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Aerospace Vehicle Design And System Integration 3 AENG30013

(AVDASI3)

Operational Performance

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&

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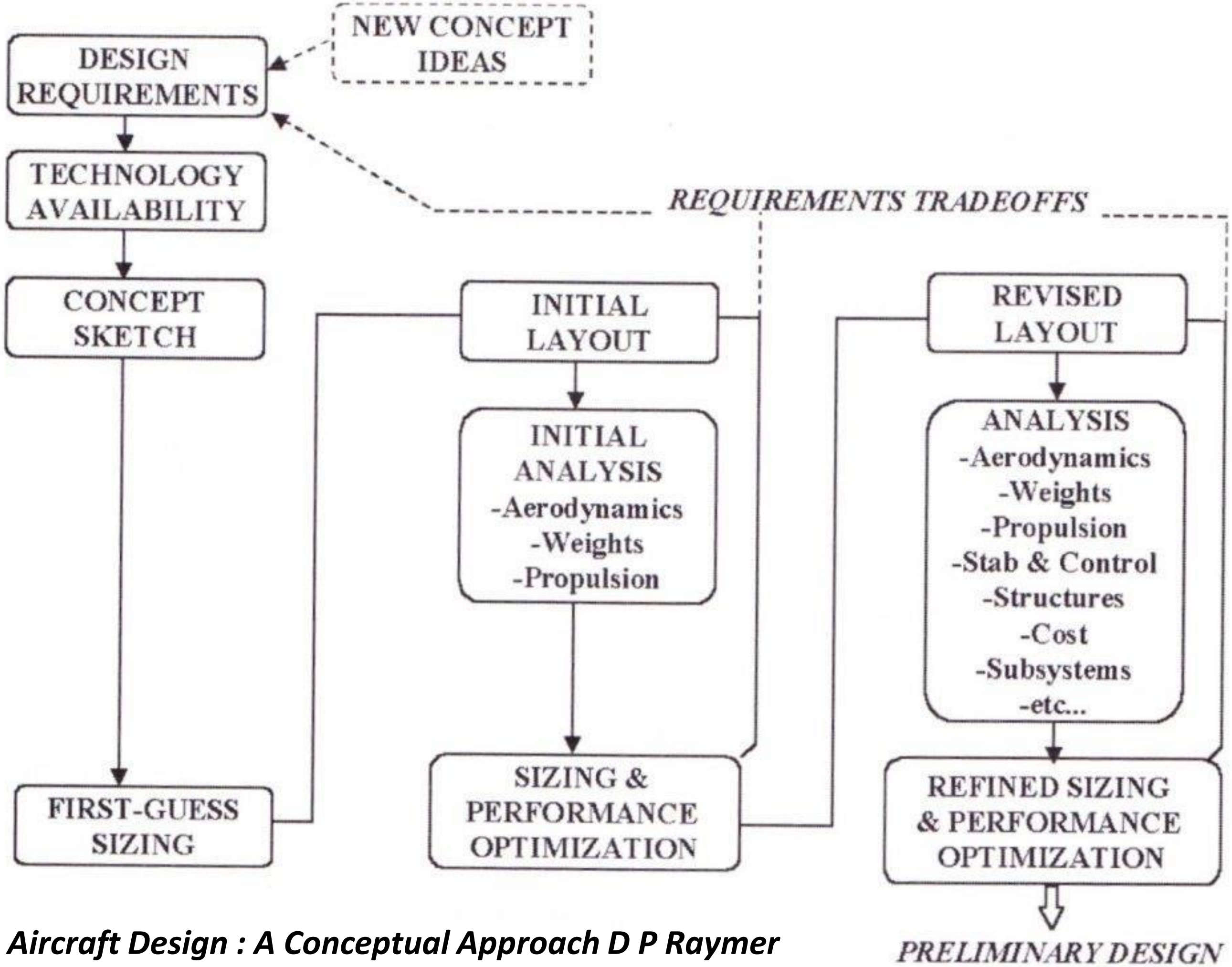
Performance Overall Objectives

- Understand Mission Performance in the context of the Overall Design Process;
- Use the MatLab Tool to calculate Mission Performance for a fixed Aircraft;
- Carry out mission studies varying key parameters.
- Carry out trade studies on the basic aircraft parameters.

The Preliminary Design Process

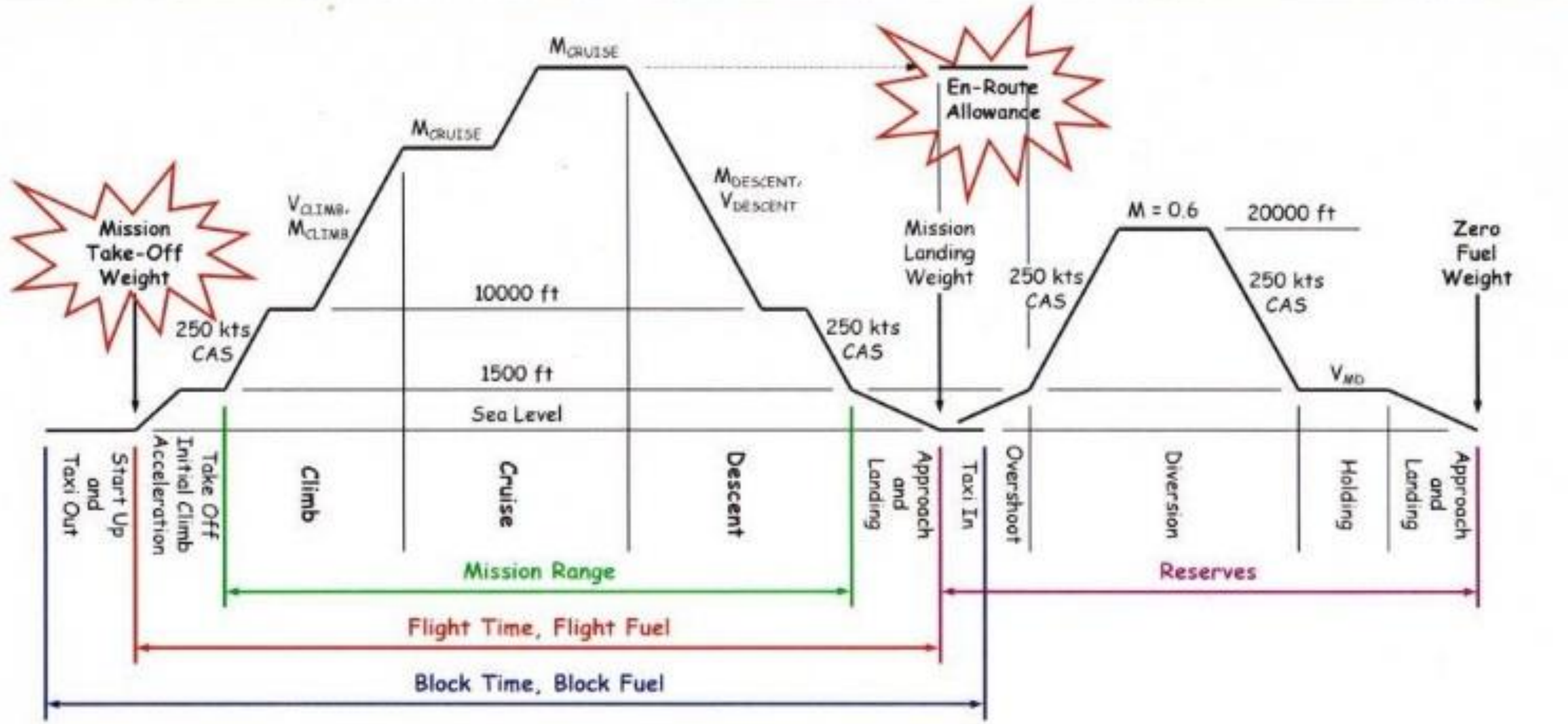
- The purpose of the Preliminary Design Process is to produce a viable aircraft design which meets the following criteria:
  - *Meets the Aircraft Specification i.e. will fly the design range with the design payload & be able to take-off & land at nominated airfields;*
  - *In addition it must be able to manoeuvre safely over the specified flight envelope;*
  - *Meet all environmental & safety requirements as laid down by the certifying bodies.*
- The "best" design is usually the one that meets all of the above using the minimum amount of fuel for the specified mission;
- The aircraft's structure, drag and engine size (and hence fuel burn) are all a first or second order function of the take-off mass.
- Generally this means that the aircraft take-off mass should be minimised.

The Preliminary Design Process

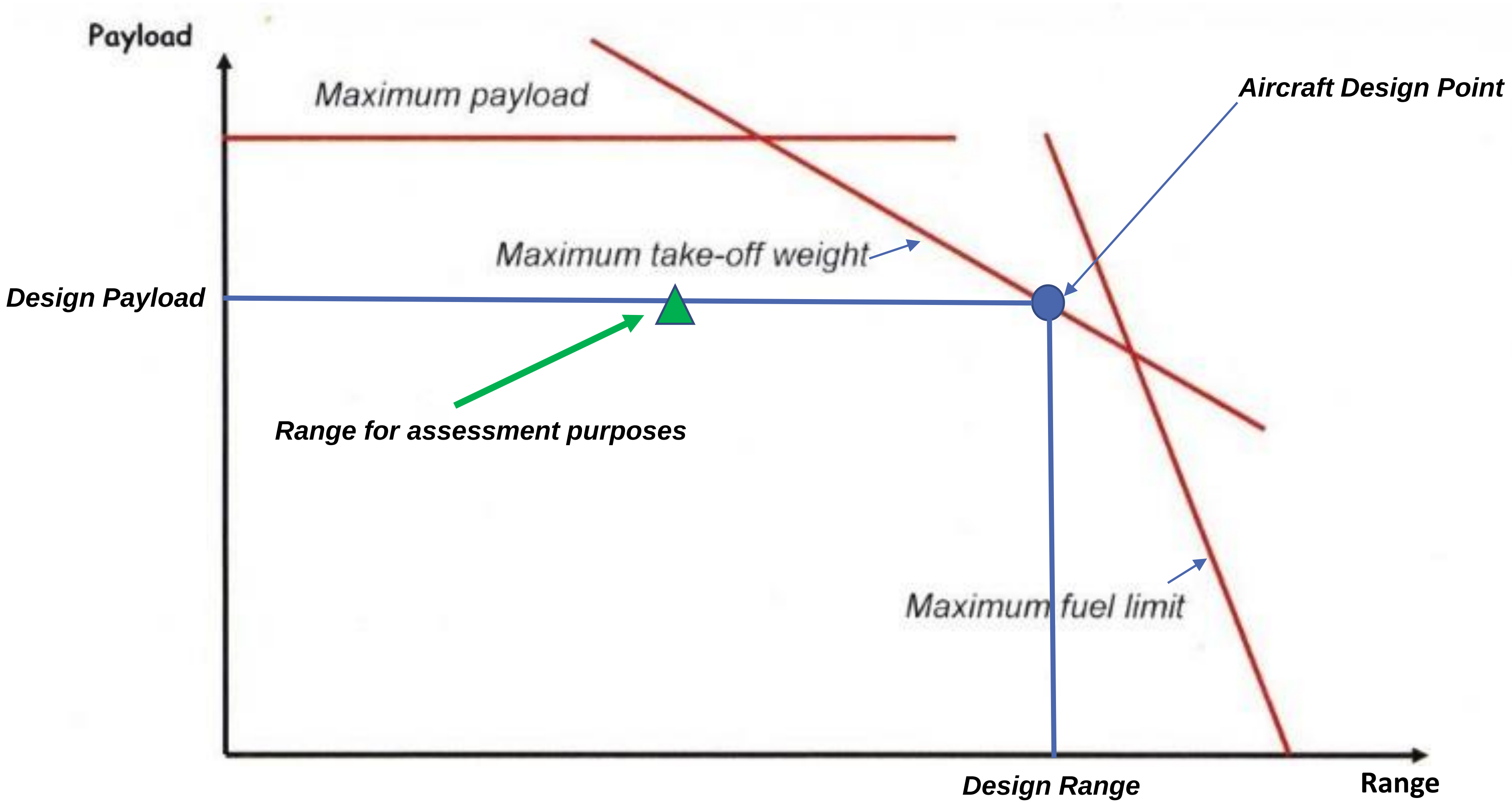


Reference: Aircraft Design : A Conceptual Approach D P Raymer

Typical Mission Profile for a Civil Airliner



Payload Range Diagram



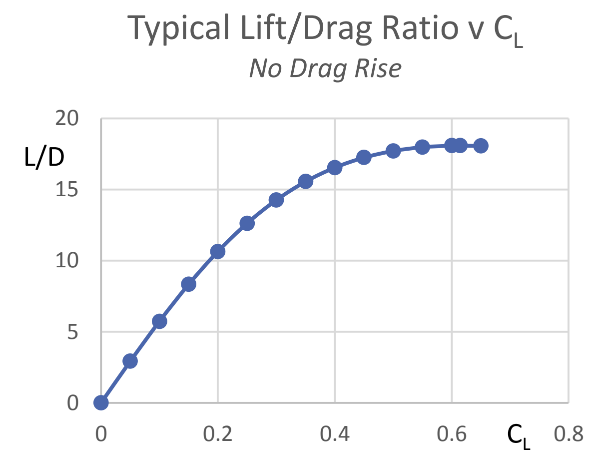
Aircraft Mass Definitions

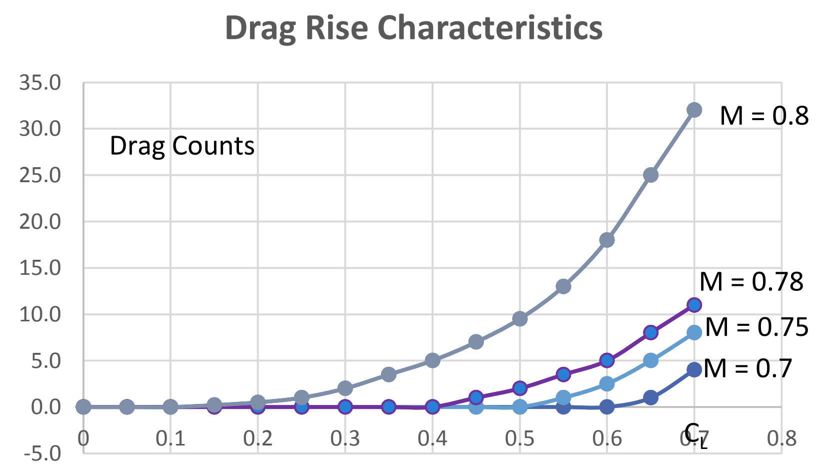
- **MME – Manufacturers Mass Empty** = Mass of aircraft as delivered by manufacturer (without operator items installed).
- **OME – Operators Mass Empty =** MME + operator items necessary for aircraft service, i.e. interior furnishings (galleys, seats, lavatories, entertainment systems), crew (flight deck and cabin attendants), unusable or trapped fuel.
- **MLM – Maximum Landing Mass =** Maximum mass at which aircraft can land safely.
- **MZFM – Max Zero Fuel Mass =** OME + passengers + baggage
- **MTOM* – Max Take-off Mass =** MZFM + full fuel
- **MRM – Max Ramp Mass =** MTOM + Taxi Fuel
- **Design Payload** - Payload at Design Range.
- **Max Payload** – Maximum Payload
- **Max Fuel Capacity** – Maximum Fuel Load

* Maximum cleared mass for take-off i.e. Design Case

Drag Characteristics

- $C_{DTot} = C_{Do} + K\, C_L^2 + \Delta\, C_{Dw} + \Delta\, C_{DRe}$
- C_{DTot} = Total Drag Co-efficient
- C_{Do} = Zero Lift Drag at a Reference Reynolds Number
- K = Induced Drag Factor
- C_L = Lift Coefficient
- $\Delta\, C_{Dw}$ = Increment in drag due to shock wave effects a function of C_L & Mach Number
- $\Delta\, C_{DRe}$ = Increment in Drag due to difference in R_e from Reference R_e

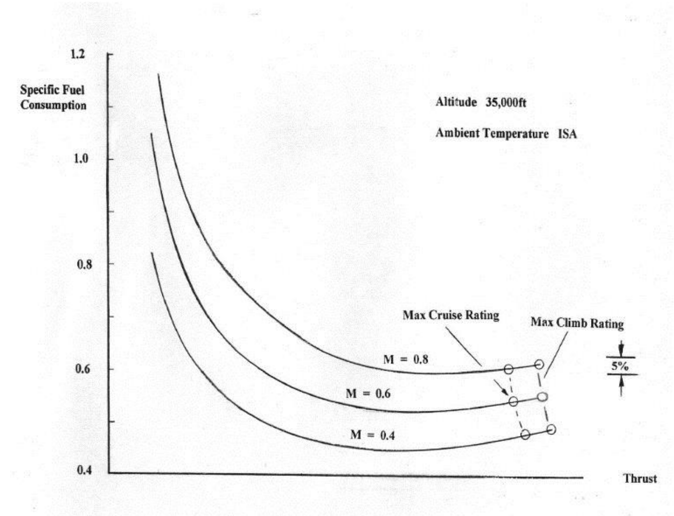


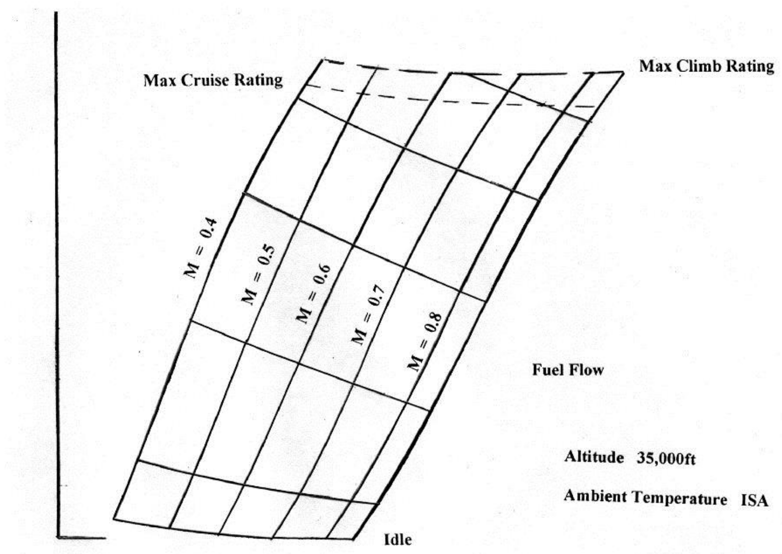


One Drag Count = 0.0001

Engine Data

- The data is in tabulated form of thrust v specific fuel consumption or fuel flow at intervals of Mach Number and altitude.
- The data will cover a range of “throttle settings” from the minimum sustainable (flight idle RC 20) to a maximum cruise (RC 35) & maximum climb (RC 40) rating.
- Thrust v fuel flow can be interpolated linearly.





Mat Lab Mission Phases

1 - 2	Taxi out	Allowance
2 - 3	Take-off to 1500ft	Allowance
3 - 4	Climb 1500ft to Initial Cruise Altitude	Calculation
4 - 5	Cruise	Calculation
5 - 6	Descent final cruise altitude to 1500 ft.	Calculation
6 - 7	Approach	Allowance
7 - 8	Taxi in	Allowance
9 - 10	Overshoot	Allowance
10 - 11	Diversion Climb	Calculation
11 - 12	Diversion Cruise	Calculation
12 - 13	Diversion Descent	Calculation
13 - 14	Diversion Approach	Allowance
15 - 16	En route allowance /Extended Cruise	Calculation

Mat Lab Mission Phases

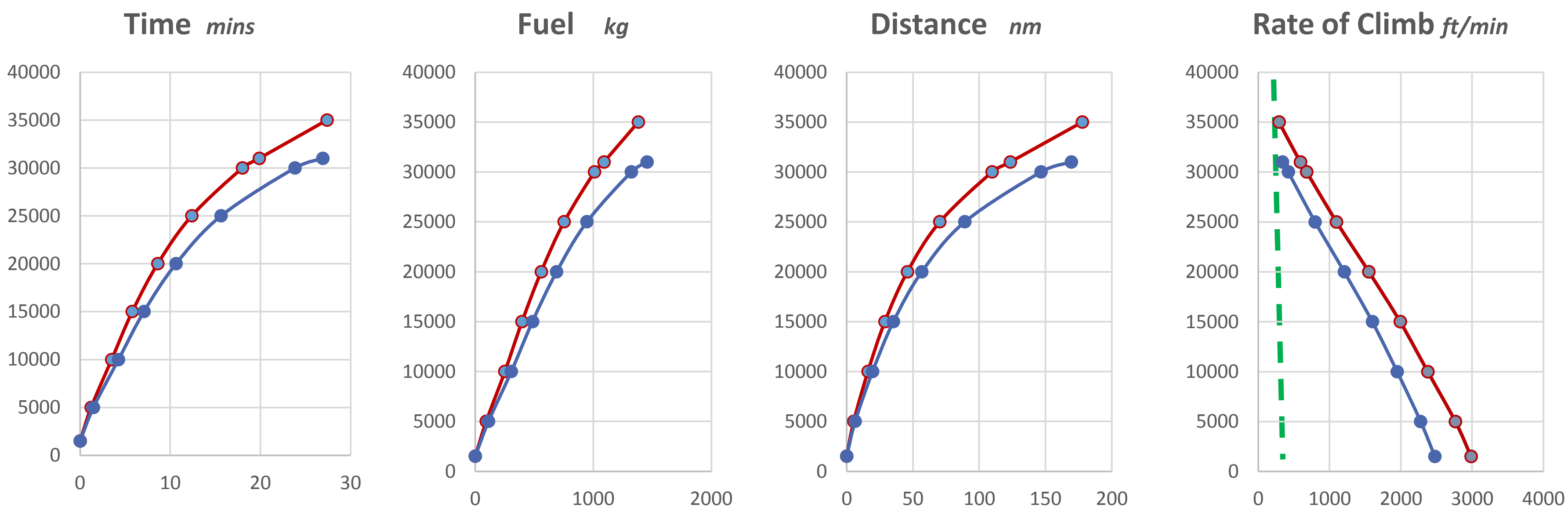
Fixed Allowances - not generally part of an iteration

Taxi out	7 minutes at ground idle fuel flow or a fixed mass of fuel.
Take-off to 1500ft	2 minutes at SLS Take off fuel flow or a fixed mass of fuel.
Approach	5 minutes at Approach Speed & Thrust (flaps down) or a fixed mass of fuel.
Taxi in	7 minutes at ground idle fuel flow or a fixed mass of fuel.
Overshoot	Typically 80% of Take-off to 1500 ft
Diversion Approach	As approach
En route allowance	10 minutes of cruise extended cruise or 5 % of cruise fuel.

Note times may vary with different specifications.

Climb Performance

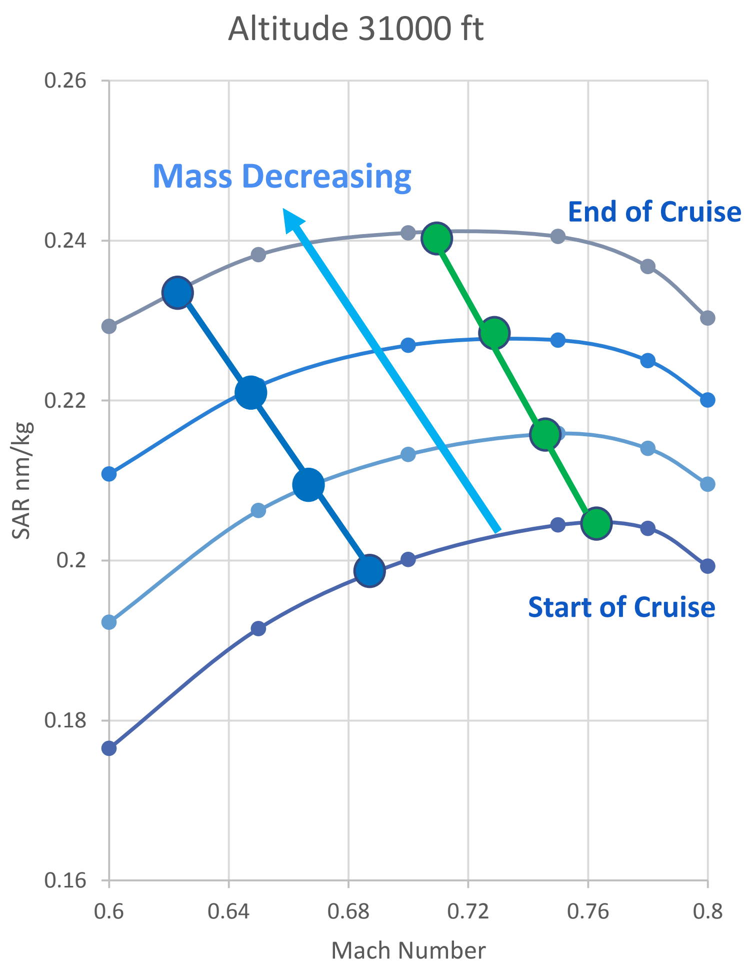
Climb Profile: 250/280 CAS / M = 0.76

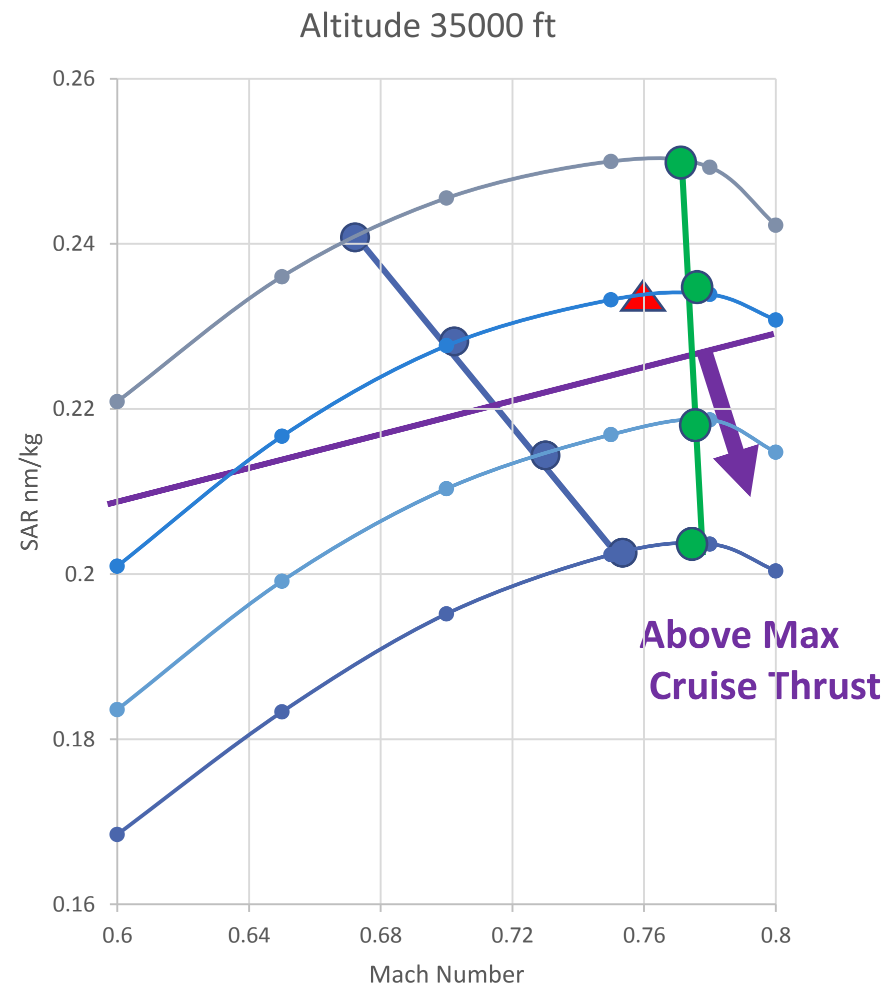


Key: Take off Max ToM   Take off Reduced ToM *(for half range)*
300 ft/min Rate of Climb

It is normal for the top of climb Mach Number to be 0.02M less than the Cruise Mach Number

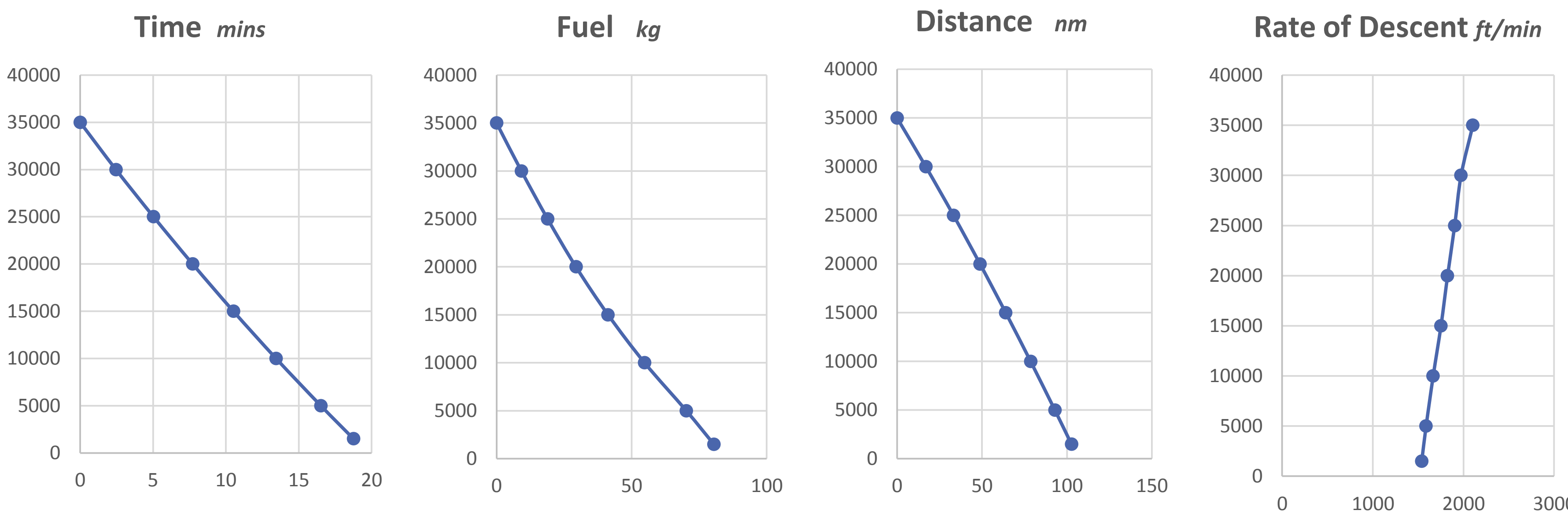
Cruise Performance *Specific Air Range Plots*





Key: Minimum Drag Maximum Specific Air Range Maximum Cruise Thrust 300 ft/min Climb Thrust

Descent Performance



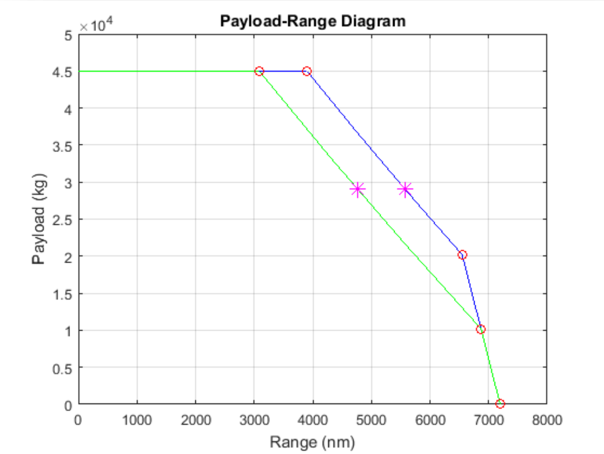
Key: Descent Speed Profile 250 knots CAS Mass at end of cruise
Cabin Altitude 8000 ft. The maximum rate of change of pressure in the Cabin must not exceed 300 ft/min. Hence Descent Time to 1500 ft should be > 22 mins.

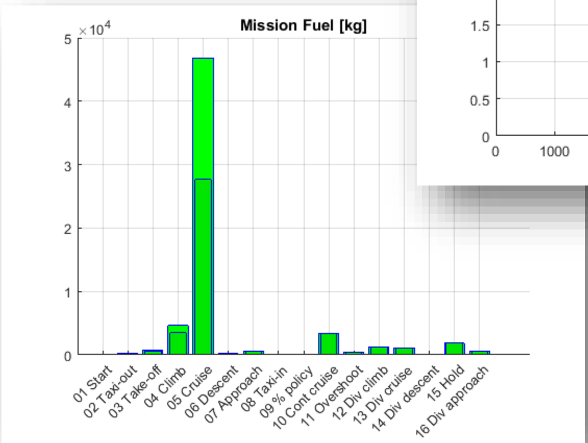
Tutorial Tasks

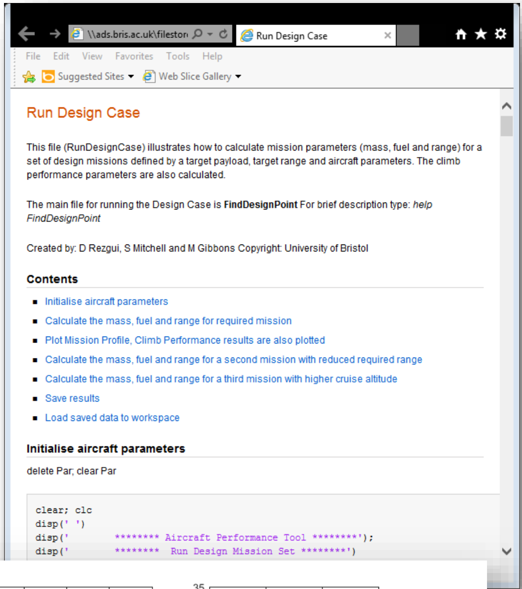
- Produce the Payload Range diagram for a notional 1990's twin engine, Airliner *.
- Show how the range at the "design case" varies with different cruise Mach Numbers & Cruise Altitudes.
- Compare the block fuel & block time at a series of ranges (e.g. London to Beijing 4461 nm plus other ranges) for variations in Cruise Mach Number & altitude.
- Carry out trade studies on the effect on block fuel at a fixed range for changes in OME, Drag & SFC.

* Based largely on the reference aircraft in Chapter 10 of Civil Aircraft Design by Jenkinson, Simpkin & Rhodes.

Fixed Wing Performance Tool







Run Design Case

This file (RunDesignCase) illustrates how to calculate mission parameters (mass, fuel and range) for a set of design missions defined by a target payload, target range and aircraft parameters. The climb performance parameters are also calculated.

The main file for running the Design Case is **FindDesignPoint** For brief description type: *help FindDesignPoint*

Created by: D Rezgui, S Mitchell and M Gibbons Copyright: University of Bristol

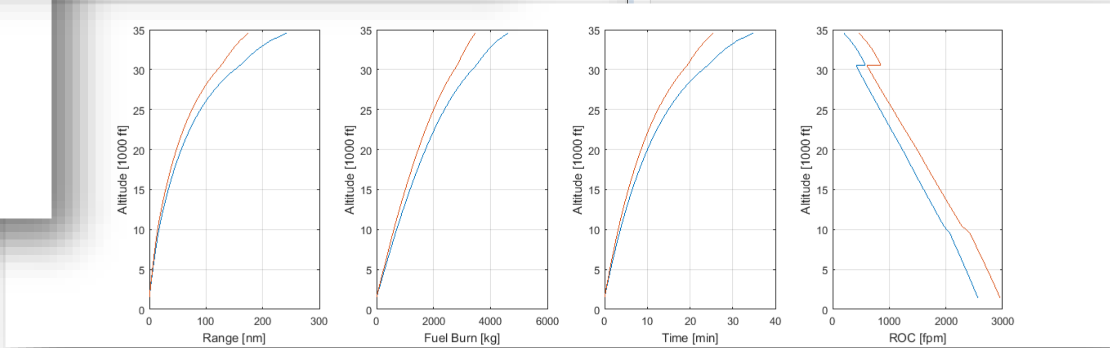
Contents

- Initialise aircraft parameters
- Calculate the mass, fuel and range for required mission
- Plot Mission Profile, Climb Performance results are also plotted
- Calculate the mass, fuel and range for a second mission with reduced required range
- Calculate the mass, fuel and range for a third mission with higher cruise altitude
- Save results
- Load saved data to workspace

Initialise aircraft parameters

delete Par; clear Par

```
clear; clc
disp(' ')
disp('        ******** Aircraft Performance Tool ********');
disp('        ********  Run Design Mission Set ********')
```



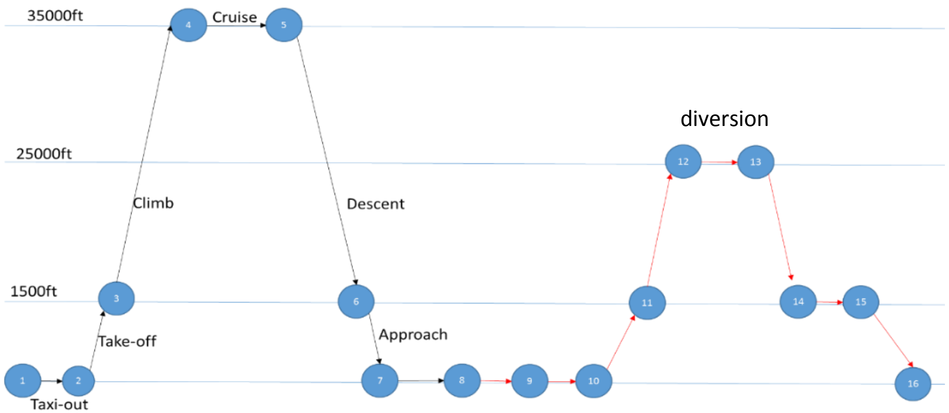
Fixed Wing Performance Tool

- In-house **MATLAB** tool created by **Rezgui, Mitchell and Gibbons**.
- Based largely on the reference aircraft in Chapter 10 of **Civil Aircraft Design** by Jenkinson, Simpkin & Rhodes, with a few modification from the Airbus design guides
- To tool generates the aircraft **Payload-Range Diagram** and calculate the **operational performance** for:
  - Given aircraft parameters (configuration, e.g. wing span, engine data, MTOM, empty mass, drag polar, …)
  - Given aircraft mission (Mach number, altitude, required range, payload, …)
- The tool is simple to use and allows flexibility to customise the run files and plotting functions
- Quick start guide available in the form of html and pdf demo files.

Fixed Wing Performance Tool

- Run files
  - RunDesignCase
  - RunDesignSet
  - RunPayloadRange

- Main function
  - FindDesignPoint
  - FindPayloadRangeDiag



Getting Started with FW Performance Tool

- Download tool from Blackboard
- Go through Quick Start-up Guide (run files and help documents)
- Attempt the tutorial tasks
- Attend labs for the FW Performance design exercise