N20217

1977 Cessna 177B Cardinal II+

Avionics Improvement Program (AIP)

Jacque La Valle, Owner/Operator

Purpose: To upgrade this Cessna Cardinal with state of the art technology that will aid in cockpit workload reduction, system automation, improved situational awareness during mission execution and simplistic redundancy for emergency contingencies. At the completion of this AIP, the model will be redesignated the Cessna Cardinal II+.

Background: This aircraft was purchased May 2019 in its basic 1977 Cardinal II configuration minus the distance measuring equipment (DME) and Automatic Direction Finder (ADF). Existing equipment included two (2) Bendix KX-155 NAV/COMS and their associated OBS/CDI indicators, a Bendix KLN-90 VFR non-WAAS GPS receiver with no external guidance indicator, a Garmin GMA-340 audio panel with Marker Beacon, a 121.5 MHz Emergency Locator Beacon and an L-3 Lynx NGT 9000 ADS-B IN/OUT Transponder. All gyros were vacuum driven and the Cessna Navomatic autopilot was deemed inoperable. An ElectroAir electronic ignition system is installed and an electronic tachometer replaced the mechanical analog gage. Overall, the 3500 hour airframe is in excellent condition. Figure 1 shows the pre-project configuration of the cockpit.

Figure 1

Pre-Project Cockpit Configuration

Requirements:

For this project to be successful, all mechanical indicating and legacy communication and navigation systems were replaced with a suite that will provide a simplistic operational environment and superior situational awareness coupled with system redundancy and safety enhancements at an affordable cost. The Dynon Certified HDX™ SkyView with dual displays coupled to two independent Avidyne® IFD series Flight Management Systems was selected. Functions of the Dynon Certified HDX™ include Primary Flight Displays (PFD), Multi Functional Displays (MFD), Engine Management System (EMS), Angle of Attack (AOA) and independent ADS-B IN for FIS-B/TIS-B. The L3 NGT9000 remained in place for ADS-B OUT and redundant ADS-B IN displayed on the IFD displays only.

After the equipment selection decision, several other requirements crept into this project. They included: installing a Whelen LED beacon; removal of all non-used wiring; replacing the aluminum bus bars with copper; replacement of all circuit breakers; installation of ARTEX ELT 345 406; compliance with Textron Service Bulletin SEL 57-09, Carry Through Spar Inspection; removal of all CAT tubing with SCEET tubing; and the replacement of both Cessna fuel level senders with CiES, Inc. magnetic fuel senders. Table 1 details the removed and installed parts list needed to accomplish this project.

Table 1

Configuration change table

N20217 Configuration		
Equipment Removed	Equipment Installed	Additional Work
• KX-155 COM/NAV 1 • KX-155 COM/NAV 2 • KLN90B GPS • NAVOMATIC 300 A/P • All analog instruments (A/S, ALT, T&B, VSI, DG, AI, Clock, EGT, engine and fuel cluster, vacuum gage, manifold pressure and digital RPM • COM 1 and 2 antennas • Entire engine driven vacuum system (pump, filter, hoses) (retain). • 121.5 ELT • Existing fuel sender units • Factory beacon	• Dynon HDX Suite ○ 10” display ○ 7” display ○ D10 Attitude Ind. ○ COM #2 ○ Selector panel ○ AOA & OAT probe ○ Engine Mgmt Sys • CIES Fuel levelers • Avidyne IFD540 • Avidyne IFD410 • New overlay panels • New COM antennas • Vacuum pump blank off plate • AIRTEX ELT 345GPS 406 with remote switch and antenna • Whelen LED Beacon	• Conduct Textron Service Letter SE-57-9 • Replace overhead air inlet CAT tubes with SCAT tubes. • Replace existing rod transponder antenna with blade antenna • Replaced circuit breakers • Remove unused wiring • Replaced aluminum bus bars with copper

Cost/Schedule/Milestone:

An exhaustive research was conducted to select the best avionic improvement equipment to meet the requirements for the 21st century. Familiarity of Garmin, Avidyne, JPI and Aspen components helped in the system design and selection. Dynon was carefully evaluated based on their 25 years of experimental market success and recent inclusion into the certification market. For primary flight and multi-function display capabilities coupled with the engine management system integration, the cost of the Dynon made the selection most attractive. Each Dynon display (two selected for this project) is an independent computer system synchronized through an Ethernet data bus. Dynon uses its own GPS receiver for navigation and flight planning functions but is only certified for VFR. Dynon require IFR capability from any IFR certified external GPS source. Dynon employs a proprietary network topology which makes system integration seamless. Unfortunately it is impossible to integrate a second source digital autopilot systems beyond RS-232 serial bus inputs from the selector panel. At risk, this project made provisions for the Dynon Autopilot configuration in anticipation of certification. Once certified, each servo will cost $750 each plus installation costs. Without the autopilot installed, the Dynon equipment cost was $37K which included AOA capability, remote selector panel for heading/baro/alt bugs, an integrated COM radio with frequency loading by airport identification, four cylinder EGT/CHT monitoring, fuel flow and carburetor temperature monitoring. The Dynon Wifi option was not purchased nor required. The required Dynon Certified HDX STC was purchased for $2K. Avidyne IFD 540 GPS/NAV/COM Flight Management System was selected for the FMS functionality, Wifi was standard (extra with Garmin), synthetic vision display and in my opinion, superior functionality over the Garmin GNS 750/650 systems. A second IFD 410 GPS NAV was selected since there was no need for a third COM system. Both the IFD 540 and IFD 410 are synchronized allowing the IFD 410 to function as a keyboard. A blue tooth keyboard (included) or the iPad IFD 100 APP allows for remote functional controls. The IFD FMS also communicates via Wifi with Fore Flight (GPS and FIS-B) and for uploading/downloading flight plans. Each IFD is integrated to the Dynon displays through an ARINC 429 data bus converter. The new overlay panel was designed by Bay Avionics with three template cuts done by their local metal shop. Final CAD drawings were sent to PaxAero Solutions where the final laser cut panels were created, powder coated to a custom color and laser etched lettering applied. Total cost for the pilot/copilot/radio blank-off plates came to $1,100.

Database management was an additional cost factor with regard to sustainment. The Avidyne requires a subscription to Jeppessen NAV and Obstacle dBases at a cost of ~$300/annually. One USB stick can be used to update both GSP navigators. NAV, Base map and Terrain dBases for Dynon are available from Dynon at no cost. Electronic charts and plates for the Dynon EFIS are available through Seattle Avionics at an annual cost of $99 with unlimited downloads. This same capability with Garmin equipment would have been substantially more for the same capability (better than $600 annually).

After exhaustive research, multiple vendor/shop quotes and reasonable schedule milestones the project was awarded to Bay Avionics, LLC of Chesapeake, VA, located at Hampton Roads airport (KPVG). Panel overlays were tailor engineered and manufactured by PaxAero Solutions of Hollywood, MD, located at St. Mary's County airport (2W6). Unfortunately, Bay Avionics, LTD was unable to meet their 8 week quoted milestone, resulting in a total schedule slip of six months and three days. Some of the delay was

related to the COVID 19 pandemic. The requirements creep additions would have only added another three weeks to the original quoted schedule.

Project Execution:

Teardown

The entire cockpit instrument equipment, overlay panels and instrument cradles were removed. The KX-155 radios were retained by Bay Avionics, LTD for trade-in value. The Garmin GMA-340 audio panel and L-3 Lynx NGT 9000 ADS-B IN/OUT Transponder remained as part of the overall system. The entire vacuum system was removed including all plumbing, filters and fittings. The engine blank off plate was installed in place of the vacuum pump. Figures 2 and 3 show the gutting of the instrument panel. What is not shown is the excessive wiring behind the panel left from over 40 years of equipment modifications and removals. All circuit breakers and aluminum bus bars were removed except the 60 amp power breaker.

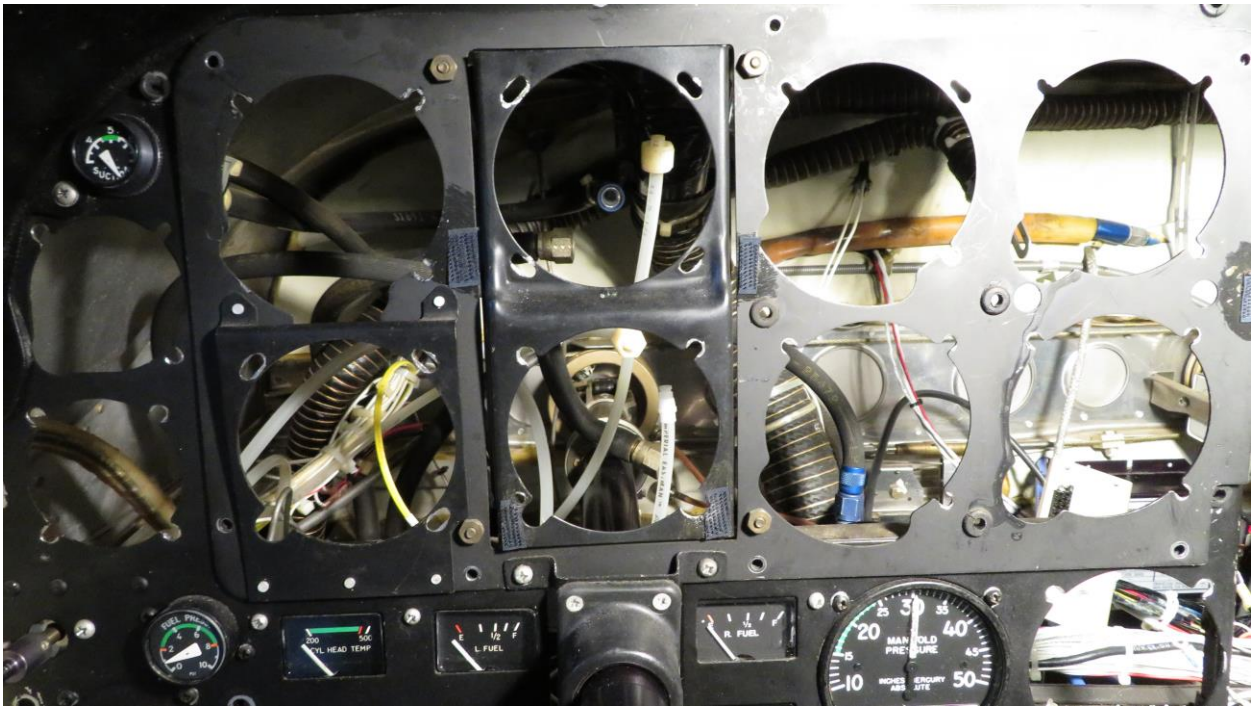

Figure 2
Instruments Removed

Figure 3
Instrument Chassis and Radio Stack Removed

Since the new equipment will require new structural supports, reinforcement structures were riveted to the panel frame. This will accommodate the installation of the display chasses, overlay panels, backup attitude indicator and remote controller heads. A blank off was incorporated into the overlay panel for the future autopilot head. All unused panel holes will be covered by the new 0.090" thickness overlay panels. Shock mounting provisions were eliminated per the STC.

Buildup

Installation of the entire suite was accomplished outside of the cockpit. Each Dynon component is provided in modular form and all harnesses were included with the system purchase. In figure 4, the pilot's display chassis shows how the modules are easily stack mounted and configured together. From the bottom of the stack you can see the engine management system module, the ADHARS and an ARINC 429 converter box. Vertically are the backup batteries for the display and the backup attitude indicator. Note that each display has dual cooling fans that exhaust into the open space behind the instrument panel. Figure 5 shows some of the interconnecting wiring needed to integrate the entire system. Figure

6 shows the installation of the AOA and OAT probes under the left wing. Figures 7 is the final powder coated overlay panels manufactured by Pax Aero Solutions.

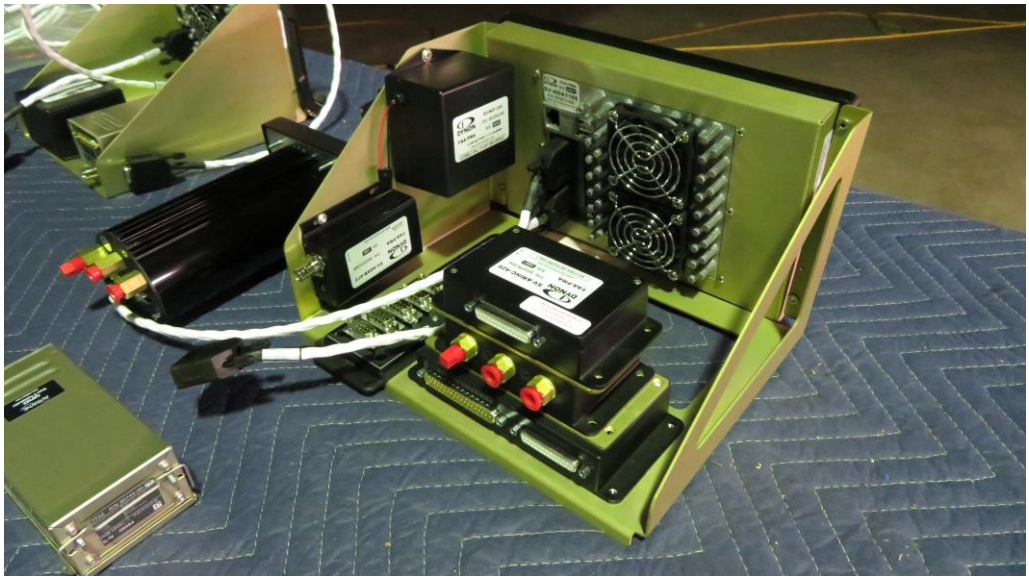

Figure 4
New System Layout

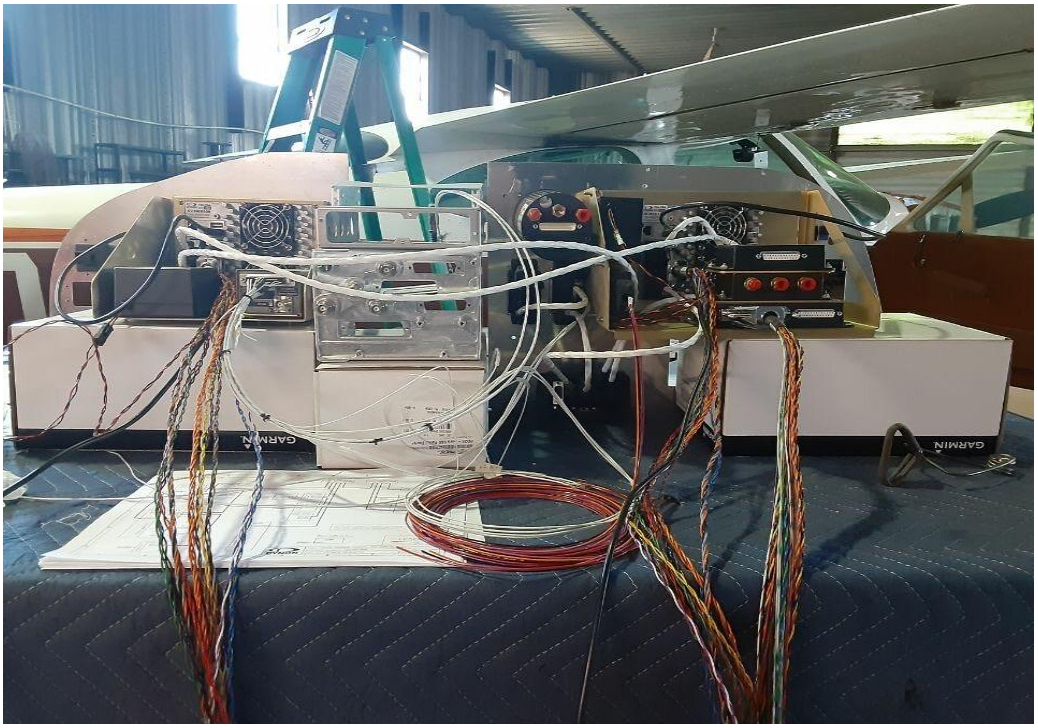

Figure 5
Interconnecting Wiring

Figure 6
AOA and OAT Probe Installation

Figure 7
Pilot's and Copilot's Overlay Panels

Not pictured is the location of the magnetometer. This is located within the right wing where the old autopilot aileron servo resided. The STC requires this location away from all other motor devices (flaps). The new autopilot aileron servo will be located in the left wing, leveraged from the C-172 and C-182 certification.

Final Product

Figure 8 details the final configuration with the PaxAero Solutions overlay panels installed. The pilot display is a 10" screen that gives a clear indication of all the information available for flight. The copilot display is a 7" screen with duplicating displays or any user selectable configuration the copilot desires. The backup display was located so that either pilot has easy access to it (as opposed to the C-172 AML configuration on the far left side). The selector panel provides a one stop kiosk for changing/syncing the heading bug, barometric pressure and altitude bug. The left most blank off plate will be for the future autopilot control head. Once installed, the autopilot functions will be selectable from the display's autopilot menu, eliminating panel ready access by the copilot. Two circuit breakers and two spare holes were added to the right of the copilot display. The breakers control the power to each display and the spares will be used for autopilot trim power and one additional power source for future growth. All other existing circuit breakers were repurposed for the new equipment installed. Each display has a USB data port dedicated for the EFIS dBases. These are required by Dynon since the data is not stored in memory. NAV and obstacle dBase files are also loaded from these ports and is capable of downloading the system performance, screen shots and diagnostic information. The center stack is typical of any panel including audio panel, transponder, GPS/NAV/COM and redundant GPS receiver. And there is still room for future expansion of capabilities down the road (radar/video/stormscope, etc.).

Figure 8
Finished Panel installation

Cardinal II+:

This is the conclusion of Phase I of this AIP program. Figures 9 and 10 are in flight pictures while flying to South Carolina. Notice the weather depicted over the Atlantic Ocean. I have to admit this system took some getting used to but it became apparent I have more situational awareness than ever before. Audio alarms are helpful to give you a heads up of potential traffic conflicts and altitude advisories and deviations, allowing early detection and mitigation options before it becomes critical. Heads down habits are easily removed with all information available without lowering the head. No more dependence on the iPad for traffic advisories. I use the IFD 540/410 as the FMS and the Dynon HDX as the EFIS. This habit keeps me proficient in using the IFR functionalities of the entire suite. On the display, I can select synthetic vision or display the customary 6 pack. All charts are a push button or two away including VFR/IFR charts, approach plates, departure procedures and airport diagrams. Georeferenced positioning is overlaid on any of these charts, which was an added subscription feature in Foreflight. In fact, except for uploading a flight plan, the iPad is no longer needed and tucked away in the map pocket of the door. Should I need the iPad, the IFD 540/410 has a USB port that provides adequate power to the iPad during flight.

The pilot's operating handbook and training videos available only scratches the surface as to how the menus and functions work but after a few hours of hands on flying, everything becomes more intuitive. The Highway In The Sky (HITS) feature help to keep you on heading and altitude. Instrument approach procedures with the equipment is actually simple as long as you understand how to display the proper heading source on the PFD and even that is only one touch away on the screen. This is where the thought process of separating the FMS and the EFIS becomes important. To date, I have practiced ILS, LPV and RNAV approaches as well as a departure procedures. The PFD automatically displays the glide slope once within range of the approach. For ILS approaches, the Avidyne automatically loads, tunes, identifies the ILS frequency and switches to OBS mode when intercepting the FAC. Missed approaches are automatically sequenced after passing the MDA/MAP point (default setup within the IFD540). Aural alarms from both the FMS and the EFIS brings you into the advanced automation world. They include the "doorbell" chimes for approaching assigned altitudes (TOC/TOD/VSR), and voice alerts for altitude deviations, 500' AGL "approaching minimums" and "minimums". EMS alarms will also sound off for the parameter out of preset limits. For instance, if I rapidly advance the power for takeoff, I will get an aural alarm that states "Fuel Flow" when the indicated pressure dips below 2 psi. FIS-B / TIS-B information are available on both the Dynon displays and the IFD (independent sources).

Figure 9
Pilot's Panel In Flight

Figure 10
Copilot's panel In Flight

Conclusion:

All of my expectations were met and exceeded with the selection of the Dynon Certified HDX system and the Avidyne IFD navigators. This completes Phase I of this AIP. After using the system at night, I should have added the optional dimming rheostat for controlling the brightness of the displays. Since I was not aware of this option, I will add it. Phase II is being planned that will install the Dynon digital autopilot and the Cygnet Ram Horn yokes once they are certified/STC'd. I would highly recommend the Dynon Certified HDX system to anyone thinking of upgrading their cockpits. Further, I highly recommend installing the Avidyne IFD series GPS navigators. In my opinion, their choice of touch screen or button use, functionality and integration are far superior to that of their competitors.