$W_{crew} := 200\ lbf$ $n_{max} := 7$ $V_{max\_sl\_wo} := 400\ kn$ $\Psi_{itr\_sl} := 30\ \frac{deg}{s}$ $S_{takeoff\_50ft} := 1400\ ft$

$W_{gun} := 2000\ lbf$ $ROC_{sl} := 10000\ \frac{ft}{min}$ $V_{slp} := 375\ kn$ $S_{landing\_50ft} := 1900\ ft$

$W_{ammo} := 2000\ lbf$ $V_{stall\_sl} := 95\ kn$ $M_{cruise} := 0.5$ $AR := 6.5$

$C_{L\_max} := 2.8$ $BPR := 5.4$

$Swet\_Sref := 2.1$ $S := 806\ ft^2$

$AR_{wet} := \frac{AR}{Swet\_Sref} = 3.0952$

$KLD := 14$ $C_{fe} := .0035$

$L\_D_{max} := KLD \cdot \sqrt{AR_{wet}} = 24.6306$ $C_{D0} := C_{fe} \cdot Swet\_Sref = 0.0074$

$e_{Oswald} := \frac{4 \cdot C_{D0} \cdot L\_D_{max}^2}{AR \cdot \pi} = 0.8734$ $K := \frac{1}{\pi \cdot AR \cdot e_{Oswald}} = 0.0561$

$\rho_{30k} := 10.97 \cdot 10^{-4}\ \frac{slug}{ft^3}$ $\rho := 23.77 \cdot 10^{-4}\ \frac{slug}{ft^3}$

$a_{30k} := 589\ kn$

$V_{30k} := M_{cruise} \cdot a_{30k} = 294.5\ kn$

$W_0 := 39900\ lbf$ $T := 19773\ lbf$

$\mu_{concrete} := 0.03$

$V_{TO} := 1.1 \cdot V_{stall\_sl} = 176.376\ \frac{ft}{s}$

$C_{L\_TO} := \frac{2 \cdot W_0}{\rho \cdot V_{TO}^2 \cdot S} = 1.3389$

$C_{D\_TO} := C_{D0} + K \cdot C_{L\_TO}^2 = 0.1079$

$q_{TO} := 0.5 \cdot \rho \cdot V_{TO}^2 = 36.9724\ psf$

$D_{TO} := q_{TO} \cdot S \cdot \left(C_{D\_TO}\right) = 3214.2933\ lbf$

$L_{TO} := q_{TO} \cdot S \cdot C_{L\_TO} = 39900\ lbf$

$K_T := \left(\frac{(70\ \% \cdot T)}{W_0}\right) - \mu_{concrete} = 0.3169$

$V_i := 0\ \frac{ft}{s}$

Table 17.1 Ground Rolling Resistance

Surface	μ-Typical Values	
	Rolling (Brakes Off)	Brakes On
Dry concrete/asphalt	0.03–0.05	0.3–0.5
Wet concrete/asphalt	0.05	0.15–0.3
Icy concrete/asphalt	0.02	0.06–0.10
Hard turf	0.05	0.4
Firm dirt	0.04	0.3
Soft turf	0.07	0.2
Wet grass	0.08	0.2

$$K_A := \frac{\rho}{2 \cdot \left(\frac{W_0}{S}\right)} \cdot \left(\mu_{concrete} \cdot C_{L\_TO} - C_{D0} - K \cdot C_{L\_TO}^{\,2}\right) = -1.7494 \cdot 10^{-5}\ \frac{s^2}{m^2}$$

$$S_G := \frac{1}{2\ g_e \cdot K_A} \cdot \ln\left(\frac{K_T + K_A \cdot V_{TO}^{\,2}}{K_T + K_A \cdot V_i^{\,2}}\right) = 1661.9738\ ft$$

$$n := \frac{\frac{1}{2} \cdot \rho \cdot S \cdot \left(0.9 \cdot C_{L\_max}\right) \cdot \left(1.15 \cdot V_{stall\_sl}\right)^2}{\frac{1}{2} \cdot \rho \cdot S \cdot C_{L\_max} \cdot V_{stall\_sl}^{\,2}} = 1.1902$$

$V_{TR} := 1.15 \cdot V_{stall\_sl} = 109.25\ kn$ $h_{obs} := 50\ ft$

$$R := \frac{V_{TR}^{\,2}}{g_e \cdot (n-1)} = 5554.6769\ ft$$

$V_{CL} := 1.2 \cdot V_{stall\_sl} = 114\ kn$

$$C_{L\_CL} := \frac{2 \cdot W_0}{\rho \cdot V_{CL}^{\,2} \cdot S} = 1.1251$$

$$C_{D\_CL} := C_{D0} + K \cdot C_{L\_CL}^{\,2} = 0.0783$$

$$q_{CL} := 0.5 \cdot \rho \cdot V_{CL}^{\,2} = 0.3056\ psi$$

$$D_{CL} := q_{CL} \cdot S \cdot \left(C_{D\_CL}\right) = 2777.5164\ lbf$$

$$L_{CL} := q_{CL} \cdot S \cdot C_{L\_CL} = 39900\ lbf$$

$$\gamma_{CL} := \operatorname{asin}\left(\frac{42\ \% \cdot T - D_{CL}}{W_0}\right) = 7.9625\ deg$$

$$S_{TR} := R \cdot \sin\left(\gamma_{CL}\right) = 769.4611\ ft$$

$$h_{TR} := R \cdot \left(1 - \cos\left(\gamma_{CL}\right)\right) = 53.5529\ ft$$

$$S_{TR} := \sqrt{R^2 - \left(R - h_{obs}\right)^2} = 743.618\ ft$$

$$S_{Total\_TO} := S_G + S_{TR} = 2405.59\ ft$$

$$\frac{S_{Total\_TO} - S_{takeoff\_50ft}}{S_{takeoff\_50ft}} = 71.828\ \%$$

$$T_{av} := 0.75 \cdot T \cdot \left(\frac{5 + BPR}{4 + BPR}\right) = 16407.383\ lbf$$

$$BFL := \left(\frac{0.863}{1 + 2.3 \cdot (0.03)} \cdot \left(\frac{\frac{W_0}{S}}{\rho\ g_e \cdot C_{L\_CL}} + h_{obs}\right) \cdot \left(\frac{1}{\frac{T_{av}}{W_0} - \left(0.01 \cdot C_{L\_max} + 0.02\right)} + 2.7\right)\right) + \left(\frac{655\ ft}{\sqrt{\frac{\rho}{\rho}}}\right) = 1038.7415\ m$$

$W := W_0 - (10\ \text{min} \cdot 10\ \% + 1\ \text{min} \cdot 100\ \%) \cdot T \cdot 0.75\ \frac{\text{lbf}}{\text{lbf hr}} = 39405.675\ \text{lbf}$

$T_{30} := T \cdot \frac{\rho_{30k}}{\rho} = 9125.3601\ \text{lbf}$

$C_{L\_min\_th\_req} := \sqrt{\frac{C_{D0}}{K}} = 0.3621$

$LD\_min\_th\_req := \sqrt{\frac{1}{4 \cdot C_{D0} \cdot K}} = 24.6306$

$C_{L\_min\_pw\_req} := \sqrt{\frac{3 \cdot C_{D0}}{K}} = 0.6271$

$LD\_min\_pw\_req := \sqrt{\frac{1}{4 \cdot C_{D0} \cdot K}} \cdot .866 = 21.3301$

$\rho := 23.77 \cdot 10^{-4}\ \frac{\text{slug}}{\text{ft}^3} \quad a_{sl} := 661\ \text{kn}$

$M_{max} := \frac{V_{max\_sl\_wo}}{a_{sl}} = 0.6051 \quad V_{cruise\_sl} := M_{cruise} \cdot a_{sl} = 330.5\ \text{kn}$

$V_{min\_pw\_req} := \sqrt{\frac{2 \cdot W}{\rho \cdot S} \cdot \sqrt{\frac{K}{3 \cdot C_{D0}}}} = 151.7444\ \text{kn} \quad V_{min\_th\_req} := \sqrt{\frac{2 \cdot W}{\rho \cdot S} \cdot \sqrt{\frac{K}{C_{D0}}}} = 199.7068\ \text{kn}$

$V_{bcr} := \sqrt{\frac{\frac{W}{S}}{3 \cdot \rho \cdot C_{D0}} \cdot \left(\frac{T}{W} + \sqrt{\left(\frac{T}{W}\right)^2 + 12 \cdot C_{D0} \cdot K} \right)} = 574.6457\ \text{kn}$

$C_L := \frac{2 \cdot W}{\rho \cdot V_{cruise\_sl}^2 \cdot S} = 0.1322$

$C_D := C_{D0} + K \cdot C_L^2 = 0.0083$

$q := 0.5 \cdot \rho \cdot V_{cruise\_sl}^2 = 2.5682\ \text{psi}$

$D := q \cdot S \cdot \left(C_D \right) = 2482.9171\ \text{lbf}$

$V_v := V_{cruise\_sl} \cdot \left(\frac{T - D}{W} \right) = 244.7558\ \frac{\text{ft}}{\text{s}}$

$\gamma := \text{asin}\left(\frac{V_v}{V_{bcr}} \right) = 14.6168\ \text{deg}$

$$V_{30k} := \sqrt{\frac{\frac{W}{S}}{3 \cdot \rho_{30k} \cdot C_{D0}} \cdot \left(\frac{T_{30}}{W} + \sqrt{\left(\frac{T_{30}}{W} \right)^2 + 12 \cdot C_{D0} \cdot K} \right)} = 579.6728 \text{ kn}$$

$$C_{L30k} := \frac{2 \cdot W}{\rho \cdot V_{30k}^2 \cdot S} = 0.043$$

$$C_{D30k} := C_{D0} + K \cdot C_{L30k}^2 = 0.0075$$

$$q_{30k} := 0.5 \cdot \rho \cdot V_{30k}^2 = 7.9004 \text{ psi}$$

$$D_{30k} := q_{30k} \cdot S \cdot \left(C_{D30k} \right) = 6834.5381 \text{ lbf}$$

$$V_{v30k} := V_{30k} \cdot \left(\frac{T_{30} - D_{30k}}{W} \right) = 33.6989 \text{ kn}$$

$$a_{30k} := \frac{V_{v30k} - V_v}{30000 \text{ ft}} = -0.0063 \frac{1}{\text{s}}$$

$$t_{30k} := \frac{1}{a_{30k}} \cdot \ln\left(\frac{V_{v30k}}{V_v} \right) = 3.8838 \text{ min}$$

$$RC_{sl} := V_{cruise\_sl} \cdot \left(\frac{T}{W} - \frac{C_D}{C_L} \right) = 14685.3453 \frac{\text{ft}}{\text{min}}$$

$$\frac{RC_{sl} - ROC_{sl}}{ROC_{sl}} = 0.4685$$

$$RC_{30k} := V_{cruise\_sl} \cdot \left(\frac{T_{30}}{W} - \frac{C_D}{C_L} \right) = 5641.7641 \frac{\text{ft}}{\text{min}}$$

$$\Delta W_{30k} := \left(\left(-\left(.6 \frac{\text{lbf}}{\text{lbf hr}} \right) \right) \cdot \left(\frac{T + T_{30}}{2} \right) \right) \cdot t_{30k} = -561.1774 \text{ lbf}$$

$$W := \left(W + \Delta W_{30k} \right) = 38844.4976 \text{ lbf}$$

$$R_{climb30k} := \frac{t_{30k}}{2} \cdot \left(V_{cruise\_sl} \cdot \left(\cos\left(\text{asin}\left(\frac{RC_{sl}}{V_{cruise\_sl}} \right) \right) \right) + V_{30k} \cdot \left(\cos\left(\left(\text{asin}\left(\frac{RC_{30k}}{V_{30k}} \right) \right) \right) \right) \right) = 28.2862 \text{ nmi}$$

$$R_{CruiseOut} := 400 \text{ nmi}$$

$$C_L := \frac{2 \cdot W}{\rho_{30k} \cdot V_{30k}^2 \cdot S} = 0.0918$$

$$C_D := C_{D0} + K \cdot C_L^2 = 0.0078$$

$$W := W \cdot e^{-\left(\frac{\left(R_{CruiseOut} - R_{climb30k}\right) \cdot 0.48 \frac{lbf}{lbf\ hr}}{V_{30k} \cdot \frac{C_L}{C_D}}\right)} = 37838.8449\ lbf$$

Conduct Sea Level Penetration for 50NM at 375 kts.

$a_{30k} := 589\ kn$

$M_{slp.30k} := \frac{V_{slp}}{a_{30k}} = 0.6367$ $M_{slp.sl} := \frac{V_{slp}}{a_{sl}} = 0.5673$

$C_L := \frac{2 \cdot W}{\rho_{30k} \cdot V_{slp}^{\ 2} \cdot S}$

$C_D := C_{D0} + K \cdot C_L^{\ 2} = 0.0099$

$D_{30k} := \frac{W}{\frac{C_L}{C_D}} = 1754.9616\ lbf$

$SR_{30k} := V_{slp} \cdot \left(\frac{41\ \% \cdot T}{W} \cdot \frac{\rho_{30k}}{\rho} - \frac{C_D}{C_L}\right) = 19.6865\ kn$

$C_L := \frac{2 \cdot W}{\rho \cdot V_{slp}^{\ 2} \cdot S} = 0.0986$

$C_D := C_{D0} + K \cdot C_L^{\ 2} = 0.0079$

$D_{sl} := \frac{W}{\frac{C_L}{C_D}} = 3029.7151\ lbf$

$SR_{sl} := V_{slp} \cdot \left(\frac{47\ \% \cdot T}{W} - \frac{C_D}{C_L}\right) = 62.075\ kn$

$a := \frac{SR_{sl} - SR_{30k}}{30000\ ft} = 0.0024\ Hz$

$t_{slp} := \frac{1}{a} \cdot \ln\left(\frac{SR_{sl}}{SR_{30k}}\right) = 8.0259\ min$

$$R_{slp} := \frac{t_{slp}}{2} \cdot \left(V_{slp} \cdot \left(\cos\left(\left(\operatorname{asin}\left(\frac{SR_{30k}}{V_{slp}}\right)\right)\right)\right) + V_{slp} \cdot \left(\cos\left(\operatorname{asin}\left(\frac{SR_{sl}}{V_{slp}}\right)\right)\right)\right) = 49.7815\ nmi$$

$$W := W - \left(.6 \ \frac{\text{lbf}}{\text{lbf hr}} \right) \cdot \left(\frac{D_{sl} + D_{30k}}{2} \right) \cdot t_{slp} = 37646.8373 \ \text{lbf}$$

Combat:

$$W := W - (15 \ \text{min}) \cdot T \ 1 \ \frac{\text{lbf}}{\text{lbf hr}} = 32703.5873 \ \text{lbf}$$

$$V_{corner} := \sqrt{\frac{2 \cdot n_{max} \cdot W}{\rho \cdot C_{L\_max} \cdot S}} = 173.0922 \ \text{kn}$$

$$n_{TR} := \left(\left(\frac{\Psi_{itr\_sl} \cdot V_{cruise\_sl}}{g_e} \right)^2 + 1 \right)^{.5} = 9.1329$$

$$TurnRate_{sl} := \frac{g_e \cdot \sqrt{n_{max}^{\ 2} - 1}}{V_{corner}} = 43.7168 \ \frac{\text{deg}}{\text{s}}$$

$$\frac{TurnRate_{sl}}{\Psi_{itr\_sl}} - 1 = 45.7227 \ \%$$

Fire All:

$$W := W - W_{ammo} = 30703.5873 \ \text{lbf}$$

Climb back again 35

$$a_{35} := 573 \ \text{kn}$$

$$V_{35k} := M_{cruise} \cdot a_{35} = 286.5 \ \text{kn}$$

$$\rho_{35k} := 8.89 \cdot 10^{-4} \ \frac{\text{slug}}{\text{ft}^3}$$

$$C_L := \frac{2 \cdot W}{\rho \cdot V_{cruise\_sl}^{\ 2} \cdot S} = 0.103$$

$$C_D := C_{D0} + K \cdot C_L^{\ 2} = 0.0079$$

$$D_{sl} := \frac{W}{\frac{C_L}{C_D}} = 2353.3265 \ \text{lbf}$$

$$RC_{sl} := V_{cruise\_sl} \cdot \left(\frac{T}{W} - \frac{C_D}{C_L} \right) = 187.3494 \ \text{kn}$$

$$C_L := \frac{2 \cdot W}{\rho_{35k} \cdot V_{35k}^{\ 2} \cdot S} = 0.3665$$

$$C_D := C_{D0} + K \cdot C_L^{\ 2} = 0.0149$$

$$RC_{35k} := V_{35k} \cdot \left(\frac{T}{W} \cdot \frac{\rho_{35k}}{\rho} - \frac{C_D}{C_L} \right) = 57.3723 \ \text{kn}$$

$$a := \frac{RC_{35k} - RC_{sl}}{35000 \ \text{ft}} = -0.0063 \ \text{Hz}$$

$$D_{35k} := \frac{W}{\frac{C_L}{C_D}} = 1246.6551 \ \text{lbf}$$

$$t_{climb35k} := \frac{1}{a} \cdot \ln\left(\frac{RC_{35k}}{RC_{sl}}\right) = 3.1468 \text{ min}$$

$$R_{climb35k} := \frac{t_{climb35k}}{2} \cdot \left[V_{cruise\_sl} \cdot \left[\cos\left[\left(\left[\text{asin}\left(\frac{RC_{sl}}{V_{cruise\_sl}}\right)\right]\right)\right] + V_{35k} \cdot \left[\cos\left[\text{asin}\left(\frac{RC_{35k}}{V_{35k}}\right)\right]\right]\right] = 14.5004$$

$$W := W - \left(0.6 \frac{\text{lbf}}{\text{lbf hr}}\right) \cdot \left(\frac{D_{sl} + D_{35k}}{2}\right) \cdot t_{climb35k} = 30646.9459 \text{ lbf}$$

Cruise back

$$C_L := \frac{2 \cdot W}{\rho_{35k} \cdot V_{35k}^{\,2} \cdot S} = 0.3658$$

$$C_D := C_{D0} + K \cdot C_L^{\,2} = 0.0149$$

Sink Rate Range Clearence

$$W := W \cdot \mathbf{e}^{-\left(\frac{\left(R_{CruiseOut} - R_{climb35k} - 15 \text{ nmi}\right) \cdot 0.4 \frac{\text{lbf}}{\text{lbf hr}}}{V_{35k} \cdot \frac{C_L}{C_D}}\right)} = 30009.9947 \text{ lbf}$$

$$C_L := \frac{2 \cdot W}{\rho_{35k} \cdot V_{35k}^{\,2} \cdot S} = 0.3582$$

$$C_D := C_{D0} + K \cdot C_L^{\,2} = 0.0145$$

$$D_{35k} := \frac{W}{\frac{C_L}{C_D}} = 1218.4719 \text{ lbf}$$

$$SR_{35k} := V_{35k} \cdot \left(\frac{T}{W} \cdot \frac{\rho_{35k}}{\rho} - \frac{C_D}{C_L}\right) = 58.9673 \text{ kn}$$

$$C_L := \frac{2 \cdot W}{\rho \cdot V_{cruise\_sl}^{\,2} \cdot S} = 0.1007$$

$$C_D := C_{D0} + K \cdot C_L^{\,2} = 0.0079$$

$$D_{sl} := \frac{W}{\frac{C_L}{C_D}} = 2360.2396 \text{ lbf}$$

$$SR_{sl} := V_{cruise\_sl} \cdot \left(\frac{T}{W} - \frac{C_D}{C_L} \right) = 191.7667 \text{ kn}$$

$$a := \frac{SR_{sl} - SR_{35k}}{35000 \text{ ft}} = 0.0064 \text{ Hz}$$

$$t_{sr} := \frac{1}{a} \cdot \ln\left(\frac{SR_{sl}}{SR_{35k}} \right) = 184.15 \text{ s}$$

$$R_{sr} := \frac{t_{sr}}{2} \cdot \left(V_{35k} \cdot \left(\cos\left(\left(\left(\text{asin}\left(\frac{SR_{35k}}{V_{35k}} \right) \right) \right) \right) + V_{cruise\_sl} \cdot \left(\cos\left(\text{asin}\left(\frac{SR_{sl}}{V_{cruise\_sl}} \right) \right) \right) \right) = 14.0553 \text{ nmi}$$

$$W := W - \left(.8 \frac{\text{lbf}}{\text{lbf hr}} \right) \cdot \left(\frac{D_{sl} + D_{35k}}{2} \right) \cdot t_{sr} = 29936.7703 \text{ lbf}$$

Loiter $E := 30 \text{ min}$

$$V_{min\_th\_req} := \sqrt{\frac{2 \cdot W}{\rho \cdot S} \cdot \sqrt{\frac{K}{C_{D0}}}} = 174.0668 \text{ kn}$$

$$C_L := \frac{2 \cdot W}{\rho \cdot V_{min\_th\_req}^{\,2} \cdot S} = 0.3621$$

$$C_D := C_{D0} + K \cdot C_L^{\,2} = 0.0147$$

$$W := W \cdot \mathbf{e}^{\left(- \frac{E \cdot 0.25 \frac{\text{lbf}}{\text{lbf hr}}}{\frac{C_L}{C_D}} \right)} = 29785.2264 \text{ lbf}$$

$$V_{ap} := 1.2 \cdot V_{stall\_sl} = 114 \text{ kn}$$

$$C_L := \frac{2 \cdot W}{\rho \cdot V_{ap}^{\,2} \cdot S} = 0.8399$$

$$C_D := C_{D0} + K \cdot C_L^{\,2} = 0.0469$$

$$\gamma_{ap} := \frac{35\,\% \cdot T}{W} - \frac{C_D}{C_L} = 10.1132 \text{ deg}$$

$$V_{TD} := 1.1 \cdot V_{stall\_sl} = 104.5 \text{ kn}$$

$$V_f := 1.15 \cdot V_{stall\_sl} = 109.25 \text{ kn}$$

$$C_L := \frac{2 \cdot W}{\rho \cdot V_f^{\,2} \cdot S} = 0.9145$$

$$C_D := C_{D0} + K \cdot C_L^{\,2} = 0.0542$$

$$R_f := \frac{V_f^{\,2}}{g_e \cdot (n-1)} = 5554.6769\ \text{ft}$$

$$S_f := R_f \cdot \left(\frac{15\ \% \cdot T}{W} - \frac{C_D}{C_L} \right) = 223.6792\ \text{ft}$$

$$h_f := R_f \cdot \left(1 - \cos\left(\gamma_{ap}\right)\right) = 86.3045\ \text{ft}$$

$$S_{FR} := 2\ \text{s} \cdot V_{TD} = 352.752\ \text{ft}$$

$$V_{TD} := 1.1 \cdot V_{stall\_sl} = 104.5\ \text{kn}$$

$$C_{L\_TD} := \frac{2 \cdot W}{\rho \cdot V_{TD}^{\,2} \cdot S} = 0.9995$$

$$C_D := C_{D0} + K \cdot C_{L\_TD}^{\,2} = 0.0634$$

$$\mu_{concrete} := 0.5$$

$$K_T := \left(\frac{(0.01\ \% \cdot T)}{W} \right) - \mu_{concrete} = -0.4999$$

$$K_A := \frac{\rho}{2 \cdot \left(\frac{W}{S}\right)} \cdot \left(\mu_{concrete} \cdot C_{L\_TD} - C_{D0} - K \cdot C_{L\_TD}^{\,2} \right) = 0.0002\ \frac{\text{s}^2}{\text{m}^2}$$

$$S_{GL} := \frac{1}{2\ g_e \cdot K_A} \cdot \ln\left(\frac{K_T + K_A \cdot V_i^{\,2}}{K_T + K_A \cdot V_{TD}^{\,2}} \right) = 2287.8071\ \text{ft}$$

$$S_{Landing} := \left(S_f + S_{FR}\right) + S_{GL} = 2864.2382\ \text{ft}$$

$$S_{Landing} = 0.5425\ \text{mile}$$

$$W := W - W_{gun} - W_{crew} = 27585.2264\ \text{lbf}$$

$$\frac{S_{Landing}}{S_{landing\_50ft}} - 1 = 0.5075$$

$$W_{Empty} := 95\ \% \cdot W = 26205.9651\ \text{lbf}$$

$$W_{Fuel} := W_0 - W_{Empty} = 13694.0349\ \text{lbf}$$

$$\frac{W_{Fuel}}{W_0} = 0.3432$$