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Roadblocks to Air Revolution in Indian War-Fighting

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The Opportunities of Gallium Nitride

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Roadblocks to Air Revolution in Indian War-Fighting*

India and the West hold very different views about what constitutes escalation. As a general observation, it can be stated that India's security establishment, for a variety of reasons, holds boots on the ground to be least escalatory, while considering air strikes to be a significant escalation. The West, on the other hand (as evident from the wars it has fought in the past decade or so), views boots on the ground to be the most escalatory option while air power – grading up slowly from drones to cruise missiles to a full-scale air campaign – is perceived to be among the least escalatory options.

While this difference in perception is the result of some very complex factors, this paper focuses specifically on what the Indian Air Force (IAF) has learnt (or not) from its Western acquisitions thus

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far. The picture is quite sobering in that it would seem the IAF is, to date, without a 4.5+-gen aircraft. Consequently, many of the doctrinal and war-fighting changes brought about as a result of the technological progression within the fourth generation are yet to be adopted by the IAF.

This is not to suggest that the IAF does not understand what these 4.5+-gen gains are, but, rather, that large decision-making pockets within the IAF and the scientific bureaucracy have drawn different lessons from various episodes, and that, while they understand the end-product – that is 'western qualitative superiority' in the air – quite well, the component lessons have not been integrated into an actionable and organic whole. What this translates into, in practical terms, is that hardware purchases are not resulting in operational gains – the classic case being the Sukhoi Su-30 MKI, which, as this paper shows, has turned into a white elephant due to lack of standardisation of knowledge, or, in some cases, wrong knowledge.

The IAF's perception of technology has, very likely, been shaped by three factors. The first is that the IAF has not fought a full-scale war since 1971. The second is that in these 43 years the IAF has transitioned from a first and second-generation fighter force in combat to one with third and fourth-generation fighters, without engaging in an all-out war. As a result, third and fourth-generation tactics have either never been applied in combat or have been tested in highly limited engagements, like Kargil.

The third – and perhaps the most important – factor is the electronics revolution that happened 'under the skin' within the fourth generation. While this revolution did not improve range or kinematics, it freed fighters almost completely from ground control and overcame many of the technology blocks to fully operational Beyond Visual Range combat. It also heralded quantum leaps in sensor and jamming technology which synergised into a whole and gave 4.5+ - gen pilots the ability to focus entirely on fighting and the tactical situation at hand, rather than on the aircraft. The easiest way to understand this transformation is to look at the corollary upgrades in consumer electronics.

In 1996, when India inked the pact for the Su-30 MKI, a Compaq Presario PC took up much of one's desk, with a five-gigabyte memory that was considered unusually large, connected to dial-up internet, which transmitted some data at rates considered 'light-speed' by the standards of the time. In 2014, however, an iPhone 6 has more processing and graphics power than 50 PCs from 1996, with 128 gigabytes of memory integrated into a package that fits in a palm. In its entirety, one person equipped with a smart phone has more productivity, connectivity and situational awareness on the move than a small industrial office did in 1996.

While the French performed the inter-generational upgrades on their fourth-generation Mirage 2000, the IAF did not. Consequently, when the IAF went in for its big 4.5-generation 'pony', the Su-

30 MKI, it did so with a baseline that existed in the very first model of the Mirage 2000, rather than the Mirage 2000-5 (or the middle models, the C and N).

This was primarily due to the fact that the H model, which India purchased with its older, 'pre-revolution' electronics, was not that much different or better than the MiG-29, and the latter's superior kinematics were prized more. At another level, while the IAF learnt from Operation Desert Storm as well as the Bosnia and Kosovo operations, this was distant theoretic absorption of knowledge rather than an organically developed expertise.

The French themselves experienced this learning bottom-up, as and when AdA (Armee de l'air) pilots learnt to do much more with successive upgrades - and their learning filtered through to the high command. With India, this option did not exist. Consequently, what came about with the Sukhoi was a top-down hybrid approach that combined Eastern kinematic superiority with Western electronic superiority, without understanding the philosophical, operational, logistical or integrational difficulties that would ensue.

Contrary to popular belief of the Sukhoi being "India's two front ace", owing to the confusion and lack of intra-generational learning, the fighter jet has, in fact, become an albatross around the IAF's neck. Instead of bringing combat synergies into play, it is actually creating massive negative synergies. The negative synergies born of a failed integration have led to increased vulnerability, reduced availability and reliability, each debilitating by itself, but a death blow in combination.

The first issue seems to be that of the Sukhoi's construction and quality. Its engines are highly prone to foreign object damage. This was an issue that had been flagged as far back as 2006 during the Cope India exercises with the United States, when it was noticed that the Sukhois would follow each other into the air after a one-minute gap to avoid foreign object ingestion.[1] Other problems identified included the inordinately long periods – even upto a month – of time it takes to calibrate new engines onto the aircraft. Similarly, the radar seems to have an abysmally low Mean Time Between Failure (MTBF) – of around 100 hours. This is combined with a persistent problem – evident since at least 2005 – of a repeated blanking of the displays. (As of late 2014, it was reported that this had been fixed and that the problem was a software glitch; confirmation could not be acquired through independent means, however.) Some crews, for example, insisted that wires were frizzing, which they believed indicated a power-management problem rather than a software problem per se.

The integration of the Elta ELM-8222 jammer too has been a failure. This was confirmed through sources in the IAF, within the Government of India and independently from Russia – as well as by Elta competitors in India. While, apparently, the ELM-8222 succeeded in some jamming functions because it could share information with the DRDO-developed Tarang RWR (radar warning

1. Stephen Trimble, "USAF pilot describes IAF Su-30MKI performance at Red Flag 08," Nov. 5, 2008. Accessed at http://www.flightglobal.com/blogs/the-dewline/2008/11/usaf-pilot-describes-iaf-su30m/

receiver), its lack of integration with the core electronics of the Sukhoi was a major problem; no integrated picture of threat and counter-measures could be generated by the system, with the jammer being used in generic frequencies.

Moreover, flight crews consistently referred to the high false-alarm rate of the Tarang RWRs, which abruptly activated counter-measures, creating a whole new set of problems and additional workload for flight crews. Thus, its ability to synergise operations with the Phalcon radar is highly suspect and integration problems have led to serious combat vulnerability for the crews. This vulnerability in combat, combined with the reliability problems described earlier, has snowballed into a major availability issue. In interviews conducted for this paper, the availability appears far lower than the publicly stated 50 percent; it is possibly as low as 25 percent.

Compounding these issues, the Sukhoi's weapons wiring does not appear to be NATO-style plug-and-play. Rather, it appears that the programming of the bomb and of data must be fed into the aircraft computers separately. This results in an average turnaround time, depending on payload, of at least an hour-and-a-half. This means an abysmal availability rate is further worsened by long intervals between sorties. Individually, these problems would be quite serious; in combination, they appear to have a debilitating effect on the Sukhoi fleet.

While this situation was brought about by the lack of experience and organic learning, it has been perpetuated by associated myths. Consequently, 'arms lobbies' and 'technology denial regimes' are being blamed across the scientific bureaucracy and air force for what is, in effect, a stubborn refusal by both to absorb technological lessons.

To be fair, there is a political problem, but one believed to be surmountable. Russian officials interviewed for this paper were emphatic that the Israelis or French would not be given access to the core electronics of the Sukhoi. Similarly, the Israelis have no intention of offering up their jamming algorithms and technology to the Russians, under the guise of integration, on a silver platter. For commercial purposes, the Americans are equally adamant that Israel will not be allowed to sell India stand-alone AESA radars and that if India wants to get its hands on these it will have to buy a US system (implying one complete with electronics).

However, the main hurdle seems to be that India still doesn't understand the technological problems involved, preferring instead to blame the 'politics of the issue'. For example, raising some of the issues with DRDO (Defence Research & Development Organisation) officials brought robust denials and an insistence that these problems were surmountable – and that the author was exaggerating the problems. Even while acknowledging the significant problems, they felt these were not of a technological nature but political, with the Russians and Western suppliers mutually suspicious of each other and refusing to grant full access.

They also acknowledged the lack of testing infrastructure and budget as well as human capability to tackle the issue. They conceded that large sections of the government reject this latter fact and prefer to focus on the "political barriers." As a result, the institutional view appears to be that political barriers have prevented India's scientific establishment from optimising the full potential of the aircraft. The author, however, chooses to stand by his assessment of negative synergies at play, as opposed to the view of mere under-optimisation or lack of political will.

The Rafale procurement was criticised by large sections of the strategic community, including this author, based on the belief that the Rafale was superfluous and that it brought sub-standard capacity duplication at many times the cost of the Sukhoi. Clearly, this assessment was wrong. The reality is that the Rafale, and indeed the Medium Multi Role Combat Aircraft (MMRCA) contest, at some point mutated into a failure-compensation device for the Sukhoi. Much of the confusion surrounding the MMRCA contest – the deeply contradictory and confusing statements regarding weight, cost, numbers, effects, and, especially, the implied nuclear delivery role for the Rafale – indicated that the Rafale would not be complementary to the Sukhoi but, rather, a face-saving gap-filler making up for the Sukhoi's disastrous failure.

It seems the IAF, at least up to 2012, did not understand the technological challenges of systems integration, given the deeply confused nature of the MMRCA RFP (request for proposal). The reality is that the Rafale will bring a seamlessly integrated system into play, that will further be able to integrate into a system of systems with India's other Western sources – the ISR (Information, Surveillance and Reconnaissance) platforms like the Phalcon and P-8s – should the need arise.

However, the persistent refusal of the IAF to internalise the political or technological dimensions of integration is worrying and may scuttle the integration of the Rafale as well. The clearest sign of this is the rejection by the IAF of the Rafale's organic SEAD (Suppression of Enemy Air Defence) solution based on the AASM glide bomb during the negotiation phases of the MMRCA programme. After naively soliciting the American AGM-88 HARM for the role (which the Americans refused), the IAF is now insisting that Dassault should integrate the Kh-31A krypton. It remains to be seen if this stipulation holds with the new deal for 36 aircraft. This points to significant knowledge bottlenecks in the system, where lessons supposedly learnt from the Sukhoi are simply not being absorbed or internalised. Much of this has to do with the integration of the French top-sight helmets with the VYMPEL R-73 and previous successes with integrating the Matra Magic onto the MiG-21 and the Israeli Litening targeting pod onto various IAF platforms.

While the Rafale may very well solve most of the current problems of reliability, availability and vulnerability that the Sukhoi faces, its cost – of both procurement and support – will create problems of a very different kind for the Air Force. Ultimately, one cannot maintain first-world capabilities with third-world budgets, and yet this is exactly what the IAF thinks it can do. Even first-world countries like France are able to do this only because of their reliance on the NATO Alliance

ISR assets, or massive previous seed spending on their own intelligence gathering networks, complemented by a very advanced first world manufacturing economy.

India has none of these deep assets or alliances nor can it economically sustain a stand-alone turn-key technological capacity for just one combat aircraft type. For example, much of the recent French power projection in Libya and Mali was dependent on alliance assets like refuelling infrastructure, among others. Similarly, the Rafale subsystems are manufactured by a string of French and US small and medium sector companies that have other businesses and do not have their entire financial viability fixed simply on the Rafale project. These are not options open to India and given the proposed procurement of a mere 36 aircraft, creating a complex intelligence apparatus to harness the required capabilities is simply not economically feasible. Consequently, it would seem that the IAF is jumping from the frying pan into the fire.

The implications for India are profound. The first is that the 4.5+-generation revolution is yet to happen in India. In fact, the first of these fighters have just joined the IAF: the upgraded Mirage 2000s, the first of which arrived in late March this year. The second is that the confusion has basically created an artificial dilemma – that either we are faced with severe cost consequences (should a full-scale purchase of the Rafale or the current limited procurement go through) or a huge capability gap (given the failure of the Sukhoi). Consequently, the IAF will not be able to downsize in the near future or transition to a purely qualitative air force to counter the Chinese quantitative threat. India will, therefore, continue for the next 15 years to resort to quantity compensation of some sort.

On a strategic level, this would mean that India will not, in the foreseeable future, be able to wage the kind of aerial blitz warfare that has been the hallmark of Western campaigns. Clearly, such options will not be available to the political leadership, given the complications of a high-quality low-quality mix (as opposed to a high-low capability mix that the West emphasises). The corollary to this is the fact that army-centrism in India will continue for a few decades yet and the IAF will not be prioritised, as it will consistently fail to deliver the sort of finely calibrable options that a true 4.5+-generation air force can.

Ominously, as a result of a presidential decree, Chinese President Xi Jinping forced an end to army-centrism and put greater focus on the PLAAF (People's Liberation Army Air Force, of the People's Republic of China) in 2013. Such a political top-down decision unleashes its own dynamics, which will see a far more air-focused Chinese posture, facing off against a dangerously land-focused Indian military posture. This scenario is one on which India will have to ponder long and hard – whether it is a risk worth accepting for the next decade-and-a-half.

The Opportunities of Gallium Nitride*

Radar, if one simplifies it down to the basics, is a strikingly simple technology: radio waves go out, hit something, and bounce back. With a little analysis of the return signal, you can "see" whatever is out there.

The radar 'buzzword' over the last few years has been AESA–Active Electronically Scanned Array. To understand the importance of AESA, it is perhaps pertinent to explore the capabilities and limitations of mechanically steered antennas, and the first-generation (that is, passive) Electronically Steered Arrays (ESAs), before getting into the details of modern AESAs and the types of semiconductors used in their production.

Radar basics

The radar antenna on an aircraft transmits electromagnetic waves in a beam, and receives reflected waves from targets, or terrain, or anything in the way of that beam. To locate targets, it points this beam all over the sky, or ground, or both. So, a good radar antenna is not only defined by its emitting power and receiving sensitivity, but also by how quickly and precisely it can be steered.

Early fighter radar antennas were mechanically-steered concave dish antennas, which then evolved into planar arrays, but still with mechanical steering. Most 1970s and 1980s fighters, like the F-16 and F-18, were equipped with these when they entered service. The planar arrays led to significant gains in radar beam quality, but because mechanical steering was retained, they were still slow and, of course, had reliability issues, as all moving parts do.

Mechanically-steered antenna on an F/A-18C/D undergoing maintenance (photo: Raytheon)

***Adapted from a talk given by the author as part of a session on 'Emergent Technologies & Warfare: Opportunities, Costs, Implications' at the Observer Research Foundation, New Delhi.**

Around this time, computing was really coming into its own. It was finally becoming practical to adapt the electronically steered antenna technology, which was already in use on ground-based radars, to airborne applications. These early electronically-steered antennas had individual electronically-controlled modules in an array, which would manipulate the time delay – or, in electromagnetic wave terms, the 'phase' – of the microwave signal passing through each element. This is where the term 'phased array' comes from. By adjusting the phase at each module, the beam direction is manipulated without any mechanical intervention. Given that the phase changes were all computer-controlled and electronically-commanded, the earlier issues with speed and precision of beam steering were solved.

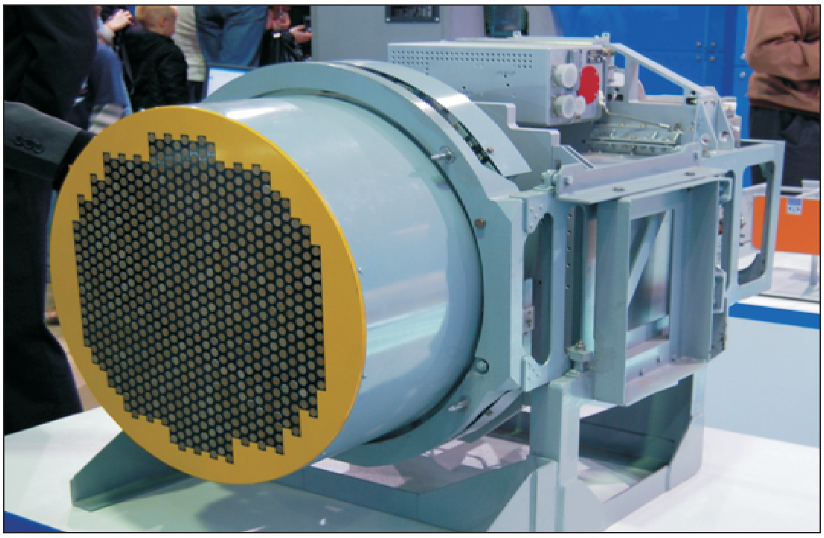
It's important to note here that the source of the radar waves, the microwave emitter, usually a travelling wave tube, was still a separate element of the radar installation. The 'active' element remained off antenna, which is why such radars are usually referred to as 'passive' electronically-steered arrays (PESAs).

The Tikhomirov BRLS-8B 'Zaslon' was the first PESA to be installed in an aircraft—the MiG-31 interceptor (photo: USAF)

PESAs were a major step forward in technology, and the beam agility alone made radars far more versatile, which, with the growing importance of 'multi-role' aircraft, obviously had positive implications for the future. However, the new design introduced a few new headaches as well. The phase shifters caused signal losses during 'transmit' and 'receive', so microwave generators had to become that much more powerful. The mix of analogue and digital technology undid to a certain extent the reliability improvements realised by eliminating mechanical antenna steering.

The next development step brings us to the present day. Instead of keeping various major radar components separate, the rapid pace of semiconductor technology development meant that all the disparate elements of a radar could, by the late 1980s, all be integrated together. The phased-array concept remained, but instead of phase shifters arrayed across an antenna, each spot on the array was made a miniature microwave transmitter and receiver. With the 'active' element of the radar now taking centre-stage, the name is self-explanatory.

An AESA unit is crammed with Transmit/Receive Modules (TR Modules), each one an independent package comprising a low-noise receiver, power amplifier, and digitally-controlled phase and gain elements. Along with the obvious packaging and reliability improvements, the AESA approach yields improvements by virtue of design; for its potential, it is worth investing in this technology. For instance, having the TR module's low-noise receiver within the antenna itself results in a massive reduction in receiver thermal noise and, by extension, sensitivity. In practice, this improves detection range.



A Phazotron Zhuk-A on display at MAKS 2009 with TR modules visible on the array (photo: Allocer/Wikipedia)

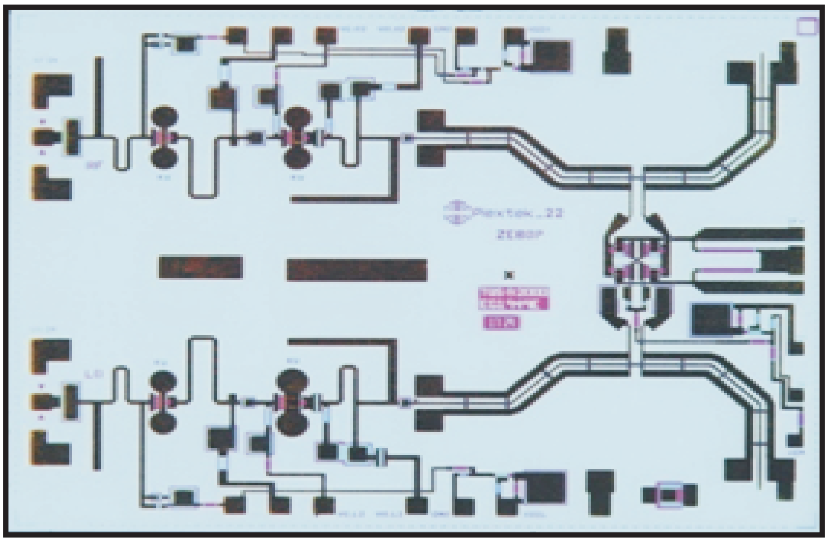
The cluster of individual modules do not need enormous amounts of power compared to early passive arrays, and can be driven by low-voltage power supplies, increasing reliability of each element as well as the system as a whole. Improved power management also directly impacts the LPI (low probability of intercept) or 'stealthy' characteristics of the radar.

MMICs and Gallium Arsenide

The technology that really enabled this revolution was the Microwave Monolithic Integrated Circuit (MMIC), a microwave circuit on a single chip. The material behind viable AESA MMICs is a semiconductor compound called Gallium Arsenide (GaAs). GaAs is a III-V semiconductor, which means one element in the compound, Gallium, comes from Group III of the periodic table, and the other, Arsenic, comes from Group V. This is important, because III-V semiconductors have some very specific characteristics.

Compared to more common semiconductors, such as silicon, for example, GaAs has around six times higher electron mobility than silicon, which allows faster operation of a transistor. It has a wider band gap, which allows sustained operation at higher temperatures, and results in lower thermal noise in low-power applications at room temperature. As a material, therefore, it is ideally suited to the power and sensitivity requirements of radar.

On the other hand, however, silicon is cheap and easy to process, while GaAs is brittle, expensive, and tends to be more difficult to work with. It took quite some time for the technology to mature – close to two decades – but development has been helped along by commercial demand and, today, reliable, high-quality GaAs MMICs for AESAs can be produced at costs that are not unreasonable.



A GaAs MMIC (photo: Lmdlmd/Wikipedia)

Gallium Nitride for the future

GaAs was just the first step on the AESA road. It may be a key enabler, but it also has limitations. As air combat shifts further into the BVR sphere, transmit powers will have to go up to maintain the 'first shot' advantage. The present generation of GaAs MMICs do not perform well at extremely high temperatures. Cooling electronics in an aircraft is always a difficulty because there is a lot of equipment competing for the limited thermal cooling capacity available on board.

Additionally, by nature of the semiconductor itself, GaAs does not operate effectively beyond a certain voltage, which limits heat management options from the power supply side as well. Conventional wisdom dictates that an increase in voltage should result in a commensurate reduction in current for a given power level, resulting in lower heat generation (since heat produced in electronics is directly proportional to current drawn); but, because GaAs MMICs are already operating toward the upper limits of their voltage range, there is no way to take advantage of low-current power supply.

This is where Gallium Nitride (GaN) comes in. It is a relatively new development in the semiconductor industry, and while GaAs was already in limited production as far back as the 1980s, the first serious work with GaN only began about a decade later. However, it is a highly promising material for AESA MMICs, as evidenced by the significant investment into its development, particularly in Europe and the United States. Where GaAs opened the gateway to the AESA world, GaN will pave the way for development that will really unlock the benefits of active arrays.

Like GaAs, it is a III-V semiconductor, but with a few key differences that make it incredibly attractive for the future improvement of AESA technology.

First, it operates stably and reliably at much higher temperatures than comparable GaAs chips. Second, it handles high supply voltages – around five times as high as GaAs – without any issues. This makes GaN an ideal material for a power amplifier because, overall, it outperforms GaAs by a factor of five in RF (Radio Frequency) power per unit chip size. The higher voltage supply has additional benefits: it simplifies on-board power conditioning, lightens cabling, reduces on-board interference, and also helps with cooling. (As noted previously, voltage goes up, current and heat comes down.)

In fact, GaN power efficiency is so high, it appears that further development of this will see chips limited not by electrical constraints but, once again, by available cooling.

The time is now

Militaries around the world know why AESA is the 'next big thing'. Well, GaN is something that is going to make it bigger and better and it has not yet gained critical mass. It is not limited only to military applications either; as a semiconductor, GaN will be incredibly useful for almost any microwave application. GaAs technology, incidentally, came about, in no small part, thanks to DARPA (Defense Advanced Research Projects Agency) funding for radar development. Yet today the military market is one of the smallest consumers of GaAs MMICs, with telecommunications and other markets being key growth drivers.

However, military applications have benefited tremendously from the economies of scale that followed in the wake of commercial adoption of this technology. There is no reason why GaN would not have similarly broad levels of acceptance across the board.

Today, the groundwork for GaN to take over from GaAs has been laid, but GaN is nowhere close to the maturity of GaAs, in either the commercial or military sectors. Like GaAs in the past, it will take time for various non-military electronics sectors to decide whether or not investing in GaN is worth the effort and expense and, then, for production to ramp up to provide reasonable economies of scale. This is a window of opportunity for countries that are behind the technology curve to leapfrog to the front, at least in this specific field. The window, however, is not very large, and it will require a significant amount of human resources and funding to take advantage of this emerging trend. Any mis-steps or significant delays could see the opportunity wasted, and given how rare it is to have such a chance to close the gap to the traditional 'leading edge' nations, this would be tragic indeed.

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