Come Fly with Me—The eCFI PART 2

Homebuilt eCFI: *toward plug-and-play systems*

BY BRIEN A. SEELEY M.D., PRESIDENT, CAFE FOUNDATION

James P. Hauser's excellent series of three articles for KITPLANES® (June 2004) presented valuable guidelines for a do-it-yourself electronic flight instrument system (EFIS). There is a growing synchronicity between the array of hardware available for such systems, the capabilities they can provide and the network of knowledgeable builders interested in assembling such systems. This article describes how building an eCFI (electronic Certificated Flight Instructor) into one's EFIS can dramatically enhance safety.

The connection and software features of homebuilt eCFIs will develop best with collaboration amongst kit aircraft builders and their consultants. Toward that end, I have begun an email list-serve of interested, knowledgeable builders and industry pros who want to network their talents. Send an email to cafe400@sonic.net if you wish to join this list-serve. By sharing their creations with others, builders who develop eCFIs will enhance personal aircraft safety for all.

From Simple to Sophisticated

The more sensors, instruments, datastreams and actuators that an eCFI has, the more functions it will be able to perform, and the more sophisticated and appropriate those functions will be. Many of the sensor technologies listed here were well established in military and airline use decades ago, but some are more recent. Following is a list of the things that should communicate with the eCFI, from basic to advanced.

Basic eCFI: Issues prompts, alerts and warnings, without command/control.

Its components are: GPS receiver (database, imaging, TAWS, etc. already inside the eCFI); ADAHRS (air data-attitude heading reference system); intercom; engine monitoring sensors; flat panel display(s); angle of attack sensor; G meter (digital); and warning buzzer or horn.

Intermediate eCFI: Includes all of the above, plus adding control of aircraft-control actuators.

Advanced eCFI: Includes all of the above, plus control of avionics, autolanding, DAA (detect and avoid software). It requries: a agnetically slaved compass; aircraft communications radio; transponder; throttle servo or FADEC (full authority digital engine control); pilot health monitors (pulse oxymeter); strain gauges and position sensors from controls; strain gauges and squat switches on landing gear; downlinked weather (satellite radio); uplinked traffic (ADS-B, automatic dependent surveillance-broadcast); FLIR—forward looking infrared (detection of runway obstacles, deer); and radar altimeter.

The basic eCFI can be programmed to monitor for changes or conditions that would merit these kinds of safety prompts and alerts:

Low on fuel

Engine temperature

Restricted area ahead

Lower nose, don't stall

Pull up—terrain

Excessive bank angle

Water in fuel

Check landing gear at less than 300 feet AGL.

Induction icing: Use carb heat now!

Change in any engine temperature or pressure

Terrain awareness warning system (TAWS)

Default back on after 30 seconds (timing may vary)

G forces

Engine out: Best glide is 120 mph (need thrustmeter or temp drop in EGT/CHT).

Carb heat. Maintain flying speed. Check fuel tank. Wind is 340° at 12.

Oxygen needed

Verbal to nearest airport: 334°, 9 miles.

AOA excessive

If flaps down (as for landing or take-

Illustration/Photo: Brien Seeley, Marc Cook

Operational Example of the eCFI Decision and Command Flow Paths

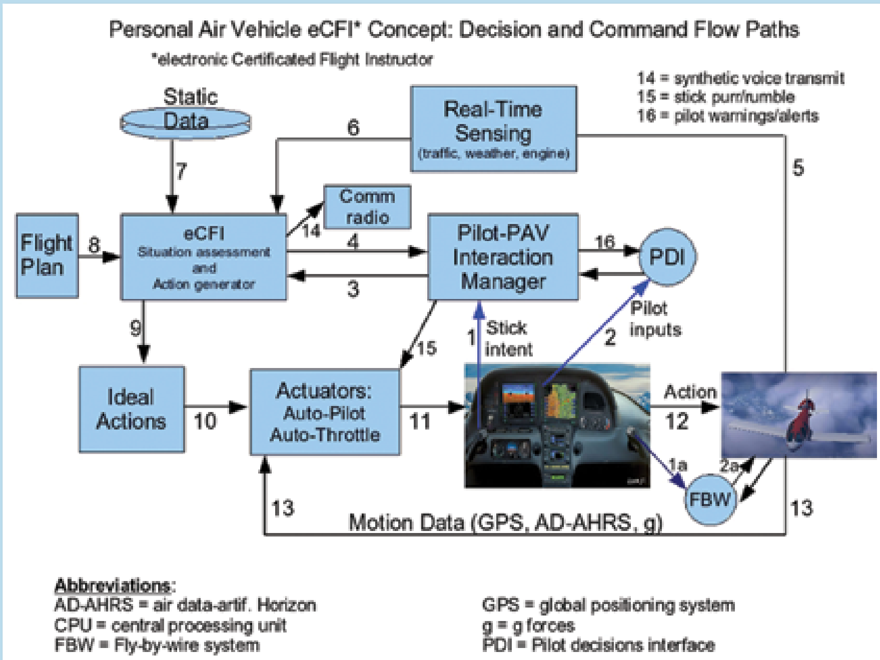

Figure 1. The chart at left was derived with guidance from Ken Goodrich at NASA, whose great work on the Naturalistic Flight Deck inspired these articles.

See the path numbers on the flow chart for each action described below. This example is for an eCFI that has a force-feedback control stick with mechanical linkage to ailerons and elevator. Each blue box represents either hardware or software or combined hardware/software units.

In this example, a pilot is flying at 2000 feet eastbound past the South Tower of the Golden Gate Bridge and under the San Francisco Class B airspace. Wishing to sightsee along the Embarcadero shoreline toward the Bay Bridge and AT&T Park, the pilot decides to turn right when above Pier 39 to head toward the Bay Bridge.

1) With intent to turn right, the pilot rotates the control stick to the right with no fore/aft elevator input.

2) The Pilot-PAV Interaction Manager (PPIM) is set for "active" mode, in which the eCFI is "on-duty" in a shared control arrangement with the pilot. This means that eCFI pathways 2 through 16 are all potentially active. The movement of the control stick, via rotary position sensors, is conveyed to the PPIM. The PPIM's rotary position sensors are also strong, clutch-coupled DC servo motors that can provide force feedback to the stick and can actually move the controls of the aircraft. The Pilot Decisions Interface (PDI), along path 2, observes that the pilot makes no change in throttle setting, heading bug, GPS waypoint or com radio frequency.

3) The PPIM asks the eCFI if a level right turn is "acceptable and safe" at this point in the flight.

4) Using Static Data from path number 7, the eCFI tells the PPIM that it has received and understands that inquiry and that an airspace floor limit of 1500 feet will be approached if the requested level right turn is executed. Path 16 is used by the PPIM to send flashing on-screen and audio intercom warning/alerts to the pilot indicating "Airspace floor ahead." Absent acknowledgment from the pilot, the PPIM uses path 15 to apply a slight rumble vibration to the control stick.

Paths 5, 6 and 8: The eCFI simultaneously receives and examines the current weather, traffic, engine temperatures and pressures, along with the filed flight plan for compatibility with the action intended, a level right turn. Just like a human CFI, the eCFI examines questions such as: Does nearby traffic conflict with the intended path? Would the new direction aim toward adverse weather? Will there remain sufficient fuel to reach the flight plan's destination airport?

9) The eCFI decides that a level right turn is unacceptable because the floor of the local Class B airspace ahead is 1500 feet. The eCFI therefore creates an appropriate revision to the intended flight path. The revision will command that the aircraft descend to remain under the 1500 foot floor of the airspace.

10) The Ideal Actions processor complies and computes the ideal, allowable path and power setting for the aircraft to follow.

11) The Actuators unit evaluates incoming Motion Data (path number 13) and blends these with the ideal path/power from the Ideal Actions processor. This results in the proper amount of forward stick movement and force being sent to the control system actuators. No change in throttle is needed.

12) The aircraft responds to these corrections as the actual stick force and motion applied by the pilot are modified by a resistance force to the pilot's attempt to hold the aircraft level. Right turning is allowed, and the descent is accomplished by a forward stick motion.

13) The resultant descending right turn is executed by the aircraft. The aircraft's changing position is continuously monitored by the system as eCFI operation remains active.

Path 14 is not active since no eCFI radio communications are needed.

The 1a and 2a Fly-By-Wire inner loop control circuit does not apply here with mechanical control linkages. —*B.S.*

off), give wind, if calculable.

The intermediate eCFI, by adding control actuators, becomes capable of maneuvering the aircraft in time to avert problems that the basic eCFI can only announce. This amounts, in effect, to having a smart autopilot. The eCFI's actuators for each aircraft control must be limited by a clutch or other means so as to be over-powerable by the pilot in the event of some system error. Limited actuator power demands that the aircraft's control system be designed to have low friction, and have a trim system that can keep maneuvering forces and control breakout forces manageable. Such features distinguish the excellent side-stick control system from the Questair Venture, whose design will be presented in Part 3 as a model for kit aircraft builders to emulate.

The advanced eCFI is the fullest and the best expression of the safety enhancement potential in a self-aware aircraft. By coupling the eCFI to the avionics, a vast expansion of information and safety enhancements becomes possible. However, this degree of sophistication will need to evolve from those with special computer skills and background. To facilitate such evolution, the previously mentioned eCFI interest group will share ideas on the web and on hardware lists through AeroElectric's Bob Nuckolls, along with open source code and an effective partnership with avionics manufacturers who have the information needed for interoperability. Web video demonstrations and flight experience sharing will further the urgently needed progress in this area.

The block diagram (Figure 1) shows the decision and command flow paths of an eCFI. The sidebar provides an example that illustrates how these paths work.

The CAFE Foundation, in conducting NASA's $250,000 flight competition on August 4-12, will be assessing and crediting those aircraft that demonstrate eCFI functionality. (See http://cafe foundation.org/v2/pay_home.php). Part 3 of this series will present nuts and bolts hardware examples to help kit builders get started in building their own eCFIs. ✈