

## AAE 565 Addendum to Notes on Phugoid Trim Analysis

D. An algorithm for solution  
of the 2 nonlinear equations of equilibria

$$f_1(\bar{x}, \bar{u}) = T \cos(\phi_r + \alpha) - W \sin \gamma - D$$

$$f_2(\bar{x}, \bar{u}) = L \cos \gamma + T \sin(\phi_r + \alpha + \gamma) - W - D \sin \gamma$$

$$\text{where } \sin \gamma = h/v$$

Define two specified variables  $\alpha$  and  $T$  as variables that can be set by the pilot. He sets  $\alpha$  with his pitch stick (push/pull), and he sets  $T$  with his throttle/engine controls.

$$\bar{u} = \begin{bmatrix} \alpha \\ T \end{bmatrix}$$

Define two unknown variables  $v$  and  $h$

$$\bar{x} = \begin{bmatrix} v \\ h \end{bmatrix}$$

Given  $\bar{u}$ , find  $\bar{x}$  to make  $\bar{f} = \bar{0}$

where  $\bar{f}$  is a nonlinear function of  $\bar{x}$

An algorithm for finding the zeros of a nonlinear vector function

Given  $\bar{u}$   
 Find  $\bar{x}$  that makes  $\bar{f} = \bar{0}$   
 This is the equilibrium condition where  $\bar{u}$ ,  $\bar{x}$  and  $\bar{f}$  are vectors.

An Algorithm given  $\bar{u}$  and a guess for  $\bar{x}$ ,  $\bar{x}_0$   
 Use Taylor series expansion about  $\bar{x}_0$

$$\bar{f}(\bar{x} + \Delta\bar{x}, \bar{u}) = \bar{f}(\bar{x}_0, \bar{u}) + \left. \frac{\partial \bar{f}}{\partial \bar{x}} \right|_{\bar{x}_0, \bar{u}} \Delta\bar{x} + \text{not ignore}$$

we want to be zero. Solving for  $\Delta\bar{x}$

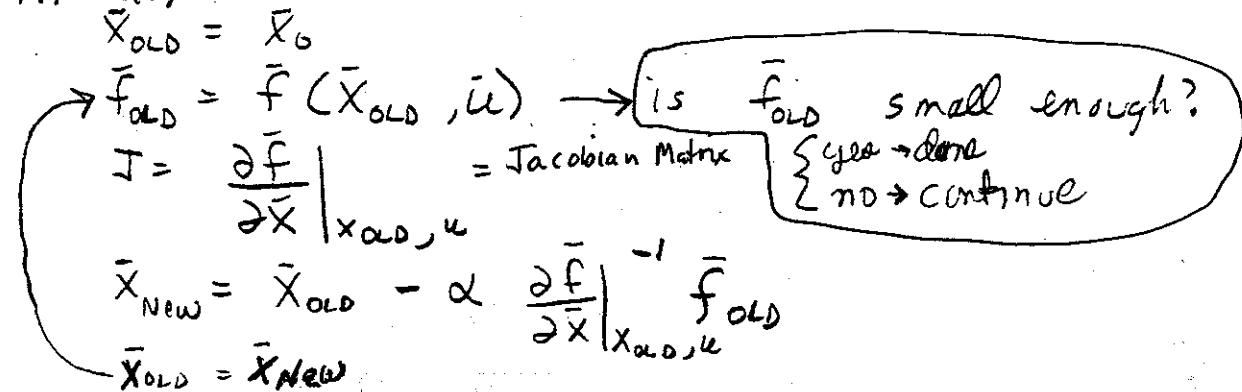
$$\Delta\bar{x} = - \left. \frac{\partial \bar{f}}{\partial \bar{x}} \right|_{\bar{x}_0, \bar{u}}^{-1} \bar{f}(\bar{x}_0, \bar{u})$$

update  $\bar{x}$

$$\bar{x}_{\text{NEW}} = \bar{x}_{\text{OLD}} + \Delta\bar{x} = \bar{x}_{\text{OLD}} - \left. \frac{\partial \bar{f}}{\partial \bar{x}} \right|_{\bar{x}_{\text{OLD}}, \bar{u}} \bar{f}(\bar{x}_{\text{OLD}}, \bar{u})$$

But since we are using linearization, let's not take all of the  $\Delta\bar{x}$ .  
 Let's add in  $\alpha \Delta\bar{x}$  where  $\alpha < 1$  (is a scalar).  
 Let  $\alpha = .25$  and let's use at least 4 iterations around the loop.

The algorithm:



# F. Flight Path Stability

Re: Military Specification on  
Flying Qualities

MIL-F-8785C

3.2.1.3 Flight-path stability. Flight-path stability is defined in terms of flight-path-angle change where the airspeed is changed by the use of pitch control only (throttle setting not changed by the crew). For the landing approach Flight Phase, the curve of flight-path angle versus true airspeed shall have a local slope at  $V_{0min}$  which is negative or less positive than:

- a. Level 1 ----- 0.06 degrees/knot "Good"
- b. Level 2 ----- 0.15 degrees/knot
- c. Level 3 ----- 0.24 degrees/knot. "Bad"

The thrust setting shall be that required for the normal approach glide path at  $V_{0min}$ . The slope of the curve of flight-path angle versus airspeed at 5 knots slower than  $V_{0min}$  shall not be more than 0.05 degrees per knot more positive than the slope at  $V_{0min}$ , as illustrated by:

