Wing received aircraft all the way up through Block 53 in the first two years. The basic implications of this were that these jets incorporated changes, some small, some significant, that earlier block Strike Eagles did not have, and in some cases, those on the ramps of Seymour Johnson, Mountain Home (see 366th AEW, below) and Luke also lacked.

One significant change was the introduction of the Molecular Sieve Oxygen Generation System (MSOGS – AF 90-0261 and up), which replaced the traditional liquid oxygen system used for crew breathing. Another was the installation of the VHSIC CC (AF 90-0261 and up), and a small change to the anti-skid system to prevent damage to the tires on touchdown (AF 90-0248 and up).

Less obvious changes were also made, including a change of power source for the MPDP that addressed reliability problems; an upgrade to the remote map reader that allowed faster loading of film for the TSD; an expanded fire detection circuit introduced in the aft fuselage; and a new maintenance diagnostic panel installed in the nose gear wheel well.

The biggest change of all though, was the engines: F-100-PW-229s were installed in F-15E AF 90-0233 and upwards.

MSOGS was unique to the F-15E and provided a

Taliban in the Carolinas!

With no deployment scheduled in 2002, the Rocketeers once again turned their hand to developing TST tactics using FDL, and planned to send their Operations Officer over to Kuwait to brief the Chiefs on the results of two days' of TST trials.

On 13 and 14 March, they flew a succession of sorties to develop TST techniques and intra-platform coordination. Both days brought bad weather, and that would limit the usefulness of the AAQ-14. Despite this, the crews packed the briefing room for an 06:15 briefing in anticipation of an 09:45 take-off.

They briefed to use two Military Operating Areas - Whiskey 122 Warning Area off the coast, the R-5306A electronic threat range (where Atlantic Airfield is), and the Echo MOA – and would attempt to find Visual Flight Rules weather somewhere amid a 25,000' cloud ceiling, medium level overcast at 10,000' and low level overcast at 2,000'.

The scenario called for three kill boxes (KB) to be set up on the Carolina coast, each of which represented areas where "Taliban and Al Qaeda activity had been detected".

KB#1 had seen suspected cave activity, fortifications and troop movements; KB#2 had armoured personnel carriers, troops, tanks, and utility vehicles; and KB#3 had seen troop activity in and around compounds and cave entrances – recently shot video of suspected troop movements was shown on a projector to demonstrate this.

JSTARS and AWACS would be orbiting off the coast, and the exercise was to start with both platforms placing a target track on the Seymour Johnson ramp so that the tightness of their navigation systems could be verified. It was established that the command Authority would be thus: AWACS, JSTARS, and finally, TACPs (ground based FACs).

Intel reminded the crews that there would be a lack of Radar Warning Receiver Indications as the threat mainly consisted of IR shoulder fired missiles such as the SA-7 and Stinger. 100mm KS-19 anti-aircraft artillery and AK-47 small arms fire was also to be expected.

Both days proved successful in raw terms. Pop-up SAM threats (actual SA-6s) and AAA threats (actual ZSU-23-4) systems were located at Atlantic airfield in one of the kill boxes and the widebodies had successfully picked up these and passed them onto the F-15Es. Several were killed with cluster weapons dropped through the weather by the Strike Eagles, which had cued the APG-70 from the FDL tracks, and expeditiously located and struck the vehicles.

However, the widebodies had quickly become task saturated as more aircraft joined the net and reported ready for tasking. Worst of all, there had been some very wide positional errors in the data passed from one aircraft to another. Some Strike Eagle crews reported that targets passed to them by JSTARS or AWACS were as far as two miles away from their actual location. The FDL screens in the aircraft had also been overwhelmed by the amount of information to display, and comm had suffered as a result. This was in part down to the JSTARS and AWACS crews sharing too much information, and sharing information the F-15E crews didn't need.

In essence though, the system was working adequately and the Rocketeers passed on their findings to the Chiefs: as a powerful as FDL was for air-to-air, it was even more so for air-to-ground.

no-frills, maintenance friendly system that took bleed air from the engines, cooled it, filtered out the nitrogen and other pollutants with the molecular sieve, and then fed the resultant gas (enriched oxygen) to the crew via a CRU-74 oxygen attachment that clipped to the parachute harness of each crewman.

It was installed in the right forward nose avionics bay, and was metallic green in colour. A back-up system was provided in case MSOGS failed or detected pollutants in the gas supply, and this was constantly charged by MSOGS itself so that maintenance input was not required.

In later years, as Combat Edge life support equipment (advanced G-suit, helmet and oxygen mask) arrived, MSOGS provided a positive pressure breathing mode that provided a steady flow of air through the oxygen mask as g increased, helping to counter the effect of oxygen starvation to the brain caused by blood pooling in the lower extremes of the body.

Deployments

Within a month of achieving IOC, the Bolars deployed six jets to Incirlik AB, Turkey, as part of Operation Provide Comfort (see Chapter 4). The Bolars stayed from 2 August until 2 November, at which time they were replaced by six jets from the Panthers.

In 1994, the Wing was once again tasked with Provide Comfort duties and also deployed to Aviano AB, Italy, as part of Operation Deny Flight – eight F-15Es left on 30 February and returned on 19 December.

From 19 January to 17 February, 1995, the Wing participated in its first Red Flag deployment since converting to the F-15. Eight F-15Es selected from both squadrons deployed to Nellis alongside eight Grim Reaper F-15Cs. After Red Flag, they moved directly to Tyndall AFB, Florida, where they took part in a Combat Archer air-to-air weapons evaluation. The 493rd and 492nd FSs returned home thereafter, although the 494th FS once again travelled to Nellis to participate in Green Flag – an exercise run principally to simulate an electronic warfare environment.

Throughout 1995, the Wing continued to send F-15Es to Deny Flight and Provide Comfort. 1996 saw both Strike Eagle squadrons attend RAF weapons school exercises at RAF Leuchars (five F-15Es from the 16 to 26 November), and this was one of the first opportunities for the crews to work closely with the RAF.

1996 concluded with a valuable deployment to Sidi Slimane AB, Morocco, for African Eagle '96. This afforded both F-15E squadrons the ability to train in dissimilar air combat training (DACT), in which different aircraft types fight against each other. Morocco operated Mirage F.1EQs, which were also operated by Iraq, and much was learned about the Mirage and its capabilities.

There was some humour surrounding the deployment, too – Major Gary Klett attended the exercise, and recalled that the Moroccan pilots tended not to stick to the rules of play. They would vigorously deny being shot down and when the F-15E got the better of them, would resort to attacking the Strike Eagles from below the hard deck!

By virtue of its commitment to NATO, the Liberty Wing was probably the most highly tasked F-15E operator in the USAF. Between 1993 and 2002, its F-15Es participated in more than twenty-nine exercises either directly through NATO or by individual agreement with NATO member countries. These ranged from NATO Tactical Leadership Programs hosted by such countries as Belgium, the UK, Norway and Denmark, to Tactical Fighter Weapons meetings.

In addition, the 48th FW not only had to stage and pass USAFE Operational Readiness Inspections, but also NATO inspections. These were conducted without disturbing the flow of obligations to worldwide trouble spots. From 1997 onwards the Wing was seemingly constantly deployed on Air Expeditionary Force and impromptu taskings, rarely having time to pause between them.

Col. Steve Kwast, 492nd FS commander, explained that the pressure was often so great that it was necessary to call on other Air Force fighter units to swap tasking slots. Kwast made it his business to know as many key figures in the Air Force as possible; the end game being to develop key relationships so that he could pick up the phone to another squadron commander and arrange, for example, to swap Red Flag dates.

With such an arrangement made, he could better assign resources to other more important commitments such as AEF. This enabled him to cut his aircrew and maintainers a bit of slack.

Rarely would either F-15E squadron have a full complement of twenty-four Strike Eagles (sometimes twenty-six), as the odds were always in favour of six or more jets being deployed to any one or more of a range of locations around the world. It is no surprise that some dubbed Lakenheath, Laken-pain!

OPPOSITE
The 48th FW flag ship readies for flight. (Author)

Crews averaged around twenty hours flight time per month, and low-time pilots (less than 500 hours) would often be prioritised to fly a little more.

Maintenance

Despite inter-squadron rivalries, the Bolars and Panthers shared maintenance facilities, including centralised LANTIRN, egress, PHASE, engine and munitions shops.

Once again, bargaining was an oft used tool to get the job done, and Kwast and his senior maintenance NCOs would hold regular meetings with their counterparts in the Panthers to see how each could aid the other.

PHASE was a key element in keeping the Strike Eagle flying. It comprised of a large hangar with dedicated space for several aeroplanes. It ran hourly post flight (HPO) inspections on aircraft at 200 hour intervals. The inspection usually took about five days, and would average 115 fault fixes per aircraft resulting from 400 separate inspection item checks. It was conducted in five phases:

"Pre-dock" was an administrative phase that took existing discrepancies already documented by aircrew and the aeroplane's crew chief, and effectively drew up a contract with the squadron to confirm what would be fixed and how long it would take.

The crew chief would then pass the jet over to the PHASE mechanics for the "look phase".

Look phase involved examining every square inch of the aircraft and inspecting internal systems to identify additional faults – no work would be carried out other than logging the problems, all the better to make sure there was no rush to fix a fault that might cause another to go unnoticed.

Phase three was the "fix phase" and involved calling in PHASE specialists to fix whatever discrepancies had been found.

"Post inspection" was the penultimate phase. It took the aircraft and powered up engines and systems to ensure they performed as expected. The jet was also observed for leaking fluids.

Finally, "post dock" ended the procedure as relevant data was input into the Air Force's antiquated CAMS maintenance database and the crew chief arrived to check that his jet was in working order. With this accomplished, he'd sign the jet back into the squadron roster.

Even though PHASE sounded like it was being run like a corporation, standards were the real priority and deadlines were allowed to slip if the PHASE shop felt the jet was not safe.

ACES II Ejection Seat

Weapons and Egress shops also had their own dedicated space. Egress ran the maintenance facilities for the ACES II ejection seat.

ACES II offered an enhanced escape envelope for anyone finding themselves in the unenviable position of having to eject. One such example occurred on 16 September, 1994, when F-15E AF 91-0601 crewed by Capt. Brad Robert and WSO Capt. Mike "Grease" Panarisi were flying low level over Wales. A duck penetrated the side of the canopy and impacted Panarisi square in the face. Disoriented and unsure of the condition of the aircraft, he ejected. While the three-way command selector valve in the rear cockpit had been set to AFT INITIATE, the system failed and Robert's ejection seat did not go off. He eventually

BELOW
Inside the blast door of the secure, cold war era mission planning facilities at Lakenheath. (Author)

realised the Panarisi had ejected, so he made his own seat safe and landed safely at RAF Valley.

Panarisi, meanwhile, had been 'rescued' by a farmer who took him to a nearby pub. There, he was presented with a tray of beer and spirits, and given a phone to call home. He duly called the squadron, announcing, 'Hey, this is Grease. We hit a bird. I had to eject. I'm in a pub in Wales. Tell my wife I'm OK', to which he heard the immortal *non sequitir*, 'OK. I'll let him know. Grease is flying at the moment'.

'601 was eventually repaired and returned to service, and it was quickly established that the command eject system in the Strike Eagle was not to be trusted.

The ACES II enjoyed a good reputation and a success rate of better than 97% when used within its operating envelope. It featured a small onboard computer that used data from two sensors mounted on either side of the head rest, and signals from the F-15E's air data computer, to automatically sequence the ejection into one of three modes. This then activated the drogue chute, man-seat separation and main parachute deployment.

Mode 1 was a low-speed mode, Mode 2 a high-speed mode, and Mode 3 a high altitude mode that delayed main parachute deployment until a safe altitude was reached (typically 15,000' AMSL).

The F-15E was not initially fitted with a canopy jettison lever, as pulling the ejection handles automatically fired a circuit to accomplish this and was backed up by the main canopy open/close lever. But this was changed following at least one inadvertent activation of the unguarded canopy lever whilst in flight. Reports indicate that on one occasion a 4th FW jet lost its canopy after the cuff of the WSO's sleeve snagged on the lever. The lever thenceforth incorporated a locked position, and a canopy jettison handle was mounted in both cockpits on the left instrument coaming.

Flying in the UK

Like other F-15E Wings, Lakenheath played a crucial role in the Air Expeditionary Forces structure (see Chapter 4, Combat Records). But when not on exercises or deployed to other global hotspots, the Panthers and Bolars made use of a small number of ranges for unguided bombing practise (such as Donna Nook, Wainfleet, Holbeach etc.), and the excellent low-level operating areas over Wales.

For air-to-air combat practise, it used URITS – an advanced airborne instrumentation system that used GPS to provide a self-contained, ACMI debriefing facility. URITS was carried in place of an AIM-9 and recorded the movements of the F-15E as well as data from the radar and missiles also loaded onto the jet. Because it was GPS driven, an actual ACMI range, such as that over the North Sea, was not required. Each jet simply carried a URITS pod, flew the sortie, landed and removed a small data transfer cartridge from the back of the pod to load into a URITS computer terminal in the debriefing room. There, the computer merged the data from each cartridge and provided a 3D replay of the events that had just unfolded.

Each day, the Meteorological faculty provided weather forecasts for the UK mainland and coastal regions, and these were checked early on each flying day. Wing policy prohibited flying over water when sea swells exceeded 4 metres and the wind was gusting to greater than 25 knots. Poopy suits – dry suits with rubber neck, cuff and leg seals – were worn all year round when UK based crews were likely to fly over water, because even in Summer the sea temperatures were low enough to make hypothermia a real risk.

On days when the weather was inclement, the squadrons would pick targets further afield. Belgium, Germany and France were often better alternates where clear weather would allow effective training.

The met team also produced IR range vs. time graphs, which depicted expected delta temperatures (IR temperature) and the range at which the crew might be able to see a discernible view of the target through the target pod. A folder of these graphs, updated daily, was necessary because the detection range changed depending upon location (visibility over Newcastle might be worse than over Leicester, for example); attack altitude (haze in the air reduced visibility – the closer to the ground the less haze); target size, target material (wood, metal, cement etc.); time of day; humidity; materials surrounding the target (vegetation, other buildings, water etc.); and attack run-in heading, which might place the TP directly into the sun.

NOTAMS were checked manually, although the Air Force's mission planning software (MPS) could be updated via CHUM (Chart Update Manual) to display new danger areas.

Most sorties fell under the Ready Aircrew Proficiency (RAP) programme, meaning that the flight was necessary to maintain Mission Ready status. Each crewman had their own chart that they filled in as they completed each sortie. Thus, Night, Night Vision Goggle, Surface Attack Tactics, BFM, Close Air Support, Terrain Following, Defensive Counter Air, Sweep, Lane Defence, Combat Air Patrol defence and a range of other sortie types could be executed in a structured manner over the course of each year.

The same prerequisites existed for air-to-ground

OPPOSITE AND ABOVE

The PHASE hangar at RAF Lakenheath had room for several jets to undergo tear down and inspection at any one time. Note the edge protectors installed on the horizontal stabs to protect the maintainers from gashes to the head. (Author)

weapons practise, where 50% of bombs (of which there were twelve categories) had to hit the target.

Realistic target training (RTT) was a key focus alongside RAP. RTT involved picking targets across the length and breadth of the country, and offered relief from the monotony of revisiting the same ranges over and again for the duration of the three year tour (some F-15E aircrew served three tours at Lakenheath!).

Planners and Intelligence teams therefore picked hundreds of innocuous looking structures and buildings across the UK. Each was filed to a separate target folder along with satellite imagery and similar targeting data, and was subsequently pinned to the wall of a large room along with hundreds of others. The crews could therefore arbitrarily pick a target folder and begin the complex science of weaponeering – taking target and weapon data and planning an effective attack.

Weaponeering was more complex than it sounded – one could hit the target, but if the bomb was not fused correctly, of the right type, travelling at the right velocity or struck the target at the wrong angle, it might still survive.

Of course, with multiple bombs impacting the same area, there was also blast fragmentation and smoke to be considered.

As each member of the sortie completed his planning, the flight would come together to brief *en masse*. This involved confirming standard tactics, radio communications and procedures. However, these often remained the same from one sortie to another, and more time was devoted to discussing targeting procedures and expectations.

ABOVE
Strike Eagle aircrew brief at Lakenheath ahead of splitting into groups to conduct detailed mission planning. (Author)

Desired mean point of impact (DMPI) was the aircrew vernacular meaning "target". Each crew was assigned one or more DMPIs, and from that they could work out their attack plan.

Previsualisation was the discussion of what the target would look like on an HRM map and TGT IR, and how it would be located. It was a combination of art, science and experience. At the very early stages, crews learned big-to-small: taking a large-scale patch map and working their way down into smaller resolutions so the target could be acquired.

The same rule applied for TP work. It sounds simple, but previsualisation required practice to get good at, as the grazing angle, range, physical layout of the site, and a host of other factors all played a part in what the target would look like through both sensors.

Crews sketched how they expected their DMPIs to appear, and made use of Ordnance Survey maps and template rulers to identify what their HRM and TP field of views would be at selected ranges/FOV settings.

Two hours after the mission had been planned

OPPOSITE
Lakenheath is the only F-15E base where Hardened Aircraft Shelters are used regularly. (Author)

Bombs Away! - Delivery Modes In Detail

The Strike Eagle featured two computer aided modes: CDIP and AUTO.

Continually Designated Impact Point mode was a visual release mode most often used for unguided deliveries by the pilot, and used a pipper in the HUD to display where the weapon would impact the ground. A dynamic impact line ran from the pipper to the velocity vector, and this allowed the pilot to accurately align the target as he brought the pipper to bear. CDIP offered great flexibility and was ideal for targets of opportunity. Once the pickle button (release consent) had been switched on the control stick, the weapons computers would then initiate weapons release or wait until their computations indicated the weapons should be released. Simultaneously, a target designation diamond would appear over the point at which the bombs would impact the ground.

AUTO mode was by far the most popular, however. It allowed all weather, night and day attacks, and required that a target be designated via the AAQ-14 or the APG-70. Once again, the CC took the target designation point and computed its position relative to the jet. Steering commands to place the fighter's nose towards the target were then generated in the HUD, and a TD box was overlaid onto the target. Weapon time of flight was calculated (based on altitude, Coriolis effect, air density, airspeed, target altitude etc.) and in a matter of milliseconds the HUD was filled with more detail: time to release (TREL), target heading on the heading scale, and the azimuth steering line (ASL).

AUTO mode worked similarly to CDIP from then on. The ASL lacked a pipper at the bottom, but still represented the bomb fall line. To release the bombs, the pilot manoeuvred the ASL over the TD box, pressed the pickle button and watched the TREL counter reduce to 0. For added accuracy, the crew could input updated wind data into the UFC for up to ten altitudes, which the CC used to refine its weapon release computations. Logic prevented any stores release when the ASL was more than 20° either side of the aircraft's ground track. If the wrong target had been designated, or the designation was slightly askew, the pilot could use the TDC to slew the TD diamond provided that he could see the real target though the HUD line of sight. The CC stored target data and entered re-attack mode when the jet overflew the target, and provided updated steering commands to the pilot to allow him to manoeuvre for a second pass should he wish to.

One final element of PACS programming and weapons release properties was the attack profile itself: level, loft, dive, and dive-toss, were available in both CDIP and AUTO.

Level was self explanatory, and the jet simply flew at a constant altitude until the bomb dropped. It offered an accurate delivery as the delivery platform was stable, but was not suitable for high threat environments where AAA could conceivably track and strike an aircraft that failed to jiink and evade.

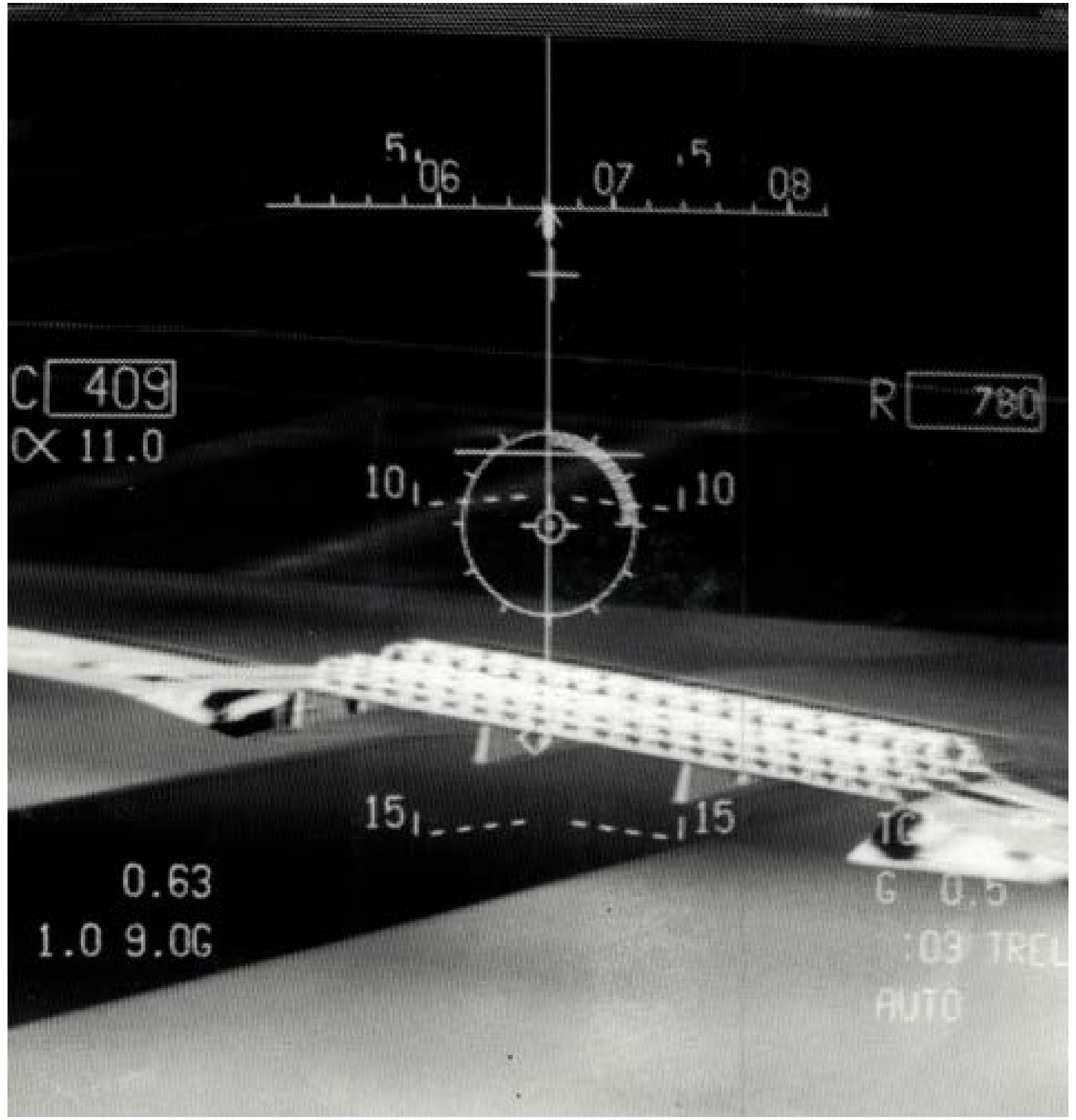
Loft offered some respite from this scenario as it required the Strike Eagle top fly a parabolic curve, releasing its bomb at the apogee – effectively sling-shotting it towards the target. A loft delivery required first that the aircrew input the loft angle into the PACS. The CC would compute the effects on the jet following a 4g pull at current airspeed and altitude to that loft angle, and could then project the ballistics of the bomb and provide steering cues.

Loft also featured an elevation steering command in the HUD that gave the pilot a visual guide during the 4g pull and would rise up the HUD pitch ladder when time-to-pull (TPULL) reached zero – the pilot simply had to keep the velocity vector coincident with the ESL line to maintain valid weapons release parameters. Under-pulling or over-pulling could cause the bomb to miss, and it was therefore essential that the pilot was smooth on the stick. Equally imperative was that the pull-up manoeuvre was executed on time, as indicated by the TPULL counter in the HUD.

Dive and dive-toss were both well adapted to visual deliveries, as they often placed the target in the HUD line of sight. Dive maintained a constant dive angle, whilst dive-toss required that a parabolic curve was flown following target acquisition and designation.

and briefed, the crews would be airborne, typically heading north-west under radar advisory service before turning due west and traversing an 80 mile corridor to reach enemy territory – Wales.

Lakenheath was the first F-15E Wing to receive DMS – Digital Mapping System, which dispensed with the old style tape and RMR used with the TSD and replaced it with digitally stored maps. It was installed in F-15E AF 96-0200 and up, and later retrofitted to the rest of the Strike Eagle fleet. Its advantages were many, but the main ones were the full use of colour, the ability to store several maps (low-level, Ordnance Survey, Sectional etc.) and to switch between them in-flight. DMS also introduced the ability to program three-dimensional threat circles into the system,



ABOVE
The F-15E HUD in AUTO bombing mode. (Boeing via Paul F. Crickmore)

which operated very much the like the TSD, but was far more powerful.

Systems checks were run both as the crew transited north and upon reaching Wales. With all systems go, the Strike Eagles would roll inverted and descend to between 500' and 1,000'. The low-level gauntlet would begin, usually in an echelon formation, and the valleys of Wales provided ample cover for terrain masking and evasive manoeuvring. They also provided their own share of dangers, not least birds and other airborne traffic.

Once on the attack run-in heading, or upon reaching the IP, the ARMT page would be used to select the PACS controlled release program or to manually input weapons release parameters. Reaching their Initial Point (IP) following twenty-minutes of low-level, they would zoom to altitude to perform a medium altitude LGB delivery.

Impromptu air-to-air practice was sometimes possible inbound and outbound from the target – RAF Tornados, Jaguars, Harriers and Hawks could squawk 1111 on their IFF transponders, thus signalling that they were fair game for other tactical aircraft to run intercepts on – they might not respond to the attack, but they were happy to be used as targets.

All of this could be recorded on the jet's video tape recording system (VTRS), which was programmable from the back seat, and comprised a single 'off the shelf' Sony manufactured 8mm tape recorder wired into the MPDP. It usually filmed the HUD and a user selectable MPD, although recording several combinations could be used. In the event of a CC failure, a back-up bombing reticle was available, but this was prehistoric in sophistication by comparison, and perhaps superfluous to requirement – a failure of this sort would undoubtedly result in an abort.

When air-to-air practise was required, the adversary role – Red Air – would usually also be fulfilled by F-15Es.

Red Air simulated Russian and Chinese tactics and capabilities in detail, emulating radar detection ranges, tactics, ECM employment, air-to-air missile WEZ, shot doctrine and other parameters. Lessons were learned, but frustration could also arise. For example, Blue Air might have executed an evasive manoeuvre they believed would cause Red Air to lose radar lock, only to find the adversary F-15Es maintaining lock and then killing them.

White Jets

From April to August 2000, the Bolars began to receive newer F-15Es in the form of serial numbers 97-0222, and 98-0131 through 98-0135. These '98 jets were officially Block 59s, but were colloquially referred to as E-222 jets on account of the fact that 98-0131 had been the two-hundred-twenty-second F-15E built.

The Bolars had earlier received a batch of E210 jets, having acquired 96-0201 through 96-0205 – Block 58 F-15Es. These so-called "white jets" had been built by Boeing without the Air Force having ordered them, and required that the whole F-15E fleet be shuffled to accommodate them because they were PW-229 equipped and could only be sent to Lakenheath or Elmendorf (see 3rd Wing, below).

BELOW

Lakenheath was often the recipient of the newest and most capable F-15Es. Here, a brand new jet arrives straight from the factory in St.Louis. (Author)

While it was nice to have received them, their arrival caused problems because the squadron was limited by the Defence Planning Guidance as to the number of combat coded jets it could receive funding for. The 492nd FS had little choice but to categorise them as attrition reserves. Eight went to Lakenheath and four to Elmendorf. Most squadrons had eighteen Primary Authorised Aircraft, but the Bolars were operating more than twenty-four!

These later Block aircraft were the most modern in the fleet. E210 jets had been the first to receive the digital mapping system; a new air data computer called the Air Data Processor; revised CFTs with a reduced length of vulcanised rubber seal (which were not backward compatible with pre-E210 jets); a composite and strengthened speedbrake that did away with the need to manufacture an individual board to suit the peculiarities of each F-15E; and other less obvious improvements.

E210 jets were also first to receive Embedded GPS INS (EGI), although this, like many of the new toys, was subsequently retrofitted to the entire F-15E fleet. EGI became the primary position keeping source (PPKS) in the jet and was an incredible tool for navigation, sensors cueing and targeting. The RLG INS remained operative in the background and could be assigned as the PPKS if EGI failed.

EGI replaced two systems: AHRS and MN. AHRS was the Attitude Heading Reference Set, which was a back-up to the INS. MN was the Mission Navigator, a software routine in the CC that used INS velocities to calculate aircraft position and thence to cue the radar and other sensors during the attack phase.

Prior to the arrival of EGI, the crew had to take a PVU, assign the MN as the PPKS and then find, identify, and designate the target - all in no more than five minutes (because the MN calculations were only valid for that period of time, after which less accurate INS velocity data were used).

Replacement of the old Air Data Computer with a digital APD was also a significant improvement. It provided more accurate true air speed, air density and AoA to the CC for weapons release computations.

Combined, all three systems improved the capability of the aircraft to get to and from a target whilst dropping munitions accurately and without fanfare.

The E-222 aircraft were originally slated to be the last F-15Es to roll off of the St. Louis production line, although the USAF later ordered ten more attrition replacements – numbered E-227 to E237 – heralding the end of USAF F-15E orders. These jets were manufactured at a time of ongoing foreign military sales of F-15 aircraft, and the Air Force was able to make significant cost savings as a result.

In contrast to the Bolars, the 494th FS retained their older '91 and '92 serial numbered Strike Eagles, and that contributed to an even more demanding maintenance schedule.

Lakenheath Losses

The 48th FW lost F-15E 96-0203 when it suffered a left main undercarriage failure on landing on 12 September, 2000.

The undercarriage leg failed to align properly on extension, leading to the left main tyre being 90° out of alignment. A single gear unsafe light had illuminated upon take-off from Langley, Virginia, USA earlier on in the transatlantic ferry flight, but had subsequently gone out following cycling of the undercarriage in accordance with the flight manual. 1,180' after touchdown, the aircraft dramatically careered off of the runway and pivoted onto its nose following failure of the left gear strut and contact of the left wing-mounted external fuel tank with the runway arrestor cable. As the aircraft pirouetted about the nosecone, it split into two. Shedding wing tanks, LANTIRN pods and captive carry missiles as it dug into the soft earth, it could quite easily have resulted in fatalities. The pilot escaped without serious injury, but the WSO's left arm was almost completely severed in two places following the disintegration of the aft cockpit bulkhead. He later returned to Lakenheath to fly again. The Air Force decided to cannibalise the rear fuselage section, but planned to mate the nose section with a spare rear fuselage and return it to service.

A month and one day prior, F-15E (91-0335 of the 494th FS) suffered extensive damage when its arrestor hook slipped away from a hold back mechanism during an engine test. The resulting impact with the hangar door resulted in more than $1m of damage.

February 2002 brought yet another Class A mishap when an unidentified F-15E suffered an in-flight engine fire and returned to base without further incident.

This mishap bore resemblance to an uncontained turbine failure on take-off of an F-15E on 16 June, 1998. The explosive failure ruptured the fuel tanks of F-15E AF 91-0237 as it began its acceleration down the runway. The pilot managed to abort the take-off and the crew exercised an emergency egress once the aircraft had stopped. Following $1.5m of repairs, the jet was flown once again on 7 August, 2000, and was then delivered to Nellis AFB.

3rd Wing, Elmendorf AFB, Alaska

The 3rd Wing was the host unit at Elmendorf Air Force Base, Alaska. It was the largest and principal organization in Eleventh Air Force, training and equipping an Air Expeditionary Force lead wing.

F-15C (19th & 54th FSs), F-15E (90th FS), E-3 (962nd ACS), C-130, and C-12 (both 517th AS) aircraft were operated by the Wing, which provided air superiority, surveillance, tactical airlift, and agile combat support forces for global deployment, whilst maintaining the installation for critical force-staging and throughput operations in support of worldwide contingencies.

The 90th FS, Pair o' Dice, was the Strike Eagle operator, and received its first F-15E in early 1990 when two maintenance/instructional airframes arrived. Operational jets followed shortly after, and sported a red fin stripe. IOC was declared in Spring 1991, following which the squadron participated in a great many peacetime exercises.

The 3rd Wing was excused commitments to Operation Northern and Southern Watch because it came under control of PACAF – Pacific Air Forces, rather than ACC (4th Wing, 366th AEW) or USAFE (48th FW).

1992 saw the Pair o' Dice participate in several high profile exercises, including Combat Hammer (live air-to-ground weapons drops) in Florida; Green Flag at Nellis AFB, and Keen Edge at Misawa AB, Japan (an annual exercise in coordination with the Japanese Defence Forces).

In 1993, they visited Korea for joint exercises under the banners 'Team Spirit' and 'Sabre Spirit' (the latter of which was a weapons loading competition); they also attended 'Gun smoke '93' – an aerial gunnery competition held at Luke AFB, Arizona.

M61A1 Vulcan

Gunnery in the F-15E used the M61A1 Vulcan, and two types of rounds could be carried: the M-56 and PGU-28/B, the latter of which saw reduced usage because of a propensity for the round to disintegrate as it was being fired.

The M-56 had a 3,300 feet per second muzzle velocity, and the PGU-28 a slightly higher 3,375 FPS. The gun was boresighted on the ground and harmonised to 2,250'.

Cockpit (thus HUD) flexing under high g loads was compensated for by "flexure compensation", a routine run by the CC to determine the difference between HUD and gun boresight angles.

In air-to-air master mode, two gunsight types were available – gun director sight (GDS) and funnel (FNL)

Funnel provided an accurate indication of where the bullets would fall based on real time aerodynamic data. It assumed a target with a 40' wingspan.

GDS was the most sophisticated mode. It comprised a 50-milliradian reticle with a range bar indicating feet along its perimeter. An indicator ticked anti-clockwise on the range bar as distance to target decreased.

As the pilot manoeuvred to place the reticle over the target, the TD box would disappear when a valid shot could be taken, acting as a visual cue.

A solid line extended through the reticle up to a cross at the top of the HUD (which represented the gun boresight), and this also aided the pilot in manoeuvring the reticle over the target.

For training purposes, a RATR (rounds at target range) inverted triangle would appear when the pilot squeezed the trigger without live rounds on board. RATR represented the place at which bullets would have impacted and allowed useful VTRS post-flight analysis.

A combined mode was also available, and this allowed use of GDS or FNL gunsight in conjunction with a short-range missile such as the AIM-9 – it was the F-15Es answer to the F-16's dogfight mode!

In 1994, the 90th FS attended Anderson AB, Guam for Tandem Thrust, a global power projection exercise. A year later they flew to Cold Lake, Canada, for exercise Northern Pike. They joined Operation Deny Flight later on that year, and were based from Aviano AB, Italy to enforce United Nations Resolutions 816, 836, and 958.

1997 saw them participate in three individual Cope Thaw exercises - Nellis AFB, Nevada (Cope Thaw 97-3); Hill AFB, Utah (Cope Thaw 98-3); and Nellis AFB, Nevada (Cope Thaw 98-3a). In 1998 they deployed to Kwang Ju AB, Korea, to backfill US forces after the departure of the USN Carrier Battle Group from the theatre of operations, following which they flew to Paya Lebar, Singapore for exercise Commando Sling, a joint training exercise between the USAF and Republic of Singapore Air Force.

The AK tail coded jets once again covered for their USN counterparts in 1999 under the code name

OPPOSITE

90th FS flagship poses for the camera in front of an Alaskan landscape. Note the small white dice on the red tail stripe. (USAF)

Pacific Bear: a deployment to Kwang Ju AB, Korea to cover for the absence of the Carrier Battle Group. In 2000, the squadron went to Red Flag as well as a host of other US based exercises, including one with the USMC at Yuma Marine Corps AS, Arizona.

PW-229 Improved Performance Engine

The 3rd Wing was the only other Air Force F-15E operator of the PW-229 engine, besides the 48th FW.

Pratt & Whitney had continued to develop the F-100 following development of the PW-220, and in 1992 introduced the F-100-PW-229IPE on F-15Es 90-0233 (E20) under CCPs -357, -385, and -379. P&W had competed with General Electric (F-110-GE-129) to win this contract under the Improved Performance Engine program.

PW-220 testing in Test & Evaluation (Phase II) had established that the F-15E's modified air inlet was suitable for a follow-on IPE engine. It had also evaluated the engine's ability to power the increased capacity generator. Engine air start envelope affirmation with increased electrical generator loads had been flight tested. So too had ECS testing with increased heat loads from added avionics. Much of this testing had occurred with the PW-229 or GE-129 in mind.

Plumbing commonality in the common engine bays meant that the F-15E could be powered by either the PW-229 or the GE-129 without modification. The development and test program for the GE-129 had been flown at Edwards AFB, but the actual competition and operational evaluation had been conducted at Nellis AFB.

There was a strong contingent in defence and Air Force circles who viewed the GE engine as superior to the PW-229. Indeed, GE never gave up promoting the -129 and even offered the Air Force the chance to operationally trial the motor on E-227-E237 (the last USAF F-15Es).

The Air Force declined, despite a 99.8% mission completion rate demonstrated over an intensive 17-month evaluation. This independent evaluation accumulated 1,573 engine flight hours in 536 sorties, did not see a single stall, missed after burner (A/B) light, removal or aerodynamic integration issue (two spare engines assigned to the evaluation were left untouched).

Once selected, the PW-229 was directly tested against the PW-220. Michael Ludwig, Lead Test Engineer for the evaluation, commented:

> We would have the two aircraft fly identical profiles. The PW-220 jet would always have to return to base sooner than the PW-229. It was a significant increase in capability and range for the Air Force.
>
> In fact, the F-15E could, in a clean configuration and without CFTs, fly supersonic without using afterburner. This was fairly sensitive at the time as the F-22/F-23 had been targeted to achieve this goal. The Air Force really didn't like to advertise the fact that an F-15E could supercruise because they wanted people to associate the F-22/F-23's Mach 1.3+ capability as the real meaning of super cruise, not Mach 1.02 or whatever.

The two PW–229s increased aircraft weight by 1,200lbs, although they increased total thrust output several thousand pounds in both dry and afterburning modes.

The engine required additional cooling and this led to the development of the Type V CFT under CCP-379. It differed principally because of the addition of a large cooling scoop to replace the discreet orifice found on CAT IVs.

The PW-229 scoop was necessary because whilst the original cooling requirement of the PW-220 could be met by sucking air from the sluggish boundary layer flow over the CAT IV CFT into the heat exchanger, boundary layer air was simply too slow to provide a sufficient volume of cool air for the new engine. The scoop therefore extended beyond the boundary layer and into relatively undisturbed air flow.

The PW-229 featured an Improved DEEC (IDEEC) and also offered an increase of 22% in take-off thrust (29,100lb augmented thrust). This helped to minimise the performance penalties that were a natural and unavoidable consequence of designing an air-to-ground Eagle.

For those who flew combat missions at very high gross weights, there was no doubt that the PW-220 aircraft were significantly disadvantaged in comparison.

The –220 and –229 differed little in terms of operation, although the –229 offered both an improved response (–229 response to throttle movement from minimum power and maximum power was 4 seconds vs. 7 seconds for the –220).

The engines were controlled by direct linkage between two sets of split throttles mounted on the left-hand console in both cockpits. Pushing the throttles beyond a small detent caused DEEC/IDEEC to ignite the afterburners, and both crew could monitor engine performance and parameters via the engine display MPD page.

The pilot also had a small Engine Monitor Display near his right knee, and this presented RPM%, TEMP °C, FFPH (fuel flow per hour), NOZ POS (nozzle position) and OIL PSI in a graphical format.

Given the nature of the DEEC/IDEEC, engine start and shutdown was usually a non-event, although as with all jet and turbine engines, the pilot was required to watch FTIT/turbine temperatures on start to ensure that enough air was drawn through the fan to cool the turbine section and prevent a hot start. The PW-220 FTIT limit was 680°C while the PW-229 FTIT limit was 800°C. For more detail, see Appendix.

PW-220 engines had five stages of progressive A/B controlled via the DEEC. The PW-229 had eleven stages, and the IDEEC could anticipate snap throttle movements and prematurely light stage one just prior to MIL power being reached. Both engines utilised their DEECs to check that light-off had indeed occurred and would automatically attempt to re-light up to three times if a blowout was experienced.

The PW-229 also featured ATDPS (Asymmetric Thrust Departure Prevention System). It was designed to reduce the possibility of a directional departure following loss of a single engine at high airspeeds (500+ KCAS or Mach 1.1+).

It achieved this by driving both engines to a secondary mode of operation (see Appendix) and equalising the thrust given off by both. In the event of a sudden asymmetric thrust situation, the system offered superior reaction times and minimised the possibility that a directional departure would arise as a result of high yaw rates/uncommanded sideslip. Such an event could disrupt airflow into the other engine, causing it to flameout, too. Worse still, a single engine failure at those speeds might cause enough yaw to exceed the structural limits of the aircraft.

ATDPS worked within a tight envelope however: the aircraft had to be configured with CFTs and be within certain lateral balance constraints (i.e. similar

BELOW

PW-220 Type IV CFT (left) and PW-229 Type V CFT (right) are readily identifiable by the difference in cooling scoops. The latter is enlarged to provide greater cooling airflow to the improved performance motor. (Author)

fuel levels in left and right wing tanks, similar weapons load-outs on each wing).

Pilot throttle commands could override the system, but ATDPS automatically returned the engines to their primary operating mode once the critical flight envelope had been exited.

366th Air Expeditionary Wing, Mountain Home AFB, Idaho

The 391st FS, Bold Tigers, Mountain Home AFB, Idaho, received their first two F-15Es on 25 October, 1991. They arrived direct from the 90th FS at Elmendorf, and were serials 87-0210 and 88-1667. It is likely that these were the very same maintenance trainers that had made the trip to Alaska almost two years prior, and they were once again used as maintenance trainers until the Wing's first F-15E crews arrived.

A third F-15E (87-0207) arrived on 10 December, 1991 from the 4th Wing at Seymour Johnson.

The 366th Air Expeditionary Wing was a composite force comprising of F-16CJs, F-15Cs, F-15Es, B-1Bs and KC-135s. The composite Wing principle (into which the 3rd Wing also fell) was designed to provide an holistic, self-contained, quick reaction force for deployment to military operations anywhere around the world. In principle, the whole Wing would deploy to any location as a single entity, thus providing the initial military might in the very early days of any future conflict until reinforcements could arrive.

The Wing's platforms spent much time training together, therefore, and this gave Mountain Home Strike Eagle crews a unique insight into the strengths and weaknesses of the other platforms with whom they might one day go to war.

The Bold Tigers adopted a tiger-striped fin flash for their jets. They also took to painting the last four digits of the jets serial numbers in light grey ahead of the air refuelling door on the left-wing leading-edge extension. Bold Tigers had Eagle emblems painted on station six of the left and right CFTs, and featured the letters MO on their tails. It was not uncommon for the squadron's orange paint to be applied as a keyline on the leading edges of the undercarriage doors and access hatches.

Crew chiefs typically took almost as much pride in the way their jet looked as they did in its maintenance record, and each dreaded the prospect of crewing a hangar queen. But hangar queens were an inevitable consequence of a supply system that did not always deliver. Aircraft with poor maintenance records could be assigned this role, which effectively meant that they were the source of spares needed by the squadron. When a suitable candidate could not clearly be identified, a rota system took over and aircraft would be selected irrespective of their maintenance record.

The lot of the crew chief was therefore not always fair, and this could also be true on deployment. Illogically perhaps, aircraft deployed did not necessarily take their crew chief with them, and it was known for pristine examples to spend three months in Turkey or Kuwait, where they were serviced by indifferent maintainers. The heartache felt by crew chiefs was almost palpable as their jet returned home looking much worse for wear.

The 366th AEW operated B-52G and EF-111 aircraft prior to moving to the B-1B and F-15C. The F-15C had replaced the EF-111 by 1993, when the wing took part in exercise Bright Star in Egypt. The Wing, which was nicknamed the Gunfighters (a name dating back to the days of Vietnam and proudly continued), said goodbye to its BUFFs in 1994 and welcomed the B-1B in its place.

Two stateside deployments to Green Flag were undertaken in 1993, followed in 1994 by the largest ORI ever instigated by the Air Force. Indeed, 1994 provided the 391st FS with a busy calendar, and they participated in no fewer than eleven local and international exercises.

The dual role capabilities of the F-15E made it the main player in the majority of these, and alongside F-15C escort and F-16CJ suppression of enemy air defence (SEAD) fighters equipped with the HARM Targeting System, tactics for penetration into heavily defended territory were developed, although the squadron also trained to operate autonomously.

The squadron flew sorties in support of Operation Southern Watch, but deployed to the Middle East less regularly than the 48th FW and 4th Wing (only three times between 1996 and 2002).

The Bold Tigers deployed their full complement of twelve jets, flew 533 sorties and accrued 1,836.3 hours of combat time. The Wing also deployed as a single unit to several AEF commitments, most notably AEF V between September–October 1997, when all five squadrons deployed and undertook an ORI whilst at Shaikh Isa AB, Bahrain.

October 1996 brought the official change of name from 366th Wing to the 366th Air Expeditionary Wing.

OPPOSITE

Alaska provided some of the best flying in world. Here, a 90th FS cruises above one of the many glaciers in the region. (USAF)

The first opportunity that may have proven the expeditionary wing concept was Operation Enduring Freedom, but this fell snugly into AEF tasking rota. Thus, B-1B, F-16CJ and F-15E aircraft deployed to Afghanistan in October 2001, but fell under the command of separate operations and were geographically separated by some distance. See Chapter 4.

TFing

The rolling Salmon River Mountains to the East of the Mountain Home provided ample training opportunities for low-flying and TFing.

In manual mode, the AAQ-13 Nav Pod displayed a box in the HUD that the pilot simply needed to keep his velocity vector in or above to provide adequate terrain clearance. The Set Clearance Plane altitude could be adjusted down to 200' if required, although invariably the crew would let down to that altitude via a series of higher SCP settings as this provided the opportunity to identify malfunctions in the system.

An automatic fly up protection feature was activated when a system failure or unsafe condition existed – typically when an obstacle ahead was detected, when the aircraft was lower than 75% of SCP, or when roll angle exceeded the TF scan in any of the operating modes. Several other criteria could prompt a fly up, such as a CAS disengagement or excessive g loading, although the pilot could disarm the entire mechanism if he wished.

When initiated, the fly up took the form of one of two routines, but in general both levelled the aircraft's wings and pulled the nose up to 20° positive pitch at a steady 3g. Fly up protection was accompanied by warning lights, HUD cues and aural warnings to identify the nature of the problem -TF FAIL, LOW ALTITUDE or OBSTACLE. Both the TF page and HUD featured carets and a roll scale to provide visual TF bank limit cues, as well as OBSTACLE warnings on the side of the aircraft on which a potential hazard existed. Airspeed, turn rate, INS and TF mode information was also flashed below the velocity vector as conditions changed or limits were exceeded.

The radar altimeter provided an altitude scale to the far right of the HUD, along with an SCP caret for visual reference. It linked in with the LAW (Low Altitude Warning) system, which was accessed via the UFC and operated independently of the AAQ-13. LAW could be programmed to provide an aural and visual warning as soon as any user defined altitude had been broken.

Auto TF was very similar in the way in which the nav pod and cockpit indicators worked, although it took AAQ-13 commands and coupled them to the auto pilot.

It required that the radar altimeter be working, and initially engaged itself in a simple heading hold mode. That is to say, it maintained the SCP and flew a constant heading. Subsequent user input via the UFC was required to engage a steerpoint coupled mode, which would navigate the jet within TF limits to and from the steerpoints programmed into the CC and selected via the UFC. The manual TF box was replaced by two solid ILS type pitch and roll bars, and the pilot could monitor ATF performance by cross checking the E-Scope with the command bars, and then checking that the jet was flying the velocity vector to the centre of these bars.

If the pilot was not happy with what he was seeing, there were several methods of disengaging the system. The most popular was to pull and hold the paddle switch at the bottom of the control stick, thus activating a CSO mode – control stick override. This became an increasingly popular method of expeditiously bypassing the TF to hand fly the jet outside of TF limits without tripping the system. Releasing the paddle once back in the TF envelope automatically reinstated ATF flight.

CSO was a risky technique as it left the crew without any form of fly up protection. Crews soon came to refer to the practise as "paddle, pickle, pull", because it aptly described a common routine: the Strike Eagle would ingress the target at low-level and, once in range, the pilot would paddle to disengage the TF, pull up to visually acquire the target or set up for an automatic delivery, pickle the bombs off, roll to either side, and then pull back on the stick to return to sanctuary of low-level.

It is likely that this technique was in use when two Bold Tigers lost their lives on October 21, 1999. Lt. Col William E. Morell III and Captain Jeffrey K. Farnhlander (WSO), were flying F-15E 89-0497 on a two ship Surface Attack Tactics Night sortie near McDermitt State Airport, Oregon, when they executed a manoeuvre designed to defeat a SAM threat. The accident investigation report concluded that Morell had become disoriented and flown the aircraft into the ground. The likely cause was determined to be a combination of too steep a dive angle and flying the jet outside of TF limits. Morell did nothing out of the ordinary, as this tactic and associated technique had

OPPOSITE

MO tail codes and tiger stripes on the vertical stabilators identify these Strike Eagles as belonging to 391st FS, Bold Tigers, 366th AEW. (Author)

OPPOSITE AND ABOVE
Bold Tigers maintainers remove a CFT from a Maverick-equipped Strike Eagle in driving snow. The cold froze both jets and people alike at Mountain Home. (Author)

been used since F-111 crews came to the F-15E.

Following the incident, the Strike Eagle community revised their procedures, although they did not prohibit continued use of paddle, pickle, pull. Some crews solved the dilemma by using the brute force method: by applying 10.6lbs of back stick pressure one could momentarily override ATF and manoeuvre the jet as required: relaxing back pressure automatically resulted in ATF re-engaging. The downside to this method was that it fooled the system into thinking the TF had failed, and the cacophony of warnings and lights that followed could distract the pilot as he attempted to line up for bomb release.

Early in the Strike Eagle history, Instructors had actively discouraged the pilots from using Auto TF, the basis of this being that it was not a macho thing to do. By the late 1990s, students were taught otherwise, and there was a general appreciation amongst aircrew that the computer could fly the jet a lot more safely and smoothly at low-level than any pilot.

Systems aside, low-level training remained a highly contentious issue as the USAF entered the 21st century. A global low-fly limit of 500' was imposed on all tactical jets – a full 400' higher than training conducted by the RAF in some UK low-fly zones. Two schools of thought existed: those who felt that medium level attacks were now the only way the USAF would strike future targets, and those who believed that the former attitude was foolish.

The former reasoned that prior to sending F-15Es in to drop PGMs, any sophisticated Integrated Air Defence System or opposing Air Superiority force would quickly be dismantled though US technological superiority (SEAD etc.) and brute force. There was solid evidence to suggest that this was the only viable way in which to wage a future conflict, not least of all low-level losses in both Iraq and Vietnam, where the lion's share of kills could be attributed to the AAA or low altitude SAMs.

But there were flaws to the argument, too. Medium-level deliveries were fine when the weather allowed TGT IR operation or when GPS guided weapons were launched against large, static targets. The problem arose when a target was mobile and GPS guidance was of little use, or when the target was surrounded by collateral buildings and thus required a man-in-the-loop solution.

"Crunch", an F-15E WSO with thirteen years' experience, observed:

There is often a tendency to draw very broad reaching conclusions from the lessons of previous conflicts. We've spent almost all of our time recently at medium altitude (most of Desert Storm, Bosnia, Kosovo, Southern and Northern Watch and Enduring Freedom). By all accounts, we've had great success with this tactic - both in terms of target destruction and survival. So, some folks are tempted to say that we'll never go low again. Well, I disagree with that statement. I think this is where some of us part company with others in the community.

For all our recent successes, one glaring fact gives me a little bit of pause when thinking about a purely medium altitude war. We have significantly outclassed our last few enemies. In truth, there was never a real, significant threat to the survival of our airpower. We outnumbered them, we out trained them, we out manoeuvred them, we had more and better intelligence than them, we had the support of world opinion behind us, and in some cases, the military forces on the other side really weren't up for a fight. So, in my mind, drawing sweeping conclusions about the prowess of airpower, and our ability to maintain air supremacy at medium altitude, is pre-mature at best.

Consider some of the advertised (Janes) capabilities of some of the non-friendly countries out in the world, as well as some of the unknowns that are surely lurking in places like China. I don't think we can abandon the only capability that might be able to ensure survival for aircrew on the first few nights of a war against an enemy who is equipped to challenge us. I would be particularly troubled by an enemy who has the will and heart to remain at their third or fourth generation fire-control radars and complete the intercept.

So, while low altitude operations are not in vogue in the USAF in 2002, I (and many others like me) will continue to strive to keep low altitude ops in our tool kit. We'll continue to spend some time training down there, while we spend most of our time training for what we're being asked to do on a daily basis - medium altitude employment. In reality, the drop from 500 feet to 300 feet isn't a difficult training issue. Pilots and WSOs quickly become accustomed to flying at 300 feet. The real issue is that, since 500 feet and 300 feet are both insufficient to terrain mask against some of the highly lethal and agile systems out there, we'll have to get down close to 100 feet to survive. If we're only trained at 500 feet, then the drop to 100 feet in a high-risk combat scenario will cost some aircrew their lives. I cannot overstate the exponential increase in task saturation and channelised attention that comes with every 10 feet of descent below 300 feet at tactical airspeeds and in a tactical scenario. By the time you get to 100 feet, all you can think about and do is try to not hit the ground - and I'm talking about a crew who's comfortable down at 300 feet. If you've never been below 500 feet, you're probably toast.

57th Wing, Nellis AFB, Nevada

The 57th Wing, Nellis AFB, Nevada is home to the USAF Fighter Weapons School. FWS F-15Es wear WA tail codes and the famous chequered black and yellow fin stripe.

The FW School comprises multiple individual elements, each responsible for a particular airframe. The F-15E Weapons School Division was formally announced in Spring 1991, following prolonged development of the initial syllabus and courseware from 1989 onwards. The initial cadre of Instructors arrived in March 1991 and were formally in place by June. Thus, five IPs and three IWSOs set to work teaching the first course following an opening ceremony on 8 July, 1991.

F-15E FWS provides highly advanced instructor training to qualified F-15E WSOs and pilots from across the Air Force. Designed to produce experts in all phases of Strike Eagle tactical employment, the course runs for 315 hours of academic classroom instruction and 35 sorties. The first F-15E patch wearers graduated in December 1991, and from January 1992 onwards the School graduated twelve aircrew annually.

"Saint", an F-15E IWSO and patch wearer assigned to the 492nd FS in 2001, surmised that the course was all about making better instructors who had an in depth understanding of tactics, weapons systems and the jet itself. The course took full advantage of the excellent Nellis Test and Training Ranges (NTTR), which allowed realistic training for large force packages of up to sixty aircraft whilst permitting unlimited use of chaff and flare as well as ECM.

Towards the end of the 1990s, the school started to focus on the Mission Planning Cell concept. In times of war, this would see patch wearers called to Combined Air Operations Centres to assist in planning F-15E sorties that would be flown by frontline F-15E crews.

The 57th FW lost an F-15E and crew on 10 August, 1992. Participating in mock combat, the aircraft departed controlled flight, entered a flat spin and impacted the ground near Carp, Nevada, about 80 miles from Nellis. The crew, pilot Major Bruce "Phoid" Netardus, and WSO Lt. Col. Wendell "Sheik" Johnson, ejected but were outside the seat envelope and did not survive. It is believed that asymmetric loadout and an inadequate DFCS may have failed to check aggressive handling by Netardus. It was this accident, which followed not long after the 16 September 1991, 461st FS loss, that prompted Boeing to revise the DEFCS.

412th Test Wing, Edwards AFB, California

Edwards AFB, California, was home to the 412th Test Wing, Air Force Flight Test Centre.

Three or four F-15Es were usually stationed at the base. These aircraft bore ED tail codes and featured blue and white fin stripes with six white crosses overlaid. The 445th FTS, which operated under the 412th TW, was better known as the Combined Test Force (CTF).

The first squadron standard F-15E arrived with the CTF on March 12, 1987, following which it completed handling qualities evaluation, LANTIRN, bomb and missile compatibility work over the next

BELOW
The 391st FS was unique among F-15E units in that it operated daily with a range of other platforms, in this case, a B-1B. (Author)

two years under the leadership of the Director and Chief pilot of F-15E Operational Test and Evaluation, Lt. Col. Gary M. Rubus. Rubus commanded the unit thorough the F-15E F110-GE-129 Propulsion and Limited Performance Evaluation using F-15E AF87-0180 and through the F-15E Reliability and Maintainability Evaluation, which featured four sets of interrelated tests. The evaluation commenced on 15 August, 1988.

The Wing continued to test all manner of Strike Eagle revisions and additions, including weapons certification under the Seek Eagle programme. On 30 April, 2002, Lt. Col. Troy Fontaine and Maj. Kevin Steffenson dropped five GBU-31 Joint Direct Attack Munitions over the China Lake test range. The mission, which proved successful, was designed to target the five 2,000-pound weapons on five separate, pre-planned targets using global positioning system coordinates from the EGI. GPS weapons support required CFT 1760 MUX modifications in addition to OFP Suite 5.

The CTF ran a steady succession of test and evaluations, including: F-15E Reliability and Maintainability Evaluation (1989); F-15E/F100-PW-220 Air start Evaluation (1990); F-15E Avionics Operational Flight Program Suite (1990); F-15E Aft Centre of Gravity Flying Qualities Evaluation (1991); F-15E Air-to-Ground Flying Qualities Evaluation (1993); F-15E Performance Evaluation with F100-PW-220 Engines and Air-to-Ground Stores (1993); F-15E Advanced Up Front Control Panel (AUFCP) Flight Test Evaluation (1993); F-15E/AGM-130A SEEK EAGLE Flight Test (1993); evaluation of the F-15E CN-1655/ASN-94 Ring Laser Gyro (RLG) Inertial Navigation Set (INS) (1993); F-15E AIM-7F and MC-1 SEEK EAGLE Flight Test (1993); F-15E FY92 SEEK EAGLE Separation Effect and Ballistic Accuracy Verification (BAV) Flight Test (1993); F-15E Horizontal Stabilator and Global Positioning System (GPS) Vibration and Acoustic Measurement (1992); F-15E Air-to-Air Flying Qualities Evaluation (1992); F-15E/AGM-130 Integration Expanded Weapons Flight Test (1995); F-15E LANTIRN System in IMC and Adverse Weather Conditions Follow-On Operational Test and Evaluation (1995); Project KEEP EAGLE F-15E High Angle-of-Attack Departure and Spin Evaluation (1996); Comparative Evaluation of Manoeuvrability of MiG-29 with F-15, F-16, Tornado F2 in Support of Manoeuvre Dogfight Planning (1997); F-15E (VHSIC) Central Computer (VCC) Integration Verification Flight Test (1992); and SEEK EAGLE F-15E/GBU-27/B Certification Program (2000).

79th TEG, Eglin AFB, Florida

The 79th Test and Evaluation Group, Eglin AFB, Florida, was home to the 85th Test and Evaluation Squadron. The group was also known as the USAF Air Warfare Centre.

The squadron was assigned F-15E 87-0209, although this aircraft was later returned to operational squadron service, leaving the unit to work closely with the CTF and the 413th FTS which was the CTFs sister squadron.

F-15E testing began at Eglin with the Tactical Electronic Warfare System (TEWS) in 1985, and continued in November 1988 when two F-15Es arrived for SEEK EAGLE testing. Eglin continued to upgrade F-15E systems and certify new weapons for carriage, but was most heavily involved in TEWS testing. Initial Phase testing of the suite, the ALQ-135 in particular, had discovered deficiencies which were primarily a result of software immaturity and integration issues. Several years later, AFOTEC was directed to conduct another interim TEWS evaluation to determine the operational capabilities and limitations of existed fielded systems in 1993. The evaluation concluded in September 1994, and recommended five ALQ-135 improvements: interoperability with the APG-70 radar; system response times; built-in-test (BIT) displays; BIT accuracy; and low band frequency coverage for the F-15E (Band 1.5).

As ALQ-135 Band 1.5 was tested, the problems only worsened. Low band jamming was a key requirement as it provided not only extended spectrum coverage for the Strike Eagle, but also a waveform select feature for jamming optimisation against specific threats operating in lower frequencies.

The Air Force AWC continued to test Band 3 up until August 1996 and addressed ALQ-135 Band 3 ICS interoperability with the APG-70 radar as well as improvements in BIT displays. Additional Band 3 operational tests at the Multi-Spectral Threat Environment range located at Eglin were run to evaluate intra-flight (wingman) compatibility; the advanced threat de-interleave processor (which improves system response times); jamming effectiveness and BIT upgrades.

OPPOSITE
A 57th Wing F-15E blasts off into the skies above Nellis AFB, Nevada. The Air Force sends its best and brightest aviators to the Weapons School. The F-15E was airframe limited to Mach 2.3, although a one-minute limit of Mach 2.5 was permissible if required. In reality, these numbers were academic: the CFT airspeed limit was Mach 2.0, and LANTIRN further reduced this to an upper limit of Mach 1.2 or 650 KCAS (whichever came first). Overheating of the ECUs on both pods was likely to occur above Mach 0.9, making this a realistic limit for training purposes. (William Lewis / USAF)

The ALQ-135 Band 1.5 Test Plan was approved in April 1999. Developmental testing of the ALQ-135 began in June 1998 with initial focus on integration between the ALQ-135 ICS with Band 1.5 installed and other F-15E weapons systems such as the ALR-56C radar-warning receiver. The developmental tests were focused on response time measurements as well as correct RF threat identification and correct RF jamming.

Developmental testing was supposed to have concluded by September 1998, but was delayed until 1999 due to aircraft integration problems and software immaturity, most notably demonstrated by an unacceptably high number of system resets. IOT&E began in April 1999, and testing was conducted once again at the Multi-Spectral Threat Environment range and at the Western Test Range at Nellis.

Operational testing analysed all major effectiveness and suitability performance parameters, with the focus of testing centred on testing against a variety of available airborne and ground based threats; operating Band 1.5 equipment with aircraft systems both individually and during a multi-ship formation; and operating Band 1.5 equipment concurrently with Band 3 jamming equipment.

Problems resulted in a de-certification of Band 1.5 by AFOTEC. Partial analysis of test results indicated that Band 1.5 was potentially operationally effective against threats for which it was designed, but was plagued by unpredictable and lengthy system resets, many of which were not displayed to the aircrew. Although Band 1.5 hardware was reliable, overall suitability of the system was poor due to OFP immaturity and system integration problems.

Worse still, TEWS (both Band 1.5 and Band 3) was rendered inoperative during system resets, effectively leaving the jet unprotected. In October 1999, AFOTEC decertified the Band 1.5 OT effort and returned it to Magnavox for further work. Incredibly, it transpired that the system was only resetting itself when it was in a threat envelope with emitters actively targeting it! Additional shortfalls came in the form of a long-standing problem with the ALR-56C – in a dense signal environment it lacked adequate processing capability, as evidenced by incomplete or slow display of threat emitters.

The US General Accounting Office applied tremendous pressure and was highly critical of the Air Forces' $2b (FY91) spend on the ALQ-135 in 1990/1991. They were astonished to find that ALQ-135 Band 3 deliveries were almost complete before they had seen testing. They were even more aghast to learn that the Air Force had equipped the F-15Es sent to the Persian Gulf with these systems, even though they had been removed and placed into storage from other F-15Es.

The Band 1.5 fiasco did little to improve the situation, and the GAO recommended in 1994 that the Secretary of the Air Force exercise greater control over USAF EW projects in the future. The USAF did upgrade the ALR-56C azimuth update rate, SAM discrimination and launch determination logic, and began Band 1.5 flight testing once again (in three phases) in 1998. Initial low-rate production began in winter 1999, and by the first quarter of 2000 the Strike Eagle began to receive the sets it had waited so long for. Band 1.5 is usually housed in the 'squarer' right hand tail-boom antenna and as a blade antenna on the nose landing gear door.

53d Wing, Eglin AFB, Florida

The 53d Wing ran early operational F-15E Phase tests, following which it assumed the Operational Test role (thus the OT tail codes). Additionally, it ran Combat Hammer and Combat Archer air-to-ground and air-to-air weapons trials. Smaller sections of the Wing also evaluated EW tactics.

It is also the parent unit of the 422nd Test and Evaluation Squadron (TES), which continually refines tactics, weapons systems and new additions to a variety of airframes, including the F-15E. They wear OT codes and chequered markings, and their squadron patch depicting a caricatured bat with smoking gun and blooded knife. The 422 work closely with FWS to propagate newly devised tactics and procedures, via the students, to the operational squadrons.

The squadron is responsible for testing new OFP programs, and at time of writing (2002) was evaluating Suite 5, which was due to enter fleet service in 2004.

"BOP" served with the 422nd TES, and was part of a test team who evaluated Suite 5, which would integrate GPS guided weapons such as JSOW, JDAM, and the Wind Corrected Munitions Dispenser. He also tested the AGM-130 GPS mid-course guidance system, in addition to the Small Diameter Bomb – a weapon the size of a Mk 82 but with explosive properties comparable to the Mk 84.

> We also tested a LANTIRN modification called BDA. It looked at a multi-spectral scene, so we built a bunker, filled it with certain chemicals and then dropped a GBU-28 into it. The GBU penetrated several floors as designed, and then exploded.
>
> The resultant cloud of smoke and debris would normally

OPPOSITE
The initial 79th TEG F-15E test aircrew at Eglin, circa 1989. (USAF via Jan-Peter van Viegen)

have obscured the view of the target, precluding accurate Bomb Damage Assessment. LANTIRN BDA however, detects the chemical released and records this for later analysis – although this was achieved inside the pod and we did not see any difference from the cockpit. Once back on the ground, however, we could take the tape and extract the data, which in turn would tell us if the bomb had exploded on the right floor and how much damage it had caused.

As of 2002, there was no clear indication as to what the USAF planned to do with LANTIRN BDA. Several LANTIRN derivatives had been fielded by Lockheed Martin, the most advanced of which was the 'Sharp Shooter' which had been outfitted on select F-16s despite the fact that the F-15E would probably have benefited more from it. The squadron tested a range of gadgetry including covert countermeasures, enhanced EW equipment and FDL.

The 422nd TES was also the primary driving force behind Night Vision Goggles reaching the F-15E. "Jethro" was among four other F-15E aircrew who agreed with Capt. Tray Nolan's suggestion that the Strike Eagle could not continue to rely solely upon NAV FLIR and TGT IR for its night attack capabilities. Together, they took their own experience and proposed an evaluation that was duly Authorised. Two weeks of testing ensued, following which the project was deemed viable and three companies were invited to tender for a possible contract. Four jets were modified and following sorties with F-16s flying Night CAP and a classified exercise called "Spirit Hawk", the pilots made their recommendations.

The modifications made use of a screen called "Glendale Green". Following selection of the winner, Jethro and his colleagues embarked on a tour of all Strike Eagle squadrons, making their first stop at Seymour Johnson to pitch the modification to the Wing commander, but he was disinterested and sent them away. The 48th FW was very interested however and became the first F-15E unit to reach NVG IOC. They were subsequently also the first to use them in combat, albeit in limited number, in January 2000 over Kosovo. Crews from several F-15E units underwent initial training at Nellis in Winter 1999.

78th Air Base Wing, Robins AFB, Georgia

Robins AFB had only one F-15E assigned to it, 86-0189, which was used principally for engineering evaluation work. It featured RG tail codes and black and yellow chequered fin flashes.

PDM, or Pre-planned Depot Maintenance, was the primary remit of the 339th Test Squadron, which provided aircrew to perform functional test flights on F-15Es following complete overhaul and strip-down. Asides from routine inspections, the Wing also serviced mishap aircraft, such as the one involved in the engine fire on take-off at RAF Lakenheath. That aircraft was dismantled and brought to Robins in a C-5 Galaxy, following which about 25% of the airframe had to be replaced. Work commenced in May 1999 and was completed in a year. It took 10,000 man hours and cost $1.5m.

OPPOSITE

A Green Bats F-15E sits on the ramp at Nellis AFB and roasts in the Las Vegas heat. The 422s TES conduct the operational test and evaluation of the Strike Eagle for onward communication with operational units. There were two-hundred-twenty-six F-15Es in US service by 2002. (Author)

04

COMBAT RECORDS

Operations Desert Shield & Desert Storm

Operation Desert Shield, the precursor to Operation Desert Storm, began with the deployment of F-15Cs and F-15Es to the Persian Gulf.

The 1st FW at Langley AFB sent twenty-four F-15C and three F-15D aircraft to Dhahran AB, Saudi Arabia, on 7 August 1990. The next day, twenty-five Eagles arrived from the 27th TFS. On 9 August the 336th TFS' F-15Es arrived in Thumrait AB, Oman, via Dhahran, Saudi Arabia.

Thumrait had stockpiles of weapons that had been stored by the US for just such an eventuality. Initially confusion reined as the squadron, operating as the 4th TFW (Provisional) and led by Col. Russell "Rusty" Bolt, were without clear orders or directives.

The reality of their situation was stark to say the least: nine of Hussein's elite Republican Guard units stood ready at the Kuwaiti boarder to steamroller south into Saudi Arabia. It quickly became evident that the Rocketeers were the only force that could delay and harass such an advance, although the price they might pay in the process did not bear thinking about.

By 11 August, the squadron had twelve jets on alert, although this had not been achieved without considerable efforts. Capt. Mike "Smy" Smyth arrived in theatre on Christmas Day 1990. He recalled that although several weapons had been tested by the Seek Eagle program, the Strike Eagle was only cleared to release Mk 84 and Mk 82 LDGP (low-drag, general purpose). There was therefore some consternation about plans to drop the Mk 20 Rockeye CBU, as it had not been fully tested from all stations. These concerns were valid, and some crews had seen a video from Volk field that showed a 500lb bomb coming off of a CFT store only to whip back up behind the wing and slam back into the horizontal stabilizer.

OPPOSITE TOP & BOTTOM

A ramp full of Strike Eagles at Al Kharj signals clearly the intent of the United States. These aircraft would soon be leading strikes into southern Iraq on the first night of the war. (Jerry Oney via Author and USAF)

The Rockeye was an area munition that released hundreds of baseball ball sized bomblets over an area as large as a football field, and was therefore more effective in killing lightly armoured targets than LDGP.

The Air Force waived normal procedures and permitted Bolt and his men to load unauthorised stores onto the aircraft, meaning that he was clear to use Rockeye as he saw fit.

Two jets also stood ready to defend the base, or to fly escort for a strike package, and were loaded with AIM-9 Sidewinder and AIM-7MF Sparrow missiles.

Despite a high-paced start, morale amongst the squadron tumbled as they sat for two weeks without full communications with Central Command Air Force HQ (CENTAF) in Riyadh: they were effectively grounded and not permitted to fly unless the Iraqis started to move south.

When they did return to flying, Bolt imposed a 300' training limit, but this was broken by many of the pilots, who felt that they needed to be below 200' if they were to survive. Such insubordination ultimately cost at least one pilot his wings.

It was at this time that F-15E 87-0203 was lost.

The crew had been flying intercepts against a pair of RAF Jaguars when it ploughed into the desert on 30 September with the loss of its pilot, Major Pete Hook, and WSO, Captain Jim Poulet.

Inexperience in handling the F-15E with external fuel tanks was deemed to be a major contributing factor in the accident, which was followed by the fatal crashes of an RF-4C and an F-111F, also at low level, in the lead up to war.

CENTAF consequently issued a diktat directing that all aircraft, with the exception of the B-52, were forthwith restricted to a 500' minimum training altitude. It was greeted by F-15E crews with a mixture of exasperation and incredulity.

Tactics determined in impromptu meetings by senior squadron staff consisted primarily of the pop manoeuvre that Anderegg had banned. Dive and dive-toss methods were viewed as alternatives, although the medium altitude SAM threat might have made these impractical.

Tactical Air Control Centre, Riyadh, Saudi Arabia

A hastily created Mission Planning Cell in Oman did what it could to prepare the Rocketeers for war, but a centralised input was really needed.

Back in Riyadh, CENTAF and coalition representatives formed the Tactical Air Control Centre. The TACC planned the air war, as defined by a 600-page document called the Air Tasking Order. The ATO was the route map for the air campaign against Iraq, and detailed every sortie that was to be flown.

The F-15Es were to fly sorties in unison with F-4G Wild Weasels and EF-111 Jamming aircraft against SAM sites and key airfield complexes, but were also assigned to what were politically the most problematic target – Scuds. The Iraqis operated four Scud types, all based on the original Soviet SS-1, a surface launched missile with a range of over 200 miles. The weapon could carry chemical or biological warheads and its use had the potential to upset the entire balance of neutrality of other Arab nations in the region. As it turned out, between January 18 and February 26, 1991, forty Scuds were launched against Israel and forty-six against Saudi Arabia.

Iraq boasted a combination of fixed Scud sites, which would easily be attacked, and mobile units, which posed the greatest concern and ultimately proved nearly impossible to track down.

Smyth, who was the Fighter Duty Officer (FIDO) in the TACC for part of the war and flew combat missions for the other part, explained:

As the F-15E FIDO I was the F-15E representative at the TACC. Any questions about F-15E capabilities, tactics, range, payload were directed at me. I also helped coordinate take-off times, refuelling times and locations. I would work closely with the aircrew, often talking over phone to flight leads several times before crews briefed or took off. I had two phones on my desk, one was a hotline to the F-15E command post, over which a sergeant would pass me all actual take-off and land times.

I could also talk to the OG (Ops Group Commander), whose rank was Col., using the same phone. What I talked to the flight leads about was usually coordinating times, locations, and call signs of other flights (usually EF-111s or F-4Gs) who would be in the area. I often had to pass new coordinates or target descriptions over the phone due to changes in the plan frag [see below].

Another example of last-minute coordination was moving the pre-strike or post-strike refuelling location or coordinating for more fuel.

The TACC was located in downtown Riyadh in one of the Ministry of Defence buildings. It was just down the street from Gen. Norman Schwartzkopf's office and was where the air war was controlled/conducted from. Gen. Chuck Horner ran the air war from our large room. Gen. Corder was the number two man at the TACC and was always present if Gen. Horner was not there. Corder was a very straightforward, likeable, honest man who was a pleasure to work with. Horner did not have the same type of personality, and hardly ever took the time to greet you or smile. He was just "give me the answer to my question NOW". He was famous for his dry sense of humour and would occasionally crack a joke, but always at someone else's expense. I liked working for both men, although I did not always agree with their decisions as they affected my squadrons.

I worked the night shift from 1900 to 0700, but you could never just show up at 1900 hours and "have your finger on the pulse" and be ready to run the air war. I almost always worked 1800 to 0800 to ensure a good hand off from my day shift counterpart. This provided a 1.5-2.0 hour overlap in our shift, which was always necessary to have a good feel for what happened while you were sleeping. There was an 0800 briefing every morning, where we gathered all the nights statistics – number of sorties, targets hit/missed, maintenance aborts, etc. This briefing was another reason for the overlap in FIDO shifts.

The TACC was three floors underground. Another two stories below us was a bomb shelter. When a Scud attack was occurring all the non-essential personnel were directed to go into the bomb shelter. The stairs leading into the bomb shelter were very long and steep and not well lit. I felt fortunate that I was considered essential personnel and never had to go into the shelter.

Gen. Glosson was in charge of the "Black Hole" at the other end of the hall. This was where targets were selected and the master plan for the next nights missions were formulated. We called it "building the Frag".

Due to lack of space, many officers such as the Brit aircrew representatives, were located in a temporary building in the parking lot, or in the next building. I often had to run up the steps and outside to coordinate with the Tornado or Jag blokes. I remember having to step over and around piles of power cables, phone lines, portable generators, satellite uplinks just to get to this Brit plywood headquarters we knew only as the White House. The White House was always a good time, there was no senior supervision (at least not in my chain of command), and the guys were always friendly and made me feel welcome. Not to mention the girlie posters on the wall! It was a good place to hang out for 15-20 minutes and avoid all the American brass who were always snooping around the TACC, although I never wasted time in the White House or anywhere else if I had jets airborne or taking off.

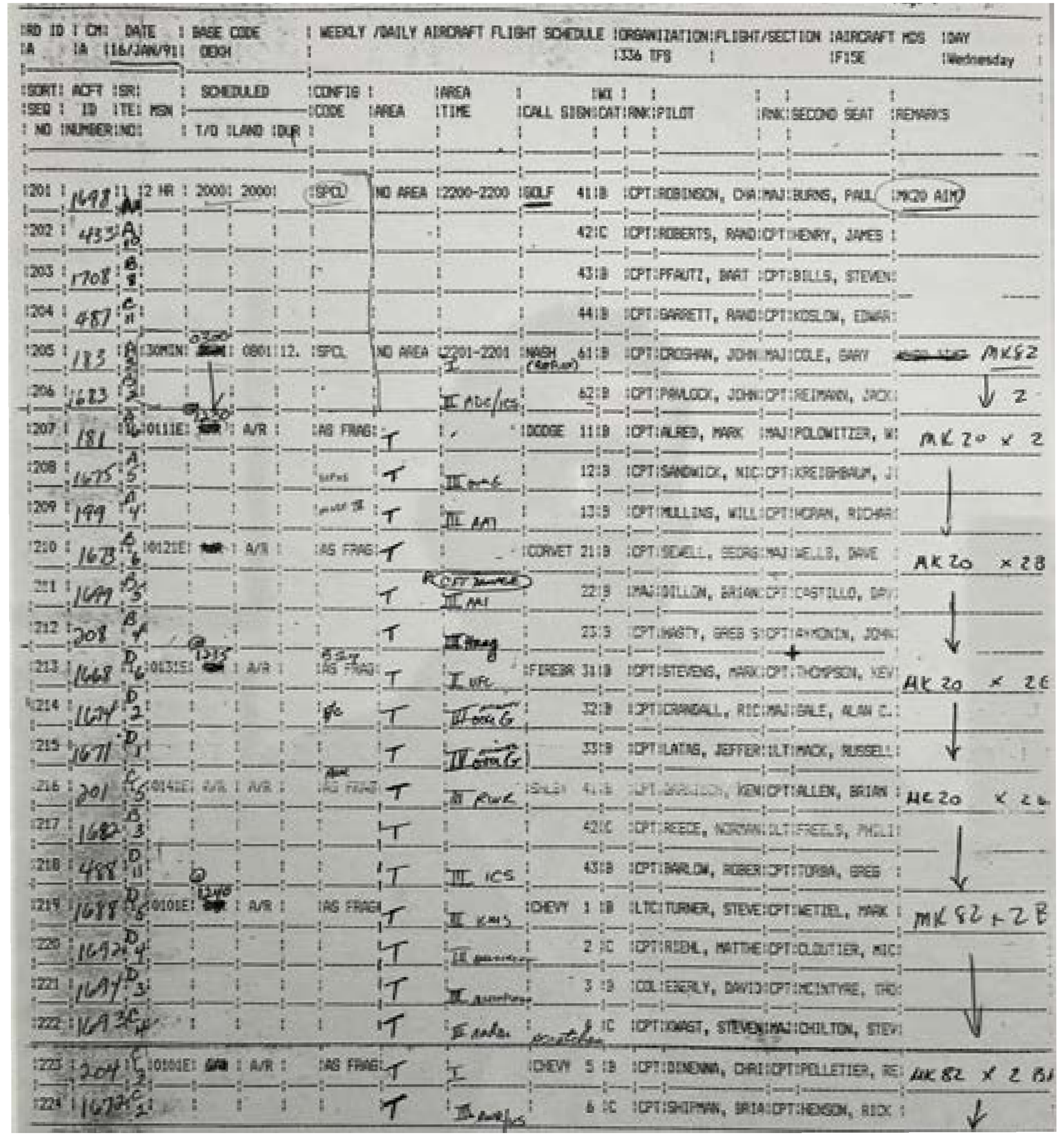
The Black Hole and TACC based their planning largely on the work of Checkmate, a Pentagon based think tank headed by Col. John Warden. Warden had assembled aircrew from all US platforms to plan the war, and whilst he himself fell out of favour with Glosson and Horner (who are often credited for his work), Checkmate was revised and adapted in Riyadh. It ultimately formed the framework for Operation Desert Storm.

In December the Rocketeers and Chiefs moved to Al Kharj AB, Saudi Arabia following the realisation that the Iraqis were not going to advance any further South.

17 January, 1991

On 17 January, 1991, the order for the first strikes was given by President Bush – Operation Desert Storm had begun.

With great media attention focused on Baghdad, waves of British Tornado GR1s, F-111Fs, F-15Cs, F-15Es, EF-111s, F-16s, F/A-18s, F-14s, A-6s, A-7s, F-4Gs and B-52s flew at low level to attack the 'eyes' and 'ears' of the Iraqi military machine. The IADS (Integrated Air Defence System) was the primary target for a lot of the first sorties, with airfields, hardened



RD ID A | CM A | DATE 16/JAN/91 | BASE CODE OEKH | WEEKLY /DAILY AIRCRAFT FLIGHT SCHEDULE | ORGANIZATION 336 TFS | FLIGHT/SECTION | AIRCRAFT MDS F15E | DAY Wednesday

SORT SEQ NO	ACFT ID NUMBER	MSN	SCHEDULED T/O	LAND	DUR	CONFIG CODE	AREA	AREA TIME	CALL SIGN	WX CAT	RNK	PILOT	RNK	SECOND SEAT	REMARKS
201	1498	12 HR	2000	2000		SPCL	NO AREA	2200-2200	GOLF	41 B	CPT	ROBINSON, CHA	MAJ	BURNS, PAUL	MK20 AIM
202	433									42 C	CPT	ROBERTS, RAND	CPT	HENRY, JAMES	
203	1708									43 B	CPT	PFAUTZ, BART	CPT	BILLS, STEVEN	
204	487									44 B	CPT	GARRETT, RAND	CPT	KOSLOW, EDWAR	
205	183	30MIN		0801	12.	SPCL	NO AREA	2201-2201	NASH	61 B	CPT	CROSHAN, JOHN	MAJ	COLE, GARY	MK82
206	1683									62 B	CPT	PAWLOCK, JOHN	CPT	REIMANN, JACK	
207	181	0111E		A/R		AS FRAG			DODGE	11 B	CPT	ALRED, MARK	MAJ	POLOWITZER, W	MK20 x 2
208	1675									12 B	CPT	SANDWICK, NIC	CPT	KREIGHBAUM, J	
209	199									13 B	CPT	MULLINS, WILL	CPT	MORAN, RICHAR	
210	1673	0121E		A/R		AS FRAG			CORVET	21 B	CPT	SEWELL, GEORG	MAJ	WELLS, DAVE	MK20 x 28
211	1699									22 B	MAJ	DILLON, BRIAN	CPT	CASTILLO, DAV	
212	208									23 B	CPT	HASTY, GREG S	CPT	[illegible], JOHN	
213	1668	0131E		A/R		AS FRAG			FIREBR	31 B	CPT	STEVENS, MARK	CPT	THOMPSON, KEV	MK20 x 2
214	1674									32 B	CPT	CRANDALL, RIC	MAJ	GALE, ALAN C.	
215	1671									33 B	CPT	LAING, JEFFER	1LT	MACK, RUSSELL	
216	201	0141E	A/R	A/R		AS FRAG			[illegible]	41 B	CPT	[illegible], KEN	CPT	ALLEN, BRIAN	MK20 x 2
217	1682									42 C	CPT	REECE, NORMAN	1LT	FREELS, PHILI	
218	488									43 B	CPT	BARLOW, ROBER	CPT	TORBA, GREG	
219	1688	0101E		A/R		AS FRAG			CHEVY	1 B	LTC	TURNER, STEVE	CPT	WETZEL, MARK	MK82 + 2 B
220	[illegible]									2 C	CPT	RIEHL, MATTHE	CPT	CLOUTIER, MIC	
221	[illegible]									3 B	COL	EBERLY, DAVID	CPT	MCINTYRE, THO	
222	[illegible]									4 C	CPT	KWAST, STEVEN	MAJ	CHILTON, STEV	
223	204	0101E		A/R		AS FRAG			CHEVY	5 B	CPT	DINENNA, CHRI	CPT	PELLETIER, RE	MK82 x 2 B
224	[illegible]									6 C	CPT	SHIPMAN, BRIA	CPT	HENSON, RICK	

ABOVE

A copy of the Day 1 frag gifted to the Rocketeers by "C-DIN" and "Beef". (Author) aircraft shelters (HAS) and aircraft also being attacked so that air superiority could be attained.

The ATO planned for later strikes against Iraqi armour, C3 (Command, Control & Communications) and logistics supplies, thus paving the way for a less protracted ground war to rid Kuwait of its uninvited guests.

F-15Es attacked fixed Scud sites in western Iraq that first night. A total of five sites were hit by twenty-four jets divided into three- or four-ship packages, each carrying two fuel tanks, twelve Mk 20 Rockeye CBU, and two AIM-9M missiles. The exception was Chevy flight, which was tasked to attack Scud sites at H-2 airfield, and carried twelve Mk 82s for the job.

All the jets would ordinarily have been loaded with four AIM-9s, but that would have taken them above the 81,000lb max weight limit. This maximum weight carried penalties, including a manoeuvring limit of 3g.

The fixed sites were simple to strike, and crews of Dodge flight chose to ingress the target area at low level at 540 Knots. Climbing briefly to altitude as they neared the target, they patch mapped the area before descending once again to 300'.

AWACS called several unidentified aircraft in their locality, but none came closer than 30 miles.

A final PVU was taken some three minutes from the target, and the Mission Navigator then provided ASL steering cues via the CC. Nearing the target, they executed either a pop or less aggressive level delivery and the first jet released its CBUs in AUTO mode at 0305 local time.

Attacking the Scud sites was risky as they were well defended, and several over-gs were recorded as evasive manoeuvres were flown to avoid seemingly impenetrable streams of AAA. In the bid to avoid the AAA, at least one Strike Eagle crew came within 90' of flying into the ground, saved only because of a 7g pull prompted by the panicked scream of the WSO, who had noted his pilot's error.

Chevy flight was the only flight to ingress their target at medium level that night. This had been a non-debatable decision for them, as H-2 was defended by five Roland SAM batteries.

The Roland was optimised for engaging fast jet targets at very low altitudes. Despite this, KARI (the Iraqi IADS) did not detect them, and they rolled in from 21,000' and rippled their bombs onto HRM designated targets in the pitch black below them.

Kwast, then a Captain, was Chevy One-Two on that sortie. He vividly recalled the sight of more than one-hundred AAA pieces firing together following the impact of Chevy One-One's bombs.

In the daytime missions that followed, dive toss was used to put bombs on target from the relative sanctuary of medium level. Rolling the jet inverted from 30,000' and diving towards the target for final visual verification, the pilot would pull out no lower than 15,000', which was the approximate ceiling for a majority of the Iraqi AAA.

When the target was not accurately designated, the pilot slewed the target diamond over the correct target with the TDC before hitting the pickle button.

With the fixed Scud sites now taken out of action, the hunt moved on to finding and attacking mobile Scud launchers. Unbeknownst to the TACC at the time, the Iraqis were hiding their mobile Scuds in specially adapted buses and underneath road bridges. They were inventive and highly skilled in the art of deception and camouflage.

E-8 JSTARS (Joint Surveillance Target Attack Radar System) had prematurely finished its own OT&E program and had been rushed to the region. It carried a massive SAR and GMT (ground moving target) radar in a canoe shaped fairing under the lower fuselage, and was able to see many miles into Iraq and Kuwait.

TACC in Riyadh assigned F-15Es and A-10s to work Scud boxes (patches of desert where Scud launches might be possible) every night with the E-8. If a suspected Scud was picked up on radar, the E-8 would pass the coordinates and the striker would put the bombs on the target. F-15Es would patrol their Scud box for four to six hours, after which they would be relieved by another flight, and would then move on to drop their ordnance on secondary targets – anything from armour, artillery pieces or known fixed Scud sites.

Throughout the war, the Strike Eagle crews were continually frustrated by the elusive search for Scuds. Diverted from its deep strike role, they failed to have much of an impact on continued Scud launches.

Despite random bomb releases in the hope of dissuading the Iraqis from setting up for a launch, many of the kills claimed during the war were discredited in post-war analysis. This was indicative of bomb damage assessment limitations and the inability at the time to identify what they were hitting from medium altitudes at night, even when they had the benefit of a target pod.

Several kills were subsequently identified as commercial fuel tankers or buses. On other occasions, the IR signature from camel herds and flocks of sheep closely resembled mobile Scuds and were

OPPOSITE
In the lead up to the shooting war, Strike Eagles carried mixed loads of CBU-20 and AIM-7s or Mk 82 and AIM-7s. (Jerry Oney via Author)

subsequently attacked!

Threats and Losses

Due to the lack of Band 1.5 protection, TEWS did not offer adequate defence against all Iraqi SAMs. The SA-2 was dotted prolifically around Iraqi targets, and despite the largely successful SEAD effort to dismantle KARI, several SAM sites remained active throughout the war.

Although some SAM spikes were noted, many crews reported being launched at without TEWS indications. There are visual or remote guidance modes available to Soviet SAMs that could explain this, but some felt that the ALR-56 was simply overloaded in the high threat emitter environment.

Similarly, the ALQ-135 could not jam or detect the SA-2 because its operating frequencies were outside of those used by the SA-2s acquisition, tracking and guidance radars.

During the course of the air war, the Strike Eagle was tracked by Iraqi fighters, notably MiG-23s and MiG-29s. TEWS provided timely warnings of this and in most instances the Strike Eagle descended to low-level where ground clutter would offer added protection in conjunction with chaff and ICS jamming activities.

There were at least two notable opportunities for the Strike Eagle to claim its first kill. Firebird flight was egressing the target on the first night, when they picked up a contact some twenty-five miles out and slightly to the right. They identified the contact as not only a non-coalition aircraft, but also as hostile. Further use of NCTR allowed them to identify it as a MiG-29. Despite difficulties in getting a good tone (lock) from the AIM-9, which was struggling to acquire the MiG-29's heat signature, they launched a Sidewinder but it missed.

With several other aircraft in Firebird flight still in trail formation following their target attack run, there were additional attempts to engage the lone MiG-29, but a catalogue of errors and bad luck prevented them from downing it.

Chevy flight also missed an opportunity as their MiG-29 target turned into a fireball way off in the distance. This was later attributed to the MiG-29 being shot down by his own wingman.

In another example, a MiG-29 flew gently into view on the NAV FLIR during another egress, the pilot choosing not shoot as he could not be certain that the aircraft was a MiG-29 – F-14s were due in the area within minutes and he did not want to shoot down a friendly.

For most of the war, the F-15E community focused on putting iron onto target, but as crews gained confidence, their attitude towards MiGs changed too. Kwast recalled:

> It depended on the flight lead's philosophy. There were lots of guys who'd brief, 'If we see a MiG out there we are going to turn cold and put it on the edge of the radar scope so that we can run around it. We'll call AWACS for an intercept, and we'll stay away. If it follows us we'll turn back home and avoid an engagement – there's no need for us to engage them while we have F-15Cs out there'. There were others who were more aggressive and would brief more along the lines of, 'If we see a MiG we'll try and skirt around him if he doesn't see us, but if he sees us we'll climb and kill him, and then we'll move to the target'. A few were full-on, 'I don't care if he sees us or not. If he's in our way we'll commit, hunt him down and kill him'. In the first few weeks the community standard was to go around them if they did not see us. Leadership allowed us to make our own tactical decisions in this respect. Later on in the war, we moved to a more aggressive stance and adopted the attitude that if we killed him on the way into the target then we wouldn't have to deal with him on the way out.

The attitude of the flight lead towards the air threat therefore determined stores configurations, and several pilots were known to carry AIM-7 Sparrows on one CFT in anticipation of coming up against MiGs.

Sorties flying deep into Iraq would also demand AIM-7 carriage, as these missions generally left the F-15Es without adequate CAP protection – the F-15C escorts lacked the range to accompany the E models over Baghdad and typically peeled away and headed home some 40 miles short of the target.

On the second day, the 4th FW(P) lost its first jet to hostile fire. Major Donnie "Chief Dimpled Balls" Holland (WSO) and Major Thomas F. "Teek" Koritz were part of the six-ship T-Bird strike against a petrol oil & lubricant (POL) station near Basrah, defended by SA-3, SA-6, SA-8, and Roland SAMs, in addition to a full range of radar directed AAA. Two other F-15E packages joined T-Bird flight en route that night, making for a total package of sixteen jets. T-Bird flight separated to ingress the target at 300', intending to Loft its Mk 82 bombs into the target – a technique suitable for a large, highly explosive target such as this. Intense fire greeted them and several jets were forced to turn tail and attempt another run at the target. Koritz and Holland were T-Bird One-Six (88–1689), the sixth jet to attack the POL station. It is unclear exactly what happened, although Holland reported coming off the target with bombs successfully released. Moments later they hit the ground, either because of pilot error or because they had been hit by hostile fire.

OPPOSITE
Waiting for war at Al Kharj. (Jerry Oney via Author)

Neither man ejected.

Two nights later came the second (and, thankfully, final) F-15E combat loss. Flying in 88-1692, Col. David Eberly and Major Thomas E. Griffiths Jr. were downed by an SA-2 on 20 January while attacking a fixed Scud site. They ejected and managed to evade capture for several days, and Eberly made contact with two coalition aircraft as he attempted to arrange a rescue.

Back in the TACC, Smyth rushed to arrange for Search and Rescue crews to plan a rescue effort, but was met with what he perceived as the battling egos of the Search and Rescue force and the special forces teams, who refused to cooperate lest the other take credit for a successful rescue.

BELOW
Mk 82 LDGP bombs provided a staple loadout for the Strike Eagle throughout the war. Note the lack of target pod on this aircraft. (Jerry Oney via Author)

Smyth was further hindered by security issues – despite tapes of Eberly's transmissions being recorded and played to Horner, he refused to allow a rescue until Eberly properly identified himself using the correct codes.

Later that evening an Intelligence Officer approached Smyth with satellite imagery of what they believed to be a rescue signal made by one of the two downed flyers. When Smyth concluded he could not positively identify the symbol as a rescue marker, he asked how they had managed to come to this conclusion. He was told that greater resolution imagery was available but he was not cleared to see it.

Smyth was powerless to help his boss (Eberly was the 4th Wing Director of Operations), and Eberly and Griffiths were captured following several days of evasion. They spent the war as POWs and were paraded on television as war trophies – an act that severely dented the confidence of the Strike Eagle crews in the integrity of the Joint Rescue Coordination Centre, but at least let them know their two colleagues were still alive.

Major Gary 'Reverend' Klett recalled his own experiences from the first few days:

I had about 600 hours in the F-4 when I was selected to convert to the F-15E. I left for the RTU (replacement training unit) at Luke AFB on the same day that the 336 FS F-15Es deployed to Oman. The whole time we were going through the conversion we kept one eye on CNN to see if we'd see any of the gang on TV. I got home from Luke just before Christmas 1990, but I didn't hurry back because I didn't think I had a chance in hell of going when the Chiefs deployed even though I had orders to the squadron. I wouldn't have enough time to complete mission qualification training (MQT) before they left, and there were about six or eight of us in the same situation [including Smyth]. I was sure all of us would get told to report next door to the 334th FS, the Eagles, since they were still in the process of converting and would not be deploying.

About eight days before Christmas I was called in to the Ops Officers office and told to get my mobility gear in order because I was going along after all. The Ops Officer said, "You won't get to fly over there but you can help plan missions and generally help out". "OK, that's better than sitting over here and watching the bros do the whole thing on CNN", I thought.

So, along with three or four other guys in the same MQT situation, I soon found myself, the day after Christmas, on my way to Saudi Arabia. We named ourselves "the MQ Maggots" in reference to the fact that we hadn't completed MQT.

However, once we arrived at Al Kharj and the bosses got a good look at the wartime frag orders it became apparent that everyone was going to be needed to fill the large number of planned sorties. It just broke our hearts!

Prior to the war starting there were relatively few training sorties available, and the guys who were already mission qualified got most of those. I ended up with only one training sortie prior to hostilities – a night "lets see what they're gonna do" sortie.

We would set up a few flights outside of Saddam's radar coverage then run at the border and see what his air defence guys would do when several flights were detected making a run straight towards them. It sounds like more fun than it was. For us it was just a couple hours of relative boredom. The worst thing was that it didn't allow me any real practice doing the things I'd have to do on an attack.

The experienced guys flew all the sorties on the first couple days of war. Experienced was a relative term in those days. With a few exceptions, the experienced guys had maybe 200 hours of F-15E time. By today's standards they wouldn't even qualify to be flight leads but back then the whole F-15E community was brand new. However, nearly everyone had several hundred hours of time in the F-4, or some other aircraft, so they did have a clue.

I sat at the duty desk and answered phones for the most part. On the first couple of nights of the war I took group photos of almost all the guys as they stepped to the jets. I later realized that I took the last photo of Donnie Holland who was killed near Basrah along with his pilot, Major Koritz. A sergeant in the squadron would pick me up in tent city every day and drive me over to the squadron to sit at the duty desk and answer the phone. Two days in a row he greeted with the bad news that we had lost a jet the night prior. Two crews lost in the first four or five days was fairly sobering. Although the fact that the overall allied force loss rate was surprisingly small helped. Fortunately, one of the crews survived, spent some time in the Baghdad Hilton, and was returned to us later on. To say that I was fairly keyed up on the night of my first combat sortie would be an understatement. My target was an SA-6 located just south of the runway at Tallil airbase in southeast Iraq. That's it. No target photo, no accurate coordinates, just a word picture. Great. I was flying with one of the other MQ Maggots, Al "Herr Pie" Pierson. He had flown one or two other combat sorties in the week prior. I ended up crewed with him for most of the war. We made a good team. We briefed up the sortie and off we went. Since it was a close target, we didn't have to air refuel so it was fairly uneventful on the trip north. I spent the whole time finding things with the radar and running through the process to designate them as targets. I wanted to make sure I didn't dork up my first attack due to some dumb-ass switch error. Map, update, target. Map, update, target. I must have done it fifty times in as many minutes.

We had six airplanes in two to four mile trail position and I was number six. There were other flights hitting targets in the area so the AAA was already active and visible before we crossed the border. Almost all of it was small calibre and wasn't reaching up to our altitude but there were a few intermittent bursts. At twenty miles from the target we checked left about 45-degrees in order to map it with the radars. I could see the runway very clearly and a few dots "south of the middle of the runway" but I couldn't guarantee

Yogi & Steep's War

"We had 80-some pilots and WSOs across the two fighter squadrons," said Lt. Col. Mark "Yogi" Alred. "Only three of them had combat experience. We were almost at the point where we had lost the art of going to war".

Yogi Alred and Steve "Steep" Turner were both part of the Strike Eagle's debut in Desert Storm. Their recollections reveal a community of aviators improving under pressure, flying an aircraft still undergoing tactical evolution, and learning to wage war in real time.

Despite its high-tech promise, the F-15E was treated by many early crews like an advanced F-4 Phantom. "We probably didn't take advantage of a lot of the systems we had," Turner said. "Without the targeting pod, the front seater flew it like a big F-4".

Yet the urgency of Desert Shield accelerated the jet's evolution. Once deployed, the Strike Eagle rapidly demonstrated its potential. And its crews began to adapt on the fly.

On the opening night of Desert Storm, Alred handed out target packets. "Each flight lead had their first three nights planned out," he said. "We did everything in advance so that if nothing changed, we could launch again".

But the mission itself was far from routine. The initial plan called for low-level ingress to avoid radar detection. "We were flying at 100 to 300 feet," Turner recalled. "We scared ourselves more than once. It's lucky we didn't have a midair".

In Turner's flight, the tactic was a high-speed fly-up – climb to 15,000 feet, roll inverted, and dive on the target. "We'd never trained for that. But it worked". His target: H2 airfield. "I rolled in, and the runway lights were on. The place was lit up like Raleigh-Durham. We were in shock".

Yogi's flight went low and flat, dropping Rockeyes on suspected Scud missile sites. "You throw out 12 canisters and you're covering 12 football fields," he said. "We didn't know exactly where the Scuds were, but we knew the general area".

Both flights survived. But it was clear the threat environment was more forgiving than expected – prompting a shift. "By night two, I was at 35,000 feet on autopilot dropping bombs," Turner said with a laugh."We didn't have any [electronic countermeasures] to defeat SA-2s or SA-3s. We found out a 2g weave at 0.9 Mach would keep us alive," Alred explained.

The aircraft's systems were still under development. "The radar stayed in the back seat at first," he said, "because it took 200 hours before the pilot's hands knew what to do".

Even refuelling was a nightmare. On the first night, Strike Eagles met tankers 600 miles from the border. "We were at 5,000 feet in a stack of KC-135s," Turner recalled. "If one of us had ejected, we'd have taken out three or four tankers".

Flexibility became doctrine. Crews were often given a planned target and a backup – or told midair to contact AWACS for new taskings. "You'd get told to hit a deadly storage site," Turner said, "and off you went".

One mission, sparked by a SATCOM call between two brothers – one Navy, one Air Force – led to the destruction of 18 parked Iraqi jets hidden on a circular taxiway. "They weren't in revetments. One pass blew up three at a time," Turner said. "It wasn't planned in any frag. We just did it".

Another strike nearly ended in disaster when the crew jettisoned bombs due to a weapons fault. "I have no idea where those bombs landed," Turner said.

The war was exhausting. Pilots often flew multiple missions per night, with little rest. "I flew 42 missions in 38 nights," said Alred. "Sometimes I thought I'd catch a break, and then they'd hand me a frag to Tikrit".

And there were constant reminders of how real it was. One mission targeted Saddam himself, based on intelligence that he was traveling by train. "We got coordinates in the clear over the radio. I dropped CBU-87s at Mach 1.15. Not supposed to do that – but it worked," said Alred.

"Another time, an SA-2 missile exploded about 2,000 feet behind me," Alred added. "All three mirrors flashed white with the explosion. We got lucky".

Turner summarised it best: "The airplane was more capable than we were ready for. But we got there. And we had the right people in the fight".

OPPOSITE
A Lakenheath F-15E patrols the Northern Watch no-fly zone in the early 2000s. Loadout is 4x GBU-12 and GBU-31 penetrator on the centerline. (USAF)

that any of them were an SA-6. Again, great. So, I just picked a dot with a few other dots clustered around it and designated it as the target. I could also plainly see the security fence that surrounded the whole complex. I always wanted to thank Saddam for putting those around most sites of military value. They show up like radar reflectors in the desert and made it very easy to ensure we weren't bombing civilian areas.

We rolled into a 30-degree dive at about five miles from the target and then waited for the computer to decide when to release the bombs. All the pilot had to do was keep the velocity vector symbol on the steering line and hold the pickle button down. The computer decided when to release the bombs in order to hit the target. We didn't have a LANTIRN Target Pod on our jet so we were loaded with 12, dumb, Mk 82, 500-pound bombs. The jet rattled around fairly good when 6,000 pounds of iron got dumped overboard in about two seconds. We pulled out of the dive and I found our element lead in the radar and pointed him out to Herr Pie. He could see him in the HUD since we did have a LANTIRN Navigation Pod, which displayed an IR view of the world.

As we ran out of the target area like the proverbial scalded-ass apes I finally had a few spare moments to actually look around and see the AAA popping. Nothing was very close to us so it was more interesting than scary. On the ingress to the target I was too busy, and scared of dorking something up to be scared of getting hit. They say dumb animals are not frightened of distant flashing lights and I guess I resembled that remark! We could see the flashes of the bombs detonating but still couldn't tell if we had actually hit anything worthwhile.

Some stuff was burning as we left. Since nobody could prove differently, we claimed a successful hit on the enemy dots. Some satellite photo analyst would have to decide if our ex-dots were once an SA-6!

When we got back we celebrated my "cherry" combat sortie with a couple shots from a highly illegal Jack Daniels bottle. (What kind of war prohibits booze, anyway?) All of the MQ Maggots eventually ended up getting credit for a tactical checkride for our first combat sortie. We even got the standard "Form 8" that normally gets filled out by the evaluator after a checkride. That officially made us mission qualified – and we probably still hold the record for the shortest MQT program in F-15E history.

That's my story and I'm sticking to it!

The First Air-to-Air Kill

For much of Desert Storm, the Strike Eagle operated without the AAQ-14.

Those pods that did arrive were quickly rushed into service, often carried only by the lead aircraft in a formation. In instances where an additional pod was available, this was usually assigned to the element lead (#3 in a formation of four).

The pod was immeasurably useful at night and was therefore mostly used by the Chiefs, who did most of the night flying and had been assigned the Scud hunting role.

The Chiefs flew almost two weeks of solid Scud kill box missions, always using the TP, not only because it helped them to identify these elusive targets from medium altitude at night, but also because it gave them a bomb damage assessment capability. This had been a weak point until now, with F-15E crews struggling to provided realistic BDA without being able to replay pod video in the debrief.

Following what amounted to a monopoly on the sixteen pods that were in theatre by the end of January, a few were finally shared with the Rocketeers, who used them to drop a limited number of laser guided bombs on high value targets such as airfields and bridges. They also augmented the Chiefs on their Scud hunting sorties.

When necessary, the two squadrons worked with each other to buddy lase LGBs onto target. On one memorable sortie, four F-15Es equipped with TPs destroyed eighteen Iraqi jets at Tallil airfield using CBU-87 and GBU-12 LGBs. Tank "plinking" was another activity for TP equipped Strike Eagles. Borrowed from the F-111F community, the term was a politically incorrect euphemism for lasing GBU-12s onto semi-buried Iraqi armour and was akin to shooting fish in a barrel.

The AAQ-14 was far from perfect, and some ex-F-111 crews would rather have had the Pave Tack, which was refined, predictable and offered both a better field of regard and clarity of view thanks to its higher video resolution. Slewing rates and tracking stability were also subject to criticism. But these shortcomings were primarily the outcome of a rushed introduction into service and were resolved in the years that followed.

On 14 February, the Strike Eagle scored its first air-to-air kill – a Mi-24 Hind attack helicopter. In response to a request for help from US Special Forces, AWACS radioed Capt. Richard T Bennett and Capt. Dan B Bakke to ask for assistance. Arming and selecting a single GBU-10 LGB, Bennett took the F-15E at full power through bad weather and into the area as directed. At fifty miles out, Bakke picked up contacts on the radar and later cued the TP as they broke through the weather at 3,000'. They closed the last twenty miles as Iraqi AAA crews fired their weapons towards where they thought the F-15E was – a technique Strike Eagle aircrew came to call derisively "sound activated AAA". With two of the three helicopters now clearly visible in the pod, Bakke pickled the GBU-10 six miles from the target – it would have a thirty second time of flight to reach the Hind. As the thirty seconds came and went, the crew assumed that the bomb had missed or failed to detonate. Bennett pulled the jet into a left turn, his intention being to come back and target the helicopters with an AIM-9 or two. But as they reefed the jet around again, the Hind blew up and literally vaporised. SF troops on the ground had estimated the helicopter to be about 800' above the ground when the bomb impacted just in front of the main rotor. The call. "Cougar, Packard Four-One, splash one helicopter", was duly made. Bakke and Bennett continued, amid much confusion caused by an incompetent AWACS controller, to target the second Hind. Despite acquiring the Mi-24 on radar, fuel considerations and a real concern that they might kill a friendly SF helicopter forced them to return to base.

The pair had just made history, but it would not be officially recognised until 2 November, 2001, when the USAF painted a green kill marking on the side of jet '487 at a ceremony attended by Bennett and Bakke.

The Unofficial Kill

Following forty-two days of intensive combat flying, a cease-fire was announced. Northern and Southern No-fly zones were established to prevent Iraqi fixed wing aircraft from posing a threat to the Coalition.

BELOW
Heading into the relative sanctuary of the night, the Strike Eagle dominated the Iraqi military regardless of time of day. (Gary Klett via Author)

Despite this, Hussein made full use of the loophole to allow helicopters to operate in the no-fly zones, and ordered Mi-24 Hind attack helicopters to strike Kurdish refugees in Northern Iraq.

Helpless and unable to offer protection, F-15E crews enforcing the no-fly-zone watched in horror as the gunships started attacking roughly 600 civilians in the village of Chamchamal, as they fled towards Turkey. Denied the ability to fire upon the Iraqis, the F-15E crews made high speed passes as close as they dared in the hope that their wake turbulence would snap a rotor blade. They also fired their lasers into the cockpit of the Hinds with the intention of blinding the pilots. Whilst the latter technique was probably ineffective, the former was enough to cause the

Grinder's War

Our squadron [492nd FS] deployed to Ahmed Al Jaber Air Base, Kuwait in support of Operation Southern Watch in March of 2001. It was our normal 90 day AEF rotation that occurs every 15 months.

We flew three kinds of sorties down there. One was a container sortie where you flew into Iraq as strikers or DCA (which we didn't do very often down there), alert sorties where you'd wait for the Bat Phone to ring and send you on your way running to investigate someone in the no-fly zone, and normal CT (continuation training) sorties where you'd go out and fight each other or other aircraft. I had some great CT sorties down there. We fought the Bahrainian Vipers [F-16s], Kuwaiti, Marine and Navy F-18s and Navy F-14s. These were firsts for me as I didn't have much experience fighting dissimilar aircraft. During an average week I'd fly 2-3 combat sorties and 1-2 CT sorties.

I'll never forget my first combat sortie. Skull was my flight lead and Gomez was my back seater. It was a night NVG mission patrolling the southern no-fly zone. I was full of adrenaline and more alert than I have ever been in my life. My visual lookout was like you read about. It amazed me how many aircraft were in southern Iraq at the same time and pretty much the same place. The amount of coordination and deconfliction were impressive. And this still occurs on pretty much a daily basis in both northern and southern Iraq. Well, while we were flying around that night, the Iraqi's shot one of their "science project" missiles in the air. All I saw was what looked like a blue firework exploding about 5 miles away from us. For a split second I thought it looked pretty! But back to reality, it was NOT pretty but it wasn't too much of a threat either. This was the case with the AAA I saw during that deployment as well.

I also won't forget my first drop in Iraq. It was actually my first time dropping live weapons as well. We were a four ship flying around in the container when the higher ups decided to execute us. This basically meant that we could then drop on pre-planned targets we walked out the door with. Sometimes we'd take off with imagery of 3-4 target areas so the powers that be would have more options when they executed us. But this time we had two target areas planned, and only dropped on one. And there were only three DMPIs. Luckily we were number two in the formation and got to drop. Barney was my back seater and did an excellent job finding the small KS-19 [AAA] amongst the desert background.

It felt great when those two GBU-12s came off the jet. And the explosion when they hit the AAA piece was awesome. So this is what we practice in training all the time! It really all came down to luck as to whether you dropped on that deployment though.

The alert sorties we flew down there were pretty cool as well. Sitting all day in a trailer in your flight gear wasn't fun, but when you got scrambled the excitement more than covered for the hours of boredom. We would get the call on the Bat Phone that we were scrambled. Then we would race into the back of the truck and haul ass out to the jets. When we got to the jets we would jump out, run up the ladder into the cockpit and start up as we were strapping in. In 2-3 minutes we'd be ready to taxi out and takeoff.

There is one particular alert sortie I will never forget as well. It occurred after sitting alert for 12 hours and already being scrambled once. Mojo was my back seater and Killer and Flak were our flight lead.

We got the second call and raced off. I had some problems with my EGI (our GPS) on the ground but none that couldn't be resolved after takeoff.

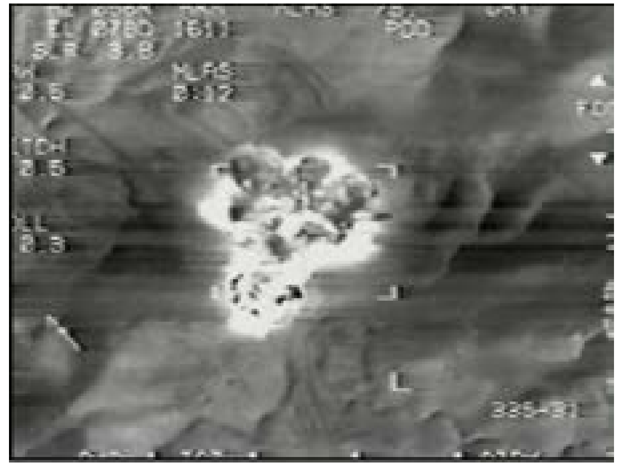
After takeoff my INS (secondary navigation system) failed and could not be fixed. The two systems were shorting each other out so no matter what we did, neither one would work.

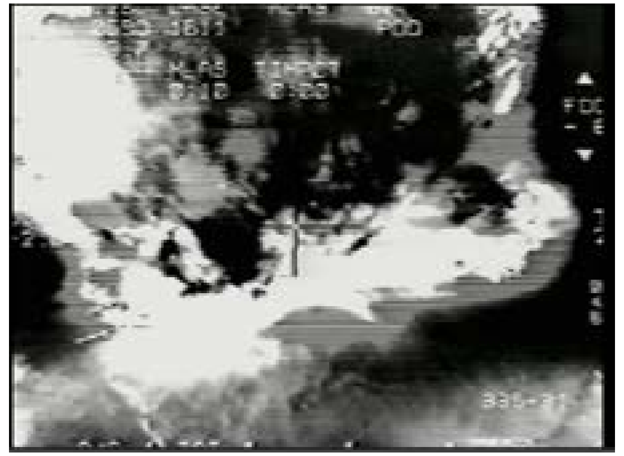
While we were trying to fix our navigation and attitude systems our flight controls started acting up. We ended up losing our CAS. That wasn't too big of a deal, it just meant we had slightly degraded aircraft control.

Then my HUD started to show incorrect information. In level flight it showed us 20 degrees nose high and in 5-10 degrees of bank. Nothing would correct this problem so I had to turn it off.

After we had burnt down enough gas to land, it was well into the night. The primary runway (the one with lights) at Al Jaber was closed so we had to land on the taxiway (also known as the secondary runway) which had no approach and very little lighting.

We ended up flying a no CAS, HUD out formation approach to land on our squadron commander's wing that night. Mojo and I were just happy to be on the ground.





ABOVE
Matt Nicoletta's view through the TP as the bunker is targeted, hit by the GBU-10 and as secondary explosions fill his screen. (Matt Nicoletta via Author)

gunships to land, and in one instance caused a Hind to crash.

Air Force leadership became wise to these activities, ordereing that the F-15Es not fly below 10,000'. The merciless killing continued.

The F-15E had played a pivotal role in the opening stages of the war. It had flown 7,700 combat hours in around 2,400 sorties. In addition to flying deep interdiction to hit Scuds, it had also flown CAS and been tasked against air defence sites on the third night of the war – when they were still highly active. It enjoyed great success in destroying Iraqi armour, artillery, troops and aircraft on the ground, and had expanded its repertoire by working with SF controllers on the ground, E-8 JSTARS in the air, and other TP equipped Strike Eagles to execute buddy lasing tactics.

That F-15E losses were so low was testimony to both the professionalism and competency of the crews, many of whom were fired at on their first ever combat sortie and had very low hours in the Strike Eagle. Tremendous obstacles had been overcome through sheer grit and determination in some cases, and with an added touch of luck in others.

Some aircrew demonstrated extraordinary heroism above and beyond that expected of them. On one occasion Kwast, the first ever Lieutenant pilot assigned to the F-15E, made a lone attack against a key target amid a dense thicket of AAA and SAMs. Kwast had sought permission to attack the target on his own following his flight lead's decision to abort the mission because the threat was so severe.

The 336th TFS returned victorious to North Carolina, while the Chiefs, who had been deployed for a lesser period of time, remained *in situ* as a deterrent to any further acts of aggression.

Following Desert Storm and as a result of several years of intensive use, the AAQ-14 started to develop problems in the slipring section of the NESA. Shorting could occur as the slipring wore out. Worse still were the small metal shaving particles (which resulted from the slipring rotating) that worked their way into the coolant seal.

The seal carried coolant via the slipring to the laser transmitter and optics. The seals deteriorated and failed, prompting design of a new seal and new nose section called a V seal, which was externally indistinguishable from its predecessor. In later AAQ-14s, the slipring was deleted altogether.

Operations Northern Watch, Southern Watch, Provide Comfort and the AEF

Operation Provide Comfort was initiated following a Kurdish uprising in Iraq's northern territories. Hussein's response was to overpower the rebel fighters and to embark on a policy of ethnic cleansing.

Unable to stand by and watch, the UN passed resolution 688, paving the way for military intervention.

Provide Comfort sought to achieve two goals: to provide relief to the refugees, and to enforce the security of the refugees and the humanitarian effort.

These two goals were maintained from April to September 1991 by a US led Combined Task Force.

Over 40,000 sorties were flown, more than 7,000,000 refugees were relocated, and 70-80 percent of villages destroyed by the Iraqis were rebuilt.

The Chiefs supported the operation until July 1991, at which time Provide Comfort II began. They flew escort for RAF and USAF transports in addition to flying combat air patrols.

The 492nd FS sent six of their newly acquired F-15Es to Incirlik AB, Turkey on 2 August, 1993 and flew four-hundred and thirty-one sorties before returning home on 2 November. They were replaced the next day by the 494th FS, who flew one-thousand-four-hundred and thirteen sorties in a three month period (leaving on 31 December, 1994).

The Bolars and Panthers returned to Incirlik twice more before 1995; eight 494th FS jets in January to February 1995; and twelve 492nd FS jets from July to September 1995.

In 1996 the Bolars made their final deployment of twelve jets, following which the 391st FS deployed six jets for three months. This Bold Tigers deployment marked the end of Operation Provide Comfort II.

ONW & OSW

Operations Northern Watch and Southern Watch policed the northern and southern no-fly zones set-up after the war.

In January 1993 the 4th FW(P) led a small package to hit Iraqi AD targets that were breaking the rules of the ceasefire by deploying below the 32nd Parallel. The SJ Strike Eagles targeted an SA-3 Goa site.

Several days later ten F-15Es led an additional punitive strike of the same nature. On the whole, most missions flown in ONW and OSW were of a defensive nature, and the F-15Es carried a broad selection of stores to allow them to retaliate if necessary.

Operating under the supervision of AWACS, crews did sometimes receive airborne taskings and subsequently flew unplanned attacks against perpetrating ground targets. Occasionally, as with the example above, pre-planned, punitive strikes would be flown, although these tended to be few and far between.

Captain Matt Nicoletta's experiences of Operation Southern Watch were perhaps not typical, but provided a good example of ongoing operations in the Persian Gulf:

> On my first OSW sortie I was shot at – I saw three white trails to my left, I said 'Missile in the air, eleven o'clock, check right'. My pilot, who had more experience than me said, 'Dude, those are roads, not missiles!'. As I kept watching them, these 'roads' began to arc towards us! I said, 'Missile in the air, check right, NOW!' My front seater looked at them once more and realised that they were indeed missiles; we broke right and evaded them, although I don't know if they would have hit us anyway. The radios then came alive as everyone starts their threat reaction, and I realise that what I should have done is told the whole formation about the missiles. Red flag prepared me for all of the responses, but it was still an interesting experience. Sometimes we responded by striking back at the SAM sites, sometimes we'd respond by hitting another target. We did fly with pre-set targets for retaliatory strikes, although command and control would have to Authorise us before we did anything. Our typical load outs included GBU-12s, GBU-10s, AGM-130s, AIM-120 and AIM-9. We did not do any work with CBU.

OPPOSITE
For operations in the Balkans, F-15Es carried both self-escort loadouts (top) and dedicated ground attack loadouts. (Gary Klett via Author)

> We executed several pre-planned attacks when we were there [335th FS, 1999 AEF deployment]. On one occasion we were being shot at with AAA, so we used GBU-10s to hit what we had been told was an ammo bunker. I was used to the size of the GBU-12 explosion, but as the bomb hit this big square bunker I thought, that looks big, even for a GBU-10. I went to WFOV and the explosion still filled up my entire screen! The radios then went mad, everyone was saying, "Holy Cow, what did you just hit!?". I looked out of the window and just thought, oh my God! – There was this huge, billowing mushroom cloud rocketing up through 7,000' – it had sucked up so much dirt and that the sky began to darken as the extended up beyond 15,000. My pilot transmitted, "One hell of a secondary!", which was a huge understatement because the explosion was so big that we had to cancel the rest of the days bombing! No one told us what it was, but it sounds cool to tell everyone that we hit a Scud propellant storage plant! The video shows an overpressure that was so powerful that a large hill next to the target was sucked up into the mushroom cloud. We like to joke that Intel. probably classified it as Possible Damage!

Nicoletta also recalled that the Chiefs hit an SA-6 during the same deployment.

AEF

As part of an effort to modernise the Air Force, the Air Expeditionary Forces concept was introduced in the early 1990s.

AEF was designed to respond to the increasing number of contingencies that called for worldwide deployments. At its core was the goal of planning far enough ahead that each USAF wing could benefit from some form of predictability. Under AEF, almost all the USAF was divided into ten force packages, each with a cross-section of Air Force weapon systems drawn from geographically separated units. A typical AEF had about one-hundred and seventy-five aircraft,

ABOVE AND OPPOSITE

The GBU-15 glide bomb. (Author)

ABOVE

An F-15E Strike Eagle deployed from the 492nd Fighter Squadron, Royal Air Force Lakenheath, England, releases a GBU-28. (USAF)

ABOVE

The AGM-65 Maverick was rarely seen loaded on the Strike Eagle. Here, a Bold Tigers jet carries a captive round for training. The squadron had just returned from Afghanistan when this photo was taken in late 2001. (Author) each more formidable than the air forces of most nations.

AEF packages were required to respond within seventy-two hours of any unexpected contingency, and AEF deployments often saw each contingent deployed for ninety days every fifteen months. Two AEF wings remained on-call at all times.

Air Expeditionary Forces were deployed wings, groups, or squadrons attached to an Air and Space Expeditionary Task Force (ASETF) - the organisation assigned to fulfil the AEF campaign objectives. F-15E squadrons (like all others) assigned or attached to an ASETF became "expeditionary" (i.e. 494th EFS), and each wing committed to a joint operation became an Air Expeditionary Wing (i.e. 366th AEW).

In August 1997, the 391st FS deployed six E models to Sheikh Isa AB, Bahrain for OSW as part of AEF V. They flew six-hundred and forty-one hours enforcing the No-Fly Zone before leaving in October. From March to June 1998, they deployed twelve jets to the same base as part of AEF VII. Whilst the Bold Tigers stayed in Bahrain for these two deployments, they were later stationed at Al Jaber AB, Kuwait, when they flew ten jets for a three-month AEF deployment in January to March 1999. They also deployed ten jets to Incirlik, Turkey, later that year as they honoured their AEF commitments to ONW.

Liberty Wing F-15Es also deployed for Northern and Southern Watch operations. The 494th FS deployed six Strike Eagles to Incirlik from January to April 1997 and dropped seventy-five tonnes of weapons on Iraqi SAM and AAA pieces. In September the 492nd FS also deployed to Incirlik, and once again took six airframes with them. In December 1998 the Panthers returned, and a two-ship top-up flight on 15th January 1999 brought their number to ten. They left in February 1999 and were replaced less than a month later by ten Bolars, who arrived in February and left in March. The Bolars were relieved by a detachment of the 336th FS from Seymour Johnson. From December 2000 to June 2001, both the Bolars and Panthers deployed consecutively for AEF II and AEF IV – both occupied Al Jaber AB, Kuwait in support of OSW.

Balkans Operations

In 1993, eight 492nd FS F-15Es deployed to Aviano AB, Italy, for Operation Deny Flight. Along with some of their sister squadron, the 494th FS, they would remain in Italy for more than a year.

Operation Deny Flight was centred around a no-fly zone that had been placed over Bosnia-Herzegovina, in the Balkans. Relationships between the different ethnic groups in the Balkans had been deteriorating for many years, but it was not until 1992 that it really caught the world's eye.

UN peace keeping troops moved in, so the no-fly zone was there to protect them. It was authorised under UN Security Council Resolution 781.

On 31 March 1993, the UN Security Council passed Resolution 816, which extended the no-fly zone's scope to cover flights by all fixed-wing and rotary-wing aircraft, except those Authorised by UNPROFOR (UN protection Force). In the event of further violations, it authorised UN member states to take all necessary measures to ensure compliance.

Deny Flight began on 12 April, 1993. It initially involved some fifty fighter and reconnaissance aircraft (later increased to over one hundred) from various alliance nations, flying from airbases in Italy and from aircraft carriers in the Adriatic. By the end of December 1994, over 47,000 sorties had been flown by fighter and supporting aircraft, including the F-15E.

By this time, matters had worsened and NATO commanded a limited strike against Serbian targets in Croatia, in particular Udbina Airfield. Eight 492nd Strike Eagles took aloft GBU-12s as part of a thirty aircraft strike package. Their target was the destruction of SA-6 SAM sites, although the sortie was cancelled mid-flight as the gaggle of Dark Greys were unable to prosecute the attack due to stringent ROEs.

Once again, Lakenheath's F-15Es were launched in December, this time to destroy a pair of SA-2 SAM sites which had recently fired upon two Royal Navy Sea Harriers.

Operation Deliberate Force commenced in August 1995, following a Serbian mortar shelling of a market square in Sarajevo. The 90th FS deployed from Elmendorf for several months, joining the 492nd FS and 494th FS who already had eight jets each in theatre and had flown well over 2,500 sorties since Operation Deny Flight began. Five punitive strikes hit Serbian armour and supplies around Sarajevo on the 30th August. A day later three more strikes were flown. GBU-10s and GBU-12s were dropped by LN F-15Es on the 5th September as the strikes became more widespread. Four days later, the GBU-15 was dropped for the very first time in anger by the F-15E – in total, nine were used to strike air defence targets around Banja Luca, including Bosnian-Serb ground forces.

GBU-15 & EGBU-15

The Boeing GBU-15 had initially started life in 1974 as a solution to the requirement for stand-off precision guided bomb. It had been carried on the F-15E during test and evaluation in March 1988. It combined either an Electro Optical, DSU-27A/B, seeker head, or one of two IR seeker heads - the WGU-33/B, which offered correlation tracking; and the WGU-10/B which was limited to centroid tracking only.

All three could be mated to a BLU-109 or Mk 84 bomb body. Several basic variations were used. The GBU-15S had a short chord wing and was designated GBU-15(V)31/B when attached to an IR seeker, or GBU-15(V)32/B with the EO head. The GBU-15L featured a long chord wing and comprised the GBU-15(V)1/B, 1A/B and 1B/B when fitted with the EO seeker head; or GBU-15(V)2/B, 2A/B and 2B/B when fitted with either IR seeker. A training round, known as the SUU-59, was carried minus wings for training.

A direct attack mode allowed the bomb to be locked on to the target prior to launch. Once released it would guide autonomously to the target. Indirect attack mode made use of either an AXQ-14 DL pod or ZSW-1 Improved DL Pod (IDLP) with which to steer the weapon to target post-launch.

Launching the GBU-15 was simple: ASL steering cues and range indications were provided in the HUD and the GBU-15 video MPD page. The bomb could be cued from the radar, HUD or TP, and would be released in either a climbing profile or a level profile. In Indirect mode the weapons seeker could be slewed via the DL to acquire the target as the bomb flew within visual range – the WSO slewed the seeker to the target, and then committed the bomb to attacking it – a process that caused the bomb's control fins to bring the bomb line of fall in line with the seeker LOS.

To help the WSO, the GBU-15 offered a ground stabilisation option. As the bomb flew out to the target area in Indirect mode, the WSO was initially limited to steering the weapon in azimuth only – this prevented him from inadvertently depleting the weapon's kinetic energy through unnecessary pitch transitions.

During this time, the weapon completed a terminal manoeuvre intended to bring it with striking range of the target. The WSO could at any time take control of pitch steering by switching the bomb from transition mode to terminal mode.

The EGBU-15 featured GPS mid-course guidance and allowed the crew to release the weapon in poor visibility. The bomb would drive itself to the pre-

BELOW
A CBU-laden Strike Eagle in loose fingertip on the way to strike another Serbian target. (Gary Klett via Author)

entered target coordinates taking steering commands from an onboard GPS receiver. Once in the target area there the WSO could take control via the DLP as normal.

Lakenheath crews returned to the UK with spectacular video of their GBU-15 exploits. In one instance, a man could be seen running from an SA-6 moments before the weapon impacted directly.

The 494th FS deployed once more to Aviano AB for Operation Deliberate Guard. Deliberate Guard was another United Nations mandated no-fly zone in the airspace over the Republic of Bosnia-Herzegovina. Six aircraft departed RAF Lakenheath on 30 September 1997 and returned on 13 January 1998, almost immediately they began preparations for their AEF deployment to Turkey for ONW. They were replaced by another six Panthers, who limited their stay in Italy to just over a month.

Operation Allied Force

Months later, Operation Allied Force was launched following the displacement of some 300,000 refugees from Kosovo. Following repeated NATO warnings to Serbian President Milosevic to remove his armed forces from Kosovo, the first Balkan AEF force arrived, including six 492nd FS F-15Es. A five-phase plan was put into effect – initially the NATO flights would act as a deterrent, becoming more aggressive if NATO's demands were not met.

Despite some gains made at the Rambouillet peace talks in France, an additional twelve F-15Es from the 492nd FS were sent to Italy on 22 January 1999 – all US assets operated under the code name Noble Anvil.

Noble Anvil commenced on the night of the 24 March, 1999. Following several cruise missile (CALCM) strikes by B-52s, the twenty-six F-15Es in theatre concentrated on striking Air Defence (SAM, AAA, GCI EW) assets, as they followed behind a wall of Lakenheath F-15Cs flying Offensive Counter Air sorties (OCA).

As the conflict progressed, the F-15E crews turned their hand to dropping CBU and other types of weapon. The GBU-28A/B, a bunker penetrating laser guided bomb, was used at this time. Originally developed for the F-111F during Desert Storm, the original GBU-28 could penetrate 100' of concrete before exploding and was suitable for use in AUTO and DIRECT release modes. It consisted of a BLU-113 bomb body with a WGU-36/B laser guidance kit and BSG-92/B airfoil group. The GBU-28A/B featured both an expanded launch envelope and an advanced Guidance and Control Unit which took into account target pressure altitude to ensure that the weapon struck the target at a minimum angle of attack – this enhanced penetration characteristics. It was used in Noble Anvil against an underground hangar at Pristina AB, although the attack would appear not to have been successful.

AGM-130 & Goldpan

The powered version of the GBU-15, the AGM-130, was also used during Allied Force. Initially used without success in Iraq during ONW that same year, the AGM-130 successfully destroyed two MiG-29s on the ground.

The AGM-130 used a modified GBU-15 as the basis for an extended range PGM. A rocket motor was mounted to the underside of the GBU-15 to provide the bomb with a glide–boost–glide operating profile. The motor was not intended to accelerate the bomb, but simply to maintain a desired minimum velocity – once the motor expired it would be jettisoned automatically. AGM-130-9/-10/-11/-12 variants also featured a GPS mid-course guidance system which allowed the bomb to navigate itself towards the target area; the latter two versions had an additional antenna installed in the bomb to help increase IDLP reception coverage; a feature known as Switchable Data Link. EO and IR versions of the AGM-130 used the WGU-40/B Television Guidance Section and WGU-42/B Improved Modular Infra Red Sensor seeker heads respectively: IMIRS bombs mated to the BLU-109 warhead were designated AGM-130C-10 or AGM-130C-12SDL; TVGS and BLU-109 bombs were designated AGM-130C-9 or AGM-130C-11SDL. With the Mk 84 bomb body they became AGM-130 with the dash designations applied as detailed above. Both seekers had a 4.2° vertical x 5.6° horizontal FOV, and gimbal limits of +30° to -54° pitch and 30° yaw.

The weapon functioned in a very similar manner to the GBU-15, although the AGM-130 could be programmed with its own transit altitude that could allow low altitude target ingress as low as 200' or as high as 2,000' (the CC automatically calculated the dynamic launch zone based on the user selection, and a missile mounted radar altimeter provided elevation data), and the IMIRS sensor made use of a Nitrogen cooled Focal Plane Array that featured two additional tracking modes (Black and White).

In instances when the weapon was deployed in indirect mode, the aircrew could subsequently designate a target in the jet via the TGT FLIR or HRM radar mode and this target data would be transmitted to the AGM-130 which would, in turn, compute the target location relative to its own position. A small triangle would subsequently be superimposed over

No Way to Run an Air War: Starbaby in the Balkans

By the spring of 1999, Michael "Starbaby" Pietrucha was flying combat missions over Serbia by night and living on Italian food and giant roast beef sandwiches by day.

As a Strike Eagle Instructor EWO deployed to Aviano during Allied Force, he had a front-row seat of NATO's chaotic 78-day air campaign. But the fight he saw wasn't the clean, strategic war some might imagine. "It was casual vandalism on a country-wide scale," he said.

One mission, flown on 5 May, 1999, stood out as the worst of the lot. As mission commander, Pietrucha received a target package with a single red square drawn on a 1:1 million scale map – "the kind airliners use to fly the jet routes".

"In the middle of that box was a village," he said. "Someone was trying to conceal this fact with bad charts and bad guidance".

To make matters worse, the tasking stipulated that the Strike Eagles would be loaded with CBU-87 cluster bombs, and they were cleared to drop from medium altitude through cloud cover. "That never happens," Pietrucha said. "CBU-87s aren't precision weapons. You don't drop them blind through weather".

He phoned the Combined Air Operations Center. "Who approved this strike?", he asked. The answer: General Short's name was on the ATO. That was all the confirmation he got.

He nearly scrubbed the mission, but his pilot – a wise and dependable veteran called War Dog – suggested flying the sortie to "take a look" and retain the option not to drop.

"You will positively identify a military target or you will not drop in the square," Starbaby told his flight. Unable to positively ID the target as having any military value, they dropped the CBU on a tree-covered corner of their dump point. "I regret that decision," he said later. "I didn't understand how many duds those CBUs would leave behind, or how dangerous they'd be to civilians".

Pietrucha didn't just fly strike missions. The F-15E's versatility had him pulling Combat Air Patrol duty, too. On one such night over Macedonia, he and his pilot detected a slow-moving radar contact flying what looked like a ground attack profile. Despite multiple calls to the French AWACS (callsign Cyrano), declaring the contact as hostile and unidentified, the response was always the same: "Picture clear".

So Pietrucha growled: "Cyrano, Sword Five-Two. I'm not asking you. I'm telling you: the picture is not clear". But despite his warning, they never got permission to engage. He believes the aircraft went on to strafe civilians. "I regret that mission to this day. It probably cost people their lives".

The problem wasn't just poor comms. It was doctrine. "The guys writing the ROE weren't the guys executing it," he said. "Senior leaders didn't trust us to make the call. And that costs lives".

On another mission, Pietrucha watched in real-time as the French AWACS fumbled through its airborne warning role. "They weren't doing Airborne Warning and Control, they were doing Early Warning. There's a difference. And it showed".

In one of the strangest twists, Pietrucha's best

bomb drop came during a surprise, no-notice combat checkride. Flying with War Dog again, they were re-tasked to hit an entire shelter complex under a mountain. They'd hit the same target ten days earlier. The original imagery? Lost. All he had were sketches from memory.

To make it work, he aimed high on the shelter's vertical face. The GBU-10 laser-guided bomb smashed into the rock and blasted the doors "into the next county".

What was inside? Not the MiG-21s Intel had promised. "We killed Serbia's aerial demo team. Red, white, and blue-painted Super Galebs. The Balkan Blue Angels".

Still, it was a clean hit. Pietrucha earned his only "exceptionally qualified" checkride of his career and a Distinguished Flying Cross.

What he saw in the Balkans wasn't a clean campaign. It was a broken command structure, bad targeting, political interference, and an enemy that often outlasted NATO's patience.

"It was a 78-day lesson in how not to run an air campaign," he concluded.

the AGM-130 video in the cockpit to provide the WSO with steering cues to help him guide the weapon to the target. Narrow and Wide FOVs were provided for enhanced target acquisition purposes.

AGM-130 launches usually worked with two jets monitoring video imagery beamed back via the AXQ-14 or ZSW-1 DLP/IDLP. If the primary jet was unable to locate the target in a timely manner, the secondary jet was used as fall back. The primary would typically transmit, "Goalkeeper, Goalkeeper", to instruct the secondary crew to take control of the missile.

Allied Force AGM-130 weapon system video showed the launch aircraft as far as fifty miles from the target at time of weapon impact. It gave a clear indication of the stand-off capabilities of the weapon and the DLP, which featured a rear facing, mechanically steered Phase Scanned Array antenna to allow continued communication with the bomb as it flew in the opposite direction.

The ZSW-1 IDLP provided added Gold Pan, a capability whose operational use was at the time a closely guarded secret within the F-15E community.

BELOW

Mk 84s were a staple munition for the duration of the 391st FS's OEF tour. (Gary Klett via Author)

Gold Pan was used for the first time in Allied Force and allowed imagery to be transmitted to the jet via the IDLP. Any ground station or air asset configured appropriately could send target pictures or video straight to the cockpit of the Strike Eagle – aiding the WSO in finding an elusive target or helping to confirm target identification.

For the first time since the 1986 raid on Libya, the 48th FW mounted offensive operations directly from RAF Lakenheath, including AGM-130 strikes.

The F-15E was the only allied aircraft to operate in all weathers day, or night, and Allied Force was also the first occasion on which NVGs were used by the F-15E community in combat.

One other significant change was the dual role of the F-15E during the conflict. The AIM-120 enabled the F-15E to come off target and revert immediately to a CAP role. Using this tactic, they could protect the rest of a strike package as they went into their target.

Strike Eagle crews without NVGs also teamed up with NVG equipped F-16s to buddy lase – the F-15Es dropped GBUs and the F-16s lased them to target.

SAMs

Much of the Federal Republic of Yugoslavia Air Force and Air Defence forces derived their tactics from standard Soviet operating procedures. In this sense, they were no different from Iraq. Where they differed was in their conviction to use their military might against a superior force like NATO.

It came as no surprise to F-15E crews arriving at Aviano that their threat briefing apportioned considerable time to defining the capabilities of a largely mobile SAM environment. The main problem was a large contingent of mobile SA-6 launchers which supplemented fixed SA-2 and SA-3 sites and would rarely stay in one location for long. Indeed, Milosevic' forces were cunning in their use of deception and in their self-control – they hid several of these potent systems, resisting the urge to fire until conditions were in their favour.

In 1995, Scott O'Grady had been downed by an SA-6 near Bosanki, Bosnia, while on a routine patrol. Although this shoot-down was attributed largely to pilot error, he likely also flew into a SAM trap – a tactic that used two or more mobile SAM systems to target the same aircraft from different locations. This tactic took full advantage of NATO aircraft using the same routes day after day.

A French Mirage 2000 had also been downed, and so too had an Italian transport aircraft and a Royal Navy Sea Harrier. Most notable of all was the loss of an F-117 Stealth Fighter, which was also lost because planners failed to alter its ingress and egress tracks.

The F-15E community went by without a single loss, although there were certainly occasions when things could have turned out for the worse, as "Skull" explained:

> Their surface to air systems were robust and widespread, it was difficult to know where they all were – the mobile SAMs were the biggest concern. We were initially flying CAP sorties until March, but we were never given a date for when we would switch to offensive operations. My first sortie was a CAP/CAS on the third day, carrying four GBU-12s, two AIM-7 and two AIM-120. We were really on station to provide defence against any attempt to attack Italy; it was not a really serious threat as we knew that they did not have the range to return home if they tried this. We [492nd FS] flew night after night, I flew almost every other night. When the weather precluded us from using PGMs we would mainly drop Mk 82s with proximity fuses and CBU-87 on area targets like ammo storage facilities and troop concentrations. We were always well away from civilian areas when we did this.
>
> One night, we were egressing a target when we received audio and visual indications of an SA-6 launch. They launched two to begin with – we think that they had an ambush site underneath us – I rolled the jet upside down and pulled towards one of the missiles. It passed by so closely that my WSO thought I had popped a flare. We then had this impromptu little 'discussion' about whether I had or not! We resolved it by looking at the TEWS page which showed that we still had a full quantity of flare onboard. A third missile was launched when the first two petered out, and once again I rolled into it and it flew by a little too close for comfort. Climbing back up to altitude they shot two more at us from an adjacent site some 10 miles to the East, but we still had good airspeed and I was able to defeat these two also. For these latter two missiles we got no TEWS indications and we later concluded that they had attempted a visual launch.
>
> Surprisingly, we were both pretty calm. I was lucky because my WSO, Major Willis, was a Desert Storm veteran and had been shot at before. It was a surreal experience, they looked like fireworks; they were beautiful. In some senses it was almost mesmerising. I remember asking Major Willis, 'Hey, is that a missile left, 10 o'clock?', he looked and responded with an emphatic 'Yes'!

Milosevic finally relented and allowed some of the thousands of displaced Kosovan Albanian refugees back to their homes. Operation Joint Guardian was subsequently activated to provide administrative oversight and security to this process. The 492nd FS deployed on 10 January 2000 for three months with six jets, so did the 494th FS on 22 May to 23 June.

Operation Enduring Freedom

Following the September 11 2001 terrorist attacks, twelve F-15Es from the 391st FS departed Idaho on 12 October and began a lengthy trip to Ahmed Al Jaber Air Base, Kuwait, where they began operations under the command of the 332nd Air Expeditionary Group.

In some respects, the thirty-six Bold Tigers (eighteen pilots, eighteen WSOs) were better prepared for this war than might have been imagined. America's tenuous relationship with Afghanistan had certainly not improved since limited cruise missile strikes targeting Osama Bin Laden had been ordered by President Bill Clinton in October 1998.

Astute planners and patch wearers within the squadron had taken it upon themselves to build up a picture of what kind of a foe Afghanistan would make. Beavering away in their squadron's secure Intelligence room, they had pieced together a basic picture which suggested a non-existent air threat and an unsophisticated Air Defence system consisting of Man Portable Air Defence Systems and Anti Aircraft Artillery equipment.

Arriving in Kuwait to a somewhat uncertain tasking, they had at least some idea as to what they would be up against. It had been obvious during the squadron's studies that Afghanistan's dilapidated infrastructure would offer few fixed targets of real value. Indeed, the squadron had specifically trained for the eventuality that much of their work would see them making full use of Forward Air Controllers, as Lt. Col. Andrew Britschgi, 391st FS CO, reflected:

> We knew that we'd end up working mostly with FACs if we were ever tasked to strike targets in Afghanistan; we therefore practiced that mission regularly over the course of our peace time schedule. We also knew that our role within any deployment would be as the primary player, and there is no doubt that our training translated well into the way in which we operated over there [Afghanistan]". The Bold Tigers believed that FACs would guide them to mobile or time critical targets over jam resistant radios. Time would soon tell just how accurate their prediction had been.


MO

The CAOC at McDill AFB, Florida, built the ATO. In late October 2001 (some two weeks after the air war had started), "TJ" led the first wave of F-15E attacks, meeting little resistance once over the target. As they returned mid-afternoon, the second Strike Eagle wave took aloft, and so began an almost continuous cycle of F-15E strikes which would run for three months.

"For the first fortnight or so, military buildings, Taliban supply depots, caves and Al Qaeda training camps were the key focus of our attack", commented "Fang", a highly experienced WSO who had already seen combat in the Balkans and ONW/OSW.

> Crews would receive the frag [ATO] the night before a mission was flown. The guys not scheduled to fly would break out the ATO and plan the next day's sorties throughout the remainder of the night. When our own resources were inadequate we used commercial sources, such as 5m resolution satellite imagery from Georgia State University, to fill the blanks. CAOC would provide suggestions for weapon types and delivery modes, but on the whole the Squadron would run things as we saw best, and only rarely did the CAOC ever tell us how to get the job done. Once the sorties had been planned, the guys flying could come in the next morning one hour before their briefing, familiarise themselves with the route, brief the mission and then step to the jets for engine start.

Caves

Both AGM-130 and EGBU-15 were employed against caves and underground facilities in the first weeks of the war. They were also used to strike targets that were difficult to identify under normal conditions or when desired weapons effects were required. It was the first time that the EGBU had been used in anger and was one of just a number of firsts achieved by the Bold Tigers in Afghanistan.

The GBU-24A/B, fitted with the BLU-109 penetrator warhead, was used for the destruction of reinforced targets and underground Taliban facilities. The GBU-24A, fitted to a Mk 84 body, was also used. Both variations featured either a WGU-12B/B or WGU-39/B laser guidance kit, which were designed to make use of the GBU-24's enhanced low altitude delivery envelope.

The GBU-28 was also used to strike Taliban command and control centres and cave entrances. A total of five were dropped. "We prepared ourselves for the arrival of the BLU-118/B thermobaric bomb, but it arrived too late in theatre for us to use", said Britschgi. That honour fell to the 335th FS Chiefs, who replaced the 391st FS in January 2002.

Often, the Strike Eagles would operate as a two-ship alongside other two-ship flights of F-16s. "The F-16s had VHF radios, and this made it much easier to talk to civilian ATC agencies, since most didn't closely monitor their UHF. All players like AWACS and the ground FACs had UHF capability, so VHF made things a little easier for going to and from the target area", said "Spear", an F-15E pilot with the Bold Tigers. "For the most part, we'd fly as two ships and would link up with the F-16's over Afghanistan. They would often fly separate orbits from us, but we'd share the same Tanker. Only rarely did we ever fly as four F-15Es", he added.

Within a matter of weeks, CAOC planners were discovering that they had almost exhausted their list of meaningful fixed targets. From very early on in the operation they had recognised that a growing number of targets were falling into the time sensitive tasking category (that is to say, targets which could move or hide if they were not attacked within a certain window of opportunity – people, vehicles etc.) and it was time to change the way in which air assets were tasked.

The Taliban had access to Soviet made SA-7 and US made Stinger MANPADS and they had AAA guns of a variety of calibres, but very little of this was radar directed. They had no air force. "A lot of their AAA was sound activated", said Spear. "They'd hear us and fire at where we had been, but they never really came close to us". Britschgi concurred, "In the time I was there, I did not get locked up by a single hostile radar".

Fixed SAM sites around such cities as Mazar-I-Sharif and Bagram were struck very early on with precision weapons, although they may not have been serviceable to begin with. In all, the Area of Operations (AOR) was classed as low-threat. Indeed, there was not a single instance of an F-15E jettisoning its external fuel tanks in response to being shot at.

Taliban who fired their shoulder mounted missiles rarely posed a threat, as most aircraft were well above the 7,000' engagement zone of these early generation infrared guided missiles. Spear commented that the Taliban "conserved their missiles early on in the campaign, but as the war progressed their frustration mounted and they began to fire more and more". Britschgi reflected that this was the way in which the air war was waged – the Taliban and al-Qaeda were powerless to defend themselves, and futile attempts to do so only brought them more misery as their location was identified and then bombed.

The Iranian Air Force launched several sorties to observe proceedings but did not cross the border

OPPOSITE
Bold Tiger F-15Es returned home in late 2001 with impressive mission markings. (Author)

and there are no reports from US aircrew of any encounters with them. "We were told not to take any unnecessary risks", said Fang, "and we had a range of divert fields that we could fly into if we had an IFE [in flight emergency]", added Spear.

Both of these factors gave comfort to the Bold Tigers, for whom an ejection over Afghanistan was a distinctly ugly prospect. Fang said, "We knew that there were huge distances involved in getting to friendly lines, and the fact that Afghanistan is so heavily mined gave us real food for thought".

As predicted, some three weeks into the operation the Bold Tigers' tasking changed from specific targets to on-call support for pre-set vulnerability times. Fang compared the system in Afghanistan with those that he had previously experienced:

> The US Army had established a grid system worked out according to Army placement of FACs. It was far better than the east/west system used in Kosovo – we had very specific areas of responsibility here. Our new tasking was geared explicitly to making sure that time sensitive targets could be hit as expeditiously as possible. Our ordnance for these sorties would typically be nine GBU-12s or a mix of GBU-12s and Mk 82s, but we also used 10 other symmetric and asymmetric loads according to mission requirements.

A third first for the Strike Eagle occurred when a GBU-28, two GBU-24s and six GBU-12s were released in a single sortie.

Night CAS

Much of the Bold Tigers' combat took place at night, when the Taliban felt safest to move.

"Calls for support were often as a result of Northern Alliance troops flushing the Taliban out of hiding and forcing them to take to the open. Our radio chatter would be intense at times, and we were far from refining the art of night CAS", Fang recalled. Spear continued:

> The lead pilot or WSO would sometimes be talking to a FAC who was not fully trained in the art of directing air strikes, so we had a very busy environment up there. NVGs helped us, but most of our work was done with the target pod.

Occasionally, humidity and smoke obscured the pod's view and the FAC would walk the F-15E's bombs onto the target with verbal corrections ("next bomb 50m north of your last", for example).

> When the target could be clearly identified, the two-ship element would discuss the placement of their bombs before actually running in on the target. We did not want the debris and smoke from one another's bombs to obscure the target.

People, vehicles and convoys were the most frequent targets called in, and the former were dispatched with proximity fused Mk 82s. The CAOC permitted the use of cluster weapons early in the campaign, but the Bold Tigers refrained from using them due to their indiscriminate nature.

For moving trucks, tanks and convoys, GBU-12s were the weapon of choice: "We became quite adept at hitting vehicles travelling at 60mph with the GBU-12. We'd simply place our crosshairs in front of the lead vehicle, release the weapon and then walk the laser spot back onto the target", said Britschgi. The GBU-12 was the precision munition most often employed not only because it was relatively low cost, but also because it did not exhibit a propensity for falling short of the target like some of the larger GBU series did. This was an important consideration when dropping weapons within close proximity of civilians or civil buildings. Extra precautions were also taken: "We used brand new seeker heads to make sure they worked right", said Britschgi.

When troops in contact (TIC) taskings came in, the Bold Tigers would venture down low to ensure maximum weapons and target identification accuracy. Several times they struck Taliban troops who were so close to friendly troops that the FAC would whisper their radio calls. In one example, a US special forces FAC requested a strike on Taliban trucks, travelling in convoy and about to requisition a key bridge. The soldier, speaking in hushed tones, requested that the Taliban be hit without the destruction of the bridge, over which the enemy was now swarming. The obliging Strike Eagle driver rolled in and decimated the Taliban convoy with several hundred rounds of 20mm M56 High Explosive Incendiary. The bridge remained standing and was used later that day by the Northern Alliance to move in reinforcements.

Sometimes, FACs used their own lasers. "The FAC would call a run-in heading, we'd synchronise laser codes so that our bomb recognised his laser beam, and we'd roll in and pickle off a GBU-12 which the FAC would then guide to target. It worked well", said Spear.

In these scenarios, the GBU-12 was favoured not only for its ballistic properties, but also for its smaller explosive footprint.

In addition to FACs, the F-15E also worked with Predator drones, although the Gold Pan was not used as the ground support equipment necessary to support it was unavailable.

Some sorties ended in frustration. All aircraft

OPPOSITE
More Bold Tiger F-15E mission markings, photographed within weeks of the squadron's return from operation Enduring Freedom in late 2001. (Author)

in the theatre were operating under strict rules of engagement (ROE), especially those providing close air support.

The Bold Tigers took HQ-assigned ROE as a minimum criterion for weapons release and added their own discriminators to the equation. Fang explained:

In all situations, targets had to be visually identified by the FAC as hostile; this had to be concurred by Lead; then concurred by his wingman before we would strike a target. If either of the three decision makers had reservations or could not see the target, then weapons would not be released.

Crews were genuinely concerned about the potential for civilian casualties and worked hard to ensure that these were avoided at all costs. Fang cited a terrorist training camp by way of example:

It measured 200' x 200' and was tasked for complete destruction, the limfac [limiting factor] was that it lay directly next to a mosque. We used GBU-12s to systematically demolish the camp, but left the Mosque standing and untouched. As an added layer of protection, we only ever employed large weapons like the GBU-24 and GBU-10 2,000lb bombs when there was very little chance of collateral damage.

The Bold Tigers also flew reconnaissance missions, often at the behest of a FAC, and would scout roads and valleys for Taliban activity using the AAQ-14.

E-8C J-STARS aircraft were also in theatre, although only a limited amount of work was accomplished with this platform.

The Longest Fighter Mission

During the course of their three-month deployment, four Bold Tigers entered the history books when they flew the longest fighter combat sortie – 15.5 hours (nine of which were over the target).

Crockett 51/52 was a two-ship F-15E flight tasked with patrolling a set of grid coordinates for the usual vul time of three hours. In the lead jet was "Slokes" and "Snitch"; #2 was crewed by Spear and "Buzzer", and each carried nine GBU-12s, two AIM-9 Sidewinder, two AIM-120 AMRAAM and two wing fuel tanks.

Once on-station, the flight received a TST from AWACS to contact a Predator drone control unit. The unit had been monitoring suspicious activity around a set of buildings believed to be Taliban command and control facilities.

Spear picks up the course of events:

Each jet set up two different laser codes (#1 had 1511 on the left CFT [Conformal Fuel Tank] and 1533 on the right CFT. #2 had 1522 on the left and 1544 on the right). #1 released four bombs [GBU-12s] from his jet giving us two with 1511 laser code and two with 1533. We programmed in 1533 on our laser so that we could guide two of the bombs, they had 1511 in on theirs so that they could guide the other two bombs. This way we took out two buildings, side-by-side, with simultaneous impacts. We actually flew two passes, the first to ensure that we had the correct targets, the second to actually drop the weapons.

Both targets were neutralised.

During the course of this action, an AAA piece had been firing at the flight, and this too would have been attacked but for the fact that it stopped firing at them and they were unable to locate it. One more building was struck and demolished following a second TST Predator tasking. Crockett flight pressed on to fly a road recce following a FAC call to request their help in identifying some road traffic he had spotted. Unsure of identity of the traffic, the flight soon came across a Taliban roadblock in the mountains and quickly dispatched it.

Having already air refuelled several times, the flight was taking fuel for their journey home, when AWACS called them and asked them to contact Predator once again. A third building was assigned to them, and each jet rippled two GBU-12s once more. The building, suspected of sheltering Taliban combatants, was directly hit and destroyed.

Crockett flight had refuelled twelve times (each refuelling giving them 1-1.5 hours of loiter time) and had been hugely successful in terms of weapons delivery accuracy and weapons effects accomplished. Although the duration of the sortie was exceptional, Spear seemed more impressed that his backside could still hurt a week later!

On 7 January, 2002, the 366th AEW welcomed the 391st FS from what had been a highly successful deployment. They were replaced by F-15Es of the 335th FS.

The Bold Tigers had achieved a sortie generation rate better than 85%, flying 2-8 sorties every day, each of which lasted 6-9 hours and involved anywhere up to 12 air refuellings.

The tactics they had used were heavily modified, and F-15E Fighter Weapons School instructors heaped praise on them for their innovation and success rate, Britschgi concluded:

Some of our most recent graduates did a fine job of making things happen in Afghanistan. Thinking through and executing non-standard tactics to achieve the desired results is more important than mastering a single mission type; our boys made us proud.

The Battle For Roberts' Ridge

The Chiefs continued the sterling work of the Bold Tigers in Afghanistan through early 2002. However, one mission stood out most prominently, as recalled by Lt. Col. James Fairchild:

On 4 March, I was flying as lead WSO with Maj. Chris Short, call sign Twister 51. Our wingman, Twister 52, was Capt. Kirk Rieckhoff and Capt. Chris Russell. Our loadout was 9 x GBU-12s, 2 x AIM-120, 2 x AIM-9, and 510 rounds of PGU-28 bullets. About 4 hours into the mission, right around first light, we got a call to support Texas 14 [a ground FAC]. We dropped a single GBU-12 (500 pound LGB) on an observation position (OP) on a ridge line known as the "Whaleback", and were prepared to continue working the ridge when we got the call to support Mako 30, a SEAL [Sea Air And Land Special Forces] team searching for a SEAL Roberts, who had fallen from a Chinook following an ambushed insertion.

Mako 30 reported he was taking fire and needed air support, so we made two passes and dropped a GBU-12. He then called that he was still taking fire and was moving east with two wounded and one KIA [Killed In Action]. A helicopter looking for Roberts on the ridge [Razor 01] was shot down at this time, but we did not know it until just after we dropped the bombs. Simultaneously, we were directed to clear the target area/restricted area where Operation Anaconda was being conducted – a B-52 was inbound to drop JDAMs in the vicinity. We took advantage of this break to go get gas and rejoin the flight – Twister 52 had already been sent to the tanker.

Coming off the tanker we were tasked to work with Texas 14 again. Twister 51 employed 3 GBU-12s on the Whaleback and Twister 52 employed 8 GBU-12s also on the Whaleback. We were then told to contact Slick 01 – the call sign of the controller with the downed crew of Razor 01 – who advised they were from the downed helicopter. They reported that they were taking fire from enemy forces that were within 75 meters of their position; this meant we would be providing CAS "Danger Close". Using the helicopter as a common reference point, Slick 01 was able to talk us on to the enemy position using visual references and the targeting pod. We made one 20mm strafe pass, but were called off dry due to GFAC calls that we were not on a good attack axis. We adjusted our run in and made three hot passes. Twister 52 also made two passes (one dry and one hot) and reported bingo fuel. We sent 52 to the tanker and talked to AWACS to get more gun capable aircraft on station, but with no luck.

We followed 52 to the tanker and took a half load of gas and took 52 back to the target area and controlled them for 4 hot gun passes. We heard Clash 7, a two-ship of F-16s from 18th FS, checking in on one of our radios, but then they checked off again. We went to the primary command and control frequency and were finally able to make contact with Clash 71. Maj. Short gave a fighter-to-fighter brief to Clash 71, talking them into the target area. We passed the target to Clash and then went back to the tanker for a full load of fuel. We got back to the target area and Clash had already bingoed out to the tanker. Both flights were Winchester bullets [out of bullets] at this time, so we talked the GFAC into letting us use GBU-12s by walking them in.

Twister 52 dropped a single GBU-12 approximately 400 meters north west of the friendly location, and the GFAC said to drop closer. So, Twister 52 then halved the distance, dropping a single GBU-12 approximately 200 meters closer. Clash 71 returned to the target area and Twister was directed to RTB.

Total mission time was 12.3 hours with approximately 6 hours spent in the working area. Follow on support was provided by B-1s, B-52s, Predator, and C-130 gunship. I can't really speak to what level of support they provided, but I know those kids were on the ground for 15 hours before they were finally pulled out.

People have made a lot out of what we did that day, but in my opinion, the real heroes of the day were the guys on the ground fighting to stay alive. I don't remember all of their names, but the two people that stand out in my mind after reading accounts of what happened are SSgt. Kevin Vance, the enlisted tactical air controller (ETAC) who fought like hell that day, and Sgt. Jason Cunningham, the PJ who was killed while collecting casualties and treating wounded.

05

AIRCREW TRAINING

Strike Eagle IPs and IWSOs

In 1995, all F-15E training was moved to Seymour Johnson. The 333rd FS, Lancers, and 334th FS, Eagles, were an integral part of the 4th FW and shared students arriving from training bases around the United States. The four F-15E squadrons of the 4th Wing became known as the Eastern Seaboard AEF.

The main training programme, the F-15E Basic Qualification Training Course (B-course), the Transition/Re-qualification (TX) course, and Instructor Qualification Training course, were run by both squadrons.

Most of the Eagles' and Lancers' jets, which carried Blue and Red tail stripes, respectively, were in their early teens and averaged between 3,500–4,000 flight hours in 2002.

The B-course accepted pilots and WSOs from Undergraduate Pilot/Navigator training schools and from other USAF platforms. In the case of the former, aircrew came from the Introduction to Fighter Fundamentals course, which taught basic fighter manoeuvres and operations in the T-38 Talon jet trainer.

The B-course was designed to take these fledgling fighter aircrew to a standard where they were proficient in basic air-to-air and air-to-ground tasks. It used two benchmarks to ascertain when students had achieved this – when they could fly a day or night, single-ship or wingman ingress and egress, at 500' to a pre-planned target; and when they could defend against, intercept or engage two enemy aircraft. This meant that they were proficient in BFM, intercepts, day or night air-to-ground weapons deliveries, and LANTIRN operation at 500' in poor weather.

B-courses ran back-to-back, often with one starting before another had finished, and at any time the Lancers or Eagles could be running three courses in parallel – TX, B-course and IWSO/IP course.

Typically, it took nine months and 370 hours of classroom, simulator and flying training to achieve this level of proficiency. Broken down, this translated into 255 academic hours, 63.5 simulator hours and up to 60 hours of flying training spread across 28 ground training days and 108 flying training days.

The majority of academic hours were devoted to aerial attack manoeuvring training, followed closely by aircraft general handling and NVG training. Flying training also focused in on BFM, ACM and intercepts initially, although around 70% of the time spent in the air was spent practicing surface attack, surface attack night and surface attack tactics sorties.

Invariably the student pilots would accrue slightly more hours than their WSO colleagues, this was because for the first ride of each phase an IP would fly in the WSO's cockpit for safety.

Hacker recalled that the learning curve was extremely steep.

> The training course progressed at full-blast rate regardless of the student's comfort level with each phase. I think that it took probably 20-30 hours or so for me to get comfortable enough with just flying the airplane before I could really pay attention to what was happening with the avionics and outside the cockpit. That occurred, I'd say, right around the middle of the surface-to-air phase when we started flying low-levels and dropping bombs. I

OPPOSITE
Seymour Johnson AFB, North Carolina, is home to the F-15E Formal Training Unit. (Author)

was definitely able to solo the jet no problem within that first 6-9 hours, but I wasn't really 'comfortable' with everything that was going on in the cockpit.

Academic training was accomplished by the 4th Training Squadron, which taught the students the fundamentals of operating the jet over a six week academic course, and was staffed largely by former F-15E aircrew employed by Boeing.

The 4th TS made use of integrated avionics trainers, weapons trainers and the flight simulators to prepare the 'studs' for their first flights. "George-Bob" commented:

The course is not that hard to begin with, as all the student is doing is taking his experience in training aeroplanes and applying it to the Strike Eagle. Most come having never used a HUD or programmable displays, so we have to teach them to adapt to this. I would prefer a trend gauge, although I have become used to a digital format. We don't see people struggle with digital displays, but we do have to get them used to looking in the right places for the information they need.

The average failure rate was one pilot or WSO every other class, which was an improvement over rates experienced at Luke in the early 1990s.

Few individuals experienced problems with the academics. Instead, most were washed-out because they could not keep pace with the jet. WSOs in particular could experience problems with air sickness, although this became less of a problem as they gained experience.

Extra help and instruction were at hand for those who were finding the course more than challenging, but the onus was on the student to ensure that he was applying himself fully to the course.

Privately, some aircrew believed that the qualification standards had slipped by the early 2000s. They argued that a small percentage of those reaching operational squadrons were simply not of a high enough calibre to justify the Air Force graduating them.

It is noteworthy that pilots take their checkride on TR-6 – only the sixth time they've ever flown the aeroplane. This is significant because the Form 8, onto which the checkride is documented, is the first official evaluation in any new pilot's official records! To add some perspective, pilots who underwent tanker and cargo FTU courses received their Form 8 checkride on their last flight in the FTU, after months of sim flights and actual flights.

Students were required to demonstrate proficiency in each sortie during the course. This phrase, shortened to "demo pro", meant that the instructor graded each flight, although there was no official pass or fail mark. Those who did not demo pro could be marked on a scale of 1-4, or could even be marked down as "Dangerous".

If a student graded less than a 3, he would be required to demo pro that particular task within the next two sorties or else he might be marked as "Student Non-Progression" and asked to re-fly the sortie. This additional flight was flown with a senior squadron pilot or WSO, who would identify areas necessary for additional study or practice. It was known as a "prog" flight, and failure of this sortie would result in a board of evaluation and removal from flight training.

The syllabus was highly descriptive for each sortie in the course, thus allowing students to know exactly what they were required to do and exactly what they would be graded on. Each ride was described in minute detail in a phase manual.

Offensive and defensive BFM sorties were flown first following transition rides to get the students familiar with standard operating procedures. Instructors taught skill based tasks – fundamentals – rather than tactics. The rudiments of 1v1 intercepts led to 2v1 and 2v2 tactical intercepts, and finally to 2v4. Despite keeping BFM simple, it was often a rude awakening for the nugget pilot: under g, with another fighter 9,000' in front of him pulling a max performance turn, positioning to manoeuvre the jet was far more demanding than can be imagined, especially as the student probably had no more than ten hours in the F-15 and was still struggling with HOTAS.

To make things even trickier, and perhaps the most demanding aspect of this phase, was learning to make use of air-to-air missiles such as the AIM-7, AIM-9 and AIM-120.

The F-15E offered fairly benign general handling characteristics and was similar to fly to the T-38 – often the only fast jet type that students had flown before. With the gear out and flaps down, it remained easy to fly and had no nasty tendencies. Despite having a flap blow-up feature (which retracted the flaps when 230 Knots was exceeded), most pilots got into the habit of using the flap lever to manually control flap position. They did not want the flaps automatically lowering when they got slow in BFM.

High AoA manoeuvring was good, but not in the same league as the F/A-18. Students learned to fly up to 25 units angle of attack, where the Strike Eagle still maintained good roll Authority via the two rudders when the ailerons became ineffective. The horizontal stabilisers provided some pitch movement at high AoA: "Enough to move the nose 10 degrees maybe, but that's it". Even so, this was still impressive as the F-15 stabilizers were approximately the same size as the wing on the T-38! Because they were so large, they could move a lot of air when positioned to full deflection, even in the high-AOA, low speed regime, where control authority was diminished.

Single engine operations in a clean (50,000lbs –60,000 lbs) Strike Eagle offered much less of a challenge than in the T-38, despite there being less thrust asymmetry in the Talon. To fly straight and level, the student applied about half deflection on the rudder pedals, depending on throttle setting. The big twin rudders deflected enough air to combat the rolling tendency, so a little aileron input was applied to keep the wings level. Even in full afterburner, the PW-220 jets at Seymour did not require full opposite rudder deflection.

FTU students flew with air-to-ground munitions on only two rides, carrying Mk 82s and a single GBU-12 for the final two missions, but would otherwise only operate with AAQ-14, AAQ-13, a captive AIM-9 and SUU-20 practice bomb dispenser.

The final two sorties – SAT 5 & 6 – were flown at about 65,000lbs. Pilots would often experience their first flight in a really heavy jet only once they arrived in their operational squadron, and the difference in performance took some adjusting to.

Surface attack rides taught students to employ the F-15E in the air-to-ground role, including use of the TF, NAV FLIR and the TP. Demo pro was expected in low-level formation flying down to 500', as well as in low-level attack profiles, such as the pop, level, loft and dive attacks.

Medium altitude attacks and LGB profiles were practiced in preparation for surface attack night sorties, which came next. Once again, the emphasis was on systems and procedures, so the student would be taught not only delivery profiles, but also inter-flight and intra-cockpit communications, switchology, weapons selection procedures and basic tasks like patch mapping.

Naturally, the course paid close attention to emergency procedures (EPs), and the simulator was used to teach students that the digital cockpit could also hold disadvantages. There was such a huge combination of flashing lights, MPD cautions, telelight caution panel lights, audio tones, and voice warnings, that an emergency could easily become very confusing. A good percentage of EP training was therefore dedicated to interpreting all of the pops, buzzes, and squeals that emanated from the cockpit when things went wrong. 4th TS instructors taught their students not to focus on actual cockpit indications when first trying to understand the nature of a problem. Instead, they taught to work from big

ABOVE
A line up of red tails of the 333rd FS, Lancers, on the ramp at Seymour Johnson. Note the SUU-20 practice bomb dispenser under the right wing. (Author)

to small – identifying what was and what was not working on the aeroplane. Hacker continued:

> For instance, if an engine failed, you would get an electrical generator failing, two hydraulic systems failing, etc. If that were to happen, you might look at the MPD caution and say, 'Oh, I just lost my PC hydraulic system', or, 'we've got a generator problem', and try to solve that one problem, accidentally ignoring the other. If you just looked at the EMD, you'd see that you had lost an engine, and that was causing the other failures. I've had multiple weird failures before that I couldn't figure out until I stepped back and looked at the big picture. The bottom line was that sometimes the many emergency warning indicators could complicate sorting out exactly what was wrong with the jet and could unnecessarily task saturate the aircrew. With that being said, once you knew what was wrong, the digital warning systems were great for pinpointing the precise nature of the problem.

Surface attack tactics sorties demonstrated canned threat reaction tactics for AAA (aimed and barrage), SAM and AI threats. It was based around an amalgamation of all previous phases with a realistic tactical flavour. Air-to-air intercepts and short-range engagements were re-introduced, often with Red Air played by dissimilar aircraft. The missions were also conducted as a package, with GCI and AWACS support.

At this stage, students also became more heavily involved in planning the sorties and they were challenged by more complex weaponeering and targeting problems. Electronic Warfare interference was also introduced. The formation size increased from a 2-ship to a 6-ship, and the last two sorties would often allow for release of twelve inert Mk 82 and a single inert GBU-12.

Pilot and WSO students were extremely busy on these flights, managing the sensor hierarchy, checking wind table data on the UFC, practising PVUs (even though EGI negated the necessity to do this), achieving TOTs, and setting up for bomb release.

When BDU-33 practise bombs were released, defined criteria were applied not only to the accuracy of the drop, but to the precision with which the manoeuvre was flown, said Hacker.

> For example, to 'demo pro' in indirect pop attacks the student pilot must achieve the correct run in parameters (+/- 25kts, +/- 100'), the correct pull-up attitude (+/- 5 degrees), initiate correct pull-down (+/- 500'), fly to the correct track point adjusted for wind (+/- 500'), and release the weapon at or above minimum release altitude. This makes it very easy for the instructor to decide whether a student has done enough to pass a sortie, as the detailed requirements are set out in black and white.

IWSOs monitoring student pilots faced a harder challenge during SAT sorties as they were fairly task saturated already. RAF exchange Navigator, Squadron Leader Graeme Davis, recalled:

> You had about a minute and a half to check the PACS, wind model, PVU and INS updates before the bomb had to come off. So, as WSO, I had to do all of that and monitor what the guy up front was doing in the pattern. If I became too focused and lost track of what he was doing, how could I grade him? Sometimes I just gave him a designation and then QCd what he was doing. I'm trying to teach him to fly altitude, airspeed and headings with precision. If I became too saturated it nearly always ended up with him busting those parameters.

By 2002, the MN was very rarely used as the PPKS, thus simplifying weapons release procedures for the student crews. Dare County range was used for most sorties, and the Lancers and Eagles benefited from good airspace, with a large oversea area approximately 100 miles east of Seymour Johnson, from sea level to 50,000'. Supersonic flight and chaff and flares were Authorised in this MOA. The course was a hard one that concentrated on creating good wingmen rather than autonomous flight leads.

By 1993 there was still a limited number of AAQ-14s with which to train, and while most WSOs flew with the TP at some point during the FTU course, most aircrew would actually receive a checkride for it upon arriving at the squadron. As has already been noted, software upgrades to the AAQ-14 continued to improve its performance, particularly as the jet flew directly over the object being tracked.

Computer Based Training

CBT was a relatively new form of training for the USAF at time of writing. It comprised of digitised briefing guides and training aids burned onto a CD-ROM for student use on computers.

The benefit derived from CBT was the ability to take work home and to study anywhere where a laptop or computer was available.

These unclassified CDs complemented the computerised briefing suites that were introduced to the 333rd FS in 2000 by Davis. He spent over a year planning and designing a Briefing Room Interactive (BRI) suite for the squadron, describing it as:

> A lean-ahead computerised briefing suite that comprises a ceiling mounted projector, and a large 'smart board', which acts as a 6' x 4' touch-sensitive computer screen. The software allowed aircrew to select a specific mission from the student syllabus and navigate his way through an entire mission brief using just the computer. The software contains thousands of pictures relating to the syllabus missions, all cleverly interlinked to be readily available and easy to find. Also, BRI contains the latest air force publications and regulations, removing the need for hard copy versions in each briefing room. My job was to create nine new briefing rooms using the hardware, and once that was done, massage and improve the software to allow all instructors to feel comfortable using BRI.

ABOVE
Night vision goggle (NVG) rides were introduced to the F-15E B Course syllabus in the early 2000s. (Author)

Davis arrived at the 333rd FS in May 1997, following which he spent five months converting to the F-15E via the TX course and then immediately entered the F-15E Instructor Qualification Training Course. The IP/IWSO course used upgrading Instructors to teach and grade individuals such as Davis prior to assigning them as instructors. The course lasted fifty-five days and ran for seventy-one academic hours, twelve training device hours and up to fifty flight hours.

On the FTU, instructor experience levels varied. The least experienced instructors had one operational tour and 500-600 hours on the F-15E; the most experienced had 2,000+ hours on type, and for many this included 1,000+ instructional hours.

Teaching such a varied and demanding course meant that the FTU squadrons had to go to great lengths to ensure standardised training for the students. They worked hard to ensure that all administrative paperwork was correctly filed and filled – if a student failed the course, a sizeable legal battle could ensue, and instructors and supervisors would have been required to appear as witnesses.

The 334th FS lost one jet on 11 July ,1997. Maj. Pete Whelan, instructor pilot, and Capt. Ramiro Martinez, student weapon systems officer, ejected safely from AF 89-0491 and were picked up at approximately 13:15 by a helicopter from the Coast Guard Station at Elizabeth City, N.C. Circumstances surrounding the accident remain unclear, although there it may have resulted from a bleed air duct failure or an actual engine fire. Whelan applied corrective action and pressed one engine's fire warning light (which shut off the fuel flow automatically), but he then inadvertently shut off the throttle of the remaining good engine. The ensuing dual-engine flameout gave them no other option but to eject. The

aircraft crashed in a remote, densely wooded area on the Dare County Bombing Range.

Night Vision Goggles

In 1999, the F-15E FTU introduced an 8.5 hours NVG phase to all of their courses. The following narrative describes NVG conversion and operations from an operational squadron perspective. The B-Course NVG syllabus and conversion works along very similar lines, as Hacker recalled:

F-15E crews spend a considerable amount of time learning to effectively fly and fight in the dark. Although US military aircraft have been flying at night for a dozen or more years with Night Vision Goggles (NVGs), when I started flying the F-15E in 1999, we were still solely reliant on the pod-mounted LANTIRN system for our night capability. Less than a year later, however, NVGs began arriving at Seymour Johnson and we began to transform how we did business at night. It wasn't until I was already a Mission Ready pilot in the Rockets that I began upgrading to flying with NVGs. That was in April 2001, when I had about 230 hours in the Strike Eagle.

USAF fighter aircrew wear F4949 (also called the AN/AVS-9) Night Vision Illumination System (NVIS) goggles. They are affixed to our standard HGU-55/CE helmets via a "banana clip" bracket which fits over the area where our visor normally rests. The HGU-55 must be modified slightly to use the banana clip by adding two small aluminium brackets (mounts for the goggle clip) on the forehead area. Unlike earlier types of binocular NVGs used by the Army and Special Operations community, the set-up used in the fighter community does not use a separate battery pack Velcroed to the back of the helmet. Instead, two AA-sized lithium batteries inserted into the sides of the mounting bracket provide power – one as a primary source of power, and the other one as a backup. The manufacturer claims that one battery is good for 20 hours of active NVG use.

Learning to fly (or more importantly, fly tactically) with NVGs is more than just waiting until it gets dark and then flying as if it were daytime. The NVG training syllabus in the F-15E consists of four flights to become qualified; the first sortie is an introduction to formation manoeuvring at night, 1 v 1 intercepts, and practicing all-aspect missile defence; the three remaining rides build on that experience, practicing 2 v 2 intercepts, basic surface attack, and finally a surface attack tactics sortie.

As with every flight training program, the NVG qualification process begins with familiarization training on the ground. After 6 hours of academics about how NVGs work and their limitations, we get some touchy-feely practice on how to handle and adjust the goggles. We practice inserting the NVGs into the helmet bracket and replacing the batteries while the helmet is on our cranium (this is a lot more complicated than in sounds – especially in the dark!). An important aspect of flying with NVGs is adjusting and aligning them so they fit properly, as well as focusing them prior to stepping out the door to fly. As such, we spend about 10 minutes prior to the pre-flight briefing using a low-light Hoffman "20/20" eye lane in a special blacked-out room in the squadron. Vision through the goggles naturally reduces visual acuity, although some who require glasses or contact lenses claim that properly adjusting the goggles can actually improve their vision in some instances. I see 20/15 normally and about the best I can do on NVGs is about 20/25. Proper focusing is essential to making sure that you can maximize your vision and get the most benefit out of wearing the nogs.

Cockpit Modifications

F-15E cockpit lighting was not originally designed to be NVG compatible. Consequently, the small amounts of white light produced by backlit switches and buttons can wash out the view of the goggles in flight. Even with these cockpit lights at their lowest rheostatic setting, their reflection off the inside of the canopy creates a giant glare that can significantly degrade the capabilities of the goggles.

McDonnell Douglas offered to sell the Air Force kits to make the cockpit compatible (like the export versions of the Strike Eagle are), but the AF decided not to buy them. The alternative solution to the problem is an after market modification to the cockpit lighting that is made prior to each NVG flight.

Hacker continues:

The cockpit mod consists of green-tinted plastic filters Velcroed into place over the offending lights – lights that can't be turned off or are necessary to have on for safety or tactical considerations. In the front cockpit, these covered-up lights include the lock/shoot lights on the canopy bow, the master mode lights, the caution/warning panel, the UFC display, the AI/SAM light panel, the Master Caution light, and finally a big filter over the MPCD – nine pieces in the front cockpit and seven pieces in the back. In addition, three other cockpit lights have their ordinary light bulbs replaced with NVG-friendly green bulbs; the storm/flood lights, the chart light, and the map light.

The cost for the kit and light replacement is a few thousand dollars. Ironically, one of the more valuable pieces of the NVG-modification is black electrician's tape! Anytime there is a light source that must be obscured, placing a piece of black tape over the offending light does the trick. Each time a jet is to be flown using NVGs, the aircrew must check out a modification kit from the Life Support shop and take it out to the jet with them when they step to the jet.

Once strapped into the aeroplane, a little extra time is required to get ready prior to taxiing to set up the cockpit with this nine-piece NVG kit. I keep mentioning the number of pieces because

OPPOSITE
Modifications to the cockpit lighting to create NVG compatibility included Velcro filters like the one over the caution lights in the upper image. (Author)

we were continually reminded how may pieces are in the kit, so that we don't forget to remove a piece after the flight and have it become possible FOD (foreign object damage) in the cockpit. Installation of the light filter kit is simple and straightforward, with everything mounted with Velcro, clips, or set-screws. It takes about two or three minutes to set up before taxiing and an equal time after shutting down to clean up the cockpit.

It's tough to explain what it's like flying an airplane with NVGs on. Up front, I'll note that it's probably nothing like you may be picturing it. When you wear them, they do not turn night into day, as people frequently say. A more accurate simulation is this one: take a toilet paper tube and hold it about ¾ of an inch from your eyeball. What you see through the tube is approximately the same field of view that you have while looking through the NVGs (they say it's about 40°). Think about what a challenge it would be to drive your car relying solely on the picture you see through the tube – how would you change lanes?? The problem is roughly the same while flying with NVGs. Because they have such a limited field of view, peripheral vision is essentially non-existent and I have to physically move my head to maintain situational awareness and spatial orientation. Another explanation (that I'll steal from an IWSO friend of mine) is that it's like looking at the world through a convenience store security camera – it's got a somewhat fuzzy monochromatic picture that is focused at one particular point in space and it must constantly keep moving to keep track of everything that's going on in the store.

Another interesting fact is that, since NVGs are focused out to infinity, I cannot look in the cockpit with them. To see what's happening inside the cockpit you must look around the goggles and use your normal and peripheral vision. The challenging part is that all the regular night cockpit lighting must be turned off while the 'nogs' are on. Even with the NVG compatible floodlights, the light is very dim and it's essentially a completely blacked-out cockpit. I learned that I must use pinpoint lighting from an NVG-compatible penlight affixed to my index finger to see any cockpit instrumentation, select push buttons on the UFC, or make any side-console switch changes. Normal night-flying habits dictate that a pilot should know where all the cockpit switches are by feel, but I don't want to accidentally do something irreversible simply because I misidentified a switch by touch! My previous night-flying habit was to wear the finger light on my left hand (I'm left handed and that's where I write, plus I generally place my approach plates and attack cards under my left thigh strap). On my first NVG flight I discovered that having that light on my left hand makes in difficult to see some important instrumentation on the right side of the lower instrument panel, such as the engine monitor display, the fuel display, and the hydraulic gauges. My fix on subsequent flights was to buy another finger light for my right hand as well – it works well, but I don't think most pilots wear dual finger lights. Eventually I also figured out that if I take a chemical light stick (which is NVG-compatible light) and stuff it in my G-suit near my knee such that about half of it is sticking out, it shines light on both the engine and fuel displays.

Although learning to fly with NVGs requires this re-thinking of how to setup the cockpit, the benefits significantly outweigh the inconvenience. The big advantage of flying with NVGs, obviously, is what you can see. NVGs work by taking ambient light in the visible and near-IR part of the frequency spectrum and amplifying it up to 5,000 times. This means that you can see just about anything within 100 miles producing any significant amount of light – they say that you can even see a lit cigarette at 5 miles. Aircraft strobes, of course, can be seen from much further away than that.

During my first training flight far off the North Carolina coast over the Atlantic Ocean, I could clearly see the strobes of airliners on approach into Washington Dulles and Baltimore/Washington International a hundred miles to the north and Charleston, SC, a hundred miles to the south. If I looked down, I could also see the lights of boats scattered all over the ocean that were not visible with the goggles off. Looking up, though, was the most stunning view I'd ever seen of the Heavens – there were more stars than you could possibly count. This capability is, of course, very tactically valuable. The ability to see any aircraft lighting at a great distance often means that you can actually visually see your bandits while they are still well beyond normal visual range because of the extreme sensitivity of the goggles. I learned this lesson first hand during my 2 v 2 NVG flight when, on a 60-mile set-up, I was literally tally-two [visual with two bandits] at the 'fight's on' call! I'm sure, however, that very few bandits in future conflicts will be kind enough to leave their navigation lights on for us!

The same benefits of NVGs in the air-to-air arena can be said for locating surface threats that may be shot at you. Although many SAMs leave bright flame plumes during their fly out and are easy to visually follow at night, some of the newer systems burn out and cannot be seen. Picking out these stealthier launches is significantly easier than with the naked eye. Gunfire from AAA batteries can also be seen clearly in the goggles, even without tracer bullets. When it's time to go offensive against enemies on the ground, NVGs also offer big benefits. First and foremost, the enemy can no longer hide their movements under cover of night. This lesson was painfully learned by some recently during Operation Anaconda in Afghanistan. While Al Qaeda and Taliban forces thought that the dark of night allowed them to move unobserved, NVG-equipped Strike Eagles and A-10s were able to identify and attack them with ease. Secondly, we are able to visually identify cultural and geographic features to locate ground targets, which is much easier and requires less planning than using the air-to-ground radar or the LANTIRN targeting pod.

Another important benefit of wearing goggles in a tactical airplane at night is that we can use our eyes to maintain positional and situational awareness instead of relying on-board systems such as the radar (for air-to-air engagements) or the LANTIRN system (when low level). This not only frees up sensors for use tactically, but also frees us from many of the limitations of those systems. Much of the F-15E's excellent night capability has been due to our use of the LANTIRN TF radar and FLIR systems. Although this is an excellent system, it has its limitations. One of its major limits is its ability to provide terrain protection down low while flying at steep bank angles and aggressive turn rates. This can be a major drawback in a combat environment when aggressive manoeuvring at low altitude is sometimes the singular key to survival against many of the world's formidable surface to air threats.

The terrain-following radar in the LANTIRN Navigation pod, for example, only provides fly up protection when less than 70 degrees of bank or 15 degrees of pitch. If we want to manoeuvre outside those TF limits, our safety rules dictate that we must be at least at the Minimum Safe Altitude (MSA) for the area we're flying in – 1000' above the highest object within 5 miles. In North Carolina where we train, it's not a big deal to climb up to MSA to manoeuvre because the terrain is flat and MSAs are low. In a place like Afghanistan, where there are 15,000 foot mountains, climbing to MSA to tactically manoeuvre isn't really all that practical. As you can gather, that limits the amount of tactical manoeuvring we can do while down 'in the weeds.' With NVGs, however, we are allowed to manoeuvre outside of TF limits below MSA (depending on the moon illumination level). The goggles allow us to visually detect the ground and things that are attached to it – things that would really ruin our evening if we were to hit while flying at night. Flying low with NVGs is really something that must be experienced to be appreciated properly. After having the LANTIRN NAV FLIR as my only outside view at night for so long, the clear view afforded through the NVGs is stunning.

After a half dozen flights with NVGs, I began to get comfortable flying with NVGs. Early on, I spent most of my time looking at the view through the goggles – that tended to reduce my SA level about other things that were happening outside the 'green goo in the toilet paper tube'. With a little more experience, I reduced my reliance on the NVGs, and the goggles simply became part of my night flying crosscheck along with the radar, RWR, and other instruments. I consider it now to be another sensor – like the radar, NAV FLIR, or targeting pod – that just happens to follow my helmet around. NVGs are a real tactical asset, allowing me greater situational awareness after the sun goes down. Now more than ever, it's just another way that the F-15E owns the night.

06

VARIANTS & EXPORT MODELS

F-15I Ra'am (Thunder)

On 27 January, 1994, the Israeli government announced that they intended to purchase the F-15I for their long-range, all-weather precision strike requirement.

They had evaluated the F-16, F-15E and F/A-18A for the role and selected the F-15E despite a failed last-minute attempt by Lockheed's Fort Worth Division (formerly General Dynamics) to interest them in a new version of the Fighting Falcon – the F-16ES, or Enhanced Strategic.

The F-15I was to be tasked with the destruction of "high quality targets" and was to be able to perform its mission over long ranges and in inclement weather, night or day.

The Israeli order was quickly approved by the US DoD, and a letter of offer and acceptance was signed on 12 May, 1994, between the governments of the United States and Israel.

McDonnell Douglas were to build an initial batch of twenty-one F-15Is for the IDF/AF under the Foreign Military Sales designation, Peace Fox. Peace Fox IV saw four more airframes ordered in November 1995, bringing the total to twenty-five.

The first F-15I flight took place at Boeing's St. Louis plant on 12 September, 1997.

The contract between the two parties called for full operational support in the form of spares, training and technical documentation, and Boeing and the USAF therefore worked together to provide this. Curiously, the IAF was somewhat secretive about a number of its requirements. They instructed Boeing to leave certain chapters of the F-15I technical manuals blank and to wire avionics racks to a certain voltage but to otherwise leave them empty. When Boeing replied that they could not write the manuals if they were not told what was going to fill the racks, the Israelis responded, "you do not need to know". In truth, Israel's secretive behaviour was expected. The IAF has relied for many years upon its indigenous electronics and defence industry to develop and supply leading edge avionics equipment.

OPPOSITE
A stunning portrait of the IAF's F-15I Ra'am - the F-15I. (IDF)

Minister of Defence, Yitzhak Mordechai, officially took receipt of the first F-15I at a roll out ceremony in St. Louis on 6 November, 1997. He applied an IAF decal to the freshly painted F-15 fuselage in a symbolic gesture of acceptance, and said:

> I wish to extend my heartfelt gratitude to the government of the United States, to the Boeing Company, to all of the American and Israeli employees who laboured to build this aircraft, and of course, to the aircrews who will fly it. The F-15I will provide a significant contribution to Israel's air deterrence power. I pray this aircraft will bestow upon us the wings of peace and not the ghosts of war.

Soon after, in January 1998, deliveries began to 69 Squadron 'The Hammers', Hatzerim AB, in south west Israel: the only IAF squadron to operate the Thunder. The Hammers transitioned from the F-4 to the F-15I as deliveries from St. Louis were sustained at a rate of about one aircraft per month.

Simultaneously, Martin Marietta provided thirty LANTIRN pods that had originally been destined for the F-16I fleet, and which are said to be identical to those used on frontline F-15Es.

The F-15I fleet was powered exclusively by the F-100-PW-229 engine.

Flight Training

Following receipt of its first F-15I, a small cadre of pilots and WSOs accomplished their training on a six week course in the US, but most were gradually introduced to the Eagle through an initial six month tour with other IAF F-15A/B or C/D operational Squadrons.

Many pilots had flown the F-4, and this introduction to the Eagle served the purpose of making sure that they appreciated the importance of thinking much further ahead than they were used to, according to Major Lachs, an Israeli F-15I pilot and the Hammers' Deputy Squadron Commander.

Having been operational for several years, the Hammers began to accept new recruits into the squadron fresh out of flying school. These young crews were trained from scratch to get the most out of the jet, and this was accomplished though bespoke training programs run and taught *in situ* at the Squadron.

There was no set time limit (ability notwithstanding) in which a pilot or WSO had to grasp the complexities of the aircraft. "It took a lot of practice to get good at our mission. We went slow on training to get capable crews who were confident in their aircraft and themselves". Lachs added, "The systems were very complex, and required solid training to use safely, especially at night, low level. There were no short cuts, and we were very thorough".

Eagles of a Different Feather

Whilst the F-15I was outwardly very similar to the F-15E, its avionics suite differed markedly in many respects. Internal changes could be externally identified by the lack of a bulbous AN/ALQ-128 EWWS antennae on the left vertical stabiliser; missing antenna blades for the AN/ALQ-135 ICS normally found under the forward fuselage; additional upwards facing chaff and flare dispensers on the tail booms; dual square tail boom ICS antennas; and blanked out formation strip lighting.

In addition to this, the aircraft carried small sensors mounted inside of the canopy which were part of the Elbit Helmet Mounted Sight (DASH – Display And Sighting Helmet) system.

One other obvious external difference was that the F-15I retained the so-called turkey feathers on the PW-229. The feathers were in fact petals that covered the exhaust nozzles on each PW-229 – the USAF had removed them from all PW-equipped F-15s because they were deemed to be too maintenance intensive (they were also reputed to cost about US$12,000 each). Turkey feathers also reduced drag slightly.

Breaking with the standard IAF F-15 Eagle colour schemes, Israel painted her F-15Is in a two-tone brown, green and grey scheme consisting of FS 30219, FS 33531, FS 34424 and FS 36375.

The F-15I was delivered with a revised APG-70I radar, which was detuned in HRM, EP, EA and special air-to-air modes, including the deletion of NCTR. Improvements to the radar were subsequently Authorised by the US DoD, and the APG-70I was updated to support the highest resolution 0.67nm patch maps.

Similarly, the DoD refused to allow export of the TEWS, so the Israelis installed their own Elisra SPS-2100 IEWS (Integrated Electronic Warfare System) instead. This included a missile approach warning system. KY-58 Have Quick radios were removed in favour of Israeli supplied systems. Israel installed a slightly different VTRS, indigenous CC (Central Computer), a GPS navigation system similar to EGI that gave them a CEP of 10 metres in zero-visibility, and US supplied Liquid Crystal, NVG compatible UFCs.

Lachs commented that the combination of the new VTRS and EGI system allowed them to, "Off-load target co-ordinates to other aircraft in a strike package". This was probably achieved through designating a target with the AAQ-14 or radar and then passing very precise GPS co-ordinates on to other aircraft over the Israeli manufactured secure radios. Another way in which this could have been achieved was to replay the VTRS (a feature not available in the US F-15E) in the cockpit on the way home from a strike mission to pass on GPS co-ordinates to other aircraft entering the area.

DASH Helmet Mounted Sight

Target pod, radar and EGI could all be slaved to the most obvious change of all, the Elbit Systems DASH (Display And Sight Helmet) Helmet Mounted Sight (HMS).

This system, used by all operational crews (front and back seat) had arguably turned the F-15I into the most potent weapons platform in operational use in 2002. "The most important thing that DASH gives us is line of sight. We can cue the radar or targeting pod to track or lock any air or ground threat that we can see. We don't have to work the sensors, we just look out, seek the target and designate it".

ABOVE

The Display and Sight Helmet was produced by Elbit systems and fully harnessed the F-15I's combat capabilities. It has since been replaced by Targo (pictured). (Elbit)

While low level, inclement weather and night missions may have negated some of the advantages gained from DASH, it still provided the crew with the advantage of being able to spend more time heads-up.

DASH worked by projecting a small set of information very similar to that shown on the HUD directly onto the inside of the helmet visor in front of the pilot's right eye. The brain took this image and merged it with what the left eye was seeing, in effect creating a virtual HUD. The inside right-hand side of the visor was laminated with a special matte coating to prevent glare. It was similar, if less demanding, to the monocle system used by AH-64 crews. It was powered by a battery mounted and encased in the back of the helmet. This was connected to a lead upon entry into the cockpit, at which time the pilot boresighted the system.

DASH offered a customisable de-clutter feature, which effectively removed most data from view once it observed the pilot looking into the HUD. The pilot and WSO's line of sight (LOS) was established by means of canopy mounted sensors. The battery at the back of the helmet created a very powerful magnetic field which these sensors then monitored for changes brought about by head movements. These were then translated into LOS values.

Targeting using the HMS was very simple: look and designate. A TD box appeared over any aerial target designated, or a diamond over any ground target. Conversely, the pilot/WSO could visually acquire a target designated by the TP or APG-70 by looking in the general direction of either sensor.

Full flight information was provided, including radar and weapons status. DASH made it possible to specifically target an IR missile seeker against a WVR threat. Visually locking a target that was outside of the HUD FOV helped to make sure that the target was not wingman or another friendly. Israeli F-15I pilots were eager to engage in air-to-air when the opportunity arose, although had yet to score their first kill when this book went to print in 2002. Over 50% of their missions were air-to-air oriented, and the IAF belonged to the school of thought that said, if you're a good air-to-air pilot, air-to-ground will follow naturally. "If the opportunity arose to engage a bandit, and there were F-15Cs onsite", said Lachs, "I'd happily engage and would be really pleased to steal a kill from them!".

Performance & training doctrine

The F-15I was slightly heavier than A model and pre-MSIP (Multiple Stage Improvement Program) C model Eagles, which both had lighter noses and could rate, or bring the nose to bear on an enemy fighter, faster.

Despite this, Israeli pilots maintained that it was a better air-to-air fighter than their F-15Cs, and, when used properly, was a far better package than the F-16.

Lachs, who flew A-4s, F-4s, F-16s, F-15Cs and the F-15I, explained: "We didn't furball [dogfight], we didn't have to. We'd fly through, seek, target and destroy. The F-15I had the same sort of performance as the 'C' [post-MSIP], maybe a degree or two a second less turn rate, but that's all. Our avionics, DASH and radar package were really impressive". Of the F-16, he said "It was fun to fly. You'd point the stick and the jet went where you told it to. An F-16 with a mediocre pilot could beat a good pilot in an F-15 – the F-16 was the dominating factor, not the pilot. But, in overall terms, the F-15I was superior".

His sentiments echoed Smyth's, "You didn't want to mix it up [dogfight] with the F-16 if you could help it, but I pitied the poor guy in the F-16 who had to try and even get close to the Strike Eagle".

Lachs liked the Ra'am because:

> It provided a lot of confidence when flying it, especially at night. I never felt as confident in a jet as I did in the Ra'am. It was almost as if there were no outside influences that could prevent this jet from carrying out its mission - if one system went down, another would kick in and take its place. The F-16 was nice, you didn't have to think about flying it – it was very simple. In the F-15I you had to constantly think ahead. It was much closer to the real aircraft of WWII & I, where you flew by feel and instinct. I was always using rudder, if you didn't use it, you could not get the maximum performance from the jet. In other airplanes the computer cancelled rudder out for most of the flight, and you could stand on the rudder and nothing would happen. Not so in the Thunder.

The IAF trained roughly 20% of their missions at night, and whilst trying not to fly over inhabited areas when possible, practised hard to be comfortable and effective at the long range night strike and strategic strike missions. This was a luxury that UK based F-15E crews were not afforded until winter.

The F-15I flew combat sorties regularly from the moment it entered service. Most missions flown involved the use of unguided bombs, of which the IAF had a plentiful stockpile. Even so, the F-15I was wired for AIM-7, AIM-120 and Python 4 air-to-air missiles, as well as a range of PGMs such as the GBU-10 & GBU-12 PAVEWAY I series and other indigenous stand-off weapons.

F-15I production serials:

IAF Tail Numbers	
1276/I001	1308/I014
1278/I002	1310/I015
1286/I003	1313/I016
1288/I004	1315/I017
1290/I005	1317/I018
1292/I006	1319/I019
1294/I007	1321/I020
1296/I008	1323/I021
1298/I009	1325/I022
1300/I010	1329/I023
1302/I011	1333/I024
1304/I012	1337/I025
1306/I013	

F-15XP (F-15S) Saudi Strike Eagle

Saudi Arabia made significant new aircraft purchases following Operation Desert Storm. Its ageing fleet of F-5E/F fighter-bombers were largely obsolete and its fleet of Tornado GR1s was beginning to show its age. The RAF had demonstrated that updating the GR1 with a FLIR and laser designator system was a sufficient modification to allow good medium level, PGM strike capability, although without extensive and costly refits, the Tornado would soon be outclassed.

On 1 October, 1992, Dick Cheney, US Secretary of Defence, announced that Congress had Authorised the DoD to sell seventy-two F-15XPs and associated support contracts and equipment to the Saudi Government under the Foreign Military Sale programme, Peace Sun. The XP, which was subsequently known as the F-15S, was a revised F-15E Strike Eagle with a degraded capability.

The F-15S was supplied with forty-eight sets of AAQ-19 Sharpshooter and AAQ-20 Pathfinder LANTIRN pods. The AAQ-20 Pathfinder was a degraded AAQ-13 and lacked the ECCM mode. The AAQ-20 was largely the same as the AAQ-14, although unable to hand off targets to the AGM-65 because it lacked a missile boresight correlator. Some of the air-to-air capabilities of the pod were also deleted.

The APG-70S was installed in the F-15S. It was a detuned version of the original radar, with only 60% of the radar bandwidth and limited to sixteen channels rather than the thirty-two available to full-up specification APG-70s. A limited resolution HRM mode was provided (4.7nm), although the US later upgraded this to the maximum resolution of 0.67nm.

To further reduce the F-15S' capability, Boeing deleted the Nuclear armament circuitry (as they did in the F-15I); altered the AWG-27 PACS to prevent carriage of certain stores; and deleted automatic TF from the ASW-51 autopilot.

OPPOSITE
The first F-15S awaits collection at the St. Louis factory ramp. (Boeing via Author)

The F-15S was delivered with INS, although a commercial grade GPS system was later installed to form a kind of EGI. ECM capabilities were de-tuned to provide the aircraft with good protection against other threats in the Persian Gulf, but to limit their capability against US aircraft. Consequently, modifications to all the TEWS components were made, including the interference blanker system. The ALQ-128 was initially deleted altogether, although some F-15Ss have been seen with an EWWS type antenna on the left vertical stabiliser. The NVG compatible, flat panel LCD UFC was added to both cockpits.

Peace Sun was thus oriented largely around limiting the Royal Saudi Air Force from conducting offensive operations against Israel, who had baulked at the announcement of the Saudi sale. The limitation of LANTIRN pods effectively prevented them from operating more than forty-eight jets in a strike capacity at any one time, although contrary to popular reports, the Saudis did not designate the remainder of their F-15S fleet as interceptors.

The PW-229 equipped S models were also supplied with Type V CFTs, but with BRU-46 and BRU-47 hardpoints deleted to further reduce offensive capability. This decision was later overturned, and the BRUs were installed on a batch of CFTs delivered between 1998 and 2000.

Extensive reliance on the US was an intentional by-product of Peace Sun, and an ongoing remote Detachment program ran from the 13th June 1995 (the date the first F-15S arrived in Saudi Arabia) onwards. "Jethro" was the first US F-15E pilot to arrive in Saudi to train new crews, and ferried the first jet to Saudi with his detachment commander Lt. Col. Maurice Jackson. His job was to teach three F-15C IPs, one Tornado IP and three Tornado WSOs instructional techniques via a TX and IP course based closely on the FTU syllabus at Seymour.

US Training Detachments

Khamis Mushait AB was home to the new RSAF Strike Eagles, all operated by 55 Squadron. The TX and IP courses ran for over nine months, at which point the class graduated and became F-15S instructors. Pilots were valued more than WSOs in RSAF culture, and the F-15S had all the TEWS controls moved to the front cockpit as a consequence of this. Prior to delivery of BRU equipped CFTs, MERs were purchased as an alternative, and most early training flights involved GBU-12 or GBU-10 practice interleaved with Mk 82 and Mk 84 sorties.

One welcome addition to the Strike Eagle was a VHF radio, which the E model lacked. Jethro and the whole US complement (Boeing and USAF) at Khamis Mushait AB had been briefed on what could and could not be shared with the Saudis.

There were military secrets to protect, but a line had to be trodden to ensure the Saudi pilots did not feel they were flying inferior machines. Given that at least one Saudi Prince was later assigned to 55 Squadron, this caution seems prudent.

Jethro and his colleagues had to be careful not to share AMRAAM tactics at a time when the RSAF was only AIM-7 equipped (they later received the AIM-120). Jethro recalled:

> The air-to-air radar was supposedly a full-up system, minus some US only modes, but to me it never seemed quite as good as the APG-70. It was not able to hold a lock during evasive manoeuvres by an opponent aircraft as well as I had been used to, although I have no data to support this – it is purely my recollection.

He recalled that Tornado crews had vastly different mindsets and capabilities to the F-15C crews, the latter of whom he described as amongst the best pilots he had ever flown with.

RSAF culture once again caused problems as their pay system worked on stature, and so IPs and IWSOs received more money.

Problems occurred, for example, when a Tornado WSO or IP became an F-15 student, demoting him two pay levels in the process.

> Because of this, we never received a Tornado IWSO, and the guys we ended up with were young and inexperienced. In many cases we had to tutor them through the course. Back in the States, they would simply have been washed out of the FTU altogether. As an example, on one of the first rides you gave the WSO the stick to make sure he could maintain basic control of the jet and fly us straight and level. Well, they simply couldn't – they would have crashed. Normally, within a minute of handing over control, I was having to take it back every time.

Language problems exacerbated the situation, and this resulted in a lack of patience from some of the US instructors who consequently became unpopular with the RSAF crews. Eventually, standards were sacrificed and the US IPs and IWSOs simply resigned themselves to teaching their students whatever they had the capacity to learn. The first US detachment left Saudi Arabia in November 1996.

Whilst the first detachment regularly saw US pilots and WSOs flying together because of the shortage of RSAF F-15S crews, this had changed by the time "Batman" served his tour from August 1999 to August 2000, and a new rule stipulated that aircraft had to be manned by one Saudi and one American.

55 Squadron was similar in make-up to a US squadron, with a director of operations, an operations officer and squadron commander, although the Operations Officer in the RSAF had less influence and control than was usual in the US. Attitude problems were an ongoing issue from the time that Jethro arrived to the time that Batman started his detachment:

> We saw lots of problems with DNIFs [Duties Not Including Flying], where a guy would look at the flying schedule and find he was crewed with someone he did not like. He'd go to the Doctor and get signed off flying so that he didn't have to fly with that person. It made it almost impossible to actually achieve the flying schedule we had set out.

By the late 1990s the RSAF was still struggling to produce talented aircrew, and many F-15S students did not apply themselves or were not aggressive enough to progress and develop. Saudi aircrew lacked initiative, and Batman found himself providing academic training on basic things such as Life Support to pilots and WSOs who already had 500 hours of fast jet time. Frustrated, he recalled that whilst some of them were hard working and astute, most wanted to be spoon fed and refused to apply themselves to basic tasks such as creating mission planning guides. The RSAF used AFMSS (AF Mission Support Software) similar to that used by US F-15E crews, although the USAF subsequently upgraded to Portable Flight Planning Software and Falcon view, which could be ported into MPS III (an improved AFMSS) and then downloaded into the DTM.

The F-15S was used along similar lines to the F-15E, with the primary job being air-to-ground. In 1999 the 55 Squadron flew sorties against F-14s and F/A-18s of a deployed USN carrier battle group in the region. They faired reasonably well when the engagements were neutral, although were less successful when the aggressor forces started to simulate AMRAAM shots. De-briefing was awkward because the RSAF did not have an ACMI or URITS system. Instead, a dual head VTRS system was used – this VTRS was exclusive to the S model and consisted of two recorders: one dedicated to capturing the HUD, the other to capture all four MPDs. The tapes would be played in de-briefing suites containing several VCRs and TVs which would be time synchronised.

The 99-00 detachment consisted of three US IWSOs and an IP, subsequent detachments saw this number reduced to a single IP and IWSO. Thirty-six jets left Khamis Mushait AB in the late 1990s and flew to Dhahran AB to become the first operational squadron, leaving 55 Squadron as the FTU.

Batman summarised:

> The Saudis were limited by their weapons and training. Whilst employing in large scale packages they really were weak, the package leadership was terrible and they really lacked good mission commanders. As individuals, some of them were pretty good; as an unit they were probably more capable than Iraq and Iran, but they had a lot more work to do.

F-15S production serials (US serials 93-852/923 and Saudi 5501/5572):

Saudi Tail Numbers	
1252/SA001	1289/SA034
1253/SA002	1291/SA035
1254/SA003	1293/SA036
1255/SA004	1295/SA037
1256/SA005	1297/SA038
1257/SA006	1299/SA039
1258/SA007	1301/SA040
1259/SA008	1303/SA041
1260/SA009	1305/SA042
1261/SA010	1307/SA043
1262/SA011	1309/SA044
1263/SA012	1311/SA045
1264/SA013	1312/SA046
1265/SA014	1314/SA047
1266/SA015	1316/SA048
1267/SA016	1318/SA049
1268/SA017	1320/SA050
1269/SA018	1322/SA051
1270/SA019	1324/SA052
1271/SA020	1326/SA053
1272/SA021	1328/SA054
1273/SA022	1330/SA055
1274/SA023	1332/SA056
1275/SA024	1334/SA057
1277/SA025	1336/SA058
1279/SA026	1338/SA059
1280/SA027	1340/SA060
1281/SA028	1342/SA061
1282/SA029	1344/SA062
1283/SA030	1287/SA033
1284/SA031	
1285/SA032	

F-15K Korean Strike Eagle

Amidst much controversy, South Korea announced that it intended to purchase forty F-15K Strike Eagles on 19 April, 2002.

The contract was worth more than four billion US dollars, and was awarded following an extended, two year selection process that evaluated the Dassault Rafale, Eurofighter Typhoon, Sukhoi SU-35 and Boeing F-15K under the F-X banner. The award was a triumph for General Electric, whose F-110-GE-129 engines were selected to power the new aircraft.

South Korea's Republic of Korea Air Force (ROKAF) wanted the F-15Ks by 2009, at which time it would retire its F-4s and F-5s, some of which had been in service for more than forty years. Dassault claimed that Boeing had applied political pressure on ROKAF, but these claims were met with revelations that Dassault had bribed senior ROKAF pilots to recommend the Rafale. As such, Dassault began legal proceedings against the South Korean Government in order to attract compensation for wasted expenditure in what they claimed had been a loaded competition.

The ROK needed a long-range strike aircraft to counter what they determined to be an omni-directional threat. No longer was North Korea the only major cause for concern, and from the early 1990s they had begun to look once again look closer at their historical enemies (Japan, China etc.).

Boeing were hopeful that the F-15K sale would help to open the market for Australian and Singapore requirements, who faced similar predicaments. The F-15E offered a better range/payload solution than the F/A-18 and F-16, and with three fuel tanks could carry twelve JDAMs over a thousand miles. A South Korean set of islands called Dok To were a constant source of concern for South Korea, as Japanese F-15Cs were able to patrol the area for extended periods of time. Historically, the main concern had been fishing rights, but in the late 90s it was found that there was a substantial petroleum reserve underneath the Islands and ROKAF became concerned about its ability to protect them.

The original F-X competition in 1997 had focused in on technology transfer. This meant acquiring source codes, capabilities and technologies with which to then create their own, autonomous defence industry.

ROKAF had already purchased the F-16, thus the emphasis on long-range. 15,000lbs of ordnance, 9g capability and twin engines were also key requirements. In late 1997, ROKAF released a Request For Information. Boeing replied with the F-15E and F/A-18. Following receipt of twelve aircraft offerings, ROKAF suggested that they would down select the list to four, and that the winner would most likely be required to deliver two lots of sixty aircraft starting in the mid-2000s. Respondents would supply training, ground support and spare parts as part of the deal.

In 1998, the Request For Proposals was issued to Dassault, Boeing, Eurofighter and Sukhoi. It demanded a detailed explanation as to how the RFI responses could be demonstrated and proved. In 1999, the South Korean economy collapsed, and the program stagnated for a year. During this time, a final RFP was issued following changes to the tender process. Boeing submitted forty cardboard boxes full of documents. Some of South Korea's requirements were particularly demanding – they wanted an IR Search and Track (IRST) sensor, which the F-15E lacked, for example - but on the whole, the growth potential of the airframe and the fact that the jet had adequate cooling and power gave them room to develop it to suit the RFI. Following the final 1999 RFP, the ROK government reduced the number of purchases to forty jets.

A flight evaluation lasted for three weeks, during which time ROKAF representatives were shown the PDM facilities at Warner Robins (although the Koreans plan to perform their own PDM); EW testing facilities; the planned APG-63(V)1 radar house; and simulator training. USAF IPs then flew the F-15E with ROKAF pilots in the front seat and conducted air-to-air and air-to-ground sorties. On one mission, the first two LGBs the Korean pilot released went right through the target.

OPPOSITE

A trio of F-15K Slam Eagles fly over South Korea. (ROKAF)

The CFTs were removed to demonstrate compliance with a brake release to climb to 30,000' in two minutes – the F-15E achieved it in eighty seconds, a performance that elicited the response from one ROKAF pilot that the jet climbed too fast.

Acceleration from Mach 0.6 to 0.95 had to be accomplished in twenty seconds: the F-15E did it in eight seconds..

Tom Lillis, F-15K Proposal Manager, described the changes made to produce the F-15K:

> First of all we looked at the radar. The USAF had given Raytheon the task of upgrading the APG-63 for the F-15C. We took the result of that (the APG-63(V)1), which had more capability than the APG-70 and APG-63 put together, and we re-hosted the air-to-ground software from the APG-70.
>
> We also added modes that the Koreans wanted – Sea Surface Search and Track, and GMTI. This new radar was more reliable, more capable and more powerful than any F-15 radar in the world, including the US, Israeli and Saudi variants. We updated all of the displays and then integrated it with the Joint Helmet Mounted Cueing System.
>
> In addition, we added chaff and flare dispensers as per the F-15I; installed 1760 wiring for J series weapons into all of the hard points; added a new PACS to accommodate these; installed the ADCP [the same as in installed in E-227 jets]; and made it suitable for AIM-9X and AIM-120C use.
>
> The jet was also modified to carry the AGM-84D Harpoon and AGM-84E SLAM missiles in order to accommodate for ROKAFs anti-ship mission requirement. So, it has a new weapons suite that is truly multi-mission.

The TEWS suite was also destined for modification, and the F-15K would feature some form of NCTR capability.

An improved ALQ-135M was developed, and this featured microwave power modules for increased jamming effectiveness and improved maintainability. The ALQ-135M included both Band 1.5 and Band 3.

F-15K LANTIRN pods were also slated for improvement. The AAQ-14 was supplied with a new, third generation FLIR sensor integrated into the LANTIRN pylon. Boeing called this Tiger Eyes.

The flat panel, NVG compatible, UFC found in the F-15I and F-15S was installed, as was complete NVG compatible cockpit lighting.

An ARC-232 radio was selected for UHF and VHF compatibility, and FDL provided the icing on the cake.

As Lillis dryly commented, "When the US Air Force guys learn about this jet, they are going to cry – this is all of the stuff that they want".

ROKAF supportability concerns were allayed by a signed contract with the ROKAF chief of staff saying that Boeing would support the F-15K for as long as it was in service. In addition, the USAF assured the ROK government that the F-15E would be in service until at least 2030.

The full FMS listing for the F-15K includes: AGM-88B HARM, AGM-130, AGM-142C/D, AGM-154 JSOW, AIM-9X, AESA APG-63(V)2 if opted for, GBU-12, GBU-24, JDAM, JHMCS and Mk 82 500lb bombs.

07

APPENDIX

F-15E Systems

The Engine System in the F-15E was made up of a collection of elements, namely; Engine Induction System, Engine Starting System, Engine Oil system, Ignition System, Engine Control System (ECS), Engine Monitoring System (EMS), Afterburner System, Variable Area Exhaust Nozzles, Engine Anti-Ice, Asymmetric Thrust Departure Prevention System (ATDPS), Engine Monitor Display (EMD), Fire Warning/Extinguishing System and Secondary Power System. The main elements are discussed briefly below:

The Engine Induction System consisted of two independent sets of variable ramps located just behind the air intake nozzles on either side of the aircraft forward fuselage. It controlled the flow of air before it reached the engine compressor blades. Each set was made up of three variable ramps, a variable diffuser ramp and a variable bypass door. Collectively, these elements worked together to stabilise and optimise the air being sucked into the engine at subsonic airspeeds. The bypass door blew open to alleviate excess pressure, thus providing unhindered operation across a range of airspeeds. Two Air Inlet Controllers (one for each inlet) monitored AoA and aircraft Mach to automatically move the doors, ramps and bypass according to a pre-programmed schedule. Pilot control of the inlet system was achieved through Inlet Ramp switches located just forward of the throttles on the left console. A two position switch for each inlet could be placed in AUTO or EMERG positions. AUTO was the usual mode of operation, where the AIC controlled the inlet system; EMERG offered an emergency override to force the Inlet System to allow maximum air to enter the inlet duct.

The Jet Fuel Starter (JFS), was a simple, scaled down, jet engine fitted centrally between the engines. It mechanically cranked the engines for starting via the CGB and AMAD. The JFS was started by accumulated hydraulic pressure and was the only means of starting the engines. The JFS was activated via a handle and a switch on the pilot's right hand console, and the start sequence was initiated by turning the JFS switch on, pulling the JFS handle, engaging the first engine with a fingerlift on the throttle, and then putting the throttle into idle after 20% rpm was reached. There were two hydraulic accumulators which automatically charged during flight.

The Engine Control System (ECS) comprised of a Primary (PRI) digital control (DEEC/IDEEC) and a hydromechanical Secondary (SEC) control mode. PRI offered all of the advantages discussed earlier of DEEC/IDEEC, and ran the engine scheduling across the full range of throttle positions. SEC was a back-up mode entered automatically when a fault was detected in the PRI mode software. SEC inhibited afterburner use and limited MIL power to 70%-80% of its normal value. As the PW–229s were more powerful than the PW–220s, IDEEC incorporated a Ground Idle Thrust (GIT) setting to mimic PW–220 engine performance in the taxi phase of the flight. IDEEC also incorporated a transient idle control logic that gave the pilot the freedom to snap the throttles to idle whilst the

OPPOSITE
A Bolars Strike Eagle taxies past a 493rd FS maintenance crew. (Author)

engines maintained approximately 79% rpm. Thrust was reduced in accordance with requested throttle settings, but the engines maintained core rpm momentum for twenty seconds – after which they returned to idle if no further throttle commands were been given. This elongated engine life and improved subsequent throttle response times. The pilot was given override on the operating mode of the ECS via Engine Control switches, allowing him to re-engage PRI mode if necessary or enter SEC mode if he suspected a fault. DEEC/IDEEC and the Engine Diagnostic Unit (EDU) formed the Engine Monitoring System (EMS).

The Secondary Power System provided two main functions – power the aircraft for starting and then power to the aircraft accessories once the engines were self sustaining. It was made up of the JFS, two Hydraulic Accumulators, Central Gear Box (CGB) and Airframe Mounted Accessory Drive (AMAD) gearboxes, of which there were also two.

The CGB provided a mechanical connection between JFS and the Hydraulic Accumulator. Once the JFS was started it then transmitted power to the left or right AMADs. One AMAD was bolted to each engine and routed power from the CGB during start to the engine itself. Once started, the CGB de-coupled from the AMAD which was then driven directly by each engine. Each AMAD then sustained various hydraulic systems and was capable of supporting aircraft systems in the event that the other failed. The Fire Warning/Extinguishing System linked into the JFS, AMADs and Engines, and was controlled from a dash mounted panel in the top left hand side of the front cockpit. It featured three illuminating push buttons, a one shot extinguisher bottle and aural messages ('WARNING, OVERTEMP LEFT/RIGHT', WARNING, ENGINE FIRE LEFT/RIGHT', 'WARNING, AMAD FIRE and 'WARNING, AB BURN THRU LEFT/RIGHT') which informed the flight crew of AMAD fires, Engine Fires, A/B 'over temps' and Engine 'over temps' - whereby the turbine sections of the engines were exceeding design temperature limits. Pressing one of these three lamps immediately removed power to an engine (or JFS), shut off bleed air, removed fuel flow to the engine and armed the extinguisher for discharge.

Electrical System

Two main AC generators, a bus system to distribute the electricity, three transformer-rectifiers and an emergency AC/DC generator worked together to energise the Strike Eagle's electrically driven systems.

Hydraulic System

The F-15E hydraulic configuration offered redundancy in the form of three separate systems, each of which was divided into two or more circuits. Additional security was provided by sensors that monitor the hydraulic reservoir level for each system. Upon detecting a leak, these Reservoir Level Sensors closed the faulty circuit of any the affected system.

There were two Power Control (PC) Systems and a utility system which operated at 3,000psi. The utility system actually comprised of two separate pumps and operated utility hydraulic dependent systems such as Anti-Skid, Landing Gear, Radar Antenna and so on.

The PC1 and PC2 systems, which powered flight control surfaces such as the rudders, flaps and ailerons, were broken into two separate circuits – A & B. PC1B drove the right hand control surfaces, PC2B those on the left. PC1A & PC2A worked together to power each stabilator by providing equal pressure output.

Fuel System

Void Filler Foam (fire suppressant slabs) were installed in the Goodyear wing and fuselage fuel tanks to prevent the build up of static electricity in the tanks by limiting fuel movement, which generated explosive vapours. Where possible, McAir engineers also routed fuel lines inside the tanks themselves, adding another layer of protection against shrapnel damage from a nearby or direct explosion. Polyether foam filled the gaps between the fuselage and the aircraft skin as an additional form of insurance.

The Engine Fuel System differed somewhat from that of the Light Greys, and was comprised of four interconnected fuselage tanks, two wing tanks and the CFTs. These could be refuelled on the ground through a single pressure refuelling point or, in the air, via the in-flight refuelling receptacle on the left wing root. Internal fuel capacity depended on the type of fuel being carried (JP-4, JP-8 or JP-5), but was usually around 13,500lbs. CFTs each carried 4,950lbs of fuel, in addition to the three 4,150lb external fuel tanks mounted on the wing and centre-line hardpoints. Total fuel load, including CFTs and three 'bags', came to 35,000lbs. Engine bleed air was used to transfer fuel from one tank to another, and redundancy existed in the form of gravity feed.

The fuel system was driven by three main boost pumps (two normal, one emergency), all of which were controlled via a series of switches in the Pilot's cockpit, located on the front left console. An aural message 'WARNING, TRANSFER PUMP' was transmitted to the crew upon failure of any pump, and, provided that electrical power was maintained, each pump was capable of feeding both engines with fuel in the event of the other failing. Pilots had to be wary of CG limits as the aircraft depleted internal and externally carried fuel, and the CFTs could trap fuel which led to CG limit boundaries being exceeded (and possibly a subsequent departure from controlled flight). Although an automatic schedule controlled the rate and quantity of fuel feed from each tank in order to preserve the aircraft CG, fuel could be transferred during flight by the pilot. To ensure that CG concerns were minimised, the fuel feed schedule was automatically accomplished by the Strike Eagle's computers, and the pilot was equipped with a switch that allowed him to automatically prioritise fuel transfer from the CFTs first. In this way, a CFT fuel pump failure would have a nominal impact of CG travel and allow the crew to quickly diagnose the problem before it became a safety of flight issue.

Fuel Capacity

Tank	Usable Fuel, US Gallons
Tank 1	604
Tank 2 (Right Engine Feed)	234
Tank 3 (Left Engine Feed)	189
Internal Wing tanks (x2)	496 (x2)
Total Internal Fuel without CFTs	2,019
Total Internal Fuel plus external Wing Tanks, without CFTs	3,239
External CL Tank	610
Total Internal Fuel plus external CL Tank	2,629
Total Internal Fuel plus three external Tanks, without CFTs	3,849
Conformal Tanks	728 (x2)
Total Internal Fuel plus CFTs	3,475
Total Internal Fuel plus external Wing Tanks, plus CFTs	4,695
Total Internal Fuel plus external CL Tank, plus CFTs	4,085
Maximum Fuel Load	5,305

Production Figures (to 2002)

F-15E	236 USAF
F-15S	72 RSAF
F-15I	25 IAF
	333 Total
USAF	
71-29	McDonnell Douglas F-15B-4-MC Eagle
	Used for evaluation of FAST Pack conformal fuel tanks and LANTIRN pod. Also became development aircraft for F-15E Strike Eagle
86-183/184	McDonnell Douglas F-15E-41-MC Strike Eagle
86-185/190	McDonnell Douglas F-15E-42-MC Strike Eagle
87-169/189	McDonnell Douglas F-15E-43-MC Strike Eagle
87-190/210	McDonnell Douglas F-15E-44-MC Strike Eagle
87-211/216	Cancelled contract for McDonnell Douglas F-15E
88-1667/1687	McDonnell Douglas F-15E-45-MC Strike Eagle
88-1688/1708	McDonnell Douglas F-15E-46-MC Strike Eagle
89-471/488	McDonnell Douglas F-15E-47-MC Strike Eagle
89-489/506	McDonnell Douglas F-15E-48-MC Strike Eagle
90-227/244	McDonnell Douglas F-15E-49-MC Strike Eagle
90-245/262	McDonnell Douglas F-15E-50-MC Strike Eagle
91-300/317	McDonnell Douglas F-15E-51-MC Strike Eagle
91-318/335	McDonnell Douglas F-15E-52-MC Strike Eagle
92-364/366	McDonnell Douglas F-15E-53-MC Strike Eagle
92-607/608	McDonnell Douglas F-15E Strike Eagle
96-200/205	McDonnell Douglas F-15E-58-MC Strike Eagle c/n 1327/E210, 1331/E211, 1335/E212, 1339/E213, 1341/E214, 1343/E215
97-217/222	Boeing F-15E-61-MC Strike Eagle E216 to E221
98-131/135	Boeing F-15E-62-MC Strike Eagle E-222 to E226
00-300/304	E-227 - E231
01-2000/2004	E232 - E236

LEFT
A weapons crew assemble a GBU-10, starting with the seeker head at the front. (Author)

USAF F-15E Block numbers

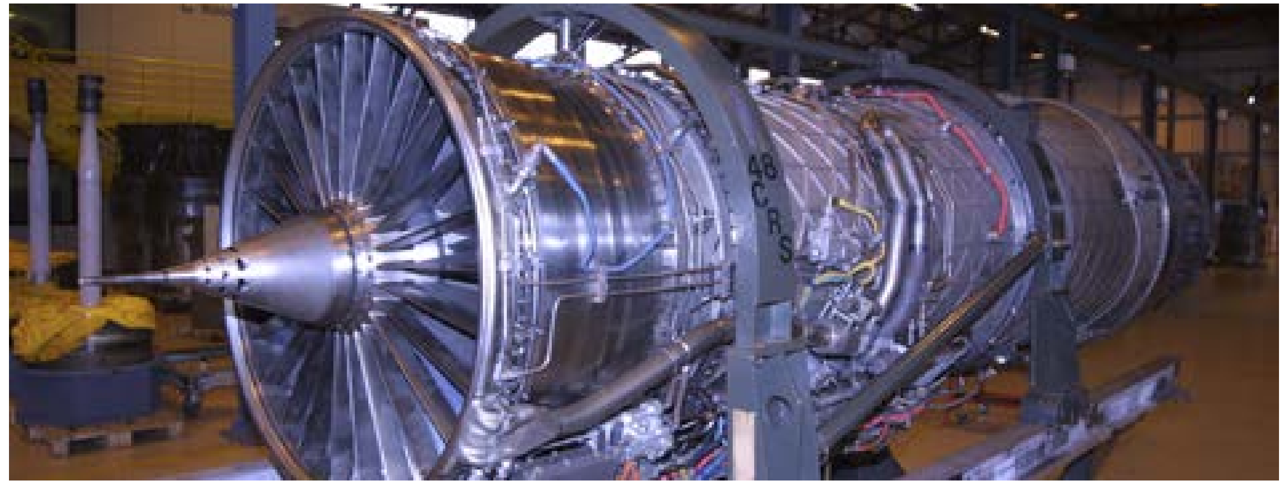
Block 41 86-0183 and 86-0184
Block 42 86-0185 through 86-0190
Block 43 87-0169 through 87-0189
Block 44 87-0190 through 87-0121
Block 45 88-1667 through 88-1687
Block 46 88-1699 through 88-1708
Block 47 89-0471 through 89-0488
Block 48 89-0489 through 89-0506
Block 49 90-0227 through 90-0224
Block 50 90-0245 through 90-0262
Block 51 91-0300 through 91-0317
Block 52 91-0318 through 91-0335
Block 53 91-0600 through 91-0605 and 92-0364 through 92-0366
Block 58 96-0200 through 97-0222 ('E210' standard)
Block 59 98-0131 through 98-0135 ('E-222' standard)
Block 60 E-227 through E237

F-15E approved stores

AGM-65A/B/D/G
AGM-130
BDU-38
BLU-107/B
CBU-52. CBU-58, CBU-71, CBU-87, CBU-89, CBU-97
GBU-10
GBU-12
GBU-15, EGBU-15
GBU-24
GBU-28
Mk 20
Mk 82 AIR, Mk 82 LDGP, Mk 82 SE
Mk 84 AIR, Mk 84 LDGP
610 Gallon Fuel Tank
AXQ-14 DLP
ZSW-1 IDLP
MXU-648 Travel Pod
AIM-7F/M
AIM-9M/L/P
AIM-120A/B/C
AN/ASQ-17/20/21/25/27/27(V)1/29 AIS pods
SUU-59A/C
SUU-20B
SUU-73A
B-61-3/-4/-10

Technical Specifications

Power plant: Two Pratt & Whitney F100-PW-220 or 229 turbofan engines with afterburners
Thrust: 25,000 - 29,000 pounds each engine
Wingspan: 42.8 feet (13 meters)
Length: 63.8 feet (19.44 meters)
Height: 18.5 feet (5.6 meters)
Speed: Mach 2.5 plus
Maximum takeoff weight: 81,000 pounds (36,450 kilograms)
Service ceiling: 50,000 feet (15,000 meters)
Combat ceiling: 35,000 feet (10,500 meters)
Unit cost: $31.1 million (fiscal 98 constant US dollars)
Range: 2,400 miles (3,840 kilometers) ferry range with conformal fuel tanks and three external fuel tanks



ABOVE
The PW-229 engine is visually distinguishable from the PW-220 by the hatched casing and the pointed compressor spike. (Author)



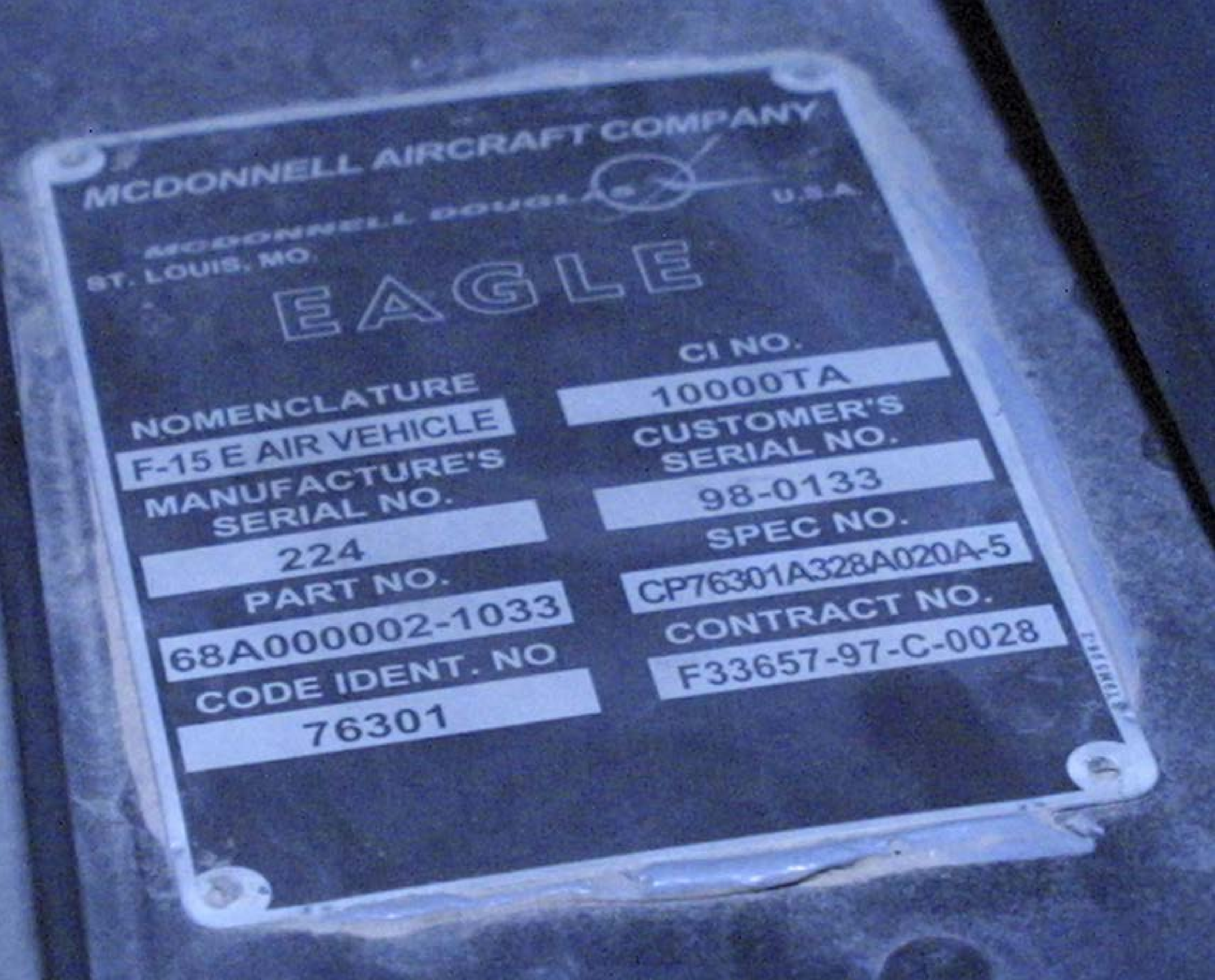
08

GLOSSARY

Acronym	Definition
A/B	Afterburner
AAA	Anti Aircraft Artillery
AAI	Air to Air Interrogator
AC	Alternating Current
ACM	Air Combat Manoeuvring
AEF	Air Expeditionary Forces
AFCD	Advanced Fighter Capability Demonstrator
AGL	Above Ground Level
AGM	Air-to-Ground Missile
AHRS	Attitude Heading Reference Set
AIC	Air Inlet Control unit
AMAD	Airframe Mounted Accessory Drive
APG-70	F-15E radar
ASL	Azimuth Steering Line
ATDPS	Asymmetric Thrust Departure Prevention System
ATF	Auto TF
ATO	Air Tasking Order, also known as the 'frag'.
AWACS	Airborne Warning And Control System
BFM	Basic Fighter Manoeuvres
BIT	Built In Test
BLATS	Built up Low cost Advanced Titanium Structure
BRU	Bomb Release Unit
CAOC	Combined Air Operations Centre
CAP	Combat Air Patrol
CAS	Control Augmentation System, or Close Air Support
CBU	Cluster Bomb Unit
CC	Central Computer
CDIP	Continuously Designated Impact Point
CFT	Conformal Fuel Tank
CG	Centre of Gravity
CGB	Central Gear Box
CMD	Counter Munitions Dispenser
DASH	Display And Sighting Helmet
DC	Direct Current
DEEC	Digital Electronic Engine Control
DEL	Direct Electric Link
DFCS	Digital Flight Control System, also known as DAFCS
DLL	Design Load Limit
DLP	Data Link Pod
DMS	Digital Mapping System
DTC	Data Transfer Cartridge
DTM	Data Transfer Module
ECCM	Electronic Counter Counter Measures
ECM	Electronic Counter Measures
ECS	Engine Control System
EDU	Engine Diagnostic Unit
EGBU	Enhanced GBU
EGI	Embedded GPS/INS
EID	Electronic Identification
EMD	Engine Monitoring Display
EMU	Engine Management Unit
EP	Electronic Protection
ESL	Elevation Steering Line
EW	Electronic Warfare, or Early Warning

EWWS	Electronic Warfare Warning System
FAST	Fuel And Sensor Tactical
FCP	Front Cockpit
FDL	Fighter Data Link
FLIR	Forward Looking Infrared
FMS	Foreign Military Sales
FOFA	Follow On Forces Attack
FOR	Field Of Regard
FOV	Field Of View
FTU	Formal Training Unit
GBU	Guided Bomb Unit
GIT	Ground Idle Thrust
GMTI	Ground Moving Target Indicator
GMTR	Ground Moving Target Rejection
GPS	Global Positioning System
HMS	Helmet Mounted Sight
HOTAS	Hands On Throttle And Stick
HRM	High Resolution Map, also known as a 'patch map'.
HUD	Heads Up Display
IADS	Integrated Air Defence System
IAF	Israeli Air Force
ICMS	Internal Countermeasures Set
ICS	Intercom System
IDEEC	Improved DEEC
IDLP	Improved Data Link Pod
IFF	Identify Friend or Foe
ILS	Instrumented Landing System
INS	Inertial Navigation System
JFS	Jet Fuel Starter
JSTARS	Joint Surveillance, Targeting and Attack Radar System
LDGP	Low Drag General Purpose
LHC	Left Hand Controller
LOS	Line Of Sight
LOX	Liquid Oxygen
LPI	Low Probability of Intercept
MER	Multiple Ejector Rack
MIL-STD	Military Standard
MN	Mission Navigator
MPCD	Multi Purpose Colour Display
MPD	Multi Purpose Display
MPDP	Multi Purpose Display Processor
MSOGS	Molecular Sieve Oxygen generation System
MTF	Manual TF
MUX	Multiplex Bus
NCTR	Non Co-operative Target Recognition
NVG	Night Vision Goggles
OFP	Operational Flight Program
ONW	Operation Northern Watch
OSW	Operation Southern Watch
OWS	Overload Warning System
PACS	Programmable Armament Control System
PB	Push Button
PFM	Pre-Fight Message software
PGM	Precision Guided Munition
PPKS	Present Position Keeping Source
PVU	Precision Velocity Update
RAF	Royal Air Force
RCP	Rear Cockpit
RF	Radio Frequency
RHC	Right Hand Controller
RLG	Ring Laser Gyro
RMR	Remote Map Reader
ROKAF	Republic of Korea Air Force
RSAF	Royal Saudi Air Force
RTU	Replacement Training Unit
RWR	Radar Warning Receiver
SAM	Surface to Air Missile
SAR	Synthetic Aperture Radar, or Search and Rescue
SCP	Set Clearance Plane
SEAD	Suppression of Enemy Air Defences
SPF/TB	Super Plastic Forming Titanium Bonding
TAC	Tactical Air Command
TACAN	Tactical Air Navigation aid
TACC	Tactical Air Control Centre
TAWRS	Tactical All Weather Requirements Study
TDC	Target Designator Control
TER	Triple Ejector Rack
TEWS	Tactical Electronic Warfare System
TF	Terrain Following
TP	Target Pod
TR	Transformer-rectifier
TSD	Tactical Situational Display
TST	Time Sensitive Targeting
UFC	Up Front Controller
VHSIC	Very High Speed Integrated Circuit
VLC	Very Low Clearance
WFOVHUD	Wide Field Of View Heads Up Display
WSO	Weapons Systems Officer
ZCL	Zero Command Line

OPPOSITE
Be afraid of the dark. (Author)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ST. LOUIS, MO.
U.S.A.
EAGLE
NOMENCLATURE
F-15 E AIR VEHICLE
MANUFACTURE'S SERIAL NO.
224
PART NO.
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CODE IDENT. NO
76301
CI NO.
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