Employee Time Card

Team Number:______

Week starting Monday (fill in Monday's date) ______________________________

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Week Total
Hours Worked								

Employee Signature __________________________________

Team Leader Signature ________________________________

Employee Time Card

Team Number:______

Week starting Monday (fill in Monday's date) ______________________________

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Week Total
Hours Worked								

Employee Signature __________________________________

Team Leader Signature ________________________________

Employee Time Card

Team Number:______

Week starting Monday (fill in Monday's date) ______________________________

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Week Total
Hours Worked								

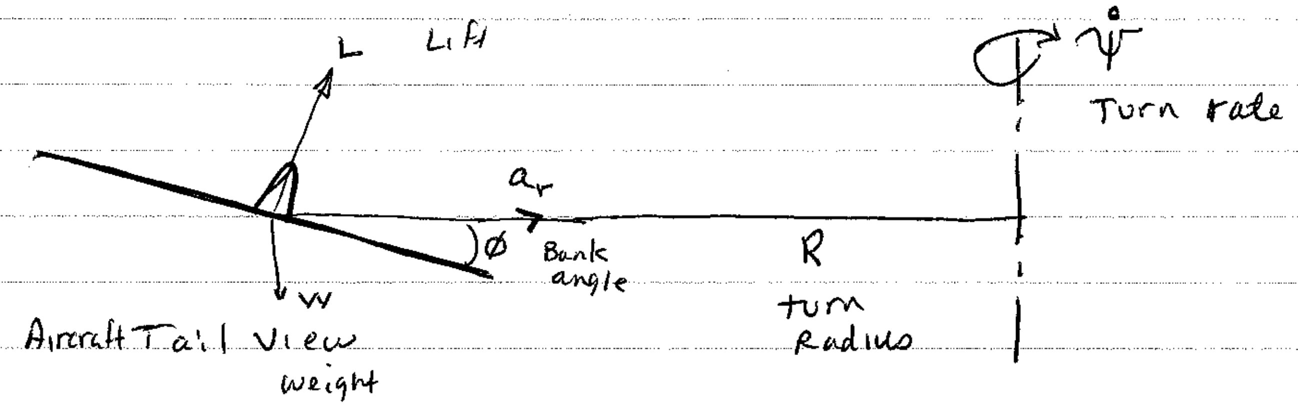
Employee Signature __________________________________

Team Leader Signature ________________________________

Notes: Data must be logged by the group leader.
Time Cards are due to the team leader on Tuesday for the preceeding week.
Hours worked include hours of class actually attended and productive hours spent outside of class working on the aircraft design.

AAE 451

Steady Turning Flight



<u>Objective</u>: Find R, $\dot{\psi}$ as a function of ϕ and V

V = forward speed $\qquad$ ϕ = Bank angle

R = Turn radius $\qquad$ $\dot{\psi}$ = rate of change of heading angle

m = mass of aircraft $\qquad$ W = weight of aircraft = mg

<u>Equilibrium Conditions</u>

- Horizontal Direction

$$m a_r = L \sin\phi = m \dot{\psi}^2 R = m V \dot{\psi}$$

$$V = \dot{\psi} R \Rightarrow m a_r = m\left(\frac{V}{R}\right)^2 R = m \frac{V^2}{R}$$

- Vertical Direction

$$L \cos\phi = W = mg$$

$$\frac{L}{W} = \frac{1}{\cos\phi} \equiv n \equiv \text{load factor}$$

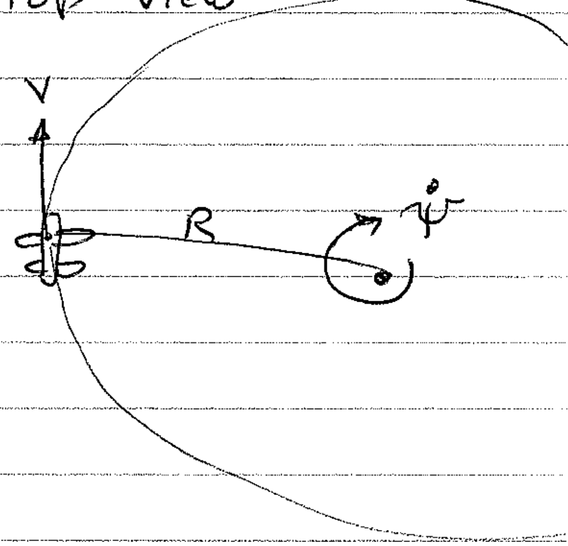
$$L = mg/\cos\phi$$

$$L\sin\phi = \frac{mg}{\cos\phi}\sin\phi = \frac{mV^2}{R}$$

$$\therefore \; R = V^2/(g\tan\phi) = \frac{V}{\dot{\psi}}$$

$$\therefore \; \dot{\psi} = g\tan\phi/V$$

Top View



Steady Turn in Mollenkopf

V_{TURN} = turning speed

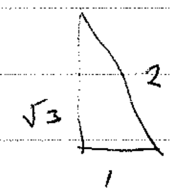
R = radius of turn = 80 ft

$$R = \frac{V_{TURN}^2}{g \tan\phi} \Rightarrow \tan\phi = \frac{V_{TURN}^2}{g R} \qquad \frac{ft^2}{sec^2}\ \frac{sec^2}{ft}$$

Assume V_{TURN} = 30 ft/sec

$$\tan\phi = \frac{(30)^2}{(32.2)80} = .35 \Rightarrow \phi = 19.3^0$$

$$n = \frac{1}{\cos\phi} = 1.06\ g$$



V_{TURN} = 40 ft/sec

$$\tan\phi = \frac{40^2}{(32.2)(80} = .62 \Rightarrow \phi = 31.8^0$$

$$n = \frac{1}{\cos\phi} = 1.18\ g$$

V_{TURN} = 50 deg/sec

$$\tan\phi = \frac{50^2}{(32.2)\cdot 80} = .97 \Rightarrow \phi = 44^0$$

$$n = \frac{1}{\cos\phi} = 1.39\ g$$

AAE-541 Aircraft Design
Preliminary Vehicle Sizing

A. Getting Started
B. Constraint Analysis
- **1.Stall Speed Constraint**
- **2. Cruise Speed Constraint**
- **3. Climb Constraint**
- **4.Take-off Constraint**
- **5. Other Constraints (see Raymer or Roskam)**

C Preliminary Weight Estimation
- **Method 1: Using Mission Requirements to Compute Battery Weight Fraction**
- **Method 2: Using Historical Data**

not included in this packet

See course web site for software that will help with some of these

Index of /~andrisan/Courses/AAE451_Fall_2006/AAE451_Buffer_F06

Name	Last modified	Size	Description
Parent Directory	21-Aug-06 10:40	-	
Constraint3.m	30-Aug-05 10:41	2k	
TakeOffConstraint.m	08-Feb-05 12:30	1k	
TakeOffEOM.m	02-Feb-05 18:36	1k	
Takeoff Analysis Resu..	03-Feb-05 18:21	28k	
Takeoff2.m	30-Aug-05 10:39	3k	
Weight_2.m	08-Feb-05 12:44	2k	
hash_left.m	02-Feb-05 16:18	1k	
hash_right.m	02-Feb-05 16:18	1k	
text2.m	14-Nov-96 10:58	1k	

D. Andrisani

AAE 421 Rough Notes on Preliminary Sizing

A. **How Do we Get Started in Design?**
(Initial Vehicle Sizing)

Remember the design process is non-unique

One way is as follows

PRELIMINARY WEIGHT ESTIMATION

- Given mission requirements + weight historical data

⇓

make rough estimate of weight of fuel W_F and Take off weight W_{TO}

See Roskam I - ch 2

CONSTRAINT ANALYSIS

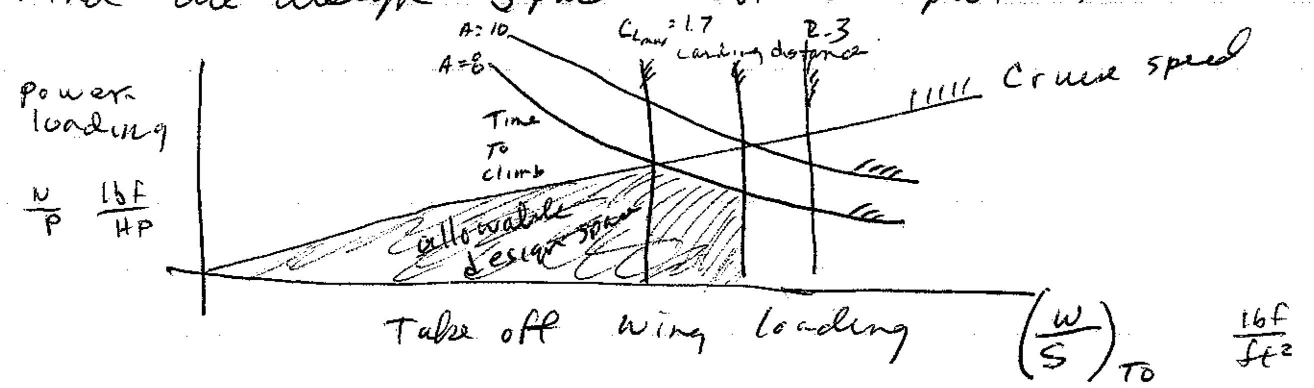
See Vol-1 Ch 3

- Given W_o mission Requirements and
  - Stall speed
  - take-off field length
  - landing field length
  - cruise speed
  - climb rate
  - time to climb
  - Maneuvering requirements

} Perform constraint analyses using constraint diagram

CONSTRAINT DIAGRAM

Find the design space in a plot of

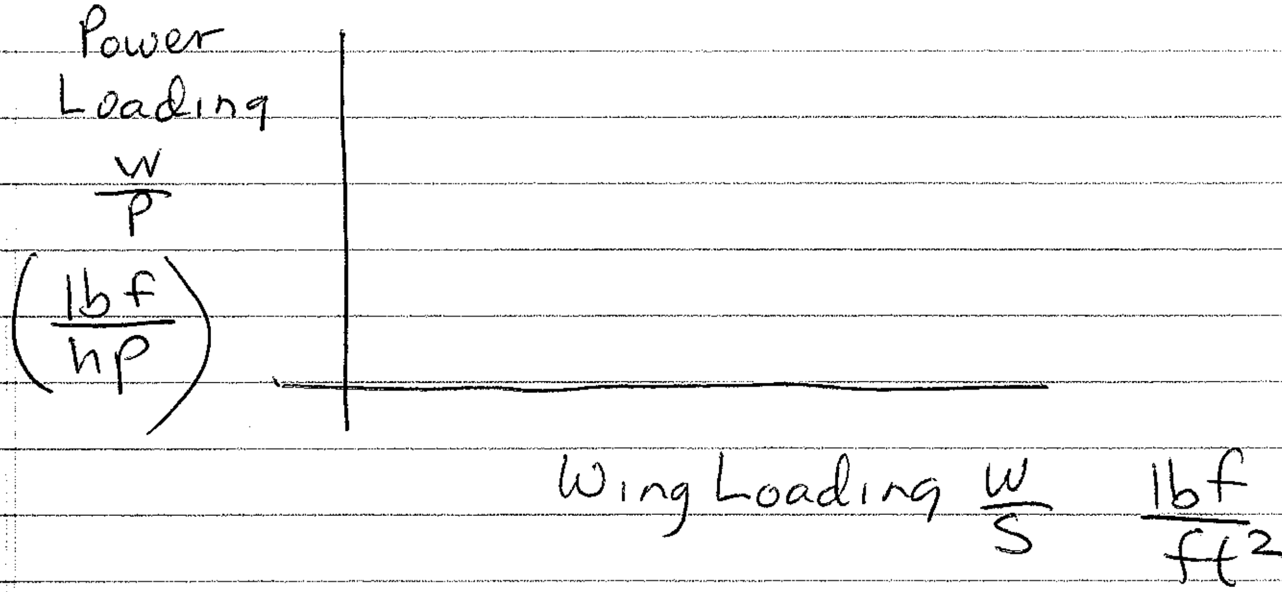


From this select design parameters

- Wing area
- take-off Thrust
- Max required TO Lift Coef Take off / Land

NOTES:

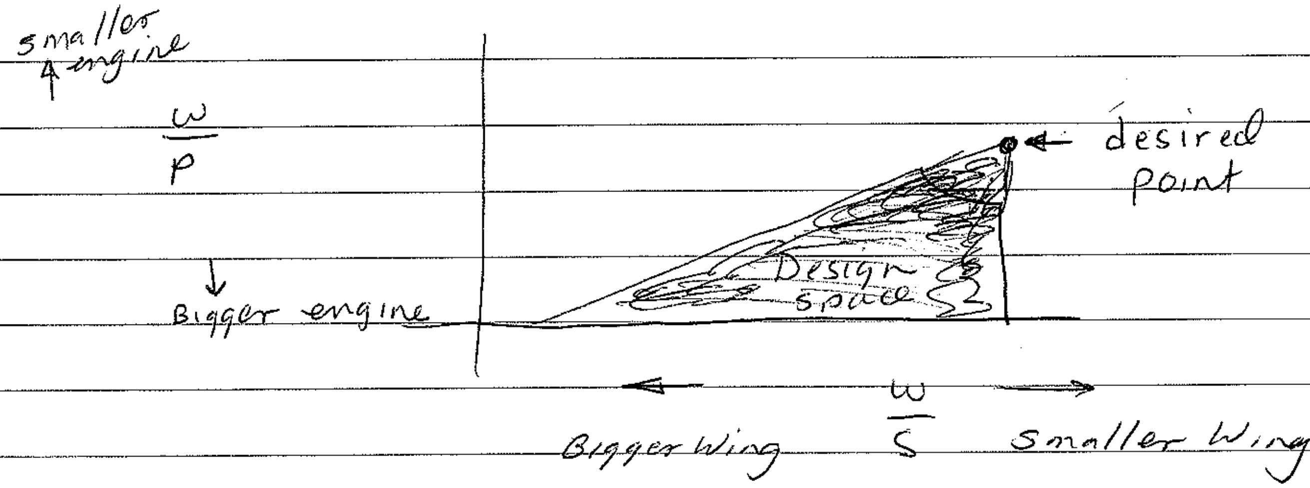
1. To help communicate among teams and Professor ANDRISANI we should all use the same units on constraint diagrams. Let's agree to use the following units and plot format.



2. Be sure to add hash marks on constraint lines so you know which side of the lines you want to be on

3. Design space is that region within which all the constraints are met.

4. Where do we want to be in the design space?



5. From this analysis we learn

W_{TO} from prelim. weight est.

$\frac{W_{TO}}{P_{sea\ level}}$, $\frac{W_{TO}}{S_{Ref}}$ } from design space for given $C_{L_{max}}$, L/D etc.

$P_{sea\ level}$

S_{Ref}

This information constitutes a preliminary vehicle sizing.

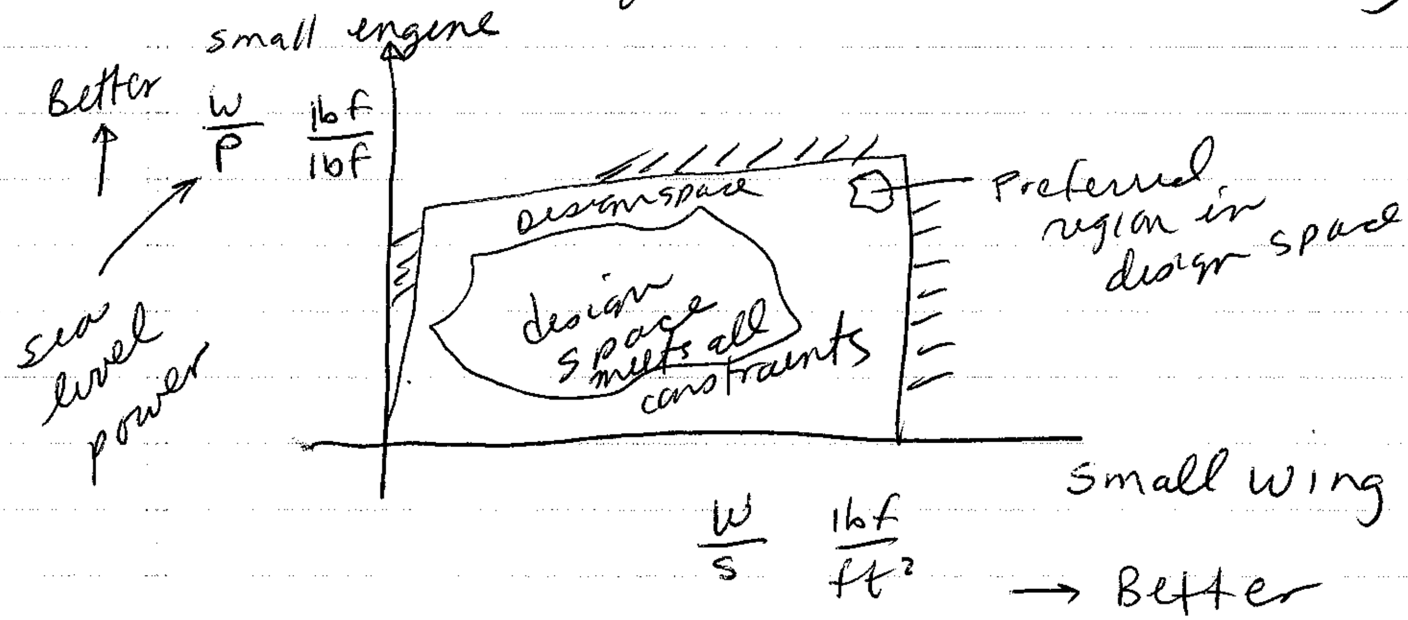
CONSTRAINT DIAGRAMS + Constraint Analyses

B. For each quantitative requirement of the mission
Find the relationship between
wing loading $\frac{W}{S}$ $\frac{lbf}{ft^2}$ and
power loading $\frac{W}{P} = lbf/hp$ that exactly satisfies that requirement. Find the region where the vehicle violates that requirement and indicate the forbidden region with a hash mark

→ Plot this as a line on a plot of $\frac{W}{P}$ vs $\frac{W}{S}$

Ref: Chapter 3 of Roskam Volume 1
Chapter 19 of Raymer

This is in fact a trade study.



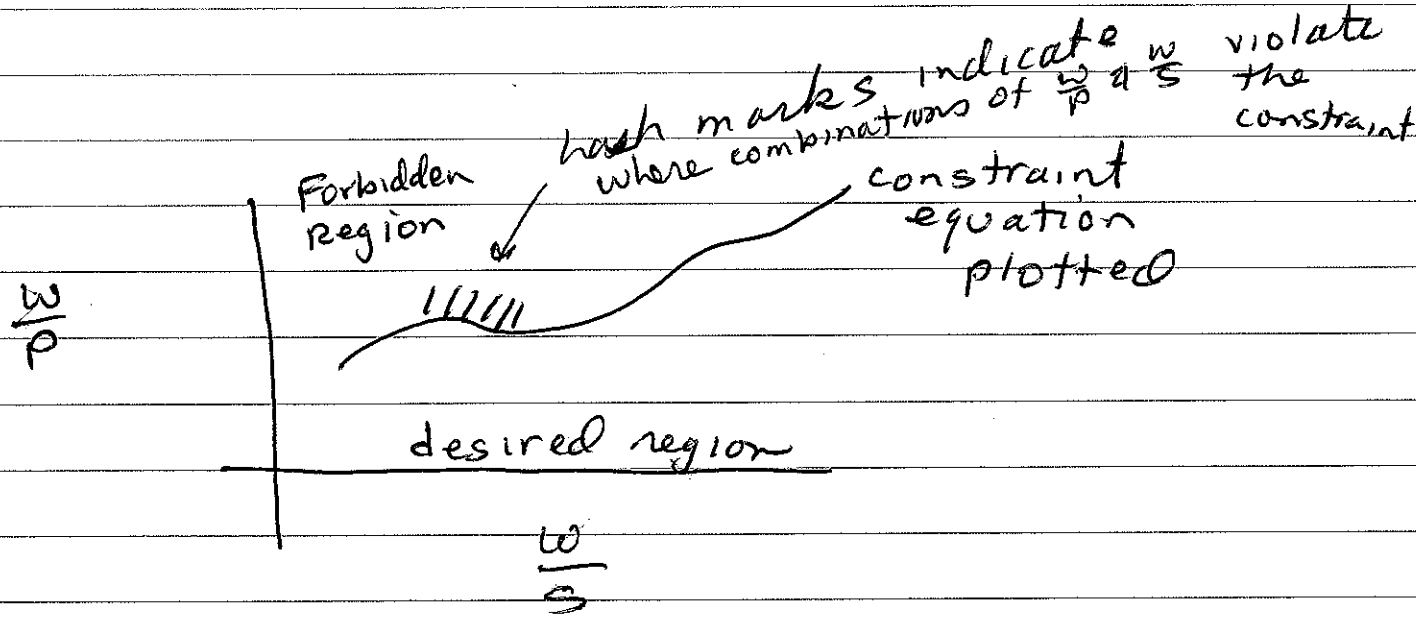
(Take-off Weight / Wing area)

The general form of a constraint equation is as follows

$$\frac{W_{take\text{-}off}}{P_{sea\ level}} = f\left(\frac{W_{take\text{-}off}}{S_{reference}}\right)$$

↑ is some function of

It is important to be able to determine



Constraint Analysis

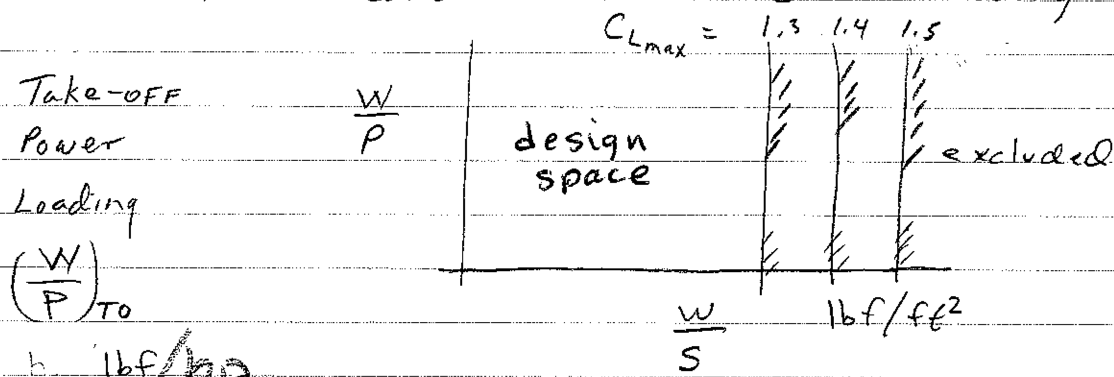
1. Sizing to stall speed requirements p. 90

Assume you know the desired stall speed V_s and $C_{L_{max}}$ of your 3-D wing

$$C_{L_{max}} = \frac{W}{\frac{1}{2}\rho V_s^2 S}$$

$$\therefore \frac{W}{S} = \frac{1}{2}\rho V_s^2 C_{L_{max}}$$ ⇐ CONSTRAINT EQUATION (valid for all power loadings)

This becomes a constraint on wing loading



If the aircraft is heavier then indicated by the line then w/s will be greater then the line and the aircraft will stall. So the region to the right of the line is excluded

2. Sizing to Cruise Speed Requirements (Wings Level) p 162

Power Required $= TV = DV = \bar{q} S C_D V$

$550\ SHP\ \eta_p = \frac{1}{2}\rho V^3 S C_D$

SHP is the shaft horsepower of the motor

η_p is the propeller efficiency

V is the velocity (cruise in this case)

D is drag

C_D is drag coefficient

Cruise speeds are typically computed at 75 – 80% power. In that case it can be shown that induced drag is small compared to profile drag. Frequently the assumption

$$C_{D_i} = .1\, C_{D_0}$$

$$C_D = C_{D_0} + C_{D_i} = 1.1\, C_{D_0}$$

$$\therefore \quad \frac{550\, \eta_p}{.5 \rho V^3 S\, 1.1 C_{D_0}} = \frac{1}{SHP}$$

multiplying both sides by weight

$$\frac{550\, \eta_p}{.5 \rho V^3 (1.1 C_{D_0})} \frac{W}{S} = \frac{W}{SHP}$$

If we apply this at cruise altitude

$$SHP_{\substack{cruise\\altitude}} = \phi(\sigma)\ (.75)\, SHP_{\substack{sea\\Level}}$$

$\phi(\sigma)$ = power drop-off factor (Gagg – Farrar, Lowry 195)

σ = ratio of air density at altitude to air density at sea level

$\phi(\sigma) = (\sigma - c)/(1 - c)$ $\quad c =$ typically **0.12**

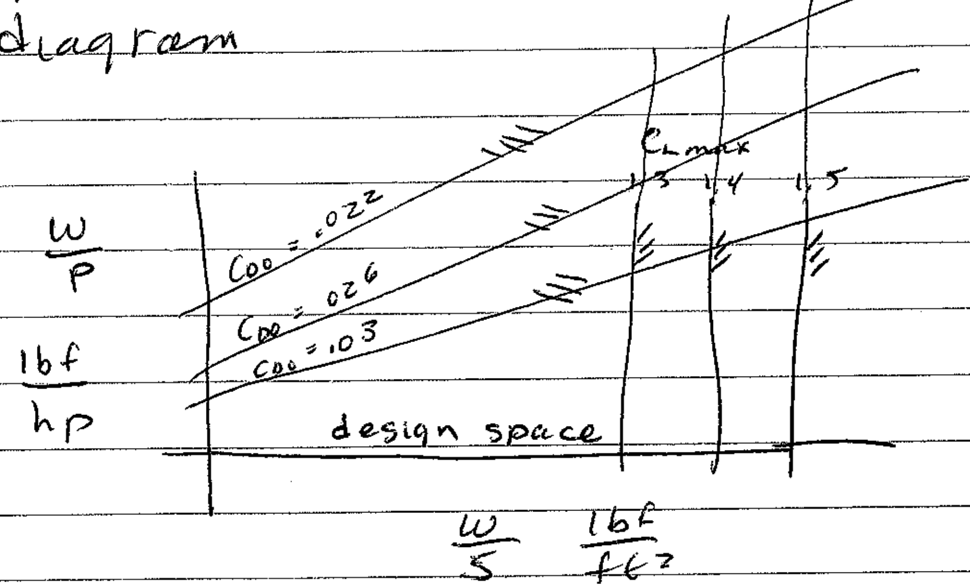
If cruise is at sea level then

$$\frac{550\, \eta_p}{.5 \rho V_{CR}^3 (1.1 C_{D_0})} \left(\frac{W}{S}\right) = \frac{1}{.75} \left(\frac{W}{SHP_{sea\ Level}}\right)$$

Which gives us a straight line thru the origin of our constraint diagram

$$\frac{W}{SHP_{sea\ Level}} = \left[\frac{(.75)(550)}{(.5)(1.1)\ \rho} \frac{\eta_p}{V_{CR}^3\, C_{D_0}}\right] \frac{W}{S} \quad \Leftarrow \text{CONSTRAINT EQUATION}$$

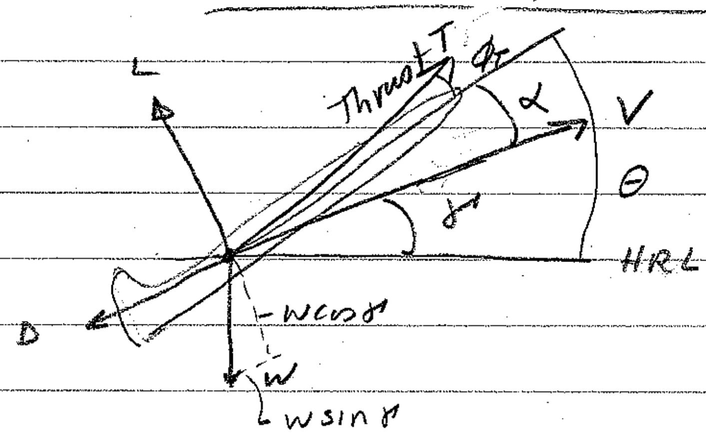
We can now add the cruise speed constraint to the constraint diagram



Think thru the hash marks.

Constraint Analyses Continued

3. Climb Constraint (wings level)



ϕ_T = thrust inclination angle

α = angle of attack

θ = pitch ang

γ = F.P.A.

In the Drag direction

$$D + W\sin\gamma = T\cos(\phi_T + \alpha)$$

In the lift direction

$$L + T\sin(\phi_T + \alpha) = W\cos\gamma$$

Assume $\phi_T + \alpha$ are small enough that

$$L \gg T\sin(\phi_T + \alpha)$$

Assume γ is small enough that

$$W\cos\gamma \approx W$$

$\therefore$ $L = W$

$$D + W\sin\gamma = T$$

Assume $D = \frac{L}{L/D} = \frac{W}{L/D}$

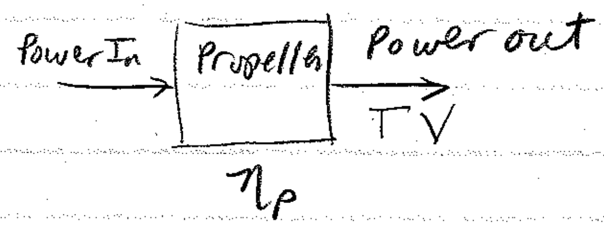
Assume climbs at

$$L/D = .866\ L/D_{max}$$

$$\frac{W}{.866\ L/D_{max}} + W\sin\gamma = T$$

Multiplying by $\frac{V}{W}$ gives

$$\frac{V}{.866\, L/D_{max}} + V\sin\gamma = \frac{TV}{W}$$



For propeller $\frac{\text{Power Out}}{\text{Power In}} = \frac{TV}{\text{Power In}} = \eta_p$

Power In $= 550\ Bhp$ $\quad$ ∴ $TV = 550\, Bhp\, \eta_p$

∴

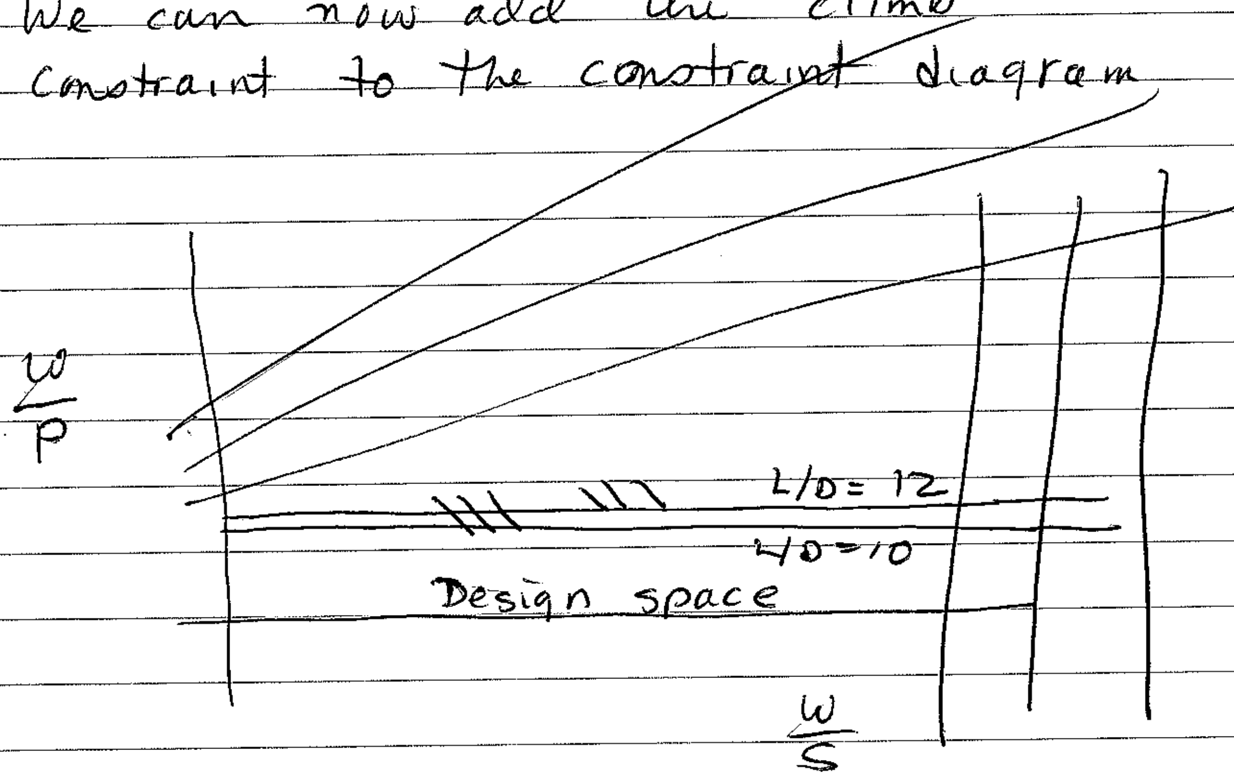
$$\frac{V}{.866\, L/D_{max}} + V\sin\gamma = \frac{1}{W}\, 550\, Bhp\, \eta_p$$

$$= \frac{1}{\frac{W}{Bhp}}\, 550\, \eta_p$$

$$\boxed{\frac{W}{Bhp} = \frac{550\, \eta_p}{V\left(\frac{1}{.866\, L/D_{max}} + \sin\gamma\right)}}$$

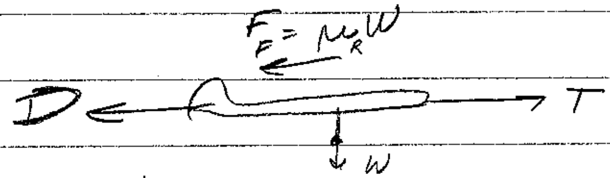
⇗ Constraint equation
(same value for every
wing loading)

We can now add the climb constraint to the constraint diagram



Constraint Analyses Continued

4. Take-off Constraint



ON the RUNWAY

Assume L = 0

$$\frac{W}{g}\ddot{x} = m\ddot{x} = T - D - \mu W$$

$$D = \frac{1}{2}\rho V^2 S C_{D_0} = \frac{1}{2}\rho \dot{x}^2 S C_{D_0}$$

$C_{D_0} =$ ~~.025~~ .023

$$\ddot{x} = \frac{g}{W}\left(T - \frac{1}{2}\rho\dot{x}^2 S C_{D_0} - \mu W\right)$$

$$= g\left(\frac{T}{W} - \frac{1}{W}\frac{1}{2}\rho\dot{x}^2 S C_{D_0} - \mu\right)$$

$$T = \frac{550\, bhp}{V}\eta_p = \frac{550\, Bhp\, \eta_p}{\dot{x}}$$

$$\ddot{x} = g\left(\left(\frac{Bhp}{W}\right)\frac{550\,\eta_p}{\dot{x}} - \left(\frac{S}{W}\right)\left(\frac{1}{2}\rho\dot{x}^2 C_{D_0}\right) - \mu\right)$$

($\frac{Bhp}{W}$: $\frac{1}{\text{powerloading}}$; $\frac{S}{W}$: $\frac{1}{\text{wingloading}}$)

$\mu = .02 - .0$

car tire on dry pavement .006 - .01

Hard Turf $\mu = .04$ Roskam p 290

$$\dot{x}(t) = \int_{t_0^+}^{t_f} \ddot{x}(\tau)\, d\tau = V_{TO}$$ Find t_f

$$x = \int_{t^+}^{t} \dot{x}(\tau)\, d\tau \leq 120\text{ ft}$$

Reqt

Procedure

Integrate these equations forward in time.

Two things must happen for there to be a successful takeoff.

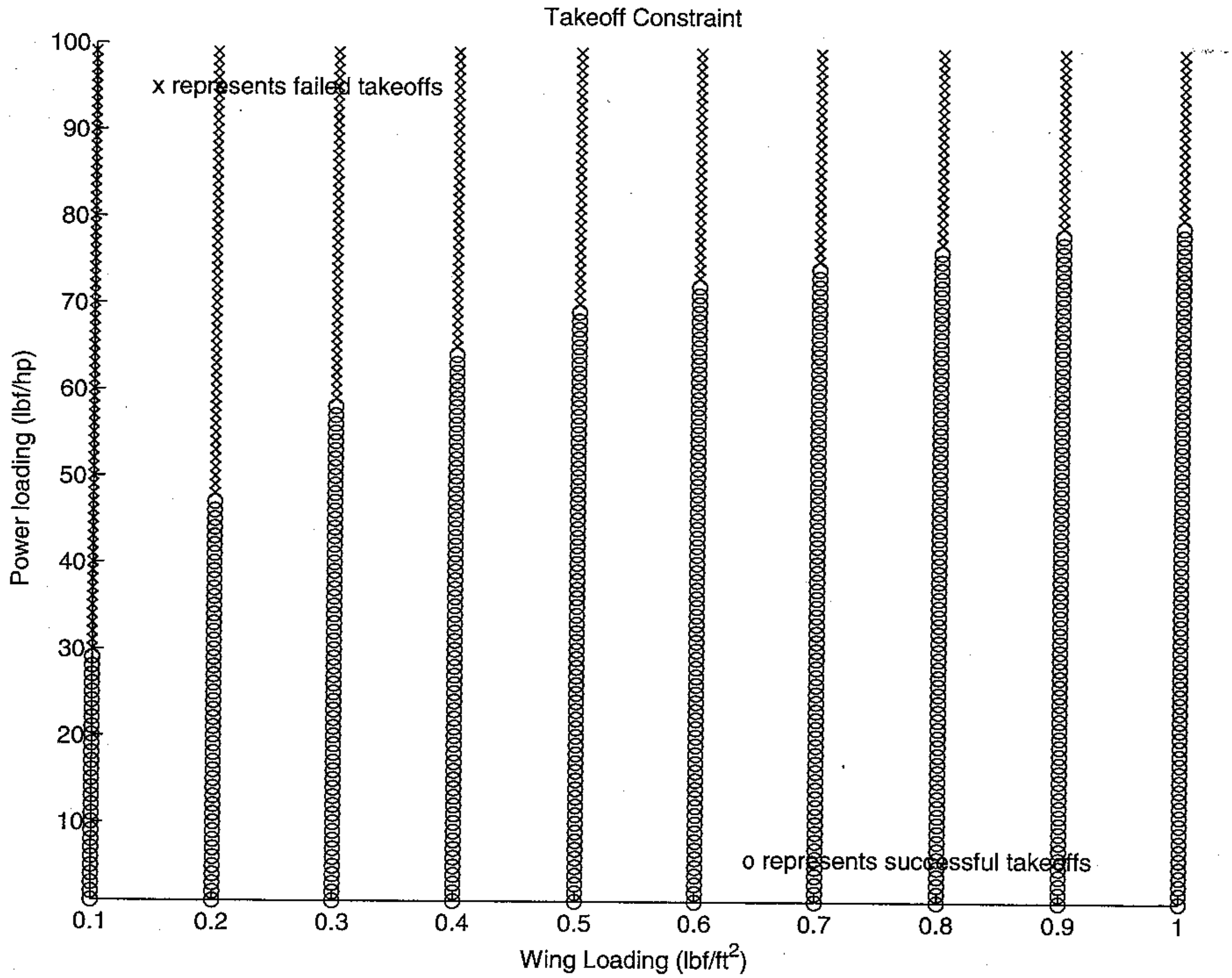
1. The aircraft must reach take-off velocity
2. It must do this within the allowable take-off distance
3. and do this within a reasonable length of time.

For Example

$V_{takeoff} = 28$ ft/sec

Maximum take-off distance = 120 ft

Maximum take off time = 60 sec


Takeoff Constraint
x represents failed takeoffs
o represents successful takeoffs
Power loading (lbf/hp)
Wing Loading (lbf/ft²)
100
90
80
70
60
50
40
30
20
10
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

```
% File: Takeoff2.m
% Script to perform takeoff analysis on electric powered aircraft
% The output is stored in an array called DATA
%         DATA(k,1)=WperS(i);    % wing loading, lbf/ft^2
%         DATA(k,2)=WperBhp(j);  % power loading, lbf/hp
%         DATA(k,3)=TakeOffTime; % takeoff time, sec
%         DATA(k,4)=TakeOffDistance; % takeoff distance, ft
%         DATA(k,5)=WbPerW;      % battery wright fraction, nondimensional
%         DATA(k,6)=FailedTakeoff; % =1 if takeoff was NOT performed within the allowed T ↙
O distance
%                                  % =1 if takeoff was performed within the allowed TO dis ↙
tance
% INPUTS
ETAp=0.5       % propeller efficiency
ETAm=0.6       % Motor efficiency
rho=0.002377   % air density slugs per ft^3
Cd0=0.0300     % paracite drag coefficient
mu=0.05        % coefficient of rolling friction
Vtakeoff=28       % Take-off velocity, ft/sec
MaxTOdistance=120 % Maximum allowable take off ground roll, ft
RHOeNiCAD=  72900 % Energy density of NiCad (joule/lbf)
RHOeNiMH=   92500 % Energy density of NiMH (joule/lbf)
RHOeLiPoly=239000 % Energy density of Lithium Polymer (joule/lbf)

WperS=0.1:.1:1;   % lbf/ft^2
WperBhp=1:1:100; % lbf/Bhp
rows=length(WperS)*length(WperBhp)
DATA=zeros(rows,5);

k=0;
for i=1:length(WperS)
    for j=1:length(WperBhp)
        k=k+1;
        %str1=['wing loading= ',num2str(WperS(i)),', powerloading= ',num2str(WperBhp(j))];
        %disp(str1)
        %[T,Y]=ode45(@TakeOffEOM,TSPAN,Y0,[],wingloading,powerloading,ETAp,rho,Cd0,mu);
        Tmax=60;  % Maximum amount of time to integrate, sec
        [T,Y]=ode45(@TakeOffEOM,[0 Tmax],[0 .1],[],WperS(i),WperBhp(j),ETAp,rho,Cd0,mu);
        % YI = INTERP1(X,Y,XI)
        TakeOffTime=interp1(Y(:,2),T,Vtakeoff); % will be NaN if the velocity was ot atta ↙
ined.
        if isnan(TakeOffTime);
            disp('ERROR: You have not integrated long enough to achieve Vtakeoff');
            last=length(Y(:,1));
            TakeOffDistance=Y(last,1);
        else
            TakeOffDistance=interp1(T,Y(:,1),TakeOffTime);
        end
```

see: http://roger.ecn.purdue.edu/~andrisan/Buffer/AAE451/

```
        if TakeOffDistance>MaxTOdistance | isnan(TakeOffTime);
            FailedTakeoff=1; % Takeoff failed for either of two reasons
        else
            FailedTakeoff=0; % Takeoff was successful
        end
        % Battery weight fraction for takeoff
        WbPerW=745.7*TakeOffTime/(ETAm*WperBhp(j)*RHOeNiCAD); % nondimensional
        % store data
        DATA(k,1)=WperS(i);    % wing loading, lbf/ft^2
        DATA(k,2)=WperBhp(j);  % power loading, lbf/hp
        DATA(k,3)=TakeOffTime; % takeoff time, sec
        DATA(k,4)=TakeOffDistance; % takeoff distance, ft
        DATA(k,5)=WbPerW;      % battery wright fraction, nondimensional
        DATA(k,6)=FailedTakeoff; % =1 if takeoff was NOT performed within the allowed TO ↙
distance
                                % =1 if takeoff was performed within the allowed TO dista ↙
nce
    end
end

%SAVE FILENAME X Y Z  saves X, Y, and Z
save DATAfile DATA

[rowsDATA,colDATA]=size(DATA)
DATA
figure(1)
clf
axis([WperS(1),WperS(length(WperS)),WperBhp(1),WperBhp(length(WperBhp))])
hold on
% Find and plot points that represent successful takeoffs
k=find(DATA(:,6)==0);
plot(DATA(k,1),DATA(k,2),'ko')
disp('Battery weight fractions for successful takeoffs (mean, max, min).')
WbPerWmean=mean(DATA(k,5))
WbPerWmax=  max(DATA(k,5))
WbPerWmin=  min(DATA(k,5))
TakeOffTimeMean=mean(DATA(k,3))
TakeOffTimeMax=  max(DATA(k,3))
TakeOffTimeMin=  min(DATA(k,3))


% Find and plot points that represent failed takeoffs
k=find(DATA(:,6)==1);
plot(DATA(k,1),DATA(k,2),'rx')
xlabel('Wing Loading (lbf/ft^2)')
ylabel('Power loading (lbf/hp)')
title('Takeoff Constraint')
```

```
text2(.05,.95,'x represents failed takeoffs')
text2(.6,.05,'o represents successful takeoffs')
hold off
```

```
function ydot=TakeOffEOM(t,y,wingloading,powerloading,ETAp,rho,Cd0,mu)
% Differential equations for take-off.
%
% [y(1) y(2)]=[x xdot]
% [ydot(1) ydot(2)]=[xdot xdotdot]

ydot(1,1)=y(2);
ydot(2,1)=32.17*(550*ETAp/(y(2)*powerloading)-0.5*rho*y(2)*y(2)*Cd0/wingloading-mu);
```

Matlab function containing the equations of motion for take-off.

Takeoff Analysis Results

INPUTS

ETAp =
0.5
ETAm =
0.6
rho =
0.002377
Cd0 =
0.03
mu =
0.05
Vtakeoff =
28
MaxTOdistance =
120
RHOeNiCAD =
72900

Take off acceleration

$$\ddot{X} = g\left(\frac{Bhp}{W}\frac{550\eta_p}{\dot{X}} - \frac{S}{W}\left(\frac{1}{2}\rho\dot{X}^2 C_{D_0}\right) - \mu\right)$$

Battery weight fraction

$$\frac{W_b}{W} = \frac{745.7}{\eta_m}\frac{Bhp}{W}\frac{T_{take\text{-}off}}{\rho_E}$$

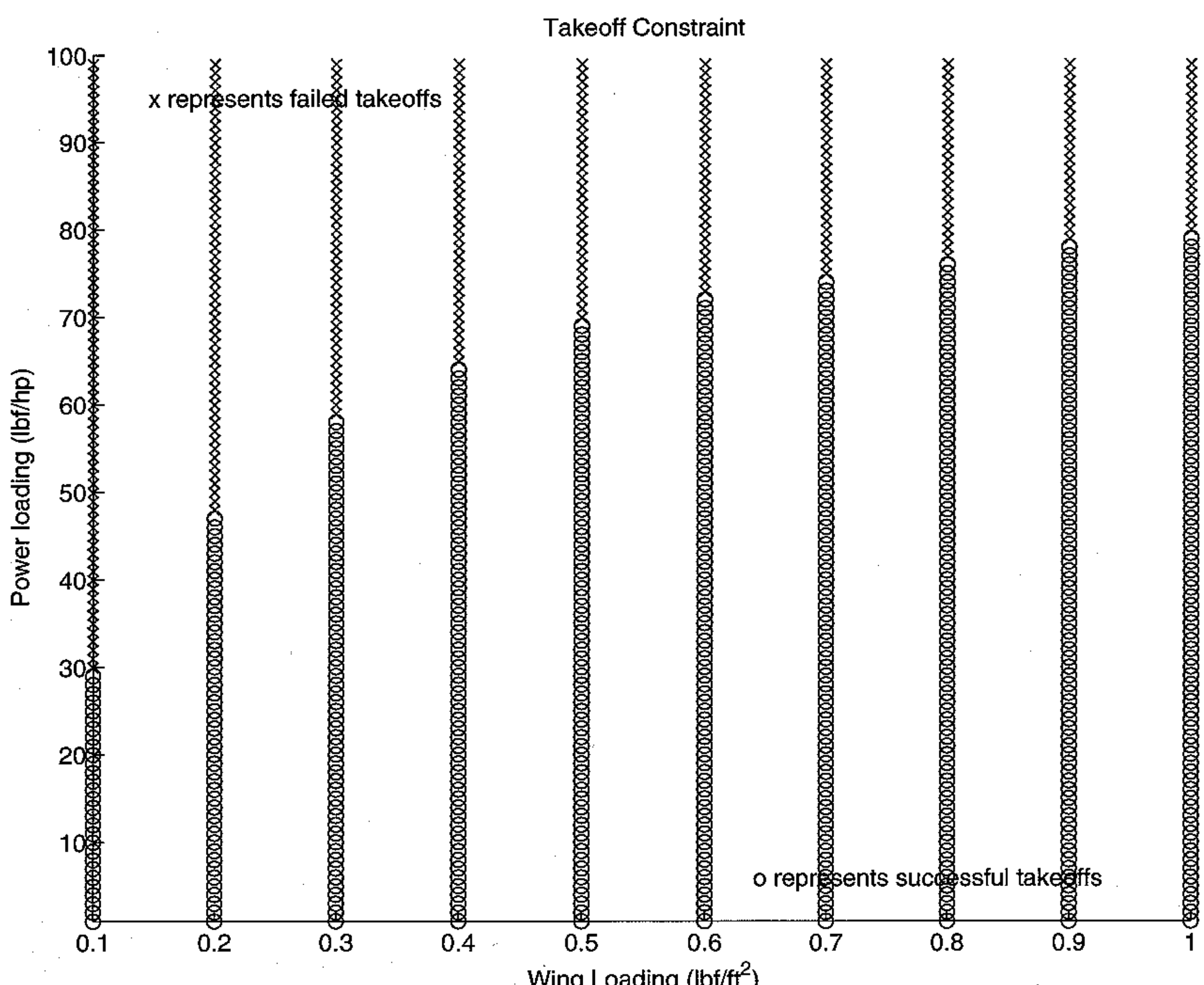
NiCAD batteries assumed.

OUTPUTS

Battery weight fractions for successful takeoffs (mean, max, min).
WbPerWmean =
0.00099928

WbPerWmax =
0.0024007

WbPerWmin =
0.00076056


Takeoff Constraint
x represents failed takeoffs
o represents successful takeoffs
Power loading (lbf/hp)
Wing Loading (lbf/ft2)
100
90
80
70
60
50
40
30
20
10
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

5. Other Constraints

There are many other possible constraints. See Raymer and Roskam. Each individual mission may have unique constraints.

The informed student should examine the other constraints in the references and be alert to unique constraints in his/her design problem that might lead to unique constraint equations.

Note: Constraint diagrams represent a type of trade study where the impact of one design variable upon another design variable is studied.

AAE 451

Constraint Analyses

Run in order

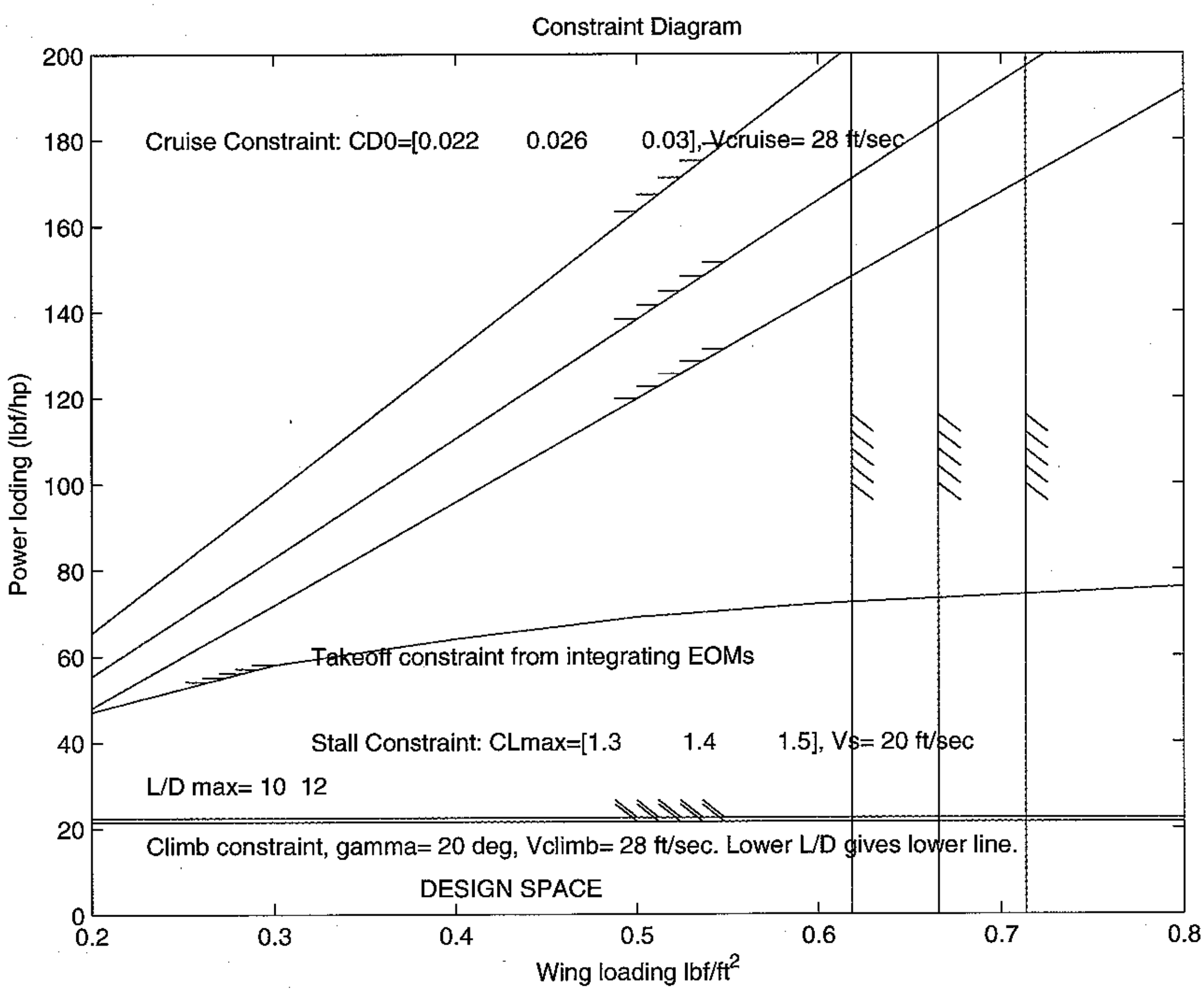
Takeoff2.m

Constraint3.m

TakeOffConstraint.m

The following plot results.

See http:// roger.ecn.purdue.edu/nandrisan/Buffer/AAE451



```
% FILE: Constraint3.m
% Script to generate constraint diagram:
%
%
disp(' '); disp('*** Start here ***'); disp(' ')
% DataSection
WperSmin=.2   % Limit on the axes of the constraint diagram (lbf/ft^2)
WperSmax=.8   % Limit on the axes of the constraint diagram (lbf/ft^2)
WperPmin= 0   % Limit on the axes of the constraint diagram (lbf/hp)
WperPmax=200   % Limit on the axes of the constraint diagram (lbf/hp)
Vs=20 % Stall speed (ft/sec)
CLmax=[1.3,1.4,1.5] % Possible values of maximum lift coefficient (nondimensional), use 3 ↙
 of them
rho=0.002377 % air density (slugs/ft^3)
Vcr=28       % cruise speed (ft/sec)
EtaP=.5 % propeller efficiency (nondimensional)
CD0=[.022,.026,.030] % Possible values of CD0, use 3 of them
LoverDmax=[10,12] % estimated maximum lift to drag ratio
gamma=20/57.3 % Take-off flight path angle


% Stall speed constraint
WperS1=.5*rho*Vs^2*CLmax; % wing loading constraints
numCLmax=length(CLmax);
ifig=0;
ifig=ifig+1; figure(ifig)
clf
WperSdat=[WperS1(1),WperS1(1)];
WperPdat=[WperPmin,WperPmax];
plot(WperSdat,WperPdat)
axis([WperSmin,WperSmax,WperPmin,WperPmax])
hold on
title('Constraint Diagram')
hash_right(WperSdat,WperPdat)
%hash_left(WperSdat,WperPdat,30)
WperSdat=[WperS1(2),WperS1(2)];
plot(WperSdat,WperPdat)
hash_right(WperSdat,WperPdat)
%hash_left(WperSdat,WperPdat)
WperSdat=[WperS1(3),WperS1(3)];
plot(WperSdat,WperPdat)
hash_right(WperSdat,WperPdat)
%hash_left(WperSdat,WperPdat,-30)
string1=['Stall Constraint: CLmax=[', num2str(CLmax),'], Vs= ', num2str(Vs), ' ft/sec'];
text2(.2,.2,string1)


% Cruise speed constraint
```

```
slopes=((.75)*(550)/(.5*rho*1.1))*EtaP./(Vcr^3*CD0);
inc=(WperSmax-WperSmin)/10;
WperSdat=WperSmin:inc:WperSmax;
plot(WperSdat,slopes(1)*WperSdat)
hash_left(WperSdat,slopes(1)*WperSdat,0)
plot(WperSdat,slopes(2)*WperSdat)
hash_left(WperSdat,slopes(2)*WperSdat,0)
plot(WperSdat,slopes(3)*WperSdat)
hash_left(WperSdat,slopes(3)*WperSdat,0)
string2=['Cruise Constraint: CD0=[', num2str(CD0),'], Vcruise= ', num2str(Vcr), ' ft/sec' ↙
];
text2(.05,.9,string2)
text2(.3,.03,'DESIGN SPACE')

% Climb constraint
WperPclimb=550*EtaP./(Vcr./(.866*LoverDmax)+Vcr*sin(gamma))
plot([WperSmin WperSmax],[WperPclimb(1) WperPclimb(1)])
plot([WperSmin WperSmax],[WperPclimb(2) WperPclimb(2)])
hash_left([WperSmin WperSmax],[WperPclimb(1) WperPclimb(1)])
hash_left([WperSmin WperSmax],[WperPclimb(2) WperPclimb(2)])
string3=['Climb constraint, gamma= ',num2str(gamma*57.3),' deg, Vclimb= ',num2str(Vcr),' ↙
ft/sec. Lower L/D gives lower line.']
text2(.05,.08,string3)
string4=['L/D max= ',num2str(LoverDmax)]
text2(.05,.15,string4)

xlabel('Wing loading lbf/ft^2')
ylabel('Power loding (lbf/hp)')

%disp('Click twice on the desired design point')
% [X,Y] = GINPUT(N)
%[WperSin,WperHPin]=ginput(1)
%plot(WperSin,WperHPin,'rx')
%weight=2.5
%S=weight/WperSin
%Bhp=weight/WperHPin

hold off
```

```
% File: TakeOffConstraint.m
% Script to plot the take off constraint line on an existing constraint
% diagram. It used data computed from the takeoff EOMs and stored in
% and array called DATA.

WperS=0.1:.1:1;
WperHP=zeros(size(WperS));
for i=1:length(WperS)
    y=find(DATA(:,1)==WperS(i))
    DATA(100,:)
    DATA2=DATA(y,:);
    size(DATA2)
    y2=find(DATA2(:,6)==0)
    WperHP(i)=max(DATA2(y2,2))
end

hold on
plot(WperS,WperHP)
hash_left(WperS,WperHP,80)
string5=['Takeoff constraint from integrating EOMs'];
text2(.2,.3,string5)
hold off
```