Aircraft design: a conceptual approach sixth edition book pdf downloads

begins with Conceptual Design where the designers look at a wide range of aircraft configuration concepts, perform trade studies of both the designs and the requirements, and ultimately settle on a single best design and, with significant customer input, select a well-balanced set of requirements. 8.3 illustrates two common problems with "real" wings. This is one of the most important lessons that a student of aircraft design must absorb. I.. Furthermore, our derivation of Eq. (17.24) implicitly assumed that CDo and β do not vary as velocity changes when we solve for V in Eq. (17.25), which we also know to be only a rough approximation. (14.21) and (14.22) using the centroids and areas of the simple shapes. This is not to say that "outsiders" have no role to play or have no chance to get funding for a design project. To determine the effect of building the aircraft out of composite materials, the designer must adjust the empty-weight equation.

turbulent flow, which will remain attached longer than would laminar flow. Methods for analy si s of such members can be found in[1 06, 1 08] . lations that determine what should be designed and how the design should be modified to better meet the requirements. 7] 0 . If the theoretical pressure forces in a perfect fluid are integrated over a streamlined body without flow separation, it is found that the pressures around the front of the body that create a rearward drag force are exactly matched by the pressures around the rear of the body, which create a forward force. Unless the wind is very strong, these will only change your airspeed by perhaps 5-10% or so, gaining just a few percent in range over the range if you flew at the no-wind optimal speed. The statistical empty-weight equation used here for sizing was based upon existing military cargo and bomber aircraft, which are all aluminum. 1800 1600 Range trade. Drag forces that are a strong function of lift are known as drag due to lift. Also, magnesium should not be used in areas that are difficult to inspect or where the protective finish would be eroded by rain (leading edges) or engine exhaust. However, when maximizing range, the aircraft flies at a higher velocity [31.6% faster-divide Eq. (17.25) by Eq. (17.13)] . Development o f these equations represents a major effort as just described, and each comp any develops its own equations. Is the landing gear as simple as it could be? 37) Braced-Wing Analysis A wing braced with a strut will have the bending moments greatly reduced compared to a fully cantilevered wing. The low horizontal tail position shown in solid line would offer the lightest structure, but may place the tail in the exhaust stream of the engines, so other positions for the horizontal tail are shown in dotted lines. In 1 856 aluminum cost $90 a pound. However, magnesium is very prone to corrosion and must have a protective finish. Cargo floor area, mechanics, military officers over pictures of aircraft sitting open hatchbacks and landing system (British Units, Results) in Pounds. Therefore, the vertical shear distribution must be related to the horizontal shears in the beam. By 1935 the cost had dropped to 2 3 cents per pound. This is done by guessing the takeoff gross weight, calculating the statistical empty-weight fraction, and then calculating the takeoff gross weight. Unfortunately, a short, fat fuselage has a lot of separation in the back causing a huge pressure drag. Table 3.1 does not provide an equation for statistically estimating the empty weight fraction of an antisubmarine aircraft. The camber also increases lift by increasing the circulation of the airflow. Sizing of the fourth concept, a wing aspect ratio of 10 was selected. The warm-up, takeoff, and landing weight fractions can be estimated historically. Compression lift was 219 220 Aircraft Design: A Conceptual Approach a concept proposal submitted by Richard Child and George Owl of North American Aviation to configure a huge supersonic bomber that literally rode its own shock wave, the B-70. At that time we could not calculate the actual characteristics of the design because the aircraft had not been designed yet! Now there is an actual design layout. Table 3.1 Empty weight fraction vs Wo. A large fuselage and wing make for a heavy airplane. The remaining unknowns in both range and loiter equations are the L/D, or lift-to-drag ratio, which is a measure of the design's overall aerodynamic efficiency. It is common for promising interns to be offered real jobs when they graduate, and often at slightly higher pay since their true work abilities are known. These laminar flow airfoils work by having the pressure continuously drop from the leading edge to a position close to the trailing edge, a = P/A (14.29) Remember that the stress level at the limit load should be compared to the yield stress, or, for composite materials, the stress level correspond ing to a strain equal to the ultimate strain capability of the material divided by the selected factor of safety (often 1.5, matching that used for metals). Design: How Does It Sta rt? 17: The 45-deg orientation is frequently used in structure that must resist torque. There will be an increase in up-front costs, but in the long run, those are trivial compared to the benefits. Also, many of automatic CAD systems and always check the results for reasonable ness using rough approximations such as those provided in Chapter 7. Wortmann, Richard Eppler, and Robert Liebeck. Complicated adjustments can be made to the range-optimization equations (see [126]), but as was already discussed, the use of pure equations for optimizing for range is not the preferred method anyway. 88 35 w - 0 - 0 7 WO, calculated 5 1 ft 10 5 1 ,668 5 1 ,598 5 1 , 59 1 5 1 ,587 CHAPTER 3 Sizi n g from a Conceptual Sketch 3.1 Introduction For example, the empty weight is approximately the takeoff gross weight from 56,702 lb (25,720 kg) to 53,185 lb (23,399 kg), yet the aircraft can still perform the same mission. Table 3.2 gives typical historical values for initial sizing. 1 4.22 . The methods presented here will get you close, and then the analysis and optimization methods described later will help to finalize things. No loads are applied except at the pins, and no moments are applied anywhere. It is equally common to show the drag polar with the drag coefficient as the vertical axis, creating a U-shaped plot. Write these down-it is sometimes more difficult than you would think. As an introduction to the design process, this chapter presents a quick sizing method, which will allow you to estimate required takeoff weight from a conceptual sketch and a sizing mission. 0.8 <. These resemble the FARs and even share the same numbering scheme. For a positive bending moment such as shown, the lower surface experiences tensile compression on the upper part of the beam and tension on the lower part. However, we need to know about those that do affect the overall configuration design and its analysis. This also delays stalling at high angle of attack, as described in Chapter 4. For propeller aircraft, the endurance is obtained by using the equivalent C obtained from Eq. (17.4). Also note that the term "profile drag" is sometimes used for the zero-lift drag of an airfoil, which is sometimes called the wing profile. Cost? A key ability is a collection of tools that permit one to rapidly develop a notional design concept (in approximately one day), and to continuously revise design concepts and perform geometric trade studies. The center of pressure is usually behind the aerodynamic center, and it moves back and forth as the angle of attack is changed. (14.26) and (14.27) can be used to transfer the moments of inertia of the simple shapes to the combined centroidal axes. Note that this is not the point of minimum drag! Lift Figure 12.5 shows typical wing lift curves, how lift increases as angle of attack increases. They are all correct. 14) An accurate estimate of internal volume can be found by a graphical integration process much like that used for wetted area, shown as a circular flow direction in Eq. (17.6) 4. In the design process, the conceptual design segments the airplane, and then the customers decide if they want it. 16 allows converting from one sweep angle to the other. While strict accuracy should not be expected, this simple sizing method will usually yield an answer in the "right ballpark." Figure 3. 3 CHAPTER 3 Sizing from a Conceptual Sketch The center of gravity as when its fuel is almost gone. The extensive ASW avionics would not be included in that equation, so it is treated as a separate payload weight. 3.9.4 1 II. Truss structure was used extensively in welded steel-tube fuselages. Trade studies will be done to determine the best combination of design parameters (T/W, W/S, aspect ratio, etc.) to meet all mission and perform ance requirements at the minimum weight and cost. A statistical approach can be used to determine (there is enough room in the design to accommodate all components. These are defined in Eqs. Req u i rements A irc r a ft design is an iterative process. 207 0 3 1 3 0 333 0 3 1 0 ,333 Solid rectangular members can be analyzed with Eqs. Box 3.3 shows the sizing calculations assuming payload weights of 5000 and 20,000 lb. 82 0 .8 - compression. These are legally defined by Title 14 of the U.S. Code of Federal Regulations and have the weight of law. The given payload requirement is 10,000 lb of avionics equipment. 8.3. At the upper left there is an airfoil with its pressure contours shown, and four pressures are depicted with dots. The right side of the beam being a free body, the sum of the vertical forces, and the sum of the moments must equal zero. The charts in Fig. Typically, one can assume for 0.8 except for a fixed-pitch propeller during loiter, where Y (p 0.7. These can be used for rough initial sizing. However, this reduced wing area is offset by the wetted area of the fuselage, nacelles, and tails. The appendix describes a supercritical section suitable for transports and other high subsonic aircraft, using a hybrid of the method used by NASA section for general aviation. Today it is common for aerodynamics to propose a design all-new airfoils just for that design, as John Roncz did for many of Burt Rutan's record setting airplanes. A Trans- Exponential Equation is of form [constant times constant raised to a variable power] . Prototypes are usually built on "soft" or temporary tooling and are often built with fabrication processes different from those envisioned for the pro-duction run. Fig. (0 / ... By placing a "fence" just outboard of where the stall has been found to begin, the stall can be prevented from spreading outward until such a high angle of attack is reached that the outboard part of the wing stalls on its own. The reference wing area (S) includes the part of the reference wing that sticks into the fuselage, plus the missing areas where the wingtips have been rounded. A K value between the clamped and simply supported values should be used in such a case. At joint three, there are three unknown struts at this Fuselage m = 22 1 0 4000 1 b ... 50 2 ; 20 0 2 - - - 6000 1 b Fig. Preparations for the next iteration should begin today! Student design projects should always include a substantial write-up on what was learned and what will be done in the next iteration. 1) summarizes the takeoff-weight buildup: Wo = Wcrew + Wpayload + Wfuel + Wempty (3 . Actually, the wing sweep theory is based not just on leading-edge sweep, but on the sweep of the wing pressure "isobars." Isobars are lines connecting regions with the same pressure. Total airfoil camber is defined as the maximum distance of the mean camber line from the chord line, expressed as a percent of the chord. CHAPTER 8 Special Considerations in Configuration Layout Di scontinuous Li ft Distribution Cl cCl Distribution Ten d s to separate here. As men tioned earlier, mission legs involving combat, payload drop, and refuel are not permitted in this simplified sizing method but will be discussed in a later chapter. 545 546 Aircraft Design: A Conceptual Approach Sizing Fuel Fractions 1 41 5 Fig. Note that Figure 4. The center of pressure moves rearward as well, causing a CHAPTER 4 Lift (+) A irfoil and Wing Planform Selection ... Wing Selection Pitch ing moment about a reference point ... Fig. 1 0 Fig. 1 2 Fig 0 .35 0 .373 0 . By definition, the lift force is perpendicular to the flight direction while the drag force is parallel to the flight direction. Today, wood is used largely in homebuilt and specialty, low-volume production aircraft. Figure 12.3 shows typical separation points for various shapes, but realize that the actual separation point location is dependent upon Reynolds number. A value of 6 to 8 is typical for supersonic fighters, the aircraft would be of military aircraft, the maximum is flight. Also, the camouflage paints used on military aircraft are corrosive, and special efforts are required to isolate the paint from the metal of the aircraft structure. 1) Avoted Wet-Wing Ret: Wt ret Figure 3.5 plots maximum L/D for a number of aircraft vs the wetted aspect ratio and shows clear trend lines for jet, prop, and fixed-gear prop air craft. 1 r" C G IS be r ln s 13 A 3 - J"S Wd Sf: I. Do not "fall in love" with your design-there is always room for improvement. Supersonic designer will ever receive: "Re (or designs will have a fineness ratio of 10 to 15 or more. 1 02 0. 6 o. wmp = 0.0650 .758 whe. 6 ... " Eq. 2) Stability and trim on single dispersion on the test reveals that lot of the conceptual analysis is used, or both structural or structural. Exponential Line 9 wing No 0 ... Hm - 1 1 Cb (cruise) - f 1 hr a 1 lb E Bi (2) Dihedral 3 Tail Wing Lift Re. Rational Bracket Fig. 1 4 (0 hom 0 n C. 4 (0.5) u 5 ... The structural analyst and a detailed development of all the distribution at the rear of the fuselage depicted in this chapter. CHAPTER 2 Overview of the Design Process During detail design, the actual parts get designed including all the individual structural components, and all the systems including landing gear, hydraulic, electrical, pneumatic, fuel, propulsion, and all the rest. This is avoided with a pusher propeller and is the reason that few modern jets have conformal nacelles in which the exhaust rubs along the aft fuselage. In the past, the aircraft designer would select airfoils from a "catalog," most likely the famous book by Abbot and Von Doenhoff. For example, in the simple cruise mission the legs are numbered 1) warm-up and takeoff, 2) climb, 3) cruise, 4) loiter, and 5) land (see the example mission at the end of this chapter). The required amount of mission fuel depends upon the mission to be flown, the aerodynamics of the aircraft, and the engine's fuel consumption. They are too good! Typically, they've been tailored for production part design, not the "everything will change" environment of conceptual design. cross-section Fig. Do these requirements that drive the design, such as those set by the FAA, adapt airfoils to the design? Then, during conceptual design a number of alternative designs are studied to determine which design approach is preferred. [xcc d 4 / 4 . Chapter 21 covers vertical flight including helicopters and "vertical take off" jets, might be preferable today. We sometimes "cancel" the pounds and say "per hour" (1 /h) as the units-but it is just a joke! In metric terms we use the more reasonable mg/Ns. Figure 3.3 shows trend lines of SFC vs Mach number. 4.8. The speed of which supersonic flow first appears on the airfoil is called the "critical Mach" Merit - At higher speeds, the shock gets stronger. This is illustrated by the ratios of wetted area to wing reference area (Swet /Sref). For the determination of the limit stress, this equation can only be applied to parts that are very short compared to cross-sectional dimensions (such as fittings) or to parts that are laterally constrained (such as spar caps and sandwich face sheets). 0025 0.01 2 0 .004 0 .0036 11 - - 10 - 0 .025 0 - 0 18 23 2 1 1 0 0 1 6 1 95 204 219 1 65 200 23 2 4 0 1 6 0 1 0 4 4 .85 7 4 1 0 2 4 3 23 0 1 00 183 33 1 11 73.9 69 40 1 1 1 1 1 1 1 1 11 23 3 0 10 48 0 1 8.5 22 .4 33 20 Ws(1) 1 ... 5 As, it would appear that the vertical area ratio (Swet /Sref) is around 0.5. This yields a wetted aspect ratio of 1.27 (i.e.,) 5.5). You will be calculated as much as possible to maximize communication between team members. Heat treatment begins by raising the temperature of the steel to about 1400-1600°F (760-870°C) at which point the steel becomes very ... The unchanged wing has no lift at zero angle of attack, while the cambered wing has a positive lift at zero angle of attack. The tension lines of Fig. The team is typically larger too, going from a handful of people to 50 or more in a large company. The main concern is the development of a good structural arrangement and its provision of efficient "load paths"-the structural elements by which opposing forces are connected. 5 Wdhydraulics = 1 1 wdg Wdelectrical 12.5 7 (Wfuel system + Wavionics) 0 . 7. his type of trade study comprises the majority of the design effort during the conceptual design process. Control. A negative angle of attack is required to obtain zero lift with a cambered wing. It is different from cargo handling gear, which includes the powered rollers that move pallets into position and lock them down. she) can see air." Good lofting also produces good aerodynamics. A base area fill-in effect is difficult to predict. 1 7 .6; ... This, however, imposes some drag penalty during regular flight. Designs are iterative in nature A C S 1 0 Wing Planform Selection. Exce ll spreadsheet of this sizing example illustrating both methods is available at the author's website, www. If two 0. A typical fuselage with a trapezoidal wing will have an irregularly shaped volume distribution with the maximum cross-sectional area located near the center of the wing. The aerodynamic center is not the same as the airfoil's center of pressure, the location where the vertical forces balance. ... In Freestream velocity vector as obtained from Eq. (17.6) etc. In fact, Roncz wrote his own computer codes for airfoil design, starting with the methods of [19]. 1 8 0 . Flying Magazine 5 6 Aircraft Design: A Conceptual Approach 6 Wing Of R. A/aircraft de The Book: What Is Here and How It Is Organized Aircraft Design: A Conceptual Approach attempts to describe the process used to develop a credible aircraft conceptual design from a given set of require ments. We'll approximate the empty-weight fraction for a composite aircraft by multiply ing 0.95 times the appropriate statistical empty-weight fraction calculated from the table. The strakes do add to the aircraft wetted area, which reduces cruise aerodynamic efficiency. The portion of the wing outboard of the strut is analyzed as before, and the bending moment at the strut location is determined The root bending moment is usually zero unless the hinge point is above or below the neutral axis, causing a bending moment due to the compression load P. 2.2 Three phases of aircraft design. Enter the AIAA student design competitions. The side view is usually drawn first in the design layout. The lift coefficient and the aspect ratio are two other "critical" regard the pressure distribution on the wing. 0 1 .. 1 1 1 1 1 .. 1 0 .. 0 0 1 1 1 1 0 6 1 .. 2 1 0 3 3 1 0 1 3 0 .. 1 6 1 0 4 . .09 15 1 1 9 1 1 9 6 5 5 1 2 3 1 5 ... The cost of the vertical tail was taken as 2% of the wing. The Y/B and 3-D wing sizing lift coefficient ... 0 1 3 0 0 3 1 0 .. 2 0 3 1 0 1 0 2 0 1 3 0 . 1 1 .. 2 1 0 0 7 1 2 5 3 ... 0 ... These can be used to improve flow over the wing flaps, or to fix a flow problem at the horizontal tail, or both. 7 .39 \ \ Automated revision of wing geometry. 48ff] Aluminium Aluminum remains by far the most widely used aircraft material. However, the wing is located aft of the center of gravity whenever a canard is used, so that the fuel located in the wing is also aft of the center of gravity. The major fuselage loads are carried to the wing by "longerons," which are typically I- or H-shaped extrusions running fore and aft along the sides of the fuselage. At a later date, an airfoiling optimization code will be run to define the best airfoil geometries. 3 Effects of wind. The properties of steel are strongly influenced by heat treatment and tem pering. A more sophisticated density checking method called net design volume is given in Chapter 19. Note also that the drag polar does not ... ...

contributors to the cross-sectional area by the wing and the fuselage. 020 0.01 6 0.01 6 1 4 .8 1 5.5 1 0 .8 1 1 .5 9. The airflow over the wing tends to separate toward the trailing edge. •$" //.O"I (k= sooo .ft) •lft A LTI "TrDc: • A ConceptualApproach .9 "' f>" Vv - ft/; s 1...,.l Soo 2... This design technique, developed by R. This solution is seen on the Beech Starship among others. FUSE L.A.€ 16.:?.5) 6lft$ j_ A? (s. 2 3 Composite material types. Strakes below the cockpit were found to cure this problem, even though they are located ahead of the wing. It is clear that the weight of the aircraft would be distributed along the span of the wing exactly as the lift is distributed (Fig. 42 1 9 0 42 1 9 2 1 .803 33,756 33,835 33,839 33,842 WO. calculated 8 9 6 7 1 80,265 80,22 1 80,2 1 9 80,2 1 7 sizing equation (3.4) is parametrically varied by assuming different payload weights. Also, the real world usually offers a wind that is neither a headwind nor a tailwind. Moment of inertia is the sum of Arbitra r y body Bsym metric body Centroid --11-11*T---y Fig. c,, 1 I>€Nc.e C.G. ... 0.4 0.2 -0.2 t C&1C\USE" • O N L.'(Lift coefficient 0.8 w•§ :: ® (c i..c.fid A ConceptualApproach = .. However, only the part of the rudder not blanketed by the horizontal tail will aid the recovery (SR 1 and SR2). 0 AL E • •...;./ I • 1 1 I c · 7 · 4 · -3 ... - I 2 L- I • · .... .i. • I I I Subsonic •Ico-I- Su perso n i c 0.5 - 1 I U n swept I 1 5 I3 ta n t- I 1 an LE 4 - 0 I3 ' 3 0.2 = 1 A L- / · .1.O•I' /· (/. 7 . Bernoulli's equation shows that higher velocities produce lower pressures, so that the upper surface of the airfoil tends to be pulled upward by lower-than-ambient pressures while the lower surface of the airfoil tends to be pushed upward by higher-than-ambient pressures. No textbook can contain the methods actually used, which tend to be proprietary and highly computerized. 14.27, bottom). Production designers frequently wish to modify the design for ease of manufacture; that modification can have a major impact on performance or weight. An example for a new general aviation is shown as Fig. The laminar airfoils require extremely smooth skins as well as exact contour over the actual, as-manufactured shape. It is also assumed that the shear is constant within the web, and therefore the maximum shear stress equals the average shear stress (shear divided by web area). It is only in three-dimensional flow that drag due to lift is produced. An old rule of thumb is that the negative angle of attack for zero lift (in degrees equals the airfoil's percent camber (the maximum vertical displacement of the camber line divided by the chord). All of the aerospace companies have developed their own design handbooks and "best practices," which have served them well. The further along a design progresses, the more people are involved. In this author's experience, it is more common for the companies to get the initial idea, do some design studies, and then take them to the potential military customers. * There is another way of looking at lift-behind the wing there will be a downwash, geometrically caused by the airfoil angle of attack and camber. Optimization techniques are used to find the lightest or lowest-cost aircraft that will both perform the design mission and meet all performance requirements. Since the airfoil is generating lift, the velocity of the air passing over its upper surface is increased. Appendix D provides geometry and section characteristics for a few air foils useful in conceptual design. Airfoil lift changes linearly with angle of attack, up to an angle near stall where flow separation starts to occur. Welded steel tubing structure is usually normalized after all welding is completed to return the steel material to the original strength. There is a big problem when airfoils get fast. Figure 14.30 provides the buckling coefficient K for Eq. (14.34) based upon panel length-to-width ratio and end constraints. I S u perso n i c I (n d w ing Tip Fig. Transonic airfoil design is beyond the scope of this book. The ratio of rudder size to lower rudder area is. This is not necessarily the same as the maximum takeoff weight. The goal at this point is to see if it actually meets the required mission range as estimated in the initial sizing. 3.1, developed by the author from data taken from 'I'i and other sources. To reduce cost, some airplanes have been designed with simple square cross-section shapes.

[...]

However, the lower-pressure air on the lower surface of the fuselage then tends to "flow" toward the center of the fuselage and, the shear stress (total shear divided by cross-sectional area) is 1 .5 times the averaged shearing stress. Because of the design constraints in the vertical tail, the lift will be spread over a larger area. Modern composite techniques permit the design of wing skins that are thicker, with lower "equivalent" stress. Using the design method that, even though this is a new aircraft, the general design approach of the old "Dash-Two" may be appropriate for the new design as well. Figure 14.34 shows a simple beam with a distributed vertical load. Since the pressures acting on the upper and lower surfaces of a lifting airfoil do something bad to at subsonic speeds. Profiles Typical mission profiles for various types of aircraft are shown in Fig. CHAPTER 1 4 Structures and Loads. The aerodynamic design process follows the general pattern of all designs: conceptual design, preliminary design, and detail design. Propulsion 10 is very important when it comes to the cost of an airplane. The original analysis, which may take too long, uses the simple fixed-engine sizing. However, the fuel used for cruise sections of the mission and to the aircraft's performance, all calculated the total fuel weight fraction. A good conceptual design must take into account the many different needs which may be in conflict. This is what Prof. Anderson describes as "the process of bringing together all design parts into a complete aircraft." CHAPTER 2 Overview of the Design Process rate of climb, takeoff distance, and similar performance items. An airfoil is the cross-sectional shape of the wing, which is the most important factor in aircraft performance. Design Principles 14.15 The Mach number at which flow first becomes sonic is called the critical Mach number. In an ideal world, the design would be developed with all the details fully optimized before the design is frozen. Airfoils are referred to as "shock-free" designs. A 'hp' is reduced and the effective aspect ratio and the Oswald efficiency factor e are also affected. That book is included as a reference, and has been updated by the designer.

forebody has sharp lower corners or even corners that just aren't rounded enough, a separated vortex can be formed at high angles of attack. 86 c 2 . F i n a l i z e weighfa n d performance esti mates (NOW you learn the rea l n u m bers!) Fabrication Fig. These ideal assumptions guarantee that the struts carry only compression or tension. The book has 24 chapters. Redraw the baseline and do it all again until someone says "enough!" CAD tools used during conceptual design should be tailored toward the fluid environment of conceptual design. The buckling load for inelastic buckling can be determined by Eq. (14.32), with one modification. The value of J(is obtained from Fig. It just doesn't work like that. What We've Leo rned Aircraft conceptual design is a separate discipline, with its own history, methods, and rules of thumb. An overly optimistic estimate of the technology availability will yield a lighter, cheaper aircraft to perform a given mission, but will also result in a higher development risk. 3 Aerodynamic Coefficients Lift and drag forces are usually treated as nondimensional coefficients as defined in Eqs. For them the exact details of performance, range, and payload will matter far less than the crazy idea of going from blank sheet of paper to the ultimate retort when climbing out at a favorite airport restaurant: "Actually, it's my own design." Most aircraft designs do start with stated requirements, but initially these are rather fuzzy and essentially amount to "win the war" for a military design, or "make money" for a civilian design. Introduction T he start of this chapter represents a turning point in the book. Both are large airliners. The ultimate objective during preliminary design is to ready the company for the detail design stage, also called full-scale development (FSD). © 1996-2014, Amazon.com, Inc. X x · f -/. Such reframed air foils have poorer L D than an airfoil designed without this constraint, losing some of the drag benefit that flying wings experience due to their reduced wetted area. The empty-weight fraction (We/ Wo) can be estimated statistically from historical trends as shown in Fig. Long unconstrained members in compression, called "columns" or "struts," are discussed next. wflight controls includes the mechanisms, actuators, control linkages, and in-cockpit controls but not the weight of the actual control surfaces such as ailerons and flaps. Get pretty good at computer-aided design (CAD). For example, if you need an immediate estimate of the takeoff weight of an airplane to replace the Air Force F-15 fighter, use 44,500 lb. Composite parts are usually molded and can be cured at room conditions or at elevated temperature and pressure for greater strength and quality. 3.7. Design Example: ASW Ai rcraft As a design and sizing example, Fig. Figure 2.4 depicts the conceptual design process in greater detail. LX· dA Y. Note that the angle of attack is a indicated here by tic marks along the polar curve. Such an airfoil tends to have a large nose radius, a fairly flat top, and, oddly enough, negative camber. 17, it should be remembered that the vertical shear stresses on an element are balanced by and equal to the horizontal sh ear stresses, and pull this boundary-layer air in the direction the aircraft is travelling produces skin-friction drag. 14.27) are found from Eqs (14.21) and (14.22). For a complete built-up shape, the combined centroid must be determined, and then Eqs. The term {3 [Eq. (12.13)] divided by the tangent of the leading-edge sweep is calculated and found on the horizontal axis of the chart. 14.28. In previous chapters, an approximate tail volume coefficient method was used for tail sizing. For the single cruise mission segment, which is the warm-up and takeoff. 5 !;t . 13 J Darold Cummings, chief configuration designer for the Northrop YF-23, says, "If Dan's aircraft design textbook covers the 'ethos' of the aircraft design arena, then this companion book covers the 'pathos'; the warm, ironic, joyful, frustrating, rewarding, agonizing, and downright Zen experience of being an aircraft designer." It's available at the usual online booksellers. When we take the derivative in our stab illity equations, constant moment terms disappear-a nice result that simplifies those complicated equations. The airfoil affects the cruise speed, takeoff and landing distances, stall speed, handling qualities (especially near the stall), and overall aerodynamic efficiency during all phases of flight. 4llIlf Torsion Figure 14.41 shows a solid circular shaft in torsion. The second concept is much like the first except for the engine location. 539 540 Airc raft Desi gn : A Concept u al Approa c h ing speed. A final wing design example with a simple cross-section shape is shown in Fig. rx other, one step at a time. ...♦ ... ... •. Fr' ' • Fig. r... A V.c '" ".S.C= I S -fm At (1. This resulted in the creation of the European Aviation Safety Agency CS's (Certification Specifications). . 02 A x (15 .47) h o n d Tate 7 1 l l t + 0 2 Ht (K) Wdg) 0 . For an infi nite aspect-ratio wing (the two-dimensional airfoil case) the theoretical low-speed lift-curve slope is two times 7T (per radian). To maximize cruise or loiter efficiency, the aircraft should fly at approximately the velocity for maximum L/D. The analysis process as discussed in the next chapters will result in a revised sizing calculation that will almost always tell you that the design you drew doesn't really work! Usually, the detailed calculations using actual numbers from your design indicate that the as-drawn aircraft cannot really meet the range of performance requirements. There is no reason to design the actual parts at this point because everything is still changing. Gottingen, 398 ♦ c Clark Y ===== M u n k M-6 Modern NASA Early < 001 2 (4 Dig it) c e ' ;..... x (c of H/-3 RA NGE: Y/ : ... Wc:..'w ♦ = ' S Z.2D (1S5S /ON "" L p). The weapons drop refers to the firing of gun and missiles and is often left out of the sizing analysis to ensure that the aircraft has enough fuel to return safely if the weapons are not used. The initial selection of these parameters is discussed in the following subchapters. 21 1 212 Airc raft D e s i g n : A C o n ceptu a l A p p roach Special Considerations in Configuration Layout ♦£(• • W h i l e d o i n g t h e r mecha n i c a l tasks of a ircraft layout design, the designer is thinking a bout many other things to m a ke a good a i r p l a n e. • All a ir e n in parant..and a l l m u s t be considered. Often "good t h i n g s" n o n a re u n l i conft ict with one another: it's a bother that ... many are rather found ... ; The conference ... to ... on the aircraft ... . The conf g u ration designer m u s t learn how to interpret a number of ... ; that has been ... . on a r ect of ... (is) ... the. ..

Often a ... rather a ... to ... design ... which ... ; • The configuration ... is in equipment. Integration ... (.e.) . In performance ... ... the ... data, and ... to ... as ... . Use of Us by the relevant cross section is perpendicular to the load. Arrangement of the design ... in the wing ... . The upper left ... of the ... are ... . Sharp edges on the nose fix this. This should be done by the designer as a check after the design layout is completed. / W6 = 0.995 = W7 / / o'-' Centrifu g a l force ♦ ... / / // Less lift Spin axis Fig. Does the design have growth potential, or would a future fuselage stretch be impossible due to, say, tail-down ground angle? If the board level is allowed to air-cool (to be "normalized"), it becomes much stronger but retains. 05) - 0 . 05 1 . 260 -2.o (15.2) S♦t806 Wvortictnal tail 3.316 1 + ♦: Wvertical tail 0. The P-51 was regarded as the finest fighter of World War II in part because of its radical laminar-flow airfoil. Watch out for this trap: If a cambered airfoil needs to be scaled in thick ness, the camber line should remain unchanged to avoid changing the lift and pitching moment. One solution to this problem would be to add fuel tanks in the fuselage, forward of the center of gravity. If we define the relative wi n d an gle such that a tailwind has angle zero, and a headwind has angle of p radians (180 deg), then we can derive the following: V sin (7f - L) tailwind - sin - I (Vwind cos L)tailwind J V airspeed]) J Vgroundspeed - airspeed - Lj tailwind sin (7 3.5) The traditional pilot's "flight computer" solves this equation graphically. If a tail wheel design is used, and you should fly faster into a headwind so that you do not fight it as long, and slower if a tailwind is pushing you forward. This is the "back of a napkin" drawing of a proposed design and gives a rough indication of what the design may look like. CHAPT E R 1 2 U n ca m be red Aerodyna m ics Cam bered Camber d ra g zero l ift Fig. The "instantaneous endurance" as defined in Eq. (17.29) is the amount of time the aircraft will remain aloft from the next increment of fuel burned the r ... 0 . 0 39.80 45.25 49 .50 210 210 I 56 I 65 235 L 9 5 L 51 ... 56 ... The ... 1 2 0 ... . 5. Benefits include reduced manufacturing cost and better product quality, with fewer required engineering changes in production. Mission leg one is usually engine warm-up and takeoff for first-order sizing estimation. The energy required to produce these vortices is extracted from the wing as a drag force and is proportional to the square of the lift (see Sec. .fonvar,-(-tt, ,...,s+ (CrvdV ♦ &I SS u"" c, the wing contributes about two-thirds of the total The top designers lift so the designer should avoid disturbing the top 2/3 of the lift! of the wing. 2 . 022 0 . Nothing very stupid will result, but nothing brilliant either. Some aircraft use strakes at the rear of the fuselage for the same reason. The aspect ratio of the con ventional design is higher not because of a greater wing span, but because of a smaller wing area. Profile drag is usually referenced to the maximum cross-sectional area of the body. This increases boundary-layer thickness, and that tends to cause flow separation and wing stall. T = T/2A((14.47) (14.48) . In conceptual design we usually have no such aerodynamic problems, and if we did, we would revise the overall arrangement to avoid them. "Here's what's wrong with it and here's how the next iteration will be better" gets the A . Thus, if skin friction is ignored, the net drag is zero! This beautiful theoretical result was known to be false and came to be called d'Alembert's paradox (1752♦. 40 9 (15.50) Woodandnoggear 0. Most columns used in aircraft are below these critical slenderness values, so the elastic Euler equation cannot usually be used in air craft column analysis. 2 W W0 0 . Also, the actual increase in effective aspect ratio is a function of velocity and lift coeffi cient. For short or laterally constrained parts in compression, the ultimate cross-sectional strength is usually assumed to equal the tensile value. I t is very important to avoid confusing these two sweep angles. "Bubble" of a person (c five Fig. In the SAWES standard weights format they are lumped together. 1 5.2. The ratios in this sample were taken from a number of GA and homebuilt airplanes including the BD-5, Cessna 172, and T-34C. This increases the dynamic pressure, which increases the actual drag magnitude. Production begins with the design and fabrication of the production tooling. 8M0 . Airfoil characteristics are strongly affected by the Reynolds number at which the airfoil is operating. Figure 12.5 also shows the effect of aspect ratio on lift. If you hope to become an aircraft designer, you might enjoy my book Have Living in the Future-The Education and Adventures of an Advanced Aircraft Designer,l2l This is a non-technical book that is half biography and half insider's history of projects the author worked on. The resulting difference in air velocity creates a pressure differential between the upper and lower surfaces of the wing, which pro duces the lift that supports the aircraft. 1 ' ...... From the calculated groundspeed, the cruise range or the mission segment weight fraction equation can be adjusted as shown before. 9]} that accounts for the fact that the fuselage of diameter d creates some lift due to the "spill-over" of lift from the wing. This is very similar to the aspect ratio except that it considers total wetted area instead of wing reference area. For the sizing example, this equipment is assumed to weigh 10·000 lb (4536 kg). 3.3 Specific fuel consumption trends (at typical cruise altitudes) . The drag becomes much higher, and the lift and pitching moment are also affected. 6 - 7 .38 Aircraft volume plot. Conversely, use of only "yesterday's technol ogy" will result in a heavy and underperforming airplane that nobody will buy! This leads to arguments, with self-serving statements like "our concept is low risk." To clarify the terminology, NASA and the Department of Defense have defined the "technology readiness level" (TRL) scheme, which is used to communicate technology developmental status and risk. The resulting curve is called a "drag polar" because it resembles a parabola. 2 7 Section property definitions. In moderation, such tools have merit during the earliest stages of a project, but this author has seen a ten dency to devote excessive time and effort to such methods, to the detri ment of actual aircraft design layout and layout-based trade studies. Multidisciplinary IPTs bring together design, engineering, production, and operations personnel along with custo mer representatives to define and develop new products, up to and including entire new aircraft. The tail lift-curve slope should be reduced about 20% if the elevator gap is not sealed. 'R. Rarely used today in production aircraft, wings designed with 2D airfoils tend to stall first at the tips, ... The aircraft takes off, cruises, accelerates, and finally turns to ...

... Vortex lift, and ... CY Eq. (14.23), the moment of inertia is the total cross-sectional area times p squared, so p is obtained as follows: p= VTIA (14.28) The main use of p is in column-buckling analysis. You haven't drawn the airplane yet! The methods described in this book allow the rapid calculation of real numbers based on initial requirements and an actual design layout. Fixed . 3 CS23 1500 2500 1 500 300-3788 :;:J ...... One more word of advice-make sure that you take enough classes in one of the technical specialties so that, if all else fails, you can "reposition" your resume to get that first job in something other than aircraft design. Preliminary Design Freeze the confi g u ration Develop lofting (su rface d efi n ition) Develop test a n d a n a lytica l database Design m ajor items Develop actual cost estimate (mainly) The "You bet you r compa ny!") Detail Design Design actual pieces to be b u i l t Design tooling a n d fa brication process Test major items-structure, la n d i n g g ear,... "70 1 . ; ... To solve the isobar unswept problem at the root, two aerodynamic strategies can be employed. 4.6 Ga -04 1 3 Liebeck L 1 003 ♦ G-SA ("Peak ky") 5 ♦ percentile typical airfoils. () . This is illustrated in Fig. Also, the tail angle of attack must account for the downwash effect E, which will be estimated later [Eq. (16.24)]. 3.9 ASW concept sketches. The exposed area shown in Fig. 3773 - W0, calculated 75,000 78,808 78,865 0 . 8.2 \ . 5 m a l l rad i u s corners Oyerlapped - sharp corners Fuselage-wing cross section. (What happens at higher " ' ♦ ♦ 0 : :::: o Q " " ♦ o .. .. ♦ ... Fuselage stations Fig. Although admittedly simplified, this method introduces all of the essential features of the most sophisticated sizing methods used by the major aerospace manufac turers. To change number without changing the thickness distribution, scale the camber line vertically as desired then add back the original thickness distribution. 20 (I cs yaw x 10 - 6) 0 . 12.l, there are only two ways in which the air mass and the airplane can act upon each other. . There are also the NASA Supercritical airfoils developed by Richard Whitcomb and others, and the newest NASA Natural-Laminar-Flow (NLF) airfoils. An extensive discussion of aluminum alloys can be found in [10]1. Wood must be properly maintained and 51 7 518 A i r c raft Design : A C o n c e p t u a l A p p r o a c h should not be left exposed to the elements. The location of the stiffness centroid is identified as a point referred to as point (C), and provided as a function of the distance from the leading edge. Experience A (Ι + . 80 o. The DC- 10, perhaps the first to use such nacelle strakes, needed them because the nacelle and pylon were causing the flow to separate resulting in a premature stall. 3 Pre l i m i n a ry design Deta l l design 0 / 0 o o o 0] Design phases: final work "spike" . *f£] Fuel-Fraction Estimation Using historical values from Table 3.2 and the equations for cruise and loiter segments, the mission-segment weight fractions can now be estimated. 3.4 Conventional 393 Delta wing 244 1 55 6.2 1 000 2 1 56 55 2.2 1 . 2 15 2 1 00 1 ... A 16 2 1 00 7.7 Does aspect ratio predict drag? Classical airfoil design methods worked just this way, with one computer code to optimize the wing modeled as a zero-thickness curved camber line. RD Swin is described at www. For a wetted aspect ratio of 1 .27, Fig. Had the longerons been placed lower, they would have required a kink to pass over the box. 8. Trade studies and an ever-increasing level of analysis sophistication cause the design to evolve on almost a week-by-week basis. Serious testing begins in areas such as aerodynamics, propulsion, structures, and stability and control. 1 4.39 (. Chapter 22 introduces the extremes of flight-very low to very fast-with subchapters on spacecraft, hypersonics, and airships. While still some what subjective, the TRL of a technology can be assessed by specific events as described here: • • • • • TRL 1: Basic principles observed and reported TRL 2: Technology concept and/or application formulated TRL 3: Analytical and experimental function or characteristic proof-of-concept TRL 4: Component and/ or breadboard validation in laboratory environment TRL 5: Component and/ or breadboard validation in relevant environment TRL 6: Model or prototype demonstration in a relevant environment TRL 7 : System prototype demonstration in an actual environment 19 20 A i r c raft D e s i g n : A C o n c e p t u a l A p p r o a c h • • • TRL 8: Actual system completed and qualified through test and demonstration TRL 9: Actual system proven through successful mission operations The actual conceptual design effort usually begins with a conceptual sketch (Fig. For such projects, the design must begin with the definition of design requirements. C o n c e p t u a l A p p r o a c h "Selling" the new concept or technology. However, it is often difficult to put large flaps on the wing, so the wing must be oversized. 25 0 .5 x D0 . In between these extremes of sizing procedure lie the methods used for most conceptual design activities. / Wo = (0.97)(0.985)(0.858) (0.9277)(0.858) (0.9917) (0.995) = 0.6441 W1 / Wo = 1 .06 (1 - 0.6441) = 0.3773 We / Wo = 0.93 wo 0 · (Table 3.1) 10,800 We = 1 -0.3773 - · We /Wo Imm1111llIllm50,000 60,000 56,500 56,700 0.436 1 0.4305 0.4326 0. 50 100 4 6 8 10 00 0 .239 0.246 0 .258 0.267 0.282 0.299 0 . !>' ... ... Strut travel (? deg bend) Static ground l in e / Fig. The sum total of the weights of all sources. ... Design ... cross section ... ... : Design rational airfoils design programs are spit out an airfoil defined by coordinates with no relationship at all to the proper "zero-ℓ♦♦o-at-the-leading-edge" axis system. = == = 2 A (3 . For any mission segment the mission segment weight fraction can be expressed as If these weight fractions can be estimated for all of the mission legs, they can be multiplied together to find the ratio of the aircraft weight at the end of the total mission, (assuming n segments altogether) divided by the initial weight. This ratio can then be used to calculate the total fuel fraction required, a plane that cuts only three members, for the upper strut and the inner strut analysis. 5 (0.085) 0.5 (0.085) 0.5 (0.085) 0.5 (0.085) Because the number of designers working on the geometry will grow, some means of managing access to the geometry is essential to avoid chaos. Either format should give the same answer. It is about 77 for 2024 aluminum, 5 1 for 7 07 5 aluminum, 91.5 for 4130 steel, and 59-76 for alloy steel depending upon heat treatment. A variable-sweep wing is heavier than a fixed wing and is accounted for at this initial stage of design by multiplying the empty-weight fraction as determined from the equations in Table 3.1 by about 1 .04. This process offers both cost reduction and also is more expensive to fabricate in titanium than aluminum due to tooling and handling issues. In later chapters more detailed procedures for calculating these values, which change as a function of altitude, velocity, and power setting, will be presented. While a substantially lighter structure was obtained, the difficulties experienced with the idea should be noted by the designers of the next-generation shuttle. 93 {0 . Frequently the thickness is varied from root to tip. The preceding takeoff gross weight calculations have thus implicitly assumed that the new aircraft would also be built of aluminum. The most common aluminum alloy is 2024 (or 24ST), sometimes called "duraluminum." This 2024 consists of 93.5% aluminum, 4.4% copper, 1.5% manganese, and 0.6% magnesium. 7.37). 1 1) - 0. The shape of the reference wing is deter mined by its aspect ratio, taper ratio, and sweep. For aircraft such as transports, which have fewer cutouts and cement (ed) ... design pylons transferred to the fuselage ... under a ... of "strings", which are distributed around the circumference of the fuselage (Fig. Co♦01..s E !♦C.lR.IC♦L. C HAPTER 4 H ig h subsonic low ♦ 8c M ercritical A i rfoi la n d Wing ... Fa i l Geometry Selection ♦ ♦o ♦ "Bubble" of a ... ♦ person ... . The standard ... . nominal " " . ... Once is friction ... . Thinking ... ... The ... ... geo ... ((... 17) _ 15. Something similar happens at the wing tips, as shown. 12.1) C1. The wing weight will be determined in the next chapter and can be assumed to be distributed proportional to the chord length. 1 4.35 Actua l loads Bend i n g moment Wing loads, shear, and bending moment. 3.6 for guidance. ... One is friction caused by shear layers, and the other is pressure. The points go where the computer sticks them. !S!> (♦11t : ::: ai•o.,. (ff: ! (s ... The alternative, seen on the F-22, is an all-titanium structure around the engine. This is accomplished by the wing's angle of attack and/ or wing camber. 2.3 depicts the design of a front wing spar in the amount of detail expected during the conceptual design. 1 0 1 250 80 71 71 48 1 0.3 3.9 250 250 250 250 84 72 74 81 76 64 63 72 75 63 66 72 42 43 43 42 1 0.4 1 0.3 1 0 .0 1 0.4 4 3.9 Mi 4.0 Magnesium Magnesium H K 3 1 A 0 .0674 700 34 24 22 23 6.5 24 -HM21 A 1 0.0640 800 30 21 17 19 6.5 2.4 1500 - 1000 1 60 1 70 1 45 1 60 1 54 1 62 1 00 1 62 1 00 1 5 1 5 5 1 2 1 000 - 1 500 1 200 - 1 800 1 400 1 55 1 68 1 00 1 00 1 27 45 1 00 1 35 1 01 1 07 3 1 1 00 2.64 1 2 3 0.38 Titanium Titanium-Ti-6A1-4V -Ti-1 3V- 1 1 Cr-3Al 0 . 14.38. The strength and stiffness properties of aluminum are affected by the form (sheet, plate, bar, extrusion, or forging) and by heat treatment and tempering. = Tr/tp cp = TL/Gtp (14.45) T/ (14.46) For a noncircular member under torsion, the analysis is generally much more complex. When a wing is stalled, most of the flow over the top has separated. Fuselage wetted area can be minimized by tight internal packaging, that is, less internal volume. "0 ICI0 110 12.P I0 I'o ♦ V trts !f'+ kf] ♦. If you are sizing to a required range, you must increase the required cruise range R in the mission segment weight fraction (19.10) by the ratio of velocities (Vairsp eed / 647 648 A i rcraft D e s i g n : A C o n cepts a l A p p ro a c h Jet: Prop: The aircraft will be flying at the actual airspeed for V in the equation . 3.10 to the ♦amples of Fig. About 10 to 20 spanwise stations will provide an accurate enough approximation for most layout purposes. Yet another problem for students is that the aircraft design course can easily become the "learn how to use a certain CAD system" course. It is "designed" as nothing more than a flat plate from root to tip at the desired location of the spar. These charts actually estimate the slope of the "normal force" coefficient Cn , that is, the lift-curve slope in a direction perpendicular to the surface of the wing. If the body is rectangular in cross section, the wetted area will be four times the average projected area. At subsonic speeds L /D is most directly affected by two aspects of the design: wing span and wetted area. The aerodynamic interaction between different components should be visualized in designing the aircraft. 14.34, the bending moment at a cross-sectional cut is opposed by a combination of tension and compression forces in the span wise direction. Reference [103] gives a more detailed discussion of titanium and its alloys. X . The shear loads of the braced wing are analyzed as before, taking into account the large concentrated vertical load at the strut. Note that the volume removed at the center of the fuselage must be provided elsewhere, either by lengthening the fuselage or by increasing its cross-sectional area in other locations. Thus, it is crucial that realistic esti mates of empty weight be used during early conceptual design, and that the weight be strictly controlled during later stages of design. Laminar flow is very dependent upon the actual surface smoothness. = 9.1 14,000 (T c = 0.5 1fsr = 0.0001389 1/s) C = 0.6 W X (994.8 ft/s) = 5 9 6.9 ft/s (1/s) = 0.6 1/ = 0.6 1/s L/D = 16 x 0.866 = 13.9 W3 / W2 = e(-RC/ VL/D) = e -0.153 = 0.858 E = 3 hr = 10,800 s C = 0.4 1/hr = 0.0001 1 1 1 1/s L/D = 16 W4 / W3 = e(-EC/L/D) = e -0.075 = -0. Actual aerodynamics, weights, and installed propulsion characteristics are analyzed and sub sequently used to do a detailed sizing calculation. 1 0 . 32 1 Nmx - 0. 5 ti wall to mainlandinggear = 0 · 0.0061 · m wl0 .88BN10 . Bending stresses - ;:::E:> • ♦ y Shear stress d i stribution x Fig. While composite materials are considered the latest state of the art for lightweight aircraft structures, there are new aluminum alloys such as aluminum lithium that offer nearly the same strength and can be formed by standard aluminum techniques. This table is useful for understanding the relationship between lift, drag, and angle of attack. The computer simply does not want to spend time on the fly. They can design and order, say, a die for stamping fenders and know that the actual fender shaping will be enough like the last one that the die can be revised at the last minute to the desired contours. C H A P T E R 1 4 Structu res a n d Load s Lift d istri bution w Fig. Conceptual design is characterized by a large number of design alternatives and trade studies and a continuous, evolution ary change to the aircraft concepts under consideration. 12.6. A wing is considered to be in purely supersonic flow when the leading edge is "supersonic," that is, when the Mach cone angle is greater than the leading-edge sweep [see Eq. (12.14)] . ... ::;-J - r·c :::: ;] Well done, this structural arrange ment will create a design that seems to glide through detailed structural design and produces a lighter-than-usual structures group weight. A clumsily done wing-fuselage intersection can cause lift losses or disruption of the desired elliptical lift distribution and can cause high drag at transonic speeds. 2. "parasite" drag is the drag that is not related to lift. When summing forces at a joint, the positive or negative force is added to the sum if it is up (when summing vertical forces) or to the right (when summing horizontal forces) and subtracted if down or to the left. Vcrnsse) (17. 24) Effects of Wind on Cruise and Loiter While the design mission for an aircraft often assumes zero wind, the real world is usually not so cooperative. Figure 16.32 presents a re empirical estimation of the required tail volume coefficient and that for spin recovery for straight-winged aircraft. /) ... The upward curve in the subsonic region and the corresponding downward curve in the supersonic region are found by the theoretical Prandtl-Glauert correction shown in the denominator . 222 (15. P.fl] Isobar Tai loring In Chapter 4 the importance of wing sweep for delaying the formation of shocks over the wing was discussed. These are the subject of detail design (bottom of Fig. The airfoils presented in Appendix D are not being recommended as the "best" sections for those applications, but rather are reasonable airfoils used in those applications. The molecules closest to the skin act as if they are stuck to it, moving with the aircraft (no-slip condition) . .... The Reynolds number strongly influences the parasitic drag coefficient, whether the flow will be laminar or turbulent, and when and where the flow will separate. ... design ... aircraft internal volume can be quickly estimated in a similar fashion to the wetted-area. l X-1 5 X-20, very difficult to form Engine parts (") :(... If quenched with water or oil, the steel becomes "martensitic" with a needle-like grain structure, great strength, and extreme brittleness. • These i n itia l choices w i l l be revised l ater, so d o n ' t spend t o o m uch t i m e o n them . 0 0 0 ::::. Corner 30 25 10 5 1 00 200 300 -400 500 2 600 700 Velocity (ktn) Fig. Only symmetrical airfoils, or those carefully designed with this in mind, will have both pitching moment and moment derivative equal to zero about the quarter-chord. It extends through the fuselage to the aircraft centerline and has its tip usually cut off square but is really l'o rounded. Note that by calculating the unknown strut force both ways (vertical and horizontal summation), a check of your result can be made. For early conceptual layout, the selected airfoil is important mostly for determining the thickness available for structure, landing gear, and fuel. 1 1 5 l ...... Static taildown a n g l e :(;f!') Fi m Chapter 23 a number of unconventional designs are discussed, including flying wings, canard pushers, joined wings, and asymmetric aircraft. 9 2) - 0 . At widely different values of Reynolds number, an airfoil will act like two different airfoils! The drag polar in Fig. However, the Pres s u re ro fores Shear forces Pa rsisite d ra g Separation Visco u s separation Skin friction Scru b i n g d r a g "Shock Wave d ra g C i rcu lation 5 b oc k - l i n d uced wings Fig. 2.3 Spar design shown in this book was flying during ... the ... on ... design ... . are ... by ... at ... .

... ... MIL-A-8860-8864,8870 curves airplane strength and rigidity. The third use of the lift-curve slope in conceptual design is for longitudinal stability analysis, as discussed in Chapter 16. of its energy. i 1 75° "+S" 4SI.... Use the appropriate effective length for welded, riveted, or bolted columns from Fig. CHAPTE R 8 Idea l fy s pe Loaded wings Spar Load s p e c i a l Considerations i n Config u ration Layout Wing (rea r view) Weight d i stribution Center line Box lists . Figure 3.10 is a conceptual sketch prepared, in more detail, for the selected concept. We know by sizing. All two dimensional airfoil drag is produced by skin friction and pressure effects resulting from flow separation and shocks. 5 Wflight controls = 0.053 L 1.536 B w0 .371 (N z . . . . . . 10 -4) 0 .80 x (c o s A) -1 . The only variable in this equation is the fuel-fraction. Reference a viscosity ratio Sweet D and al ♦ Fig. ! 1 ... Schematic: Viscosity-based models ... Figure ... ... The cruise ... ... the ... ... for vertical tail area with elevator positions. You must tune and remember that it is the weights that we choose to estimate. This is the very reason that we choose the quarter-chord location for reference for the airfoil moments. The results of this optimization include a better estimate of the required total weight and fuel weight to meet the mission. 8.1, where a nicely-enlarged front suddenly transitions to a smaller, that is, with push on the skin as shown in Fig. In concept four, the wing is high with the engines mounted below. 1 2 . C in the landing page, click the link beneath "Supplemental Materials," select the password ADACA6E, and follow the directions provided. 10Lo . We don't care what color a certain wire has to be. A fat and unswept wing will suffer an extra lift loss from shocks in the transonic regime whereas a thinner, swept wing does not. It also depends upon the strength of the wing's tip vortices, so a wing with a higher aspect ratio or lower span loading (weight/ span) will obtain less improvement by the use of winglets. Pre liminary design is characterized by a maturation of the selected design over a period of many months, with an ever-increasing level of understanding of the design, an ever-increasing level of design and analysis detail, and an ever increasing level of confidence that the design will work. 08 Wair conditioning and anti-ice = 265 wdgs. Thus, an iterative process must be used for aircraft sizing. For a cambered airfoil there is some negative angle at which no lift is produced, the "angle of zero lift." As a rule-of-thumb, this negative angle is approximately equal in degrees to the percent camber of the airfoil. Drag tends to be roughly flat at lifts around 100% correct. The net rearward components of these pressures produce additional drag. These range from the X-3 1 to the BQM- 177 and include early involvement in the programs that became F-22, B-2, F-35, T-45, and more. 14). The Boeing 787, today's state-of-the-art for com ♦ercial aircraft structure, is almost 50% composites by structural weight. Those are included in the wing and tail weight equations. 2 I n d u ced d rag Tri m d rag Wave d rag d u e t o l ift (Vo l u m e d i stribution) Drag terminology matrix. When you step on an upright soda can, it fails in a form of local buckling called "crippling." The walls of the cross-section collapse without warning, and the load-carrying ability drops to almost zero. The NACA five-digit airfoils were developed from a family of four-digit airfoils whose position of maximum camber forward of the quarter chord position. What We've Learned Design is done in three phases: conceptual, preliminary, and detail. Figure 15.7 shows four common arrangements for fabricating fiber orien tation. This means that the pressure is doing the opposite-it is steadily reducing until roughly the point of maximum thickness. This is the maximum velocity, and then it "recovers" to the original pressure as the flow continues to the rear. Table 3.1 presents statistical curve-fit equations for the trends shown in Fig. aircraftdesign.com. (RTE) Sizing concept. Fleet Conditions Table 3 and the mission profile of the aircraft with a limit of 4 hours 1 day. 3 The ratios Determine design goal ... ... for mission ... ...

... When ... ... the ... , ... on ... . Once known, ... cal column strength ...

... For example, if a wing is tapered, the chord ... . If is suspended, the ... rear ... ... the analysis is an estimate ... distribution. ... (reduced) ... ... - ... ... Fig. 1 . 2 The ... 550 term converts horsepower to power in British units and assumes that is in feet per second. Equation (3. The airfoil section lift, drag, and pitching moment are defined in nondi mensional form in Fig. F L , Being relatively soft, pure aluminum is alloyed with other metals for air craft use. There is a point on any airfoil about which the pitching moment remains nearly constant as the angle of attack is changed. would be the W2 33 3A i r c raft D e s i g n : A Concepta a l A p p roac h W3 aircraft weight at the end of the climb. C H A P T E R 1 4 Structu res a n d Load s Gyro a-fa rce are physically present that occurrence and your are a powerful / looks for thing be a n a ture a n d so ... to ... . Here, we assume the airplane is stabilized and controlled to the desired angles of attack, bank, and sideslip. This minimizes weight but complicates both fabrication and repair of the aircraft. Their final determination is done using optimization methods after the initial design layout is completed. 16.3. Note that for cambered airfoils, the zero lift angle is a negative value. However, the use of airfoil catalogs and families is becoming a thing of the past. ♦ ♦ ♦ ♦ 011 t 1 4 q0 1.68 580 . 1 1 Sweet = Swepsed [1.977 + 0.52 (t/c)] (12) 0 05, ... 0 ♦ ... 0 ... ... ; ... . 1 ... 1 0; 0, ... airplane ... . Fig. Airline companies do not normally contact Boeing or Airbus with requirements for a new airliner. The 3-4 term assumes that CHAPTER 7 Confi g u ration Layout and Loft the cross-section shape is intermediate between a square and a circle. This works just like ♦ the download seen on horizontal tails. More important, how do you know? C H A P T E R 1 4 Table 1 4. l wmg = 0 · 005l(W.dgNz) 0 .557 Sw0 .649A 0 .5 (t/c) root x (cos A) - 1 . 14.33 shows the use of the method of moments to solve the force in the top strut of the motor mount. This increase in profile drag with increasing angle of attack is not technically caused by the gener ation of lift but does vary as the lift is varied so it gets "lumped in" with the actual induced drag in the parameter we call "drag due to lift." Many designers (and this author) get sloppy with the terminology, saying "induced" drag when the broader "drag due to lift" is meant. An aircraft with less-than-typical internal volume for its weight will probably experience problems in development and will likely have poor maintainability in service due to tight packaging. 0 5 t w Fuselage = 0 052 5) 9 = Solving the equations yields Fe 57 ♦ S 9 (tension) and Ff of - 9463 lb (compression). If a design is to be built in the near future, it must use only currently available technologies as well as existing engines and avionics. o> 10VtutO wo ,"38 (f//,016 13i / r(s ,2 VKrs 60 ♦ 100 120 ("f () ... ... ≡ 12.. Figure 14.36 shows the trapezoidal approximation for a distributed load, giving the total equivalent force and the spanwise location of that force. The shape of the fuselage cross section affects the drag. • If you do the right thing i n the wrong phase, it ' s the wrong thing. ... ... C1 ... ♦ ... z Ct ... ♦ 2 3 4 5 0 Mach n u m ber Fig. In this case, the load is transformed to a force line in top view from root to tip, and the spar is assumed to be the depth of the wing airfoils at that location. Two-dimensional airfoil drag, or profile drag, is a combination of skin friction drag and viscous separation drag. A few specialized terms are used in conceptual design. 1 2 A i rcraft De s i g n : A C o n cepta a l A p p ro a c h This is no accident, but rather the product of a lot of knowledge and hard work by the designer. If the airfoil lift-curve slope as a function of Mach number is not known, the airfoil efficiency 7) can be approximated as about 0. 3. (17.1) and (17.2). On the other hand, the purpose of the longerons is to prevent fuselage bending. Fig. Aircraft usually have a lot of unused space because so many items must be reached. Lengths 2 ... ... Wing/tail wetted-area estimate. The wheel turns, again and again, until the emergence of a well-balanced design based on a now-well-balanced set of requirements. On a computer-aided design system, the design work is usually done in full scale (numerically). Fairly sophisticated methods are used to perform a structural analysis of the overall spar, with the objective of determining the thickness (or number of composite plies) required to handle the expected loads. The most common example of this is chopped fiberglass, which is used for low-cost fabrication of boats and fast-food restaurant seats. If not, we will resize the aircraft until it does. 13) Sta b i l ity. M:f]) Design "Flaws" Real airplanes have many "things" on them that are not seen on a concept design layout. The radius of the turn is found by substituting Eq. (17.75) into Eq. (17.79), as shown 659 660 A i rc raft Des i g n : A C o n c e p t u a l Approach in Eq. (17.81): V= R= (-1 T dK) 2W pSCDg ox R= ? 5 ♦ ... ... IVc,TE ln: Near the stall this can cause confusing loops in the line as the lift drops down while moment breaks one way or the other. 1 n e ""REC.O}fl£e. This creates the characteristic "bucket" shape. There are greater pressures behind the shocks. 1 4.34 Shear and moment in beams. A symmetrical cross section always has its centroid on the axis of symmetry, and if a cross section is symmetric in two directions it also has its centroid at the intersection of the two axes of symmetry. N ote: , a n u mber of pioneers of Wo that bound the likely solution have been made. Figure 3.4 shows two widely different aircraft concepts, developed to illustrate this. This substitution introduces a velocity term into the loiter endurance equation, so the condition for best prop loiter will not simply be the maximum L/D. 39 1 392 A i r c raft De s i g n : A C o n c e p t u a l A p p r o a c h f l f the aircraft i s traveling near o r above the speed of sound, additional pressure forces are produced by the shock waves around the aircraft. A free side can rotate and bend perpendicularly and provides the least strength. Also, wing top engines often suffer from interference drag. I illustrates the key geometric parameters of the fuselage or its parts. Thin-wall tubes will feel less sensitive airfoils. Furthermore, c urves with smooth and Fig. 13 14 Airc raft Desig n : A Concepts a l A p p ro a c h Level of detail in configuration design is not very deep. (14.49) and (14.50) u sing the values from Table 14. Curving the airfoil (i.e., camber) allows the airflow to remain attached, thus increasing lift and reducing drag. In a big aircraft company, the designer can ask a functional specialist for a reasonable initial tire size, inlet capture area, weight savings due to the use of composites, or similar estimates. On the other hand, active laminar flow control by suction pumps shows great payoff analytically and in several flight tests, but would be considered by many to be too risky to incorporate into a new transport jet in the near future. 4.4 Effect of camber on separation. Because of fuselage effects, the root airfoil of a subsonic aircraft can be as much as 20-60% thicker than the tip airfoil without greatly affecting the drag. When you push down on an upright soda can, the middle part bends outward in a direction perpendicular to the load. Poorly done, nothing awaits but blood, toil, tears, and sweat. For our simplified form of initial sizing, the empty weight will be limited to warm-up and takeoff, climb, cruise, loiter, and land. Cruise segments as 19 6. The design features are all working together, and many of the design components do more than one task and offer more than one benefit. 2.5 Initial sketch. The sweep of the quarter-chord line is the sweep most related to subsonic flight. Fig. 1 2.80 80 Spin recovery criteria . Carried to the extreme, this leads to the flying wing concept. The new 1 is determined from the new lx and ly using Eq. (14.25): Ix = Ixc + ly ♦e = Ae; + Ae (14.24) Once the radius of gyration is determined, the critical stress for a column of material with no imperfections is determined, and the trend of the vertical thickness of the material can be determined from the buckling... 70 2 .34 1 .23) . 1 I) - 0 .09 1 5 (1 . Equation (7.14) uses the side- and top-view projected areas as used for Eq. (7.13) to estimate volume. 4 7) - 0 . 10 4 Thickness ratio historical trend. 4.8 ♦ 0 ''''''' ; ' • • 2 3 4 Design Mach n u m ber (maxi m u m) Fig. The flying wings pioneered by John North rop were not conceived in response to a specific Army Air Corps requirement at that time, but instead were the product of one man's idea of the "better air plane." Northrop pursued this idea for years before building a flying wing to suit a particular military requirement. 3 . For design purposes the limit loads should be reduced, usually to two-thirds of these values. 29 30 A i r c raft D e s i g n : A C o n c e p t u a l A p p r o a c h S ized ta keoff weight 0.8 W0 (kg) 10,000 1000 100 100,000 ♦ ... ... , 0.6 'iiii 3: >- c_ E UJ 0.5 0.4 100 1000 S ized ta keoff weight Fig. 2.5). As a part of the AIAA Education Series, the book is written with the college student in mind and is self-contained as much as possible. In a similar fashion, a "payload trade" can be made. o c c " 0 :j Q. Solving the equations shown yields Fe of 4400 lb (tension) and Fb of - 4400 lb (compression) . 1 10 Fi. 0 ::: !. However, many advanced design projects had difficulties justifying a cd located home because the functional heads of the different disciplines pre ferred to keep their people together. Modern military aircraft have 1 0-30% of their structure made from titanium (by weight). Design requirements include parameters such as aircraft range and payload, takeoff and landing distances, and maneuverability and speed requirements. Aspect ratio range from under 1 for reentry lifting bodies to over 30 for sailplanes. !55> ♦ · E. Representative material properties are at the back of this section. The resultant of the shear flows are formed over the top of the wing due to the increased velocity causing the air to go supersonic. In aircraft wing spar analysis, it is common to assume that the caps absorb all of the bending stresses and that the web (extended to the full depth of the spar) absorbs all of the shear. The top and bottom wing surfaces are modeled in a way that permits the computer code to make para metric shape variations, "playing" with the geometry until the lowest drag configuration is found. This is to improve the survivability of the aircraft as it approaches its target. :l ... ...

... ... W/f ... . Fig. 2. For a typical aircraft with a propeller efficiency of about 0.8, 1 hp equals one pound of thrust at about 440 ft/s, or about 260 kt (484 km/h) . 10) shows the derivation of the equivalent-thrust SFC for a propeller-driven aircraft. " 0 1 = " 532 E nd o ft h e n g i n e s : A C o n c e p t u a l Approach Wing. Thin Side-Step Ahead design Tr 1 "Ni 1 0 0 ... ... to ... ...

... ... 1 2 3 4 5 6 7 8 9 10 Stress strain. Sum of the thickness. An aircraft's ... ...

Conceptual design is so miraculously glide through sketch and refinement ... ... : ... Lift, pressure ... ...

... ... The "circulation" is the theoretical basis for the classical calculation of lift and drag due to lift. 6 a/ 4 Turn rate and corner speed (sample data at one altitude). 9(2) .92W-no (15.52) i = 0 (= W r (includes propeller and engine mounts) 0 363 Wfuel system = 2.49Vt0 . 7 3 95 .49 250 70 52 49 34 1 0. Computing the aircraft tail. .n a !.i1ll'uitt}l[T!ima The in a r foi l l T h c l a i r foi l 8 ♦ -0 . Typical unswept 9 c Aerodyna m ics Typical swept wings High as pect ratio Low as pect ratio 5 0' 4 3 2 1 0 0 0 0 Fig. 5) (15.15) (15. The equations before for fighter and GA aircraft do include the seats (ejection seats for the fighters), but the equation for transport aircraft does not (see Table 1 5.3 instead). Moment of inertia can be viewed as the cross-section's resistance to rotation about some axis, assuming that the cross-sectional shape is rigid. It is normally such that composite materials in that it offers different properties in different directions. Composite materials are a rapidly-grown area replacing aluminum in every new aircraft. Another very important goal is a "build-to" drawing is created. 05 0.91 {0 . This "circulation" is the theoretical basis for the classical calculation of lift and drag due to lift. A lift increment as the wing ... ...

Typical drag of the tail is called "trim drag." Trim drag also includes the additional lift required of the wing to counter any download produced by the tail. In fact, most of the engineers who go to work for a major aerospace company will work in preliminary or detail design. Simply follow around the perimeter of the cross section making tic marks on the paper, and then measure the total length using a ruler. 3 Factors for spin recovery estimation. nose-down pitching moment that must be corrected for somehow. The following equations describe M . 9) Bh = Winglet: = A effective A (l + h / b) 2 (12 . The arrows represent airflow velocity vectors, with the vector length indicating local vel ocity magnitude. The fuel tanks should be placed so that the fuel is evenly distribu ted about the aircraft center of gravity (estimated location shown by the circle with two quarters shaded). This normally involves placing the centroid of the lift curve graph. 23 24 A i rcraft Desi g n : A C o n c e p t u a l A p p r o a c h Furthermore, design information provided from above by people who weren't involved in or aware of all the tradeoffs and constraints often demoralized the team and de-optimized the design. Titanium is extensively used in jet-engine components and is also used in lower-speed aircraft for such high-stress airframe components as landing gear beams and spindles for all-moving tails. At supersonic and even higher subsonic speeds, the true aerodynamic center moves rearward, migrating from the 25% point to around 35% or even 40% of chord. To provide an initial aspect ratio for aspect ratio fighter's, ... 1 4.40 ... A ... ... 7 ... ... M:f]] COMPERTER Lift A successful yet almost forgotten aerodynamic concept can be used to improve lift-to-drag ratio at supersonic speeds. Lofting and grinding at shipyards was originally done with long flexible rulers called "splines." This work was done in a loft over the shipyard, hence the name. This is largely based on the lowest drag form to limit the allowable wing span, in some cases to a lower-than optimal value. One can also delay spin entry or enhance spin recovery by reshaping the wing leading edges to minimize the lift imbalance. Span (ft). The wing reference area, Sref or simply S, is the full trapezoidal area extending to the aircraft centerline. This was actually the case for several of the classes of aircraft in Table 3.1. Fuel-Fraction Esti mation We also need to estimate the fuel available to perform the mission. Sometimes flow separation is favored by geometry, not the effects of vis cosity. At some point, as column length is reduced the internal compressive stresses produced at the onset of buckling will exceed the pro portional limit, and the column will no longer be experiencing elastic buckling. 3773 M(MH) ((}ild 50,000 52,000 53,000 53,300 53,320 Payload = 10,000 lb Payload = 10,000 lb W0 = 56,650 lb We W0 = 0.436 1 0 .4899 0 .4489 2 1 ,803 1 4,397 1 8,4 1 9 4,398 9,380 21,000 18,000 ... 0,41 1 3,1 ... ... 0 .074 33,563 3 3,576 33,32 1 3 33,31 8 We Wo 1 - 0 . However, the various component radiators have largely replaced wood in homebuilt aircraft. 9 7) - 0 . Also, for a production fighter the windshield would be a bulletproof material. TDPF = (TDR) (UDVC) (16.67) (16 . One of the wo m t impurity elements for "embrittling" titanium is hydrogen, followed by oxygen and nitrogen. But aerodynamic design doesn't start with calculations, it starts with the initial design layout. Aspect ratio is defined as the square of the wing span divided by the wing reference area. Enough cross sections are shown to verify that everything fits. For a fixed design, if the part has rivet or bolt holes, the smallest cross-sectional area must be reached from the center of mass. ... ... Although ... ... has been a ... for 6 years. ... ...

... wing ... . Flow separation over a wing or fuselage often occurs because the air near the aircraft has been slowed down too much by viscous effects and no longer has much energy. 4.3 Airfoil flowfield and circulation . Figure 14.23 shows the two major composite forms, filament-reinforced and whisker-reinforced. Aluminum will remain important in aircraft design for many years to come. You must solve for the groundspeed along the desired flight direc tion using the Law of Sines and a wind vector diagram as shown at the botto m of Fig. 1 7 14] } } H igh strength, not weldable, subject to stress-corrosion High strength, not weldable, common in high-speed aircraft High-temp & strength subject to corrosion 8-70 SR-7 1 Titanium High-temperature n ickel alloys Inconel X-750 Rene 4 1 Hastelloy B 0.300 0 .298 0.334 1 1 .0 1 2 . 006 AO . ICf£l High-Temperature Nickel Alloys In conel, Rene 41, and Hastelloy are high-temperature nickel alloys used in extremely high-speed vehicles. Obviously, the new design should not cost more than the other ways to accomplish the same mission, when all factors are con sidered. These include such obvious things like range, payload, and speed, and often add more subtle requirements such as low development risk, survivability, or an ability to fit into an existing commercial aircraft parking spot. 68 Mavionics Wfurnishings = 0.0582Wdg - 65 l ' r = = = ♦ = We/Wo lbs 8 f' a. a atoms Term i n ol ogy A R5 aspect ratio (with subscript vertical tail horizontal tail span, ft " or "b" for horizontal tail) (15.53) (15.54) (15.55) (15.56) (15.57) (15.58) (15.59) "r" for C H A P TE R 8 b D Lfw Weights wing span, ft fuselage length, ft engine m ount the intersection, ft horizontal tail height above fuselage, ft Ht 0.0 for conventional tail; 1.0 for "T" tail Ht/ Hv vertical tail height above fuselage, ft Hv yawing moment of inertia, lb-ft2 (see Fig. Computer Graphics Applica tion techniques include all manner of computer code as well as cor relations to wind-tunnel and other tests. . . . 2 - 4Eacleci. Historically the NACA, [26l] is referred to as "area-ruling" or "coke-bottling" and can reduce the wave drag by as much as 50%. = = = ! Heat treatments 80 60 40 20 0 0 20 40 60 80 100 120 140 Column buckl ing Euler (round tubing) . Even curvature (second derivative) discontinuities should be avoided as much as possible. Titanium is still relatively expensive, costing about five to ten times as much as aluminum per pound. ' . Much of the Wright Brothers' success can be traced to their development of airfoils using a wind tunnel of their own design, and the in-flight validation of those airfoils in their glider experiments of 1 90 1 - 1 902. ♦ MOST-fiFT • C. 3.2. The Simple Cruise mission is used for many transport and general-aviation designs, including homebuilts. /0 cos A 100 t l c - 0 - 3 (N W)o .49 x c (g cos A (Ignore second term if Whe O) w... In level flight, the lift is known. It must equal the aircraft weight. The resulting CHAPTER 14 Structu res a n d Loads strut loads are then summed for the various members. The aircraft is sized to provide some required cruise range. 0) ♦ ((°O 0 ((o-Oo "O"O 0 0 0 (o (..) 24 30 36 40 46 50 x x x x x x x x 0 xx! (r 1.4) 18 16 14 12 10 8 1 74 kt 230 2 1 7 kt 1 74 kt 225 225 1 5 1 ... ! Historic trends 1 4 ... ...

Fig. 15 ... ... 1 7 40 ... ... to calculate the weight of each com ponent using several different equations and select an average, reasonable result. Sweeping the C H APTE R 8 Spec i a l Considerations i n Confi g u ration Layout "Bubbl e" a rou nd root a n d ti ps Improves performance i n s wept al root a n d ti ps Improves Isobars u n swept at root a n d tips Restoring isobar sweep with "peaky" root a i rfoil Restore isobar sweep with pla nform Fig. The L/D when flying at the minimum power velocity was shown to be 86.6% of the best L /D. As can be seen, the type of aircraft also has a strong effect, with flying boats having the highest empty-weight fractions and long-range military aircraft having the lowest. 1 7 a Typical CD ... ... CD ... . The drag and lift of the fuselage, nacelles, and other components are usually known as parasite drag or zero-lift drag. Remember that the two dimensional airfoil characteristics are denoted by lowercase subscripts (i.e., Cr). Wing section is primarily the motor mounts plus engine-associated equip ment. Once the loads in each member of the truss are known, the struts can be properly sized. The sized aircraft's weight and turn fraction, as it ... ... 5 ... ...

... is ... ... for ... ... This format is useful because the data become fairly linear, but the fig This requires the use of wing mean load distributions and a symmetric lift distribution. Quite simply, what is done during conceptual design, the things that are critical, and the tasks that are boring and repetitive (and therefore ideal for computerization) are different from those in other, later phases of aircraft design. In inviscid flow there is no drag due to lift for the two-dimensional airfoil [0 ... Lift ...] ... ... perpendicu lar to the freestream direction. [c r = M(2y (14. Multiple thin plies of woven mat are placed in molds along with a resin glue and subjected to pressure during cure. However, Johnson warns "there is a tendency today, which I hate to see, toward design by committee-reviews and recommendations, conferences and consultations, by those not directly doing the job. 9 8. 536B0 . By placing the wing above these shocks, the increased pressure beneath the wing provided the 4 Stab- C- 'Enaabhn "Rout of the wing"... a wing would ... ...

... ... Wg ... ... ♦ ... .

*f£] M lssion-Segment Weight Fractions For analysis, the various mission segments, or "legs," are numbered, with zero denoting the start of the mission. 7 132 W/ / Wo = 1 . However, the dozens of classification schemes for aero dynamic forces can create confusion because of overlapping terminology. 1 4. Some of the most famous airplanes, starting with the very first, were designed without a firm requirement. Such engines are usually rated and analyzed at sea level. A lift ... ... Supersonic wind tunnel tests alone will take many months, and you'll need sufficient time to take the results, modify the design, and test it again. 1 2.9 In the past, some supersonic airfoils had a sharp leading edge to reduce wave drag. 7 2-4 A i r c raft Desi gn : A Concepts a l ... ...

... ... The calculations for resizing the aircraft using composite materials are shown in Box 3.4. Box 3.4 Composite Materia l Trade We / Wo = We = (0 . I I . Turbulent air has more energy than laminar air, so a turbulent boundary layer tends to delay separation. This increase in two-dimensional airfoil drag is due to an increase in viscous separation caused by a greater pressure drop on the upper surface of the airfoil as the angle of attack is increased. 24 I 2 (4 D/g ii c»» ≡ ... ... For selecting structural materials, aircraft ... ...

... aircraft are ... ...

... given an x-versus-z table. It works. For swept-wing supersonic aircraft, the NACA 64A and 65A sections are good airfoils for initial design. 88} - 0.05 1 .19 {1 . ' £N61/UE: ... 4.6. The early airfoils were devel oped mostly by trial and error. To the right is a top view of part of the wing with those same four dots shown and lines (isobars) connecting those dots with other points on the top of the wing having the same pressure. This equation, with the weight fraction equation, and using the equivalent concentrated lift loads as discussed earlier. The applied torque J produces a twisting deformation cp that depends upon the length of the shaft As shown at the right of the figure, the torque is resisted by shearing stresses ♦ that increase linearly with distance from the center of the cross-section. This process ... ... It is only ... ... This procedure extra lift 2-Over-wi ng nacelles 1 -Conventional 4-T a l e r a ft Fig 3-Ca na rd, low wing Fig. Today's best methods model the actual upper and lower surfaces for sophisticated optimization, but the old methods worked quite well for their day and can now be used to "trim" the room-sized tape-driven monstrosities of the 1960's. This is done by recalculating the weight fractions for the cruise mission segments, using arbitrarily selected ranges. This is a lower drag coefficient than the drag coefficient for best L/D, which was shown to be 2.0 times the zero-lift coeffi cient. 7 8 A i rc raft D e s i g n : A C o n c e p t u a l A p p r o a c h Overview of the Design Process * IC\ 10 (0 o J A i rcra ft desi g n is a d i s ti n ct d i s c i p l i n e ... ... the different methods ... ... 7 0 0 > - < 0 . Fig. 15. ... 5 ... ...

... ... in ... . However, a base design in ... ... the ... ... in ... ... 2 ... ... The airfoil is a weighted aeroshaped ... ... of aircraft ... ... With any ... ... to optimize ... ... for ... ... in the ... the ... ... the ... IPTs ... ...

... more cost-effective solution to the customer's real needs. This will be discussed in Chapter 12. Sometimes we plot the pitching-moment coefficient vs the lift coefficient rather than the angle of attack This gives a better picture of how the airfoil affects the aircraft trim and stability. For the analysis to be performed. One of the ... the ... is ... ... but ... of ... ... of ... ...

... ... /1000) ø .735 Whandlinggear = .3 2 X 10 -4 wdg (15. If it looked worthwhile, they'd develop a set of mission requirements, probably changing them based on what they'd learned. The Mach 3 XB-70 (Fig. It's a skill that takes education and experience to perfect. This action permits the flow to follow a much greater turn. Table 15.3 tabulates various miscellaneous weights. Note that two-dimensional airfoil characteristics are denoted by lowercase subscripts (e.g., Cr) whereas the three-dimensional wing characteristics are denoted by uppercase scripts (e.g., Cr). 1 4.29 length is in the load direction, the width b, the thickness, and the manner in which the sides are constrained. Toward the rear of the airfoil, various pressure recovery schemes are employed to prevent separation near the trailing edge. The upper surface pressures are expressed mathematically, as in the original NACA airfoil families. Many airfoils were invented with constant-pressure but are often provided ... ...

... possibly get wind-tunnel experience. 10Ngen o . Design also depends upon the many can be built. ... Centroids for simple shapes are provided in Table 14.6. The centroid o f a complex shape built up from simple shapes can be determined using E q s. 1 1) where h = endplate or winglet height; b = wing span. bending-moment distribution, maximum bending moment, and spanwise location of the maximum bending moment 1 ♦ 68) 4W= (. Mod u s = Ci sin(x(j) + C2 cos (x(j) + wJ2 Wmax + tan (Xm) j = · (14.38) Di j + W]..2 cos 2 (x j) (14. 7 This saves time and money and does a better j ob of identifying and fixing component interference problems and potential difficulties of aircraft integration of major components. The effective length of a column is determined by the end connec tions (pinned, fixed, or free) as shown in Fig. In these, the first digit defined the percent camber, the second defined the location of the maximum camber, and the last two digits defined the airfoil maximum thickness in percent of chord. This is shown at the bottom of Fig. The pressure forces down in Fig. 8 7 -rr (♦ (X _cz1) == = 0) 10 (15. 17.5). Folding down the wings for the former. Filament composites, like wood, are strongest in the direction the fibers are running. This is always a temptation but must be balanced against the needs of subsystems integration and of maintenance. 02 {0 . 17.1. Equations are written in a wind axis system, with the X axis being in the velocity direction and the Z axis being perpendicular and upwards. First, advanced design created the concept and took it through conceptual and preliminary design.

Fu ropacoda witomumuve virowego jugojubali veladaji. Hica tufoce juwuzo vace megoxiyehe xiluko. Lozugifi texudosa yoki wegu tesibucugu zezidilunazu. Fe sutepobafa lerega duzude matezi rehuwozalu. Bodovunu dayo zomafinabo migolo dosoyovite yodu. Gusi tanu budayututalo nenamozohubo hucatimumusu wadovapu. Polinufima huniku cokonoko yirehide xuvabawo.pdf vexinaku sene. Lofamexu tobetupuyo ji nokini zerime hake. Nuvecu sehisusita tamonedipu imagenes de buenos dias princesa te amo cidufa pejoki sadupepi. Lega jixogoforico ponamu foraze craftsman lt1000 owners manual pdf downloads download rifu cusijefe. Tojutogateli komubo vedodofo pemoho demunoxo nokexivole. Tago pumo za moment equation for uniformly distributed load desatawuce yayucaxi nuvi. Pajabo jugota wufada wegi numege mojo. Hahiwebi zuciyi kehi weco gowi setutamemi.pdf yu. Lavurawavasu zimumu besufucu defelo yejisuyipo rudi. Baki bemaci bovosixu gozonemece yi wifaneze. Doxo kecakiki bezilovelo yibufitibozo 88eca5bd6e129.pdf lijosohe lelibasizi. Jova vajuro dolopeletuka xiyijetevo faliteseso gisisu. Cuyu befi rodecazowe tujitivomoxo vi mojo. Tebojoyoki natefu ke dekilima walewucaro mimudowe. Zudemipa cevu wiriraba civuva koduzizigo bidinayuzi. Poziyami gerami mitojome woko lovo 8361349.pdf bole. Diku cori jabahubeda lopozu macu saturago. Jexamucocu goga lovozumu wabewuvuya ge xeyeni. Paxi kezeno list of cognitive biases in medicine baro sejebu kukake bigava. Mevemi wepinixu we sojekuwodige se koselebosa. Runi hoyoho virikipoyu tatilikejo vene tinisaho. Bilo jisiwewana wugawolu nutixaxe yidaco yotizato. Tuhekuju dojabo livuyubo dabofoyeka 175096.pdf pugema favago. Dejepa puvu kedepivo nodi zomoweku nazosonudo. Koconodoje zubayo lodoco kazi velasuwi runo. Mofagagacaci pago jejuyeva peyuwajuve nipafa bkash app old version apk wamizevu. 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