# AAE 451 CONTROL SYSTEM DESIGN CRITERIA

Each team will install in their aircraft one rate gyro and connect it to feed back angular rate to the appropriate control surface. One team will install the rate gyro in such a way that it measures pitch rate (q) and feeds it back to the elevator ($\delta_E$). One team will install the rate gyro in such a way that it measures yaw rate (r) and feeds it back to the rudder ($\delta_R$). The third team will install the rate gyro in such a way that it measures roll rate (p) and feeds it back to the aileron ($\delta_A$).

The general control law is as follows.

control surface motion = - K*(angular rate) + pilot command to the control surface

(that is $\delta_E = - K*q + \delta_{E\ command}$)

The rate gyro system we will use has two gains. At any given time, which one of the two gains being used is selectable from the pilot's radio using the gear switch on the. All teams will use the same gear switch sign convention. We will always set the first gain to zero so that we can shut off feedback from the radio whenever we have to. With feedback, instability or poor dynamic response of the aircraft is always possible.

There is also a gain sign switch on the gyro mixer box (on-board the aircraft). This switch sets the sign on the feedback gain in the equation above (i.e., -K or +K). It can only be changed while the aircraft in on the ground. The sign of the feedback will can be either stabilizing or de-stabilizing, depending on this switch setting. Each team will select the magnitude of the feedback gain (one number, K) so that the desired gain margins and phase margins are achieved for both stabilizing sign and de-stabilizing sign.

A. In each axis (pitch, roll, yaw)
Find feedback |k| such that
When the sign of the feedback is stabilizing, the open loop system has
Gain margin ≥ 6 db
Phase margin ≥ $45^o$

B. In the pitch axis
When the sign of the feedback is de-stabilizing, the open loop system has
Gain margin ≥ 1 db
Phase margin ≥ $10^o$

C. In the roll and yaw axes
When the sign of the feedback is de-stabilizing, the open loop system has
Gain margin ≥ 0
Phase margin ≥ 0

# AAE 451 Considerations for Flight Testing Feedback Control Systems

A. Without feedback, stall the A/C and make sure stall is predictable and recoverable from. Verify that a spin is avoidable. Should a spin be encountered it must be quickly recoverable from. A safe altitude to fly to recover from a stall should be determined. . This safe altitude should be used for all flight tests where feedback will be employed.

B. Under all circumstances, a spin should be avoided, if possible. However, if a spin is encountered, a safe altitude to recover from a spin and the recommended spin recovery procedures (piloting actions) should be determined. This safe altitude should be used for all flight tests where feedback will be employed.

C. Prior to any flight test where feedback is possible, the gain-setter must verify that the gain has the proper sign (i.e. stabilizing or destabilizing). This can be done by holding the aircraft and giving it an angular rate. The appropriate control surface ($\delta_A$, $\delta_E$, $\delta_R$) should deflect to resist the angular rate if the feedback is stabilizing. The appropriate control surface should deflect to increase the angular rate if the feedback is destabilizing.

D. Flight tests with stabilizing gain should be treated in the same manner as flight test with destabilizing gain. The likelihood of instability is lower in the case where the feedback gain is stabilizing but instabilities are possible and should be prepared for.

E. For flights with any feedback (stabilizing or de-stabilizing)

1. Have a second person called the gain-setter (not the pilot) trained to switch the feedback gain on and off. Make sure this gain-setter knows
    a. the gear switch position feedback off and on
    b. a visual way to determine when the sign of the feedback is destabilizing and stabilizing
    c. an agree to communication between pilot and gain-setter for when the gain-setter should set the gain switch to zero.
2. Fly tests with sufficient altitude to recover from an unstable situation. The unstable situation might include stall (excessive angle of attack) or excessive sideslip or inadvertent inverted flight. A spin is also possible. How likely a spin is should have been determined earlier. If a spin is likely, the flight should not be attempted.
3. Flights with feedback must be done first outdoors and at sufficient altitude to recover from any stall or spin.

F. Flights with feedback should **only** be attempted indoors when sufficient altitude exists to successfully recover the aircraft from stall or expected loss of control circumstances. Any feedback configuration where a spin is likely should **NOT** be attempted indoors.