AERO 456
FLIGHT TEST TECHNIQUES

AERONAUTICS

LESSON FQ1



Flying Qualities Intro

Longitudinal Stability

A Shift In Thinking

Performance

- Sells airplanes
- Individual Specifications
- Data measured by instruments
- Most data are standardized
- Data values are usually most important
- Propulsion & airframe are driving factors
- Measurements are basis for decisions

Flying Qualities

- Determines if pilots like airplane
- Common Specification
- Data measured by instruments & feel
- Most data are not standardized
- Data slopes are usually most important
- Flight control systems & airframe are driving factors
- Measurements and pilot opinion are basis for decisions

Overview

- MIL-STD-1797
- Flight Control Systems
- Longitudinal Static Stability (Long-Stat)

MIL-STD-1797

- We will use MIL-STD-1797 (2006)
  - Specification for acceptable flying qualities
  - Open & Closed loop Flying Qualities (FQ)
  - Based on research/experience
  - Characterizs good and *bad* flying qualities
- Not an exact science!
  - Can have “good” FQ and still fail MIL-STD-1797
  - Can fully satisfy MIL-STD-1797 and still have “bad” FQ
- MIL STDs use in Acquisition have varied/evolved

Test Objective 1

- **Evaluate Longitudinal Static Stability**
  - **MOP 1-1 :** *Stick-Fixed Neutral Point*

Description	The C.G. location where neutral stability is achieved when the controls are fixed.
Test Methodology	*Long-Stat Stabilized Method FTT* (Appendix C). Vary C.G. between flights to determine the neutral point. Yoke forces will be measured using a handheld force gauge. Yoke deflection will be measured from the firewall using a ruler.
Success Criteria	Four C.G. datasets spanning at least 3.0 inches. Efforts will be made to gather data at the following C.G.s: 40, 41, 42, 43 inches. Each dataset must contain at least 4 airspeed Δ's from trim, one of which less than 60 kts.
Evaluation Criteria	Static Margin: distance between neutral point & Flight Manual (FM) C.G. limits

Criteria -- inches aft of FM limit	**Rating**
> 2"	Satisfactory
1 – 2"	Marginal
< 1"	Unsatisfactory

  - **MOP 1-2 :** *Stick-Free Neutral Point(s)*

Description	The C.G. location(s) where neutral stability is achieved when reversible flight controls are free to float. This location varies with C_L.
Test Methodology, etc.	*Same as MOP 1-1*

  - **MOP 1-3 :** *MIL-STD-1797 Compliance*

Description	Select MIL-STD-1797 criteria have been selected for evaluation.
Test Method. Success Crit.	*Same as MOP 1-1*
Evaluation Criteria	The following MIL-STD-1797 paragraph(s) will be used: 5.2.2.1.2.4 Speed Response to Attitude Changes 5.2.2.1.2.4.1 Direction of Speed Change 5.2.2.1.8.5 Pitch Controller Breakout Forces (Wheel) 5.2.8.3.2 Control Centering 5.2.8.3.3 Control Free Play 5.2.8.3.4 Control Displacement Limits

Refer to the Test Plan

Aircraft Class (p. 84)

- Class I: "Small, light aircraft"
  - T-41D, T-6 Texan II
- Class II: "Medium weight, low-to-medium maneuverability aircraft"
  - C-130, Twin Otter
- Class III: "Large, heavy, low-to-medium maneuverability airplanes"
  - B-52, KC-10, C-17
- Class IV: "High-maneuverability airplanes
  - F-16, A-10, F-22"
- Procuring authority assigns class









Flight Phase Category (p. 44, 88)

- Category A: "Nonterminal, rapid/precision maneuvering/ tracking/control"
  - Air-to-air combat, Air-to-ground bombing, Airdrop, terrain following, receiver refueling



- Category B: "Nonterminal, non-precision tracking"
  - Climb, cruise, descent, refueling (tanker)



- Category C: "Terminal flight phases"
  - Takeoff/catapult, landing, go-around



Flying Qualities Level (p. 46)

- **Level I (Satisfactory)**
  - Flying qualities clearly adequate for the mission…
- **Level II (Tolerable)**
  - Flying qualities adequate to accomplish the mission…
  - but some *increase in pilot workload*
    or *degradation in mission effectiveness*, or both, exists.
- **Level III (Controllable)**
  - The air vehicle can be controlled in the context of the mission
  - even though pilot *workload is excessive*
    or mission *effectiveness is inadequate*, or both.
  - safe.

Flight Envelopes

For each Aircraft Normal State the Flight Envelope is divided into three regions defined in terms of speed, altitude, and load factor, plus any other parameters which may form flight limits (such as sideslip), within which the flying qualities requirements apply. The three regions are:

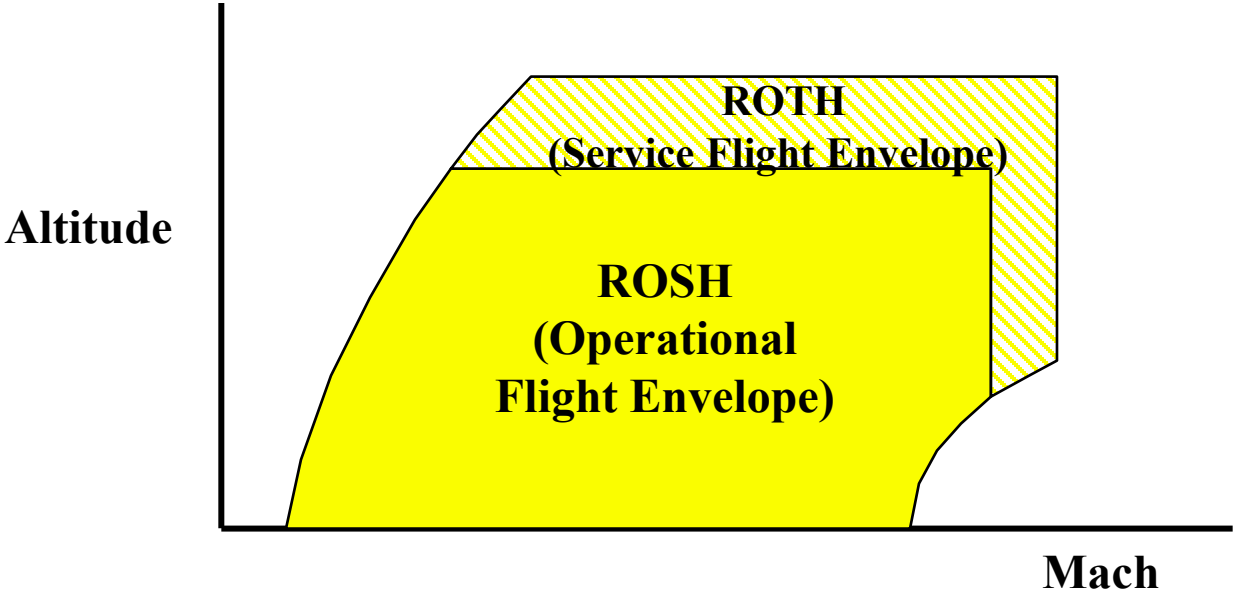
1. Region of Satisfactory Handling (ROSH)
The boundaries of the ROSH are determined by the speed, altitude, and load factor ranges which the aircraft must be able to achieve in order to accomplish the missions of 4.1.1 with Level 1 flying qualities for normal operation.

2. Region of Tolerable Handling (ROTH)
The boundaries of the ROTH are based on speed, altitude, and load factor limits which are derived from aircraft performance margins, such as service ceiling, at or beyond the limits of the ROSH and within which the aircraft must have at least Level 2 flying qualities for normal operation.

3. Region of Recoverable Handling (RORH)
The boundaries of the RORH encompass all regions of the Flight Envelope in which operation of the aircraft is both allowable and possible, and which the aircraft is capable of safely encountering.

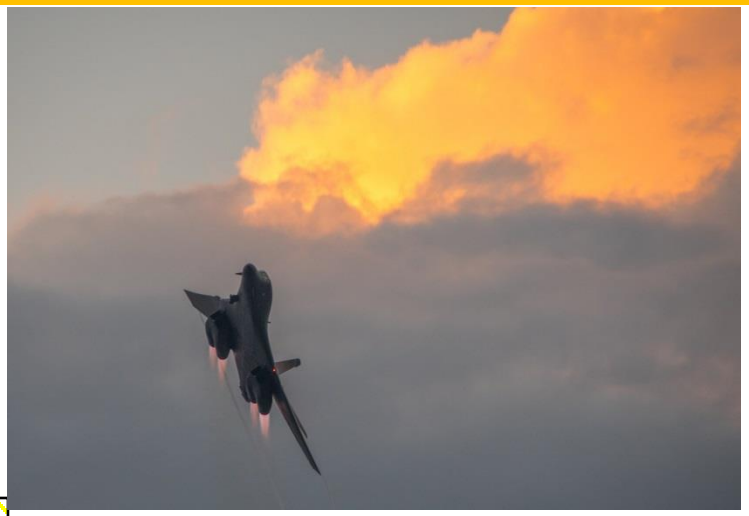
Flight Envelopes (p. 106)

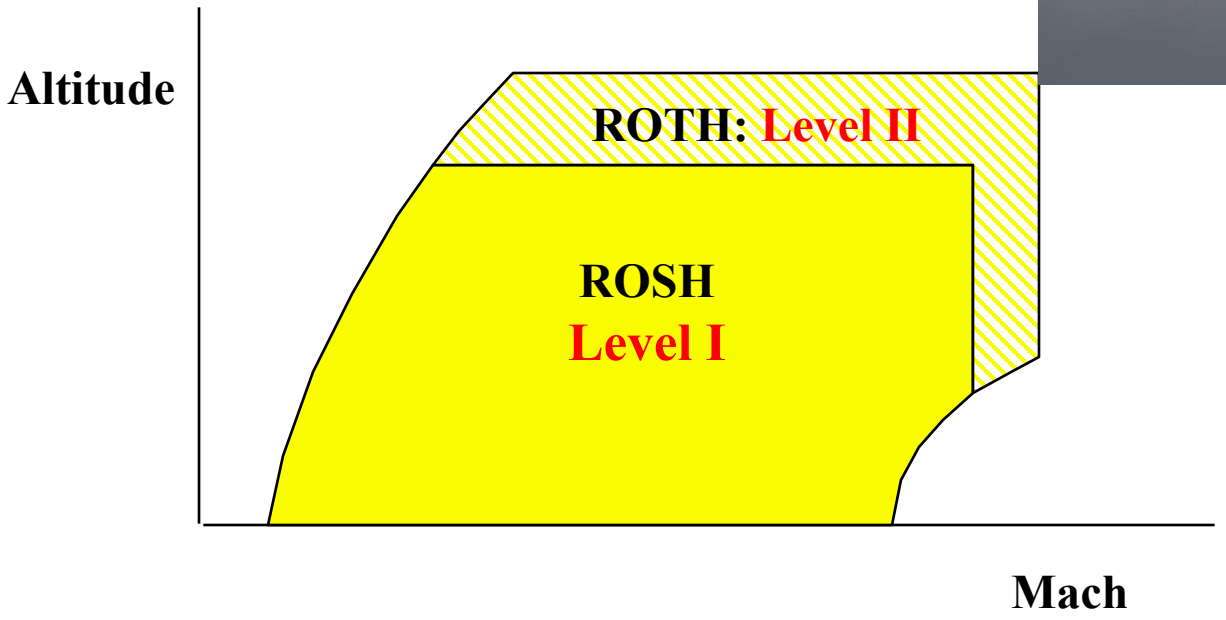
- ROSH (Region of Satisfactory Handling)
  - Often times the Operational Flight Envelope
  - Boundaries defined by mission
- ROTH (Region of Tolerable Handling)
  - Often times the Service Flight Envelope
  - Boundaries set by aircraft limits



Required FQ Levels

- Normal states
  - ROSH: Level I
  - ROTH: Level II





Failure States

Example : The A-10 aircraft incorporates an emergency backup control mode, the Manual Reversion Flight Control System (MRFCS). Maintaining effective control in this mode is a *demanding pilot task*

Level	Probability	
	ROSH (Operational)	ROTH (Service)
2	$<10^{-3}$ per hour	Acceptable
3	$<10^{-4}$ per hour	$<10^{-2}$ per hour

Pg 154

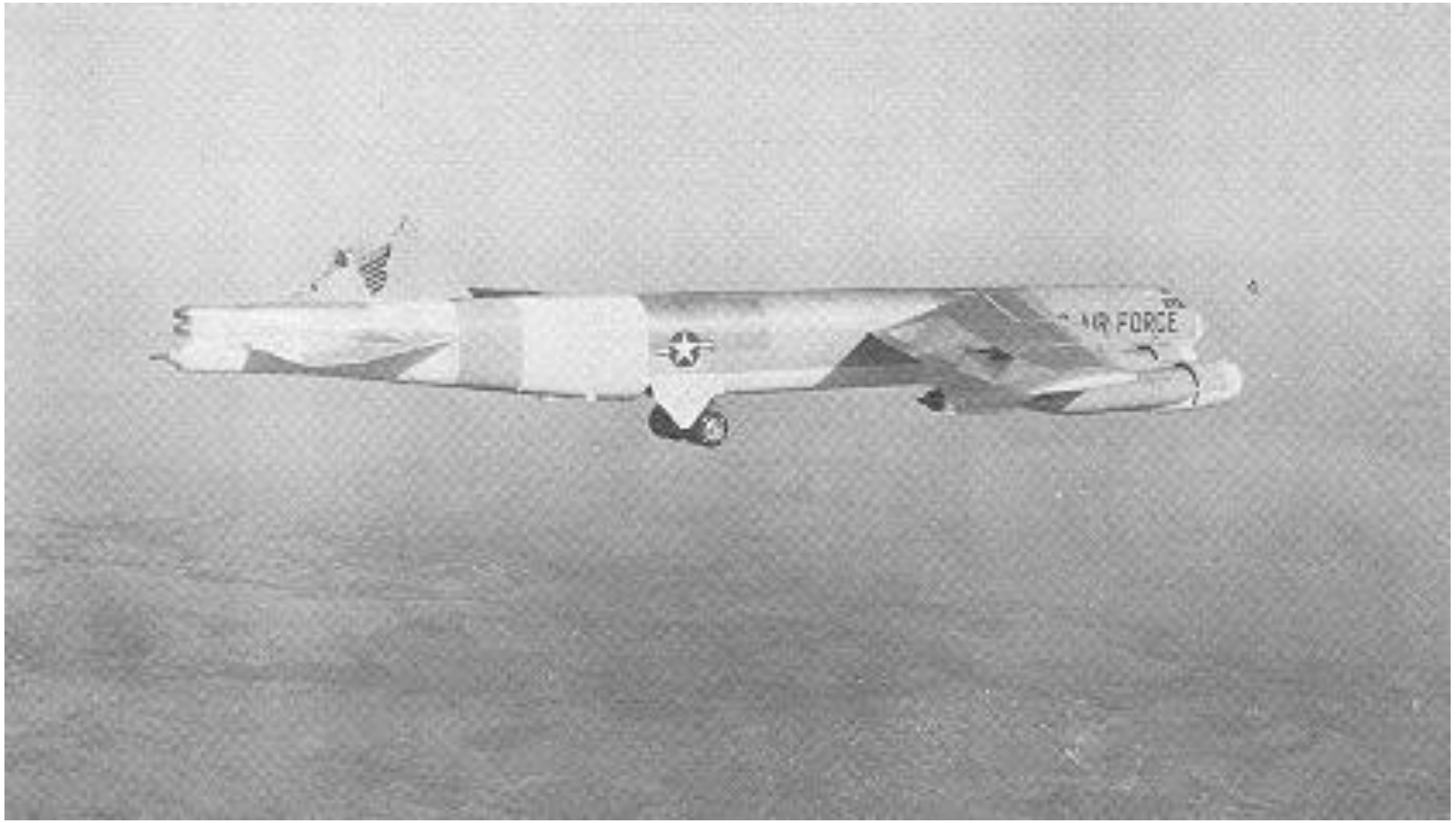




Captain Campbell was asked to divert from her original mission to provide close air support to the troops which was taking heavy fire from the enemy. After a quick situation update and target area study, Captain Campbell expertly employed 2.75 inch high explosive rockets on the enemy position that had been threatening the ground forces, scoring a direct hit and silencing the opposition.
During her recovery from the weapons delivery pass, a surface-to-air missile impacted the tail of Captain Campbell's aircraft. Immediately taking corrective action, she isolated the hydraulic systems and placed the A-10 into the manual reversion flight control mode of flight and prepared for the long and tenuous return flight to Kuwait.

- **Example:** in ROSH Envelope (Level 1 required) aircraft flying qualities, can go to Level II only if the failure state has $<10^{-3}$ /hour chance of occurring.
- **Never below Level III** (except for approved, extremely rare, failure states)

Extremely Rare Failure State?



Reporting MIL-STD Compliance

Example - Briefing

MIL-STD-1797 Paragraph	Requirement	Flight Test Result	Pass/Fail
4.8.4.2.1 Stall Approach.	The aircraft shall exhibit the following characteristics in the stall approach: a. The onset of warning of stall approach (4.8.4.1) shall occur within the following speed range for 1-g stalls: Min: Higher of 1.05 V_s (42 KIAS) or V_s+5 knots (45 KIAS) Max: Higher of 1.15 V_s (46 KIAS) or V_s + 15 knots (55 KIAS) b. An increase in intensity of the warning with further increase in angle of attack shall be sufficiently marked to be noted by the pilot. The warning shall continue until the angle of attack is reduced to a value less than that for warning onset. Prior to the stall, uncommanded oscillations shall not be so severe as to require the pilot's full attention to retain control in the maneuver. c. At all angles of attack up to the stall, the cockpit controls shall remain effective in their normal sense, and small control inputs shall not result in departure from controlled flight.	a. Vs was 40 KIAS, Warning occurred at 45 KIAS (1.12 Vs) b. No Buffet experienced until stall. No uncommanded oscillations prior to stall. c. All controls effective in their normal sense up to the stall	**PASS** **FAIL** **PASS**

- Always state Paragraph # (difficult to find otherwise)
- Procuring authority determines paragraphs to be met

Reporting MIL-STD Compliance

Example - Briefing

4.8.4.2.2	Stall Characteristics
a. Stalls shall not exhibit rolling, yawing, or downward pitching at the stall which cannot be controlled to stay within 20°.	a. No yawing or pitch down tendencies observed. Rolling controllable to within ±15°.
b. No pitch-up tendencies.	b. No pitch-up tendencies observed.

PASS

Reporting MIL-STD Compliance

Example - Briefing

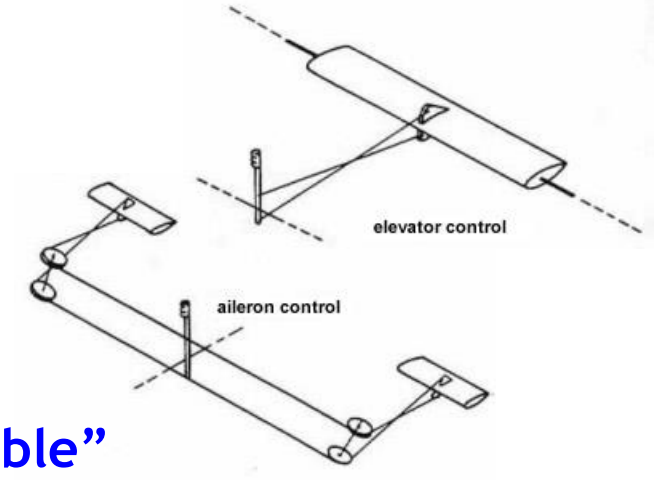
4.8.4.2.2	Stall Characteristics
a. Stalls shall not exhibit rolling, yawing, or downward pitching at the stall which cannot be controlled to stay within 20°. b. No pitch-up tendencies	a. No yawing or pitch down tendencies observed. Rolling only controllable to within ±30°. b. No pitch-up tendencies observed

FAIL

Flight Control Systems

1) Reversible Flight Control Systems

- Stick connected to control surfaces by cables / pushrods
- Control surface movement is proportional to stick movement
- T-41D flight control system is "fully reversible"



2) Boosted-Reversible Flight Control Systems

- Cables move control surface & hydraulic actuators which increase the control force
- Power steering, power brakes in your car
- Can still control surface even with a hydraulic failure (though it may be extremely difficult)
- C-130, C-141 flight control system



Irreversible Flight Control Systems

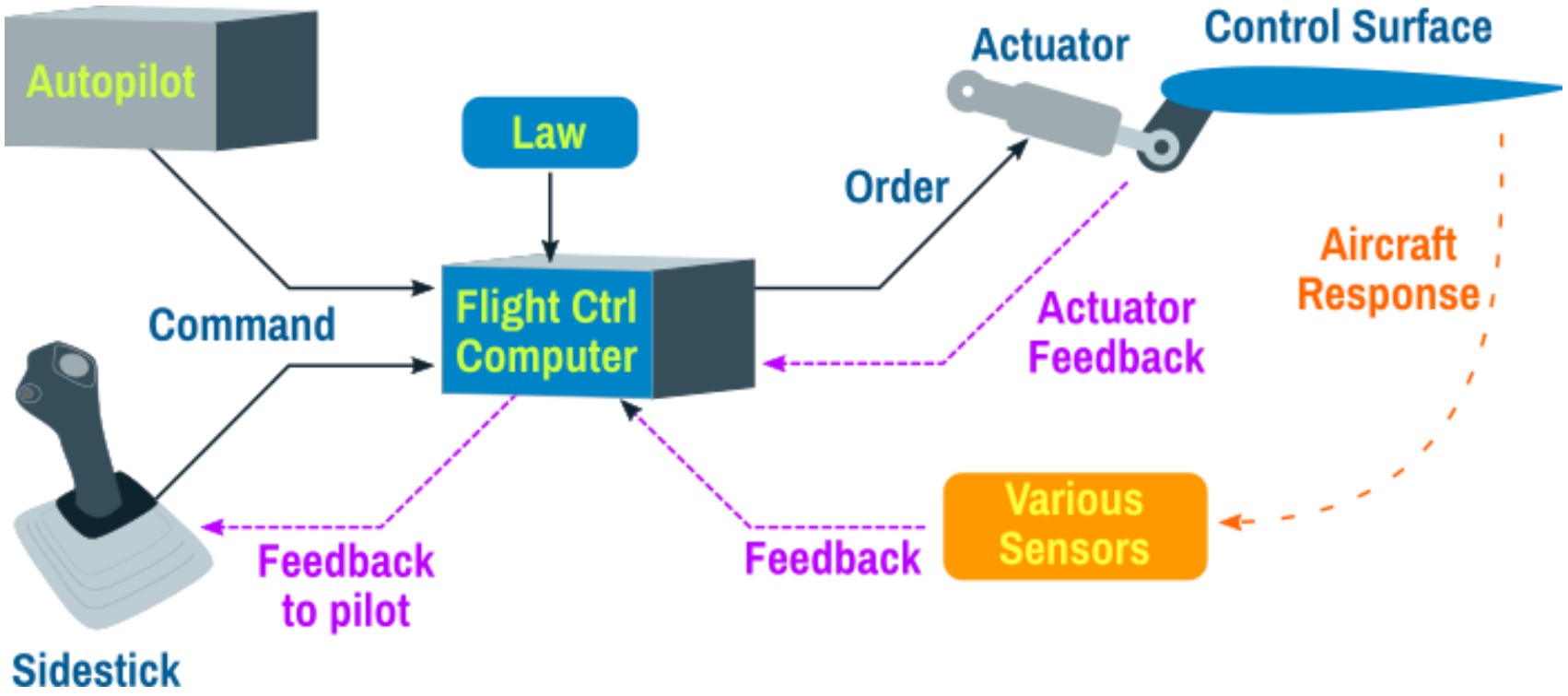
3) Hydro Mechanical:
   - Cables/pushrods connected to hydraulic actuators
   - Requires an artificial feel system
   - Requires redundant hydraulic systems
   - May not be geared proportionately
   - T-38 / KC-10 flight control system



4) Fly-by-Wire:
   - Electrical commands sent to hydraulic actuators
   - FCS computer enables dynamic relationships between stick/pedals and control surfaces
   - Allows flight with statically unstable aircraft
   - Requires redundant hydraulic systems
   - Requires computers, air/inertial data feedback
   - F-16/F-22/F-35, C-17 (FBW) / NASA F-18 (FBL)



Irreversible Flight Control Systems



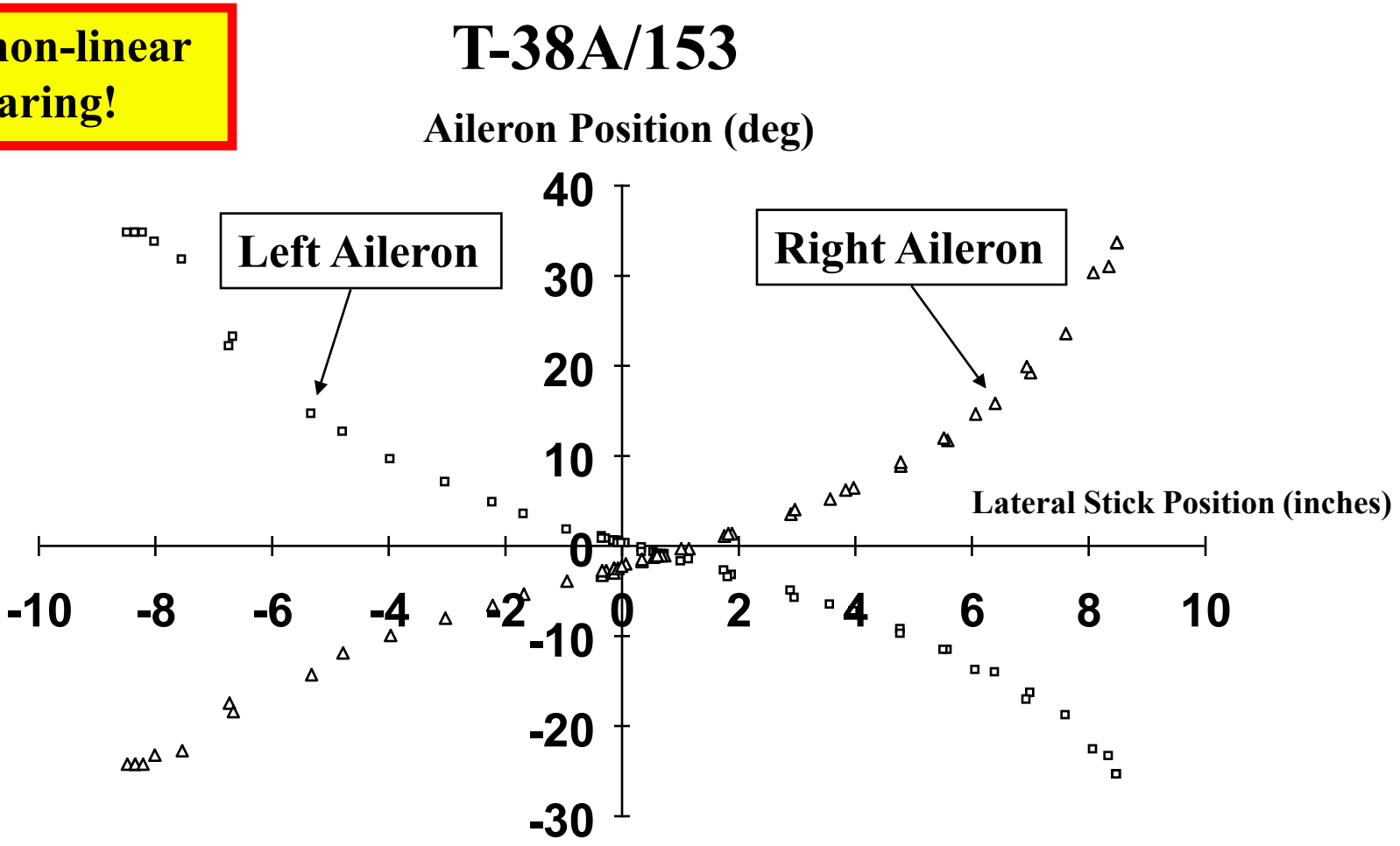
Reporting Flying Qualities

IT IS CRITICAL TO DESCRIBE THE AIRCRAFT FLIGHT CONTROL SYSTEM IN ANY FLYING QUALITIES REPORT

- **Example: The T-38 lateral control system is not proportional**
  - **The initial 3/4 lateral stick deflection give the first 1/2 aileron deflection linearly**
  - **The remaining 1/4 lateral stick deflection gives the remaining 1/2 aileron deflection**
  - **Hint: Remember this for your T-38 report/briefing test item description**

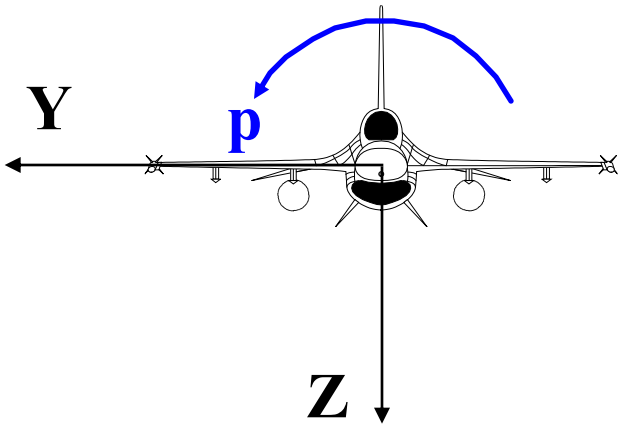
T-38 Lateral Flight Control System

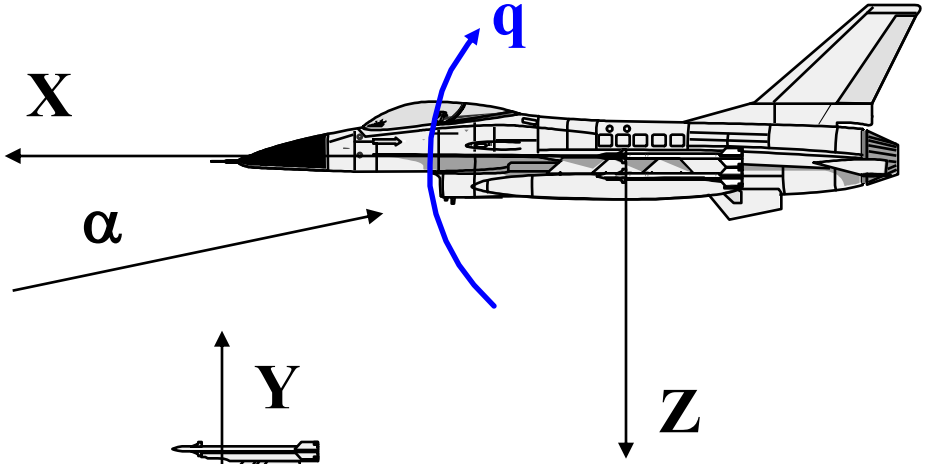
Note non-linear gearing!

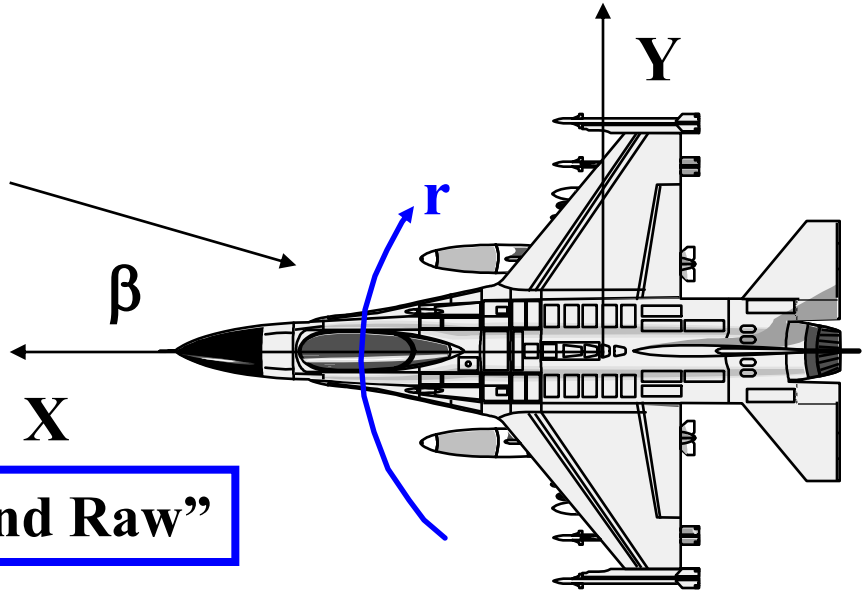


Axes Convention

- Aero Engr 456 will use the following sign convention







"Proll, Quitch and Raw"

All directions shown are positive

TPS Sign Convention

Control Force	Surface Deflection	Aircraft Response	Rate	Moment	Angle
Aft Stick (+)	Elevator TEU (-)	Pitch Up	(+Q)	(+M)	(+Δα)
Forward Stick (-)	Elevator TED (+)	Pitch Down	(-Q)	(-M)	(-Δα)
Left Stick (-)	*Right Aileron TED (+)* *Left Aileron TEU (-)* Composite Aileron (-)	Roll Left (LWD)	(-P)	(-L)	(-ΔΦ)
Right Stick (+)	*Right Aileron TEU (-)* *Left Aileron TED (+)* Composite Aileron (+)	Roll Right (RWD)	(+P)	(+L)	(+ΔΦ)
Left Pedal (-)	Rudder TEL (+)	Yaw Left	(-R)	(-N)	(+Δβ)
Right Pedal (+)	Rudder TER (-)	Yaw Right	(+R)	(+N)	(-Δβ)

Basic surface deflections correspond to the right hand rule (except aileron).

Longitudinal Static Stability (Long-Stat)

- Good long-stat is required for a stable bombing platform
- XB-35/YB-49 Flying Wing
- B-2 achieves this through active flight controls





Definitions

- C.G. location (h):

$$h = \bar{x}_{cg} = \frac{x_{cg}}{c}$$

x_{cg} ← from LE MAC

c ← MAC

- Trim: $\Sigma M_{cg} = 0$ $\Sigma F_{cg} = 0$
  - Not necessarily level flight! (Unaccelerated climbs, dives, …)
  - Stick and pedal forces = 0
- Static stability: initial tendency of aircraft when displaced from trim condition to return to trim
- Long-Stat: pitch stability (gust stability)
  - Returns to a trim C_L (or α at low angles of attack)

Stick Fixed/Free Neutral Point

- Stick-fixed neutral point (h_n)
  - C.G. where aircraft displays neutral long-stat with controls held

$$\frac{\partial C_m}{\partial C_L} = 0$$

- Stick-free neutral point (h_n')
  - C.G. where aircraft displays neutral long-stat with controls free
  - Reversible flight control systems only

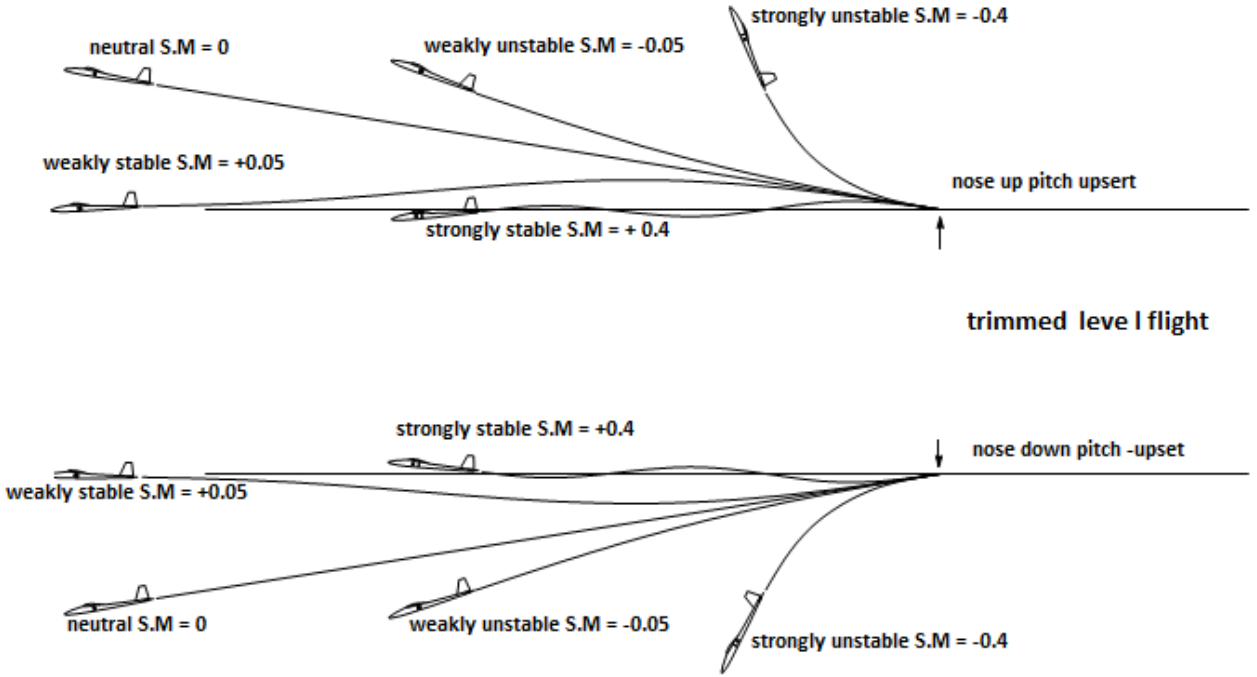
    (Apparent stability for irreversible FCS)

$$\frac{\partial\left(\frac{F_e}{q}\right)}{\partial C_L} = 0$$

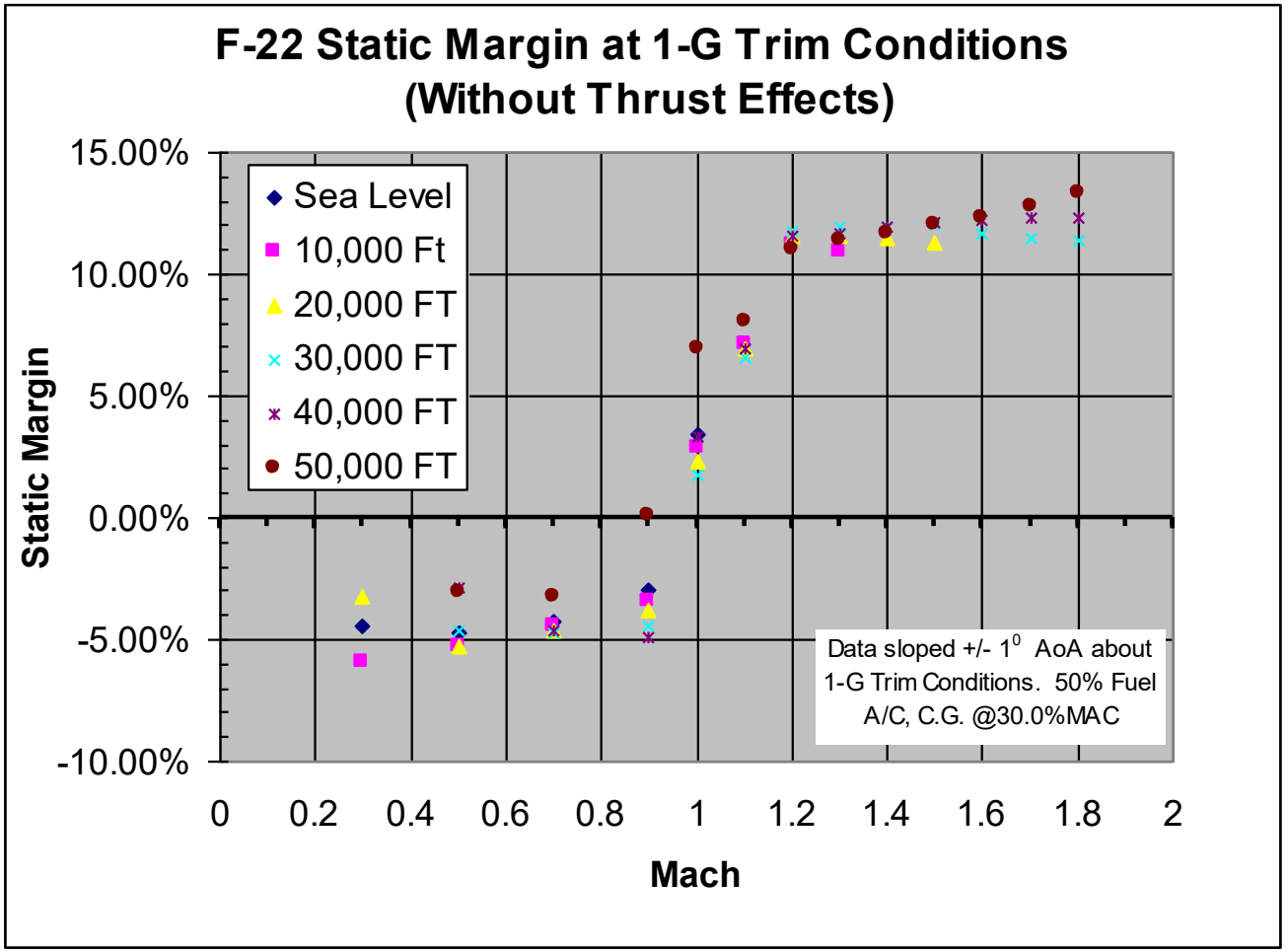
Static Margin

- **Static Margin: $SM = h_n - h$**
  - **Measure of the magnitude of longitudinal static stability**
  - **Uses stick fixed neutral point**
  - **Neutral: SM =0**

Ex. F-16<1.0M SM<0 F-16>1.0M SM>0

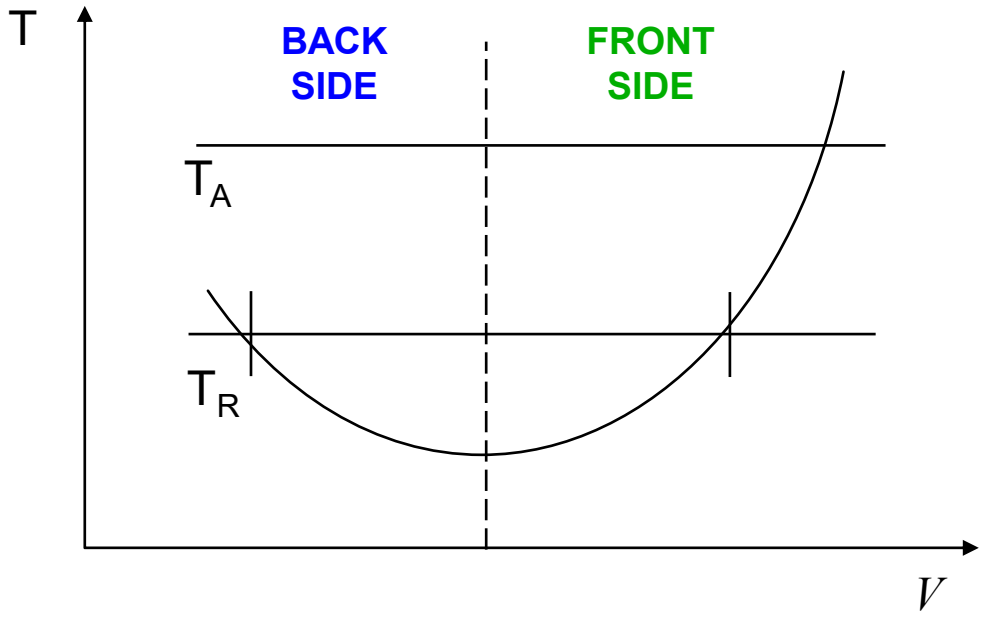


F-22A Static Margin



Speed Stability

- Speed Stability
  - Returns to trim speed if disturbed
  - Primarily related to front side v. back side of the T_R curve
  - T-38: Trim forward as speed increases
  - F-16: No speed stability (g-command FCS)

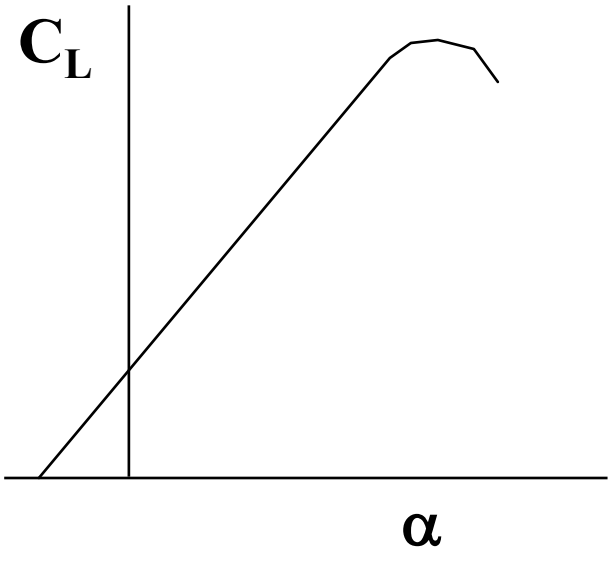


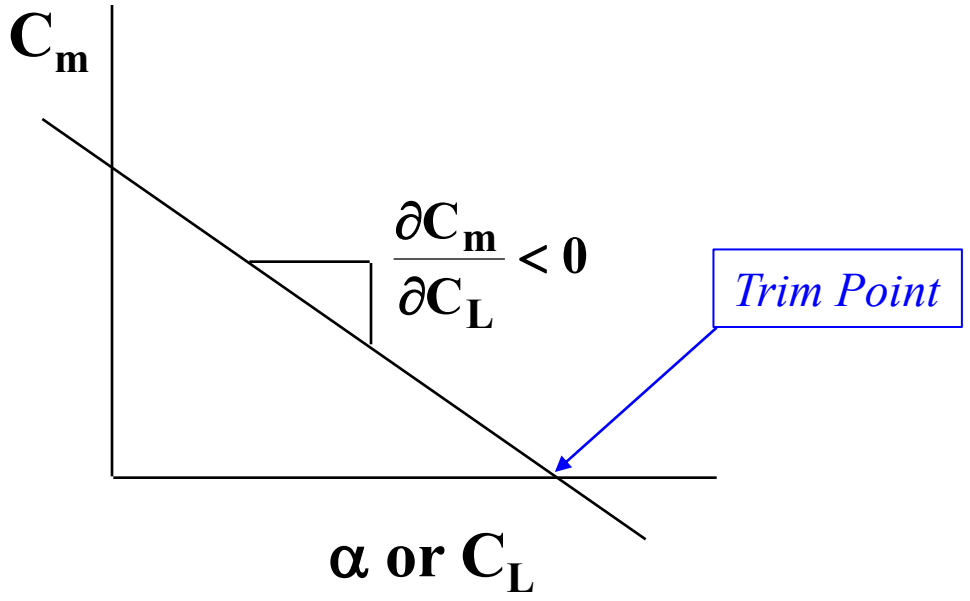


Stability Criteria

- To be useful, an aircraft must be able to be trimmed
  - $C_m = 0$ *at a useful (positive)* C_L

- To be stable, the slope of C_m vs C_L must be negative





Stability Equations

- Assumes: fixed horizontal tail, elevator and trim tab *(T-41D)*

$$V_H = \frac{\ell_t S_t}{Sc} \longleftarrow \text{Tail Volume Ratio}$$

$$C_{m_\alpha} = C_{L_\alpha}\left[\left(h - h_{ac_{wb}}\right) - V_H \frac{C_{L_{\alpha_t}}}{C_{L_\alpha}}\left(1 - \frac{\partial \varepsilon}{\partial \alpha}\right)\right] \longleftarrow \text{Slope}$$

(think stability level)

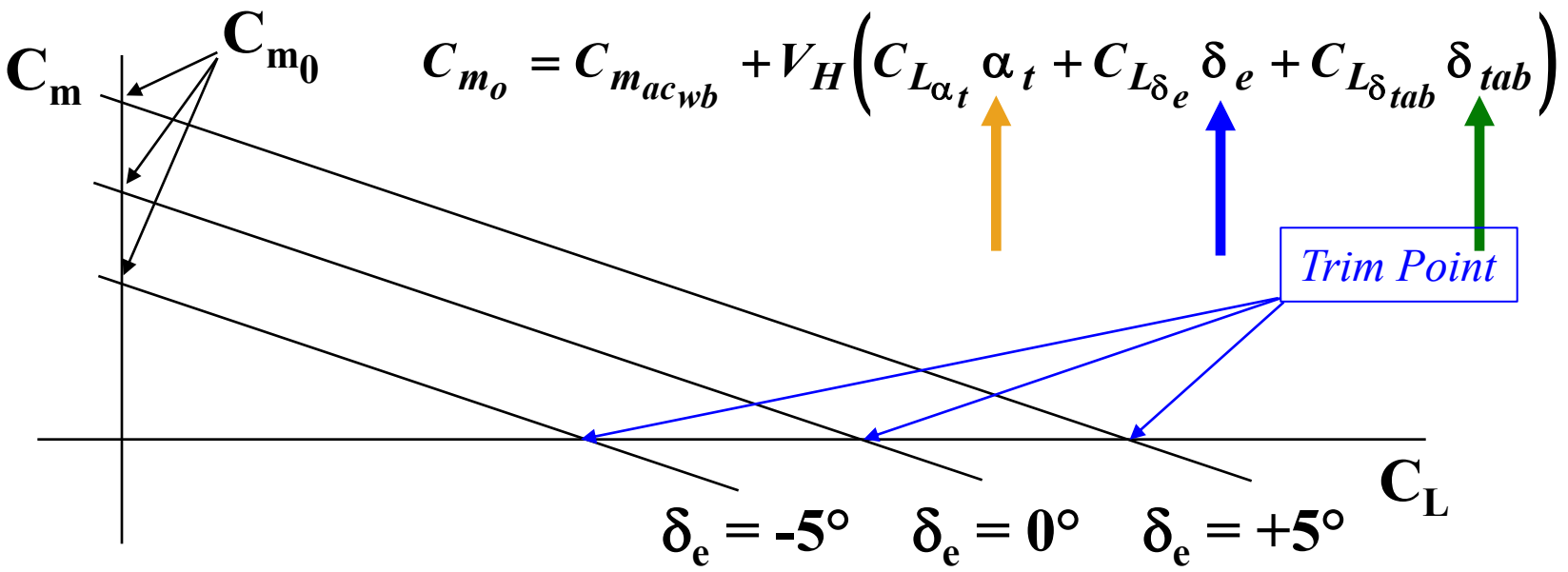
$$C_{m_o} = C_{m_{ac_{wb}}} + V_H\left(C_{L_{\alpha_t}}\alpha_t + C_{L_{\delta_e}}\delta_e + C_{L_{\delta_{tab}}}\delta_{tab}\right) \longleftarrow \text{Intercept}$$

(think trim point)

So what can we do to an existing airplane to change the slope and intercept of the stability curve?

Elevator Deflection

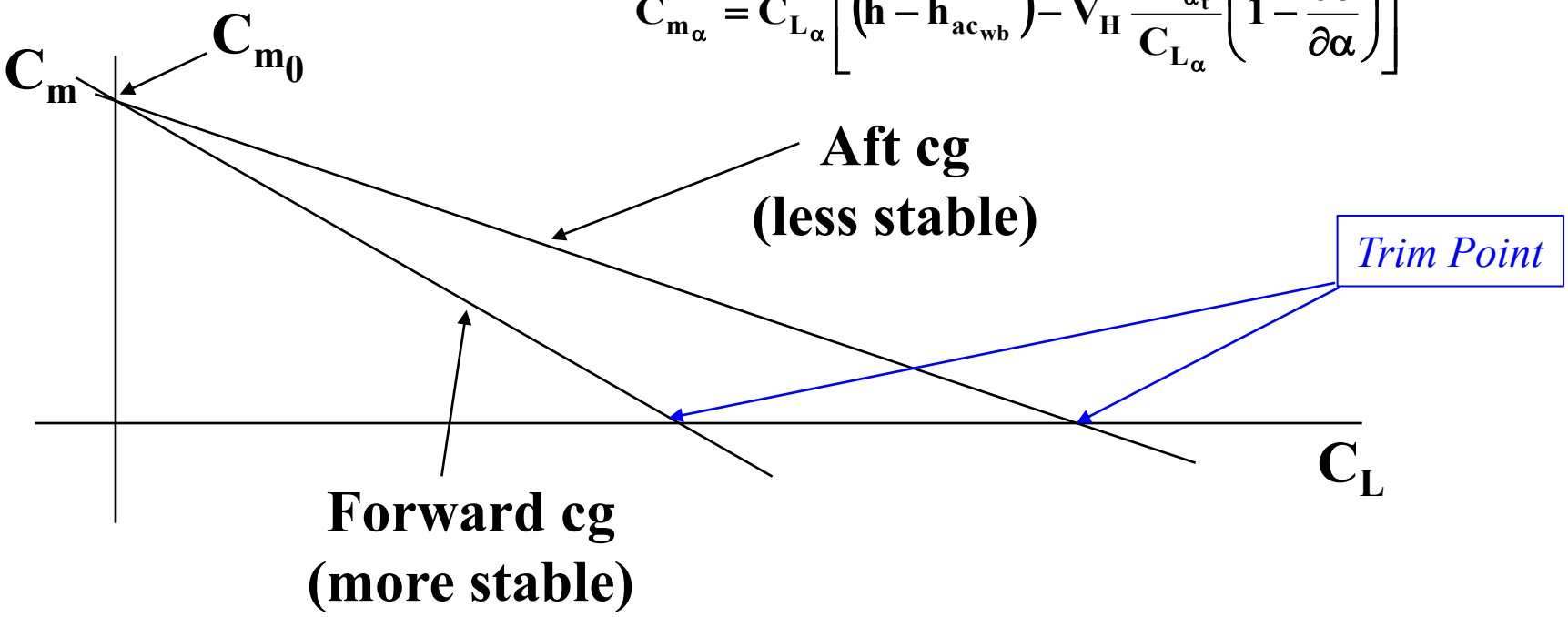
- **Elevator deflections affect the _intercept_** *(ultimately trim point)* **but not the _slope_** *(stability)*
  - Thus, elevator deflections change the trim C_L (or α)
  - Trim tabs ultimately affect the elevator deflection
  - Incident angles of the tail don't change but set baseline



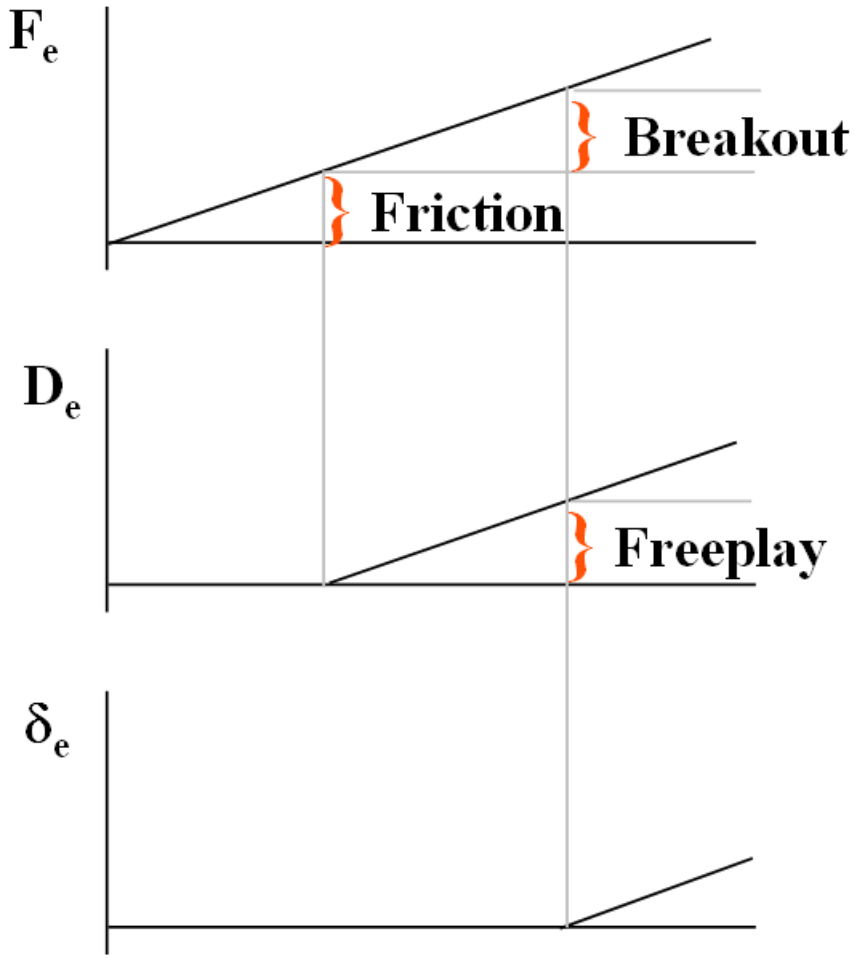
C.G. Location

- C.G. location affects the slope *(stability)*
but not the $C_L=0$ intercept *(trim points are affected)*

$$C_{m_\alpha} = C_{L_\alpha}\left[\left(h - h_{ac_{wb}}\right) - V_H \frac{C_{L_{\alpha_t}}}{C_{L_\alpha}}\left(1 - \frac{\partial\varepsilon}{\partial\alpha}\right)\right]$$



Friction & Breakout (F+B), Deadband & Freeplay



- Friction: *force* required to start stick/yoke moving
- Breakout: *additional force* to start control surface moving
  - Very difficult to separate out effects, so usually considered combined (F&B)
    - Too low: too sensitive to inputs
    - Too high: large deadband
- Freeplay: stick/yoke *movement* that doesn't result in any movement of the rest of the flight control system
- Deadband: *additional movement* that doesn't result in any movement of the control surface

Stick-Fixed Stability

- Stick-fixed stability - stability of the aircraft with the control surfaces (thus the stick) fixed in one position
  - Thus, we are interested in the control surface positions

- Consider the equation at a trimmed condition:

$$C_{m_0} = C_{m_{ac_{wb}}} + V_H\left(C_{L_{\alpha_t}}\alpha_t + C_{L_{\delta_e}}\delta_e + C_{L_{\delta_{tab}}}\delta_{tab}\right)$$

fixed fixed fixed Controls-trimmed condition fixed

Flight Test Relationship

- **Need to determine how elevator deflections affect C_L, so we can get the relationship**

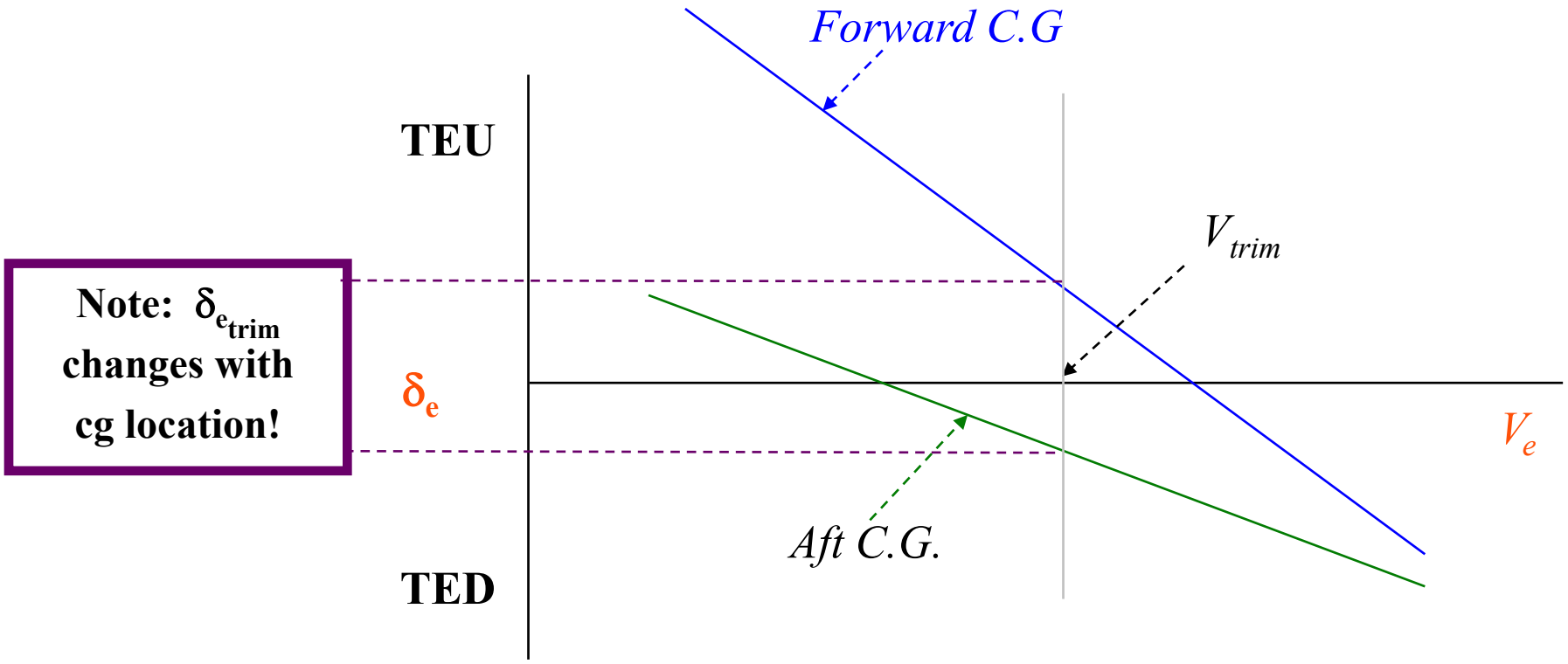
$$\frac{\partial \delta_e}{\partial C_L} = \frac{h_n - h}{C_{m_{\delta_e}}} = \frac{SM}{\text{Elevator Power}}$$

Measure of stick fixed stability

So how can we use this relationship in flight test to determine stick fixed stability?

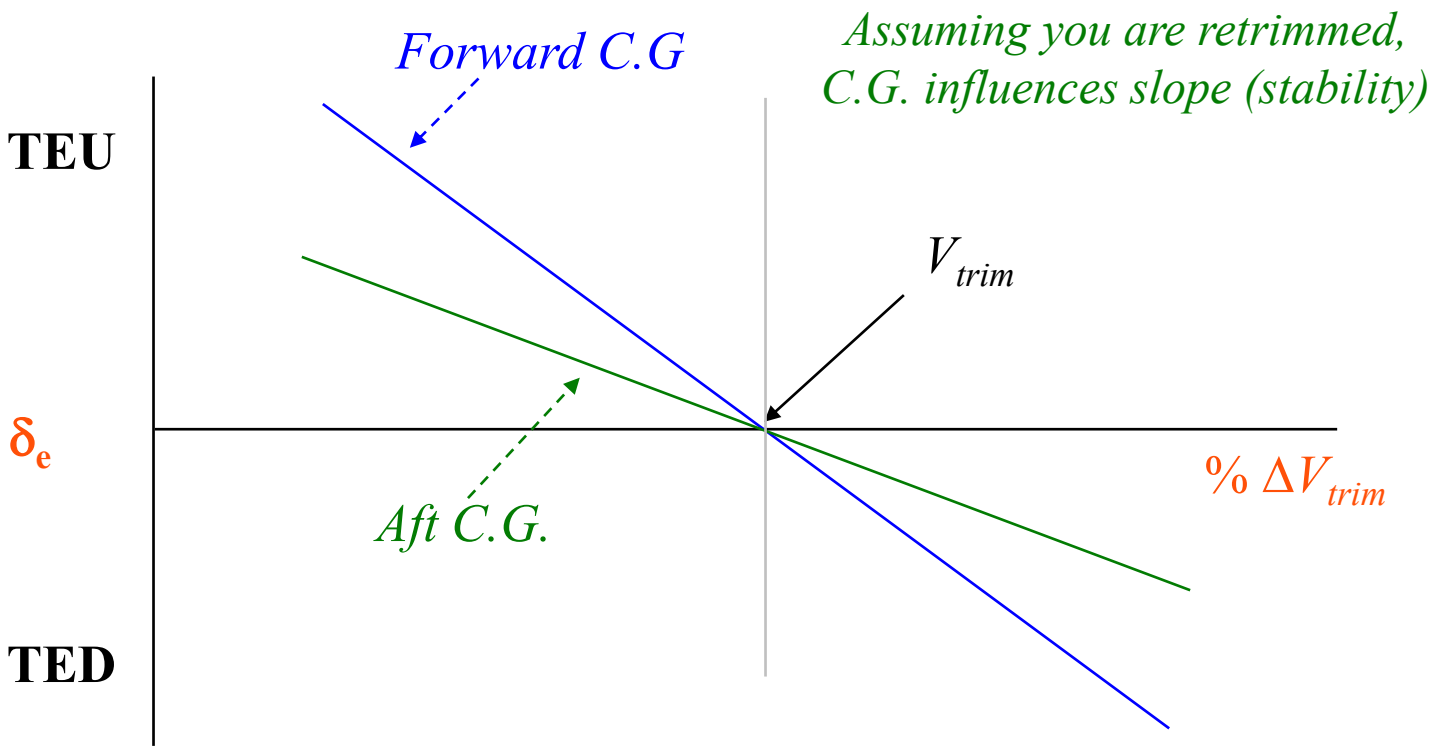
Finding Stick Fixed Stability

- Measure δ_e (or yoke displacement) & V_e and *calculate* C_L



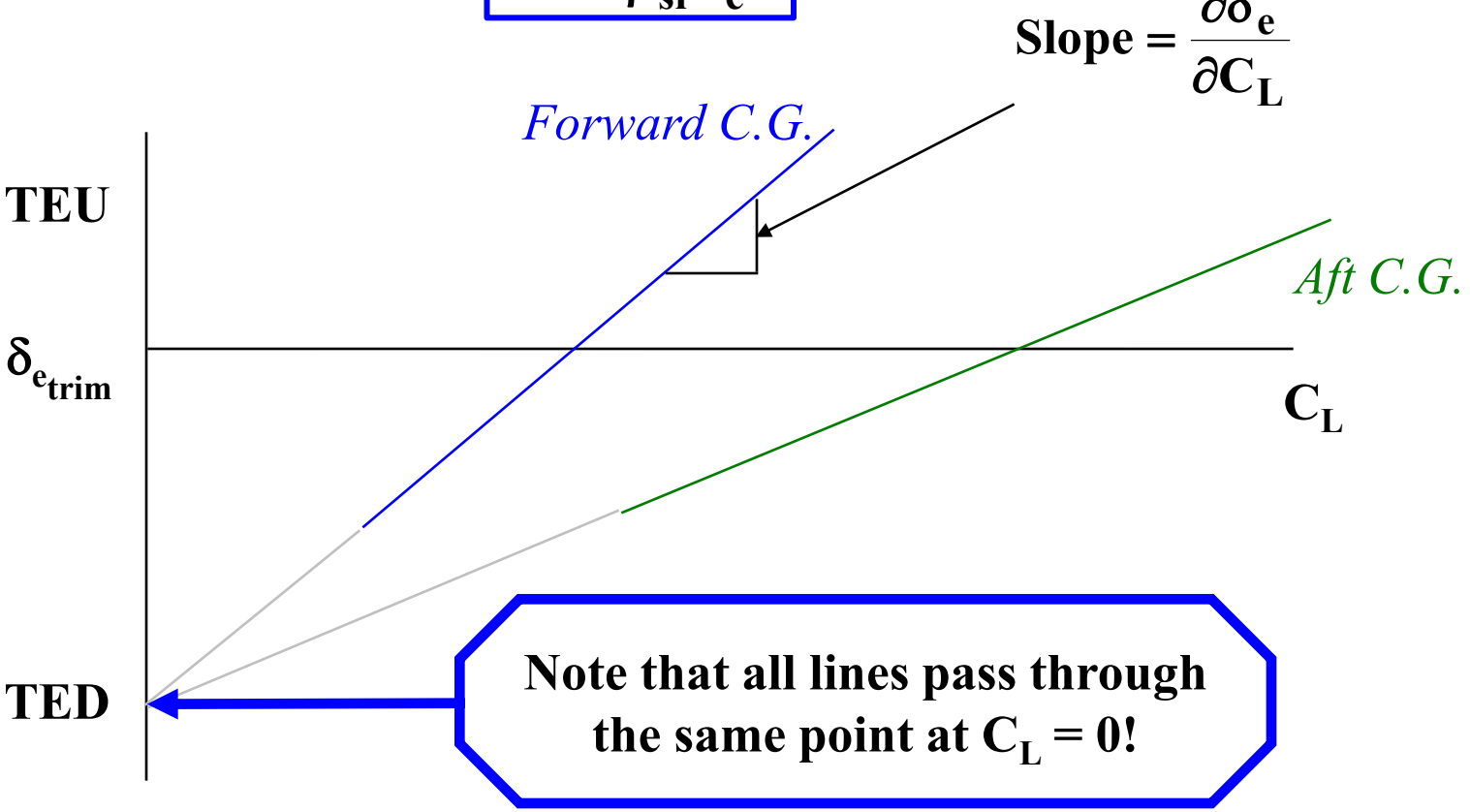
Finding Stick Fixed Stability

- Measure δ_e (or yoke displacement) & V_e and *calculate* C_L



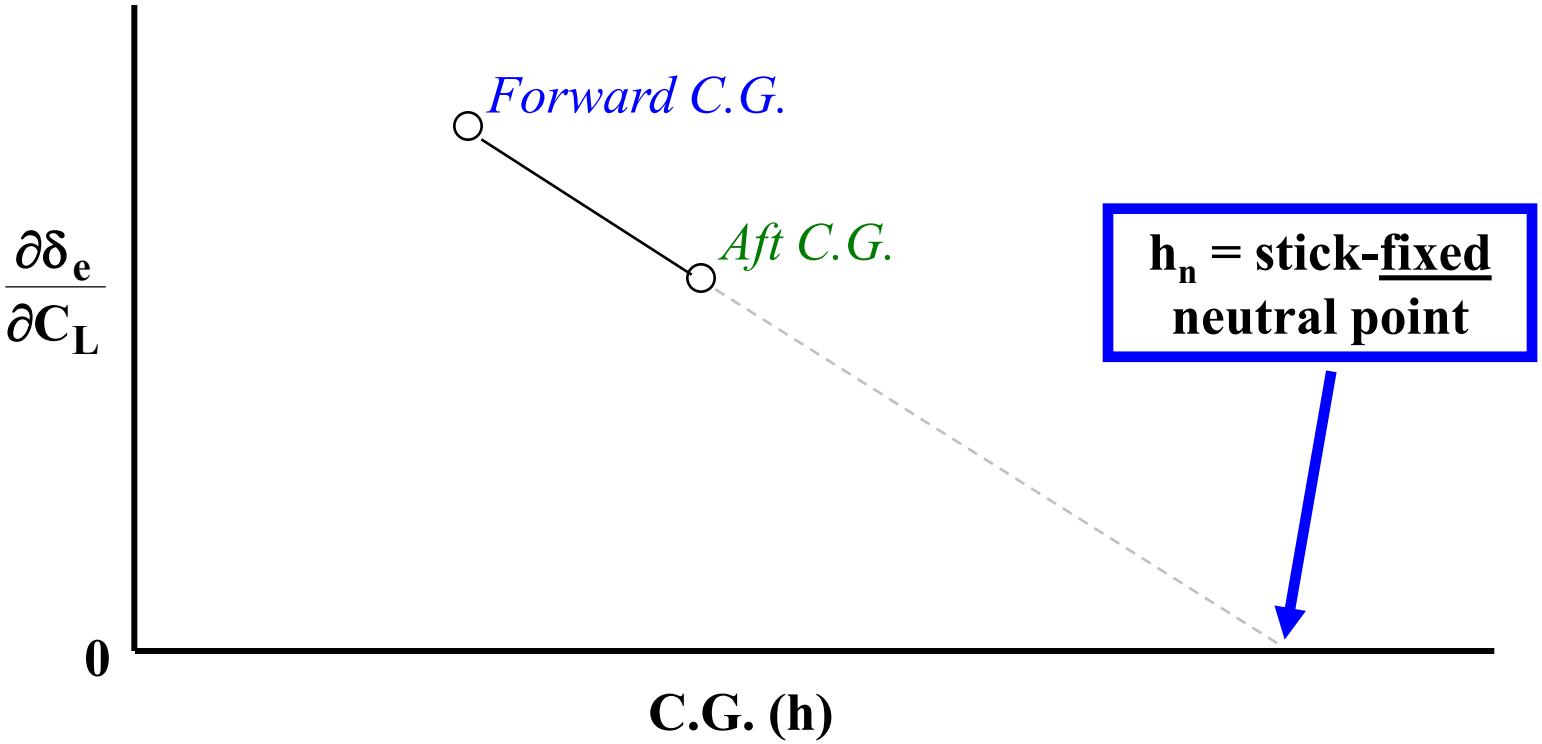
Finding Stick Fixed Stability

- Convert V_e to C_L by $C_L = \frac{2W_t}{\rho_{sl} V_e^2 S}$



Finding Stick Fixed Stability

- Now plot the slopes vs cg locations



Stick-Free Stability

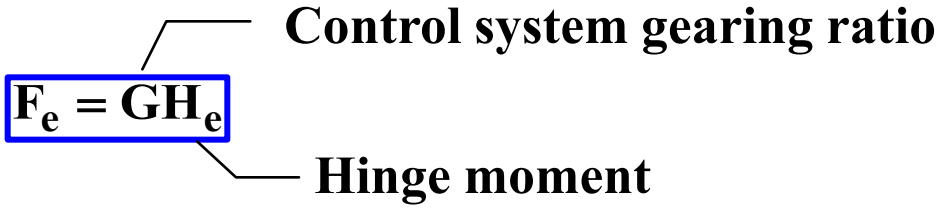
- Stick-free stability - stability of the aircraft when the elevator is allowed to float
  - Applies to reversible control systems only
  - Irreversible systems--"apparent" stability through control feel system
- When the elevator is allowed to float, the control force will be zero
- The trim tab setting determines the elevator float angle, since the hinge moment will go to zero

$$C_{m_0} = C_{m_{ac_{wb}}} + V_H\left(C_{L_{\alpha_t}}\,\alpha_t + C_{L_{\delta_e}}\,\delta_e + C_{L_{\delta_{tab}}}\,\delta_{tab}\right)$$

fixed — fixed — fixed — free to float — controls trimmed condition

Stick-Free Stability

- Hinge moments (H_e) are related to the stick force by the control system gearing ratio
  - C_h – Coeff. of hinge moment



In coefficient form:

$$H_e = C_h q S_e c_e$$

$$C_h = C_{h_0} + C_{h_{\alpha_t}} \alpha_t + C_{h_{\delta_e}} \delta_e + C_{h_{\delta_t}} \delta_t$$

So we have:

$$F_e = G C_h q S_e c_e$$

Flight Test Relationship

- Divide by q and differentiate by C_L:

$$F_e = GC_h qS_e c_e$$

$$\frac{F_e}{q} = GC_h S_e c_e$$

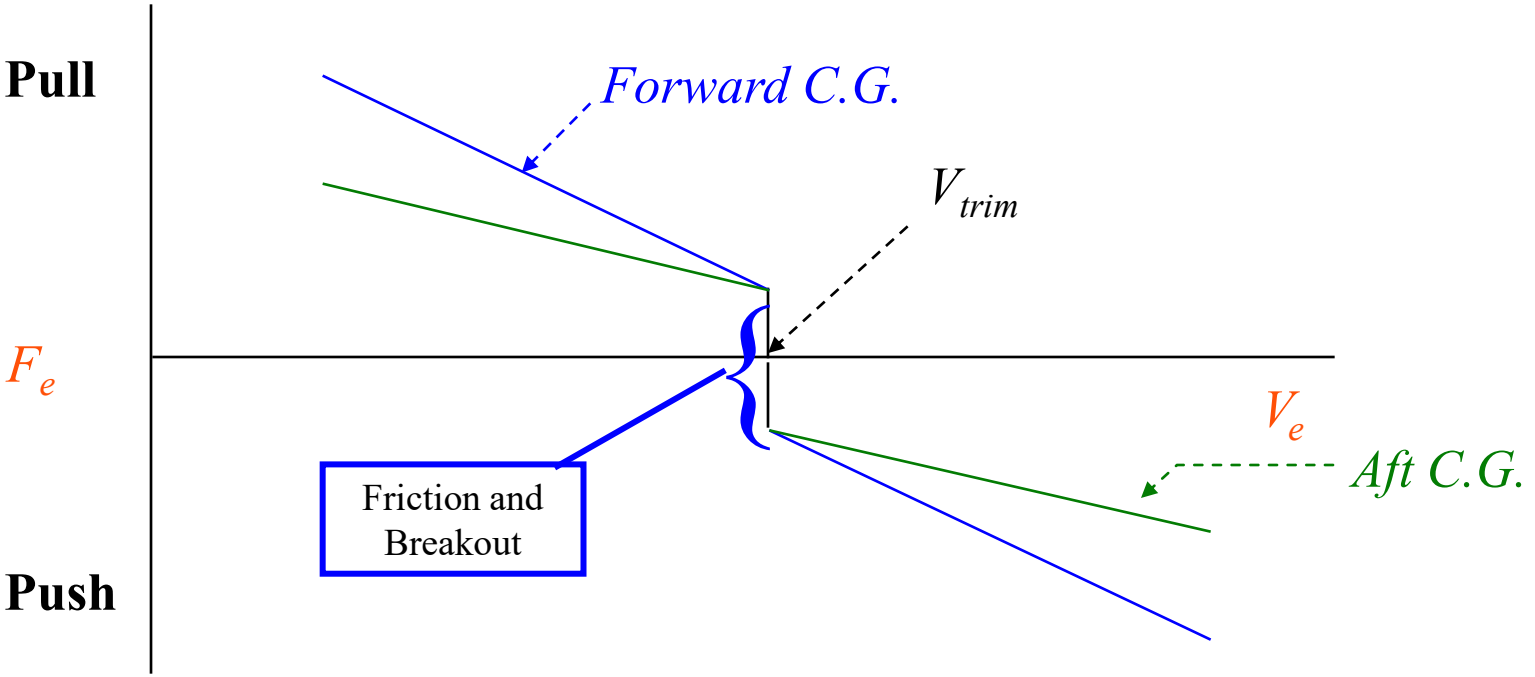
Measure of stick free stability

$$\frac{\partial\left(\frac{F_e}{q}\right)}{\partial C_L} = f_1\left(\frac{\partial C_h}{\partial C_L}\right)_{stick\ free} = f_2\left(\frac{\partial C_m}{\partial C_L}\right)_{stick\ free}$$

So how can we use this relationship in flight test to determine stick free stability?

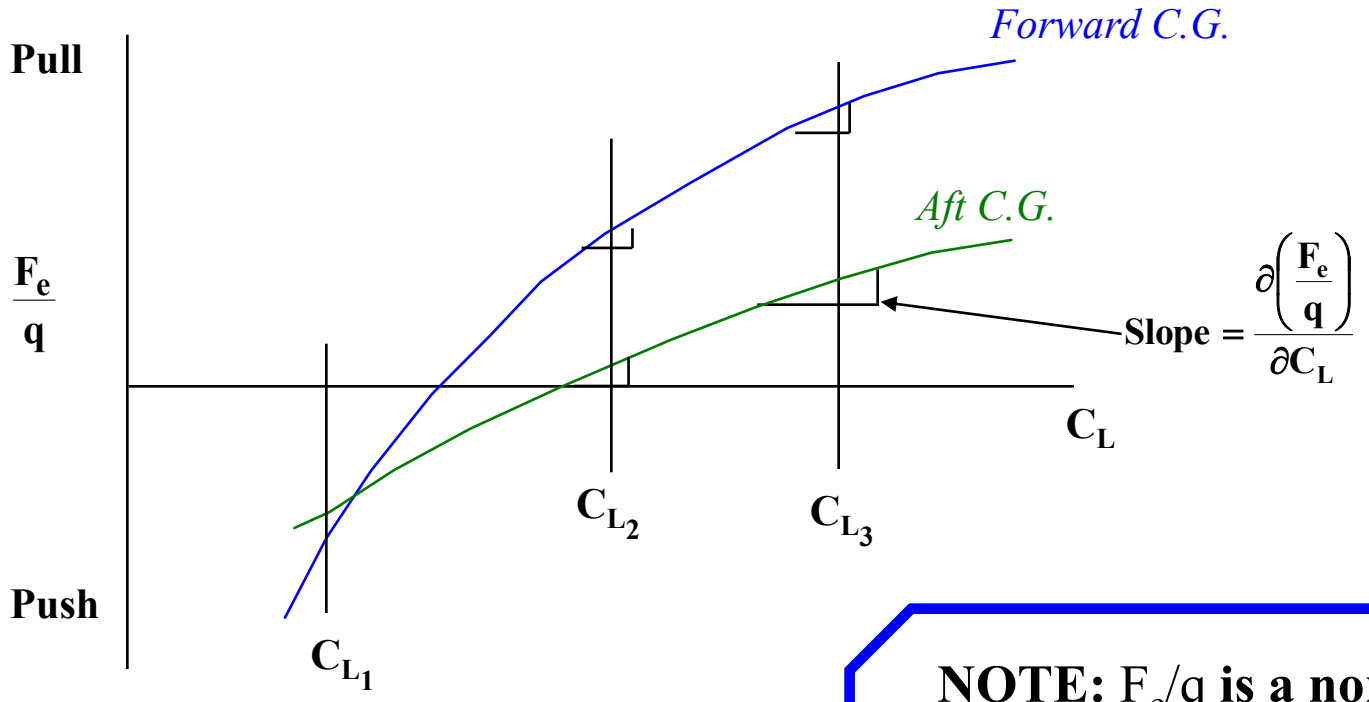
Finding Stick-Free Stability

- In flight test, we measure F_e and V_e and *calculate* C_L



Finding Stick Free Stability

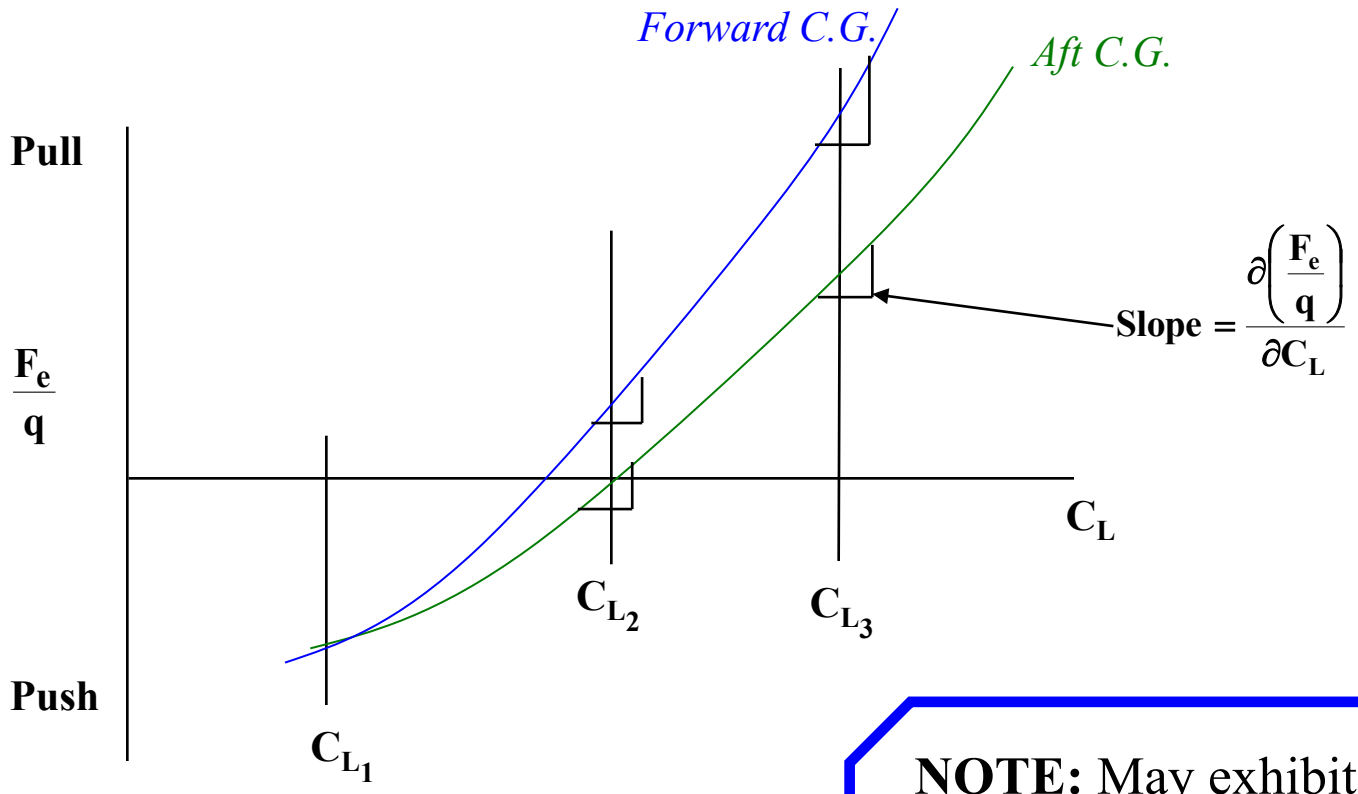
- Convert V_e to C_L and q by $C_L = \frac{2W_t}{\rho_{sl} V_e^2 S}$ and $q = \frac{\rho_{sl} V_e^2}{2}$



NOTE: F_e/q **is a nonlinear function of** C_L**!**

Finding Stick Free Stability

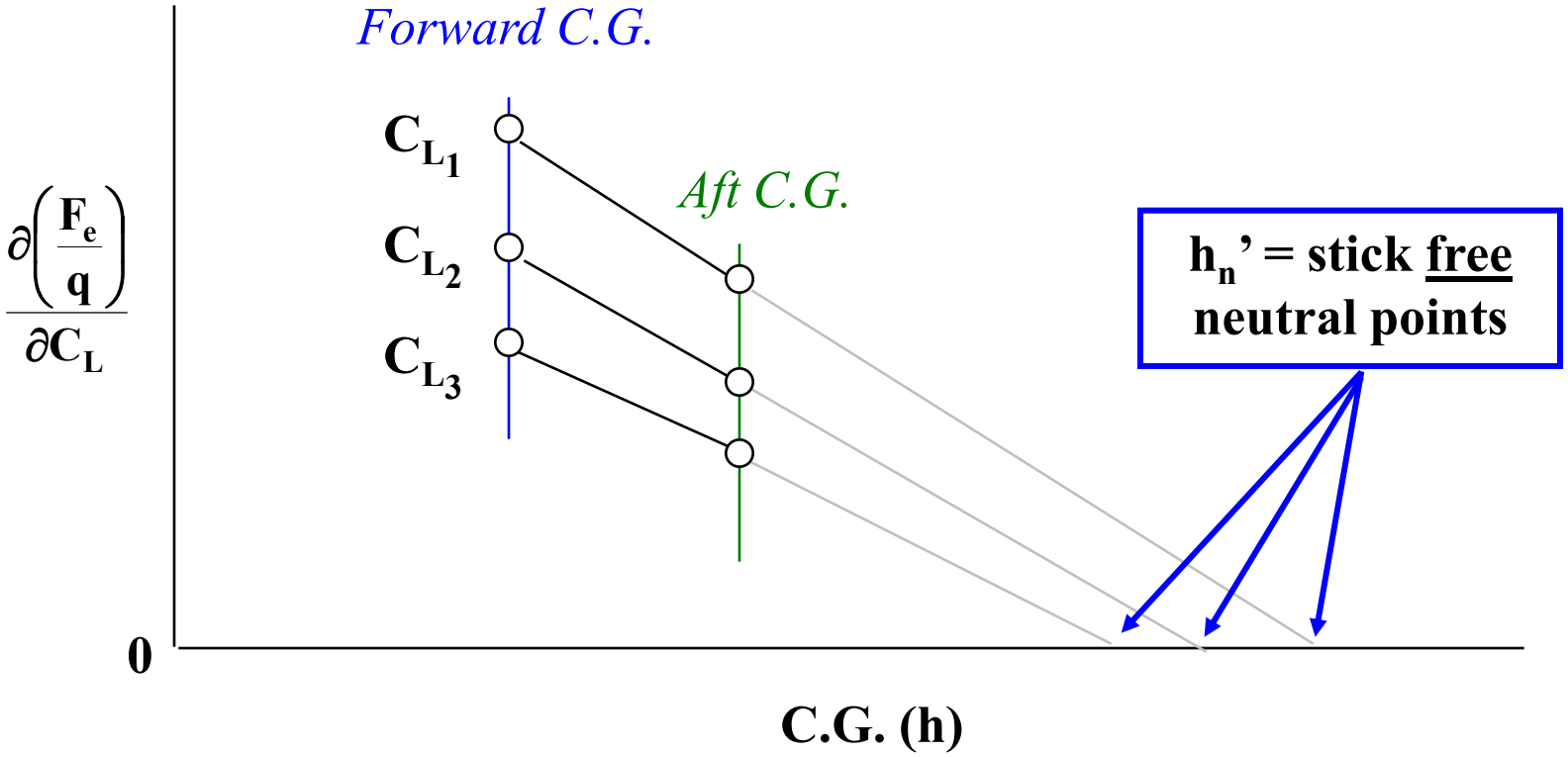
- Convert V_e to C_L and q by $C_L = \frac{2W_t}{\rho_{sl} V_e^2 S}$ and $q = \frac{\rho_{sl} V_e^2}{2}$



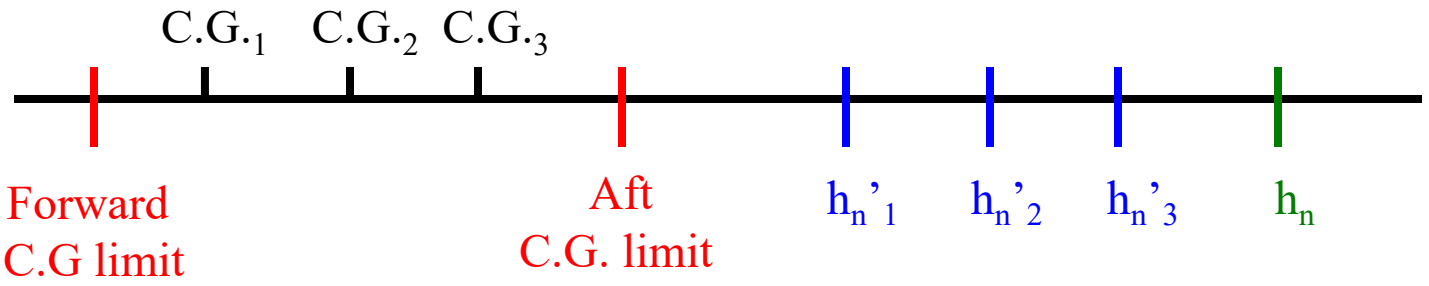
NOTE: May exhibit opposite behavior

Finding Stick Free Stability

- Now plot the slopes vs C.G. locations at selected C_L's
  - Just pick several different C_L values for your analysis



Presenting Neutral Point Results



- **Show:**
  - **Range of acceptable C.G. values for aircraft tested**
  - **Single stick-fixed neutral point (h_n)**
  - **Multiple stick-free neutral points for multiple C.G. locations (h_n')**
- **Highlight any problems/discrepancies with data**

Flight Path Stability

- Applies to power approach and landing phases
- Primarily determined by performance characteristics of aircraft
- Related to S&C only by being another requirement on handling qualities
- Concerns change in flight path angle with velocity changes caused by the pitch controller only (constant throttle setting)

Pitch Controller Movement	Change in Rate of Descent	
	Front Side of Thrust Curve	Back Side of Thrust Curve
Pull	Decreases	Increases
Push	Increases	Decreases

Not addressed in AE 456

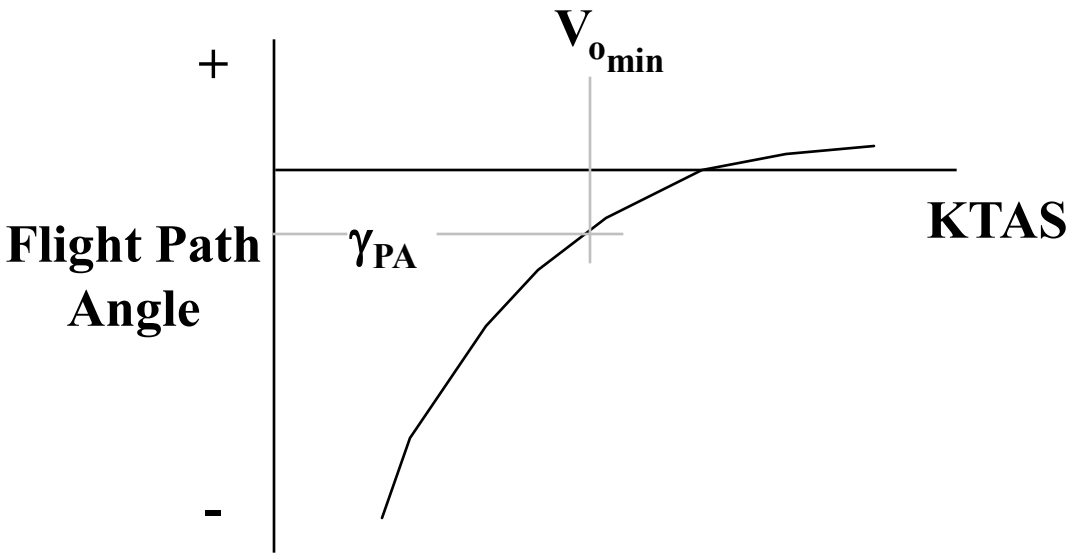
Flight Path Stability

- If approach speed is on the front side of the thrust curve, flight path stability is satisfied
- Remember, this is not speed stability
  - Speed stability concerns returning to trim airspeed when airspeed is disturbed



Flight Path Stability

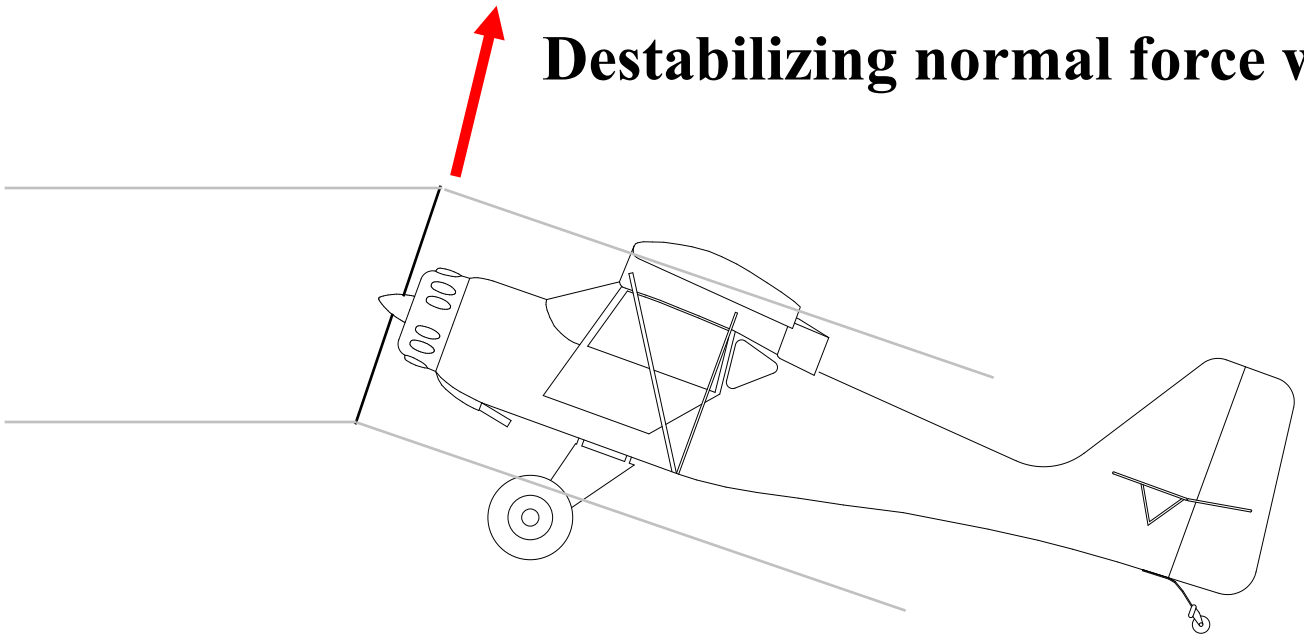
- If approach speed is on the back side of the thrust curve, flight path stability must be investigated
- Concern: Do not want a sudden increase in descent rate from a pitch up induced loss of airspeed
- Steepness of slope of flight path angle vs KTAS is related to steepness of back side of thrust curve



Trim Changes

- Must be able to trim aircraft throughout the flight envelope
  - T-38 with forward C.G. cannot be trimmed on final approach
- Trim rate should not be "too fast" or "too slow"
  - Too fast: overshoot desired trim setting
  - Too slow: sluggish, get "behind" airplane (C-141 electro-hydraulic 4 sec)
- Configuration changes (landing gear, flaps, etc.)
  - T-38 flap/slab interconnect
  - C-17 speedbrakes (spoiler & flap scheduling)
- Weapons releases
  - F-15 CFT fore/aft stations
- Power changes
  - Thrust line does not pass through cg (e.g. amphibians)
  - Other effects

Propeller Normal Forces



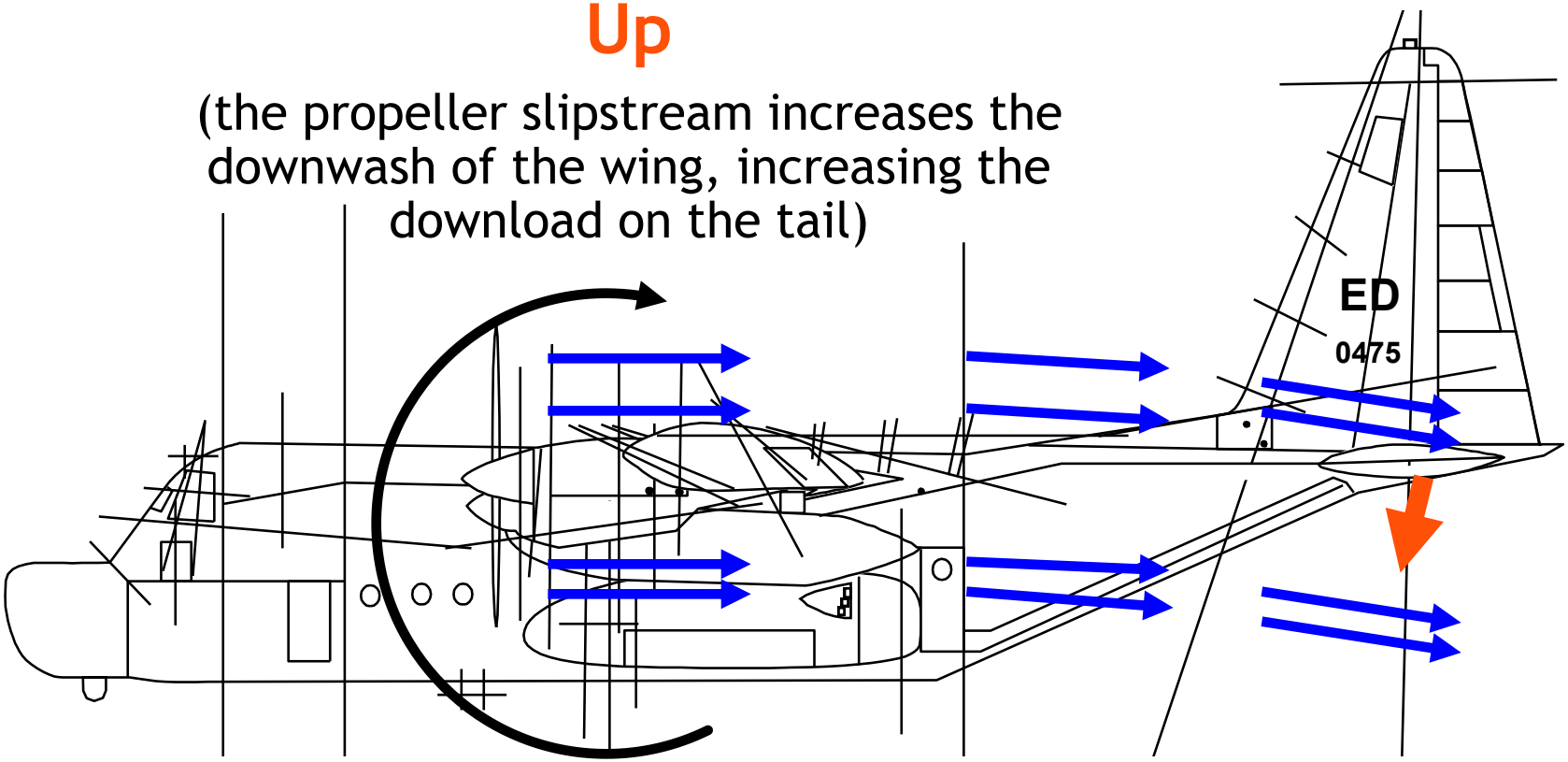
Pusher prop opposite!

Question

- **Which way does the MC-130H pitch when the throttles are advanced?**

Up

(the propeller slipstream increases the downwash of the wing, increasing the download on the tail)



Closed-Loop Flight Test Incident

- F-22, PR filming mission at EDW
  - XB-70 crash was also on a PR photo shoot!
  - Thrust vectoring supposed to be switched off (now integral to FCS)
  - Gain/slope error in FCS compounded problem
  - Pilot-Induced-Oscillation (PIO)
  - Minor damage to the aircraft
  - Pilot walked away



Click Picture for Video

Long-Stat FTTs

Flight Test Techniques (FTTs)

1. Long-Stat Stabilized Method
   (we'll do this one in the T-41D)
2. Level Accel/Decel Method
3. Flight Path Stability





1. Long-Stat Stabilized

Procedure: (Payne 13-12)

- Perform Trim Shot
- Measure friction & breakout
- Pull yoke aft with target force
  - Allow speed to decrease/stabilize
- Measure stick force and position at intervals out to ±15% V_{trim} or 50 KIAS (whichever is less)
- Repeat at different C.G.'s
- Record:
  - H_i, V_i, δ_{yoke}, F_e

Assumptions/Constraints:

- Stabilized conditions
- Yoke forces kept on same side of friction band
- Altitude changes = little effect

Data Reduction:

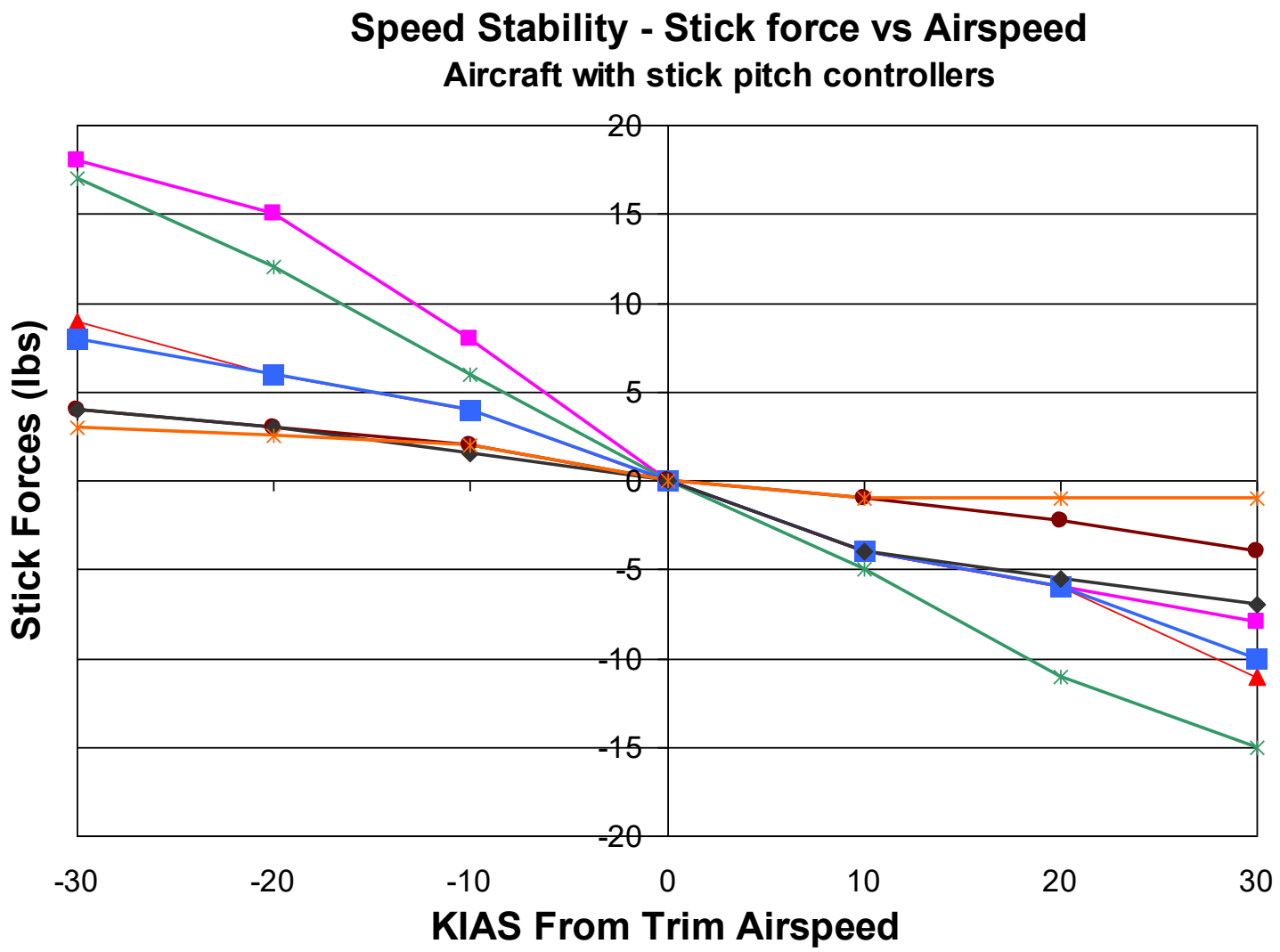
Solve for : $\frac{\partial \delta_e}{\partial C_L}$ and $\frac{\partial\left(\frac{F_e}{q}\right)}{\partial C_L}$ as a function of C.G.

$$C_L = \frac{2W_t}{\rho_{sl} V_e^2 S} \qquad q = \frac{\rho_{sl} V_e^2}{2}$$

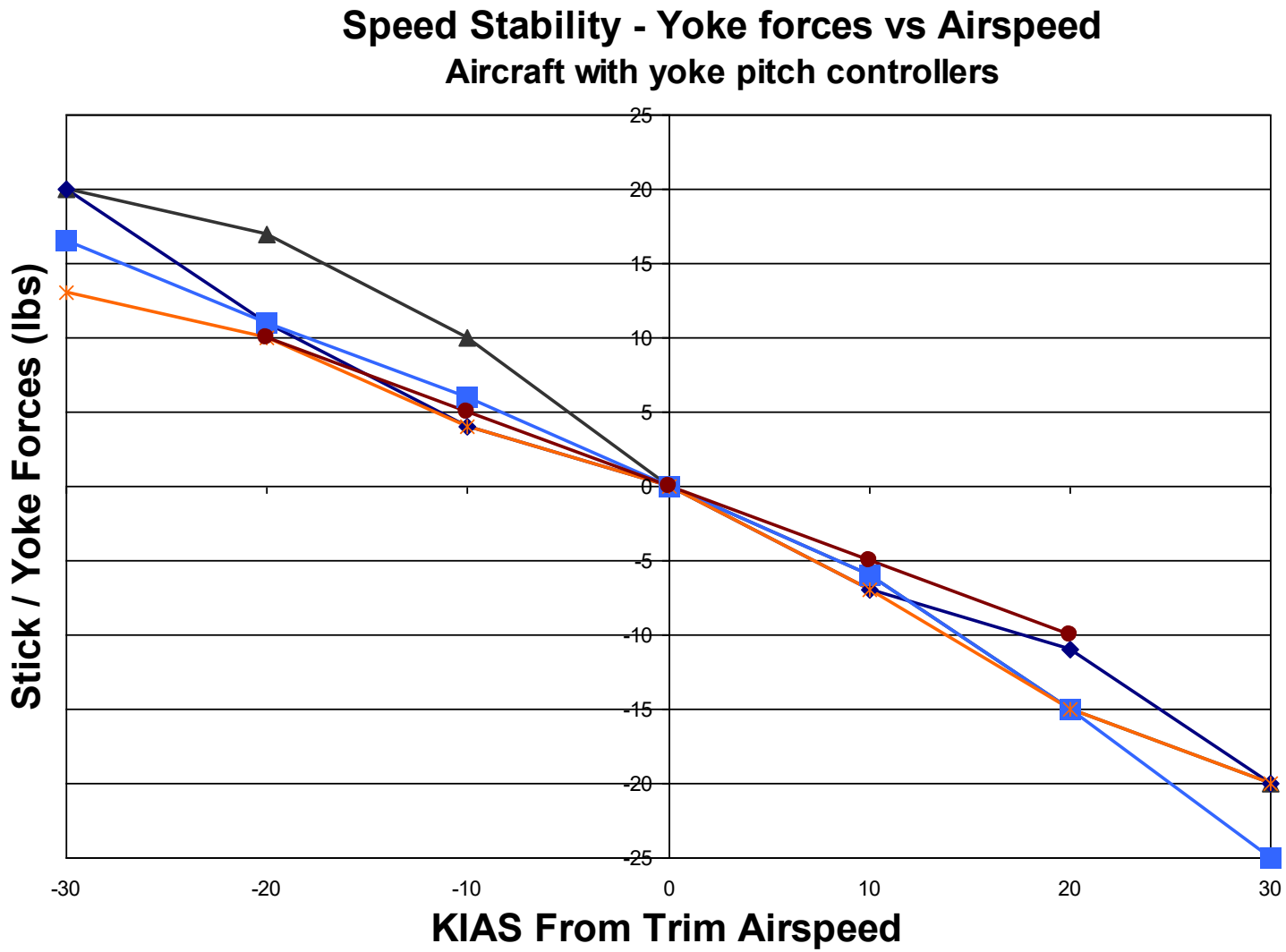
1. Long-Stat Stabilized

- Advantages
  - Good for propeller aircraft (avoids slipstream effects on tail)
  - Aircraft with small speed ranges
  - Easy for hand held data
- Disadvantages
  - Slow technique
  - Possible altitude effects

Flight Test Data



Flight Test Data



2. Level Accel / Decel

Procedure:

- Perform Trim Shot
  - Record Power Setting
- Accelerate beyond test condition
  (15% V_{trim} or 50 KIAS, whichever is less)
- Reset trim power
  - Record data as aircraft decelerates – remain level
- Decelerate beyond test condition (15% V_{trim} or 50 KIAS, whichever is less)
- Reset trim power
  - Record data as aircraft accelerates – remain level
- Repeat at different C.G.'s
- Record: H_i, V_i, δ_{yoke}, F_e

Assumptions/Constraints:

- *Level* accel/decel
- Yoke forces kept on same side of friction band

Data Reduction:

Solve for : $\frac{\partial \delta_e}{\partial C_L}$ and $\frac{\partial\left(\frac{F_e}{q}\right)}{\partial C_L}$ as a function of C.G.

$$C_L = \frac{2W_t}{\rho_{sl} V_e^2 S} \qquad q = \frac{\rho_{sl} V_e^2}{2}$$

2. Level Accel / Decel

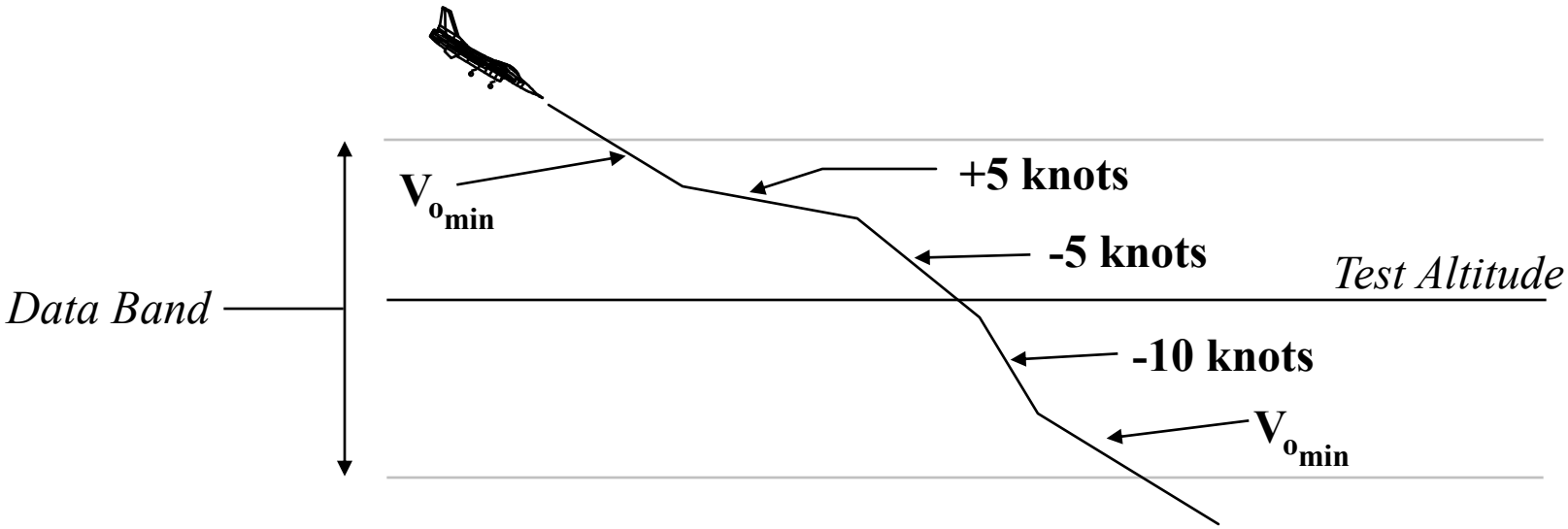
- Advantages
  - Aircraft with large speed ranges
  - Quicker technique
  - No altitude effects

- Disadvantages
  - Hard for hand held data (DAS is almost essential)
  - Possible power effects

3. Flight Path Stability

Procedure:

- Perform Trim Shot
- Stabilize aircraft in PA config at approach speed above data band
- Data band: ± 500 feet from target altitude
- Record:
  - ROD, V_i, H_i, and OAT at V_{trim}, +5, -5, -10 knots, and repeat at V_{trim}



Summary

- FQ requires a Shift in Thinking
- MIL-STD-1797
- Flight Control Systems
- Longitudinal Static Stability (Long-Stat)

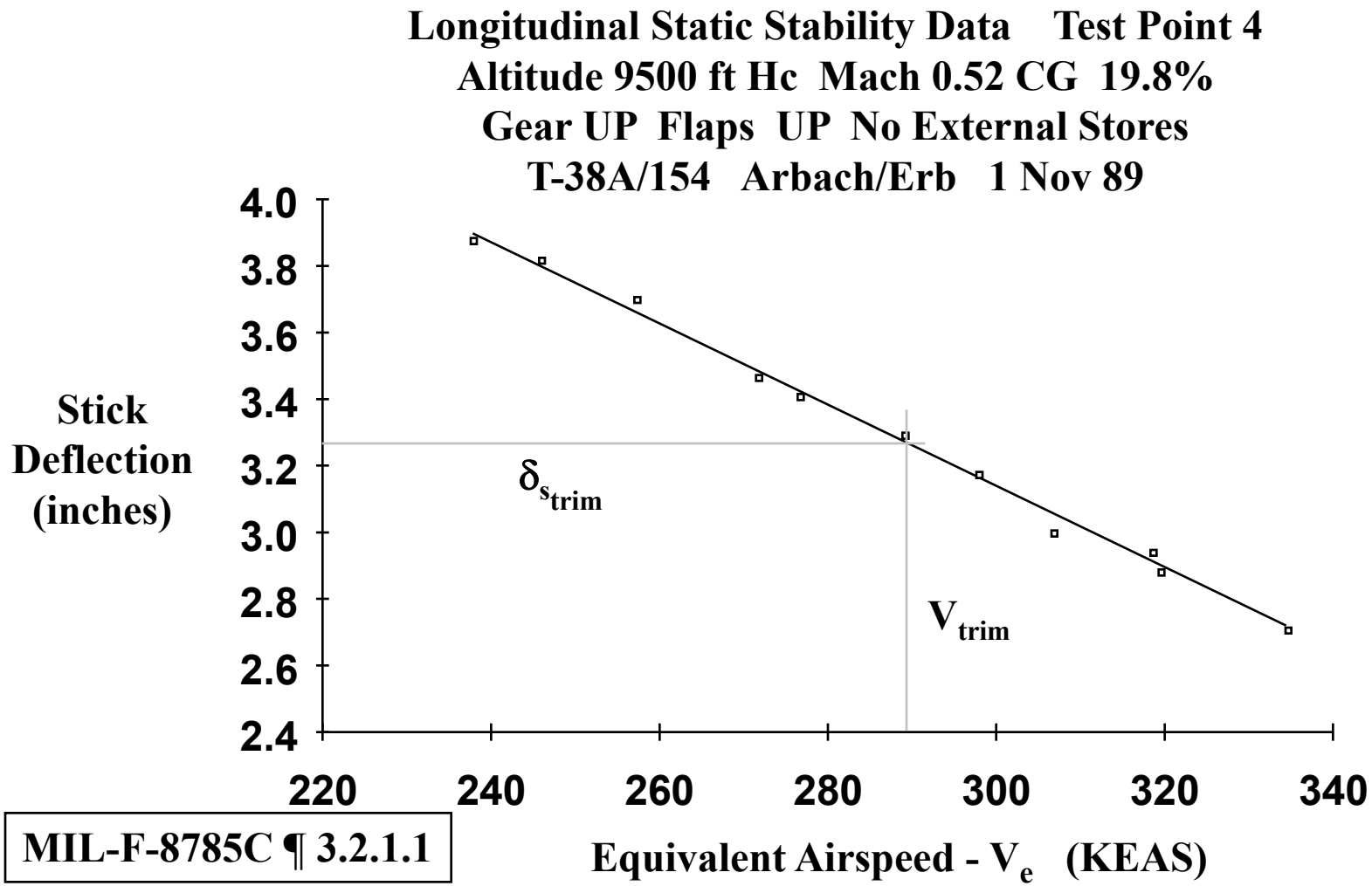
Next Time

FQ-2: Maneuvering Stability

In Class Exercise

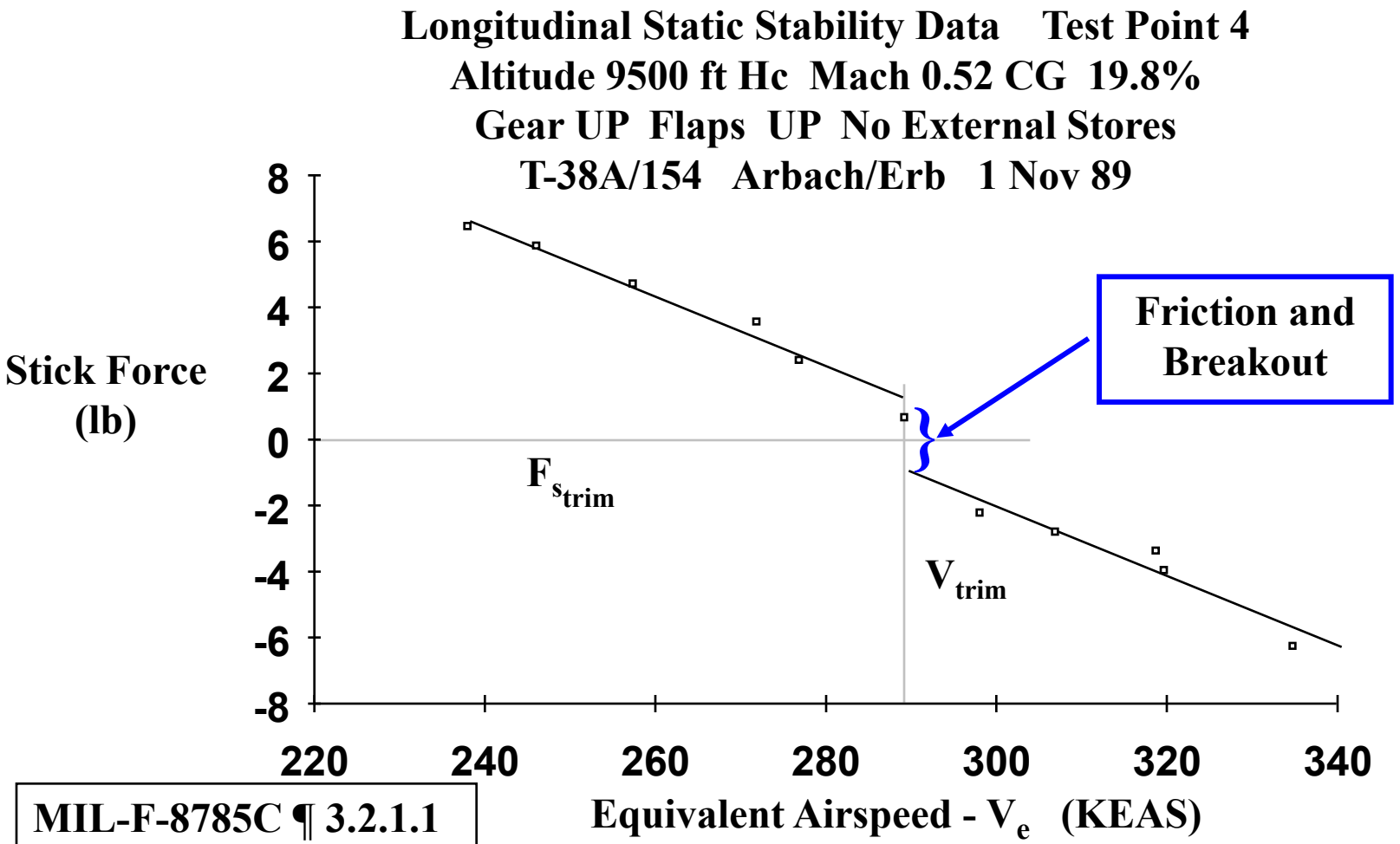
- Given T-38 example data in slides FQ1-83 through FQ1-85, determine PASS/FAIL for these MIL-F-8785C paragraphs:
  - 3.2.1.1
  - 3.5.2.1
  - 3.2.1.3
- Be prepared to explain your ratings.

T-38A Example Data



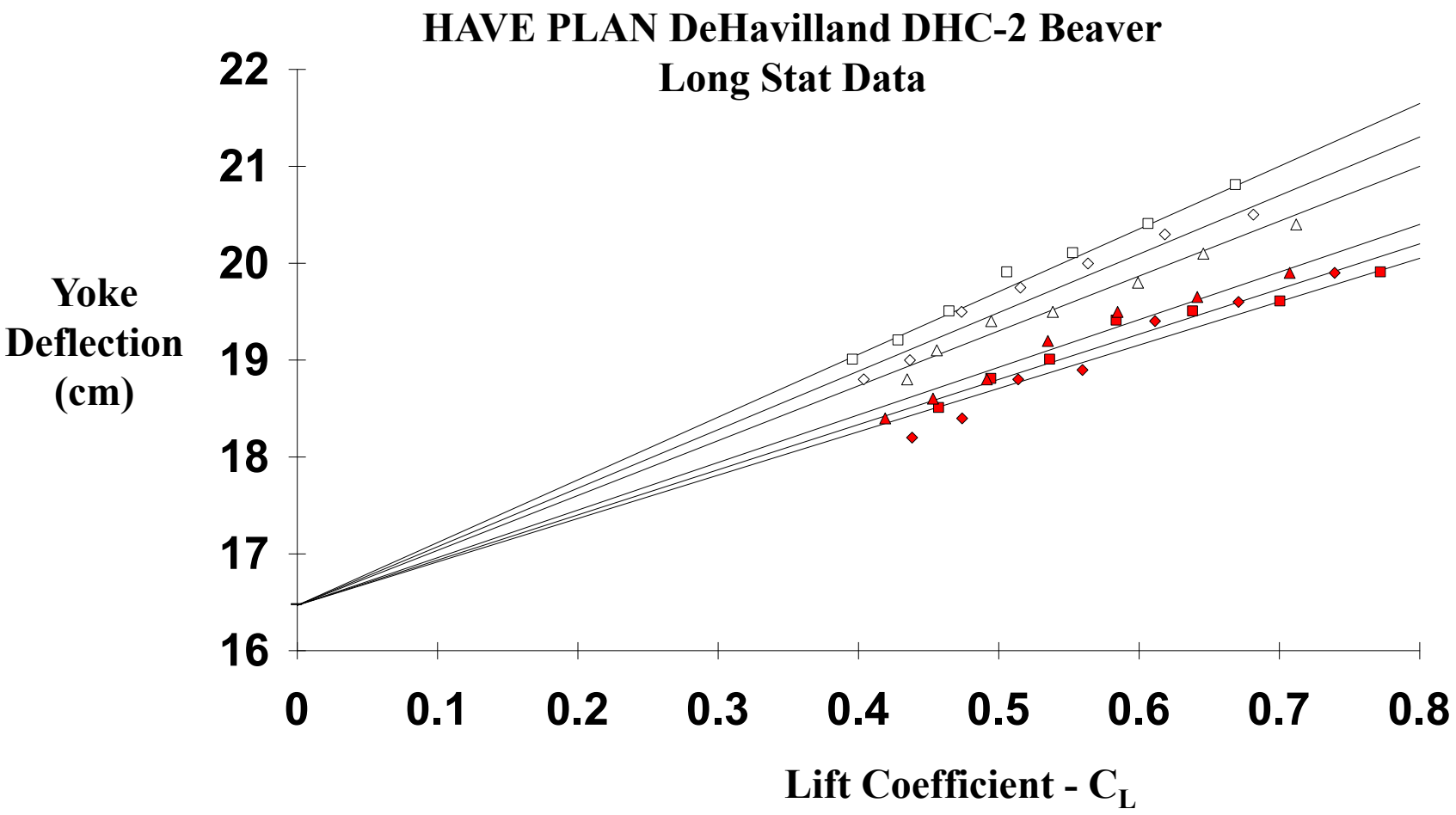
MIL-F-8785C ¶ 3.2.1.1

T-38A Example Data



MIL-F-8785C ¶ 3.2.1.1
3.5.2.1

Example Data



Example Data

