Corso di PROGETTO GENERALE DEI VELIVOLI

STIMA DEI PESI DI UN VELIVOLO

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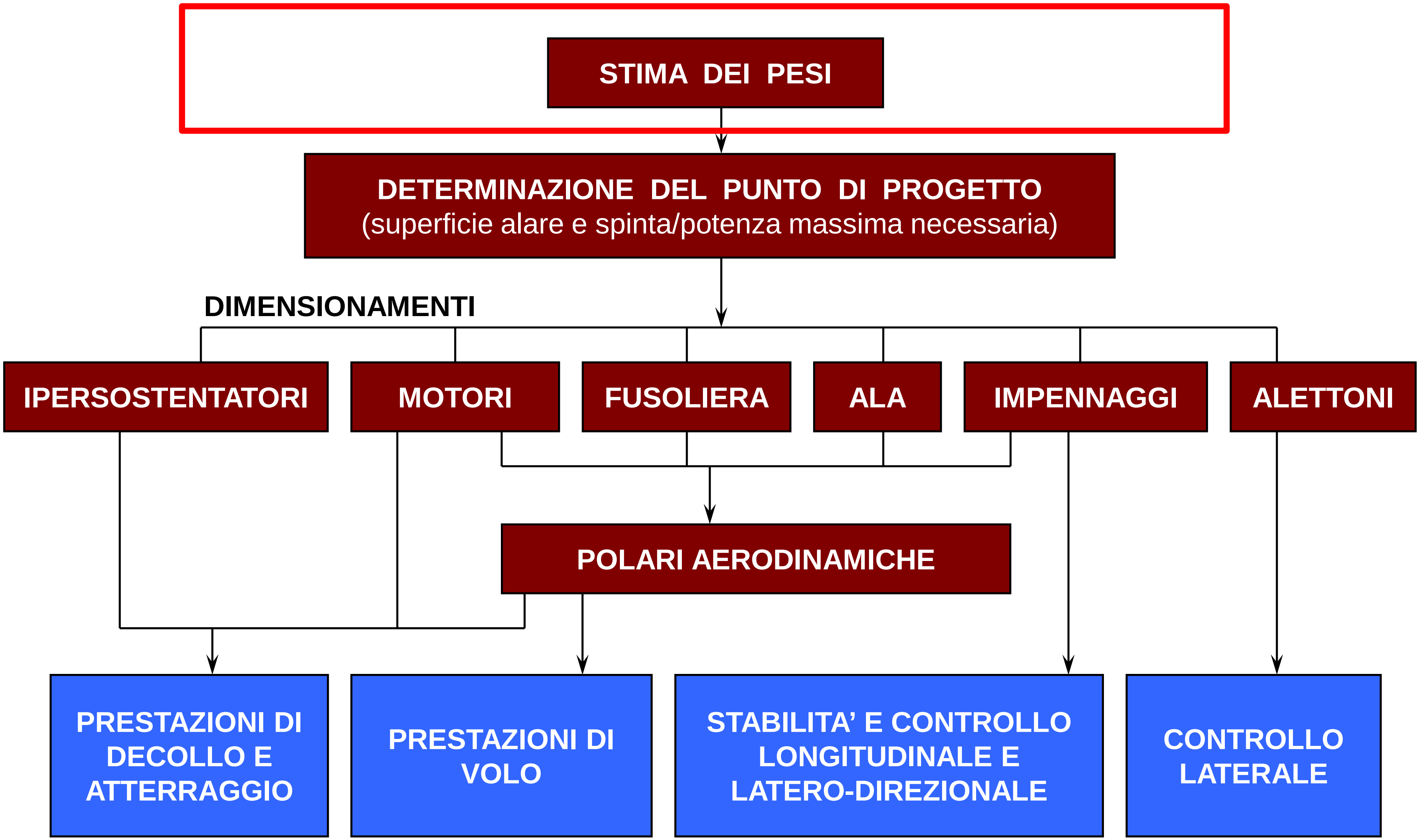
PROGETTO PRELIMINARE



Passo n° 1

SPECIFICA DI PROGETTO

Passo n° 2

STIMA PRELIMINARE DEI PESI

PESI di un velivolo

6) COMBUSTIBILE

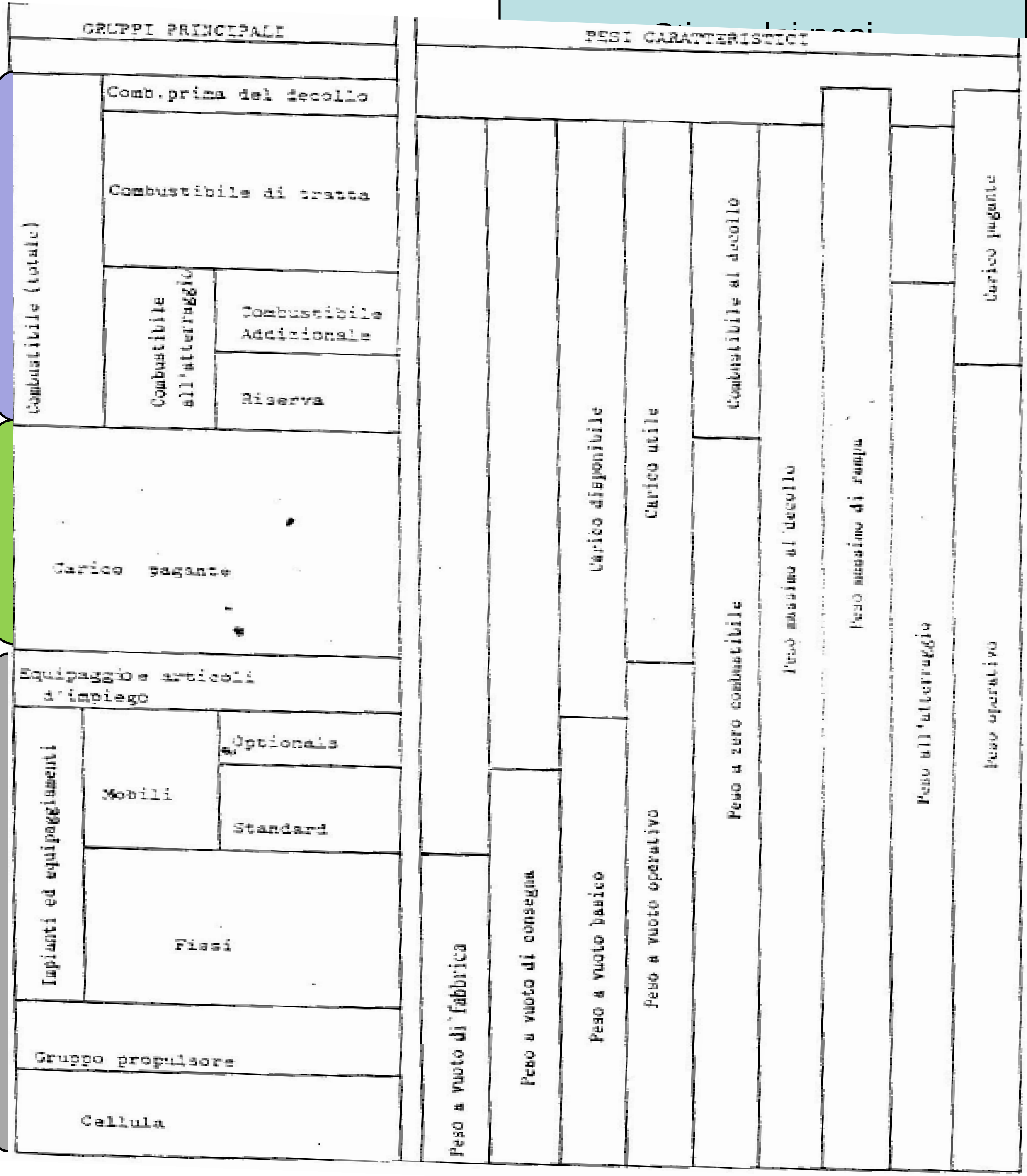
5) CARICO PAGANTE

4) Equipaggio
Articoli d'impiego

3) Impianti
Equipaggiamenti

2) Propulsore

1) Cellula



CARATTERISTICHE DEL METODO

- **Metodo semiempirico**
- **Metodo basato sulla risoluzione di un sistema di due equazioni in due incognite**

INCOGNITE FONDAMENTALI

W_{TO}

Max Take-Off Weight

W_E

Empty Weight

CONDIZIONI ED EQUAZIONI

1 - Definizione di W_{TO}

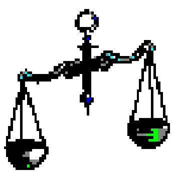
$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$

2 - Legge statistica

$$\log_{10} W_{TO} = a + b \cdot \log_{10} W_E$$

STUDIO DELLA CONDIZIONE 1

$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$



Incognite del problema

STUDIO DELLA CONDIZIONE 1

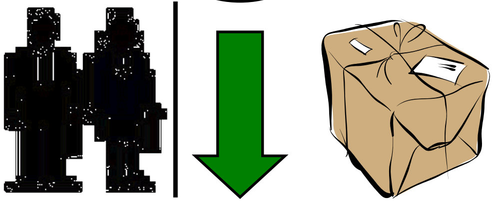
$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$

Il numero di persone dell’equipaggio è riportato nella specifica di progetto

Assumere sempre 175 + 30 lbs per ogni componente……circa 80 kg + 14 kg

STUDIO DELLA CONDIZIONE 1

$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$



Il numero di passeggeri ed il carico merci sono riportato nella specifica di progetto

Assumere sempre 175 lbs per ogni passeggero + 30/40 lbs per il rispettivo bagaglio

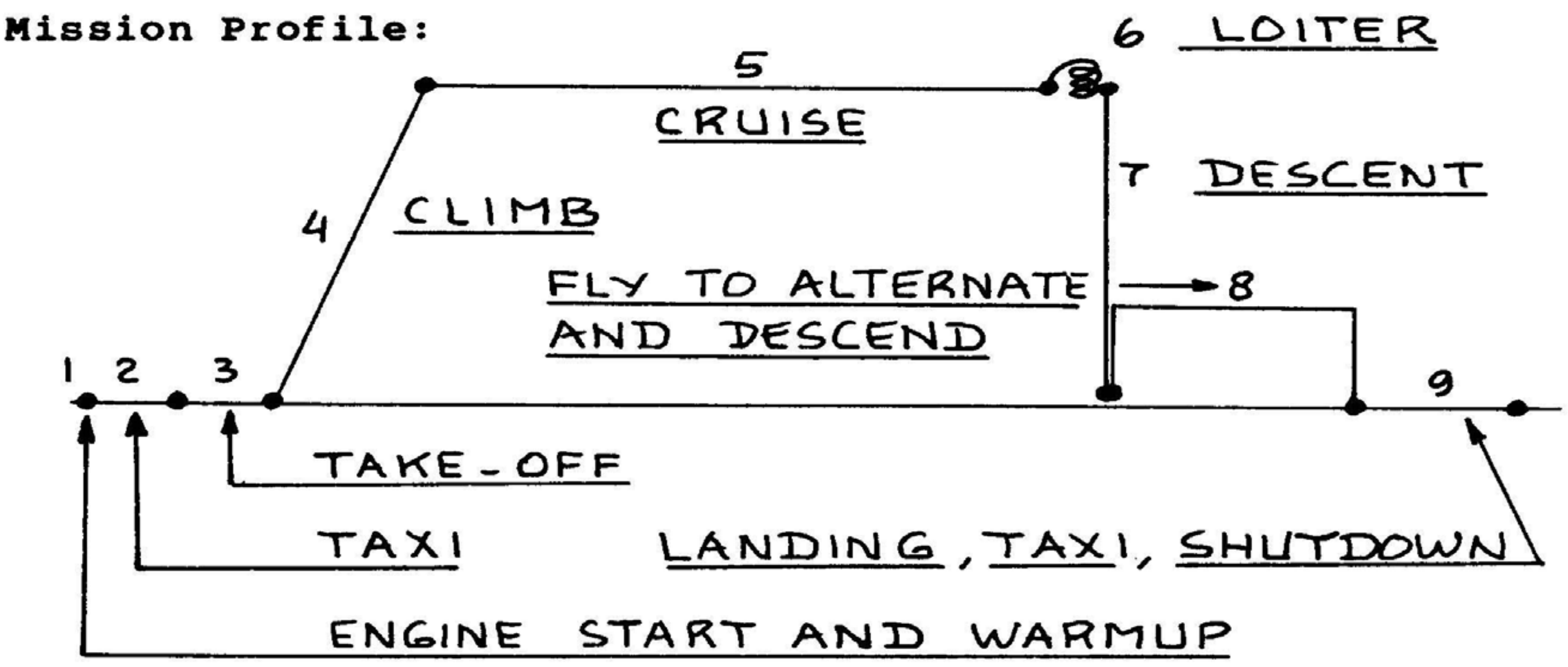
STUDIO DELLA CONDIZIONE 1

$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$

$$W_F = W_{F\ used} + W_{F\ reserve}$$

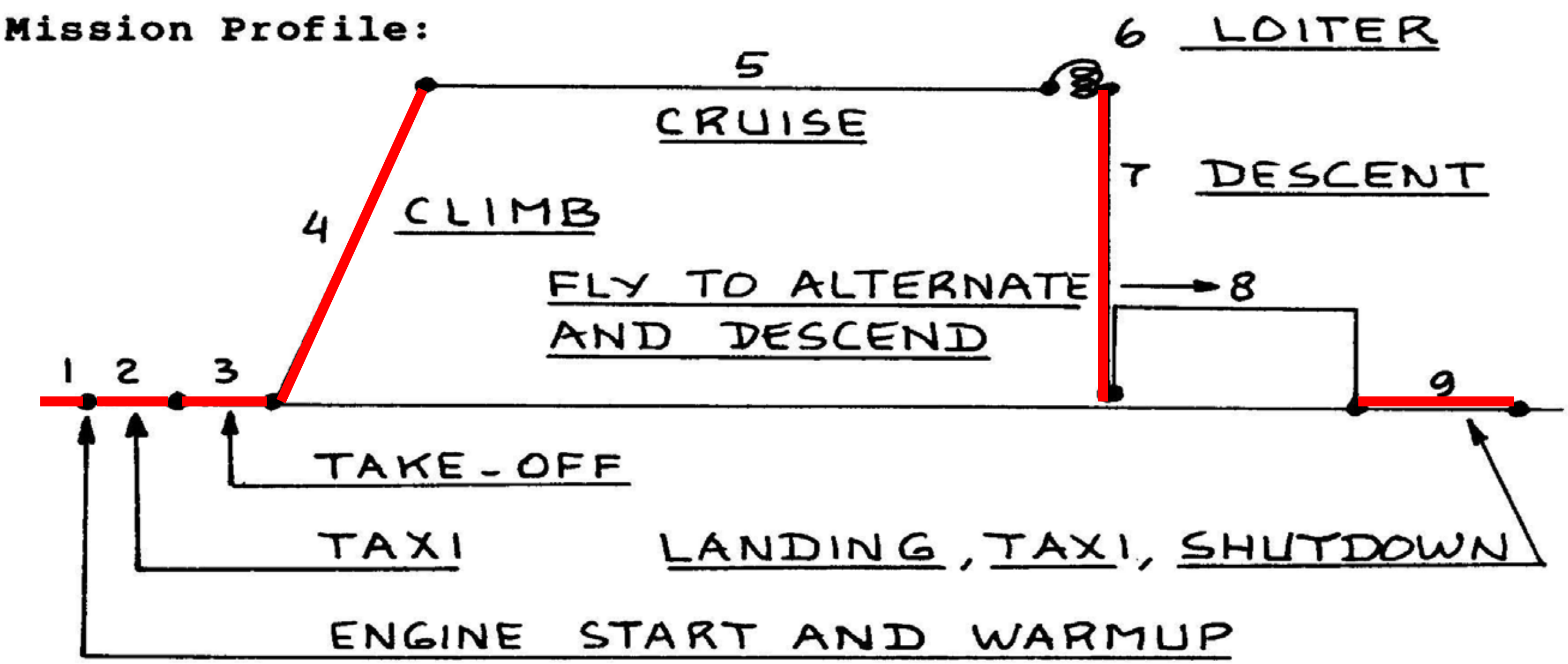
PROFILO DI MISSIONE → **FUEL FRACTION METHOD**

FUEL FRACTION METHOD



Per ciascuna fase si determina la frazione di combustibile $\dfrac{W_{finale}}{W_{iniziale}}$

FUEL FRACTION METHOD



STATISTICA → $\left(\dfrac{W_{finale}}{W_{iniziale}}\right)_i$

FUEL FRACTION METHOD

Table 2.1 Suggested Fuel-Fractions For Several Mission Phases

Mission Phase No. (See Fig. 2.1) Airplane Type:	Engine Start, Warm-up 1	Taxi 2	Take-off 3	Climb 4	Descent 7	Landing Taxi, Shutdown 8
1. Homebuilt	0.998	0.998	0.998	0.995	0.995	0.995
2. Single Engine	0.995	0.997	0.998	0.992	0.993	0.993
3. Twin Engine	0.992	0.996	0.996	0.990	0.992	0.992
4. Agricultural	0.996	0.995	0.996	0.998	0.999	0.998
5. Business Jets	0.990	0.995	0.995	0.980	0.990	0.992
6. Regional TBP's	0.990	0.995	0.995	0.985	0.985	0.995
7. Transport Jets	0.990	0.990	0.995	0.980	0.990	0.992
8. Military Trainers	0.990	0.990	0.990	0.980	0.990	0.995
9. Fighters	0.990	0.990	0.990	0.96-0.90	0.990	0.995
10. Mil.Patrol, Bomb, Transport	0.990	0.990	0.995	0.980	0.990	0.992
11. Flying Boats, Amphibious, Float Airplanes	0.992	0.990	0.996	0.985	0.990	0.990
12. Supersonic Cruise	0.990	0.995	0.995	0.92-0.87	0.985	0.992

FUEL FRACTION METHOD

SALITA VELIVOLI PROPULSI AD ELICA

1 – Quota di crociera non elevata

2 – Velocità di salita sulla traiettoria non elevata

Il segmento di crociera percorso è trascurabile

FUEL FRACTION METHOD

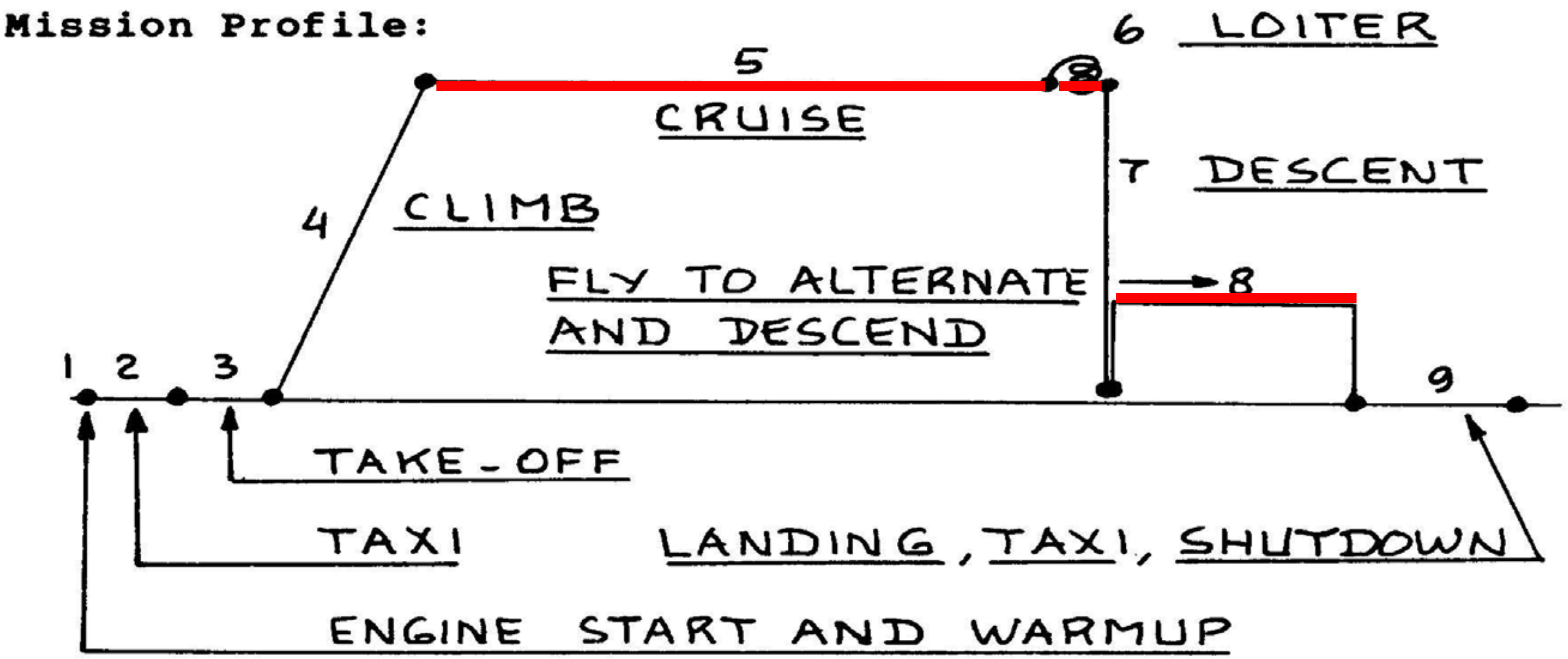
SALITA VELIVOLI PROPULSI A GETTO

1 – Quota di crociera elevata

2 – Velocità di salita sulla traiettoria elevata

Il segmento di crociera percorso non è trascurabile

FUEL FRACTION METHOD



BREGUET → $\left(\frac{W_{finale}}{W_{iniziale}} \right)_i$

FUEL FRACTION METHOD

FORMULE DI BREGUET

Velivoli ad elica

$$\text{Autonomia di distanza} \quad R = 375 \cdot \frac{\eta_p}{c_p} \cdot \frac{L}{D} \cdot \ln\left(\frac{W_i}{W_f}\right)$$

$$\text{Autonomia oraria} \quad En = 375 \cdot \frac{1}{V} \cdot \frac{\eta_p}{c_p} \cdot \frac{L}{D} \cdot \ln\left(\frac{W_i}{W_f}\right)$$

Velivoli a getto

$$\text{Autonomia di distanza} \quad R = \frac{V}{c_j} \cdot \frac{L}{D} \cdot \ln\left(\frac{W_i}{W_f}\right)$$

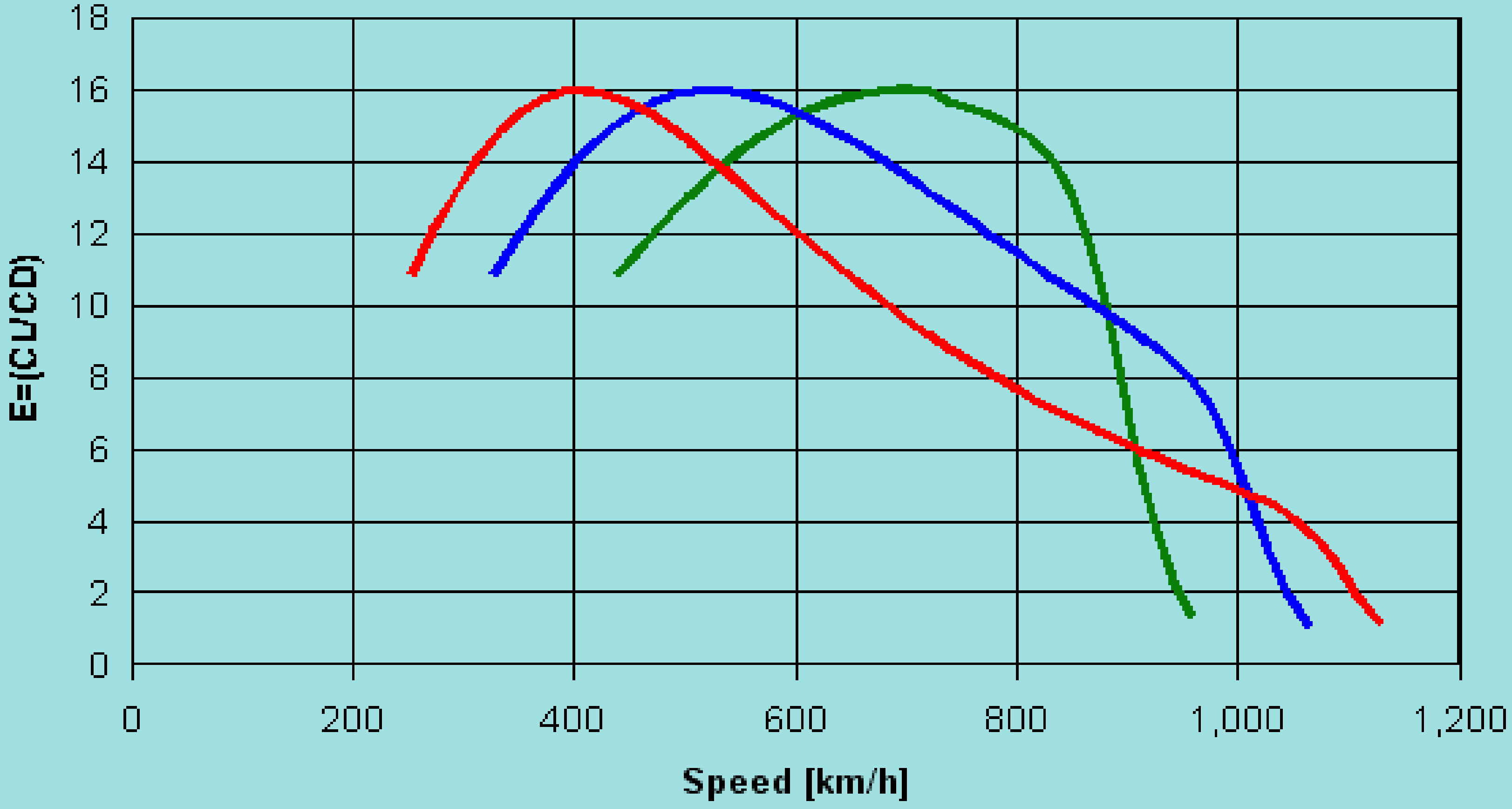
$$\text{Autonomia oraria} \quad En = \frac{1}{c_j} \cdot \frac{L}{D} \cdot \ln\left(\frac{W_i}{W_f}\right)$$

FUEL FRACTION METHOD

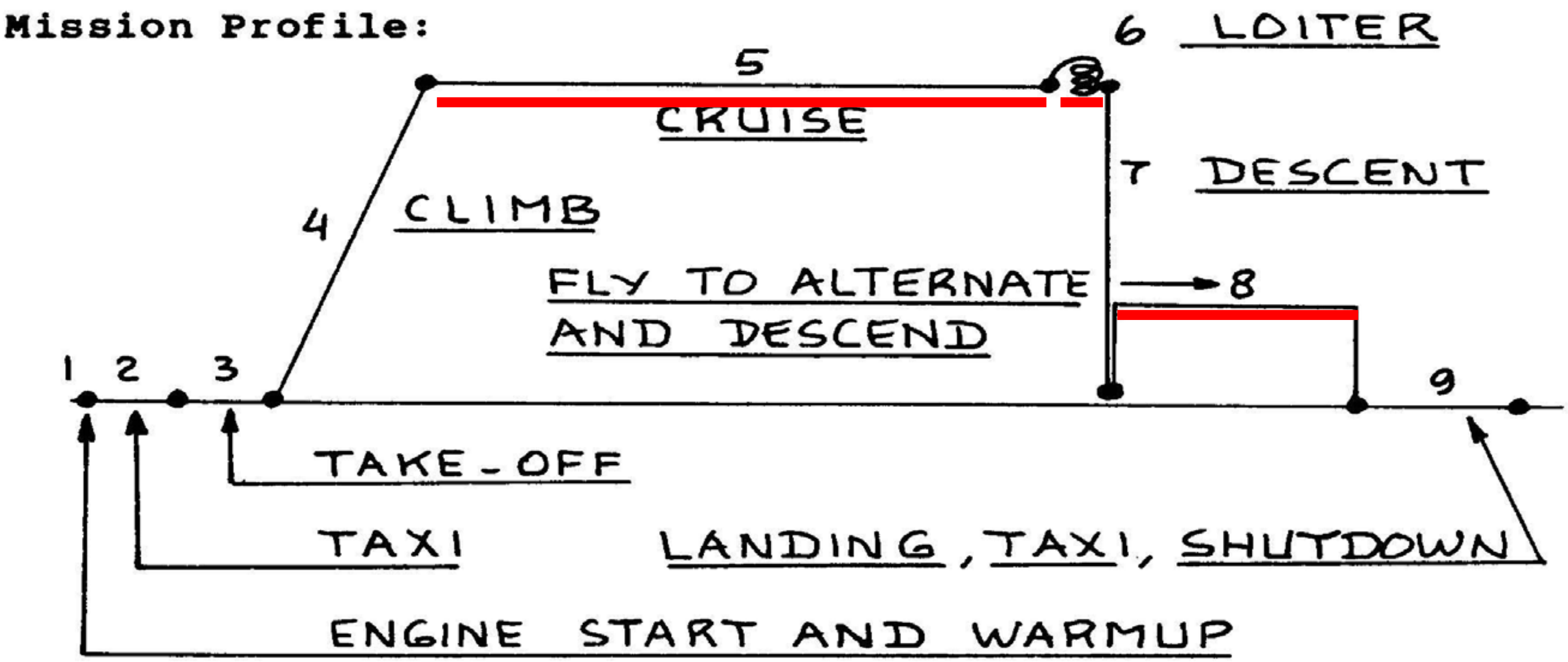
Table 2.2 Suggested Values For L/D, c_j, η_p, And For c_p For Several Mission Phases

	Cruise				Loiter			
	L/D	c_j	c_p	η_p	L/D	c_j	c_p	η_p
Mission		lbs/lbs/hr	lbs/hp/hr			lbs/lbs/hr	lbs/hp/hr	
Phase No. (See Fig. 2.1)		5				6		
Airplane Type								
1. Homebuilt	8-10*		0.6-0.8	0.7	10-12		0.5-0.7	0.6
2. Single Engine	8-10		0.5-0.7	0.8	10-12		0.5-0.7	0.7
3. Twin Engine	8-10		0.5-0.7	0.82	9-11		0.5-0.7	0.72
4. Agricultural	5-7		0.5-0.7	0.82	8-10		0.5-0.7	0.72
5. Business Jets	10-12	0.5-0.9			12-14	0.4-0.6		
6. Regional TBP's	11-13		0.4-0.6	0.85	14-16		0.5-0.7	0.77
7. Transport Jets	13-15	0.5-0.9			14-18	0.4-0.6		
8. Military Trainers	8-10	0.5-1.0	0.4-0.6	0.82	10-14	0.4-0.6	0.5-0.7	0.77
9. Fighters	4-7	0.6-1.4	0.5-0.7	0.82	6-9	0.6-0.8	0.5-0.7	0.77
10. Mil.Patrol, Bomb, Transport	13-15	0.5-0.9	0.4-0.7	0.82	14-18	0.4-0.6	0.5-0.7	0.77
11. Flying Boats, Amphibious, Float Airplanes	10-12	0.5-0.9	0.5-0.7	0.82	13-15	0.4-0.6	0.5-0.7	0.77
12. Supersonic Cruise	4-6	0.7-1.5			7-9	0.6-0.8		

FUEL FRACTION METHOD



FUEL FRACTION METHOD



$$\left(\frac{W_{finale}}{W_{iniziale}}\right)_i$$

FUEL FRACTION METHOD

$$M_{ff} = \frac{W_1}{W_{TO}} \cdot \frac{W_2}{W_3} \cdot \ldots \cdot \frac{W_{n-1}}{W_{n-2}} \cdot \frac{W_n}{W_{n-1}} = \frac{W_n}{W_{TO}}$$

$$M_{res} = \frac{W_{F\ reserve}}{W_{F\ used}}$$

$$W_{F\ used} = W_{TO} - W_n = \left(1 - \frac{W_n}{W_{TO}}\right) \cdot W_{TO} = (1 - M_{ff}) \cdot W_{TO}$$

$$\boxed{W_F = W_{F\ used} + W_{F\ reserve} = (1 + M_{res}) \cdot (1 - M_{ff}) \cdot W_{TO} = f\left(W_{TO}\right)}$$

STUDIO DELLA CONDIZIONE 1

$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$

Può essere espresso come una funzione del peso massimo al decollo attraverso l'applicazione del Fuel Fraction Method

STUDIO DELLA CONDIZIONE 1

$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$

$$W_{tfo} = 0 \qquad \text{se } W_{TO\ atteso} < 100000\ lbs$$

$$W_{tfo} = 0.005 \cdot W_{TO} \qquad \text{se } W_{TO\ atteso} \geq 100000\ lbs$$

STUDIO DELLA CONDIZIONE 1

$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$

Fuel Fraction Method

? ? S S $W_F = f(W_{TO})$

STUDIO DELLA CONDIZIONE 1

$$W_{TO} = W_E + W_{crew} + W_{PL} + W_F + W_{tfo}$$

$$\Downarrow$$

$$\begin{cases} c = 1 - (1 + M_{res}) \cdot (1 - M_{ff}) - M_{tfo} \\ d = W_{PL} + W_{crew} \\ W_E = c \cdot W_{TO} - d \end{cases}$$

CONDIZIONI ED EQUAZIONI

1 - Definizione di W_{TO}

$$\boxed{W_E = c \cdot W_{TO} - d}$$

2 - Legge statistica

$$\boxed{\log_{10} W_{TO} = a + b \cdot \log_{10} W_E}$$

STUDIO DELLA CONDIZIONE 2

$$\log_{10} W_{TO} = a + b \cdot \log_{10} W_E$$

I coefficienti della legge statistica dipendono da

Categoria di velivolo	**Tecnologia di costruzione**

STUDIO DELLA CONDIZIONE 2

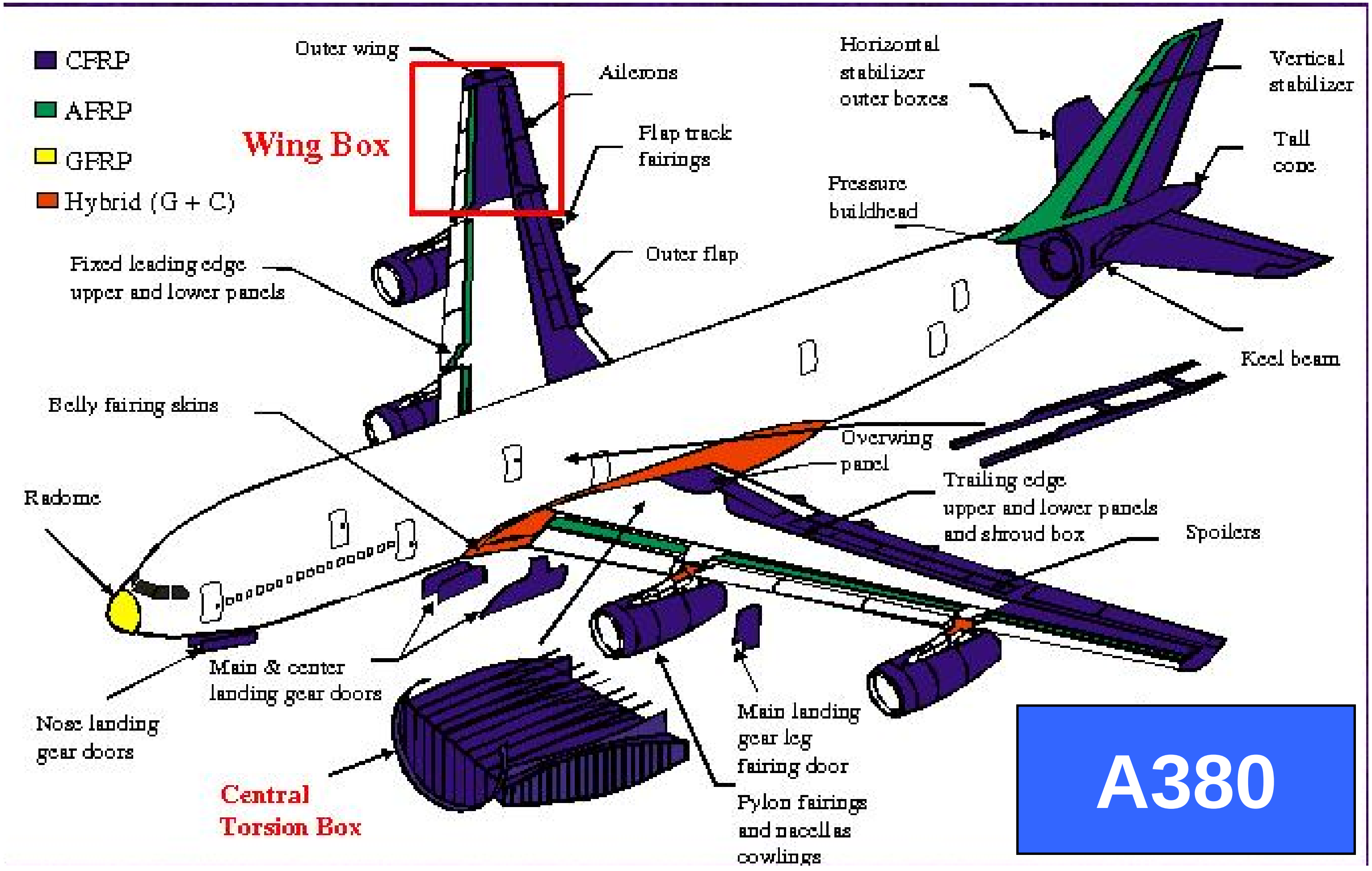
Table 2.15 Regression Line Constants A and B of Equation (2.16)

Airplane Type	A	B
1. Homebuilts		
Pers. fun and transportation	0.3411	0.9519
Scaled Fighters	0.5542	0.8654
Composites	0.8222	0.8050
2. Single Engine Propeller Driven	-0.1440	1.1162
3. Twin Engine Propeller Driven	0.0966	1.0298
Composites	0.1130	1.0403
4. Agricultural	-0.4398	1.1946
5. Business Jets	0.2678	0.9979
6. Regional TBP	0.3774	0.9647
7. Transport Jets	0.0833	1.0383
8. Military Trainers		
Jets	0.6632	0.8640
Turboprops	-1.4041	1.4660
Turboprops without No.2	0.1677	0.9978
Piston/Props	0.5627	0.8761
9. Fighters		
Jets(+ ext.load)	0.5091	0.9505
Jets(clean)	0.1362	1.0116
Turboprops(+ ext.load)	0.2705	0.9830
10. Mil. Patrol, Bomb and Transport		
Jets	-0.2009	1.1037
Turboprops	-0.4179	1.1446
11. Flying Boats, Amphibious and Float Airplanes	0.1703	1.0083
12. Supersonic Cruise	0.4221	0.9876

Equation (2.16) is repeated here for convenience:

$$W_E = \text{invlog}_{10}\{(\log_{10} W_{TO} - A)/B\}$$

STUDIO DELLA CONDIZIONE 2



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STUDIO DELLA CONDIZIONE 2

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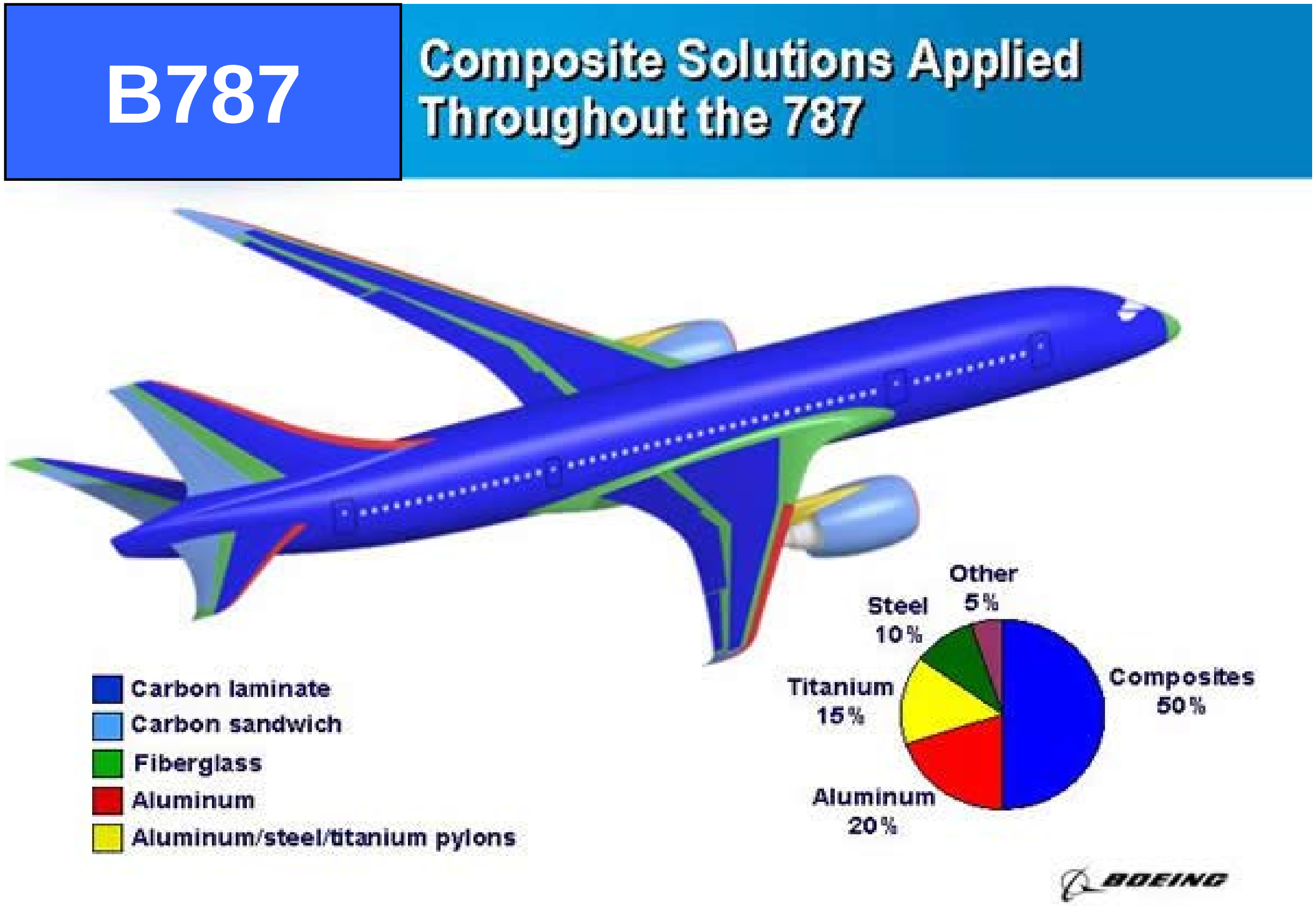


STUDIO DELLA CONDIZIONE 2

Velivoli da trasporto a getto convenzionali

$$a = 0.0833$$

$$b = 1.0383$$

Velivoli da trasporto a getto a lungo raggio

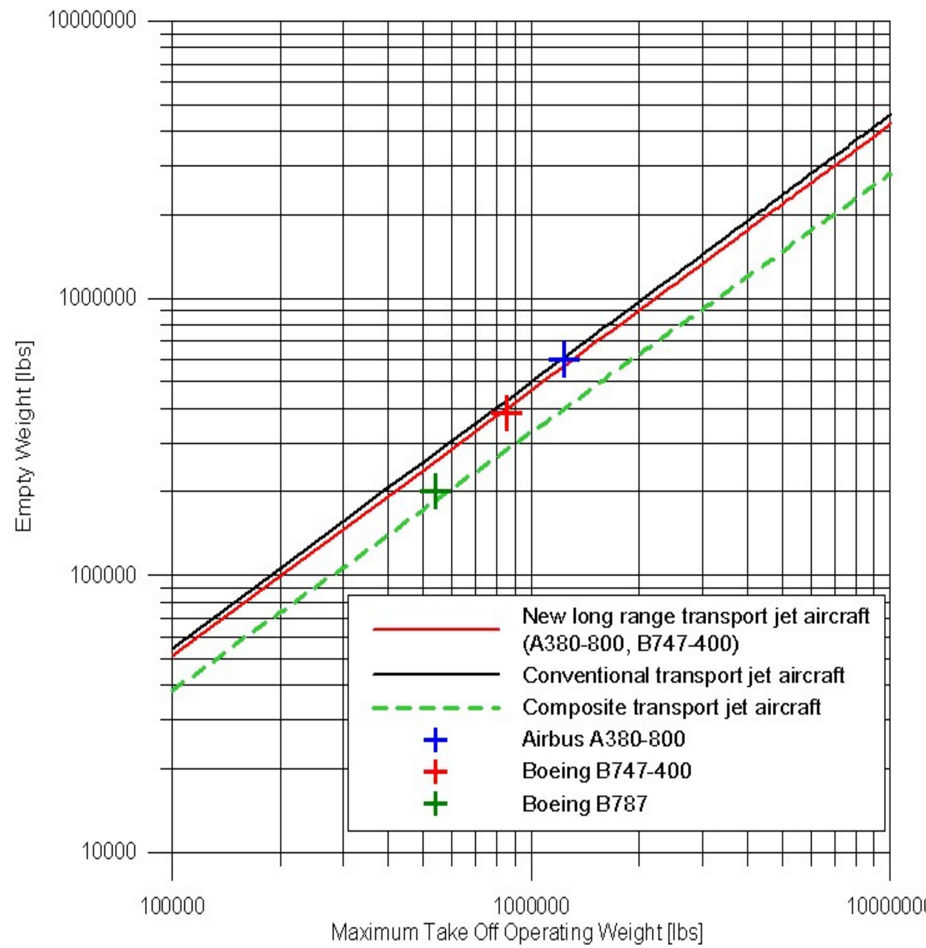
$$a = 0.0913$$

$$b = 1.0425$$

Velivoli da trasporto a getto in composito

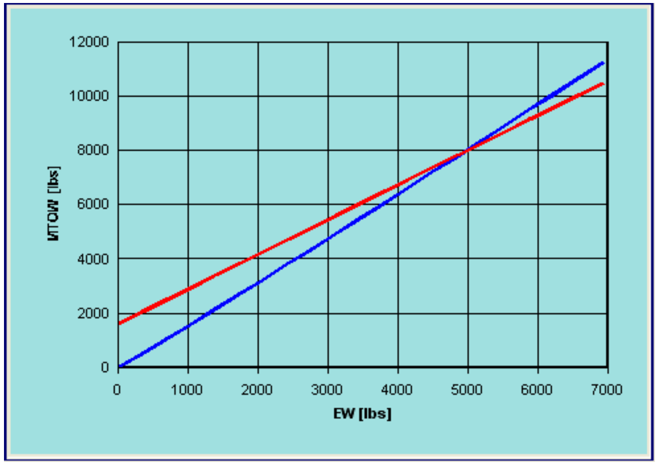
$$a = 0.0810$$

$$b = 1.0730$$



RICERCA DELLA SOLUZIONE

$$\begin{cases} W_E = c \cdot W_{TO} - d \\ W_E = inv\log_{10}\left(\dfrac{\log_{10} W_{TO} - a}{b}\right) \end{cases}$$



Il sistema di equazioni va risolto mediante algoritmo numerico

APPLICAZIONE DEL METODO AL CASO DEL

BOEING B787-8