



FAST JET OPERATING COSTS

COST PER FLIGHT HOUR STUDY OF SELECTED AIRCRAFT

EDWARD HUNT
SENIOR CONSULTANT, AEROSPACE & DEFENCE CONSULTING

13TH MARCH 2012

PREPARED FOR:



WHITE PAPER

FAST JET COST PER FLIGHT HOUR (CPFH) ASSESSMENT

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EXECUTIVE SUMMARY

IHS Jane's is pleased to provide this Fast Jet Operating Cost White Paper for Saab AB, covering cost per hour of flight calculations (CPFH) for the Lockheed Martin F-16, Boeing F-18 E / F Super Hornet, Lockheed Martin F-35 Joint Strike Fighter, Saab Gripen, Dassault Rafale and EuroFighter Typhoon. IHS Jane's undertook this project through use of primary and secondary source research, combined with our in-house databases and a modelled assessment of relative cost based on fuel usage. Owing to the differing methods of calculating aircraft operating cost per flight hour and the large number of interlinked factors that affect such a calculation, IHS Jane's believes that any flight hour cost figure can only be regarded as indicative and that there is no single correct answer to such a calculation. However, we believe that our results are of considerable merit and provide a useful benchmark when considering the costs associated with operating contemporary high performance combat aircraft. Based on our research and analysis, IHS Jane's has concluded the following:

1) The Saab Gripen is the least expensive of the aircraft under study in terms of cost per flight hour (CPFH). This is based on reported costs covering only:

- Fuel used*
- Pre-flight preparation and repair*
- Scheduled airfield-level maintenance together with associated personnel costs*

2) At an estimated \$4,700 per hour (2012 USD), the Gripen compares very favourably with the Block 40 / 50 F-16s which are its closest competitor at an estimated \$7,000 per hour

The F-35 and twin-engined designs are all significantly more expensive per flight hour owing to their larger size, heavier fuel usage and increased number of airframe and systems parts to be maintained and repaired. IHS Jane's believes that aircraft unit cost and size is therefore roughly indicative of comparative CPFH

3) IHS Jane's has been unable accurately to determine the constituent costs of fuel, spare parts, repairs and personnel that constituted each of the aircrafts'

stated CPFH. However, based on a 2005 USAF study of F-16s, IHS Jane's believes the CPFH is composed of approximately:

- 10-15% Consumable Supplies (small parts, wiring, basic electrical components)*
- 20-25% Sortie Aviation Fuel*
- 60-70% Depot Level Repair and Systems Maintenance*

4) *IHS Jane's believes that individual aircraft or air force CPFH will also depend on the impact of less tangible CPFH constituent factors. Such variable likely to impact CPFH include:*

- Flight Profile*
- Onboard Systems*
- Aircraft Age*
- Unit Location*
- Sortie Rate*

CAVEATS

IHS Jane's stresses that without access to comprehensive military data over a significant timeframe these conclusions can only be regarded as approximate and are an average cost across an entire fleet. Individual aircraft CPFH will vary significantly. However, based on the level of data available IHS Jane's is able to ascribe the following probability to our results:

- The F-18, F-16 and Gripen CPFH results are the most certain, with good primary and secondary source data supported by logical results from our deductive modelling
- The EuroFighter and Rafale figures are less certain owing to the incomplete nature of the data available, though the comparative modelling output appears to confirm IHS Jane's estimates
- The F-35 costs remain less certain owing to the absence of actual in-service data; IHS Jane's does not feel that the modelled fuel cost figure is representative of likely CPFH costs

INTRODUCTION

The cost of military equipment has been a highly contentious issue for both governments and armed forces. The lack of direct threat faced by many nations, rising government commitments to health and welfare and the continued uncertainty across the world economy have all highlighted the need for cost effective military procurement. While the initial purchase costs of advanced systems such as aircraft have grown significantly, the cost to support and operate such platforms accounts for a significant proportion of an annual defence budget. Given the competition among aircraft manufacturers for the limited fighter aircraft market, a low maintenance and operating cost is an increasingly core part of the offering. Though the 'headline figure' of an aircraft unit cost remains important, lower through-life and CPFH allows savings over multiple years and may therefore offer better value than an equivalent aircraft with a lower unit cost.

This relationship between unit cost and CPFH has become of further significance with the increased possibility of leasing fighter aircraft, as in the case of the Hungarian Air Force. Though the exact payment details of a given lease contract will vary, the CPFH of an aircraft under lease is likely to prove a more important determinant of selection than the unit cost, though the latter will be reflected in the contract terms. As the market for military equipment becomes increasingly dynamic, this mode of acquiring capability may prove attractive and hence the importance of the through-life rather than initial cost is increasingly important.

Though all costs in this white paper will be quoted in 2012 US Dollar values, this should not obscure an important corollary in terms of actual operating environments. The dollar value of an aircraft's CPFH represents the opportunity cost of the maintenance personnel's time as well as use of the limited stocks of spare parts, both large and small, in addition to aviation fuel. These items are of concern as part of the logistical organisation of an air force and become of critical importance when operating in a wartime environment and / or overseas.

Therefore the costs estimated by IHS Jane's for this white paper should be considered not simply in terms of a percentage of an air force's budget, but also in terms of the time and effort required by personnel to generate sorties. While a more expensive aircraft with a higher CPFH might offer greater capability, it is also likely to prove a higher consumer of non-reusable items such as time, spares and fuel. This may therefore impact an air force's ability to deliver a required sortie rate or capability, particularly if defence spending remains under pressure.

It has been fairly common to suppose that a less-expensive aircraft will offer lower capability than a more expensive competitor. While this is not untrue, the ability to generate sorties from limited defence resources must be viewed as an extremely important calculation when considering aircraft performance. In this study, IHS Jane's has found the

Saab Gripen and Lockheed Martin F-16 to offer the lowest CPFH which suggests that – everything else being equal – both types will therefore offer the highest serviceability and most economical cost per mission. While the larger Rafale, EuroFighter and F-18 E / Fs are generally considered to offer high performance and capability (to say nothing of the 5th generation F-35), the types of operations flown by Western nations over the last decade have not shown the smaller F-16 or Gripen to be at a significant disadvantage compared to the larger, twin-engined types. This does not mean that a larger, more sophisticated aircraft does not have their uses, but it does show that marginal superiority in performance may not be required for many military operations.

There is a significant argument, therefore, that lower CPFH and through-life cost deserve to given greater consideration when evaluating aircraft if the average sortie does not necessitate a platform of completely unmatched capability but merely one that is capable of exceeding requirements.



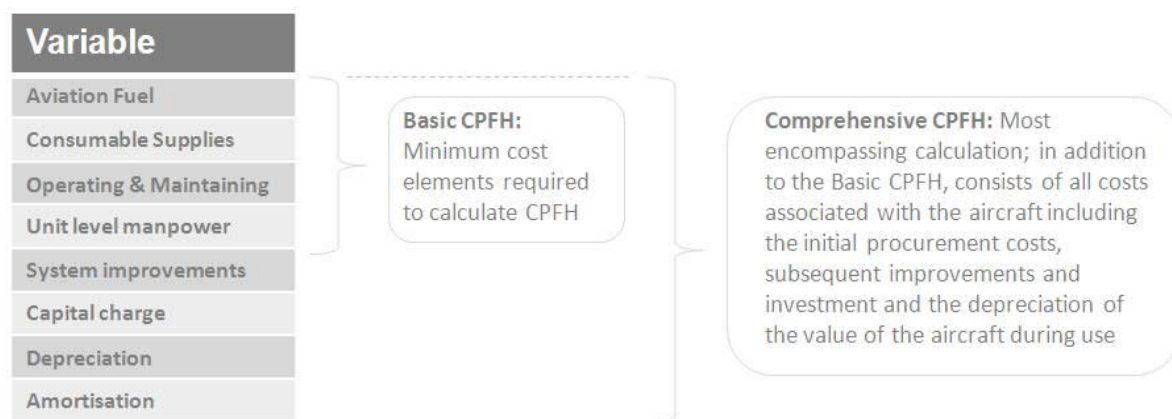
Swedish Gripen taking off from NAS Sigonella for its first sortie over Libya, April 2011 (Source: BlogSpot)

FIGHTER OPERATING COST CALCULATIONS

In order to provide representative assessment of aircraft CPFH, IHS Jane's attempted to reconcile differing methodologies of calculating this cost. There does not exist a standard global approach towards calculating this cost and statement by aircraft manufacturers and operators do not usually give a clear breakdown of the constituent elements behind a particular figure. After speaking with serving and ex-military contacts, IHS Jane's determined that any given CPFH figure would be composed of some or all of the following variables:

- *Aviation Fuel*
- *Consumable Supplies*
- *Operation and Maintenance*
- *Unit Level Manpower*
- *System Improvements*
- *Capital Charges*
- *Depreciation*
- *Amortisation*

As a result of our research, IHS Jane's determined that these variables feed into two distinct categories; Basic cost calculations and Comprehensive cost calculations



Through assessment of various sources, IHS Jane's determined that the Basic CPFH was the more common value stated and that this was therefore regarded as a more accurate and useful indication of the cost of sortie generation for a particular aircraft. Though the cost of improvements and upgrades was considered and the capital charges, depreciation and amortisation taken into account, this was more usually considered as part of the platform's capital cost rather than the daily service cost of which the Basic CPFH was felt to be a more useful representation. Despite this, CPFH figures provided for use by parliamentary bodies have tended to include both the Comprehensive variables as well as those for the Basic support elements used during an operation. Figures provided for the UK Parliament

concerning EuroFighter Typhoon sorties during the Libyan campaign, for example, covered the full comprehensive cost of the aircraft including include forward and depth servicing, fuel costs, crew costs, training costs, cost of capital charge, depreciation and amortisation

In order to provide differing calculations of overall cost of aircraft, official government figures for some aircraft have been released that include the running costs of the airbase and ground equipment and personnel. The efforts among many Western countries to reduce government spending and the relatively high cost of the fighter aircraft studied has resulted in their development, procurement or continued usage being questioned. This has been noted in several discussions of the RAF EuroFighter costs, related to the ongoing debate about general defence spending and aircraft fleets in particular. It should be noted that the reporting of these costs has usually been tied to a political view on the cost versus utility of the aircraft; in the case of the UK, this has been tied to the Harrier fleet retirement decision and the relative merits of this option. The EuroFighter operators have, in general tended to release comprehensive flight cost data, though IHS Jane's has been unable to determine if this is of particular significance.

A similar debate has occurred over the projected costs of the F-35, with political discourse a contributory factor. This is reflected in the larger number of differing cost figures stated in open source documents and studies. Since the aircraft is not yet in service, forecast costs, including CPFH, are based on predicted annual flying hours and sorties types. This means that any cost data for the F-35 should be viewed with extreme caution.

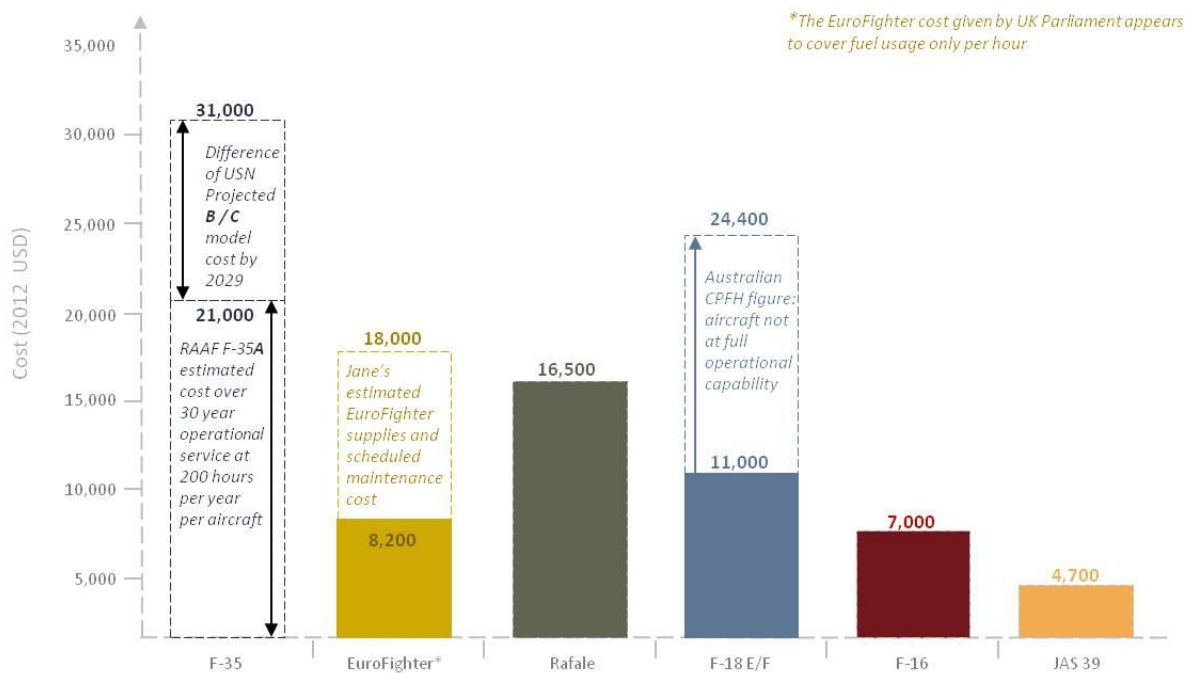
In order to provide a CPFH figure limited to the factors attributable to the individual aircraft rather than the complexity of the operation, weapons or support elements, IHS Jane's has used the Basic CPFH figure for all six aircraft under study.



F-18 E/ F (Source: IHS Jane's)

CORE FINDINGS

Based on assessment of a large number of primary and secondary sources, IHS Jane's has estimated the Basic CPFH of the six aircraft under study to be as follows:



The figures were estimated based on the following sources:

- *Military / Government figures (all aircraft)*
- *Disclosed international fighter competition cost figures (Rafale, F-18 E / F, Gripen)*
- *Manufacturer stated figures (F-35, Rafale, F-18 E / F, Gripen)*
- *IHS Jane's estimates (all aircraft)*

Despite inquiries, IHS Jane's was not able to determine an official complete Basic CPFH for the EuroFighter Typhoon. Though we were able to gain a fuel usage cost for the aircraft, we have used discussion with military figures to estimate the Consumable Supplies and Operating and Maintenance costs for this aircraft.

IHS Jane's attempted to determine the breakdown in the CPFH for aircraft through published documentation. However, none of the sources contacted by IHS Jane's were willing or able to provide such precise cost information and thus IHS Jane's has had to compromise with a roughly standard figure

Based on a US 2005 study of their F-16 fleet, CPFH were divided according to the following:

- *11% Consumable Supplies (small parts, wiring, basic electrical components)*
- *24% Sortie Aviation Fuel*
- *65% Depot Level Repair and Systems Maintenance*

The study also concluded that intangible constituent factors had a significant but inconstant affect on CPFH. The study noted that the following could be concluded across the entire F-16 fleet:

- *The average CPFH increased by 1.7% to 2.5% per extra aircraft age year*
- *CPFH variations were attributed to different base locations; for example hot climates increased CPFH*
- *While sortie rate was a key variable, there was no evidence that the average sortie duration influenced the CPFH*

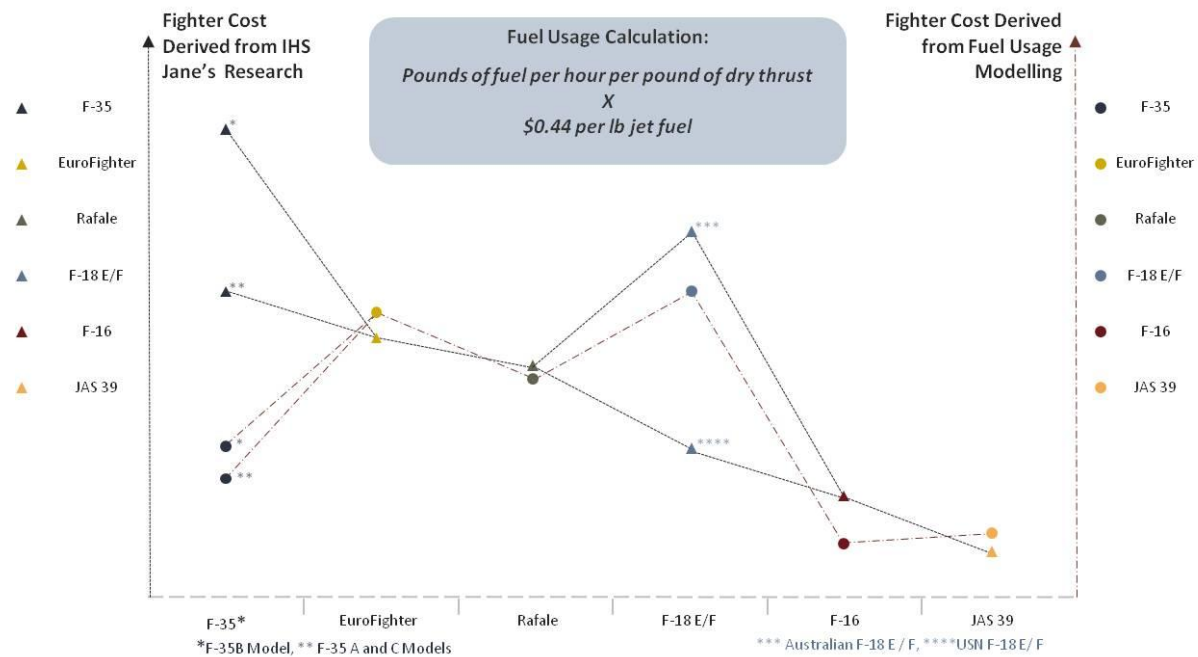
For the purposes of this study, IHS Jane's has not been able to take into account variations such as aircraft age, base location or sortie rate as such a breakdown of figures was not available. However, given that these non-constant aspects of fighter usage and deployment impact the CPFH, the figures collated by IHS Jane's are likely to be accurate only as an average and would therefore not apply as the fleet aged or its usage and basing location changed. Indeed, CPFH appears to vary within individual squadrons based on differing individual aircraft service and operational lives.

IHS Jane's has not looked specifically at the impact of aircraft navalisation on CPFH and the degree to which this will result in significantly differing costs for naval aircraft operating in a maritime environment. However, though it is impossible to forecast the exact change in CPFH that this would cause, anecdotal evidence suggests that this would rise owing to the more harmful environment and stressful elements of each sortie. This should be borne in mind when considering use of the F-35 B / C or F-18 E / F or Rafale from aircraft carriers



CPFH: COMPARATIVE DATA

Owing to the difficulty in determining a true CPFH figure, IHS Jane's attempted to provide a benchmark for comparison and relative assessment of the aircraft under study. As a standardisation model, IHS Jane's determined the aircrafts' fuel usage, hence cost, based on a theoretical one hour sortie at max dry thrust. Though such a continued use of a single power setting is unlikely over an entire sortie, it provides a standard baseline from which to calculate and hence an opportunity for comparative examination. **Note that IHS Jane's does not believe that the results provided by this model are necessarily reflective of actual fuel consumption and hence fuel cost of a one hour sortie**



*The different F-35 costs arise from the differing power and specific fuel consumptions of the A / C and B models. The B model is the top figure in both cases

Though the modelled fuel cost is not accurate in USD terms, Jane's believes the following observation can be made:

- The modelled cost follows a similar pattern to the CPFH data with twin - engine aircraft (EuroFighter, F-18 E/F and Rafale) giving higher values
- The F-35 has a powerful single engine (28,000 lbs dry thrust) , resulting in a modelled fuel cost equivalent to twin-engined designs
- Increased CPFH of twin engine aircraft is attributable to factors other than increased fuel usage (est. ~25%)

- *Generally larger aircraft carrying more systems and payload resulting in increased O&M and manpower requirements*
- *The modelled F-35 cost benefits from the fuel-efficiency of a single engine, though the sophistication of its on-board systems is the highest under study*
- *The low modelled-cost of the F-16 is indicative of its relatively low-thrust engine, which corresponds to a small, mature design with few highly sophisticated systems*

Though fuel model cost of most of the aircraft under study seem to form a similar pattern to the CPFH data collected by IHS Jane's, the F-35 and F-18 E / F seem to vary significantly. In the case of the F-18 E / F, IHS Jane's believes this is due to the size of the fleet and the experience the US Navy has in operating the Super Hornet and its previous incarnation (F-18 A to D variants) when compared to the small fleet of the Royal Australian Air Force (RAAF) that has yet to reach Full Operational Capability. RAAF CPFH has fallen significantly as familiarity with the aircraft has grown, and is likely to fall further as this continues to improve.

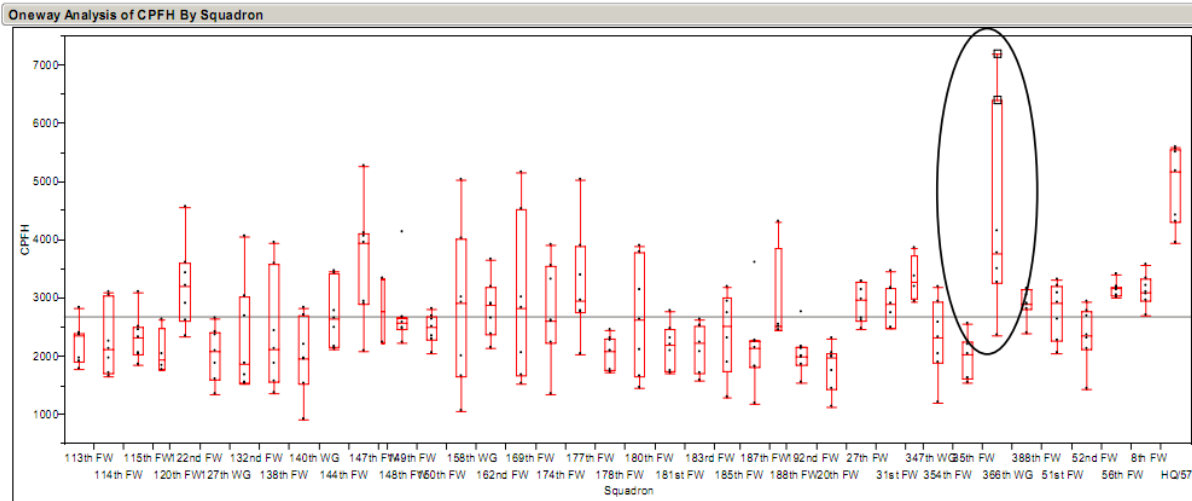
In addition, the F-18 E / F has relatively high dry thrust ratings while the GE F414 engine is less efficient in specific fuel consumption than the engines of the similar-sized Rafale and EuroFighter aircraft. Thus, while the US Navy sources report that the F-18 E / F has a relatively low CPFH, the engines use more fuel and are hence relatively costly when operating under similar conditions to the SNECMA or Eurojet power-plants of the similar European aircraft.

In the case of the F-35, the single P&W F-135 engine is relatively fuel efficient for its power, resulting in a lower fuel burn at maximum dry thrust than might be expected. However, the aircraft itself is an extremely sophisticated design carrying a large number of new and unproven onboard systems. Though accurate CPFH for in-service aircraft does not, of course, exist, the US and Australian forecast costs both suggest it will not offer lower CPFH than current aircraft.

Despite the disparities in the F-18 E / F and F-35 fuel model versus reported CPFH, IHS Jane's believes that the link between aircraft size and weight / onboard systems and engine power means that modelled cost remain a valid if rough means of comparing likely CPFH between aircraft types. Crucially, where the two values differ sharply this approach encourages further assessment in order to understand why the two costs are in variance and whether this indicates an inaccuracy in the CPFH calculation.

AIRCRAFT CPFH VARIANCE

As part of our research in to CPFH calculation, IHS Jane’s used a 2005 US study of this calculation across its F-16 fleet. This clearly illustrated the large variation of CPFH for F-16 aircraft within the same squadrons as well as the USAF’s entire F-16 fleet.



The study concluded that the most significant influences on the CPFH – and hence reason behind the variation in CPFH for a common aircraft – was the *aircraft sortie rate per day*, the *average sortie flight profile* and the *location of the unit’s home base*. While it is not possible to determine the exact weight or mixture of these factors, IHS Jane’s determined the following likely impact of these intangible factors on aircraft CPFH:

	Fuel Costs	Consumables Cost	Maintenance Cost
Flight Profile	<ul style="list-style-type: none"> Mission type and engine usage will have a significant effect on fuel usage and hence CPFH Engine efficiency may be impacted 	<ul style="list-style-type: none"> Aggressive manoeuvring, low altitude flight and heavy payloads all inflict higher stress on systems and structure Will result in higher consumables cost 	<ul style="list-style-type: none"> Stressful flight profiles will likely result in more intensive maintenance to guarantee serviceability Will result in higher maintenance cost
Onboard Systems	<ul style="list-style-type: none"> More sophisticated systems carriage will have limited direct impact on fuel usage and hence cost Higher weight will increase fuel usage 	<ul style="list-style-type: none"> More sophisticated systems likely to result in greater consumption of consumables per flight hour Higher consumables cost likely 	<ul style="list-style-type: none"> Systems maintenance remains a significant proportion of overall maintenance cost Carriage of multiple, sophisticated systems will hence increase maintenance cost per hour
Aircraft Age	<ul style="list-style-type: none"> Older airframes may exhibit greater drag while newer carry more systems Combined with reduced engine efficiency, likely to increase fuel cost 	<ul style="list-style-type: none"> Likely to require more consumables due to older average age of parts Degree of additional cost likely to be aircraft and air force dependent 	<ul style="list-style-type: none"> Might prove higher and hence higher cost with older airframes Less sophisticated systems on older aircraft may conversely reduce maintenance cost
Unit Location	<ul style="list-style-type: none"> High altitude operations likely to see greater fuel usage Restriction on mission profile may also impact engine and hence fuel 	<ul style="list-style-type: none"> Hard environments likely to result in greater wear on exposed surfaces and environmental systems Some cost increase likely 	<ul style="list-style-type: none"> Should not significantly impact maintenance costs though some cost rise likely Prolonged operations in difficult environments may result in cumulative cost increases
Sortie Rate	<ul style="list-style-type: none"> High sortie rate will increase number of high-fuel-usage periods of operation, such as takeoff and climb Fuel cost there for likely to be higher 	<ul style="list-style-type: none"> Wear on parts likely to be higher, with resulting higher cost of consumables Wearing of some parts may have effect on connected elements 	<ul style="list-style-type: none"> Heavy system usage likely to drive maintenance costs upwards High pace of operations may result in force prioritisation of some systems, leading to uneven maintenance and higher wear

IHS Jane’s believes that the relative impact of each of these factors will be specific to an individual aircraft and it is therefore not possible to feed these into our fuel model calculation.

CONCLUSIONS

Though IHS Jane's continues to stress the limited utility of a general CPFH figure for a given aircraft type, this study suggests that the Saab Gripen and Lockheed Martin F-16 offer an extremely competitive CPFH when compared to larger and more complicated contemporary fighter aircraft. In part this is due to the greater sophistication and capability that the larger aircraft were designed to offer. Though the USAF F-16 study shows the significant variation in CPFH among aircraft of the same type, IHS Jane's believes that the smaller Gripen and F-16s will, on average, offer a lower CPFH than the F-18 E / F, EuroFighter and Rafale. Military forecasts suggest they will also offer a lower CPFH than all F-35 variants.

Given the impact of intangibles factors, particular sortie rate, sortie type and basing location, a CPFH that is true for a given aircraft in a domestic location is likely to be significantly different than the CPFH for the same aircraft on overseas operations. Indeed, given the likelihood of a combat deployment significantly increasing the CPFH of a fighter aircraft, the lower this figure under benign operating conditions the fewer difficulties are likely to be experienced in an operational environment. While a USD figure for CPFH is useful shorthand, it represents in reality time, energy and materials that may be in short supply in austere locations or during periods of downward budgetary pressure. Under such conditions, the ability to generate the requisite number of sorties for as fighter aircraft may prove extremely challenging.

A key lesson of aerial warfare has been that the performance of the aircraft is only one factor in success; the capabilities of the air and ground crews married to the weapons carried are of equal importance. Though this study has not sought to evaluate the benefits of a more sophisticated, more expensive aircraft over a lower sophistication, lower cost platform, the high-tempo operations of many militaries over the last decade have resulted in extremely high operating and sustainment cost for equipment. In the case of fighter aircraft, these operations have often been undertaken in a relatively low-threat environment in which the full capabilities of the aircraft have not been used. Though militaries are disinclined to procure equipment that does not offer the full range of possible capabilities to answer every operational need, the marginal difference in performance between the aircraft at the high- and low-end of the CPFH range in this study is limited. This is particular true when considering the types of operations their users have undertaken over the past decade, with an emphasis on ISTAR and precision strike.

IHS Jane's therefore believes that the low CPFH offer of the Gripen and F-16 will remain an extremely competitive part of these platforms' portfolio despite the availability of types that offer higher performance in some if not all areas. The high cost of sustaining fighter aircraft through a campaign compared to the relatively low CPFH – yet competitive capabilities – of a Gripen or F-16 in the face of most threats are a significant mark in favour of these smaller yet capable aircraft.