MAE 158 Lecture 18
Dec. 3 2024

Announcements: HW week 10 posted
Drag project due Friday 11:59pm
-note- if late, submission will be marked down -25% for every 24 hours late

Today's Objectives: Stability (Finish)
Propulsion

Last time: Jet w/ following properties

$S_w = 2927\ ft^2$, $b_w = 148.4\ ft$ } $AR = \frac{b^2}{S} = 7.52$

$S_H = 559.1\ ft^2$, $b_H = 47.5\ ft$ } $AR_H = 4.04$

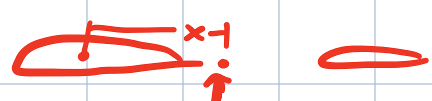
$\bar{c} = 22.73\ ft$ ← aerodynamic MAC

l_H = distance between wing, horiz tail $= 71.2\ ft$

$\eta_H = 0.9$ & $\eta = 0.95$

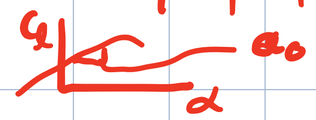
assume $d\varepsilon/d\alpha = 0.43$ $\quad \left(\frac{dC_m}{dC_L}\right)_F = -0.016$

what is $\frac{x}{\bar{c}}$ such that $\frac{dC_m}{dC_L}$ is @ least -0.10 ?



$$\frac{dC_{m_{CG}}}{dC_L} = \frac{X}{\bar{c}} - \left[\frac{dC_{L_H}/d\alpha_H}{dC_{L_W}/d\alpha}\left(1-\frac{d\varepsilon}{d\alpha}\right)\cdot\frac{S_H \ell_H'}{S_W \bar{c}}\,\eta_H - \frac{dC_m}{dC_L}_F\right]\cdot\left[\frac{1}{1+\frac{dC_{L_H}/d\alpha_H}{dC_{L_W}/d\alpha}\left(1-\frac{d\varepsilon}{d\alpha}\right)\frac{S_H}{S_W}\cdot\eta_H}\right]$$

$$\rightarrow \frac{dC_L}{d\alpha} = \frac{a_0}{1+a_0/\pi AR} \sim a_0 = 2\pi\eta$$



$$= \frac{X}{c} - \left[\frac{0.0708}{0.0831}(1-0.43)\cdot 0.9\cdot\frac{559.1\left(\frac{71.2}{22.7}\right)}{2927} - (-0.016)\right]\cdot\left[\frac{1}{1+\frac{0.0708}{0.0831}(1-0.43)\frac{559}{2927}(.9)}\right]$$

$$= -0.10$$

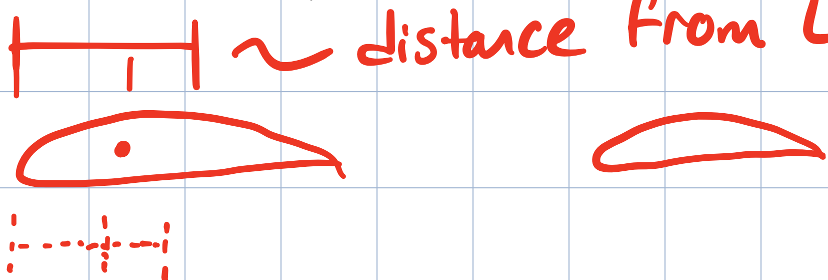
$\frac{dC_m}{dC_L}$ that I want

$$-0.1 = \frac{X}{c} - 0.2561$$

$$\frac{X}{c} = 0.1561$$

a few notes,

~ distance from Leading edge where you can place CG such that $\frac{dC_m}{dC_L} = -0.10$

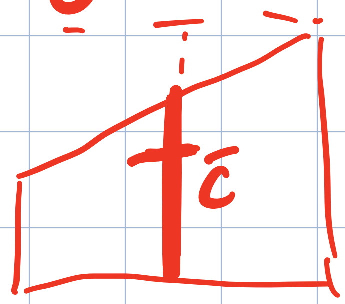


$\frac{X}{c}$

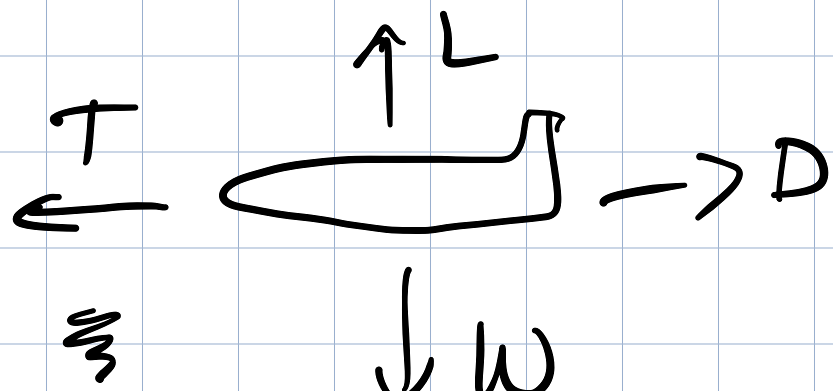
~25% of chord

$.25 + 0.1561 = \underline{0.4061}$

Note, this Refers to the location on wing where chord $= \bar{C}$



Propulsion



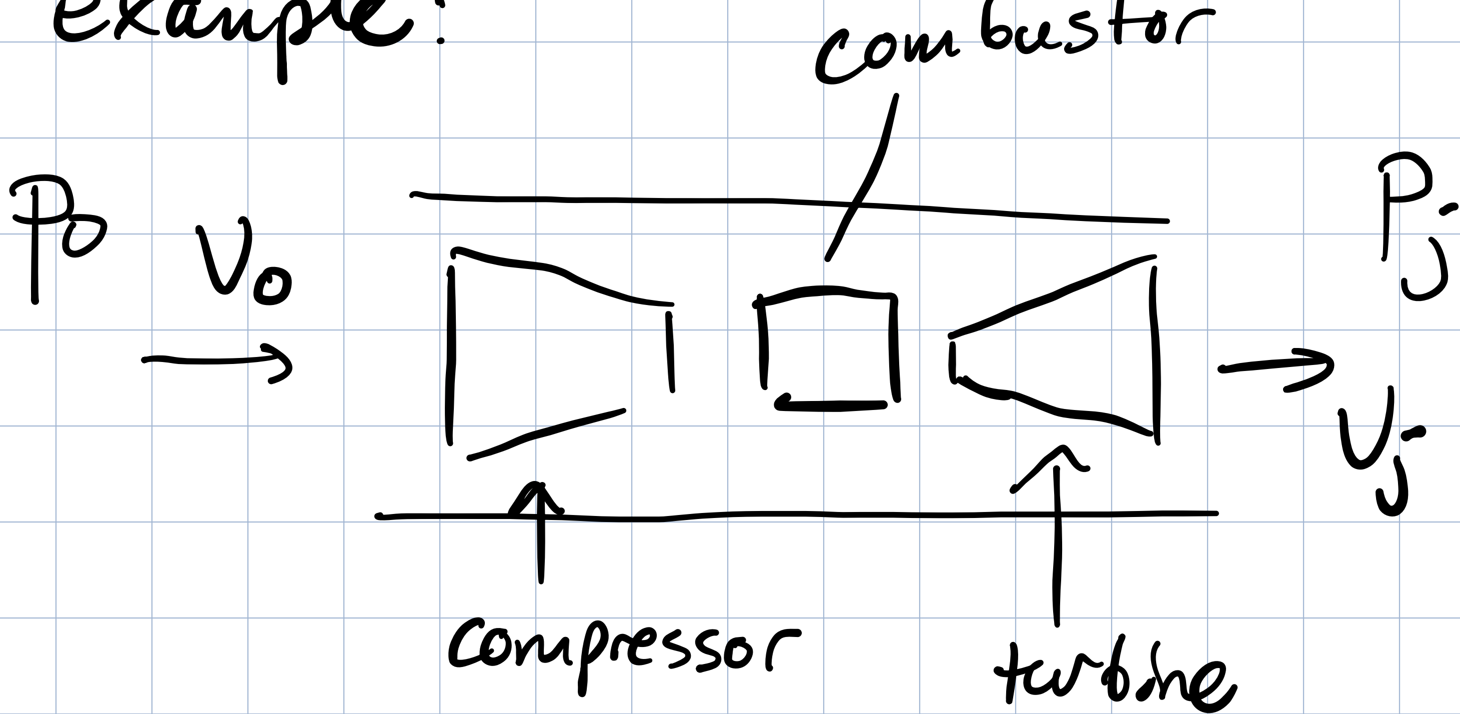
propulsion unit push air & air pushes back $\rightarrow$ Thrust

Thrust = Rate of change of momentum in the fluid

Common propulsors:

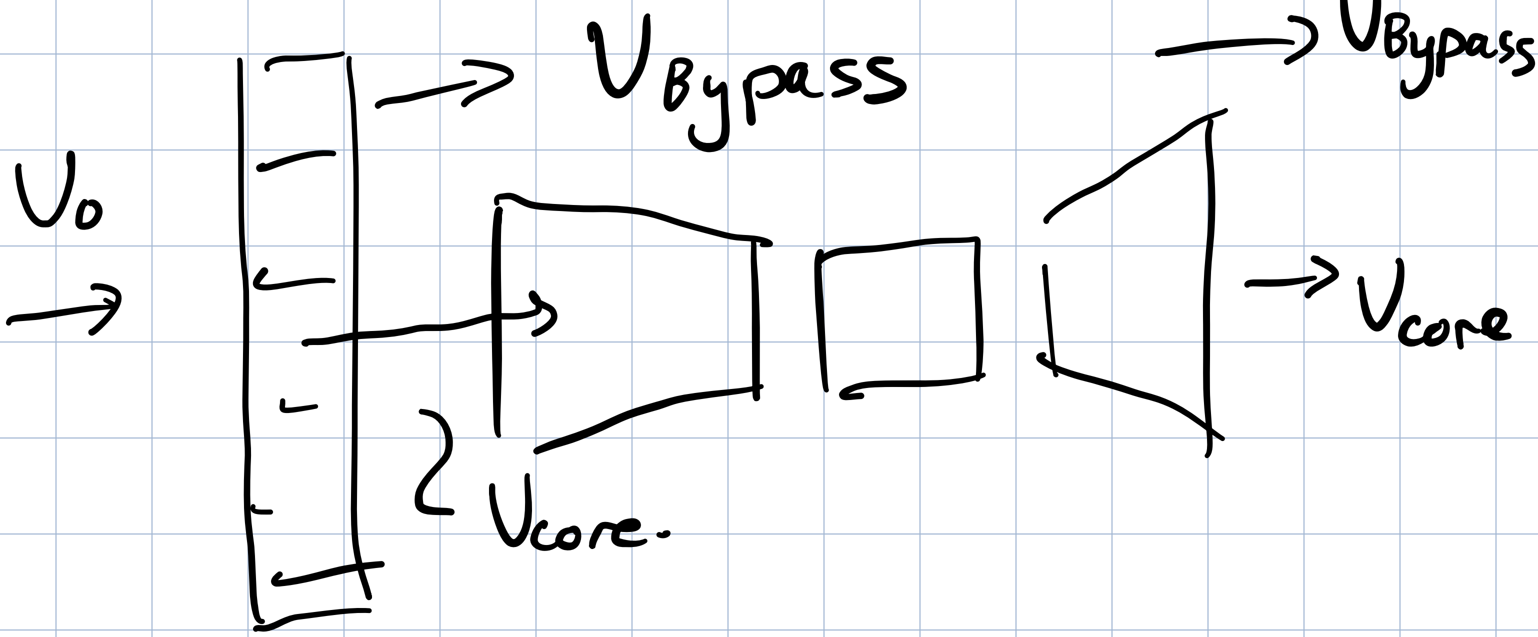
- turbojets, turbofans
  turboprops, turboshaft
- propellors

Gas turbine → air intake through inlet → compressed in a compressor → heated in combustor → expand & speed up in a turbine → exit flow hot, fast example:



turbojet

turbo fans:



$$\text{Thrust} = \frac{d(mv)}{dt}$$

<u>turbojet</u> → solve for thrust

$$\text{thrust}_{net} = \text{Gross thrust} - \text{Ram}_{\text{drag}}$$

$$= \dot{m} V_j - \dot{m} V_0$$

$$+ (P_j - P_0) \cdot A_e$$

$$= \dot{m}(V_j - V_0) + (P_j - P_0) A_e$$

↑

mass flow through engine

kg/s , lbs/s

V_j = exit velocity

V_0 = inlet velocity

P_j = exit pressure

P_0 = inlet pressure

typically $P_j - P_0 \simeq 0$

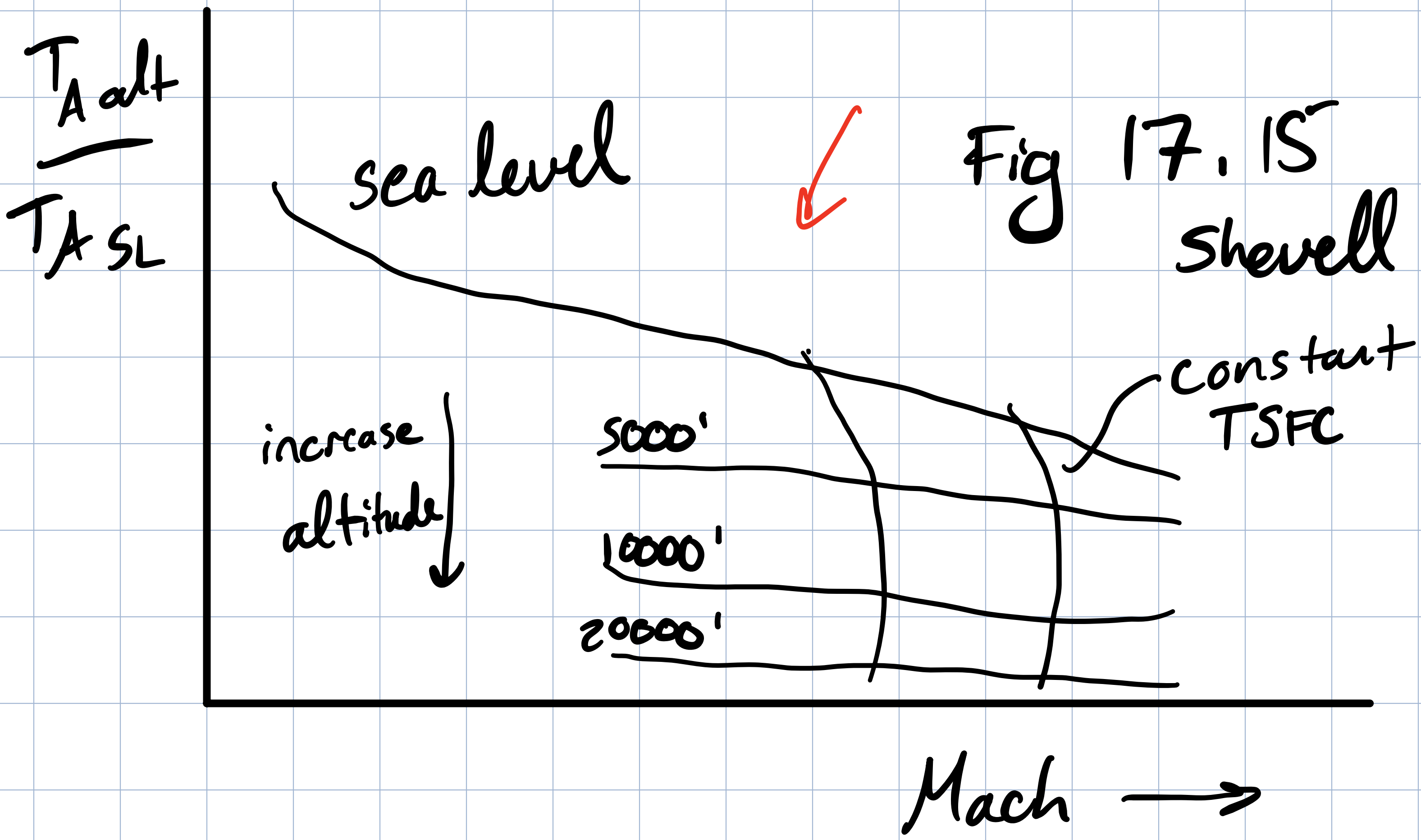
thus, $T = \dot{m}(V_j - V_0)$

$\dot{m} = \rho V_0 A$

simplest form

(costant Area engine)

Behavior of T_A changes with altitude



$T_{A\,alt}$ ↓ with altitude

doesn't vary much with Mach #

TSFC → specific fuel consumption
can also change with altitude

$\eta_o \rightarrow$ jet Aircraft overall Efficiency

$$\eta_o \equiv \frac{\text{useful work performed by system}}{\text{heat available from combustion of fuel}}$$

$$= \frac{T \cdot V_0}{T \cdot \underset{\uparrow \atop \text{TSFC}}{C_T} \cdot h_f} = \frac{V_0}{C_T \cdot h_f}$$ for turbojets

$h_f \equiv$ heat energy available in the fuel per weight of fuel

$h_f = 14.3$ million $\frac{\text{ft-lb}}{\text{lb}}$ for jet fuel can split $\eta_o = \eta_p \cdot \eta_t$

$\eta_p \equiv$ propulsive efficiency

$$= \frac{\text{useful work}}{\text{mechanical energy produced in system}}$$

$\dot{m}(V_j - V_o)$

$$= \frac{T \cdot V_o}{\frac{\dot{m}V_j^2}{2} - \frac{\dot{m}V_o^2}{2}} = \frac{2}{\frac{V_j}{V_o} + 1}$$

$\eta_t \equiv$ thermal efficiency

$$= \frac{\text{mechanical energy produced}}{\text{heat energy}}$$

$$= \dot{m}\,\frac{V_j^2 - V_o^2}{2} = \frac{V_j + V_o}{2\,C_T\,h_f}$$

$$\frac{\qquad}{\underbrace{T}_{\dot{m}(V_j - V_0)} \cdot C_T \cdot h_f}$$

$$\eta_0 = \frac{V_0}{C_T \cdot h_f}$$

Recal Breget Range Equation

$$R = \frac{V}{C_T} \cdot \frac{L}{D} \cdot \ln\left(\frac{W_0}{W_1}\right)$$

$$= \underbrace{\eta_0}_{\text{overall efficiency}} \cdot \underbrace{h_f}_{\text{type of fuel}} \cdot \frac{L}{D} \cdot \ln\left(\frac{W_0}{W_1}\right)$$

for a type of Engine ~ approximate