# A BRIEF HISTORY OF EOL/RAF AIRCRAFT DATA SYSTEMS

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In the early days of the RAF (mid 1960s) the fleet of research aircraft consisted of several Beechcraft Queen Airs and in 1967 a North American Sabreliner joined the fleet. These were all equipped with data acquisition systems developed in house with few analog input channels, 560 bpi tape recorders, strip charts and a digital LED readout that was only capable of displaying the digitized voltage, not engineering units, in real time. These systems were called “ARIS” (Airborne Research Instrumentation System) and evolved through ARIS I, II, and III. Some of the improvements were CRT alpha numeric displays, more sophisticated and faster op amps and analog-to-digital conversion with higher resolution (10 bits). There was no data link to the ground.

In 1968 NCAR acquired a de Havilland “Buffalo” aircraft declared surplus by NASA and transferred to the RAF via the GSA. It was a prototype STOL turbine powered aircraft that had a large payload capacity and the first aircraft in the fleet to have an inertial navigation system, a Litton LN-15D. The data system was developed in conjunction with the Desert Research Institute (DRI) and the aircraft began flying research around 1970. This was the first aircraft in the fleet to have turbulence measurement capabilities using a boom mounted gust probe in conjunction with the inertial system. It also had a radar altimeter and microwave refractometer and these new instruments required higher sample rates (100 sps) and synchro/resolver-to-digital converters. Displays were still strip charts and x-y plotters.

In 1973 NCAR took delivery of a Lockheed Electra aircraft which had previously been used as a corporate aircraft. The Electra was modified to have a boom mounted gust probe and a Litton LTN 51 inertial system. A new data system was developed for the first

project, GATE, to be flown in 1974 in Africa. The system was named the Electra Data Management System (EDMS). The system consisted of a Data General computer with in-house developed interfaces for serial and analog inputs. The Electra had a Litton LTN-51 inertial system and high altitude radar altimeter. An onboard line printer and multiple stations for CRT alpha-numeric displays in engineering units were available. The system had a 10 bit A/D converter and multiple sample rates (1,10,25,50 sps) and dual magnetic tape drives with 9 tracks and 1600 to 6250 bpi density. This system was unique to the Electra and not ported to the other aircraft.

With the acquisition of the Beechcraft King Air 200T in 1984 a new data system architecture was developed called the Air Data System (ADS). This was the first of a series of three data systems: ADS I, II, III. The ADS I consisted of an HP-1000 computer running HP RTE-M operating system and software written in FORTRAN 66, and a DEC LSI 11/23 16 bit microprocessor. The LSI 11 software was written in assembly language and downloaded from the HP on start up. The data interface and acquisition (sample rates of 250, 50, 10, and 1 samples/sec [sps] were available) was performed by the LSI 11. Analog inputs were first filtered to prevent aliasing with 4-pole active Butterworth filters having cutoff frequencies determined by the A/D sample rate. The A/D converter had a resolution of 14 bits.

In addition to the analog (48 channels), ARINC (INS), synchro/resolver and serial data interfaces, this was the first RAF system capable of sampling PMS 1D and 2D probe data via asynchronous inputs (input boards provided by PMS). It was also the first to have graphical displays of calibrated data and particle images via video monitors. Several of these displays were distributed throughout the cabin. Other hardware included dual Kennedy 9800 magnetic tape drives and a HP 9876 printer.

This system was installed in the Sabreliner in 1987 and the Electra in 1991. Due to the larger cabin the Electra system had more displays and a larger and faster line printer.

In 1993 the Electra flew the first missions with the newly installed ELDORA radar during the TOGA-COARE project. The ELDORA had its own data acquisition and display system, however it received data from the ADS (e.g., inertial, wind data) to include in real time calculations and for post-processing.

With acquisition of the Lockheed C-130 from the U.S. Navy surplus (c.1992) the RAF developed a new data system, ADS II. This was the first RAF system to use distributed data system architecture. Data sampling modules (DSMs) were located in the wing pods, nose and cabin of the C-130. They used a Motorola 68000 microprocessor with a VME data bus and the real time operating system was vxWorks (Wind River Systems) with the data acquisition, timing, signal processing software written in the C language. A Sun Microsystems Sparc 5 running the Solaris operating system was used as the central data server. The DSMs were connected to the server via an Ethernet network. In addition to the data acquisition software, several new software packages were written for data computations, display and ADS setup. NIMBUS is a package that was written for post processing, but a version also runs on the ADS. Onboard it performs calculations of derived parameters (several hundred) at the one second rate and then these are displayed on LCD monitors with the WINDS (WINdow Display System) software developed in house. Xbuild was an interactive program written to set up the sample rates and configuration for data acquisition system. It generated the software for the DSM microprocessors. Other features of the ADS II were digital signal processing software, Exabyte digital tape drives, on board “mass storage” of several gigabytes of solid state memory and disk, UPS power back up, 16 bit A/D

conversion, a dual network architecture, and a two way interface to the AVAPS dropsonde system.

The dual network concept of a network for the instrument and data interfaces and the display network provides interface for the various displays and other output devices (e.g., printers) and outside users can connect to it to access data in-flight. The two networks were bridged with a Sparc 5 DSM control computer which also interface to the data storage and tape units.

The digital signal processing provides for 10 KHz synchronous sampling of all analog channels with 40 pole window based FIR digital filtering and decimation. Programmable output sample rates of 5, 25, 250 and 1000 sps for each analog channel were available, with higher rates available on special request.

As part of the Gulfstream GV (HIAPER) development a new generation data acquisition and display system was designed and fabricated in-house. The new system was named the ADS III with a subcomponent called NIDAS (NCAR In-situ Data Acquisition System). While many of the same concepts from the ADS II system were carried forward, ADS III has more computing power, smaller size, less power consumption, more data storage, higher speed networking and instrument interfaces, high bandwidth satellite communications and a new onboard data display program, AEROS (Airborne Environment Research Observing System). This system has taken advantage of more COTS (commercial off-the-shelf) hardware and therefore fewer custom cards. The system was installed in 2005 on the GV and after a short test program it was used for research for the first time on the Progressive Science campaign. Later, in 2007, the ADS III was installed in the C-130, with PASE (August/September 2007) as the first field project.

One of the principal design changes was replacing the DSM 11-slot VME chassis with the PC104 architecture, an embedded computer standard which has a defined form factor and computer bus (ISA, 16 bit data bus). The PC104 has no backplane but instead modules are stacked together allowing for a smaller size and also allowing for a larger selection of COTS instrument interfaces. (Because of this flexibility the DSM modules may be made smaller for tight spaces such as the wing store pylons and user instrument racks.) The processor in the DSMs is an Intel Viper 400 MHz Xscale processor. Interface boards include serial data (asynchronous RS-232,-422, ARINC 429, synchronous HDLC), 16 bit sigma-delta A/D conversion (1,10,100, 1000, 10KHz sample rates), parallel digital I/O (configurable data widths from 1 to 32 bits wide) and USB version 1.1. (*The older generation PMS 1-D and 2-D interfaces have been replaced by RS-232 and USB interfaces.)* The C-130 and the GV have access to the avionics ARINC 429 data bus and various parameters from the Flight Management System are routinely recorded by ADS. The main data server is a Dell 2850 Power Edge computer with 2 Gbytes of memory. The operating system is linux and the programming language is C and $C^{++}$. The display software (AEROS) is multiplatform and will run on Windows, linux and MAC computers. Ethernet connections are available throughout the aircraft (category 6 cable) for data sharing and display. Data are stored on redundant removable disk drives and other portable media. Aircraft users may connect to the network with portable computers for access and send data from their instruments via UDP/IP packets.

Both the GV and the C-130 have high bandwidth Inmarsat Swift Broadband (SBB) satellite data communications capabilities transmitting and receiving at 64 to 128 kbits/sec. The C-130 system is a Honeywell HD-710 and the GV system is a Thrane & Thrane TT-503. The satcom is used to transfer 1 second data, camera images from the aircraft to the ground, and radar and

satellite images from the ground to the aircraft. Most recently the RAF has developed a software interface for a Mission Coordinator station on the aircraft where the aircraft track is overlaid on the various images (including dropsonde, video, and other flight and mission related data) are shared between the aircraft and the ground project coordination center in real time. In addition there is a chat room communications connection via satcom for critical and efficient real time decisions for direction of the aircraft mission.

The ADS III encompasses the entire onboard system with subsystems comprised of data display(AEROS), data acquisition and recording (NIDAS), data processing (NIMBUS), and Mission Coordination display and communications. The NIDAS system was a collaborative development in EOL and it is being used throughout the laboratory on various research platforms.