THE SIMPLE LIGHT FIGHTER AIRCRAFT REINCARNATED

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INTRODUCTION

Evolution of fighter aircraft has followed a relatively predictable path with each generation adding greater capability than its predecessor. Technological developments have pushed the envelope of capability to make each new generation of fighter aircraft more sought after by the world's air forces. An attendant problem in this evolution has been the increase in complexity that accompanies greater capability being built into fighter aircraft. Increased complexity has two attendant adverse effects on fighter programmes. These are delays in the design and development programme completion as complex technology incorporation leads to the possibility of unforeseen problems arising, which could take considerable time to resolve satisfactorily. The second issue is that of higher cost as development of new cutting edge technologies and incorporating these into new designs leads to increased cost of Research and Development (R&D) as well of production, driving up the per unit cost of each machine finally delivered. While most modern fighter aircraft manufacturing nations are working on advanced highly capable cutting edge designs, there is a parallel discourse in favour of developing simple and light low cost fighters which may not on an individual basis be as capable as their cutting edge cousins, but still deliver value to their operators.

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FIGHTER AIRCRAFT DEVELOPMENT MILESTONES

Till the last years of World War II , fighter aircraft were powered by piston engines driving air screws or propellers. The basic technology was similar to that which powered the first heavier than air aircraft on December 17, 1903, though much more advanced, given the almost half century that had elapsed since that first flight at Kitty Hawk.[1] The last few years of World War II saw development of jet engine technology.[2] While Britain's Frank Whittle is credited with developing the first centrifugal compressor-based British jet engine, the Germans developed the world's first axial flow compressor equipped jet engine, the Jumo 004B, which powered the world's first operational jet fighter, the Messerschmitt Me-262.[3] The jet engine helped overcome the limitations of power output and propeller linked speed limitations and, hence, rapidly became the power plant of choice for fighter aircraft. Jet fighter aircraft are classified into "generations" by the West. Generation 1 (Gen1) comprised fighters with all metal bodies and non-afterburning jet engines with primarily gun and/or cannon armament. These were capable of only subsonic speeds in level flight. Air-to-ground armament carried by these aircraft comprised unguided bombs and rockets only. These fighters lacked effective airborne radars and advanced avionics for offensive and defensive use. Gen 1 fighters were the state-of-the-art from the mid-1940s till the mid-1950s. Examples of these include the British Vampire and Gnat, French Ouragan and Mystere, American F-86 Sabre jet and Swedish SAAB J-32 "Lansen", Soviet MiG-15 "Fagot" and MiG-17 "Fresco". Gen 2 fighters built upon the

1. "1903 Wright Flyer ",http://www.wright-brothers.org/Information_Desk/Just_the_Facts/Airplanes/Flyer_I.htm, accessed on September 4, 2014.
2. "The Jet Engine: A Historical Introduction", http://cs.stanford.edu/people/eroberts/courses/ww2/projects/jet-airplanes/planes.html, accessed on September 4, 2014.
3. "Messerschmitt Me 262 Schwalbe / Sturmvogel", ,http://www.fighter-planes.com/info/me262.htm, accessed on September 4, 2014.

earlier technology by fielding jet engines equipped with afterburners. These afterburning engines in combination with more aerodynamically advanced airframes gave them supersonic speed capability, up to around Mach 2.0 in most cases. This generation of fighters also carried airborne radars able to pick up and track airborne targets and Radar Warning Receivers (RWRs). The armament of Gen 2 jet fighters added Air-to-Air (A-A) missiles with Infra-Red (IR) and Semi-Active Radar Homing (SARH) to the earlier machine gun and cannon armament. Gen 2 jet fighters still had basically unguided air-to-ground armament capability. This generation was the state-of-the-art from the mid-1950s till the mid-1960s. Examples include early models of the French Mirage-III, the British English Electric "Lightning", American F-5 "Tiger-II" and F-104 "Starfighter", Swedish J-39 "Draken", and Soviet Su-7, Su-9, Su-11, MiG-19 and MiG-21. Gen 3 jet fighters further improved upon the previous generation in incorporating, firstly, better airborne radars that were able to acquire aerial targets even against the high clutter background of the earth's surface. This enabled "Look Down Shoot Down (LDSD)" capability. These radars also delivered Beyond Visual Range (BVR) aerial target engagement capability and "off boresight" engagement capability through use of better A-A missiles. This latter capability meant that aerial targets that were not directly in front of the Gen 3 fighter could be engaged with fair chances of success. These fighters also introduced better multi-role capability than previous generations. The avionics suites of this generation were also more capable. Examples of this generation include later models of the French Mirage-III, Soviet MiG-23MF, American F-4 "Phantom-II". Gen 3 fighters were the state-of-the-art in the 1960s. Gen 4 fighters were the next step that took performance to a still higher level. These were characterised by more

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advanced aerodynamic designs that gave considerably higher aircraft performance; for the first time making the pilot the weakest link in the execution of tight manoeuvres. Sustained 9 'g' manoeuvres became standard and pilots were hard pressed to retain useful consciousness, in the face of high centripetal and centrifugal acceleration, during execution of tight manoeuvres. In earlier times, aircrew had been required to be cautious to carry out manoeuvres that were within the aircraft's structural limits; in Gen 4 fighters, the human ability to withstand very high accelerations became the limiting factor and not the aircraft structural limitations. Gen 4 fighters also fielded advanced avionics such as Head Up Displays (HUDs), Fly By Wire (FBW) control systems, advanced pulse Doppler radars with Low Density Supersonic Decelerator (LDSD) capability and well developed BVR capability. These fighters also brought in true multi-role capability, including use of guided Air-to-Ground (A-G) weapons, or Precision Guided Munitions (PGMs), for precision attack. The advanced avionics on board gave these aircraft the ability to switch quickly between A-A and A-G roles. Examples of this generation include the American F/A-18A/B "Hornet", F-16A/B "Fighting Falcon", French Mirage-2000, and Soviet Su-27 "Flanker" and MiG-29 "Fulcrum". This generation was the state-of-the-art from the mid-1970s till well into the 1990s. Currently, Gen 5 jet fighters represent the state-of-the-art. This generation has a few unique distinguishing characteristics. Firstly, they are Low Observable (LO) or "stealth" designs which incorporate advanced aerodynamic shaping as well as advanced materials to reduce their radar, IR, acoustic, and visual signatures appreciably. The F-22 "Raptor" is claimed to have a Radar Cross-Section (RCS) of a mere 0.0001 m^2 while a typical Gen 3 or Gen 4 fighter had RCS of between 1 and 5 m^2.[4] Secondly, these aircraft also possess capability to "supercruise" which implies that they can sustain supersonic flight in "dry" or non-reheat power settings, an ability absent in most previous generation fighters. The ability to supercruise indicates a very high energy capability which means that the

4. "Radar Cross-Section (RCS)", http://www.globalsecurity.org/military/world/stealth-aircraft-rcs.htm, accessed on September 4, 2014.

aircraft can sustain high speeds without burning as much fuel as earlier generation aircraft did for similar speed maintenance. This translates into higher radii of action in all profiles. Tactically, it implies that such aircraft have very high energy agility, a crucial factor in modern aerial combat. Lastly, Gen 5 aircraft display a very high degree of multi-sensor fusion which is the ability to take inputs from several different sensors such as radar, IR Search and Track (IRST), data links from other platforms, etc.; and fuse this information into one seamless coherent whole, thus, increasing the pilot's situation awareness manifold. The ability to interface seamlessly with several other platforms and command structures to deliver highly software dependent 'networked' fighting ability is also incorporated in Gen 5 fighters. These characteristics make these fighters extremely lethal. Examples of this generation include the American F-22 "Raptor" and F-35 "Lightning-II" (the F-22 is in squadron service while the F-35 is at the last stages of its troubled development period), the Russian under development Prospective Aviation Komplex [for] Frontal Aviation (PAK FA); the Chinese J-20, and J-31, [the former under development at the Chengdu Aircraft Corporation (CAC) and the latter under development at the Shenyang Aircraft Corporation (SAC)], and Indian collaboration with Russia for the PAK FA derived Fifth Generation Fighter Aircraft (FGFA) which is also under development. The large gap in capability between Gen 5 and Gen 4 fighters led to attempts to retro-apply a few Gen 5 technologies on Gen 4 aircraft. This led to the new Gen 4.5 class of fighters. The changes incorporated include modifications to the airframe through shape changes and application of Radar Absorbent Materials (RAMs) to reduce the RCS, treatment of the engines for reduced IR signature was also applied and advanced avionics from Gen 5 aircraft installed, most prominent among these being the Active Electronically Scanned Array (AESA) radars and sensor fusion technologies. Gen 4.5 fighters remain below Gen 5 in performance but represent an appreciable advance over Gen 4 fighters. Examples of Gen 4.5 fighters are the American F-18E/F "Super Hornet" and F-16 Block 52 upwards and late models of the F-15 "Eagle", Swedish Gripen NG, Soviet Su-35S, European Eurofighter Typhoon and French

"Rafale". Gen 5 fighters started to become the state-of-the-art from the early 2000s and continue till date.[5] In this case, the Gen 4.5 occupy a similar time period in ascendency as Gen 5 fighters.

The technological and capability enhancements incorporated from Gen 1 to Gen 5 fighters as described above have come at two major costs. These are the cost of complexity and the increased financial cost. The time taken between commencing the design of a fighter and its induction into service has increased considerably due to the increased complexity with each new generation. The Gen-1 F-86 Sabre jet took under five years from commencement of design till it entered operational service.[6] The Gen-2 F-104 "Starfighter took a shade over six years from initiation of the programme to entry into service.[7] The Gen-3 F-4 "Phantom-II" took a little over seven years from design initiation till entry into operational service.[8] The Gen-4 F-18 took almost a decade from initiation of design to service entry.[9]The Gen-5 F-22 took twelve years from design initiation till service entry.[10] The F-35 "Lightning-II" programme was initiated in the early 1980s and as this is written, in late 2014, it remains short of readiness for entry into operational squadron service. The operational service entry of the cutting edge Gen-5 F-35 is at least ten years behind schedule. With new problems continually surfacing with this aircraft, it is apparent that the sad saga of development delays in the F-35 programme is not yet over. These delays have led to several partner countries scaling back their F-35 purchase plans.[11] The narrative above brings out very clearly the implications of increased complexity of

5. "Five Generations of Jets", http://www.fighterworld.com.au/az-of-fighter-aircraft/five-generations-of-jets, accessed on September 4, 2014.
6. "North American Aviation….. The Sabres Fly", http://www.boeing.com/boeing/history/narrative/n046naa.page, accessed on September 4, 2014.
7. "Lockheed F-104 "Starfighter"", http://www.oocities.org/uriyan/chap3/chap3.html, accessed on September 4, 2014.
8. "McDonnell Douglas F-4 Phantom II Multi-Role Fighter", http://www.aerospaceweb.org/aircraft/fighter/f4/, accessed on September 4, 2014.
9. McDonnell Douglas (now **Boeing**)/Northrop F/A-18 Hornet Multi-Role Fighter", http://www.aerospaceweb.org/aircraft/fighter/f18/, accessed on September 4, 2014.
10. "F/A-22 Raptor, Lockheed", http://www.fighter-planes.com/info/f22.htm, accessed on September 4, 2014.
11. "Britain 'Should Consider Scrapping F-35 Stealth Fighter'", http://www.telegraph.co.uk/news/uknews/defence/10838453/Britain-should-consider-scrapping-F-35-stealth-fighter.html, accessed on September 4.

each generation as compared to the previous one on the time required to get the aircraft from the drawing board to the squadron tarmac. Very often, these delays, especially if not accurately forecast, could lead to yawning gaps in the operational capability of air forces planning to induct such new machines till such time as the new fighters finally arrive. The flyaway cost of each F-86E in the early 1950s was a little above $200,000.[12] F-4G specialised electronic attack aircraft cost $ 18.4 million each in the late 1960s.[13] In the year 1998, an F-16C/D cost $26.9 million.[14]Each F-22 "Raptor" is assessed to cost $412 million per aircraft at the final production run of just 187 aircraft built.[15] The F-35 is estimated to cost $299.5 million per aircraft.[16] The world's first and only operational stealth bomber, the B-2 "Spirit", cost as much as $ 0.7 to 2.4 billion each in their limited 21 aircraft production run.[17] These facts bring out the huge cost escalation with each new generation of fighter aircraft starting from Gen 1 through Gen 5. These costs combined with the time overruns due to incorporation of cutting edge technology, some of which is typically developed in parallel with the aircraft development, lead to unforeseen delays. The imperative to field the best available weapon systems has driven the race towards development of ever more advanced aircraft. However, the twin shocks of time and cost escalations is forcing a rethink about the viability of fielding large numbers of very advanced high Gen aircraft against the acceptability of larger numbers of less capable machines inducted on time and within reasonable cost.

The higher cost and complexity of the advanced generation such as Gen 5 fighters in comparison to less capable earlier generation fighters is justified in terms of the ability of advanced generation fighters to seize

12. "THE F-86E", http://sabre-pilots.org/classics/v1286e.htm, accessed on September 4.
13. "F-4 Phantom II F-4G Advanced Wild Weasel", http://fas.org/man/dod-101/sys/ac/f-4.htm, accessed on September 4, 2014.
14. "F-16 Fighting Falcon", http://fas.org/man/dod-101/sys/ac/f-16.htm, accessed on September 4, 2014.
15. "F-22 Program Produces Few Planes, Soaring Costs", http://www.latimes.com/business/la-fi-advanced-fighter-woes-20130616-dto-htmlstory.html, accessed on September 4, 2014
16. "How Much the F-35 Really Cost?", http://defense-update.com/20140103_much-f-35-really-costs.html#.VAhK9KO41Kg, accessed on September 4, 2014.
17. "B-2 Stealth Bomber Made its Maiden Flight 25 Years Ago", http://www.latimes.com/business/la-fi-stealthy-b2-bomber-turns-25-20140717-story.html, accessed on October 1, 2014.

Given the likelihood of opponents deploying effective counter-measures to weapons launched by the F-22 and the claimed lower than advertised Single Shot Kill Probability (SSKP) of the weapons launched by the F-22 in the real world, a single F-22 could be expected to be able to defeat three or four opposing fighters with a reasonable degree of success.

the first launch of a weapon advantage over opponents and the ability to engage multiple opponents at the same time or within a very short time period through quick successive launches of weapons at different opponents. The lack of this capability in earlier fighters is touted to give an unassailable advantage in combat to the more capable machines.

A closer examination of the combat advantage above is educative. A typical Gen 5 fighter carries its weapons in internal weapons bays in order to avoid compromising on its Low Observable (LO) characteristics. Thus, while the Gen 5 fighter's LO, supercruise and advanced avionics capabilities give it a definite first shot advantage over less capable adversaries, it cannot carry enough ordnance to take on more than a relatively limited number of opponents due to the constraints of internal stowage space available. The F-22 can carry a maximum of six AIM-120C BVR missiles and two AIM-9 IR guided all aspect Air-to-Air Missiles (A4M) for close combat, in its four internal weapons bays at a time. Such weapons carriage would limit the F-22 to a maximum of six BVR shots and two close combat shots in a mission.[18] Given the likelihood of opponents deploying effective counter-measures to weapons launched by the F-22 and the claimed lower than advertised Single Shot Kill Probability (SSKP) of the weapons launched by the F-22 in the real world, a single F-22 could be expected to be able to defeat three or four opposing fighters with a reasonable degree of success. Now it is interesting to dwell upon the fact that even with the very advanced LO features incorporated on the F-22 and the first operational US stealth, or LO, aircraft (the F-117 and B-2), the RCS and other signatures cannot be reduced

18. "F-22 Raptor Weapon Carriage Capability", http://www.aerospaceweb.org/question/planes/q0105.shtml, accessed on September 15, 2014.

to zero. Thus, adequately powerful enemy sensors will finally detect the advanced Gen 5 aircraft albeit at ranges much closer than those achieved for earlier generation fighters. Once the Gen 5 fighter is detected, it can be shot down. In the real world, a USAF F-117 "Nighthawk" stealth aircraft was actually shot down on March 27, 1999, over Kosovo by an antiquated Soviet era SA-3 "Goa" or SAM-3 "Pechora" Surface-to-Air Guided Weapon (SAGW) manned by the Serbian forces.[19] In situations where it is finally detected by hostile forces' sensors, it is likely that earlier generation fighters opposing the Gen 5 fighter would have detected it at fairly close ranges and would have been exposed to weapons fire from the Gen 5 fighter much earlier. A limited number of opposing fighters could all be destroyed well before they achieve detection range on the LO fighter. However, if the opposition uses mass tactics of accepting the sacrifices of a number of fighters to enable other fighters to close in adequately on the Gen 5 fighter to defeat it, the Gen 5 could be vulnerable. A single F-22 may be able to, given real world constraints and uncertainties, shoot down about four opposing lower generation aircraft with high probability of success, however, it could be defeated if it faces, say, five or more lower generation fighters that act in concert and some of them achieve acquisition on the F-22 by virtue of closing in while other members of their formation (or attack team) are being destroyed by the F-22.

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Accountants could be pleased by this financial tally where, say, the loss of four or five fighters costing about $20-25 million each leads to the destruction of a Gen 5 fighter that costs about $300-400 million. The accountant may see merit in the cost benefit balance achieved. Issues of morale and aircrew losses would make the trade-off much more complex. These latter issues,

19. Larkins Dsouza, "This is How the F-117A was Shot Down in Serbia by a SA-3 (S-75) Goa SAM in 1999", http://www.defenceaviation.com/2007/02/how-was-f-117-shot-down-part-1.html, accessed on October 1, 2014.

that transcend cost alone, are the drivers for the development of complex and costly Gen 5 fighters in most advanced nations. Coupled with this is the desire and military imperative to field capabilities seen as near 'undefeatable' and superior to earlier generation machines. Despite all these factors, the extremely high cost of the current generation of cutting edge fighters of Gen 5 is causing concern in all countries. Even the world's largest economy, the US, is unable to provide funds for large production runs of the very expensive Gen 5 fighters. The US was able to build just 21 B-2 "Spirit" stealth bombers at a cost of between $ 900 million and $ 2.4 billion each. It should be borne in mind that modern Gen 4.5 aircraft too are not cheap. A single Eurofighter Typhoon costs about 126 million British Pounds or $204 million[20], while the French Rafale carries a price tag of approximately Euro 142.3 million or $ 179.54 million each. India is reportedly negotiating so as to be paying approximately between Euro 80 to 87 million or $ 100.9 to 109.77 million each for the Rafale fighters as part of its Medium Multi-Role Combat Aircraft (MMRCA) project.[21] The production run of the F-22 "Raptor" has been capped at 187 aircraft primarily due to the aircraft's very high cost. Expected production numbers of the F-35 continue to fluctuate with several partner nations either cancelling or cutting back their initial induction plans, driving the US to find new customers to keep the numbers as high as possible. India has also scaled back its initially declared intention to induct 250 FGFA to a lower number of 144 aircraft for a variety of reasons.

A situation wherein the world's most wealthy nation is unable to field adequate numbers of advanced Gen 5 aircraft has spurred a relook at other options. It has been established through war- gaming that numbers do matter for military forces. A smaller number of very advanced aircraft may be more constrained in delivering the military results required through engaging multiple surface or aerial targets in a conflict situation as compared to a larger number of less capable aircraft. It is likely that a

20. Richard Norton-Taylor, "RAF Typhoon Jets Draw MPs' Flak Over £20bn Price Tag", http://www.theguardian.com/uk/2011/apr/15/raf-typhoon-jets-mps-flak, accessed on October 1, 2014.
21. Suman Sharma, "Rafale Cost Could Soar Into Skies", http://www.sunday-guardian.com/investigation/rafale-cost-could-soar-into-skies, accessed on Ocober 1, 2014.

single aircraft may be able to take on say two targets effectively. Beyond this, it could be severely limited by its inability to carry adequate ordnance and the impossibility of being at more than one geographic location at the same time. Less capable fighters fielded in larger numbers could be present in more locations and take on more tasks, thus, achieving the required military ends even if with relatively higher losses. In case the less capable fighters fielded in larger numbers were to incorporate a few crucial Gen 5 technologies to reduce their RCS, etc and field advanced avionics, the gap in capabilities could be shrunk further, thus, making the cost-benefit ratio tilt even more towards the lower cost, less capable fighter. This thinking has led to the development of several such lower capability simple, light and low cost fighters in the recent past. Cost though often scoffed at by earlier military leaders, is becoming increasingly important in the face of the global economic slowdown since 2008 and consequently shrinking defence budgets in most parts of the world. Compared to the very high costs of Gen 5 and even Gen 4.5 fighter aircraft, typical Gen 4 fighters cost a mere $ 20 to 30 million. Moreover, the Gen 4 fighter aircraft are mature and stable designs in which most quirks and shortfalls have been ironed out; hence, these machines have no unpleasant surprises in store for their operators. A fighter of mature and well established design gives greater reliability but possibly lower capability per unit than a cutting edge fighter. However, on the flip side, given real world monetary constraints, a given sum of money can enable buying of much larger numbers of the earlier Gen fighters than those of the latest Gen. These real world realities have led several manufacturers to either offer established designs in upgraded *avatars,* such as the US Lockheed Martin F-16IN "Viper" and Boeing F-18E/F "Super Hornet", or use existing systems and sub-systems to rapidly develop new aircraft that incorporate earlier proven systems in order to keep costs and lead times low.

A few such new built offerings are the Russian Yak-130 and the American Scorpion. The former aircraft started out as an advanced trainer. The performance achieved by the design coupled with the perceived niche need for a low cost mass produced fighter has led

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the Yakolev design bureau to further develop the design into a light fighter *avatar*. In the US, the Scorpion light fighter has been designed on a modular thought process. The Scorpion is a fully company funded project on the lines on which the company concerned, Textron AirLand, also manufactures the Cessna aircraft. A market need is identified and then a product developed to meet that perceived need, using company funds. Sales to the niche market identified earlier help the company recover its investment and make a profit. In order to cut down on both lead time and cost, the Scorpion uses off-the-shelf available components from earlier or existing Gen 4 and Gen 3 fighter programmes put together to deliver a low cost but capable machine. Use of existing component parts means that there is no cost or lead time of new R&D, thus, making the final product cost effective while incorporation of a few advanced features such as modern composite materials, sub-systems such as weapon system computers, and advanced avionics such as the AESA radars give a better combat effectiveness score than the Gen 3 and Gen 4 fighters from which it borrows its component parts. The Scorpion has reportedly moved from the design board to flight in a mere 23 months at a cost per piece of just $ 20 million.[22] This new pragmatic approach is an innovative solution to retaining needed combat effectiveness for modern military aviation while ensuring that the overall costs are within reasonable limits. Such an approach deserves attention from countries like India, that are starting out to build a modern and capable domestic aircraft industry. The light low cost fighter may be more achievable in a reasonable timeframe than a more advanced machine. Once this capability is in place, a system of ongoing innovation and

22. Russell Hotten, "Farnborough Airshow: The Scorpion in Search of a Customer", http://www.bbc.com/news/business-28260781, accessed on October 3, 2014.

progressive improvements could close the gap with more advanced aircraft in a cost-effective manner, without compromising on national security.

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IMPLICATIONS FOR AEROSPACE ASPIRANTS

For countries aspiring towards greater domestic capability in aerospace, this modular approach could yield dividends, especially if their industry has achieved at least some pockets of success. For instance, the Indian aircraft industry could build upon its earlier pockets of success with the HJT-16, HF-24, to marry the successful and usable technologies, components or/and techniques from these earlier programmes with newer learning and successes in the Light Combat Aircraft (LCA) "Tejas", Advanced Light Helicopter (ALH) "Dhruv", Airborne Early Warning and Control (AEW & C), and Jaguar/MiG-27ML upgrade programmes amongst others to develop similar products as the Scorpion as the low or even medium end of the country's future fighter aircraft force, at affordable costs. Such new modular products, if built at reasonable cost and in reasonable timeframes through using existing sub-parts from earlier programmes, could help India close the gap with more advanced aircraft manufacturing nations without any compromise in national security. These new products could see high volume production while costlier more capable machines, say, such as the upgraded Su-30MKIs, Rafales and Fifth Generation Fighter Aircraft (FGFA) could fill the high technology needs, though in fewer numbers.

CONCLUSION

Fighter aircraft development has been driven by technology to a great extent. Starting with very simple machines in the early years of the last century, the fighter has developed into a very complex system of systems. These advances have been spurred on by technological advances in diverse fields ranging from high strength but lightweight materials, power plants to digital computing. The incorporation of ever more advanced technology has invariably made the development time cycle of each new generation of fighters lengthier while, at the same time, adding to the development and per unit cost. These increases in cost have constrained even the world's richest nation from going in for large numbers of the latest generation fighters. In parallel, a debate on the virtues of lower capability and cost fighters which could be fielded in large numbers has developed further into many manufacturers in the world seeing a market for relatively simple light fighter aircraft. This has led to modification of some earlier generation fighters to make them more effective at reasonable cost while also spurring other manufacturers to develop "modular" designs that build upon available proven component parts and systems to rapidly build cheap but effective fighters. The renewed interest in this new type of fighter aircraft holds out promise for nations with a few successes in building aircraft and that are trying to establish themselves as aircraft manufacturing countries.