What is Criterion?

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During the next thirty minutes, I would like to review with you some of the highlights of the Criterion system, and to share with you some of the background which has made this major new product line possible.

There have been some dramatic advances in hardware and software technology and in system architecture in recent years, and I want to show you how NCR has exploited these advances in the Criterion System.

Hardware technology has changed primarily with respect to cost per function. Today we can offer powerful systems at low cost that permit users to develop applications which, until now, had been economically infeasible. Examples of this new technology are Emitter Coupled Logic (ECL) which has opened the way for faster processors, and the Metal Oxide Silicon (MOS) 4K x 1 memory chip which permits construction of large, low-cost main memories.

In the realm of software technology, we have witnessed the emergence of virtual storage as a valuable tool for both the software writer and the application programmer. We have also seen the adoption of higher level languages, structured programming, and systematic testing techniques, in a general trend toward what is often called "software engineering". By using these techniques in the development of new Criterion software, we have been able to achieve improved levels of functional capability, usability, and reliability in the software.

In system architecture, the key advances have been in the areas of firmware and distributed intelligence. Firmware is a relatively new technology which permits us to implement more easily and more efficiently many functions which, in previous systems, were implemented in hardware. Firmware has two main advantages. First, it permits one hardware machine to perform as several different "Virtual Machines," depending on the firmware it is executing. And, second, firmware is capable of implementing higher level "Virtual Machines" than were previously feasible just through hardware, so that in effect it takes over some of the repetitive functions previously performed by software, performing them, at much higher speed.

Firmware provides a trade-off between the speed of hard-wired functions in the processor and the flexibility of easily programmed functions. The hardware required in a firmware-driven processor is less complex and as a result can be made faster and more reliable. The speed gained in this way is used to offset the multiple firmware commands which must be executed to provide complex functions.

The trend toward distributed intelligence is manifest in the way the system functions are distributed among several processors or intelligent controllers, each of which is driven by specific firmware. In Criterion, these distributed elements share the workload and communicate with each other across the Internal Transfer Bus, in order to operate as one harmonious system.

The architecture of the Criterion has embodied many techniques that are proven and mature in other systems. By using this approach, the success of the product is much more assured. At the same time, the combination of techniques used in Criterion is unique and gives the product a distinct advantage when compared to other systems using only certain of the techniques. It is this combination of proven technologies in a unified architecture that we believe makes Criterion a unique and attractive price/performance competitor.

Product History

A basic ground rule of the Criterion system design from the start was full compatibility with existing NCR Century software and user programs. The product strategy was, and still is, to initially introduce the hardware to run existing software, and subsequently to introduce new software as a second step. This approach eases the migration path for the user and NCR. It is an approach that lowers the risk during such a major product introduction.

Ground rules for the new software system were that it should run existing programs without change, and that the customer would be able to convert to it with very little effort or cost. We have fully achieved the objective for compatibility of the hardware. This has been demonstrated by both our internal testing and the experience of the customer pilot installation where systems running on a Century 200 were moved to a Criterion 8550 with no changes to the system or application programs and the customer operator required less than two hours training.

In order to satisfy the compatibility requirement, it was decided that the new software Virtual Resource Executive (VRX) would utilize B-series code, either unchanged or, where necessary, modernized, to meet the interfaces expected by existing NCR Century B-series programs. The B4 operating system was chosen as the starting point for developing VRX. Alongside the existing or modernized B-series code, a new set of software interfaces was designed and implemented. The goal of this new code was to introduce new capabilities primarily in the areas of virtual storage, data management, telecommunications, and COBOL '74.

The current status of the product is that the Criterion 8550 and 8570 systems are both in production, and the first units have already been delivered to customers. These are running with Release 9 of Century B-series software. The first release of the new VRX software has been written, is currently in system test, and will be delivered to the first

customer pilot site in November, 1976. The demonstration this afternoon will include operation of the VRX.

Criterion Hardware

The Criterion mainframe is self-contained in a single cabinet which houses the Internal Transfer Bus (ITB), and several processor, memory, and input/output control subsystems which fit on the bus, together with the power supplies. This cabinet occupies 9.8 square feet and thus the Criterion mainframe requires considerably less floor space than most present-day computer systems of equivalent power. You will see the contrast of size between Criterion and the Century during the demonstration this afternoon.

Most of the subsystems within the mainframe are implemented on 11" x 14" cards, and the primary logic circuitry is Emitter-Coupled Logic (ECL).

Internal Transfer Bus (ITB)

The focal point of the Criterion system architecture is the Internal Transfer Bus (ITB). It is a high-speed data path across which all Criterion subsystems communicate with each other: these include the Main Processor, the Service Processor, the Memory Subsystems, the Common Trunk Subsystems, and the Integrated Disc Controller.

The main advantage of a bus-oriented architecture is that it permits us to design hardware in a modular fashion, to satisfy a wide range of capabilities. When we need to add a certain hardware capability to the system (for example, a new type of peripheral controller, or a new type of main memory), we design it in the form of a subsystem that fits on the bus.

Thus future enhancements, as well as field upgrades, are easily implemented - they take the form of additional cards that are simply added to the bus back-panel. In addition, this hardware modularity eases the task of fault isolation and correction, contributing to high system availability.

The use of the bus architecture is an extension of a technique used in smaller, slower systems to reduce costs of system element interconnection. The use of the bus in Criterion is primarily to provide an open ended and flexible architecture. The 72 megabyte per second bandwidth of the bus provides a wide margin to avoid contention between subsystems for bus access and for fast data transfer between subsystems such as a processor and memory.

This open-ended design accommodates architectural extensions such as multiple processors, future I/O subsystems, and future integrated controllers and is especially suited to distributed processing applications.

Criterion Firmware

The use of firmware technology is a major departure from the Century architecture and I would now like to explain in a little more detail exactly what firmware is, and how it contributes to the Criterion system architecture.

Firmware is really a form of programmable hardware. In a firmware-based system such as Criterion, instead of having a processor with hard-wired control logic, we have a micro programmable processor executing firmware which is contained in a high-speed memory called a "control store." And we go one step further by making this a "writable control store," which is loaded with the required firmware from a flexible disc. Because we can tailor the firmware to perform exactly the required functions, this gives the system much more power and flexibility, and we can use one processor for a variety of different functions, simply by selecting the firmware we load into its control store. Thus firmware gives the hardware a specific set of attributes or a "personality."

Firmware is used throughout the Criterion system for such functions as input/output control and microdiagnostics. Where the firmware interfaces directly to software, it takes the form of a "Virtual Machine." A virtual machine is simply a machine, implemented in firmware, which executes software. It may be designed to emulate, or execute programs like an existing machine, as is the case with the Criterion RS firmware which emulates an NCR Century and runs existing B-series software. Or it may take the form of a new machine designed to match the needs of new software or to reflect the attributes of a programming language. In this latter case, the existence of firmware permits the virtual machine to be designed to execute instructions much closer to the source language than was previously feasible with hard-wired logic. Virtual machine commands may correspond nearly one-for-one with the verbs of the higher-level language as is the case with the Criterion COBOL Virtual Machine. This results in greatly improved performance for COBOL programs.

The Criterion Virtual Storage (VS) firmware includes the COBOL Virtual Machine, as well as a virtual machine designed to match the needs of the new VRX operating system software. This VRX Virtual Machine is a superset of the NCR Century Virtual Machine, and, therefore, also satisfies the compatibility requirement that existing Century B-series programs must run under VRX.

The VS Firmware thus includes two virtual machines: COBOL and VRX.

These reside together in firmware control store, and are executed concurrently as required by the software. This we call "Multiple Virtual Machine" operation. The switching between virtual machines is performed in a very few processor cycles by a firmware routine, and does not involve any control store load process or program awareness while the switching is occurring.

Firmware can also give the Criterion the "personality" of other machines although only the Century and COBOL Virtual Machines are currently offered. I said earlier that firmware is used extensively throughout the Criterion system. If we review the various subsystems on the bus, we can see that several of them are firmware-driven: the Main Processor, the Service Processor, the Integrated Communications Module, and the Integrated Disc Controller. Each of these subsystems has firmware loaded into its writable control store as part of the start-of-day procedure, under control of the Service Processor.

Firmware is a central architectural element to Criterion and brings to the system great flexibility, extension possibilities, and performance improvements over traditional architectural approaches.

In order to complete the technical picture, I will review some of the details of the Criterion hardware subsystems.

The Main Processor is designed for fast interpretation and execution of object programs by firmware. The firmware executes out of a high-speed control store, which operates at the same cycle time as the main processor which is 112 ns. for the Model 8550 or 56 ns. for the Model 8570. Through the use of a pipeline, firmware instructions are executed effectively at the speed of one processor cycle per instruction.

The pipeline consists of three phases of instruction processing: Fetch, Interpretation, and Execution. Each phase requires one processor cycle; however, the pipeline is designed such that three firmware instructions are processed in parallel, one in each phase. This is made possible by the fact that each instruction in the firmware instruction set, with a few exceptions, has been designed to complete within the three cycles. The pipeline organization has been utilized in much larger systems to achieve similar results and the Criterion brings this technique now to its system class.

Memory Subsystem

The Memory Subsystem consists of one or two memory interface units, each of which may control up to four 64,000 byte memory cards; these may be further extended to provide up to 1 megabyte of main memory in the Criterion 8570 Model.

Memory technology is perhaps the technology that has changed most rapidly in recent years with respect to cost. Today, by packaging the 4K MOS memory chip on 11" x 14" cards, we can attain a density of 64,000 bytes per card. When we take into account the cost of the necessary memory interface and control hardware, this works out to a cost of less than one-twentieth of the cost of the core memory first used in the NCR Century 200 in 1970, which itself was about one-half the cost of the original NCR Century rod memory in 1968.

Input/Output Subsystems

Peripherals which use the NCR Century common trunk discipline may be connected to the Criterion system through one of three types of common trunk: low-speed, medium-speed, or high-speed. The trunks have been designed for various processing requirements, and can be selected for the most economical peripheral configuration. Thus, most Century peripheral devices and controllers can be utilized in the Criterion system including the complete line of Century communications equipment and terminals.

The new 6590 Data Module Disc unit interfaces to an Integrated Disc Controller (IDC), which is another firmware-driven subsystem that connects to the bus. The Integrated Disc Controller, in fact, is basically the same hardware unit as the Service Processor, but is driven by different firmware designed specifically to perform disc control functions.

In addition to the communications capability of the Century 621-103 Multiplexor, which allows connection of one to 255 lines depending on line speed, the Criterion offers a one

to ten line communication capability for smaller terminal systems. This capability is provided by an Integrated Communication Controller which connects to the bus. This controller uses a microprocessor to emulate the operation of the 621-103 and provides the same facilities to the program and communication lines.

Service Processor

The Service Processor operates in parallel with the Main Processor, and is concerned primarily with input/output control and diagnostics. It controls and drives the card reader, flexible disc, console CRT, and any hard-copy console devices. It also performs the firmware load function, where firmware is read from the flexible disc and distributed to each firmware-driven subsystem.

The Service Processor has primary responsibility for error control and system diagnostics, including a start-of-day diagnostic which is run as part of the initial firmware load process. Should a malfunction occur in the system, the Service Processor provides the tools for detection and isolation of the problem. The diagnostics operate at the micro-program level and in addition to the usual fault detection and isolation facilities, offer two unique features.

One set of diagnostics are designed for customer operation. These programs can be loaded by the customer operator when errors are suspected. They will test the system and notify the operator if there is a failure and also display the most likely boards required to correct the failure. When the customer calls field engineering he can tell them what has been displayed and thus increase the likelihood of having the correct board for repair.

The second feature is Remote Diagnostics. By granting permission at the system console, the customer can allow connection of a remote CRT terminal as a dual console. The field engineer at this remote console can see all the console displays and through the terminal keyboard control the system operation of diagnostic programs. In this way, expertise deeper than that available at the customer's site or a local office can be utilized to solve the more difficult failure problems.

Criterion Software

The NCR Criterion is being offered as two different machines. With real storage firmware, it is an NCR Century machine which runs existing B-series software and user programs. With virtual storage firmware, it operates under control of the VRX operating system providing a virtual storage system.

B-series Software

The B-series Software offered with Criterion is the most current release and is currently operating at pilot Criterion customer installations. The B1, B2, and B3 operating systems are available to Criterion users, together with the full set of Century B-series compilers, utilities, and applied programs.

The initial pilot site experiences have been totally successful, and have proved beyond any doubt that the compatibility between Criterion and the NCR Century is real. I think we can claim that compatibility across NCR products has been, and remains, second-to-none.

Virtual Resource Executive (VRX)

With the VRX system we have maintained our commitment to compatibility, so that, by and large, any program running today on any NCR Century system will run as is, without recompilation, under VRX. Similarly, all files supported on NCR Century systems are supported under VRX, as are the B-series compilers, utilities, and applied programs. A few obsolete peripherals, such as CRAM and 655 Disc, are not supported under VRX; but files using those peripherals can be quickly and easily transferred to newer, fully compatible devices.

VRX, while remaining compatible, is a new software system, offering many significant features which make it competitive with any software system in the industry. VRX represents a large software effort and investment by NCR, and is the culmination of three years of intensive work.

One of the primary goals of VRX has been to improve the usability of our software, and thereby, to reduce the time and cost required for users to develop their computer applications. This we have done by making the system more automatic, more responsive, and more interactive.

The Virtual Resources Executive is called "VIRTUAL," because it supports two new capabilities: Virtual Machines and Virtual Storage. The Multiple Virtual Machine operation of the VRX and COBOL Virtual Machines has already been covered. Virtual Storage, or Virtual Memory, is new to NCR, but has been available on competitive systems for several years.

This approach reduces the cost to develop and maintain programs and improves reliability for both user programs and system software.

Burroughs has had its own form of virtual storage for many years, and IBM popularized virtual storage on a wide scale when it was introduced on the System/370 in 1972. NCR's implementation of virtual storage in VRX is similar to the most sophisticated of IBM's several implementations known as OS/MVS, which is available only on systems renting for over $30,000 per month. We consider our implementation of virtual storage to be a cost breakthrough. We are providing sophisticated capabilities on systems well below the cost of comparable competitive systems.

Another primary feature of VRX is a new data management system called the Criterion Access Method (CAM). Initially designed to support just Disc peripherals, CAM fully supports the input/output requirements of the COBOL '74 language. It supports three different me organizations: sequential, relative, and indexed. These three access methods permit file organizations to be designed in an optimum way for each specific application. VRX includes new telecommunications software which supports two new programming interfaces for development of on-line systems; a Message Control System (MCS) interface, and a Low-Level Interface (LLI). The Message Control System is compatible

with the COBOL '74 language, and provides a simple, terminal-insensitive interface to the application programmer. The Low-Level Interface is a more basic interface, giving the programmer more control over his telecommunications devices.

Two new compilers are provided with VRX: COBOL '74, and NEAT/VS.

The VRX COBOL '74 compiler is primarily a high-level implementation of the ANSI 1974 Standard. It produces object code for the COBOL Virtual Machine (CVM) which runs under VRX, and is designed to match the needs and characteristics of the COBOL language.

The NEAT/VS compiler is compatible with the NCR Century NEAT/3 language, and provides programming interfaces to the new software features available under VRX.
A new Link Editor is also supplied with VRX, to assist users in writing modular programs. The Link Editor binds together program modules written either in COBOL '74 or NEAT/VS, prior to program execution.

Throughout the design and implementation of VRX, a •strong emphasis has been placed on performance and reliability. User programs should generally run faster under VRX than on comparable NCR Century systems. And the VRX software should prove more reliable and error-free than any previous NCR software system, due to the application of improved development tools, comprehensive programming and documentation standards, rigorous test programs and procedures and the modular structure of the programs.

I am confident that with VRX, NCR is offering a significant software advance which will attract both existing NCR Century users and users of competitive systems. This confidence is supported by our analysis of major software features, which shows that VRX has a significant edge over competitive software systems in the same price range and compares favorably to systems priced much higher than Criterion.

The release of the VRX software as a second step in the release of the Criterion to the market is part of a planned phasing of the product introduction. The VRX software has been in development since late 1973. The software elements that make up the system completed individual test phases in December of last year and they have been in test as an integrated system since March of this year. The testing has gone well and we expect the pilot installation in November, 1976 to be a success.

Criterion Models

The basic Criterion 8550 system includes a 112-nanosecond processor with 128KB of main memory, an integrated 600-card/minute reader, a 1,200-line/minute printer, and two 100-megabyte 658 disc units. Under as-year lease agreement, it rents for $5,900 per month. Memory can be expanded in 64KB increments to 512KB.

The basic Criterion 8570 system includes a 56-nanosecond processor with 256KB of main memory, a 600-card/minute reader, a 1,200-line/minute printer, and three 100-megabyte 658 disc units. Under a 5-year lease agreement, it rents for $10,300 per month.

Most Century peripherals and terminals can be transferred directly to Criterion systems. This includes the 656, 657, and 658 disc units.

A new type of disc unit, the 6590 Data Module Disc, is available with Criterion. The 6590 has a capacity of 70 megabytes or 140 megabytes per dual disc unit; it has an 885KB/second transfer rate, and an average access time, including latency and seek time, of 35.1 milliseconds.

Three other new peripherals are available with Criterion. These are a 600-card/minute card reader, a 1,000-character/second paper tape reader, and a 173-character/second matrix printer.

I would like to give you some perspective on performance of the Criterion.

We have analyzed performance of the product throughout the development project. Simulation models and similar methods were used in the early phases to predict the performance and as elements became available we have measured their actual performance. The correlation between the predicted performance and measured performance has been very high and gives us high confidence in the performance that will be seen in customer applications. Still, system performance is a complex interaction of many complex factors and simple statements about performance can be misinterpreted. The most meaningful statement I can make at this time is the result of measured performance of actual system operation using customer programs. These results show the 8550 to be about 20 percent faster than an equivalent configuration Century 201 running the B1 Executive and about 30 percent faster running the B3 Executive.

We expect more significant improvements in performance when executing under VRX with the COBOL Virtual Machine, but have not fully qualified our test results at this time.

The Future

Whenever a manufacturer introduces a major new series such as Criterion, the product provides a cost-performance advantage over competitive systems. But, with Criterion, I think the advantage is so striking that I am confident it will create a significant impact in the market for many years to come.

What, then, of the future? If competitors respond with price cuts and new product announcements, how will this affect our position?

Well, I can tell you that we also anticipate significantly improved cost-performance in Criterion systems over the next few years, based on manufacturing learning curve cost improvements and on planned enhancements to the product line.

Taking, as an example, the cost of memory, we can anticipate a further reduction in cost within the next two years with the availability of a 16K x 1 bit MOS memory chip. With the Criterion bus architecture, we are well equipped to take advantage of such developments: we will simply implement memory cards with the new memory chip, and they will plug into the bus back-panel.

We also anticipate the release of other Criterion models in the future to fill out the line and we fully intend to announce multiprocessor versions of Criterion. Here again, the bus architecture lends itself very well to such extensions. And we expect further integrated controller developments for future Criterion peripherals.

Further advances in the areas of firmware and software are also planned, with new or extended virtual machine emulators, further releases of VRX software which will emphasize the areas of transaction processing and data base management, and vocational application packages to meet specific customer needs.

In summary, I believe that with Criterion we are in an excellent technological position to respond to any future competitive development for many years.

I would now like to introduce Mr. Gil Williamson, Vice President of CI/MEG Marketing who will discuss Criterion Marketing.