

16.82 HALE Gpkit Models and Variables

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Objective Function

minimize W [lbf]

Constraints

Steady Level Flight Condition $W = 0.5C_LSV^2\rho$
 $Thrust \geq 0.5C_DSV^2\rho$

Aerodynamic Model $C_D \geq 0.3183 \frac{C_L^2}{ARe} + 2C_fK_{wing} + C_L^{16}cl_{16} + C_{d0}$
 $b^2 = ARS$
 $C_{L-max} \geq C_L$
 $Re = \frac{S^{0.5}V\rho}{AR^{0.5}\mu}$
 $C_f \geq \frac{0.074}{Re^{0.2}}$
 $C_{L-max} \leftarrow 1.5$
 $C_{d0} \leftarrow 0.02$
 $K_{wing} \leftarrow 1.3$
 $\mu \leftarrow 1.5 \times 10^{-5} \frac{\text{N}\cdot\text{s}}{\text{m}^2}$
 $cl_{16} \leftarrow 0.0001$
 $e \leftarrow 0.9$

Engine Weight Model $W_{eng} \geq \frac{P_{shaft}^{1.2}eng_{cnst}}{\eta_t^{1.2}}$
 $W_{eng-tot} \geq 2.572W_{eng}^{0.92}$
 $\eta_t \leftarrow 0.5$
 $eng_{cnst} \leftarrow 0.0013$

Fuel Volume Model $Vol_{fuel} = \frac{W_{fuel}}{\rho_{fuel}}$
 $\rho_{fuel} \leftarrow 6.01 \frac{\text{lbf}}{\text{liquid}_g\text{allon}}$

Structural Model

$$m_{skin} \geq 0.52 S r h o_{skin} t o v e r c + 1.977 S r h o_{skin}$$

$$F = L F W_{cent}$$

$$c = \frac{S}{b}$$

$$M o m = 0.125 F b$$

$$L_{cap} \geq \frac{M o m}{h_{spar}}$$

$$A_{capcent} \geq \frac{L_{cap}}{\sigma_{capma_{cap}}}$$

$$V o l_{cap} \geq 0.3333 A_{capcent} b$$

$$m_{cap} = V o l_{cap} r h o_{cap}$$

$$c t o v e r c \geq h_{spar}$$

$$w_{cap} = \frac{A_{capcent}}{t_{cap}}$$

$$\delta_{tip} = 0.25 \frac{b^2 \sigma_{capma_{cap}}}{E_{cap} h_{spar}}$$

$$0.125 b \geq \delta_{tip}$$

$$E_{cap} \leftarrow 2 \times 10^7 \text{ pound_force_per_square_inch}$$

$$L F \leftarrow 5$$

$$r h o_{cap} \leftarrow 1.76 \frac{\text{g}}{\text{cm}^3}$$

$$r h o_{skin} \leftarrow 200 \frac{\text{g}}{\text{m}^2}$$

$$\sigma_{capma_{cap}} \leftarrow 4.75 \times 10^8 \text{ Pa}$$

$$t_{cap} \leftarrow 0.028 \text{ in}$$

$$t o v e r c \leftarrow 0.1$$

Weight Model

$$W_{cent} \geq W_{avionics} + W_{eng-tot} + W_{fix} + W_{fuel} + W_{fuse}$$

$$W_{wing} \geq g m_{cap} + g m_{skin}$$

$$W \geq 1.3 W_{wing} + W_{cent}$$

$$W_{zfw} \geq 0.2248 g m_{cap} + 0.2248 g m_{skin} + W_{avionics} + W_{eng-tot} + W_{fix} + W_{fuse}$$

$$L o v e r A = \frac{W}{S}$$

$$W_{avionics} \leftarrow 2 \text{ lbf}$$

$$W_{eng} \leftarrow 6 \text{ lbf}$$

$$W_{fix} \leftarrow 10 \text{ lbf}$$

$$W_{fuse} \leftarrow 20 \text{ lbf}$$

$$g \leftarrow 9.81 \frac{\text{m}}{\text{s}^2}$$

Breguet Range Model

$$z_{bre} \geq 0.1432 \frac{B S F C C_D V t}{C_L \eta_{prop}}$$

$$\frac{W_{fuel}}{W_{zfw}} \geq 0.1667 z_{bre}^3 + 0.5 z_{bre}^2 + z_{bre}$$

$$B S F C \leftarrow 0.6 \frac{\text{lbf}}{(\text{hp} \cdot \text{hr})}$$

$$t \leftarrow 6 \text{ day}$$

Atmospheric Model

$$2 \times 10^4 \geq h$$

$$T_{sl} \geq 0.3048 L_{atm} h + T_{atm}$$

$$\frac{T_{atm}^{4.3} p_{sl}}{R_{spec} T_{sl}^{5.3}} \geq \rho$$

$$a_{atm} = R_{spec}^{0.5} T_{atm}^{0.5} \gamma^{0.5}$$

$$L_{atm} \leftarrow 0.0065 \frac{\text{K}}{\text{m}}$$

$$R_{spec} \leftarrow 287.1 \frac{\text{J}}{(\text{K} \cdot \text{kg})}$$

$$T_{sl} \leftarrow 288.1 \text{ K}$$

$$\gamma \leftarrow 1.4$$

$$p_{sl} \leftarrow 1.013 \times 10^5 \text{ Pa}$$

Propellor Model	$Thrust = \frac{C_{Thrust} P_{shaft}}{C_{Power} D_{Prop} RPM}$ $MTip = 0.01596 \frac{D_{Prop} RPM}{a_{atm}}$ $0.85 \geq MTip$ $C_{Power} \leftarrow 0.25$ $C_{Thrust} \leftarrow 0.5$ $D_{Prop} \leftarrow 2 \text{ ft}$ $\eta_{prop} \leftarrow 0.85$
Footprint Model	$h \geq 0.008727 \theta_{look-up} d_{footprint} + 0.125 \frac{d_{footprint}^2}{R_{earth}} + 8.861 \times 10^{-7} \theta_{look-up}^3 d_{footprint}$ $R_{earth} \leftarrow 6371 \text{ km}$ $\theta_{look-up} \leftarrow 5$ $d_{footprint} \leftarrow 100 \text{ km}$
Wind Velocity Model	$V_{wind} \geq h w d_{cnst} + w d_{ln}$ $V \geq V_{wind}$ $h \geq h_{min}$ $h_{max} \geq h$ $h_{max} \leftarrow 2.087 \times 10^4 \text{ ft}$ $h_{min} \leftarrow 1.18 \times 10^4 \text{ ft}$ $w d_{cnst} \leftarrow 0.0015 \frac{\text{m}}{(\text{ft} \cdot \text{s})}$ $w d_{ln} \leftarrow 8.845 \frac{\text{m}}{\text{s}}$