HEWLETT hp PACKARD

APPLICATIONS OF COMPUTERIZED DIGITAL DATA ACQUISITION SYSTEMS

# *In-Flight Data Analysis Improves Airborne Research*



A Solution to a Measurement Problem for: GODDARD SPACE FLIGHT CENTER
NASA
Greenbelt, Maryland

## THE APPLICATION

At the National Aeronautics and Space Administration Goddard Space Flight Center in Greenbelt, Maryland, a multitude of research programs are providing essential information in many areas of scientific discipline. Particularly significant are contributions being made by airborne research studies in aerodynamics, earth resources, meteorology, geophysical observations, and studies of the sun, stars, and planets. Because much of the work is actually of a pioneering nature, the very instruments on board the research aircraft are themselves the subject of investigation. Much of the knowledge gained from research flights is used to develop instrumentation for space vehicles such as the weather satellite, NIMBUS, and the orbiting geophysical observatory, OGO. Prototypes of these instruments, which cost only about one-tenth that of the actual instruments to be installed in the spacecraft, can be tested and calibrated in the NASA aircraft. And, of course, the cost of an aircraft mission is far below that of a space flight.

Instrumentation to perform the studies is installed in a Convair 990A aircraft operated by NASA, Ames Research Center, Mountain View, California.

## THE MEASUREMENT PROBLEM

The aircraft has been flown on research missions by NASA from 1965 to mid-1970 utilizing off-line data reduction; that is, data acquired in-flight had to be stored for subsequent evaluation upon return to base. It was not uncommon to wait as long as six months for the final report. Repeat missions to replace or supplement invalid or insufficient data are costly (approximately $2000/hour) and may even be impossible if conditions of the original experiment cannot be duplicated.

The problem facing the NASA scientists was *how to automate the taking of measurements from their many instruments on board and reduce the raw data in real time.* This would allow the scientists to maximize the yield of useful new information and, at the same time, check out apparent anomalies while still in flight.

## THE SOLUTION

NASA scientists selected the Hewlett-Packard computerized data acquisition system shown in the block diagram. Now, data can be acquired, reduced, and printed out in real time for use by scientists during the course of a flight.

The computer consists of a mainframe with 16 input-output channels and 16K words of memory plus an extender with 32 additional I/O channels and 8K additional words of memory. A wide variety of peripheral devices adds considerable flexibility to the airborne data acquisition system. The scientists are particularly pleased with the easy changeover of I/O configuration, which simply involves plugging in an interface card and assigning interrupt priority by card placement. This is very important to the scientists because of the continually changing nature of their experiments.

## SYSTEM OPERATION

NASA-Ames has flown research missions all over the North and South American continents, from tropical environments such as Barbados, to the frigid reaches of Alaska, as far as 75° north. The altitude of the aircraft varies, from very high (the aircraft has been flown to 47,000 feet) to quite low (around 500 feet), as required by the nature of the experiment. A mission over the Salton Sea in California actually took place below sea level.

In mid-1970, the aircraft began making research flights using the HP data acquisition system in conjunction with various sensors. Some typical measurements made on these flights are briefly described below. These are only representative since the aircraft has been and will continue to be used for many different investigations including the aurora borealis, particles suspended in the atmosphere, and atmospheric electricity.

Microwave radiometers are used to measure radiation, in the range of 1 to 94 GHz, emanating from the earth's surface. This effect is known as "surface brightness temperature". (Part of the radiation received is incoming radiation reflected from the earth's surface and is measured by upward-looking radiometers.) Measurement of microwave surface brightness temperature is still a relatively new and unexplored technique. Some of the phenomena being investigated are:

(a) Characteristics of sea ice, with a view of discovering possible new navigable routes. New ice can be distinguished from old ice and icebergs can be distinguished from water.

(b) Determination of "sea-state"; that is, the roughness of the ocean surface.

(c) Moisture content of the earth's surface and depth of snow; from this the extent of the spring run-off can be predicted.

(d) Detection of precipitating clouds over the ocean (must have a uniform base such as the ocean).

Infrared radiometers are used in various ways:

(a) Upward looking, to measure the amount of water vapor above the aircraft.

(b) Sideward looking, to measure the static atmospheric temperature.

(c) Downward looking, to measure the surface temperature of the earth. This reading will differ from the surface brightness temperature measured by microwave methods (it is closer to the true surface temperature) and is used as a reference for the microwave measurements.

A laser geodolite is used to measure the surface roughness of the sea or ice crust. The instrument is extremely precise, measuring to within an inch or two per thousand feet.

Besides the main scientific measurements, the HP system is used for various support experiments. These include: temperatures outside and inside the aircraft, humidity sensing, and dew and frost point determination.

All raw measurements are recorded on a pair of digital magnetic tape units (up to four of these HP units can be interconnected and operated from the same computer interface). The two-unit arrangement assures continuous recording by eliminating the 5-minute loss of data incurred while changing reels in a single-unit system. Comments from the scientific observers, generally conveying visual descriptions of the meteorological and surface conditions, are recorded on the magnetic tape along with the sensor readings. These comments are typed in via a typewriter. (A typical comment, as made on a recent flight, was, "Aircraft descending below the stratus for three legs; first leg above stratus; second leg through stratus; third leg below stratus. Each leg will be 10 minutes in duration".)

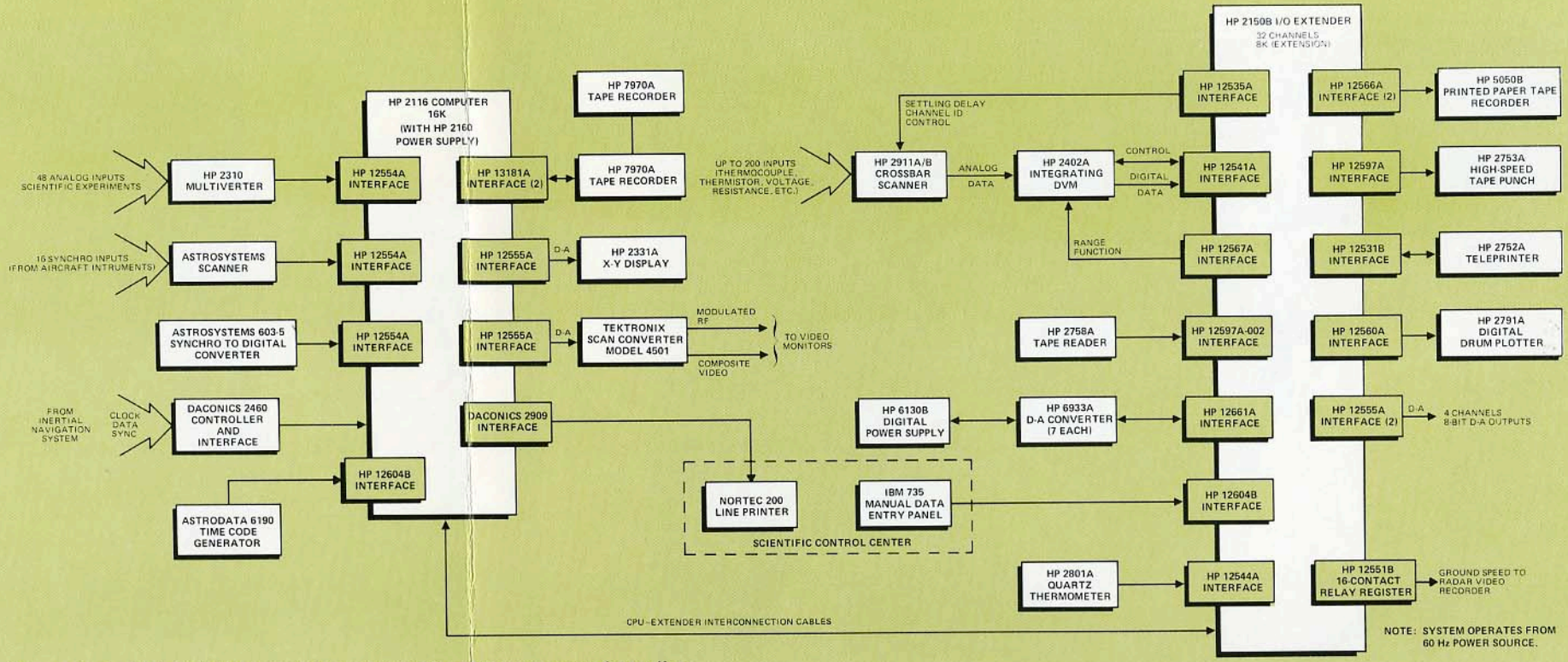
Usually about 40 of the various measurements being made are selected for on-line reduction, printout, or display in physical units on the teleprinter, digital plotter, or TV monitors, thus allowing the scientists to evaluate the experiments while in progress. This is considered a "quick-look" data reduction because, in general, low-order calibration curves are used for the sensors. Subsequently, however, the data are analyzed using more precise, higher order calibrations.

In addition to reducing and recording the scientific data, the HP system records the aircraft position (from information supplied by the aircraft navigation system) throughout each mission. At one-second intervals, the system records on magnetic tape a very detailed compilation of positional information so that raw measurements also being recorded on magnetic tape can subsequently be ground-referenced very precisely. The positional information can be printed out on a high-speed line printer on demand. A typical printed page is shown on the right.

For the most part, ambient temperatures are equivalent to typical laboratory conditions, but sometimes, as on a trip to Barbados, temperatures can exceed 90°F, and humidity may reach 90%. Because the aircraft is equipped with jet engines, vibration is well above 100 Hz, and poses no problem. Moderate g loadings are experienced in flight, perhaps reaching 2.0 g. All equipment, including the computer and magnetic tape transports, is bolted directly into the rack; no shock mounts are used.

## BENEFITS OF COMPUTERIZED DATA ACQUISITION

The HP computer system allows scientists to better evaluate and interpret data while an airborne experiment is in progress. In-flight data reduction makes it possible to recognize bad or insufficient data in time to fly over the area again to replace or augment the data as required.

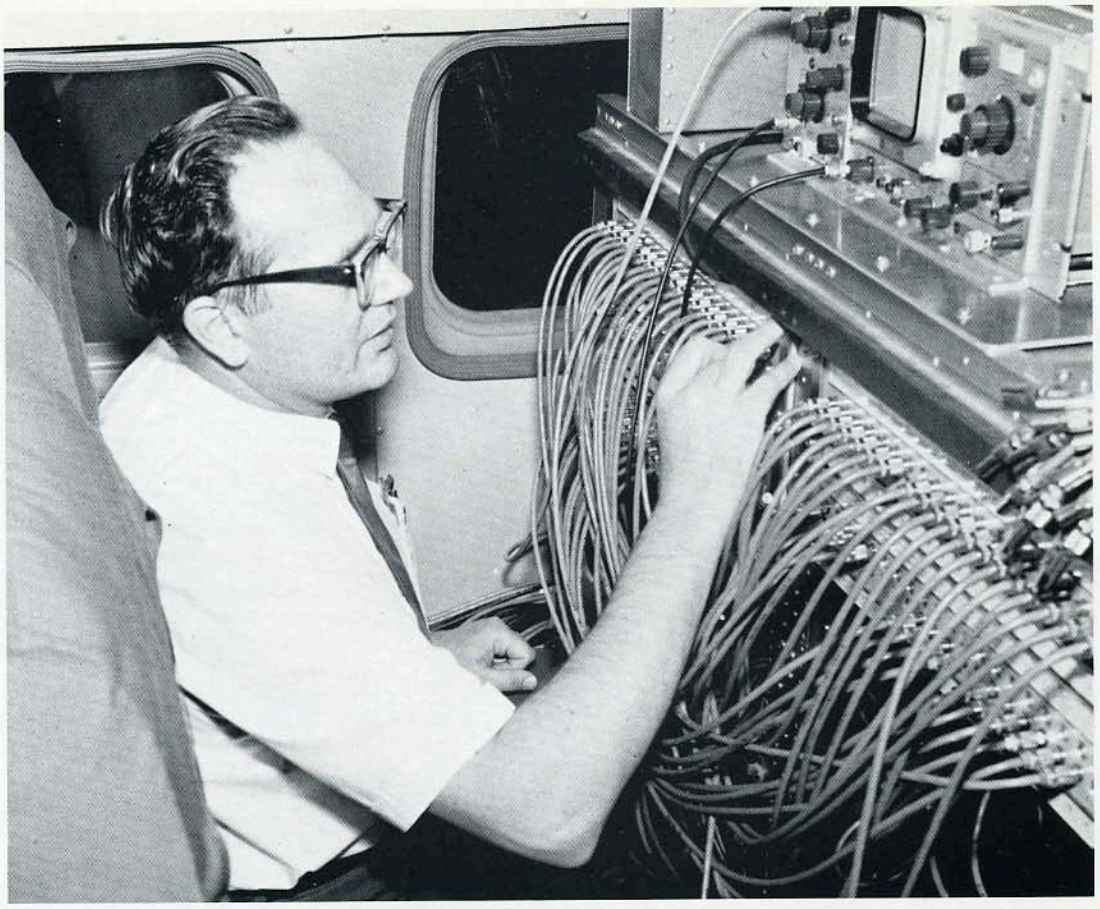



*Computerized digital data acquisition system for airborne research studies.*

| JULIAN DAY | TIME HR | MN | SC | LATITUDE DEG MN | LONGITUDE DEG MN | GRND SPD | TAS SPD | PRESR ALT | RDAR ALT | PITCH ANGLE | ROLL ANGLE | TRUE HDG | WND SPD | WND ANG | TRACK ANGLE | STATIC TEMP | TOTAL TEMP | 70MM IRIS | V R 35 | L D MM | WILD RC-8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IR AIR TEMP | IR SFC TEMP | MIRR POS | DEW/ FROST | 1.42 KRTV | 1.42 KRTH | 1.42 KRTC | 2.69 NO.AM. | 4.99 KRTV | 4.99 KRTH | 4.99 KRTC | 9.3 ZEN | 10.69 NADIR | 31.4 ZEN | 37.0 KRTV | 37.0 KRTH | 37.0 KRTC | 94.0 KRTV | 94.0 KRTH | 94.0 KRTC | | |
| 2441061 | 18 | 15 | 24 | 00.00.0N | 000.00.0E | 0000 | 494 | 14,413 | 0000 | 358.4 | 359.7 | 000.0 | 161 | 039 | 000.0 | 10.6C | -40.1 | 11.0 | | L | |
| XXXXXC | XXXX | | | -70.00 | 579.9 | 442.2 | 000.0 | 000.CK | 293.3 | 148.5 | 000.0 | 152.8 | 504.4 | 122.6 | 094.5 | 000.0 | 000.0 | 000.0 | 000.0 | 000.0 | |
| 2441061 | 18 | 15 | 25 | 37.24.9N | 122.03.5W | 0000 | 494 | 50,000 | | 358.4 | 359.7 | 040.1 | 161 | 039 | 040.1 | 10.6C | 50.0 | 22.0 | | | |
| XXXXXC | XXXX | | | 20.00 | 927.9 | 919.5 | 999.8 | 323.9K | 906.7 | 899.4 | 999.8 | 619.8 | 020.0 | 619.8 | 956.7 | 919.2 | 999.8 | 932.1 | 980.2 | 999.8 | |
| 2441061 | 18 | 15 | 26 | 37.24.9N | 122.03.5W | 0000 | 494 | 50,000 | | 358.4 | 359.7 | 040.1 | 161 | 039 | 040.1 | 10.6C | 50.0 | 22.0 | | | |
| XXXXXC | XXXX | | | 20.00 | 929.2 | 920.6 | 999.8 | 324.2K | 907.7 | 900.4 | 999.8 | 619.8 | 020.0 | 619.8 | 957.7 | 920.2 | 999.8 | 933.1 | 981.1 | 999.8 | |
| 2441061 | 18 | 15 | 27 | 37.24.9N | 122.03.5W | 0000 | 494 | 50,000 | | 358.4 | 359.7 | 040.1 | 161 | 039 | 040.1 | 10.6C | 50.0 | 22.0 | | | |
| XXXXXC | XXXX | | | 20.00 | 928.8 | 920.6 | 999.8 | 324.2K | 907.7 | 900.4 | 999.8 | 619.8 | 020.0 | 619.8 | 957.8 | 920.6 | 999.8 | 933.3 | 981.2 | 999.8 | |
| 2441061 | 18 | 15 | 28 | 37.24.9N | 122.03.5W | 0000 | 494 | 50,000 | | 358.4 | 359.7 | 040.2 | 161 | 040 | 040.2 | 10.6C | 50.0 | 22.0 | | | |
| XXXXXC | XXXX | | | 20.00 | 929.0 | 920.4 | 999.8 | 324.2K | 907.4 | 900.2 | 999.8 | 619.8 | 020.0 | 619.8 | 957.7 | 920.4 | 999.8 | 933.1 | 981.1 | 999.8 | |
| 2441061 | 18 | 15 | 29 | 37.24.9N | 122.03.5W | 0000 | 494 | 50,000 | | 358.4 | 359.7 | 040.2 | 161 | 040 | 040.2 | 10.6C | 50.0 | 22.0 | | | |
| XXXXXC | XXXX | | | 20.00 | 928.7 | 920.0 | 999.8 | 324.2K | 907.2 | 900.0 | 999.8 | 619.8 | 020.0 | 619.8 | 957.5 | 920.2 | 999.8 | 932.9 | 981.0 | 999.8 | |
| 2441061 | 18 | 15 | 30 | 37.24.9N | 122.03.5W | 0000 | 494 | 50,000 | | 358.4 | 359.6 | 040.1 | 161 | 040 | 040.1 | 10.6C | 50.0 | 22.0 | | | |
| XXXXXC | XXXX | | | 20.00 | 929.4 | 920.8 | 999.8 | 324.3K | 907.8 | 900.6 | 999.8 | 619.8 | 020.0 | 619.8 | 958.0 | 920.7 | 999.8 | 933.3 | 981.4 | 999.8 | |
| 2441061 | 18 | 15 | 31 | 37.24.9N | 122.03.5W | 0000 | 494 | 50,000 | | 358.4 | 359.6 | 040.1 | 161 | 040 | 040.1 | 10.6C | 50.0 | 22.0 | | | |
| XXXXXC | XXXX | | | 20.00 | 929.0 | 920.5 | 999.8 | 324.2K | 907.4 | 900.3 | 999.8 | 619.8 | 020.0 | 619.8 | 957.8 | 920.5 | 999.8 | 933.2 | 981.2 | 999.8 | |

*A typical page of navigational flight data which is available on demand in-flight. Equally detailed printouts of reduced measurement data pertaining to specific experiments are available on demand to the scientific observers.*

**COVER:** *Another airborne research mission begins. The aircraft, operated by NASA, Ames Research Center, Moffett Field, California, carries a wide variety of measuring instruments. Scientific observers have immediate access to measurement results by means of an onboard HP computer.*



*Instruments feeding into the computer, from various date-gathering stations onboard, are connected to the instrumentation monitoring panel. By simply patching into the 'scope, Mr. Earl Peterson, Meteorological Flight Director, is monitoring the status of a meteorological instrument to verify that it is properly inputting to the computer.*



*Scientific measuring instruments occupy most of the space onboard the research aircraft. At the left are the meteorological flight director's desk and control panel, and in the right foreground are the scientific control center's printer and typewriter.*



*At the scientific control center, Mr. Harold Reed, Experiment Coordinator, examines an in-flight printout of scientific data while the operator awaits instructions for typing comments into the computer for recording on magnetic tape.*



*Onboard the NASA Research aircraft, an HP computer performs on-line data reduction and other functions to aid scientific observers in their data gathering missions.*

For more information, call your local HP Sales Office or East (201) 265-5000 • Midwest (312) 677-0400 • South (404) 436-6181
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