Inquiry into the planned acquisition of the F-35 Lightning II (Joint Strike Fighter)

Submission
on
Terms of Reference (ToR) Item e.
"*Potential Alternatives to the Joint Strike Fighter*"

WHAT IS THE ONLY ALTERNATIVE TO THE F-35A JSF AND WHY?

"What is America and its closest allies like Canada, Japan and Australia going to do in the post-2015 ***'stealth-on-stealth'/'counter-stealth'*** world where all the ***leading reference threats***, both ***airborne*** and ***surface based***, being ***proliferated around the globe*** by some of the world's ***best new-age capitalists***, have the ***common design aim*** of being ***competitive*** with in ***challenging*** the F-22A Raptor; especially when there are ***so few*** of these aircraft to be a ***persuasive deterrent***, let alone an ***effective defence***?"

Testimony provided to the Parliament by senior defence officials shows what not to do while asserting beliefs, feelings and conjecture based on hearsay, perceptions, indifference to what is real and very little else.
(Refer Annex F)

Air Power Australia Submission to the
Senate Standing Committees on Foreign Affairs Defence and Trade

Structure of Submission: 5 Pages (incl Title Page + Endnotes) plus 33 Pages of Annexes
Filename: A3-Only One Alternative and Why_26Jan16_Final.pdf

F-35 JSF advocates emotively argue *"There Is No Alternative".* Trying to persuade their audience to ignore the many shortcomings of this failed design is dubious, at best, and a contempt for customers' needs [1]. It is, in itself, an alternate reality [2].

The starting point for any discussion of alternatives to the F-35, and indeed the viability of the F-35, has to be centred on the capabilities of the threat systems any future fighter force must be able to effectively defeat and, thus, credibly and persuasively deter. **(Annex A)**

The benchmark over the next three decades for air superiority are the performance and capabilities of the new generation of Russian and Chinese combat aircraft along with the related surface based threats, all developed to fight and defend against the F-22A Raptor.

The Russian PAK-FA, Su-35S and Chinese J-20 designs are all capable of supersonic cruise without the use of thirsty afterburner; sustaining almost twice the speed at almost twice the altitude at which the F-35 is optimised to operate.

Supersonic cruise capability and all that entails is, thus, essential; as is agility (see below).

The Russian PAK-FA, Su-35S and Chinese J-20 have capable long range sensor suites, mandating both robust broadband and all aspect stealth capabilities to deny these fighters long range missile shots. F-35 stealth is not all aspect; it is optimised for nose on threats.

No less important, the Russian PAK-FA, and Chinese J-20 and J-31 have similar though likely better stealth optimisations to the F-35, mandating a sensor suite built to detect low signature targets at long ranges. The F-35 sensor suite was optimised from the outset for ground attack, not the long-range detection/engagement of low signature aerial targets[3].

The Russian PAK-FA and Su-35S and Chinese J-20 and J-31 are built for exceptional agility in all aerial combat, to deny or spoil an opponent's missile engagement opportunities. Yet senior USAF officials admit *"any F-16 beats the F-35 in basic fighter maneuvering"*, while another test report confirms the mediocre F-35 aero performance.[4].

The RAAF leadership has consistently stated the need for a *"5th Generation Fighter"*. **Annex A** tabulates and compares cardinal parameters for *"5th Generation Fighters"*. The conclusions are self evident to subject matter experts. The F-35 is "5th Gen" only in vendor marketing literature.

Legacy fighters are not viable for air combat against advanced stealthy super-cruising opponents such as the Russian PAK-FA and Chinese J-20 fighters.

Both reference threat aircraft will enter service over the next two years, and will almost certainly be built and evolved for decades to come, to satiate the global market, as block replacements for hundreds of export FLANKER variants[5].

Vendor claims that upgraded variants of the Boeing F-15 and F/A-18, LM F-16, Eurofighter Typhoon, Dassault Rafale or SAAB Gripen will be viable do not stand up to scrutiny. While all outperform the F-35 aerodynamically and aero/propulsively, and some have limited (~Mach 1.2) super-cruise, they lack the stealth capabilities of the PAK-FA, J-20 and J-31.

The simple reality is that to defeat foreign fighters designed to challenge the F-22A Raptor, a fighter as good as or better than the F-22A Raptor is required. The notion that the F-35 is such a fighter is patently absurd. This was well understood a decade ago. **(Annex B)**

Confronted with stealthy super-cruising extremely agile adversaries, there is no alternative to the F-22A Raptor & evolving that sound design as originally intended[6].

In 1998, one of the APA co-founders proposed that Australia procure an export variant of the F-22A Raptor. This led to the APA *"F-22/Evolved F-111 Option"* that proposed a force mix option of F-22A Raptors and cost effectively evolved, upgraded F-111s for the RAAF[7].

In 1998, the USAF and its F-22 principal contractors developed and gained approval to implement a plan for provision of the F-22A Raptor as a candidate air combat aircraft system for the AIR 6000 NACC Project. This work, done between 1998 and early 2002, included addressing the LOEXCOM (Low Observable Executive Committee) requirements developed to satisfy the Obey Amendment to the US DoD Appropriations Bill.

However, very senior ADF officials decided to exclude the F-22A from consideration. This decision was made around the time of release of the Defence 2000 White Paper, pre-empting the Cabinet decision of June 2002 and by some degree. **(Annex C)**

Production of the F-22A Raptor was halted in 2011, after an acrimonious Congressional debate in 2009, which saw SecDef Robert M. Gates sack or "early retire" a number of senior USAF personnel[8]. Gates reneged on the promise by the Clinton Administration to supply the F-22 to Israel, and reneged on his public promise to ask Congress for permission to supply the F-22 to Australia[9].

Provisions were made for F-22 production restart should the need arise, and two studies by RAND were commissioned to explore shutdown alternatives, and identify issues and costs in a future F-22A Raptor production restart, assuming that the original production line and plant would have to be re-assembled for this purpose. Critical items of tooling were preserved and placed into mothball storage[10].

A restart of F-22A production could be executed in 12-18 months, sooner and cheaper if the APA-SASD[11] plans were to be adopted. As with any aircraft, the unit cost of the aircraft depends mostly on the annual production rate and the integrity of the design. There are no integrity issues with the F-22A design. It is well suited for the application of the evolving design and development doctrine inherent in all good Systems Engineering designs[12].

An important observation is that the final batches of F-22A Raptors delivered were built for a unit flyaway cost (UFC) under US$137 Million, which is considerably less than the current and expected UFC for the F-35A configuration offered to Australia back in 2002. [13]

The strategically obsoleted F-35 is a failed experiment in procurement methods, joint development, and design. Continuation of this program qualifies at best as corporate welfare for the military industrial congressional complex (MICC) and, at worst, as throwing good money after bad with little if any return on investment (ROI) in the national interest.

Significant ROI can be achieved if all that great wherewithal pulled together under the JSF Program now being used to build the wrong aircraft is transitioned over to building the right aircraft. Meanwhile, Russia (nor China) is not waiting around and TIOE! [14] **(Annex D&E)**

The extensive production infrastructure and network of subcontractors built up for the JSF Program should be employed to manufacture and evolve additional F-22 Raptors for the US Air Force, and trusted US Allies, with an F-22 based option for other partner nations[15].

Endnotes

[1] Henry Ford's famous quote *"Any customer can have a car painted any colour that he wants so long as it is black"* comes to mind. The needs of the customer are less important than the pursuit of a market monopoly position.

[2] Goon ,P.A.,*JSF Alternate Realities…and from whence they come*, APA NOTAM #31, 19th February, 2009, URI: http://www.ausairpower.net/APA-NOTAM-190209-1.html

[3] Refer Pelosi M.J. and Kopp C., A Preliminary Assessment of Specular Radar Cross Section Performance in the Sukhoi T-50 Prototype, *Air Power Australia Analyses*, vol IX, issue 3, Air Power Australia, Australia, pp. 1-37;

Kopp C. and Goon, P. A., Assessing the Sukhoi PAK-FA, *Air Power Australia Analyses*, vol VII, issue 1, Air Power Australia, Australia, pp. 1-27;

Pelosi M.J. and Kopp C., A Preliminary Assessment of Specular Radar Cross Section Performance in the Chengdu J-20 Prototype, *Air Power Australia Analyses*, vol VIII, issue 3, Air Power Australia, Australia, pp. 1-35;

Kopp C., An Initial Assessment of China's J-20 Stealth Fighter, *China Brief*, Volume: 11 Issue: 8, The Jamestown Foundation, Washington, DC 20036, USA, 6th May, 2011; Kopp C., Assessing the Tikhomirov NIIP L-band active electronically steered array, *Air Power Australia Analyses*, vol VI, issue 6, Air Power Australia, Australia, pp. 1-19;

Kopp C., *Advances in Russian and Chinese active electronically steered arrays (AESAs)*, Phased Array Systems & Technology, 2013 IEEE International Symposium on (ARRAY-2013), 15-18 Oct. 2013, Waltham, MA, USA, doi: 10.1109/ARRAY.2013.6731796, pp. 29 - 42. [Invited, Plenary Paper], URI: http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=6731796

[4] Refer Sweetman W., Cognitive Dissonance, *AVIATION WEEK & SPACE TECHNOLOGY*, DECEMBER 21,2015-JANUARY 3, 2016, p20 and Axe, D., Test Pilot Admits the F-35 Can't Dogfight; New stealth fighter is dead meat in an air battle, *War is Boring*, Jun 29, 2015, URI: https://medium.com/war-is-boring/test-pilot-admits-the-f-35-can-t-dogfight-cdb9d11a875 - .nxn58m7cg

[5] Russian media and advertising for the PAK-FA has explicitly argued that the aircraft should replace all Russian Aerospace Forces (VKS) FLANKERs, export to India was agreed from the outset, and export to Iran actively promoted. The closer Russia gets to insolvency, the less restrained Russian export policy will be.

[6] Kopp C., *When America's Stealth Monopoly Ends, What's Next?*, APA NOTAM, 4th March, 2009, URI: http://www.ausairpower.net/APA-NOTAM-040309-1.html

[7] Kopp C. and Goon, P.A., *Review of Defence Annual Report 2002-03: Analysis of Department of Defence Responses: Proof of Prior Knowledge: Regional Capability Growth and Joint Strike Fighter Limitations vs The 1998 F/A-18 Replacement Study*, Submission to JSCFADT, July 2004, URI: http://www.aph.gov.au/Parliamentary_Business/Committees/House_of_Representatives_Committees?url=jfadt/defenceannualreport_2002_2003/dar_subs.htm; and

Kopp C. and Goon, P.A., *Inquiry into Australian Defence Force Regional Air Superiority: Attaining Air Superiority in the Region: Testing the Evidence*, Submission to JSCFADT, February 2006, URI: http://www.aph.gov.au/Parliamentary_Business/Committees/House_of_Representatives_Committees?url=jfadt/adfair/subs.htm

[8] Dorr R. F., *Air Power Abandoned: Robert Gates, the F-22 Raptor and the Betrayal of America's Air Force*, Published by Robert F. Dorr, Oakton, VA, 2015, URI: http://www.amazon.com.au/Air-Power-Abandoned-Betrayal-Americas-ebook/dp/B013CJEBP0

[9] News Report, Aussies can be trusted with F-22: Gates, *Sydney Morning Herald*, February 25, 2008, Cite: *"I think it probably is at the end of the day not appropriate for Australia to make its case directly to the Congress, to change the law. I think that's my job and the job of the administration," he told ABC Television."; "When asked if there was any reason why Australia could not be trusted with the F-22, Mr Gates replied: "Absolutely not."*; URI: http://www.smh.com.au/national/aussies-can-be-trusted-with-f22-gates-20080225-1unz.html

[10] Graser J.C., et al, *Retaining F-22A Tooling, Options and Costs*, TR831, RAND Project Air Force, RAND Corporation, January, 2011; and Younossi, O., *Ending F-22A Production, Costs and Industrial Base Implications of Alternative Options*, MG797, RAND Project Air Force, RAND Corporation, February, 2010.

[11] Details of the APA-SASD (Air Power Australia – Solution to the Air Superiority Debacle) plans are outside the scope of this very public Submission though the basis of these plans is, like all such things, very rational and logical as well as being very Australian.

[12] The Russian Flanker family of air combat aircraft wherein every new model has been a significant advance in performance and capabilities on previous models is a text book example in the application of the evolving design and development doctrine. Another is the 911 Porsche series of high performance sports cars wherein the original innovative and robust but technologically demanding 1964 design of Dr Ferdinand Porsche has been refined and evolved, using this doctrine, into one of the world's automotive icons.

[13] The Block 3 F-35A JSF configuration and capabilities inherent in what is on offer today is markedly and significantly less than the Block 3 configuration and capabilities offered to Australia back in 2002 through to 2004.

[14] TIOE! – Time Is Of (the) Essence! A term of imperative, commonly used in contracting.

[15] Refer Kopp C., United Kingdom: F-35 or F-22?, APA NOTAM, 25th February, 2009, URI: http://www.ausairpower.net/APA-NOTAM-240209-1.html;

Kopp C., F-35 JSF: Can It *Meet Canada's Needs?,* APA NOTAM, 19th October, 2010, URI: http://www.ausairpower.net/APA-NOTAM-191010-1.html.

Moreover, a navalised variant for operation from US Navy carriers is feasible, and would address extant capability gaps for the US Navy and Marine Corps.

Refer Mills C.L. and Goon P.A., *Navalising the F-22 Raptor, Restoring America's Maritime Air Dominance*, APA NOTAM, 23rd February, 2009, URI: http://www.ausairpower.net/APA-NOTAM-230209-1.html; and

Mills, C.L., *F-22A Raptors for the Marine Corps*, APA NOTAM, 9th February, 2009, URI: http://www.ausairpower.net/APA-NOTAM-090209-1.html

Annex A to APA Submission to SFADT Inquiry
What is the Only Alternative to the F-35 JSF and Why?
Terms of Reference (ToR) Item e.
Dated 23 January 2016

ANNEX A

AIR POWER AUSTRALIA

ZOCT TABLE:

IS THE JSF REALLY A FIFTH (5TH) GENERATION FIGHTER?

Senate Estimates, 02 & 03 June 2014

Senator CONROY: …..You have been very emphatic that ***generation five*** against ***generation four*** is ***not a contest***. Other than the countries you have named, are there any other countries that you are aware of who have developed the fifth-generation fighter capacity at this stage?
Air Marshal Brown: The Chinese have two aircraft in development and the Russians have an aircraft as well. But the way I would characterise their development is that the JSF flew two prototypes probably 10 to 12 years ago, and that is about where both of those countries are at the moment. There is a fair bit of work to be done on all three aircraft. I do not believe that any of those three aircraft have the same stealth characteristics of an F-35.
Air Marshal Brown: I think it is on two bases: probably stealth technology, the inability to have low probability of detection on electronic emissions, and engine technology. This is where both the Russians and the Chinese are significantly behind Western engines.
Air Marshal Brown: No, I think that they *[the Russians]* would like to see it *[Su-50]* as a pure fighter aircraft. At the moment I am not aware of any air-to-ground munitions that it is able to drop.
Air Marshal Brown: One [Chengdu J-20] is probably a pure fighter. I would classify it more as an interceptor. The other one [Shenyang J-31] is a little bit more like an F35.
Some Data and Facts: ***Beliefs, feelings and conjecture are negotiable; data and facts are not!*** (1) Two X-35's flew in 2000; were Dem/Val proof-of-concept test articles; not representative of F-35. (2) Sukhoi contracted to design/develop the Su-50 in 2002, same year JSF SDD contract was signed. (3) Reports of Chengdu J-20 scaled and full scale test articles flown circa 2006. (4) Quality of finish of J-20 noted back in 2011 as being at level of pre-production prototype. (5) J-20 has equivalent of 4 x large weapon bays + 6 x external store wing stations. J-20 Serial No 2021 is first production aircraft. (6) Su-50 (T-50 PAK-FA) has similar weapon/store carrying configuration; is equipped with new A-A and A-G weapons as well as weapons/stores from extant inventory. Su-50 in full scaled production by 2017. (7) Unlike the F-35A JSF, the J-31 is a twin-engined, large finned, LO 'stealthy' design aircraft with shaping features more akin to those of the F-22A Raptor. Likely will also be carrier suitable.

Annex A: ZOCT (*Zero-One Comparative Technique*) Table

Is the JSF Really a Fifth Generation Fighter?

(Updated: 13 January 2016)

5th Generation Air Combat Fighter Capability Metrics	Operating Post 4th Gen Air Combat Capability Aircraft				Current Threat	NACC Aircraft
	F-22A Raptor	T-50 PAK-FA	Chengdu J-20	F-35A JSF Lightning II	Gen 4++ Su-35S	Super Hornet F/A-18F
	USA	Russia	China	Internat'l	Russia	USA
Super Cruise, Mach 1.5 or greater in MILPWR	Yes (0)	Yes (0)	Yes (0)	No (-1)	Yes (0)	No (-1)
Super Agility Supersonic / Subsonic	Yes (0)	Extreme Plus (+1)	Extreme (+1)	Neither (-1)	Extreme (+1)	Neither (-1)
Very High Specific Excess Power - P_s	Yes (0)	Yes (0)	Yes (0)	No (-1)	Yes (0)	No (-1)
Thrust Vectoring Control - TVC 2-D	Yes 2-D (0)	Yes 3-D (+1)	Accommodated	No (-1)	Yes 3-D (+1)	No (-1)
Advanced Highly Integrated Avionics	Yes (0)	Yes (0)	Yes (0)	Yes (0)	Yes (0)	Yes (0)
Electronically Steered Array (ESA) Radar	High Power Aperture (+1)	High Power Aperture (+1)	Yes (0)	Medium Power Aperture (0)	High Power Aperture (+1)	Medium Power Aperture (0)
Additional ESA Apertures	FFBNW (0)	Yes + L Band (+1)	Insufficient Data	No (-1)	Yes + L Band (+1)	No (-1)
High Situational Awareness (SA) - Onboard/Offboard	Yes (0)	Yes (0)	Yes (0)	Yes (0)	Yes (0)	Yes (0)
Large Supersonic Weapons Delivery Envelope	Yes (0)	Yes (0)	Highly Probable	Limited (Slab Doors / Toed-In SS) (-1)	Yes (0)	Limited (Toed-Out Carriage) (-1)
Large Thrust to Weight Multi-Engine Thrust Growth	Yes 2 Engines Large Growth (0)	Yes 2 Engines Large Growth (0)	Yes 2 Engines Large Growth (0)	Middling T/W Single Engine Little Growth (-1)	Yes 2 Engines Large Growth (0)	Middling T/W Little Growth (-1)
High Combat Ceiling Loiter/Operate (> 7 deg /sec sustained @ 30 kft)	Yes, > 55 kft Yes (0)	Yes, > 60 kft Yes (0)	Yes, > 50 kft Yes (0)	No, < 45 kft No (-1)	Yes, > 55 kft Yes (0)	No, < 45 kft No (-1)
Very Low Observable (VLO) RF Stealth	All Aspect Wideband (+1)	Yes but Partial (0)	Yes but Partial (0)	Yes but Partial (0)	No (-1)	No (-1)
Good Non RF Low Observables	Yes (0)	Yes (0)	Yes (0)	No VOVS/WVE (-1)	Yes (0)	Yes (0)
Large Internal Usable Fuel Load / Persistence (klbs)	Yes >18k lbs PLUS thermal cooling fuel (0)	Yes, ~23k lbs (+1)	Yes, ~25k lbs (+1)	18.2k lbs MINUS thermal cooling fuel (0)	Yes >23k lbs (+1)	No <13.5k lbs (-1)
Internal Weapon Carriage Hard Point Stations	Yes 6 + 2 (0)	Yes 6+2 (0)	Yes 6 + 2 (0)	Yes 4 (0)	Partial (Tunnel Pod) 2 - 4 (-1)	No (-1)
ZOCT Scoring by 5th Gen Metrics	+2	+5	+2	-9	+3	-11

ZOCT Scoring:
-1 Does not meet 5th Gen Metric
0 Meets 5th Gen Metric
+1 Meets 5th Gen Metric with Enhancing Characteristic/s

Notes:
(1) Though outside scope of this ZOCT Table, suitable and effective A-A/A-G weapons are crucial metrics of the overall air combat capability.

(2) Price is not a 5th Gen metric. Though, when it comes to comparative/competitive pricing of any aircraft let alone 5th Gen air combat aircraft, the fundamental tenets of any such analysis include:

a. Compare the 'total price', not some subordinate 'cost' (e.g. unit recurring flyaway cost).
b. Compare in US$'s applicable at the time of purchase, cogniscant of purchasing power parity (PPP) and the influence this has on comparative/competitive pricing outcomes.
c. Match 'price' to 'capabilities'- the price being total payment at time of purchase for what is needed.
d. Beware of 'order splitting', 'price splitting' and other techniques used to spread the price over various activities other than the acquisition. For example, in relation to the F-35 JSF, '*the never ending price*' baked into the designs.

Summary of Observations

a. Relative to most Fourth (4th) and evolved Third (3rd) Generation air combat fighter aircraft, Fifth Generation Fighters are large, twin engined quite stealthy (VLO-RF/LO-Other) designs with Super to Extreme Agility over the aircraft's total flight envelope (from post-stall to high supersonic), capable of super-cruising at up to Mach 1.5 or higher, with sufficient specific exess power (Ps) for both BVR and WVR engagements, inherent survivability and persistence (both weapons and fuel), and the ability along with the sensors and information processing and networking capabilities to provide their pilots and other operators with high levels of precise and accurate situational awareness in real time.

b. In terms of Fifth (5th) Generation Air Combat Fighter Capability Metrics, the F-35A JSF scores poorly, rating only slightly ahead of the F/A-18F Super Hornet - a Gen 4.5 design - yet well behind the Su-35S - the Russian Gen 4++ design.

Conclusions

1. The F-35A JSF's shortfalls in most of the cardinal Fifth (5th) Generation capabilities do not warrant this aircraft being called a Fifth (5th) Generation Fighter Aircraft, as defined by the marketplace.

2. This should come as no surprise to anyone familiar with the JSF JORD and its origins which sought a medium stealth fighter (MSF) with a single engine and relaxed aero-propulsive performance, both for reasons of affordability, and commonality of design with the STOVL F-35B variant being the baseline design for all three JSF design variants.

Annex B to APA Submission to SFADT Inquiry
What is the Only Alternative to the F-35 JSF and Why?
Terms of Reference (ToR) Item e.
Dated 23 January 2016

ANNEX B

APA 2009 FIGHTER RECAPITALISATION STRATEGY BRIEFINGS

In 2003 in a paper entitled '*Meeting the Anti-Access and Area-Denial Challenge*', the now Deputy Secretary for Defense, Robert Work, along with colleagues at the Center for Strategic and Budgetary Assessments (CSBA), a US Defense Think-Tank, wrote:

"*Granted, one could argue or assume that A2/AD threat, as depicted in this report, is overblown and will not emerge within this decade—or the next. Doing so, of course, would be tantamount to judging the risk of encountering serious A2 or AD capabilities before 2020 as unlikely or remote. In other words, foreseeable opponents concerned about United States projecting power into their regions of the world will not really be serious for a long while to come. At the end of the day, however, this viewpoint appears to be a huge gamble and one that neither prudence nor history could recommend with much confidence.*"

In 2014, over a decade later, in a Tasking Memo to the Chairman of the Defense Science Board, the Under Secretary of Defense – Acquisition, Technology and Logistics, Frank Kendall, wrote:

"*Our military forces are facing serious challenges from rapidly advancing threat capabilities and employment of anti-access/area-denial (A2AD) strategies. In heavily denied A2AD environments, where our traditional operational and warfighting effectiveness is challenged in the air, on land and on the ocean's surface, the United States currently retains an advantage undersea. This undersea advantage should be exploited as a means of potentially offsetting the severe warfighting challenges in other domains."*

The problem of A2/AD capability growth has been plainly visible since the mid-late1990s, when Russian analysts produced a series of widely propagated A2/AD strategy papers, and Russian industry launched a major campaign to promote the export of A2/AD weapons.

Despite repeated efforts by Bob Work and others in the USA, and APA in Australia, the response by senior defence officials, especially in Australia, has been over a decade of wilful blindness, and stubborn rejection of the strategic ground truth.

Annex B: APA 2009 Fighter Recapitalisation Strategy Briefings

In 2009 APA produced five strategy briefings, to illuminate and explain the risks arising from insufficient numbers of F-22 Raptor fighters in Western air force fleets. These were widely distributed in the United States, especially to Congressional staff.

Notable is that the briefings show the extent to which the US and its allies rely upon the precondition of air superiority to perform land, sea and other air operations. If this implicit assumption is not met, strategic impacts are pervasive and manifold. The briefings do not account for later developments, such as the disclosed progress in production of stealthy Chinese J-20 and J-31 fighters, evolution of the Russian S-300VM/V4 9M82ME missile to 400+ km range capability, further variants of the Russian 55Zh6 Nebo family of counter-stealth radars, and advances in Chinese and Russian X-band AESA radar technology.

The original briefings are available online:

1. Kopp C. and Goon P.A., *The Global Impact of Anti-Access Weapons*, Briefing Slides, Air Power Australia, June, 2009, URI: http://www.ausairpower.net/PDF-A/APA-Anti-Access-Brief-June-2009-A.pdf
2. Kopp C. and Goon P.A., *High Technology Air Defense Weapons vs Planned US Force Structure*, Briefing Slides, Air Power Australia, May, 2009, URI: http://www.ausairpower.net/PDF-A/APA-SAM-Brief-May-2009-A.pdf
3. Kopp C. and Goon P.A., *Why 187 F-22s Are Not Sufficient*, Briefing Slides, Air Power Australia, May, 2009, URI: http://www.ausairpower.net/PDF-A/APA-Air-Superiority-Brief-May-2009-A.pdf
4. Kopp C. and Goon P.A., *The Failed Fighter Recapitalisation Plan*, Briefing Slides, Air Power Australia, May, 2009, URI: http://www.ausairpower.net/PDF-A/APA-Red-Fighter-Brief-May-2009-A.pdf
5. Kopp C. and Goon P.A., *The Proliferation of Counter-Stealth Systems*, Briefing Slides, Air Power Australia, May, 2009, URI: http://www.ausairpower.net/PDF-A/APA-CVLO-Brief-May-2009-AE.pdf

Annex C to APA Submission to SFADT Inquiry
What is the Only Alternative to the F-35 JSF and Why?
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Dated 23 January 2016

ANNEX C

THE F-22 FMS* STORY

(* Foreign Military Sales)

A PRÉCIS OF HISTORICAL HAPPENINGS AND COMMUNICATIONS OVER THE PERIOD 1998 TO 2004 IN RELATION TO PROVISION OF THE F-22A RAPTOR AIR DOMINANCE FIGHTER FOR AUSTRALIA.

"*Air superiority is at the heart of Australia's military strategy. We need to be able to ensure that the full range of ADF operations—land and maritime—can be conducted without threat from adversary air operations*."

"*The F/A-22 will be the most outstanding fighter aircraft ever built. It may even represent the end of the line in manned fighters. Every fighter pilot in the Air Force would dearly love to fly it.*"

"*As already stated, there is no question that the F/A-22 will be the world's best aircraft for the air superiority task. It is not surprising then, when comparing the F/A-22 with the JSF, nearly all discriminators favour the F/A-22.*"

Air Marshal Angus Houston, August 2004
https://www.aspi.org.au/publications/strategic-insights-9-is-the-jsf-good-enough

Back then and, even more so today, such comments beg the question:

"Why aren't we buying the best for the defence and security of Australia?"

~~*AIR POWER AUSTRALIA EXECUTIVE EYES ONLY*~~
~~*PRIVATE AND STRICTLY CONFIDENTIAL*~~

Controlled Copies to: Dr Brendan Nelson, Minister for Defence
Dr Dennis Jensen, MP; Mr David Fawcett, MP
LtGen David Hurley, Head of Capability Development Executive

Subject: **THE F-22 FMS STORY**

The following is a precis of advice received from associates in the USA who have been closely associated with the F-22 Program. This precis is a compilation of crosschecked communiques dating back to 2000.

- In the mid to late 90's, a LM/Boeing team was established to develop an export configuration for NATO type countries - not included was the UK due to their total commitment to the Euro-Fighter.

- At the same time, the USAF sponsored the F-22 FMS Team in educating the Team on "anti-tamper" techniques (this was just after the shoot-down of the F-117 in Bosnia). Over the next several years, the FMS team plus various officers from the Secretary of the Air Force (SAF) divisions (with FMS team doing all the work and USAF reviewing/approving) developed a comprehensive anti-tamper/technology transfer plan for the F-22 (cost LM $US5M-$US8M). The Team looked at every piece/part of the jet, sub-systems, combination of sub-systems, and total weapon system in terms of classification, combat effectiveness, impact of Allies flying F-22 exports with us and against us, technology gained from a downed aircraft, inadvertent disclosure , and technology transfer for country gain (this has happened on other systems - details extremely sensitive politically).

- The Team then used this anti-tamper/tech transfer model to develop an exportable F-22 configuration (this model for anti-tamper/tech transfer was adapted by DoD as their standard - at no cost to them).

- The Team briefed this configuration to SAF/AQP (Acquisition Programs Tactical) who was MajGen Carlson - He was very supportive of our efforts and directed us to explore a configuration specifically for Australia - about this time Gen Ryan had taken over as the CSAF.

- The Team was then asked to build an unclassified F-22 briefing for Gen Carlson to give at an Air Power Australia Conference in Canberra – Members of the Team were invited as technical advisors (this turned out to be the kick-off for the RAAF Air 6000 effort). The Team briefed the then CAF (AM Les Fisher) and his staff, the Air 6000 team, several RAAF general officers and briefed some Aussie named Carlo Kopp in the LM offices - briefing given by George Standridge. During this time Bob Bauerline was SAF/IA.

- Gen Ryan was very supportive of a configuration for the RAAF. When he was younger he had spent an exchange tour with the RAAF, so he knew many of the RAAF senior staff when he became CSAF. When Ryan attended the USAF Air Command and Staff College or the Air War College (not sure which), Errol McCormack attended also. Ryan had known McCormack previously and was his neighbour at the school - they and their families became very close friends.

- McCormack came to the US during Ryan's term as CSAF and was briefed on the F-22 in Ryan's office. The briefing was given at the highest classification level - to the Team's knowledge, this was the one and only time an Allied military member was invited an unrestricted look under the F-22 skirt.

- In June 2000, the School of Advanced Air Power Studies at the Air University at Maxwell AFB, AL published the treatise entitled, "U.S. Military Aircraft for Sale: Crafting an F-22 Export Policy" by Lt Col M. H. Molloy, USAF. The purpose of this paper was twofold. First, to offer "a general framework for junior and senior decision makers to use as a touchstone when considering the transfer of advanced air technologies". Second, to "specifically address(es) the exportability issues associated with the F-22".

- In the meantime – the LM/USAF FMS Team worked on an Australian configuration. LM was leaning forward while the USAF (SAF/AQL) was dragging the anchor. The Industry members (principally LM) did over 25 major ops analyses in developing Configuration A (Australia) and Configuration B (NATO). The Air Force briefed Gen Ryan on Configuration A and the tech transfer impasses among the team. The Team (LM/USAF) were sent back to the drawing board by Ryan with very specific guidance on Configuration A in order to brake the impasses. These were the Chief's guidelines:

  1. Same engine - no degrade
  2. Same signature
  3. Jet will not be used against us
  4 Tech transfer concern is downed aircraft scenario / inadvertent disclosure only - same as USAF
  5. Full knowledge of all capabilities - information to remain in the embedded training system resident in the jet
  6. Withhold some hardware until needed, but full knowledge and training capabilities remains in the jet

- The Australian Configuration (A) was briefed to Ryan and the SecAF and both approved, directing the Team to build two briefings for the RAAF:

  1. F-22 performance specifications
  2. Value of stealth (generic secret to include F-22 known examples and JSF projected examples)

  Three of the Team developed these briefs for the Air Force. During this time frame Gen John Jumper became the CSAF, Dr James Roche became the SecAF, Mr Willard Mitchell became SAF/IA, and AM Houston became the RAAF CAF. Mitchell was given the two briefs, but directed us to give them to the new CSAF and SecAF - we did and got enthusiastic approval to brief the RAAF and made plans for a Sept 01 visit.

- Somewhere around this time, the new CAF, AM Angus Houston, visited Washington (around mid 2001) and had a one-on-one meeting with Mitchell. Houston came to the LM offices for briefs but was late and the Team's F/A-22 brief was cut from 45 mins to only 10 mins so that JSF could brief for a full hour.

- One of the Team members recalls that the only question Houston asked him was "you were a fighter pilot, right"? He says that then and there he knew and it was obvious, based on this

question and Houston's demeanour, that he (Houston) had no real interest, for whatever reason, in the F/A-22.

- During 2001, the latter half in particular, other senior officials (both military and civil service) from the Australian Department of Defense visited Washington DC and had meetings with senior management of LM and senior officials at the Pentagon, including Willard Mitchell. These visitors included an AVM Ray Conroy and the Undersecretary of Defense Acquisition, a Mr Mick Roche, as well as others with the names of Gray, Learmonth, Blackburn and Air Commodore John Harvey, now the Australian JSF Program Director.

- Members of the Team travelled with the USAF to Australia to give the two F/A-22 briefs to the RAAF, in particular, the Air 6000 Project Office, as these were in response to their RFI. But, they were cancelled by Mitchell while the members of the Team were enroute. The Team landed and were told to go home once they got to Canberra, but 9-11-01 delayed that somewhat. From that point on, the Team members were told by their respective bosses to shelve the F/A-22 for Australia, as they had been told by senior defence officials (uniformed RAAF and civil service) that Australia wanted the JSF.

- End of the RAAF F-22 story.

Extracts from Additional Comments -

Japan has been showing increasing and considerable interest in the F/A-22 for over 12 months (now has RFI in with USAF) and apparently are not concerned with cost. We believe that they will be presented the "B" type configuration. This configuration will be much more costly than the "A" configuration because the "A" required very minimal changes. This is the configuration which, if Australia was to be the international launch customer for the F-22, the development and manufacture of the parts for this configuration could be considered as part of the industrial participation package.

Well, Peter, that's the best we can do - some sensitive stuff here, especially the story in total - please use bits and pieces judicially as you need them.

Addenda:

The US$1.2 billion being cited for developing an export version of the F-22 was the figure calculated by the Team for Configuration 'B' back in the late 1990s. This figure is seriously inflated since the instructions provided to the Team included:

1. Costs for developing Configuration 'B' export version would not be paid for by the USAF but by State, considering the State for which this version was intended.

2. As a result, cost was not a consideration in the development of this estimate.

3. The nature and resulting highly inflated estimate for Configuration 'B' was due to the results of the releaseability risk analysis which showed significant risks for compromise, which unlike for Australia, would require considerable development to address.

Annex D to APA Submission to SFADT Inquiry
What is the Only Alternative to the F-35 JSF and Why?
Terms of Reference (ToR) Item e.
Dated 23 January 2016

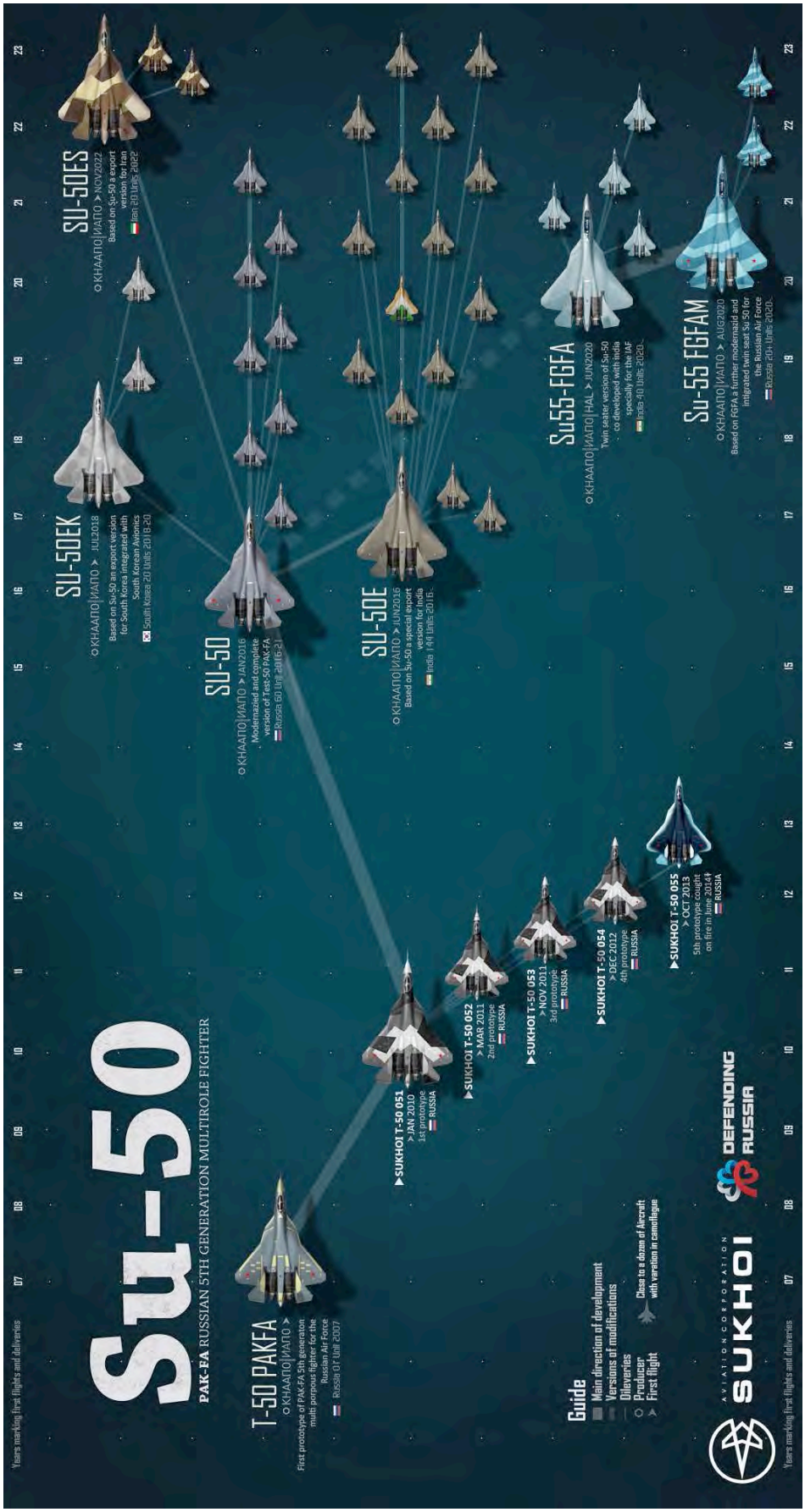
ANNEX D

PLANNED AND PROPOSED SU-50 EXPORT VARIANTS

Senate Estimates, 02 June 2014

Senator CONROY: You mentioned that you thought that the developmental stage of those other fighters would be in the early 2020s. Someone is suggesting to me that the T50 PAK FA and the Chengdu J20 are both scheduled for initial operating capacity in 2019. Are you able to shed any light on those claims?
Air Marshal Brown: I suspect that it is a bit like saying the initial operation of the JSF would be in 2012 or 2013. You tend to be very optimistic at the start of these programs.
Air Marshal Brown: Nobody has bought into the Chinese platforms, but the Indians have got a co-development project with the Russians on the PAK T50. **Senator CONROY:** And Indonesia? **Air Marshal Brown:** Not that I am aware of.
Some data and facts: *Supposition and guessing have no place in strategic planning.* 1. Sukhoi Design Bureau has been under contract since 2002 to develop and produce the T-50 PAK-FA. Chengdu has almost certainly been working on the J-20 since 2002. 2. Official reports put both of these 5th Generation aircraft reaching their nation's equivalent of IOC by 2019 though risk analysis puts this as likely sooner due to the evolving design and development doctrines under which theses jets are being produced. 3. Indonesia's stated plan is for a 180 x Modern Flanker Fleet by 2025. Indonesia has ordered the Sukhoi Su-35 Super Flanker as has China. 4. Like the Su-35S, the Su-50 has been specifically designed with export as part of this jet's life cycle planning.

Annex D: Planned and Proposed Su-50 Export Variants



Descriptions of Export Variants:

KnAAPO/IAPO [Irkut] Su-50:

Russian Federation Vozdushno-Kosmicheskiye Sily (Aero Space Forces) Variant

KnAAPO/IAPO [Irkut] Su-50E:

“Special Export Variant” for Indian Air Force (initial deliveries)

KnAAPO/IAPO [Irkut]/Hindustan Aeronautics Ltd Su-55 FGFA:

“Dual Seat Co-Developed Variant” for Indian Air Force (later deliveries)

KnAAPO/IAPO [Irkut] Su-55 FGFAM:

Russian Federation Vozdushno-Kosmicheskiye Sily Dual Seat Variant

KnAAPO/IAPO [Irkut] Su-50EK:

Variant for Republic of Korea Air Force using South Korean avionic components

KnAAPO/IAPO [Irkut] Su-50ES:

Variant for Islamic Republic of Iran Air Force based on Russian VKS Su-50

Annex E to APA Submission to SFADT Inquiry
What is the Only Alternative to the F-35 JSF and Why?
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Dated 23 January 2016

ANNEX E

T-50/SU-50 PAK-FA PRE-PRODUCTION PROTOTYPE #055

Senator CONROY: As you say, the *commentariat*, others, have made the comment that they believe that the ultimate Russian fifth-generation fighter will be superior as a fighter aircraft to our fifth-generation planes.
Air Marshal Brown: Can I just give you an example? We actually did an exercise, probably about three months ago—again, this was with the Super Hornets. They have 4.5 gen with an AESA radar. It was against the specialist aggressor squadron from the United States. I think the kill ratio was in excess of 20 to one in favour of the Super Hornets. I am very confident given the training that we do and the knowledge that we have of these systems and that is why I tend to dismiss the *commentariat* out of hand.
Analysis of Response: 1. Response avoids and does not answer the question which is about Su-50 vs F-35A and which capability is superior, with explanation of how and why being implicit and self evident. 2. Rather, response is misdirection to an unrelated activity replete with suppositions, logical fallacies, and hubris. 3. The particular Aggressor Squadron operates early block F-15's and F-16's fitted with legacy systems. 4. Stating 'kill ratios' is nugatory without the context in which the engagements were flown and scored. '*First Look-First Shoot-First Kill*' is more a marketing meme than what is real. 5. Defence advocacy of 5th Generation fighter capabilities led one Senator to say: "*You have been **very emphatic** that **generation five** against **generation four** is not a contest.*" 6. How can senior defence officials claim to know whether Russian (and Chinese) Fifth (5th) Generation fighters are inferior (or superior) to the F-35A JSF when they don't have access to let alone knowledge of the 'classified' data and information on these designs?
Observations on RAAF fighter pilot/air combat training: **1. Since the mid-1990s, the need to husband the fatigue lives of the F/A-18 Hornets has severely and increasingly limited the training envelopes and, thus the recency in and ability of RAAF fighter pilots to operate these aircraft to their maximal performance.** **2. The past decade and a half has seen the risk averse attitudes and resulting behaviours of RAAF senior leadership, direct consequences of the 1999-2002 purge for conformity/compliance in Defence, dominate to the point where (1) capability and preparedness continue in decline and (2) risks and the proper management of risks, at best, are process driven administrative burdens.**

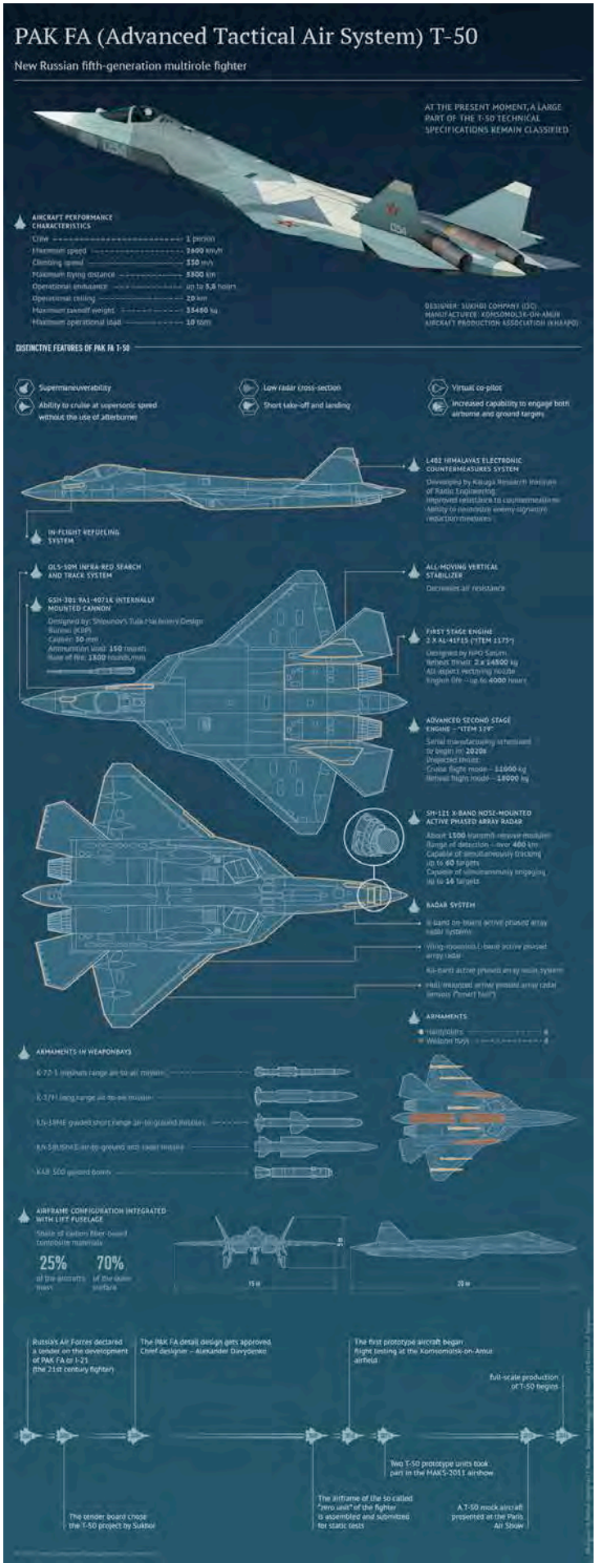
Annex E: T-50/Su-50 PAK-FA Pre-Production Prototype #055


055
(C) Alexsey (photo ID 136786)
RussianPlanes.NET


055
(C) Roman Tregubov (photo ID 124987)
RussianPlanes.NET


055
(C) Nickolay Krasnov (photo ID 124992)
RussianPlanes.NET


055
(C) Vladimir Vorobyov (photo ID 130034)
RussianPlanes.NET


PAK FA (Advanced Tactical Air System) T-50
New Russian fifth-generation multirole fighter
AT THE PRESENT MOMENT, A LARGE PART OF THE T-50 TECHNICAL SPECIFICATIONS REMAIN CLASSIFIED
AIRCRAFT PERFORMANCE CHARACTERISTICS
Crew 1 person
Maximum speed 2600 km/h
Climbing speed 350 m/s
Maximum flying distance 5500 km
Operational endurance up to 5,5 hours
Operational ceiling 20 km
Maximum takeoff weight 35400 kg
Maximum operational load 10 tons
DESIGNER: SUKHOI COMPANY (JSC)
MANUFACTURER: KOMSOMOLSK-ON-AMUR AIRCRAFT PRODUCTION ASSOCIATION (KNAAPO)
DISTINCTIVE FEATURES OF PAK FA T-50
Supermaneuverability
Ability to cruise at supersonic speed without the use of afterburner
Low radar cross-section
Short take-off and landing
Virtual co-pilot
Increased capability to engage both airborne and ground targets
L402 HIMALAYAS ELECTRONIC COUNTERMEASURES SYSTEM
IN-FLIGHT REFUELING SYSTEM
OLS-50M INFRA-RED SEARCH AND TRACK SYSTEM
GSH-301 9A1-4071K INTERNALLY MOUNTED CANNON
ALL-MOVING VERTICAL STABILIZER
Decreases air resistance
FIRST STAGE ENGINE
2 X AL-41F1S ("ITEM 117S")
ADVANCED SECOND STAGE ENGINE - "ITEM 129"
SH-121 X-BAND NOSE-MOUNTED ACTIVE PHASED ARRAY RADAR
RADAR SYSTEM
ARMAMENTS
ARMAMENTS IN WEAPONBAYS
AIRFRAME CONFIGURATION INTEGRATED WITH LIFT FUSELAGE
25%
70%
Russia's Air Forces declared a tender on the development of PAK FA or I-21 (the 21st century fighter)
The PAK FA detail design gets approved. Chief designer – Alexander Davydenko
The first prototype aircraft began flight testing at the Komsomolsk-on-Amur airfield
full-scale production of T-50 begins
Two T-50 prototype units took part in the MAKS-2011 airshow
The tender board chose the T-50 project by Sukhoi
The airframe of the so called "zero unit" of the fighter is assembled and submitted for static tests
A T-50 mock aircraft presented at the Paris Air Show

Annex to APA Submission to SFADT Inquiry
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ANNEX F

ADVANCES IN RUSSIAN AND CHINESE AESA RADAR TECHNOLOGY

"I think it is on two bases: probably stealth technology, the inability to have low probability of detection on electronic emissions,…"

Air Marshal Geoff Brown,
Senate Estimates, 02 June 2014

The claim made in mid June, 2014, by then Chief of Air Force Air Marshal Brown, that Russia and China are way behind the F-35A JSF due to "…*the inability to have low probability of detection on electronic emissions*,…", in their radar technology is extraordinary, courageous, and without any doubt contrary to publicly available data at that time. The most charitable interpretation is that Air Marshal Brown's comment to the Senate Committee was unsupported personal opinion with no basis in fact or what is real.

Air Marshal Brown's statement yet again, demonstrates the serious levels of deskilling that have been hallmarks of Defence capability development and acquisition projects for nigh on 15 years, since the great purge of independent critical thinking from the upper levels of the Canberra based agencies of Defence back in 1999 to 2002.

Importantly, it also demonstrates another outcome of senior defence officials' directives to defence staff not to engage in collaborative contestability with and to ignore and never cite any of the works of Air Power Australia or its principals on any defence or related matters.

Had such directives not been made, the need for this Inquiry, and the many expensive inquiries and reviews before it, more than likely would never have arisen on a range of Defence Matters, including the (finally) now defunct, failed experiment known as the DMO.

The most important technological prerequisite for Low Probability of Detection (LPD) capability in radar is what is termed by Engineers a "wideband low-sidelobe" antenna. This is characteristic of an AESA (Active Electronically Steered Array) radar antenna.

This Annex includes 2013 slides from a paper dealing with Russian and Chinese AESA designs (Kopp C., *Advances in Russian and Chinese active electronically steered arrays (AESAs)*, Phased Array Systems & Technology, 2013 IEEE International Symposium on (ARRAY-2013), 15-18 Oct. 2013, Waltham, MA, USA, pp. 29 - 42. [Invited, Plenary Paper]), and some slides published in 2013 by OAO "NIIPP" in Tomsk, Russia, covering recent developments in this technology.

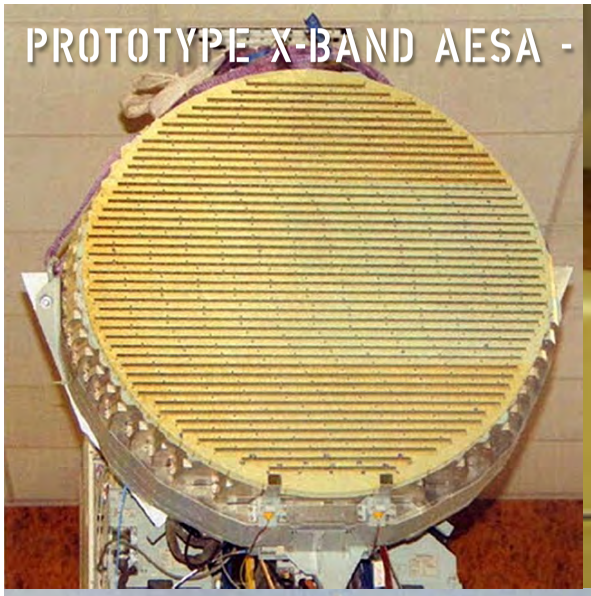
This material proves that the principal obstacle to providing an LPD capability in Russian and Chinese fighter radars was overcome and publicly disclosed well before Air Marshal Brown made his extraordinary claim at Senate Estimates.

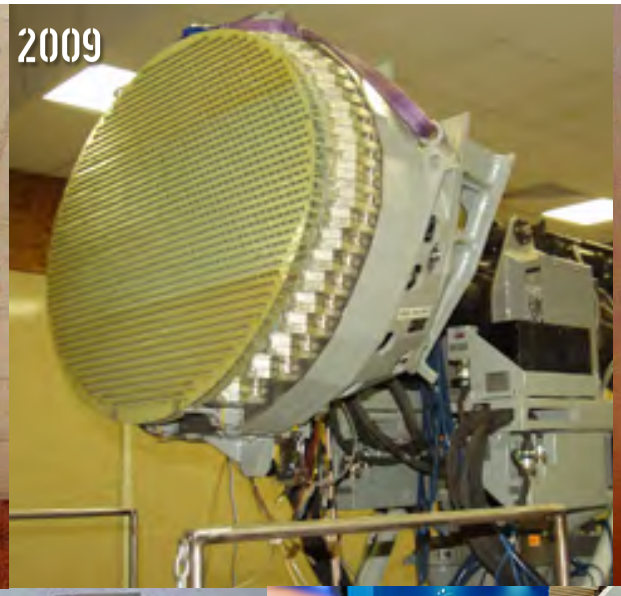
Slides F-3 through F-8 detail Russian Tikhomirov NIIP X-band AESAs using the same AESA module technology employed in the USAF APG-63(V)2 in the F-15C fighter, and the Chinese AESA developed for the J-20 stealth fighter *"NRIET: "Built in 2009, the J-20 AESA is our 3rd Generation design, using eight channel four layer GaAs 3D Multi Chip Module (MCM) technology, providing 1856 TR channels.",* which uses a similar style of tiled AESA module to that employed in the APG-81 radar carried by the F-35.

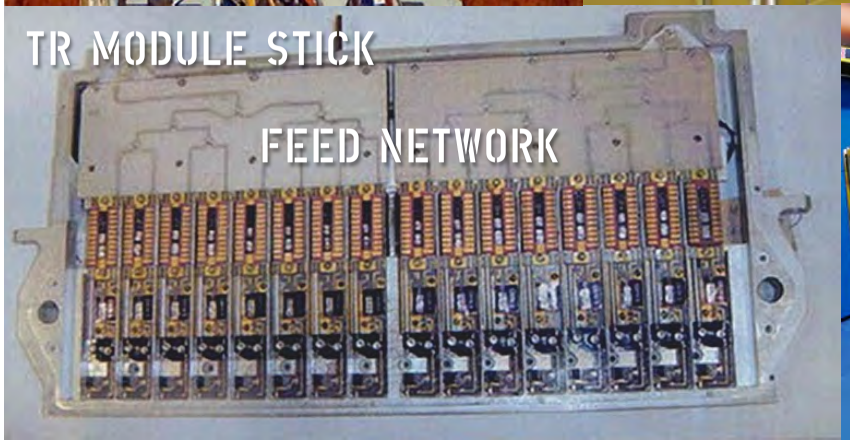
Slides F-9 through F-16 are extracted from a 2013 online presentation entitled *"JSC NIIPP Tomsk series production line for LTCC ceramic multilayer modules, with an annual production capacity in excess of 200,000 X-Band sub-modules."*, authored by Yevgeniy Aleksandrovich Monastyrev, Deputy Director for Science, Head of Department 101, JSC NIIPP Tomsk, Russia (http://player.myshared.ru/264263/).

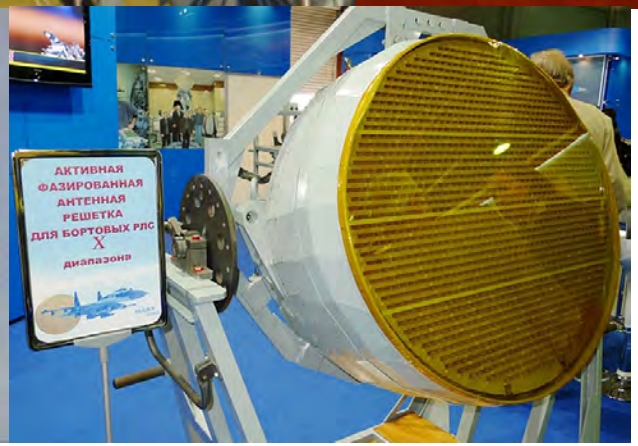
Assuming a 1600 TR channel AESA, requiring 400 x 4 channel modules, the Russian plant has a capacity to manufacture components for 500 AESA radars annually. The slides show a range of demonstration design components, including a unique AESA seeker for a radar guided missile.

Tikhomirov NIIP X-Band AESAs





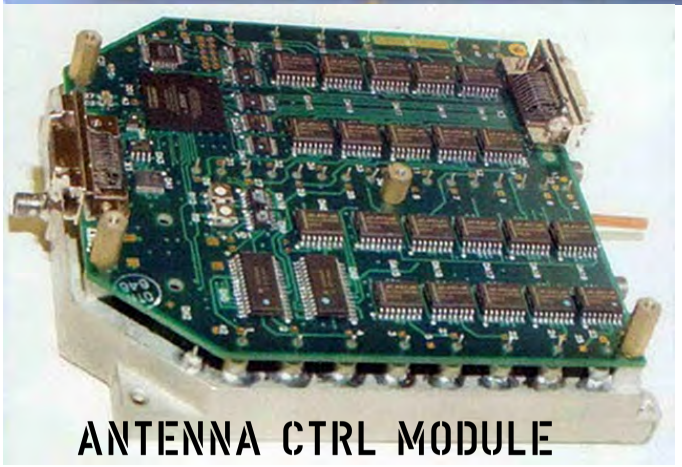




Tikhomirov NIIP X-Band AESAs

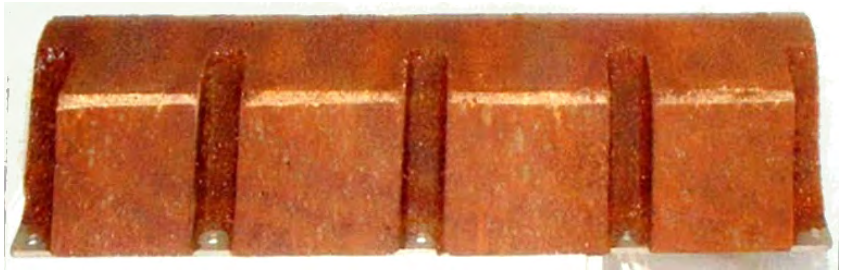
- Very limited public disclosures to date, mostly via mass media, 2009 - 2010;
- Design in development for T-50 PAK-FA stealth fighter and retrofit into T-10 FLANKER fighters;
- Demonstrators are 1524 element designs;
- Imagery indicates design is based on stacked TR stick modules, similar to APG-63(V)2 in F-15C;
- Likely power rating of AESA in 15 kW class, possibly higher if TR modules/cooling improved;

Tikhomirov NIIP L-Band AESA



ANTENNA CTRL MODULE

LEADING EDGE AESA INSTALLATION (FLANKER)

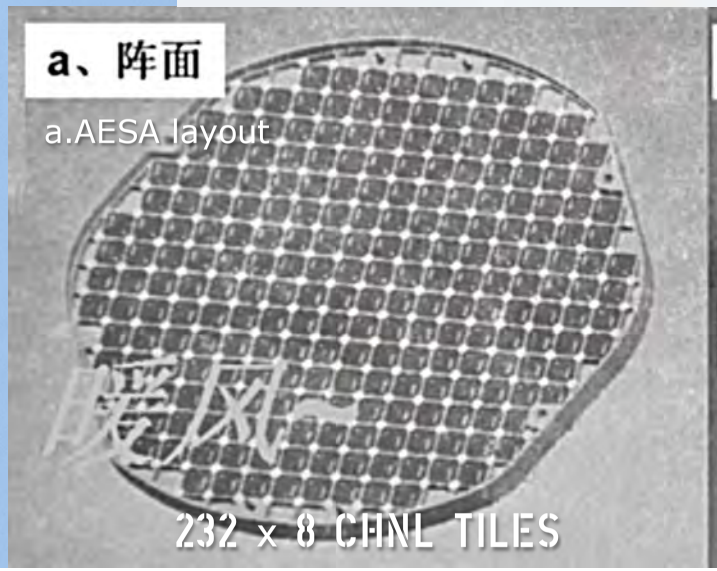


4 CHANNEL RADIATOR SUBARRAY

Tikhomirov NIIP L-Band AESA

- Unique conformal linear array design intended for embedding in leading edges of wings or strakes of fighter aircraft, displayed in 2009;
- Intended uses not disclosed, but may include *IFF interrogation, detection of low observable targets, high power jamming of L-band radar, IFF and GPS signals, weapon midcourse guidance, large baseline L-band interferometric angle tracking;*
- Paired 1 x 12 microstrip air gap element arrays, with quad TR modules, rated at 200 W / channel;
- Nett P_{out} ≈ 4.8 kW for paired AESAs;

NRIET J-20 Stealth Fighter AESA



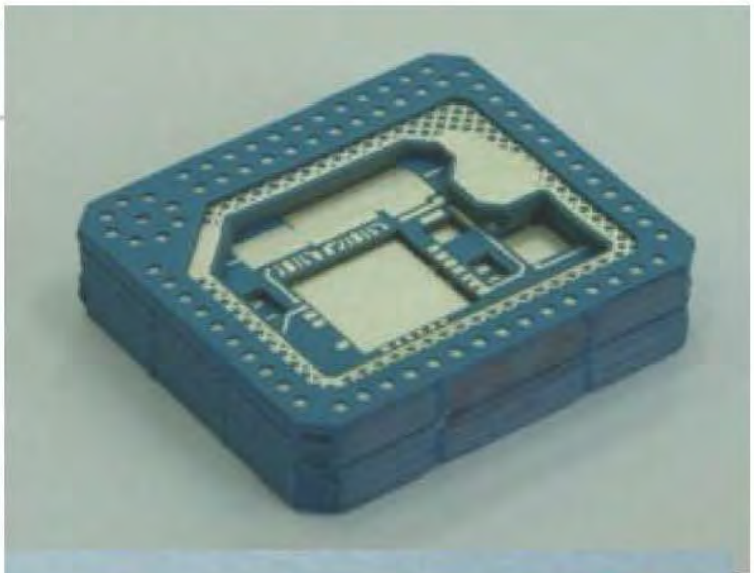
NRIET J-20 Stealth Fighter AESA

- NRIET: *"Built in 2009, the J-20 AESA is our 3rd Generation design, using eight channel four layer GaAs 3D Multi Chip Module (MCM) technology, providing 1856 TR channels."*
- 232 x 8 channel tiled 4 layer 3D MCM modules;
- 1856 TR channels, cf 1662 for Russian Zhuk MSFE PESA, and 1630 for 2008 APA model for Zhuk ASE;
- No disclosures on PAE, PT, lattice type, taper function, cooling design, or subarray partitioning.
- Dimensions suitable for retrofit into J-11B, J-11BS, J-15 and J-16 Sino-Flanker fighters;

IEEE

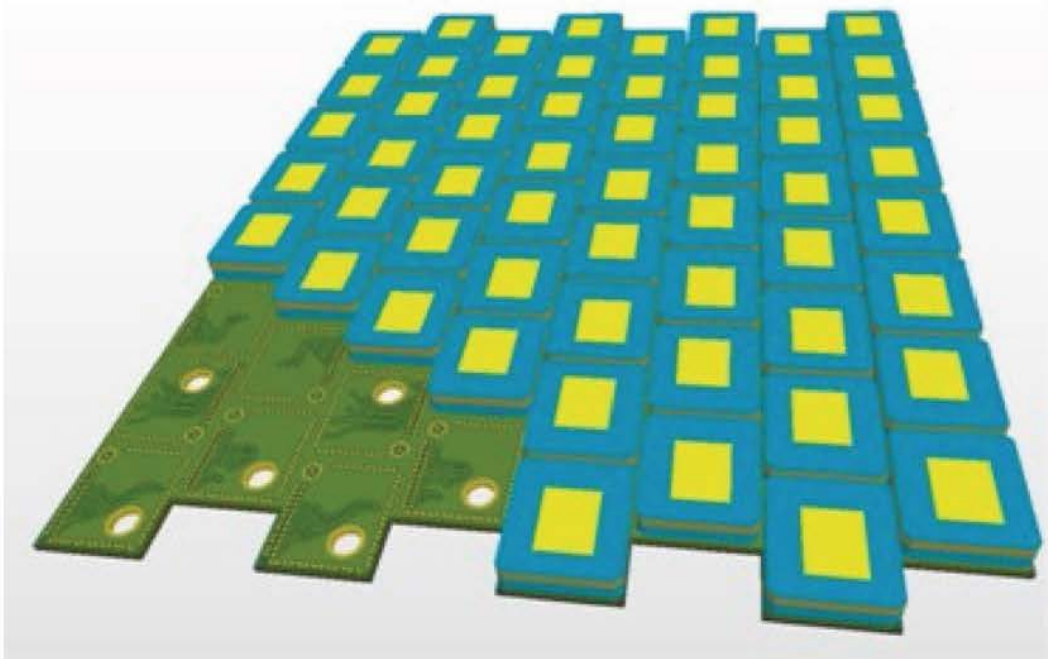
Single channel planar microwave X-band receiver submodule

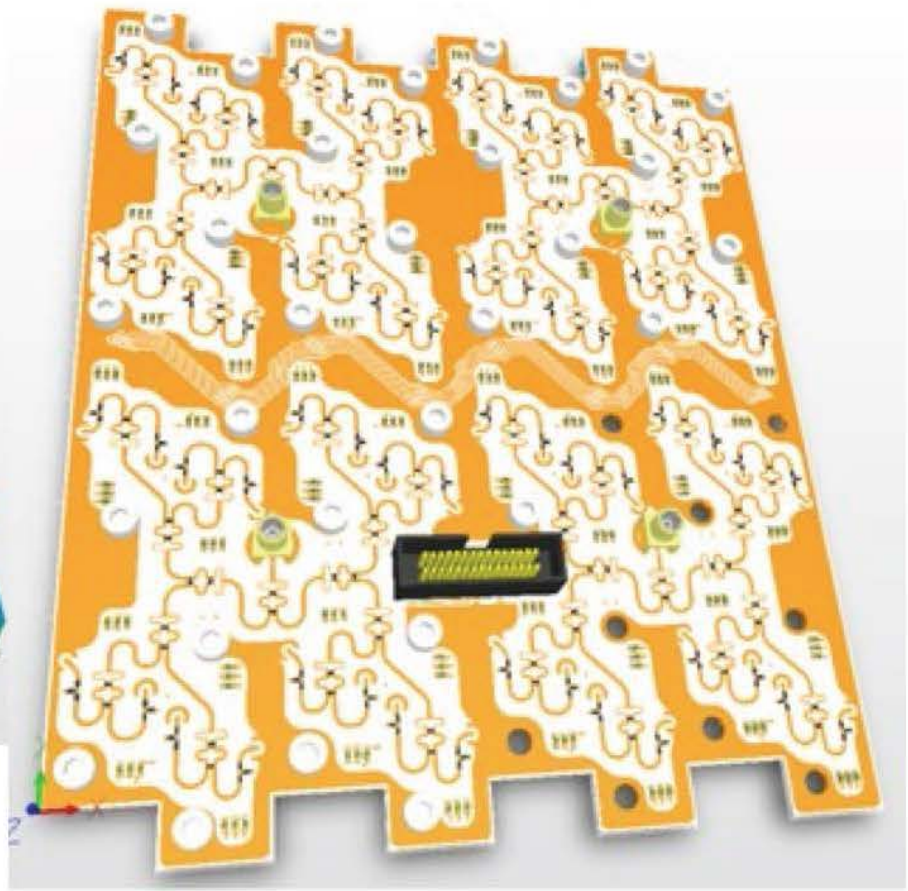
Одноканальный планарный приемный СВЧ-субмодуль X-диапазона



Cutaway of multilayer printed circuit backplane for a planar X-Band receiver AESA using single-channel modules.

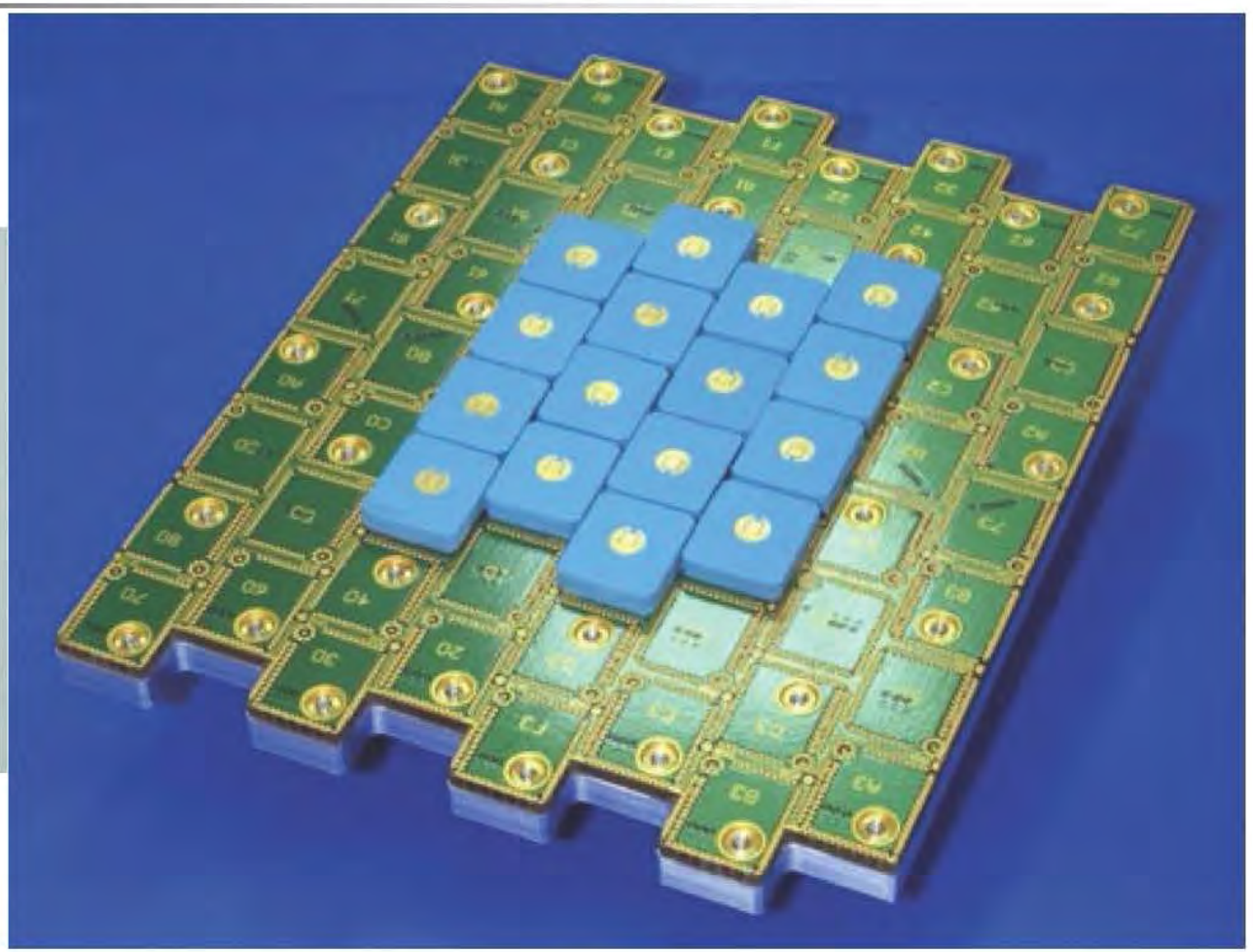
Многослойная печатная кросс-плата планарный приемной АФАР X-диапазона с одноканальными модулями





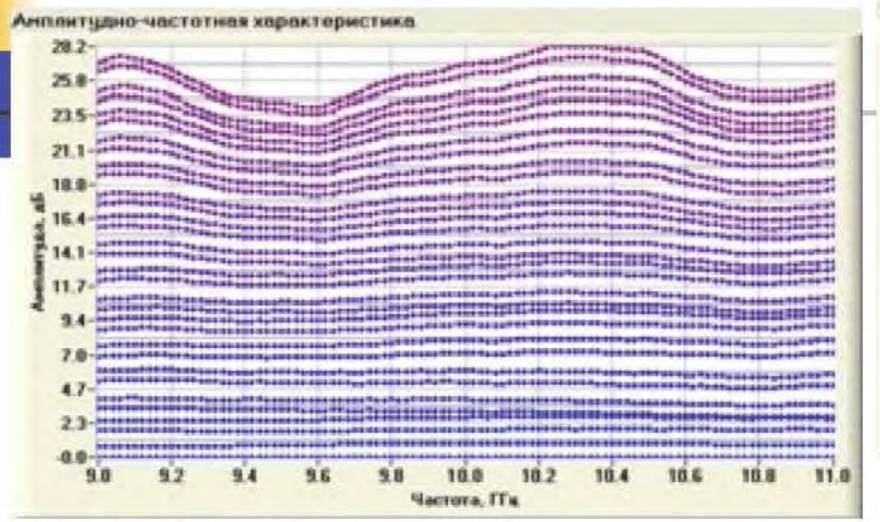
Experimental sample PCB for receiver AESA with 64 modules (16 modules loaded).

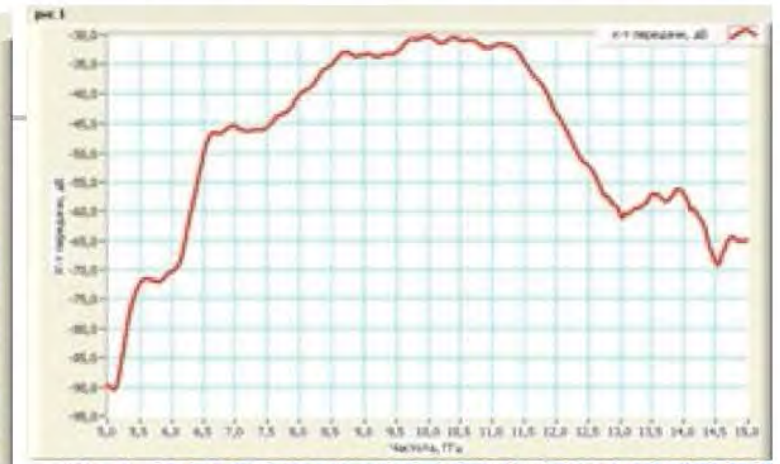
Экспериментальный образец ПМК приемной АФАР на 64 модуля (установлено 16 модулей)

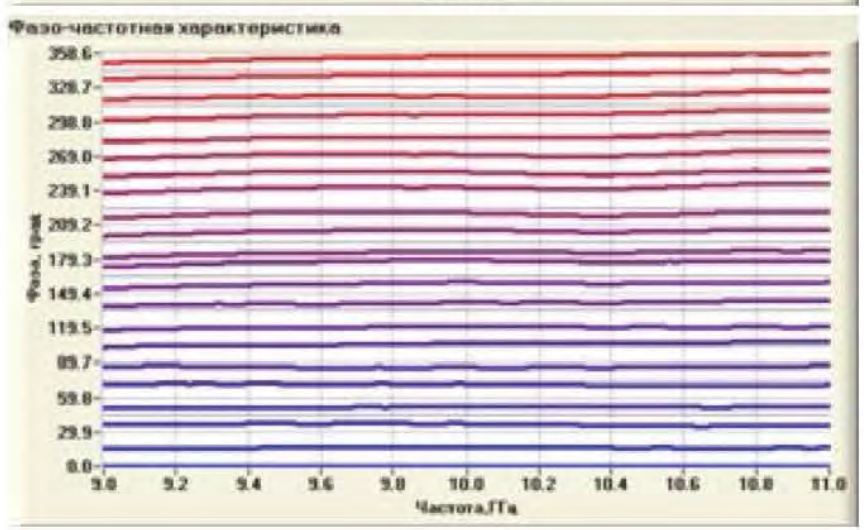


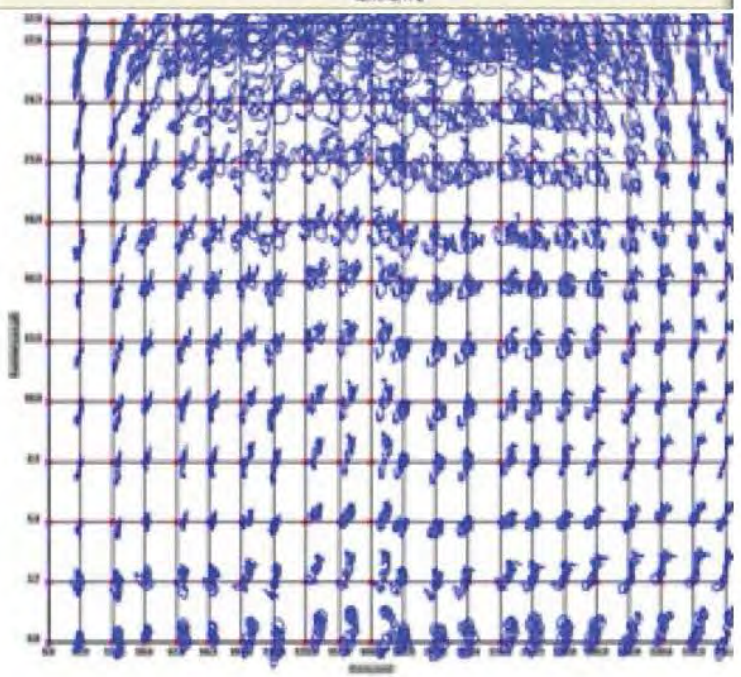
Measured parameters of a microwave planar X-band submodule [9 - 11 GHz]

Измеренные параметры планарного приемного СВЧ-субмодуля X-диапазона в составе ПМК







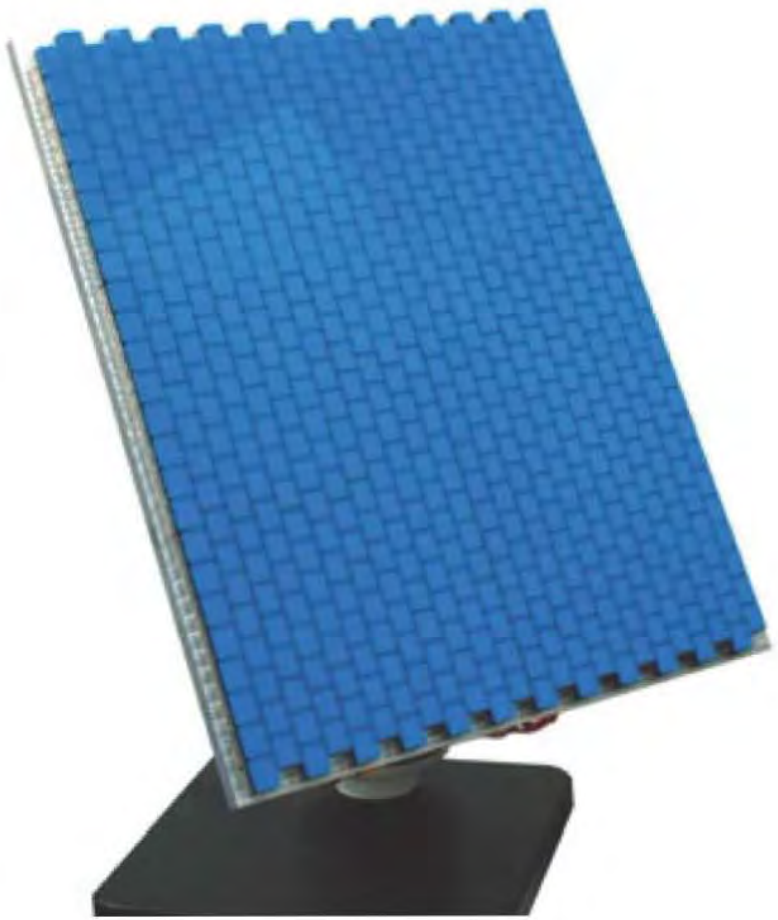


64-channel receiver AESA PCB on missile seeker gimbal

64-х канальный ПМК приемной АФАР на координаторе ГСН

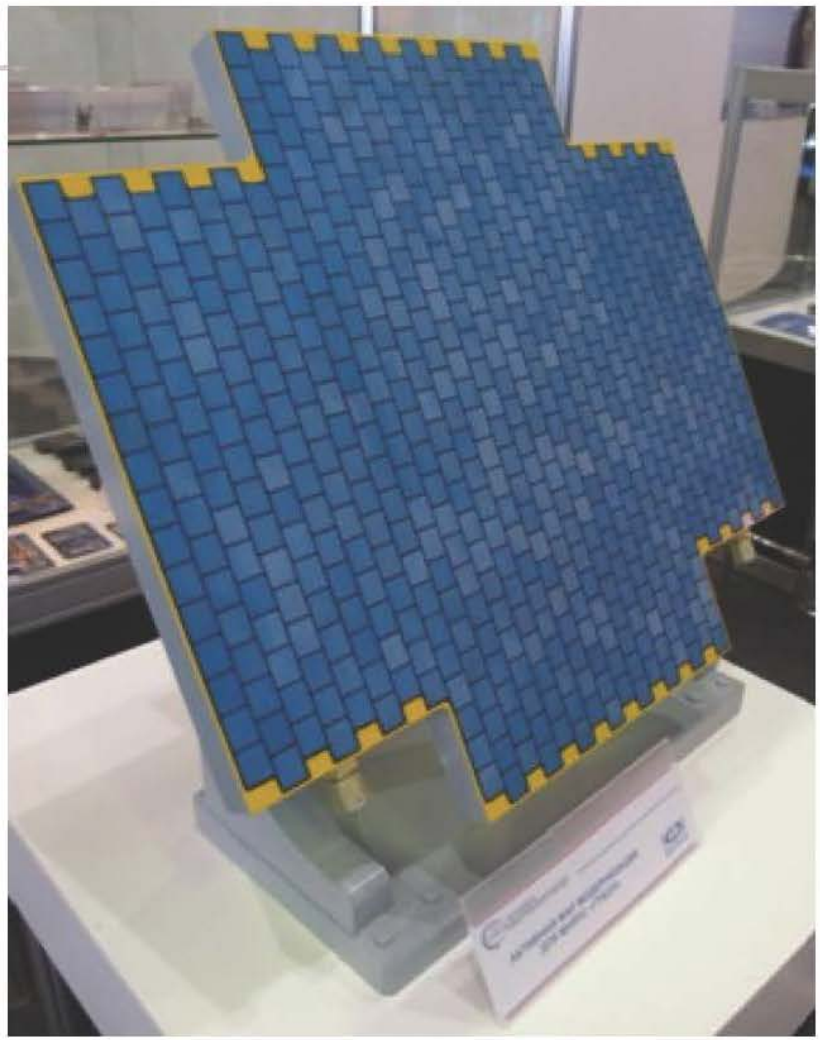
Comparison of the dimensions of a "classical" and planar AESA [Tikhomirov NIIP "stick" AESA]

Сравнение габаритов «классической» и планарной АФАР



"Classical" and planar AESA (Phazotron NIIR)

«Классическая» и планарная АФАР («Фазатрон-НИИР»)



ОАО «НИИПП»

г.Томск

СПАСИБО ЗА ВНИМАНИЕ!

Yevgeniy Aleksandrovich Monastyrev, Deputy Director for Science, Head of Department 101, JSC NIIPP Tomsk, Russia.

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