CASE STUDY

EXPERT SYSTEMS FOR CONFIGURATION AT DIGITAL: XCON AND BEYOND

Members of Digital Equipment Corporation's team of expert system experts reflect and recount a decade's worth of lessons learned in designing and building a core of configuration systems

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The XCON configuration system at Digital Equipment Corporation was the first expert system in daily production use in industry [2, 10, 11]. It is the cornerstone of Digital's knowledge network vision: a number of expert systems embedded in both the company's order process cycle and its new product introduction cycle [4]. Today, Digital is continuing to extend the knowledge network, as well as using expert systems technology in many additional aspects of the company's business. In fact, XCON is only one of several expert systems dealing with hardware and software configuration which are currently in use or under development at Digital. The configuration systems "family" includes four expert systems in production use. Several additional configuration expert systems are in the research, advanced development, or prototype stage of development.

The development of these expert systems has spanned nearly 10 years; Digital's Configuration Systems Development Group (CSDG) has thereby gained considerable understanding of all phases of the lifecycle of production quality expert systems: design, development, production, and ongoing support. In this article we highlight some of the key lessons we have learned:

- Building a successful expert system involves much more than simply putting rules into a knowledge base. Rather, to successfully develop and provide ongoing support for expert systems and to integrate them into the fabric of one's business, as has been done at Digital, one must attend to the needs of the business and to human resource and organizational issues as well as to technical issues.
- Although many software engineering practices carry over to the engineering of expert systems, we have nonetheless needed to be creative in developing practices specifically tuned to this relatively new, and still evolving, technology.

While the accompanying article by Bachant and Soloway focuses specifically on the technical issues underlying XCON and the other configuration systems, we take a more holistic, integrative approach in this article and attempt to put the aforementioned concerns into a coherent perspective.

CONFIGURATION SYSTEMS AT DIGITAL TODAY

The Digital Configuration Systems Timeline (p. 302) shows, for each of the configuration systems, key stage-of-life milestones, including initial production use where appropriate.

XCON is used to validate the technical correctness (configurability) of customer orders and to guide the actual assembly of these orders. It provides the following functionality:

- Configures CPUS, memory, boxes, backplanes, cabinets, and power supplies, disks, tapes, HSC/CI, printers, etc.
- Diagrams complete system configuration (Figure 1 overlays selected pages of a sample XCON diagram)
- Checks marketing restrictions, system building block menus, and prerequisites
- Assigns addresses/vectors and determines box power status
- Partitions multiple-cpu orders and cluster systems
- Determines and lists cabling information
- Lists components ordered with configuration-related comments
- Generates warning messages on issues affecting technical validity.

XSEL [7, 9] is used interactively to assist in the selection of saleable parts which make up a customer order.

It provides the following functionality:

- Allows interactive selection by generic component name, partial or full model number
- Performs completeness checking, adding and suggesting required parts
- Checks software compatibility, prerequisites, license and media completeness
- Checks standard and system building block menus, marketing and engineering restrictions
- Provides computer room environmental data and requirements
- Links to Automated Quotation System.

XFL is used to diagram a computer room floor layout for the configuration(s) under consideration. It provides the following functionality:

- Provides "minimum footprint" floor layout of components
- Allows custom rooms (user-specified dimensions and placement)
- Can include several configurations or a cluster in one site layout.

XCLUSTER is used to assist in configuring clusters. It provides the following functionality:

- Clusters multiple-node configurations for validation
- Specifies device quantity for dual porting
- Upgrades appropriate clusterable tapes.

In addition to these four systems currently in production use, two other configuration systems are under development:

XNET is an expert system which will be used to design local area networks, to select appropriate components for such networks, and to validate the technical correctness of the resultant network configurations.

SIZER is a research effort addressing the need for tools to assist in the sizing of computing resources required for any of a wide variety of uses in various types of organizations.

To support the ongoing development of the configuration systems in production use and to enable us to more effectively build new configuration systems, we have developed a software engineering methodology, called RIME [1, 12, 13], expressly for expert systems. Because RIME provides substantial insight into the engineering issues that require particular attention in building expert systems, it is discussed at some length in "The Engineering of XCON."

SCOPE AND USAGE

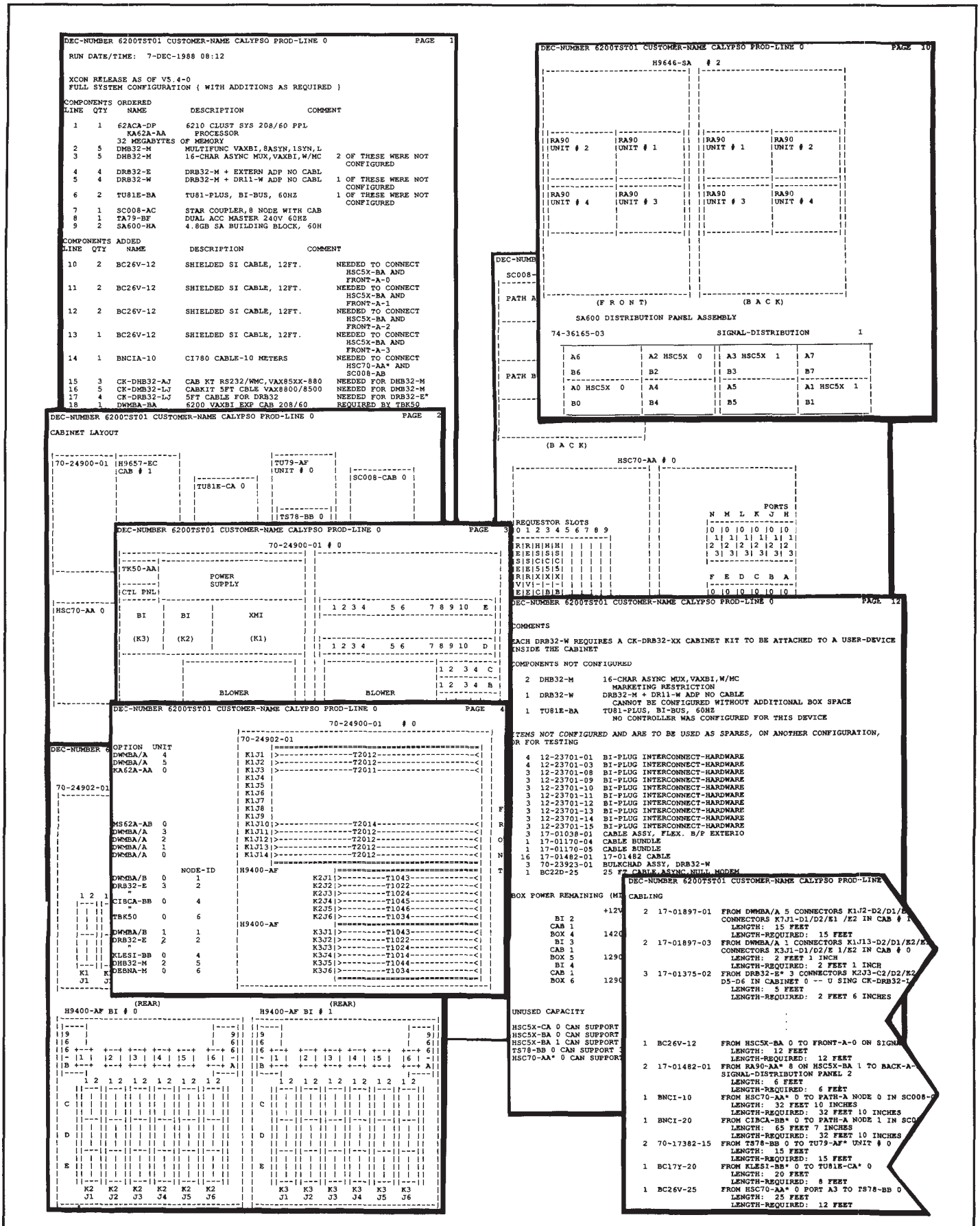
The configuration systems provide full product coverage for Digital's current product set. This product set today consists of 42 different families of central processor types and their supporting peripherals and software. In order to be useful business tools, released versions of these systems must include configuration knowledge of Digital's newest products by the time of product announcement. In practice, this means that CSDG provides major releases of these systems once each quarter, with at least one interim upgrade to insure adherence to the time-of-announcement requirement.

Hardware and software configuration is at the core of Digital's business. The configuration systems are used worldwide, throughout the corporation, by a broad set of users across the company's major functions: sales, manufacturing, field service, and engineering. The users of these systems perform functions which span Digital's complete order flow and manufacturing cycle, and, thus, are involved with many different business processes. This is a large and varied constituency to support—each has different needs and takes a different perspective on the configuration information provided:

- Sales uses the configuration systems as an integral part of the automated process to generate quotations for customers, and to insure that every order is technically valid.
- Manufacturing uses the information to verify buildability of all incoming orders, to understand physical partitioning of an order into various subassemblies to determine which plants should build which segments of an order, to guide the assembly of all orders, to determine the optimal set of diagnostics to run on each order.
- Field service has the perspective of consolidation and assembly of the order in the customer's unique environment and possibly with existing equipment already installed.
- Manufacturing and engineering benefit from the configuration systems' focus on system integration, as analysis of product knowledge for inclusion in the configuration systems identifies potential problems in system-level design and manufacturability.

This user profile has expanded dramatically over the years (see timeline). For example, the initial purpose of XCON was to assist manufacturing plant personnel in validating the technical correctness of system orders about to be built. Since then, this technical validation function has changed in response to business needs and is now performed in the field as well. In addition, the technicians in the plants who build the computers now use XCON diagrams to see how to put the systems together, and they include those diagrams in the shipment to the customer for use by field service installers at the customer site. XSEL was originally designed for use by sales representatives, and is now used by our OEM customers as well. Implementation of XNET will add specialized field support personnel to the user list in the near future. There are additional "indirect" users of these systems through automated linkages to other software systems (both traditional and expert systems) which depend on the configuration information supplied.

The configuration systems user base not only represents over 10 distinct business functions, but is also spread across the world, and has varied geography-specific needs. Overall, CSDG supports over 50 production installation sites, and the number is growing. In sum, then, the configuration systems are firmly em-



bedded in Digital's most critical business processes. The existence of these expert systems has significantly improved these processes and continues to provide insight into opportunities for the future.

BENEFITS

Only a modest amount of attention has been given to documenting the benefits of applying expert systems technology [3, 8]. The configuration systems are a success and there is a major dependency on them within the corporation, worldwide. They benefit Digital in a number of ways, contributing to customer satisfaction, lower costs, and higher productivity. These systems are recognized as a critical factor in Digital's ability to maintain its highly successful *a la carte*, build-to-order marketing strategy (customized configurations to fit each customer's specific needs); this is one of the company's key competitive advantages. Some of the benefits are difficult to quantify, but overall the net return to Digital is estimated to be in excess of $40 million per year.

The use of the configuration systems insures that complete, consistently configured systems are shipped to the customer. Incomplete orders do not get through the process. In addition, XCON generates configurations which optimize system performance, so customers consistently get the best view of our products. Before the configuration systems, we would often ship the same parts configured differently. (There are multiple ways to configure the same set of parts to create a working system.) This was a major source of customer complaints and confusion, especially for OEM's who order large numbers of the same system and in turn reconfigure them all in the same way as part of their market-specific value added process.

The process of new product introduction is enhanced greatly by the focus on configuration information provided by the configuration systems. The existence of a single source of configuration information by the time of product announcement for use on initial customer orders simplifies field and manufacturing training needs and avoids confusion about new products which can delay time-to-market significantly. This is of critical importance given the volume of new products Digital continues to introduce each year. This single source of configuration information also increases manufacturing's flexibility by enabling product manufacture (and the knowledge of how it is done) to be moved from one plant to another without costly training or disruptive re-assignment of people. The use of XCON has facilitated this re-alignment of manufacturing capacity several times.

The use of the configuration systems has significantly increased the technical accuracy of orders entering manufacturing. Straightening out problem orders is a costly and time-consuming activity which disrupts the normal processes and increases order cycle time (i.e., delays order shipment). Overall, the additional discipline of both field and manufacturing use of these systems has shortened cycle times, contributed to more flexible, smoother-running processes, and lowered the number of people who would otherwise be needed for a given volume of orders.

XCON is seen as a critical component of Digital's current process of shipping segments of an order from various component plants, to consolidation points, and from there to the customer site. The use of XCON throughout the manufacturing process assures that when the components of the order come together for the first time at the customer site the system will work. Before the use of XCON, there were special manufacturing plants where every customer order was completely assembled, tested, disassembled, and repacked prior to shipping in order to insure the system would work when installed at the customer site. The elimination of this step in the manufacturing process (called Final Assembly and Test) has had a major positive impact on cycle times, inventory levels, and manufacturing costs, especially in light of Digital's four-fold increase in systems product volume since 1980.

Thus, the configuration systems are key in Digital's ability to handle the product complexity that technology advances are enabling and that our customers are demanding.

THE CONFIGURATION SYSTEMS EXPERIENCE

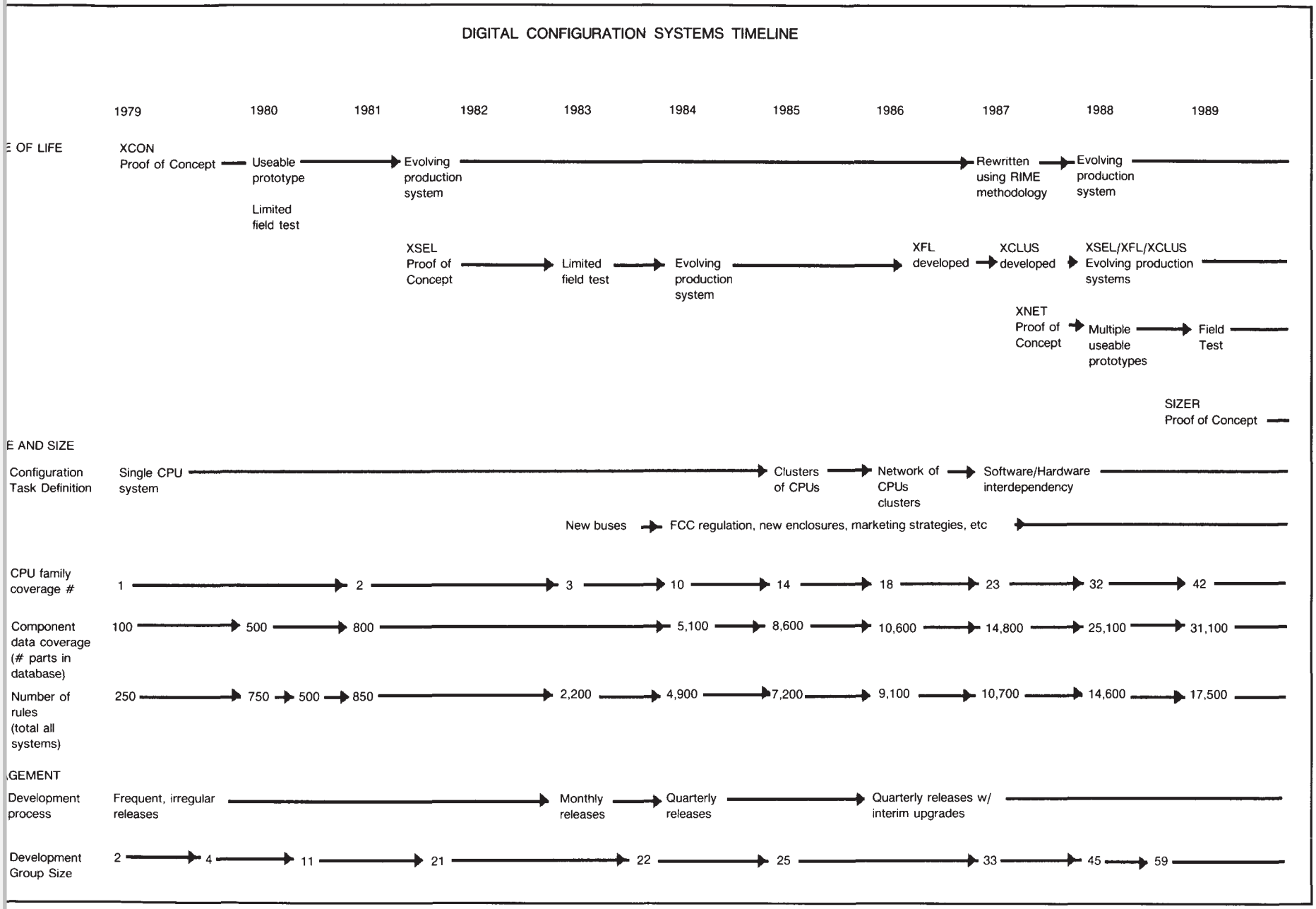
At Digital, we believe that our success in the application of expert systems technology is attributable to a conscious recognition of and careful balance among three important perspectives: strategic/business, technical, and human resource/organizational.

STRATEGIC/BUSINESS ISSUES

Digital has reaped and continues to reap enormous benefits from the configuration systems. It was, of course, an experimental effort at first but it was nurtured and allowed to progress and turned out to be a resounding success. Now Digital considers its use of expert systems technology a strategic investment.

What are the characteristics of an appropriate business problem for this type of strategic investment in a new technology? The problem must be real and systemic to the enterprise to justify the right kind of nurturing and supportive business environment. The solution will probably impact multiple organizations or functions and, hopefully, will bring about significant and positive changes in the way the enterprise operates. The configuration problem at Digital certainly qualifies. Digital's strategy of selling customized solutions is one of its critical competitive advantages, and gives rise to an indefinite number of valid configurations of its product set. In the 1970s, problems with handling this were starting to surface, and it was understood that automated support would be critically important as sales volumes increased and products became more varied and complex.

One of the main challenges we have encountered in developing systems which support strategic, cross-



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