

2008 NASA "The PAV Challenge"

Aviation Safety Prize eCFI Tasks

The Aviation Safety Prize (ASP) will be based upon a set of defined tasks that can be flight demonstrated to the CAFE Test Pilots by each team's Personal Air Vehicle (PAV). These tasks are carefully chosen by CAFE and NASA to be both important and safe to test. The list of tasks for the 2008 flight competition may be revised and expanded for subsequent years. The tasks for which ASP points will be awarded consist of both Handling Qualities Tasks and electronic Certificated Flight Instructor (eCFI) Tasks. Points will *also* be awarded for a specified list of non-task items that are desirable attributes that enhance safety, comfort or ease of use. The winner of the ASP will be the PAV team with the most points.

The CAFE Foundation has developed the following concepts for the eCFI portion of the Aviation Safety Prize (ASP). The goals for the eCFI tasks in the 2008 ASP are to advance what the FAA calls "general aviation (GA) envelope protection." The NTSB aviation accident statistics, Nall Reports and other data reveal that **stalls too close to the ground** (SCTG) and **loss of control** (LOC) are the two main sources of GA fatalities. Evidence suggests that if these two hazards were eliminated, GA safety would begin to approach that of the airlines.

Through the Aviation Safety Prize, CAFE and NASA seek to bring forth eCFI technologies with the capabilities to both avert and correct these two main hazards. The guiding principle is that the eCFI should perform as would an actual human CFI. This means that the eCFI will have both **Passive** and **Active** functions. As such, the eCFI tasks examined during ASP flight attempts will be the vehicle's ability to perform the following:

eCFI Task 1- (Passive): Automatically inform the pilot with increasing urgency as the hazard is approached. (Instruct/inform mode)

eCFI Task 2- (Active): Smoothly, promptly and safely apply control forces to both prevent and recover from unusual attitudes. (Intervention mode, automatic and "on" at all times)

eCFI Task 3- (Active): Includes all Task 1 and Task 2 capabilities plus the ability to automatically warn of impending Controlled Flight Into Terrain (CFIT) *and* maneuver the PAV to avoid it, when appropriate.

eCFI Task 4- (Active): Includes all Task 1 through Task 3 capabilities plus the ability to automatically land the PAV at an airport runway selected by the pilot.

eCFI Task 5- (Active): Includes all Task 1 through Task 4 capabilities plus the ability to automatically detect pilot incapacitation, select an appropriate nearby airfield and land the PAV there without pilot assistance.

eCFI Task 1 should involve an easily perceptible sensation, either visual, audible, or tactile and preferably a combination of the three that prepares the pilot to take *appropriate* corrective action when a safe flight parameter is in danger of being exceeded. This could be the result of pilot inattention, external upset (wake turbulence), or a deliberate but naïve control input. The warning should be of proportional intensity so as to be both instructive and informative. That means that the more the pilot departs from an appropriate flight attitude, the more intense will be the warning. Conversely, the warning will immediately become milder as the pilot restores the PAV to a safer attitude.

eCFI Task 1 Equipment:

It is anticipated but not required that to achieve these eCFI Task 1 capabilities the PAV may have the following electronic sensors and displays/indicators/warnings thereof, among others:

- 1) Stick shaker (SS): tactile: aerodynamic or electro/mechanical warning
- 2) Angle of attack: visual, audible, tactile
- 3) Airspeed: visual, audible
- 4) Rate of climb/descent: visual, audible
- 5) g force: visual, audible
- 6) Rate of turn: visual, audible
- 7) Ground proximity: visual, audible
- 8) Thrust or power in use: visual

The "personality" of the stick shaker, for example, is open to much innovation. The general concept is that a mild purr should accompany safe operation and an increasingly annoying buffet or "rumble strip" sensation should be felt as the pilot errs in the direction of increased hazard of SCTG or LOC. The SS sensations should be strong enough to be intuitive and yet not disabling to the pilot's grip on the controls. Primary Flight Displays (PFD) could be utilized as annunciators to display warnings beyond their standard functions. The sophistication of the system should anticipate an "*appropriate*" correction as being possibly different from straight and level flight. For example, on takeoff, an angle of attack that exceeds V_x could trigger a warning until V_x was restored. The system should be capable of differentiating modes of flight and applying the warnings/announcements in *context* to avoid nuisance alerts. For example, as the stall angle of attack changes with flap deployment, the sensor should compensate for changes in PAV configuration.

eCFI Task 2 asks the eCFI to be able to "intervene appropriately" in addition to the tasks covered in eCFI task 1. To "intervene appropriately" means to promptly and safely apply control forces to return the PAV to straight and level flight *or* an appropriate attitude to avoid SCTG or LOC. Again, the guiding principle should reflect the intervention a

human CFI would provide to correct a problem. Such intervention should be accomplished with a smooth application of control inputs while minimizing altitude loss and not overstressing the PAV in g loads, airspeed or loads on the control system. In addition, the eCFI intervention should be of substantial enough force to correct the attitude. It should include a reliable means (a button or switch) to allow the pilot to quickly override the eCFI by disengaging it if the pilot deems the intervention is inappropriate or due to system malfunction. Under all circumstances, a pilot of ordinary strength must be able to overcome the forces applied by the eCFI in the event that depressing the override button or switch fails to disengage it.

The fundamental difference between this eCFI capability and a 3-axis autopilot is the full-time operation of the eCFI system. The purpose is to provide continuous oversight and ever-ready feedback instruction to the pilot. The system should be transparent and unnoticeable until the PAV approaches a hazardous pitch attitude, bank angle, airspeed, turn rate, load factor, etc.

eCFI Task 2 Equipment:

It is anticipated but not required that a centralized eCFI “brain” or microprocessor/computer system will receive all sensor inputs and connect to the following:

- 1) Servo motors for pitch, roll and throttle
- 2) Clutches to engage/disengage the servo motors
- 3) eCFI "disable switch"

eCFI Task 3 is a more advanced, extra bonus capability that provides for the intervention of the autopilot function described in eCFI task 2 to initiate a heading and/or altitude change to avoid CFIT. This capability could intervene whether the PAV was in climbing, straight and level, or descending flight. It would provide a different and uniquely identifiable sensory warning/stimulus to differentiate the CFIT intervention from one dictated by an unusual attitude. This is necessary to avoid a false pilot interpretation that the intervention was a system malfunction.

eCFI Task 3 Equipment:

It is anticipated that a three dimensional terrain data base would provide the information for terrain threats. Projection of the PAV’s maneuvering path vs. terrain threats would receive additional credit.

eCFI Task 4 is an even more advanced, extra bonus point capability that incorporates the “smart nav” function of the eCFI task 3 plus an auto-land capability. Auto-land describes the capability of the eCFI to navigate to an airport runway designated by the pilot and fly the approach and land without the pilot manipulating the controls. The expectation is that the pilot remains engaged during the process to monitor the anticipated function of the eCFI and to communicate with Air Traffic Control. After touchdown and rollout, the pilot assumes ground-handling functions to exit the runway and park the PAV.

eCFI Task 4 Equipment:

A 3-axis autopilot guided by an eCFI navigation system capable of utilizing published instrument approach profiles.

eCFI Task 5 anticipates additional capability that would provide for the safe conclusion of the flight should the pilot become incapacitated. This requires a system for monitoring the pilot's interaction with the navigation and control system and his or her physiologic status to be able to automatically initiate an emergency intervention should the need arise. The task 5 auto-land capability would require the eCFI to identify the most appropriate airport for this emergency auto-land function, then navigate and conduct an approach to landing there. Synthetic voice announcement of the emergency to Air Traffic Control and changing to the appropriate emergency transponder code are valuable adjuncts to facilitate an arrival without traffic conflicts. These added capabilities would receive extra credit points. Automatic flap and landing gear extension are essential. Automated operation of the throttle, brakes and ground steering are highly desirable and will be awarded extra credit points.

eCFI Task 5 Equipment:

- 1) Substantial automation of the three dimensional navigation and communication system to provide for auto-landing capability along with coordination and automatic operation of power controls, flight controls, steering and braking.
- 2) Strain gauge monitoring of the pilot's applied forces or movement of the controls or navigation inputs into the flight director to detect pilot interaction with the system.
- 3) Physiologic monitoring of the pilot (pulse oxymeter, etc.)

Grading of Performance:

eCFI Task 1 will be tested by approaching a power-off stall and examining the warnings given in an approach to landing and cruise configuration. Warnings provided when bank angle exceeds 45 degrees will generate extra credit points.

eCFI Task 2 The test pilot will stabilize the PAV at V_a trimmed for level flight and input a pitch up of 10 degrees and roll of 20 degrees and then promptly release the controls. The desired behavior is that the PAV returns promptly and steadily to straight and level flight with a minimum of pitch or roll oscillations. The quality of the recovery, time required and altitude change will be evaluated. A second test with a 10 degree pitch down and 20 degrees of roll will be evaluated. Progressively greater pitch and roll inputs will be applied and the recovery characteristics recorded until a bank angle is reached where the PAV does not demonstrate recovery or a maximum of 60 degrees is successfully demonstrated. If the PAV employs a servo and clutch intervention mechanism, the forces applied to the control system should be smoothly engaged and not intrusive on the pilot's maneuvering flight below the threshold for intervention. Under all circumstances, a pilot of ordinary strength must be able to overcome the forces applied by the eCFI in the event that depressing the override button or switch fails to disengage it.

During landing, the eCFI should allow the pilot to flare and delicately approach a near stall condition when just a few feet above the runway pavement. During takeoff, the eCFI should allow freedom of control up to an appropriately programmed intervention threshold.

eCFI Tasks 3 through 5 Testing of capabilities for 2008 is not anticipated although extra credit points will be provided for demonstrating them if the system meets the core requirements for eCFI tasks 1 and 2.

Points to be awarded:

Handling Qualities Score, all tasks:	300 points maximum
Performance Summary Score: (a score of 80 points = very good)	200 points maximum
Judges Discretionary Score:	200 points maximum
*eCFI Task 1 (instruct/inform):	100 points maximum
eCFI Task 2 (control intervention):	200 points maximum
eCFI Task 3 (CFIT avoidance):	50 points maximum
eCFI Task 4 (CFIT + auto-land):	100 points maximum
eCFI Task 5 (CFIT + auto-land + pilot incap):	200 points maximum

***required tasks to be eligible to win the ASP**

Note: Cooper-Harper score of ≤ 3 is required to win and can be with eCFI turned on.