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RE: Submission to the Joint Standing Committee on Foreign Affairs, Defence and Trade Inquiry into **Australian Defence Force Regional Air Superiority**.



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1. About this submission

This submission:

1. Describes aspects of public awareness of Defence and Aerospace issues and how that has changed over the past couple of decades. Public scrutiny of Defence decisions is better informed than at any other time in history. Defence has a responsibility to be transparent in its decision-making processes. As much is stated in the quote “Our doctrine must be open to challenge and review”(Fundamentals of Australian Aerospace Power.’ 4th Edn. pp.21).
2. Looks at the F-111 fleet and proposes an affordable way to achieve Air Superiority in the region for the foreseeable future.

2. Politics or Prudence?

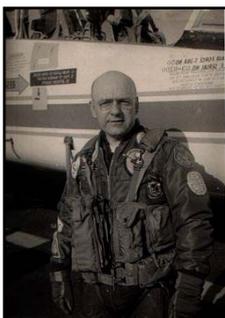
Decisions about Australia’s Defence procurements will have repercussions for generations to come. Political expediency in these decisions would be put to one side by anyone who really cares about the security of their children, or that of their children’s children.

Australia has resident professionals inside and outside defence who have already devoted much time, and published many papers, on the complexity that is Air Defence, and their opinions should be listened to and weighed up with the utmost gravity. Refer to <http://www.ausairpower.net/> for probably the most complete analyses of these problems in relation to Australia’s strategic and tactical needs.

There is a huge a reality gap between the some of the pronouncements of Defence in recent times and the **expectations** of the Australian citizens who now at least with access to information, take an interest in the RAAF procurement and strategy plans. When the publicly released statements of Defence start to read like brochures from the manufacturer these concerned citizens start to worry.

We are used to bold claims when buying software entertainment products – and even get a laugh out of the marketing material produced by arms and aerospace manufacturers, but we expect rigorous and transparent rational debate **and** lateral thinking from the people that we entrust to solve our defense problems.

The following three examples remind us of the human sides and human costs incurred in the employment of air power.



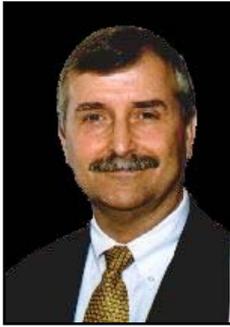
Dudley Henriques

He has flown at least seventy different types of airplanes, including experimental, prototype, and fighters, both jet and propeller, high performance airplanes for over forty of those years, holds commercial ratings for both single and multi-engine aircraft, is a certified flight instructor and a professional civilian pilot.

Dudley first got enthused about flight sims with [Janes Combat Simulations](#) 1998 sim [World War 2 Fighters](#) which modelled several a/c, including the P-51 Mustang. Dudley had previously developed airshow routines for the P-51.

Dudley Henriques on Airshow flying :

“In one instance, I was asked to take off right after a close friend was killed. The show director was a nice enough guy. He was obviously very nervous about approaching me. He said it would be better if the show continued. I flew the routine seeing the wreckage each time I went inverted in my Cuban turn around... It's not really a game for show offs. I've climbed out of my airplane soaking with sweat after only fifteen minutes of this kind of flying. I've sat down with the [Thunderbirds](#) and the Blues ([Blue Angels](#)) in their after-show debrief sessions and seen the stress in their faces from a show. It's hard, exacting work and it can and has killed many of us who took it lightly...and even some who took it seriously. “ - From [Dudley Henriques](#) contributions to the [Flight Sim Museum](#)



[J.D. Wetterling](#)

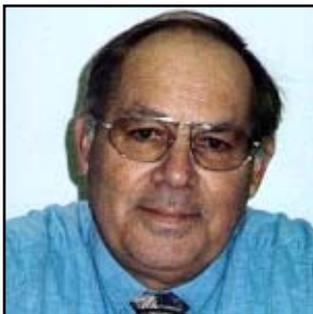
In 1968-69 J.D. Wetterling flew 268 combat missions in an F-100 in Vietnam and was awarded two Distinguished Flying Crosses, fourteen Air Medals, and the Vietnamese Cross of Gallantry. He was Top Gun in every fighter squadron in which he served in the USAF.

In his novel “Son of Thunder” he describes his own experiences flying the F-100 Super Sabre with the [629th Tactical Fighter Squadron](#) out of Tuy Hoa.

On his first mission, a “road interdiction”, his wingman is destroyed in front of him by AAA fire. He is now a deacon in the Presbyterian Church and on [his website](#) he discusses what effect this and other wartime experiences had on his life.



[J.D. Wetterling](#)'s airbase in Vietnam, taken from the cockpit of his F-100. [Larger image here](#)



[Jos Gruppung](#)

Jos grew up during World War 2 near Amsterdam. He has put together the definitive history of the Microsoft Civil Flight Simulators [here](#)

"Air Combat is something I loathe."

“ I was born in Amsterdam in 1938 and lived during WWII just outside Amsterdam, between Amsterdam and Schiphol Airport. Although I was young, I was old enough to still remember the sound of low flying screaming airplanes over our region and house. Fortunately there wasn't very much bombing, except around Schiphol.

And I still lively remember the hunger as well as the taste of sugar-beets, tulip-bulbs and the like, that we had to eat because of the lack of more normal food like potatoes, bread and milk.

So you must excuse me, I find nothing fun at combat games, how nicely finished they are (or just because they are!). This is again reinforced by the happenings in New York and consecutively in Afghanistan. "

From ([Friends of the Museum - excerpt](#))

3. Regional Air Defence Superiority for Australia			
		F-111	F-35
	<p>GREEN cells indicate a clear advantage. Explanatory notes for the table follow.</p> <p><i>Images from The Flight Sim Museum</i></p>		
1	Cost	Already in budget	Unknown
2	Maintenance	Existing facilities, skills and budget	Cost unknown.
3	Spares	Low cost, plentiful supply	Cost unknown.
4	Technology	Owned	Total technology transfer in doubt
5	Remaining life	30-40 years	Unknown
6	CAS capability	Good	Good
7	Speed	Supersonic	Subsonic
8	Supercruise	Yes, with engine upgrade	No.
9	Range	Long	Short
10	TFR	Yes	No
11	Payload	25,000 lbs	17,000 lbs (non VTOL version) and with severely compromised radar signature
12	Low Level Deep Penetration Strikes	TFR, speed at low level, avionics and 2 man crew, large payload. Able to outrun interceptors.	No TFR, subsonic, 1 man crew, small payload. Unable to outrun current interceptors.
13	Electronic Warfare	Excellent (EF-111)	Unknown
14	Avionics – AG	Good	Presumably good.
15	Avionics – AA	Poor – can be upgraded.	?
16	Potential for upgrade to BVR intercept role	Good	Poor (short range and no supersonic sprint)
17	Dogfight	Poor	Poor
18	Networking	?	Good

19	Stealth	Poor without terrain masking Good with terrain masking	Mid-range
20	Flight Envelope	Treetop level (supersonics) to 60,000 feet plus	Low level subsonic to probably 35,000 feet.
21	Crew safety	Watertight ejection capsule for both crew	Ejection seat, life-raft has to be inflated by pilot after ditching
22	Can Eject underwater	Yes	No
23	Landing with undercarriage retracted or missing	Yes	Doubtful
24	Safety Record	One of the best in the history of military aviation	Unknown
25	Two engines?	Yes.	No.

Explanatory Notes

1. **Cost.** We own the F-111 already, they are paid for. Resources currently allocated to F-35 acquisition can be diverted to increasing F-111 and other RAAF capabilities (tankers, avionics and comms/networking upgrades). Total cost of the acquisition and ownership of the F-35 is unknown.

“ The F-111s were built in the 1968 period, but put into storage for various modifications and were not flown until 1973, which means they did not start accruing flight hours until then. Due to poor serviceability in the past, they did not run up a lot of hours and a good number are now **around the 5000 hr** mark in total hours.

The design is nominally **lived at 10,000 hrs**, but it looks that the fuselages will last longer as is. The wings on the other hand are running out of life and require deep refurbishment and fixes to last longer.

[Air Power Australia](#) had the cost of manufacturing brand new wings done by a manufacturer who puts the cost of **new build wings at less than AUD 2 million** per shipset. Whether we have new wings built or refurbished from the large stock at [Aerospace Maintenance and Regeneration Center \(AMARC\)](#), we are looking at **decades of extra service life** to be had.

As for all of the other systems, the hydraulics are in great condition and [Rosebank Engineering](#) could keep them going indefinitely. Avionics you have to periodically replace in all aircraft, and engines we have original stock here and in [AMARC](#) capable of going for decades, although the [Air Power Australia](#) position is that new engines would be even cheaper to run and burn less gas.

Basically there are no issues in keeping them flying for decades yet.
No different from the B-52, C-5 and B-1B. “

Dr. Carlo Kopp. Correspondence to the author, 2006



[Aerospace Maintenance and Regeneration Center \(AMARC\)](#)

There are 200 F-111's in there somewhere.

2. **Maintenance** - Maintenance infrastructure and skillsets are already in place for the F-111. New maintenance infrastructure, inventory and skillsets will be required for the F-35. Very expensive. Does it make more sense to put a huge amount of money into starting again? Possibly - IF - there were significant gains in capability at the end of the process. However the F-35 is less capable than the F-111 in most respects.
3. **Spares** - F-111 spare parts and spare airframes are available by the hundreds, in storage in the USA. The USA only retired the F-111 to ease the passage of funding for the F-22 programme, not because they were fielding a replacement for the F-111, nor was it regarded as obsolete. As proof of this, look at the RAAF's record at the [Red Flag Air Warfare](#) exercises held in the US. **We win the bombing competitions now** - and this is up against the cream of the Western World's strike aircraft - the F-15E Strike Eagle, F-117 Stealth, B-1B Lancer and the phenomenally expensive B-2B Stealth Bomber.

The RAAF is probably the only bomber operator to ever shoot down an enemy interceptor with an AIM-9.

(During Maple Flag).

(From conversation between the author and RAAF F-111 Bomber/Navigator, 1995).



RAAF F-111G model recently acquired (1995) from the USA and with low hours, for a pittance. This model was fitted out to deliver nuclear weapons over the North Pole and the trackless wastes of Siberia. Astro-Navigation (Litton AN/ASQ-119 Astrotracker astrocompass) and Nuclear consent kit was removed by the ADF personnel. There are many more airframes like this available to Australia (over 200), as we are the only approved export customer for the F-111.

Image by the Author and from [The Flight Sim Museum](#)



The original mechanical navigation kit in the RAAF F-111.

[Image by the author](#)

4. **Technology** - There are serious questions about technology transfer from the USA. Will they allow access to all the technology of the F-35? They have already fallen short on technology transfer with Australian Army helicopters, leading to Defence deciding to go with European manufacturers. The European manufacturers have proven to be much more open on these issues.
5. **Remaining life** - The F-111 airframe is relatively young. (18 years on average). The USA plans to operate the B-52 out till at least 70 years. There is no reason why we can't plan for operate the F-111 for another 30 to 40 years or longer, remembering we have access to low-hour airframes in storage. By retiring the F-111 30+ years early we are throwing away a capability which is only half-used. I also note that Air Marshal Angus Houston's ASPI paper "Is the JSF good enough?" starts from the premise that we **need** to replace the F-111.
6. **Close Air Support** - The F-35 is designed as a CLOSE AIR SUPPORT vehicle. A replacement for the AV-8B Harrier and the F/A-18 Hornet. The F-111 performs extremely well in this role, having the supersonic **dash** capability to reach the FEBA quickly and then a **loiter** capability due to variable geometry wings and high internal fuel capacity.
7. **Speed** - The F-111's speed at low level is **unsurpassed** and only limited by the temperature limits on the airframe due to friction with the atmosphere. *SEE POINT 9 next.*
8. **Supercruise** (supersonic flight without reheat) is achievable on the F-111 by fitting the same engines used in the F-22. This would make it (with avionics upgrades) probably the most formidable long range interceptor extant.
9. **Range** - A Strategic Bomber has a LONG RANGE and large payload. The B-52 for example is a Strategic Bomber. The F-111 combines long range with Mach-2 capability (useful in sprints). The F-35 is short range and subsonic, a purely tactical machine.



A RAAF F-111 approaches the refueling boom of a U.S. Air Force KC-135 Stratotanker during an in-flight refuelling evolution in the skies over the Nevada Test and Training Range on Feb. 14, 2006. Image: US DOD

10. **TFR** - Combined with the Terrain Following Radar (TFR) this F-111's sprint capability adds greatly to aircrew/airframe survivability in hostile environments. The combination gives the F-111 the ability to out-run any interceptor at low level, at the same time using terrain masking to evade SAMs. Once again this has all proven empirically, again and again at the [Red Flag Air Warfare](#) exercises.
11. **Payload** - The JSF is really designed for internal weapon carriage only. External Air-to-Ground stores dramatically reduce the range and negate the 'stealth' elements of the design.
12. **Low Level Deep Penetration Strikes** - Flying deep penetration low level strikes is a 2 person job. There is no doubt about that. Look at 2 of the premiere aircraft designed for similar roles in Western Europe – the Panavia Tornado, and in the former Soviet Union – the Su-24 Fencer. Both have 2 man crews. What aircraft was chosen to fly the 1980's attack from the UK to Libya? The F-111. It has a proven track record of successful strike missions and it's capability in that regard has not been negated.
13. **Electronic Warfare** - The EF-111 variant has a track record of successful EW missions. It has the endurance to fly long sorties in support of strike packages, the power to generate strong signals and the sprint capability to run from interceptors if need be.
14. **Avionics – AG –**

Pave Tack laser designation pod on the F-111.

F-111 - Pave Tack Laser Targeting Pod Image
by author and from [The Flight Sim Museum](#)

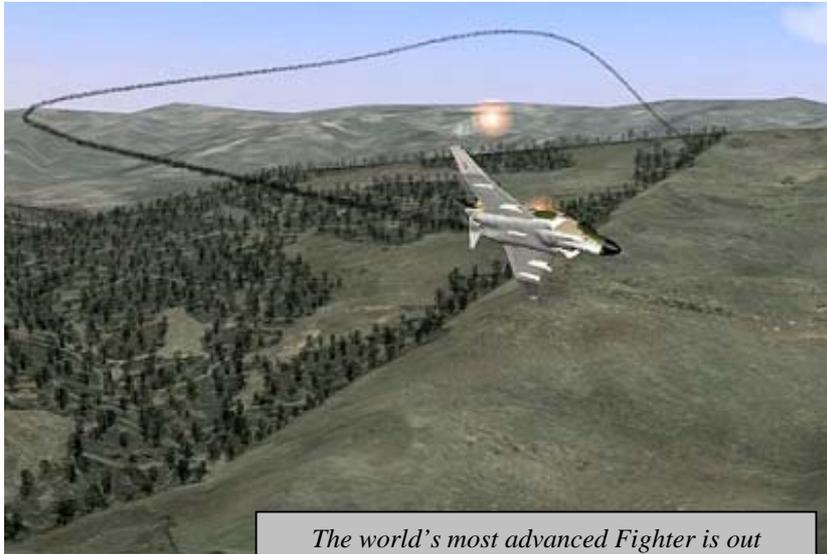


“ Despite its age the AN/AVQ-26 Pave Tack still offers sightline stabilisation and field of regard performance superior or equal to the best targeting pods in the market. Replacement of the obsolescent internal thermal imager, computer and other hardware could provide the Pave Tack with competitive reliability and superior imaging performance against production targeting pods, since the unique optical design and low drag internal carriage would be retained.”

From <http://www.ausairpower.net/DT-F-111-Update-Feb-03.html>

15. **Avionics – AA** - In recent conflicts (particularly Desert Storm) we have seen that BVR accounts for 90% of Air to Air action. The F-15 Eagles accounted for most of the kills in that conflict. Bear in mind that the F-111 **was originally designed as a joint USAF/USN interceptor** under Sec. Def. Robert McNamara. The TFX prototype actually took off from an aircraft carrier and the [F-14 \(video\)](#) (can be seen as an evolution of the F-111 design. Two large engines and swing-winged.
16. **Potential for upgrade to BVR intercept role** - . The F-111 has ample space to be fitted with state of the art AA radar. It has sprint / intercept performance up there with the current generation of dedicated interceptors, in fact exceeding the straight line performance of most of them. The F-35 is not designed as an interceptor, it's low speed precludes it from that role.

17. **Dogfight** - The F-111 is not a dogfighter due it's handling being optimised for speed. As mentioned above, dogfighting plays little role in modern air warfare. However there is an important caveat – history has shown (Vietnam War, Falklands War) that the dogfighting role is still important, so the capability for **dogfight** must be maintained **within the total force structure** – not necessarily in one airframe. Despite the claims of multi-role attack/fighters manufacturers these designs are **always** a compromise. *The F-35 is not a dogfighter* due to it's low power to weight ratio.



The world's most advanced Fighter is out manoeuvred by a smaller, cheaper adversary.

In the skies over North Vietnam the F-4 Phantom II was comprehensively trounced for a time by mass produced, cheap MiG-17's MiG-19's and MiG-21's. Of course this could never happen again... could it?

Image from [The Flight Sim Museum](http://www.migman.com)

The manufacturer admitted as much recently, adding that it was designed, using networking and stealth, to avoid getting into those situations.

Famous last words, as the US Navy interceptor F-4 Phantom pilots found in the skies over North Vietnam. They had to add guns and modify the wing slats – and then re-learn dogfighting skills to (eventually) cope with the much smaller and much cheaper MiG-15, MiG-17, MiG-19 and MiG-21. There are also many situations outside of full-scale war where an interceptor is called on to visually identify targets. Once in visual range, dogfight agility is required if the interceptor is to manage the situation.

18. **Networking** - The F-35 is designed with networking in mind. ADF personnel can upgrade the F-111 avionics, as they already have done so a number of times.
19. **Stealth** - The F-111 was designed before “Stealth Technology”, or the use of faceted (F-117, 1970's) or complex curve (F-22, 1980's) bodies specifically designed to reduce radar signature was possible. Nonetheless, it's normal low level flight profile utilising terrain masking combined with good intel and planning means that the RAAF has achieved outstanding and consistent results in penetrating the most sophisticated air Defence environments currently fielded – refer to point 3 – RED FLAG. The F-35 on the other hand, although originally marketed as a “Stealth” aircraft, has been divested of this claim in recent times. It also lacks the speed and low level TFR, which could compensate for the radar visibility.
20. **Flight Envelope** - [Ref Federation of American Scientists](#)
21. **Crew safety** - [Ref Federation of American Scientists](#)
22. **Can Eject underwater** - [Ref Federation of American Scientists](#)
23. **Landing with undercarriage retracted or missing** - Proven in 2006. RAAF pilot who was only current on the type for **2 weeks** successfully landed an F-111 which had lost a main wheel on takeoff due to maintenance error. The standard procedure for most military aircraft in this situation is to head to sea and eject.

24. **Safety Record** - The exemplary safety record ([Ref Federation of American Scientists](#)) of the F-111 is even more remarkable when you factor in the mission profile with **all weather and low level** (extremely low level) flight in a normal day's work. The only comparable mission profile was that of the 2-seater Grumman A-6 Intruder, which was subsonic.
25. **Two engines?** - Essential for safety on the long distances flown by the RAAF in Australia.

Conclusion.

- **Australia already has the potential to possess Regional Air Superiority...** by bringing a suitable portion of the existing F-111 fleet up to Long Range Interceptor specifications.
- This solution is cost effective and smart.
- It uses existing and **battle-proven** technology.
- It builds on the **existing skill sets** within the RAAF.



[The F-111 was chosen to carry the flame away from the Sydney 2000 Olympics \(VIDEO\)](#)



Picture: David Grey/Reuters.

4. Use of simulations in Planning, Training and analysis.

Accident analysis

At the **Department of National Defence...** in Ottawa, Canada. ...the study of aviation accidents, especially military ones. ...Flight Data Recorder (FDR) (data) ...analysis is done mostly using the Insight Suite software from Flightscape.

This software allows for a simple recreation of events from the point of view of the aircraft. However it doesn't recreate other things such as weather and visibility conditions, or the aircraft configuration. That's where [\(Microsoft\) Flight Simulator](#) comes in.

... they will use the same model of aircraft (or as close as possible) to fly a similar flight in flight simulator, and record it using the Flight Video option.

Then comes the tough part. All the **data in the flight video file gets cleared out, and replaced with the actual figures from the FDR.** Now instead of flying a similar path, the aircraft will do the exact same thing in Flight Simulator that the real one did. The problem with doing this is that Flight Simulator requires data input about 18 times a second, the FDR generates its data about once every four seconds. This means that the people involved have to extrapolate what happened in between to try and fill in the blanks.

Once this is done, the correct time of day and weather that was present at the time are set up, and they can let the video run. They will now see the aircraft behaving as the real one did, and will also see the same things out the window. They can even go as far as to determine if the post was in the way and preventing the pilots from being able to see.

They also use a variety of software to recreate the event as much as possible. [FSRepaint](#) comes in handy not only to make the exterior look correct, but sometimes also the interior. I was shown an example of a helicopter where if you looked back in the virtual cockpit view, you could see into the back of the aircraft. The rear of the aircraft was empty in the original, so new textures were put together to fill the rear with equipment, as the real aircraft would have appeared.

They also used [Custom Panel Designer](#) to try and make the panel as accurate as possible. The drawback was they found CPD didn't meet their needs for working with the virtual cockpits, and were quite pleased when I introduced them to [FS Panel Studio](#).

I got a chance to see up close exactly what they were seeing. Using a set of 3D glasses from eMagin along with the CF-18 from [aerialfoundry](#), I was treated to a fantastic view unlike any I'd seen before. It just goes to show how versatile the program is. How all these expansion products, both free and payware, have really come into their own.

Excerpted from article by [Andy Johnston](#) at [www.flightsim.com](#)

2006

[VIDEO - Low level flight over the Blue Mountains](#)

Image from [The Flight Sim Museum](#)



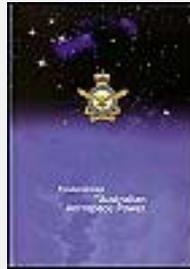
1/03/06



[Video of Kurnell and landing at Kingsford Smith 34L](#)

Image from [The Flight Sim Museum](#)

11



Page 16 of the RAAF doctrine manual AAP1000 wrongly identifies a Su-27 as a MiG-29.

Presumably a proof reading error, but nonetheless not reassuring. The Su-27 is shown in formation with a RAAF F/A-18, whose **pilot** most definitely **would** know the difference. This does beg the question however – does the RAAF still rely on “silhouette” charts to train for target aircraft recognition? Friendly fire does occur. Computer simulations are valuable aids for target recognition training, as the desired aircraft can be posed at any angle, and in any condition of lighting and weather.



MiG or Sukhoi?



For an illustration of how difficult visual identification can be, [look at this video](#) showing simulated fighter size targets at a few miles distance.

In the Korean War the first sign of enemy a/c was often the sunlight glinting off the wings or the canopy, as was well illustrated [in this simulation](#) and most simulations since the late 1990's.

Some Examples of use of simulation - Organisations which have used information from the [Flight Sim Museum](#)

Boeing	F/A-18 movies (simulated) in lecture
NASA	F/A-18 images (simulated) in lecture
US NAS Paxutent River	F/A-18 material in lecture on Carrier Circuits
Victorian Dept. of Education.	Simulation images for high school science textbook
Microsoft	Promotion of Microsoft Combat Flight Sim 3 and others. Promotion of Microsoft Sidewinder Controllers
Guillemot and Thrustmaster	HOTAS Cougar replica F-16 Side-controller and Throttle. This is an authentica replica of the original, and fully functional.



3. Increased Literacy of the general public on Aerospace and Defence.

I. Pre internet

Prior to the early 1990's information about Aerospace and Defence was available only from:

- Print media – magazines
- Print media – books for the general reader
- Print media – books for the professional reader (e.g. Janes publications)
- Print media – journals and newsletters for the professional reader (e.g. Janes defence updates)
- Print media – Manufacturer's brochures
- Video – VHS and PAL video tapes often based on Television documentaries.

The general reader would not usually even consider chasing up information from Defence. They were seen (rightly or wrongly) as being aloof and secretive. The Cold War had fostered a mentality of secrecy and to be fair, even sources such as Janes had very little information about many aspects of Soviet doctrine and capability. More information was available from US manufacturers, always keen to hawk their products.

Image of F-16A cockpit, sent to the author by the head of spare parts, Lockheed Martin, USA after a lengthy **telephone call...** there were no websites back then and no email.

Image ca. 1990. (Reproduced from 8" x 10" glossy)



Remember, for example, that the west's first good look at the MiG-29 Fulcrum was in the spectacular airshow put on by Anatoly Kvotchur at the Paris Airshow in 1989. The internet was not in existence then, so the first images the general public saw were in publications by British publisher Osprey. Publishers [Domark/Simis](#) quickly put out a simulation of the MiG called [MiG-29 Fulcrum](#) which added flesh to the bones.

II. Internet facilitates information exchange and informal networks based on common interests.

Notwithstanding that DARPA, ARPANET and CompuServe had offered networks for information exchange for some years, they were difficult for the non computer-savvy to access. It was the introduction of the **World Wide Web** (www) system of hyperlinks and browser technology, which radically transformed the scene in the early 1990s.

Here are just a few examples of contributors and visitors to the [Flight Sim Museum](#). They are typical of the participants on similar websites and forums worldwide. The internet allows them to share their knowledge and experiences with each other and we are all richer and better informed for it.

III. Hardware revolutions transform PC simulation

Since 1980 the CPU (Central Processing Unit) speeds of personal computers have increased markedly and since 1998 there has been even more rapid growth of capability in the separate GPU (Graphics Processing Unit). This new generation of GPUs were computers within a computer, containing chipsets dedicated to the simultaneous drawing of millions of polygons per second, [texture mapping](#), calculating lighting effects, anti-aliasing (smoothing), transparencies. Up until about 1998 all this had to be calculated by the CPU, thereby taking valuable processing cycles away from flight modelling, ballistics, radar etc. (see [Graphics preferences – early to mid 1990s](#)).

Nowadays the most basic personal computer or indeed any reasonable laptop ships with a 2 GHz CPU and a reasonable GPU. Graphics effects such as mentioned above are taken for granted and anti-aliasing (smoothing), multiple light sources, transparencies are expected. As any military or aviation simulation specialist knows, graphics aren't everything. But with the CPU freed of these tasks, it could concentrate on the number crunching specific to the focus of the simulation.

All this means that any desktop Personal Computer can now generate **useful** real time simulations of the air combat and air to ground environments and the aircraft and systems which operate in them.

I say "useful" because they give the operator an entrée in to the worlds of air combat that no amount of reading and study alone could emulate.

The result is today that around the world, and no less in Australia, students and amateurs of Air Warfare Tactics and



From 1990 to 1998 you had the choice of plain polygons or of applying texture mapping, which sucked up processor cycles.

Images from [The Flight Sim Museum](#)



Doctrine have an appreciation of the issues involved that just did not exist outside of professional military circles 15 years back.

	1980	2005
CPU clock speed	1 Mhz	3,000 Mhz
RAM	1 K	1,000,000 K
CPU Tasks	CPU had to calculate movement vectors in 3D and draw polygons.	CPU can hand off graphics tasks to the GPU, and then focus on flight model, AI, avionics, ballistics, countermeasures etc.
GPU (Graphics Processing Unit)	None	256K RAM. More powerful than the CPU and has chipsets dedicated to the graphics tasks.
Frame Rate / sec	2	50 – 100
Realism	Low	High in some or many areas, depending on the focus of the simulation.
<p>Example videos may be viewed at these URL's or saved from the web page for further viewing.</p>	 <p>F-15 Strike Eagle 1 - 1980</p> <p>Image from The Flight Sim Museum</p> <p>Flash animation of the original PC code.</p> <p>This looks like a primitive computer game. Unsophisticated graphics and even whether it presents a “flight model” is arguable. It represents the limits of hardware at the time.</p>	 <p>Lock On Modern Air Combat – 2003</p> <p>Image from The Flight Sim Museum</p> <p>Near cinema quality graphics. Flight models of the aircraft and the missiles modelled much more accurately. Coded by Russian Aerospace engineers.</p> <p>Please take note that this video was not rendered in a Hollywood studio over a few days or weeks – but was in fact created in real time by a standard modern desktop PC. It shows various views of a dynamic scenario, with the computer AI pilots acting tactically against a human pilot.</p>

IV. Higher Fidelity simulators are now widely available.

There have always been citizens interested in **what** their armed forces are doing, **how** they do it, and even sometimes **why** they do it! Real time electronic simulation of Air Warfare has been inaccessible to the general citizen until the past 15 years. That change has been driven by the acceleration of hardware capabilities (see TABLE).

Nowadays the fidelity of these simulations is such that

1. Military professionals regularly use PC based simulations to maintain currency in a range of areas.
2. Ex-Military professionals, Test Pilots, Aerodynamics Engineers and Tacticians are involved in developing simulations, which are then made available to the general public.

Total Air War by Digital Image Design

This sim gives the opportunity to Command and Control assets including F-22 Raptors in a Strategic Air War. The **strategic component** is based on modern air warfare theories first applied in the 1991 Gulf War and developed by Col. John Warden III. It proposed a 5 ring theory of strategic targeting: 1 – Leadership, 2 - Key Production, 3 – Infrastructure – 4 - Population – 5- Fielded Forces.

EMCON (Emissions Control) is also simulated when you fly the F-22. EMCON 1 being no transmissions and EMCON 5 full use of COMMS and radar. On EMCON 1 you can remain off enemy radar – IF you avoid EWR, AWACS and SAM sites AND carry no external stores.

The AWACS communicated to you with a spoken vocabulary of over 10,000 words, which is more than some people can claim, although certainly not Aussie AWACS operators I am sure!



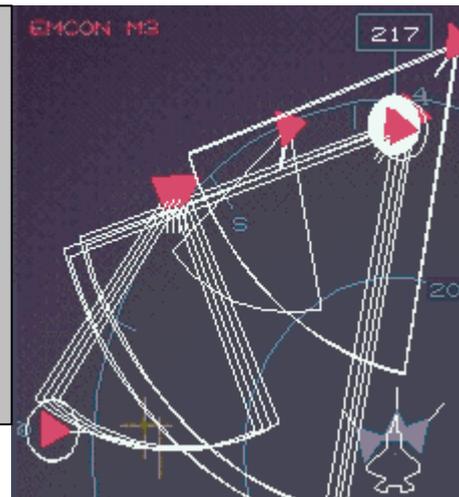
Images of the [AWACS](#) screen from [Total Air War](#).
Image from [The Flight Sim Museum](#)

Note that for a definition of [AWACS](#) also see [LDHD](#) and [HVAA](#)

Tactical display on cockpit MFD in F-22. The air targets and radar zones are sent in encrypted pulse transmissions from the AWACS. The pilot can potentially get a “God’s Eye View” of the air situation – all going well that is!

He/she still has to:
Aviate / Navigate / Communicate
and then
Observe / Orient / Decide / Act...!

Image from [Total Air War](#) in [The Flight Sim Museum](#)



Dynamic campaigns like this really have a lot of "surprise factor."

There are the odd cakewalk missions (scramble to down a single in-bound MiG-21), and some rather urgent moments too.

In one late mission, I took out the control tower of one of the two still-active enemy airfields. They still managed to sortie quite a few Su-27s and even Su-35s, so my wingman and I were quite busy, and my escort flight (F-14) even helped a bit (one thing TAW lacks is ability to ask non-wingman flights for help. They often get distracted by bandits near the base who are not mission-threats, and should be handled by CAP, or scrambles by the AI). I finally managed to reach the target and keep the LANTIRN/laser on the tower for a hit.

I had saved one AMR and one 9X for egress, but quickly used them up, then ran toward home at 800 kts, 300 feet with an Su-27 radar-locked on my tail for 100 miles! He must have been down to guns only too, but he had friends near by, so I decided to keep running. He only gave up when I overflew an allied base - SAMs must have discouraged him. Landed with Bitchin Betty yelling non-stop about my low fuel.

An after action report from [Total Air War](#) written by [Bruce “Chino” Irving](#)

Image and words from [The Flight Sim Museum](#)



“In another one, I jumped into an F-22 from the AWACS screen and quickly took out 3 or 4 Flankers.

I also hit a MiG-21 and he was burning and heading for the weeds -- I followed him down for a while and fired a few gun shots, hitting him a bit more. This was at night, and in the FLIR he seemed to be really burning. But after I turned Back toward base, he flew back up and shot me! The old U-boat trick, playing dead maybe? I had to eject -- I even had a 9X left but didn't want to "waste" it on a lowly MiG-21 that was already burning and apparently losing altitude. Not sure if this was a deliberate fake, but it sure seemed like it! I should have waited for "my" voice to say "splash 5" which is the only sure way to confirm a kill. “

An after action report from [Total Air War](#) by [Bruce “Chino” Irving](#)

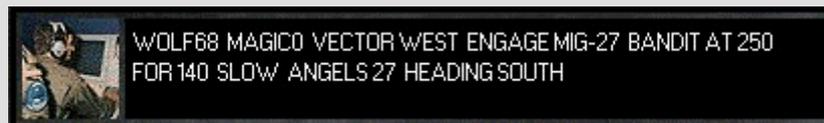
From [The Flight Sim Museum](#)



Comments : It could have been another MiG-21 which arrived on the scene during the dogfight. A demonstration of the unpredictability of complex, fluid systems. It also supports [Robert E Shaw](#)'s assertion that in over 90% of the kills in air combat - the attacker is never seen!

Despite having AWACS which survey the entire area of conflict, a tactical victory is by no means certain. Once drawn into visual or near visual range the F-22 is often destroyed by much older adversary aircraft.

Technical superiority can nullified by various combinations of factors, as these sims demonstrate.



Flight report by a RAF Pilot with over 40 years experience.

He flew the [English Electric Lightning](#) during the Cold War.

DTG 16DEC00

1532Z 2 Lightnings (001/002) airborne from GUTERSLOH to intercept 4 incoming targets.

Shortly after take-off 002 reported AC Failure and was instructed to RTB

001 continued outbound, soon making radar and visual contact with a pair of targets at a similar level. Target pair split and 001 quickly got a good lock and missile kill on one.

Whilst manoeuvring for the second target another pair appeared in the distance. Radar and missile acquired on second target and kill followed. Second pair of targets no longer visible but radar contact made shortly after. 001 chased the pair and visual contact followed.

After some hard manoeuvring a gun kill was completed. The last target was no longer visible so 001 made rapid recovery and landed.

Whilst being refuelled, the SURVEILLANCE radar and AIRCRAFT MOVEMENTS display indicated that the fourth target was recovering to ERFURT. As refuelling neared completion 001 was given clearance to start and was soon airborne heading for ERFURT.

A reheat climb was made to high level and high speed cruise of 1.7M was maintained until reaching 40 nm from ERFURT where rapid descent started. Radar contact gained on target aircraft at 15 nm with visual following shortly after.

Attacking position could not be achieved before target landed.

Remaining ammo fired at target without effect.

Target overshot end of runway before taxiing to parking position. 001 landed, eventually parking beside the target to refuel.

On completion, 001 took off, holding over the airfield for a few minutes before climbing out on heading 295.

On passing FL 220 GUTERSLOH TACAN picked up indicating range of 100 nm approximately 2 degrees starboard.

Full reheat climb through FL 350 at 80 nm TACAN (629kts/1.72M).

At 38 nm 001 level at FL 540 (429kts/1.72M) 96% cold power.

Ventral tank just about empty.

Decided for practice diversion to WILDENRATH.

Switched TACAN to 126X and picked up WILDENRATH TACAN at 100 nm, left of nose.

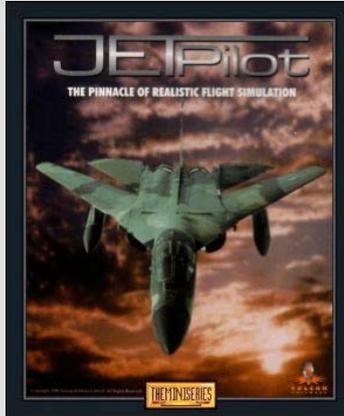
Turned to heading 247 degrees at 92 nm.

At 40 nm, IDLE/FAST IDLE descent initiated changing to fast descent from FL 437 at 25 nm.

Through 26000 at 10 nm, continuing down to complete one circuit and roller at WILDENRATH before

recovery and landing at GUTERSLOH.

This mission is not from his service diary, but from his experience of the 1996 by Vulcan Software, written for the Commodore Amiga platform. - [Jet Pilot](#) He describes it as being a fantastically accurate simulation of the [Lightning](#) and [F-104 Starfighter](#) sorties of that period.



[F-15 by Janes Combat Simulations](#) and [F-15 Strike Eagle 3](#)

A Simulation of the F-15E Strike Eagle. Description: [Comments by a USAF pilot](#)

[F-15 Strike Eagle 3](#) modelled the ability to fly front seat/back seat on two computers joined by a null modem cable or a network. It soon became apparent that survival on deep strike missions into well defended territory – and flying low around known radar sites, required all the capacity of both pilot and navigator. How can a single seater ever hope to cope in this role? Even in the F-111 in TFR (Terrain

Following Radar) mode the pilot keeps his hand near the stick ... just in case! At high speed and low level you can be on the deck in a second. My own discussions with F/A-18 pilots indicate that at low level they concentrate purely on flying – guided weapons delivery is out of the question.



Low level ingress at night. The F-15E Strike Eagle pilot concentrates on this picture.

... while the rear seater is busy with all this... .. seen here setting up an air intercept.

Image from [The Flight Sim Museum](#)



[Falcon 4.0](#)

A complex, real time, multiplayer Air and Ground War sim modelling the behaviour of over 10,000 entities and high fidelity modelling of the F-16 flight model and all avionics. This sim originally shipped to the public in 1998 with a **600 page operating manual**. It was the culmination of a series started in 1980 by Gilman Louie, who now creates similar sims for the CIA. The [Falcon 4.0](#) code has been enhanced by groups of enthusiasts and professionals to model 3 marques of the F-16, the ACMI and a weapons modelling has been upgraded, and it was republished as [Falcon 4 Allied Force](#) in 2005.



Images from [The Flight Sim Museum](#)

There are [Virtual Squadrons](#) who have logged thousands of individual pilot hours in this sim. They fly squadron missions, with

1. Current and former Air Force Pilots
2. Voice communications between squad members
3. [Voice Control of the cockpit](#)
4. [Infra Red Head Tracking](#) to control the [Virtual Cockpit](#) (example is an F-86 Sabre Jet)
5. Authentically scaled and functioning [F-16 HOTAS](#)
6. AWACS



[Eurofighter Typhoon](#) by **Digital Image Design**

This 2001 sim focussed more on the squadron leader and pilot experience and improved the WARGEN engine of [Total Air War](#) to include:

- fully dynamic ground war
- resource modelling
- territory system
- strategic planner
- extra-theatre module which models global effects (political decisions) and influences on the theatre of conflict.
- Pilot fatigue, experience, sleep patterns and aptitudes
- Squadron Leader – management of pilots
- DASS (Defensive Systems)
- Maritime attacks
- Air Combat against Su-30 series fighters
- Helmet mounted sights



[Eurofighter Typhoon](#) simulated the pilot's use of cockpit and helmet mounted displays by keeping all important information sources in the field of view at all times.

Images from [The Flight Sim Museum](#)



Reference material included with retail simulators

In the early 1990's software publishing giant [Electronic Arts](#) combined forces with military analysts and publishers [Janes](#) to form [Janes Combat Simulations](#). They developed a series of combat flight simulators for commercial release which were to combine the enormous technical resources of [Janes](#) with the programming and development track record of [Brent Iverson](#).

The flight models were not the best, but quickly fans created editors to tweak every parameter of the aircraft and ordnance. The focus had been established in consultation with [Chuck Yeager](#) and it aimed to recreate the **decision making processes** of a pilot in air combat. It certainly led to hundreds of thousands of folks spending hundreds of hours each setting up scenarios and seeing what happened.

I was one of them – spending untold hours creating a campaign with hundreds of missions between NATO forces and China and taking place near Vladivostock. Of course I had to re-do the lot when the sim was converted later from DOS to Windows. The price of progress!

The sim ([US Navy Fighters](#)) proved to have flexibility and application

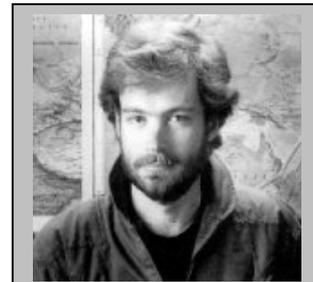


[US Navy Fighters](#) was first from the stable of [Janes Combat Simulations](#). It focussed naturally enough on US Navy operations, set in a hypothetical conflict of the future (1999) in which US forces help Boris Yeltsin.

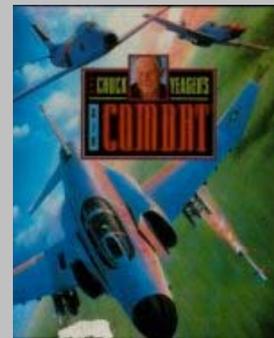
The campaign that shipped with it led you from the F-14 to a navalised F-22 and then to the Su-34 Flanker variant.

far beyond what the designers intended, which is often the case in this type of software environment. I found, for instance, the undocumented feature that you could allocate your pilot as wingman 2, 3, or 4 rather than flight

leader. This relieved you of the burden of making the tactical decisions and issuing commands (drag left, drag right, approach high, approach low etc. etc. etc.). The interesting thing was then to see whether the AI could apply effective tactics. Turns out it could! (They were better than my choices anyway!). I even found that the ground units (Tanks, artillery etc.) could be set to engage each other as the air battle raged overhead. I spent many hours pitting waves of Chinese Shenyang (MiG-21) against F-14 Tomcats and F/A-18 Hornets.

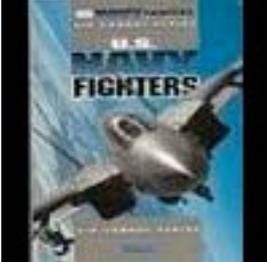
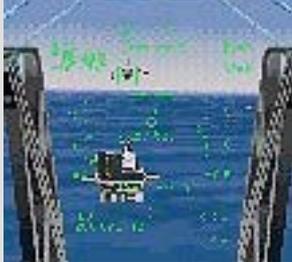
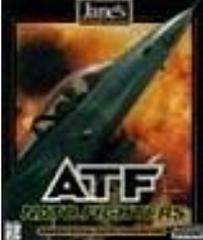


[Brent Iverson](#). His most famous sim was [Chuck Yeager's Air Combat](#), which attempted to recreate [Yeager's](#) air combat in World War 2, Korea and Vietnam.



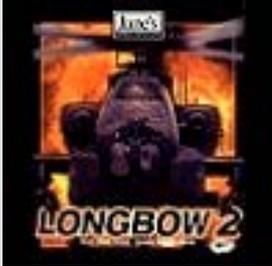
But the icing on the cake was on the second CDROM. A comprehensive multimedia encyclopaedia from [Janes](#) with video of the aircraft and reams of fact sheets covering all the vehicles – land, sea and air, and focussing somewhat on the various SAM and AAA systems. The promise of technical accuracy in the simulation was more fully realised in the last efforts from [Janes Combat Simulations](#) and they continue to be used as training and aids (usually informally) by military pilots.

This series continued until 1998, but despite covering a good range of historical and hypothetical scenarios drafted by [Janes](#), the table based flight model and code base prevented real fidelity in the flight modelling. Still, this was only the beginning.

<p>The initial series of flight sims from Janes Combat Simulations. They never lived up to the claims of fidelity but nonetheless introduced millions to experimentation with air combat tactics.</p>		
 <p>US Navy Fighters DOS. Carrier based a/c in future conflict based on Janes ‘ scenarios.</p>	 <p>Marine Fighters added VTOL aircraft.</p>	 <p>Advanced Tactical Fighters added the stealth a/c F-111, B-2B, and the latest X-aircraft such as the Su-34 with thrust vectoring and rearward mounted radar.</p>
 <p>NATO Fighters added more advanced fighters and the ability to fly any a/c in the sim. This included the F-111, which due to a clerical error only carried about 2500 lbs of fuel.</p>	 <p>USNF 97 recreated the Air War over Vietnam. At least parts of it... and not very well at that. The series was on its last gasp.</p>	 <p>Fighters Anthology collected all the series and ran in Windows.</p>



A Chinese built Shenyang MiG-21 gets behind the larger F-14 Tomcat, described by pilots of smaller fighters as “The flying tennis court!”
 Image from [Fighters Anthology](#)

<p>The penultimate Flight Sim titles from Janes Combat Simulations . These were acclaimed by serving and former military pilots the world over. They still fly them!</p>		
 <p>Longbow</p> <p>Released in 1996 it heralded a new age in fidelity and immersion.</p>	 <p>Longbow 2</p> <p>Added the BlackHawk and the Kiowa Warrior.</p>	 <p>World War 2 Fighters</p> <p>The Ardennes Region, 1944</p> <p>Integration of the reference material went a step further with a virtual museum being accessible within the sim.</p>
 <p>Israeli Air Force</p> <p>Recreated the 6 Day War, 1967, the Yom Kippur War, 1973 and contained a second CD ROM - 50th anniversary of the IAF.</p>	 <p>F-15</p> <p>Strike Missions, in what fans thought was a woefully under-powered F-15-E, but pilots of the a/c confirmed was actually quite accurate!</p> <p>Comments by a USAF pilot</p>	 <p>F/A-18</p> <p>The F/A-18E SuperHornet came alive with a 200 page manual, which was necessary to study if you were to have any chance of fighting in the machine.</p>



Israeli Lavi dogfights a MiG-29 in [Israeli Air Force](#)



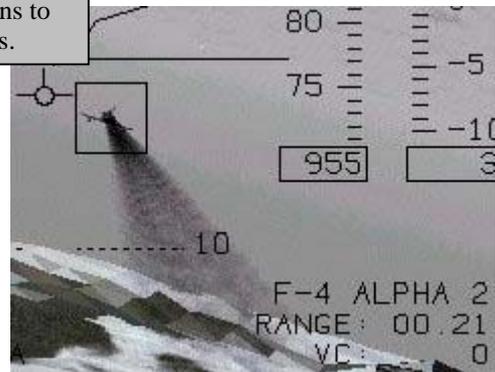
This is when having 2 engines is a distinct advantage.
 F-4 Phantom in [Israeli Air Force](#)

Internet and simulations converge.

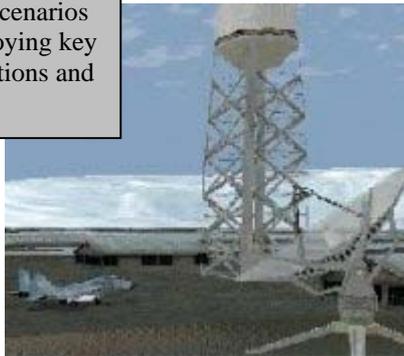
Pre 1990 you were flat out getting a picture or “[artist’s impression](#)” of a MiG-29. Suddenly you could go online and fly the plane with or against other pilots in real time in, for example [Novalogic’s MiG-29 Fulcrum](#). This was a popular sim with simplified avionics which nonetheless gave thousands of people the chance to try air combat tactics as taught to the pros, and see if they worked as advertised.



1998. Not alone anymore.
Flying on-line and using voice communications to facilitate team tactics.



Short multiplayer scenarios were won by destroying key enemy communications and infrastructure.



Images on this page from [The Flight Sim Museum](#)



Battle damage and asymmetric thrust were modelled.

The sim provided a quick way to get an appreciation of the different design philosophies in Soviet aircraft. Examples of differences in instruments were the combined AOA/G meter and the NAV displays.
You also had to think in metric! (Outside the former Soviet Union the standard system of measurement in aviation is Imperial).



Go [here](#) – to watch or download a video of the sim

5. The Author

Peter Inglis is the creator and curator of “[The Flight Simulation Museum](#)” - a unique Australian based entity which preserves and disseminates the history of Computer Flight Simulation. More information here - [About the Flight Simulation Museum](#).



From this to that in 20 years !
What's next ?

The internet has enabled phenomenal growth of special interest communities such as that of Flight Simulation fans and professionals. Ranging in experience from school children to career military pilots, they all share a passion for flight. Where does the [The Flight Simulation Museum](#) fit into all of this?

[The Flight Simulation Museum](#) provides a permanent and growing overview of the entire genre all in one conveniently organised location. It acts as a virtual hub for aviation fans from Beginners to the Military professional.

The [The Flight Simulation Museum](#)” is also accessible via <http://www.flight-sim-museum.com>

Flight Sim Expos

The author was the keynote speaker at [Australia's first international Flight Sim Expo](#), held in 2004 at Kingsford Smith Airport Sydney in the former Ansett facilities. Guest speakers included Ft. Lt. Tom 'Houch' Gleeson, RAAF F/A18 Hornet Pilot and defence simulation specialist, who spoke on 'Simulation and Defence'.



In 1995, in the capacity of research assistant for a [technothriller](#) novel about Australia's Defence Forces, the author went to [RAAF Amberley](#) and RAAF Williamtown, where he had the opportunity to :

1. inspect facilities
2. examine aircraft
3. interview personnel about tactics



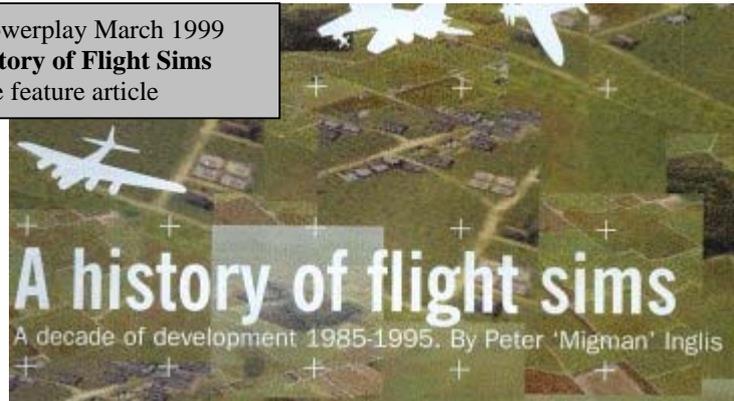
*The author in the Navigator's seat of a RAAF F-111 at RAAF Base Amberley.
Images from [The Flight Sim Museum](#)*



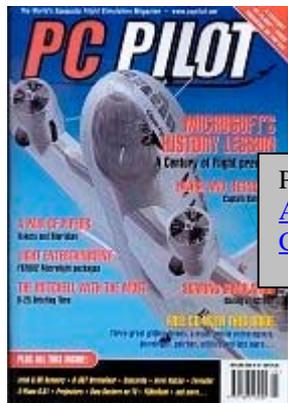
Print journalism by the author on simulation



PC Powerplay March 1999
A History of Flight Sims
6 page feature article



Computer Pilot - July 2002 - **A Brief History of Flight Sims**
6 page feature article.
An entertaining time travel piece revealing the fun of combat flight sims through personal anecdotes.



PC Pilot issue 22 - April 2003
[Avro Vulcan for Microsoft Combat Flight Sim 2](#). A review.



PC Pilot issue 23 - June 2003
- FS Falcon review



Endorsees

"Some sites aspire to be comprehensive; once achieved, they aspire to be [MiGMan's](#)."

Jim Dattilo, Computer Simulations Guide at [about.com](#) who in October 1999 awarded [www.migman.com](#) "Site of the Month".



[Flying Tigers blood chit](#). A historical tribute in leather, handpainted by [Francisco J. Campos](#)

"The team at [MiGMan's](#) have done a fantastic job cataloging the history of desktop flight simulation.

As well as the exhibits, there are a host of combat flying tips, links and resources. We owe them a great many thanks for all their combined efforts, helping us to remember the heritage of this ever-expanding hobby."

[Kenji Takeda](#)

Lecturer in the Aerodynamics and Flight Mechanics
Research Group in the School of Engineering
Sciences at the University of Southampton, UK.

Signed

Date

PETER INGLIS

August 22nd, 2006

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