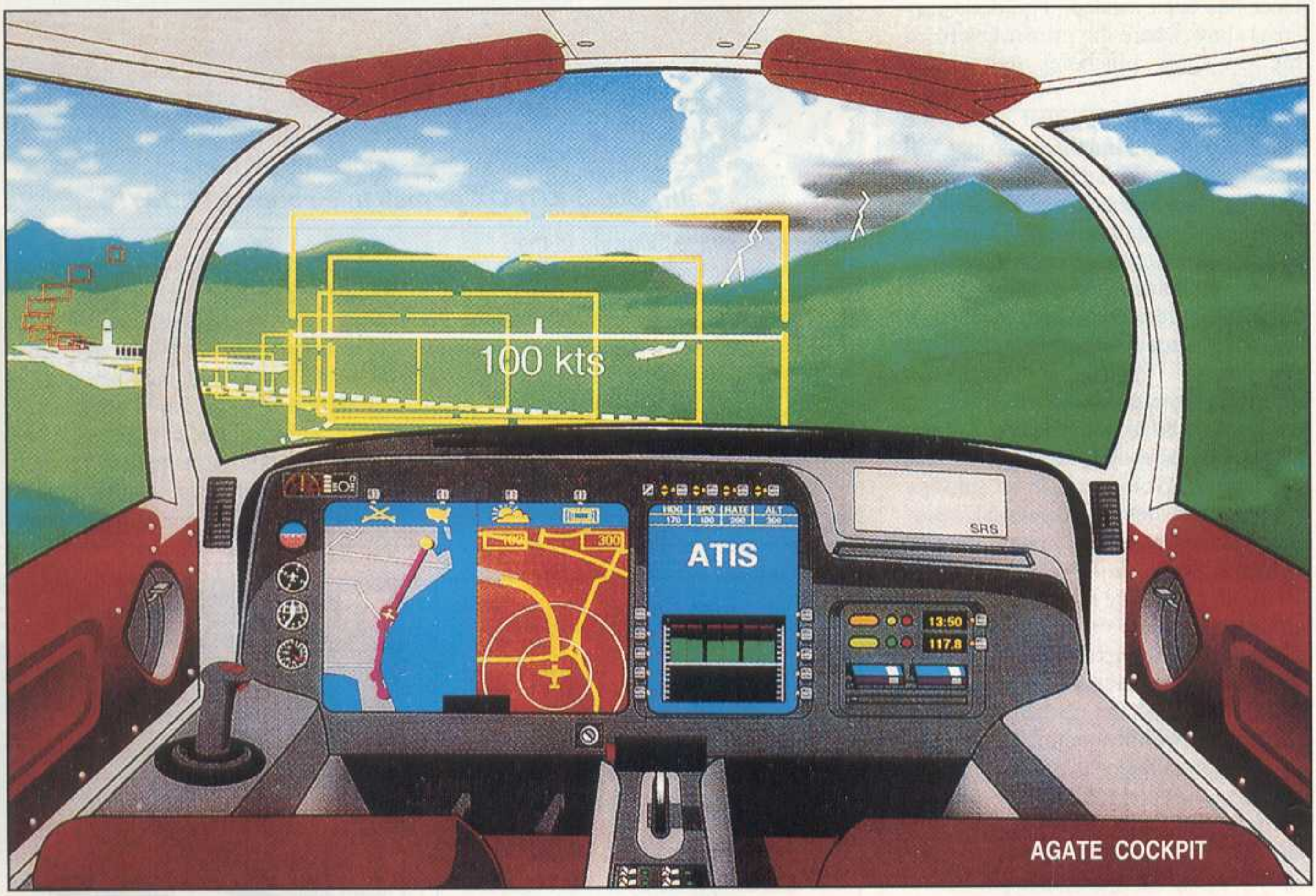
FUTURE COCKPITS

In Part 3 of this series on ergonomics, we look at

By Ricardo A. Price



In this last article in the three-part cockpit ergonomics series, we look to the future: glass cockpits! Those who have seen NASA's AGATE (Advanced General Aviation Transport Experiments) mockup have seen what the future holds.

A modern glass cockpit is shown in Figure 1. Basically, it is the ultimate expression of the ergonomic rules we have been talking about all along. The modern cockpit depicted in Figure 1 incorporates one attitude/performance instrument (the heads up display or HUD), two multi-function displays (MFDs, one configured as a navigation display, the other as an engine/aircraft configuration display), and one avionics control panel. Multiple power controls (throttle, prop, mixture, cowl flaps) have been replaced with one lever. Heavily used switches are on the throttle and stick. A cockpit like this can make our flying easier and safer—like driving a car.

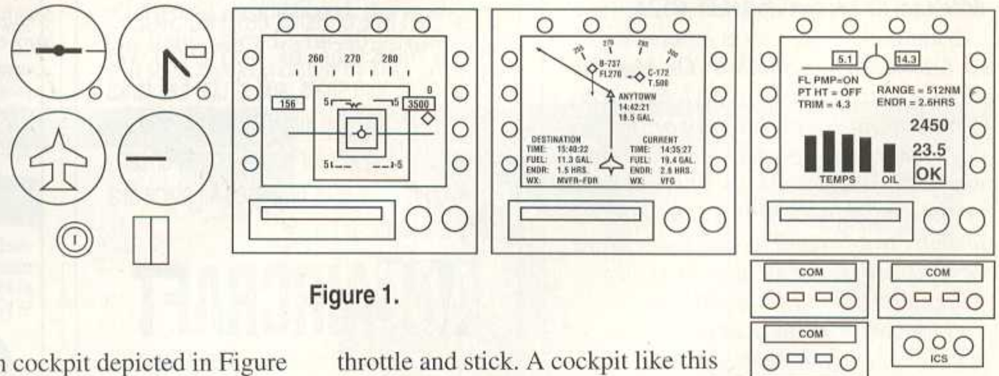


Figure 1.

Having accumulated about 1000 hours in a glass cockpit, I will now describe what the instruments do and how they do it. I think you'll agree that the future looks bright.

ILLUSTRATIONS: RICARDO PRICE

instrument panel possibilities.

Heads Up Display

The HUD is the attitude and performance instrument (Figure 2.) All the information normally found in the standard six-instrument scan is displayed in one place on the HUD. In addition, one very important feature missing in the standard six-instrument scan that makes all flying—and especially IFR flying—childsplay. This indication—which can be displayed on the HUD—is the *velocity vector*.

The velocity vector graphically displays the aircraft's flightpath. It combines vertical speed, groundspeed, course and angle of bank information into a single, logical display. Want to fly level? Place the velocity vector on the horizon. Want to descend on a 3° glideslope? Lower the velocity vector to 3° below the horizon. Want to land on the numbers? Fly the aircraft so that the velocity vector is superimposed over the numbers (or a little short of the numbers to allow for flaring distance).

Figure 2 shows what an F/A-18 HUD looks like "in the groove" to the carrier *USS Saratoga*. The upper left box shows airspeed while the upper right box shows altitude. Vertical speed is depicted just above the altitude box. Course and heading is read across the top. Just below heading is the "waterline" indicator (it looks like a "w"). The waterline indicator functions exactly like an attitude indicator—it shows bank angle and pitch attitude.

Below the waterline indicator and superimposed on the carrier deck is the velocity vector. According to this velocity vector, we are on a 3° glideslope. If the ship were to stop moving, our impact point would be at the far end of the landing area, beyond the arresting wires. The vertical difference between the waterline indicator (approximately +4.5°) and the velocity vector (approximately -3°) gives us an approximate angle of attack of 7.5°, which is slightly fast (on-speed AOA is 8.1°). We'll slow down, Paddles.

Figure 2. The velocity vector literally shows the pilot where the aircraft is going. Here, the velocity vector is placed beyond the intended point of landing because the landing area is moving!

Those with sharp eyes probably noticed a horizontal difference between the waterline indicator and the velocity vector as well. In Figure 2, the aircraft heading shown by the waterline indicator is 312° while the aircraft course shown by the velocity vector is 314°. A velocity vector makes crosswind landings easy because by placing the velocity vector on the intended point of landing the pilot automatically flies with the proper crab angle (in this case 2° left).

Until now, generating a velocity vector has required the use of expensive and complicated inertial navigation systems. With the advent of GPS, however, a general aviation velocity vector can be generated very inexpensively (Figure 3).

To generate the velocity vector, you would first use vertical speed information and combine it with groundspeed information. This gives angle of climb or descent. Aircraft angle of bank would be derived from GPS receivers installed in the aircraft wingtips. Combining the above with GPS-derived aircraft course information results in a wind-compensated velocity vector. To complete the HUD display, aircraft heading and nose position from GPS receivers in the nose and tail along with air data from a pitot-static computer would be added.

Failure Modes

In case of a GPS failure, a degraded velocity vector could be generated by combining airspeed from a pitot-static source, vertical velocity from a static source, along with angle of bank, heading and nose position from gyros (Figure 4). The degraded velocity vector would not be wind compensated but would still be far superior to an attitude indicator. The degraded velocity vector display would be different in appearance than the full GPS-derived velocity vector to alert the pilot to the absence of wind compensation.

The HUD is also the natural place to display NASA's Highway in the Sky navigation display (Figure 1). Those who have flown Microsoft's flight simulator have seen this navigation display, consisting of a series of squares forming a "tunnel" down O'Hare's ILS glideslope. Combining the Highway in the Sky navigation display with a velocity vector will make precision approaches very easy to fly. Simply fly the velocity vector right through the middle of the "tunnel" and you'll be "on and on" all the way.

The only drawback to using a HUD is the lack of a good backup system in the event of a complete HUD failure. Admittedly, such failures would be rare and good backups exist for intermediate failures. For example, in the event of a GPS failure, a degraded velocity vector could be displayed. If the HUD projector were to fail, the HUD symbology could be displayed on one of the MFDs.

However, when the HUD fails completely, the backup instruments will probably be miniaturized versions of the standard instruments with which we fly today (Figure 1). The jump from the HUD to miniature gyro and pitot-static flight instruments is much larger than going from full-panel instrument flight

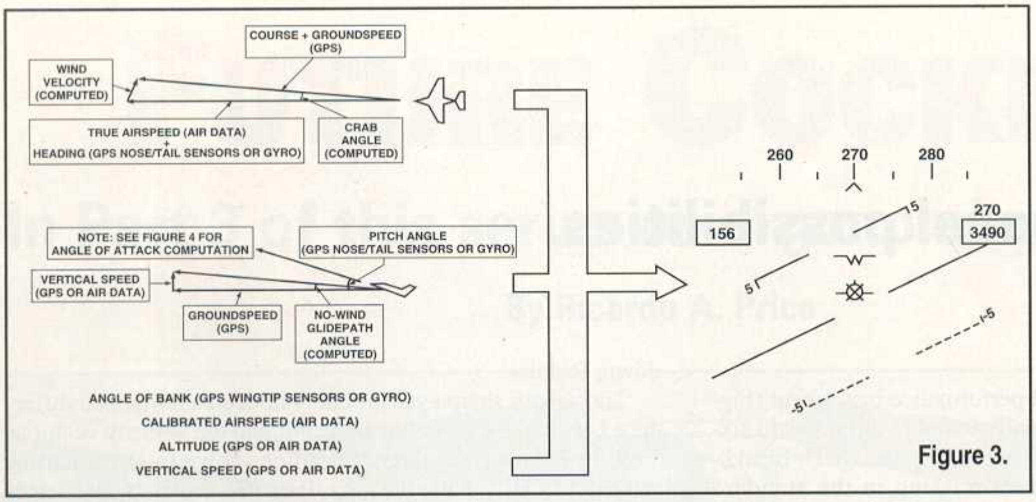


Figure 3.

information in planform view, a grown-up version of the moving maps currently coming into widespread use. In addition to a moving map, the MFD will be able to show airport information, real-time weather, traffic advisories, engine information and back-up HUD depictions (used when the HUD projector fails or when flying directly into the sun).

The MFD environment will probably be something like the MacIntosh or Win-

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to needle-and-ball instrument flying; you had darned well better be proficient with those backup flight instruments.

NASA's AGATE promoters envision a day when even the lowest-time pilot could climb into an aircraft and fly in hard IMC—entirely possible with a fully operational HUD, velocity vector, and Highway in the Sky navigation display. But will a low-time pilot flying in hard IMC be able to cope with a complete HUD failure?

Other Helps

In addition to attitude, performance and navigation guidance, other types of information can be displayed on the HUD. Two of the most useful are "targets" and special-use airspace. Target depiction would occur whenever the computer calculates (from data link information) that another aircraft should be in the HUD field of view. The computer would then generate a box on the HUD at that position (Figure 5). Peer through the box, and you should be able to see the "target" aircraft in the distance.

Airspace depiction would consist of three-dimensional projections of approaching special-use airspace such as Class B areas, MOAs and restricted areas.

Navigation Displays

In the center of "future cockpit's" instrument panel will be a large flat screen MFD (Figure 1). The MFD will either have buttons along the sides or be touch-screen controlled. The MFD may also have a trackball-like pointing device mounted on the stick.

The primary MFD's principal use will be to show navigation

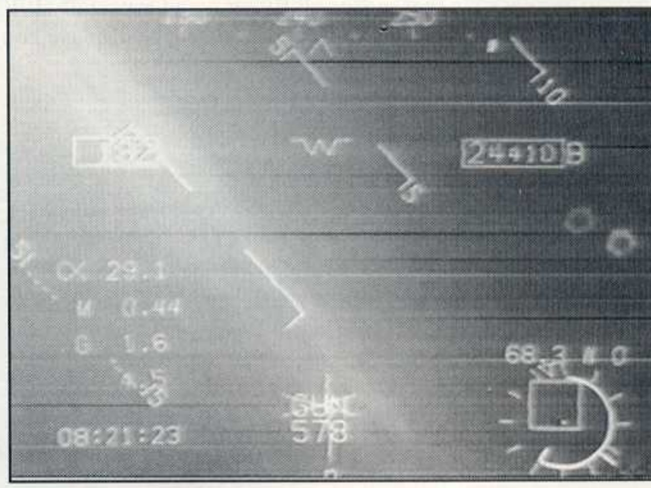

Figure 5. The target aircraft is in the lower part of the target box, beneath the gunsight pipper. Of course, civilian HUDs would not have a gunsight. Where's the velocity vector? It is well below the HUD field of view because the aircraft's angle of attack is 29.1°.

dows computer environments with the ability to display various "windows" at once. As the MFD will be computer controlled, adding capabilities to the aircraft would be a simple matter of installing necessary aircraft hardware (antennas and sensors), adding an electronic interface card to the computer, and loading software into the computer for display purposes—much like adding capabilities to a home computer. No more patchwork panels with instruments in every nook and cranny.

Real-time traffic advisories will be transmitted to the aircraft via data link. I suspect that the FAA will eventually require most aircraft to have GPS and data link capability. Thus, flying aircraft will constantly downlink position information to ground stations or satellites that will then uplink the position information to other aircraft. An ATC controller's report, "Radar contact," will be a thing of the past. The aircraft computer

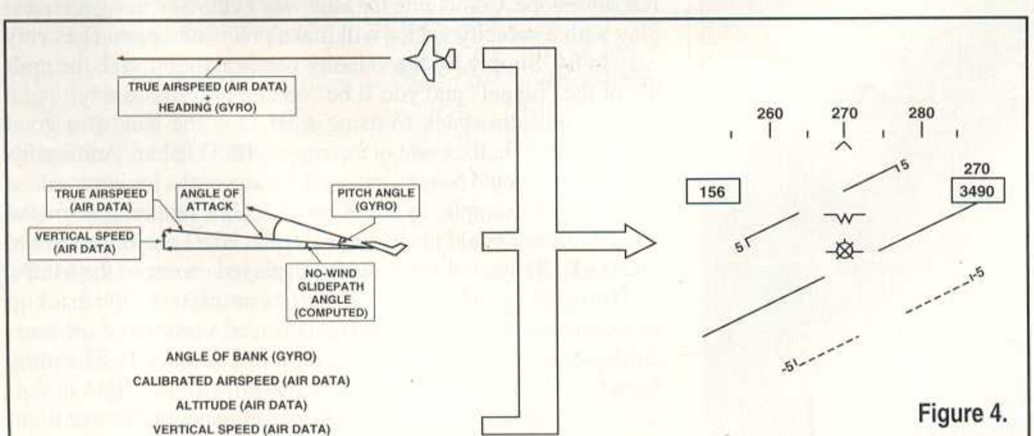

Figure 4.

will process the uplinked position and altitude information and display the locations of other aircraft directly on the moving map and HUD.

Real-time weather information will also be transmitted via data link. Just as with aircraft position information, the flow of weather information will be two-way. Imagine continuous PIREPS from all flying aircraft as they transmit basic wind, temperature, pressure and precipitation information gathered with aircraft-installed sensors that will be in the aircraft anyway as part of the electronic engine controls. And with a push of a button, all of that real-time weather information—along with satellite images, ground observations and radar—will be available to the pilot.

Add a lightning strike sensor with computer card and interface software and your aircraft will have more weather information available than the National Weather Service.

To make the information usable, graphic displays will depict the weather directly on the moving map. Simply point and click on an area of particular concern for expanded information. If you choose not to display the weather, the computer will continuously compare the weather to your preprogrammed personal weather minimums, advise of hazards, and suggest alternate routes. To accept an alternate route, push a button and the new flight plan will be filed with ATC via data link. Welcome to the information age!

You may be thinking to yourself, "Busy computer!" Yes, the computer will do a lot of work for you—as a decision-making aid, not a decisionmaker. Such a powerful tool should reduce the incidence of pilot error. To do that, designers must pay strict attention to ergonomics: the man/machine interface. This vast array of information must be intuitive and understandable. Pilots must become and remain proficient at using the equipment with less training than is needed today. One nice thing about the computerized cockpit is that the software in your aircraft could be loaded into a home computer for simulation purposes.

Engine and Aircraft Status Display

All of the technology I am describing is with us today; it just hasn't been developed and applied to general aviation. The exception so far is engine instrumentation. Homebuilders currently have many fine multifunction engine instruments available such as Vision

Microsystem's VM1000, Rocky Mountain Instrument's μMonitor, and ARNAV's MFD5000. Engine instrumentation of the future will be similar—featuring multiple functions, analog and digital presentations, audiovisual alarms, trend analysis, and parameter recording for later troubleshooting.

In the future, however, a standalone display will be unnecessary. Instead, the "engine page" will be another "window" displayable on the MFDs. Normally, the "engine page" will be displayed on a secondary MFD (Figure 1). However, at the pilot's option the primary MFD will be able to show the "engine page" just as the secondary MFD will be able to show the navigation or HUD "pages." The MFDs will be redundant.

Engine monitoring will be done by the aircraft's main computer, while actual engine control will be performed by separate and redundant engine control computers. The "engine page" will be our interface with the engine control computers. Naturally, a fuel-flow computer continuously updated with actual aircraft fuel state will be part of the "engine page." Whenever the moving map is showing a large enough area, range to empty will be shown as concentric rings. If the destination falls outside of those rings, the pilot will be alerted and an alternate route/destination suggested. Once again, all the pilot has to do to accept the computer's advice is push a button. This should prevent many fuel starvation accidents.

Aircraft status will be another "window" displayable on the MFDs. The aircraft status "window" will graphically present information like flap position, landing gear position, and exterior light illumination. It will be much like the aircraft status display discussed last month with the exception of added graphics

Recent Cockpit Display Developments

At Oshkosh '95, two companies displayed new computer-based instrumentation systems. One of these, the Touch & Go EFIS from Archangel Avionics, is the subject of a separate article beginning on page 53. This sidebar will focus on the Cockpit PC from Silvaire Avionics and how these new pieces of hardware fit into a modern homebuilt cockpit.

The Cockpit PC is exactly what its name implies. It is an IBM-compatible personal computer designed for permanent installation in an aircraft cockpit. To that end, it is built with heavy-duty industrial or custom components designed specifically for aircraft use. For example, the computer's hard drive is able to withstand a 200-G shock while in operation and the display backlighting is built to be legible on the brightest day or darkest night.

An operating Cockpit PC comes with two modules, a panel-mounted display module and a remotely mounted computer module. The display module contains a flat panel display, control buttons and a 3.5-inch floppy drive for loading data and software. The flat panel display consists of an extended temperature range Active Matrix color TFT-LCD screen available in two sizes, 5.6 inch or 8.6 inch. Touch screen control is optional on the 8.6-inch version. The custom built fluorescent backlighting has a maximum luminance of 20,000 cd/m2 (bright) and a minimum luminance of 2500 cd/m2.

The computer module houses the central processing unit (CPU), hard drive (a second hard drive is optional), and I/O (input/output) cards. Two CPUs are available: a 486-SLC running at 50 MHz and a 486-DX4 running at 100 MHz. Pentium and 686 CPUs will be offered once industrial spec chips become available. The I/O cards interface with all manner of external equipment including GPS, VOR/ILS, external pointing devices, temperature sensors, pressure sensors, gyro inputs, rate counters (for parameters such as rpm and fuel flow), data link equipment, and even intercom signals (allowing the use of voice commands or warnings). User interface with the Cockpit PC will be via the display module control buttons, external pointing devices such as a stick-mounted trackball, touch screens and voice commands.

Silvaire Avionics envisions itself primarily as a supplier of hardware. Although the company has developed some software for the Cockpit PC, designers intentionally used an IBM-compatible format so that an aircraft owner could use software from other sources. For example, existing PC flight planning/moving map programs such as RMS Technology's Flitesoft or Mentor Plus's FliteStar will run on the Cockpit PC. Multiple software sources should foster competition, keep costs lower, and get innovative software ideas to market sooner.

A side benefit is that it will make certification simpler as Silvaire would only need to certify its hardware. Software packages would be certified separately by the software companies.

Figure 1 shows what a cockpit using technology like the Cockpit PC or the Touch & Go EFIS might look like. Round instruments, with the exception of miniature standby flight instruments, would be a thing of the past. In general, three main types of software would be used: EFIS software, navigation software, and aircraft status software. The EFIS software would display all information necessary for instrument flight such as airspeed, altitude, attitude, heading and ILS needles.

The navigation software would consist of a moving map, a flight planner, and a data link interface that would allow weather and traffic information to be displayed directly upon the moving map. Aircraft status software would display aircraft system information such as engine parameters, fuel state and landing gear position.

Each Cockpit PC would be capable of running all three types of software. This will provide redundancy and will also allow a pilot to set up his display screens differently for different phases of the flight. For example, during takeoff and motion capability to enhance readability.

Avionics Control

All of the aircraft's avionics tuning and volume adjustments will be handled through one control panel rather than a separate control panel for each device. This is a big advance because most of the time the separate control panels in our airplanes just sit there and inundate us with glowing red numerals, switches and buttons. To demonstrate how effectively a single multi-purpose avionics control panel cleans up an instrument panel, consider Figure 6, which is based on Terra's

the engine screen might be more important to the pilot than the navigation screen. In that case, the pilot could select the engine screen on a display directly in his line of sight. Later in flight, the engine screen would be moved to the side with the navigation screen assuming the favored position.

Unfortunately, due to the custom built nature of these systems, costs are high. A bare bones Cockpit PC will set you back about $11,000. To that add the cost of software, sensing equipment, and options. Silvaire recognizes that it needs to get costs down and is exploring various methods to accomplish this. Among the alternatives are offering kit versions of the Cockpit PC and exploring ways to allow multiple Cockpit PC installations to share components such as floppy drives, I/O cards, external pointing devices, and computer module housings.

Even at current prices the Cockpit PC offers good value. The Cockpit PC has capabilities far beyond the most expensive avionics available today. In addition, future updating would consist of merely changing software. If the home PC revolution is any indication, it is hard to imagine what types of software will evolve. Nevertheless, the owner of a Cockpit PC can rest assured that his panel will remain state of the art for many years to come.

For more information on the Cockpit PC, contact Silvare Avionics, Attn: Dennis Collins or Dan Marsoobian, 950 W. Sierra Madre Suite 808 Azusa, CA 91702-1830; call 818/969-0347.

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popular line of avionics.

Figure 6 shows a typical arrangement of Terra avionics: two coms, two navs, a transponder and an ADF. Terra has done a good job of making the tuning and volume adjustments on its avionics operate in similar fashions. Thus, it would be simple to replace all six control panels with just one control panel and a row of switches to determine what the control panel adjusts. This is the basis of the single multi-purpose avionics control panel.

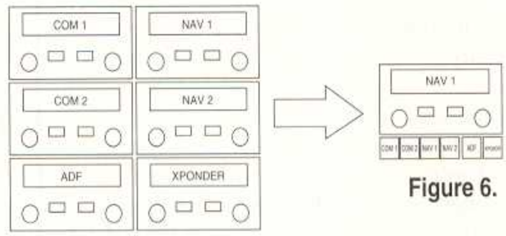

Figure 6.

In the short run, a multi-purpose avionics control panel will really simplify our instrument panels. In the long run, it will be of far less significance since pretty soon there won't be much to adjust anyway. Navigation will be done by GPS (no channels or volume to adjust).

Most communication will be done via data link rather than two-way radios. Data link does not require a volume adjustment and required frequency changes (if any) would occur automatically. While there will still be a transponder (now called a data link unit), the transponder code will probably be a permanent code assigned to a particular N-number rather than a different four-digit code for each flight. The only device that may require tuning and volume adjustment as is currently done will be a single two-way radio used as a data link backup. If this backup radio is a handheld device, the end result may be absolutely no avionics to adjust.

Single-Lever Power Control

After all these years of pushing and pulling a handful of levers or knobs, power will finally be controlled by a single lever. Mixture and ignition timing will be electronically set to optimum values based upon pressure, temperature, humidity and throttle setting.

The new powerplants will probably be liquid cooled to eliminate shock cooling, enhance engine efficiency, and reduce cooling drag. If air cooled, the powerplants will be tightly cowled with thermostatically controlled cowl flaps to provide auxiliary cooling only when needed. Propeller rpm will also be computer controlled for optimum efficiency or, at high throttle settings, optimum power. As mentioned earlier, the engine's pressure, temperature and humidity sensors will also be used for other aircraft functions such as air data calculations, weather data downlink, and automatic operation of pitot heat and de-ice gear.

Further down the road, electronic engine controls may be coupled with fly-by-wire to provide "decoupled" flight controls. With decoupled flight controls, actuation of the stick in pitch will result in a climb or descent without fluctuation in airspeed (engine power will be adjusted automatically).

Roll control will occur without any adverse yaw. Increasing throttle will result in an increase in airspeed instead of a climb at trimmed airspeed. While decoupled flight controls may not appeal to the purists among us (me included), they will make the transition from the family Ford to airplanes very easy and should significantly reduce the rate of stall/spin accidents.

Cost

Will any of this ever come to pass? The answer, of course, is yes, but when it will come about depends on cost. Theoretically, the equipment that I've described—computers, flat screen displays, electronic sensors, and software—should be less costly than the intricate electro-mechanical equipment currently in our airplanes.

The trick is in funding research, development, and early production costs. Compared with the millions of people and businesses that provide impetus for the development of home and office computers, the aviation community is minuscule. We are in a Catch-22—we need a broad base of general aviation users to fund modernization, yet we need modern equipment to attract a broad base of general aviation users.

Still, a walk through Oshkosh's commercial display area shows that the glass cockpit is coming. And, as usual, homebuilders are leading the way. Of particular significance are Archangel Avionics' EFIS system and Silvaire Avionics' Cockpit PC. No doubt, we'll soon be seeing some fantastic software written by fellow homebuilders for these new pieces of hardware. Will the pages of KITPLANES soon be filled with software advertisements? Time will tell. **KP**