

**Tektronix
4050 Series**

**Data Acquisition and
Analysis**

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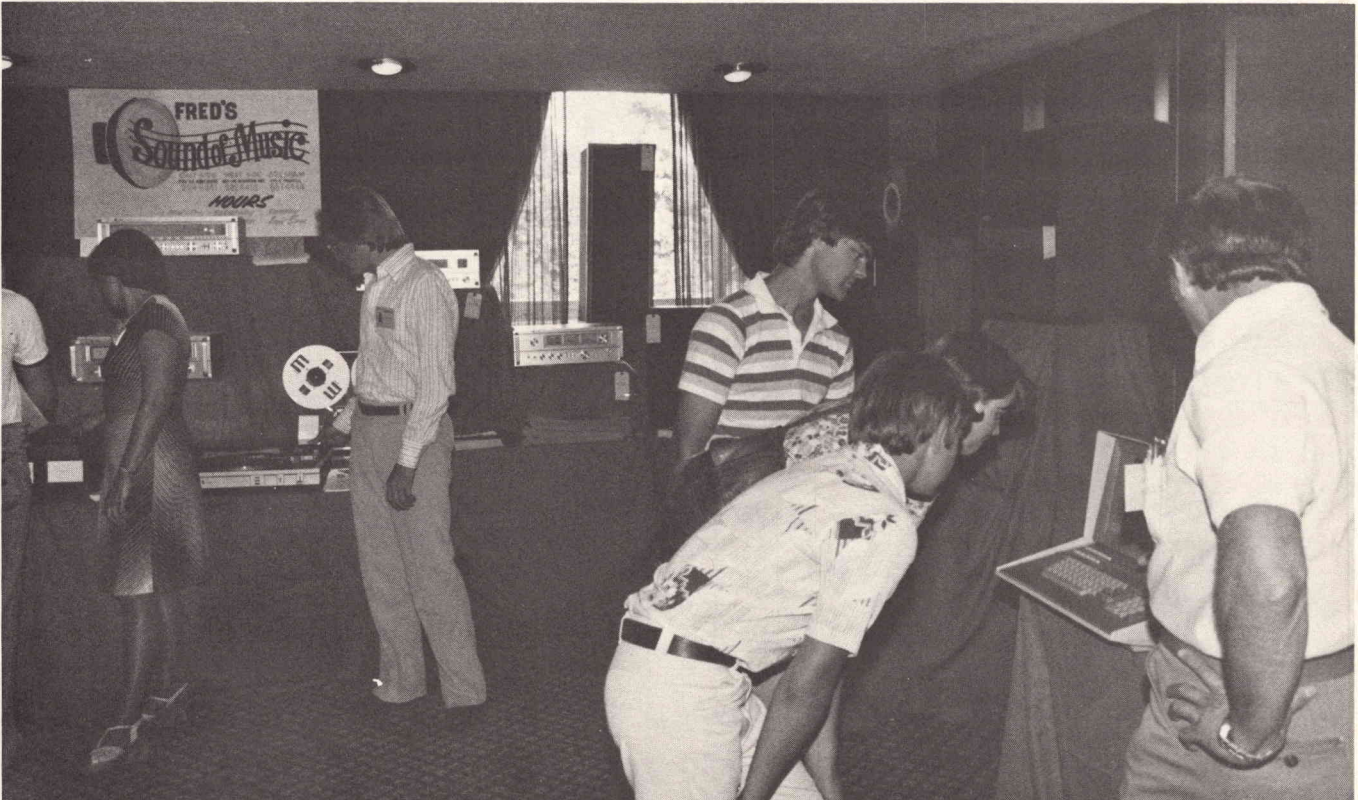
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Newsletter

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REPRINTED FROM TEKNIQUES, VOL 2 NO 3 — 4050 SERIES APPLICATIONS LIBRARY NEWSLETTER



4051 Graphic System is the center of attention as it computes frequency response curves for AR brand speakers. Pictured is FRED'S SOUND OF MUSIC display at recent "Stereo Show and Tell" in Portland, Oregon.

4051 Computes Best Speaker Placement in Traveling Stereo Roadshow

by Gary P. Laroff

"My room is 16 ft. x 12 ft. x 8 ft. high with walls made of marshmallow. Where do I put my speakers? Where should I sit? How much power will I need?..."

These and other questions are being answered at the TELEDYNE ACOUSTIC RESEARCH (AR) "Science and Sound" show traveling throughout the United States and Europe. And the answers are generated by Tektronix 4051 Graphic Systems with Tektronix 4631 Hard Copy Units attached.

Laboratory Comes to the Retail Floor

Calculations and data that formerly took weeks to work out can be drawn from the internal magnetic tape and

memory almost instantly. AR's 4051 can then provide data on ideal listening locations from room dimensions and speaker placement supplied by the customer. It shows you where you should *really* sit in your listening area. The AR 4051 is programmed to provide tweeter polar dispersion curves by simply supplying it with high frequency driver diameters. The 4051 does all of the mathematics in a matter of seconds and plots the curves while the customer watches. Hard copies of the screen graphics are given to the customer seconds later. Performance data of various AR speaker models and their use in specific installations can be shown on the 4051 screen.

The ACOUSTIC RESEARCH Traveling Roadshow, comprised of a "stack" of AR's new speaker models, a



"Just describe your room and I'll show you the best position for listening to any speaker," says Fred Lindemann of FRED'S SOUND OF MUSIC, Portland, Oregon.



"Programs developed in our large in-house scientific computer have been transferred to the 4051" states AR's Steve Johnson, traveling companion of the 4051.

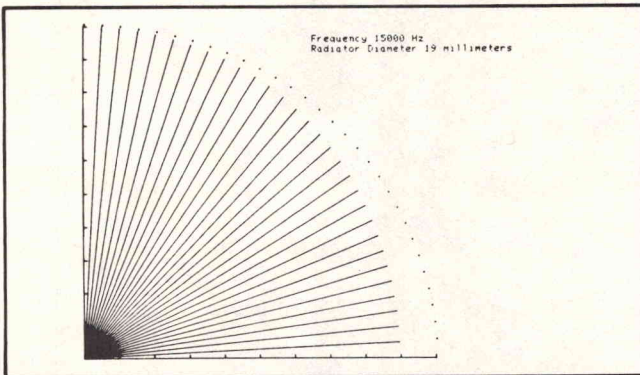


Fig. 1. Frequency response for a 19mm diameter tweeter at a frequency of 15,000 Hz.

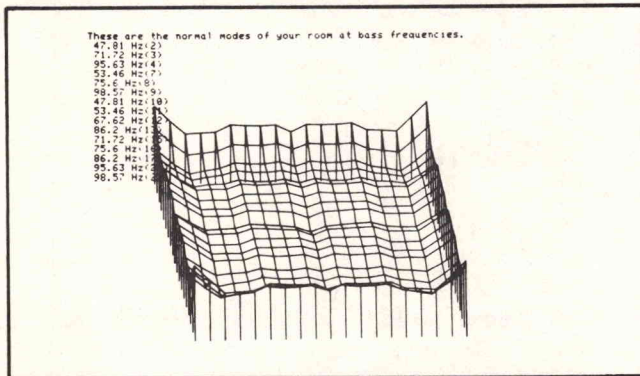


Fig. 2. Frequency response of the listener's room at 15 bass frequencies. The 4051 lists a frequency and then plots the normal modes for that frequency.

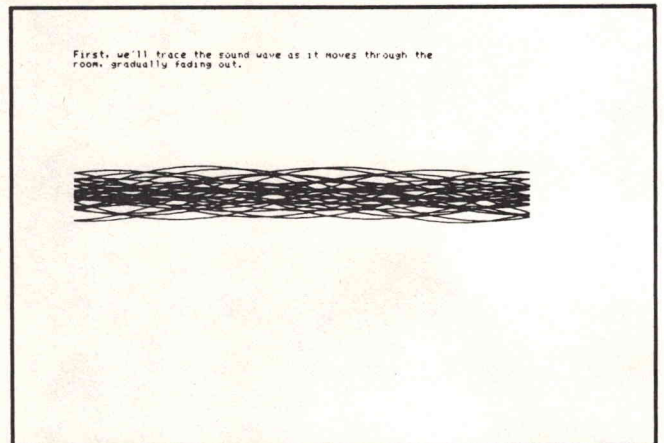


Fig. 3. How speakers work. A graphic example of one of the preliminaries: sound wave formation.

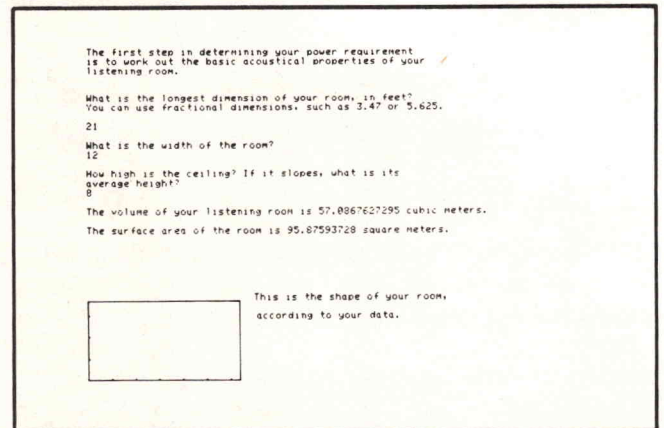


Fig. 4. Customer's room shape diagram drawn moments after the customer has supplied the data.

4051 and a 4631 Hard Copy Unit are drawing crowds wherever they go. Fred Lindemann, of FRED'S SOUND OF MUSIC in Portland, Oregon, is very enthusiastic about the response to his 4051 at the recent "Stereo Show and Tell" in Portland. Using the 4051, Fred answers questions about dispersion, power handling, listening locations, speaker placement and how speakers work.

A number of programs are demonstrated on the 4051. Some were developed on AR's large in-house scientific computer and were transferred to the 4051. Others were written especially for the 4051. Robert Berkovitz,

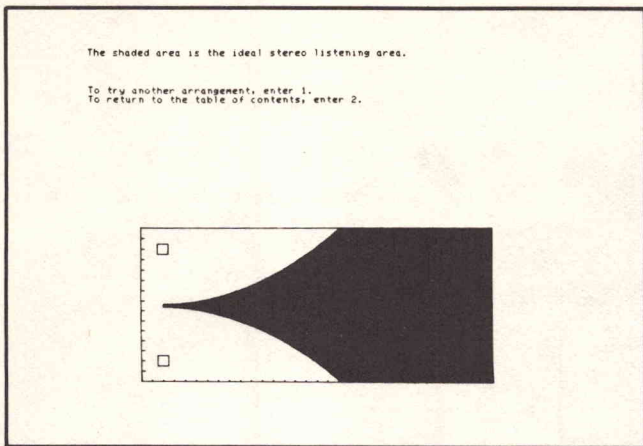


Fig. 5. Ideal stereo listening area diagram for the customer's room and speaker placement. The 4051 is programmed for rooms made of plaster, brick, sheetrock, wood, marshmallow and other exotic materials.

Research Director at AR and author of the programs, is a very enthusiastic supporter of the 4051 as a personal computer and relies heavily on interactive graphics to describe acoustic phenomena.

Hard copies of typical 4051 output are shown in the

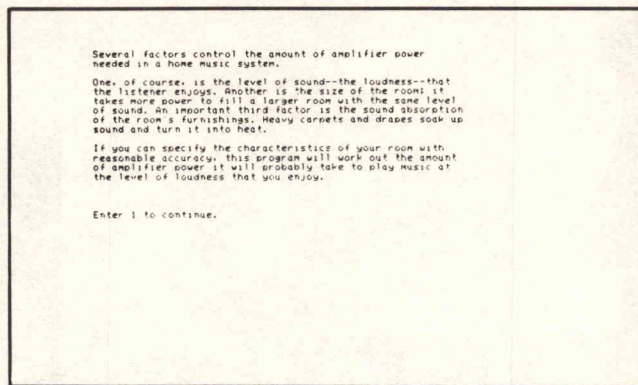


Fig. 6. Typical text on amplifier power requirements.

accompanying figures. The programs are not presently available and are proprietary to ACOUSTIC RESEARCH of Norwood, Massachusetts.

TEKniques readers who would like to see the 4051 and AR's Roadshow and Consumer Computer Clinics are encouraged to watch newspapers, magazines and television for the next visit to their area.

REPRINTED FROM TEKNIQUES, VOL 2 NO 4 — 4050 SERIES APPLICATIONS LIBRARY NEWSLETTER

Tektronix-Zonic Fast Fourier Transform (FFT), Data Acquisition and Analysis System

by L. D. Mitchell
Virginia Polytechnic Institute and State University

Virginia Polytechnic Institute and State University has assembled a very powerful data acquisition and analysis system, using the TEKTRONIX 4051 Graphic System as a key component. Working with Tektronix and Zonic Technical Laboratories, the two-function system shown above was configured. This system's first function is easy acquisition of real-world analog data and conversion of that data into digital information understood by either microprocessors or large scale computers. The system also locally processes and analyzes time domain data. The 4051 Graphic System and the Zonic Technical Laboratories High Speed Two Channel FFT share this second function.

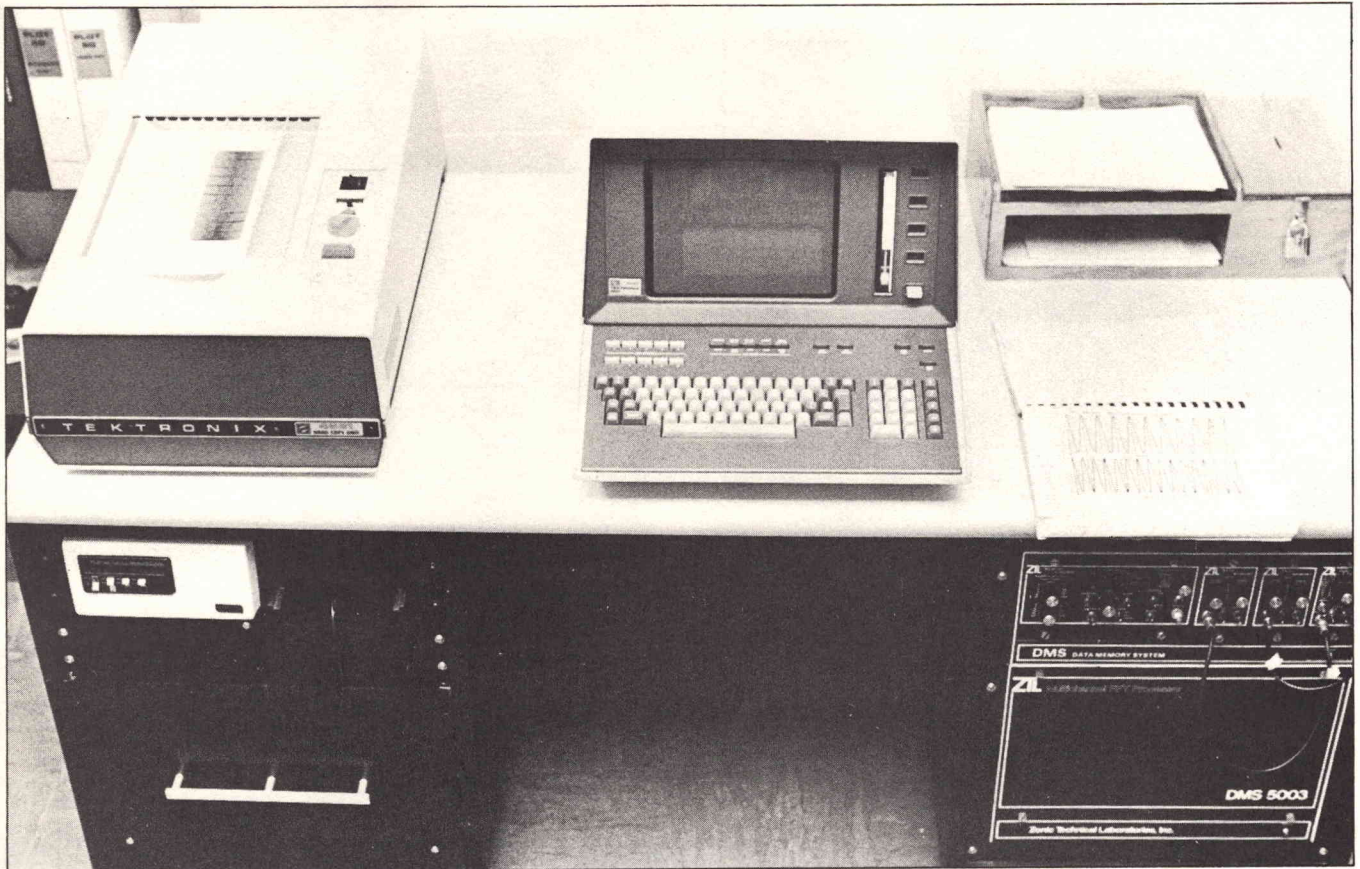
The Zonic unit performs any one of thirty-three frequency domain type functions. Statistical data is handled expeditiously, because the forward Fourier transforms are computed in 50 milliseconds. Once the Zonic unit completes the requested frequency domain operation, the 4051 display plots the graphic result, in the form of a log-log, log-linear, or linear-linear graph, labeled in engineering units. Typical of such results might be a graph of the frequency response of a physical system, in both

magnitude and phase. Any graphic display can be copied using the TEKTRONIX 4631 Hard Copy Unit included in the system.

Besides displaying graphic results, the 4051 is also used to handle analyses beyond the Zonic unit's capability. This can include data analysis that is outside the domain of the preprogrammed Zonic functions, and/or data analysis needs that go beyond the batch programming capability of the Zonic unit. For these cases, the system transfers either the data or a pre-analyzed frequency domain result to the 4051's cartridge tape unit. The data can then be analyzed in any way desired, using the programmable capability of the TEKTRONIX 4051 Graphic System.

As an example, consider amplitude time history data. This data cannot be analyzed for its amplitude probability density function by the Zonic High Speed FFT system. However, the data can be transferred to the 4051 Graphic System. This allows existing Plot 50 software, such as that in Statistics Volume 1, to carry out that analysis.

Moreover, the 4051 can be programmed to operate on the



4051, 4631 and Zonic DMS 5003 teamwork results in easy-to-read graphs of analog data.

data in any way desired. If the particular analysis requires a lot of number crunching, the raw data and/or the pre-analyzed results may be transmitted out through the Option 1 RS-232 Interface to a large-scale computer. Virginia Polytechnic Institute and State University uses an IBM 370 configured with two model 158s. One machine is in batch operation with five megabytes of core; the other machine is interactive and has four megabytes of core.

This configuration of two interlinked microprocessor-based systems, which are in turn linked to a large-scale computer, yields great flexibility in data analysis. This system also capitalizes on the inherent graphics capability of the 4051 Graphic System for the presentation of analysis results.



The Gould Flight Test Aircraft logs many air miles testing advanced navigation systems developed by Gould NavCom Systems Division of El Monte, CA.

Testing Advanced Navigation Systems With The 4051

by Robert B. Denny
Gould NavCom Systems Division
El Monte, CA

The NavCom Systems Division uses the 4051 to control and monitor tests of an advanced long-range flight navigation system (see Fig. 1). Testing is now accomplished in real time during flights as well as in the lab, replacing the previously used blind data collection and subsequent laboratory reduction. The immediate graphic feedback provided by the 4051 has greatly enhanced flight testing of developmental navigation systems.

The NavCom System provides highly accurate in-flight position data for instrument navigation. It relies on the signals from at least four of the eight VLF (Very Low Frequency) OMEGA navigation stations, and uses triangulation to achieve a position reading within a few miles. The system compares the phase differences from the stations to obtain an accurate indication of position. Of course, the accuracy of the system depends on the "noise" contained in the received signal.

The nav system can be reconfigured to accept more accurate signals from VORTAC, a sensor beacon network which is the primary navigation aid used in the United States. Relying on these signals the NavCom

System can pinpoint in-flight location within a few thousand feet.

The developmental nav system is built around a 4051 connected to a 4662 Interactive Digital Plotter and a line printer (Fig. 2). Also, connected to the GPIB is an in-house designed GPIB-to-navigation system interface, allowing control and communication between the 4051 and the navigation system's processor (an in-house bit-slice design). The 4051 remains on-line to this processor, operating as a controller rather than as a terminal or peripheral. A block diagram of the system is shown in Fig. 3.

The 4051 uses secondary addresses transferred over the GPIB to load and read the interface control, communication and breakpoint registers. This technique is used to control the nav system processor's run-halt, master clear and direct-execute interrupt lines. A direct execute interrupt causes the system processor to fetch an instruction from one of its I/O channels, which in this case is assigned to the GPIB interface. This gives the 4051 the ability to force the nav system processor to execute any

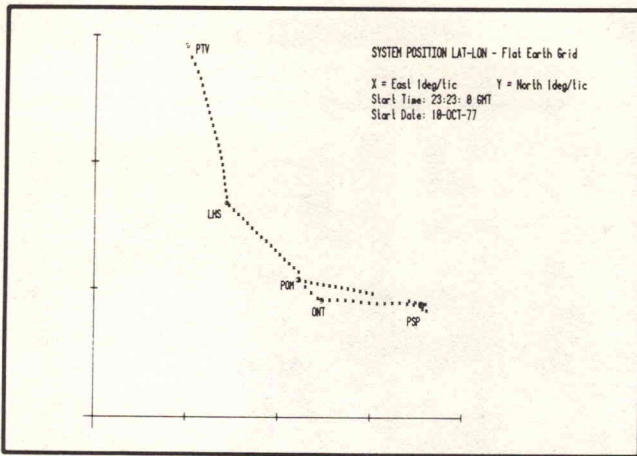


Fig. 1.

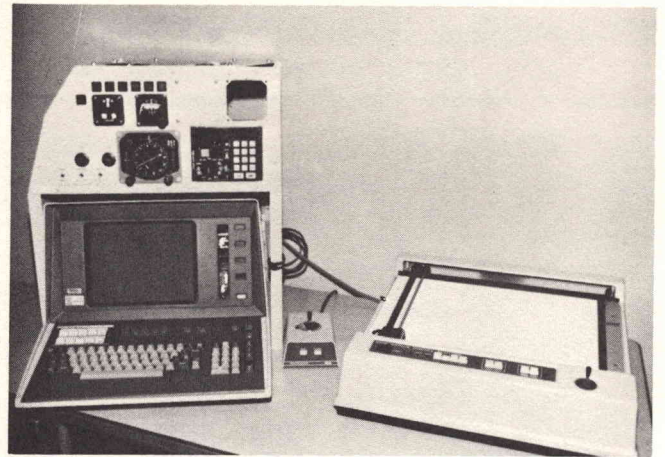


Fig. 2.

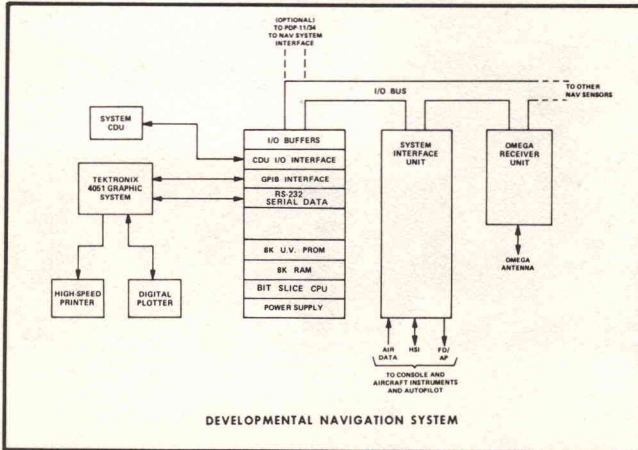


Fig. 3.

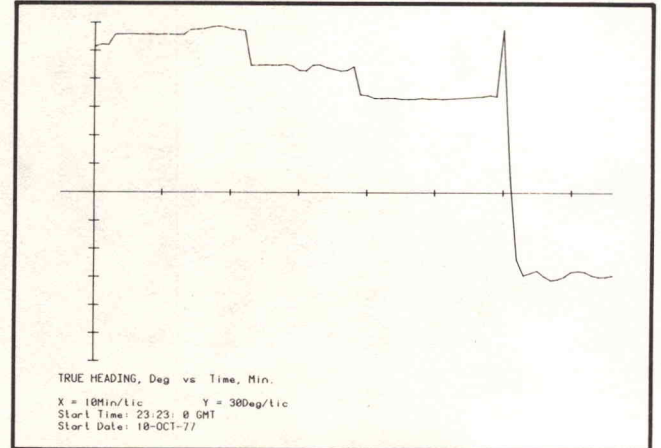


Fig. 4.

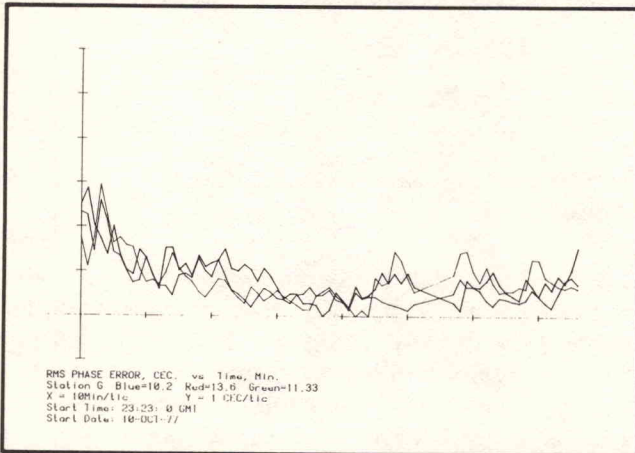


Fig. 5.

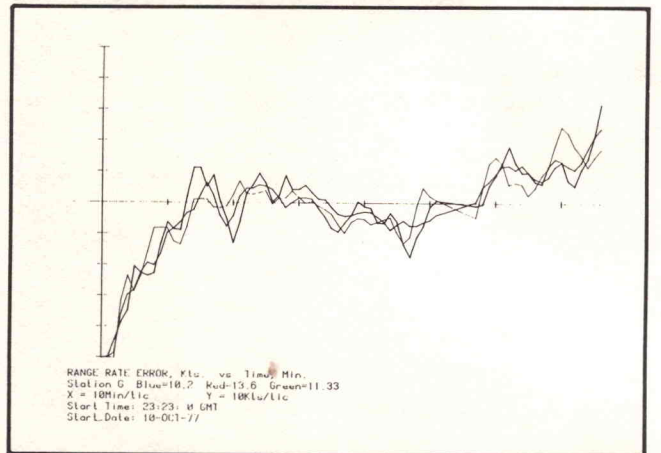


Fig. 6.

single instruction. Instruction, address and data information is supplied to the nav system processor via registers in the GPIB interface. Forcing an input instruction allows the 4051 to load a memory location in the nav system; forcing an output instruction allows reading a memory location. The 4051 converts the system processor's binary data representation into meaningful engineering data values and vice versa. Various types of graphic data display are available. In addition, this feature is used to patch the nav system program by loading new instructions into its memory.

Fig. 1. Actual in-flight data gathered from the system on a flight from Porterville, CA, to Pomona, CA, via Lake Hughes (LHS), Pomona (POM), Ontario (ONT) and Palm Springs (PSP). A temporary loss of electric power occurred on the final leg from Palm Springs to Pomona.

Fig. 2. Developmental nav system configured for the Gould NavCom Systems laboratory includes the 4051, 4662 Plotter and a line printer (not shown).

Fig. 4. Direction (heading) as a function of time.

Fig. 5. Receiver tracking filter phase RMS jitter.

Fig. 6. Receiver tracking filter velocity error for all 3 frequencies from one station (Station G, which is currently in Trinidad).

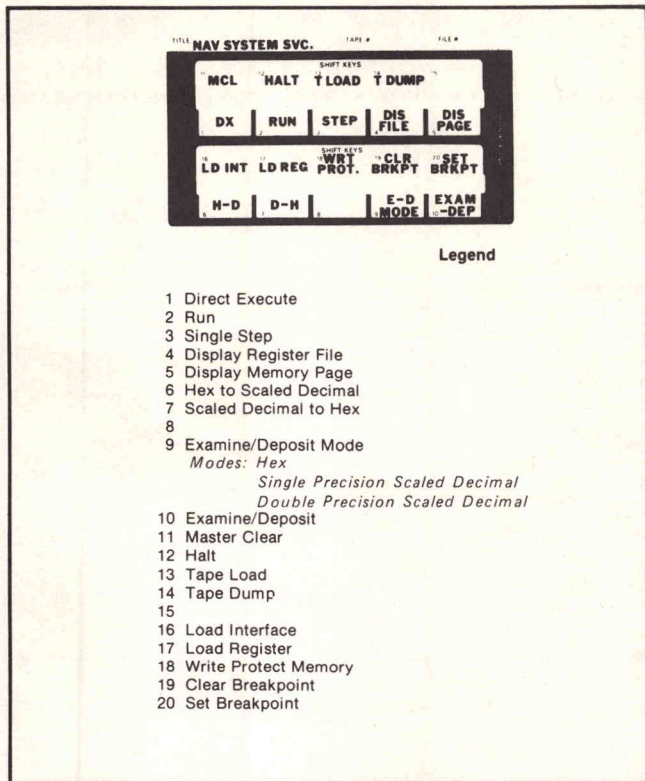


Fig. 7.

The interface provides for setting a memory access breakpoint which, when reached, generates a GPIB service request (SRQ) interrupt and, if desired, halts the nav system processor. In this way, data collection can be synchronized to the nav system program. The instant-halt feature allows detection of program faults by freezing the nav system processor upon read and/or write accesses to a memory location specified by the 4051.

Before this development, flight tests were conducted "blindly" with data collected on paper tape or magnetic tape. After the test flight, data from tape was fed to a computer for data reduction and analysis. The 4051-based system makes the data gathered more immediately useful through real-time analysis and reduction. Monitoring and displaying the key variables in the navigation system graphically in real time allows the test procedure to be modified on the spot, depending on the results observed. The data is also recorded on mag tape for further analysis back in the lab.

Operation is controlled by a fairly large software package developed by NavCom Systems Division for the 4051. The software allows the operator to control navigation system mode, data gathering, memory inspection and change, and other system functions, all through the User-Definable Keys (Fig. 7). This makes for a complex, advanced test system that is simple and easy to use.

When the 4051 is not testing navigation systems, there are other functions in the NavCom lab to keep it busy. Some

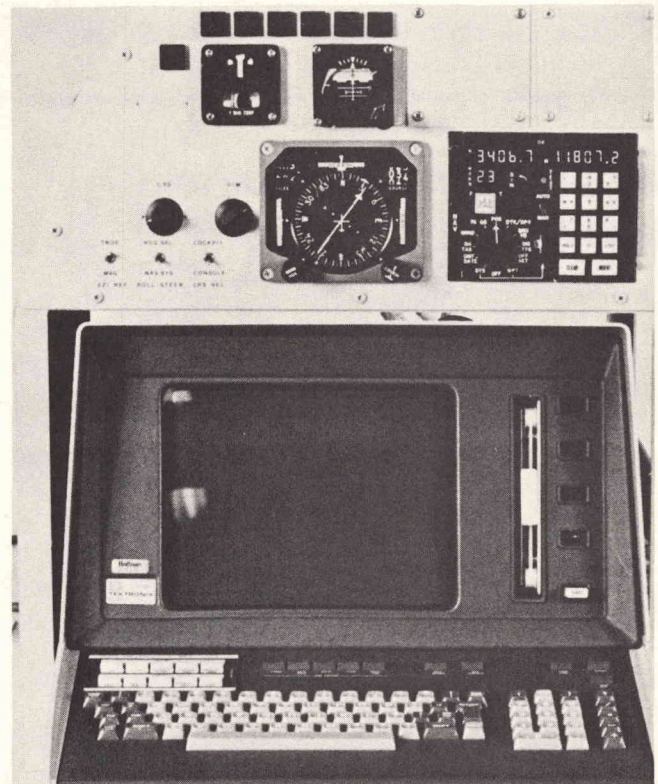


Fig. 8.

of these duties include algorithm development, closed-loop system behavior simulation, and other design-related problem solving. A plug-in PROM Programmer built for the navigation system is also connected to the GPIB. The 4051 controls the programming cycle of the PROM program so that the 4051 can transfer data from the navigation system working memory into the PROM being programmed.

The NavCom System Division of Gould is continually designing and developing state-of-the-art navigation systems. These systems will eventually be produced for military and commercial aircraft world-wide. The 4051 is playing an important part in this innovative engineering.

Fig. 7. User-Definable Keys make this complex, advanced test system simple and easy to use.

Fig. 8. The nav system which goes along on the flight is designed to fit into the curvature of the left side of the Gould Flight Test Aircraft.

4051 Tests Solar Cells at JPL

In Pasadena, California, Jet Propulsion Laboratory is using the 4051 Graphic System to control an innovative test system. Dr. Jim Liu wanted to test the performance of solar cells and solar cell material, and needed to use non-GPIB devices to do it. Dr. Liu chose the 4051 as a controller, citing the GPIB and graphics capabilities as prime reasons. The 4051 is connected, via the GPIB, to a Hewlett-Packard 6940B Multi-Programmer. The Multi-Programmer, in turn, is connected to such non-GPIB devices as Digital Voltmeters, Variable Power Supplies, Light Detectors, Monochromators, and Stepper Motors. This forms the system shown in Fig. 1, which performs laboratory tests of solar cells and materials far faster than previous methods.

The Multi-Programmer outputs all of the required device-dependent signals to the devices connected to it. Additionally, it collects the input data from several different experiments performed by the system, and passes the results along to the 4051 over the GPIB. All Multi-Programmer action is under control of the 4051 through the GPIB.

The system is used to test solar cells and solar cell materials in several experiments. Tests measure the output voltage and current as well as the spreading resistance of the material. Solar cells are measured for operating efficiency under illumination, and are tested in the dark to measure their diode characteristics. The system is used to measure diffusion length of carriers in the materials, to provide spectral response curves, and to gather and manipulate data that can be used to determine the efficiency of solar cells and solar cell material. The experiments are currently performed one at a time; the goal is to perform several in parallel. This may be done by gathering data from one test while the 4662 is plotting results of another.

Besides gathering and manipulating experimental data, the 4051 performs other controller activities. For instance, it can output commands through the GPIB to operate the stepper motors and vary light intensity. The stepper motors, in turn, can change sample placement material, allowing another portion of the sample to be tested. Other control outputs from the 4051 change wave length in the experiment. This method makes the testing virtually automatic.

Dr. Liu chose the 4051 Graphic System for this test system because of its high-resolution graphics and its GPIB capabilities. The 4051 draws data from the

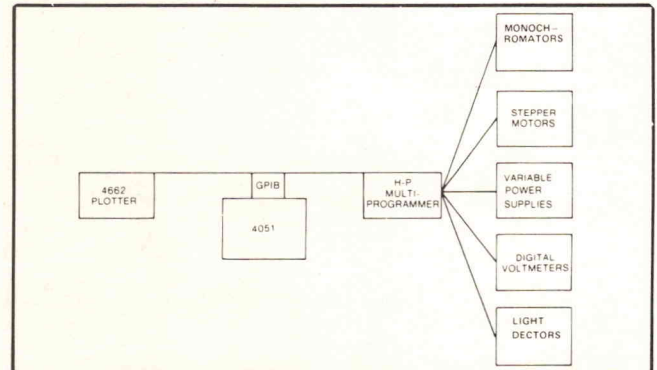


Fig. 1. Solar Cell Test System.

experiments back through the GPIB and manipulates it to provide useful results. These results take the form of several different graphs of the characteristics of solar cells and solar cell materials. Some typical outputs are Spectral Response curves, Voltage vs. Current, and plots of the conversion efficiency curve of the cells. In addition to the plotted curves, the 4051 will provide a list of all of the experimental data.

This test system is still being refined at Jet Propulsion Laboratory. As it stands, the system already provides a quantum leap in speed and efficiency over the previous data gathering methods. As an example, prior to setting this system in place, current vs. voltage data was laboriously gathered and plotted by hand, point by point. This method took between one and two hours to gather and plot 20 data points. The test system can gather 50 data samples in two **minutes**. As another example, Dr. Liu cited the plotting of Spectral Response curves. This operation previously took an entire morning of gathering data by hand, followed by subsequent computer reduction. The 4051-based test system completes the entire operation, including graphic outputs, in nine minutes. Time savings and high resolution graphics: that's what the 4051 is all about.

The 4051/7912AD: An Automatic Waveform Acquisition System

By Jim Kassebaum and Jim Kimball

When you need waveform processing but don't need the speed of standard waveform processors, you'll like the economics of interfacing the TEKTRONIX 7912AD Programmable Digitizer to the TEKTRONIX 4051 Graphic System. It's a direct connection, thanks to the IEEE 488 General Purpose Interface Bus (GPIB).

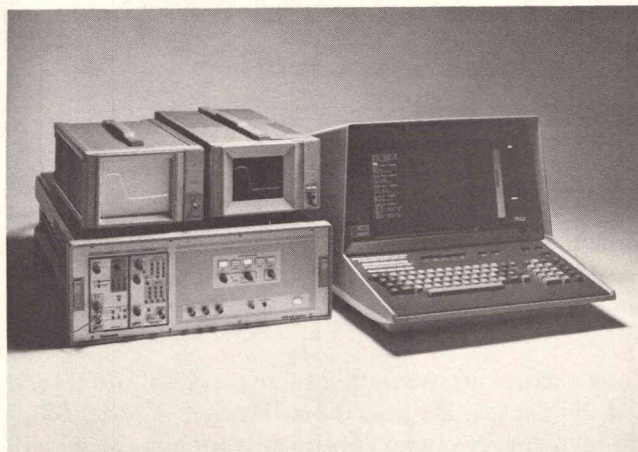
The 7912AD, with its 7A16P Programmable Amplifier and 7B90P Programmable Time Base plug-ins, is a fully programmable waveform digitizer. Input sensitivities, offset, sampling rate—all important front-panel controls can be operated either manually or under 4051 program control.

The 4051 itself provides general waveform processing capabilities. If you need more or want to go faster, there's the possibility of an RS-232-C link to a host computer.

Putting the 4051/7912AD combination to work does require some applications programming. The authors developed routines for a typical system that might be used at either a research or a production site to acquire, process, store, and display data. Besides the 4051 system controller and the 7912AD with programmable plug-ins, two monitors are used to display acquired waveforms. There is a TV monitor for a real-time display of the 7912AD input, and an XYZ monitor for a refreshed display of the digitized waveform once it is stored in the 7912AD data memory.

Although the 7912AD is useful for viewing very fast transients, its main function is acquiring transients as data and transferring the data over the GPIB for processing. Therefore, data is recovered from the scan converter by detecting the trace written on a diode matrix, in a manner similar to plotting the X-Y coordinates of points on an oscilloscope trace. Rather than a single pair of X-Y coordinates to represent a data point, however, two Y values are detected by the 7912AD for each X: one Y represents the top of the trace at that point and another Y represents the bottom of the trace. The distance between these two Y values is caused by trace width, which varies with waveform shape, sweep speed, waveform repetition rate, and writing beam intensity.

This is not as complicated as it might appear to be, however, thanks to an internal bit-slice microprocessor system. This system has several routines in firmware that can massage the data before transferring it over the GPIB.



The Tektronix 7912AD Programmable Digitizer with its 7A16P Programmable Amplifier and 7B90P Programmable Time Base plug-ins (lefthand side of front panel) operates under program control from the 4051. Sitting on top of the 7912AD, an XYZ monitor and a TV monitor display the digitized waveform in 7912AD data memory.

One routine, ATC (average-to-center) is especially handy with a controller such as the 4051. The ATC routine converts the raw data to a single-valued function by summing the top and bottom trace values and filling in any missing points.

A digitize/average statement is used to initiate a digitize operation on the next time-base sweep. It then resets the instrument mode for a TV display of the input waveform. If the waveform is repetitive, the TV monitor and XYZ monitor both display the waveform, the TV in real-time and the XYZ as a plot of ATC-processed data.

Although the ATC waveform format is the simplest and reduces much of the burden of further processing, it may not provide the ideal data for all applications. For this reason, the full internal data array as well as the data arrays that result from several other internal processing routines can be read out over the GPIB.

To see the waveform, graph the data on the 4051 screen. A graticule can be simulated by a box with tic marks around the viewing area. The data plot can be scaled by reading in the scale factors.

Thanks to the common use of the GPIB, the 4051, 7912AD, 7B90P, and 7A16P can be easily connected and can be programmed to play together as an automated waveform acquisition system.

Interfaces Increase Versatility of 4051

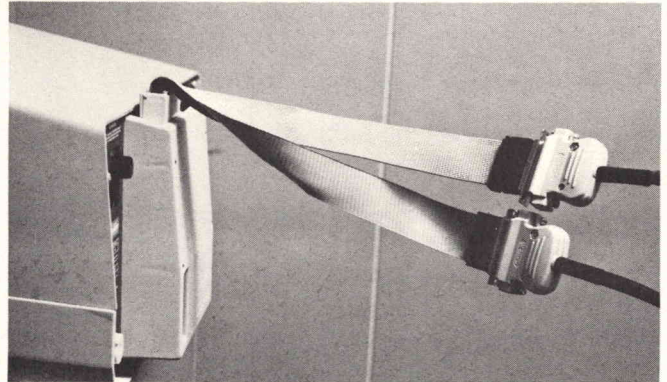
by Pat Kelley

If you want to use a 4051 with equipment not designed for use with the GPIB, there are two interfaces that may be your answer. With these the 4051 is compatible with your devices that require ASCII, BCD or Binary in a parallel format, but that do not require high data rates. Examples are paper tape readers/punches, multimeters, counters, function generators, power supplies, spectrometers, and so on.

The General Purpose Output Interface (CM021-0211-00) and the General Purpose Input Interface (CM021-0212-00) each consist of two 26-wire microribbon cables with 25-pin female connectors on each, and a ROM pack. Two male connectors are supplied with each which you wire to your peripheral cables.

The male and female connectors must be pin-to-pin compatible and explicit directions are given in the manuals accompanying the interfaces. Once your peripheral cable is wired, simply plug these two connectors together and insert the ROM pack into the backpack of your 4051 or into your ROM Expander unit. If you need only 16 data-command lines, only one connector need be wired to your peripheral cable.

The many programmable parameters, each of which has two or more values from which to choose, give the



The CM021-0212-00 microribbon cables allow pin-to-pin connection with a peripheral permitting input of ASCII, BCD or Binary data in a parallel format.

interfaces their flexibility. Only four statements are required to set these parameters. The parameters are: data code, number of data lines, data logic, commands, number of command lines (data-command lines cannot exceed 40), command logic, interrupts, handshake, data flag and four transfer signals.

Just about all I/O circumstances are covered by the nine statements transmitting data and the four receiving data.

Contact your local Tektronix Sales Engineer who will be glad to discuss these interfaces in more detail with you.

University of Minnesota Seminars Update Technical Knowledge

by Patricia Kelley

To help managers in technical fields avoid being left in the dust of galloping technology, the Department of Conferences on Continuing Education in Engineering & Science at the University of Minnesota custom designs intensive seminars on Modern Technical Concepts.

Professors Mahmoud Riaz and Jack Judy from the University's Department of Electrical Engineering recently coordinated two concurrent seminars for engineering managers from Honeywell and IBM.

Among the diverse array of teaching aids were two 4051 Graphic Systems used for problem solving with graphic display. As the seminar advanced, the 4051s also became centers of attention during the participants' free time.

Both conferences were held at two retreats on opposite sides of one of Minnesota's picturesque lakes which provided a 10-day haven from everyday demands allowing the participants to soak up the teachings. Separate computer rooms were established to hold a number of terminals including the 4051 systems.

Although other diversions were offered, many participants spent their off hours in the computer room. In a number of cases, this was the first lengthy hands-on experience with a computer.

"Problem solving and games overcame the reluctance of many to interact with the computers", noted Professor Riaz.

Honeywell and IBM are already making plans for similar seminars next year.

American ENKA Uses 4051 in Chromatographic Work

Using his 4051 as a controller, Leonard H. Ponder, Research Chemist at American ENKA Co., acquires chromatographic data over the RS-232 Interface. In stand alone mode the 4051 then plots the data. He has contributed the program for this application to the 4051 Applications Library (see new abstract 51/00-5204/0).

Ponder has also developed a quantitative analysis

program which resides in the user library of On-Line Systems. He says by using your 4051 in terminal mode the program will handle quantitative gas chromatography and liquid chromatography work. In some applications the program will also handle data from instruments other than chromatographs such as automatic analyzer and colorimetric detectors. The program is described in *Chemical Engineering*, August 28, 1978, page 114.

Meteorology and Geometric Analysis Occupy 4051

by Patricia Kelley

The Materiel Testing Directorate at the U.S. Army's Aberdeen Proving Ground, Md., takes its responsibility to be a "good neighbor" very seriously. Up-to-date technology ensures that environmental effects of the testing work are kept within acceptable limits.

Careful monitoring of meteorological conditions and the use of mathematical models provide a means for assessing the potential effect on all surrounding areas from planned testing each day. The mathematical models accurately match the actual manner in which sound is transmitted through the air.

Should conditions be such that testing would create a nuisance, it is rescheduled to a time when conditions are more favorable.

Captain Steve Sanford of the Materiel Testing Directorate converted an existing FORTRAN IV program into a sophisticated but easy-to-use program for the 4051 to assimilate environmental data and calculate the location of sound intensity (Fig. 1).

A balloon launched from the site prior to firing contains radio gear which measures temperature, relative humidity, and atmospheric pressure. It also records the time of reading. Radar following the balloon checks its location and elevation. The firing range personnel call in the data gathered by this equipment to the 4051 operator, who keys it into the 4051 (Fig. 2).

Sound gradients are plotted first. At 0 degrees Celsius and no wind, sound waves disperse at a set rate in a specific direction. However, as wind velocity and direction, temperature and humidity change, the waves speed up, slow down and switch direction resulting in varying intensities at different locations. Calculating these variables yields sound gradients for a particular area; in this case it's the firing range.

```

*** METRO II OPTIONS ***
1: ENTER RAWINSONDE DATA
11: READ RAWINSONDE DATA FROM TAPE
2: STORE RAWINSONDE DATA ONTO TAPE
12: LIST RAWINSONDE DATA

3: TABULATE BALLOON COURSE
13: PLOT BALLOON COURSE

4: TABULATE WIND DATA
14: PLOT WIND DATA

5: TABULATE SOUND GRADIENTS
15: PLOT SOUND GRADIENTS

6: TABULATE MULTIPLICATION FACTORS
16: PLOT MULTIPLICATION FACTORS

7: TABULATE OVER-PRESSURE INTENSITY
17: PLOT OVER-PRESSURE INTENSITY

8: TABULATE ATMOSPHERIC DENSITY
18: PLOT ATMOSPHERIC DENSITY

9: QUIT
19: PREPARE DATA STORAGE TAPE

10: AUTOMATIC COPY
20: MANUAL COPY

>SELECT USER-DEFINABLE KEY<

```

Fig. 1. User-Definable Key functions make a complex program easy to use.

A quick check to see if the plotted sound gradient lines are spread evenly across the screen verifies data accuracy (Fig. 3). Any data out of the ordinary generates a "haystack effect"—the lines are collapsed to the middle of the plot looking like a haystack—which prompts the operator to recheck the readings. The sound gradient data may also be inspected in tabular form (Fig. 4).

The 4051 applies the sound gradients to calculate the direction and angles the sound paths will take as they radiate from the firing charge. It translates these paths into sound focusing.

For example, the 4051 could predict where sound waves emanating from a charge meet warmer air, bounce off at an angle to focus and come back down creating greater intensity in one area.

At this point the data is reduced to multiplication factors for different ranges (Fig. 5). These factors are applied against the weight of the charge to predict sound intensity and location (Fig. 6).

The intensity is translated into blast pressure. An easy-to-

```

EDIT INPUT DATA:
  ENTER # TO DELETE
  ENTER R TO REPLACE
  ENTER <RETURN> TO LEAVE AS IS
  ENTER 0 TO QUIT

RELEASE TIME 1425
DATE: 29 AUG 1978
SURFACE DATA:
WIND DIRECTION   WIND SPEED
260              8
TIME            PRESSURE     TEMPERATURE   HUMIDITY
AZIMUTH        ELEVATION
0              1013.1      31.2         56
0.5            988.9       27.6         47
290.7          49.3
1              965.6       26.4         52
285.19        51.9
1.5            949.7       24.4         56
280.41        47.83
2              935.3       23.4         55
282.00        44.88
2.5            921.2       22.5         64
277.76        41.88
3              906.3       21.2         68
276.77        41.8
4              871.4       18.3         70
277.29        41.72
4.7            850         17.6         54
274.86        39.21
5              841.3       17.3         47
275.23        39.82
6              806.9       16.8         24
275.9         37.14
ADDITIONAL DATA? (Y/N): Y
ENTER TIME, PRESSURE, TEMPERATURE, HUMIDITY, AZIMUTH, AND ELEVATION:
999 0 0 0 0

```

Fig. 2. The operator may edit the data after it's keyed in.

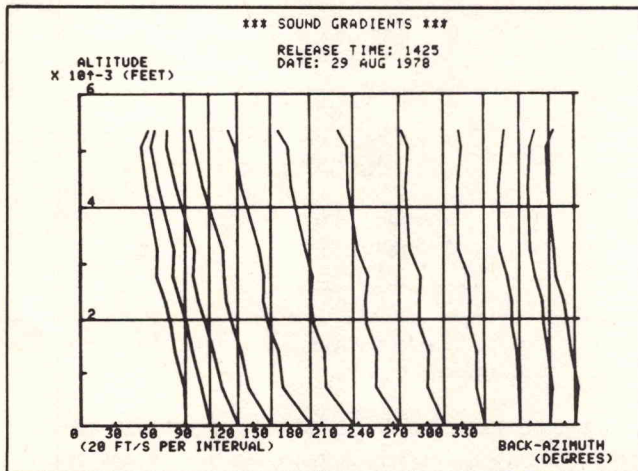


Fig. 3. Direction of sound waves and their displacement from the speed of sound (0 wind and 0 degrees Celsius) are plotted. Reduced sound velocity is indicated as the lines bear left and greater velocity as they angle right. Gradient traces for all compass directions from the Proving Ground (in 30° increments) are displaced across the chart, initially spaced one interval apart.

read tabular chart may be scanned to locate the intensity in those areas above 71 decibels (Fig. 7).

Prior to using the 4051 the data was keypunched onto cards and submitted to a host computer for sound gradient calculation and plotting. A technician would then manually analyze these gradients. With the aid of a small scale, an approximation of sound paths and subsequent intensity could be guessed.

Sanford has gone many steps beyond the original program. In addition to the calculations and graphics discussed above, several others are optional. The balloon's course may be charted, the wind direction

```

*** SOUND GRADIENTS ***
RELEASE TIME: 1425
DATE: 29 AUG 1978
ELEVATION (FEET)
BACK-AZIMUTH (DEGREES)
SOUND VELOCITY (FT/S)
VELOCITY GRADIENT TO NEXT LEVEL ((FT/S)/FT)
0.00      710.19      1,406.79      1,888.89
2,330.34  2,767.66      3,235.25      4,353.15
5,057.06

BACK-AZIMUTH: 270
1,161.96      1,161.05      1,160.08      1,157.28
1,157.24      1,154.73      1,150.22      1,149.98
1,152.10      1,153.11
-0.00120      -0.00139      -0.00501      -0.00009
-0.00574      -0.00965      -0.00021      0.00301
0.00350      0.00000

BACK-AZIMUTH: 300
1,159.39      1,160.98      1,150.42      1,156.30
1,155.38      1,151.41      1,148.64      1,147.36
1,148.34      1,151.37
0.00223      -0.00367      -0.00439      -0.00208
-0.00910      -0.00591      -0.00115      0.00148
0.01046      0.00000

BACK-AZIMUTH: 330
1,154.41      1,156.14      1,152.04      1,150.10
1,148.01      1,143.15      1,142.17      1,138.63
1,137.84      1,141.93
0.00243      -0.00589      -0.00401      -0.00474
-0.01112      -0.00208      -0.00317      -0.00112
0.01406      0.00000

```

Fig. 4. Tabular output displays elevation in feet for each reading. Then for each compass direction sound velocities followed by sound gradients for each elevation are given. Back-azimuth is the compass direction from the sound wave destination back toward the Proving Ground.

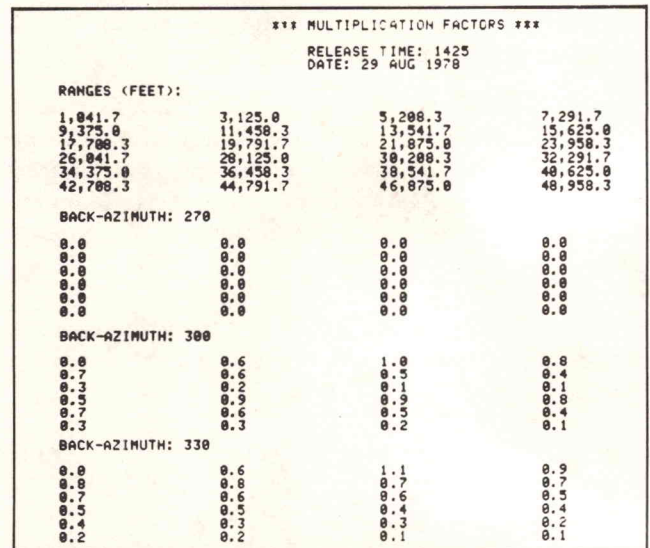


Fig. 5. Note the multiplication factors at back-azimuths 300 and 330 and the correlation with Fig. 6.

plotted or the atmospheric density graphed.

Optimizing the positions of Sky Screens is another job for which Sanford has employed the 4051. These devices, mounted on pedestals in the field, watch the ballistics rounds as they're fired down range. Since a Sky Screen has a very narrow field of view, often several must be aimed perpendicular to the flight of the round, each at a slightly different angle.

Sanford uses the analogy of a horse with blinders; it can see neither right nor left but only straight ahead. In order to see an object passing overhead, its head must be tipped upward at the correct angle. So it is with Sky Screens.

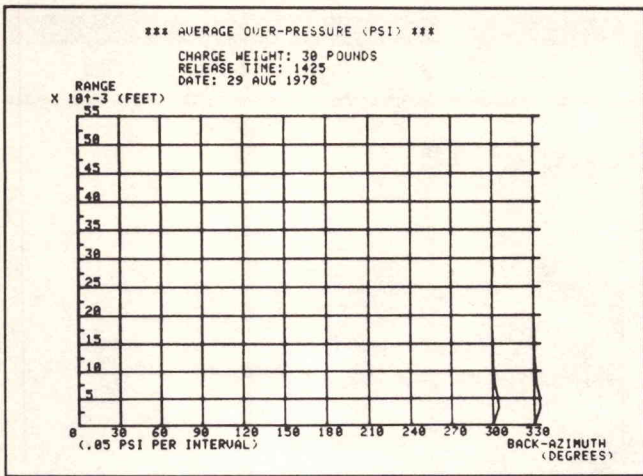


Fig. 6. Visual interpretation quickly locates the area of sound concentration.

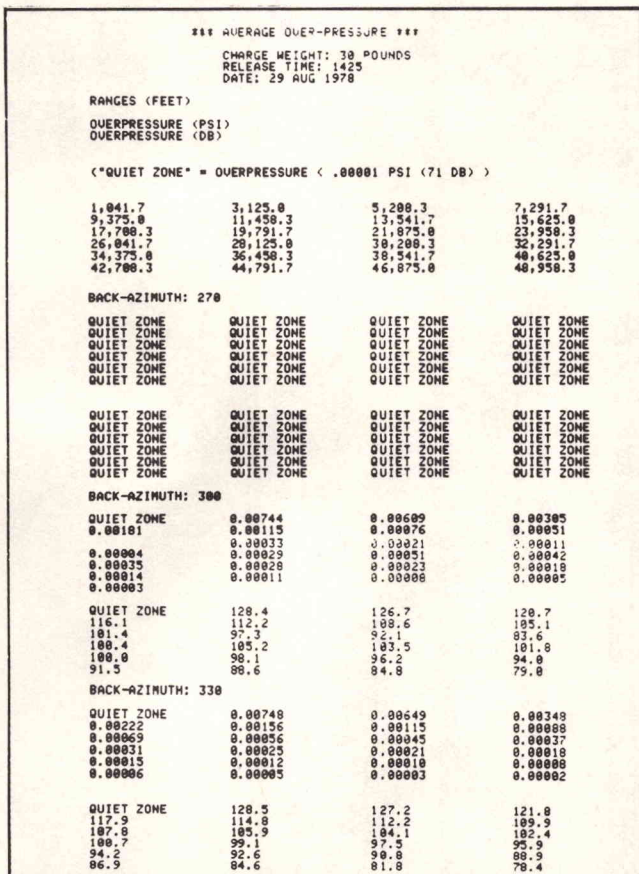


Fig. 7. Tabular output reflects sound intensity greater than 71 decibels.

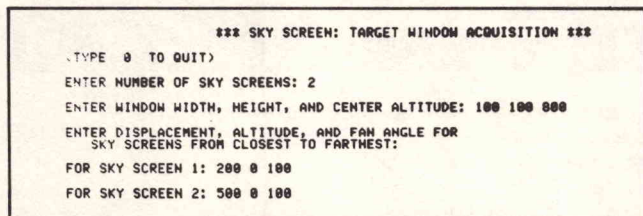


Fig. 8. Prompted input for Sky Screens includes window size and altitude, the Sky Screens' horizontal distance from the window (displacement), height above ground (altitude), and vertical field of vision (fan angle) in mils.

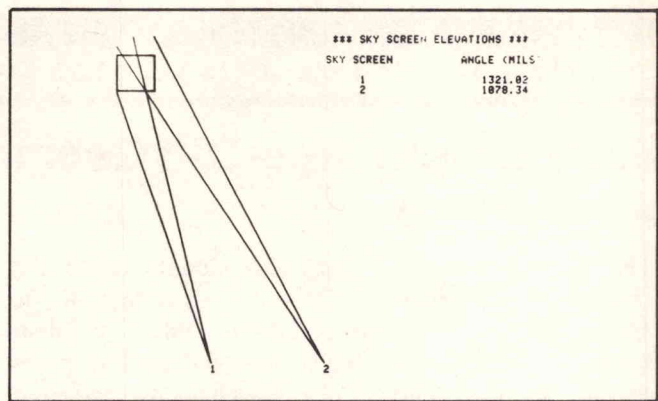


Fig. 9. Two Sky Screens positioned accurately to cover the entire window.

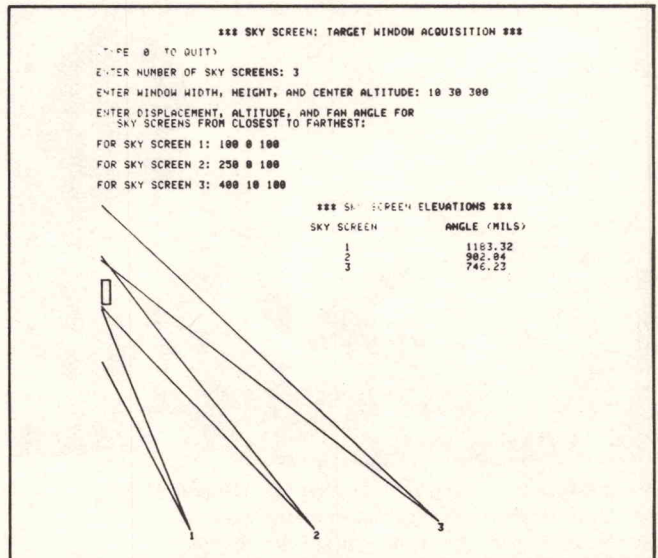


Fig. 10. The Sky Screen closest to the window is angled to view the bottom, the one farthest away to cover the top. Note that three Sky Screens are unnecessary in this case.

The Sky Screens are numbered and shown accurately in their positioning with respect to the window. The view fields are drawn showing areas of the window included.

The predicted path of a round is readily obtained from a ballistics table. An imaginary window, sized to view the path where the round will pass over the Sky Screens, is keyed into the 4051 (Fig. 8).

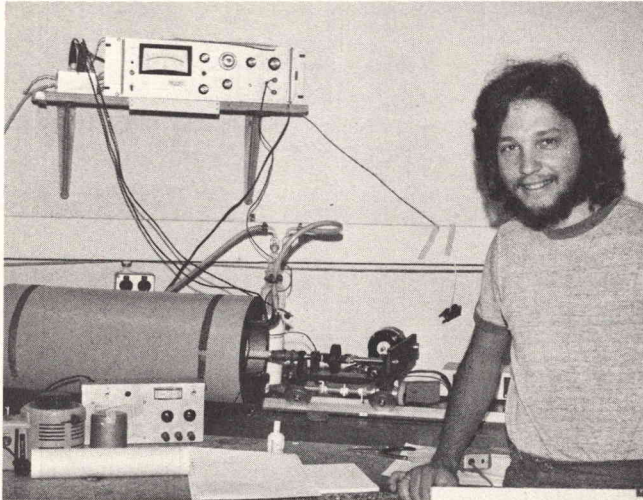
The problem is one of geometric adjustments. In a matter of seconds the 4051 calculates the correct angle for each Sky Screen and displays the configuration on the 4051 graphic screen (Fig. 9). It's easy to see if more or less Sky Screens are needed (Fig. 10). The margin of error has been within one percent.

The graphics and off-line processing capability of the 4051 have relieved the Materiel Testing Directorate of many tedious and routine tasks. These three applications are only a fraction of what Sanford has tucked away on his tapes and discs.

4051 Graphs Age-Old Geomagnetic Data

by Patricia Kelley

The Department of Geology and Geophysics at the University of Minnesota is conducting studies of the ancient history of the Earth's magnetic fields. Equipment housed in the Space Science Center on the Minneapolis campus includes a 4051 which graphs paleomagnetic and rock magnetic data.



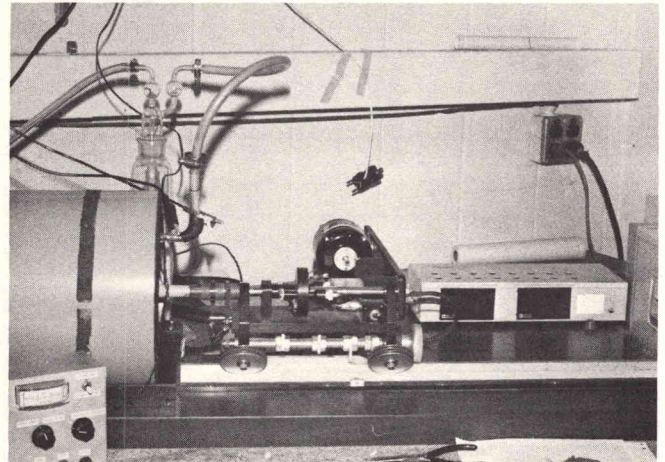
Bruce Moskowitz, geophysics graduate student at the University of Minnesota, explains how the Schonstedt spinner magnetometer and digital voltmeter gather fossil magnetization data from ancient rocks. The 4051 then graphs the data for quick interpretation.

Magnetic field history is preserved in old rocks as fossil magnetization. This is the result of miniscule particles of the rock becoming oriented with the Earth's magnetic field as it existed at the time and place of the rock's formation.

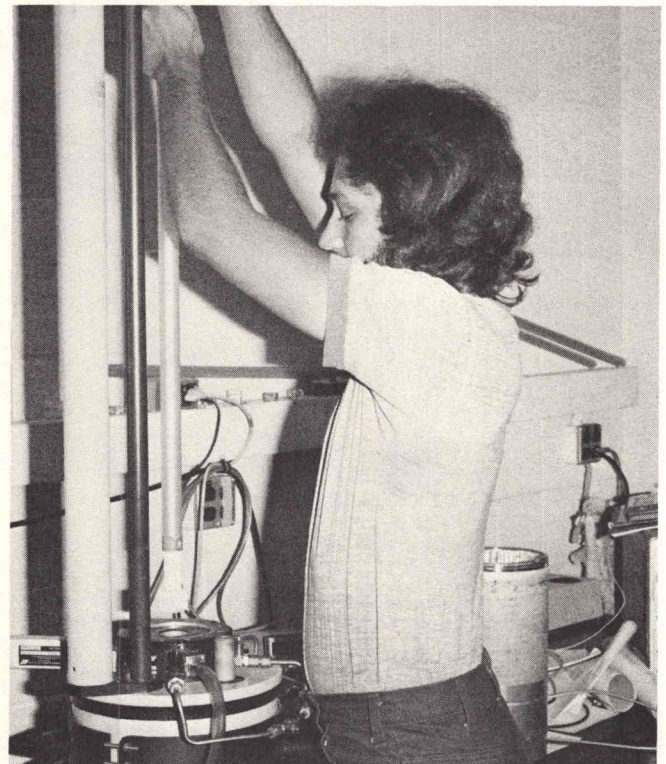
To measure this faint residual magnetic moment, a rock specimen is placed in the Schonstedt Instrument Company spinner magnetometer or the SCT superconducting rock magnetometer. As the magnetic moments are measured, the signals are passed to digital voltmeters and the data is captured by a Hewlett-Packard 2108.

At the conclusion of each experiment, the HP2108 prints out the table of results; the data is then transferred to the 4051 through the RS-232 interface. The 4051 graphs the data for quick visual examination and for preliminary modeling.

In addition to its duties in the laboratory, the 4051 is connected as a terminal to the University's Cyber 74 system for additional data handling. And in its stand alone mode the 4051 is used by department personnel to carry out independent graphics manipulation and output.



The spinner magnetometer picks up signals as faint as 10^{-7} emu total.



A more sensitive machine, the Schonstedt superconducting technology magnetometer measures signals as small as 2×10^{-8} emu total in one second. To obtain this sensitivity, a Superconducting Quantum Interface Device (SQUID) is used which must be maintained at liquid helium temperatures. As demonstrated by Moskowitz, the rock specimen is then placed into a tube and lowered into the machine for measurement.



Increased speed and reduced cost in the identification of unknown chemical compounds resulted when General Electric at Valley Forge, Pa., put together this system. A TEKTRONIX 4051 and 4907, A.M.S. Solver One interface and software, Perkin-Elmer Gas Chromatograph/Mass Spectrometer and a Columbia Scientific digital readout comprise the powerful analysis tool. (Courtesy of General Electric, Valley Forge, Pa.)

A 4051-Based Gas Chromatograph/Mass Spectrometer Data System

by Nick Bazil
A.M.S. Inc.

Gas Chromatograph/Mass Spectrometer systems are powerful tools for identifying and verifying unknown chemical compounds. They can be used to identify a pollutant in a water system, for instance, or any chemical sample. At General Electric Co. in Valley Forge, PA, a Gas Chromatograph/Mass Spectrometer system is in place in their analytical chemistry lab; its heart is a 4051 Graphic System with a 4907 File Manager. The 4051 handles the data reduction and analysis for the system, while the 4907 is the key to quickly matching the unknown sample against the library of known compounds.

In the past, data reduction and analysis for a Gas Chromatograph/Mass Spectrometer combination required a minicomputer, a requirement that could add fifty to eighty thousand dollars to the cost of a system. The high cost made it difficult to justify such data systems. But the advent of the powerful 4907 File Manager, coupled with the A.M.S. Solver One interface and application software package, has considerably reduced the cost of such systems.

The Gas Chromatograph/Mass Spectrometer system began with a 4051 Graphic System and an A.M.S. interface; the interface collected data from a Perkin-Elmer Gas Chromatograph/Mass Spectrometer system, through a Columbia Scientific digital readout connected to them. The digital readout unit reads the peaks from the

Gas Chromatograph and Mass Spectrometer, sorts the data, and performs an intensity count (Fig. 1).

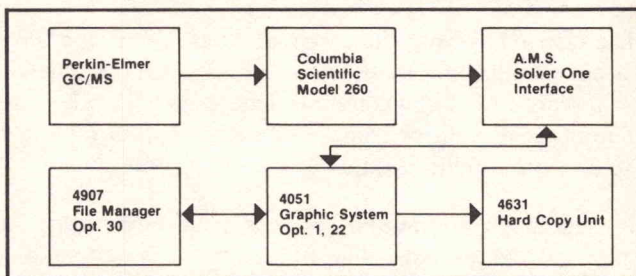


Fig. 1. System Configuration.

In this original system, G.E.'s Bob Ross intended to simply collect, normalize, graph, and tabulate the data locally, taking advantage of the 4051's high resolution display. (Refer to Figs. 2 and 3.) A time-share system could then be used to identify the unknown compounds from the mass spectrum run. A given sample in G.E.'s analytical chemistry lab could have 50 Gas Chromatograph peaks, denoting different compounds and different intensities or concentrations.

Visual interpretation and hand data entry with such complex possibilities restricted productivity in the system. Two or three days were typically required to obtain a sample identification. The 4907 File Manager was then added to the system, and A.M.S. added a

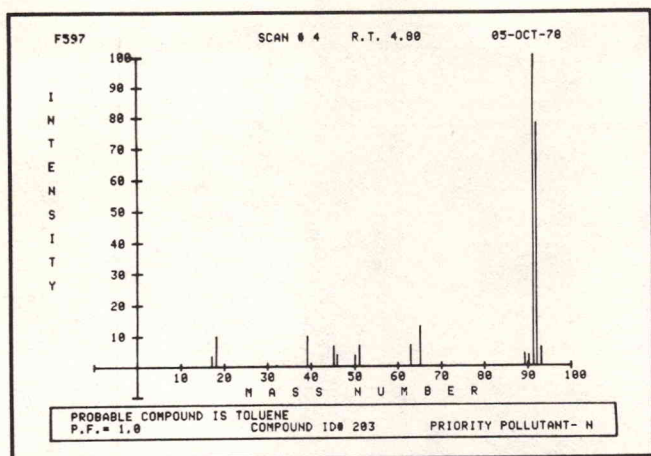


Fig. 2. Graphic Output of a mass spectra scan.

#	MASS#	INTEN	ACTUAL	SCAN # 4	R.T. 4.80	05-OCT-78
1	91.2	188.00	2914			
2	92.1	77.63	2252			
3	65.1	12.77	372			
4	39.0	9.81	286			
5	18.0	9.78	285			
6	63.0	6.76	157			
7	51.0	6.69	155			
8	45.0	6.55	191			
9	33.1	5.90	172			
10	89.2	4.19	122			
11	46.0	3.71	188			
12	90.2	3.64	106			
13	50.0	3.60	105			
14	17.0	3.47	101			
15	32.0	0.27	8			
16	28.0	0.00	-37			

PROBABLE COMPOUND IS TOLUENE
P.F. = 1.0
COMPOUND ID# 203
PRIORITY POLLUTANT- N

Fig. 3. Normalized and sorted data from the graph in Figure 2.

software package to identify compounds locally on the 4051, using the 4907 as the standard compound library. The result is a successful and pleasing system with local control and vastly increased speed and productivity.

System Capabilities

The system has two primary capabilities. One is its ability to collect multiple scans from the Mass Spectrometer, then search for known compounds to match each scan. The other is positive compound identification obtained by plotting retention time versus ion current.

To search for compound matches requires a library of standard compounds. The library for this system was created by storing the scans from a standard sample kit, on the 4907 File Manager. (The fact that this method of locally storing a standard library which reflects the characteristics of a given system is an added benefit.)

Searching for compound matches, in its purest sense, is quite simple. It requires taking the five most intense mass numbers from a scan, then searching through the standards library for a match of those numbers. This search can require thousands of iterations, but can be performed locally, with the 4907 in place, in a fraction of the time previously required.

During a search, the system will display the hit factor (5 out of 5, 4 out of 5, etc.), probable compound name, number, and priority pollutant for each of the run scans (Fig. 4). Optionally, the system will attach this information to the scan, so the scan can be replotted with the

found compound information appearing on the graph.

Plotting retention time versus ion current for any three mass numbers is a powerful tool for positively verifying the compound identification. With this routine, any three

```

ENTER YOUR FILE NAME FOR THE SEARCH F597
THERE ARE 10 SCANS IN THIS FILE

SCAN# 3 FOUND 5 OUT OF 5 : COMPOUND- 202N BENZENE
SCAN# 4 FOUND 5 OUT OF 5 : COMPOUND- 203N TOLUENE
SCAN# 5 FOUND 5 OUT OF 5 : COMPOUND- 204N XYLENE
SCAN# 6 FOUND 5 OUT OF 5 : COMPOUND- 205N PHENOL
SCAN# 7 FOUND 5 OUT OF 5 : COMPOUND- 206N OCRESOL
SCAN# 7 FOUND 3 OUT OF 5 : COMPOUND- 207N PCRESOL
SCAN# 8 FOUND 5 OUT OF 5 : COMPOUND- 207N PCRESOL
  
```

Fig. 4. Hard Copy output of the search for compounds on a run file.

mass numbers can be selected for plotting during the entire run. The desired retention time can then be set to tabulate the ratio of intensities between those three mass numbers at that retention time (Fig. 5). The three mass ratios and the associated retention time verifies the probable compound identification.

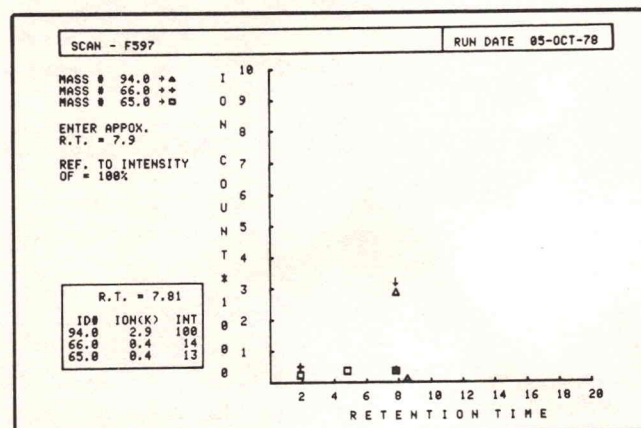


Fig. 5. Graph of retention time versus ion current for three mass numbers.

There are many other useful capabilities in the system, such as multiple background correction to compensate for column conditions. Also, any amount of mass numbers can be deleted from a run before any calculations are initiated, to clean up any bad samples that may have occurred. Data for each run can be stored on the disc for a run library and can be changed or deleted at any time. There are also utility commands for directories, automatic hard copy and disc to disc transfers.

The key to the successful operation of this system resides in the power of the 4907 File Manager coupled with the versatility of the Solver One system interface. They have made possible a desk-top Gas Chromatograph/Mass Spectrometer system, with data reduction and analysis, that produces desirable results at one-third the cost of a mini-based system. And the two or three days have been reduced to about twenty minutes, with a 4051 and a 4907 at the system's heart.

Science Fair Goes to Space: 4051 Helps

by Terry Davis

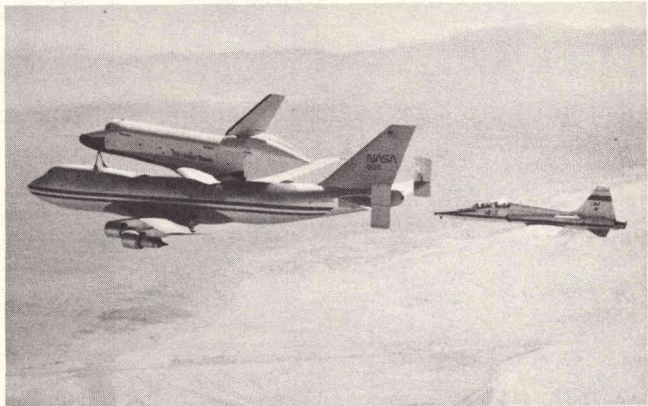
NASA's space shuttle flights, beginning early in the 1980's, will transform costly and complex space missions into routine, economical operations. The hybrid orbiter portion of the space shuttle lands like an airplane after its orbiting missions, to be checked out and launched again. The orbiter's huge cargo bay can carry heavy loads into space and bring them safely back again, landing on a three-mile strip. The many possible uses of such facilities stretch the average imagination. One early entry into the program, however, is the project of a 16-year old high school junior whose scientific interest and imagination made him a natural participant in the space shuttle project. And the 4051 is helping him on both ends of the project.

Beginnings

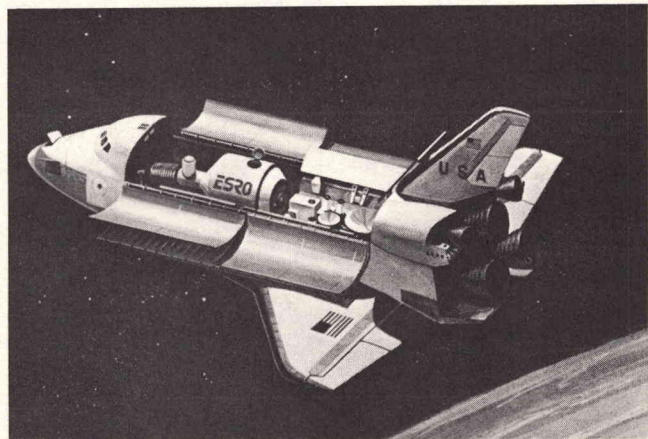
Bob Wheeler has long been interested in science. The sixth grade found him programming simple computers. In junior high his teachers allowed him an extra period to do science research, and by the ninth grade he was teaching science to seventh grade students. During this time, Bob did lots of self-imposed research, along with science fair projects. His last science fair project was measurement of lunar mountains—which placed fourth in the General Motors International Science and Engineering Fair at Anaheim, Calif. So research beyond the bounds of earth isn't new to him.

In the tenth grade, three busloads of high school students from the Ogden, Utah, area went to Edwards Air Force Base in Southern California to watch space shuttle tests. Bob was in one of those buses and was immediately fascinated by the shuttle project, from the expanding tile heat shields to the computer-assisted flight. Now Bob is sixteen years old and a junior at Weber High School in Pleasant View, Utah. He's well on his way to producing a programmable microprocessor-controlled experiment for one of the early space shuttle orbital flights.

A parallel factor in Bob's space shuttle involvement is a North Ogden neighbor, R. Gilbert Moore. He works at Thiokol, the manufacturer of the two solid-fuel space shuttle motors. When engineers at NASA decided to offer for sale portions of the so-called "get-away space," the empty test flight payload area, Moore took an immediate interest. He reserved several of these cannisters, and offered one of them to Weber High School, where his son is also a student. Dr. James West, Science Coordinator, and Earl H. Heninger, Environmental Center Director, of Weber School District, teach advanced placement science courses at Weber High School. They immediately saw the opportunity for Bob to exercise his science and programming skills, and realize some of his fascination with the



Space Shuttle Orbiter and 747 Carrier Aircraft. (Reprinted from NASA JSCL-157 (U.S. Government Printing Office: 1977 774-457))



Shuttle Orbiter Carrying Spacelab. (Reprinted from NASA JSCL-133 (U.S. Government Printing Office: 1975 671-191/6))

space shuttle program. With their encouragement, Bob started thinking about a project.

Getting Started

During June of last year, Bob attended a Space Shuttle Mini-Conference at Utah State University. There he and the other attendees were told of the requisites for a space shuttle project. Bob took particular note of NASA's Ernie Ott, who explained, "One of the biggest problems will be designing a controller to coordinate the timing and logic of the experiments." Having some experience in digital design and in programming, Bob began to think of a hardware timer as a project controller.

Two weeks after the Space Shuttle Mini-Conference, Bob was back at Utah State University for a National Science Foundation Summer Science Training Program. There Bob found a 4051 Graphic System in the math depart-



Bob Wheeler, North Ogden, Utah, hopes to find the origin of cosmic rays. To accomplish this mission, he's sending a 4051-developed project along on one of the early space shuttle flights. At the left is John Hess, Tektronix Sales Engineer, who aided Bob in getting the kit to build the controller.

ment, and got permission to use it. (Having previously read 4051 pamphlets, he was anxious to try his hand.) He and a friend, Dale Sather, spent all of their spare time during the six-week conference developing programs on the 4051. Bob says, "As with most people who are introduced to the 4051, we were convinced of its capabilities after using its powerful BASIC and excellent graphics." Bob and Dale even worked their class projects on the 4051, so they'd have more time for their own 4051 application projects.

One of their projects was a simulation of Apollo from lift-off to splash-down; this was a natural with their mutual interest in computing and Bob's love of astronomy. Working closely, Bob and Dale read up on Apollo, researching facts about the mission. Then they designed a model, a simulation of an entire Apollo flight. This effort taught the two programmers every 4051 BASIC command. They even looked at the System Software tape code to see how operations were performed, and used what they learned to speed up their own graphics operations.

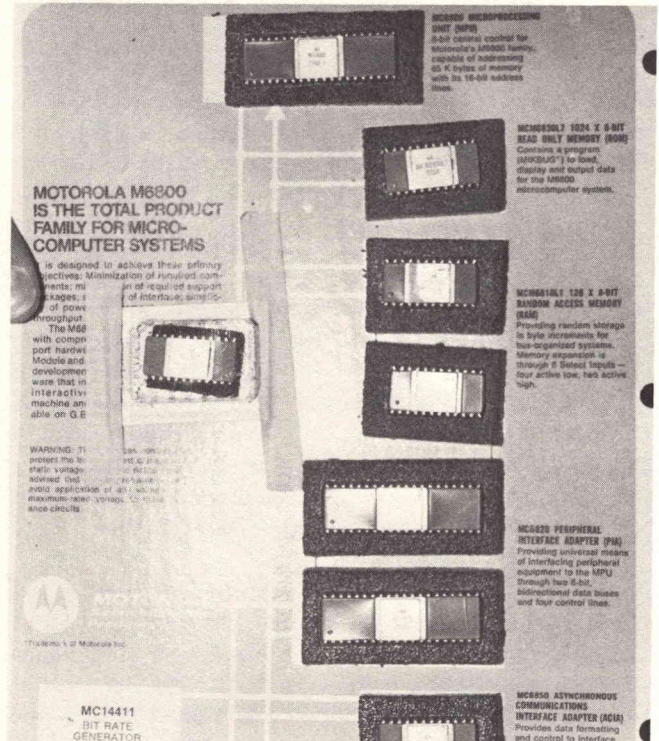
After learning that the 4051 was designed around the M6800 microprocessor, Bob wanted to know more about the 6800. For the next two months he read about the 6800, and studied 6800 Assembly Language. He soon decided that the flexibility of the 6800 made it a much better candidate for the heart of his project, and it replaced his hardware-timer idea. Then John Hess, a friend who works at the Tektronix Field Office in Salt Lake City, got together with Transera Corporation to donate a Motorola 6800 Evaluation Kit. Bob suddenly found himself with the parts he needed to build a 6800-based controller. His project was really under way!

More for the 4051

Bob was disenchanted with the time necessary to program the 6800 using its own hex code, so his next step was developing an assembler for the 6800. Again obtaining the use of a 4051, Bob developed his own assembler; most of it was developed in his room at home over Christmas vacation. The assembler runs on the 4051 and, through a special ROM, loads the 6800 controller memory with assembly-language programs. This lets Bob use the power of the 4051 and the small size of his 6800 processor for his space shuttle project.

Refining the Project

Bob soon began to feel that simply flying a working controller would be an opportunity missed. He began to think of a project that the processor could control, to examine some astronomical phenomena. Bob talked to the Electrodynamics Laboratory at Utah State University and found them willing to help design a cosmic ray detector for the project. So he began to plan a method of using his 6800-based controller to gather cosmic ray data. In the meantime, he thought there must be a way to reduce the size of the 6800 board. He called Motorola who put him in touch with Erwin Carroll at the Motorola plant in Houston. Carroll is now working with Bob to refine his controller for use with the cosmic ray detector.



The Motorola 6800 Evaluation Kit has provided Bob with the parts for his project's controller. The MIKBUG ROM loads his microprocessor with hex code sent over the RS-232 from the 4051.

The detector will fly with the experiment, delivering an analog signal proportionate to the number of cosmic rays striking its surface. This signal will be fed to an analog-to-digital converter; the digital equivalent is then relayed to the 6800. The 6800 will record the cosmic ray intensity

data on a small magnetic tape unit, along with the time of the sensor readings. This data will then be analyzed, after the orbiter returns from its mission.

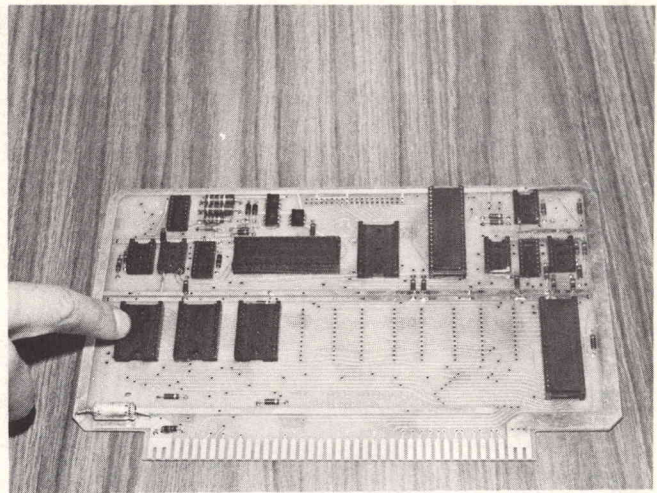
*** TEKTRONIX 4051 / M6800 ASSEMBLER OBJECT PROGRAM ***		
MEMORY ADDRESS (HEX)	MEMORY CONTENTS (HEX)	INSTRUCTION (MNEMONIC)
0000	97 34	STAA #34
0002	86 23	LDAA #23
0004	1B	ABA
0005	1B	ABA
0006	3F	SHT
READY		

To overcome the frustrations of programming in hex code, Bob developed his own assembler on the 4051. He inputs to the 4051 in mnemonic code which the 4051 segments into hex, and transmits to the 6800 microprocessor in the controller.

While the experiment is in operation, the space shuttle orbiter will be pointed in several directions. Thus readings will relate to the many directions, or points in space. After the mission, NASA will publish a report showing where the orbiter was pointed at any given time. Since the tape recorder will have intensity data recorded along with reading time, the position information can be easily extrapolated. The time and intensity data will be used as input to the 4051, which will analyze the data and provide graphic analysis. The hope is that the graph will show the general direction of cosmic ray origin in space.

The 6800 can handle several different sensors at once. Therefore, Bob plans to fly five or six experiments; he's designing additional projects with the help of the Electrodynamics Laboratory. The versatility of the 4051 Graphic System will allow Bob to look at the data in several different ways.

"So," Bob says, "the 4051 is really the main show." It will



Bob indicates where his first ROM will plug into his controller. Following this will be other ROMs and some RAMs. When NASA flips the switch on his controller, it will jump to the first address in this ROM and begin the program controlling his experiment.

help develop the programs easily and quickly, and will convert them to machine language for the 6800. The 6800 microprocessor, also the 4051's heart, will control the experiment in flight. (Bob notes that the 6800 will not only control his experiment, but will branch to sub-routines to service others' experiments.) And after the Space Shuttle flight returns, the 4051 will analyze the data and provide a detailed graphic analysis.

Scheduled for Space Shuttle flight number seven, the Weber High cannister, with Bob's controller, will fly early in the 1980's. When it returns, TEKniques will be there to cover the conclusion of this ambitious project.

Automatic Data Handling of Uranium Analysis for the NURE Program

by Stanley T. Kosiewicz
Los Alamos Scientific Laboratory
Los Alamos, NM



Fig. 1. The Tektronix 4051 Graphic System is the controller in the automated system which analyzes pelleted samples for uranium. A fluorometer modified to include a digital voltmeter (left), and a printer/storage terminal (right) complete the system.

Since 1975, the Los Alamos Scientific Laboratory (LASL) has been participating in the National Uranium Resources Evaluation (NURE) program. In that program, three laboratories are assessing the nation's potential uranium resources. LASL's responsibility area has been the Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) of New Mexico, Colorado, Montana, Wyoming, and Alaska. The other laboratories involved in the program, Oak Ridge Laboratories in the middle west and Savannah River Laboratory for the east and west coast, are performing similar studies.

Evaluating Samples

Scientists collect samples throughout the subject area. In the contiguous United States, a sample is collected every four square miles, while in Alaska a sample is collected for each 10 square mile area. The samples are then sent to the laboratory for analysis. At Los Alamos Scientific Laboratory the pellet fluorometric method determines the quantity of uranium in the sample. The method works like this: Water samples are gathered in the field for testing. These samples are dried under a heat lamp, and the resulting deposit is mixed with a matrix of lithium fluoride with sodium fluoride. This mixture is placed in a platinum cup and fused to make a pellet. Subjecting the pellet to ultraviolet light produces a fluorescence which can be measured by a fluorometer. The amount of fluorescence in the pellet is proportionate to the amount of uranium in the original sample. LASL processes about 38,000 samples per year by this method.

At the start, the analyses were done by hand. Sample readings from a fluorometer were written down on paper. When enough readings had been recorded, a technician processed them using a desktop calculator. The result was usable data on sample concentrations that could then be compared against rejection criteria. Data was later transferred to a host computer for storage. Manual processing of the analytical data for these samples demanded a lot of time and labor. Additional effort was required to check the accuracy of data collected in this manner.

Now an automated system controlled by the 4051 records the data and analyzes the readings quickly and easily, with less chance for error. The system is interactive; instructions to the operator are displayed on the 4051 screen.

The 4051 is interfaced with a fluorometer to obtain readings from the test samples; the interface occurs through a controllable digital voltmeter connected to the 4051 through the GPIB. The digital voltmeter samples the signal generated by the fluorometer upon command from the 4051 Graphic System.

After blanks, controls, standards, and sample pellets are read, the 4051 performs a least squares calculation to make a concentration curve. The uranium concentrations of all pellets read are then tested against all rejection, precision, and diagnostic criteria in the current water analysis laboratory guidelines.* Subsequently, the concentrations and diagnostics (if any) are transmitted over the RS-232 interface to a terminal for printing. If a set of samples has not been rejected, the sample identifications and concentrations are transferred directly to a magnetic tape cassette, where they are available for additional processing. Data are stored on a host computer, and are available to the public for uranium mining research.

Equipment Configuration

The following items, shown in Figure 1, were used to automate the data acquisition and processing.

- (1) Fluorometer. A Jarrell Ash 26-000 fluorometer was used, with the meter replaced by a digital voltmeter. Positive output is taken from pin 2 of the DVM, while negative output is taken from pin 10. The fluorometer DVM reads in millivolts.
- (2) Digital Voltmeter. The signal from the fluorometer is transmitted to a Fluke 8500 A DVM equipped with an optional IEEE-488 (GPIB) interface. Two DVMs are connected to the 4051. The DVMs are remotely controlled through an address of 1 or 2. The

*A Los Alamos Scientific Laboratory internal document.

instruments are operated in a dc volts mode with a maximum range of 312.5 mV. This range will never be exceeded under any conditions to be encountered in trace uranium analyses of natural waters.

- (3) **Computing System.** The Tektronix 4051 Graphic System, equipped with an RS-232 optional interface and 16K memory, processes the signal from the Fluke DVM. Using the graphic display, the computer asks questions of the technician and also displays the technician's responses entered from the keyboard (Figure 2). The BASIC language computer program is stored on the 4051's internal magnetic tape. The 4051 commands the Fluke DVM to sample the fluorometer signal and subsequently to send the data to the 4051 for processing into concentration data. The data are then sent to a TI 733 terminal, which is used merely as a controllable typewriter and tape recorder.

```

ENTER SAMPLE NUMBER
339299
IS THIS SAMPLE A CONCENTRATE? 1 FOR YES, 0 FOR NO.
0
LOAD FIRST PELLETT FOR 339299 HIT RETURN WHEN READY TO READ
*****WHAT FLUOROMETER SCALE WAS USED? .01 OR .1?*****
.01
31.729
LOAD SECOND PELLETT FOR 339299 RETURN WHEN READY TO READ
31.795
DO YOU WANT TO REPEAT THIS SAMPLE?
SAMPLE=339299
TO REPEAT TYPE 1. TYPE 0 TO CONTINUE.

```

Fig. 2. The operator interacts with the system through instructions displayed on the 4051 graphic screen.

- (4) **Hard Copy Terminal.** A Texas Instruments 733 ASR terminal prints the concentrations and also records them on a magnetic tape cassette. The terminal is remotely controlled through the RS-232 interface using an address of 40. Upon command from the 4051, the terminal prints the concentrations (Figure 3). Then only acceptable data that are within established analytical guidelines are recorded on the terminal's magnetic tape cassette, again upon command from the 4051. In addition, data from the TI 733 terminal can be sent to the LASL Central Computing Facility over the RS-232, via an acoustic coupler.

A continuing check of field water samples compares the 4051-generated data against that obtained manually with a desktop calculator. Comparisons made on more than 500 samples so far demonstrate excellent agreement between the two methods. Figure 4 displays uranium concentration data from 60 samples processed using a desktop calculator versus data obtained "automatically" using the 4051 system. The barely-visible dashed lines in the graph are the 95% confidence limits.

Conclusions

The automated data acquisition and processing system decreases labor, saves time, and eliminates manual errors

in computation. Manual keypunch operations previously required to transmit data to the Central Computing Facility are eliminated resulting in large additional time and labor savings.

```

TODAY'S DATE IS 10-31-78
BLANK AV. = 0.0280 PPB
1 PPB CONTROL = 0.51 PPB
1 OPFB STD = 9.97 PPB

SAMPLE = 339270 U PPB = -0.131
PELLET 1 = -0.136 PELLET 2 = -0.126
CONCENTRATE NEEDED***

SAMPLE = 339271 U PPB = 0.112
PELLET 1 = 0.226 PELLET 2 = -0.003

SAMPLE 339273 U PPB = -0.095
PELLET 1 = 0.027 PELLET 2 = -0.217
CONCENTRATE NEEDED***

SAMPLE = 339274 U PPB = 1.155
PELLET 1 = 2.085 PELLET 2 = 0.226
SAMPLE REJECTED***

SAMPLE = 339276 U PPB = 1.339
PELLET 1 = 1.429 PELLET 2 = 1.248

SAMPLE = 114009 U PPB = 15.04
PELLET 1 = 22.32 PELLET 2 = 7.75
TO BE REPEATED BY P-2****

```

Fig. 3. Computer-analyzed concentrations are printed at the terminal.

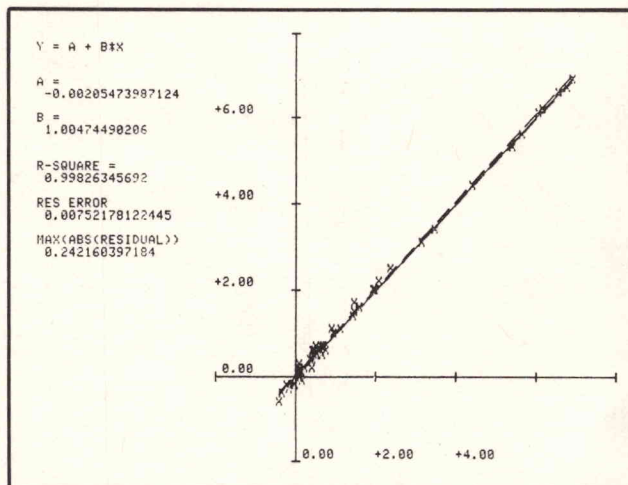


Fig. 4. Uranium concentrations obtained manually for 60 samples demonstrate excellent agreement with those obtained for the same 60 samples through the automated system.

Finally, sample throughput may also increase since the technician operator knows immediately whether a sample or set of samples must be repeated. Operator satisfaction appears to have increased because of the smoothness and simplicity with which they interact with the 4051 Graphic System and the immediate feedback they receive from it.

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