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1.3.3 Current Military Aircraft Design Trends

The military aircraft picture is not much different even when national interest has priority over commercial considerations. Whereas commercial aircraft can earn self-sustaining revenue, military operations depend totally on "taxpayer" money, with no cash flow coming in, other than export sales that carry the risk of disclosure of tactical advantages. The cost frame of a new design has risen sufficiently to strain the economy of single nations. The typical project cost of a new high-technology combat aircraft is approximately $200 billion, an amount that exceeds the total cost incurred by all Western aircraft companies half a century ago. At approximately $100 to $200 million apiece, the price of a new combat aircraft is equivalent to nearly 1,000 World War II Spitfires. Not surprisingly, the number of new designs has drastically dropped, and military designs are moving toward multinational collaborations among allied nations, where the retention of confidentiality in defense matters is possible.

Even military designs show basic similarities up to the point when a new breakthrough is introduced – one thinks instinctively of how the jet engine changed designs in the 1940s. Consider the F117 Nighthawk (Figure 1.11(a)): the prospect of incorporating stealth technology initially appeared as an aerodynamicist's nightmare, but it too is now being incorporated into the shape of the F22 (Figure 1.11(b)). We must not forget that military roles involve more than just combat: they extend to transportation and surveillance (reconnaissance, intelligence gathering, and electronic warfare). It is interesting to note that military transportation aircraft have predominantly high wings, whereas their civil counterparts have low wings. I will discuss these differences later. The F22, Eurofighter, Rapahle, Griffon, and Sukhoi 30 are the current frontline fighter aircraft. In strategic bombing, B52 served for four decades and will continue to for another two decades – some design! The latest B2 (Figure 1.11(c)) bomber looks like an advanced flying wing without vertical tail.

Combat roles are classified as interdiction, air-superiority, air defense, and, when missions overlap, multirole (see Section 4.12 for details). Action in hostile environments calls for special attention to design for survivability; systems integration for target acquisition and weapons management; and design considerations for reliable navigation and communication. All told, it is a complex system – mostly

Figure 1.10 Antanov A70

(a) F117 Nighthawk (b) F22 Raptor (c) B2 Spirit

Figure 1.11. Current combat aircraft

operated by a single pilot – an inhuman task unless the workload is relieved by microprocessor-based decision making. Fighter pilots are a special breed of aircraft operators. Their work demands the best emotional and physical conditioning to cope with the work stresses. Aircraft designers have a deep obligation to ensure combat pilot survivability. Unmanned Combat Aircraft (UCA) technology is in the offing – the Iraq war saw the successful use of Global Hawk for surveillance. UCA is also known as UAV (Unmanned Air Vehicle). Of late, UCAs have been used as weapon delivery systems.

1.4.2 Military Aircraft Design: Future Trends

Progress in military aircraft defies all imagination. Military aircraft size and shape can be as small as an insect for surveillance purposes or as large as any existing aircraft. Vehicles as small as 15 cm and 1 kg in mass have been successfully built for operations [8], and much smaller prototypes are successfully being flown. Reliance on in-built intelligence would certainly involve more remotely piloted vehicles (RPVs) in operation. Other terminologies include *unmanned*, *unoccupied*, and *pilotless*. It is best that I settle on one word: I call such military aircraft *RPV*. These are piloted remotely or autonomously. However, *unmanned* or *unoccupied air vehicle* (UAV) is also prevalent terminology, as is *unoccupied micro-vehicle*.

Figure 1.18 X47B JUCAS (RPV) and Figure 1.19 show future configuration types. Boeing X45A has a typical OEM ≈ 3,600 kg, fuel ≈ 1,200 kg, and payload ≈ 680 kg operating at 0.8 Mach and 3,5000 ft altitude.

As systems-processing power grows, the capability to make weapon delivery decisions advances to an accuracy that could eliminate onboard human interface; thereby, at one stroke, the question of pilot survivability is taken out of the design

Figure 1.18 JUCAS prototype (X47B)

Figure 1.19 Boeing X45A

process, which in turn permits the aircraft to operate at a higher load, improving combat capability. Nations that can afford to have already entered the race to develop unmanned combat aircraft (UCA). Figure 1.18 shows the joint unmanned combat air system (JUCAS) candidate aircraft already in prototype development stages in the United States.

Long-distance hypersonic attack aircraft represent a strong candidate for short-time deployment strike aircraft. Again, it is the electronics that plays the main role, although aerodynamic challenges of stealth maneuver and improved capability/efficiency are also in as much demand for structural/material considerations. Engine development is also in parallel development with all of these discoveries/inventions.

In this book, I do not deal with these futuristic designs. One must first master the fundamentals presented in this book to carry out such futuristic designs. If enough information is available, then these futuristic military aircraft could be more suited material for postgraduate teamwork on aircraft design, undertaken by those who already have some proficiency in aeronautical engineering and have the time for longer project work. Without systems integration, mere aerodynamic shaping exercises would prove meaningless. Representative details of systems architecture and their capabilities affecting aircraft performance are still not fully available in the public domain. Working on such an important aspect based on piecemeal information is not the best procedure to attempt in the undergraduate curriculum, when there is so much to learn from conventional designs. Chapter 15 briefly covers miscellaneous design considerations.

Readers are advised to search various Web sites for information on future trends in military aircraft design.

2.5.2 Military Aircraft and Its Component Configurations

Military configurations are more diverse than civil designs (see Figures 1.11 to 1.15). In this book, a military trainer of the class of RAF Hawk is discussed. An example of an advanced jet trainer (AJT) with close air support (CAS) variant is worked out as a military trainer aircraft design, significantly simplifying the objective of military aircraft design.

Figure 2.5 shows a blowout diagram, typically that of the General Dynamics (now Boeing) F16. A description of aircraft components is as outlined in Section 2.4.1.

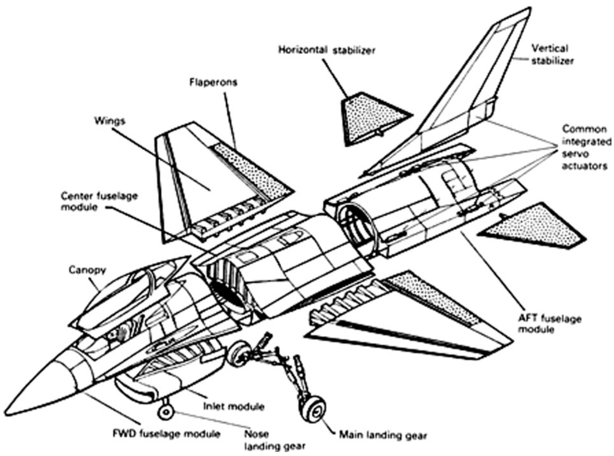


Figure 2.4. Military aircraft configuration (courtesy of Michael Niu [6.2])

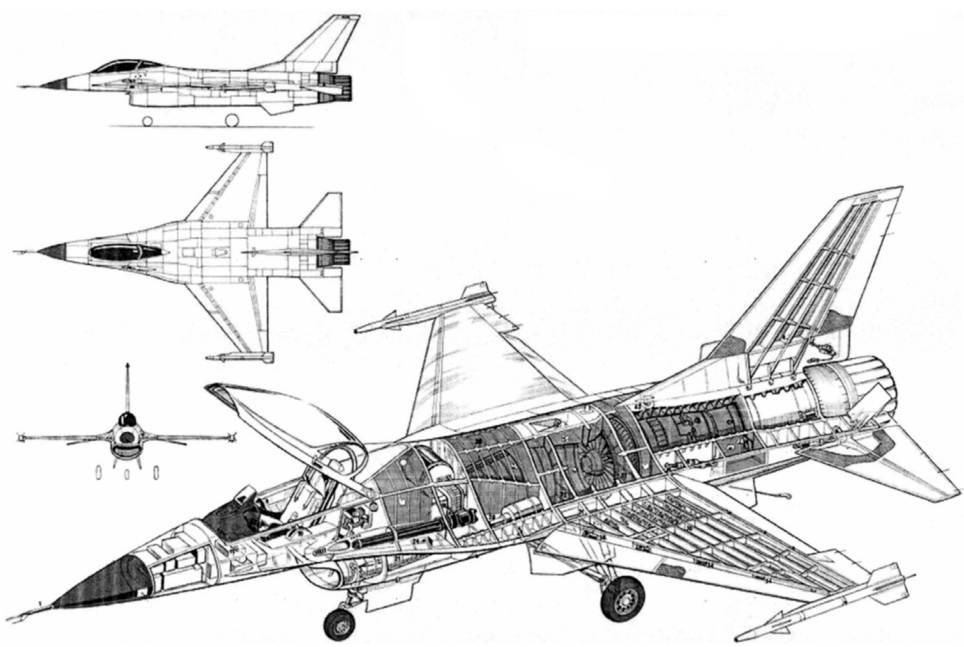


Figure 2.5 A diagram of the General Dynamics (now Boeing) F16 – internal layout

2.8 Military Market

In contrast to the civil market, the military aviation market starts with meeting the national defense requirements. The MoD organizations constantly review perceived threats and endeavor to stay ahead of the adversary. MoD floats a Request for Proposals (RFP) with Air Staff Targets (AST). Many uncertainties are embedded in the road to an operational product. The development cost for these hi-tech machines is high and in many cases exceeds projected appropriations. The dominant certification standards are the Milspecs (US) and Defense Standards 970 (earlier, AvP 970 – UK). These certification standards are not as similar as are the FAR and JAR requirements.

2.8.1 Aircraft Specifications/Requirements for Military Aircraft Case Studies

The author recommends that the introductory classroom work on military aircraft design start with the Advanced Jet Trainer specifications given here. See Design Specification 5 rather than the specifications for the Turboprop Trainer aircraft given in Design Specification 4 below.

4. Design Specifications of an Intermediate-Level Turboprop Trainer (ITPT) – UK Def Standards

Basic mission:	training in turboprop aircraft up to operational conversion to jet type
Mission profile:	small, agile for sortie profile
Payload:	two 80-kg pilots and 1,000-kg armament
Seating:	tandem
Normal training configuration (NTC):	clean configuration with four pylons
Engine:	one turboprop
Maximum speed:	500 kmph at 15,000 ft
Maximum sustained speed:	400 kmph
Stalling speed:	130 kmph (flaps extended)
Service ceiling:	10,000 m
Initial rate of climb:	1200 m/s at NTC
Time to climb to 7 km:	10 min at NTC
Turn performance:	4 g at sea level (@ mean weight)
Maneuver:	+8 g to −4 g (fully aerobatic)
Roll rate:	75 deg/s at 250 knot
Range:	1,500 km at cruise
Takeoff distance:	500 m at NTC to clear 15 m (sea level)
Landing distance:	550 m at NTC (no brake parachute – sea level)
Undercarriage:	retractable
Flight deck:	ejection seat, pressurized with oxygen supply
Cabin interior width	= 28 in

Technology level:	metal frame and with glass cockpit (conventional)

5. Design Specifications (Requirements) of a Baseline Advanced Jet Trainer (AJT)

Basic mission:	training in jet aircraft up to operational conversion to the fast jet type
Mission profile:	small, agile (see Chapter 13) for sortie profile
Certification standard:	UK Def Standards 970
Payload:	over 1,500-kg armament (prefer 1,800 kg)
Number of pylons:	5
Crew:	two 90-kg pilots in tandem seating
Normal training configuration (NTC):	clean configuration with pylons only
Engine:	one turbofan with low bypass ratio – no afterburning
Maximum speed:	Mach 0.75 (920 kmph)
Maximum sustained speed:	Mach 0.7 (860) kmph
Stalling speed:	220/180 kmph (no flaps/flaps, respectively)
Service ceiling:	14,000 m
Initial rate of climb:	40 m/s
Time to climb to 12 km:	12 min
Turn performance:	4 g at sea level (@ mean weight)
Maneuver:	+8 g to −4 g (fully aerobatic)
Roll rate:	200 deg/sec
Range:	700 km at sea level and 1,200 km at 9-km cruise altitude
Endurance:	2.5 h with reserve
Takeoff distance:	1,100 m to clear 15 m (sea level)
Landing distance:	1,000 m (no brake parachute – sea level)
Undercarriage:	retractable
Flight deck:	ejection seat, pressurized with oxygen supply
Cabin interior width:	= 30 in
Technology level:	advanced multifunctional display
Structure:	primary structure of metal frame; secondary structures are in composite
Certification standard:	UK Def Standards 970

Derivative version in the family of a Baseline AJT – a single-seat close air support (CAS) aircraft (all performance figures at NTC)

Basic mission:	close air support

Mission profile:	small, agile (see Chapter 13 for sortie profile)
Payload:	2,500-kg armament
Crew:	single 90-kg pilot
Number of pylons:	5
Engine:	one turbofan with low bypass ratio
Maximum speed:	maximum Mach 0.75 (910 kmph) level flight
Maximum sustained speed:	0.7 (850 kmph)
Stalling speed:	240/200 kmph (no flaps/flaps, respectively)
Service ceiling:	14,000 m
Initial rate of climb:	50 m/s
Time to climb to 12 km:	8 min
Turn performance:	5 g at sea level (@ mean weight)
Maneuver:	+8 g to −4 g (fully aerobatic)
Roll rate:	200 deg/s
Range:	700 km at sea level (no drop tanks); 1,500 km at 9-km cruise (with drop tank)
Sortie duration:	1.5 h (no drop tanks) with reserve
Takeoff distance:	1,400 m to clear 15 m (sea level)
Landing distance:	1,200 m (at landing weight, sea level – no brake parachute)
Undercarriage:	retractable
Flight deck:	ejection seat, pressurized with oxygen supply
Cabin interior width:	= 30 in
Technology level:	advanced multifunctional display
Structure:	primary structure of metal frame; secondary structures are in composite

4.12 Military Aircraft: Detailed Classification, Evolutionary Pattern, and Mission Profile

Military aircraft statistics and geometric details must be examined from a different angle on account of different mission roles. Combat aircraft does not have passengers and its payload has a wide variation in armament types to carry internally and/or externally. Their operational roles are extremely varied as given below. The difference between civil and military aircraft design is shown in Table 2.2 (Section 2.8). A preliminary classification of military aircraft is given in Table 4.1, consisting of fighters, bombers, reconnaissance, transport aircraft, and so on. From time to time, depending on the perceived combat, the mission requirements are examined more closely in order to arrive at the specific role; nevertheless, it must be kept in mind that there is considerable overlap in the functional capabilities between the different roles. Subdivision of the fighter role has many classifications. A large multirole combat aircraft (F14 $\sim$ 33,000 kg) can be used in air-to-air combat as well as for interdiction precision bombing at specific targets (e.g., enemy radar stations). On the other hand, an air superiority role (F16 $\sim$ 16,500 kg) calls for light agile aircraft mostly in defense mode to destroy enemy aircraft. A heavy bomber aircraft such as the B52 would operate as a strategic bomber with little high 'g' maneuver. The modern B2 bomber has stealth features to penetrate deep into enemy territories but not much is known about its all-round capabilities until now. Following are terminologies normally used in reference to various types of combat aircraft.

Air superiority – Its role is to prevent enemy aircraft retaliation over the battlefield in enemy territory so that ground attack aircraft can carry out their tasks of disabling the adversary. The aircraft should be very agile in order to carry out air-to-air combat in BVR capability. Because it has to fly longer distances into enemy territory and loiter in the vicinity in preparedness, it is a relatively heavier aircraft.

Air defense – Its role is to prevent enemy aircraft from gaining any superiority of home sky. It has to out-maneuver the best of adversaries. The air defense aircraft is smaller, lighter, and very agile and is primarily meant for air-to-air combat with BVR capabilities. It requires rapid response.

Ground attack aircraft – Caters to the tactical and other specific requirements on the battlefield. It is capable of CAS role (see below).

Close air support (CAS) – Air-to-ground support (gun/missile/light bombs) on the battlefield. It is a relatively lighter aircraft, highly maneuverable, and could be slower compared to the ground attack type. Rapid fire gunships are a variant of CAS.

Interdiction – Carries heavier bombs, JDAMs, precision bombing in battlefield. It has deep penetration capability into enemy territory.

Multirole fighter – Heavier aircraft capable of performing a variety of combat (e.g., air superiority, air defense, ground attack, interdiction).

Advanced tactical support (ATF) – F22 aircraft clearly illustrates the long-range air superiority mission that was envisaged for penetrating deep into enemy airspace to destroy enemy air defense aircraft and to disrupt offensive air operations. This represents advanced tactics with a multirole capability – hence, it is a new class.

Strategic bombing – Carpet bombing: (B52 class).

Air-to-air refueling – Larger tanker aircraft for midair refueling (K135 type)

Maritime patrol – Has special role to cover threats from oceans (antisubmarine role, etc.). In addition, it does surveillance and patrolling with long-endurance flying.

Reconnaissance – Very high performance aircraft beyond missile range (SR71, U2). Photographs enemy territory.

Airborne early warning (AEW) – Capable of early detection of threats with long-range sensors.

Electronic warfare (EW) – Capable of electronic countermeasures. RPVs play an increasing role in EW.

Military transport aircraft – Serves the logistic requirements (e.g., troop, equipment ferry) (C17 type).

Military pilot training – Specific types of training aircraft, normally through two or three types leading up to advanced combat training ready for operational conversion. Its single-seat variant can serve in CAS role.

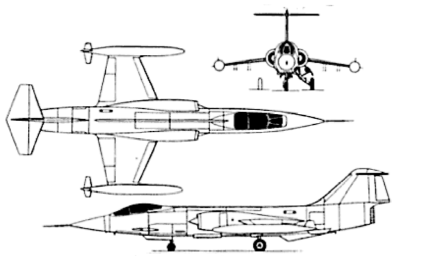
UAVs/RPVs – These lack onboard pilots and are increasingly appearing in the battlefield in the various roles; in the future, they could replace advanced manned combat aircraft.

The reality is that capabilities are a good measure of intent; it is unrealistic to assume that any nation will expend vast sums of money to acquire specific weapons systems without seeing how that expenditure will further national interests. Long-range air superiority aircraft such as the Phantom F4/Hornet F18/F22 serve a clearly defined role: offensive strategic air war.

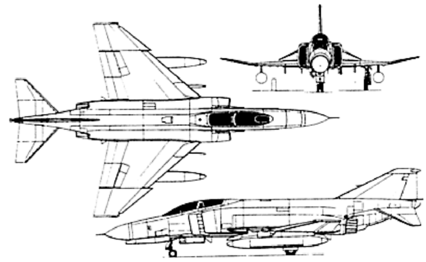
A quick review of the post–World War II fighter aircraft evolutionary pattern shows rapid progress in speed-altitude and maneuver capabilities, reflecting distinct changes taking place in fighter aircraft configuration. Examples of a few strikingly older designs are given in *Jane's All the World's Aircraft Manual* and also can be found in various Web sites; the list is too long to include here. Using the key words will help sufficiently in finding the designs if they are still on the Web.

Mission profile has a major contribution in shaping military combat aircraft. An ultimate supersonic air superiority aircraft configuration would be quite different from the subsonic close air support type of aircraft configuration. Attempts are made here to offer a broad-based coverage for an introductory course. Configurations in Figures 4.30, 4.37, 4.38, and 4.40 cover the major types of aircraft currently in operation. These are sufficient examples to study for an introductory course. Abundant three-view diagrams and photographs of many types of military aircraft are given in this book.

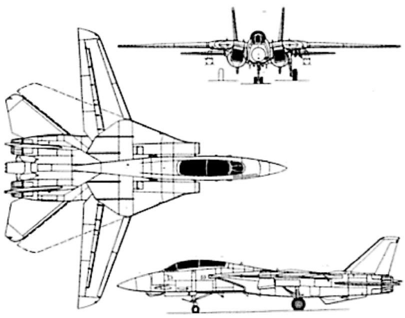
U.S. designs dominated the aircraft design scene, as compared to designs of other origins. However, there also are successful European designs. The Cold War produced fine Russian designs. Some of the Russian aircraft capabilities are yet to be surpassed. Out of many, some outstanding U.S. designs used over the past five decades are shown in Figure 4.30 – most have proven their performances in various battlefields.



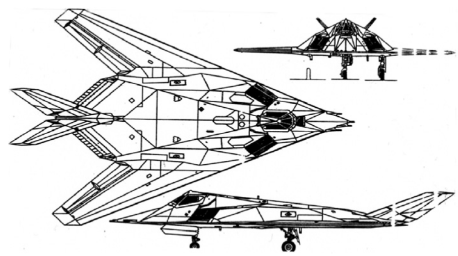
(a) 1950s–1960s: Lockheed F104, Starfighter



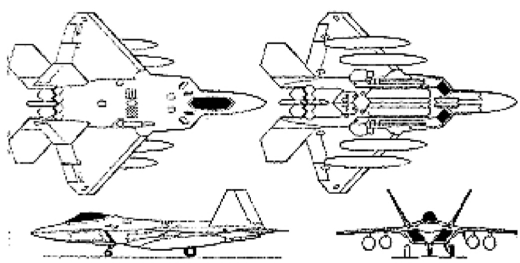
(b) 1960s–1970s: McDonnell F4, Phantom



(c) 1970s–1980s: Grumman F14, Tomcat (Swing wing design)



(d) 1980s–1990s: Northrop F117 Nighthawk (First all-stealth design)



(e) 21st century: Lockheed F22 (stealth design)

Figure 4.30. Chronology of fighter aircraft design evolution (USA)

The F117A Nighthawk (Figure 4.30(d)) is the world's first operational aircraft, specifically designed to exploit low-observable stealth technology. The unique design of the single-seat F117A provides exceptional combat capabilities. It is about the size of an F15 Eagle and has quadruple redundant fly-by-wire flight controls. The F117A can employ a variety of weapons and is equipped with sophisticated navigation and attack systems integrated into a state-of-the-art digital avionics suite that increases mission effectiveness and reduces pilot workload. Detailed planning for missions into highly defended target areas is accomplished by an automated mission planning system developed specifically to take advantage of unique stealth capabilities.

A civil aircraft operational evaluation is relatively simpler. Its DOC can be compared with the competitor to assess the viability of design. On the other hand, a military aircraft comparison is based on several criteria (e.g., operation, technology, survivability, cost, and political considerations). Each war has taught lessons on how factors other than purely technical and operational capability override decisions for next-generation designs. Weapon capability is integral to aircraft capability and therefore the design procedures must align with the kind of weapon integration envisaged.

Typical combat aircraft design must take into account the following considerations; these cover more disciplines than the civil aircraft design:

1. Number of crew – heavy workload could demand twin crew – 9-*g* physical limit
2. Number of engines – survivability consideration could demand twin engine
3. Operational strategy – air-to-air combat/air-to-ground combat, etc.
4. Configuration – stealth, external hard points for weapon/drop tank, etc.
5. Sizing – wing loading and thrust loading, control configured sizing
6. Engine – selection for matching capabilities, vector trust, etc.
7. Performance – agility, speed, altitude, range, supercruise, STOL, survivability, etc.
8. Electronics – weapon system, communication, navigation, data acquisition,
9. countermeasures, electronic warfare, etc.
10. Systems – FBW, FADEC, microprocessor-based management, etc.
11. Structure – choice of material, manufacturing philosophy
12. Weapon – type of weapon to be integrated
13. Life cycle – cost/maintenance/logistics/disposal – support from cradle to grave.

The military aircraft mission profile is extremely varied, and aircraft sizing depends considerably on the requirement to encounter perceived threats (there are many unknowns about adversary capabilities). In addition, combat and survivability considerations impose severe design constraints in shaping the aircraft (e.g., incorporation of stealth, maneuver in relaxed stability (fly-by-wire – FBW)). Inclusion of stealth and FBW features requires extended studies that would substantially exceed one term of work. Fortunately, U.S. universities could be in a position to obtain NASA software to evaluate stealth. Other nations may not be this fortunate. Control-configured FBW design would require the understanding of the control laws of relaxed stability maneuvers, which are not easy to size. A methodology to pursue these considerations in undergraduate class could be carried out, but the author does not believe that it could do proper justice before the fundamentals are mastered. The F117 is an example of a combat aircraft that incorporates stealth and FBW. It defies imagination, coming closer to the "Star Wars" shape – no wonder it was nicknamed the aerodynamicist's nightmare. This kind of design would not prove easy for introductory classroom project work.

Typically, a military aircraft structure would demand extensive use of advanced materials (e.g., having composites, lithium and boron alloying with aluminum). Usually, some of F22 external surfaces have 24% composite, 16% aluminum, and some thermoplastic material. The Eurofighter uses more than half its weight as nonmetals.

A military aircraft design exercise would be incomplete without operational evaluation (OP), which is beyond the scope of the book. In the true sense, it will require a twin dome (one flown by adversary) combat flight simulator, each flown by human pilots to assess performance capability. Here, 100% rating means "always win" and 0% rating is "always lose." An 80% capability can be expressed as 4:1

(i.e., in combat; one aircraft is lost against four enemy aircraft losses). Here, too, the enemy aircraft and weaponry performances are based on considerable guesswork, as potential adversaries are not going to declare their capabilities – it is a matter of life and death. Because today's combat would be BVR (beyond visual range), a host of other external support systems (target acquisition) are required to assess the military aircraft design beyond making unusual shapes to reduce radar cross-section signature (RCS – low observable). A credible twin-dome combat simulation is the nearest assessment platform designers can develop – yet real life is different. A twin-dome simulation could show significant differences in combat capability, depending on the selection of weapon/system, and so on. Aircraft performance capability is integral to the capabilities of the weapon system in use. In swing role (combinations of both air-to-air and air-to-ground operations), the evaluation becomes more complicated. If LCC is brought into evaluation, then constraints through national economy pose another consideration: Can these be excluded from a credible teaching exercise?

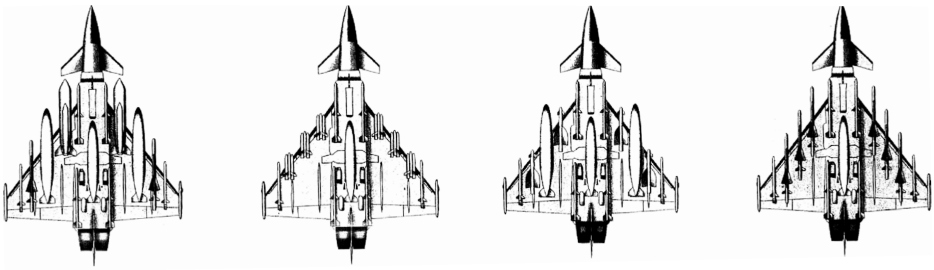
The author believes that without the considerations described above, a modern combat aircraft design exercise in the classroom would prove no better than an advanced military trainer aircraft with close support capabilities to familiarize the student with a typical mission profile and associated design consideration. Therefore, this introductory book starts military design exercise with trainer aircraft as an alternative to frontline combat aircraft design. This excludes the exercises on shaping for RCS, selection and integration of systems/weapon, and performance comparison to realize design effectiveness. Chapter 15 briefly introduces the considerations required for RCS design. This simpler introductory military aircraft design exercise offers sufficient training toward the reader's understanding of military aircraft combat aircraft design. To quote examples, readers are requested to study aircraft such as the BAe Hawk, EAD Mako, Korean KT50 aircraft, and so on. All these aircraft have versions for lead-in training to the operational level, as well as a version with light combat capabilities.

Military transport design has similarities with commercial transport design, although its operational strategies are different. This book considers military transport aircraft design to be very similar to civil design except that its certification standards (Milspecs) are different.

The statistics given in this chapter are for the following aircraft: B2, F14, F4, F15, F16, F18, F22, F35, F111. F117, SR71, SU37, MIG31, SU41, MIG25, Viggen, Rafale, Eurofighter, Gripen, Jaguar, Hawk, Mirage2000, Kfir, Lavi, and Harrier.

4.13 Military Aircraft Mission

A typical mission profile for combat is given in Chapter 13. Figure 4.31 shows some configurations for the mission profiles. To meet military aircraft mission demand, its range and armament payload are traded freely. A very high armament payload could be used for short ranges or a lighter load for long-range interdiction. A relatively light armament in air defense (high *g* maneuver) role also can be just overhead (i.e., low range while in escort role to a relatively long range). Military aircraft has in-air refueling capability (or the use of drop tanks) to extend range. Payload mass has a wide range of options – all hard points can have lighter weapons load or



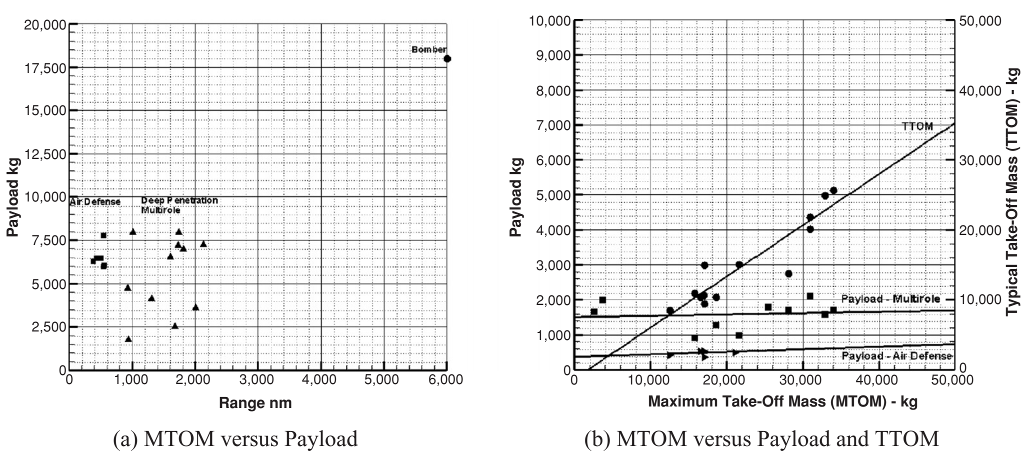
(a) Air interdiction (b) Close air support (c) Air defense (d) Maritime attack

Figure 4.31. Typical multirole missions [4.2]

heavier missiles/bombs. In general, heavier aircraft will have a heavier payload. When payload is externally mounted on hard points, aircraft drag characteristics alter substantially, affecting range capability. At a design MTOM, the payload would depend on mission range – here, weapon load and drop tank fuel load are traded. The B2 had to fly half the world (with midair refueling) to reach the target zone. For these reasons, a correlation such as that in Figure 4.4 showing passenger versus range would not offer much information for military design. Unlike civil aircraft mission profile, it clearly indicates that the same class of military aircraft can have a wide variety of payload range. It may prove convenient to assess combat aircraft with full internal fuel for the payload-range capability, as shown in Figure 4.32, quite differently from what is shown in Figure 4.4 for civil aircraft designs.

A typical multirole armament configuration of Eurofighter is shown in Figure 4.31. Generally, it consists of takeoff of heavily loaded aircraft; climb to altitude for programmed cruise that could have speed altitude specifically tailored for the terrain releasing weapon load and perceived threat; dive down to low level, high-speed dash to target zone for interdiction; then fast climb to extreme height of the lightened aircraft; and return to base. For air defense, the combat would be in closer proximity to defend from attacking aircraft, requiring extreme maneuver at high g.

In summary, the mission roles are varied, as listed in Section 4.12 – but they can be compressed into three basic types:



(a) MTOM versus Payload (b) MTOM versus Payload and TTOM

Figure 4.32. Military aircraft payload – range (no drop tank or refueling)

1. *Air defense*: Adequately armed (all missiles) but low range (e.g., $\approx$ 500-nm range – larger country) to keep it light for maximum agility, operating within its own (friendly) territory to defend against invading aircraft. A maritime attack role can be included in this class, as aircraft carrier ships can come closer to the target zone in enemy country.
2. *Deep penetration multirole*: This covers everything as listed in Section 4.12 except bomber and air defense. The longer ranges are currently limited to the order of 1,000 nm to 2,000 nm (crossing into enemy territory), but payload (combination of missiles and special purpose bombs) varies according to the specific mission. All except close air support (CAS) role have supersonic capability.
3. *Bomber*: These are slower (except B1), carrying a large bomb load to longer distances.

For ferrying, drop tanks filled with fuel are slung at the hard points to increase range, which can be more than twice the range given in Figure 4.31. Mid-air refueling would extend range capability and could be carried out more than once.

4.14 Military Aircraft Statistics (Sizing Parameters – Regression Analysis)

In line with Section 4.5 for civil aircraft designs, this section gives the statistics of military aircraft weights and geometry. Unlike civil design progressing in evolutionary tracks, military designs tend to be progressing in revolutionary tracks. Military aircraft statistics are not as consistent as those of civil design and require considerably more information for correlation. Military designs are operation specific; presenting them in a generic fashion would dilute their specialties. The author regrets that not much information is available in the public domain – understandably, these are sensitive issues. Definitions of various kinds of aircraft mass given in Section 4.5 are applicable in this section – here, payload replaces passenger capacity. To keep regression simple, linear fitment is carried out. The regression graphs given in this section can be used only for preliminary sizing.

Combat aircraft loading to MTOM would be at the sacrifice of its agility. Loading to MTOM is done when mission demands (several mission profiles are given in Chapter 13). In general, MTOM is meant for deep penetration when considerable fuel has been consumed before reaching combat zone to make aircraft lighter – it has an option to carry the amount in drop tanks and can be jettisoned (punched out) when emptied to reduce drag. For maximum effectiveness with a balanced combat capability, military aircraft uses lighter loading, termed as typical takeoff mass (TTOM), which is typically 70% of MTOM.

4.14.1 Military Aircraft Maximum Take-off Mass (MTOM) versus Payload

Figure 4.33 shows MTOM versus payload and TTOM. There is a distinct separation of armament loading capability between the air defense class fighter aircraft with an armament load of around 750 kg and the multirole class aircraft carrying nearly twice the payload to longer distances. Air defense class fighter aircraft are lighter

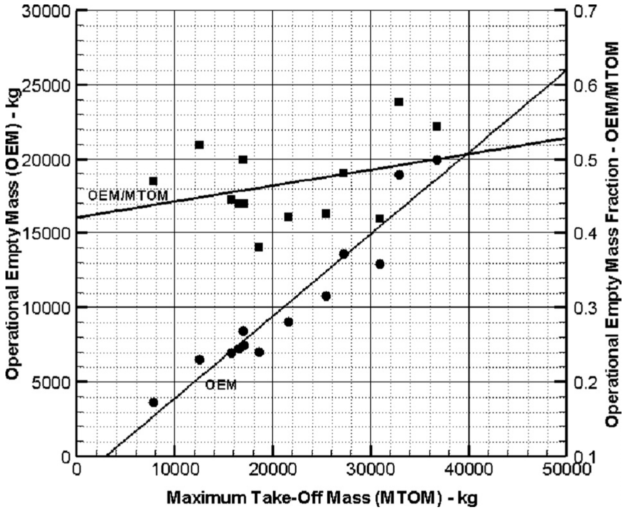


Figure 4.33. MTOM versus OEM

than the multirole class aircraft. Understandably, in both classes, the MTOM grows with increase in payload (armament).

4.14.2 Military MTOM versus OEM

Figure 4.33 gives the relationship between MTOM and OEM, as well as the operational empty mass fraction (ratio of OEM to MTOM). OEM grows with growth in MTOM, but there is a spread in the OEM fraction as a result of differing performance capabilities and system integration. Typically, the ratio of OEM/MTOM averages from 0.42 to 0.52.

4.14.3 Military MTOM versus Fuel Load M_f

Because the fuel load for combat aircraft is flexible, depending on usage of drop tanks and air-to-air refueling, onboard fuel content is taken as a standard condition to present the statistical analysis. Figure 4.34 gives the relationship between internal fuel load, M_f, and fuel fraction $M_f/MTOM$ versus $MTOM$. There is some scatter because of diversity in requirements.

Growth in MTOM would be associated with more fuel-carrying capacity to meet range, but the fuel fraction graph shows dispersion on account of difference in role (e.g., short range air defense and longer range deep-penetration types). Longer range aircraft would be heavier because they carry more fuel.

4.14.4 MTOM versus Wing Area (Military)

Figure 3.35 shows wing area, S_W, and wing loading MTOM/S_W (kg/m^2) versus MTOM. As expected, there is scatter in data.

The influence of wing loading is shown in Figure 4.35. Military designs could have moderate wing loading for hard maneuvers. Modern designs show lower wing

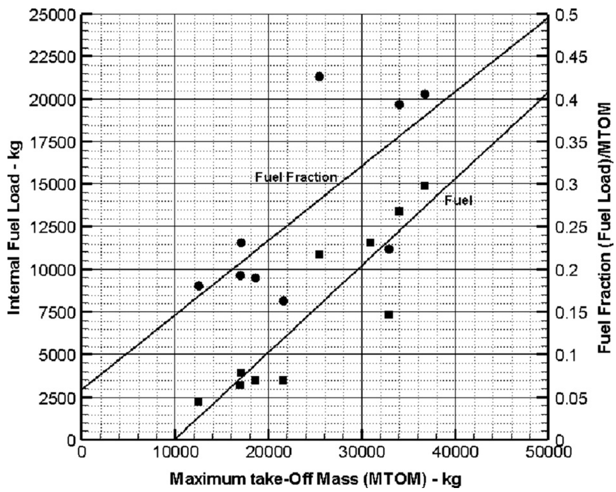


Figure 4.34. MTOM versus fuel load

loading – the F22 has the low order of 350 kg/m^2 compared to Sepecat Jaguar, which has $\approx$ 650 kg/m^2. The next section shows that the F22 also has the highest thrust loading.

4.14.5 MTOM versus Engine Thrust (Military)

Combat aircraft are invariably powered by jet propulsion (turboprop-driven close air support aircraft are few and are excluded in the statistics). Military aircraft require very high thrust loading, T/W (could exceed 1) for maneuvers and short field performance. High thrust requirement is of small duration and is met by augmenting thrust with the use of afterburners (Chapter 10).

Section 4.14 explained the need for typical takeoff mass (TTOM) for combat effectiveness. Figure 4.36 presents the relationship between total T_{SLS} and the two types of aircraft mass (e.g., MTOM and TTOM). Thrust increase is associated with aircraft mass increase. However, there is some spread in thrust loading. Typically,

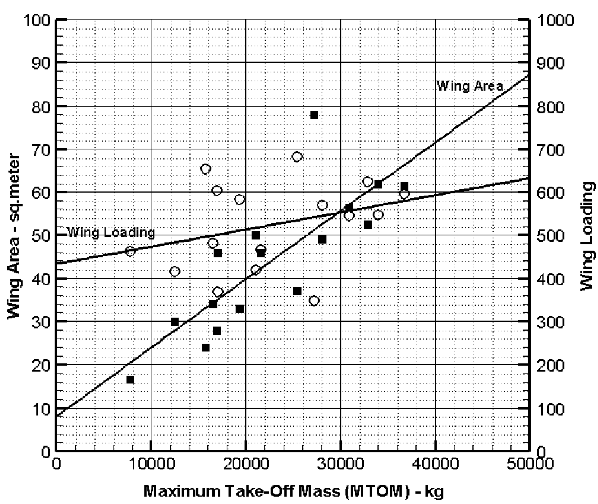


Figure 4.35. MTOM versus wing area

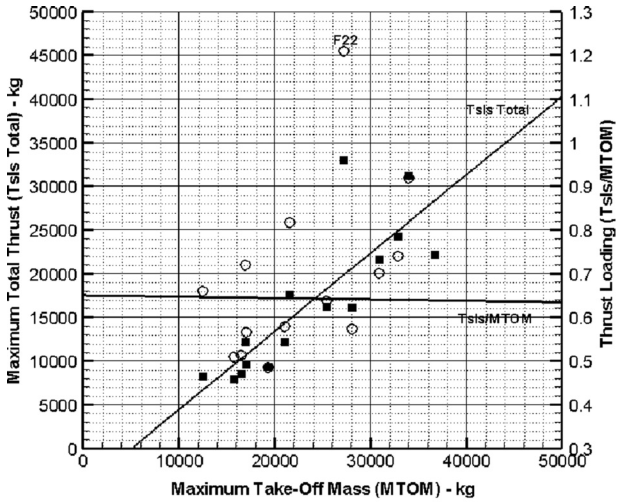
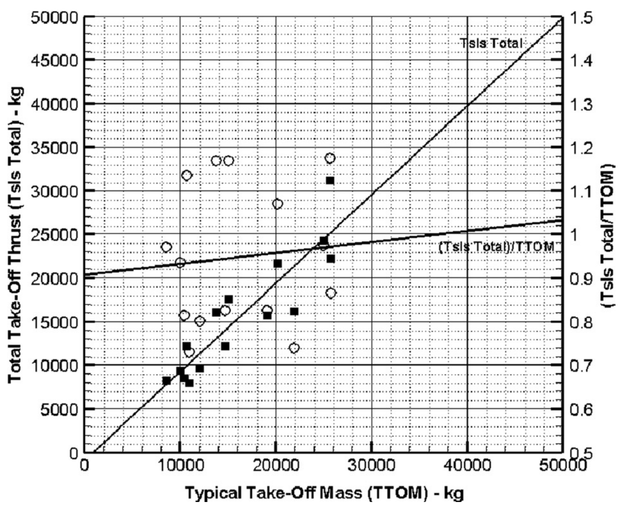


Figure 4.36. Aircraft weight versus total take-off thrust



(total $T_{SLS}/MTOM$) is averaged around 0.65 but (total $T_{SLS}/TTOM$) exceeds 1. Later generations of combat aircraft have pushed the thrust-to-weight ratio to more than one that would permit aircraft to accelerate in vertical climb. The F22 has the highest thrust loading, as well as the lowest wing loading.

4.14.6 Empennage Area versus Wing Area (Military)

The military aircraft empennage configuration should be very different from civil aircraft design. Many have a conventional design with an H-tail and a V-tail. On the other hand, an extreme example of B2 appeared to be without any tail. An examination of various configurations shows several options for aircraft control.

Stability and control of modern combat aircraft are invariably supported by microprocessor-based systems architecture, such as FBW, when onboard computers continuously fly a slightly unstable aircraft under pilot-initiated commands. Because this is beyond the scope of this book, no statistical analysis is presented here. The examples of the trainer class of aircraft follow the conventional approach with one H-tail and one V-tail designs.

4.14.7 Aircraft Wetted Area versus Wing Area (Military)

Sections 3.24.2 and 4.5.7 are valid for military aircraft designs. Military aircraft have low aspect ratio, and the growth problems are not as stringent as that of civil considerations.

4.15 Military Aircraft Component Geometries

Previous sections gave abridged statistical relations of weight and geometries for all categories of combat category aircraft. Section 2.4.2 presented some familiarization of a typical military aircraft and its components – as mentioned earlier – using a "Lego" or "Mechano" as a building block concept. Because of the large variety of combat mission profiles and technological options available, wider choices for configuring military aircraft are available. The choices are not made arbitrarily – valid reasons are associated with these choices. Following is pertinent information on fuselage, wing, empennage, and nacelle as military aircraft components.

1. **Fuselage Group:** Unlike the approach to civil aircraft configuration, military design need not start with fuselage, but it may prove convenient to do so. Fighter aircraft fuselage does not carry any internal payload – it has the singular function to accommodate the crew (or crews) and engine (or engines) along with routing of conduits of various systems (wires, pipes, linkages for the systems), fuel tanks, and encasing small arms (e.g., guns). Unlike hollow civil aircraft fuselage, it is very tightly packed, minimizing the fuselage volume requirement. With the engine (or engines) buried inside, air intake is an integral part of fuselage. The large wing root of delta (or trapezoidal wing with strake) planform offers the scope to make wing blend with fuselage. In that case, configuration of wing becomes integral to configuring fuselage, as shown in Sections 4.16 and 4.17.
2. **Wing Group:** This is the most important component of the military aircraft. The wing planform shape needs to be established based on the operational requirements (e.g., hard maneuvers, supersonic capabilities, short field performances). Unlike civil design, there is a large option for planform shape, and fuel tankage space is restricted.
3. **Empennage Group:** Combat aircraft empennage shaping and sizing are complex procedures (Section 4.14.6) primarily on account of short tail arm and the need to fly in relaxed stability to execute fast and hard maneuvers. The B2 apparently appears to be without a tail. The F22 has a large canted V-tail. Options for control surface configuration would be shown along with wing options. Delta wing has H-tail integrated with it. This book adheres to the conventional configuration of H-tail and V-tail for the trainer aircraft example. Modern designs deploy tailerons (stabilator; see Section 15.9.1) to initiate pitch and roll control by H-tail.

4. **Nacelle Group/Intake:** Military aircraft nacelle design is also a complex procedure because the power plant is kept within the fuselage, unlike a simpler pod-mounted configuration of civil aircraft. Therefore, nacelle is an integral part of fuselage configuration handled by aircraft designers. Only a schematic outline of the options is given in this chapter. Examples in Chapters 6 and 10 offer design methodologies sufficient for introductory classroom work.

These four groups of aircraft components offer the preliminary shape of candidate combat aircraft configurations. Eventually, after the wing-sizing and engine-matching exercise, the choice for configuration must be narrowed down to one that would offer the best choice for the mission. Family derivatives of military aircraft are quite different, again depending on the mission role (e.g., use of additional crew, trainer version, carrier-borne version, longer range version, improved variant version). Undercarriage information is presented separately in Chapter 7.

Military configuration study also requires some iteration to position empennage and undercarriage with regard to the wing because initially the CG position is not known. Weights are estimated from a provisional positioning, and then the positions are fine tuned through iteration when the CG is known. In classroom exercises, one iteration would suffice.

4.16 Fuselage Group (Military)

The densely packed fuselage design starts with the nose cone, which must be pointed for supersonic capability; it then houses a radar that could be $\approx$1 m in diameter. Fighter aircraft fuselage would invariably house the power plant and therefore there will not be any separate podded nacelle (some older bombers have pods). Area ruling requirements make narrowing of the fuselage necessary. Therefore, the fuselage would rarely have constant cross-sections, making fuselage shape generation quite complex.

Fuselage aft ends up as the engine exhaust system and therefore will not have closure as in civil design. In case the engine extends below the fuselage spine (Figure 4.30(b) – Phantom), then a pointed aft end closure follows. Fuselage belly fairing would house accessories – in most cases, the undercarriage. Current tendencies for the wing-body fairing have considerable blending for superior aerodynamic considerations (e.g., to improve lift to drag ratio and fly at a higher angle of attack). In blended fuselage, it is difficult to isolate fuselage (Figures 4.43(b) – B2); possibly, a convenient choice would be where the wing root is attached.

The military aircraft pilot seat is designed for more freedom to recline to shorten carotid artery height, thus reducing blood starvation to the brain at high *g* maneuvers, which can cause blackouts.

4.17 Wing Group (Military)

The evolution of fighter aircraft shows the dominant delta or short trapezoidal wing planform. This is for the obvious reason for having a high leading-edge sweep; a low aspect ratio to negotiate high *g* maneuvers would generate a high wing root-bending moment. It would restrict span growth but encourage large wing root chord of delta or trapezoid with strake planform, as shown in Figures 4.37(g) and (h). For control reasons, it could have additional surfaces. Following are configuration choices (strakes are taken as part of wing).

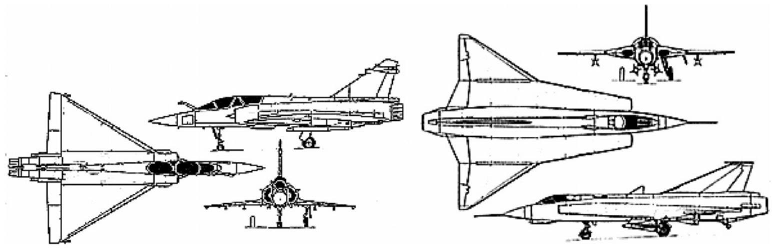
1. *One-surface Configuration*: Pure delta planform or its variation – the trailing edge of the delta- like wing can be made to work like the H-tail as an integral part of the wing (Figure 4.37(a-1) and (a-2)).
2. *Two-Surface Configuration*: Delta-like wing or trapezoidal wing with conventional H-tail for pitch control. In some designs, the H-tail is replaced by a canard surface for pitch control in relaxed stability (i.e., it has a destabilizing effect). Two-surface configuration has two possibilities – tail in back (Figure 4.37(b-1) and (b-2)) or tail in front (canard; Figure 4.37(c-1) and (c-2)). Two-surface configuration with strake is shown in Figure 4.37(d-1) and (d-2). Variants are double delta (SAAB Viggen; Figure 4.37(c-2)).
3. *Three-Surface Configuration*: The ultimate kind is the three-surface configuration (Figure 4.37(e-1) and (e-2)). It has wing, H-tail in aft end, and canard in the front end.

The Delta wing trailing edge has pitch control surface integrated into it. Trapezoidal wing planform (Figure 4.37(b-1) and (b-2)) can be associated with separate pitch control surface, typically as an H-tail. An extreme form of three-surface arrangement exists (Sukhoi 37 – Figure 4.37(e-1)). Forward sweep has aerodynamic merits to bring the wing aerodynamic center to move forward, which favors H-tail sizing. However, aeroelastic problems could aggravate wing twist, creating instability. Carefully arranged composite material has minimized the effect of twist; there are two successful flight-tested designs (Su 47 and Grumann X29).

The role of canard in military application is quite different from its role in civil aircraft designs. It has been found that strakes can also provide additional vortex lift and fast responses to pitch control with conventional tail. The choice of strake or canard still is not properly researched in the public domain. It is interesting to note that U.S. designs have strakes, whereas European designs have canards. Detailed study of aircraft control laws and FBW system architecture is required to make the choice. Until the 1990s, flaws in fly-by-wire software caused several serious accidents.

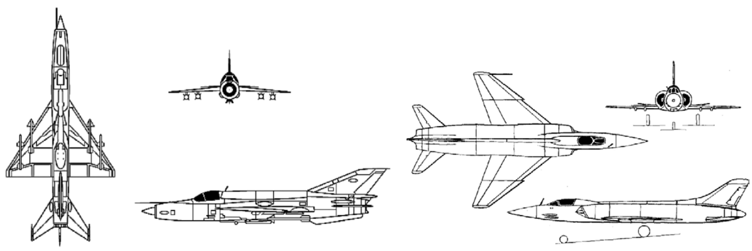
Again, it is emphasized that this book is introductory in nature. Because of insufficient information on modern fighter design considerations, the author restricts military aircraft design exercises to the trainer class of aircraft. To develop a feel for military aircraft design considerations, readers will find that there is much to learn from this class of aircraft. Figure 4.38 shows modern advanced jet trainers that have variants for close air support roles. BAe Hawk is a successful but relatively older design (still in production) that has conventional configuration. EADS MAKO is one of the latest trainer aircraft designs capable of supersonic flight and light combat capability.

Wing attachment to fuselage varies from case to case. The leading edge can have slats and the trailing edge would invariably have flaps. Centrally mounted large air brakes to decelerate have practically eliminated the role of spoilers. Landing in shorter airfield may require deployment of the brake parachute.



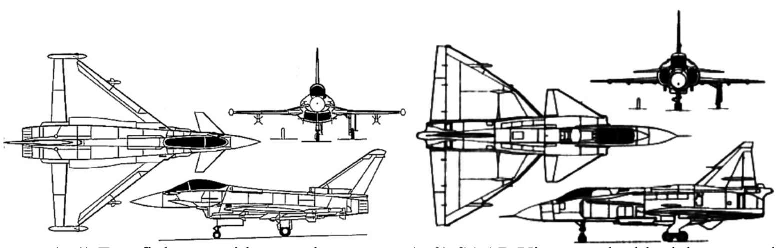
(a-1) Mirage 2000 – pure delta wing (a-2) SAAB Draken – modified delta (cranked)

(a) One-surface wing planform – trailing edge has pitch control



(b-1) MIG 21 – pure delta wing+H-tail (b-2) Mirage F1 – trapezoidal wing+H-tail

(b) Two-surface wing planform – Conventional H-tail has pitch control



(c-1) Eurofighter – with canard (c-2) SAAB Viggen – double delta+canard

(c) Two-surface wing planform – Canard+wing trailing edge has pitch control

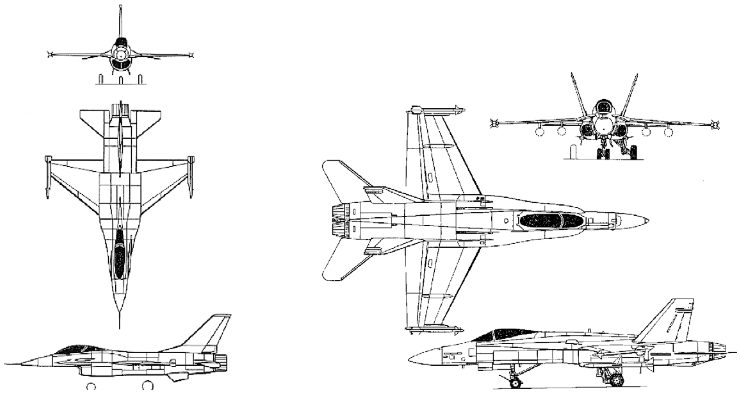
Figure 4.37. Fighter aircraft configurations

Because military aircraft are expected to encounter transonic flight, aircraft cross-sectional area distribution becomes an important consideration. A seamless, smooth distribution of cross section (area-rule) is explained in Section 3.13.

4.17.1 Generic Wing Planform Shapes

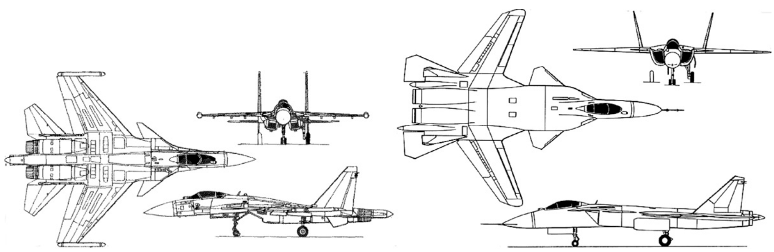
Unlike civil wing planforms, which are mostly trapezoidal, military planforms has more variety to offer. These can be presented in a unified manner and could include civil designs (i.e., from delta shape to rectangular shape, as shown in Figure 4.39) – starting from a basic triangular (delta) planform.

A combination of the basic types of modifications could bring out any planform types currently in use. For example, a trapezoidal wing is a cropped arrowhead delta with a large span. Attaching "glove" in the leading edge is cranked from cranked delta configuration. Tailless UCV wing planform could be as shown in the figure.



(d-1) F16 – pure delta wing+strake (d-2) F18 – modified delta+large strake

(d) Two-surface wing planform – Conventional layout with strakes



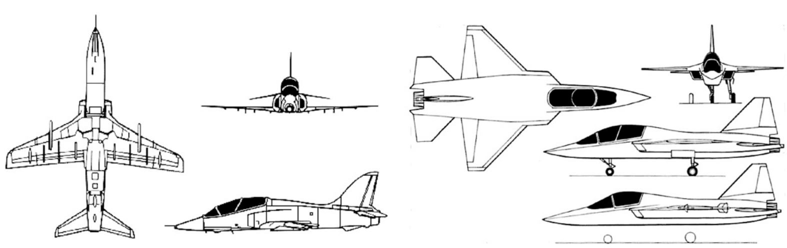
(e-1) Su 37 – Trapezoidal wing (e-2) SU 47 – Forward sweep+etc

(e) Three-surface wing planform – Canard+wing+H-tail

Figure 4.37 (*continued*)

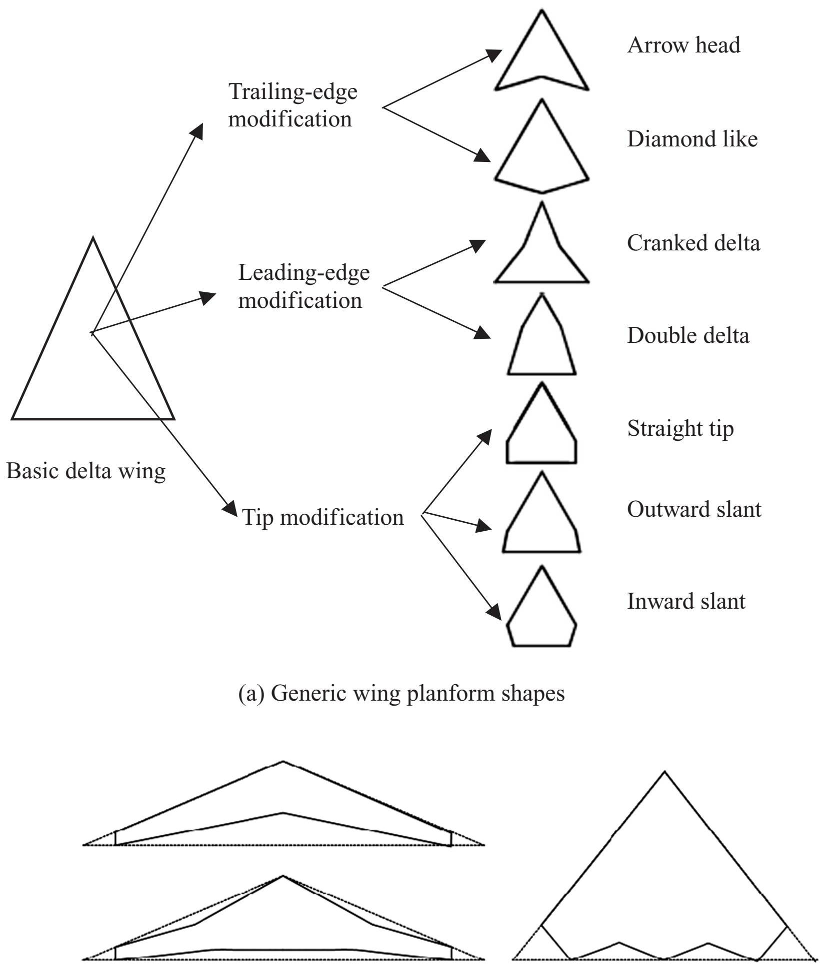
4.18 Empennage Group (Military)

Introductory comments expressed the complexity involved in control surface design, which are primarily of the empennage group. Having short tail arms (L_{HT} and L_{VT}), the stability (stabilizer/fin) and control surfaces (elevator/rudder) will necessarily need to be large in relation to the aircraft size to make fast responses. In many designs, the vertical tail is split into two (and could be placed slightly inclined in a shallow Vee for stealth reasons), as seen in the F18. The canted V-tail of the F22 is for stealth considerations. The horizontal tail is symmetrical to the vertical plane and has to be secured on the fuselage – some of the earlier designs had T-tail.



BAe Hawk – proven older design EADS MAKO

Figure 4.38. Advanced jet trainer aircraft capable of close support combat



(a) Generic wing planform shapes

(b) Example of some simple and complex wing planforms

Figure 4.39. Wing planform shape

Military aircraft control is achieved through fly-by-wire technology, which processes control deflection through onboard computers ensuring safety. If the pitch control demand is high, requiring flying in relaxed stability, then a canard surface in front of the fuselage would prove helpful. The FBW has achieved yaw control without V-tail – it is achieved through the differential use of aileron surface that can be split to open in both upward and downward directions, if simultaneously required. This book does not discuss control configured designs (CCV) – these require analysis of the control laws, which are not covered in this book.

Some military empennage configuration options are shown in Figures 4.30, 4.37, and 4.40. Older designs are dominantly conventional types (F4 Phantom – Figure 4.30(b)). Unconventional empennage exists (Figure 4.40(a)). Delta wings can have H-tail integrated within it, with reflex built-in at the trailing edge (Mirage 2000 – Figure 4.37(a)). An exception of an older design with two-canted vertical tail is shown in Figure 4.40(a) (YF12) . The YF12 design paved the way for current wing and empennage design options.

The B2 in Figure 4.40 appears to be tailless but its pitch control is at the inboard trailing edges and its directional/lateral controls are carried out by the controlled opening of the split alien on both sides. Much of the future will depend on how many lifting surfaces are used. Typically, a highly maneuverable combat aircraft will have large V-tail split into two and canted for stealth reasons. Trainer aircraft would favor the conventional type, with H-tail and V-tail.

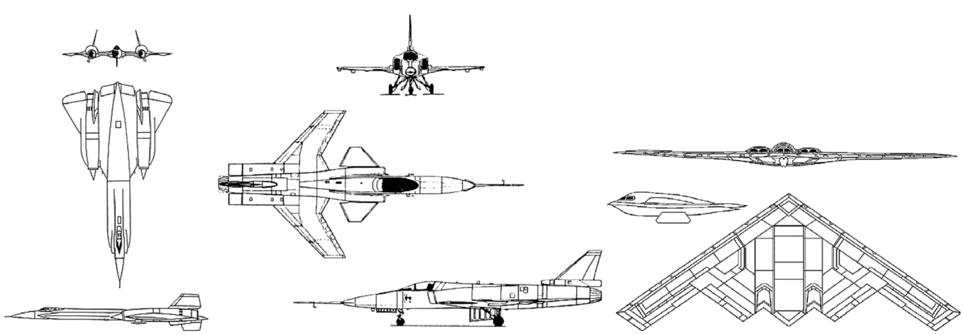
4.19 Intake/Nacelle Group (Military)

Typically, combat aircraft use aft fuselage to house the engine. A broader classification of military fighter aircraft engine-intake configuration is given in Chart 4.3 (examples in brackets). Note that the supersonic side intake has a side plate acting both as a boundary layer bleeder and a mechanism to adjust oblique shock. Engine nacelle options are shown in Figure 4.42.

Combat aircraft do not have pod-mounted nacelles. Single or multi-engines (so far, mostly two) are kept side-by-side and buried in the fuselage. Fighter aircraft intake path is longer and curvier. Older designs had forward intake at the nose (Figure 4.37(b-1) – MIG 21). For aircraft of more than Mach 1.8, capability is with a center body (bullet translates forward/backward to adjust bow oblique shock – MIG21). These have the longest intake ducts with low curvatures that pass under the pilot seat, and which incur high loss; hence, these are no longer intakes. Instead, chin-mounted (Figure 4.37(b-1) and (b-2)) or side-mounted (Figure 4.37(b-2), (c-2) and (e-2)) pursued have shorter ducts; carefully designed ducts have comparable curvature, therefore, incur with less loss. A plate is kept above the fuselage boundary layer on which the intake is placed. A center body is required for aircraft speed capability above Mach 1.8; otherwise, it would have pitot intake. Trapezoidal, slanted side intake (F22) is shown in Figure 4.30(e). The B2 has overwing/fuselage intakes (Figure 4.41(d)) more suited to a BWB type of configuration.

Bomber aircraft should have fuselage bay space for bombs and engines kept outside the fuselage. The B52 with eight pod-mounted engines is shown in Figure 4.27(b-1). Another bomber configuration has engines at the side of the fuselage in wing (Figure 4.41(f)). An odd type with over-the-fuselage engine installation is shown in Figure 4.41(c) and (d).

Intake design requires serious considerations of the full-flight envelope that must supply air to the engine without causing flow distortion at the engine face,



(a) Twin tail – inclined (b) Separate H-tail with wing (c) Appears tailless

Figure 4.40. Empennage options

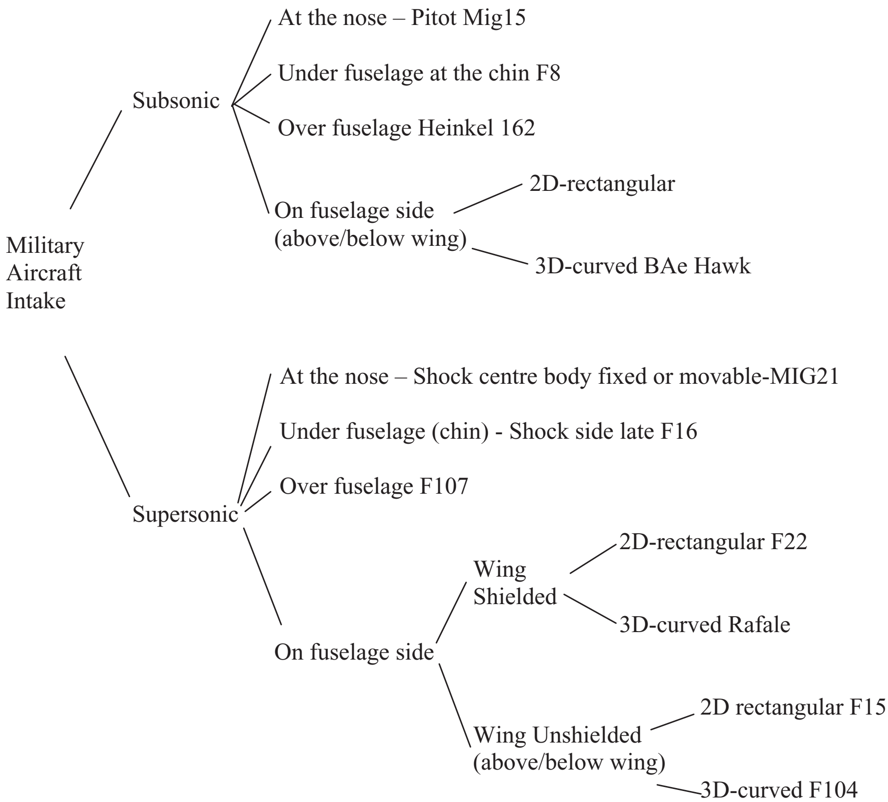
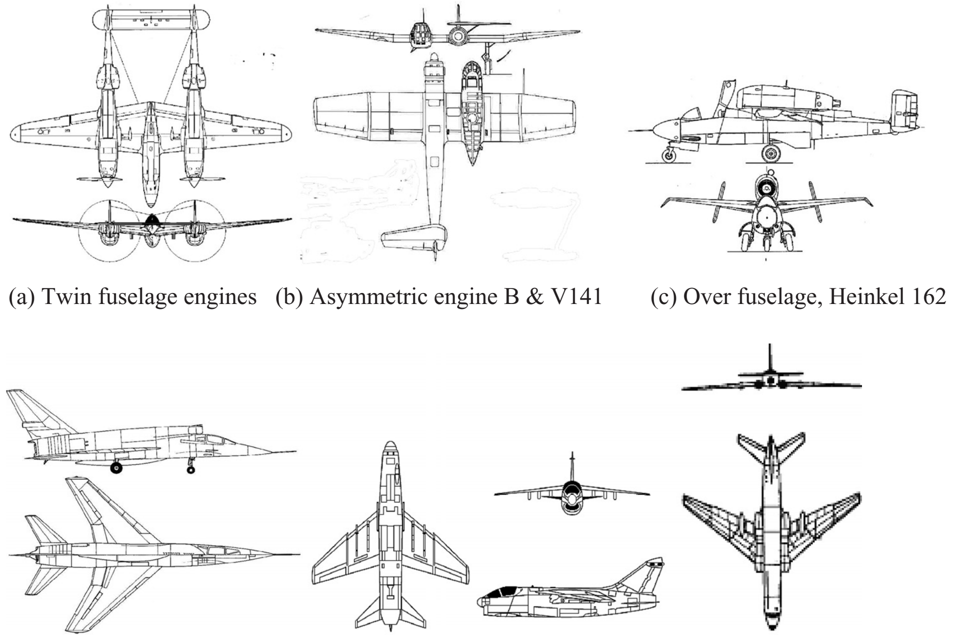


Chart 4.3. Types of empennage configurations

which can cause compressor surge and flame-out problems. The subject is discussed in Chapter 10.

In summary, intakes on fuselage have the following possibilities:

1. Central forward intake (invariably circular (MIG 21) – can be near circular (F100)). These are older designs that are no longer in use. Considerable duct loss is associated with its long length, from nose to tail; it is bent to pass under the pilot seat. For supersonic operation, a center body arrangement creates diffusion through a series of oblique shocks and a normal shock. Center intake does not have fuselage shielding at yaw and pitch attitudes.
2. Side intakes (semicircular, rectangular – e.g., F18 and F22) – cuts down the internal duct length by nearly half, but is associated with bends, which is less for two side-by-side engines. For supersonic operation, there is a splitter plate that bleeds the fuselage boundary layer to keep it outside intakes. It needs to be carefully sized for flying in yawed attitude.
3. Chin-mounted intake (near elliptical/kidney-shaped – e.g., Falcon F16, near rectangular – e.g., Eurofighter). These are later-designed aircraft. At yaw, chin intake does not have fuselage shielding as it could for side intakes; being close to ground, ground ingestion problems could occur, especially during war time. This concept has proven very successful and can handle high-incidence flying.



(a) Twin fuselage engines (b) Asymmetric engine B & V141 (c) Over fuselage, Heinkel 162

(d) Over fuselage, F107 (e) Forward intake, Corsair (f) Engines at side of fuselage

Figure 4.41. Options for engine positions of some older designs

4. Central over fuselage-mounted intake (as opposed to chin-mounted intake – e.g., Predator UCAV aircraft). This configuration is not prevalent; high-incidence flying may create serious flow distortion, affecting engine performance. This type of configuration is gaining ground because of stealth considerations.
5. Future designs will have stealth features and F22/B2/JUCAS-type nacelles will become common shapes of intake design.

4.20 Undercarriage Group

Undercarriages are discussed separately in Chapter 7.

4.21 Miscellaneous Comments

Sometimes, stability and control necessities require additional surfaces (e.g., ventral fin, dorsal fin, delta fin). Fairing between two intersecting bodies or the ability to enclose protruding objects plays an important role as flow modifier. Vortex generators are placed wherever necessary and are prominently seen on wing upper surfaces. Antennas/ducts, essential features that serve specific purposes, are seen in various places. Readers are encouraged to examine real aircraft kept statically on the tarmac. Every item seen on the external surface counts and contributes to drag.

In general, during the conceptual design phase, sizing of these features is done schematically. Sizing of trim surfaces becomes more appropriate when aircraft configuration is frozen. Initially, control surface sizing is done empirically during the CFD analysis in the second phase of the study and gets fine tuned by tailoring the surface during flight trials. In this book, trim surfaces are schematic – the main task of this book is to size aircraft and freeze the configuration during the first phase of the project.

4.22 Summary of Military Aircraft Design Choices

Presented in this chapter are building blocks for aircraft configuration that are used in Chapter 6. After establishing the specification requirements from a market study (Chapter 2), the classroom work starts in Chapter 6 by laying out aircraft configurations using the typical building blocks presented in this chapter. A quick browse of this chapter before starting aircraft layouts will prove beneficial. Following is a quick summary of military aircraft configuration layout.

Military Aircraft Layout*

1. Guesstimate the MTOM from Figure 4.38 (statistical value) for the payload range for the class.
2. Pick a wing area from Figure 4.39 for the MTOM. Decide on a single surface, two-surface, or three-surface design. (The decision needs aircraft control analysis – in this book, design is kept as a two-surface conventional design.) Next, decide wing geometry (e.g., sweep, taper ration, and t/c for the high-speed Mach number capability).
3. Decide on high wing, midwing, or low wing, based on customer requirements. Decide on wing dihedral or anehedral, based on wing position.
4. Decide on number of engines required. For fighter aircraft, this number is unlikely to exceed two engines. In this book, the choice is a single engine. The engine is invariably housed in the fuselage.
5. Shape the fuselage to house the engine and fit the wing and empennage. Guesstimate H-tail and V-tail sizes for the wing area.

Supersonic compressibility effects dictate military aircraft design. It invariably requires reactionary thrust, such as that of jet engines. Sharp-pointed nose features, large wing sweep with low aspect ratio, stealth features, and control configured features offer wider options. However, designers tend to be conservative in approach, taking pilot survivability as the most important consideration, while incorporating newer concepts to stay ahead of perceived threats. As combat technology leads toward unmanned battlefield operations, relaxed stability flying with FBW will make aircraft fly in higher *g*'s beyond human limits. *Star Wars* shapes for UAV aircraft are not an impossibility.

6.11 Configuring Military Aircraft – Shaping and Laying Out

Combat aircraft is a class of military aircraft, and this book keeps treatment general, concentrating on the trainer class design. Military transport aircraft have considerable similarity with civil transport aircraft design methodology, but the certification and equipment standards differ. To avoid duplication of the conceptual design work, a military transport design study is not covered in this book. Therefore, the term *military aircraft* in this book deals with military trainer aircraft with at least one variant in the combat role.

The military aircraft design methodology is outlined in Chart 6.2, which differs from Chart 6.1 on civil aircraft. The difference is in Step 1, after which the routine is about the same. The general approaches to military (combat) aircraft starts with guessing *MTOM* from statistics obtained from weapon load as payload and the radius of action as range. Combat aircraft return to base station and therefore the definition of range is not similar to the range of civil missions unless the aircraft is used for ferrying without weapons load. For trainer aircraft, even *radius of action* is meaningless because practice ranges are normally close to base. Training mission time substitutes for range and, with practice weapons load, are the statistical parameters used to obtain trainer aircraft *MTOM*. The training mission's endurance is nearly the same for all major Air Forces – in general. The requirement for a sortie is about 60 min to 75 min (can extend to 90 min) with a reserve of 30 min.

Unlike civil aircraft that has a "hollow" fuselage for variable payload accommodation, the combat aircraft fuselage interior is densely packed with fixed equipment. It does not have a constant fuselage cross section – each is design specific to suit its configuration, which is dictated by multiple considerations. Figure 6.15 shows the F16 fuselage (each cross section is different), typical in today's trend of having fuselage sides that blend with the wing – the mould lines could vary from design to design, but the considerations are about the same. The blending of fuselage with wing makes the fuselage contribute to body lift; improved area distribution reduces transonic drag and provides better wetted-area-to-volume ratio and a thicker wing root. Note the positioning of fuel storage and engine placement.

After obtaining *MTOM* from the statistics of existing aircraft, the next step is to get the wing reference area and engine thrust requirements, also initially from statistics. After the engine is selected and its dimensions are known, the fuselage can then be configured to house the engine at the aft end, two pilots and avionics at the front end, and fuel in the center between the intake ducts. The next step is to

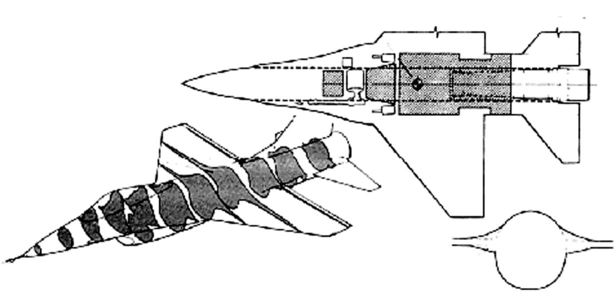


Figure 6.15. Falcon F16 fuselage cross section and layout

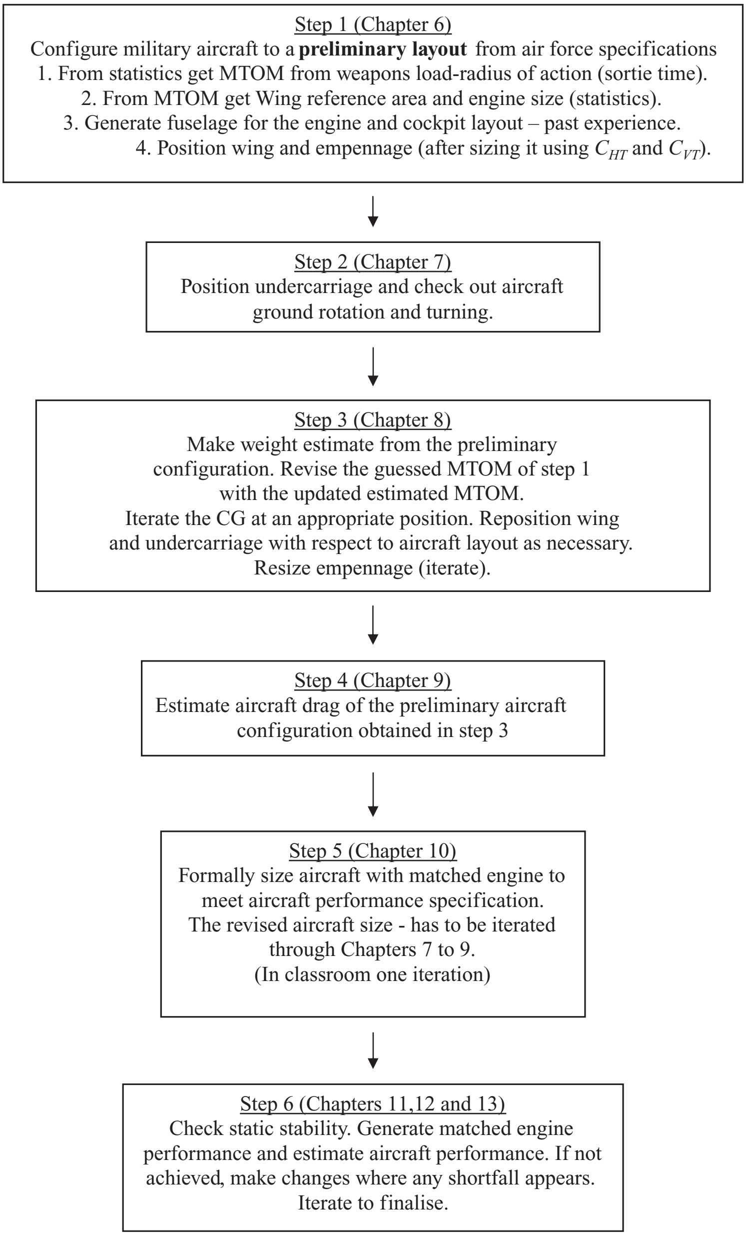


Chart 6.2. Phase I, conceptual Study: methodology to freezing military aircraft configuration. (Decision loops are similar to chart 6.1 but are not shown here.)

configure the wing, choose an aerofoil, and find empennage sizes and a location on fuselage. The worked-out example is an Advanced Jet Trainer (AJT) of the class of BAe Hawk.

Flight Deck design (cockpit – see Section 15.8) is an integral part of fuselage layout, as shown in Figure 6.16. A raised bubble canopy offers unrestricted view for the pilot in the upper hemisphere. The nose cone cavity houses the forward-looking radar and other black boxes.

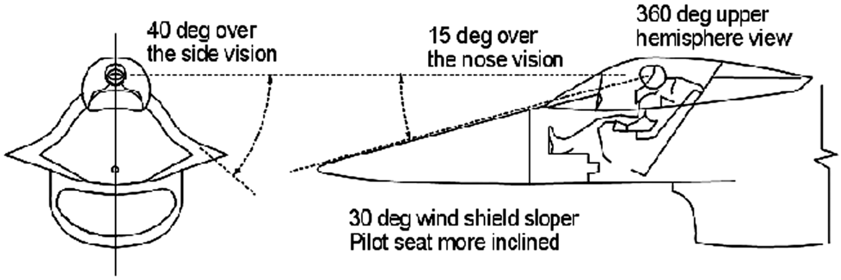


Figure 6.16. Flight deck (cockpit) layout – military aircraft

Stealth features are integral to current combat aircraft deigns. The basic concept of stealth is to reduce the aircraft signature to enemy sensing – more details are given in Section 15.10.3. The F16 is nearly a four-decades-old design and does not have stealth features. The F117 Nighthawk is an early stealth design; its configuration shows the difficulty associated with design. Designing a stealth configuration is beyond the scope of this book. With this in mind, a military trainer aircraft design study is given here, exposing some major considerations for combat aircraft design. The worked-out example is restricted to the turbofan-powered Hawk class trainer with a Close Air Support (CAS) variant.

Military aircraft operate at much higher '*g*' loads, both in pitch and lateral maneuver. Military aircraft with the same flight Mach number require a higher sweep and low aspect ratio to cater for maneuver and other considerations. Section 4.17.1 gives the generic wing planform choice for military aircraft. The dominant main wing planform shape is that of a delta or its variant; the low aspect ratio trapezoidal shape also is a candidate. For trainer aircraft, it would be the latter kind.

Military aircraft empennage sizing is quite complex. The military aircraft fuselage tail-arm is shorter. A higher rate of maneuver demands relatively large empennage areas. For stealth consideration (radar signature), the elimination of the V-tail is desirable. If such is not possible, then reduce the area with twin-canted V-tails and position above the fuselage to get blanking by it. The F22, F14, F15, F18, MIG29, and SU30 all have twin V-tails; the B2 does not have a V-tail.

Pitch control can be shared in many ways (e.g., a canard, vector thrusting). Today's military aircraft incorporate the proven technology of FBW system architecture (MIL1553 bus); therefore, the computer is flying the aircraft within the safe envelop; hence, empennage size can be reduced to the smallest size using the contribution derived from flying with relaxed stability margins for all the three axes of flight. A good knowledge of aircraft control laws is required at the conceptual design stage. However, this book does not venture into an area that goes beyond its scope when such information is lean.

Figure 6.17 gives a detailed exposé of military aircraft (F18) components, internal structural layout, and typical armament (payload) capabilities.

A variant of an AJT considered in this book is an aircraft with the CAS role. This aircraft is a single-seat version obtained by taking out one pilot seat with its associated instruments and equipments to reduce weight by about 200kg. However, a combat version has more advanced avionics, including forward-looking radar: the

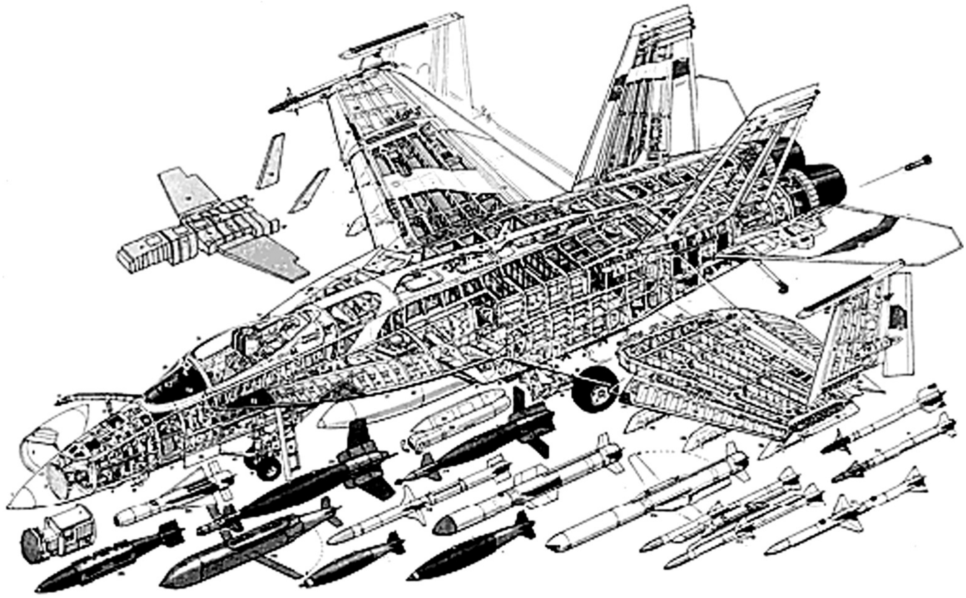


Figure 6.17. USAF F18 details showing internal structural layout and armament load

net result could make *MTOM* heavier than the fully loaded training mission load. The AJT has two *MTOM*, one at Normal Training Configuration (NTC) with no armament represented by $MTOM_{NTC}$ and the other, with full training weapon load using all hard points represented by *MTOM*. CAS has only one – *MTOM* with a full combat armament load. Training weapons are different from combat weapons: the former are low-cost practice weapons. (The concept of TTOM is introduced in Section 4.14.)

6.12 Worked-Out Example – Configuring Military Advanced Jet Trainer

The following subsections systematically develop the preliminary configuration of the AJT. There is no single way to start a conceptual study within the frame as given in Chart 6.2. Again, the author emphasizes that the example worked out here is merely to substantiate a methodology. Readers have the choice to decide their own configuration and explore freely. Example 5 of Section 2.7 is taken as the Air Force AST requirements for the AJT. Following are the given specifications.

Basic mission:	Combat training in jet aircraft up to operational conversion
Payload:	two 80 kg pilots and 1800 kg of practice armament
Training Mission:	Sortie duration of a maximum of 75 min + 30 min reserve
Engine:	one turbofan with low bypass ratio – no afterburning
Maneuver limits:	+7g to −3.5g
Maximum level speed	= 0.75 Mach

Because the variant design must be considered, its details are as listed below.

Basic mission:	Close air support
Payload:	one 90 kg pilot and 2500 kg of armament
Mission Profile:	Hi-Lo-Hi (see Chapter 11)
Sortie duration:	100 min +15 minutes reserve
Engine:	one turbofan with low bypass ratio – afterburning as option
Maneuver limits:	+7g to −3.5g
Maximum level speed	= 0.8 Mach

Military designs require some early decisions on how to configure the aircraft. In general, details can come with the AST of the Request for Proposal (RFP) from the MoD. In this case, a tandem seating arrangement (instructor's seat raised) with a high wing is desired by the Air Force (manufacturers may be consulted). A high wing is considered to be superior for aerodynamics and accessibility.

Earlier, it was mentioned that military aircraft design approach differs from that of civil aircraft design (see Table 2.2). Trainer aircraft conceptual study requires special attention. Here, a relatively inexperienced student pilot (typically with < 200 hr) is learning to fly in a stretched flight envelop, as opposed to two experienced pilots in the flight deck sharing routine work load in a safe flight envelop, and together they have logged thousands of flying time. A trainer aircraft needs to be safe and forgiving, with low wing loading. It has to satisfy two take-off weights (mass) conditions – that is, at (1) Normal Training Configuration (NTC) and at (2) Maximum Take-off Mass (MTOM) with practice weapons load. There is a discrete jump in aircraft mass with weapons load affecting aircraft handling qualities.

At this stage, some idea of aircraft geometry, weights, and thrust level have to be extracted from the statistics, and the figures subsequently will be formally sized. Statistical data on military trainers are relatively scarce and extracting information will require some experience. Whereas mass (weights) data could show some consistency, the wing area and the T_{SLS} requirements may exhibit scatter as a result of differing specifications. It is important here to lean closely to the type that the designer is intending to design.

Competing in the class is one of the World's bestAJT, the BAe Hawk200. Every attempt should be made to conceive a design that is better than the Hawk200, at least on paper. AJT's speed capability is slightly curtailed to reduce weight – this does not degrade training obligations, but the maximum speed of the CAS variant would be slightly higher than that of the Hawk100 (combat variant).

Military aircraft fuselage design is different from civil aircraft design. Every military aircraft fuselage design differs in its special requirements. The nacelle is integral with the fuselage because engines are buried into it. The wing and empennage designs follow almost the same step-by-step procedure as those of civil aircraft design and hence are not repeated here.

6.12.1 Use of Statistics in the Class of Military Trainer Aircraft

Statistics given in Section 4.14 relate to the operational Combat class. It is better to generate more refined statistics of the military trainer class of aircraft to work

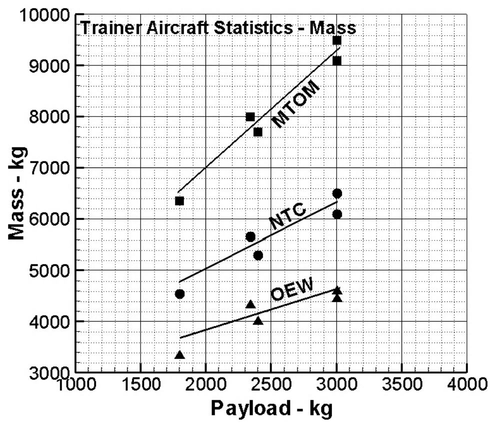


Figure 6.18. Military trainer aircraft – MTOM

with the task in hand. The author recommends that the readers make such graphs in better resolution for the class of aircraft under consideration.

Because trainer aircraft has to deal with two take-off masses (at NTC and at MTO), it is convenient, first, to extract data for the aircraft masses using the payload as the driver, hoping that its wing and engine sizes from the statistics would give satisfactory results as compared to the existing kind. These subsequently will be properly sized – this point will be emphasized again and again.

Figure 6.18 gives the statistics of payload (armament load) versus MTOM. Also shown in the graph is the OEM of theAJT. Aircraft used in the statistics are MB339 (Italy), MIG AT (Russia), L159 (Czech), Hawk (UK, NTC mass = 6100 kg), and YAK 130 (Russia). After MTOM is decided from the payload, statistics in Figure 6.19 (with scatter) are used to obtain wing reference area and engine size. These are the only preliminary data that will be formally fine tuned in Chapter 11 by proper wing sizing with a matched engine.

With the AJT armament load of 1800 kg, Figure 6.18 indicates a $MTOM$ of = 6500 kg and OEM = 3700 kg. (It will be shown that the $MTOM_{NTC}$ = 4800 kg without armament. The values will be updated when AJT mass is computed in Chapter 8.) Its reinforced and modified structure is the CAS variant. With the CAS armament load is 2500 kg; the $MTOM$ is expected to be around 8000 kg. The fine-tuned weight after proper weight estimation would be different from what is

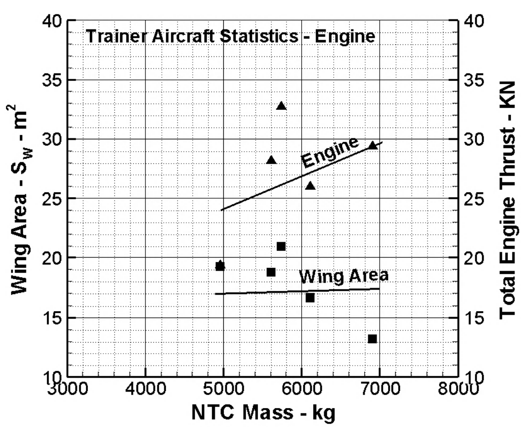


Figure 6.19. Military trainer aircraft wing area and engine size

indicated by the statistics. The figures would be iterated as more information is generated. The aim is to make new design better than any existing aircraft in the class. This is where the experience of designers counts.

Training aircraft wing is considered in relation to $MTOM_{NTC}$ to cater for training. Figure 6.19 exhibits scatter in statistics because of scanty data; military aircraft specifications also can vary considerably. Corresponding to $MTOM_{NTC} = 4800$ kg, the figure gives the wing reference area as S_W of 17 m^2. The same graph gives engine size as 24KN (5390 lb) – subsequently, it will be formally sized. The importance of referring to existing designs to make a preliminary aircraft configuration as a starting point can now be appreciated.

It is important that a proven, reliable engine from a reputed manufacturer be chosen. Only one engine in the market gives this range of thrust – the RR-Turbomeca Adour 861 with 0.75 bypass ratio gas turbine. The Honeywell ATF120 could compete, but this book takes the more established, proven engine, constantly upgraded to stay abreast with technology. The Adour 861 (Ref. 6.1) has a length of 1.956 m (77 in), fan face diameter of 0.56 m (22 in), maximum depth of 1.04 m, maximum width of 0.75 m, and dry weight of 603 kg (1330 lb). The engine can be tweaked to 30 KN for the CAS role.

6.12.2 Worked-Out Example – Advanced Jet Aircraft (AJT) – Fuselage

Because the military aircraft fuselage houses the engine, the intake design is integral to fuselage layout. The choice of intake positioning is given in Section 4.19. In this example, a high wing configuration takes the proven type of side-mounted intakes. The inlet duct area will be sized in Chapter 10. At this stage, a statistical value is taken.

Figure 6.20 outlines in detail a tandem seating arrangement for the AJT, with the instructor's rear seat raised for a better view above the student in front. The overall length is 12 m (39.4 ft) Note the varying cross section of the fuselage housing the turbofan. Provision for internal fuel tanks is made between the two air intakes at each side of the fuselage and in the wing (Figure 6.21). The fuselage is split into front and rear sections to facilitate variant designs. The front fuselage can be replaced by a single-seat version, with the cockpit layout arranged to suit CSA variant. In the example, the front fuselage shows a similarity with the Jaguar trainer front fuselage mould lines.

Wing

The main wing planform shape is that of a low aspect ratio trapezoidal shape. At this stage, most of the geometric dimensions are taken from the statistics. The high rate of roll maneuver restricts aspect ratio to minimize the wing root bending moment. It may initially be positioned with mid-MAC approximately in the center of the fuselage. In practice, aspect ratio should be decided in consultation with structural designers. Rigorous aerodynamics optimization to decide best aspect ratio would prove unrealistic without structural consideration. Wing aspect ratio in this class varies from 4.7 to 5.7. In the absence of structural considerations, a statistical value of 5.3 is taken. Sensitivity studies in Table 11.8 shows that within the small variation, a 0.1 change in aspect ratio changes about 40 kg in weight – it is a relatively small

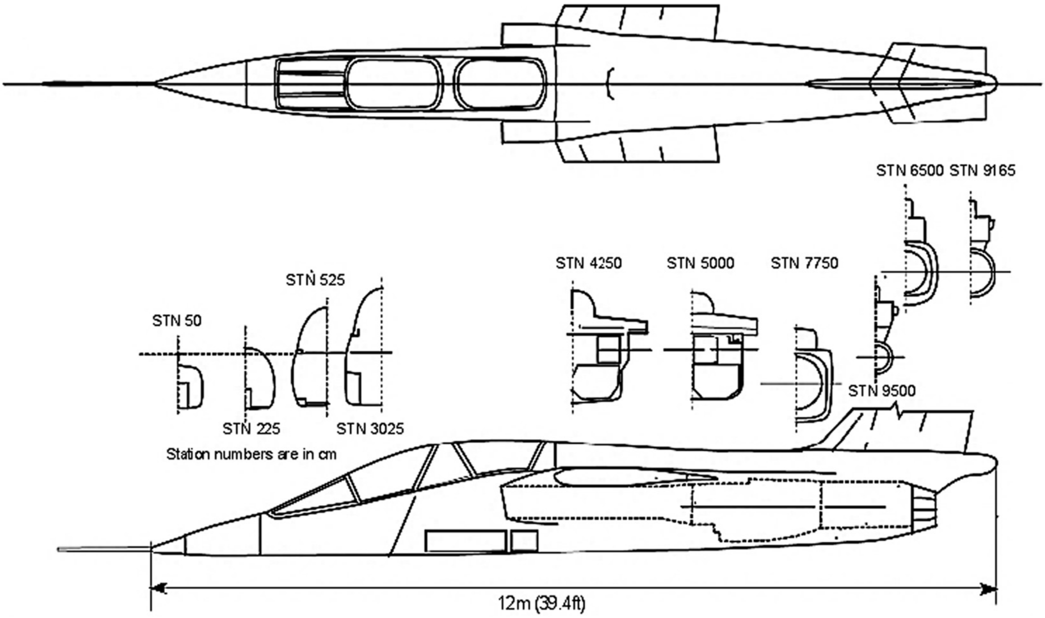


Figure 6.20. AJT fuselage layout

amount. Wing taper ratio $\lambda = 0.35$, wing sweep $\Lambda_{1/4} = 20$ deg, and average aerofoil thickness-to-chord ratio =10% are taken for its maximum speed of Mach 0.82. The trapezoidal planform area = 17 m^2 (183 ft^2). A high wing arrangement is the AST requirement – this gives better spanwise lift distribution. It also gives enough under-wing clearance for movement and inspection. Refueling is done over the wing.

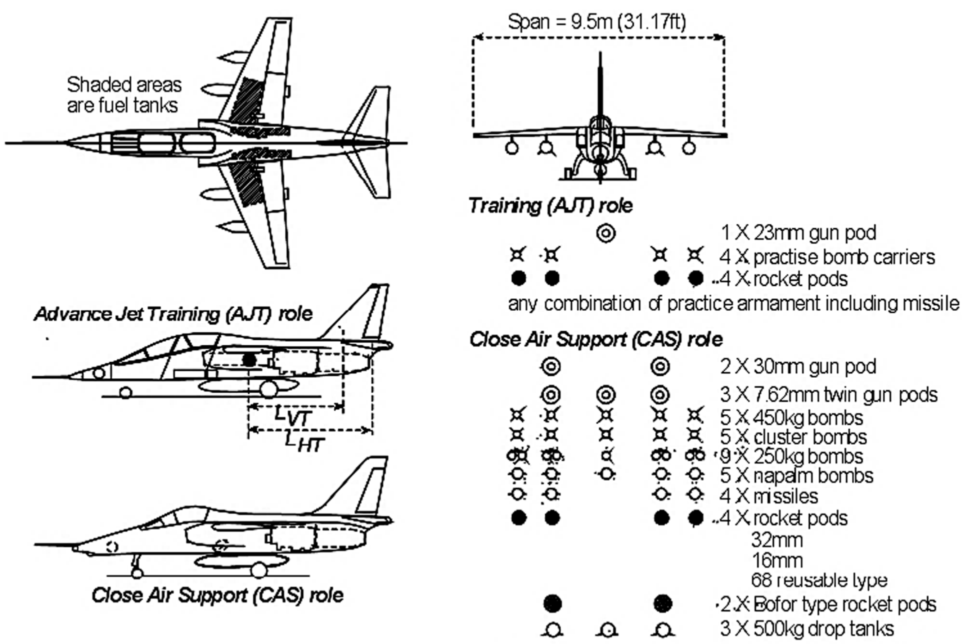


Figure 6.21. AJT and its CAS variant

Table 6.3. *Flap setting versus CL_{max}*

Flap/slat deflection – deg	0/0	8/4	20/10	40/20
$C^L max$	1.5	2.0	2.2	2.5

Aerofoil section is the well-known NACA 65_3-211 section at the root and NACA 65_3-210 at the tip. Like the civil aircraft example, the following are worked out: span 9.5 m (31.17 ft), root chord = 2.65 m (8.69 ft), tip chord = 0.927 (3.04 ft). Using Equation 3.21, the MAC works out to be 1.928 m (6.325 ft). Other parameters of interest are twist of 2 deg (wash out). Being a high wing and having a 20-deg sweep, it will have a high roll stability for a military aircraft. Therefore, an anhedral of 2 deg is used to improve agility by reducing roll stability. It is understood here that this is a heuristic approach to design, depending on designer experience, and has to be substantiated through CFD and wind tunnel testing. This is part of the learning process.

Figure 6.21 gives the three-view diagram of the AJT, showing wing planform and other details. Flap and aileron areas are taken from statistics to be 2.77 m^2 and 1.06 m^2, respectively. Single-slotted Fowler action trailing edge flaps and leading edge slats are chosen. Eventual performance analysis will ascertain whether these assumptions satisfy field performance specifications; if not, the design will have to be iterated with a better flap design. From test data, the following maximum lift coefficients are taken (Table 6.3).

The wing could be manufactured in one piece: the fuselage internal structural layout is complex, with integrally milled frames that include wing attachment points. Integrally milled structures ease maintenance, thus they suit military operations. Position the wing in relation to the fuselage at approximately the middle. Note that a high wing design does not necessarily need a fairing under the wing to house undercarriage, which is housed in the fuselage.

Empennage

AJT is configured as high wing design. The CG position (shown in Figure 6.21) of the aircraft may be taken at the quarter chord of MAC. A military aircraft tail arm is shorter than that of civil aircraft and along with higher rate of maneuver, it demands a relatively large empennage. The main wheels are positioned initially at about 60% of *MAC* (guess). This will be revised with iteration as soon as component weights are estimated.

Place the H-tail at the extreme end of the fuselage to maximize tail arm [L_{HT} = 4.9 m (15.74 ft). Then place the V-tail (typical geometry conforming to statistics) slightly forward so that it is not shielded by the H-tail (keep at least 50% of the rudder area unshielded). The V-tail arm is positioned with L_{VT} = 3.8 m (12.47 ft). Empennage areas are still preliminary and will be iterated to final size. Make the H-tail sweep $\Lambda_{1/4}$ = 25 deg and V-tail sweep $\Lambda_{1/4}$ = 35 deg. These are slightly higher than the wing sweep to gain tail arm. The tail volume coefficients are C_{HT} = 0.7 and C_{VT} = 0.08. The vertical tail volume coefficient is higher than in the civil aircraft example to ensure that sufficient rudder is available for spin recovery.

Wing reference area = 17 m^2 and MAC = 1.844 m have already been established.

V-tail sizing: Equation 3.30 gives

Vertical tail reference area $S_{VT} = (C_{VT})(S_W \times wing\ span)/L_{VT}$

Hence, $S_{VT} = (0.08 \times 17 \times 9.5)/3.8 = 3.83$ m^2 (41.1 ft^2)

Finalize the V-tail design with other pertinent details:

V-tail area = 3.83 m^2
$\Lambda_{1/4} = 35^\circ$, t/c = 9%
AR = 1,52, span = 2.135
tail arm = 4 m (13.1 ft)

Keeping fin area = 2.85 m^2 (30.6 ft^2), the rest being rudder area.

With properly computed geometry, find a more accurate L_{VT} and iterate a more accurate V-tail geometry.

H-tail sizing: Equation 3.31 gives

H-tail reference area, $S_{HT} = (C_{HT})(S_W \times MAC)/L_{HT}$

Then $S_{HT} = (0.7 \times 17 \times 1.928)/4.8 = 4.78$ m^2 (51.45 ft^2), which is partly buried into fuselage.

This area has to be shared by the elevator and the stabilizer. Normally, rudder takes 18% to 25% of V-tail area; in this case, 20% is taken. This gives an elevator area of 0.956 m^2 (10.3 ft^2).

Finalize the H-tail with other pertinent details:

H-tail area = 4.78 m^2 (51.45ft^2)
$\Lambda_{1/4} = 25$
t/c = 9%
AR = 3.5
Span = 4.2m
Tail arm = 4.9m
Elevator = 1.5m^2

With properly computed geometry, find a more accurate L_{HT} and iterate an accurate H-tail geometry.

It is interesting to note how the aircraft is gradually taking shape – still based on designer past experience and statistics. It will be formally sized in Chapter 11. A preliminary 3-view diagram of the AJT aircraft can now be drawn, as shown in Figure 6.21. This will be revised as soon as the aircraft component weights are estimated and proper CG location is established. The next iteration would be after aircraft sizing (Chapter 11). Final iteration is to be carried out after performance estimation (Chapter 13).

Undercarriage Positioning

Chapter 7 gives the details of AJT undercarriage (landing gear) design. Undercarriage positioning is CG dependent, but at this stage the CG position is not established. Position the undercarriage – guessing the CG position – and check rotational tail clearances. Make sure that the aircraft does not tip in any direction for all possible weight distributions.

6.12.3 Miscellaneous Considerations – Military Design

Intake: As indicated earlier, combat aircraft have engines buried inside the fuselage and do not have podded nacelles. It makes the term *nacelle* redundant; instead the term *intake* is used. If there is more than one engine, these are kept close coupled within the fuselage to minimize asymmetric thrust in case one engine fails. Figure 6.21 gives a good perspective of where the engine is installed inside the fuselage. Side intakes start just behind the rear pilot so as not to obstruct the side, downward view.

CG Position: To keep the CG forward, the engine position should be brought as far forward as possible for the layout without creating excessive intake duct curvatures – here is where design experience counts. An engine buried inside the fuselage requires fuselage side intakes with bent ducts joining the engine on the centerline. An intake duct with a gradual bend not exceeding 6 deg at any point enables the engine position. The bends should be gentle to avoid separation, especially at asymmetrical flight attitudes.

Nozzle: Exhaust jet pipes could be longer to suit the engine position in relation to fuselage length. It goes right up to the fuselage end. There could be significant problems with engine exhaust entrainment interfering with the low H-tail. Here a *pen-nib* type fuselage profile could save weight by limiting the exhaust pipe length. Military engines do not have large *BPR*. Mission profiles are throttle-dependent during training/operation. Weapons release involves serious considerations for CG shift, aerodynamic asymmetry, and store separation problems. These are tackled through careful analysis using CFD and wind tunnel testing.

6.13 Variant CAS Design

Figure 6.21 also gives the CAS variant of AJT with possible combinations of weapons within a disposable maximum armament load of 2500 kg. The CAS variant is derived from AJT by exchanging the two-seat front fuselage module with a single-seat pilot module. The CG position is unaffected by carefully positioning additional avionics black boxes, especially the forward-looking radar at the nose.

6.13.1 Summary of the Worked-Out Military Aircraft Preliminary Details

Chapter 11 sizes the aircraft to final dimensions to freeze the configuration, after which, aircraft and component mass iteration is made.

AJT Market Specifications

Payload = 1800 kg	Range = 1200 km 9 km altitude
HSC Mach = 0.75	LRC Mach = 0.7
Initial climb rate = 40 m/s	Initial cruise altitude = 9 km
Take-off distance = 1100 m	Landing distance = 1000 m

Baseline Aircraft Mass (from statistics – needs to be generated from the variant CAS design). See end of the Section for the CAS specifications.

$MTOM = 6500$ kg (15210 lb)	$NTCM = 4800$ kg (10800 lb)
$OEM = 3700$ kg	Fuel mass = 1300 kg

Baseline External Dimensions

Fuselage (determined from capacity)
Length = 12 m (39.4 ft)
Maximum overall width = 1.8 m   Overall height (depth) = 4.2 m
Cockpit width = 0.88 m   Fineness ratio = 12/1.8 = 6.67

Wing

Planform (reference) area = 17 m^2 (183 ft^2)   Span = 9.5 m (31.17 ft)
Root chord, C_R = 2.65 m (8.69 ft)   Tip chord, C_T = 0.927 m (3.04 ft)
MAC = 1.928 (6.325 ft)   Taper ratio, λ = 0.35 $\Lambda\frac{1}{4}$ = deg
Dihedral = –2deg (anhedral – high wing)   Twist = 1 deg (wash out)
Flap = 2.77 m^2 (29.8 ft^2)   Aileron = 1.06 m^2 (11.4 ft^2)

V-tail

Planform (reference) area = 3.83 m^2 (41.1 ft^2)   Span = 2.135 m (7 ft)
Root chord, C_R = m (ft)   Tip chord, C_T = m (ft)
MAC = 2.132 (7 ft)   Taper ratio, λ = 0. $\Lambda\frac{1}{4}$ = 35 deg
Aspect ratio = 1.52   Tail arm = 4 m (13.1 ft)
Rudder area = 0.98 m^2 (10.5 ft^2)   t/c = 9%

H-tail

Planform (reference) area = 4.78 m^2 (51.45 ft^2)   Span = 4.2 m (13.8 ft)
Root chord, C_R = m (ft)   Tip chord, C_T = m (ft)
MAC = 2.132 (7 ft)   Taper ratio, λ = 0. $\Lambda\frac{1}{4}$ = 25 deg
Aspect ratio = 3.5   Tail arm = 4 m (13.1 ft)
Elevator area = 0.956 m^2 (10.3 ft^2)   t/c = 9%

Engine

Take-off static thrust at ISA sea level = 5390 lb   BPR = 0.75
Dry weight = 603 kg (1330 lb),   Length = 1.956 m (77 in)
Fan diameter = 0.56 m (22 in)   Maximum width = 0.75 m (2.46 ft)
Maximum depth = 1.04 m (3.4 ft)

Nacelle: None as engine is buried into fuselage.

CAS Variant (All component dimensions except fuselage length are kept unchanged.)

Market Specifications

HSC Mach = 0.8   LRC Mach = 0.7
Initial climb rate = 50 m/s   Initial cruise altitude = 9 km
Take-off distance = 1400 m   Landing distance = 1200 m

CAS Aircraft Mass (from statistics)

$MTOM = 8200$ kg   Payload = 2500 kg
$OEM = 4600$ kg   Fuel mass = 1800 kg

Fuselage

Length = 12 m (39.4 ft)   Overall height (depth) = 4.2 m
Maximum overall width = 1.8 m   Fineness ratio = 12/1.8 = 6.67
Cockpit width = 0.88 m

8.6.2 Military Aircraft (Combat Category)

Generic military aircraft component mass is listed in MIL-STD-1374 in exhaustive detail, which is not required in the conceptual design stage. As with civil aircraft design, this section presents a consolidated generalized group for what is required at the conceptual design phase. Note that military aircraft do not have cabin crew and passengers. The payload is weaponry and is mostly carried externally. Guns are installed internally and are integral to the structure. Firing rounds are seen as consumable.

Structure Group ($M_{STR} = M_F + M_W + M_{HT} + M_{VT}\ M_N + M_{FARM} + M_{PY} + M_{UC} + M_{MISC}$)

The first seven components of the structures group are the same as those in a civil aircraft case. Add the following. Here, the purpose of pylons is to carry weapon.

8. Fixed armament (M_{FARM}), e.g. internal guns, etc.
9. Pylon – to carry armament load/drop tank

Power Plant Group ($M_{PP} = M_E + M_{RD} + M_{EC} + M_{FS} + M_O$)

The five components of the power plant group are the same as those in a civil aircraft case. These are renumbered from 10 to 14. Thrust reverser is replaced by a retarding device (M_{RD}) (e.g., brake parachute, arrester hook).

10. Dry Equipped Engine (M_E)
11. Thrust Retarder (M_{RD})
12. Engine Control System (M_{EC})
13. Fuel System (M_{FS})
14. Engine Oil System (M_{OI})

Systems Group (M_{SYS})

15. Environmental Control system (M_{ECS}) – considerable less number to serve
16. Flight Control System (M_{FC}) – considerably complex
17. Hydraulic/Pneumatic System (M_{HP}) – sometimes lumped with other systems.
18. Electric System (M_{ELEC})
19. Instrument System (M_{INS}) – more extensive
20. Avionics System (M_{AV}) – more extensive
21. Ejection Seat System – no longer treated as furnishing (M_{EJ})
22. Oxygen System – no longer treated as furnishing. (M_{OX})

Furnishing (M_{FUR})

23. Paints (M_{PN}) – (stealth coating is heavy)
24. Contingencies (M_{CONT}) – a margin to allow unspecific weight growth

MEM (Manufacture's Empty Mass) – total of above items

25. Crew (M_{CREW}) – flight crew/crews
26. Consumables (M_{CONS}) – generally firing rounds (long-duration flight have consumables for the crew)

OEM (Operators Empty Mass)

27. Payload – armament (M_{ARM})

28. Fuel (M_{FUEL}) – for the design range, which may not fill all tanks

[If drop tank are carried, then add (M_{DT}) + ($M_{DT\cdot FUEL}$).]

MRM (Maximum Ramp Mass)

In this book, treat ***MTOM* = *MRM*** in military design. Military Aircraft $MTOM$ is the sum of masses of all component groups listed below.

$MTOM = \int M(x)\,\mathrm{d}x = \sum M_i$, where subscript i stands for each component group listed above.

$$\begin{aligned} MTOM = {} & (M_F) + (M_W) + (M_{HT}) + (M_{VT}) + (M_N) + (M_{PY}) + M_{FARM} + (M_{UC}) \\ & + (M_{MISC}) + (M_E) + (M_{RD}) + (M_{EC}) + (M_{FS}) + (M_{OI}) + (M_{ECS}) \\ & + (M_{FC}) + (M_{HP}) + (M_{ELEC}) + (M_{INS}) + (M_{AV}) + (M_{EJ}) + (M_{OX}) \\ & + (M_{PN}) + (M_{CONT}) + (M_{CREW}) + (M_{CONS}) + (M_{ARM}) + M_{FUEL} \\ & + (M_{DT}) + (M_{DT\_FUEL}) \end{aligned} \tag{8.11}$$

National defence requirements made military designs evolve rapidly, incorporating new technologies at a considerable cost to stay ahead of potential adversary. Whereas miniaturizations of electronic and other equipments reduce onboard mass, increased demand in combat capabilities worked in the opposite direction to add mass. Combat aircraft size kept growing to exceed 35000 kg for multirole fighter aircraft. Earlier, it was holding on to around 16000 kg. With improved missile capabilities, aircraft performance demand is now somewhat changed, especially in reaching maximum speed. Combat aircraft take-off mass varies according to mission requirement. The Typical Take-off Mass ($TTOM$) is less than $MTOM$. It is beneficial to have a small lightweight fighter, but currently with less than 12000 kg of $MTOM$, armament capacity and radius of action would suffer. The following points are pertinent to military aircraft component mass estimation methodologies.

1. Predominantly, engines are buried in the fuselage; hence, there is no wing relief benefit.
2. A combat role has a wide spectrum of activities, as outlined in Section 4.12. In general, Close Support/Ground Attack aircraft (no afterburning engines) are subsonic with quick turning capabilities, whereas Air Superiority Aircraft have supersonic capabilities with afterburning turbofans.
3. Modern supersonic combat aircraft configurations show considerable wing–body blending. It becomes relatively difficult to identify the delineation between the fuselage and wing. The manufacturing joint between the wing section and fuselage block is a good place to make the partition, but at the conceptual phase the manufacturing philosophy is unlikely to be finalized. For classroom purposes, one way to decouple the wing and fuselage is to see the blend as a large wing root fairing that allows the fuselage to separate when the fairing part is taken as part of the wing.
4. Dominantly, all payload is externally mounted except for bigger designs, which could have internal bomb load. Modern military aircraft have external load that is contoured and flushed with mold lines. Internally mounted guns are

permanent fixtures. Training military aircraft pylons to carry external load are not taken as permanent fixtures.

5. Consumables (e.g., firing rounds) are internally loaded. In general, for long-range missions, there is more than one crew and some consumables meant for the crew.
6. Military designs are technology specific and as a result, unlike civil design, military designs exhibit large variations in statistical distribution.

8.13 Rapid Mass Estimation Method – Military Aircraft

Military aircraft follow the same procedure for rapid mass estimation method as that of civil aircraft but have a different mass fraction (shown in percentage) of maximum take-off mass ($M_i/MTOM$), where subscript i represents ith component. Unlike civil aircraft, each generation of military aircraft takes a bigger leap toward advanced technology driven by the requirements of national security more than profit. Reference [8.4] gives an exhaustive list of weight breakdown for many relatively older military aircraft designs. A new design should show improvements, especially of newer technologies (e.g., new materials, lighter systems). Section 8.6 explains how to obtain component mass per unit wing area (M_i/S_W, kg/m^2). Tables 8.8 (combat and trainer aircraft) gives ballpark figures of mass fraction (in percentages) for arriving quickly at a starting point for the initial configuration obtained in Chapter 6. This time, a wider variation of ±15% (may exceed in a few designs) may be allowed to accommodate a wide range of variation.

Note that the *OEM* fraction in the table agrees with the trend of actual aircraft data shown in Figure 4.34. Lighter aircraft would show a higher mass fraction. A fuselage-mounted undercarriage is shorter and lighter for the same *MTOM*. These tables give some idea of component masses at an early project stage. It is best to use more accurate semi-empirical relations (Section 8.15) to obtain component masses at the conceptual phase. These tables would prove useful to guess masses (e.g., fuel mass, engine mass, etc.) required as a starting point for some semi-empirical relations.

8.14 Graphical Method to Predict Aircraft Component Weight – Military Aircraft

Not much graphical statistical data on military aircraft component mass is available in the public domain. References [8.1] and [8.4] are good sources from which to obtain military aircraft component mass. Note that graphs are in the FPS system (raw data taken from Reference [8.4]). As expected, they show wide variation, yet there is a trend through linear regression. Figures 8.5 to 8.10 give the component weight graphs.

8.15 Semi-empirical Equation Methods (Statistical) – Military Aircraft

Like civil aircraft, military aircraft have their own sets of semi-empirical relations derived from theoretical formulation and refined with statistical data. As in civil mass estimation, there are several forms of semi-empirical weight prediction formulae proposed by various analysts, all based on the key drivers and with refinements as perceived by the proposer. They are similar in nature and yield close enough results. References [8.2] to [8.6] offer more information on weight prediction. The following subsections provide aircraft component weight (mass) semi-empirical formulae, component by component.

8.15.1 Military Aircraft Fuselage Group (SI System)

Military aircraft do not have a constant section fuselage and are more densely packed. A combat aircraft fuselage is not pressurised (only the cockpit is). In a

Table 8.8. *Military trainer aircraft mass fraction (see Section 8.6.1 for symbols)*

		Trainer		Combat (all turbofan)		
		Turboprop	Turbofan	Close support	Fighter	Bomber
Group			10–12	9–11	8–10	
Fuselage	*Ffu* = *MF/MTOM*		7–9	11–14	7–10	
Wing	*Fw* = *Mw/MTOM*		1.4–1.8	1.2–1.6	1–1.5	
H – Tail	*Fht* = *Mht/MTOM*		0.7–0.9	0.8	0.7–1	
V – Tail	*Fvt* = *Mvt/MTOM*		0.8–1.2	1–1.2	1.5–2	
Intake	*Fin* = *Min/MTOM*		0.3–0.5	0.2–0.4	0.2–0.3	
Pylon (weapon)	*Fpy* = *Mpy/MTOM*		3–5	5–7	2.5–4	
Undercarriage	*Fuc* = *Muc/MTOM*		1–1.2	1–1.2	1–1.2	
Fixed Armament	*Farm* = *Marm/MTOM*		9–11	11–12	8–12	
Engine	*Fuc* = *Muc/MTOM*		0	0.4–0.6	0.5–0.8	
Retarding Device	*Ftr* = *Mtr/MTOM*		0.5–0.8	1–1.6	0.7–0.9	
Engine Con.	*Fec* = *Mec/MTOM*		0.5–0.6	2–3	2–3	
Fuel Sys.	*Ffs* = *Mfs/MTOM*		0.2–0.4	0.2–0.4	0.3–0.4	
Oil Sys.	*Fos* = *Mos/MTOM*		2–2.5	2–2.5	1.5–2	
Flight Con. Sys.	*Ffc* = *Mfc/MTOM*		0.5–0.8	0.5–0.8	0.8–1	
Hydr/Pneu Sys.	*Fhp* = *Mhp/MTOM*		2–2.5	1.5–2	1–1.4	
Electrical	*Felc* = *Melc/MTOM*		0.6–1	0.4–0.5	0.5–0.6	
Instrument	*Fins* = *Mins/MTOM*		3–4	3–6	4–6	
Avionics	*Fav* = *Mav/MTOM*		0.6–1	0.5–0.8	1–1.2	
ECS + oxygen	*Fecs* = *Mecs/MTOM*		1.2–1.5	1–1.4	1–1.4	
Seat + Escape Sys.	*Ffur* = *Mfur/MTOM*		0	1	1	
Misc.	*Fmsc* = *Mmsc/MTOM*		0.01	0.01	0.01	
Paint	*Fpn* = *Mpn/MTOM*		1	1	1	
Contingency	*Fcon* = *Mcon/MTOM*					
MEW – %			52–56	58–64	49–53	
Crew			5–6	0.8–1.2	0.8–1	
Consumable			0	0	0	
OEW – %			57–60	60–65	50–54	
Payload and fuel are traded						
Payload			15–25	15–20	20–25	
Fuel			15–20	18–20	20–25	
MTOM – %			100	100	100	

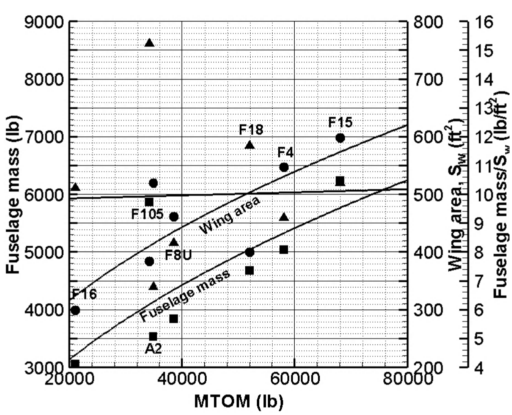


Figure 8.5. Military aircraft fuselage mass

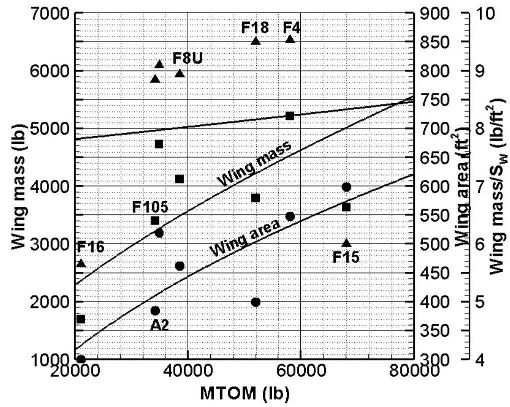


Figure 8.6. Military aircraft wing mass

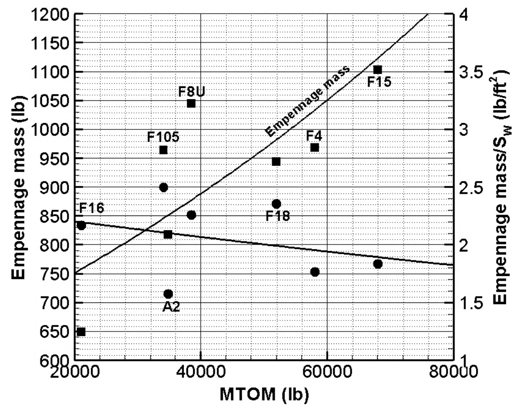


Figure 8.7. Military aircraft empennage mass

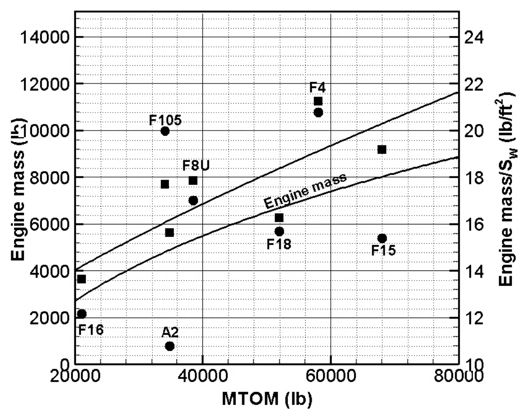


Figure 8.8. Military aircraft engine mass

blended body, it is not easy to lineate fuselage line from the wing. The best would be construction specific, where the joining line of the wing is the line for fuselage. It is much simpler for the example of the AJT in hand. In this case, take D_{ave} = average of the shape around the engine (see Figure 6.32). The expression includes fuselage-mounted side/chin intakes.

$$M_{Fmil} = c_{fus} \times k_{uc} \times k_{mat} \times k_{para} \times k_{intake} \times (MTOM \times n_{ult})^{0.002} \times (L \times D_{ave} \times V_D{}^{0.5})^{1.52}$$

where $c_{fus} = 0.175$

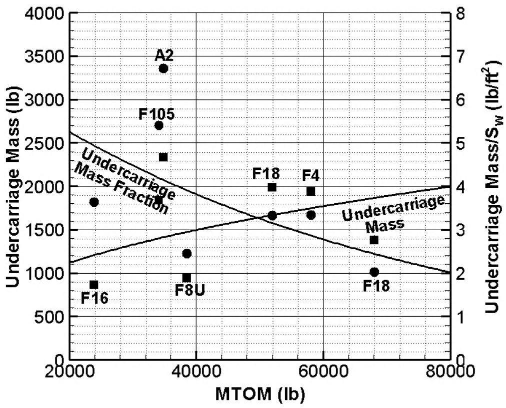


Figure 8.9. Military aircraft undercarriage mass

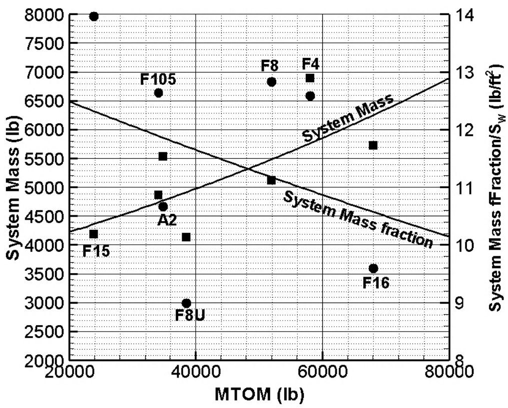


Figure 8.10. Military aircraft system mass

k_{uc} = 1.05 for fuselage mounted undercarriage with bulge and 1.03 without bulge.

k_{mat} = 1.0 for metal otherwise make the percent weight reduction.

k_{para} = 1.002 if there is brake parachute otherwise 1.

k_{intake} = 1.005

$$M_{Fmil} = 0.175 \times 1.0 \times 1.05 \times 1.002 \times 1.005 \times k_{mat} \times (MTOM \times n_{ult})^{0.002} \times (L \times D_{ave} \times V_D{}^{0.5})^{1.5} = 0.185 \times k_{mat} \times (MTOM) \times n_{ult})^{0.002} \times (L \times D_{ave} \times V_D{}^{0.5})^{1.5} \quad (8.54)$$

8.15.2 Military Aircraft Wing Mass (SI System)

The equation is simplified by the author for classroom usage. Remarks made pertaining to civil aircraft are also applicable to military cases, except that the values of factors change. Military wings are thinner. In many cases, the wing does not carry fuel (e.g., F104) and do not have winglets.

k_{mat}, = effect of material change as in the case of the fuselage

k_{uc} = 1.002 for wing mounted undercarriage, otherwise 1.0

k_{sl} = 1.004 for use of slat and

k_{sp} = 1.005 for spoiler (Flaps are standard.)

Writing the modified equation in terms of the book's notation, Equation 8.8 is changed to:

$$M_W = 0.021 \times k_{uc} \times k_{mat} \times k_{sl} \times (MTOM \times n_{ult})^{0.48} \times S_W{}^{0.78} \times AR \times (1+\lambda)^{0.4} \times (1 - M_{fuel\_mass\_in\_wing}/MTOW)^{0.4}/(Cos\Lambda \times t/c^{0.35}) \quad (8.55)$$

8.15.3 Military Aircraft Empennage

The equation is simplified by the author for classroom usage. Remarks made pertaining to civil aircraft are also applicable to military cases, except that the values of factors change as follows.

k_{mat}, = effect of material change as in the case of fuselage

Writing the modified equations in terms of notations in Equation 8.21, the following are obtained.

Horizontal Tail
For all tail movement, use $k_{conf} = 1.05$, otherwise 1.0.

$$M_{HT} = 0.2 \times k_{mat} \times k_{conf} \times (MTOM \times n_{ult})^{0.484} \times S_W{}^{0.78} \times AR \times (1+\lambda)^{0.4}/(Cos\Lambda \times t/c^{0.4}) \quad (8.56)$$

Vertical Tail
For tail configurations, use $k_{conf} = 1.1$ for T-tail, 1.05 for mid tail, and 1.0 for low tail.

$$M_{VT} = 0.0215 \times k_{mat} + k_{conf} \times (MTOM \times n_{ult})^{0.484} \times S_W{}^{0.78} \times AR \times (1+\lambda)^{0.4}/(Cos\Lambda \times t/c^{0.4}) \quad (8.57)$$

8.15.4 Nacelle Mass Example – Military Aircraft

Typical combat aircraft does not have a nacelle and a pod – intake weight is taken integral with fuselage weight.

8.15.5 Power Plant Group Mass Example – Military Aircraft

This is estimated from statistics until it is sized in Chapter 10. From the engine T_{SLS} the engine dry mass can be obtained from its thrust-to-weight ratio, which typically varies from 5 to 8. Refer to Section 8.10.7 to obtain engine dry mass. However, it is always better to use engine manufacturer's supplied data, freely available in the public domain.

The total power plant group mass can be expressed semi-empirically as

$$M_{ENG} \text{ per engine} = 1.25 \times M_{DRYENG} \quad (8.58)$$

8.15.6 Undercarriage Mass Example – Military Aircraft

Use Equations 8.36 to 8.39.

8.15.7 System Mass – Military Aircraft

$$\text{Take } M_{SYS} = 0.12 \text{ to } 0.16 \times MTOW \text{ for trainer class aircraft.} \tag{8.59}$$

$$\text{Take } M_{SYS} = 0.16 \text{ to } 0.20 \times MTOW \text{ for combat class aircraft.} \tag{8.60}$$

8.15.8 Aircraft Furnishing – Military Aircraft

$$\text{Take } M_{FUR} = 0.01 \times MTOW \text{ for trainer classaircraft.} \tag{8.61}$$

$$\text{Take } M_{FUR} = 0.05 \times MTOW \text{ for combat classaircraft.} \tag{8.62}$$

8.10.9 Miscellaneous Group (M_{MISC}) – Military Aircraft

Carefully examine what structural parts are left out (e.g. delta fin, etc). If any item does not fit into the standard groups listed here, include it in this group. Typically, this be expressed as

$$M_{MISC} = 0 \text{ to } 1\ \% \text{ of } MTOM. \tag{8.63}$$

8.15.10 Contingency (M_{CONT}) – Military Aircraft

A good designer keeps provision for contingency, that is,

$$M_{CONT} = (0.01 \text{ to } 0.25) \times MTOW \tag{8.64}$$

8.15.11 Crew Mass

There are trainer and trainee pilots. Take 90 kg per crew.

8.15.12 Fuel (M_{FUEL})

Fuel load is mission specific. This can be determined by proper performance estimation shown in Chapters 11 and 13. At this stage, statistical data is the only means to guesstimate fuel load that can be revised in Chapters 11 and 13.

Military aircraft is mission specific and also has to depend on statistical data at this stage of the design until accurate fuel load can be estimated through performance estimation.

8.15.13 Payload (M_{PL})

Military aircraft payload is the armament specified by the user requirements. Internal guns are taken as systems weight.

8.16 Classroom Example of Military AJT/CAS Aircraft Weight Estimation

User requirement for practice bombs and missiles is 1800 kg; this is a reasonable practice armament load. Therefore, $M_{PL} = 1800$ kg. To maintain commonality, AJT uses CAS aircraft stressed components except front fuselage is modified. At this point, fuselage weights of both the variants are considered to be identical. In other words, both the variants will have the same OEW. (This penalizes AJT weight by about 5% heavier than what it could have been, but if required wing, fuselage, and undercarriage structural weights could be lightened.)

CAS maneuver limits are $+8g$ to $-4\ g$ and MTOW = 8200 kg. Evidently, the hard maneuvers are not performed at MTOW. It has to reach the battlefield in which, in this example, 400 kg fuel is considered to be consumed. Therefore, except for undercarriage weight, all other structural component weights are computed at 7800 kg and $8g$ ultimate load. AJT weight is based on CAS loading, except that it takes a lighter Adour871 turbofan.

8.16.1 AJT Fuselage Example (Based on CAS Variant)

Consider a 10% weight saving as a result of composite usage in secondary structures – that is, $k_{mat} = 0.9$. $MTOM = 7800$ kg. $L = 12.1$ m, $D_{ave} = 0.5 \times (1.8 + 0.9) = 1.35$ m, and $V_D = 620$ knots = 1150 kmph = 319.4 m/s.

Equation 8.54 gives:

$$M_{Fmil} = 0.185 \times k_{mat} \times (MTOM \times n_{ult})^{0.002} \times (L \times D_{ave} \times V_D{}^{0.5})^{1.5}$$
$$= 0.1665 \times (7800 \times 8)^{0.002} \times (12.1 \times 1.35 \times 319.4^{0.5})^{1.5}$$
$$= 0.166 \times 1.0223 \times (12.1 \times 1.35 \times 17.87)^{1.5} = 0.1702 \times (291.9)^{1.5}$$
$$= 0.1702 \times 4987.1 = 849 \text{ kg}$$

8.16.2 AJT Wing Example (Based on CAS Variant)

Consider a 5% weight saving as a result of composite usage in secondary structures – that is, $k_{mat} = 0.95$. $MTOM = 7800$ kg. $S_W = 17\text{m}^2$, $AR = 5.3$, $\lambda = 0.3$, $M_{WR} = 828$ kg, $\Lambda = 20$ deg, $t/c = 0.105$, and $V_D = 620$ knots = 1150 kmph = 319.4 m/s. It has no slat making $k_{sl}. = 1$, and has 828 kg fuel in wing. For spoiler, $k_{sl} = 1.005$, and the undercarriage is not wing mounted $k_{uc} = 1$.

Equation 8.55 gives:

$$M_W = 0.021 \times 0.95 \times 1.005 \times (7800 \times 8)^{0.48} \times 17^{0.78} \times 5.3 \times (1+0.3)^{0.4}$$
$$\times (1 - 828/7800)^{0.4}/(\text{Cos}20 \times 0.105^{0.35})$$
$$M_W = 0.02 \times 200 \times 9.115 \times 5.3 \times 1.11 \times 0.8938^{0.4}/(0.94 \times 0.454)$$
$$M_W = 4 \times 53.62 \times 0.956/(0.427) = 205/0.427 = 480\text{kg}$$

8.16.3 AJT Empennage Example (Based on CAS Variant)

Horizontal Tail:

Consider a 10% weight saving as a result of composite usage in secondary structures – that is, $k_{mat} = 0.9$. $MTOM = 7800$ kg.

AJT horizontal tail is all moving, that is, configuration factor $k_{conf} = 1.05$. Note that the exposed area constitutes the empennage mass as constructed.

$$S_H = 3.91(\text{exposed}),\ AR = 3.5,\ \lambda = 0.37,\ \Lambda = 25\text{deg},\ t/c = 0.09,\ M_{HT} = 95kg,\ \text{Tailarm} = 4.475\text{m}$$

$$M_{HT} = 0.02 \times 0.9 \times 1.05 \times (7800 \times 8)^{0.48} \times 3.91^{0.78} \times 3.5 \times (1 + 0.37)^{0.4}/(\text{Cos}25 \times 0.09^{0.35})$$

$$= 0.0189 \times 200 \times (2.9 \times 3.5 \times 1.134)/(0.906 \times 0.43) = 3.78 \times 11.51/0.39$$

$$= 112\text{kg}$$

Vertical Tail: *Equation 8.57 gives:*

$$S_V = 3.0,\ AR = 1.52,\ \lambda = 0.3,\ \Lambda = 35^\circ,\ t/c = 0.09,\ M_{HT} = 55kg,\ \text{Tailarm} = 4.1\text{m}$$

$$M_{VT} = 0.0215 \times 0.9 \times (7800 \times 8)^{0.48} \times 3.0^{0.78} \times 1.52 \times (1 + 0.3)^{0.4}/(\text{Cos}35 \times 0.09^{0.35})$$

$$= 0.01935 \times 200 \times (2.36 \times 1.52 \times 1.11)/(0.82 \times 0.43) = 3.87 \times 3.892/0.352$$

$$= 43kg$$

8.16.4 AJT Nacelle/Intake Mass Example (Based on CAS Variant)

The AJT does not have a pod – intake weight is taken integral with fuselage weight.

8.16.5 AJT Power Plant Group Mass Example (Based on AJT Variant)

Suitable engines in the class are the following. Both have BPR = 0.75 and engine diameter = 22 in.

For CAS – Adour 811 producing 37.4KN (8400 lb): dry weight = 738 kg (1627 lb).

For AJT – Adour 871 producing 26.66KN (8400 lb): dry weight = 603 kg (1330 lb).

Take Adour871 for AJT (weights will not change with final engine sizing in Chapter 11). Total power plant group mass can be expressed semi-empirically as (Equation 8.58 gives)

M_{ENG} per engine $= 1.25 \times M_{DRYENG} = 1.25 \times 603 = 754$ kg

8.16.6 AJT Undercarriage Mass Example (Based on CAS Variant)

$MTOM$ = 7500 kg (for the variant – to maintain commonality). Fuselage mounted

$M_{U/C\backslash fus} = 0.04 \times 8200 = 328$ kg (could be lightened to 300 kg)

8.16.7 AJT Systems Group Mass Example (Based on AJT Variant)

CAS system requirements are higher; hence, AJT variant MTOW is used. Equation 8.59 gives

$MTOW = 6500$ kg; use Equation 8.32, $M_{SYS} = 0.12 \times 6500 = 780$ kg

8.16.8 AJT Furnishing Group Mass Example (Based on AJT Variant)

CAS system requirement is different; hence, AJT variant MTOW is used. Equation 8.61 gives

$MTOW = 6500$ kg; use Equation 8.37, $M_{FUR} = 0.01 \times 6500 = 65$ kg

8.16.9 AJT Contingency Group Mass Example

Equation 8.64 gives

$MTOW = 6500$kg; use Equation 8.37, $M_{CONT} = 0.015 \times 6500 = 98$ kg

8.16.10 AJT Crew Mass Example

There are trainer and trainee pilots. Therefore, $M_{CREW} = 2 \times 90 = 180$ kg

8.16.11 Fuel (M_{FUEL})

Fuel load is mission specific. From AJT statistics in Section 6.12.1, $M_{FUEL\_NTC} = M_{NFC}$ – OEW = 4800 – 3700 = 1100kg. It will be properly computed in Chapter 13. The AJT $M_{FUEL} = MTOM$ – OEW – armament load = 6500 – 3700 – 1800 = 1000 kg. This includes some reserve fuel. (It is assumed that practice range is less than 100 miles away and AJT reaches the range at economic cruise to make two to three passes for armament training at a sortie duration of about 50 min.) The tankage capacity can hold 2000 kg fuel for ferry flights and if required, AJT armament practice sortie can be made longer at a slightly higher MTOM.

8.16.12 Payload (M_{PL})

Military aircraft payload is its armament that is specified by user requirements. Internal guns are taken as systems weight. Table 8.9 gives the armament weight.

8.16.13 Weights Summary – Military Aircraft

Table 8.9 gives the weight summary of the classroom examples.

The CAS variant needs to be computed by the readers. It has incremental weights, Δ Power plant group = 168.5 kg, Δ Systems = 204 kg, Δ Fuel = 500 kg, and Δ Payload = 700 kg. This makes $MTOM_{CAS} \approx 8130$ kg.

8.17 CG Position Determination – Military Aircraft

Table 8.10 gives the CG positions of aircraft components of the classroom examples: *x, y, and z* are measured from the nose of the aircraft, and then convert to MAC_w.

Table 8.9. *AJT component and weight summary*

	Component	From zero reference (m)	AJT aircraft (kg)
1.	Fuselage Group (45%)	849	
2.	Wing Group (30% wing MAC)	112	
3.	H-Tail Group (30% H-tail MAC)	43	
4.	V-Tail Group (30% V-tail MAC)	300	
5.	Undercarriage Group (≈ wheel center)		
6.	Nacelle + Pylon Group (75%)		not applicable
7.	Miscellaneous	nil	
	Structures Group total		**1,784**
8.	Power Plant Group (engine center)	750	
9.	Systems Group (as positioned)	780	
10.	Furnishing Group (as positioned)	65	
11.	Contingencies (as positioned)	98	
	MEM		**3,477**
12.	Crew	180	
	OEM		**3,657**
13.	Fuel (as positioned)	1,100	
	Normal Training Configuration (NTC) Mass		**4,757**
14.	Payload (as positioned)	1,800	
	MTOM		**6,557**
	MRM		**6,600**

Table 8.10. *Typical values of component CG locations –military aircraft*

	Component	Military AJT aircraft Typical % of component characteristic length
1.	Fuselage Group	45 to 50%
2.	Wing Group	No slat – 30% of MAC With slat – 25 % MAC
3.	H-Tail Group	30%
4.	V-Tail Group	30%
5.	Undercarriage Group	At wheel center
6.	Nacelle + Pylon Group	Generally not applicable
7.	Miscellaneous	As position – use similarity
8.	Power Plant Group	70 to 80%
9.	Systems Group	As position – use similarity (typically 35% of fuselage)
10.	Furnishing Group	As position – use similarity
11.	Contingencies	As position – use similarity
	MEM	compute
12.	Crew	As position – use similarity
	OEM	compute
13.	Payload	As position – use similarity
14.	Fuel	As position – use similarity
	MTOM and MRM	Compute

Table 8.11. *Typical values of component CG locations – AJT*

Item Group	Mass – kg	X – m	Moment	Z – m	Moment
Fuselage	849	5.2	4414.8	1.5	1273.5
Wing	480	6.8	3264	1.9	912
H-tail	112	11.31	1266.72	1.95	218.4
V-tail	43	10.66	458.38	2.6	111.8
Undercarriage (nose)	80	2.08	166	0.33	26
Undercarriage (main)	220	7.4	1628	0.5	110
Nacelle + pylon	none				
Miscellaneous	none				
Power plant	754	9.1	6861.4	1.6	1206.4
Systems	780	5	3900	1.3	1014
Furnishing	65	4	260	1.2	78
Contingencies	98	4	392	1.2	117.6
MEM	**3477**				
Crew	180	4	720	1.7	306
OEM	**3657**				
Fuel	1100	7.5	8250	1.4	1540
Total NTC mass	4757	30675.5	6913.4		
CG at *NTC* mass		$\bar{x} = 6.64$ m		$\bar{z} = 1.45$ m	

*This gives the CG angle, $\beta = \tan^{-1}$ (7.4 – 6.64)/1.45 = $\tan^{-1}$ 0.524 = 27.65 deg.

Armament payload	1800	6.8	12240	1.4	2520
Total *MTOM*	**6557**		42915.5		9433.4
CG at *MTOM*		$\bar{x} = 6.55$ m		$\bar{z} = 1.44$ m	

*This gives the CG angle, $\beta = \tan^{-1}$ (7.4 – 6.55)/1.44 = $\tan^{-1}$ 0.59 = 30.54 deg.

Table 8.10 may be used to determine the CG location. Coordinate origin X = 0 at the nose tip, and Z = 0 at ground level, which is kept horizontal.

Equations 8.54 to 8.56 are valid to compute CG coordinates. See Section 8.12.1 for the classroom Bizjet example to compute $\bar{x}$ and $\bar{z}$. The important "potato" curve for *CG* variation for all loading conditions is left out.

The readers should make sure that it has the static margin with full crew. The *CG* should be at around 18% of MAC when fully loaded and at around 22% when empty, in between only with pilots. *CG* is always forward of the neutral point (where is it? Take 50% of the *MAC*). This is for static stability reasons.

If the computation does not indicate the *CG* within the specified ranges, then move the wing and/or engine to bring the CG to the desired percentages of the *MAC* until a satisfactory solution is reached. Fuel tankage can be slightly modified. Batteries are heavy items and can be located at a desirable position to fine tune the CG location to the desired position.

8.17.1 Classroom Worked-Out Military AJT CG Location Example

Table 8.11 gives the CG locations of aircraft components of the classroom examples.

The CG angle, β for NTC, and MTOM cases are within the acceptable range. Readers may compute the CAS center of gravity location. Proper CG positioning can be established after aircraft neutral point (NP) is established when the forward and aft CG limits can be ascertained by fine tuning component positions. Determination of aircraft neutral point is not done in this book but taken at $\approx$55% of wing MAC.

This is a satisfactory angle covering maximum fuselage rotation angle at take-off. Also note that both mass and CG location are slightly different from preliminary data.

8.17.2 First Iteration to Fine Tune CG Position and Components Masses

Preliminary aircraft configuration started in Chapter 6 with guessed $MTOM$, engine size, and CG position. It is unlikely that the computed aircraft mass worked out in this Chapter would match the guessed one. In fact, the example shows that it is lighter, with more accurate CG position. This replaces the guesstimated values of 6900 kg by a more accurately estimated $MTOM$ of 6500 kg.

In principle, the aircraft configuration needs to be revised at this stage of progress as the first iteration. Readers may go through the iterative cycle of computation once.

Final sizing is carried out in Chapter 11 when another iteration is required. As it converges fast, one iteration would suffice for classroom purposes.

10.8.2 Military Aircraft Intake Design

Military aircraft has supersonic capabilities and therefore has to manage the shock losses associated with its intake. Ideally at design point (at supersonic cruise), the bow shock wave just attaches with the intake lip, which is sharp compared to subsonic intake lip. For aircraft operating above Mach 2, a movable center body keeps the oblique wave to the lip as the shock angle changes with speed change. The simplest center body is a cone (or half cone for side-mounted nacelles). The cone could be in steps to make multiple oblique shocks at reduced intensity (i.e., lowering shock loss). The best design is an Oswatitsch curved contour design that generates infinite weak shocks with minimum loss.

Supersonic intake shaping is much more complex, and this book is not in a position to offer more than basic considerations to arrive at a reasonable configuration for classroom usage. Reference [10.21] may be consulted for a formal methodology for supersonic intake design.

Figure 10.25 gives four kinds of flow regimes associated with ideal supersonic intake with a fixed center body.

1. In the design, flight speed is seen as a critical operation when it is desirable that the oblique shock wave just touches the lip, followed by other shocks and culminating with a normal shock at the throat beyond which airflow becomes subsonic (1st diagram). The captured free stream tube is the same as the high-light area. The intake area is sized to inhale air mass at critical operation.
2. If the back pressure is lower than the critical operation (because of throttle action), then more air mass is inhaled and the throat area remains supersonic, pushing back a stronger normal shock. This is known as supercritical operation (2nd diagram). The captured free stream tube remains the same as the high-light area, and oblique shock position depends on the aircraft speed.
3. When the back pressure is high, especially when below critical speed still at supersonic level, the oblique shock is wider and is followed by a normal shock pop outside, ahead of the nacelle lip, and is known as a subcritical operation (3rd diagram). The captured free stream tube is smaller than the high-light area. It is not as efficient as in the critical operation, but loss is less than a supercritical operation.
4. The last one could happen at a particular combination of aircraft speed (below critical) and air mass inhalation when the normal shock outside keeps oscillating, making the engine starve and run erratically, possibly leading to flameout.

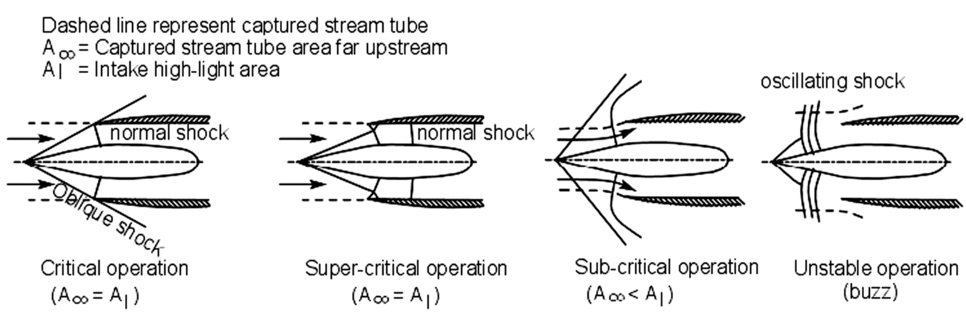


Figure 10.25. Types of ideal supersonic intake demand conditions (Ref [10.21])

This is known as *buzz*. Aircraft must avoid this situation, and modern designs have *FBW/FADEC* to keep clear of it.

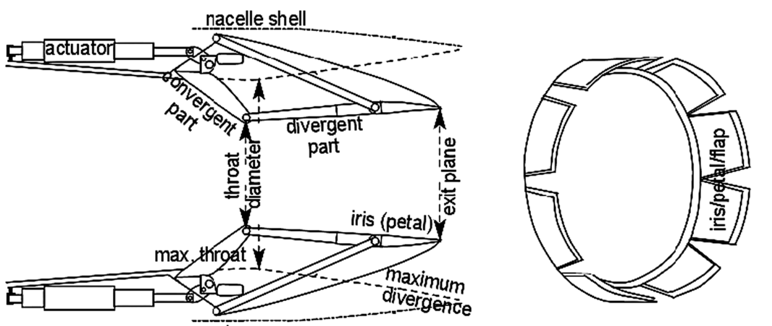
Modern combat aircraft with advance missiles have BVR capabilities. Rapid maneuvers more than high speed is the combat specification, for which typical speed is at Mach 1.8 when the requirement for a movable center body is not stringent. For side intakes, boundary layer bleed plates serve as the center body to position oblique shock at the lip (critical design point operation).

It is suggested that for classroom exercise, the throat area be computed first for the cruise condition (with or without center body) and intake kept relatively straight with sharp leading edge lips.

10.9.4 Military Aircraft Thrust Reverser Application and Exhaust Nozzles

Afterburning military engine *TR* is integral with the nozzle design and is positioned at the fuselage end. An afterburning engine's nozzle always runs choked at maximum cruise rating and has a variable convergent–divergent nozzle (de Laval) to match throttle demands. Of late, all the latest combat aircraft have thrust-vectoring capabilities by deflecting the exhaust jet at the desired angles. Figure 10.28 schematically shows a mechanism that not only varies the convergent–divergent area ratios but also makes the nozzle asymmetric by adjusting individual petals (iris/flaps) of the nozzle for thrust vectoring.

The lower diagram of Figure 10.29 shows that the integral mechanism can provide a mild form of in-flight thrust, reversing to spoil thrust (braking action) to wash out high speed at its approach to land or in combat to a considerably lower speed. Full *TR* is shown in the last figure. This has an integral mechanism capable of adjusting for all demands.



(a) Mechanism for nozzle adjustment (b) Individual petal movement

Figure 10.28. Military aircraft nozzle adjustment scheme (from Ref [10.19])

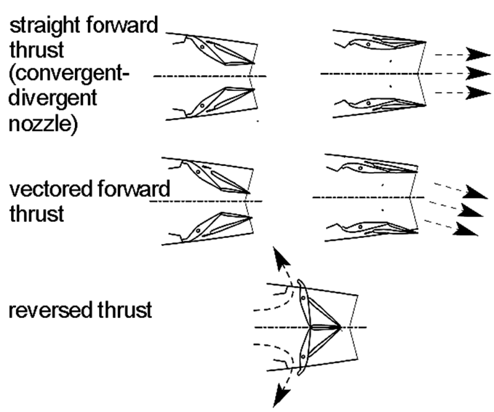


Figure 10.29. Supersonic nozzle area adjustment and thrust vectoring

10.11.4 Turbofan Engine – Military

Military turbofan ratings are slightly different from civil turbofan ratings. Military engines are allowed to run longer at *maximum ratings* not only at take-off but also for fast acceleration in combat. Of course, these still operate within a limited period (e.g., at take-off, say 5 min and at combat, say 10 min, if required in several bursts).

Reheat (afterburning) is added at maximum rating when throttle is set to a fully forward position. Running at a relatively longer duration at this high power (higher combustion temperature) is at the price of a shorter engine life span and shorter time between overhauls (*TBO*). In addition, the hot zone components use more expensive material to withstand stress at elevated temperatures.

Military engines operate at considerably varying throttle demands. Here, cruise is less meaningful unless it is ferry flight. Flight to operation theater or return-to-base is not exactly cruising – this period can be executed at a lower throttle setting as mission demands. Therefore, typically but not always, instead of having separate *maximum climb rating* and *maximum cruise rating,* military engines lump together as *maximum continuous rating*. This is at about 90% of the maximum rating.

A typical military turbofan engine performance at maximum rating suited to the classroom example of an Advanced Jet Trainer (AJT) with a derivative in *CAS* role is given in Figure 10.51. *Sfc* for this engine at T_{SLS} is 0.75 lb/hr/lb when operating without reheat and 1.1 lb/hr/lb when under reheat (afterburner lit). Rated (maximum) air mass flow is 95 lb/s.

Currently, not much information can be supplied on military engines. However, for the classroom example, this would prove sufficient as shown in Chapter 11.

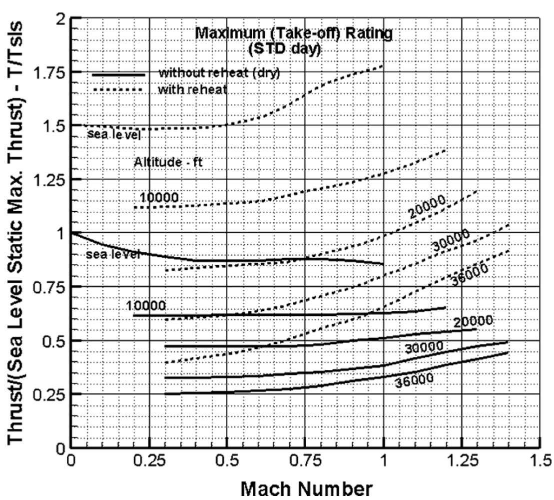


Figure 10.51. Military turbofan engine with and without reheat (BPR = 0.75). Take 90% of maximum rating as the maximum continuous rating

11.5 Classroom Exercise – Military Aircraft (*AJT*)

Both FPS and SI units are worked out in the examples. Figure 9.16 gives the *AJT* drag polar. The military aircraft example of *AJT* operates in two take-off weights at (1) Normal Training Configuration (*NTC* – clean) at 4800 kg and at (2) fully loaded for armament training at 6800 kg (i.e., a growth of 41.7%). In this example, the *NTC* is more critical to meet the specification of TOFL = 800 m. The readers may work out both cases. The fully loaded aircraft need to satisfy the longer field length requirement of 1800 m (<6000 ft), the rest (e.g., climb and cruise capabilities) are taken as fallout of the design. After the armament practice run, the payload is dropped and the landing weight is the same for both the missions. It may be noted that the *AJT* should have a *CAS* version.

11.5.1 Take-off – Military Aircraft

Requirements: $TOFL = 800$ m (≈ 2600 ft) to clear 35 ft (10.7 m) at ISA + sea level at NTC. The maximum lift coefficient at TO (20 deg flaps down and no slat) is taken as $C_{Lmax \cdot TO} = C_{Lstall \cdot TO} = 1.85$. Military designs follow Milspecs, not FAR, airworthiness requirements.

Using Equation 11.11a, the expression becomes
$W/S = 2600 \times 1.85 \times (T/W)/18.85 = 255.2 \times (T/W)$

Using Equation 11.11b, it becomes
$W/S = 8.345 \times 800 \times 1.85 \times (T/W) = 12350.6 \times (T/W)$

Computing and listing in tabular form:

Table 11.4. *AJT take-off sizing*

W/S (FPS – lb/ft^2)	40	50	60	70	80	90
W/S (SI – N/m^2)	1916.2	2395.6	2874.3	3353.7	3832.77	4311.5
T/W (nondimension)	0.157	0.2	0.235	0.274	0.313	0.353

11.5.2 Initial Climb – Military aircraft

From market requirement, initial climb speed is $V = 350$ knots $= 350 \times 1.68781 = 590.7$ ft/s and the required rate of climb, $RC = 10000$ ft/min (50 m/s) = 164 ft/s (50 m/s). From the Adour 861 class engine data, T_{SLS}/T ratio (factor k_2) = 1.06 (see Section 10.12.4, Military Engine).

Lift coefficient, $C_{Lclimb} = W/(0.5 \times 0.002378 \times 590.7^2 \times S_W) = 0.00241 \times W/S_W$

Using Equation 11.15,
$[T_{SLS}/W]/1.06 = 164/590.7 + [(C_D \times 0.5 \times 0.002378 \times 590.7^2 \times S_W)/W]$
$T_{SLS}/W = 0.294 + 440 \times C_D \times (S_W/W)$

Computing and listing in tabular form:

Table 11.5. *AJT climb sizing*

W/S (lb/ft^2)	40	50	60	70	80
W/S (N/m^2)	1916.2	2395.6	2874.3	3353.7	3832.77
C_{Lclimb}	0.097	0.12	0.145	0.169	0.193
C_D (from Figure 9.16)	0.0222	0.0225	0.0258	0.026	0.0263
T_{SLS}/W	0.538	0.492	0.483	0.457	0.439

11.5.3 Cruise – Military Aircraft

Market Specification: Initial cruise speed and altitude is 0.75 Mach and 36000 ft (most of training takes place below the tropopause), for which take $k = 0.975$ in Equation 11.14.

In FPS at 36000 ft,
$\rho = 0.0007$ slug/ft^2 and $V^2 = (0.75 \times 968.07)^2 = 726.05^2 = 527152.2$ ft^2/s^2.

In SI, altitude = 11000 m,
$\rho = 0.364$ kg/m^3, $V^2 = (0.75 \times 295.07)^2 = 221.3^2 = 48974.8$ m^2/s^2.

Equation 11.18 gives initial cruise,
$C_L = 0.975 \times MTOW/(0.5 \times 0.364 \times 48974.8 \times S_W) = 0.0001094 \times (W/S_W)$, where W/S_W is in N/m^2.

Equation 11.19 gives
$T_{SLS}/W = k_1 \times 0.5\rho V^2 \times C_D/(W/S_W)$ (Take factor $k_1 = T_{SLS}/T_a = 3.6$; see Figure 11.53)

In FPS,
$T_{SLS}/W = 3.6 \times 0.5 \times 0.0007 \times 527152.2 \times C_D/(W/S_W) = 664.2 \times C_D/(W/S_W)$

In SI,
$T_{SLS}/W = 3.6 \times 0.5 \times 0.364 \times 48974.8 \times C_D/(W/S_W) = 32088.2 \times C_D/(W/S_W)$

Again, make a table and plot. Computing and listing in tabular form:

Table 11.6. *AJT cruise sizing*

W/S (lb/ft^2)	50	60	70	80	100
W/S (N/m^2)	2395.6	2874.3	3353.7	3832.77	4791
C_L	0.262	0.314	0.367	0.419	0.524
C_D (from Figure 9.16)	0.026	0.0292	0.0315	0.035	0.042
T_{SLS}/W 41000 ft	0.346	0.324	0.30	0.29	0.279

11.5.4 Landing – Military aircraft

From market requirement, $V_{app} = 110$ knots $= 110 \times 1.68781 = 185.7$ ft/s (56.6 m/s)

Landing $C_{Lstall} = 2.5$ at 40 deg double-slotted flap setting.

Using Equation 11.22,
In FPS system, $W/S_W = 0.311 \times 0.002378 \times 2.5 \times (185.7)^2 = 63.75$lb/ft^2
In SI system, $W/S_W = 0.311 \times 1.225 \times 2.5 \times (56.6)^2 = 2885$ N/m^2
Because at landing the thrust is taken zero, the W/S_W remains constant.

11.7 Sizing Analysis – Military Aircraft

The methodology for AJT as military aircraft is the same as in the case of civil aircraft sizing and engine matching. The four sizing relationships between wing loading, W/S_W, and thrust loading, T_{SLS}/W, would meet (1) take-off, (2) approach speed for landing, (3) initial cruise speed, and (4) initial climb rate. These are plotted in Figure 11.5. Frontline fighters have additional requirements (e.g., rate of turn, etc.).

Military aircraft sizing poses an interesting situation. The variant in combat role (e.g., in CAS role) has to carry externally more armament load (≈ 50% more), contributing to drag rise. The overall geometry does not change much except that the front fuselage is now redesigned for one pilot, saving a weight of about 100 kg (the weight of seat, escape system, etc., are replaced by radar, combat avionics). The aircraft still has the same engine tweaked to up-rated thrust level.

Therefore, a conservative sizing of an *AJT* should benefit *CAS* growth. Figure 11.5 shows the sizing point is at slightly lower wing loading at $W/S_W = 59$ lb/ft^2 to benefit CAS performance. Thrust loading is taken as $T_{SLS}/W = 0.5$. The circled point in Figure 11.5 simultaneously satisfies all requirements. A slightly higher value of T_{SLS}/W would benefit the take-off performance of an AJT with full practice armament load.

Chapter 8 works out the mass of the preliminary configuration of AJT aircraft as:

$MTOM$ = 4800 kg (10582) lb at Normal Training Configuration (NTC), which gives the matched engine thrust $T_{SLS} = 0.5 \times 10582 \approx 5300$ lb (23583N).

Checking out the sized Wing Loading $W/S_W = 59$ lb/ft^2, the wing area comes out at 185 ft^2 (17.2 m^2), about 1% error from the preliminary wing area, hence kept unchanged. The matched engine thrust gives a lower value compared to the statistical estimate of 5860 lb, which is good. Again, iteration is avoided.

11.7.1 Single-Seat Variants in the Family of Aircraft Design

Military aircraft are no exceptions in offering variant designs, depending on their mission role, in addition to the typical payload-range variation. The F16 and F18

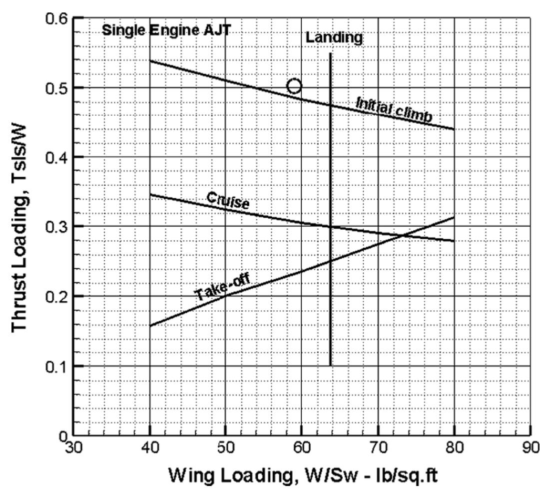


Figure 11.5. Aircraft sizing – military aircraft

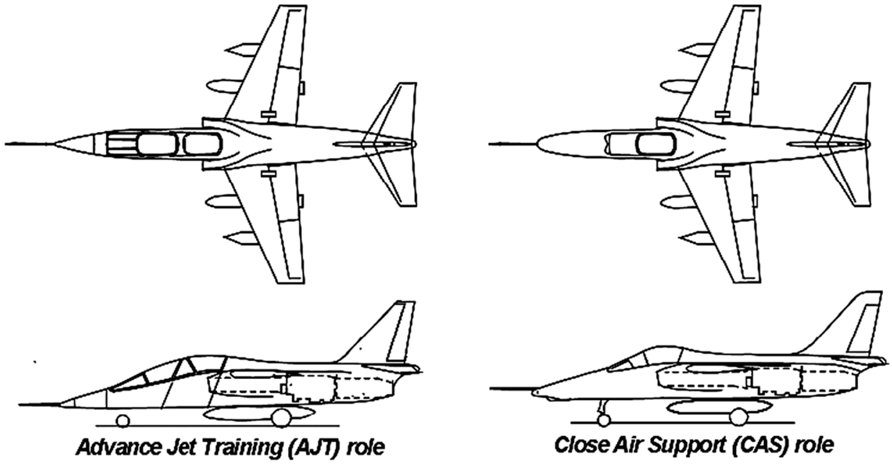


Figure 11.6. Variant designs in the family of military aircraft

have had modifications since they first appeared with increasing envelope of combat capabilities. The F18 has increased in size. The BAe Hawk100 jet trainer has produced a single-seat close support combat derivative as Hawk200.

The CAS aircraft is the only variant of the AJT aircraft (Figure 11.6). The details on how this is achieved with associated design changes are described below.

Configuration

Configuration of CAS aircraft variant is achieved by splitting the AJT front fuselage, then replacing the tandem seat arrangement with a single-seat cockpit. The length could be kept the same because the nose cone needs to house more powerful acquisition radar. The front loading of the radar and single pilot is placed in a way that the CG location is kept undisturbed. Wing area = 17 m^2 (183 ft^2).

Weights

A summary of mass changes is outlined in Table 11.7.

Armament and fuel can be traded for range. Drop tanks can be used for ferry range.

Thrust

The CAS variant will require 30% higher thrust variant of the engine. This is possible without a change in external dimension but will incur an increase of 60 kg in engine mass.

CAS turbofan (has small bypass) thrust = 1.3 × 5300 ≈ 6900 lb (30700N)

Thrust loading at *MTOM* becomes. $T_{SLS}/W = 0.417$ (a satisfactory value).

Drag

The drag level of the clean *AJT* and *CAS* aircraft may be considered about the same. There will be an increase in drag because of the weapons load. For the *CAS* aircraft, there is a wide variety. To give a general perception – the typical drag coefficient increment for armament load is $C_{D\pi} = 0.25$ (including interference effect) each for

Table 11.7. *AJT/CAS sized mass*

	AJT – kg	CAS – kg	Remark
OEM	3700	3700	Remove one pilot, instrument ejection seat, etc. (260 kg), and include radar, combat avionics (100 kg). There is an increase of 60 kg in engine mass.
Fuel	1100	1300	Internal capacity 2390 kg (max)
Clean aircraft ***MTOM***	**4800 (10582 lb)**	**5000 (11023 lb)**	
Wing loading*, W/S^W	282 kg/m^2 (57.8lb/ft^2)	294 kg/m^2 (60.23 lb/ft^2).	
Armament mass	1800	2500	
MTOM **kg (lb)**	6600 (14550 lb)	7500 (16535 lb)	
Wing area, S^W	17 m (183 ft^2)	17m (183 ft^2)	
Wing loading, W/S^W	388.7 kg/m^2 (79.5 lb/ft^2)	441.2 kg/m^2 (90.36 lb/ft^2).	

∗ Sized wing loading for *AJT* at *NTC* came out close to it.

five hard points as weapon carrier. Weapon drag is based on maximum cross section area (say, 0.8 ft^2) of the weapons.

Parasite drag increment, $\Delta C_{Dpmin} = (5 \times 0.25 \times 0.8)/183 = 0.0055$, where $S_W = 183$ ft^2.

Performance

Chapter 13 enables students to check whether designs meet aircraft performance specifications.

12.9 Military Aircraft – Nonlinear Effects

Military aircraft often perform extreme maneuvers involving large disturbances, hence requiring nonlinear stability analyses. Military aircraft *Flying Qualities* are addressed in MIL-STD-1797A, which supersedes MIL-STD-8785. In studying the stability of military aircraft, design considerations (e.g., small disturbances involving linear treatment similar to civil aircraft) are initially used; however, additional features associated with large disturbances and involving nonlinear treatment must also be considered. These include the following.

1. inertial pitch and yaw divergence in roll maneuver
2. aerodynamic yaw departure at high angles of attack
3. wing rock.

These topics however are beyond the scope of this book. Considerable data generation is required to initiate studies in these areas. Technology demonstrator aircraft would offer considerable insight into these problems. Even designing a technology demonstrator would require extensive wind-tunnel and CFD analyses at the conceptual stages, as configuration is still unproven and little or no statistical data in use. Wind tunnel test results may override CFD analyses but, in principle, they compliment each other.

There are yet other problems arising from weapons being released simultaneously or asymmetrically, causing sudden *CG* shift that could severely affect aircraft stability. Provision has to be made for quick recovery by fuel transfer completed in a short time – this is microprocessor-based management that is incorporated in *FBW* technology. Stealth of aircraft is a source of additional constraints to aircraft configuration. These constraints present considerable challenges to the resolution of stability issues. The F117 Nighthawk (Figure 4.30d) is a classic example of such consideration – it is an unstable aircraft, that cannot fly without *FBW*.

A modern two-surface combat aircraft configuration is shown in Figure 12.16. A delta wing design with one large V-tail and a typical swing wing twin-tail configuration are shown.

Supersonic flights would require an all-moving H-Tail as shown in the figure. Also at a high angle of attack, it is immersed in its wing trailing vortex system, thus becoming ineffective. In rare examples, the fins (V-tail) are all-moving surfaces. In many designs, the all-moving surfaces are split, with some elevator and rudder authority primarily serving as redundancy to protect against failures. A single large V-tail is not desirable for high-performance combat aircraft. It cannot be canted and

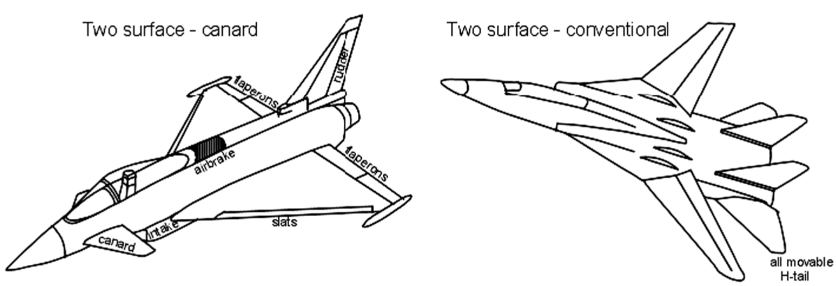


Figure 12.16 Typical modern fighter aircraft

does not offer stealth. A tall single fin also would generate higher rolling moments in yaw; its stability would depend on the *CG* position.

The use of twin-canted fins (strictly speaking, not a vertical tail) for military aircraft (Figure 4.30e) currently is common for the following reasons. A twin-canted tail is not a Vee tail, as there is a separate horizontal tail. (A Vee tail must combine the work of both pitch and directional control; required size then must be large in order to achieve the required authority.)

1. A vertical tail (fin) should be canted for stealth reasons (to deflect radar signals); hence, two such tails are required. A twin fin also reduces size to half, easing structural considerations with very little weight penalty.
2. When the aircraft is yawed, an upwind canted fin is less effective than a downwind fin, but together they provide the desired authority.
3. Twin-tail aircraft do not need to have separate speed brakes. To achieve braking action, the two rudders are deflected in opposite directions (similarly for spoiler and flaps).

Actuators are designed to cope with the desired rate of control surface movements, which can be from 30 deg/s to as high as 80 deg/s. Using *FBW* technology, the movement of leading-edge slats has a programmed relationship with the angle of attack. Aircraft roll rate could be as high as 200 deg/sec.

At supersonic speed, the aerodynamic center moves aft, making the aircraft more stable. At low speed, as the aerodynamic center moves forward, thrust vectoring in pitch plane (±20 deg) is helpful. Thrust vectoring is mainly used in low-speed extreme maneuvers. In high Mach or high q (low altitude) conditions, AOA is low.

High-performance combat aircraft forebody shapes are important. A circular cross section with high fineness ratio is less stable at high AOA. But with a small fineness ration, it may become acceptable. A vertically elongated cross section is undesirable – a horizontally elongated cross section is better. A good solution is to have a Vee lower section (see F22 – Figure 4.30e) for radar deflection with the upper part horizontally elongated. The chine causes vortex generation at high AOA, providing additional lift to assist the aircraft maneuver at unusual attitudes.

The early–1990 demonstrations by MIGs doing the spectacular "Cobra" maneuver initially was seen more as stunt-flying by many experts. Yet today's designs may exceed such capabilities, demonstrating combat potential in a twin-dome combat simulator and/or mock combat practice in flight. Fortunately, in most advanced countries, the operators (Air Force) and designers work together to understand and explore advanced capabilities.

Delta or all wing designs use wing reflex. If the V-tail is eliminated to avoid radar signature, then splitting the ailerons for directional control is necessary (as in B2 bomber). Such features will invariably require *FBW* designs.

It easily can be seen that advanced military aircraft configuration design is much more complex, and that it incorporates features not yet used in civil aircraft designs. Scarce technical information is available in the public domain on these areas of complexity.

13.3.3 Military Turbofan (Advanced Jet Trainer/CAS Role – Very Low BPR) – STD Day

Section 10.12.4 describes how military turbofans differ from civil turbofans. Figure 10.51 gives the typical available uninstalled thrust in nondimensional form for the *AJT/CAS* class of aircraft. Section 10.12.4 argues that only one graph at the maximum ratings would prove sufficient for use in this book. In the aircraft industry, separate graphs are used for each rating.

Installation loss of a single-seat military aircraft is low and taken as 3.33% reduction of thrust. Section 11.7 sizes the *AJT* that requires installed T_{SLS} of 5800 lb (uninstalled $T_{SLS} = 6000$ lb) for *NTC*. Using Figure 10.51, the installed thrust at the maximum (take-off) rating for the *AJT* is shown in Figure 13.4. Maximum continuous rating (primarily for climb) is at 95% of the maximum take-off rating. High speed runs are done at 90% of the maximum take-off rating (combat could demand up to 100% thrust in short bursts). For the CAS role, the thrust values need to be scaled up by 30% with an up-rated engine.

The AJT *sfc* at T_{SLS} is 0.7 lb/h/lb, and the fuel flow rate is based on the uninstalled T_{SLS}. Therefore, fuel flow rate = 0.7 × 6000 = 4200 lb/h.

Unlike civil aircraft, the *AJT* training profile is throttle-dependent. A training profile operates in varying speeds and altitudes. At normal training configuration (*NTC* – meant for airmanship and navigational training with low level of armament practice), the average throttle setting may be considered at ≈75% to 85% of the maximum rating. At a 30000-ft altitude and Mach 0.7, the average operating install–ed thrust is $T = 0.75 \times 1980$ (Figure 13.4) = 1485 lb (uninstalled thrust of 1538 lb) and average *sfc* is given as 0.7 lb/h/lb. It gives the average fuel flow rate = 0.7 × 1536 = 1076 lb/h. On-board fuel carried is 2425 lb.

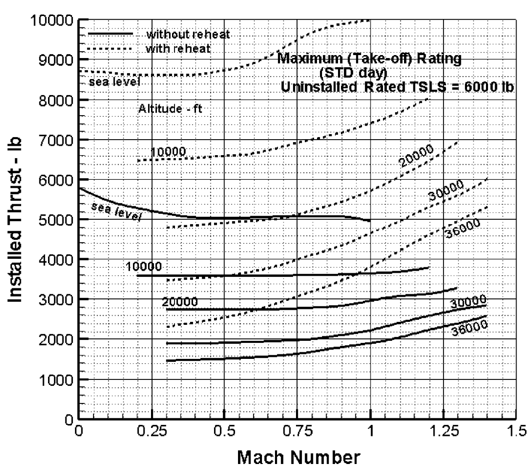


Figure 13.4 Installed maximum rating – military turbofan ($BPR = 0.75$)

15.10 Military Aircraft Survivability

Quite different from civil aircraft requirements, military survivability is separately treated in this section. The survivability considerations do not end with what is discussed here.

15.10.1 Military Emergency Escape

During World War II, pilot escape from damaged aircraft involved the pilot climbing out of flight deck and then jumping out to deploy his parachute to safety. Since then, considerable advancements in escape system technology have been implemented in line with the gain in aircraft speed–altitude capabilities.

Today, military emergency exit takes a drastic measure: simply pull the D-ring rip-chord and ejection follows in a sequence of automatic operations. The D-ring is located between the pilot's two legs and at the top of the seat, above the headrest, to suit the type of high *g*-load (Figures 15.42). Many designs include separate firing handles. A fully equipped ejection seat weighs about 200 to 400 lb (90 to 180 kg), depending on the manufacturer and performance capabilities (e.g., at what speed, altitude).

At the pull of the D-ring, rockets under the seat are fired, sending the seat into a ballistic catapult with the pilot strapped in. A typical sequence of ejection is shown in Figures 15.42 and 15.43. In the automatic sequence, just before the rockets fire, the canopy is released or made to explode along laid-out explosive lining to make a hole through which the seat assembly passes. Hands and legs are kept retrained with straps to avoid injury during escaping through a relatively small canopy opening.

The sustainer-rocket steers the pilot with the seat to a clear space when the seat separates and the parachute opens in the sequence shown in Figure 15.44. The dynamics of ejection is a complex one. The ejection can be made at zero altitude

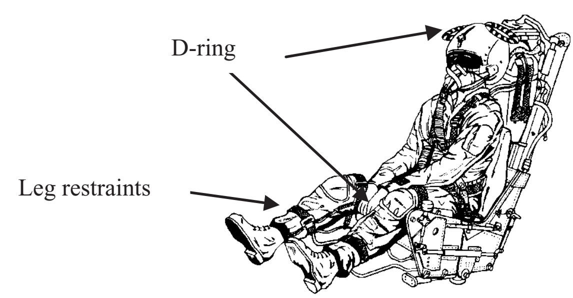


Figure 15.42. Typical military aircraft ejection seat (http://www.geocities.com/cap17.geo/Ejection.html)

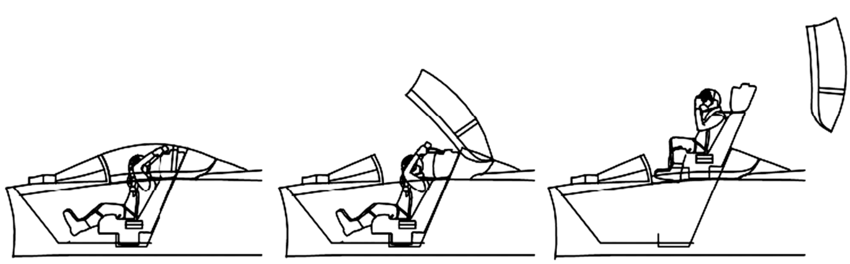


Figure 15.43. Typical ejection sequence

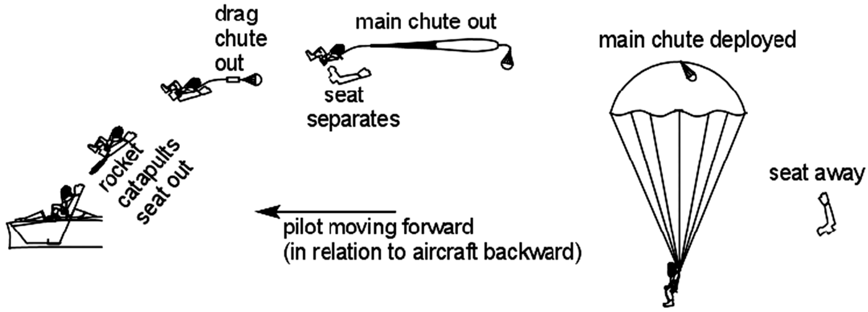


Figure 15.44. Typical ejection sequence showing separation of seat and parachute deployment

(failure at take-off or landing) – this is known as zero-zero ejection. In case the aircraft is close to the ground in inverted flight, the ejection could be successful if there is enough height at which the seat could turn around to a safe distance. Bear in mind that escape via an ejection seat is a serious matter and requires pilot drill to avoid injury. Restraints are placed to prevent the pilot's limb from flailing and to keep the body in a safe position at the time of passing through the flight deck. Peak *g*-load at ejection can exceed 25*g*. A few pilots have suffered injury during ejection but have saved their lives and recovered. Thousands have already been saved without injuries.

There are other kinds of simpler rescue systems for basic military trainer type of aircraft. For the home-built category, parachutes can be deployed to bring the entire aircraft down to safety.

Few manufacturers worldwide manufacture military ejection seats. Major manufactures are in the UK (Martin-Baker), the USA (ACES), and Russia (Zvezda). There is not much classroom work for readers, but they can contact the manufactures for free brochures, which give accurate size, weights, and other descriptions. These can be useful for weight and size estimation, and allow readers to stay updated with the latest developments.

15.10.2 Military Aircraft Stealth Consideration

The most important consideration for military aircraft designers is to maximize the chances for pilot survival in dangerous combat action. Pilot survival at combat involves consideration of many areas. This section will discuss some of the areas that affect aircraft configuration and weight. A brief discussion is given here on how aircraft configuration is affected by stealth considerations. Stealth design is an issue of pilot survivability.

The parameters affecting combat stealth aircraft design for survivability follow:

1. Minimize audio-visual detection: Make the airframe as small as possible and eliminate/reduce engine emission (noise and smoke). Very small aircraft may not prove combat effective.
2. Minimize radar signature: Make aircraft surface reflect radar beam away and use suitable paint coating to absorb radar emission.

3. Minimize heat signature: High temperature of engine exhaust is detectable, especially when the afterburner is used. Incorporation of super-cruise capability is to make aircraft fly at supersonic speed without the use of the afterburner.
4. Use of onboard passive system: Have infra-red search and track, forward looking cameras, night vision aids, etc. These minimize electronic radiation that can be detected from a distance.
5. Use of defensive aids: Incorporate Beyond Visual Range (BVR) capabilities and other capabilities to detect the enemy without being revealed.
6. Incorporate secure communication: A pilot should be able to receive communication, but radio transmission can reveal the aircraft's position. Therefore, the radio system must have a secure system to prevent detection.
7. Incorporate on-board stand-alone navigational system: A combat mission may have to fly over unfamiliar territory. Pilots require terrain map gathered from earlier reconnaissance flight and nonradiative on-board navigational tools to fly accurately as planned and be certain of aircraft position at any time and at any place.

The threats from hostile environment are getting more dangerous as technology advances. Pilot survival issues are addressed in the following three main segments of a combat profile.

1. *Before combat:* A surprise entry into the combat zone acts as a preventive measure by minimizing the reaction time for hostile retaliatory action, possibly to the point of making eney retaliatory action an inefficient attempt. The overriding objective of a surprise entry is to make the aircraft approach in stealth. Apart from the electronic counter measures to block signatures and sophisticated stand-alone navigational capabilities for complex approach route planning, stealth technology affects aircraft configuration. Although stealth configuration does not make aircraft completely invisible, it makes it become a Low Observable (LO) combat platform that reduces the warning time.
2. *During combat:* Combat is in an unpredictable scenario and involves many factors, some unknown, depending on the capabilities of the adversary. At the combat zone, the presence of attack aircraft is known. The aircraft should be capable of extreme maneuvers. Also, the aircraft should be designed with strong armor plating to protect against penetrative projectiles, especially against small arms firing from the ground.
3. *After combat:* The scenario is now completely changed. If the mission is successful without getting hit, then the only role for the pilot is to escape as effectively as possible – aircraft high-speed and altitude capability are now in demand. If hit, then the extent of damage would dictate what action the pilots should take. In case of a catastrophic damage, the only option is to eject. Survival through ejection is discussed in the previous section. If the aircraft is flyable but the pilot is injured to unconsciousness, then the aircraft should be capable of automatically flying back and landing at the home base. This technology is now available and can be a good candidate for commercial aircraft as a counter terrorist measure. The decision to take whatever action and measures are necessary after aircraft is damaged is the pilot's, who is trained to tackle such situations.

Returning to Home Base

An injured/stunned pilot as a result of enemy action can become temporarily unconscious even when the aircraft is still flyable. Combat aircraft can be designed with capabilities to switch to automatic mode so it can follow preprogrammed sequences and immediately return to home base. In time, the pilot could regain consciousness and, if required, land the aircraft with assistance from ground instructions. Saving one life is worth the investment.

15.10.3 Low Observable (LO) Aircraft Configuration

A fighter aircraft with LO configuration characteristics for stealth design will require compromises on performance (aerodynamic andmaneuver) affecting weapon-carrying capability, thereby limiting combat effectiveness. Aircraft designers have to make trade-off studies to maximize combat capability. The weapon load of conventional design will not offer stealth.

In addition, evasive maneuvers, radar jamming, spraying heat sources, etc., are other types of measures to confuse missile attack.

The missile finds its target by homing through the signals it receives and then locking on to it in an attempt to hit the target, unless countermeasures can fool the missile system. A stealth design would require suppressing the following parameters.

Table 15.13. *Stealth parameters*

1. Heat signature	3. Noise signature
2. Radar signature	4. Visibility

Heat signature

Infra-red seeking homing device is a potent method as long as there is a single, clear identifiable target emanating a sufficient signal, such as engine exhaust. The drawback is that the missile can be easily fooled by when heat flares are sprayed out. Missiles aiming at downward targets or facing the sun can lock onto a stationary target elsewhere within its capture angle.

Aircraft designers should aim to reduce aircraft heat signature at below 350°C by mixing engine exhaust with cool atmospheric air through entrainment at the exhaust. Shielding of engine exhaust by its wing is an effective method against ground-launched heat-seeking missiles.

Radar signature

The radar system works by transmitting radio waves to an object and then capturing the echoes from the radio waves reflected from that object. If the object is a moving aircraft, the radar technology adjusts with the Doppler Shift phenomena to give an accurate position of the aircraft; its speed, altitude, and range in real time, which come as alarm and homing signals. The fundamental objective of radar stealth is to delay the reaction time of the adversary by reducing the radar cross section (RCS) area (i.e., reducing the echo strength so that it is noticed much later).

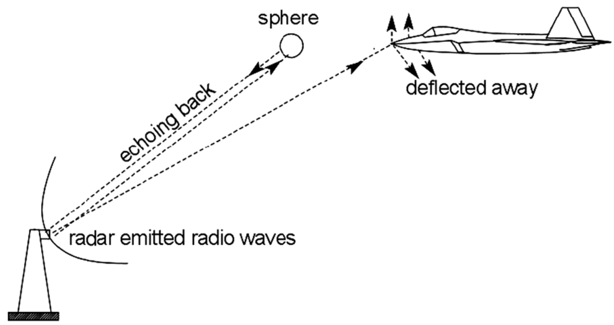


Figure 15.45. Typical comparisons of radar signatures (sphere versus stealth aircraft)

RCS area is defined as the projected area of an equivalent perfect reflector with uniform properties in all directions, such as from a sphere, and which returns the same amount of power per unit solid angle in steradians as the object under consideration.

The intensity of reflected radar beam (echo) depends on the surface from which it is reflecting. The parameters that influence reflection are area, orientation, and the nature of the surface. The maximum is when the surface is normal to it and to the extent of area capturing the radiation. Figure 15.45 compares echoing from a sphere to a pointed sharp corner of inclined surfaces.

Even a small sphere would offer a larger normal (and near normal) surface compared to a point, such as the tip of a nose cone. The inclined surfaces deflect the reflected beam away. In addition, if the surface is coated with radiation-absorbing paints, then the echoing can be further reduced. Radar absorbing coat is heavy, difficult to maintain, and increases costs.

Earlier designs (e.g., F117 Nighthawk) had inclined, flat plate-like surfaces with sharp edges, which succeeded in radar signature reduction – however, evidently not sufficient enough as one was shot down by a missile in the Kosovo conflict. The stealth configuration at the time was aerodynamically inefficient – nicknamed "aerodynamicists' nightmare." The B2 bomber showed improvement with a more streamlined shape, engine intake, and exhaust over the wing, shielding the hot zones against heat signature. The latest F22 Raptor is a fine example of improvement in shaping and incorporating better streamlined shape, cutting down drag. Figure 15.46 compares configurations and Table 15.14 compares several combat aircraft RCS values.

All modern combat aircraft design will have a specification for maximum RCS area. Therefore, modern combat aircraft design that does not assess the RCS area to satisfy requirements is meaningless. Computing RCS area is not difficult but is time consuming, making it unsuitable for undergraduate classroom work. There are

Table 15.14. *RCS values of combat aircraft*

Aircraft type	RCS area (m^2)	Aircraft type	RCS trea (m^2)
(Older designs)		(Newer Designs)	
F15 Eagle	40.50	F117 Nighthawk (1970s)	0.0030
B1 Bomber	10.00	B2 Spirit (1980s)	0.0014
SR-71	0.01	F22 Raptor (1990s)	0.0065

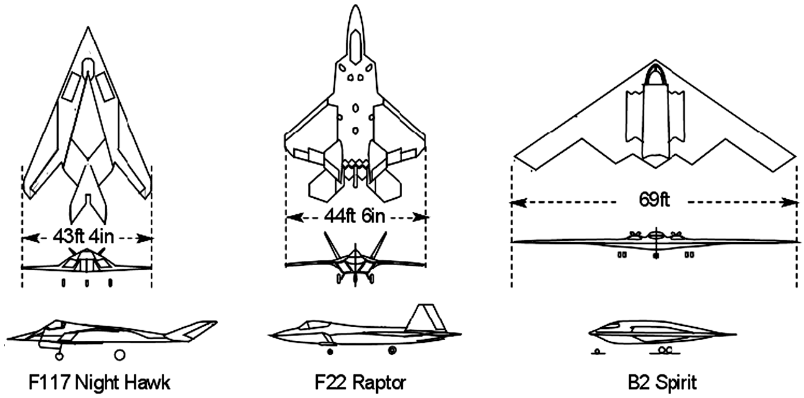


Figure 15.46. Three stealth aircraft configurations

application software that can measure RCS area and interactively tailor aerodynamic surfaces with minimum compromise. Currently, however, there is no such software available in public domain.

The downing of the F117 in Kosovo opened an argument on the extent of stealth affectivity. In addition, stealth features degrade aircraft performance and handling. Advances in missile technology would make stealth technology less effective. The author thinks that currently stealth continues to be a desirable feature that designers must exploit. The F117 is an older design and the stealth technology is also advancing. Aircraft designers have a difficult task in that they must reach a compromise on stealth, performance, and cost in a changing environment with newer technologies. The result from future combats will resolve some of these controversies.

APPENDIX C

Aerofoils

WHITCOMB INTEGRAL SUPERCRITICAL AEROFOIL

1.00000	−0.00080	0.00000	0.00000
0.97500	0.00740	0.00750	−0.01760
0.95000	0.01440	0.01250	−0.02160
0.92500	0.02040	0.02500	−0.02810
0.90000	0.02550	0.03750	−0.03240
0.87500	0.03000	0.05000	−0.03580
0.85000	0.03370	0.07500	−0.04080
0.82500	0.03700	0.10000	−0.04440
0.80000	0.03980	0.12500	−0.04720
0.77500	0.04220	0.15000	−0.04930
0.75000	0.04420	0.17500	−0.05100
0.72500	0.04600	0.20000	−0.05220
0.70000	0.04760	0.25000	−0.05400
0.67500	0.04890	0.30000	−0.05480
0.65000	0.05010	0.35000	−0.05490
0.62500	0.05110	0.40000	−0.05410
0.60000	0.05190	0.45000	−0.05240
0.57500	0.05270	0.50000	−0.04970
0.55000	0.05330	0.55000	−0.04550
0.50000	0.05430	0.57500	−0.04260
0.45000	0.05480	0.60000	−0.03890
0.40000	0.05500	0.62500	−0.03420
0.35000	0.05470	0.65000	−0.02820
0.30000	0.05400	0.67500	−0.02150
0.25000	0.05280	0.70000	−0.01490
0.20000	0.05070	0.72500	−0.00900
0.17500	0.04930	0.75000	−0.00360
0.15000	0.04760	0.77500	0.00120
0.12500	0.04550	0.80000	0.00530
0.10000	0.04280	0.82500	0.00880
0.07500	0.03940	0.85000	0.01140
0.05000	0.03470	0.87500	0.01320
0.03750	0.03160	0.90000	0.01380
0.02500	0.02760	0.92500	0.01310
0.01250	0.02150	0.95000	0.01060
0.00750	0.01760	0.97500	0.00600
0.00000	0.00000	1.00000	−0.00130

section 4
DATA SECTION – TIRES

three-part name sizes

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
18x4.25-10	6	TL	210	2,300	100	3450	6900	Flight Eagle DT	181K63-2	11.8
13x5.0-4	14	TL	180	3,100	143	4650	9300	Rib DT	135F48-2	7.8
14.5x5.5-6	14	TL	120	3,550	155	5330	10600	Rib	145K41-1	10.2
14.5X5.5-6	14	TL	210	2,800	144	4200	13100	Flight Eagle DT	145K13-1	11.4
18x5.7-8	18	TL	250	8,600	300	12900	25800	Rib	461B-3563-TL	16.1
18x5.7-8	20	TL	250	9,000	315	13500	27000	Rib	461B-3434-TL	16.1
17.5X5.75-8	12	TL	210	5,000	180	7500	15000	Flight Eagle	178K23-5	14.7
17.5X5.75-8	14	TL	210	6,050	220	9080	18200	Flight Eagle	178K43-1	16.7
18x5.75-8	8	TL	190	3,050	105	4570	9200	Flight Eagle DDT	186K88-5	13.7
22x5.75-12	10	TL	190	5,700	180	8550	17100	Flight Eagle	226K08-4	19.9
22x5.75-12	12	TL	210	7,100	220	10650	21300	Flight Eagle	226K23-2	23.4
13.5x6.0-4	14	TL	230	3,450	135	5000	10000	Rib	461B-3470-TL	6.8
15x6.0-6	6	TT	160	1,950	68	2830	5300	Flight Custom II	156E66-1	7.3
15X6.0-6	6	TT	120	1,950	68	2830	5300	Flight Special II	156E61-3	7
15X6.0-6	6	TT	160	1,950	68	2830	5300	Flight Custom III	156E66-4	9
15x6.0-6	10	TL	160	3,200	112	—	—	Flight Custom II	156E06-1	9.25
17.5x6.25-6	8	TT	190	2,350	65	3410	6300	Rib DDT	175K88-4	10.5
17.5X6.25-6	10	TL	160	3,750	90	5650	10150	Flight Special II	175K08-1	10.9
17.5X6.25-6/6.00-6	8	TL	190	2,900	70	4200	7800	Flight Special II	175K88-2	10.4
17.5x6.25-11	8	TL	139K	3,600	167	5400	10800	Smooth	461B-2271-TL	12.5
18x6.5-8	12	TL	223K	5,000	150	7500	15000	Rib	461B-3325-TL	12.4
22x6.5-10	6	TL	190	2,800	61	4200	8400	Rib	222K68-2	13.4
22x6.5-10	10	TL	190	5,200	125	7800	15600	Rib	222K08-1	15.9
24x6.5-14	18	TL	200K	12,900	375	18750	37500	Rib	461B-2592-TL	32.1
22x6.6-10	18	TL	200K	10,700	260	16050	32100	Rib	461B-3226-TL	24.5
22x6.6-10	18	TL	244K	9,200	260	13800	32100	Rib	461B-3343-TL	28.7
22x6.6-10	20	TL	190K	12,000	270	18000	36000	Rib	461B-2515-TL	26.5
19.5x6.75-8	8	TL	210	3,300	86	4950	9900	Flight Leader DT	196K83-1	17.3
19.5x6.75-8	10	TL	190	4,270	110	6400	12800	Rib	196K08-9	15.9
19.5x6.75-8	10	TL	190	4,270	110	6400	12800	Rib DDT	196K08-A	17.2
H19.5x6.75-10	8	TL	160	4,000	120	5800	10800	Flight Eagle	197K86-1	16
20.5x6.75-10	10	TL	210	5,450	158	8175	16350	Flight Leader	206K03-1	19.8
22x6.75-10	8	TL	160	4,450	99	6700	12000	Flight Custom III	265F86-8	20
22x6.75-10	10	TL	190	5,900	125	8550	15950	Flight Special II	265K08-1	21.5
22x6.75-10	18	TL	174K	10,600	245	15900	31800	Rib	461B-2687-TL	22.7
25.75x6.75-14	14	TL	210	10,300	199	14930	27800	Rib	256K43-3	28.4
25.75x6.75-14	14	TL	210	10,300	199	14930	27800	Rib	256K43-2	33.1
26x6.75-14	16	TL	190	11,900	270	17850	35700	Flight Eagle	265K68-2	37.6
21.5x7.0-10	12	TL	139K	6,700	135	9720	18100	Rib	710G26B2	18.8
23x7.0-12	12	TL	210	7,800	160	11700	23400	Flight Eagle	237K23-2	27.9
21X7.25-10	10	TL	225	5,150	135	7730	15500	Flight Eagle DT	217K02-2	19.5
21X7.25-10	12	TL	225	6,400	166	9600	19200	Flight Eagle DT	217K22-1	19.3
21X7.25-10	12	TL	210	6,400	166	9600	19200	Flight Eagle DT	217K23-1	19.6
24X7.25-12	12	TL	190	8,150	164	12200	24500	Flight Leader	247R28-1	26.8
22x7.75-9	26	TL	210K	12,400	305	18600	32200	Rib	461B-3592-TL	23
22x7.75-10	10	TL	190	5,500	110	7980	14900	Rib	277K08-1	20.9
22x7.75-10	12	TL	190	6,700	133	10050	20100	Rib	277K28-1	25.4
25x7.75-10	12	TL	190	6,900	115	10350	20700	Flight Leader	257K28B1	25

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER											
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX				WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
18.25	17.75	4.7	4.45	16.75	4.15	7.9	6.7	0.874	18x4.25-10	3.63	10	0.6	0.85	HS	C62c
13.25	12.7	5.25	4.95	11.6	4.6	5.3	4.1	0.88	13x5.0-4	4.25	4	0.75	0.8	Dassault	C62b
14.5	14	5.5	5.15	13	4.85	6.1	5.1	0.775	14.5X5.5-6	4.25	6	0.88	1.5	Sikorsky	C62c
14.5	14	5.5	5.15	13	4.85	6.4	5.1	0.775	14.5x5.5-6	4.25	6	0.88	1.5	Dassault	C62c
17.9	17.3	5.7	5.35	16.2	5	7.55	6.1	0.869	18x5.5	4.25	8	0.88	1.5	Lockheed	16VL027-E
17.9	17.3	5.7	5.35	16.2	5	7.55	6.1	0.869	18x5.5	4.25	8	0.88	1.5	GenDyn	GD 16VL036
17.5	16.95	5.75	5.4	15.8	5.1	7.4	6.1	0.827	18x5.5	4.25	8	0.88	1.4	Lear	C62c
17.5	16.95	5.75	5.4	15.8	5.1	7.4	6.3	0.827	18x5.5	4.25	8	0.88	1.4	Lear	C62c
18	17.4	5.75	5.4	16.2	5.1	7.6	6	0.87	18x5.5	4.25	8	0.88	1.25	Dassault	C62c
22	21.4	5.75	5.4	20.2	5.05	9.6	8	0.87	22x5.5	4.25	12	0.88	1.35	Cessna, Dassault	C62c
22	21.4	5.75	5.4	20.2	5.05	9.6	8.3	0.87	22x5.5	4.25	12	0.88	1.35	Rockwell	C62c
13.75	13.2	6.1	5.75	12	5.4	5.35	3.6	0.8	13.5x6.0-4	4.75	4	0.55	0.94	HS, McDonnell-Douglas	USN MILT MS
15.2	14.55	6.3	5.9	13.55	5.55	6.15	4.8	0.727	6.00-6	5	6	0.75	0.85	GUA	C62c
15.2	14.55	6.3	5.9	13.55	5.55	6.15	4.8	0.727	6.00-6	5	6	0.75	0.85	GUA	C62c
15.2	14.55	6.3	5.9	13.55	5.55	6.15	4.8	0.727	6.00-6	5	6	0.75	0.85	GUA	C62c
15.2	14.55	6.3	5.9	13.55	5.55	6.1	4.8	0.727	6.00-6	5	6	0.75	—	Eurocopter	C62d
17.5	16.85	6.25	5.9	15.45	5.5	6.9	4.8	0.92	6.00-6	5	6	0.75	0.9	Snias	C62c
17.5	16.85	6.25	5.9	15.45	5.5	6.9	4.8	0.92	6.00-6	5	6	0.75	0.95	Piper, Sikorsky	C62d
17.5	16.85	6.25	5.9	15.45	5.5	6.9	4.8	0.92	6.00-6	5	6	0.75	0.9	Saab	C62c
17.7	17.3	6.1	5.7	16.5	5.45	7.95	7.6	0.551	17.5x6.25-11	5.25	11	0.81	1.25	Kaman	USN KAMAN
18	17.45	6.5	6.2	15.95	5.7	7.6	6.1	0.766	18x6.5-8	5.25	8	0.88	1.5	Northrop	USAF 63J4242
22.1	21.35	6.65	6.25	19.9	5.65	9.1	6.9	0.909	6.50-10	4.75	10	0.81	1.2	DeHavilland	C62d
22.1	21.35	6.65	6.25	19.9	5.65	9.25	6.9	0.909	6.50-10	4.75	10	0.81	1.2	Cessna	C62d
24	23.4	6.65	6.25	22.4	5.9	10.6	9.7	0.752	25x6.0	4.75	14	0.88	1.65	Douglas	USN MS14178
22.2	21.6	6.8	6.4	20	6	9.45	7.4	0.902	22x6.6-10	5.5	10	1	2.05	McDonnell-Douglas	USAF 8412568
22.2	21.6	6.8	6.4	20	6	9.7	7.4	0.902	22x6.6-10	5.5	10	1	2.05	—	5041G
22.2	21.6	6.8	6.4	20	6	9.35	7.4	0.902	22x6.6-10	5.5	10	1	2.05	Grumman	USN MS14168
19.5	18.9	6.75	6.2	17.45	5.95	8.05	5.9	0.865	6.50-8	5.25	8	0.81	1.25	Embraer	C62d
19.2	18.9	6.35	6.2	17.45	5.95	8.05	6.1	0.865	6.50-8	5.25	8	0.81	1.25	Fairchild	C62d
19.5	18.9	6.75	6.2	17.45	5.95	8.05	6.1	0.865	6.50-8	5.25	8	0.81	1.25	Beech	C62d
19.5	18.9	6.75	6.35	17.8	5.95	8.25	6.8	0.702	H19.5x6.75-10	4.25	10	0.75	1.5	Beech	C62c
20.5	20	6.75	6.35	19.45	6.1	8.8	7.3	0.779	20.5x6.75-10	5.25	10	1	1.8	Canadair	EDD00046
22	21.3	6.75	6.35	19.85	5.95	9.1	7.1	0.889	6.50-10	4.75	10	0.81	0.95	Beech, Lockheed	C62d
22	21.35	6.75	6.35	19.85	5.95	9.1	7.1	0.891	6.50-10	4.75	10	0.81	1.3	Beech	C62d
22	21.35	6.75	6.35	19.85	5.95	9.3	7.4	0.891	22x6.6-10	5.5	10	1	2.05	Lockheed	USN MS14161
25.75	25.1	6.75	6.35	23.65	5.95	11.05	9.3	0.872	26x6.6	5	14	1	1.7	Canadair	C62d
25.75	25.1	6.75	6.35	23.65	5.95	11.05	9.4	0.872	26x6.6	5	14	1	1.7	Canadair	C62c
26	25.3	6.75	6.35	23.85	5.95	11.3	9.6	0.889	26x6.6	5	14	1	1.9	Rockwell	C62c
21.76	21.14	7.05	6.73	18.9	6.14	9	7	0.831	175x254x545	5.9	10	0.75	—	Aeromacchi	5041H
23.2	22.6	7.2	6.8	21.15	6.3	9.9	7.9	0.779	23x7.0-12	6.25	12	0.65	1.25	HS	C62c
21.25	20.6	7.2	6.8	19.25	6.35	9.05	7.1	0.78	22x6.6	5.5	10	1	1.25	Grumman	C62d
21.25	20.6	7.2	6.8	19.25	6.35	9	7.1	0.78	22x6.6	5.5	10	1	1.8	Gulfstream	C62d
21.25	20.6	7.2	6.8	19.25	6.35	9	7.1	0.78	22x6.6	5.5	10	1	1.95	Canadair	C62d
24.5	23.95	7.5	7	22.25	6.5	10.4	7.8	0.843	24X7.25-12	6.25	12	0.7	1.75	Embraer	C62d
22.2	21.5	7.8	7.35	19.85	7.12	9.2	6.7	0.848	22x7.75-9	6.25	9	1.13	2.15	MCAir	5041H
22	21.3	7.75	7.3	19.85	6.8	9.05	6.9	0.774	6.50-10	4.75	10	0.81	0.95	Cessna	C62d
22	21.3	7.75	7.3	19.85	6.8	9.05	6.9	0.774	6.50-10	4.75	10	0.81	0.95	Cessna	C62d
25	24.2	7.75	7.3	23.5	7	10.3	7.1	0.97	25x7.75-10	6	10	1	1.94	Embraer	C62c

three-part name sizes

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
26x7.75-13	10	TT	210	7,250	110	10880	21750	Rib DT	267R03G1	30.6
27X7.75-15	12	TL	225	9,650	200	14475	29000	Flight Leader	275K22-1	38.9
22x8.0-8	6	TT	120	2,500	40	3620	6700	Flight Special II	228K61-1	13
22x8.0-10	10	TL	190	6,500	110	9750	17500	Flight Eagle	220K08-3	24.1
22x8.0-10	12	TL	190	7,900	135	11450	21300	Flight Eagle	220K28-1	27.7
24x8.0-13	18	TL	230K	12,500	285	18750	37500	Rib	461B-2506-TL	28.3
25.5x8.0-14	20	TL	217K	16,200	310	23500	43700	Rib	461B-3529-TL	39.5
26x8.0-14	16	TL	239K	12,700	235	18420	34300	Rib	461B-1905-TL-1	35.9
26x8.0-14	16	TL	280	12,700	235	18420	34300	Rib	268K67G3	38.4
H22x8.25-10	14	TL	190	8,300	156	12500	22400	Flight Eagle	229K48-1	27.2
H22x8.25-10	14	TL	190	8,300	156	12500	22400	Flight Eagle	229K48-2	31
22x8.5-11	16	TL	217K	10,000	210	15000	30000	Rib	461B-2513-TL	25.9
H27x8.5-14	16	TL	210	13,300	207	19950	35900	Flight Eagle	274K63-1	42
25.5x8.75-10	14	TL	190	8,500	101	12750	22950	Rib	259K48G1	33.5
27.75x8.75-14.5	24	TL	225K	21,500	320	31175	58050	Rib	461B-3680-TL	52.03
28x9.0-14	22	TL	185K	18,100	280	27150	54300	Rib	461B-3140-TL	53.2
H29x9.0-15	16	TL	210	14,500	196	21750	39200	Flight Leader	299K63-1	43.9
H30x9.5-16	16	TL	210	15,350	202	23025	46050	Flight Leader	302K63-1	53
35x9.0-17	16	TL	210	17,920	178	26880	53800	Rib	359R63G1	65.1
34x9.25-16	18	TL	210	17,800	190	26700	53400	Flight Eagle	348F83-2	68.4
H34x9.25-18	18	TL	225	19,400	213	29100	52400	Flight Eagle	349K82-2	59.5
B24x9.5-10.5	18	TL	210	12,200	160	18300	32900	RS-700	249K83-3	40.2
30x9.5-14	16	TL	210	13,700	177	20600	41100	Flight Leader	304K63-2	48.1
30x9.5-14	16	TL	210	13,700	177	20600	41100	Flight Leader	304K63-1	48.1
H31x9.75-13	12	TL	190	9,350	90	14020	23400	Flight Leader	319K28-1	39.9
31x9.75-14	12	TL	190	11,100	115	16650	33300	Flight Leader	318K28-1	39.2
32x9.75-18	22	TL	250	23,700	345	35550	71100	Rib	461B-3309-TL	81.5
34.5x9.75-18	26	TL	203K	32,000	360	48000	96000	Rib	461B-3440-TL	81.2
34.5x9.75-18	26	TL	225K	30,100	340	45150	90300	Rib	461B-3268-TL	77.9
26X10.0-11	12	TL	139K	9,700	140	14550	30400	Rib	461B-3251-TL	30.2
26x10.5-6	6	TL	120	2,765	25	4010	7465	Smooth	260K61-1	22.7
31x10.75-14	20	TL	264	14,615	174	21920	43800	Flight Leader	310K07G2	65.2
32x10.75-14	12	TL	160	10,200	85	14790	27500	Rib	321R26T1	52.6
33.5x10.75-15	12	TL	160	12,200	100	17690	32900	Flight Leader	331K26-2	48.2
34x10.75-16	12	TL	190	13,000	95	18850	35100	Flight Leader	347K28G1	58.8
34x10.75-16/10.50-16	10	TL	190	10,870	80	15760	29300	Flight Leader	347K08T1	62.5
34x10.75-16/10.50-16	12	TL	190	13,000	95	18850	35100	Flight Leader	347K28T1	71.6
29x11.00-10	10	TL	210	7,070	69	10605	21210	Rib	110T03-1	40.6
29x11.0-10	10	TL	120	7,070	60	10250	19100	Rib	110T01-1	36
H35x11.0-18	20	TL	225	23,400	216	35100	63200	Flight Eagle	350K02-1	81.4
36x11.0-18	30	TL	227K	35,800	305	53700	85150	Rib	461B-3477-TL	85.2
30x11.5-14.5	24	TL	210K	25,000	243	36250	67500	Rib	301K45G1	66.7
30x11.5-14.5	24	TL	215K	25,000	243	36250	67500	Rib	461B-2573-TL	66.5
30x11.5-14.5	24	TL	215K	25,000	245	36250	67500	Rib	461B-3197-TL	66.4
30x11.5-14.5	26	TL	210K	25,000	245	36250	67500	Rib	461B-3204-TL	74.2
30x11.5-14.5	26	TL	220K	26,600	265	38570	71800	Rib	461B-3430-TL	72.4
32x11.5-15	12	TL	225	11,200	120	16800	33600	Flight Leader DT	321K22-2	61.1

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER											
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX				WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
26.3	25.5	7.9	7.45	23.9	6.95	11	8.6	0.84	26x7.75-13	6.62	13	0.7	1.5	Snias	C62c
27	26.3	7.75	7.3	24.85	6.85	11.8	9.8	0.774	29x7.7	6	15	1	1.65	Boeing	C62c
22	21.3	8	7.55	19.5	7.05	8.75	6	0.878	22x8.0-8	6	8	0.88	1.1	GUA	C62c
22	21.35	8	7.55	19.85	7.05	9	6.9	0.751	22x8.0-10	5	10	0.63	1.4	Cessna	C62c
22	21.35	8	7.55	19.85	7.05	9	7.1	0.751	22x8.0-10	5	10	0.63	1.4	Cessna	C62c
24	23.4	8	7.55	22	7.05	10.45	8.9	0.688	24x8.0-13	5.75	13	1	2.05	Northrop	USAF 73453C
25.5	24.8	8	7.55	23.14	6.84	11	9.4	0.717	25.5x8.0-14	5.75	14	1	2.1	Lockheed	USAF 16VL028
26	25.3	8	7.5	23.85	6	11.2	9.6	0.752	26x8.0-14	6.38	14	1.13	2.1	Lockheed	USAF 61D3001E
26	25.3	8	7.5	23.85	6	11.2	9.6	0.752	26x8.0-14	6.38	14	1.13	2.1	Lockheed	USAF
22	21.35	8.25	7.8	20.8	7.45	9.15	7.1	0.727	H22x8.25-10	5.25	10	0.85	2.14	Cessna	C62d
22	21.35	8.25	7.8	20.8	7.45	9.15	7.1	0.727	H22x8.25-10	5.25	10	0.85	2.14	Cessna	C62d
22	21.4	8.5	8.1	19.65	7.5	9.4	7.8	0.645	22x8.5-11	7.25	11	0.88	1.88	Northrop	USAF 63J4241F
27	26.3	8.5	8	25.7	7.65	11.45	9.4	0.767	H27x8.5-14	5.5	14	0.95	2.15	Canadair	C62d
25.6	24.7	8.65	8.25	22.85	7.7	10.25	7.2	0.896	24x7.7	5.5	10	0.91	1.5	Dornier	C62c
27.75	27.05	8.75	8.25	24.6	7.48	11.85	9.9	0.759	27.75x8.75-14.5	6	14.5	1.2	2.35	Lockheed	USAF 16VL032
27.85	27.3	9.1	8.6	25.25	8	12	9.6	0.767	28x9.0-14	7.25	14	1.13	2.25	Vought	USAF 74201
29	28.2	9	8.5	27.7	8.55	12.3	9.9	0.777	H29x9.0-15	6	15	0.95	2.15	Canadair	C62c
30	29.35	9.5	8.95	28.6	8.55	12.85	10.6	0.741	H30x9.5-16	6.25	16	1.1	2.2	Embraer	C62d
34.8	33.95	9.4	8.9	31.6	8.2	14.75	11.2	0.949	35x9.0-17	7.25	17	1.1	2.25	Snias	C62c
34	33.15	9.25	8.75	30.75	8.15	14.35	10.7	0.976	32x8.8	7	16	1.13	2	Grumman	C62c
34	33.15	9.25	8.75	30.75	8.15	14.5	11.6	0.865	H34x9.25-18	6	18	1.2	2.4	Gulfstream	C62d
24	23.3	9.5	8.95	21.6	8.4	9.85	7.7	0.713	B24x9.5-10.5	6	10.5	0.88	1.9	IAI	C62c
30	29	9.5	8.95	28.4	8.55	12.65	9.6	0.84	30x9.5-14	7	14	1.13	2.25	Embraer	C62d
30	29	9.5	8.95	28.4	8.55	12.65	9.6	0.84	30x9.5-14	7	14	1.13	2.25	Embraer	C62d
31	30.1	9.75	9.2	27.72	8.3	12.4	8.8	0.926	26.5x8.0-13	6.5	13	1	2.05	DeHavilland	C62d
31	30.1	9.75	9.2	29.4	8.8	12.95	9.3	0.873	31x9.75-14	8	14	1	2.15	DeHavilland	C62c
32	31.3	9.75	9.2	29.5	8.6	14.05	12.2	0.72	34.5x9.75-18	7.5	18	1.25	2.55	—	5041G
34.5	33.7	9.75	9.15	31.55	8.4	14.85	11.9	0.852	34.5x9.75-18	7.5	18	1.25	2.55	McDonnell-Douglas	IAF
34.5	33.7	9.75	9.15	31.55	8.4	14.85	11.9	0.852	34.5x9.75-18	7.5	18	1.25	2.55	McDonnell-Douglas	USAF 8412569
26	25.5	10	9.45	23.3	8.8	10.85	7.8	0.758	26X10.0-11	8	11	1	1.95	Sikorsky	5041G
26	25.1	10.5	9.95	22.4	9.25	9.65	5	0.956	9.00-6	6.75	6	0.88	1.45	—	C62b
31.42	30.58	11.05	10.45	28.28	9.72	13.2	10	0.791	31x10.75-14	9	14	1.25	3.25	Snias	C62d
32.55	31.65	10.95	10.55	28.55	9.5	13.25	9.3	0.842	32x10.75-14	9.25	14	1.05	2	HS	C62b
33.5	32.65	10.75	10.15	30.2	9.15	13.7	9.8	0.865	33.5x10.75-15	8	15	1	1.9	DeHavilland	C62c
34.5	33.65	10.45	9.9	31.15	8.9	14.25	10.5	0.888	34x10.75-16	8.25	16	1.05	1.85	Fokker, Shorts	C62c
34.5	33.65	10.45	9.9	31.15	8.9	14.25	10.3	0.888	34x10.75-16	8.25	16	1.05	1.85	Fokker, Shorts	C62c
34.5	33.65	10.45	9.9	31.15	8.9	14.25	10.5	0.888	34x10.75-16	8.25	16	1.05	1.85	Fokker, Shorts	C62c
29	28.1	11	10.4	25.6	9.35	11.4	7.3	0.867	29x11.00-10	8.5	10	1	1.4	Alenia	C62d
29	28.1	11	10.4	25.6	9.35	11.4	7.3	0.867	29x11.0-10	8.5	10	1	1.4	Rockwell	C62b
35	34.15	11	10.4	33.3	9.9	14.8	11.8	0.775	H35x11.0-18	7	18	1.2	2.8	Gulfstream	C62d
35.8	34.9	10.4	9.85	34.1	9.35	15.25	12.4	0.857	36x11.0-18	8.5	18	1.75	3.2	McDonnell-Douglas	USAF
29.75	28.75	11.5	11	27	10.1	12.5	10.1	0.656	30x11.5-14.5	9.75	14.5	1.25	2.75	McDonnell-Douglas	USAF
29.75	28.75	11.5	11	27	10.1	12.5	10.1	0.656	30x11.5-14.5	9.75	14.5	1.25	2.75	McDonnell-Douglas	IAF
29.75	28.75	11.5	11	27	10.1	12.4	10.1	0.656	30x11.5-14.5	9.75	14.5	1.25	2.75	McDonnell-Douglas	CAF
29.75	28.75	11.5	11	27	10.1	12.5	10.6	0.656	30x11.5-14.5	9.75	14.5	1.25	2.75	McDonnell-Douglas	USN MS14171
31	30.45	11.5	10.9	27.54	10.2	12.5	10.1	0.724	30x11.5-14.5	9.75	14.5	1.25	2.75	McDonnell-Douglas	USAF MS21781
32	31.1	11.5	10.8	29	10.5	13.55	10	0.742	32x11.5-15	9	15	1.25	1.9	Boeing	C62d

three-part name sizes

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
32x11.5-15	26	TL	210K	27,800	290	41700	83400	Rib	461B-3675-TL	84.4
35X11.5-16	22	TL	222K	23,000	210	34500	69000	Rib	461B-3418-TL	66.9
37X11.5-16	28	TL	190K	31,200	245	46800	93600	Rib	461B-3245-TL	85.9
37x11.75-16	12	TL	190	13,000	80	18850	35100	Flight Leader	371K28G1	69.7
H36x12.0-18	18	TL	225	21,525	177	32288	58125	Flight Leader	362K82-1	82.9
H38x12.0-19	20	TL	210	25,300	193	3800	68300	Flight Eagle	382K03-2	86.08
H31x13.0-12	20	TL	225	17,200	155	25800	51600	Flight Leader	313K02-1	68
37x13.0-16	26	TL	225	29,300	220	43950	87900	Flight Leader	373K62-3	111.2
34x14.0-12	24	TL	174K	17,300	155	25950	51900	Rib	461B-3518-TL	87.9
37x14.0-14	24	TL	225	25,000	160	37500	75000	Flight Leader	374F42-4	107.9
H37x14.0-15	22	TL	225	24,100	165	36150	72300	Flight Leader	375K22-1	111.8
H37x14.0-15	22	TL	235	24,100	165	36150	72300	Flight Leader	375K29-1	111.8
H40x14.0-19	20	TL	225	27,100	166	39295	73200	Flight Leader	409K02-1	125.5
H40x14.5-19	22	TL	225	30,100	180	43640	81300	Flight Leader	419K22-2	144.4
H40x14.5-19	24	TL	225	33,200	200	48140	89600	Flight Leader	419K42-3	146.3
H40x14.5-19	24	TL	225	33,200	200	48140	89600	Flight Leader	419K42T1	142.9
H40x14.5-19	26	TL	225	36,800	220	53360	99360	Flight Leader	419K62-3	150.4
H40x14.5-19	26	TL	225	36,800	220	53360	99360	Flight Leader	419K62T1	156.6
41x15.0-18	24	TL	225	31,400	190	47100	94200	Flight Leader	415K42G6	133.8
H41x15.0-19	24	TL	225	33,650	187	48800	90900	Flight Leader	416K42-1	144.9
40x15.5-16	28	TL	235	39,500	195	57270	106600	Flight Leader	405K89-2	155.1
40.5x15.5-16	28	TL	235	34,200	190	51300	105600	Flight Leader	406K89-1	137.9
47x15.75-22.1	32	TL	279	51,500	223	74670	139000	Flight Leader	472K27G3	200.4
H42x16.0-19	26	TL	225	37,800	190	56700	102100	Flight Leader	426K62-2	166.8
43x16.0-20	28	TL	174K	38,600	215	56900	115800	Rib	461B-3517-TL	158.8
H43.5x16.0-21	26	TL	225	40,600	210	60900	109600	Flight Leader	431K62-1	169.8
B46x16.0-23.5	30	TL	240K	53,800	260	80700	161400	Rib	461B-3355-TL	184.9
44.5x16.5-18	30	TL	225	42,500	195	63750	127500	Flight Leader	456F02-4	199.4
H44.5x16.5-20	28	TL	225	42,800	195	64200	115600	Flight Leader	446K82-2	178.4
H44.5x16.5-21	26	TL	225	41,100	198	61700	111000	Flight Leader	441K62-1	186
H44.5x16.5-21	28	TL	225	44,700	214	64800	121000	Flight Leader	441K82-1	189
H45x17.0-20	26	TL	225	40,000	195	60000	120000	Flight Leader	457K62-1	199.4
H46x18.0-20	26	TL	225	41,500	170	60150	112000	Flight Leader	468K62T1	239.9
H46x18.0-20	28	TL	225	44,200	180	64100	119300	Flight Leader	468K82-2	218.6
H46x18.0-20	28	TL	225	44,200	180	64100	119300	Flight Leader	468K82T1	206.2
H46x18.0-20	32	TL	235	51,100	205	74100	138000	Flight Leader	468K29-2	257.1
H46x18.0-20	32	TL	235	51,100	205	74100	138000	Flight Leader	468K29T1	257.1
47x18-18	36	TL	217K	54,000	215	81000	162000	Rib	461B-2481-TL	191.3
49x18.0-22	30	TL	225	50,900	219	76400	152700	Flight Leader	498F02-1	198.8
49x18.0-22	—	TL	225	52,235	219	78353	156705	Flight Leader	498FL2-1	195.9
49x19.0-20	32	TL	235	51,900	195	77800	155700	Flight Leader	491K29-3	233.3
49x19.0-20	32	TL	235	51,900	195	77850	155700	Flight Leader	491K29T3	259.9
49x19.0-20	34	TL	245	55,700	215	83550	167100	Flight Leader	491K45G2	254.5
49x19.0-20	34	TL	235	55,700	215	83550	167100	Flight Leader	491K49T2	281
H49x19.0-22	24	TL	225	41,000	155	61500	110700	Flight Leader	499K42T1	228.5
H49x19.0-22	32	TL	235	56,600	205	84900	152800	Flight Leader	499K29T1	267.3
H49x19.0-22	32	TL	235	56,600	205	84900	152800	Flight Leader	499K29-3	248.5
50x20.0-20	34	TL	225	57,000	205	85500	171000	Flight Leader	500K42-6	276.1
56x20.0-20	24	TL	210	38,500	110	57750	115500	Flight Leader	560F43-1	225.9

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER											
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX				WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
32	31.45	11.5	10.9	29	10.5	12.8	10.5	0.747	32x11.5-15	9	15	1.25	3	MDA	Navy
35	34.1	11.5	10.9	31.8	10.1	14.75	10.8	0.828	36x11	9	16	1.38	2.8	Rockwell	USAF
37	36.1	11.5	10.9	33.2	10.1	15.45	11	0.917	37X11.5-16	9	16	1.38	3.15	Grumman	USN MS14152
37	36.1	11.75	11.15	33.25	10.35	15.05	10.3	0.897	37x11.75-16	9.25	16	1	1.63	Fokker	C62c
36	35.2	12	11.35	34.2	10.8	15.2	11.8	0.753	H36x12.0-18	7.75	18	1.2	—	Canadair	C62d
38	37.1	12	11.35	36.1	10.8	16	12.5	0.794	H38x12.0-19	7.75	19	1.3	2.73	Canadair	C62d
31	30.1	13	12.3	27.6	11.45	12.7	8.6	0.733	H31x13.0-12	8	12	1.2	2.7	Boeing	C62c
37	36.1	13	12.3	33.2	11.45	15.45	11.4	0.812	36x11	9	16	1.63	3.2	Lockheed	C62c
34	32.6	14	13.2	30.5	12.35	13.7	9.2	0.782	34x14.0-12	11	12	1.38	3	Boeing	5041G
37	36.05	14	13.3	32.85	12.3	15.15	10.5	0.825	37x14.0-14	11	14	1.5	3	Douglas	C62c
37	36.1	14	13.3	33.05	12.3	15.25	10.4	0.789	H37x14.0-15	9	15	1.3	2.8	Boeing	C62c
37	36.1	14	13.3	33.05	12.3	15.25	10.4	0.789	H37x14.0-15	9	15	1.3	2.8	Boeing	C62d
40	39.1	14	13.2	36.25	12	16.6	12.3	0.756	H40x14.0-19	9	19	1.2	2.5	Fokker	C62c
40	39.1	14.5	13.75	36.25	12.8	16.65	12.7	0.727	H40x14.5-19	9.5	19	1.4	2.9	Boeing	C62c
40	39.1	14.5	13.75	36.25	12.8	16.65	12.7	0.727	H40x14.5-19	9.5	19	1.4	3.1	Boeing	C62c
40	39.1	14.5	13.75	36.25	12.8	16.65	12.7	0.727	H40x14.5-19	9.5	19	1.4	3.1	Boeing	C62c
40	39.1	14.5	13.75	36.25	12.8	16.65	12.9	0.727	H40x14.5-19	9.5	19	1.4	3.1	Boeing	C62d
40	39.1	14.5	13.75	36.25	12.8	16.65	12.9	0.727	H40x14.5-19	9.5	19	1.4	3.1	Boeing	C62c
41	40.05	15	14.25	36.9	13.2	17.2	12.5	0.77	41x15.0-18	12.75	18	1.63	3	Boeing, Convair, Douglas	C62c
41	40.1	15	14.25	38.8	13.5	17	12.9	0.736	H41x15.0-19	9.75	19	1.4	3.1	Boeing B717	C62d
40	39.05	15.5	14.75	35.7	13.65	16.1	11.2	0.778	40x15.5-16	10	16	1.25	3.2	Douglas	C62c
40.5	39.5	15.5	14.7	38.1	14	16.7	11.4	0.795	40.5x15.5-16	11.5	16	1.75	3.6	BAe, Snias	C62c
48.1	47.2	16	15.2	43.4	14.05	19.95	14.8	0.819	47x15.75-22.1	12.75	22.1	1.75	3.75	Snias	C62d
42	41.1	16	15.2	37.9	14.1	17.3	12.9	0.723	H40x14.5-19	9.5	19	1.4	3.1	Boeing	C62c
43	42.1	16	15.2	38.9	14.15	17.95	13.7	0.723	43x16.0-20	13	20	1.75	3.45	Boeing	5041G
43.5	42.55	16	15.2	41.25	14.4	18.2	14	0.706	H43.5x16.0-21	10.5	21	1.6	1.24	Boeing	C62d
46	45.1	16	15.2	42.2	14.1	19.65	15	0.707	B46x16.0-23.5	10.5	23.5	1.25	3.15	Rockwell	USAF L194C2025
44.5	43.5	16.5	15.7	39.7	14.5	18.35	12.8	0.807	44x16	13.25	18	1.63	3.55	Douglas	C62c
44.5	43.5	16.5	15.7	40.1	14.55	18.35	13.6	0.745	H44.5x16.5-20	10.5	20	1.6	3.5	Douglas	C62c
44.5	43.5	16.5	15.7	42.2	14.5	18.55	14.1	0.714	H44.5x16.5-21	10.5	21	1.6	3.3	Douglas	C62d
44.5	43.5	16.5	15.7	42.15	14.8	18.5	13.5	0.714	H44.5x16.5-21	10.5	21	1.6	3.3	Boeing, Douglas	C62d
45	44	17	16.2	40.5	15	18.85	13.6	0.738	H45x17.0-20	11	20	1.6	3.25	Boeing	C62c
46	45	18	17.15	41.3	15.85	18.85	13.7	0.725	H45x17.0-20	11	20	1.6	3.35	Boeing	C62d
46	45	18	17.15	41.3	15.85	18.85	13.7	0.725	H45x17.0-20	11	20	1.6	3.55	Boeing	C62c
46	45	18	17.15	41.3	15.85	18.85	13.6	0.725	H45x17.0-20	11	20	1.6	3.55	Boeing	C62d
46	45	18	17.15	41.3	15.85	18.85	13.7	0.725	H45x17.0-20	11	20	1.6	3.8	Boeing	C62c
46	45	18	17.15	41.3	15.85	18.85	13.7	0.725	H45x17.0-20	11	20	1.6	3.8	Boeing	C62d
46.9	46	17.9	17.25	41.6	15.75	19.25	13.1	0.809	47x18-18	14.75	18	1.75	3.9	GenDyn	USAF 65J1971
49	48	18	17.2	46.3	16.2	20.6	15	0.753	49x18.0-22	13.75	22	1.88	3.75	Snias	C62d
49	48	18	17.15	46.3	16.2	20.6	15	0.754	49x18.0-22	13.75	22	1.88	3.75	Aerospatiale	C62d
49	48	19	18.15	43.8	16.7	20.3	14	0.767	49x17	13.25	20	1.88	3.75	Boeing	C62c
49	48	19	18.15	43.8	16.7	20.3	14	0.767	49x17	13.25	20	1.88	3.75	Boeing, Snias	C62c
49	48	19	18.15	43.8	16.7	20.3	14	0.767	49x17	13.25	20	1.88	3.75	Boeing, Snias	C62c
49	48	19	18.15	43.8	16.7	20.3	14	0.767	49x17	13.25	20	1.88	3.75	Boeing, Snias	C62c
49	48	19	18.15	46.3	17.1	20.2	14.8	0.713	H49x19.0-22	12	22	1.7	3.95	Boeing	C62d
49	48	19	18.15	46.3	17.1	20.2	14.8	0.713	H49x19.0-22	12	22	1.7	3.95	Boeing	C62c
49	48	19	18.15	46.3	17.1	20.2	15	0.713	H49x19.0-22	12	22	1.7	3.95	Boeing	C62c
50	49	20	19.1	44.6	17.6	20.65	14.2	0.754	50x20.0-20	16.25	20	1.88	3.95	Douglas, Lockheed	C62c
56	54.8	20	19.1	49.5	17.6	22.7	14	0.905	20.00-20	15.5	20	2	3.4	Lockheed	C62c

three-part name sizes

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
52X20.5-20	36	TL	225	62,500	200	93750	187500	Flight Leader	521K62-3	333.7
52x20.5-23	30	TL	235	63,700	195	95500	172000	Flight Leader	520K09-7	293.7
50x21.0-20	30	TL	225	49,000	160	73500	132300	Flight Leader	501K02-1	279.5
54x21.0-23	36	TL	235	68,500	223	102750	205500	Flight Leader	542K69-4	281
H54x21.0-24	36	TL	235	72,200	212	104700	194900	Flight Leader ER	541K69-2	293.7

type I

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
27	10	TL	120	5,500	70	7980	14850	Rib	270A01B3	30.8

type III

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
5.00-4	6	TT	120	1,200	55	1740	3200	Rib	504C61-2	4.3
5.00-4	14	TL	120	2,550	115	3700	6900	Rib	504T41-2	6.4
5.00-4.5	6	TL	120K	1,650	78	2390	4500	Twin Contact	545M6CB1	7.4
5.00-5	4	TT	120	800	31	1160	2200	Flight Special II	505C41-4	4.9
5.00-5	4	TT	160	800	31	1160	2200	Flight Custom III	505C46-4	6.6
5.00-5	6	TT	120	1,285	50	1860	3500	Flight Special II	505C61-8	4.9

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER					WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX										
52	51	20.5	19.6	46.25	18.05	21.3	14.6	0.786	50x20.0-20	16.25	20	1.88	4.2	Lockheed	C62c
52	51	20.5	19.6	46.8	18.05	21.3	15.1	0.711	52x20.5-23	13	23	1.5	3.25	Douglas	C62d
50	49	21	20.05	44.6	18.5	20.2	14.2	0.719	49x17	13.25	20	1.75	3.6	Boeing	C62c
54	53	21	20.15	50.9	18.9	22.5	16	0.741	54x21.0-23	16.25	23	2	4.2	Airbus	C62d
54	53	21	20.1	51	18.9	22.2	16	0.718	H54x21.0-24	13	24	1.8	4.25	Douglas	C62d

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER					WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX										
27.78	26.95	9.75	—	—	—	11.6	8.8	0.728	27	8.94	14	0.69	—	—	C62b

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER					WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX										
13.25	12.7	5.05	4.75	11.6	4.3	5.2	3.8	0.916	5.00-4	3.50	4	0.75	0.80	Beech	C62b USAF
13.25	12.7	5.05	4.75	11.6	4.3	5.2	4	0.916	5.00-4	3.50	4	0.75	1.10	Sikorsky	C62c
13.45	13.0	5.30	5	13.3	3.6	5.3	4	0.845	5.00-4.5	4.00	4.5	0.65	0.94	—	5041G
14.2	13.7	4.95	4.65	12.6	4.2	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	GUA	C62b
14.2	13.65	4.95	4.65	12.55	4.19	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	GUA	C62d
14.2	13.7	4.95	4.65	12.6	4.2	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	Cessna	C62c 5041G

type III

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
5.00-5	6	TT	160	1,285	50	1860	3500	Flight Custom III	505C66-5	6.7
5.00-5	10	TT	120	2,150	88	3120	5800	Flight Special II	505C01-2	5.7
5.00-5	10	TT	139K	2,150	88	3120	5800	Rib	461B-2464	5.6
5.00-5	10	TT	139K	2,150	88	3120	5800	Rib DDT	461B-3162	7.4
5.00-5	10	TL	139K	2,150	88	3120	5800	Rib	461B-2464-TL	6.7
5.00-5	10	TT	160	2,150	88	3120	5800	Rib	505C01-1	5.6
6.00-6	4	TT	120	1,150	29	1670	3100	Flight Special II	606C41-6	8.8
6.00-6	4	TT	160	1,150	29	1670	3100	Flight Custom III	606C46-6	11.1
6.00-6	6	TT	139K	1,750	42	2540	4700	Rib	461B-3344	7.4
6.00-6	6	TT	160	1,750	42	2540	4700	Flight Custom III	606C66-8	11.2
6.00-6	8	TL	160	2,350	55	3410	6300	Rib	461B-2297-TL	9.5
6.00-6	8	TT	160	2,350	55	3410	6300	Flight Custom III	606C86-6	11.3
6.00-6	8	TL	160	2,350	55	3410	6300	Flight Custom III	606T86-3	12.1
6.00-6	6	TT	120	1,750	42	2540	4700	Flight Special II	606C61-6	8.9
6.00-6	8	TT	160	2,350	55	3410	6300	Flight Special II	606C86-3	9
6.00-6	8	TT	160	2,350	55	3410	6300	Flight Special II	606C86-3	9
6.00-6.5/420x150	4	TT	120	1,750	45	2540	4725	Rib	607C41-1	6.1
6.50-8	6	TT	160	2,300	51	3340	6200	Flight Custom III	658C66-2	13.7
6.50-8	8	TT	120	3,150	75	4570	8500	Flight Special II	658C81-3	12
6.50-8	8	TL	139K	3,150	75	4570	8500	Rib	461B-2145-TL	11.2
6.50-8	8	TT	160	3,150	75	4570	8500	Flight Custom III	658C86-4	13.9
6.50-8	8	TL	160	3,150	75	4570	8500	Flight Custom III	658T86-3	14.9
6.50-10	6	TL	160	2,770	60	4020	7500	Flight Custom III	650T66-3	16.8
6.50-10	8	TT	120	3,750	80	5440	10100	Flight Special II	650C81-5	14.3
6.50-10	8	TT	160	3,750	80	5440	10100	Flight Custom III	650C86-3	15.8
6.50-10	10	TL	139K	4,750	100	6890	12800	Rib	461B-2058-TL	16.4
6.50-10	10	TT	160	4,750	100	6890	12800	Flight Custom III	650C06-3	16.6
6.50-10	10	TL	160	4,750	100	6890	12800	Rib	650Y0A-1	16.4
6.50-10	12	TL	160	5,750	120	8340	15500	Flight Special II	650T26-2	21.6
6.50-10	14	TL	160K	7,738	143	11600	23200	Rib	650G4KG1	20.3
6.50-10	14	TL	174K	7,738	159	11600	23200	Rib	650G4EG1	18.7
7.00-6	6	TT	120	1,900	38	2760	5100	Flight Special II	706C61-4	9.5
7.00-6	6	TT	160	1,900	38	2760	5100	Flight Custom III	706C66-3	12.8
7.00-6	8	TT	160	2,550	54	3700	6900	Flight Custom III	706C86-3	12.9
7.00-6	10	TL	160	3,595	73	5225	9700	Flight Custom II	706T01-1	11.6
7.00-8	10	TL	120	6,750	126	10130	18230	Rib All Weather	708C01-1	14.4
7.00-8	16	TL	130K	6,650	125	9640	18000	Rib	461B-3294-TL	18.6
7.50-14	12	TL	160	8,700	130	12620	23500	Rib	754C26-2	36.1
8.00-4	4	TT	120	1,100	24	1600	3000	Rib	804C41-1	9.7
8.00-6	6	TT	120	2,050	35	2970	5500	Flight Special II	806C61-5	10.9
8.00-6	8	TT	120	2,800	48	4060	7600	Flight Special II	806C81-2	11
8.50-6	6	TT	120	2,275	30	3300	6100	Rib	856C61-3	13.3
8.50-10	8	TT	160	4,400	55	6380	11900	Flight Custom III	850C86-2	24.4
8.50-10	8	TL	160	4,400	55	6380	11900	Flight Custom III	850T86-2	26.6
8.50-10	10	TL	120	5,500	70	7980	14800	Rib	850H0A-1	21.3
8.50-10	10	TL	139K	5,500	70	7980	14800	Rib	461B-3332-TL	21.3
8.50-10	10	TL	160	5,500	70	7980	14800	Flight Custom III	850T06-3	28

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER					WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX										
14.2	13.65	4.95	4.65	12.55	4.19	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	GUA	C62d
14.2	13.7	4.95	4.65	12.6	4.2	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	GUA	C62c
14.2	13.7	4.95	4.65	12.6	4.2	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	—	C62b 5041F
14.2	13.7	4.95	4.65	12.6	4.2	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	SIA	5041G
14.2	13.7	4.95	4.65	12.6	4.2	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	—	5041F
14.2	13.7	4.95	4.65	12.6	4.2	5.65	4.3	0.930	5.00.5	3.50	5	0.75	0.80	—	C62b 5041F
17.5	16.8	6.30	5.9	15.5	5.35	6.9	4.8	0.914	6.00-6	5.00	6	0.75	0.80	Beech, Cessna	C62b
17.5	16.8	6.30	5.9	15.44	5.34	6.9	4.8	0.913	6.00-6	5.00	6	0.75	0.80	GUA	C62d
17.5	16.8	6.30	5.9	15.5	5.35	6.9	4.7	0.914	6.00-6	5.00	6	0.75	0.85	GUA	5041G
17.5	16.8	6.30	5.9	15.44	5.34	6.9	4.8	0.913	6.00-6	5.00	6	0.75	0.85	GUA	C62d
17.5	16.8	6.30	5.9	15.5	5.35	6.9	4.8	0.914	6.00-6	5.00	6	0.75	0.90	GUA	5041
17.5	16.8	6.30	5.9	15.44	5.34	6.9	4.8	0.913	6.00-6	5.00	6	0.75	0.90	GUA	C62d
17.5	16.8	6.30	5.9	15.44	5.34	6.9	4.8	0.913	6.00-6	5.00	6	0.75	0.90	GUA	C62d
17.5	16.8	6.30	5.9	15.5	5.35	6.9	4.8	0.914	6.00-6	5.00	6	0.75	0.85	GUA	C62b
17.5	16.8	6.30	5.9	15.5	5.35	6.9	4.8	0.914	6.00-6	5.00	6	0.75	0.90	GUA	C62c 5041G
17.5	16.8	6.30	5.9	15.5	5.35	6.9	4.8	0.914	6.00-6	5.00	6	0.75	0.90	GUA	C62c 5041G
17.3	16.8	5.90	5.6	15.3	5	6.95	4.9	0.917	6.00-6.25	3.79	6.5	0.72	0.75	—	C62c
19.85	19.15	6.90	6.34	17.7	5.84	8	5.9	0.867	6.50-8	5.25	8	0.812	0.95	GUA	C62d
19.85	19.2	6.90	6.35	17.7	5.85	8	5.9	0.868	6.50-8	5.25	8	0.81	0.95	GUA	C62b
19.85	19.2	6.90	6.55	17.7	5.9	8	5.9	0.868	6.50-8	5.25	8	0.81	0.95	Vought	USAF 5041E
19.85	19.15	6.90	6.34	17.7	5.84	8	5.9	0.867	6.50-8	5.25	8	0.812	0.95	GUA	C62d
19.85	19.15	6.90	6.34	17.7	5.84	8	5.9	0.867	6.50-8	5.25	8	0.812	0.95	GUA	C62d
22.1	21.4	6.65	6.25	19.9	5.65	9.1	6.9	0.909	6.50-10	4.75	10	0.81	0.85	GUA	C62d
22.1	21.4	6.65	6.25	19.9	5.65	9.1	7.1	0.909	6.50-10	4.75	10	0.81	1.10	GUA	C62c
22.1	21.4	6.65	6.25	19.9	5.65	9.1	6.9	0.909	6.50-10	4.75	10	0.81	1.10	GUA	C62d
22.1	21.4	6.65	6.25	19.9	5.65	9.1	7.1	0.909	6.50-10	4.75	10	0.81	1.10	Sikorsky	USN 5041E
22.1	21.4	6.65	6.25	19.9	5.65	9.1	7.1	0.909	6.50-10	4.75	10	0.81	1.10	GUA	C62d
22.1	21.4	6.65	6.25	19.9	5.65	9.1	7.1	0.909	6.50-10	4.75	10	0.81	1.10	Canadair	C62d
22.1	21.4	6.65	6.25	19.9	5.65	9.1	7.1	0.909	6.50-10	4.75	10	0.81	1.10	GUA	C62c
22.1	21.4	6.65	6.25	19.9	5.65	9.1	7.1	0.909	6.50-10	4.75	10	0.81	1.10	BAe	—
22.1	21.4	6.65	6.25	19.9	5.65	9.25	7.1	0.909	6.50-10	4.75	10	0.81	1.10	BAe	—
18.75	18.0	7.00	6.45	16.5	5.95	7.3	4.8	0.920	6.00-6	5.00	6	0.75	0.85	GUA	C62b
18.75	18.0	7.00	6.44	16.45	5.94	7.3	4.8	0.920	7.00-6	5.00	6	0.75	0.85	GUA	C62d
18.75	18.0	7.00	6.44	16.45	5.94	7.3	4.8	0.920	7.00-6	5.00	6	0.75	0.90	GUA	C62d
18.75	18.0	7.00	6.45	16.5	5.95	7.3	4.8	0.920	6.00-6	5.00	6	0.75	0.90	Eurocopter	C62d
21.36	20.1	7.59	6.85	19.0	6.45	8.4	5.9	0.882	7.00-8	5.50	8	0.81	1.30	Westland	C62d
20.85	20.1	7.30	6.85	18.6	6.2	8.35	6.3	0.882	7.00-8	5.50	8	0.81	1.30	Cessna	USAF 67J1951D
27.75	27.0	7.65	7.2	25.3	6.5	11.65	9.1	0.901	7.50-14	5.50	14	0.81	1.65	Gulfstream	C62b
18	17.2	8.30	7.8	15.5	7.05	6.65	3.8	0.843	8.00-4	5.50	4	0.69	0.61	GUA	C62b
19.5	18.8	7.95	7.35	17.1	6.75	7.55	4.8	0.858	6.00-6	5.00	6	0.75	0.85	GUA	C62c
19.5	18.8	7.95	7.35	17.1	6.75	7.55	4.8	0.858	6.00-6	5.00	6	0.75	0.85	GUA	C62c
22.1	21.2	8.85	8.3	19.2	7.5	8.4	5	0.911	8.50-6	6.00	6	0.88	0.90	GUA	C62c
25.65	24.7	8.70	8.2	22.8	7.4	10.2	6.9	0.898	8.50-10	6.25	10	0.81	1.35	GUA	C62d
25.65	24.7	8.70	8.2	22.8	7.4	10.2	6.9	0.898	8.50-10	6.25	10	0.81	1.35	GUA	C62d
25.65	24.7	8.70	8.2	22.8	7.4	10.2	6.9	0.898	8.50-10	6.25	10	0.81	1.35	McDonnell-Douglas	C62d
25.65	24.7	8.70	8.2	22.8	7.4	10.2	6.9	0.898	8.50-10	6.25	10	0.81	1.35	McDonnell-Douglas	5041H
25.65	24.7	8.70	8.2	22.8	7.4	10.2	7.2	0.898	8.50-10	6.25	10	0.81	1.35	GUA	C62d

type III

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
8.50-10	12	TL	139K	8,000	100	11600	21600	Rib	461B-3388-TL	28
8.50-10	14	TL	120	8,700	110	12600	23500	Rib	850G4A-1	23.6
8.50-10	16	TL	104K	9,900	129	14900	26700	Flight Custom II	850G6A-1	35
8.90-12.50	6	TL	160	4,200	50	6090	11300	Rib All Weather	892C61B1	24.1
8.90-12.50	6	TL	160	4,200	50	6090	11300	Rib	892C66B1	28.8
9.00-6	10	TL	120	4,500	58	6530	12100	Rib	906T06-1	20.6
9.25-12	8	TL	160	5,600	60	8120	15100	Rib DDT	922T86G1	40.8
9.25-12	8	TL	160	5,600	60	8120	15100	Flight Leader	922C86T1	35.4
9.25-12/28x9.00-12	8	TL	160	5,950	65	8630	16100	Rib	982T86G1	34.5
9.25-12/28x9.00-12	12	TL	160	8,850	100	12800	23800	Rib	982T26G1	39.9
9.50-16	12	TL	160	11,200	110	16240	30200	Flight Leader	956C26-1	58.1
11.00-12	10	TL	160	8,200	60	11890	22100	Rib	112T06-3	44
12.50-16	10	TL	160	10,600	60	15370	28600	Rib	126G06G1	69.8
12.50-16	12	TL	160	12,800	75	18560	34600	Rib	461B-1876-TL	75.1
13.0/85-16	32	TL	5	—	—	—	—	Smooth	12377516	104.3
15.00-12	14	TL	160	12,700	65	18410	34300	Rib	152T46-1	59.4
15.00-16	10	TL	160	12,200	53	17690	32900	Rib	156G06G1	87.2
15.00-16	16	TL	160	19,700	80	28560	53200	Rib	156T66G1	94.9
15.50-20	14	TT	139K	20,500	90	29730	55400	Rib	461B-920-TT	112.3
17.00-16	12	TT	160	16,000	60	23200	43200	Rib	176C26B1	97.6
20.00-20	26	TL	174K	46,500	125	67420	125600	Rib	461B-2598-TL	264.6

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER					WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX										
25.65	24.7	8.70	8.2	22.8	7.4	10.2	7.1	0.898	8.50-10	6.25	10	0.81	1.50	Grumman	USAF 5041G
25.65	24.7	8.70	8.2	22.8	7.4	10.2	7.1	0.898	8.50-10	6.25	10	0.81	1.15	Westland	C62c
25.65	24.7	8.70	8.2	22.8	7.4	10.2	7.6	0.898	8.50-10	6.25	10	1.13		Sikorsky	USN MS
27.7	27.3	9.00	8.67	25.0	7.65	11.35	8	0.849	8.90-12.50	6.75	12.5	0.88	1.20	—	C62b
27.7	27.3	9.00	8.67	25.0	7.65	11.35	8	0.849	8.90-12.50	6.75	12.5	0.88	1.20	—	C62c
22.4	21.4	9.25	8.55	19.5	7.85	8.45	5.1	0.893	9.00-6	6.75	6	0.88	1.45	Shorts	C62c
28.2	27.4	9.50	9	25.3	8.1	11.45	8.1	0.854	9.25-12	7.00	12	0.88	1.12	Fokker	C62b
28.2	27.4	9.50	9	25.3	8.1	11.45	8	0.854	9.25-12	7.00	12	0.88	1.12	Fokker	C62b
28.3	27.4	9.40	8.9	25.4	8	11.4	8	0.866	28x9.0-12	6.63	12	0.75	1.50	Fokker	C62b
28.3	27.4	9.40	8.9	25.4	8	11.4	8	0.866	28x9.0-12	6.63	12	0.75	1.50	Bae	C62c
33.35	32.5	9.70	9.1	30.3	8.25	13.85	10.4	0.900	9.50-16	7.00	16	1.00	1.75	Fairchild	C62b
32.2	31.0	11.20	10.5	28.6	9.5	12.7	8.1	0.903	11.00-12	8.25	12	1.00	1.40	GUA	C62d
38.45	37.5	12.75	12	34.4	10.85	15.6	10.5	0.888	12.50-16	10.00	16	1.25	1.80	Northrop, Douglas	5041E
38.45	37.5	12.75	12	34.4	10.85	15.6	10.7	0.888	12.50-16	10.00	16	1.25	1.90	GenDyn, Lockheed	USAF 64F1880B
—	—	—	—	—	—	—	—	—	39x13	10.00	16	1.88		Airbridge	—
36.3	35.4	14.70	13.95	32.0	12.5	14.1	8.4	0.832	15.00-12	11.00	12	1.00	2.50	DeHavilland	C62c
42.4	41.4	15.30	14.4	37.7	13	16.8	10.6	0.872	15.00-16	11.25	16	1.19	1.75	Snias, MBB, Fokker	5041F
42.4	41.4	15.30	14.4	37.7	13	16.8	11	0.872	15.00-16	11.25	16	1.38	1.90	Canadair	C62b
45.25	44.3	16.00	15.05	40.7	13.6	18.6	12.9	0.798	17.00-20	13.25	20	1.63	2.20	Douglas, Fairchild	USAF 5041B
45.05	43.7	17.40	16.35	39.8	14.8	17.7	10.6	0.841	17.00-16	13.25	16	1.38	2.00	—	C62b
56	54.3	20.10	19.2	49.5	17.1	22.1	13.8	0.894	20.00-20	15.50	20	2.00	3.50	Lockheed	USAF 65D1542J

type VII

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
16x4.4	4	TL	210	1,100	55	1650	3300	Flight Eagle	164F43-2	8.3
16x4.4	6	TT	139K	1,700	85	2550	5100	Rib	461B-2494	6.2
16x4.4	6	TL	210	1,700	85	2550	5100	Flight Eagle	164F63-1	9.6
16x4.4	6	TL	210	1,700	85	2550	5100	Flight Eagle DT	164F63-2	10.1
16x4.4	6	TL	160	1,700	85	2550	5100	Rib	164F66-2	6.2
16x4.4	10	TL	190	2,900	155	4400	7800	Flight Eagle	164F08-1	8.7
16x4.4	10	TT	210	2,900	155	4400	7800	Flight Eagle DT	164F03-1	10.3
16x4.4	12	TL	190	3,475	185	5213	10425	Flight Eagle	164F28-1	8.7
18x4.4	6	TL	190	2,100	100	3150	6300	Rib DDT	184F68-1	10.7
18x4.4	6	TL	174K	2,100	100	3150	6300	Rib	461B-2741-TL	8.5
18x4.4	10	TL	190	3,550	185	5320	10600	Rib DDT	184F08-1	13.0
18x4.4	10	TL	210	3,550	185	5320	10600	Flight Eagle DT	184F03-2	12.3
18x4.4	10	TL	210	3,550	185	5320	10600	Rib DDT	184F13-5	13.5
18X4.4	10	TL	210	3,550	185	5320	10600	Rib DDT	184F10-2	12.8
18x4.4	12	TL	210	4,350	225	6520	13000	Flight Eagle DT	184F23-2	13.2
18x4.4	12	TL	210	4,350	225	6520	13000	Rib DT	184F23-4	12.8
20x4.4	12	TL	195K	5,150	225	7730	15500	Rib	461B-3072-TL	14.8
20x4.4	14	TL	255	6,000	265	9000	18000	Rib	461B-3484-TL	14.5
18x5.5	8	TL	210	3,050	105	4570	9200	Flight Leader	185F83G1	11.7
18x5.5	12	TL	174K	5,050	170	7570	15200	Rib	185P2EG1	15.2
18x5.5	14	TL	239K	6,200	215	9300	18600	Rib	185P4HG1	15.6
18x5.5	8	TL	139K	3,050	105	4570	9200	Rib	461B-3075-TL	12.3
18x5.5	14	TL	239K	6,200	215	9300	18600	Rib	461B-2585-TL	15.7
18x5.5	8	TL	120	3,050	105	4570	9200	Flight Special II	185F81-1	11.1
18X5.5	8	TL	190	3,050	105	4570	9200	Flight Eagle	185F88-6	12.6
18X5.5	10	TL	210	4,000	140	6000	12000	Flight Eagle	185F03-5	13.9
20x5.5	14	TL	174K	7,200	230	10800	21600	Rib All Weather	461B-3462-TL	17.7
22x5.5	10	TL	230	5,700	185	8550	17100	Rib	225P09G1	21.5
22x5.5	12	TL	174K	7,100	235	10650	21300	Rib All Weather	461B-3247-TL	20.2
24x5.5	12	TL	139K	8,070	250	12110	24200	Rib All Weather	461B-3246-TL	21.6
24x5.5	16	TT	174K	11,500	355	17250	34500	Rib All Weather	461B-2482-AS	27.4
26x6.6	10	TL	210	6,900	155	10350	20700	Flight Eagle	266F03-2	26.0
26x6.6	10	TL	225	6,900	155	10350	20700	Flight Leader DT	266F02-6	33.5
26x6.6	12	TL	225	8,600	185	12900	25800	Flight Leader	266F22T1	31.0
26x6.6	12	TL	225	8,600	185	12900	25800	Flight Leader	266F22-3	33.2
26x6.6	14	TL	174K	10,000	225	15000	30000	Rib	266P4EG1	30.7
26x6.6	14	TL	174K	10,000	225	15000	30000	Rib	461B-3027-TL	35.6
26x6.6	14	TL	210	10,000	225	15000	30000	Flight Eagle	266F43-2	30.6
26x6.6	10	TL	225	6,900	155	10350	20700	Flight Leader	266F02G6	28.8
26X6.6	12	TL	225	8,600	185	12900	25800	Flight Leader	266F22G1	31.0
24x7.7	8	TL	160	4,150	75	6220	12500	Flight Leader	247F86T1	22.5
24x7.7	6	TL	190	2,950	55	4420	8800	Flight Leader	247F68G1	22.8
24x7.7	16	TL	210	9,725	165	14590	29200	Flight Leader	247F63T2	35.2
24x7.7	10	TL	225	5,400	90	8100	16200	Flight Leader DT	247F02G1	28.5
24x7.7	14	TL	190	8,200	135	12300	24600	Flight Leader	247F48-3	28.8
24x7.7	14	TL	217K	8,200	135	12300	24600	Rib	461B-2681-TL	29.7
24x7.7	16	TL	210	9,725	165	14590	29200	Flight Leader	247F63-3	32.1

INFLATED DIMENSIONS (IN) – OUTSIDE DIA – MAX	INFLATED DIMENSIONS (IN) – OUTSIDE DIA – MIN	INFLATED DIMENSIONS (IN) – SECTION WIDTH – MAX	INFLATED DIMENSIONS (IN) – SECTION WIDTH – MIN	INFLATED DIMENSIONS (IN) – SHOULDER – DIA MAX	INFLATED DIMENSIONS (IN) – SHOULDER – WIDTH MAX	STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN) – WHEEL SIZE	WHEEL (IN) – WIDTH BETWEEN FLANGES	WHEEL (IN) – SPECIFIED RIM DIAMETER	WHEEL (IN) – FLANGE HEIGHT	WHEEL (IN) – MIN LEDGE WIDTH	AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	0.8	IAI	C62c
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	0.8	Cessna	USAF 57D793
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	0.9	IAI	C62c
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	0.9	IAI	C62c
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	0.8	Embraer	C62b
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	0.9	SWE	C62d
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	0.9	Cessna	C62d
16	15.5	4.45	4.15	14.55	3.9	6.9	5.9	0.901	16x4.4	3.5	8	0.81	3.5	Sino Sweringen	C62d
17.9	17.4	4.45	4.15	16.5	3.9	7.85	6.9	0.89	18x4.4	3.5	10	0.81	1.05	Cessna	C62d
17.9	17.4	4.45	4.15	16.5	3.9	7.85	6.9	0.89	18x4.4	3.5	10	0.81	1.05	Northrop, Rockwell	USAF 56D1172
17.9	17.4	4.45	4.15	16.5	3.9	7.85	7.1	0.89	18x4.4	3.5	10	0.81	1.25	Cessna	C62c
17.9	17.4	4.45	4.15	16.5	3.9	7.85	7.1	0.89	18x4.4	3.5	10	0.81	1.25	Lockheed, Rockwell	C62c
17.9	17.4	4.45	4.15	16.5	3.9	7.85	7.1	0.89	18x4.4	3.5	10	0.81	1.25	Cessna, Mitsubishi	C62c
17.9	17.4	4.45	4.15	16.5	3.9	7.85	7.1	0.89	18x4.4	3.5	10	0.81	1.25	Cessna	C62c
17.9	17.4	4.45	4.15	16.5	3.9	7.85	7.2	0.89	18X4.4	3.5	10	0.81	1.25	Lockheed, Canadair	C62c
17.9	17.4	4.45	4.15	16.5	3.9	7.85	7.1	0.89	18x4.4	3.5	10	0.81	1.25	Canadair	C62c
20	19.5	4.45	4.15	19.45	3.95	8.9	8.1	0.901	20x4.4	3.5	12	0.81	1.25	Northrop	USAF 56D1171L
20	19.5	4.45	4.15	19.45	3.95	8.9	8.1	0.901	20x4.4	3.5	12	0.81	1.25	Northrop	USAF
17.9	17.3	5.7	5.35	16.2	5	7.55	6	0.869	18x5.5	4.25	8	0.88	1.25	Saab	C62c
17.9	17.3	5.7	5.35	16.2	5	7.55	6.1	0.869	18x5.5	4.25	8	0.88	1.25	Saab	5041F
17.9	17.3	5.7	5.35	16.2	5	7.55	6.3	0.869	18x5.5	4.25	8	0.88	1.5	Lockheed	5041F
17.9	17.3	5.7	5.35	16.2	5	7.55	6.1	0.869	18X5.5	4.25	8	0.88	1.25	—	USN MS26535-2
17.9	17.3	5.7	5.35	16.2	5	7.55	6.3	0.869	18X5.5	4.25	8	0.88	1.5	McDonnell-Douglas	USAF 66D1895
17.9	17.3	5.7	5.35	16.2	5	7.55	6.1	0.869	18x5.5	4.25	8	0.88	1.25	Beech, Cessna	C62c
17.9	17.3	5.7	5.35	16.2	5	7.55	6.1	0.869	18x5.5	4.25	8	0.88	1.25	Embraer, Lear	C62c
17.9	17.3	5.7	5.35	16.2	5	7.55	6.1	0.869	18x5.5	4.25	8	0.88	1.25	Embraer, Lear	C62c
20.15	19.55	5.7	5.35	19.3	4.95	8.65	7.2	0.891	20x5.5	4.25	10	0.88	1.38	Grumman, Vought	USN MS26540-B
22.15	21.55	5.7	5.35	21.3	4.95	9.65	8.3	0.891	22x5.5	4.25	12	0.88	1.25	Saab	—
22.15	21.55	5.7	5.35	21.3	4.95	9.65	8.3	0.891	22x5.5	4.25	12	0.88	1.45	Douglas, Vought	USN MS26539-C
24.15	23.55	5.75	5.35	23.3	4.95	10.65	9.1	0.887	24x5.5	4.25	14	0.88	1.38	Rockwell	USN MS26526-C
24.15	23.55	5.75	5.35	23.3	4.95	10.65	9.5	0.887	24x5.5	4.25	14	0.88	1.38	McDonnell-Douglas	USN MS18060
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.1	0.884	26x6.6	5	14	1	1.4	Dassault	C62c
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.3	0.884	26x6.6	5	14	1	1.4	Douglas	C62c
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.3	0.884	26x6.6	5	14	1	1.7	Douglas	C62c
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.4	0.884	26x6.6	5	14	1	1.7	Douglas	C62c
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.4	0.884	26x6.6	5	14	1	1.7	Saab	—
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.4	0.884	26X6.6	5	14	1	1.7	Rockwell	USAF 60C4280C
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.4	0.884	26x6.6	5	14	1	1.7	AMD, LAC, Rockwell	C62c
28.7	25.05	6.65	6.25	23.55	5.85	11.2	9.3	0.884	26x6.6	5	14	1	1.4	Douglas	C62c
25.75	25.05	6.65	6.25	23.55	5.85	11.2	9.3	0.884	26x6.6	5	14	1	1.7	Douglas	C62c
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7	0.924	24x7.7	5.5	10	0.91	1.25	Casa	C62c
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7	0.924	24x7.7	5.5	10	0.91	1.25	Fokker	C62c
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7.2	0.924	24x7.7	5.5	10	0.91	1.7	Boeing	C62c
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7	0.924	24x7.7	5.5	10	0.91	1.25	Fokker	C62c
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7.2	0.924	24x7.7	5.5	10	0.91	1.6	BAC, Saab	C62d
23.75	23	7.65	7.2	21.28	6.75	9.85	7.4	0.901	24x7.7	5.5	10	0.91	1.6	Fairchild	USAF 58D510H
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7.4	0.924	24x7.7	5.5	10	0.91	1.7	Boeing, Mitsubishi	C62c

type VII

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
24x7.7	16	TL	225	9,725	165	14590	29200	Flight Leader	247F62-1	31.9
24x7.7	10	TL	210	5,400	90	8100	16200	Flight Leader	247F03G3	26.0
24x7.7	14	TL	190	8,200	135	12300	24600	Flight Leader	247F48-4	27.2
28x7.7	14	TL	174K	11,000	195	16500	33000	Rib	461B-3356-TL	34.8
30x7.7	14	TL	200	12,000	185	18000	36000	Rib	307P40G1	41.3
30x7.7	18	TL	230	16,500	270	24750	49500	Rib	307P89G1	48.4
24.5x8.5	10	TL	210	5,700	85	8550	17100	Flight Leader DT	248F03G2	36.2
24.5x8.5	12	TL	160	6,900	90	10000	18600	Flight Leader	248P26G1	27.2
24.5x8.5	10	TL	210	5,700	85	8550	17100	Flight Leader	248F03T1	35.7
30x8.8	16	TL	225	14,200	200	21300	42600	Flight Leader	309F62G1	53.1
32x8.8	14	TL	210	13,000	170	19500	39000	Flight Leader	328F43G1	46.1
34x11	22	TL	225	20,500	185	30750	61500	Flight Leader	341F22-2	81.4
36x11	22	TL	190	23,300	200	34950	69900	Rib	461B-3383-TL	89.6
36x11	22	TL	225	23,300	200	34950	69900	Flight Leader	361F22-2	87.5
36x11	24	TL	201	26,500	235	39750	79500	Rib	461B-3219-TL	72.9
40x12	20	TL	210	23,900	170	35850	71700	Flight Leader	402F03G1	113.1
39x13	16	TL	225	17,200	115	25800	51600	Flight Leader	393F62T2	99.4
39x13	16	TL	225	17,200	115	25800	51600	Flight Leader	393F62G5	87.4
39x13	16	TL	195K	17,200	115	25800	51600	Rib	461B-2787-TL	81.2
39x13	14	TL	210	15,000	100	22500	45000	Flight Leader	393F43-1	80.0
39x13	14	TL	210	15,000	100	22500	45000	Flight Leader	393F43-1	80.0
39x13	18	TL	210	19,400	130	29100	58200	Flight Leader	393F83-1	87.0
39x13	24	TL	210	27,400	188	41100	82200	Flight Leader	393F53-1	103.7
40x14	16	TL	210	17,300	105	25950	51900	Flight Leader	404F63T2	111.3
40x14	16	TL	210	17,300	105	25950	51900	Flight Leader	404F63-1	96.3
40x14	24	TL	225	27,700	170	41550	83100	Flight Leader	404F42-9	129.1
40x14	24	TL	225	27,700	170	41550	83100	Flight Leader	404F42T2	136.4
40x14	28	TL	174K	33,500	200	50250	100500	Rib	461B-3208-TL-AS	107.8
40x14	28	TL	225	33,100	200	49650	49650	Flight Leader	404F82G3	134.2
44x16	28	TL	174K	38,400	185	57600	115200	Rib	461B-2886-TL	167.7
44x16	30	TL	225	41,700	210	62550	125100	Flight Leader	446F02-4	176.0
46x16	28	TL	195K	41,800	210	62700	125400	Rib	461B-3562-TL	154.4
46x16	28	TL	225	41,800	210	62700	125400	Flight Leader	466F82T6	198.4
46x16	30	TL	225	44,800	225	67200	134400	Flight Leader	466F02-6	207.7
46x16	32	TL	225	48,000	245	72000	144000	Flight Leader	466F22G1	208.0
46x16	30	TL	225	44,800	225	67200	134400	Flight Leader	466F02T5	206.9
49x17	26	TL	195K	39,600	170	59400	118800	Rib	461B-2688-TL	194.1
49x17	26	TL	174K	39,600	170	59400	118800	Rib	461B-3505-TL	157.9
49x17	32	TL	225	50,400	210	75600	151200	Flight Leader	497F22T4	243.3
49x17	30	TL	225	46,700	195	70050	140100	Flight Leader	497F02-7	217.0
49x17	30	TL	225	46,700	195	70050	140100	Flight Leader	497F02T5	241.9
49x17	32	TL	235	50,400	210	75600	151200	Flight Leader	497F29T1	223.0
49x17	30	TL	225	46,700	195	70050	140100	Flight Leader	497F02T6	221.4
49x17	32	TL	235	50,400	210	75600	151200	Flight Leader	497F29-3	215.1

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER											
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX				WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7.4	0.924	24x7.7	5.5	10	0.91	1.7	Boeing	C62c
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7	0.924	24x7.7	5.5	10	0.91	1.25	Namco, Saab	C62d
24.15	23.3	7.65	7.2	21.5	6.75	9.95	7.4	0.924	24x7.7	5.5	10	0.91	1.7	Saab, DO, BAe	C62d
27.4	26.6	7.85	7.4	24.9	6.95	11.75	9.3	0.852	28x7.7	6	14	1	1.75	Lockheed	USN MS17838
29.4	28.6	7.85	7.4	26.9	6.95	12.75	10.6	0.852	30x7.7	6	16	1	1.65	Saab	—
29.4	28.6	7.85	7.4	26.9	6.95	12.75	10.8	0.852	30x7.7	6	16	1	2.15	Saab	—
24.5	23.75	8.5	8	21.9	7.5	10.05	7.2	0.856	24.5x8.5	6.25	10	0.81	1.35	Fokker	C62c
24.5	23.75	8.5	8	21.9	7.5	9.85	7.1	0.856	24.5x8.5	6.25	10	0.81	1.35	Casa, Cessna	5041F
24.5	23.75	8.5	8	21.9	7.5	10.05	7.1	0.856	24.5x8.5	6.25	10	0.81	1.35	Fokker	C62c
30.3	29.5	8.9	8.3	27.4	7.9	12.95	10.1	0.866	30x8.8	7	15	1.13	2.25	Snias	C62c
31	30.05	8.9	8.35	28.05	7.9	13.3	10.4	0.842	32x8.8	7	16	1.13	1.75	Saab	C62c
33.4	32.6	11.3	10.6	29.9	9.95	13.95	10.1	0.868	34x11	9	14	1.5	2.7	Douglas, Lockheed	C62c
35.1	34	11.5	10.8	31.65	10.1	14.75	11	0.832	36x11	9	16	1.38	2.9	Fairchild	USAF 8631526
35.1	34	11.5	10.8	31.65	10.1	14.75	11.2	0.832	36x11	9	16	1.38	2.6	Lockheed	C62c
35.1	34	11.5	10.8	31.65	10.1	14.75	11	0.832	36x11	9	16	1.38	2.8	—	USN MS14482
39.4	38.4	12.35	11.7	35.5	10.9	16.6	12.5	0.869	40x12	10	18	1.5	2.6	BAC	C62c
38.25	37.3	13	12.25	34.25	11.45	15.8	10.7	0.862	39x13	10	16	1.25	2.3	Boeing	C62c
38.25	37.3	13	12.25	34.25	11.45	15.8	10.5	0.862	39x13	10	16	1.25	2.3	Boeing, Fokker	C62c
38.25	37.3	13	12.25	34.25	11.45	15.8	10.9	0.862	39x13	10	16	1.25	2.3	Boeing	USAF 63D3009
38.25	37.3	13	12.25	34.25	11.45	15.8	10.7	0.862	39x13	10	16	1.25	2.2	Lockheed, Aeritalia	C62c
38.25	37.3	13	12.25	34.25	11.45	15.8	10.7	0.862	39x13	10	16	1.25	2.2	Lockheed, Aeritalia	5041
38.25	37.3	13	12.25	34.25	11.45	15.8	10.5	0.862	39x13	10	16	1.25	2.3	Alenia	C62d
38.25	37.3	13	12.25	34.25	11.45	15.85	11	0.862	39x13	10	16	1.38	2.8	BAe	C62d
39.8	38.85	14	13.25	35.1	12	16.45	11.1	0.856	40x14	11	16	1.63	2.4	Fokker	C62c
39.8	38.85	14	13.25	35.1	12	16.45	11.1	0.856	40x14	11	16	1.63	2.4	Fokker	C62c
39.8	38.85	14	13.25	35.1	12	16.45	11.4	0.856	40x14	11	16	1.63	2.95	Boeing, LAC, Snias	C62c
39.8	38.85	14	13.25	35.1	12	16.45	11.4	0.856	40x14	11	16	1.63	2.95	Boeing, LAC, Snias	C62c
39.8	38.85	14	13.25	35.1	12	16.45	11.3	0.856	40x14	11	16	1.63	3.1	Lockheed	USN MS26563AS
39.8	38.85	14	13.25	35.1	12	16.45	11.4	0.856	40x14	11	16	1.63	3.1	Boeing, LAC, Snias	C62c
43.25	42.3	16	15.05	38.2	13.7	17.95	12.6	0.798	44x16	13.25	18	1.63	3.25	Lockheed	USAF 61F4307H
43.25	42.3	16	15.05	38.2	13.7	17.95	12.8	0.798	44x16	13.25	18	1.63	3.4	Douglas	C62c
45.25	44.3	16	15.05	40.7	14.1	19	13.7	0.798	46x16	13.25	20	1.75	3.25	Boeing	C62d 5041H
45.25	44.3	16	15.05	40.7	14.1	19	13.7	0.798	46x16	13.25	20	1.75	3.25	Boeing, Snias	C62c
45.25	44.3	16	15.05	40.7	14.1	19	14	0.798	46x16	13.25	20	1.88	3.4	Boeing	C62c
45.25	44.3	16	15.05	40.7	14.1	19	14	0.798	46x16	13.25	20	1.88	3.4	Boeing, Snias	C62c
45.25	44.3	16	15.05	40.7	14.1	19	14	0.798	46x16	13.25	20	1.88	3.4	Boeing, Snias	C62c
48.75	47.7	17.25	16.4	43	14.5	20.15	13.5	0.839	49x17	13.25	20	1.75	3.25	Boeing	USAF 60D2561P
48.75	47.7	17.25	16.4	43	14.5	20.15	13.4	0.839	49x17	13.25	20	1.75	3.25	Lockheed	USAF 71203
48.75	47.7	17.25	16.4	43	14.5	20.2	14	0.839	49x17	13.25	20	1.88	3.65	Boeing	C62c
48.75	47.7	17.25	16.4	43	14.5	20.2	14	0.839	49x17	13.25	20	1.88	3.5	Boeing	C62c
48.75	47.7	17.25	16.4	43	14.5	20.2	14	0.839	49x17	13.25	20	1.88	3.5	Boeing	C62c
48.75	47.7	17.25	16.4	43	14.5	20.2	14	0.839	49x17	13.25	20	1.88	3.65	Boeing	C62d
48.75	47.7	17.25	16.4	43	14.5	20.2	14	0.839	49x17	13.25	20	1.88	3.5	Boeing	C62d
48.75	47.7	17.25	16.4	43	14.5	20.2	14	0.839	49x17	13.25	20	1.88	3.65	Boeing	C62d

metric

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
360x135-6	12	TL	235	2,925	168	4610	8775	Rib	461B-3701-TL	7.7
380x150/15x6	6	TL	120	1,600	45	2320	4300	Rib	385M61-1	7.9
380x150-4	8	TL	179K	1,855	58	2780	5560	Rib DDT	AP-87-045M1	10.7
605x155-13	10	TL	233	6,610	164	9580	17800	Rib	605M09G1	27.7
450x190-5	10	TL	190	3,600	75	5400	10800	Flight Leader	459M08-2	15
450x190-5	10	TL	230	3,822	90	5730	11500	Rib	459M09B1	15.4
450x190-5	22	TL	206	8,880	225	13320	26640	Rib	459M23B1	22.1
670x210-12	18	TL	200K	13,700	205	20550	41100	Rib	670M8FB1	37.2
670x210-12	10	TL	160	6,800	95	9860	18400	Rib	670M06-2	33.4
615x225-10	12	TL	244	8,000	123	12000	24000	Rib	612M2GG1	28.8
750x230-15	14	TL	262	13,151	152	19730	39500	Rib	753M47G2	50.3
750x230-15	22	TL	257	15,620	232	23430	46900	Rib	753M25G3	61.1

radial

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
26x6.6R14	12	TL	190	8,600	185	12900	25800	Flight Radial	266Q82-1	25.8
26x6.6R14	14	TL	225	10,000	225	15000	30000	Flight Radial	266Q42-1	26.2
25.75x6.75R14	14	TL	210	10,300	199	14930	27800	Flight Radial	256Q43-1	26.0
26x7.75R13	10	TL	230	8,100	125	12150	21200	Flight Radial	461B-3598-TL	26.8
27x7.75R15	12	TL	225	9,650	200	14475	28950	Flight Radial	275Q22-1	37.4
25.5x8.0R14	20	TL	217K	16,200	310	23500	36500	Flight Radial	AP-92-053M1	39.7
27.75x8.75R14.5	24	TL	225K	21,500	320	31175	58050	Flight Radial	461B-3568-TL	51.1
27.75x8.75R14.5	24	TL	225K	21,500	320	31175	58050	Flight Radial	461B-3676-TL	53.2
30x8.8R15	16	TL	225	14,200	199	21300	42680	Flight Radial	309Q62-2	52.0
32x8.8R16	12	TL	190	11,000	140	16500	29700	Flight Radial	328Q28-2	43.2
H34x10.0R16	14	TL	190	13,400	130	20100	36180	Flight Radial	346Q48-3	56.4
30x11.5R14.5	24	TL	205K	27,600	335	41400	74525	Flight Radial	461B-3708-TL	60.9
30x11.5R14.5	24	TL	205K	25,000	243	36250	67500	Flight Radial	461B-3583-TL	65.6
46x17.0R20	30	TL	225	46,000	222	69000	138000	Flight Radial	467Q02-3	180.8
1050x395R16	28	TL	235	34,200	190	51300	102600	Flight Radial	109Q89-1	130.1
1400x530R23	40	TL	235	74,950	249	112425	224850	Flight Radial	140Q09-1	314.0

INFLATED DIMENSIONS (IN)						STATIC LOADED RADIUS (IN)	FLAT TIRE RAD (IN)	ASPECT RATIO	WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA		SECTION WIDTH		SHOULDER											
MAX	MIN	MAX	MIN	DIA MAX	WIDTH MAX				WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
14	13.6	5.25	4.95	13.1	4.9	6.1	5.1	0.76	14.5x5.5-6	4.25	6	0.88	1.5	Dassault	—
15.2	14.72	5.91	5.59	13.4	5.3	5.9	4.1	0.866	380x150	3.75	5	0.51	—	GUA	C62c
15.43	14.76	6.1	5.7	13.62	5.51	6	3.8	0.94	380x150-4	5.04	4	0.71	0.98	Dassault	5041G AIR8505A
24.13	23.38	6.46	6.02	22.28	5.83	10.3	8.6	0.862	605x155-13	5.43	13	0.8	1.58	Dassault	—
18.31	17.52	7.68	7.28	15.94	6.89	7.1	4.3	0.85	450x190-5	6.3	5	0.71	1.38	Aeritalia	C62c
18.11	17.32	7.72	7.24	15.87	6.81	7.05	4.5	0.85	450x190-5	6.3	5	0.71	1.38	Dassault	5041G
18.11	17.32	7.72	7.24	15.87	6.81	7.15	5.1	0.85	450x190-5	6.3	5	0.94	2.6	IAI	5041G
26.77	25.79	8.46	7.87	24.21	7.48	11.1	8.1	0.874	670x210-12	6.93	12	0.79	2.05	Aeritalia	5041G
26.77	25.79	8.46	7.87	24.09	7.44	10.9	7.9	0.874	670x210-12	6.93	12	0.79	2.05	Embraer	C62d
24.61	23.82	9.06	8.66	21.26	7.68	10.24	7.2	0.803	615x225-10	7.87	10	0.89	1.58	BAC, Sepecat	C62d 5041G
29.96	29.09	9.33	8.78	27.2	8.15	12.75	10.1	0.802	750x230-15	7	15	0.95	2.16	Dassault	AIR8505A
29.96	29.09	9.33	8.78	27.2	8.15	12.75	10.2	0.802	750x230-15	7	15	0.95	2.16	IAI	AIR8505A

INFLATED DIMENSIONS (IN)								STATIC LOADED RADIUS (IN)		WHEEL (IN)					AIRCRAFT MANUFACTURER	QUALIFICATION SPEC
OUTSIDE DIA			SECTION WIDTH			SHOULDER										
NEW MIN	NEW MAX	GROWN MAX	NEW MIN	NEW MAX	GROWN MAX	DIA MAX	WIDTH MAX	GROWN MIN	GROWN MAX	WHEEL SIZE	WIDTH BETWEEN FLANGES	SPECIFIED RIM DIAMETER	FLANGE HEIGHT	MIN LEDGE WIDTH		
25.05	25.75	26.32	6.25	6.65	6.92	24.02	6.08	11.15	11.60	26x6.6	5.00	14.0	1.000	1.70	Cessna	TSO-C62d
—	—	26.32	—	—	6.92	24.02	6.08	11.15	11.60	26x6.6	5.00	14.0	1.000	1.70	Cessna, Falcon	TSO-C62d
—	—	26.35	—	—	7.05	25.15	6.35	11.20	11.60	26x6.6	5.00	14.0	1.000	1.70	Canadair	TSO-C62d
—	—	27.36	—	—	8.32	24.47	7.54	10.60	11.39	26x7.75-13	6.50	13.0	0.700	1.60	Navair	USN MS14483
—	—	27.70	—	—	8.10	25.40	7.15	11.75	12.20	29x7.7	6.00	15.0	1.000	1.65	Boeing	TSO-C62d
—	—	26.65	—	—	8.04	23.28	6.89	10.94	11.35	25.5x8.0-14	5.75	14.0	1.000	2.10	Lockheed	16VL028
—	—	28.68	—	—	9.19	25.31	7.85	11.85	12.30	H27.75x8.75-14.5	6.00	14.5	1.200	2.35	Lockheed	16VL032
—	—	28.68	—	—	9.19	25.31	7.85	11.85	12.30	H27.75x8.75-14.5	6.00	14.5	1.200	2.35	Lockheed	16VL032
29.49	30.39	31.10	8.35	8.90	9.30	29.50	8.30	12.90	13.50	30x8.8	7.00	15.0	1.125	2.10	Airbus	TSO-C62d
—	—	31.80	—	—	9.25	28.70	8.53	13.00	13.60	32x8.8	7.00	16.0	1.125	1.65	Alenia	TSO-C62d
—	—	34.85	—	—	10.40	32.95	9.35	14.00	14.75	32x8.8	7.00	16.0	1.125	2.15	Alenia	TSO-C62d
—	—	30.75	—	—	11.96	27.82	10.50	12.00	12.65	30x11.5-14.5	9.75	14.5	1.250	2.75	Panavia	DASA
—	—	30.75	—	—	11.96	27.82	10.50	12.00	12.65	30x11.5-14.5	9.75	14.5	1.250	2.75	Panavia	DASA
44.76	45.98	47.50	15.98	17.00	17.70	44.75	15.95	19.20	20.15	46x16	13.25	20.0	1.875	3.70	Airbus	TSO-C62d
40.59	41.34	42.65	14.53	15.55	16.15	40.00	14.20	16.60	17.55	40.5x15.5-16	11.50	16.0	1.750	3.50	Airbus	TSO-C62d
—	—	56.85	—	—	21.70	53.45	19.10	22.35	23.60	54x21.0-23	16.25	23.0	2.000	4.20	Airbus	TSO-C62d