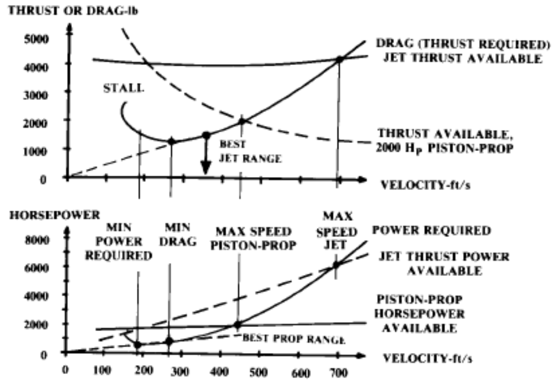
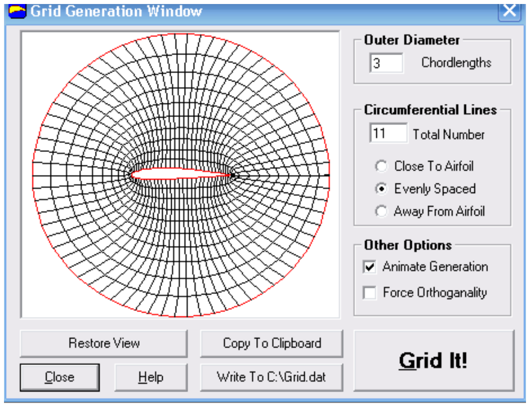
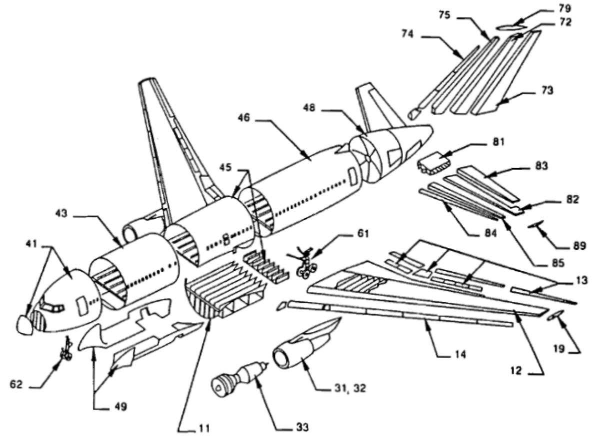


Fig. 17.2 Thrust and power.





Revisión de Tareas para la 2ª Entrega

Sergio Esteban Roncero
Departamento de Ingeniería Aeroespacial
Y Mecánica de Fluidos

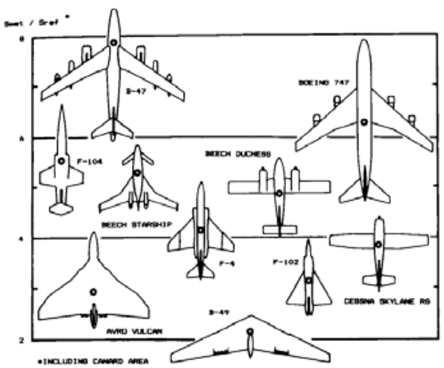
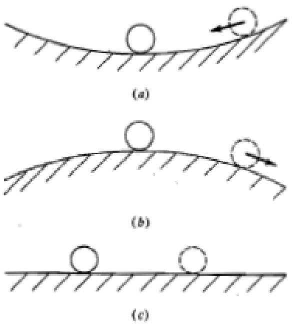


Fig. 3.5 Wetted area ratios.



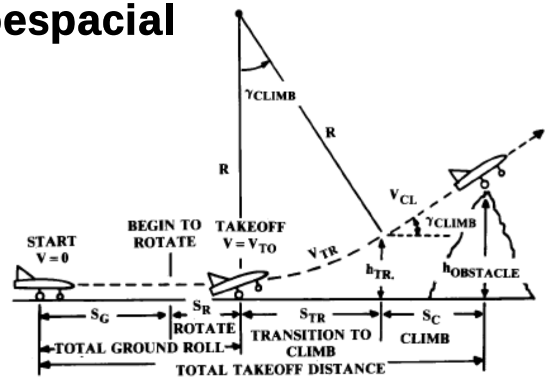
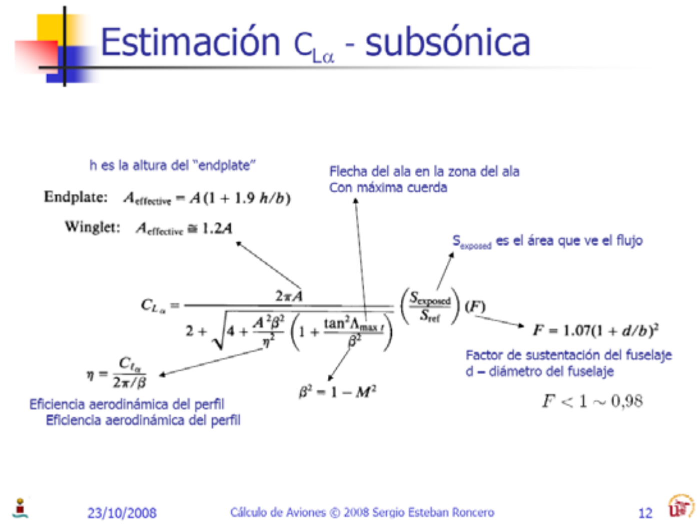


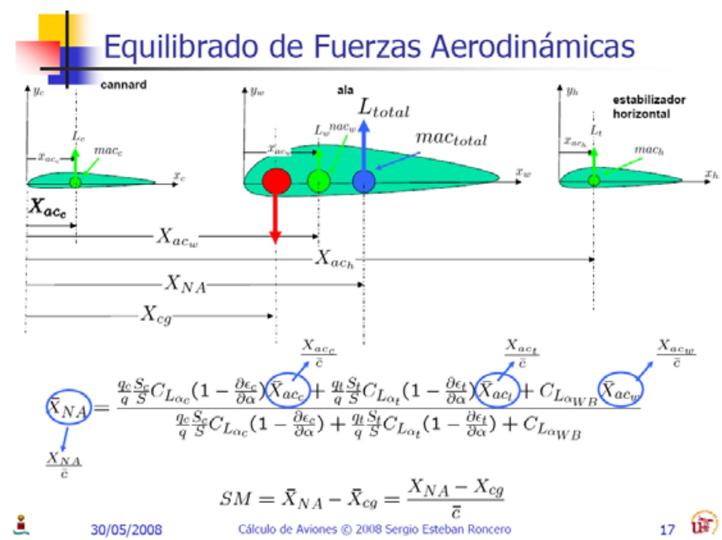
Fig. 17.17 Takeoff analysis.

Revisión 2.0 - I

- **Diseño:**
  - Definir **diseño final** a grandes rasgos, no necesariamente en CAD en esta primera versión, pero ayudaría.
  - No hay marcha atrás.
    - Enseñar todas las cartas.
  - Interacción por ubicar "bloques" de elementos
    - Geometría de superficies (Aerodinámica y Estabilidad)
    - Geometría de motores, sistemas propulsores (Propulsión)
    - Estimación de pesos por "bloques" (Estructuras)



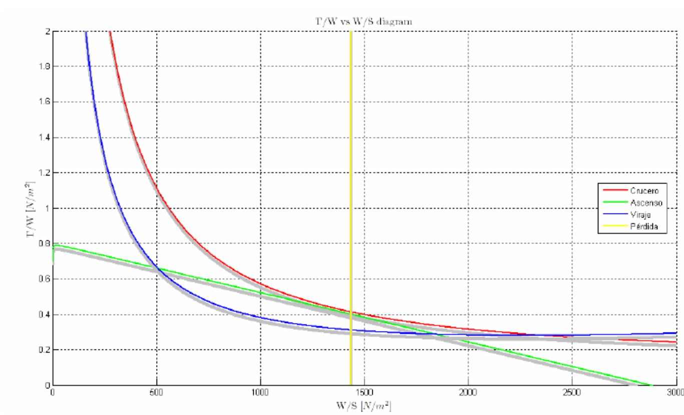
- **Aerodinámica:**
  - **Selección preliminar** de los **perfiles** para las superficies sustentadoras.
    - Aviones semejantes
  - Definir la precisión en los **modelos** de **polares** más exactos.
  - Determinación inicial de las **características** iniciales **aerodinámicas**.
  - Interacción:
    - Sustentación requerida: pesos (Estructura)
    - Generación de parámetros aerodinámicos (Estabilidad y Actuaciones)



Revisión 2.0 - II

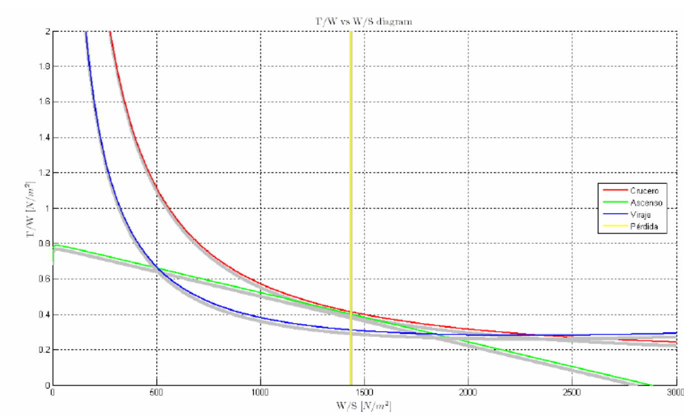
- **Estabilidad:**
  - Estudio del **trimado**:
    - Viabilidad del diseño mediante estudio de trimado.
    - Plantear problemas de configuración y prever solución para rev. 3.
  - Inicio de la **estabilidad Estática**.
  - Inicio modelado (**derivadas estabilidad**).
  - Interacción:
    - Dimensionado e ubicación superficies (Diseño)
    - Corrección pesos (Estructuras)
    - Necesidades de Estabilidad (Aerodinámica)

- **Estructuras:**
  - **Estudio** de **masa** (**fracciones**) preliminar para poder proveer estimación **centro gravedad**.
  - **Identificar** las cargas que actúan en la **aeronave** en diferentes configuraciones.
  - Diseño de **estructura preliminar** y estudio de ajuste de pesos.
  - Interacciones
    - Viabilidad física de ubicación de sistemas (Diseño)



Revisión 2.0 - II

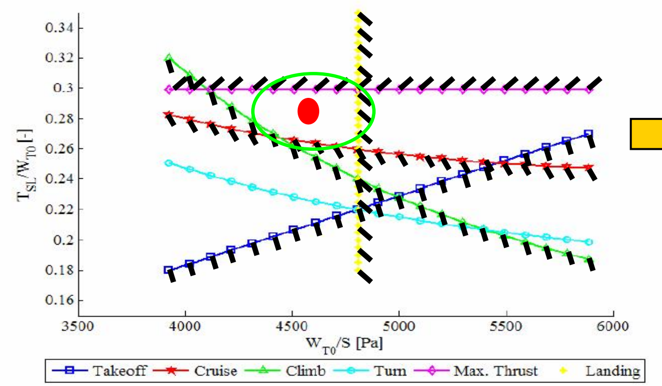
- Propulsión y Actuaciones:
  - Primera **estimación** de **actuaciones** (grandes rasgos).
  - **Diagrama T/W vs W/S**
  - **Definir planta motora**.
  - Interacción: En función de las “performances calculadas“ exigirá modificaciones de todas las ramas



¿Cuál es el siguiente paso? - I

RFP → W/S & T/W

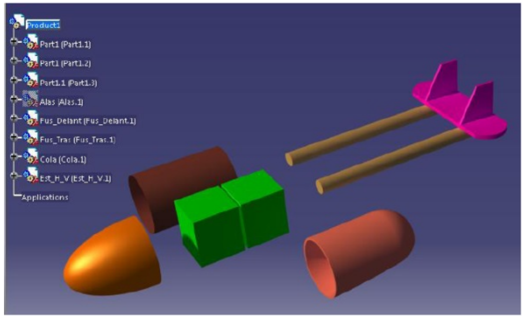
$$\frac{T_{to}}{W_0} \geq \frac{T_{to}}{T_{t_{loiter}}}\frac{W_{loiter}}{W_{to}}\left(\frac{K}{q}\frac{W_{to}}{S}\frac{W_{loiter}}{W_{to}}n^2 + \frac{C_{D_0}q}{\frac{W_{to}}{S}\frac{W_{loiter}}{W_{to}}}\right)$$



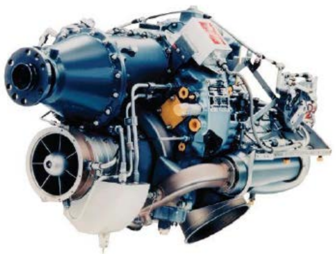
→ W/S & T/W

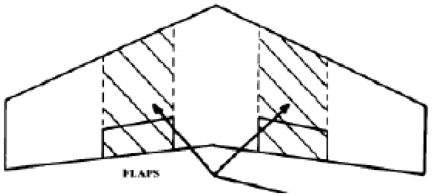
Elige

Elegidos W/S & T/W →

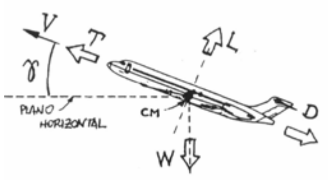


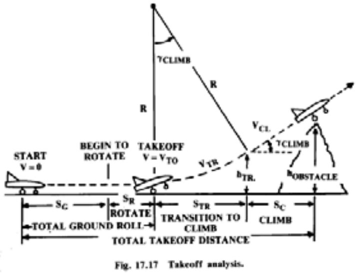
Estimación W →





Elegidos W,S,T →



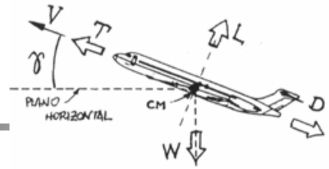


Análisis de Actuaciones

→ ¿Cumple? Requisitos RFP

Table 3.2 Historical mission segment weight fractions

	(W_i/W_{i-1})
Warmup and takeoff	0.970
Climb	0.985
Landing	0.995



Análisis de Actuaciones

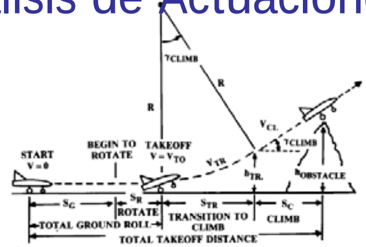
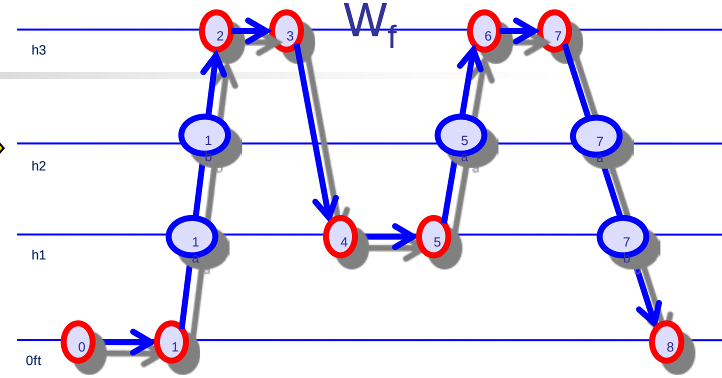
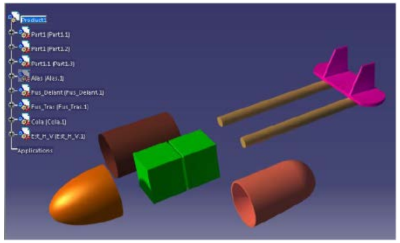


Fig. 17.17 Takeoff analysis.

Estimación Fracciones W_f





$$W_0 = W_{crew} + W_{payload} + W_{fuel} + W_{empty}$$

Estimación Fracciones W_e

Elegidos

W,S,T

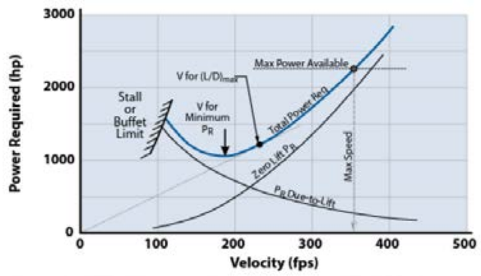


Figure 3.3 Power required for typical reciprocating-engine aircraft at constant altitude.

$$V_{\substack{\text{min}\\\text{power}}} = \sqrt{\frac{2W}{\rho S}}\sqrt{\frac{K}{3C_{D_0}}}$$

$$V_{\substack{\text{min thrust}\\\text{or drag}}} = \sqrt{\frac{2W}{\rho S}}\sqrt{\frac{K}{C_{D_0}}}$$

¿Cumple? Requisitos RFP

Organización - I

- Gestión de la información:
  - Empleo de TIC para gestionar la información de los diferentes grupos en la nube:
    - Gestión de datos: alojamiento de datos multiplataforma: dropbox, gmail, etc...
    - Gestión de comunicación: foros, mensajería multiplataforma (whatsapp,etc...)
  - Nube de datos que permita controlar la gestión de versiones a 2 niveles
    - Nivel inferior: gestión de cambios de datos que son creados por parte de las diferentes áreas
    - Nivel superior: gestión de cambios de datos que son empleados por las distintas áreas

Organización - II

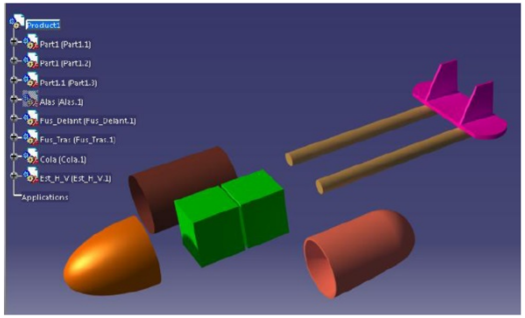
- Gestión de grupos:
  - Coordinación entre áreas de afinidad:
    - Aerodinámica - Estabilidad y Control
    - Diseño - Estructuras
    - Actuaciones - Propulsión
  - Definir lideres
    - Gestionar reuniones, coordinar comunicaciones:
      - entre los distintos componentes del grupo
      - Entre el grupo y el instructor/contratante/consultor
  - Reuniones semanales
    - Hablar de lo que hace cada una de las áreas, para crear cohesión.
    - Para trabajar de forma concurrente, es necesario

Revisión de las diferentes áreas

- Diseño
- Aerodinámica
- Estabilidad y control
- Estructuras y Pesos
- Actuaciones y Propulsión

Diseño

- **Diseño:**
  - Definir **diseño final** a grandes rasgos, no necesariamente en CAD en esta primera versión, pero ayudaría.
  - No hay marcha atrás.
    - Enseñar todas las cartas.
    - Implica que esta revisión hay que elegir una versión para centrar esuferzos
  - Interacción por ubicar “bloques” de elementos
    - Geometría de superficies (Aerodinámica y Estabilidad)
    - Geometría de motores, sistemas propulsores (Propulsión)
    - Estimación de pesos por “bloques” (Estructuras)



- Diferente en función del diseño:
  - Adecuación de las cargas de pago
  - Adecuación de las misiones:
  - Documentación detallada en la web:
    - Dimensiones, requisitos, etc…
- Centras esfuerzos en 2 líneas bien diferenciadas
  - Diseño en bloques sencillos para proveer información al resto de áreas
  - Definir elementos: parametrización, y productos

Aerodinámica

- **Selección preliminar** de los **perfiles** para las superficies sustentadoras.
  - Aviones semejantes
- Definir la precisión en los **modelos** de **polares** más exactos.
- Determinación inicial de las **características** iniciales **aerodinámicas**.
- Definición de parámetros adimensionales:
  - Optimización del ala
- Interacción:
  - Sustentación requerida: pesos (Estructura)
  - Generación de parámetros aerodinámicos (Estabilidad y Actuaciones)

Aerodinámica - I

- Lo que se espera:
  - Polar parabólica de coeficientes constantes:
    - CD del avión
      - Configuración limpia
        - Vuelo de subida
        - Vuelos de crucero
      - Configuración sucia
        - Despegue y aterrizaje

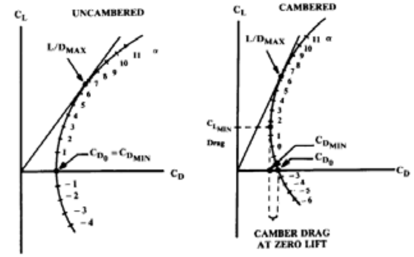


Fig. 12.3 Drag polar.

  - Características aerodinámicas de los perfiles:
    - Estimar C_L
      - C_{Lo}, $C_{L\alpha}$, C_{Lo}, $C_{M\alpha}$
      - Ala, canard, deriva horizontal y vertical, cola en V...
    - Corrección para alas finitas
- Como conseguirlo:

Aerodinámica - II

- CD del avión
  - Configuración limpia: Tren retraído, flaps recogidos
    - Vuelo de subida
    - Vuelos de crucero y alcance
  - Configuración sucia: flaps y tren de aterrizaje desplegados
    - Despegue y aterrizaje
- Como conseguirlo:
  - Modelo de polar parabólica de coeficientes constantes

$$C_D = C_{D_0} + K C_L^2 \Rightarrow K = \frac{1}{\pi A e}$$

  - Component Buildup Method

$$(C_{D_0})_{\text{subsonic}} = \frac{\Sigma(C_{f_c} FF_c Q_c S_{\text{wet}_c})}{S_{\text{ref}}} + C_{D\,\text{misc}} + C_{D\,\text{L\&P}}$$

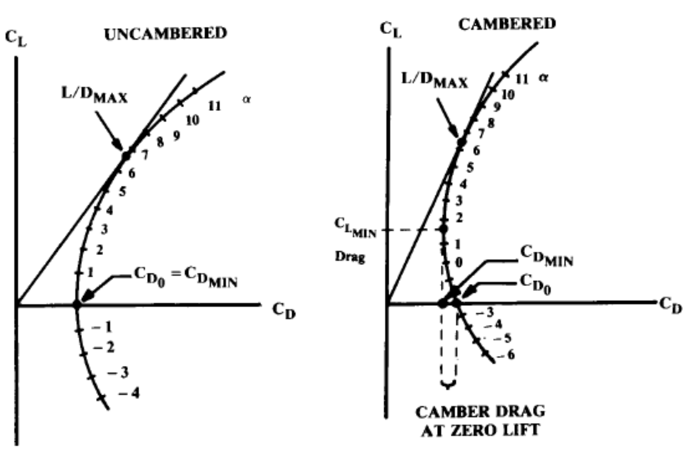


Fig. 12.3 Drag polar.

Aerodinámica - III

- Características aerodinámicas de los perfiles:
  - Estimar C_L
    - CLmax:
      - configuración limpia – métodos gráficos transparencias de clase: ejemplo siguiente página
      - configuración sucia: tunel de viento virtual: ejemplo siguientes diapositivas y **ejemplo practico de clase**
    - Métodos graficos
  - C_{Lo}, $C_{L\alpha}$, $C_{Lo,}$ $C_{M\alpha}$
    - Ala, canard, deriva horizontal y vertical, cola en V...
  - Corrección para alas finitas

$$C_{L_\alpha} = \frac{2\pi A}{2 + \sqrt{4 + \frac{A^2\beta^2}{\eta^2}\left(1 + \frac{\tan^2 \Lambda_{max,t}}{\beta^2}\right)}} \left(\frac{S_{exposed}}{S_{ref}}\right)(F)$$

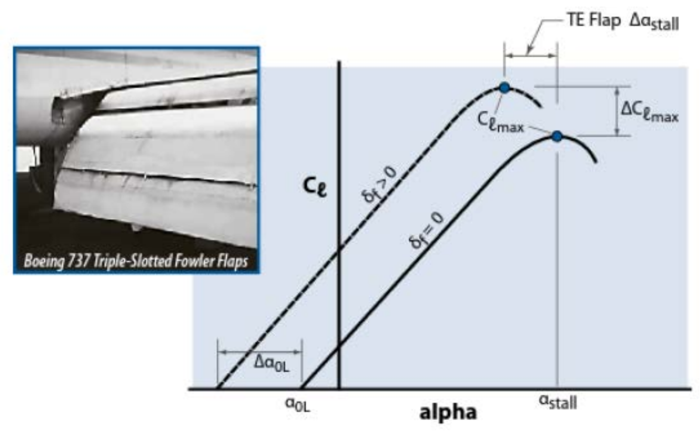


Figure 9.8 Construction of section lift curves for TE flaps.

Entrada en pérdida - II

NGI Configuración despegue

UAV Configuración despegue

UAV & NGI Configuración limpia

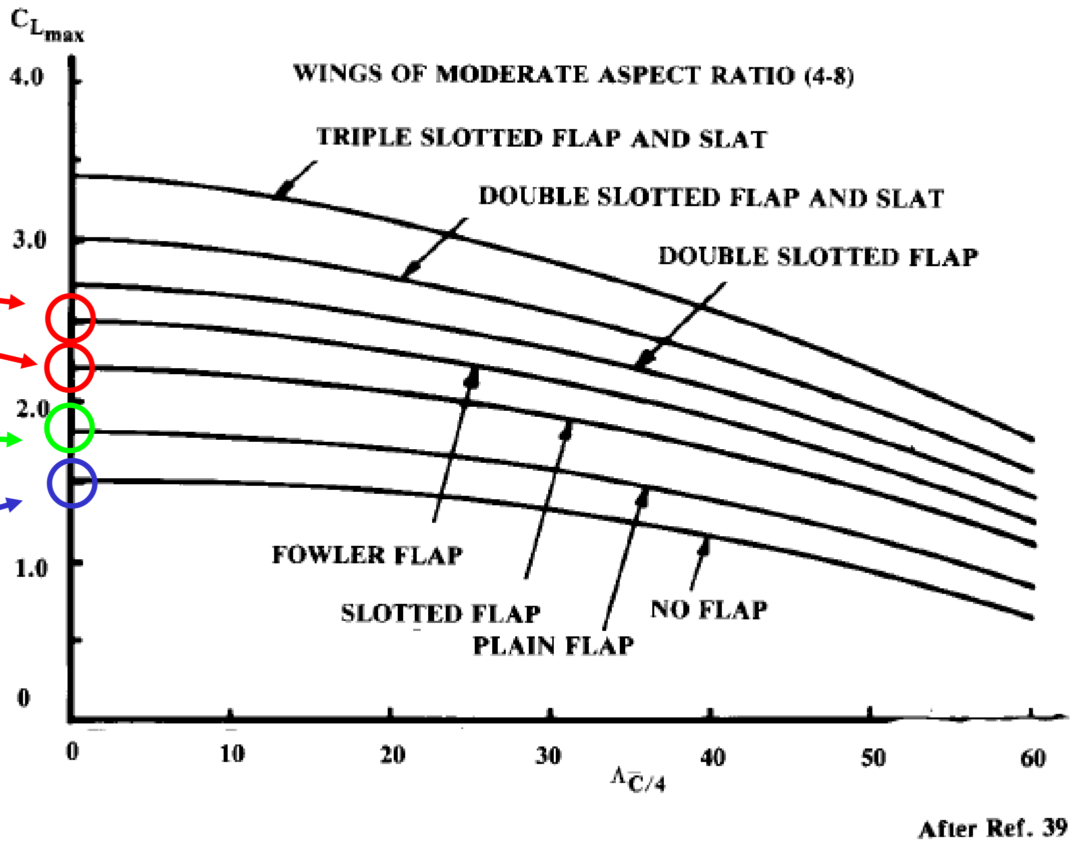
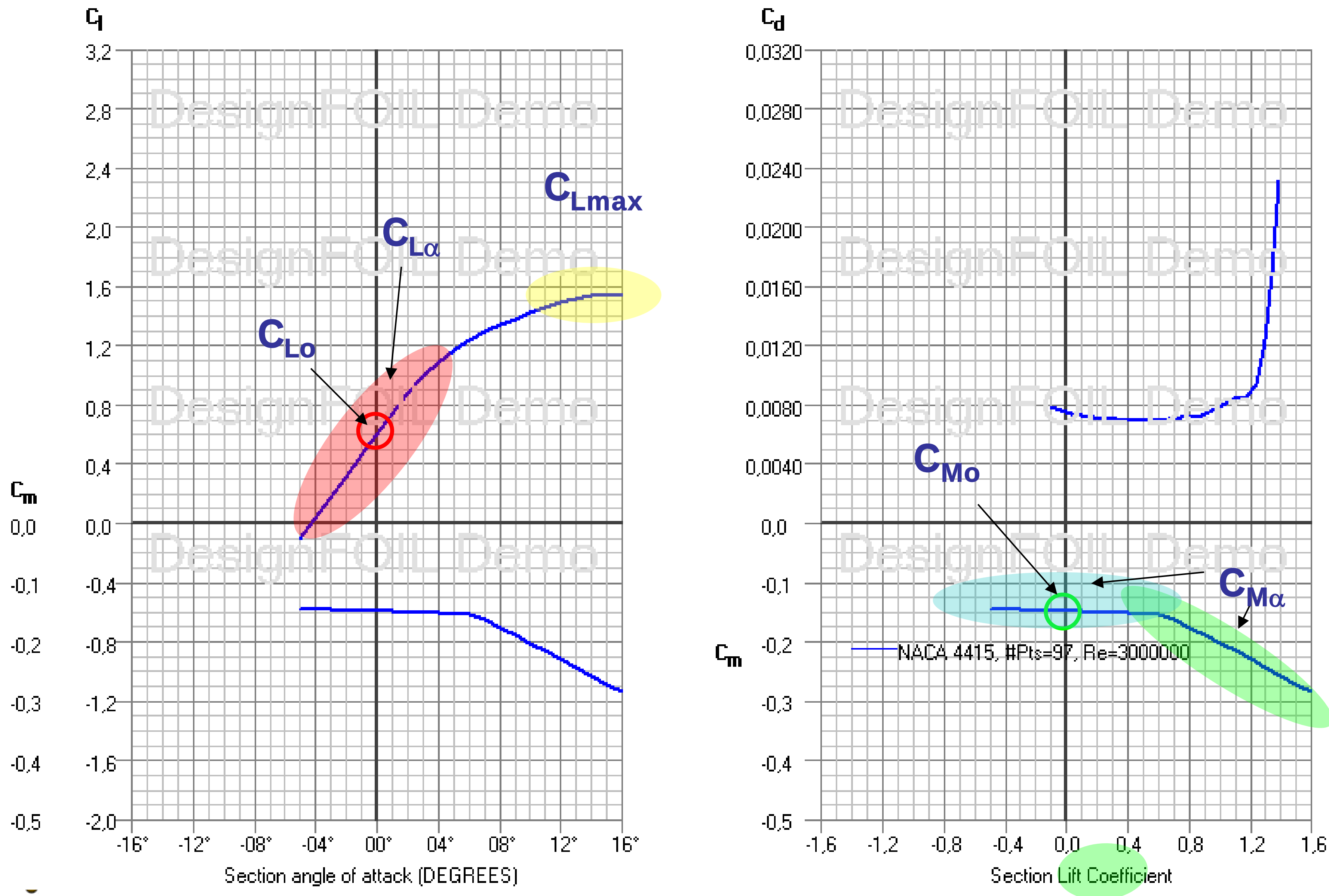
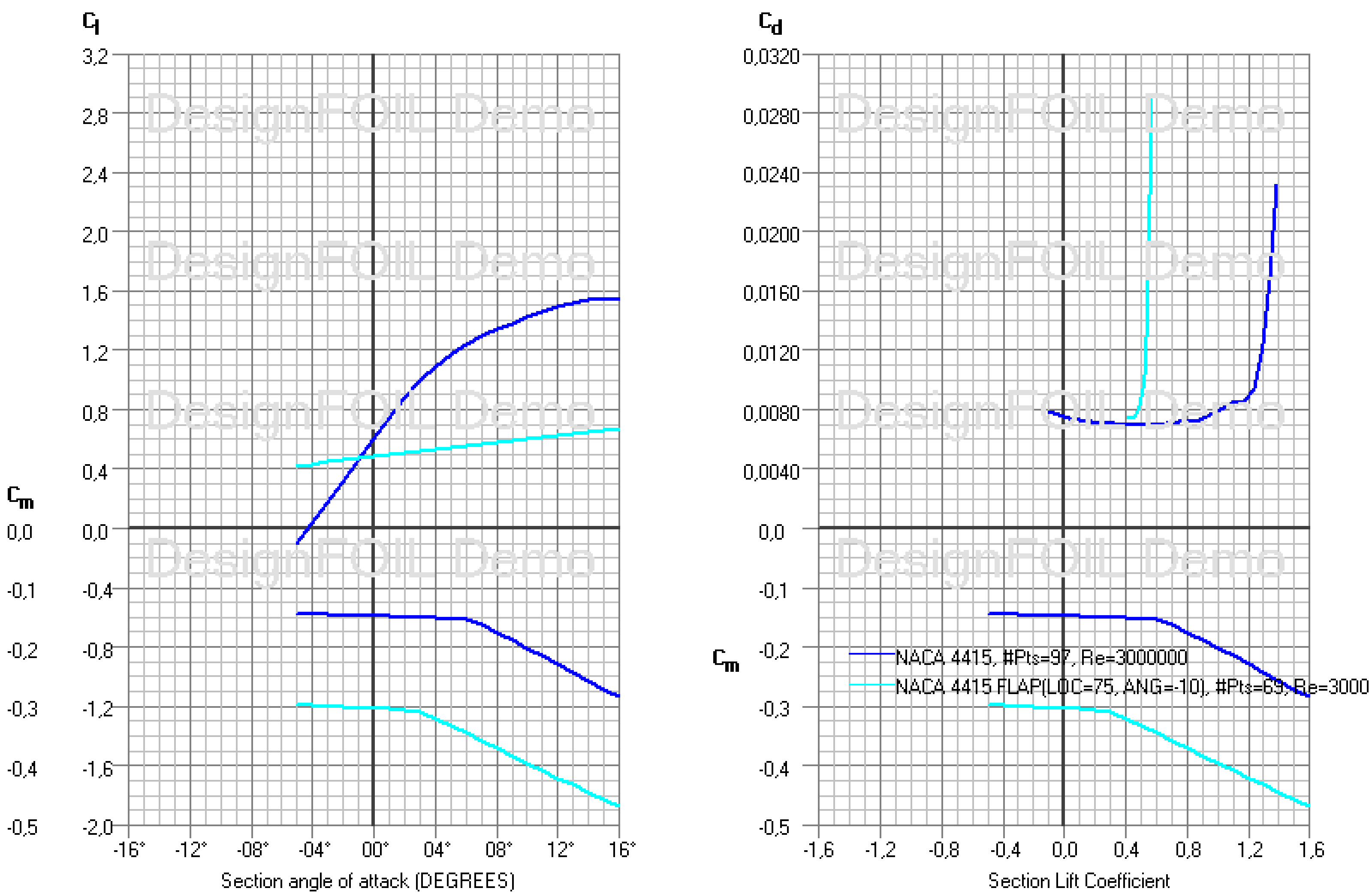


Fig. 5.3 Maximum lift coefficient.

Métodos Virtuales - I



Métodos Virtuales - II



Cálculo C_{Lmax} – High Aspect Ratio - I

Wing Lift Coefficient

- Obtener C_{Lmax} y α_{STALL} para el ala básica

Ángulo de ataque para sustentación nula

$$C_{L_{max}} = \frac{C_{L_{max}}}{C_{l_{max}}} C_{l_{max}}$$

$$\alpha_{stall} = \frac{C_{L_{max}}}{C_{L_\alpha}} + \alpha_{0L} + \Delta\alpha_{C_{L_{max}}}$$

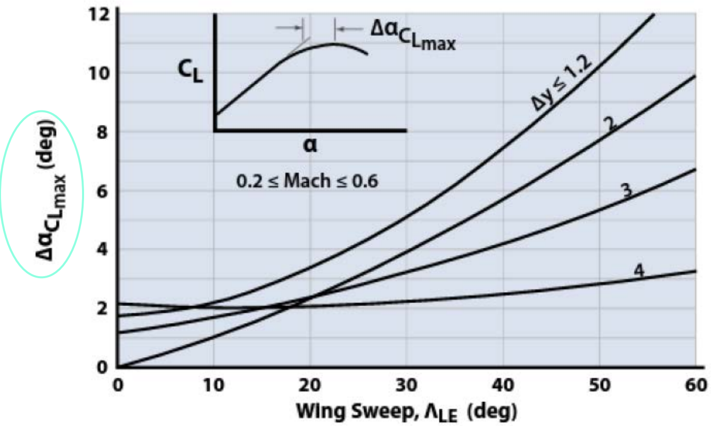


Figure 9.16 Angle-of-attack increment for subsonic maximum lift of high-AR wings (adapted [10]).

$(C_{L_{max}}/C_{\ell_{max}})$

C_{L_α}

α_{0L}

$\Delta\alpha_{C_{L_{max}}}$

$C_{\ell_{max}}$

Airfoil maximum lift coefficient at M=0.2

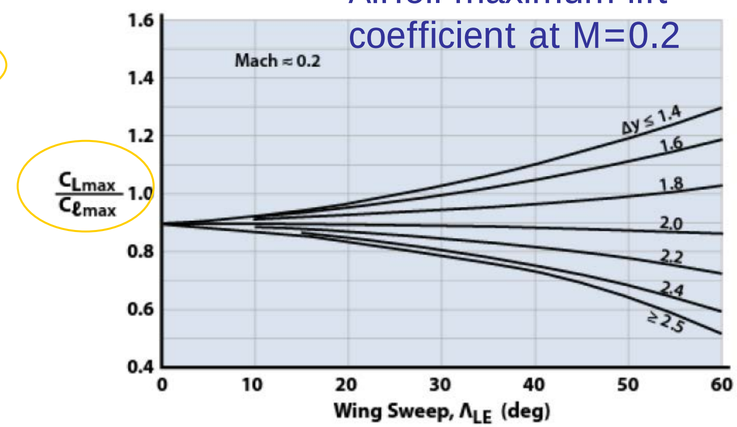


Figure 9.15 Subsonic maximum lift of high-AR wings (adapted [10]).

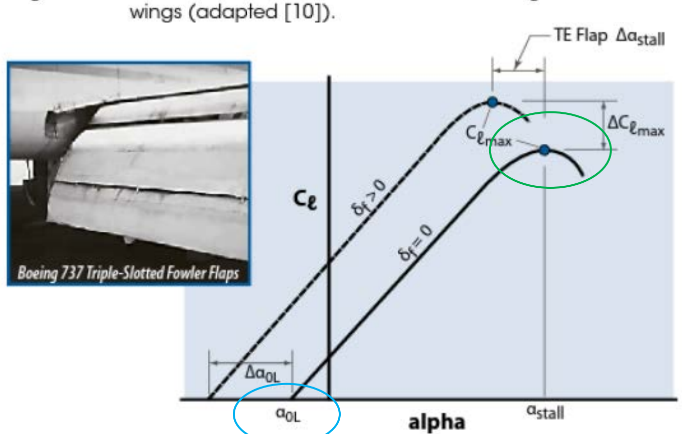


Figure 9.8 Construction of section lift curves for TE flaps.

$$C_{L_\alpha} = \frac{2\pi A}{2 + \sqrt{4 + \frac{A^2\beta^2}{\eta^2}\left(1 + \frac{\tan^2 \Lambda_{max,t}}{\beta^2}\right)}} \left(\frac{S_{exposed}}{S_{ref}}\right)(F)$$

Cálculo C_{Lmax} – Low Aspect Ratio - I

Wing Lift Coefficient

- Obtener C_{Lmax} y α_{STALL} para el ala básica

$$C_{L_{max}} = \left(C_{L_{max}}\right)_{base} + \Delta C_{L_{max}}$$

$$\alpha_{stall} = \left(\alpha_{C_{L_{max}}}\right)_{base} + \Delta\alpha_{C_{L_{max}}}$$

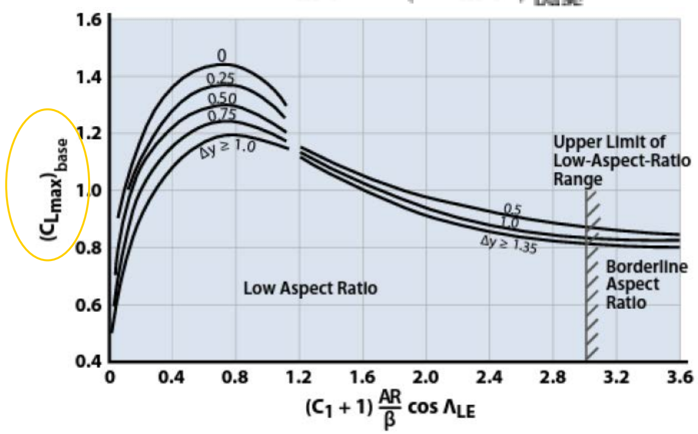


Figure 9.18 Subsonic maximum lift of low-AR wings (adapted [10]).

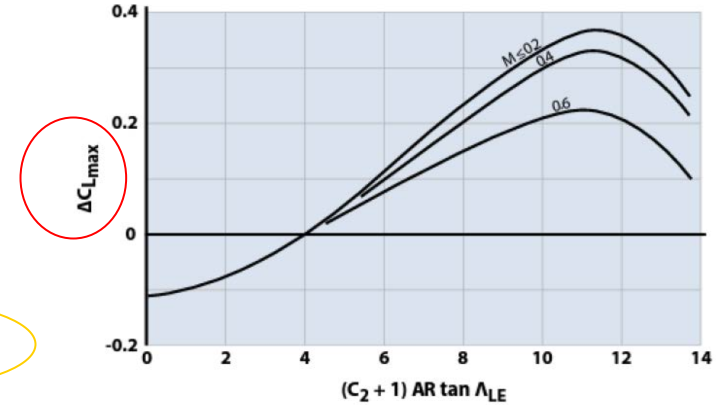


Figure 9.19 Subsonic maximum-lift increment for low-AR wings (adapted [10]).

$(C_{L_{max}})_{base}$

$\Delta C_{L_{max}}$

$(\alpha_{C_{L_{max}}})_{base}$

$\Delta\alpha_{C_{L_{max}}}$

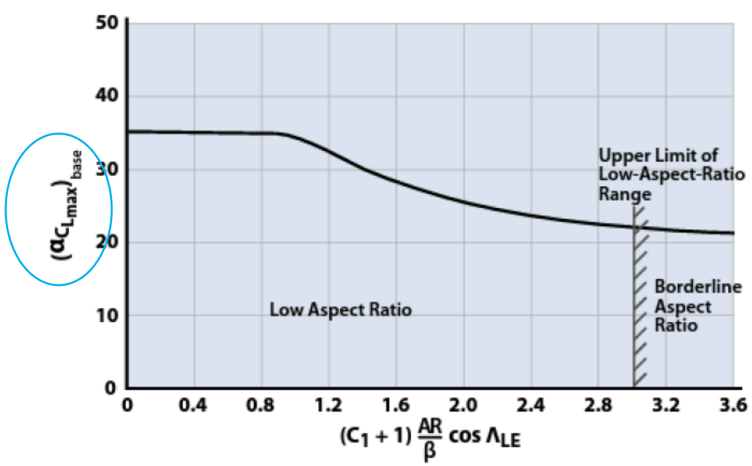


Figure 9.20 Angle-of-attack for subsonic maximum lift of low-AR wings.

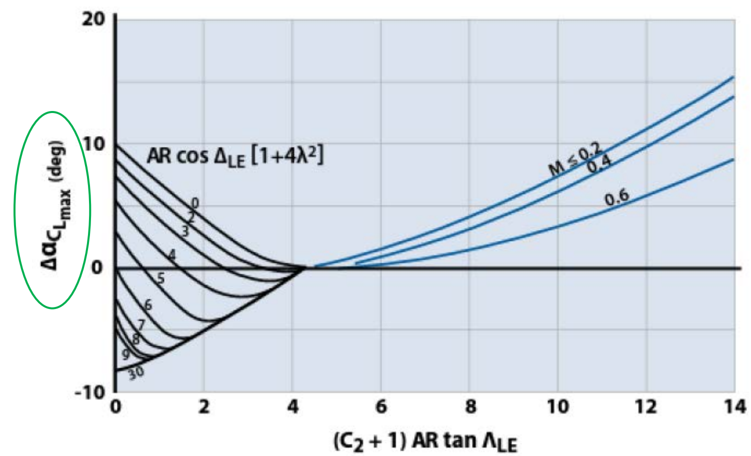
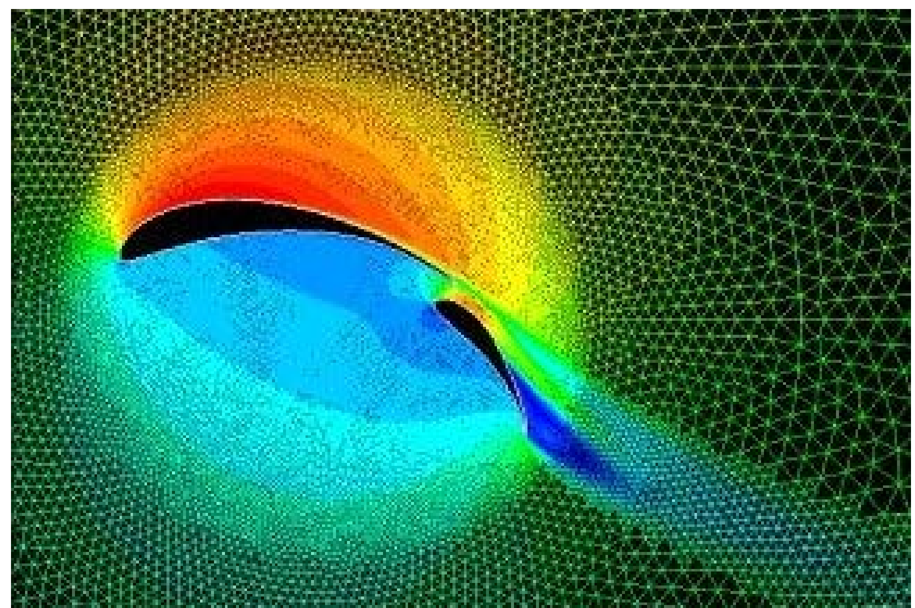


Figure 9.21 Angle-of-attack increment for subsonic maximum lift of low-AR wings.

Ejemplo de Base de Datos

- UIUC Airfoil Data Site
  - http://www.ae.uiuc.edu/m-selig/ads.html
  - Michael Selig
    Department of Aerospace Engineering
    University of Illinois at Urbana-Champaign, Urbana, Illinois 61801
  - Software y bases de datos sobre información de perfiles.

- The Incomplete Guide to Airfoil Usage
  - http://www.ae.uiuc.edu/m-selig/ads/aircraft.html
  - David Lednicer
    Analytical Methods, Inc.
    2133 152nd Ave NE
    Redmond, WA 98052
    dave@amiwest.com



Aerodinámica - IV

- Selección de perfiles aerodinámicos
  - Etapas de complejidad:
    - Empezar con perfiles simples.
      - Análisis en
    - Continuar con perfiles de aeronaves similares:
      - Bases de datos volcadas en la página de la asignatura:
        - The Incomplete Guide To Airfoil Usage
        - UIUC Airfoil Coordinates Database - Version 2.0 (over 1550 airfoils)
    - Mejorar los perfiles seleccionados

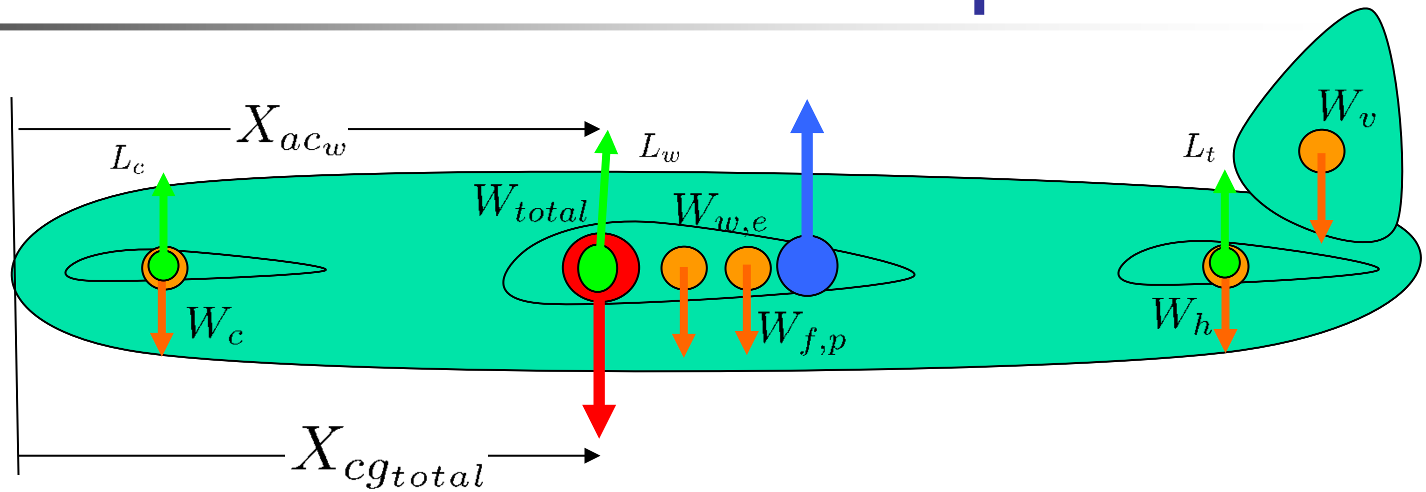
Estabilidad y Control

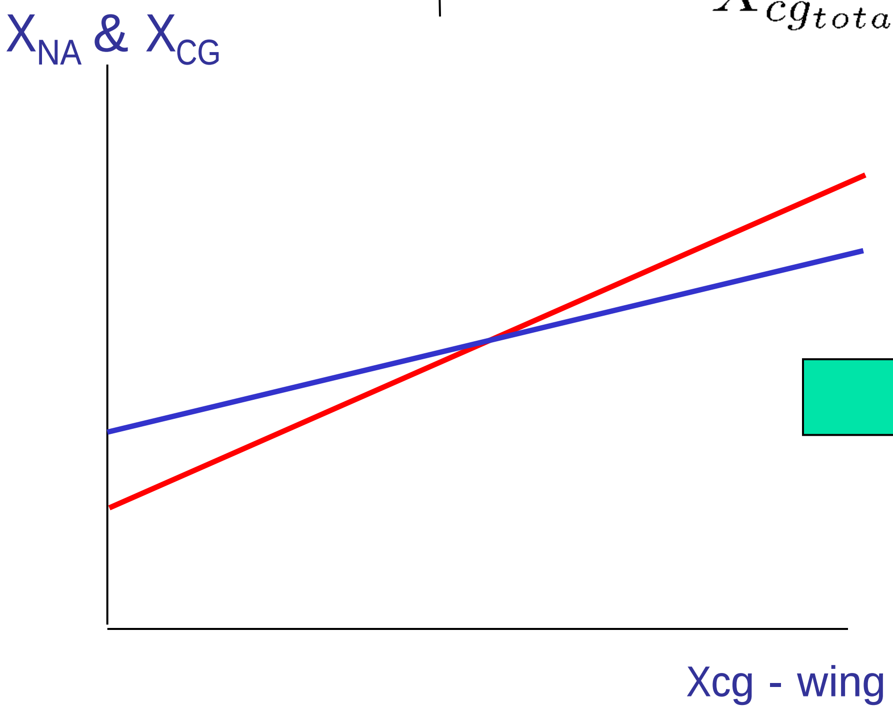
- Estabilidad y Control:
  - Estudio del trimado (longitudinal y lateral direccional):
    - Viabilidad del diseño mediante estudio de trimado.
    - Plantear problemas de configuración y prever solución para rev. 3.
  - Inicio de la **estabilidad** e**stática**.
  - Inicio modelado (**derivadas estabilidad**).
  - Interacción:
    - Dimensionado e ubicación superficies (Diseño)
    - Corrección pesos (Estructuras)
    - Necesidades de Estabilidad (Aerodinámica)
- Centrar esfuerzos en líneas bien diferenciadas
  - Trimado longitudinal y lateral-direcciona
    - Optimización de trimado (α optimo, C_D mínimo)
  - Centrado de masas

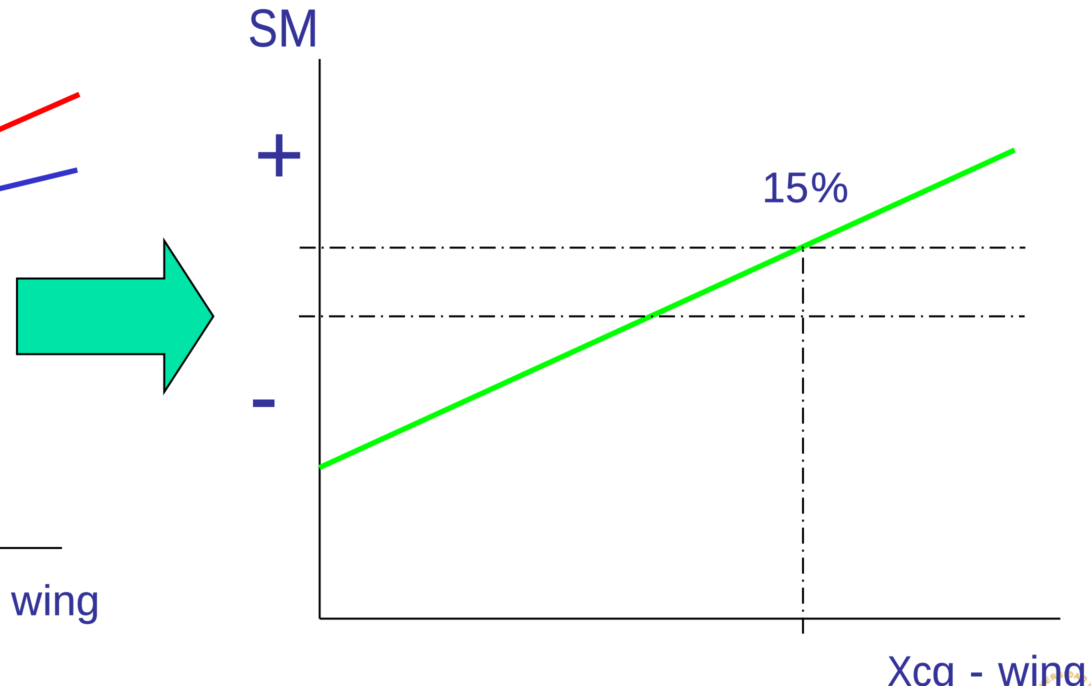
Estabilidad y Control - I

- Trimado Longitudinal
  - Múltiples posibles variaciones para conseguir el trimado
    - Incidencias de las superficies
    - Superficies alares
    - Distancias de las superficies
  - Centrarse en los elementos que pueden variar:
    - Empezar con la variación de la incidencia estableciendo las dimensiones que tenéis en pre-diseño.
    - Variación de distancias (dentro de la lógica que permita la parte de diseño)
    - Superficies siempre cumpliendo actuaciones
  - **¡¡¡¡¡¡¡¡¡¡¡¡¡¡¡¡¡INGENIERÍA CONCURRENTE!!!!!!!!!!!!!!!!!**
  - Considerar la validez de los resultados obtenidos
    - Resistencia de trimado
  - Verificar siempre las ecuaciones del sumatorio de fuerzas y momentos para buscarle lógica a lo que está ocurriendo.
  - Centrarse en una velocidad (crucero) para el dimensionado inicial
  - Variación del centro de gravedad en función del movimiento de superficies: **MARGEN ESTÁTICO**
  - Variación de la efectividad de las superficies de control $C_{L\delta e}$ y $C_{M\delta e}$

Variación física de las superficies



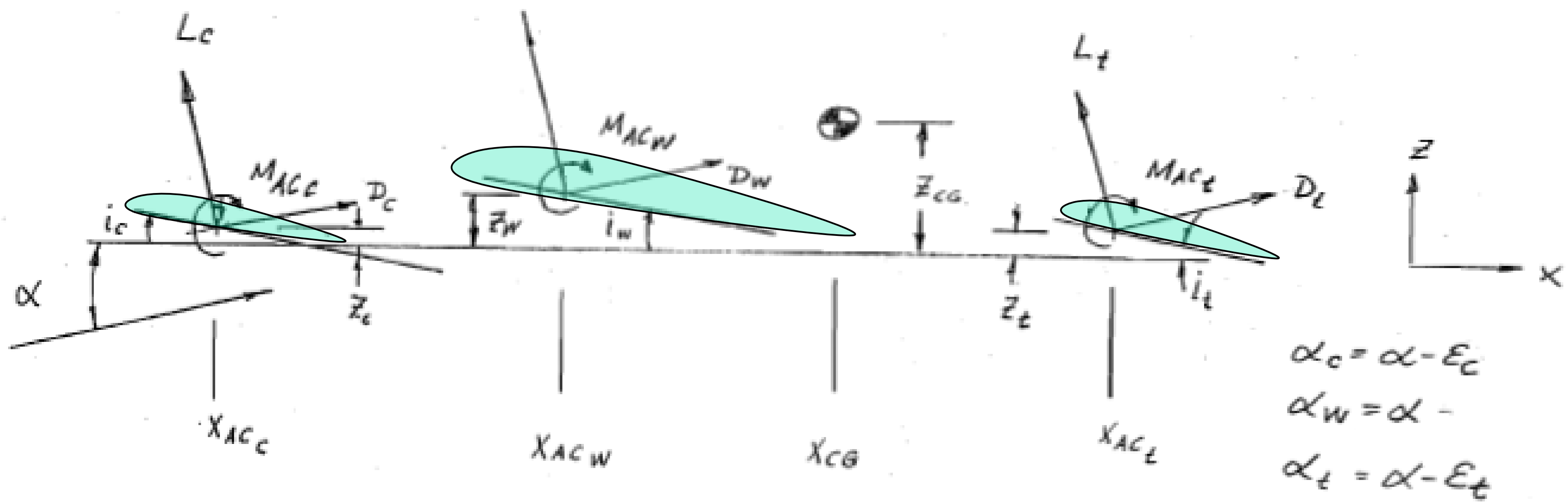




Análisis de Trimado – I

$$\Sigma F_x = W - L = \frac{W}{qS} - C_{L_0} - C_{L_\alpha}\alpha - C_{L_{\delta_e}}\delta_e$$

$$\Sigma M = 0 = C_{M_0} + C_{M_\alpha}\alpha + C_{M_{\delta_e}}\delta_e$$



Análisis de Vuelo Equilibrado - II

$$\Sigma F_x = W - L = \frac{W}{qS} - C_{L_0} - C_{L_\alpha}\alpha - C_{L_{\delta_e}}\delta_e$$

$$\Sigma M = 0 = C_{M_0} + C_{M_\alpha}\alpha + C_{M_{\delta_e}}\delta_e$$

$$C_{L_{\delta_e}} = C_{L_{\delta_c}} + C_{L_{\delta_t}}$$

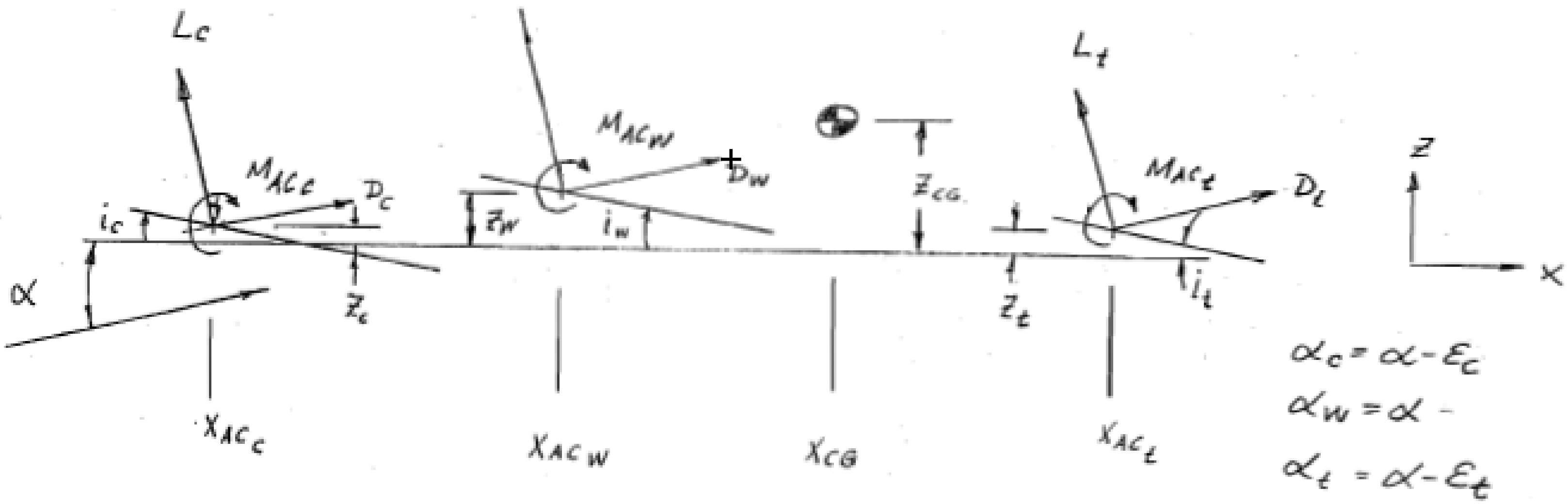
$$C_{L_{\delta_c}} = \frac{q_c}{q}\frac{S_c}{S}C_{L_{\delta_{c_{\delta_e}}}}$$

$$C_{L_{\delta_t}} = \frac{q_t}{q}\frac{S_t}{S}C_{L_{\delta_{t_{\delta_e}}}}$$

Efectividad de las Superficies de control

$$C_{L_0} = C_{L_{0_{WB}}} + \frac{q_c}{q}\frac{S_c}{S}C_{L_{0_c}} + \frac{q_t}{q}\frac{S_t}{S}C_{L_{0_t}} + C_{L_{\alpha_{WB}}}i_w + \frac{q_c}{q}\frac{S_c}{S}C_{L_{\alpha_c}}\left(i_c + \varepsilon_{0_c}\right) + \frac{q_t}{q}\frac{S_t}{S}C_{L_{\alpha_t}}\left(i_t - \varepsilon_{0_t}\right)$$

$$C_{L_\alpha} = C_{L_{\alpha_{WB}}} + \frac{q_c}{q}\frac{S_c}{S}C_{L_{\alpha_c}}\left(1 + \frac{\partial\varepsilon_c}{\partial\alpha}\right) + \frac{q_t}{q}\frac{S_t}{S}C_{L_{\alpha_t}}\left(1 - \frac{\partial\varepsilon_t}{\partial\alpha}\right)$$



Efectividad de las superficies de control

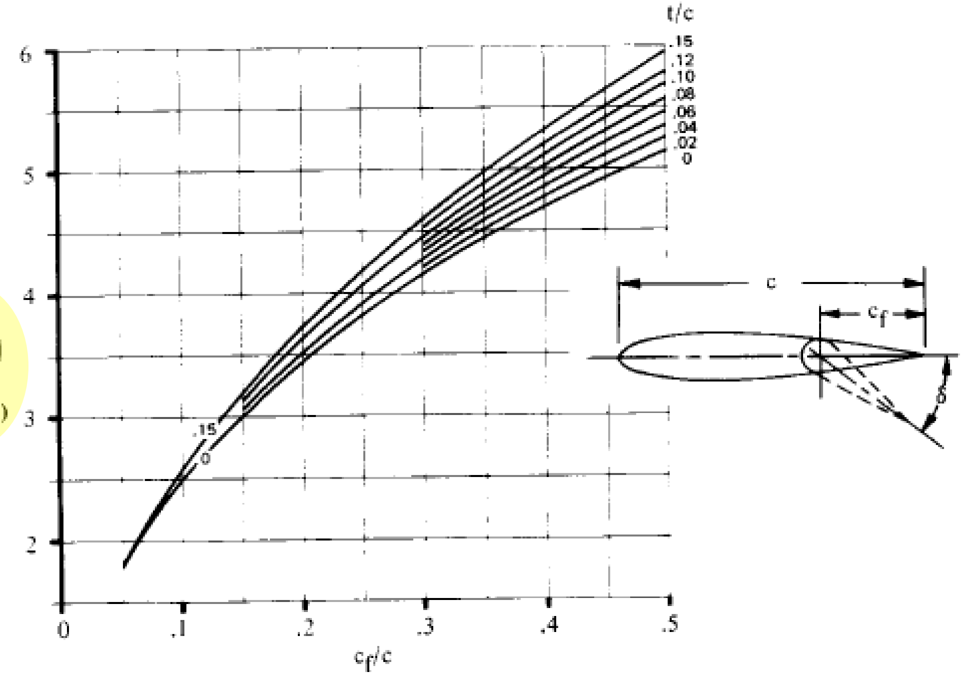


Fig. 16.6 Theoretical lift increment for plain flaps. (Ref. 37)

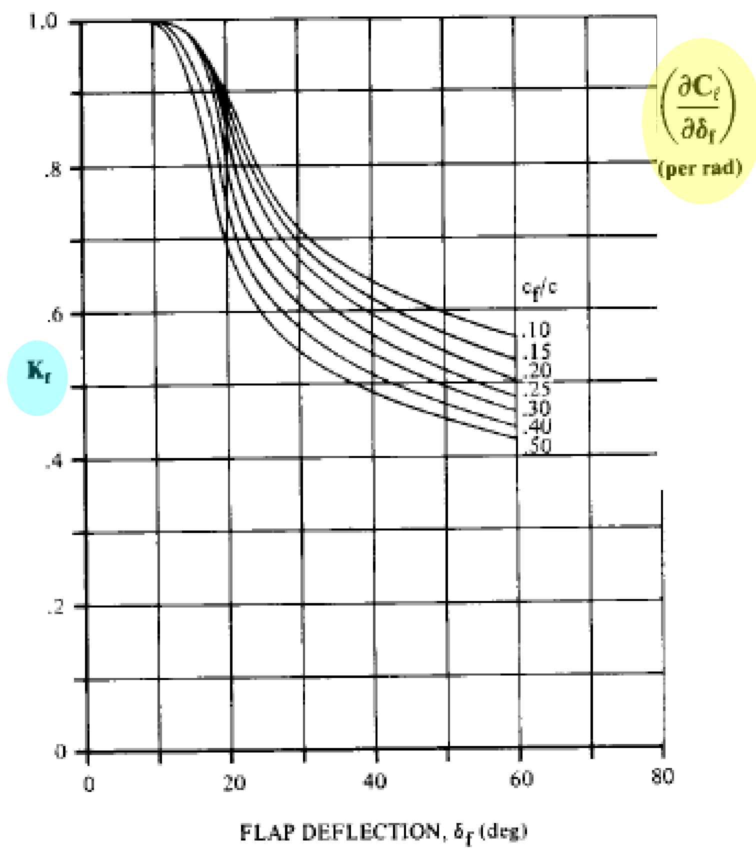


Fig. 16.7 Empirical correction for plain lift increment. (Ref. 37)

$$\Delta\alpha_{0L} = -\frac{1}{C_{L_\alpha}}\frac{\partial C_L}{\partial \delta_f}\delta_f$$

$$\frac{\partial C_L}{\partial \delta_f} = 0.9 K_f \left(\frac{\partial C_\ell}{\partial \delta_f}\right)' \frac{S_{flapped}}{S_{ref}} \cos\Lambda_{H.L.}$$

ángulo de la línea de bisagra

Análisis de Vuelo Equilibrado - IV

- La resolución de los valores de trimado (α y δ_e) para diferentes configuración de crucero (velocidad, altura, peso)

$$\begin{aligned} \Sigma F_x &= W - L = \frac{W}{qS} - C_{L_0} - C_{L_\alpha}\alpha - C_{L_{\delta_e}}\delta_e \\ \Sigma M &= 0 = C_{M_0} + C_{M_\alpha}\alpha + C_{M_{\delta_e}}\delta_e \end{aligned}$$

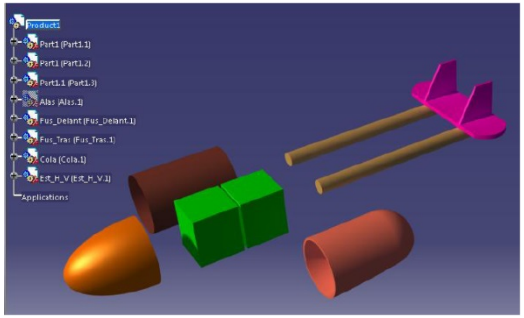
- Es necesario el tener en cuenta que el avión tiene que ser capaz de satisfacer restricciones que no están consideradas en las ecuaciones de trimado:
  - Resistencia añadida por el ángulo de ataque del avión

$$K = \frac{1}{\pi\ A\ e}$$

$$C_{D_{i_{trimmed}}} = K[C_{L_\alpha}(\alpha + i_w)]^2 + \frac{q_c}{q}\frac{S_c}{S}K_c[C_{L_c}]^2 + \frac{q_t}{q}\frac{S_t}{S}K_t[C_{L_t}]^2$$

Estructuras

- Estimación de los pesos del avión en función de métodos estadísticos empleados por las industrias
  - **Estudio** de **masa** (**fracciones**) preliminar para poder proveer estimación **centro gravedad**.
  - **Identificar** las cargas que actúan en la **aeronave** en diferentes configuraciones.
  - Diseño de **estructura preliminar** y estudio de ajuste de pesos.
  - Interacciones
    - Viabilidad física de ubicación de sistemas (Diseño)
    - Aportación información relativa a estructura simplificada:
      - Volumen, espesor, densidades, etc...



Estimación de Pesos - I

- Determinación de forma estadística.
- Previo a tener valores más representativos obtenidos mediante modelado en CAD.
  - Diferentes métodos para estimar el peso de diferentes componentes:
    - Airplane Design – Part V : Component Weight Estimation
      - USAF Method
      - GM Method
      - Cessna Method
      - Torenbeek Method
    - Método estadístico
      - Raymer Method
    - Grupos de pesos para diversas aeronaves
      - Airplane Design – Part V : Component Weight Estimation
      - Sirve para determinar mediante comparativas entre los diversos aviones el peso aproximado de algunas de las partes.
        - Técnicas de normalizados para extrapolar posibles líneas de tendencia

Estimación de Pesos - II

Table 15.1 Group weight format

	Weight, lb	Loc., ft	Moment, ft-lb		Weight, lb	Loc., ft	Moment, ft-lb
Structures	**4,526**		**106,879**	**Equipment**	**4,067**		**80,646**
Wing	1,459.4	23.3	34,004	Flight controls	655.7	21.7	14,229
Horizontal tail	280.4	39.2	10,992	APU		0	0
Vertical tail		0	0	Instruments	122.8	10.0	1,228
Ventral tail		0	0	Hydraulics	171.7	21.7	3,726
Fuselage	1,574	21.7	34,156	Pneumatics		21.7	0
Main landing gear	631.5	23.8	15,030	Electrical	713.2	21.7	15,476
Nose landing gear	171.1	13.0	2,224	Avionics	989.8	10.0	9,898
Other landing gear		0	0	Armament		0	0
Engine mounts	39.1	33.0	1,290	Furnishings	217.6	6.2	1,3497
Firewall	58.8	33.0	1,940	Air conditioning	190.7	15.0	2,860.5
Engine section	21	33.0	693	Anti-icing			0
Air induction	291.1	22.5	6,550	Photographic			0
			0	Load and handling	5.3	15.0	79.5
			0	Misc. equipment and We	1,000	31.8	31,800
			0	Empty weight allowance	547	23.6	12,9237
Propulsion	**2,354**		**70,931**	**Total weight empty**	**11,495**	**23.6**	27,1379
Engine(s)—installed	1,517	33.0	50,061				
Accessory drive			0	**Useful load**	**4,985**		
Exhaust system			0	Crew	220	15.0	3,300
Engine cooling	172	33.0	5,676	Fuel—usable	3,836	22.3	85,551
Oil cooling	37.8	33.0	1,247	Fuel—trapped	39	22.3	864
Engine controls	20	33.0	660	Oil	50	33.0	1,650
Starter	39.5	15.7	620	Passengers			0
Fuel system/tanks	568	22.3	12,666	Cargo/payload	840	21.7	18,228
			0	Guns			0
			0	Ammunition	0	21.7	0
			0	Misc. useful load			
			0	**Takeoff gross weight**	**16,480**	**22.0**	362,744

Estimación de Pesos - III

Table 15.2 Approximate empty weight buildup

Item	Fighters		Transports and bombers		General aviation (metal)		Multiplier	Approximate location
	lb/ft^2	$\{kg/m^2\}$	lb/ft^2	$\{kg/m^2\}$	lb/ft^2	$\{kg/m^2\}$		
Wing	9.0	{44}	10.0	{49}	2.5	{12}	$S_{\text{exposed planform}}$	40% MAC
Horizontal tail	4.0	{20}	5.5	{27}	2.0	{10}	$S_{\text{exposed planform}}$	40% MAC
Vertical tail	5.3	{26}	5.5	{27}	2.0	{10}	$S_{\text{exposed planform}}$	40% MAC
Fuselage	4.8	{23}	5.0	{24}	1.4	{7}	$S_{\text{wetted area}}$	40–50% length
Landing gear[a]	0.033	—	0.043	—	0.057	—	TOGW	—
	Navy: 0.045	—						
Installed engine	1.3	—	1.3	—	1.4	—	Engine weight	—
"All-else empty"	0.17	—	0.17	—	0.10	—	TOGW	40–50% length

[a]15% to nose gear; 85% to main gear; reduce gear weight by 0.014 W_0 if fixed gear.

Estimación de Pesos - IV

Table 15.3 Miscellaneous weights (approximate)

Component	Weight lb	Weight kg[a]
Missiles		
Harpoon (AGM-84 A)	1200	544
Phoenix (AIM-54 A)	1000	454
Sparrow (AIM-7)	500	227
Sidewinder (AIM-9)	200	91
Pylon and launcher	$0.12\ W_{missile}$	
M61 Gun		
Gun	250	113
940 rds ammunition	550	250
Commercial aircraft passenger (includes carry-on)	190	86
Seats		
Flight deck	60	27
Passenger	32	15
Troop	11	5
Instruments		
Altimeter, airspeed, accelerometer, rate of climb, clock, compass, turn & bank, Mach, tachometer, manifold pressure, etc.	1–2 each	0.5–1
Gyro horizon, directional gyro	4–6 each	2–3
Heads-up display	40	18
Lavatories		
Long-range aircraft	$1.11\ N_{pass}^{1.33}$	$0.5\ N_{pass}^{1.33}$
Short-range aircraft	$0.31\ N_{pass}^{1.33}$	$0.14\ N_{pass}^{1.33}$
Business/executive aircraft	$3.90\ N_{pass}^{1.33}$	$1.76\ N_{pass}^{1.33}$
Arresting gear		
Air Force-type	$0.002\ W_{dg}$	
Navy-type	$0.008\ W_{dg}$	
Catapult gear		
Navy carrier-based	$0.003\ W_{dg}$	
Folding wing		
Navy carrier-based	$0.06\ W_{wing}$	

[a]Mass equivalent of weight.

Estimación de Pesos - IV

- General Aviation Airplanes:
  - Pesos de ala
    - Cessna Method

$$W_w = 0.04674 (W_{TO})^{0.397} (S)^{0.360} (n_{ult})^{0.397} (A)^{1.712}$$

$$W_w = 0.002933 (S)^{1.018} (A)^{2.473} (n_{ult})^{0.611}$$

    - USAF Method

$$W_w = 96.948[(W_{TO} n_{ult}/10^5)^{0.65} (A/\cos\Lambda_{1/4})^{0.57} (S/100)^{0.61} \times \{(1+\lambda)/2(t/c)_m\}^{0.36} (1 + V_H/500)^{0.5}]^{0.993} \qquad (5.4)$$

    - Torenbeek Method

$$W_w = 0.00125 W_{TO} (b/\cos\Lambda_{1/2})^{0.75} [1 + \{6.3\cos(\Lambda_{1/2})/b\}^{1/2}] \times (n_{ult})^{0.55} (bS/t_r W_{TO} \cos\Lambda_{1/2})^{0.30} \qquad (5.5)$$

  - Pesos de cola
    - Cessna Method

$$W_h = \frac{3.184 (W_{TO})^{0.887} (S_h)^{0.101} (A_h)^{0.138}}{57.5 (t_{r_h})^{0.223}}$$

$$W_v = \frac{1.68 (W_{TO})^{0.567} (S_v)^{1.249} (A_v)^{0.482}}{15.6 (t_{r_v})^{0.747} (\cos\Lambda_{1/4_v})^{0.882}}$$

    - USAF Method

$$W_h = 127\{(W_{TO} n_{ult}/10^5)^{0.87} (S_h/100)^{1.2} \times 0.289 (l_h/10)^{0.483} (b_h/t_{r_h})^{0.5}\}^{0.458}$$

$$W_v = 98.5\{(W_{TO} n_{ult}/10^5)^{0.87} (S_v/100)^{1.2} \times 0.289 (b_v/t_{r_v})^{0.5}\}^{0.458}$$

    - Torenbeek Method

$$W_{emp} = 0.04\{n_{ult}(S_v + S_h)^2\}^{0.75},$$

Estimación de Pesos - V

- General Aviation Airplanes:
  - Raymer Method

$$W_{wing} = 0.036 S_w^{0.758} W_{fw}^{0.0035} \left(\frac{A}{\cos^2\Lambda}\right)^{0.6} q^{0.006} \lambda^{0.04} \left(\frac{100\ t/c}{\cos\Lambda}\right)^{-0.3} (N_z W_{dg})^{0.49}$$

$$W_{\substack{\text{horizontal}\\ \text{tail}}} = 0.016 (N_z W_{dg})^{0.414} q^{0.168} S_{ht}^{0.896} \left(\frac{100\ t/c}{\cos\Lambda}\right)^{-0.12} \left(\frac{A}{\cos^2\Lambda_{ht}}\right)^{0.043} \lambda_h^{-0.02}$$

$$W_{\substack{\text{vertical}\\ \text{tail}}} = 0.073 \left(1 + 0.2\frac{H_t}{H_v}\right) (N_z W_{dg})^{0.376} q^{0.122} S_{vt}^{0.873} \left(\frac{100\ t/c}{\cos\Lambda_{vt}}\right)^{-0.49} \left(\frac{A}{\cos^2\Lambda_{vt}}\right)^{0.357} \lambda_{vt}^{0.039}$$

$$W_{fuselage} = 0.052\ S_f^{1.086} (N_z W_{dg})^{0.177} L_t^{-0.051} (L/D)^{-0.072} q^{0.241} + W_{press}$$

$$W_{\substack{\text{main landing}\\ \text{gear}}} = 0.095 (N_l W_l)^{0.768} (L_m / 12)^{0.409}$$

$$W_{\substack{\text{nose landing}\\ \text{gear}}} = 0.125 (N_l W_l)^{0.566} (L_n / 12)^{0.845}$$

$$W_{\substack{\text{installed engine}\\ \text{(total)}}} = 2.575\ W_{en}^{0.922} N_{en}$$

$$W_{\text{fuel system}} = 2.49\ V_t^{0.726} \left(\frac{1}{1 + V_i/V_t}\right)^{0.363} N_t^{0.242} N_{en}^{0.157}$$

$$W_{\substack{\text{flight}\\ \text{controls}}} = 0.053\ L^{1.536} B_w^{0.371} (N_z W_{dg} \times 10^{-4})^{0.80}$$

$$W_{hydraulics} = 0.001\ W_{dg}$$

$$W_{electrical} = 12.57 (W_{\text{fuel system}} + W_{avionics})^{0.51}$$

$$W_{avionics} = 2.117\ W_{uav}^{0.933}$$

$$W_{\substack{\text{air conditioning}\\ \text{and anti-ice}}} = 0.265\ W_{dg}^{0.52} N_p^{0.68} W_{avionics}^{0.17} M^{0.08}$$

$$W_{furnishings} = 0.0582\ W_{dg} - 65$$

Estimación de Pesos - VI

- Cargo Transport Airplanes:
  - Raymer Method

$$W_{wing} = 0.0051 (W_{dg} N_z)^{0.557} S_w^{0.649} A^{0.5} (t/c)_{root}^{-0.4} (1+\lambda)^{0.1} (\cos\Lambda)^{-1.0} S_{csw}^{0.1}$$

$$W_{\substack{\text{horizontal}\\ \text{tail}}} = 0.0379 K_{uht} (1 + F_w/B_h)^{-0.25} W_{dg}^{0.639} N_z^{0.10} S_{ht}^{0.75} L_t^{-1.0} \times K_y^{0.704} (\cos\Lambda_{ht})^{-1.0} A_h^{0.166} (1 + S_e/S_{ht})^{0.1}$$

$$W_{\substack{\text{vertical}\\ \text{tail}}} = 0.0026 (1 + H_t/H_v)^{0.225} W_{dg}^{0.556} N_z^{0.536} L_t^{-0.5} S_{vt}^{0.5} K_z^{0.875} (\cos\Lambda_{vt})^{-1} A_v^{0.35} (t/c)_{root}^{-0.5}$$

$$W_{fuselage} = 0.3280 K_{door} K_{Lg} (W_{dg} N_z)^{0.5} L^{0.25} S_f^{0.302} (1 + K_{ws})^{0.04} (L/D)^{0.10}$$

$$W_{\substack{\text{main landing}\\ \text{gear}}} = 0.0106 K_{mp} W_l^{0.888} N_l^{0.25} L_m^{0.4} N_{mw}^{0.321} N_{mss}^{-0.5} V_{stall}^{0.1}$$

$$W_{\substack{\text{nose landing}\\ \text{gear}}} = 0.032 K_{np} W_l^{0.646} N_l^{0.2} L_n^{0.5} N_{nw}^{0.45}$$

$$W_{\substack{\text{nacelle}\\ \text{group}}} = 0.6724 K_{ng} N_{Lt}^{0.10} N_w^{0.294} N_z^{0.119} W_{ec}^{0.611} N_{en}^{0.984} S_n^{0.224}$$
(includes air induction)

$$W_{\substack{\text{starter}\\ \text{(pneumatic)}}} = 49.19 \left(\frac{N_{en} W_{en}}{1000}\right)^{0.541}$$

$$W_{\substack{\text{engine}\\ \text{controls}}} = 5.0 N_{en} + 0.80 L_{ec}$$

$$W_{\substack{\text{fuel}\\ \text{system}}} = 2.405 V_t^{0.606} (1 + V_i/V_t)^{-1.0} (1 + V_p/V_t) N_t^{0.5}$$

$$W_{\substack{\text{flight}\\ \text{controls}}} = 145.9 N_f^{0.554} (1 + N_m/N_f)^{-1.0} S_{cs}^{0.20} (I_y \times 10^{-6})^{0.07}$$

$$W_{\substack{\text{APU}\\ \text{installed}}} = 2.2 W_{\substack{\text{APU}\\ \text{uninstalled}}}$$

$$W_{instruments} = 4.509 K_r K_{tp} N_c^{0.541} N_{en} (L_f + B_w)^{0.5}$$

$$W_{hydraulics} = 0.2673 N_f (L_f + B_w)^{0.937}$$

$$W_{electrical} = 7.291 R_{kva}^{0.782} L_a^{0.346} N_{gen}^{0.10}$$

$$W_{avionics} = 1.73 W_{uav}^{0.983}$$

$$W_{furnishings} = 0.0577 N_c^{0.1} W_c^{0.393} S_f^{0.75}$$

$$W_{\substack{\text{air}\\ \text{conditioning}}} = 62.36 N_p^{0.25} (V_{pr}/1000)^{0.604} W_{uav}^{0.10}$$

$$W_{anti\text{-}ice} = 0.002 W_{dg}$$

$$W_{\substack{\text{handling}\\ \text{gear}}} = 3.0 \times 10^{-4} W_{dg}$$

$$W_{\substack{\text{military cargo}\\ \text{handling system}}} = 2.4 \times (\text{cargo floor area, ft}^2)$$

Estimación de Pesos - VII

- Se utilizan factores de corrección sobre las ecuaciones anteriores en función de los materiales empleados y del tipo de estructura

Table 15.4 Weights estimation "fudge factors"

Category	Weight group	Fudge factor (multiplier)
Advanced composites	Wing	0.85–0.90
	Tails	0.83–0.88
	Fuselage/nacelle	0.90–0.95
	Landing gear	0.95–1.0
	Air induction system	0.85–0.90
Braced wing	Wing	0.82
Braced biplane	Wing	0.6
Wood fuselage	Fuselage	1.60
Steel tube fuselage	Fuselage	1.80
Flying boat hull	Fuselage	1.25
Carrier-based aircraft	Fuselage and landing gear	1.2–1.3

Comparativa de pesos – Aviones similares - I

- Comparativa de pesos por grupos para aviones similares:
  - Airplane Design – Part V
    - Turbo/propeller Driven Military Transports (pp 176-177)

Table A10.2a Group Weight Data for Turbo/Propeller Driven Military Transports

	A.W.(HS) Argosy	Douglas C-133A	Lockheed C-130H	Breguet 941*
Number of engines:	4	4	4	4
Weight Item, lbs				
Wing Group	10,800	27,403	13,950	4,096
Empennage Group	1,300	6,011	3,480	1,387
Fuselage Group	11,100**	30,940	14,695	6,481
Nacelle Group	1,200	3,512	2,756	in wing
Land. Gear Group	3,180	10,635	5,309	2,626
Nose Gear			730	
Main Gear			4,579	
Structure Total	27,580	78,501	40,190	14,590

Comparativa de pesos – Aviones similares II

	A.W. (HS) Argosy	Douglas C-133A	Lockheed C-130H	Breguet 941*
Number of engines:	4	4	4	4
Weight Item, lbs				
Wing Group	10,800	27,403	13,950	4,096
Empennage Group	1,300	6,011	3,480	1,387
Fuselage Group	11,100**	30,940	14,695	6,481
Nacelle Group	1,200	3,512	2,756	in wing
Land. Gear Group	3,180	10,635	5,309	2,626
Nose Gear			730	
Main Gear			4,579	
Structure Total	27,580	78,501	40,190	14,590
Engines		10,470	13,746	
Air Induct. System				
Fuel System		1,338	3,105	
Propeller Inst.		5,403	in eng.	
Propulsion System		2,081	in eng.	
Power Plant Total		19,292	16,851	
Avionics + Instrum.		578	3,582	
Surface Controls	in struct.	1,804	1,673	1,056
Hydraulic System		2,678	664	
Pneumatic System				
Electrical System		2,004	2,459	
Electronics		2,047	in avionics	
APU		188	651	
Oxygen System			231	
Air Cond. System***		2,973	1,684	
Anti-icing System			797	
Furnishings		3,632	4,472	
Auxiliary Gear		117	6	
Operating items			532	
Fixed Equipm't Total		16,021	16,219	
$W_{oil} + W_{tfo}$		1,693	1,089	
Max. Fuel Capacity		60,000	45,240	
Payload (Max.)		97,162	33,461	

Type	A.W. (HS) Argosy	Douglas C-133A	Lockheed C-130H	Breguet 941
Flight Design Gross Weight, GW, lbs	82,000	275,000	155,000	58,421
Structure/GW	0.336	0.285	0.259	0.250
Power Plant/GW		0.070	0.109	
Fixed Equipm't/GW		0.058	0.105	
Empty Weight/GW	0.561	0.414	0.473	0.508
Wing Group/GW	0.132	0.100	0.090	0.070
Empenn. Group/GW	0.016	0.022	0.022	0.024
Fuselage Group/GW	0.135	0.113	0.095	0.111
Nacelle Group/GW	0.015	0.013	0.018	in wing
Land. Gear Group/GW	0.039	0.039	0.034	0.045
Take-off Gross Wht, W_{TO}, lbs	82,000	275,000	155,000	58,421
Empty Weight, W_E, lbs	46,000	113,814	73,260	29,675
Wing Group/S, psf	7.4	10.3	8.0	4.5
Emp. Grp/S_{emp}, psf	2.3	4.2	4.2	2.6
Ultimate Load Factor, g's	3.75*	2.50	3.75*	3.75*
Surface Areas, ft^2				
Wing, S	1,458	2,673	1,745	902
Horiz. Tail, S_h	327	801	536	320
Vert. Tail, S_v	250	641	300	223
Empenn. Area, S_{emp}	577	1,442	836	543

*Assumed

Comparativa de pesos – Aviones similares

Table I.1 Jet Transport Aircraft Weights Summary (Weights in Pounds)

Aircraft	McDonnell Douglas MD-80	McDonnell Douglas DC-10-30	Boeing 737-200	Boeing 727-100	Boeing 747-100	Airbus A-300
Wing	15,560	58,859	10,613	17,764	86,402	44,131
Empennage	3,320	14,676	2,718	4,133	11,850	5,941
Fuselage	16,150	47,270	12,108	17,681	71,845	35,820
Nacelle	5,340	9,127	1,392	3,870	10,031	7,039
Landing gear	5,340	25,761	4,354	7,211	31,427	13,611
Nose gear	550	1,832	—	—	—	—
Main gear	4,790	23,929	—	—	—	—
Structure total	42,490	155,693	31,185	50,659	211,555	106,542
Engine	8,820	26,163	6,217	9,325	34,120	16,825
Nozzle system and $T_{reverser}$	1,540	6,916	1,007	1,744	6,452	4,001
Air induction system[a]	0	0	0	0	0	0
Fuel system	640	4,308	575	1,143	2,322	1,257
Propulsion install	—	—	378	250	802	814
Propulsion total	11,000	37,387	8,177	12,462	43,696	22,897
Avionics and instruments	2,130	4,274	625	756	1,909	377
Surface controls	2,540	6,010	2,348	2,996	6,982	5,808
Hydraulic system	540	2,587	873	1,418	4,471	3,701

[a]Engines in pods, weight included in nacelle.

Comparativa de pesos – Aviones similares

Aircraft	McDonnell Douglas		Boeing			Airbus
	MD-80	DC-10-30	737-200	727-100	747-100	A-300
Pneumatic system	1,720	5,912	—	—	—	—
Electrical system	—	—	1,066	2,142	3,348	4,923
Electronics	—	—	956	2,142	3,348	4,923
Auxiliary power units (APU)	840	1,643	836	1,591	4,429	1,726
Oxygen system	220	256	—	—	—	—
Environmental control system (ECS)	1,580	2,723	1,416	1,976	3,969	3,642
Anti-icing system	550	471	—	—	—	—
Furnishings	8,450	34,124	6,643	10,257	37,245	13,161
Miscellaneous	3,650	16,274	124	85	421	732
Equipment total	25,460	76,194	14,887	21,281	63,062	35,053
Empty weight (lb)	78,950	269,274	60,210	88,300	353,398	168,805
Fuel	39,362	247,034	34,718	48,353	331,675	76,512
Oil	—	—	—	—	—	—
Payload (lb)	43,950	98,726	34,790	29,700	140,000	69,865
TOGW (lb)	140,000	555,000	115,500	160,000	710,000	302,000
Wing span (ft)	107.7	165.3	94.0	108.0	195.7	147.3
Wing area, S (ft^2)	1,270	3958	980	1,700	5,500	2,799
Horizontal tail area, S_H(ft^2)	314	1,338	321	376	1,470	748
Vertical tail area, S_V(ft^2)	168	605	233	356	830	487

Comparativa de pesos – Aviones similares

Table I.2 Business Jet Aircraft Weights Summary (Weights in Pounds)

Aircraft	Lockheed	Gates	Cessna	HawkerSid-deley	Gulfstream
Item[a]	Jetstar	Learjet28	CitationII	HS125	GII
Wing	2,827	1,939	1,288	1,968	6,372
Empennage	879	361	295	608	1,965
Fuselage	3,491	1,624	1,069	1,628	5,944
Nacelle	792	214	220	(Infuse)	1,239
Landing gear	1,061	584	465	659	2,011
Nose and main	—	102/482	87/378	—	321/1690
Structure total	9,050	4,722	3,337	4,863	17,531
Engine	609	792	1,100	—	6,570
Nozzle system and $T_{reverser}$	—	—	15	—	—
Air induction system	135	0	26	—	—
Fuel system	360	237	189	—	316
Propulsion install	230	255	105	—	—
Propulsion total	2,475	1,284	1,435	—	6,866
Avionics and instruments	153	383	87	—	1,715
Surface controls	768	275	203	217	1,021
Hydraulic system	262	114	96	—	959
Pneumatic system	—	—	—	—	—

Comparativa de pesos – Aviones similares

Aircraft	Lockheed	Gates	Cessna	HawkerSid-deley	Gulfstream
Item[a]	Jetstar	Learjet28	CitationII	HS125	GII
Electrical system	973	603	340	—	1,682
Electronics	868	—	313	—	—
APU	—	—	—	—	258
Oxygen system	—	26	—	—	140
ECS	510	285	264	—	927
Anti-ice system	—	162	98	—	—
Furnishings	1,521	768	800	—	4,501
Miscellaneous	10	—	50	—	—
Equipment total	5,065	2,605	2,251	—	11,203
Empty weight (lb)	16,590	8,611	7,023	12,260	35,620
Fuel	11,229	4,684	5,009	9,193	23,300
Oil	204	177	143	—	—
Payload (lb)	2,100	1,962	1,500	1,905	5,380
TOGW (lb)	30,680	15,000	13,500	23,300	64,800
Wing span (ft)	55.0	43.8	52.3	47.0	68.8
Wing area, S (ft^2)	521	265	279	353	794
Horizizontal tail area, S_H (ft^2)	149	54	70	100	182
Vertical tail area, S_V (ft^2)	110	37	51	52	155

[a]Abbreviations: APU, auxiliary power units; ECS, environmental control system; TOGW, takeoff gross weight.

Comparativa de pesos – Aviones similares

Table I.3 General Aviation Aircraft Weights Summary (Weights in Pounds)

Aircraft	Cessna					Beech	
Item[a]	150	172	182	210J	310C	QueenAir	TwinBonanza
Wing	216	226	235	335	453	670	656
Empennage	36	57	62	86	118	153	156
Fuselage	231	353	400	408	319	601	495
Nacelle	22	27	34	28	129	285	261
Landing gear	104	111	132	191	263	444	447
Structure total	**609**	**774**	**863**	**1048**	**1282**	**2153**	**2015**
Engine	197	254	417	450	852	1008	1008
Air induction system	2	1	1	7	7	27	27
Fuel system	17	21	26	24	76	137	137
Nozzle	0	0	0	0	0	0	0
Propeller	22	33	64	64	162	258	258
Installation	28	36	37	36	153	180	180
Propulsion total	**267**	**345**	**545**	**581**	**1250**	**1610**	**1610**
Avionics and instruments	3	4	6	18	46	72	89

Comparativa de pesos – Aviones similares

Aircraft	Cessna					Beech	
Item[a]	150	172	182	210J	310C	QueenAir	TwinBonanza
Surface controls	31	31	36	48	66	132	120
Electrical system	43	38	43	57	121	166	184
Hydraulics	0	0	0	51	0	0	0
ECS	1	1	1	10	46	90	81
Anti-ice	—	—	—	—	—	—	—
Furnishings	33	85	87	130	154	438	333
Misc	0	0	0	20	65	5	7
Equipment total	**102**	**159**	**173**	**335**	**498**	**903**	**814**
Empty weight (lb)	946	1243	1545	1964	3032	4701	4459
Fuel	156	252	390	464	612	1380	1380
Oil	11	15	22	24	45	60	60
Payload (lb)	398	702	715	693	1186	1287	1311
TOGW (lb)	1500	2200	2650	3400	4830	7368	7150
Wing span (ft)	33.3	36.0	36.0	36.8	37.0	50.3	45.3
Wing area, S (ft^2)	160	175	175	176	175	277	277
Horizontal tail area, S_H (ft^2)	28.5	34.6	34.1	38.6	54.3	79.3	79.3
Vertical tail area, S_V (ft^2)	14.1	18.4	18.4	17.2	25.9	30.8	30.8

[a]Abbreviations: ECS, environmental control system; TOGW, takeoff gross weight.

Comparativa de pesos – Aviones similares

Table I.4 ISR Aircraft Weights Summary (Weights in Pounds)

Aircraft	Lockheed				Boeing	N/G
Item[a]	U-2A	U-2S	Darkstar	SR-71	Condor[b]	GlobalHawk
No. of Engines	1	1	1	2	2	1
Engine model	PWA J-57-37	GE F118-100	Williams FJ44-2D	PWA J-58	TCM GTSIOL	Allison AE3007H
Wing	2,034	4,585	1,111	14,054	2,519	—
Empennage	320	674	0	1,503	253	—
Fuselage	1,410	2,719	847	6,911	823	—
Landing gear	263	596	391	3,486	243	—
Structure total	4,027	8,573	2,349	25,954	3,838	—
Engine	4076	4,814	448	12,966	1,121	—
Nozzle	204	350	104	1,565	—	—
Air induction	164	235	57	4,941	—	—
Fuel system	311	556	161	1,700	235	—
Propulsion install	111	57	42	481	833[D]	—
Propulsion total	4,865	6059	812	21,653	2,189	—
Avionics and instruments	57	137	417	372	530	—
Surface controls	362	497	287	1,682	295	—
Hydraulic system	66	138	111	1,222	—	—
Pneumatic system	—	—	—	—	—	—
Electrical system	290	1,060	384	898	319	—
Electronics	166	478	—	1,427	—	—

Comparativa de pesos – Aviones similares

Aircraft	Lockheed				Boeing	N/G
Item[a]	U-2A	U-2S	Darkstar	SR-71	Condor[b]	GlobalHawk
APU	0	0	0	—	0	—
ECS/Anti-Ice	135	159	187	1,325	157	—
Oxygen system	61	—	0	75	0	—
Furnishings	82	287	0	520	0	—
Miscellaneous	21	127	31	200	550	—
Equipment total	1,240	2,883	1,394	7,646	1,851	—
Empty weight	10,180	17,616	4,554	55,253	7,878	9,200
Fuel	5,810	17,677	2,846	80,650	11,077	13,015
Oil and trapped fuel	146	57	76	644	221	427
Payload	518	2,714	1,123	3,411	1000	2,300
Crew	0	0	0	570	—	—
Miscellaneous, communications gear	0	0	0	0	0	658
TOGW	17,000	40,000	8,600	140,750	20,300	25,600
Wingspan	80	103	69	56.7	200	116
Wing area, S	600	1000	300	1,605	1,107	540
Horizontal tail Area, S_H	—	145	0	0	110	56
Vertical tail area, S_V	—	55	0	301	71	69
C_H	—	0.34	0	0	0.53	0.32
C_V	—	0.014	0	—	0.012	0.0186

[a]Abbreviations: APU, auxiliary power units; ECS, environmental control system; TOGW, takeoff gross weight.
[b]Condor propulsion install weight includes the propeller installation, cooling system for engine and two-stage turbochargers, lubricating system, and engine controls. Engine weight includes the weight of the two Teledyne Continental 175-hp liquid-cooled engines and the two-stage turbochargers (25:1).

Comparativa de pesos – Aviones similares

Table 1.5a Fighter Aircraft Weights Summary (Weights in Pounds)

Type	NAA F-100F	McD F-101B	McD RF-101	GD F-102A	Republic F-105B	GD F-106A	NAA F-107A	NAA F-86H	Vought F8U-3	McD F4H	Grumman F11F	Grumman F9F-5	Grumman A2F(A6)
No. of engines	1	2	2	1	1	1	1	1	1	2	1	1	2
Weight item (lb)													
Wing group	3896	3507	3680	3000	3409	3302	3787	2702	4128	4343	2180	2294	4733
Empennage group	979	812	837	535	965	693	1130	329	1045	853	669	404	819
Fuselage group	4032	3901	3955	3409	5870	4401	4792	2035	3850	4042	3269	1779	3538
Engine section	104	99	103	39	106	39	260	42	92	125	47	0	64
Landing gear group	1509	1592	1596	1056	1848	1232	1410	989	949	1735	907	728	2343
Nose gear													
Main gear													
Outrigger gear													
Structure total	10520	9911	10171	8039	12198	9667	11379	6097	10064	11098	7072	5206	11497
Engine(s)	5121	10800	9676	4993	6187	5816	6100	3646	6010	6940	3489	2008	4010
Air induction system	504	729	638	693	524	975	833	167	673	1037	159	225	61
Fuel system	761	1226	1412	394	608	777	983	845	849	953	463	529	936
Propulsion system	414	892	599	278	406	503	368	340	338	106	192	116	632
Power plant total	6800	13647	12325	6358	7725	8071	8284	4998	7870	9036	4303	2878	5639
Avionics + instrumentation	303	318	204	141	227	190	288	111	191	166	118	82	133
Surface controls	1076	772	780	413	1311	445	1454	358	1425	919	760	345	932
Hydraulic system	157	433	359	318	449	431	150	339	150	441	166	267	170
Pneumatic system													
Electrical system	568	825	819	594	700	606	447	476	439	502	459	458	695
Electronics	496	2222	629	2001	737	2743	382	230	840	1386	439	292	2652
Armament	794	228	36	589	719	626	1006	828	376	446	358	416	323
Air conditioning system	435	270	362	259	168	407	390	205	329	341	76	85	164
Anti-icing system													
Furnishings	427	480	242	227	243	290	282	182	210	321	166	144	476
Auxiliary gear	77	84	91	78	92	69	42	12	183		131	51	
APU					224								
Photographic system													

Comparativa de pesos – Aviones similares

Type	NAA F-100F	McD F-101B	McD RF-101	GD F-102A	Republic F-105B	GD F-106A	NAA F-107A	NAA F-86H	Vought F8U-3	McD F4H	Grumman F11F	Grumman F9F-5	Grumman A2F(A6)
Ballast													
Manufacturing variation													
Fixed equipment total	4333	5632	3522	4620	4870	5807	4441	2741	4143	4522	2673	2140	5545
W(oil) + W(tfo)	166	223	223	216	198	303	143	57	196	131	72	0	195
Max. fuel capacity	7729	8892	9782	7053	7540	8476	11050	3660	14306	13410	6663	7160	8764
Payload (max. fuel)	250	1881	704	1241	757	1374	2560	420	1197	1500	340	0	2000
Expendable payload													
Fixed payload													
Flight design GW, lb	29391	39800	37000	25500	31392	30590	29524	19012	30678	34851	17500	14900	34815
Structure/GW	0.358	0.249	0.275	0.315	0.389	0.316	0.385	0.321	0.329	0.318	0.404	0.349	0.330
Power plant/GW	0.231	0.343	0.333	0.249	0.246	0.264	0.281	0.263	0.257	0.259	0.246	0.193	0.162
Fixed equipment/GW	0.147	0.142	0.095	0.181	0.155	0.190	0.150	0.144	0.135	0.130	0.153	0.144	0.159
Empty weight/GW	0.737	0.733	0.724	0.750	0.797	0.767	0.816	0.728	0.722	0.707	0.771	0.686	0.651
Wing group/GW	0.133	0.088	0.099	0.118	0.109	0.108	0.128	0.142	0.135	0.125	0.125	0.154	0.136
Empennage group/GW	0.033	0.020	0.023	0.021	0.031	0.023	0.038	0.017	0.034	0.024	0.038	0.027	0.024
Fuselage group/GW	0.137	0.098	0.107	0.134	0.187	0.144	0.162	0.107	0.126	0.116	0.187	0.119	0.102
Engine section/GW	0.004	0.002	0.003	0.002	0.003	0.001	0.009	0.002	0.003	0.004	0.003	0.000	0.002
Land. gear group/GW	0.051	0.040	0.043	0.041	0.059	0.040	0.048	0.052	0.031	0.050	0.052	0.049	0.067
Take-off gross weight, lb	30638	41288	37723	28137	34081	33888	39405	18908	38528	40217	21233	17500	34815
Empty weight, W_e, lb	21653	29190	26774	19130	25022	23448	24104	13836	22092	24656	13485	10223	22680
Wing group/S, psf	9.7	9.5	10.0	4.3	8.9	4.7	9.6	8.6	8.9	8.2	8.5	9.2	9.1
Empennage group/ S_{emp}, psf	6.3	5.1	5.2	5.6	5.2	6.6	6.4	4.1	7.2	5.2	5.8	3.5	4.4
Ultimate load factor, gs	7.33	10.2	11	10.5	13	10.5	13	11	9.6		9.8	11.3	
Surface areas, ft^2													
Wing, S	400	368	368	698	385	698	395	313	462	530	255	250	520
Horizontal tail, S_h	98.9	75.1	75.1	0	96.5	0	93.3	47.2	67.2	96.2	65.5	48	120
Vertical tail, S_v	55.6	84.9	84.9	95.1	88.1	105	83.8	32.2	78.6	67.5	50.3	66	68.4
Empennage area, S_{emp}	155	160	160	95.1	185	105	177	79.4	146	164	116	114	188

Comparativa de pesos – Aviones similares

Table I.5b Fighter Aircraft Weights Summary

Type	McD F3H-2	NAA A3J	Vought F7U-1	McD F-4E	Boeing F-15C	Boeing F/A-18A	Boeing AV-8B	LM F/A-16A	LM F/A-16C	Boeing F/A-18E	LM F/A-22A
No. of engines	2	2	1	2	2	2	1	1	1	2	2
Weight item (lb)											
Wing group	4314	5072	3583	5226	3642	3798	1443	1829	2145	4799	4586
Empennage group	576	1358	726	969	1104	945	372	719	898	1526	2580
Fuselage group	3551	6851	937	5050	6245	4685	2060	3325	3923	6054	12049
Engine section	93	80	0	166	102	143	141	322	449	175	231
Landing gear group	1458	2173	1181	1944	1393	1992	1011	881	1116	2623	1467
Nose gear				377	264	626	334	166	200	743	253
Main gear				1567	1129	1366	400	627	832	1880	1214
Outrigger gear							277				
Structure Total	9992	15534	6427	13355	12486	11563	5027	7076	8531	15177	20913
Engine(s)	4960	7260	2790	7697	6091	4294	3815	3026	3945	5218	10286
Air induction system	614	767	690	1318	1464	423	236	298	351	682	1426
Fuel system	1262	979	1080	1932	1128	1002	542	361	385	1253	1206
Propulsion system	70	353	937	312	522	558	444	357	412	412	594
Power plant total	6906	9359	5497	11259	9205	6277	5037	4042	5093	7565	13512
Avionics + instrumentation	145	210	108	270	151	94	80	103	107	63	303
Surface controls	1067	1845	482	1167	810	1067	698	727	839	1242	1327
Hydraulic system	474	275	317	543	433	364	176	311	310	447	764
Pneumatic system											
Electrical system	535	821	371	542	607	547	424	457	791	799	1207
Electronics	984	2239	328	2227	1787	1538	697	1054	1683	1979	1924
Armament	662	45	367	641	627	387	152	593	608	319	327
Air conditioning system	101	424	79	406	685	593	218	255	321	888	1290
Anti-icing system						21		3	5	21	4
Furnishings	218	676	279	611	294	317	298	309	334	380	456
Auxiliary gear	253		128	412	119	189		63	71	276	203

Comparativa de pesos – Aviones similares

Type	McD F3H-2	NAA A3J	Vought F7U-1	McD F-4E	Boeing F-15C	Boeing F/A-18A	Boeing AV-8B	LM F/A-16A	LM F/A-16C	Boeing F/A-18E	LM F/A-22A
APU								165	170	232	384
Photographic system					24						
Ballast					318	36				188	
Manufacturing variation				57	–97	–19	–16	–9		78	114
Fixed equipment total	4439	6535	2459	6876	5758	5134	2727	4031	5239	6912	8303
W(oil) + W(tfo)	147	320	97					176	186	476	579
Max. fuel capacity	9789	19074	5826	12068	13455	17592	7759	13732	13606	21093	34439
Payload (max. fuel)	216	1885	502								
Expendable payload				2193	2571	5453	4271	338	338	6045	2472
Fixed payload				0	0	2231	832	1856	1930	3461	7731
Flight design gross weight, lb	26000	46028	19310	37500	37400	32357	22950	22500	26910	43900	54313
Structure/GW	0.384	0.337	0.333	0.356	0.334	0.357	0.219	0.314	0.317	0.346	0.385
Power plant/GW	0.266	0.203	0.285	0.300	0.246	0.194	0.219	0.180	0.189	0.172	0.249
Fixed equipment/GW	0.171	0.142	0.127	0.183	0.154	0.159	0.119	0.179	0.195	0.157	0.153
Empty weight/GW	0.818	0.679	0.746	0.840	0.733	0.710	0.557	0.673	0.701	0.675	0.787
Wing group/GW	0.166	0.110	0.186	0.139	0.097	0.117	0.063	0.081	0.080	0.109	0.084
Empennage group/GW	0.022	0.030	0.038	0.026	0.030	0.029	0.016	0.032	0.033	0.035	0.048
Fuselage group/GW	0.137	0.149	0.049	0.135	0.167	0.145	0.090	0.148	0.146	0.138	0.222
Engine section/GW	0.004	0.002	0.000	0.004	0.003	0.004	0.006	0.014	0.017	0.004	0.004
Land. gear group/GW	0.056	0.047	0.061	0.052	0.037	0.062	0.044	0.039	0.041	0.060	0.027
Takeoff gross weight, TOGW, lb	32037	53658	21638	58000	68000	51900	29750	35400	42300	66000	84200
Empty weight, W_e, lb	21272	31246	14397	31514	27426	22974	12791	15149	18863	29654	42728
Wing group/S, psf	8.4	7.2	7.1	9.5	6.1	9.5	6.3	6.1	7.2	9.6	5.5
Empennage group/S_{emp}, psf	4.5	3.4	8.3	5.8	4.7	4.9	5.0	6.9	7.6	6.4	8.2
Ultimate load factor, gs	11.25			9.75	11	11.25	10.5	13.5	13.5	11.25	13.5
Surface areas, ft²											
Wing, S	516	700	507	548	599	400	230	300	300	500	840
Horizontal tail, S_h	82.5	304	0	100	111	88.1	48.5	49	63.7	120	136
Vertical tail, S_v	45.4	101	88	67.5	125	104	26.6	54.75	54.75	120	178
Empennage area, S_{emp}	128	405	88	168	236	192	75.1	103.75	118.45	240	314

Comparativa de pesos – Aviones similares

Table I.6 Sailplane Weight (data from [1])

Sailplane Item	Nimbus II	Nimbus 4T	ASW 17	ASW 22BL	ASW 12	LS-9	SB-12	SB-8	PW-5	Eta
Span (ft)	67	86.6	66	86.6	60	59	49	59	44	101.4
Aspect ratio	28.6	39.2	27	41.8	25.8	27.7	22.5	23	17.8	51.3
Wing area (ft^2)	155	192	160	179	140	126	110	152	109	200
Wing MAC (ft)	2.3	2.08	2.32	1.9	2.28	2.065	2.22	2.43	2.26	2.25
Wing taper ratio	0.36	0.23	0.43	0.25	0.34	0.25	0.43	0.46	0.2	0.35
Wing wt (lb)	506	686	532	678	427	484	257	284	185	814
Fuselage/vert wt (lb)	264	436	279	304	257	319	205	167	220	532
Horiz tail (lb)	13	18	24	18	18	15	15	13	13	18
Empty wt (lb)	783	1140	889	1000	702	818	474	464	418	1364
Max wt (lb)[a]	1276	1760	1342	1650	946	1155	990	735	660	1870
Water ballast (lb)	295	422	255	452	46	139	318	73	44	506
Water ballast/empty wt	0.376	0.37	0.287	0.45	0.07	0.17	0.67	0.16	0.11	0.37
Empty wt/max wt	0.614	0.648	0.662	0.61	0.74	0.71	0.48	0.63	0.633	0.73
Max wt/wing area (psf)	8.23	9.17	8.39	9.22	6.76	9.17	9	4.8	6.05	9.35
Wing wt/wing area (psf)	3.26	3.57	3.33	3.79	3.05	3.84	2.34	1.86	1.7	4.07
Horizontal Tail										
Area (ft^2)	10.98	14.64	15.39	13.67	10.76	10.76	12.4	14	14.85	14.1
Moment arm (ft)	15.1	16.1	13.85	15.65	13.7	13.45	12.3	15.26	12.47	20.44
C_{HT}[b]	0.465	0.59	0.57	0.63	0.46	0.56	0.62	0.58	0.75	0.64
Vertical Tail										
Area (ft^2)	13.35	15.93	14.53	18.41	12.92	10.87	9.58	14	7.2	21.64
Moment arm (ft)	14.63	15.75	14.53	15.13	14.11	12.8	12.24	15.49	11	19.88
C_{VT}[b]	0.019	0.015	0.021	0.018	0.022	0.0187	0.022	0.024	0.0165	0.0212

[a]Max weight = empty weight + 198 lb pilot + water ballast.
[b]Tail volume coefficient (see Chapter 11).

Actuaciones y Propulsión - I

- Propulsión y Actuaciones:
  - Primera **estimación** de **actuaciones** (grandes rasgos).
  - **Diagrama T/W vs W/S**
  - **Definir planta motora**.
  - Interacción: En función de las “performances calculadas“ exigirá modificaciones de todas las ramas

Actuaciones y Propulsión - II

- Definir las actuaciones de forma precisa en función de sus necesidades:
  - Alturas de vuelo
  - Regímenes de vuelo: crucero, autonomía, ate
  - Velocidades de vuelo (max, min, stall, etc...)
  - Configuración sucia y limpia
    - Velocidades de entrada en pérdida
  - Corrección de los empujes:
    - Corrección para representarlos
    - Corrección para obtener valores razonables

$$W = L = \frac{1}{2}\rho V_{STALL}^2 S C_{L_{max}}$$

$$\frac{W_{h_1}}{W_{h_2}} = \frac{\frac{1}{2}\rho_{h_1} V_{STALL_{CLEAN}}^2 S C_{L_{max_{CLEAN}}}}{\frac{1}{2}\rho_{h_2} V_{STALL_{DIRTY}}^2 S C_{L_{max_{DIRTY}}}}$$

$$V_{STALL_{DIRTY}} = \sqrt{\frac{W_{h_2}}{W_{h_1}} \frac{\frac{1}{2}\rho_{h_1} V_{STALL_{CLEAN}}^2 S C_{L_{max_{CLEAN}}}}{\frac{1}{2}\rho_{h_2} S C_{L_{max_{DIRTY}}}}}$$

- Análisis concurrente:
  - 1ª etapa — RFP → W/S & T/W
  - 2ª etapa — W/S & T/W → RFP

$$\frac{T_{loiter}}{W_{loiter}} \geq \left(\frac{K}{q}\frac{W_{loiter}}{S}n^2 + \frac{C_{D_0} q}{\frac{W_{loiter}}{S}}\right)$$

$$\frac{T_{t_0}}{W_0} \geq \frac{T_{t_0}}{T_{t_{loiter}}}\frac{W_{loiter}}{W_{t_0}}\left(\frac{K}{q}\frac{W_{t_0}}{S}\frac{W_{loiter}}{W_{t_0}}n^2 + \frac{C_{D_0} q}{\frac{W_{t_0}}{S}\frac{W_{loiter}}{W_{t_0}}}\right)$$