# Strike Fighters

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# Aircraft

This study will investigate the classic "Teen-Series" of fighters as well as the aircraft that have or will replace them. The following aircraft will be investigated in depth. Air aircrafts performance data will come from the source listed below. Most aircraft will be evaluated at a 2020 standard with the following exceptions; the F-14D will be at a 2004 standard just before retirement of the Phoenix.

F-15C Eagle – data taken directly from F-15C -1 using F100-PW-220 data, A-A only
F-15E "Mudhen" – data taken directly from F-15E -1 using F100-PW-229 data, A-G only
F-22A Raptor – data estimated from stated performance and engineering analysis

F-16C "Viper"– data taken directly from HAF -1 using F110-GE-129 data
A-10C "Hog"– Data taken directly from A-10A -1, A-G only
F-35A "Stubby" – data estimated from stated performance and engineering analysis

AV-8B Harrier– data derived from partial NATOPS and engineering analysis
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## Size

Strike and fighter aircraft come in a wide variety of sizes. As with any engineering endeavor there are tradeoffs to be made in deciding how large of a fighter aircraft to design and it is largely based on the primary role of the aircraft. If one lists the pros and cons of large aircraft size the following is seen.

| **Pros:** | **Cons:** |
|---|---|
| more fuel | higher fuel burn |
| more weapons | greater basing restrictions |
| more room for systems | reduced agility |

Aircraft size can be measures many ways such as length (from 72.8ft for the Su-35S to 46.3ft for the AV-8B), span (from 64ft for the F-14D to 30.3ft for the AV-8B), wing area (from 667ft$^2$ for the Su-35S to 243ft$^2$ for the AV-8B), or empty weight (from 43,735lb for the F-14D to 13,968lb for the AV-8B). For our purposes we will use box volume (length times span times height) and density (empty weight divided by box volume). A larger box volume will indicate greater size for the pro-con list above and a greater density will indicate how tightly packaged everything is. All figures listed will be relative to the smallest/least dense aircraft.

| **Box Volume:** | **Density** |
|---|---|
| AV-8B – 1 | A-10C - 1 |
| F-35A/B – 1.53 | F-15C – 1.05 |
| F-16C – 1.58 | F-14D unswept – 1.23 |
| F/A-18C – 1.86 | F/A-18E – 1.35 |
| F-35C – 1.89 | F/A-18C – 1.36 |
| F-14D swept – 2.33 | F-15E – 1.38 |
| F/A-18E – 2.62 | F-16C – 1.42 |
| A-10C – 2.75 | AV-8B – 1.54 |
| F-22A – 2.81 | F-22A – 1.70 |
| F-15C/E – 3.08 | F-35C – 2.03 |
| F-14D unswept – 3.92 | F-14D swept – 2.07 |
| | F-35A – 2.09 |
| | F-35B – 2.32 |

From this we can see a few interesting date points. The Eagles are extremely large, second only to the Tomcat, but very light. The F-35 family is extremely dense as it has many things internally that most aircraft have externally.

# Load

The public often only sees fighter aircraft at airshows flying with clean wings for maximum performance. A warplane is no good without a warload however so we will look at the fuel load, systems, and both the air-to-air loadings and air-to-ground loading potentials of each aircraft. Loads are carried on one of five types of stations; light (L), heavy (H), heavy/wet (H-W), wet (W), TGP. Light stations typically carry only air to air missiles however Russian ECM systems typically go on the wingtip light stations and the Hornet series carries TGP on them. Heavy stations are typically rated to carry bombs, missiles (both air-to-air and air-to-surface), TGP, or ECM pods. Heavy/Wet stations gain the ability to carry external fuel tanks but often lose the ability to carry air-to-air missiles. Wet stations are dedicated to drop tanks only and are only found on the Tomcat. TGP stations are used exclusively to carry additional targeting and navigation equipment. These dedicated stations are only found on the F-16C and the F-15E.

## *Fuel*

Fuel is carried both internally and externally for most fighters. External fuel is carried in drop tanks mounted to either a "heavy/wet" station or a dedicated "wet" station. The trade-off of external fuel tanks is that while they are being carried they add significantly to drag and while they can be dropped they are not very cheap. Below we will look at each aircrafts internal, external, and total fuel loads as well as the number of external stations used for carrying said external fuel load. The aircraft will be sorted based on total fuel weight

| **Aircraft** | **Internal** | **External** | **Total** | **"H-W"** | **"W"** |
|---|---|---|---|---|---|
| AV-8B | 7,500 | 4,080 | 11,580 | 2 | 0 |
| F-35B | 13,326 | 0 | 13,326 | 0 | 0 |
| F-16C | 7,162 | 7,072 | 14,234 | 3 | 0 |
| F/A-18C | 10,810 | 4,480 | 17,530 | 3 | 0 |
| F-35A | 18,498 | 0 | 18,498 | 0 | 0 |
| F-35C | 19,624 | 0 | 19,624 | 0 | 0 |
| F-14D | 16,200 | 3,630 | 19,830 | 0 | 2 |
| A-10C | 11,000 | 12,240 | 23,240 | 3 | 0 |
| F/A-18E | 14,400 | 9,792 | 24,192 | 3 | 0 |
| F-15C | 13,850 | 12,261 | 26,111 | 3 | 0 |
| F-22A | 18,000 | 16,320 | 34,320 | 4 | 0 |
| F-15E | 22,300 | 12,240 | 34,540 | 3 | 0 |

Here we see that the F-35 family chose to forgo external tanks for combat loadings altogether while the F-15C, F-16C, and F-22A roughly double their fuel loads with them. The F-22A, however, only uses four external tanks for ferry missions. The F-15C and F-22A are essentially dedicated air-to-air platforms in practice so they do not sacrifice load carrying capability with fuel tanks while the F-14 uses dedicated fuel stations and the A-10 has stations to spare (11 in theory) however the fuel tanks for the A-10 are not rated for combat according to a former pilot.

## *Systems*

One of the most common systems associated with tactical aircraft is the radar. Radar uses, in a most simplified form, radio waves transmitted through an antenna in the nose and then received through the same antenna. Radar has evolved greatly over the ages and continues to evolve. Early fire-control radars need to "lock" a target in order to get accurate enough azimuth, elevation, range, heading, and velocity data to guide a missile. If the enemy aircraft was equipped with a Radar Warning Receiver (RWR) then the RWR was able to distinguish this difference in pulse pattern and could warn the pilot that he was being engaged. Once RWRs became common a new way of surprising your enemy was needed. This lead to Track-While-Scan (TWS) technology in which the radar transmitted a normal sweeping scan while noting the delta of a targets location on each pass and using that information to derive all the needed data for a weapons lock.

A more recent advancement is that of the Active Electronically Scanned Array (EASA) radar with Low Probability of Intercept (LPI) in which the radar does not have a single large transmitter but hundreds of individual Transmit-Receive (TR) modules. These TR modules allow a radar to have as big or small of an antenna as needed for a given task by working in groups. Each group can transmit in unique directions and on separate frequencies. They also will change the frequency transmitted, and power of the transmission, a thousand times a second. By doing this the AESA radar can mask it's transmissions as noise and can likely only be detected by a system of equivalent sophistication. This is supported by numerous statements made about "teen-series" aircraft engaging in BVR training with F-22s (the first LPI AESA equipped fighter) in which none of their systems, radar or RWR, ever detected the F-22. For Very Low Observable (VLO) aircraft this is an important ability as it minimizes the chances of an enemy knowing even the direction from which the VLO aircraft are attacking. Some AESA radars take the next step and have Electronic Attack (EA), active jamming, built in to the radar system. The following will list the specified aircrafts radar systems and what special modes they use.

| **Aircraft** | **Radar** | **LPI** | **EA** | **1m2 detection range** |
|---|---|---|---|---|
| F-15C | AN/APG-63(V)3 | Yes | No | 112 |
| F-15E | AN/APG-82(V)1 | Yes | No | 112 |
| F-16C | AN/APG-68 | No | No | 58 |
| A-10C | none | - | - | - |
| AV-8B | AN/APG-65 | No | No | 40 |
| F-14D | AN/APG-71 | No | No | 72 |
| F/A-18C | AN/APG-73 | No | No | 40 |
| F/A-18E | AN/APG-79 | Yes | No | 80 |
| F-22A | AN/APG-77 | Yes | Yes | 150 |
| F-35A/B/C | AN/APG-81 | Yes | Yes | 90 |

Other common systems carried by strike fighters are ECM for protection from enemy aircraft and ground threats as well as EO/IR systems for air-to-air and/or air-to-surface targeting work. Before the “Fifth Generation” aircraft these systems were very large and were often carried externally in self-contained pods. The below list gives the systems used by the selected aircraft and, if externally carried, what type of station is used to carry it in parentheses.

| **Aircraft** | **ECM** | **EO/IR** |
|---|---|---|
| F-15C | AN/ALQ-135 | None |
| F-15E | AN/ALQ-135 | LANTIRN/Sniper XR/LITENING (TGP) |
| F-16C | AN/ALQ-131 (H-W) | LANTIRN/Sniper XR/LITENING (TGP) |
| A-10C | AN/ALQ-131 (H) | LITENING (H) |
| AV-8B | AN/ALQ-131 (H-W) | LITENING (H-W) |
| F-14D | AN/ALQ-165 | AN/AAS-42 |
| F/A-18C | AN/ALQ-131 (H-W) | LANTIRN/Nighthawk/ATFLIR (L) |
| F/A-18E | AN/ALE-214 | LANTIRN/Nighthawk/ATFLIR (L) |
| F-22A | none listed | none |
| F-35A/B/C | AN/ASQ-239 | EOTS and EODAS |

## *Weapons*

All the above items are to enable the aircraft to deploy their weapons effectively. Weapons will fall into two major categories: Air to Air and Air to Ground.

Air to Air weapons again fall into the categories of missiles and cannon. Missiles are typically judged by their speed, range, and turning ability. However, all three of these parameters will vary greatly based on many factors. For now we will just discuss the missiles employed by these aircraft.

## Missile

### AIM-9X

The current standard of short range missile is the AIM-9X which has become, arguably, one of the best InfraRed missiles in the world. With an Imaging InfraRed seeker it is very resistant to traditional flares and it possesses a high off-boresight (HOBS) capability to lock a target up to 90 degrees off its nose and a Thrust-Vectoring Control (TVC) system for rapid orientation right off the rail. It has smaller fins than previous versions of the Sidewinder giving it greatly improved rated range of 19nm. The AIM-9M carried by the Tomcat only had a rated range of 14nm, a 45 degree field of regard, and no TVC.

### AIM-7M

The Sparrow missile is no longer in service due to the prevalence of the AIM-120. It will be used on the F-14D only as the Tomcat was never operationally cleared for the AMRAAM. In Viet ‘Nam the AIM-7 proved an agile missile in a dogfight once its control laws were altered. With a warhead four times that of the Sidewinder its lethal blast radius was twice as large. The M model has a rated range of 38nm.

## AIM-54C

The Phoenix missile was only carried by the F-14 and was retired before the Tomcat was itself. It will be used for the F-14D only as the Tomcat was never operationally cleared for the AMRAAM. While the AIM-54 is a heavy missile and not agile enough for most anti fighter work it carries a warhead over six times as large as the Sidewinder for a lethal blast radius nearly two and a half times larger. The AIM-54C had a rated range of 100nm.

## AIM-120D

The AIM-120D is the latest version of the AMRAAM line which combined advanced datalinking, optimized trajectory and guidance, and improved HOBS while maintaining a small package in both weight and diameter. A warhead only 81% larger than the Sidewinder gives a lethal blast radius increase of 34.5%. The AIM-120D has a rated range of 97nm, nearly equaling the much larger Phoenix.

# Cannon

## M61A1

The six-barreled Vulcan cannon was designed in 1946 and was first used on the F-104 and has been used on nearly every US fighter aircraft up to the F-22. At 248 pounds and nearly 72 inches in length it is a rather compact weapon system. It fires a 20x102mm cartridge at a rate of 6,000 rounds per minute and a velocity of 3,450 feet per second (fps). The projectiles weigh 102.4g with a 10g bursting charge. This gives a Weight of Fire (WoF) of 10.24kg/s raw and 1kg/s burst.

## M61A2

The six-barreled Vulcan cannon was lightened for the F-22. This model weighs 202 pounds and is also 72 inches in length. It fires a 20x102mm cartridge at a rate of 6,600 rounds per minute and a velocity of 3,450 feet per second (fps). The projectiles weigh 102.4g with a 10g bursting charge. This gives a Weight of Fire (WoF) of 11.22kg/s raw and 1.1kg/s burst.

## GAU-8

The seven-barreled Avenger was built for destroying tanks and armored vehicles in the Cold War and was the starting point of the A-10 design. The gun is 620lb and over 112in long, but the system is almost 20ft long and weighs 5,000lbs fully armed. It fires a 30x173mm cartridge at a rate of 3,900 rounds per minute and a velocity of roughly 3,500fps. The projectiles weigh 367g for HEI. While the heavier API round is the most famous, the use of Depleted Uranium is now highly frowned upon. If we assume a similar percentage of charge weight between the HEI for the Avenger and the round used in the Vulcan this gives a WoF of 23.86kg/s raw and 2.33kg/s burst for HEI.

## GAU-12

The five-barreled Equalizer is based on the much larger Avenger cannon that has been scaled down for use on the AV-8B.  The system is 270lb and over 83in long, but the external case gives a total weight of 1,230lb.  It fires a 25x137mm cartridge at a rate of 3,600 rounds per minute and a velocity of roughly 3,350fps.  The projectiles weigh 184g for HEI and 215g for API.  If we assume a similar percentage of charge weight between the HEI for the Equalizer and the round used in the Vulcan this gives a WoF of 11.04kg/s raw and 1.08kg/s burst.

## GAU-22

The GAU-22 is a version of the Equalizer that uses four barrels instead of five for use in the F-35.  The internal system weighs 416lb while the external system weighs 735lb.  The rate of fire is slightly reduced to 3,300 rounds per minute.  While the GAU-8 and GAU-12 had two distinct types of ammunition the GAU-22 uses a combined APEX projectile.  The 223g projectile with a similar burst charge percentage as the Vulcan ammunition would give a 21.8g burst charge.  This would give a WoF of 12.27kg/s raw and 1.2kg/s burst.

# Physical Factors

There are many factors that determine the performance of a combat aircraft. The most commonly used metrics are Wing Loading (W/S) and Thrust to Weight (T/W). These two parameters are often used by those who do not grasp the complexities of aircraft performance and below we will look at why these can be very misleading.

Wing Loading is a measure of aircraft weight per unit area of wing and is often used to compare instantaneous turn capability. This value can be very misleading as different wing planforms allow for different maximum lift coefficients ($C_{Lmax}$), lift curve slopes, load limits, and only takes into account the reference wing area. While many people recognize that the bodies of many fighter aircraft generate a sizable portion of lift they often fail to recognize that a sizable portion of the reference area is also "inside" the body of the aircraft. A prime example of this is the F-15, one of which famously lost almost an entire wing and flew home "on body lift." While essentially the entire right wing was missing, that only accounts for roughly 25% of the "wing area." The pilot was also using left roll input that generated positive lift on the right side with the horizontal tails. While a single horizontal tail only equals 8% of the "wing area" it can be deflected to a greater degree relative to the local airflow (given the medium speed and low maneuver environment of the remainder of the flight) to allow it to make up the lost lift. Tail area is not accounted for in the "wing area" and its effects vary with stability. We will look at this shortly.

Thrust to Weight is a measure of the combined engines uninstalled sea-level static thrust divided by the weight and is often used to compare straight line speed, acceleration, climb, and sustained turn capability. The first problem is that no aircraft ever operated with uninstalled engines and are almost never at zero airspeed at sea level. Installing an engine in the aircraft reduces thrust available in two ways. The intake reduces the airflow through surface friction and flow distortion. Think of breathing in through a curved straw compared to without. The equipment gearbox allows the turbine section of the engine to power all the systems onboard an aircraft. To help visualize this reduction in power think of pedaling a bicycle with the back tire off the ground. The tire can easily be spun up to almost any speed with a hand. Once the tire presses onto the road however work is being done by the system and the energy required to rotate the tire at a given rate increases. The summation of these effects on sea-level static thrust is typically about 25% of the military thrust rating based on data of installed thrust ratings for various aircraft. Thrust will then change drastically with speed and altitude increase, generally increasing with speed to the inlet/airflow limit and decreasing with altitude as density drops. Lastly, all the above performance parameters are dependent on excess thrust, or thrust remaining after drag has been subtracted.

## *Stability*

Stability is the tendency of an aircraft's nose to pitch down under normal flight conditions. The cause of this is the center of mass of the aircraft being in front of the center of lift. Think of a paper airplane on a string with the string representing the lifting force. If the string is behind the center of mass the nose will point down.  This has traditionally been countered using negative lift on the tails, a string on the back pulling the tail down and the nose up.

This has two negative effects.  The first is that the lifting surfaces, the “main string” if you will, now have to pull that much harder to balance the total force.  This means that at any given time a stable aircraft is using less than 100% of the lift being generated by the wing/body to maintain flight or turn.  The second is that there is now an increase in the induced drag.  There is induced drag on the tail and an increase in induced drag on the wing/body.  This is called “trim drag.”

These effects were mitigated by trying to minimize the stability margin.  Starting with the F-16 there was a new option.  Fly-by-Wire (FBW) controls allowed for an unstable aircraft’s disturbances to be monitored and corrected dozens to hundreds of times a second.  In an unstable “paper aircraft” the nose points up when hanging from the string.  A second string is then added to the tail to lift that up as well.  This reverses the drawbacks mentioned in the previous paragraph.  The aircraft not only gets all of the lift generated by the wing/body, but also that of the tail.  As a result of this level flight is maintained with a lower $C_L$.  This reduces the induced drag by a second order.

We will now analyze stability estimates of our aircraft.  Estimated were determined by looking at the Idle Descent charts and measuring L/D to determine total drag and thus find the induced drag which gives us the absolute value of the total $C_L$ and comparing that to the $C_L$ required to maintain flight, in effect measuring the trim drag.  When that was not available the author used experimental values to find the point at which the benchmark specifications were met.  It is important to note that stability changes with fuel burn and weapon load, it is not static.  This is most notable in the F/A-18E which has a 15% range which goes from the neutral end of stable to unstable.  In contrast the F-15E only has a range of around 4%.  Stability listed is the percentage of the main wing/body lift that the tail is producing as downforce.

| **Aircraft** | **Stability** |
|---|---|
| F-15C | 4.7% |
| F-15E | 3.3% |
| F-16C | -11.0% |
| A-10C | 10.6% |
| AV-8B | 12.0% |
| F-14D | 5.7-7.8% |
| F/A-18C | 3.0% |
| F/A-18E | 2.0% |
| F-22A | -10.0% |
| F-35A/B/C | -8.0% |

## *Drag Area*

So just as we have seen how stability can have positive or negative impacts on aircraft performance we shall now also look at airframe drag. Drag always has a negative impact. The primary factors for drag are the raw surface area and shaping. More surface gives more skin friction but this is mitigated on aircraft designed for large degrees of radar stealth as the required surface tolerances result in a dramatically smoother surface. Shaping based drag can be intersections between surfaces or antennae sticking up from the surface and even the angle at which a surface meets the airflow. Again, airframe drag is found using the Idle Descent charts where available, elsewise found with wind tunnel data or experimentally matching the benchmark specifications. Drag Area will be the Zero-Lift Drag Coefficient multiplied by the reference wing area and represents the flat plate area in square feet of the clean aircraft.

| **Aircraft** | **Drag Area** |
|---|---|
| F-15C | 11.55 |
| F-15E | 14.08 |
| F-22A | 12.60 |
| F-16C | 8.92 |
| A-10C | 19.73 |
| F-35A | 9.75 |
| AV-8B | 7.45 |
| F-35B | 10.03 |
| F-14D | 13.73 |
| F/A-18E | 12.13 |
| F/A-18C | 9.76 |
| F-35C | 12.40 |

## *Lift Area*

Just as there is a Drag Area there is also a maximum Lift Area representing the total $C_{Lmax}$ of the aircraft multiplied by the reference wing area. Lift Areas are calculated either using stall speeds from flight manuals, where available, and otherwise are found using either a CFT analysis or a formula to approximate the lift curve slope based on wing thickness, aspect ratio, taper ratio, sweep, stability, and high lift devices. The formula was first tested against known aircraft for validation. The F-16 is the anomaly here in that it reduces its max angle of attack as speed increases and as such it's maximum value of $C_{Lmax}$ changes. This study shows the difference of the values for 25 degrees (1G max AoA) and 15 degrees (9G max AoA) angle of attack. All stability corrections are already made at this point and this number would be a better reference than traditional wing loading to examine turning ability below corner velocity. At the lowest speeds of course there are controllability issues but that is outside the scope of this review. Weight for wing loading will be clean plus a 20% fuel fraction, where 20% of the total aircraft weight is fuel not a 20% full fuel tank, as a reference only

| Aircraft | Wing Area | Wing Loading | Lift Area | Lift Loading |
|---|---|---|---|---|
| F-15C | 608 | 60.6 | 997 | 37.0 |
| F-15E | 608 | 76.1 | 997 | 46.4 |
| F-22A | 840 | 64.5 | 1680 | 32.2 |
| F-16C | 300 | 84.2 | 330-501 | 80.2-50.4 |
| A-10C | 506 | 69.2 | 810 | 43.2 |
| F-35A | 460 | 79.1 | 851 | 42.7 |
| AV-8B | 230 | 73.1 | 345 | 48.7 |
| F-35B | 460 | 87.8 | 851 | 47.4 |
| F-14D | 565 | 96.8 | 1288 | 42.4 |
| F/A-18E | 500 | 78.8 | 975 | 40.4 |
| F/A-18C | 400 | 76.6 | 668 | 45.8 |
| F-35C | 620 | 70.2 | 1147 | 37.9 |

Note: $C_{Lmax}$ values for F-35 series taken as 1.85 despite data implying values of 1.91 and 2.1 for the A/B and C respectively based on calculations of lift enhancing effects. A value of 2.0 was used for the F-22A based on an analysis of the Low Speed Pass procedure and the amount of thrust available under said circumstance.

# Mission Performance


All of the previous reviews and data only serve to get help one understand some of the factors that impact mission performance. Several different mission types will be reviewed and they will be reviewed in stages of flight for the mission. “Red” air will be assumed to be flying from Komsomolsk-na-Amur Khurba (ICAO UHKK) and “Blue” land forces will be assumed to be flying from Misawa Air Base (ICAO RJSM) while “Blue” sea based forces will be assumed to be at an identical distance from UHKK but in the ocean to the east of RJSM.

## *Interception*

The basis of this mission is that the early warning radar systems have detected four fighter-class aircraft inbound to Misawa. Spy photography showed Su-34s being loaded with Kh-59MK(2) missiles that have a 150nm range. Last radar contact showed the aircraft 300nm out, two of them descending. Aircraft are launched in pairs to intercept.

The scenario includes two SU-34 Fullbacks at 1,000ft and 0.85M. Once 150nm from Misawa they will launch the Kh-59MK2s and perform a military power egress from the launch position. The Fullbacks will be armed with (2) KH-59MK2, (2) R-73, (2) R-77-1, and will have Khibiny jamming pods. Two Su-35S Flankers are providing escort. Roughly 100nm before the launch point they will accelerate to 1.6M and climb to 50,000ft where they will be ready to launch a maximum range missile shot. The Flankers will be armed with (2) R-73, (2) R-27ET, (2) R-77-1 and will have Khibiny jamming pods.

Each interceptor will have missiles for four BVR shots and will have at least two missiles in reserve for a potential shot against the missiles. The Su-34 and Su-35S will have an assumed RCS of $3m^2$, and the Kh-59 will have an assumed RCS of $0.1m^2$. It will be assumed that radar missiles fired against the Su-34 and Su-35S will be fired two per target, one from each interceptor, to account for maneuvers and countermeasures while infrared missiles will be fired one per target given the higher combat reliability. Missile shots against the Kh-59 will be one per. Gun shots, if needed, will be assumed to need a one-second burst to down the target from a close range.

The flight profile being used by the interceptors is a maximum power take off followed by acceleration to maximum thrust climb profile speed. The maximum thrust climb profile will be followed until the aircraft reaches an altitude at which it can accelerate to its maximum physical speed. The interceptor will then accelerate to the highest speed at which it can attain a maximum altitude as altitude is more beneficial to missile launch than speed alone. If the max subsonic altitude is higher than the max supersonic altitude then the supersonic altitude will be chosen for additional energy. After the combat phase they will perform a military power climb to their optimum cruise altitude as needed and perform an idle maximum range descent back to base/ship with a 13.5% internal fuel reserve unless another load is explicitly given in the manuals. 13.5% was chosen as in several manuals where reserve fuel is specified it averages to be 13.5% of the internal fuel capacity. Any External Fuel Tanks (EFT) will be jettisoned as soon as they are empty.

The simplified metrics that would often be used to determine Intercept performance would be T/W and fuel fraction, the percentage of total weight that is made of fuel. This study will also look at Drag Area, which will impact top speed.

A missile guidance simulator was created to see the effects of avoidance maneuvers on a missiles end state energy. A higher launch speed and/or altitude allow the missile to carry more energy into the top of its flight profile. This serves to greatly extend the range of the missile.

Each fighter will be given a total score on the mission performance based on the outcome as follows:

+25 per aircraft destroyed

+1 point per mile away from launch point the bombers are stopped

-1 point per mile of flight for the Kh-59MK2s

-1 per ton of fuel burned by each interceptor

-1 per AAM fired by both sides

-25 per interceptor destroyed

With two bombers and two fighters as targets this nets a theoretical maximum of 100 points without range based modifiers. Per the above described firing doctrine this means a realistic limit of 80 points without range based modifiers. Destroying the bombers before the launch point will net additional points to help offset the missile and fuel point losses.

F-15C

## Timeline Narrative

T: 0.0min Early warning radars tracking four targets indicate that two have dropped in altitude while the remaining pair continues inbound at 39,000 feet and 0.89M. A pair of F-15Cs on ready alert start their engines.

T: 5.0min The F-15s lift off to intercept the targets.

T: 6.0min The two Su-35s light their afterburners and descend to 36,000 feet while accelerating. The TEWS begins to pick up the Irbis-E transmissions and initiates jamming.

T: 7.3min The two Su-35s hit 1.6M at 36,000 feet and begin to climb at 1.6M.

T: 7.8min The F-15s drop their external fuel tanks as they top off their initial climb to 36,000 feet where they level off to accelerate.

T: 9.4min The F-15s have accelerated to 1.6M and begin climbing.

T: 9.8min The F-15s detect the Su-35s 147nm away climbing at 1.6M. The LPI AESA characteristics of the APG-63(v3) are too subtle for the Khibiny to detect or jam. The pilots get an immediate, near Rmax, launch indication for the AIM-120D and each pilot fires one missile at each Flanker. The Irbis-E overcomes the TEWS and begins tracking the F-15s.

T: 11.2min The APG-62(v)3 detects the Su-34 Fullbacks 132nm away at an altitude of 1,000 feet and 0.85M.

T: 11.5min The Russian pilots lock on to the F-15 pair and each fire an R-77 at each Eagle. They immediately begin pulling back the throttle to Military power.

T: 11.6min The F-15s finish their climb to 46,000 feet. Each Eagle pilot fires an AIM-120D at the Fullbacks from a range of 120nm. Seeing the speed of the Flankers start to drop rapidly the Eagle pilots also realize their first shots there are going to fall short so they fire another round at the Flankers as well. They pull back the throttle to Military power and begin to decelerate. The TEWS picks up radar transmission from the Fullbacks and begins jamming them. The Flanker pilots see the deceleration of the Eagles and know their R-77 shots are going to fail.

T: 12.5min The first volley of AIM-120Ds fired almost three minutes prior begins to fall out of the sky several miles short of the decelerating targets.

T: 13.1min The Flankers have decelerated to 0.9M. At 60nm from the Eagles the pilots have a launch indication for the R-27ET due to the altitude and they fire. The RWR indicates a missile radar is now tracking them and they try to begin evasive maneuvers. The

Khibiny system begins deceptive jamming against the missile however the datalink on the AIM-120D is still being fed target information from the APG-63(v)3 which the Khibiny cannot jam. Within seconds of the RWR alert the Su-35s are destroyed as each plane is targeted by two missiles being guided by two planes that were well under Rmax when the shots were taken.

T: 14.2min The RWR on the Fullback indicates a missile radar is now tracking them. Much like on the Su-35, the Khibiny cannot overcome the missile/radar combination and the Su-34s are destroyed 174nm out from Misawa. Around this time the R-77s fired fall out of the sky.

T: 14.5min The F-15s turn around and return to base on an idle descent due to their altitude.

T: 16.0min The R-27ETs fall out of the sky.

T: 34.7min The F-15s begin their landing pattern on return to Misawa with 8,000 pounds of fuel remaining, having burned almost 10,000 pounds during the mission.

| | | |
|---|---|---|
| Targets Hit: | 4 | +100pts |
| Distance modifier: | 24nm | +24pts |
| Missiles fired: | 20 | –20pts |
| Fuel Burned: | 5t | –5pts |
| Interceptors lost: | 0 | –0pts |
| Total Score: | | 99pts |

## Statistics and Performance

As we can see from the figures and charts below, the physical performance of the F-15C leaves little to be desired. It can rapidly gain energy when needed and has great high altitude turn ability. The upgrade to state of the art weapon systems and avionics has ensured that it remains a capable aircraft. The TEWS is expected to be replaced with EPAWS in the 2020s to further enhance ECM capabilities. Even at take-off the F-15C has great textbook metric values. At also carries a large air-to-air load which is to be expected of an Air Superiority aircraft.

| Aircraft | # of EFT | # of AIM-120D | # of AIM-9X | Sec of cannon fire |
|---|---|---|---|---|
| F-15C | 1 | 6 | 2 | 9.4 |

**Figure 1 - F-15C Payload**

| Aircraft | T/W | Fuel Fraction | Drag Area | Wing Loading | Lift Loading |
|---|---|---|---|---|---|
| F-15C | 0.93 | 0.35 | 13.97 | 84.4 | 68.1 |

**Figure 2 - F-15C Takeoff Physical Characteristics**

The F-15s never get closer than 50nm to the Su-35s and as a result their respective WVR performance does not come into play. We will look at the comparative physical performance of the two planes as of T=13.1min after the SU-35s have fired their R-27ETs. Altitude dependent performance will be measured at both the altitude they are at in that moment and at a 20,000ft baseline.

Note: T/W below uses Sea Level and Static Installed Thrust, while above it was Uninstalled Thrust, and is not representative of performance potential at any speed or altitude.

| | Weights | | | | Loading | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Empty | Fuel | Payload | Total | Wing | Lift | T/W* | DI | DA |
| F-15C | 29,500 | 8,850 | 1,760 | 40,110 | 66.0 | 40.2 | 0.96 | 18.3 | 12.7 |
| Su-35S | 40,570 | 11,500 | 1,950 | 54,020 | 81.0 | 44.0 | 0.96 | 32.5 | 16.3 |

**Figure 3 - Comparative Specifications**

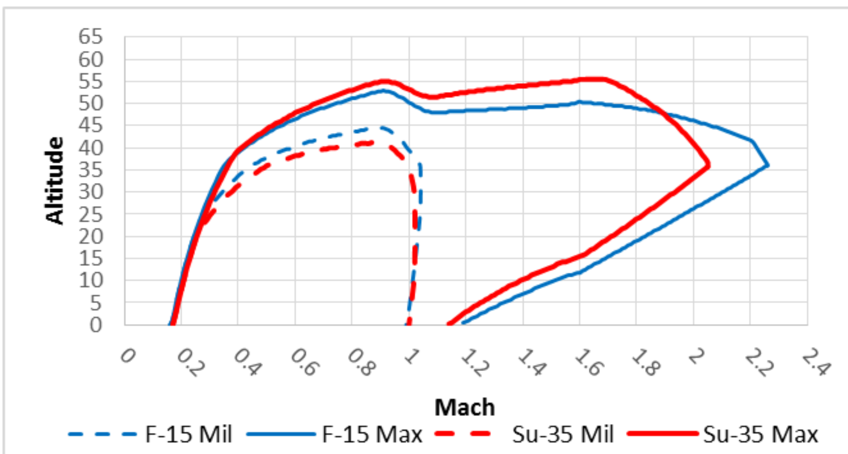


**Figure 4 – Comparative Envelopes**

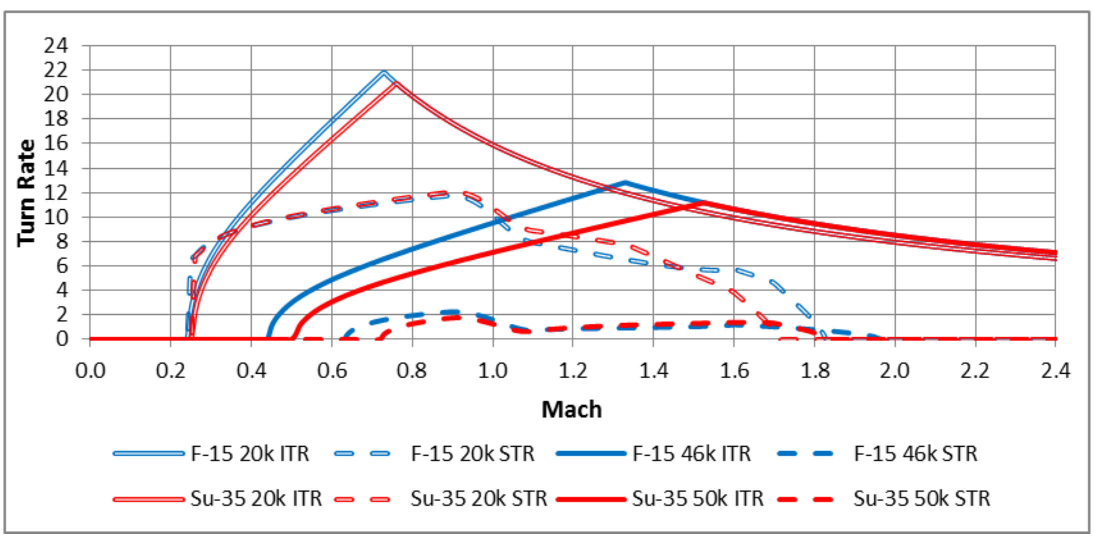


**Figure 5 – Comparative Turn Rates**

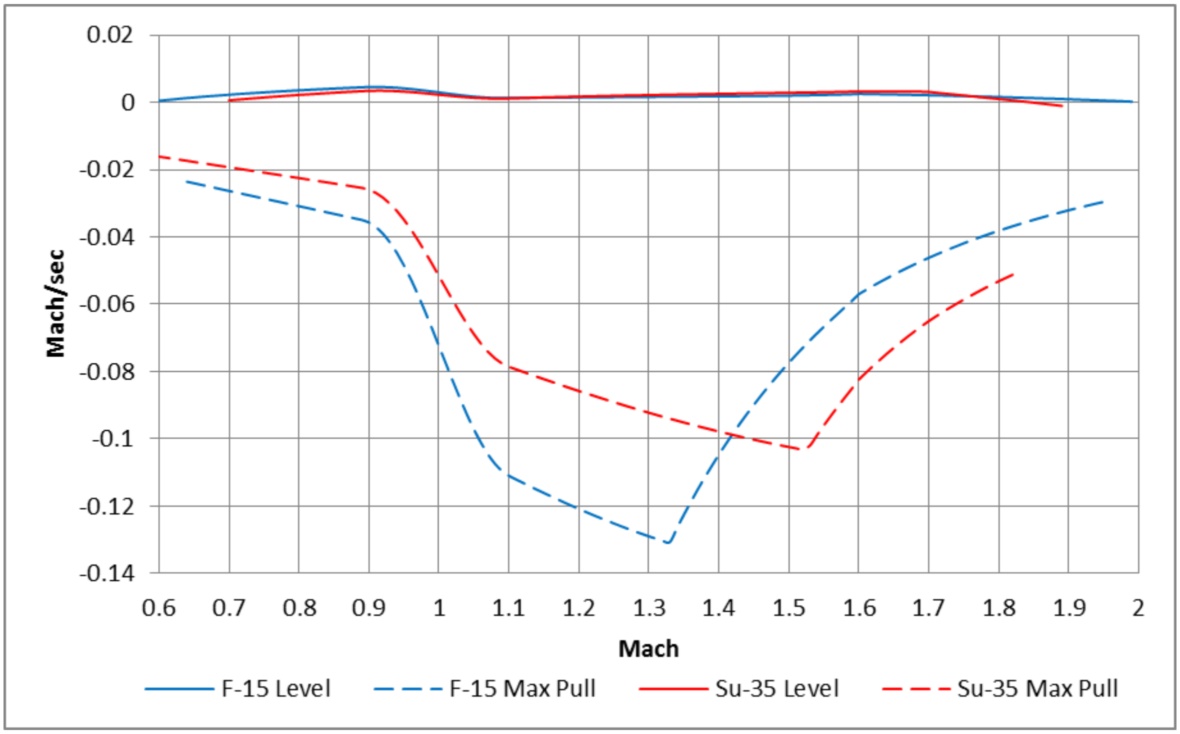


**Figure 6 - Combat Altitude Accelerations**

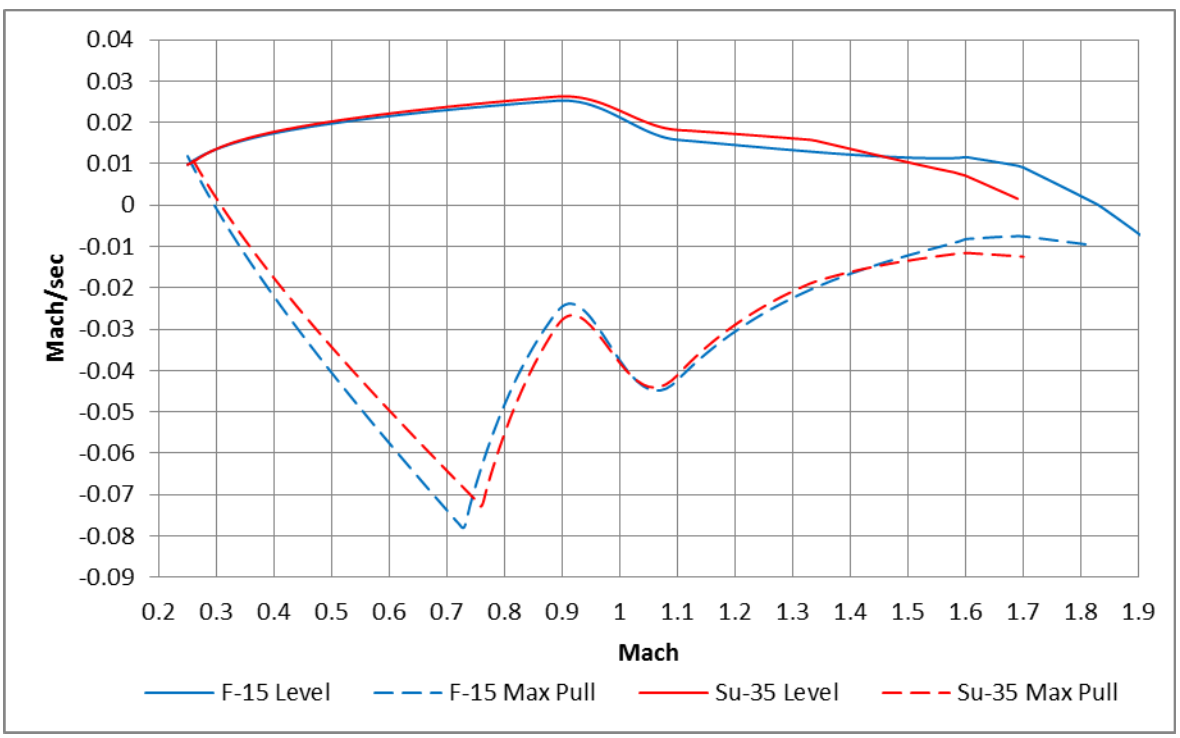


**Figure 7 - 20,000ft Accelerations**