F16 Capstone Reading - Stevens 181-199

Note - English units have been used rather than SI units

HX is the engine angular momentum constant at 160 slug-ft²

Steady state trim data will be given for: 1) both wings level
2) Non sideslipping flight
3) Turning flight

3.6) Steady State flight

A generic trim program links to any nonlinear model and produces a file containing the steady state values of the control and state vector

Steady state flight conditions cannot be calculated analytically because of the look-up tables
- must be done with an iterative numerical algorithm.

For steady state flight, we specify the altitude and velocity
- control vector is adjusted through SS numerical calculation

→

The state variables, P Q R, ϕ are all zero. ψ can be specified freely. V_T, α, β, θ can be considered.

The book specifies V_T and γ where γ is the flight path angle.

ROC can be determined through trimmed conditions

Steady state turning flight -
ϕ, P, Q, R flight variables are non-zero

The turn is specified by $\dot{\psi}$ - the rate the plane changes headings
θ can be determined from the ROC constraint if ϕ is known
ϕ can be ~~generally~~ freely "specified, but need to be careful of "skidding turns"

ROC constraint -
rate of climb = $V_T \sin(\gamma)$

The turn coordination constraint -
Forces along y-axis sum to 0.
$\dot{V}_T = 0$
$\dot{\phi}\ \dot{\theta} = 0$

$= \sin\phi = G \cos(B)(\sin\alpha \tan\theta + \cos\alpha \cos\phi)$
$G = \dot{\psi} V_T / GD$

Used in conjuction with ROC
this simplifies to:

$$\tan\phi = \frac{G}{\cos(\alpha)} = \frac{\dot{\psi}}{GD}\frac{V_T}{\cos(\alpha)} = \frac{\dot{\psi}}{GD}\frac{V_T}{\cos(B)}$$

This applies to a level non slipping turn

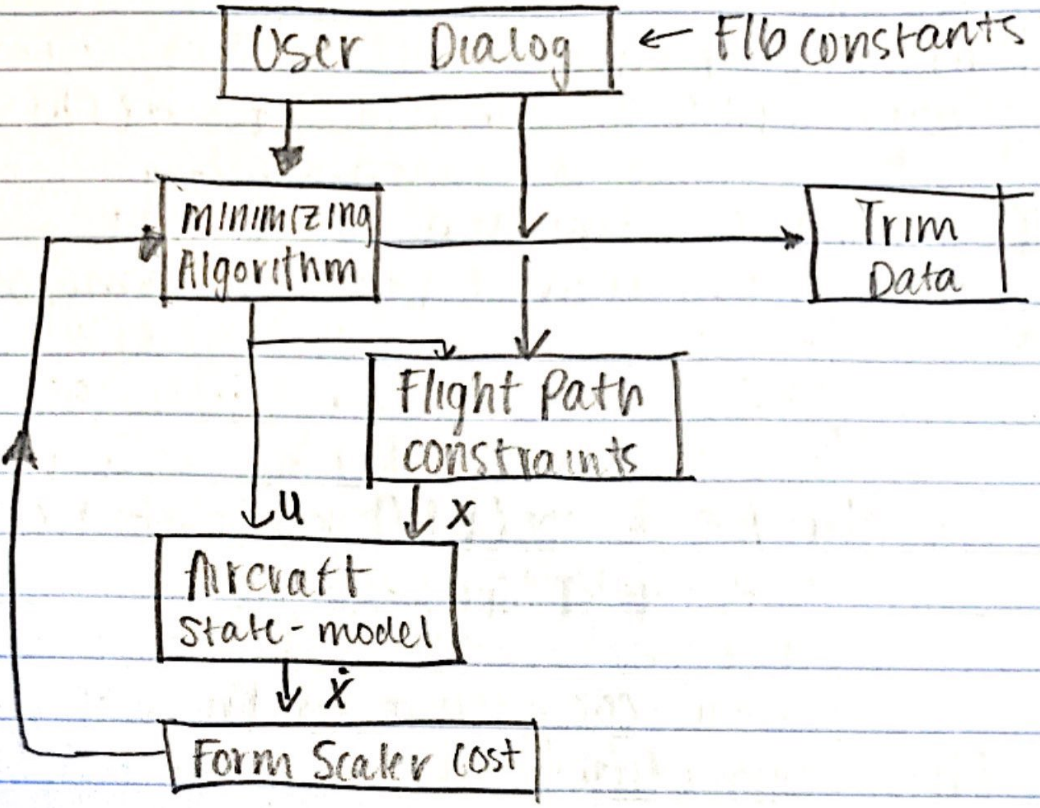
SS Trim Algorithm -

As stated before, flight conditions are determined by making the state derivatives, $(\dot{V}_T\ \dot{\alpha}\ \dot{B})$ and $(\dot{P}\dot{Q}\dot{R})$ zero.

To form the trim Algorithm it is easy to make a "cost function" from the sum of the squares

Scanned with CamScanner

Example of a Scaler Cost Function



Trim Flow chart

Ex 3.6-1 Provides example trim Funct for a 3-DOF model
- This does not implement the above Flow chart, but we can implement on our end.

In appendix B they trim the F-16 model w/ 6DoF dynamics

The F16 cost function sets the engine dynamics to steady state.

coordinated turn SS for full scale F16

$X_1 = 502$ $X_8 = 0.02933811$

$X_2 = 0.2392628$ $X_9 = 0.006084932$

$X_3 = 5.061803E-4$ $X_{10} = 0$

$X_4 = 1.366289$ $X_{11} = 0$

$X_5 = 0.005000808$ $X_{12} = 0$

$X_6 = 0.02340769$ $X_{13} = 64.12363$

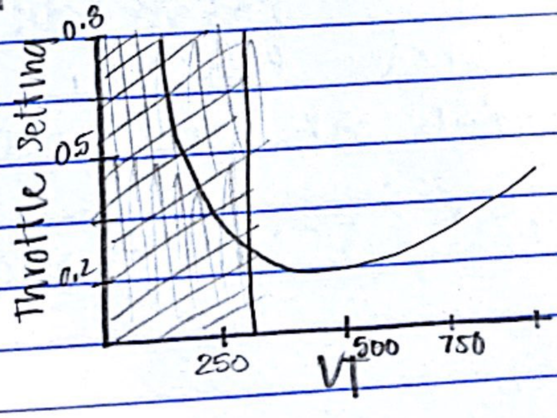
$X_7 = -0.001499617$

$U_1 = 0.8349601$ $U_3 = 0.009553108$

$U_2 = -1.481766$ $U_4 = -0.4118124$

Trimmed conditions for studying aircraft dynamics:

- Steady state performance can be thoroughly investigated through trimmed flight conditions



Power Curve

The region to the left (shaded) is the backside of the power curve when increasing throttle increases Altitude, not velocity.

Using the steady state turn conditions, we can plot Distance N vs distance E and compare the results to the Textbook.