Preliminary Design Review (PDR)
Aerodynamics #2
AAE-451 Aircraft Design

Aircraft Geometry (highlight any significant revisions since Aerodynamics PDR #1)

Airfoil section for wing, vertical and horizontal tails.
Wing and tail geometry including sweep angle, taper ratio, dihedral angle.
Aircraft wetted area, Aspect ratio of wing
3-view drawing drawn to scale and dimensioned.

Aerodynamic mathematical model (highlight any significant revisions since Aerodynamics PDR #1)

Please provide numerical values of all the coefficients listed below. Take account of three dimensional effects and be sure to include the effects of the horizontal tail.

Lift Coefficient
$C_L=C_{Lo} + C_{L\alpha}*\alpha +(C_{L\delta e}*\delta e)$
Pitching Moment Coefficient about the quarter chord point
$C_M=C_{Mo} + C_{M\alpha}*\alpha +(C_{M\delta e}*\delta e)$
Drag Polar
$C_D=C_{Do}+k*C_L*C_L$

L/D max

Flight conditions for maximum endurance (airspeed, angle of attack, CL, CD, δe (optional))

Stability and Control Derivatives and dimensionalizing constants (e.g. inertias) required by your dynamics and control group for your feedback control system design

Trimability Considerations (Important! If you don't complete this, include it in the Flight Performance, Stability & Control PDR)

- Construct an Aircraft Trim Diagram (Roskam, Vol VII, p. 12, or Vol VI, . 344)
- Do you have enough nose up elevator to fly in steady flight at the stall speed?
- Do you have enough nose down elevator to fly in steady flight at the maximum speed of your aircraft?
- Answer these questions for the least favorable c.g. locations.

The trim considerations mentioned above help size control surfaces for trimming, i.e., balancing moments. However, do you have enough control power available to maneuver your aircraft?

Stability Considerations (optional, but you will need these for the Flight Performance, Stability & Control PDR)

- range of center of gravity locations for your design;
- X-plot (see Roskam, Volume II, Chapter 11)
- aerodynamic center location (stick fixed neutral point) (be sure to include the effects of downwash of large forward surfaces of smaller aft surfaces);
- range static margin;
- desired static margin with justification;
- volume of horizontal tail with reason for selecting this tail volume;
- volume of vertical tail with reason for selecting this tail volume.
- dihedral angle and the reason for selecting this amount of dihedral

The Design Issue: Is the vehicle stable in all axes?

To check dynamic stability requires full equations of motion (including many aerodynamic stability and control derivatives) and getting them is a lot of work. A simpler procedure is to insure that the static stability criteria are met in each axis.

Static Stability

Longitudinal Static Stability (C_{m_α}) achieved by making sure you have sufficient volume ratio of the horizontal tail (a Class I method of sizing the empennage as described in Roskam Airplane Design, Part II, Chapter 8). See historical examples of aircraft built by previous classes at Purdue.

You need also check to insure that you have sufficient static margin (Xac-Xcg)/c using a longitudinal X-plot. See Roskam Airplane Design, Part II, Chapter 11. The thesis of Mark Peters ("Development of a Light Unmanned Aircraft for the Determination of Flying Qualities Requirements," May 1996) suggests that you need a static margin of at least 15%.

Lateral-Directional Static Stability

Weathercock Stability (C_{n_β}) achieved by making sure that your design has sufficient volume ratio of the vertical tail. It is useful to check the volume ratio of the horizontal tail (a Class I method of sizing the empennage as described in Roskam Airplane Design, Part II, Chapter 8). You need also check to insure that you have sufficient static directional stability using a directional X-plot. See Roskam Airplane Design, Part II, Chapter 11.

Dihedral Effect (C_{l_β}) achieved using wing geometric dihedral angle. See the paper handed out in class ("Wing and Tail Dihedral for Models," by William F. McCombs, *Model Aviation*, 12/94). Note that amount of wing geometric dihedral angle you need is also influenced by whether you are turning with aileron or turning with rudder alone (requires more wing geometric dihedral angle).

Controllability Considerations (optional, but you will need these for the Flight Performance, Stability & Control PDR)

- size of the elevator with the reason for selecting this control surface size;
- size of the rudder with the reason for selecting this control surface size;
- size of the aileron (if any) with the reason for selecting this control surface size;
- discussion of why or why not you have included ailerons.

The Design Issue: Sufficient control power (control surface size and deflection limits) must be provided to trim the aircraft (i.e., balancing forces and moments) at all desired flight conditions and to maneuver the aircraft about the trim condition.

Pitch, elevator size, $C_{m_{\delta e}}$

It is useful to size the elevator using historical data (a Class I method of sizing the elevator as described in Roskam Airplane Design, Part II, Chapter 8). See also historical examples of aircraft built by previous classes at Purdue.

You will need to construct an airplane trim diagram to insure that you have enough elevator to trim at all desired angles of attack (see Roskam Airplane Design Part VI, Chapter 8, Section 3, or see Roskam Airplane Flight Dynamics and Automatic Flight Controls (the AAE-421 book)).

Yaw and/or roll, rudder size, $C_{n_{\delta r}}$

It is useful to size the rudder using historical data (a Class I method of sizing the elevator as described in Roskam Airplane Design, Part II, Chapter 8). See also historical examples of aircraft built by previous classes at Purdue.

If you plan to use the rudder for turning you will need to also consider how much wing geometric dihedral you need.

Roll, aileron size, $C_{l_{\delta a}}$ (optional)

It is useful to size the aileron using historical data (a Class I method of sizing the elevator as described in Roskam Airplane Design, Part II, Chapter 8). See also historical examples of aircraft built by previous classes at Purdue. If you intend to roll with rudder alone, you may not need ailerons at all.

Flight Performance, Stability & Control PDR
AAE-451 Aircraft Design

Stability and Control

- Class 1 sizing (tail volume method) of
- horizontal and vertical tails
- Class 1 sizing (historical data) of
- control surfaces (elevator, ailerons, rudder)
- surface deflection limits
- Location of aerodynamic center
- Location of c.g.
- Determination of desired static margin
- Class 2 sizing of the horizontal and vertical tail using X-plots
- Determination of dihedral angle

Desirable but not required

- Short period mode damping ratio and natural frequency
- Phugoid mode damping ratio and natural frequency
- Dutch roll mode damping ratio and natural frequency
- Roll mode time constant
- Spiral mode time constant
- Dymamic simulation of vehicle flight mechanics

Flight Performance

- Take-off performance (take-off distance)
- Climb performance (maximum climb angle, distance at which to abort the takeoff)
- Turning performance (maximum turn rate)
- Endurance mission (take-off, climb, cruise, descent, land flying a figure eight pattern in Mollenkopf Athletic Center)
- Will your aircraft meet the endurance requirement?