AAE 565
Semester Project
Flight Control of Autonomous Operation of the Predator UAV

SUMMARY
Part 1: Development of the Aerodynamic Model of a Predator (RQ-1)
Part 2: Development of a nonlinear simulation and linear dynamic models (longitudinal and lateral-directional)
Part 3: Longitudinal Autopilots (altitude hold, airspeed hold)
Part 4: Lateral-directional Autopilots (bank angle hold, heading hold)
Part 5: Longitudinal command control system (rate of climb command, speed command)
Part 6: Lateral-directional command control system (Turn rate command, including turn to desired heading and hold the desired heading)
Part 7: Navigational Autopilot using waypoints (ground track command with and without steady winds)

PART 1

A: Teams

Form three person teams. Each team should hand in a sheet of paper listing team members and team leader by Wednesday January 30, 2002. Your team will be given a team number from 1-6.

B. Gather Background

Read the list of basic constants required for the AAE421 Aerodynamic Modeling software. Refer to the attached list of basic constants for the Cessna 182 aircraft. Use as your primary reference the document ***Methods of Estimating Stability and Control Derivatives of Conventional Subsonic Airplanes*** by Jan Roskam. Software that uses the basic constants to compute the aerodynamic model in the form (called ConstantForm) used by subsequent AAE421 software can be found at the following web site.

http://roger.ecn.purdue.edu/~andrisan/Courses/AAE421_Fall_2001/421_Project/ProjectFall2001.html

Subsequent AAE421 that use aerodynamic data in ConstantForm can be found at the following web site.

http://roger.ecn.purdue.edu/~andrisan/Courses/AAE421_S2001/Docs_Out/DC_Software/index.html

C. Determining the Basic Constants for the Predator

Determine as best you can all the basic constants for the Predator (RQ-1). Use the Internet and any other non classified or un-sensitive information you can find. If you are stuck on a basic constant make an educated guess.

Write a MATLAB script patterned like the one called **BasicConstants_Cessna182.m**. Team X will then name their script **BasicConstants_PredatorX.m**. Modify the script **RunFirst.m** to use your **BasicConstants_PredatorX.m** script . This will then compute the "constant" required for AAE421 Dynamic analysis Software.

This is due on Wednesday, February 6, 2002. Teams may work together on this effort. Each team (e.g., Team X) must turn in paper copies of the following scripts, **BasicConstants_PredatorX.m**, **RunFirstX.m.**

D. Believability checks of your results

Check the results of **RunFirstX.m** for believability. Compare stability and control derivatives with those of similar aircraft and with those of other teams. Run **PredatorXLongSC.m** and **PredatorX_LatSC.m** and check to make sure that your eigenvalues make sense. These two scripts are patterned after **CessnaLongSC.m** and **CessnaLatSC.m** but use the basic constants you determined for the Predator. Modify the bacis constants as required. Hand in the from the MATLAB command window when you run scripts **PredatorXLongSC.m** and **PredatorX_LatSC.m.** Comment on whether you think your eigenvalues make sense. Comment on whether you think the signs of all elements of the MATLAB array "constant" make sense. Do you believe your mathematical model for the Predator is correct? Are you ready to spend the rest of the semester designing flight control software for the Predator that you have modeled?

This is due on Friday, February 8, 2002.

On this Friday in class we will discuss each teams results and believability assessment. We will try to agree on one mathematical model of the Predator to use for the rest of the semester.

Script BasicConstants_Cessna182.m

```
% **********************************************
% BasicConstants_Cessna182
%
% **********************************************
% BasicConstants - Identifies, describes, and assigns all of the
%                  the most basic variables for analyzing the control
%                  and stability of a generic aircraft.
% **********************************************
%
% A&AE 421 Fall 2001 - Purdue University
%
% Note: This code is provided for a first order approximation of the dynamic
%       analysis of an airplane and is not intended for final designs.
%
% Equations/Figures can be found in :
%
% (Ref.1) Roskam, Jan. "Airplane Flight Dynamics and Automatic Flight
%         Controls"
%         Published by DARcorporation
%         120 E. Ninth St., Suite 2
%         Lawarence, KS 66044
%         Third Printing, 2001.
%
% (Ref.2) Roskam, Jan. "Methods for Estimating Satbility and
%         Control Derivatives of Conventional Subsonic Airplanes"
%         Published by the Author
%         519 Boulder
%         Laurance, Kansas 66044
%         Third Printing, 1997.
%
% (Ref.3) Roskam, Jan. "Airplane Design: Part IV: Preliminary Calculation
%         of Aerodynamic, Thrust and Power Characteristics"
%         Published by Roskam Aviation and Engineering Corporation
%         Rt4, Box 274
%         Ottawa, Kansas 66067
%         Second Printing, 1990.
%

aircraft='Cessna182, cruise configuration';

adelf = 0;              % Two dimensional lift effectiveness parameter Ref.(2),
Equ(8.7)alpha = 0;            % Angle of attack [deg]
alpha_0 = -.2;               % Airfoil zero-lift AOA [deg]
AR_h = 3.93;            % Aspect ratio of the horizontal tail
AR_w = 7.45;            % Aspect ratio of the wing
b_f = 20;               % Span of the flap [ft]
b_h = 11.33;                 % Span of the horizontal tail [ft]
b_h_oe = 5.8333;        % Elevator outboard position [ft]
b_h_ie = 0.5;          % Elevator inboard position [ft]
b_w = 36;               % Span of the wing [ft]
b_v = 5;                % Vertical tail span measured from fuselage centerline
[ft]
b_v_or = 4.95;          % Outboard position of rudder [ft]
b_v_ir = 0.0;           % Inboard position of rudder [ft]
c_a = 1.0;              % Chord of aileron [ft]
C_bar_D_o = .0270;      % Parasite drag
Cd_0 = 0.027;           % Drag coefficient at zero lift (parasite drag)
c_e = 2.70;              % Elevator flap chord [ft]
cf = 1.2;               % Length of the wing flap [ft]
c_h = 6.3;              % Mean aerodynamic chord of the horizontal tail [ft]
CL = 0.307;             % Lift coefficient (3-D)
CL_hb=.307;             % Lift coefficient of the horzontal tail/body
CL_wb=.307;             % Lift coefficient of the wing/body
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```
Cl_alpha_h  = 2*pi; % 2-D Lift curve slope of wing
Cl_alpha_v   = 2*pi;  % 2-D Lift curve slope of vertical tail
Cl_alpha = 6;          % Two-dimensional lift curve slope
Cl_alpha_w=Cl_alpha;   % Two-dimensional lift curve slope
Cm_0_r = -.2;          % Zero lift pitching moment coefficient of the wing root
Cm_o_t = -.2;          % Zero lift pitching moment coefficient of the wing tip
c_r = 1.52;            % Chord of the rudder [ft]
c_w = 4.9;             % Mean aerodynamic chord of the wing [ft]
c_v = 3.8;             % Mean aerodynamic chord of the vertical tail [ft]
D_p = 4;                        % Diamter of propeller [ft]
d = 4.5;                            % Average diameter of the fuselage
[ft]
delf = 0;              % Streamwise flap deflection [deg]
delta_e = 0;           % Elevator deflection [deg]
delta_f = 0;           % Streamwise flap deflection [deg]
delta_r = 0;           % Rudder deflection [deg]
dihedral = 0;          % Geometric dihedral angle of the wing [deg]
dihedral_h = 0;        % Geometric dihedral angle of the horizontal tail [deg]
e = 0.9;               % Oswald efficiency factor
epsilon_t = -.421;   % Horizontal tail twist angle [deg]
epsilon_0_h=epsilon_t;% Horizontal tail twist angle [deg]
eta_h = 0.85;          % Ratio of dynamic pressure at the tail to that of the
free stream eta_ia = .06;        % Percent span position of inboard edge of
aileron
eta_oa = 1.0;          % Percent span position of outboard edge of aileron
eta_p = 0.70;              % Propeller Efficiency
eta_v = 1;                     % Ratio of the dynmaic pressure at the
vertical tail to that of the freestream
Gamma = 2*pi/180;    % This is the geometric dihedral angle, positive for
dihedral, negative for anhedral [rad]
h1_fuse =4;            % Heighth of the fuselage at 1/4 of the its length
h2_fuse =3;            % Heighth of the fuselage at 3/4 of the its length
h_h = 1.7;             % Height from chord plane of wing to chord plane of
horizontal tail [ft] – Fig 3.7, Ref. 2
hmax_fuse = 5;         % Maximum heighth of the fuselage [ft]
Ixx = 948;
Iyy = 1346;
Izz = 1967;
Ixz = 0;
i_h = 2;               % Horiz tail incidence angle [deg]
i_w    = -.2;              % Wing incidence angle [deg]
k = 0.0554;                    % k
Lambda=0;              % Wing sweep angle [deg]
Lambda_c4=0;           % Sweep angle at the quarter-chord of the wing [deg]
Lambda_c2=0;           % Sweep angle at the half-chord of the wing [deg]
Lambda_c2_v = 0.35;  % Sweep angle at the half-chord of the vertical tail
[deg]
Lambda_c4_v = 0.35;  % Sweep angle at the quarter-chord of the vertical tail
[deg]
Lambda_c2_h = 0;     % Sweep angle at the half-chord of the horizontal tail
[deg]
Lambda_c4_h = 0;     % Sweep angle at the quarter-chord of the vertical tail
[deg]
lambda = 0.75;         % Taper ratio of the wing
lambda_h = 0.75;     % Horizontal tail taper ratio
lambda_v      = 0.5;       % Vertical tail taper ratio
lambda_w = lambda;   % Taper ratio of the wing
l_b = 25;                % This is the total length of the fuselage [ft]
l_f =12;               % The horizontal length of the fuselage [ft]  (*******)
l_h = 12;              % Distance from c/4 of wing to c/4 of horizontal tail
[ft]
l_v = 13;                   % Horizontal distance from the aircraft CG to the
vertical tail aero center [ft]
M = 0.2;               % Mach number
q_bar = 1;                       % Dynamic pressure ratio (free stream)
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q_bar_h = 1;            % Dynamic pressure ratio at the tail
Rl_f=10^6;              % Fuselage Reynold's number
rho = 0.00204;                  % Air density at 5000ft [slugs/ft^3]
S_b_s =60;              % Body side area [ft^2]
S_b = S_b_s;            % Body side area [ft^2]
S_h   = 48;                     % Area of the horizontal tail [ft^2]
S_h_slip    = 8;            % Area of horiz. tail that is covered in prop-wash
- See fig.(8.64) Ref.(3) [ft^2]
S_o = 6;                % Take X1/l_b and plug into:
.378+.527*(X1/l_b)=(Xo/l_b), S_o is the fuselage x-sectional area at Xo.
(ft^2) Ref.(2), Fig. 7.2
S_w = 174;              % Aera of the wing [ft^2]
S_v = 25;                   % Surface area of vertical tail [ft^2]
T = 0;                      % Temperature [F]
tc_w = .10;                % Thickness to chord ratio of the wing
tc_h = 0.10;               % Thickness to chord ratio of horizontal tail
theta = 0;              % This is the wing twist in degrees, negative for
washout [deg]
theta_h = 0;            % Horizontal tail twist between the root and tip
stations, negative for washout [deg]
two_r_one = 2;          % Fuselage depth in region of vertical tail [ft]
Ref.(2), Figure 7.5
U = 129.73;                     % Free Stream Velocity [knots]
U1  = 220.1;            % Cruise flight speed [ft/s]
W = 2650;               % Weight of Airplane [lbf]
wingloc = 1;            % If the aircraft is a highwing: (wingloc=1), low-wing:
(wingloc=0)
wmax_fuse = 5;          % Maximum fuselage width [ft]
X1 = 12.5;              % Distance from the front of the fuselage where the x-
sectional area decrease (dS_x/dx) is greatest (most negative) [ft] - Ref.(2),
Fig. 7.2
x_AC_vh =1;             % X distance from LE of vertical tail to AC of
horizontal tail [ft]
Xh = 18;                % Distance from airplane cg to the horizontal tail ac
[ft]
x_m = 5;                % Center of gravity location from the leading edge [ft]
x_over_c_v = .5;        % X distance from leading edge of vertical fin mean
chord to horizontal aero center [ft]
Xref = 6;               % Arbitrary reference point located on the airplane's
axis of symmetry.
                                        % Measured as positive aft,
starting from the leading edge of the mean aero. chord. [ft]
Xw = 0.2;               % Distance from the airplane cg to wing ac (positive
aftward) [ft]
Z_h = -2.5;                 % Negative of the hoizontal distance from the
fuselage centerline to the horizontal tail aero center (negative number) -
Ref.(2), Fig. 7.6
Z_v = .5;                       % Vertical distance from the aircraft CG to
the vertical tail aero center - Ref.(2), Fig. 7.18
Z_w = 2;                                % This is the vertical distance from
the wing root c/4 to the fuselage centerline, positive downward - Ref.(2),
Equ(7.5)
Z_w1 = -.5;             % Distance from body centerline to c/4 of wing root
chord, positive for c/4 point below body centerline (ft) - Ref.(2), Fig. 7.1
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