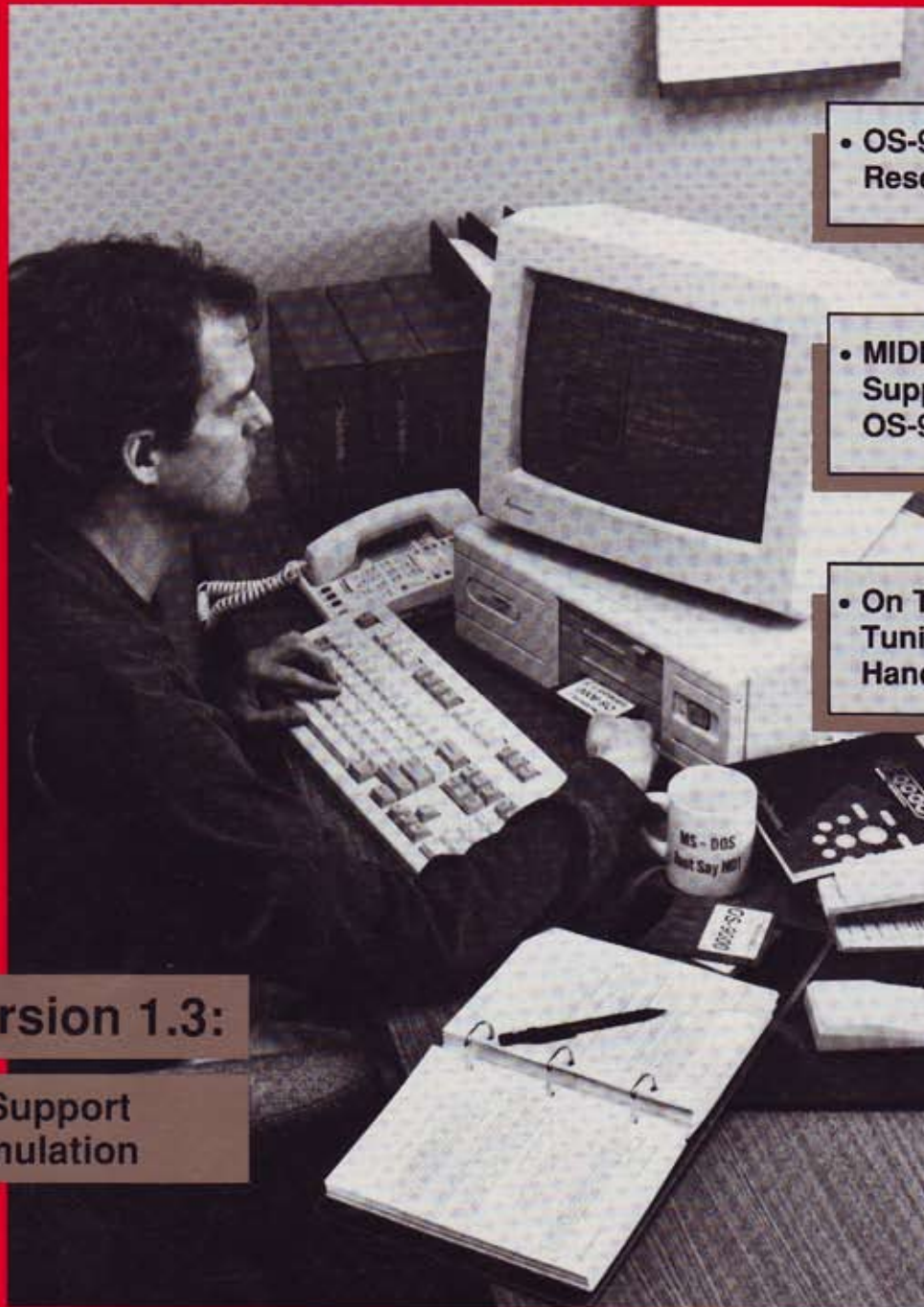


PIPELINES

Volume 7 Number 2

Covering Microware's Real-Time System Solutions

Spring 1992



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OS-9000 Version 1.3:

Featuring Support for DOS Emulation

microware

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On The Cover

Version 1.3 of the OS-9000 Real-Time Operating System for 386/486 PCs provides an automatic **Install** utility and Virtual PC (VPC) for DOS emulation. See story at right for details.

Cost-Efficient Alternative for the Future



Ken Kaplan,
Microware's President

THE AFFORDABLE PRICE, EXTENSIVE PERIPHERAL support and huge number of DOS applications have made PCs an extremely popular computing platform for industrial control and factory floor automation. However, system integrators have been faced with the difficult task of trying to adapt their DOS-based systems to handle these demanding real-time situations. But with Microware's OS-9000 for 386/486 PCs, system integrators have a solution that takes full advantage of the PC's processor power for their real-time applications.

This has some important implications for our customers, both OEMs and end users. It means that system integrators—particularly those who have specialized in VME hardware—have an additional, lower cost

NEW PRODUCT

OS-9000 Version 1.3 Includes VPC for DOS Emulation Support

MICROWARE ANNOUNCES THE RELEASE OF Version 1.3 of the **OS-9000 Real-Time Operating System** for 386/486 PCs. This release introduces Microware's new **Virtual PC (VPC)**, OS-9000 system enhancements and an easy-to-use, fast **Install** program.

VPC for DOS Emulation

OS-9000 V1.3 includes VPC, a DOS emulation program that supports execution of DOS tasks under OS-9000. Now programmers can run OS-9000 and DOS tasks concurrently, including Windows 3.0, on the same 386/486 PC/AT. OS-9000 with VPC provides a powerful environment that allows users to run their favorite DOS program for editing, displaying or post-processing alongside OS-9000.

VPC is easily invoked as a user state OS-9000 module to execute DOS and DOS tasks. The module emulates the DOS BIOS from OS-9000 system RAM for fast execution of all DOS I/O requests. VPC runs as a standard OS-9000 task allowing DOS I/O and user-installed interrupt handlers to execute within the OS-9000 unified I/O system. This allows OS-9000 and DOS applications to share devices simultaneously and provides an efficient means to transfer data between the two operating systems. DOS formatted diskettes, as well as hard disks and partitions, can be read and written through both OS-9000 and DOS commands.

DOS In The OS-9000 Environment

The ability to share devices and transfer data also means that applications under

alternative for future real-time hardware offerings.

This is also welcome news for those engineers who may have been forced to use PCs running DOS for real-time applications. One PC running OS-9000 can serve as a real-time platform performing multiple tasks simultaneously. No longer will engineers have to add a new PC board for each process in their applications.

OEMs are already adding PC platforms to their product lines. In this issue of *PIPELINES*, we've included a story about one Irish firm that has begun offering their OS-9 VME industrial control package under OS-9000 on 386 PCs. B. McDonnell recognized the opportunities available in the DOS market by providing their VME-bus 680X0-based package on a PC platform. This represents the spirit with which Microware developed OS-9000.

The latest release of OS-9000, detailed below, is exciting for us as well. The addition of OS-9000 Virtual PC (VPC) gives OS-9000 users the ability to run DOS and DOS applications under OS-9000. This puts familiar tools in the hands of DOS users. Plus, it offers a tight integration of DOS and our OS-9000 Real-Time Operating System on a single PC platform.

OS-9000 represents a continuing effort by Microware to bring powerful real-time solutions to a broader range of computing platforms. Microware wants to allow users to select the hardware that best meets the needs for their real-time application. It's all part of our on-going commitment to provide state of the art real-time software to our customers.

—Ken Kaplan

Mike Burgher Named Vice President of R&D

IN MID-MARCH OF THIS YEAR, MICROWARE named Mike Burgher as the new vice president of research and development. A native of Des Moines, Mike joined Microware in 1987 as technical director of the then-new Western Regional Office (Santa Clara, California). Before coming to Microware, Mike spent ten years with Control Data Corporation (Los Angeles and San Jose, California) where he specialized in operating systems, networking and performance analysis.

In 1990, Mike took over as manager of the Western Regional Office. While there, he oversaw the development of PCBridge and OS-9/N.F.S., and the porting of the POLYTRON Version Control System, as well as OS-9/Force product development.

Mike holds a Bachelor of Arts degree in political science from Drake University (Des Moines).

Looking to the Future

"There are two keys to Microware's continued success: quality and industry standards," stated Mike. "This means putting quality first in every product we ship. This also means supporting established and emerging standards such as POSIX, IEEE 695, ISDN, CD-I and MPEG." MSG



Mike Burgher, vice president of R&D at Microware.



OS-9000 Version 1.3 for 386 and 486 PCs includes Virtual PC (VPC) for DOS and DOS application emulation. This new version also includes an easy-to-use installation program.

each operating system can interact with one another. Under this scenario, OS-9000 could be used as a real-time data acquisition back-end that collects data from and provides control over a series of industrial controllers. Data from these controllers could be preprocessed and ma-

nipulated by OS-9000. DOS could run on the same 386/486 system and collect the necessary data from OS-9000 to provide a graphics front-end for trend display and user control of the low-level controllers.

OS-9000 Version 1.3

Please turn to Page Eleven

OS-9 in Underwater Research

by Douglas Humphrey
Massachusetts Institute of Technology,
Charles Stark Draper Laboratory, Inc.

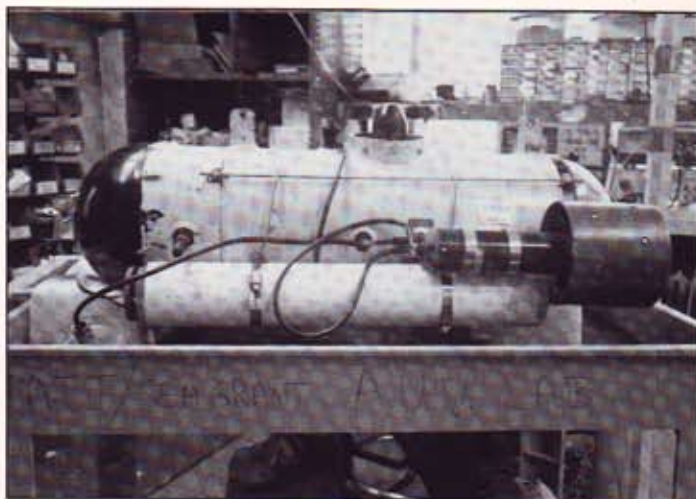
THE UNDERWATER VEHICLES LABORATORY of the Sea Grant College Program at the Massachusetts Institute of Technology (Cambridge) with support from The Charles Stark Draper Laboratory, Inc. (Cambridge) is actively conducting research into small, affordable, autonomous underwater vehicles. One of the key enabling technologies for this class of vehicle is the software which allows the vehicle to successfully complete a specified mission in the uncertain underwater environment without human intervention. The laboratory has one operational vehicle, *Sea Squirt*, with two more under construction.

OS-9, with its pre-emptive multi-tasking capabilities, flexible configuration, modest memory requirements and its many methods of interprocess communication, has proven well suited to this task. The vehicle software runs on a GESPAC MPU-20 system (16 MHz 68020 with 512K RAM) currently in a diskless configuration, although a SCSI hard disk drive is being added.

The vehicle software can be divided into three major functional groups with different needs regarding time scheduling. These groups are sensory data acquisition, vehicle control and mission planning. In order to achieve good command following, the vehicle control algorithms are designed to be executed five times each second, and since new data is required each time, the data acquisition process must also execute at this rate. Mission planning processes operate with a longer time horizon and can be scheduled less frequently.

Sensory data acquisition is a single process which reads from both a serial port

The *Sea Squirt* (top) is a hardware and software testbed for autonomous underwater vehicle research. Two production models are under development. The *Odyssey*—one of the production models—is shown open (bottom) to expose its OS-9 68020 system.



and an analog/digital converter. The raw data is then processed and the results placed in a memory module for use by the other processes. The event mechanism is used to indicate that new data is available. This process then sleeps until it is time to run again. The time requirement is met by assigning this task a high priority so that when it wakes it will run without interruption from planner processes.

The vehicle control process wakes up upon detecting the new data event. It reads data from the data memory module and commands from the planner memory module. The control algorithm then calculates actuator settings and makes the necessary adjustments to the vehicle hardware. The control process then sleeps until the next new data event.

OS-9, with its pre-emptive multi-tasking capabilities, flexible configuration, modest memory requirements and its many methods of interprocess communication, has proven well suited to this task.

Mission planners are built with one process per planner, with provisions made for multiple planners to be running concurrently. The planners are not synchronized to the new data event, but execute at a rate determined by the type of planning being done. The planners read from the data memory module and write the results of their planning into the planner data module. A priority-based arbitration scheme then decides which of the competing planner outputs are delivered to the vehicle control process for action.



One of the advantages to this type of software structure is flexibility. Configuring the vehicle for a mission is accomplished by loading the necessary planners along with the control and data acquisition software. Changing the mission only requires loading a different set of planners.

Another advantage is in software development. The source code for each process is compiled and linked separately from all others, so a new planner or control algorithm can be written and tested without affecting the source code to other processes. This reduces the possibility that a new function will introduce errors into existing, debugged code.

OS-9 provides the tools which allow us to concentrate on building intelligent behavior into autonomous underwater vehicles in a way which is largely independent of the underlying processor and vehicle hardware.

Douglas Humphrey is working to complete his Ph.D. in mechanical engineering at the Massachusetts Institute of Technology (Cambridge). Doug holds a Master of Science in mechanical engineering from MIT and a Bachelor of Science in mechanical engineering from Bucknell University (Lewisburg, Pennsylvania).

Microware Announces MIDI and CD+G Support

by Eric Miller
Microware Systems Corporation

MICROWARE HAS RECENTLY RELEASED TWO new products for consumer-oriented OS-9 computer systems, such as CD-I and the MM/1. The first is support for the Musical Instrument Digital Interface (MIDI). The second is support for the CD+G standard of encoding "low-bandwidth" graphics on ordinary music discs.

MIDI Support

The OS-9 MIDI system is implemented as an advanced SCF (sequential character file manager) driver for OS-9. Its basic features include support for all MIDI 1.0 File Formats, System Exclusive Events, System Real Time Events and a software MIDI Thru feature.

For "smart" applications, the MIDI control features of the driver are transparent. It will support the common set of SCF I/O functions including *ISRead*, *ISWrite*, *SS_Sig*, *SS_Rdy* and *SS_Rel*. In this mode, the application is responsible for all of the data timing and running status management.

However, by setting the driver into "MIDI Message" mode, the driver becomes an intelligent MIDI processor. In this mode, the driver essentially functions as a 32-track digital tape recorder. One track may be specified as the recording track and any combination of the other tracks

may be specified as output tracks.

The driver manages running status within each of the tracks as well as at the output stage to create the most efficient data stream. On input, the data is time-stamped and placed in a special message buffer, where it is later processed and put into the actual recording buffer.

All play, record and overdub functions of the driver are handled asynchronously. This gives the application the ability to concurrently perform graphics or other operations while the song is played.

The MIDI Thru function is a unique addition to the driver which will echo any input at MIDI In to the MIDI Out port. Unlike the standard *echo* function of SCF, a *Read* does not have to be pending to echo the input. Additionally, there is the issue of merging this input with any output generated by an active *Play* function. MIDI messages must be kept intact, along with the correct running status information.

Applications for the MIDI System

Applications for OS-9 MIDI fall into three categories. First is the playing of pre-recorded MIDI songs. Companies such as Passport Designs (Half Moon Bay, California) have thousands of popular songs recorded in MIDI format. Professional and amateur musicians alike have

found these products very useful for practicing or even performing.

The second category is music education. Today, even very inexpensive synthesizers come equipped with MIDI jacks. This means that the computer could actually "listen" to the notes that are played and suggest ways to improve. By a creative use of lesson plans and games, children can learn to play keyboard instruments very rapidly.

The third category of application is composition. Professional musicians and serious hobbyists spend hundreds of thousands of dollars every year for computer-based MIDI sequencing programs on Macintosh, Amiga or Atari computers. By providing a standardized package of software for OS-9- and CD-I-based systems, we open up the market for these systems to compete there as well.

CD+Graphics Support

The CD+G *Graphics Display Library* is designed to interpret and display CD+G data for CD-I systems. The CD+G standard describes a way to store a small amount of data in the subcode area of standard CD-DA audio discs. Effectively, this amounts to about 7K of data per second.


At this resolution, it takes about eight to ten seconds to reconstruct a full-screen image. Other graphics commands allow scrolling of the image, changing the border color and changing the CLUT contents for the images.

Because there may be up to 16 different channels of information in the CD+G data stream, we also provide mechanisms for choosing which channels should be active. Although few discs, if any, really make use of these different channels, they were designed so that song lyrics could be displayed on the screen in many different languages.

For more information on either of these extensions, contact Microware or your authorized Microware representative.



The MIDI Jukebox CD-I disc from Passport uses Microware's MIDI support to play back prerecorded MIDI songs.

Eric Miller is the director of Microware's Multimedia Group and the co-author of *Discovering CD-I*. 



Using OS-9 in Space, Atomic Research

TWO FRENCH ORGANIZATIONS ARE CURRENTLY USING OS-9 IN ADVANCED SYSTEMS. AETA HAS DEVELOPED A SYSTEM USED IN SPACE VEHICLES TO TEST AN ASTRONAUT'S ORIENTATION FACILITIES. ESRF USES OS-9 SYSTEMS TO COLLECT DATA FROM AND CONTROL EXPERIMENTS ON THEIR PARTICLE ACCELERATOR.

Testing Orientation in Space

AETA (Applications Electroniques des Techniques Avancées, Fontenay aux Roses, France) was founded in 1978 to design, develop and manufacture special purpose electronics for the aeronautic/space industry. AETA provides these specialized products for international space organizations and private companies including Aerospatiale, CNES (Centre National D'Etudes Spatiale for both itself and NASA), CNRS (Centre National de Recherche Scientifique), Matra and Mors (for Boeing).

AETA has developed for the CNES, and under the responsibility of the CNRS, the system **Viminal 92**. This project is part of the long-term cooperation with the former Soviet Union and using the Russian Progress-Mir-Soyouz system for the Antares 92 project.

An astronaut sits at AETA's Viminal 92 (above right) to test for disorientation while in a zero-G environment. The astronaut must respond to images projected by the system. A close-up view (below right) shows the 68030-based system.

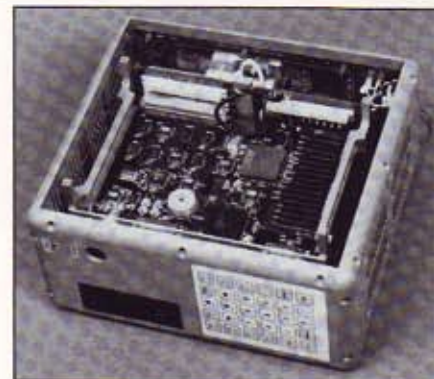


Viminal 92 was developed to test the neuro-sensorial reactions of pilots while under zero gravity conditions.

In a zero-G situation, one can observe a modification after four to five days of the otolithic functionality. The information derived from the otoliths corresponds to a free fall situation, which in terrestrial conditions is accompanied by rapid visual movement.

Under zero-G conditions, the absence of convergence of these two sensorial inputs creates a conflicting situation for the central nervous system, which has to try and cope with rearranging the sensorial inputs.

The experiment essentially consists of showing a series of images to the astronaut taken from one of three catalogs of scientific objectives (OS1 to OS3). The



response time and the time between each image is then measured.

In OS1, for example, the response concerns the perception of the similarity or difference of two objects in an image.

The system is built around a VME crate, containing a 68030 CPU card with a 68882 FPCP, and a QPDM-based graphics card. This computer is connected to the monitor module, which consists of the graphics monitor and optic tunnel fixed to the test seat.

On board the Mir station, the astronaut is strapped onto the seat with the optical tunnel between his eyes and the graphics monitor.

The Viminal 92 software contains three experiments for the astronaut. Each of these experiments consists of two parts:

- The parameterizing of the experiment, allowing the generation of different types of stimuli depending on the different scientific criteria, and variables such as the



Aerial view of the Storage Ring at the European Synchrotron Radiation Facility. Photo provided by Arnaud Childeric, Les Studios Canubis (Grenoble).

length of the test, size and number of stimuli, etc.

- The actual test, executed as described in the first section, with the results written to flexible disk.

The software takes up 200K in memory, and was written under OS-9, principally using the C language, except for some interrupt routines in assembly language.

Monitoring Atomic Research

ESRF (The European Synchrotron Radiation Facility, Grenoble, France) commissioned its main 850 meter (2,805 foot) Storage Ring on February 15, 1992. The operators manipulate and monitor experiments in this particle accelerator with a hardware and software package called the **Machine Control System**.

The Machine Control System is comprised of four functional layers of hardware under the control of OS-9 and HP-UX. The first layer of hardware includes monitoring devices that are connected to a series of VMEbus systems—the second hardware level. These OS-9 VMEbus systems are built around 20MHz 68030 CPUs with 4M RAM and on-board Ethernet controllers. The OS-9 systems gather data from the monitor devices either directly or from ESRF's proprietary FBUS network.

The top two layers of hardware are comprised of Hewlett Packard UNIX workstations. One set of workstations is dedicated to application processing. The other set is used as X Window graphics consoles. These top layers receive information from the VME systems via Ethernet using OS-9's **Internet Support Package** and **Network File System**.

The ESRF Controls Group has implemented a device server model that allows users to transparently access low-level devices using a set of three C language calls. Each device is treated as an object that belongs to a particular class. Classes represent the different types of devices that share common code and variables. This device server model has proven useful in implementing device access for many different kinds of devices with various physical interfaces.

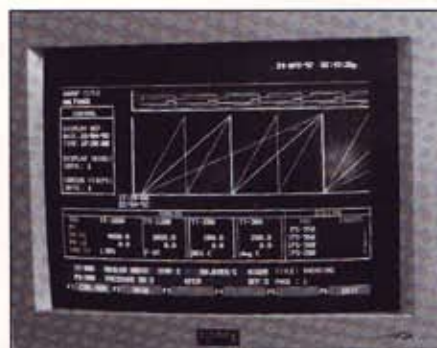
Editor's Note: The ESRF information is from two papers by Mr. Klotz and Mr. Götz of the Controls Group at ESRF. MSC

Industrial Control Package Migrates from OS-9 to OS-9000

by John McDonnell
B. McDonnell Limited

B. McDONNELL LIMITED (DUBLIN, IRELAND) was presented with the challenge of developing a PC-based system that would provide monitoring, bar graphs, alarm management and trending in real time with data handled simultaneously. The data was to be received from a number of programmable logic controllers and other intelligent devices, all of which would be from different manufacturers.

The effectiveness of OS-9000 in providing an operating system capable of efficiently meeting this specification has been demonstrated by a software package developed for the mid-range user in process industries. **INPLANT** was originally developed and proven for VMEbus-based computers running OS-9. **INPLANT** was completely updated and brought over to OS-9000 when it was clear that available IBM-compatible hardware had reached the level of performance which would support such a powerful package. Now running on a 40 MHz 80386 platform, performance is as good as it ever was on the VME platform. And there is a clear upgrade path, together with access to the large range of peripheral hardware.



B. McDonnell's **INPLANT** is an OS-9000-based industrial control package.

Although not yet compiled to run on the 80486 platform, this is not expected to present any difficulty. With this development path open, the speed of operation available would allow larger systems to be implemented. This software is modular in construction and new modules will be added as they are developed.

The system is extremely user friendly, and a major part of its development has been devoted to making it very highly configurable by the user. A wide range of options can be selected either at the time of installation or any time later. Built-in language support currently includes English, French and German. The trending module is particularly versatile with wraparound and archiving. These provide an historical record which can be accessed by precise times and which will give numerical values of process variables for any graph reading.

John McDonnell is head of software engineering at B. McDonnell Ltd. He has extensive experience in the area of continuous process control and monitoring in the brewing, pharmaceutical and dairy industries. MSC

Microware Attends Japanese VME Trade Show

THE FIFTH VME-VXI-FUTUREBUS+ JAPAN trade show was held April 14-17, 1992 at the Tokyo International Trade Center. This show, specializing in the whole range of VME-related products, was held as a branch of the Technology Japan '92.

Microware Systems K.K., along with 33 manufacturers of VME-related hardware and software, participated in this growing show. For the whole Technology Japan '92 show, 160,000 visitors had booths from 328 companies to visit.

Microware Systems K.K. showed a variety of OS-9 products, including the OS-9/167 Development Pak which was just released in Japan. Most of the board manufacturers showed OS-9 as part of their exhibit, suggesting the strength of OS-9 in the Japanese market. MSC

ON THE **C** SIDE

Fine Tuning Signal Handling

by Peter Dibble
Microware Systems Corporation

MICROWARE'S MANUALS ARE SERIOUS DOCUMENTS. ONCE A FEATURE OF OS-9 is published in a manual, it becomes almost impossible to change. This is, in general, a good thing, but the unfortunate side effect is that many things about OS-9 that an advanced programmer needs to know remain undocumented. OS-9 *Insights* is not a manual, and it takes considerable advantage of the freedom that comes with its unofficial status.

The following is an excerpt from the discussion in OS-9 *Insights*, *Second Edition* of performance optimization tricks for queued signals. It suggests two unofficial ways to tune an application's signal handling.

Excerpted from OS-9 *Insights: An Advanced Programmer's Guide To OS-9, Second Edition*, Peter Dibble, Microware Systems Corporation, Des Moines, Iowa.

Queued Signals

OS-9 does not "throw signals on the floor" when signals are sent to a process that has a signal pending; it keeps pending signals in a queue and delivers them in the order they were sent. This is a powerful feature. It means that even processes that run at low priority or mask signals extensively see every signal that is sent to them.

Depending on the number of memory colors and the amount of memory fragmentation, queuing signals can be quite expensive. It is best to assume that sending a signal to a signal queue can take ten times as long as sending an unqueued signal, though it would be very hard to make a queued signal that slow. Signal queuing also causes OS-9 to mask interrupts for a comparatively long interval.

Signal queuing occurs when high-priority processes send rapid sequences of signals to low-priority processes or when a process masks signals for a long time compared to the interval at which signals are sent to it. To avoid these situations:

- Reduce the length of stretches of code that mask signals.
- If a low-priority process is expected to service signals from a high-priority process, raise its priority. Especially if the process is sleeping while it waits for signals, raising the priority is painless. A sleeping process doesn't use any cycles until it is awakened by a signal. The following code is a stub for the mainline of a signal handler:

```
#include <stdio.h>
#define TRUE 1
#define HIGH_PRIORITY 400
#define LOW_PRIORITY 50

main()
{
    int myid;
    myid = getpid();
    printf("Ready\n");
    OS9intercept(Catcher);
    while(TRUE){
        setpr(myid, HIGH_PRIORITY);
        sleep(0);
        setpr(myid, LOW_PRIORITY);
    }
    exit(0);
}
```

Depending on the desired result, the priority of the process could be set back to the low priority in the mainline, as show in the example, or in the intercept routine. The response of the signal handler can also be varied by setting the priority low before or after performing any computation motivated by the signal.

The following code fragment is unlikely to cause queued signals, but it steals processor time from other high-priority processes.

```
while(TRUE){
    setpr(myid, HIGH_PRIORITY);
    sleep(0);
    DoHeavyComputation();
    setpr(myid, LOW_PRIORITY);
}
```

The next code fragment is more likely to cause queued signals, but has no effect on high-priority processes. It will cause queued signals if `LOW_PRIORITY` is low enough to let several signals arrive between this process' time slices. The longer the computation and the lower the priority, the more likely signal queuing becomes. Generally, it is better to keep priorities high only around the sleep, and set the background priority of the process high enough to handle its work load with at least a few ticks of sleep time as padding.

```
while(TRUE){
    setpr(myid, HIGH_PRIORITY);
    sleep(0);
    setpr(myid, LOW_PRIORITY);
    DoHeavyComputation();
}
```

A programmer can choose to view queued signals in any of three ways:

- They are too expensive and must be avoided.
- They are a nifty communication tool and the cost is fine.

- Signal queuing is a form of graceful degradation which lets designers cut timing tolerances much closer than they could without signal queuing.

The last point needs a little discussion. If the priority of a process like the one that calls *DoHeavyComputation()* is set high enough, signals will never queue, but other processes with even more crucial tasks might be degraded. If its priority is set low enough, the computation will take longer than the inter-signal time and the signal queue will grow until it uses all of memory. In the middle ground are a range of priorities that cause signals to queue occasionally. For instance, a priority of 200 might cause a queued signal every 10 minutes and a priority of 202 might cause a queued signal every 4 hours. The designer can balance the cost of a queued signal against the cost of various arrangements.

Performance

Here I need to emphasize that this book [OS-9 *Insights*] is not Microware documentation, and details of OS-9 in this book are not specifications. This section involves kernel implementation details of signal processing. These facts are important for the most demanding applications, but they are also subject to change as we find better ways to do things. If you don't find something in a manual, it isn't "official." Future releases of OS-9 might make the tricks in this book official, or they might stop working. It would be good policy to look carefully at tricks after each kernel upgrade.

The first trick makes use of OS-9's ability to quickly dispose of signals. OS-9 calls the intercept routine repeatedly until the end of the process' time slice or until the signal queue is empty. It has a high-performance path for this loop. Combining that with the undocumented fact that OS-9 passes the number of queued signals to the intercept routine gives a program enough information to throw signals on the floor when it chooses.

```
SigTrap(QueueL, signal)
int QueueL, signal;
{
    if(signal == VERYIMPORTANT)
        HandleIt(signal);
    else if(QueueL <= 1)
        HandleIt(signal);
    rts();
}
```

The above code uses some judgment. When there are queued signals, it only handles very important signals—all others it throws on the floor. When there is no queue, it handles all signals. (A process could also raise its priority when it sees a signal queue and lower it when the queue length stays at one for a lengthy period.)

The other trick is entirely undocumented: OS-9 allocates a small block of memory to store each queued signal. The process descriptor has room for one non-queued signal. A process with eight pending signals has one in the process descriptor and another seven in structures attached to the process descriptor. For up to eight pending signals per process, OS-9 keeps the signal node after the signal is received and reuses it for future queued signals to that process. If there are more than eight empty signal slots, the surplus is freed after the signal is delivered.

Allocating or freeing memory is by far the most undesirable aspect of queued signals. The time to send a queued signal varies according to the structure of the freed memory, and the memory allocation part of *F\$Send* masks interrupts unless the memory is allocated

from a process' fragment list. The other costs of queued signals are fairly trivial. Sending a signal that queues but does not require allocation of a new node takes about ten instructions more than sending a signal to a process with an empty signal queue. An eight-deep queue of signals is either a sign of very serious trouble, or a sign that the designer is using signal queues as a buffering mechanism and signal performance is secondary.

For signal queues with fewer than eight pending signals, the first signal at each depth of queuing bears the start-up cost for that level, and no *F\$RTE* from queue lengths up to eight does an *F\$SRtMem*. A process can prime its signal queue and save other processes the cost of expensive *F\$Sends*.

The following code segments illustrate this method.

```
#include <stdio.h>
#define TRUE 1
#define Q_DEPTH 9
#define JUNK_SIG 256

Catcher(QLength, Signal)
int QLength;
short Signal;
{
    printf("Signal code: %d. Queue length: %d\n", Signal, QLength);
    fflush(stdout);
    rts();
}

main()
{
    int MyID;
    int i;

    MyID = getpid();

    OS9intercept(Catcher);
    sigmask(1);

    for(i=0; i<Q_DEPTH; ++i)
        kill(MyID, JUNK_SIG);
    sigmask(-1);

    printf("Ready\n");
    while(TRUE)
        sleep(0);
    exit(0);
}
```

```
OS9intercept - OS9intercept
00001          psect    OS9intercept,0,0,0,0
00002          nam     OS9intercept
00003          ttl     OS9intercept
00004 * d0 points to function to use as intercept routine
00005 0000 4e55 OS9intercept:link a5,#0
00006 0004 2f08          move.l a0,-(sp)
00007 0006 2040          move.l d0,a0
00008 * a0 and a6 are set
00009 0008=4e40          os9     F$icpt
00010 000c 7000          moveq.l #0,d0      Return value
00011 000e 205f          move.l (sp)+,a0
00012 0010 4e5d          unlk   a5
00013 0012 4e75          rts           :2
00014
00015 * This function knows it will be called from a C
00016 * function, so it does magic to unwind the stack.
00017 *
00018 0014 4e5d rts:      unlk   a5
00019 0016=4e40          os9     F$RTE
00020
00021 0000001a          ends
Errors: 00000
```

Peter Dibble is a computer scientist at Microware and author of *OS-9 Insights, An Advanced Programmer's Guide to OS-9*.

New Faces at Microware

Bobby Allen joins Microware's "Hotline" as a technical support engineer. Before coming to Microware, Bobby was stationed at Ramstein Air Base (Germany) with the U.S. Air Force. In the service, Bobby worked extensively with OS-9, networking, C, Basic and Ada. He holds an Associate of Applied Science degree in communication computer system technology from the Community College of the Air Force. He enjoys model rocketry, dancing and reading science fiction novels in his spare time.

Dana Campbell joins Microware's CD-I publishing services group as a graphic designer. Previously, Dana was with CDC-Quester (West Des Moines, Iowa) as a graphics artist. She holds a Bachelor of Arts degree in graphic design from Iowa State University (Ames) and enjoys tennis, and water and alpine skiing.

Lynn Christiansen joins Microware as a senior software engineer. She comes to Microware from Iowa State University Telecommunications (Ames) where she was responsible for the campus data network. Lynn has also worked as a teacher at Iowa State and as an applications engineer with General Motors Company (Ypsilanti, Michigan). She holds a Master of Science degree in electrical engineering and computer engineering and a Bachelor of Science degree in computer engineering, both from Iowa State University. Lynn enjoys alpine skiing, biking and weight lifting.

Mitch Cochran comes to Microware as an accounts payable/CD-I accountant. Prior to joining Microware, Mitch was an office manager and accountant for Q-A Incorporated (Des Moines, Iowa). He holds a Bachelor of Science degree in accounting from Northwest Missouri State University (Maryville) and enjoys biking and basketball.

Wendy DeLisi is Microware's Midwest regional sales manager. She comes to Microware from ACI (Woodbridge, New Jersey) where she sold contract computer programming. Wendy holds a Bachelor of Science degree in health planning ad-



Pictured front row (left to right): Xiao-Lin Lu, Dana Campbell, Lynn Christiansen and Wendy DeLisi. Back row: Leanne Richards, Greg Hickman, Bobby Allen and Mitch Cochran.

ministration from Pennsylvania State University (College Station). In her spare time, she enjoys following professional baseball.

Greg Hickman is Microware's central states sales manager. He comes to Microware from Zenith Data Systems (Minneapolis, Minnesota and Des Moines) where he sold systems to educational institutions. Greg holds a Bachelor of Science degree in marketing from the University of Iowa (Iowa City) and enjoys golf, tennis and scuba diving.

Xiao-Lin Lu joins Microware as a senior software engineer. Before joining Microware, Xiao-Lin was an associate instructor at the Indiana University (Bloomington) Computer Science Department. She holds a Master of Science degree in computer science from Indiana University, a Master of Science degree in computer engineering from Hangzhou University (Hangzhou, China) and a Bachelor of Science degree in electrical engineering from Zhejiang University (Hangzhou). Xiao-Lin enjoys listening to music, watching movies and playing racket sports.

Leanne Richards is Microware's receptionist. Before joining Microware, Leanne was a customer service representative with Norwest Bank Iowa (Des Moines). In her spare time, she enjoys boating and playing softball. MSC



Summer Schedule

THE FOLLOWING U.S. OS-9 SEMINARS WILL be held during the coming months in the cities listed. For five-day classes, students may sign up either for the full five-day seminar or for each of the individual sections.

JUNE 8-12
OS-9 Starter/Intermediate/Advanced
ANAHEIM, CALIFORNIA

JUNE 15-16
OS-9 Drivers
DES MOINES, IOWA

JULY 13-17
OS-9 Starter/Intermediate/Advanced
MELBOURNE, FLORIDA

JULY 20-21
OS-9 Drivers
MELBOURNE, FLORIDA

To sign up for Training and Education sessions or for more information, please call Microware's Kristin Doane at (515) 224-1929. Outside the U.S. and Canada, contact your authorized Microware representative. MSC

OS-9000 Version 1.3

Continued from Page Three

VPC also allows users to toggle the console display between DOS and OS-9000 without process interruption.

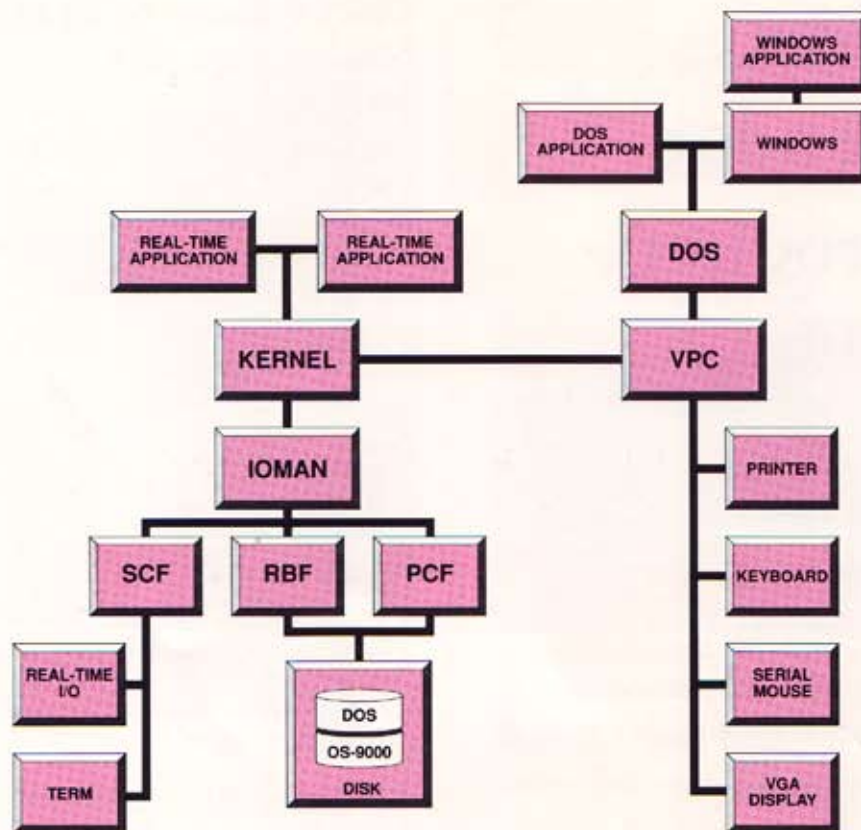
The following DOS applications have been tested by Microware for use with VPC:

- Crosstalk 4.0
- Lotus 1-2-3 2.1
- Microsoft C 6.0
- Microsoft Programmer's Work Bench
- Norton Utilities 6.0
- PCBridge 1.2
- PC Paintbrush IV Plus
- PCTools 5.1
- Procomm Plus
- SuperCalc 5.1
- Windows 3.0 (real mode)
- Word Perfect 5.1
- WordStar 6.0

System Enhancements

In addition to VPC, OS-9000 Version 1.3 includes enhancements to system modules and utilities along with a new, easy-to-use installation program. The new version of OS-9000 includes:

- Configuration and validation on a large suite of popular 386/486 PC/ATs.



Example system configuration for a PC running OS-9000 Version 1.3 with VPC.

- New, fast, memory-based disk copy utility.
- Improvements to hardware floating point (387 and 487) and software floating point emulation.
- Additional options on Shell utilities.
- Source code compatibility with Version 1.2.

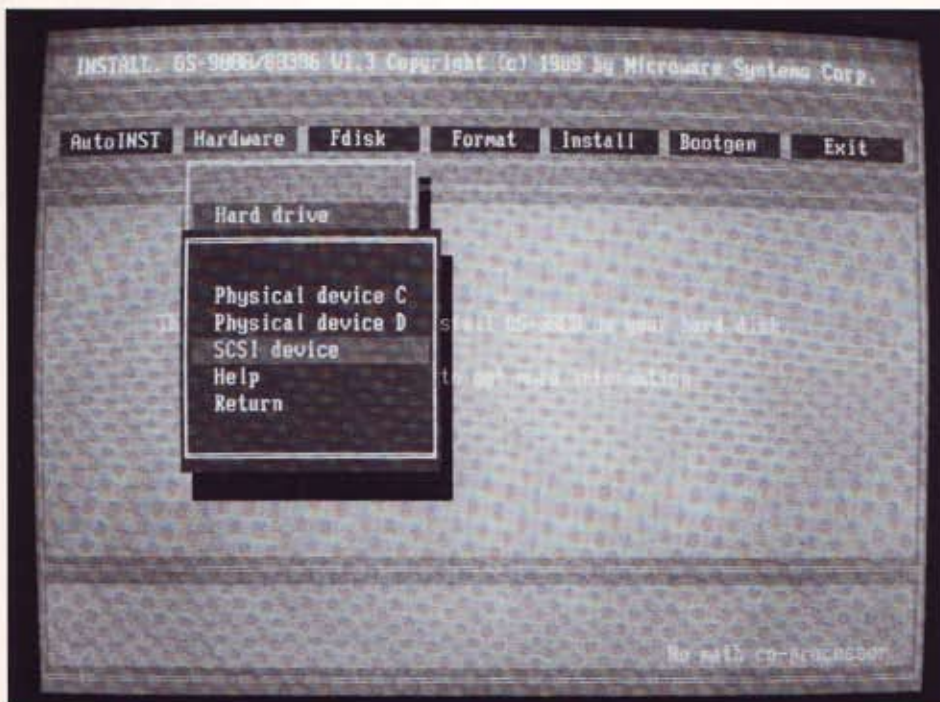
New Installation Utility

OS-9000 V1.3 includes a new, graphics-based, *Install* program that simplifies configuration of 386/486 PC/AT hardware and loading of the operating system. A graphical display with pull-down menus allows users to easily:

- Identify boot device (hard disk or SCSI drive).
- Identify and format an OS-9000 disk partition, and make disk active.
- Install OS-9000 on disk partition.
- Generate OS-9000 bootfile, low-level boot and IPL.

Now Available

OS-9000 Version 1.3 is now available. To order, contact Microware or your authorized Microware representative.



OS-9000's *Install* program lets you specify the boot device on your OS-9000 PC.

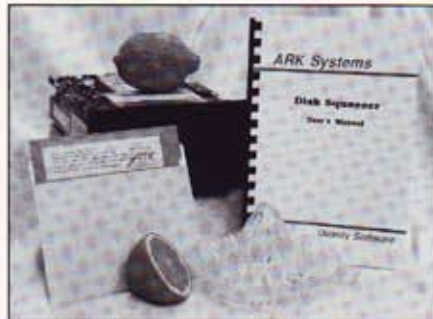
New Vendor Products

ARK Systems USA
BVM Limited
Chatham House Company
Datacube, Inc.
Dipl. Phys. M. Kämmerer
System Forschung
GESPAC, Inc.
Heurikon Corporation
Ironics Incorporated
KD Consulting Group
MATRIX Corporation
Micro-Link Products
Mizar Inc.
oettle+reichler GmbH
SBE Inc.
Syntel Microsystems
Tascomp Systems Limited
Whiteley Industries, Inc.

IF YOU HAVE NEW HARDWARE OR SOFTWARE products that run under OS-9 or OS-9000, please submit a press release and black & white photograph of the product for consideration for publication in *PIPELINES*. All materials should be sent to the Editor of *PIPELINES* at the address on page 2. For more information, call Steve Simpson at (515) 224-1929.

Disk Organizer, GPIB File Manager from ARK Systems

Disk Squeezer from ARK Systems USA (Santa Clara, California) is a utility package used to reorganize OS-9 disk contents that may have become fragmented by frequent creation, expansion or deletion of files. The package includes utilities that determine disk and file fragmentation, as well as a "safe algorithm" to protect data.



Disk Squeezer from ARK Systems.

ARK Systems' IBF is an OS-9 file manager for IEEE488.1/GPIB devices. The file manager package also includes device driver source code for both TMS9914A and μ PD7210 chips, as well as the MC68450 Direct Memory Access Controller.

CALL OR WRITE

Ikuko Kato
ARK Systems USA
P.O. Box 23
Santa Clara, California 95052-0023
Phone/Fax: (408) 244-5358

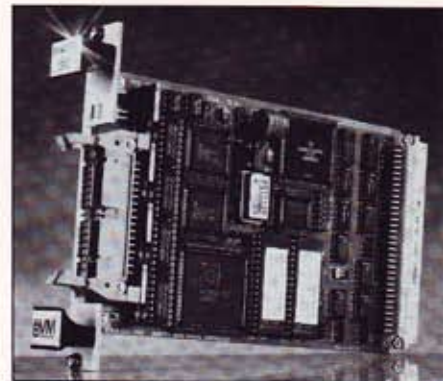
New Boards from BVM

BVM Limited (Southampton, England) recently released four new products. The BVME065 is a 3U VME memory card that provides up to 12M of Flash EPROM, SRAM or traditional EPROM.

The BVME390 is a 3U VMEbus 68040 SBC. The board includes a 25 MHz 68040 CPU, up to 32M dual-ported DRAM and up to 8M of Flash EPROM.

The BVME780 is a 6U VMEbus graphics board offering 768 x 576 PAL or 640 x 480 NTSC video, as well as an Hitachi HD63484 ACRTC graphics processor. The board enables users to combine text and graphics from the ACRTC processor with software-selected output from one of four video channels.

The BVME771 is a 3U VMEbus intelligent serial controller that features a 16 MHz 68HC001 CPU, four RS-232/422/485 serial channels, up to 256K dual-ported SRAM and up to 256K EPROM.



BVM's new intelligent serial controller.

CALL OR WRITE

Rod Clarke
BVM Limited
Flanders Road, Hedge End
Southampton, Hampshire SO3 3LG
England
Phone: (44) 703 270770
Fax: (44) 489 783589

New Publication for OS-9 Users

The 68XXX Machines is a bimonthly publication from Chatham House Company (Wyoming, Delaware). The magazine covers technical tips and software information for OS-9-based computers like the MM/1.

CALL OR WRITE

The 68XXX Machines
Chatham House Company
RD #1, Box 375
Wyoming, Delaware 19934
Phone: (302) 492-8511

Warping Module from Datacube

Datacube, Inc. (Peabody, Massachusetts) recently introduced their *MiniWarper* module for the MaxVideo 20 system. *MiniWarper* is designed to perform complex spatial warps of live video images up to 1K x 1K pixels at a rate of 20 million pixels per second. Arbitrary image warping can be accomplished using a unique "Comes From" addressing technique based on a fixed destination-to-source transform that is stored in the MaxVideo 20's system image memory. *MiniWarper*

can process both grey-scale and color images.

CALL OR WRITE
Datacube, Inc.
4 Dearborn Road
Peabody, Massachusetts 01960
Phone: (508) 535-6644
Fax: (508) 535-5643

Intelligent Ethernet/ Cheapernet Board

The MPVME 1055 controller from Dipl. Phys. M. Kämmerer System Forschung (Bonn, Germany) provides an intelligent interface between OS-9 and other systems. In addition to TCP/IP, network protocol modules are available for DECNET/VME, UDP, SINEC API and ISO communications. The 3U VME board features a 68010 CPU up to 16.6 MHz, up to 256K dual-ported SRAM, up to 2M EPROM, Ethernet/Cheapernet DMA controller, timer interrupt, mailbox interrupt and VMEbus interrupter.

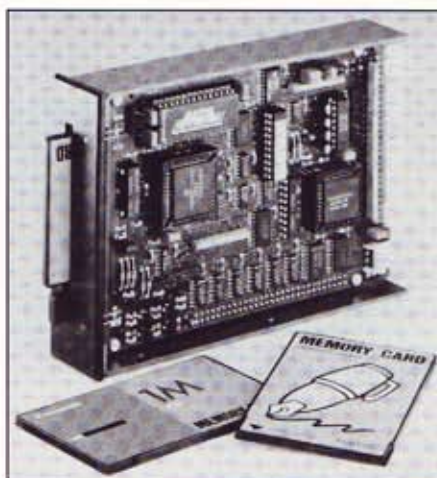
CALL OR WRITE
Dipl. Phys. M. Kämmerer System Forschung
Königstraße 33a
5300 Bonn 1
Germany
Phone: (49) 228 22 31 51
Fax: (49) 228 22 90 29

New Boards from GESPAC

GESPAC, Inc. (Mesa, Arizona) recently announced several new products. The GESUCI-1 is a 68340 SBC designed to operate as an intelligent I/O controller bus in master/slave system architectures. The G-64/G-96 GESUCI-1 features a 16 MHz 68340 microcontroller, 1M EPROM and 1M battery-backed SRAM. The board can drive two GESPAC XSB expansion submodules which can be equipped with serial, parallel, analog I/O, SCSI or Ethernet. The 68340's two serial ports can be configured as RS-232, 422 or 485.

The MCDISK-1 is an open frame Memory Card Drive that is fully compatible with all types of JEIDA 4.0 and PCMCIA memory cards, including SRAM, Flash EPROM and One Time PROMs. The drive features a built-in SCSI and SCSI-2 compatible interface

and an on-board microcontroller with a 64K RAM buffer.



GESPAC's MCDISK-1 Memory Card Drive.

The GESSBS-30 is a single board computer featuring a 32 MHz 68030 CPU, optional 68882 FPCP, up to 4M battery-backed CMOS RAM, up to 2M EPROM, two RS-232/422/485 ports, triple 16-bit counter/timer and a battery-backed real-time clock/calendar.

GESPAC's MPL-4079 single board computer operates in extended temperature ranges from -40 to +85°C. The board includes an 8 MHz 68000 CPU, up to 512K PROM, up to 256K battery-backed RAM, two RS-232 ports, battery-backed clock/calendar, two 16-bit timers and four-channel 8-bit A/D converter.

The GESVIG-4VME video graphics board is a 6U VMEbus board capable of displaying up to 800 x 600 pixels with 256 of 250,000 colors available. The board includes interfaces for an IBM PC/AT-style keyboard and a serial mouse. The GESVIG-4VME is designed to work with any Multisync or VGA-compatible monitor.

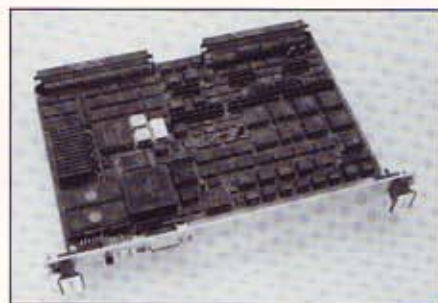
CALL OR WRITE
Don Bizios
GESPAC, Inc.
50 West Hoover Avenue
Mesa, Arizona 85210
Phone: (602) 962-5559
Fax: (602) 962-5750

Intelligent Serial Board from Heurikon

Heurikon Corporation (Madison, Wisconsin) recently introduced their HK68/VSIO intelligent 6U VMEbus serial interface board. The HK68/VSIO fea-

tures a 32 MHz 68EC030 CPU, 18 RS-232C ports, up to 4M DRAM and three programmable 16-bit counter/timer channels.

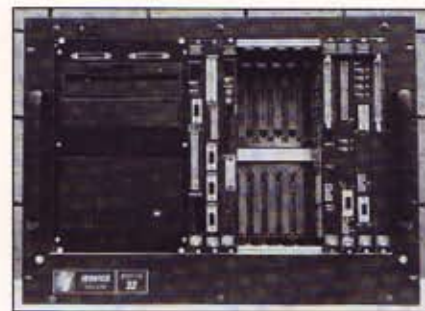
CALL OR WRITE
Abe Hirsch
Heurikon Corporation
8000 Excelsior Drive
Madison, Wisconsin 53717
Phone: (608) 831-0900
Fax: (608) 831-4249



The HK68/VSIO from Heurikon.

Ironics Offers Rugged, Fully-Integrated System

Ironics Incorporated (Ithaca, New York) now offers its SYSTEM 32, a rugged and complete OS-9 development/target system. In addition to OS-9, SYSTEM 32 is provided with an on-line User Tutorial, TOPS utilities libraries, Microware's Source Level Debugger and a GNU C Compiler. Options include an Internet/Ethernet interface, X Windows and RAMNET support.



Ironics' SYSTEM 32.

SYSTEM 32 is based on Ironics' patented ICEBOX VMEbus system enclosure. The enclosure is optimized to provide exceptional power, cooling, suppression of electrical noise, physical toughness and ease of access to internal components. Within this platform, Ironics installs a 32 MHz 68030 CPU, 68881/2 FPCP, 4M RAM, four serial ports, one Centronics port and SCSI, Ethernet and VSBbus interfaces. A

50 MHz 68030 with 16M RAM is optionally available.

Ironics also offers a line of products to customize the SYSTEM 32. These options include monochrome and full-color (24 bit/pixel) frame grabbers, high-resolution full-color displays, high-speed graphics elements and dedicated image processing CPUs. Ironics also offers its INSTANT REPLAY bundle, a hardware/software solution for real-time image capture, storage, retrieval and display.

Ironics' Systems Integration Group can adapt SYSTEM 32 to fit custom requirements and applications. The Systems Integration Group can handle projects at any level.

CALL OR WRITE

R. Chris Martens, Director of Marketing
Ironics Incorporated
798 Cascadilla Street
Ithaca, New York 14850
Phone: 1-800-334-4812 (U.S. and Canada)
or (607) 277-4060

Sculptor Support for North and South America

KD Consulting Group (Hamilton, Ohio) recently became the Sculptor distributor for North and South America.

KD Consulting Group will provide all technical and sales support for North and South America. Currently, the firm is offering the latest release of Sculptor, version 2.1. Features in this release include the ability to scroll any fields anywhere on the screen, reading of data without locking and full compatibility with previous versions of Sculptor.

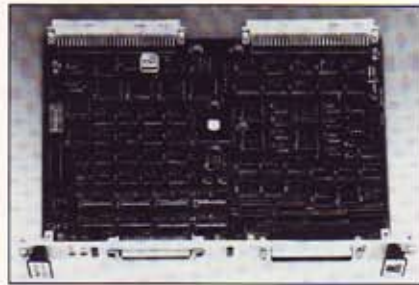
CALL OR WRITE

Kurt Johnson
KD Consulting Group
3880 Citation Drive
Hamilton, Ohio 45011
Phone: (513) 887-0337
Fax: (513) 887-0338

New High-Speed Communications Board

MATRIX Corporation (Raleigh, North Carolina) recently introduced their DB-PCOMM Parallel Communications Module that acquires or outputs data at rates up to 33M/sec. The 6U VMEbus board is designed to function as a digital front-end where continuous 32-bit data must be transferred to a VMEbus system.

The DP-PCOMM features VSB and Dbus-68 interfaces, DMA controller, large FIFO buffer, 8 parallel input lines and 8 parallel output lines.



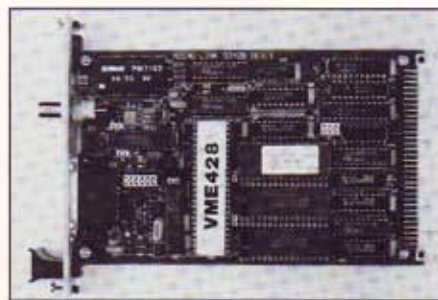
High-speed communications board.

CALL OR WRITE

Stephen Beer
MATRIX Corporation
1203 New Hope Road
Raleigh, North Carolina 27610
Phone 1-800-848-2330 (U.S. only)
or (919) 231-8000
Fax: (919) 231-8001

Micro-Link Offers Ethernet Controller, '030 SBC

The VME428 Ethernet controller from Micro-Link Products (Carmel, Indiana) supports IEEE 802.3 or 10Base5 Thick Ethernet, as well as 10Base2 Cheapernet. The board features a LANCE chip set and up to 1M RAM.



Micro-Link's VME428 Ethernet controller.

Micro-Link's 3U VME203 features a 68030 or 68EC030 CPU at up to 40 MHz, optional 68882 FPCP, two RS-232 ports, one 16-bit interrupt timer, up to 1M EPROM, up to 4M 32-bit DRAM and watchdog timer.

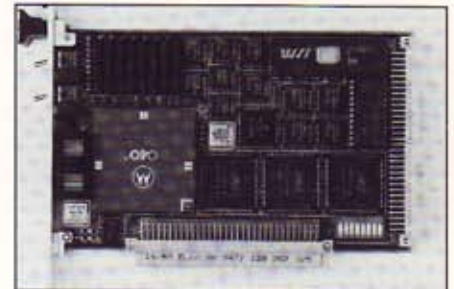
CALL OR WRITE

Jan Collins
Micro-Link Products
14602 North U.S. Highway 31
Carmel, Indiana 46032
Phone: 1-800-428-6155 (U.S. and Canada)
Fax: (317) 848-2254

Two New '040 Boards from Mizar

Mizar Inc. (Carrollton, Texas) recently introduced two new 68040-based single board computers. The 6U VMEbus MZ 7140 features a 25 MHz 68040 CPU, up to 32M dual-ported DRAM, up to 2M EPROM, 8K internal cache, on-board SCSI and Ethernet interfaces, and one Centronics port.

The MZ 8140 is a 3U VMEbus SBC featuring a 25 or 33 MHz 68040 CPU, up to 4M DRAM, up to 1M EPROM, 2K battery-backed SRAM, two serial ports, battery-backed real-time clock, two timers and support for the Mizar Expansion Bus (MXbus).



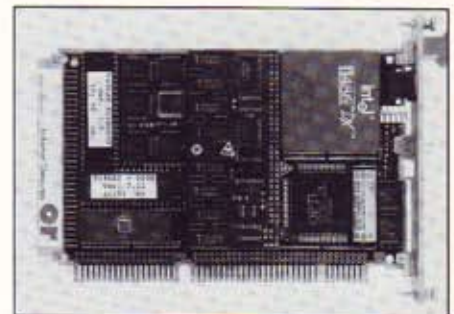
Mizar's MZ 8140 68040-based SBC.

CALL OR WRITE

Mizar Inc.
1419 Dunn Drive
Carrollton, Texas 75006
Phone: 1-800-635-0200 (U.S. only)
or (214) 446-2664
Fax: (214) 242-5997

oettle+reichler Introduces New Boards

oettle+reichler GmbH (Augsburg, Germany) has added three new boards to their product line.



The 80486-based V486.

The 3U VMEbus VCPU-30 features a 50 MHz 68030 CPU, 2M dual-ported battery-backed SRAM or 8M dual-ported DRAM, up to 2M EPROM, two

RS-232/422 ports, real-time clock and watchdog. With all-CMOS design, the VCPU-30 is designed for extended temperature ranges of -40 to +85°C.

The V486 is a 3U VME board featuring either a 20 MHz 80486SX CPU or a 33 MHz 80486DX CPU. The V486 includes up to 8M DRAM and up to 1M Flash EPROM, and is designed for extended temperature ranges from -25 to +85°C.

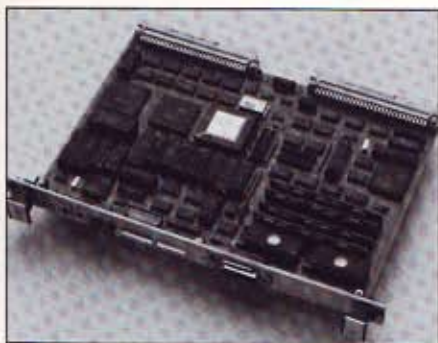
The VADC-30 is a 3U VMEbus A/D board available in 12-, 14- and 16-bit analog to digital conversion. The VADC-30 is also designed for extended temperature ranges from -40 to +85°C.

The VGA-34 graphics controller is a 3U VMEbus board based on a 40 MHz TMS-34020 and includes up to 1M VRAM, up to 4M DRAM, VGA interface, IBM-compatible keyboard interface, TTL open emitter for a speaker, and RS-232 port for mouse or digitizer. The board offers up to 1024 x 1024 pixel resolution with 256 colors available from a palette of 16 million.

CALL OR WRITE

oettle+reichler GmbH
Sieglingenstraße 19 1/2
D-8900 Augsburg 1
Germany
Phone: (49) 821 50340
Fax: (49) 821 5034119

SBE Introduces New Intelligent Ethernet Board



The VLAN-E2 from SBE.

SBE, Inc. (Concord, California) recently introduced their VLAN-E2 6U VMEbus intelligent Ethernet communications controller board. The board features a 16 MHz 68020 CPU, 1M DRAM, 256K EPROM and the LANCE/SIA chip set. The VLAN-E2 offers a user-configurable Ethernet IEEE 802.3 port on the front panel or P2 connector, and VME block mode transfer.

CALL OR WRITE

SBE, Inc.
2400 Bisso Lane
Concord, California 94520
Phone: (510) 680-7722
Fax: (510) 680-1427

Real-Time Workbench from Syntel

Syntel Microsystems (Huddersfield, England) recently introduced their Real-Time Workbench system, as well as two new boards. Real-Time Workbench is a software/hardware package that seamlessly combines OS-9 and Windows 3.0. The package includes a 68000 core microprocessor PC plug-in board running Professional OS-9 in up to 4M dual-ported RAM. The board shares the PC's hard disk with no need to partition or reformat the disk. Multiple OS-9 terminals appear as windows on the PC screen. The board is small enough to fit into a laptop 80X86 PC.



Real-Time Workbench seamlessly integrates OS-9 with Windows 3.0.

Syntel's VM030 is a 3U VMEbus SBC built around a 40 MHz 68030 or 68EC030 CPU. The board includes up to 4M 32-bit wide DRAM, up to 2M Flash EPROM, up to 1M EPROM, up to 128K battery-backed SRAM and two RS-232/422/485 ports.

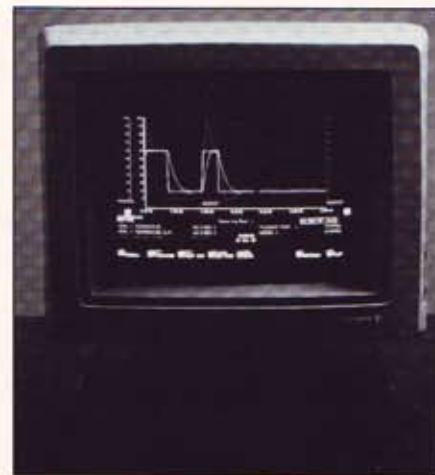
The SYN-RXI01 is a 16-channel I/O controller for Syntel's Reflex industrial I/O network. The board offers eight digital outputs capable of switching up to 30V DC at up to 2A and eight digital inputs reading from 12 to 24V DC.

CALL OR WRITE

Paul Wilson
Syntel Microsystems
Queens Mill Road
Huddersfield HD13PG
England
Phone: (44) 484 535101
Fax: (44) 484 519363

Graphics Package from Tascomp

TASCMaster is a new graphics display package for OS-9 from Tascomp Systems Limited (Stockton-on-Tees, England). TASCMaster provides communication and supervisory facilities for industrial settings.



The TASCMaster graphics package.

The TASCMaster system features color display of dynamically updated mimics, history trend graphs with zoom and interactive status displays. Printers and plotters may be connected for reports and graphics.

CALL OR WRITE

Alan Robinson
Tascomp Systems Limited
4 Bishopston Lane
Stockton-on-Tees, Cleveland TS18 2AA
England
Phone: (44) 642 604455
Fax: (44) 642 618080

Flow Test System from Whiteley Industries

The Flowmaster 4400 from Whiteley Industries, Inc. (Tewksbury, Massachusetts) is a fully integrated test management system. Featuring a 16 MHz 68000 CPU, the Flowmaster 4400 is designed to sequence and regulate pressure testing of components, calculate and certify pass/fail results, and generate printed reports.

CALL OR WRITE

Fred Coyle
Whiteley Industries, Inc.
939C East Street
Tewksbury, Massachusetts 01876
Phone: (508) 640-1177
Fax: (508) 640-1015



NEW PRODUCT

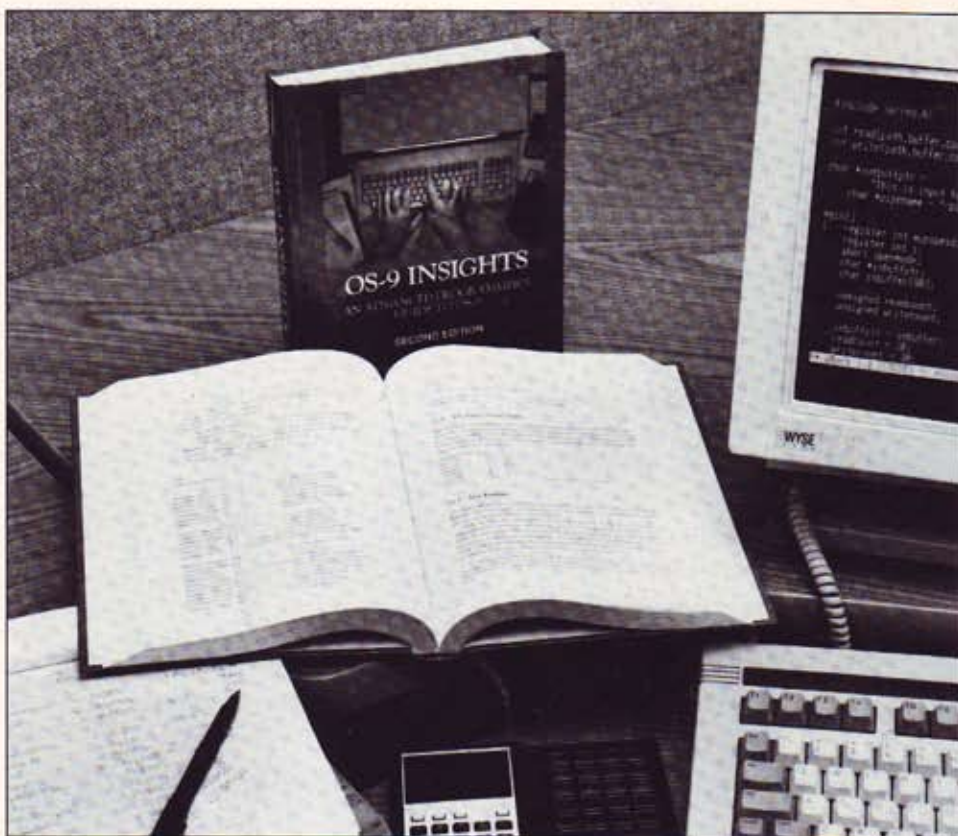
New Edition of OS-9 Insights Now Available

PETER DIBBLE RECENTLY COMPLETED WORK on an expanded, new hard-bound edition of *OS-9 Insights: An Advanced Programmer's Guide To OS-9*. "I've gained an appreciation for the fact that OS-9 users are pushing the envelope on real-time development," Peter says. "This book is written so that designers can put even more power into their real-time applications."

In *OS-9 Insights, Second Edition*, Peter has included technical information and sample programs to help developers explore the internal structures of OS-9, customize OS-9 systems and tap additional resources from the OS-9 Kernel.

This new version includes:

- An in-depth examination of the OS-9 design philosophy.
- Detailed discussion of OS-9 Kernel operation and real-time features.
- Practical uses of I/O management.
- Tips on building device descriptors



and adding new device drivers.

- Sample file manager and source listings.

Peter holds a Ph.D. in computer science from the University of Rochester (New York) and currently works as a computer scientist at Microware.

OS-9 Insights, Second Edition is available from Microware for \$75 (plus applicable shipping and taxes). Call Microware's order line at 1-800-475-9000 to order by credit card. Call Microware at (515) 224-1929 or your authorized Microware representative for more information.

microware[®]

MICROWARE SYSTEMS CORPORATION
1900 N.W. 114th Street
Des Moines, Iowa 50325-7077

Bulk Rate
U.S. Postage
PAID
Des Moines, IA
Permit #2864