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# Technology for the Future IAF: The Case for Hypersonic Craft

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## Summary

Currently Fifth Generation Fighter Aircraft (FGFA) are the most advanced aircraft. The US has the F-22 in service while it has the F-35 under development as China has the J-20 and Russia the PAK FA under development. High cost and technological difficulties make these projects very risky. A poorer country like India can ill affoard these risks and in place of putting its faith in under development FGFA she may gain from looking at other means of achieving assured penetration capability. Here hypersonic technology (under development by both ISRA and DRDO) provides a possible viable alternative.

The IAF, after a long hiatus, is currently going through the process of a major modernisation. This involves replacement of obsolete fighters with modern machines, an upgrade in air-lift capabilities amongst other projects dealing with weapons systems (Medium Range Surface-to-Air Missiles [MRSAMS] and Long Range Surface-to-Air Missiles [LRSAMS]) and war-fighting enablers such as networking.

## FGFA and their Characteristics

The modernisation process involves development and/or purchase of a few weapons systems that are expected to form the cutting edge of the IAF for many years to come. These are also expected to give the IAF "state-of-the-art" combat capability.[1] The most powerful aerial weapon platform today is the Air Dominance Fighter (ADF). The only in-service ADF, as on date, is the United States' Air Force's (USSAF) F-22 "Raptor". The Chinese, meanwhile, are developing their own ADF in the J-20[2] programme while the Russians are developing the PAK FA (the Russian acronym for the term "**Ï**åðñïåêòèâíûé **À**âèàöèîííûé **Ê**îìïëåêñ **Ô**ðîíòîâîé **À**âèàöèè"[3] ( phonetically "Perspektivniye Aviatsyenye Komplex Frontovoi Aviaentsei", which translates into English as "Prospective Aviation Komplex (for) Frontal Aviation")[4]. The PAK FA is to be based on the Russian Sukhoi aircraft design bureau's T-50 prototype, which first flew in 2010. India is reportedly funding part of the development of the PAK FA and collaborating on joint development of a variant of the PAK FA to meet the IAF's FGFA requirement.[5] While it is claimed that India is taking part in the design and development of the PAK FA, it is difficult to determine how this is so as the aircraft's prototype has already been designed and has been undergoing flight trials since 2010.[6] The US is also developing the F-35 "Lightning-II" Joint Strike Fighter (JSF) as a multinational project. The striking similarity between these four aircraft designs is that all conform to what the US has dubbed as FGFA, which have the following characteristics:

- Stealth: Low observability in radar, Infra red and acoustics.
- Supercruise: The ability to sustain cruising flight at supersonic speeds in dry (without the use of fuel guzzling afterburners) power settings.

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1 See "FGFA: Indian Iron", available at http://indiandefenceinformation.blogspot.in/2010/12/fgfa-indian-iron.html, accessed February 14, 2012.

2 See http://www.ausairpower.net/APA-2010-01.html, accessed February 14, 2012.

3 Carlo Kopp and Peter Goon, "Assessing the Sukhoi PAK-FA", available at http://www.ausairpower.net/APA-2010-01.html, accessed February 25, 2012.

4 Ibid., accessed February 14, 2012.

5 "FGFA: Indian Iron", n. 1.

6 Ibid., n. 1.

- Sensor Fusion: The capability to efficiently combine the information from several sensors (radar, Infra red Search and Track (IRST), radar warning receivers (RWRs), etc.) and present a seamless and combined display to the pilot, thus increasing his situational awareness manifold.
- Large radius of action.

## High Cost of FGFA

All the characteristics of these ADFs involve cutting edge technologies that require great expense and technical skills in development. The F-22 Raptor is so expensive (approximately US $143–350 million per aircraft)[7] that the USAF has been forced to cap its F-22 buy at just 187 aircraft.[8] The F-22 is expected to replace the F-15 "Eagle" in the USAF service. With regard to the latter aircraft, the US built more than 800 F-15s, of which 522 aircraft served in the USAF alone. The F-15 is also flown by the air forces of Israel, Saudi Arabia, and Japan.[9]

The F-35 "Lightning-II" is yet to enter service and the programme remains behind schedule and well above cost. This is despite attempts to achieve economies of scale through making it a multinational programme, thus getting more countries to share the cost and leading to a larger number of aircraft to be produced. (A larger production run would enable fixed development costs to be recovered over a larger number of aircraft produced, thus dividing the cost more and bringing it down per unit.) Despite the attempt to achieve "economies of scale", the F-35 "Lightning-II" is expected to cost about $ 112 million per aircraft against the initial expectation of $ 62 million apiece.[10] The F-35 was initially expected to be a relatively cheap replacement for the USAF's F-16 fleet; each F-16 costs approximately $ 14.6–18.8 (in 1998 value).[11]

## IAF Capability Enhancement: the Option of Leapfrogging

The F-22 and F-35 programmes demonstrate vividly the very high cost of US-developed high technology as well as the financial implications of following in the West's footsteps in a linear fashion when it comes to the development of our own Air Power capabilities.

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7 See http://www.military.com/opinion/0,15202,187737,00.html, accessed February 24, 2012.

8 See http://www.globalsecurity.org/military/systems/aircraft/f-22-production.htm, accessed February 24, 2012.

9 See *Jane's All the World's Air Forces*, Issue 32, August 2010 for details.

10 See http://www.dodbuzz.com/2010/06/01/jsf-price-tag-now-112-million-per-plane/, accessed February 24, 2012.

11 "F-16 Fighting Falcon", available at http://www.af.mil/information/factsheets/factsheet.asp?id=103, accessed March 4, 2012.

The relatively safe avenue of going along a beaten track—following the USAF induction history in the development of the IAF's future force structure—may have led us to follow the USAF in planning on inducting the FGFA as a follow-on to Air Superiority Aircraft, such as the MiG-29, Mirage 2000H, and Su-30MKI which are roughly equivalent to the USAF's F-16s, F-15s, and US Navy and US Marine Corp's F-18s. The US, despite all dire predictions, still remains the most technologically advanced country on the planet with the largest economy, yet is struggling to put adequate ADFs or FGFAs into service. It has found that it cannot affoard to induct large numbers of such aircraft due to their extremely high cost. In this context, it may be unwise for a developing country like India, even one that stands on the threshold of becoming a future economic power, to aspire to field technology similar to the USAF's ADFs, if for no other reason but cost alone. The successful development of the very advanced technologies required is also likely to be difficult. The Russians have built some very good aircraft over the past century, but at no stage have they been able to really compete with the US in cutting-edge advanced technology, especially in the field of avionics. The PAK FA will someday fly but most likely, going by the US experience, at very high cost. And, in all probability, if our past experience with Russian technology (MiG-21, Sukhoi-7BMK, An-32, Il-76, MiG-23, MiG-27, MiG-29, MiG-21Upgrade and Sukhoi-30MKI) is any indicator, with superlative capabilities in aerodynamics and agility, but also with capabilities that fall woefully short in the vital field of avionics.

## Chinese Manufacturing Prowess

The Chinese have made tremendous strides in upgrading their technological capabilities. They have proven their skills in low-cost manufacturing at least in the civil sector, thus earning the title, "factory of the world". It should be kept in mind that expertise in manufacturing modern consumer electronic goods involves much of the same, or very similar, manufacturing technology that would be needed to manufacture advanced modern combat aircraft. Modern consumer goods often incorporate advanced materials, including composite materials, and feature embedded information technology (IT) in a manner very similar to the way that IT is integrated with modern military, and even civil, aircraft. Moreover, there is now an increasing trend to utilise Commercial Off The Shelf (COTS) items in military equipment. This trend towards the acceptability of COTS is due to two reasons. Firstly, the technology available in the civil market has been found to be advanced and robust as is required for military platforms. Secondly, the use of COTS leads to reduction in costs through greater economies of scale for the components concerned.[12] Given the Chinese track record in low-cost manufacturing over the past three

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12 James J. Barbarello and Walter Kasian, "United States Army Commercial Off-The-Shelf (COTS) Experience: The Promises and Realities", Fort Monmouth: US Army Communications-Electronics Command, March 2000, available at http://ftp.rta.nato.int/public//PubFulltext/RTO/MP/RTO-MP-048///MP-048-05.pdf, accessed March 5, 2012.

decades, their J-20 ADF project could reasonably be expected to fructify as far as the concerned technology integration and project costs are concerned.[13] However, given the lack of transparency about the J-20 project, in particular, and the Chinese Aircraft Industry, in general, it is difficult at the current time to analyse more precisely the future prospects of the Chinese ADF project.

## Risks in Development of High Technology

Cost apart, ADFs require integration of very advanced airframe shaping to reduce the aircraft's radar signature. This extends even to the size and shape of the jet engines' inlets and exhausts to reduce radar reflections. Reports in reputed aviation journals such as *Aviation Week & Space Technology* indicate that great cost and technical expertise is required for such intricate shaping of the airframe.[14] India does not posses such expertise as on date. Even the Russians and Chinese are developing this expertise in the wake of the Americans, who are the pioneers in this field. It must be kept in mind that in the development of such advanced technology an element of risk (or of failure) is inevitable. The issue here is to determine, costs apart, whether the possible benefits of the FGFA platform outweigh the risks of delay and/or eventual sub-optimal performance in its stealth qualities.

## Supercruise

The second characteristic of ADFs is "supercruise". Supercruise refers to the ability to fly for sustained periods of time at supersonic speeds in non-reheat power settings. This specification indicates the requirement for very powerful engines that can generate as much thrust in dry power settings as is delivered by current advanced engines with afterburners on. Such supercruise-capable engines are at the cutting edge of turbojet and turbofan aero-engine technology today. Only the US has proven engines of this type in service—the Pratt & Whitney F119-PW-100 on the F-22 Raptor and the Pratt & Whitney F-135 engines on the F-35 prototype aircraft—that are undergoing development flight testing. The current Sukhoi T-50 prototype is flying with upgraded variants of AL-31 / AL-41 engines used originally on Su-27 and Su-30 aircraft, while the definitive Saturn 117S engines remain under advanced development. Even China's J-20 is flying with interim engines as

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13 Peter K. Schott, "The Relative Sophistication of Chinese Exports", pp. 5, 6, Yale School of Management: March 2007, available at http://faculty.som.yale.edu/peterschott/files/research/papers/chinex_310.pdf, accessed March 4, 2012, and Andy Hoffman, "Made in China Takes on Whole New Meaning", available at http://m.theglobeandmail.com/report-on-business/economy/manufacturing/made-in-china-takes-on-whole-new-meaning/article2107206/?service=mobile, accessed March 4, 2012.

14 "F-22 Raptor Stealth", available at http://www.globalsecurity.org/military/systems/aircraft/f-22-stealth.htm, accessed March 5, 2012.

work on building a suitable engine continues to progress independently in Russia and China for their respective FGFA programmes. India does not possess turbojet or turbofan aero-engine technology of this calibre. In fact the "Kaveri" jet engine, the first to be designed in India, is yet to achieve normal operating performance for conventional fighter use on the non-supercruising Tejas LCA.

The Russians, it appears, are developing the T-50 based PAK FA in a manner similar to that followed by India in the LCA project. The design and development of the aircraft and engine is proceeding in parallel, in place of the much safer conventional procedure of always designing and building an aircraft around a proven engine. The risks in parallel development of engine and aircraft are most clearly illustrated by the Tejas LCA that continues to fly with an interim engine—the American GE F404 and, soon, the GE F414; these engines do not enable it to meet its design parameters, which were based on the presumed availability of the more powerful Kaveri engine. This amply illustrates the technological risks inherent in the PAK FA project and in other ADF projects. These risks come into clearer focus in the context that the US, which has already successfully fielded the F-22 in operational squadron service, is struggling to complete the development of the F-35. The F-35 programme remains over budget and behind schedule primarily due to technological challenges.

## Sensors and Sensor Fusion

Sensor fusion requires, firstly, sensors. India lacks these as on date. However, efforts to develop the Multi Mode Radar (MMR) for the LCA are in progress. The MMR is not likely to be equivalent to the advanced Active Electronically Scanned Array (AESA) technology needed for an ADF. Russia is developing its capabilities towards AESA radars, an area where, again, the US holds the lead. Other relevant sensors for FGFAs are the IRST systems (which India lacks but in which Russia has a proven and robust expertise). Sensor fusion refers to the seamless integration of the information gleaned from AESA radars, IRST systems, RWRs, and the like, to fuse these to form an up-to-date and seamless picture of the environment and display this in a suitable and simplified manner for easy aircrew assimilation. This needs advanced information technology capabilities. India has a well-developed Information Technology (IT) industry biased towards civil commercial skills and with negligible expertise in the military field. Over time Indian IT skills should be adapted to military needs, especially as the IAF itself runs a specialised IT skills unit the Software Development Institute (SDI).[15] Russia has a traditional historical weakness in IT and avionics. The risks involved in the Indo-Russian collaborative FGFA (for India) and PAK FA for Russia can be seen to increase further in this aspect.

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15 Details on the Software Development Institute are available on the Indian Air Force website on the following link: http://indianairforce.nic.in/show_page.php?pg_id=143, accessed March 5, 2012.

## Radius of Action

Large radius of action (ROA) is the last characteristic of ADFs. A large ROA is a function of large fuel availability and engines that combine very high thrust with the diametrically opposite trait of fuel efficiency. Once again, this is very high-end turbofan engine technology. The F-22, reportedly, has a ROA of more than 3,000 km while the PAK FA is said to be designed to have a ROA of more than 4,000 km. The Chinese J-20 could be expected to aspire to a similar ROA.

## Alternative to Stealth

Having seen the technological and financial problems associated with following the US' lead in modern aviation technology, it is prudent to seek a viable operational solution suited to India's needs and pockets. This aspect becomes more pertinent in view of reports in national newspapers about reductions in the defence budget in view of the slowing GDP growth of the country. Here, the very first step is to clarify that "stealth" is not an end in itself but rather a means towards the end of achieving "assured" or, at least, "very high probability" of penetration of hostile airspace in order to effectively address desired targets. Accepting that "stealth" is a means towards this end; if "Stealth" is not affordable then what is?

## The Way Forward: Hypersonic Craft

Hypersonic craft fly at above Mach[16] (M) 5.0 (typically between M5.0 and M 20). At such speeds, nothing short of a very agile Ballistic Missile Defence (BMD) system would be capable of effectively intercepting a hypersonic craft (unlike ballistic missiles, hypersonic military craft would posses greater manoeuvrability thus making their interception more difficult as compared to ballistic missiles).[17]

US Research and Development (R&D) into hypersonic technology has followed their R&D into ADF requirements and technology.

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16 The Mach number is indicated as single number though it is actually a ratio. It refers to the ratio of an aerospace craft's speed to the local speed of sound. Mach 1.0 indicates a craft flying at the speed of sound.

17 Hypersonic speeds approach those of ballistic missiles. Conventional anti-aircraft missile systems have target upper speed limits that fall well below the hypersonic speed range; hence to intercept hypersonic craft missile systems designed to engage very high speed targets are required. Currently, only BMD systems are being designed for this speed range.

## State of Indian Hypersonic Technology Development

In the Indian context, the Indian Space Research Organisation (ISRO) and the Defence Research and Development Organisation (DRDO) have both been working on supersonic combustion ramjet (scramjet) engines that are needed to power hypersonic craft.[18] Ground tests at above M6.0 have been successfully carried out.[19] The integration of a scramjet in a projectile is the next test stage. In this field, only the US with its X-43 and X-51 craft is ahead of India; Russia, China, and Australia are all at the same stage as India, of having ground-tested a scramjet to about M6.0 to M7.0, and are preparing to test an engine airframe combination in free flight. This gives India the scope to leapfrog the very costly ADF stage to a near unstoppable hypersonic craft stage, achieving the desired end of assured hostile airspace penetration and target attack and, possibly, also of assured space access through the same or a similar platform. The beneficial spin-offs here would be great self-confidence through having built a cutting-edge technology domestically at costs that are likely to be a fraction of those involved in developing/co-developing/buying a "Stealth" design.

India has already proven the domestic availability of advanced materials for high hypersonic speed flight through its re-entry vehicle demonstration.[20] Software programming skills are readily available both in the domestic civil IT sector as well as within the Government, with the IAF's SDI, DRDO's Aeronautical Development Agency (ADA), and Centre for AirBorne Systems (CABS).

Hypersonic craft designed for military purposes will require suitable sensors which, in view of the game changing speed characteristic of such craft, may deliver required results with lower-rung radars, such as variants of the MMR for LCA, rather than high-end AESA radars. Sensor fusion would be a requirement, but here the new speed advantage should give a window of time to develop/acquire such technology without major compromises in operational effectiveness. The ROA of hypersonic craft is very large as these have an inherent ability to operate in outer space (above 100 km altitude above mean sea level [AMSL]). Moreover, a hypersonic craft is expected to provide practically global ROA.

## An Opportunity to Leapfrog

The main advantage of following this route is that the technology for most of the craft, save the sensor (under development for the LCA) and sensor fusion (also under

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18 See http://spacefellowship.com/Forum/viewtopic.php?f=38&t=11781 (accessed Feb 26, 2012)and http://www.defencenews.in/defence-news-internal.asp?get=new&id=242 (accessed Feb 26, 2012)

19 See "ISRO conducts flight testing of advanced sounding rocket" available at http://www.thehindu.com/sci-tech/article145746.ece

20 See http://www.isro.org/satellites/sre-1.aspx (accessed Feb 26, 2012)

development for the LCA), is available from domestic sources: materials able to sustain very high temperatures from ISRO and DRDO; scramjet engines from ISRO and DRDO; sensors of capability below the cutting edge from DRDO labs in the near future; sensor fusion capabilities from DRDO; and IAF labs as a follow on to the LCA project. Unlike most weapons acquisitions in the past, India, for the first time, appears to possess the required technology for most parts of the potential hypersonic combat craft. This could potentially shift India from being a follower in the international aerospace technology arena to an eventual leader. Such a shift would have major beneficial spin-off effects on the nation's economy as well as for national pride.

## Need for Detailed Unbiased Study

There needs to be an unbiased, in-depth, and serious study on the subject of identifying suitable technology for the future IAF, given the technological capabilities available within India as well as the costs involved. Such an exercise would assist in a pragmatic and cost-effective look at the equipment plans for the future IAF, thus enhancing overall security of the nation.