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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 as 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 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 hypothesised that any conventional attack into Western Europe 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 re-enforcements, it would be decimated by NATO forces who had quickly deployed to the area from further afield.

The F-111 was an ideal platform to accomplish this role. It had extensive range and could carry many tonnes of bombs to even the most distant European choke points. The Pave Tack pod was a combined FLIR tracking system and laser designator that gave the F-111F a fully autonomous precision guided munition capability – it could 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 on NATO. Each was assigned seventy or so aircraft (of which only one Wing, the 48th TFW, RAF Lakenheath, operated the F model), and so there was some concern that there were simply not enough airframes to get the job done.

(Left) The F-111F was the mainstay of the FOFA attack concept and was highly capable. (USAF)

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.

The Aardvark was looking more and more vulnerable to air attack, and NATO strategy had to evolve in response to this. TWARS was the answer.

McAir and the F-X Program – the 1960s

Some 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 was beginning to show signs of its age though, and the Air Force knew that a replacement would have to be found.

A study and lengthy tender process began in 1965 called F-X, or Fighter Experimental, concluding in McDonnell Douglas being awarded a contract in December 1969 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 for it to carry 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, which 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. 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 bombing techniques that used fixed reticules, which 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. It therefore represented 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

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

the Strike Eagle concept – as yet unborn – was the FAST pack.

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 gaps between the two were inevitable at some points.

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

The team also evaluated other locations for FAST packs to be attached, such as in the form of a slipper tank under the bottom of the fuselage, but there were too many problems caused by landing gear and missile placement.

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. To maintain this equilibrium, each pack consisted of 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 these, 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 co-efficients 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 which became inaccessible once the FAST pack was installed.

While 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 that would use FAST packs to 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) and would be categorised by 'type', thus Type I was the earliest form of CFT.

Creech

General Wilbur Creech became Commander of Tactical Air Command in the late 1970s. During his tenure, TAC sat in the shadow of Strategic Air Command and its bomber Generals, such was the nature of the Cold War. Consequently, TAC sortie generation rates were at an all-time low and aircrew regularly falsified flight records to satisfy rules and regulations concerning minimum flight hours, combat efficiency, and bombing accuracy. In addition, intimidation, fear and aggression were the tools of rule and order .

Creech was a visionary leader though, and through incentivisation, high profile dismissals of those not towing 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, Creech was a fighter pilot known for attention to detail and acumen. He 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 'missionized' 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, yet it might struggle against the rapidly evolving family of Russian MiG and Sukhoi fighters. By way of illustration, '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!" . As such, Creech was keen to ensure that contenders should also be able to adequately defend themselves from hostile airborne interceptors.

Creech was also familiar with the company funded, extra-curricular work being conducted on the air-to-ground capabilities of the F-15 at McAir, but protocol prevented him from approaching the company in an official capacity. Instead, he was vocal in his support of their continued work and unofficially advised them that the Air Force would be most receptive to their latest proposal: Strike Eagle.

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

Requirements

TAWRS was subsequently renamed Enhanced Tactical Fighter, and then Dual Role Fighter in 1982, but the minimum expectation remained unchanged: the winning airframe had to 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 provided the WSO (Weapons System Operator) with 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.

Hughes, which had already made the revolutionary APG-63 radar for the F-15A/B, had already teamed together with McAir to produce an Advanced Fighter Capability Demonstrator in 1979. But despite the strong pairing, nothing was taken for granted and there were several areas that would have to be addressed if the project was to be a success.

One of these was range. TWARS called for similar range and penetration capabilities to the F-111, as 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 1,000 miles: a performance envelope that 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 , the AFCD would still be limited to an effective combat radius of only 680nm – more than 30% less than that required.

In addition, there was concern about the effect of the F-15's low wing loading. Wing loading was a term used to describe, in a rough sense, the lift-to-weight ratio per square meter of wing surface area. High wing loading came about from a small wing (F-104, for example), while low wing loading often indicated a large wing. Being high- or low-wing loaded therefore conferred certain 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.

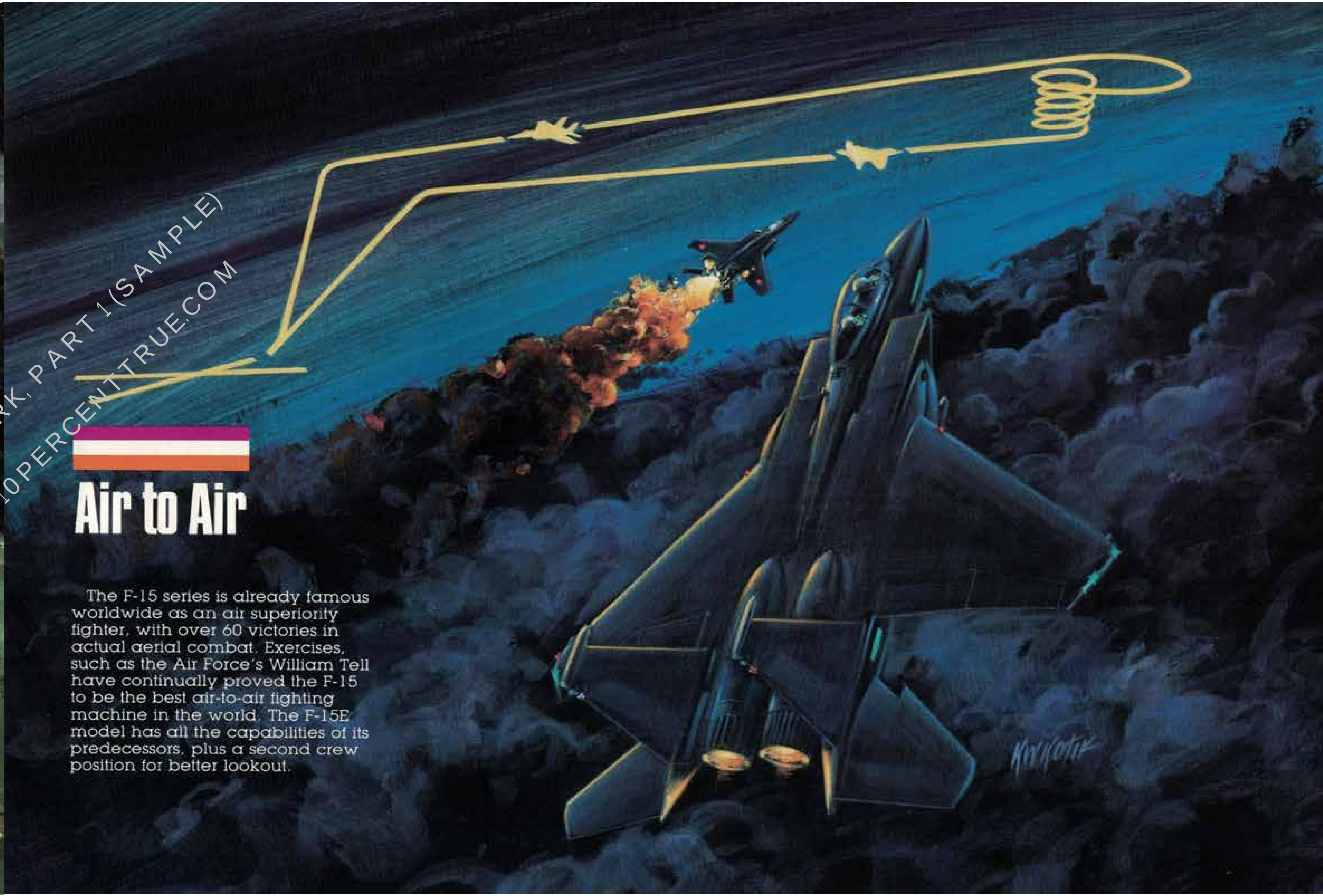
Advanced Fighter Capability Demonstrator, 1980 - 1982

McAir used F-15B AF 71-0291 (formerly designated a TF-15A) for the AFCD platform.

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

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.

both its intended mission and its intended theatre of operation . It first flew on 8 July, 1980, at around the same time the Laacke and his colleagues had begun to refer to FAST packs as CFTs.

The two-seat F-15B/D offered the ideal platform for the deep strike, precision guided role. With a weapons systems officer occupying the rear seat, there would be someone who could 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 exciting range of features . The Heads Up Display 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.

The Eagle's 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 subconsciously. It consisted of a combination of switches and buttons mounted on the control stick and throttle that allowed the pilot instant access to weapons and sensors without having to move his 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 of choice 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 jet fighters.

Finally, the APG-63 was a high frequency, pulse Doppler attack radar designed primarily for air-to-air combat. Consisting of several Line Replaceable Units, it was rammed with new radar search and track modes with which to detect and sort targets. A passive Sniff mode allowed emission control without having to turn off the radar, and Electronic Counter Counter Measures 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 and Auto Acquisition modes would lock onto the first target detected within 10nm in a dogfight. To top it all off, it gave the pilot the ability to non-cooperatively identify radar targets based on the characteristics of their radar echoes (Non Co-operative Target Recognition).

The first Missionized 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" & 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 which moved to accurately reflect 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 the years to come would see it revised to become one of the most important tools available to the aircrew during flight operations.

To make full use of this tool and the proposed Synthetic Aperture Radar, the AFCD also had its Litton LN-31 Inertial Navigation System re-programmed to offer a 500% increase in velocity update rate,

(Left) F-15B '291 first flew in July 1980. She is seen here with early CFTs and light grey colour scheme. AFCD later on in 1981, in the camouflage chosen by McAir and Hughes. (Boeing via author)

although this modification did not make it any more accurate.

A new 1553 Multiplex Data bus was also installed to allow continuous data traffic to pass between the many new computerised systems without interruption.

To help control these new cockpit systems, 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 seat 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 that, during an attack run, the WSO buried his head in to view the TF 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 an AVQ-26 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 APG-63 radar set but, crucially, be focused on the air-to-ground mission. That meant a number of things, but none more important that the development of a Synthetic Aperture Radar mode to locate, 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 WSO and featured a range of switches and buttons with which 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 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. Despite significant modifications though, 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 missile, 30mm gun pod, 500lb Durandel anti-runway bomb and the MK-82, -83 and -84 series of general purpose bombs. For good measure, McAir also displayed the AN/AVQ-26 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 launched the Dual Role Fighter competition in 1982.

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 worlds most successful multi-role aircraft. (Boeing via author)

Volk Field

McAir had been working hard at Volk Field, Camp Douglas, Wisconsin, to develop the CFT concept over several years, ultimately achieving success with the CFTs ordered by the Air Force for the F-15C/D.

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 not 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 MSIP II enhancement effort. 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 a straightforward and 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 of the CFT program 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 subsequent to the Dual Role Fighter competition.

Early proposals cantered 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, comparative testing between the Strike Eagle and the F-16XL forced McAir to follow the example set by General Dynamics, which had developed individual, conformal pylons, for each weapon. This approach reduced drag and offered both an improvement in weapons separation characteristics and additional ground clearance that were much to the advantage of the Strike Eagle.

Volk Field was also home to a concentrated APG-70 radar development effort and had been since the days before CFT testing began. 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 weapons release 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 at this time called for extensive testing of the fire control system's ability to automatically release weapons in a full 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 releases were practised to record weapons separation characteristics and to further demonstrate to the Air Force the tactical utility of real-time, SAR imagery generation. Accuracies being achieved were so great that range controllers observing the hits moved in far 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 muscles – a food for which he had an intense dislike – at a local fish restaurant.

McAir always knew that Pave Tack was not going to be the FLIR system of choice for the 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.

The Strike Eagle demonstrator shows off early FAST Packs. As they became more advanced, these conformal fuel tanks were categorised into 'types'. Type IV and V would ultimately make their way onto the F-15E. (Boeing via author)

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)

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 FLIR pod within 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 on radar would provide radio directives for turns to keep the jet within these lanes, but as they grew more confident, they would stop 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 their airspace clearances. '291's crew, of course, were simply flying off their TSD.

By 1980, tests had already taken the shape of nine weapons release flights flown by Jennings. The first test flight 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.

With this testing underway, the Strike Eagle concept was more than ready to meet the forthcoming Dual Role Fighter Competition.

Dual Role Fighter, 1982 - 1984

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

The competition actually 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 influences made the purchase of such an aeroplane an impossibility, and the competition centred around just two entrants.

General Dynamics had been successful with its small, lightweight fighter aircraft, the F-16 Fighting Falcon. Developed at the behest of group of very powerful Pentagon based fighter pilots known as the Fighter Mafia, the diminutive jet was designed to fill a void left by the F-15: 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 completely revising the wing to form a cranked delta 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: single and dual seat airframes, respectively. The single seater first flew on 3 July 1982. 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 more than one airframe 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 for six months by USAF and McAir test pilots at Edwards AFB, whilst '291 continued to earn her keep as an in-house test bed for MCD 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.

"Pilots from each airframe went to Edwards for about six months to take part in this fly-off", Banholzer recalled. "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. 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 broken into two halves: 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, "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 of 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.

It is almost certain that the two contenders were also flown against the MiGs of the 4477th Test and Evaluation Squadron, a then-secret unit base at Tonopah in the north-western corner of the Nellis ranges, whose role was to expose tactical air force units to secretly acquired MiG-17, MiG-21 and MiG-23 fighters.

Of the Strike Eagle F-15E, Banholzer offered, "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-

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)

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 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 vortice 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 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?

But there were also concerns about the Strike Eagle, some of which by this time were starting to subside.

For example, while crews evaluating the Strike Eagle were all too aware that it lacked the legs of the F-111, the clear advantages it had in capability, accuracy and survivability outweighed any disadvantage that this might pose.

DRF aircrew 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.

There was also concern that the CFTs could jettison their fuel only via the main tanks – 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 some way of jettisoning fuel directly into the airflow (pumping it into the main tanks and then out of the right wing dump mast was a slow process). Laacke, who had observed the effectiveness of the Strike Eagles low altitude escape manoeuvres, never took the 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' .

The Strike Eagle's formidable air-to-air performance further vindicated any decision the Air Force might make to select it as the winner.

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; the problem was that 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.

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 it proved useful in making accurate target designations possible from SAR radar maps.

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. 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 DRF F-15s 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 F-15A-D, 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 missionized 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 influential input into the final lay out and operation of the crew compartment.

The USAF had originally requested that 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 insisted that this was not implemented because McAir managed to prove to the Air Force that a glass cockpit would be cheaper to install. It was true: mechanical displays were more expensive than CRTs. By way of an example, a single Engine gauge, of which previous F-15s had ten, was more costly than the Engine Display LCD 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 which 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 when it became obvious that gloves and high G forces made this a less realistic option than had originally been hoped, and 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, and it would be years before the technology was mature enough for Boeing to implement on the F/A-18E/F.

Banholzer and his colleagues also advised on extensive HOTAS modifications, and the front seat stick grip was completely re-designed 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-18, was further developed.

A principle underpinning all this was the importance of building a cockpit 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

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.

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, otherwise it closely resembled the production standard lay-out. (Boeing via author)