THE USE OF TELEMETRY DATA IN AN AIR DATA SYSTEM

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ABSTRACT

Telemetry data are usually collected for analysis at some later time and can be monitored to follow the progress of a test. In the case of an Air Data System the signals from the sensors are sent to a computer that calculates the air data parameters for use on multiple LabView-generated displays, as well as to the Data Acquisition System. The readouts on the multiple displays need to be real-time so they are useful to the flight crew. Equations that control the different air data values are determined by what telemetry data are available and the preference of those doing the test planning. These systems need to display the information in a format useful to the flight crew and be reliable.

KEY WORDS

Air Data System (ADS), Indicated Airspeed, Indicated Barometrically-corrected Altitude, Indicated Mach Number, Indicated Angle of Attack (AOA), and Indicated Angle of Sideslip (AOS).

INTRODUCTION

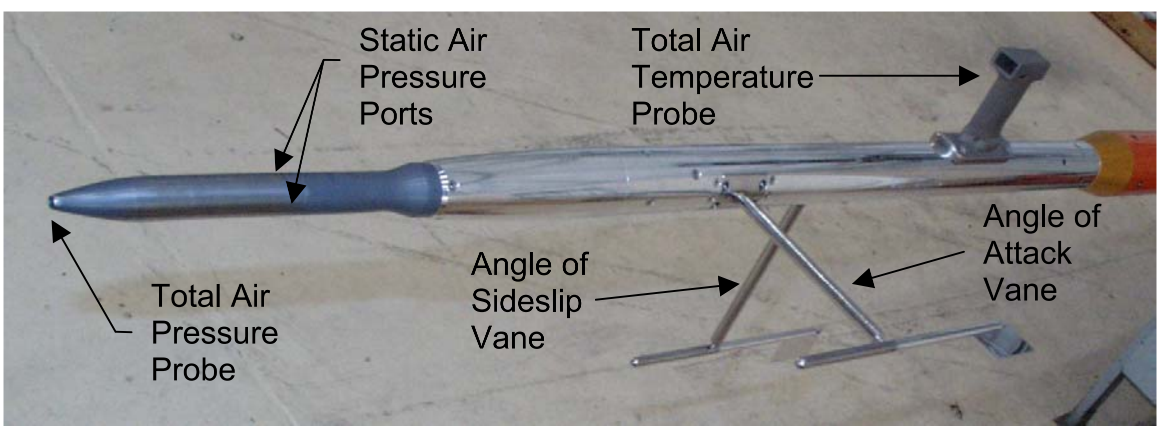
All new aircraft, for their initial series of flight tests, use an independent Air Data System (ADS) that records the parameters for postflight analysis. There are many variations of the USAF C-130, *Hercules* aircraft, which are under going an Avionics Modernization Program (AMP). As part of this AMP effort, old sensors for static and total air pressures and total air temperature (TAT) are being replaced. These sensors are being replaced with a new set of sensors that the new avionics system will use to calculate the indicated airspeeds and altitude for display in the new glass cockpit. Because these new sensors are untested in this application, the risk factors dictated that this aircraft be treated like a new aircraft. It was also determine that there was a need for a secondary or backup set of cockpit indications of these values for the flight crew to use during the initial phase of flight testing.

Because the Data Acquisition System (DAS) collects the indicated airspeeds and altitude values, it was assumed that these values from the DAS could easily be sent to additional displays in the cockpit to fulfill this AMP requirement. Upon further research, it was discovered that this assumption, having the DAS collect and display these values in the cockpit, had never been done before. The closest past solution was using a secondary set of mechanical altitude and airspeed indicators. Using this secondary set of mechanical values would not meet the new accuracy requirements of today.

It was determined that another computer system was needed to do the engineering unit calculations since the DAS was unable to handle the intensive mathematical calculations and also drive the displays. The LabView programming language by National Instruments was researched and it was determined it could handle the mathematical calculations and generate the different kinds of displays required.

SENSORS

The sensors used with the DAS and ADS start with an air data boom mounted on a pipe protruding out the front of the right wing-tip of the C-130 aircraft. The air data boom is manufactured by Space Age Controls, Inc., and has five sensors and ports as part of the assembly. This boom is pictured in figure 1. The first sensor is a port at the far left that takes in air for a total air pressure measurement. Then 5 inches down the front part of the boom are eight small ports (four on top and four on the bottom), which are for the static air pressure measurements. About half way down the main body of the boom are two rods perpendicular to the boom and at 90 degrees from each other. On the ends of these rods are vanes with fins. The vane pointing straight down from the boom is for the angle of sideslip (AOS) measurement and the vane pointing out to the left, as you look forward, is for the angle of attack (AOA) measurement. The AOA is sometimes called ALPHA and the AOS is sometimes called BETA. Toward the rear of the boom is the TAT probe.



◄ Figure 1. Air Data Boom

These signals (static pressure, total pressure, AOS, AOA, and TAT) originate at the wing-tip over a 100 feet from where they are to be used resulting in signal degradation if some conversion or amplification was not used. The two pressure readings are made by a pressure transmitter manufactured by Paroscientific, Inc., that takes the reading and converts it into a digital signal that is then sent to the DAS and ADS. If these pressure readings were not converted to a digital signal then the air pressure would have to be plumbed to a sensor in the aircraft or it would have to be converted to an analog signal. Both methods would result in significant loss in the process. The same would occur with the temperature sensors in the TAT probe if nothing was done out at the wing-tip. An amplifier was used that was designed for the TAT probe which was produced by Quad-Tron, Inc. The two vanes' outputs were not buffered because the readings of the attached potentiometers were well within the parameter limits.

EQUATIONS

With these five parameter values (total air pressure, static air pressure, TAT, AOS, and AOA), equations are needed to get the altitude, airspeed, and Mach number of the aircraft. Some minor differences exist in the equations used today and one of these differences is the use of a correction factor. Goodrich Sensor Systems publishes an Air Data Handbook that give equations for altitude depending on your altitude range and uses temperature to derive true airspeed. (See reference 1 for a link to this handbook.) The equations used at Edwards AFB involves a barometric setting to correct the altitude reading and only the lower altitude equation is used for the aircraft being tested if the aircraft does not go above 40,000 feet. The indicated, barometrically-corrected altitude, H_i, equation is found in the Manual of Barometry (WBAN) (reference 2) and is as follows:

$$H_i = 145442\left[\left(\frac{P_{as}}{P_{a_{SL}}}\right)^{0.190262} - \left(\frac{P_{s_i}}{P_{a_{SL}}}\right)^{0.190262}\right] \quad (1)$$

Where $P_{a_{SL}} = 29.92126$ inches of-Hg

P_{as} = altimeter setting in inches of-Hg (Barometric correction)

P_{s_i} = indicated ambient (static) air pressure from the pressure transmitter in inches of Hg

The indicated airspeed, V_i, uses the following equation:

$$V_i = a_{SL}\left\{5\left[\left(\frac{q_{c_i}}{P_{a_{SL}}}+1\right)^{\frac{2}{7}} - 1\right]\right\}^{\frac{1}{2}} \quad (2)$$

Where $a_{SL} = 661.48$ knots

$q_{c_i} = (P_{t_i} - P_{s_i})$

P_{t_i} = indicated total air pressure from a pressure transmitter in inches of Hg.

The indicated Mach number, M_i, uses the following equation:

$$M_i = \left\{ 5 \left[\left(\frac{q_{c_i}}{P_{s_i}} + 1 \right)^{\frac{2}{7}} - 1 \right] \right\}^{\frac{1}{2}} \qquad (3)$$

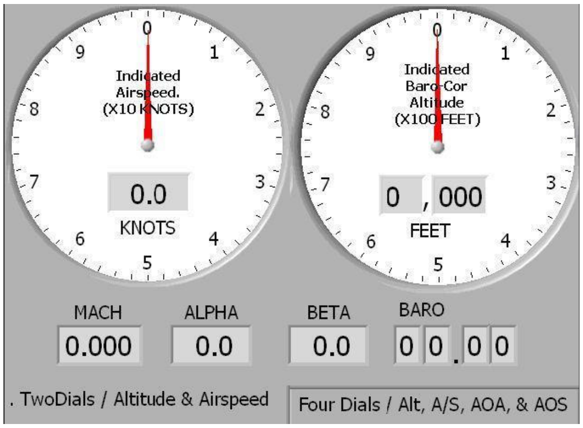
The source for the equations for the indicated airspeed, V_i, and the indicated Mach number, M_i, may be found, among other places, in the Flight Test Engineering Handbook (reference 3).

DISPLAYS

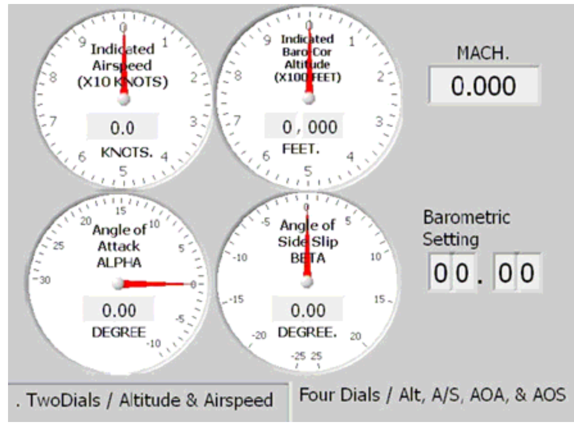
With the equations, the five parameter values are available for display and are: 1) airspeed in knots, 2) barometrically-corrected altitude in feet, 3) Mach number, 4) AOA in degrees, and 5) AOS in degrees. Also the barometric or altimeter setting in inches or Hg will be included in the displays.

These parameter values were first going to be displayed on an alpha-numeric readout with a single display sitting on the glare-shield between the pilot and copilot. This would meet the requirements, but would not give the flight crew enough real-time information to evaluate aircraft performance. It was determined that analog trend dials of the airspeed, altitude, AOA, and AOS were needed so that the movement could be seen without concentrating on the digital/numeric meters.

Obviously electronic computer-generated displays were the answer. Therefore, there are two display layouts available—one display having two dials (airspeed and altitude) and the other display having four dials (airspeed, altitude, AOA, and AOS). The pilot or copilot can switch between the two displays by touching the indicated title at the bottom of the display. The two display layouts are shown in figure 2.



Two-Dial Display



Four-Dial Display

Figure 2. Two- and Four-Dial Displays

Each one of the dials is made up of multiple parts that work together as a unit and the value like airspeed has to be separated to drive the different parts of the display. The Indicated Airspeed dial shows the digital airspeed in knots but the analog dial only shows each 100 knots moving clockwise with a major divider indicating 10 knots and is subdivided into 2-knot increments. The Indicated Barometric Corrected Altitude dial has three components with the altitude in feet separated into a thousands of feet digital display and the remaining parts of a 1,000 feet shown next to it as a separate digital display. The third part of the altitude display is the analog dial which only shows each 1,000 feet moving clockwise with a major divider indicating a 100 feet and is subdivided into 20-foot increments. The Barometric Setting is four single digit dials with the most left dial showing 10 inches of mercury, then 1 inch of mercury, a period, then tenths of an inch of mercury, and the most right is hundredths of an inch of mercury. The MACH number on both displays is just the digital value.

Finally the AOA (ALPHA) and the AOS (BETA) are shown as digital values on both displays, but on the Four Dial display there is an added analog display. The AOA analog display has two parts with the top showing degrees going from the right half way point of zero to the left half way point of 30 degrees. The bottom half again starts with the right half way point of zero but only goes part way down never pointing straight down to a negative 10-degree value. Each part is subdivided into a single degree with major indicators every 5 degrees. The AOS starts at the top at zero and goes most of the way down each side to 25 degrees with the left being negative. Again the major divisions are 5 degrees but only zero to plus or minus 10 degrees have subdivision of a degree.

PROGRAMMING

A software language was needed that could easily create the displays shown in figure 2 and have the mathematical capabilities needed to encode the equations. National Instrument’s LabView software was chosen to be used for its strong graphic component and its ability to do complex mathematics. Figure 2 shows the two displays generated by

LabView programming and figure 3 shows that portion of the code where the equations were encoded.

At the heart of the program is a free running '*While Loop*' that collects the data, executes the equations and other logic icons, and displays the results. At the beginning of program execution, there are setup routines that are executed once before entering the '*While Loop*'. A *'Formula Node'* is employed to encode the equations specified earlier and is shown in figure 3. The lines joining the different icons are numeric values that are passed from the source to other routines. A *'Case Structure Node'* then allows the two different displays shown in figure 2 to be switched between. One other important routine is the *'Call Library Function Node'*, which allows the third-party software drives to be used by the LabView programming software. Overall, the National Instrument's LabView program was easy to use and made a good tool to perform the mathematical equations and generate the required displays.

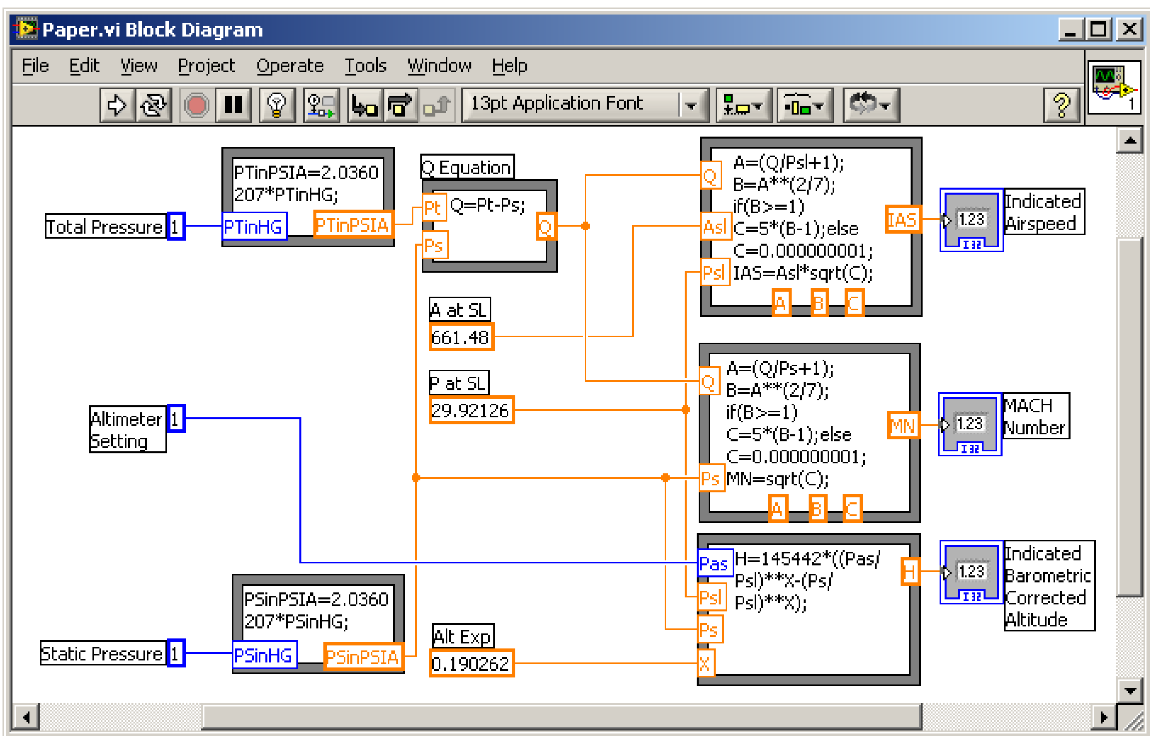


Figure 3. Portion of LabView Block Diagram Showing Equations

SYSTEM

To have an efficient Air Data System, a computer is necessary along with two serial data inputs, an analog input channel for two or more signals, and a digital input that will handle the four digit barometric (altitude) setting. This system should also be ruggidized for aircraft use and should be able to take the 28 volts of available DC power. A PC-104 computer stack from Real Time Devices with a digital I/O, an analog I/O, a quad serial port, and a power supply was used and it also came with a shock mount base. To drive the single video output to the two cockpit displays, a two-channel VGA video splitter/booster from Black Box performed the task. The cockpit displays needed to be small so a 6.4-inch open frame LCD monitor from Stealth Computers was put in an aluminum frame for mounting on each side of the cockpit instrument panel. These monitors have a touch screen that is connected to one of the computer's serial ports and allows the pilot or copilot to touch the lower part of the display and toggle between the two-dial and four-dial displays. The operating system is Windows® XP and many functions, like the screen saver, must be disabled so the output display may be free running without interruption. Both Windows and LabView buffered the serial lines that supplied the total and static pressures, which caused a delay, so this buffering in both the Windows and LabViews software was removed.

CONCLUSION

Necessity is the mother of invention and that was the driver for this Air Data System. There were requirements for collecting total and static air pressures from a wing-tip boom, but the requirement for air data displays in the cockpit was realized after the fact. This ADS delivers the needed displays to be a backup to the new avionics suite, but is not robust and free enough from interruption to be the sole provider of basic information for aircraft operations.

REFERNCES

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