

Evolution of Global Key-System Platforms

Vincent J. Silverio
Sandra J. Brown
Warren B. Houck
Giorgio Marinzoli
Stacey D. Sern

In this paper, we examine the processes used to globalize AT&T's small key systems, recounting the experiences of the AT&T Partner® key system development team from AT&T Global Business Communications Systems. We trace a product history where a strong North American market has been the tradition. To meet the challenges of a global market, the development team elected a two-phase approach: product reuse and customized development. *Reuse* includes using existing products and creating new products from parts of existing products. *Customized development* has evolved in three stages: First, being well versed in the design of key systems for the United States, the development team applied its knowledge and that of AT&T's other international organizations to redesign existing products to meet immediate, global business needs. Many near-term choices were made to meet customer needs and reduce risk. Next, the team examined strategies for developing global platforms. It addressed issues of a shorter development interval and efficient manufacturing. Finally, the team applied this knowledge to gain efficiencies in design and manufacture. It sought the right balance of platforms and compatibility to meet the needs of internal and external global customers.

Introduction

AT&T Global Business Communications Systems product line of Partner key systems was initially developed in 1989 for small businesses in the United States and Canada. Throughout the product's history, a strong North American market has been the tradition. This market is characterized by large volumes of product that meet one set of standards. In contrast, international products are sold in smaller volumes and must meet different standards in each country. Thus, in January 1990, the Partner system product team from AT&T Global Business Communications Systems faced new challenges when it became responsible for the globalization of small key systems. (Panel 1 defines terms and abbreviations used in this paper.)

To meet these challenges, the team members followed two approaches: product reuse and customized development. Reuse is

characterized by the:

- Use of existing products without modification
- Interchange of parts of existing products to create new products.

Customized development has evolved in three stages:

- Build an international design by making incremental changes to existing Partner system products to meet immediate business needs. Although well versed in the design of U.S. key systems, the members of the team sought design knowledge from other international organizations in AT&T to solve specific problems. The team made many near-term choices to meet customer needs and reduce risk.
- Examine strategies for developing global platforms after the knowledge base had grown sufficiently. The team built a library of Type Approval requirements and features that was used to determine the scope

Panel 1. Abbreviations, Acronyms, and Terms

CO — central office
codec — coder-decoder
CPU — central-processing unit
development team — engineers in Middletown, New Jersey, who are responsible for product development including systems engineering, software design, control-unit or telephone-set electrical design, physical design, and systems assurance
ESD — electrostatic discharge
ETR — enhanced tip-and-ring
key system — a small telephone switching system that allows several telephone lines to be connected to a number of telephone sets that use keys or buttons to select the lines directly
PBX — private branch exchange
product team — core team consists of the development team and representatives from product planning, product marketing, and product management. Extended product team adds representatives from services, technical support, and manufacturing.
R&D — research and development (i.e., the development team)
ROM — read-only memory
Type Approval — the process through which a government agency in a country ensures certification of a product to the local regulatory standards for product safety and electrical compatibility. These standards and the approval process vary from country to country.

of broader, global platforms. The platform strategy addressed the goals of a shorter development interval, fewer unique product codes, and efficient manufacturing through the use of flexible hardware and software designs. (*Type Approval* is the process whereby a government agency ensures certification of a product to a country's regulatory standards for product safety and electrical compatibility. The standards and the process through which approval is granted vary significantly among countries. The *library* is a collection of information about Type Approval standards.) In this issue, the

paper by Heirman, Crosby, and Smith discusses¹ mandatory product standards.

- Apply the knowledge and use the strategies to design and manufacture Partner systems efficiently for global markets. This stage involved finding the right balance of platforms and compatibility that still allowed the team to meet the needs of global customers within and outside the company.

The customized development of control-unit hardware, telephone-set hardware, and software has evolved through these three stages to a set of global platforms. This paper is a study of the globalization process and summarizes the team's experiences with the process.

The North American Product

Figure 1 is a family portrait of the global product line of Partner systems.

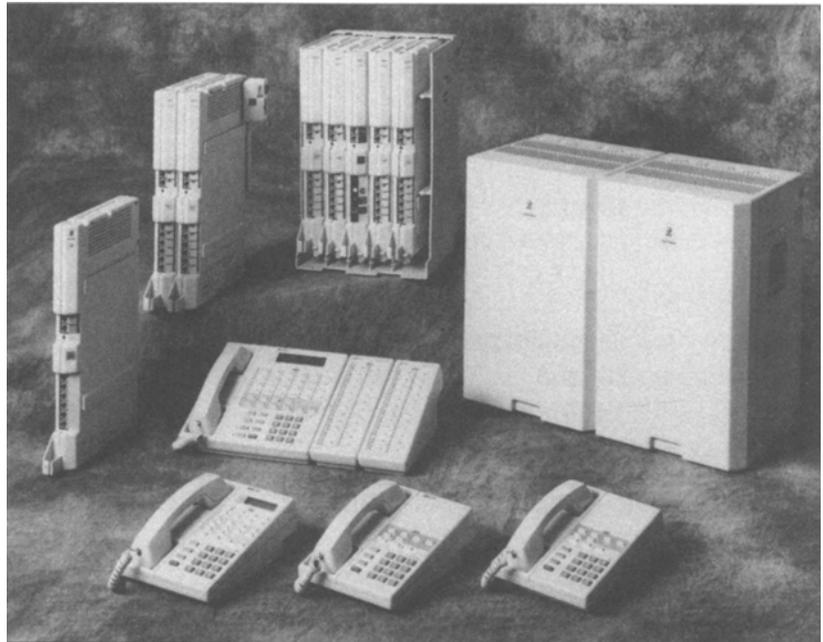
The smallest member of the Partner system family is a 206 module, a digital switch that supports two loop-start, central-office lines and six enhanced tip-and-ring (ETR) ports. This unit, which appears on the far left in the photograph, is self-contained; i.e., it includes its own power supply. This Partner system can operate alone, or it can be combined with another 206 module using a backplane connector to provide a maximum configuration of four central-office lines and twelve station ports. (The two-module unit appears on the upper left in Figure 1.)

The Partner Plus system consists of a cabinet that can accommodate up to four of these 206 modules and has a separate processor module for additional functionality. Its maximum configuration is 8 central-office lines and 24 ETR station ports. (The Partner Plus system is at the top center of the photograph.)

The Partner II system builds on the Partner Plus system by adding an expansion processor mounted in a second cabinet to support a maximum configuration of 16 central-office lines and 48 station ports. Or, if a four-line module is used, a square configuration can be achieved with a maximum size of 24 central-office lines and 24 station ports. The Partner II system is at the right in the photograph.

The ETR station ports support the proprietary, multiline AT&T Partner system telephones, as well as industry-standard tip-and-ring devices—such as single-line telephone sets, facsimile machines, credit-card

Figure 1. The global product line. Multiline, Partner system telephone sets appear in the center and in the front row of this photograph. On the left is a 206 module, the smallest Partner key system, which supports two central-office lines and six enhanced tip-and-ring (ETR) station ports. This self-contained unit can operate alone, or be combined with another 206 module (upper left) to provide up to four central-office lines and twelve station ports. The Partner Plus system (top) uses several 206 modules plus a separate processor module for additional functionality to support up to 8 lines and 24 station ports. The Partner II system (right) adds an expansion processor and a second cabinet to support 16 central-office lines and 48 station ports. If four-line modules are used, its maximum size is 24 central-office lines and 24 station ports.



readers, and modems. The tip-and-ring devices connect directly without adapters. In addition, the Partner system is the first in the industry to support both set types simultaneously on the same physical control-unit port. This is accomplished using patented port circuitry and a simple bridging connector.

By building on its experience with the development of AT&T's Merlin[®] key system, the Partner system product team had a good understanding of the needs of small-business customers in the United States. These customers need a reliable telephone system that is easy to use and relatively low in cost. Because these customers are so sensitive to product and service costs, the team made design decisions and tradeoffs to keep the cost of the delivered U.S. product to a minimum. To achieve this objective, the Partner system was designed to be very functional with only a few different modules.

The design goals were to make Partner systems:

- Easy enough to install that customers could install the system themselves
- Easy to repair to keep servicing costs low
- Easy to use to keep training costs to a minimum.

The basic Partner key system has only a few user-programmable options. Although the Partner Plus and Partner II systems have larger feature sets and are more

flexible, providing more programmable options, they, too, are easy to install, repair, and use.

All the Partner systems are programmed from a proprietary Partner system telephone set. In addition, a customer who has difficulties with programming the system can dial a toll-free number and be *talked through* the procedures by technical support personnel at Global Business Communications Systems' National Service Assistance Center in Englewood, Colorado.

The Partner systems, which are designed specifically for the small-business market in North America, have been well received by customers in that market. Certain features, such as the dial plan, were optimized for use in the United States and are not necessarily a good match for global markets. In addition, the systems were designed to meet:

- North American ac (alternating current) power standards,
- The Federal Communications Commission and Canadian Department of Communications rules for connection to the public telephone network, and
- Underwriters' Laboratories and Canadian Standards Association requirements for user safety.

These standards do not strictly align with other international standards, such as the signaling and transmission characteristics of non-U.S. telephone networks, the

International Electrotechnical Commission 950 standard for user safety, or the predominant use of 220-Vac (volts ac) power outside North America.

Beyond the North American Market

The Partner system product team has followed two approaches as it has advanced the evolution of the Partner system to a global presence. One approach has been to reuse existing products without modification whenever possible. The second approach has focused on customized development for specific international markets, expanding and building on existing products.

Product Reuse. The first approach followed in pursuit of a global presence has been to achieve more market gain with little or no change to existing products. The product team has identified numerous markets where existing versions of the Partner systems might meet the local standards and customer needs.

"As is" has become the paradigm for this activity, and the standard U.S. product has been introduced successfully in many countries including Taiwan, Mexico, Ecuador, Costa Rica, Panama, and Bermuda. In addition, a version of the Partner system product developed for Italy was found to work well in eastern and southern Europe. For example, customers in Hungary, Poland, the Czech Republic, Bulgaria, and Greece have been able to use this second product. A third product expands on these two by merging components of the North American product with the 220-Vac power-supply module developed for Italy. With this product, we have been able to take advantage of opportunities in South America, the Far East, the Middle East, and Africa—e.g., in Chile, Singapore, Thailand, Saudi Arabia, Kuwait, Egypt, and Ghana.

The availability of potential new markets for the Partner systems in other countries has also created new challenges. While the product's features and capabilities may appear highly desirable for a given local market, the introduction of the product in the country often demands efforts and solutions that are not required for the U.S. market. One challenge for the Partner system product team has been how to maintain comprehensive support for the local customer with technical support from General Business Communications Systems' U.S.-based R&D organization. Cultural diversities, language and accent barriers, and longer delays for information exchange are factors that affect the level of support that can be

provided via facsimile, telephone, or the rarely available electronic-mail medium.

Another challenge for the development team has been to verify that the product can interface correctly with the country's telephone network. This process has been difficult because members of the team often cannot be present to conduct the tests.

The key mechanism for determining the technical compatibility and user acceptability of the product for a given market is the *international field-trial process*. This process consists of an extensive set of activities that range from gathering technical and environmental data to evaluating the results of a series of tests.

Engineers from the local distributor's organization become familiar with the system through the product documentation and by consulting with the development team in the United States. Then, they perform the tests outlined in a *field-trial evaluation checklist* and document the results for analysis by the development team.

This process has proved successful for testing the product's technical compatibility with the local public network before AT&T invests in the launch of a product. It has also helped to identify areas for enhancements in the next generation of products.

Customized Development. The product team's strategy to expand the Partner system's global presence has included opening new markets where current products will not meet the regulatory standards or customer needs. The first opportunity for custom development of the Partner key systems outside North America was the result of a 20-percent equity purchase of Italtel Telematica in 1989 by AT&T Network Systems International.

To support the rapid development of the Partner system for Italtel, a development team was formed with one objective: quickly modify an existing key-system product to meet the needs of Italian customers. To meet this goal, the members of the newly formed team adopted a "delta" approach to the project; i.e., they tried to preserve as much of the existing U.S. product as possible, and quickly learn what changes were needed to achieve the schedule and development-cost goals while still meeting customer expectations. These changes included ac power, switch transmission, and feature operation (e.g., Italian-language display messages, improved tip-and-ring telephone support, and privacy enhancements).

To ensure the project's success, Italtel contributed five of its own engineers who then worked in the United States with the development team. The assembled team—its members new to the concept of global design—focused on the near-term needs of the Italian customers and avoided radical product changes that could lead to longer-term benefits, but with a longer schedule. The resulting key-system product met the customer's needs and became a new Partner key system platform in its own right. We have already mentioned some of the opportunities for reusing this platform beyond the Italian market.

Evolving Platform Requirements

The need for custom designs has brought with it the need to streamline the development process. By maximizing the reuse and overlap of platforms, R&D resources are optimized, reducing development costs and the time to market.

A totally different version of the product could be designed to meet the standards and requirements of each country (as was done for the Italian product). However, the team decided to identify a superset of requirements and use them to design platform products that would meet the needs of several markets. The intent was to align with and stay ahead of the opportunities that the product team was pursuing for new-market development.

To design a global product, requirements in two categories must be investigated:

- Local standards (i.e., power standards, transmission requirements, and dial plans)
- Local tastes (i.e., software features, and physical design of the telephone).

If the first item is not addressed, then the local safety or government regulations would not permit us to introduce the product into a market. If the second item is not addressed, we could introduce the product into a market but it might perform poorly compared to competing products. This is especially true for low-end, small-business products such as the Partner system.

One complex task was to understand Type Approval requirements for the target markets, focusing attention on those requirements with the widest range of values across the markets. The next step was to identify the strictest safety standards and network-dependent parameters from this group to ensure that the resultant design would have wide applicability. The team began by networking with other AT&T organizations that were

involved in the design of global products and compiling a library of applicable international standards for key systems.

As part of the investigation of the Type Approval and feature requirements for a target market, we send an existing platform—deemed to be a best fit—to a local representative for evaluation. This person must be someone who knows the country's regulatory requirements. The feedback received and the knowledge gained about Type Approval regulations helps to determine the scope of the modifications needed to design a system for that market. For the customized development for Italy, the team also had the benefit of resident technical support during the development phase.

Ready access to Type Approval contacts and customer representatives simplifies decision making and ensures that the right product is being developed. This is especially critical where AT&T does not control the distribution channel or does not have direct contact with the product's user, but the product must still meet AT&T's standards for quality as perceived by all members of the value chain, including the users.

As we investigated the requirements for target countries and for countries with similar requirements in the same geographic area, we learned more about the parameters and requirements that were most likely to change for different marketplaces. From these, we identified a set of parameters that would have to be modified for each country if the product is to interface correctly with the country's network and meet that market's Type Approval requirements. To serve as *platform* products, the Partner systems would have to be designed so that these parameters could be altered easily when we develop the product for a new market. This process of identifying the platform requirements has added time to the development schedules, but the ability to adapt the platforms quickly to new markets has outweighed the initial costs.

Because of the differences in feature requirements among the target markets and, more important, in customer expectations in different parts of the world, it became apparent that there were four distinct customer groups:

- Northern and western Europe
- Southern and eastern Europe
- North America
- South America, Central America, the Far East, and the Middle East.

Each of these groups has certain standards and expecta-

tions for small key systems that differ from those of the other groups.

Although it is technically possible to develop one version of the product that would be flexible enough to be marketed in each group, it would cost more than customers would be willing to pay and would become more difficult to install and use. Instead, we chose to develop several platform products. (For larger systems, such as the Definity® telecommunications system, where the cost is not as critical a factor, we have been able to justify a single global platform.²)

Hardware Platforms

In the first derivative development of the Partner system, i.e., the one done for Italy, the schedule was very important to the customer. Therefore, we chose an architecture that retained most attributes of the U.S. system in terms of telephone sets and control units. However, several transmission parameters were adjusted, and the 220-Vac power supply was designed to meet Italy's Type Approval requirements. This approach allowed us to go from defining the system requirements to shipping the first units of the product in one year.

Since then, the product team has pursued a large number of markets with different hardware requirements that have demanded more-flexible platforms with broader applicability. The driving forces have been both R&D and manufacturing efficiencies. Evolving to these platforms has been a challenge because early versions of the hardware (both central control units and telephones) for the Partner system were optimized for a single, high-volume, North American market, and international sales are characterized by multiple markets with lower volumes. (The developers of the Definity system used a similar approach for its hardware platform.³)

Control-Unit Hardware. The goal has been to design platforms that are very flexible, yet appear to the manufacturing group to be the same product. For example, Figure 2 shows how the control-unit architecture has evolved. As time has progressed, later platforms have subsumed the functions of earlier ones. However, it has not been the product team's policy to discontinue the older platforms immediately, primarily because of the obvious additional work needed to get the newer platforms approved again in many countries.

The most recent evolution of the Partner system control unit comprises two platform products that

achieve a balance between customization and flexibility. One platform, which is targeted for North American and non-European markets, satisfies the need for lower cost and high volume at the expense of universal flexibility. The other, targeted for European markets, is more adaptable to several similar but distinct customer groups.

To achieve this flexibility, we used *software-reconfigurable hardware*; i.e., a hardware configuration that can be altered by changing certain variables in its stored-program control. One key component is a codec (coder-decoder) that is based on a digital-signal processor. The codec is a transmission-processing device that permits software control of gain, hybrid balance, equalization, and termination impedance. Use of the codec was a natural design extension, given that the Partner system's switch fabric consists of digital, time-division multiplexing across 256 time slots. (*Switch fabric* refers to the fundamental hardware elements that effect the cross connection of ports on the control unit.) Although this design approach has resulted in slightly higher component costs, it has eliminated the one-time setup charges for low-volume manufacture, which offsets the product's total delivered cost. (This approach was also used in the Definity system's global design.³)

Our first opportunity to try this new platform architecture was for a western European platform that was targeted for release almost simultaneously into Spain and the United Kingdom. Except for the software and some changes to component values for detecting central-office ringing, the control-unit hardware for these two markets is identical, despite the large differences in the transmission and termination requirements of these markets.

By using the concept of *selective-component population* during manufacture, we have provided flexibility for such parameters as the:

- Type of digital encoding (e.g., μ -law or A-law) used in the switch fabric
- Duration of memory holdover for customer programming
- Need for different fusing and grounding arrangements in the power supply.

The country-specific components that are selected during manufacture can be discrete devices or optional sub-assemblies, such as circuit boards for dial-tone detection and periodic pulse metering. Because all tone-frequency information is kept in an inexpensive, read-only memory (ROM) device, tone generation is another function that is

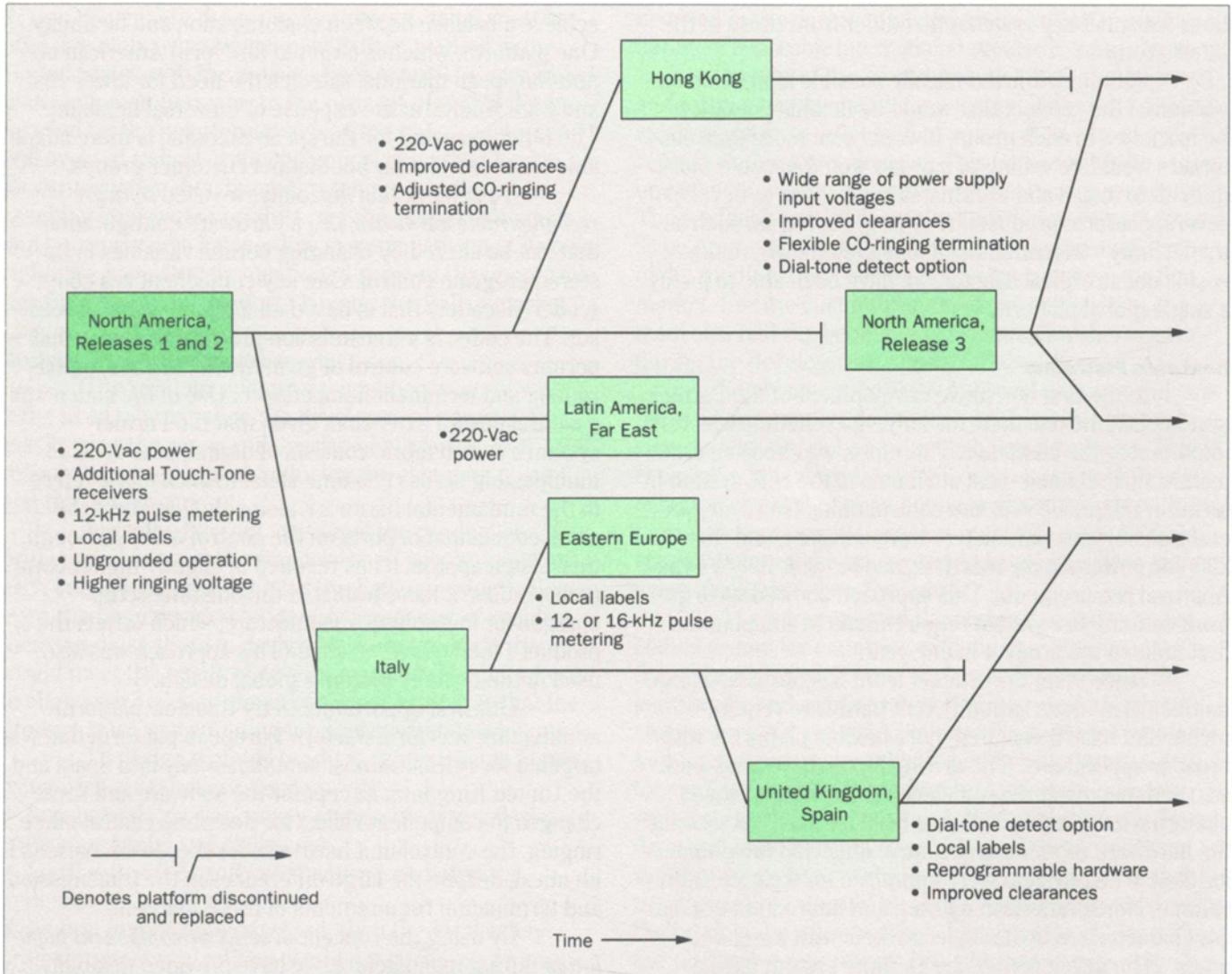


Figure 2. The goal has been to design flexible platforms that appear to the manufacturing group to be the same product. Here, we show how the Partner system control-unit platforms evolved. Later platforms subsume the functions of earlier ones. The two most recent control-unit platforms achieve a balance between customization and flexibility. One platform satisfies the need for lower cost and high volume at the expense of universal flexibility. The other is more adaptable to several common but distinct markets.

easily changed. Simple hardware reads the digital-tone samples into permanently dedicated, switch time slots. The tone cadences and all critical signaling and timing parameters are controlled by software in replaceable ROM devices.

Other areas of hardware have met the need for flexibility because we combined the broadest requirements from among the target markets. An example is power-supply design, where the team has focused on a wide range of input voltages and worst-case standards for component spacing, dielectric breakdown, and thermal environments.

Telephone-Set Hardware. For the Partner system telephone sets, the foundation of a global platform has been a common, bare, circuit board and common plastic housing. Adapting the sets to a new country has entailed changing some components on the circuit board, and has also involved modifying the dial pad and the printing on the plastic housing. A global telephone-set design must provide flexibility in the areas of transmission gains, termination impedance, and local wiring plans. To achieve the needed flexibility in the design, the parts that frequently vary have been handled as discrete components, instead of being integrated into larger devices that are difficult to modify. Other requirements that vary among countries are transmission distortion and audio noise. By meeting the most stringent requirement, the design has also met the less strict ones.

Figure 3 shows the evolution to this global telephone-set platform. Branches from the horizontal lines show how one set served as a platform for other markets. For example, the Italian set was developed from the U.S. version by component substitution on the existing circuit board to meet Italian transmission requirements. In addition, the Italian system had to operate in ungrounded environments. Therefore, we developed a differential interface to the handset's microphone to reduce the acoustic noise that would be picked up in this environment. Labels on the telephone dial and housing were also modified to use Italian, instead of English. To develop the eastern European set, we simply used an Italian circuit board in a housing that had English-language labels. (English is commonly accepted in many eastern European countries.)

A second-generation board used the circuitry of the Italian version but, through selective-component population, had the ability to support various cabling schemes, set impedances, and transmission characteristics. Also, cost-saving manufacturing techniques were introduced with this board. This board was first introduced in the Hong Kong telephone set and now serves as the platform for all other countries.

In general, the hardware-design philosophy has been to follow the platform requirements and develop as versatile a platform as possible, given the development budget and schedule dictated by the product team's plans. Newer platform designs continue to follow the product team's market road map but also fold in the advances in technology and any lessons learned during the introduction of earlier designs.

Software Platforms

In the first country-specific development, the system software was modified to meet Type Approval requirements and reshape the product to conform to the Italian concept of a key system. With this experience and exposure to other European requirements as a base, the members of the software and system engineering team undertook a three-part strategy to make entering other markets easier and quicker, while requiring fewer development resources. First, we enhanced the feature set—a process that began with the Italian key system—to develop a product that is attractive in Europe. Then, we increased flexibility by adding administration options to allow the product to move more easily from market to market without software changes. Finally, the software team devised a method to make it possible to compile by country the basic characteristics that were likely to change.

Enhancing the Feature Set. The first international development accentuated the fact that telephone systems are used differently outside the United States. In the U.S. market, proprietary-set use dominates, but the Italian system was to be marketed primarily with standard, single-line telephones. Much of the software effort was directed at providing better feedback and access to features for single-line telephones. A more-efficient, Touch-Tone receiver usage algorithm was added, as was support for additional receivers. Features such as call waiting and call back for an idle facility were added to accommodate the user of a single-line set, even though these features are normally found in private branch exchanges, not key systems.

We also added and changed features to conform to a different view of how telephone systems are used. For instance, privacy is valued more highly by Italian users than American users. Therefore, we added an intrusion tone to the Italian key system to signal that more than two people are on a call, and we reduced the probability of accidental bridging.

Adding Flexibility. As its members explored prospects for growth in other countries, the software and systems engineering team recognized the need to make the software more generic for use as a platform. Features likely to vary among countries that use the same version of the product were made programmable.

An example is call restriction, where the toll, international, and emergency numbers had been

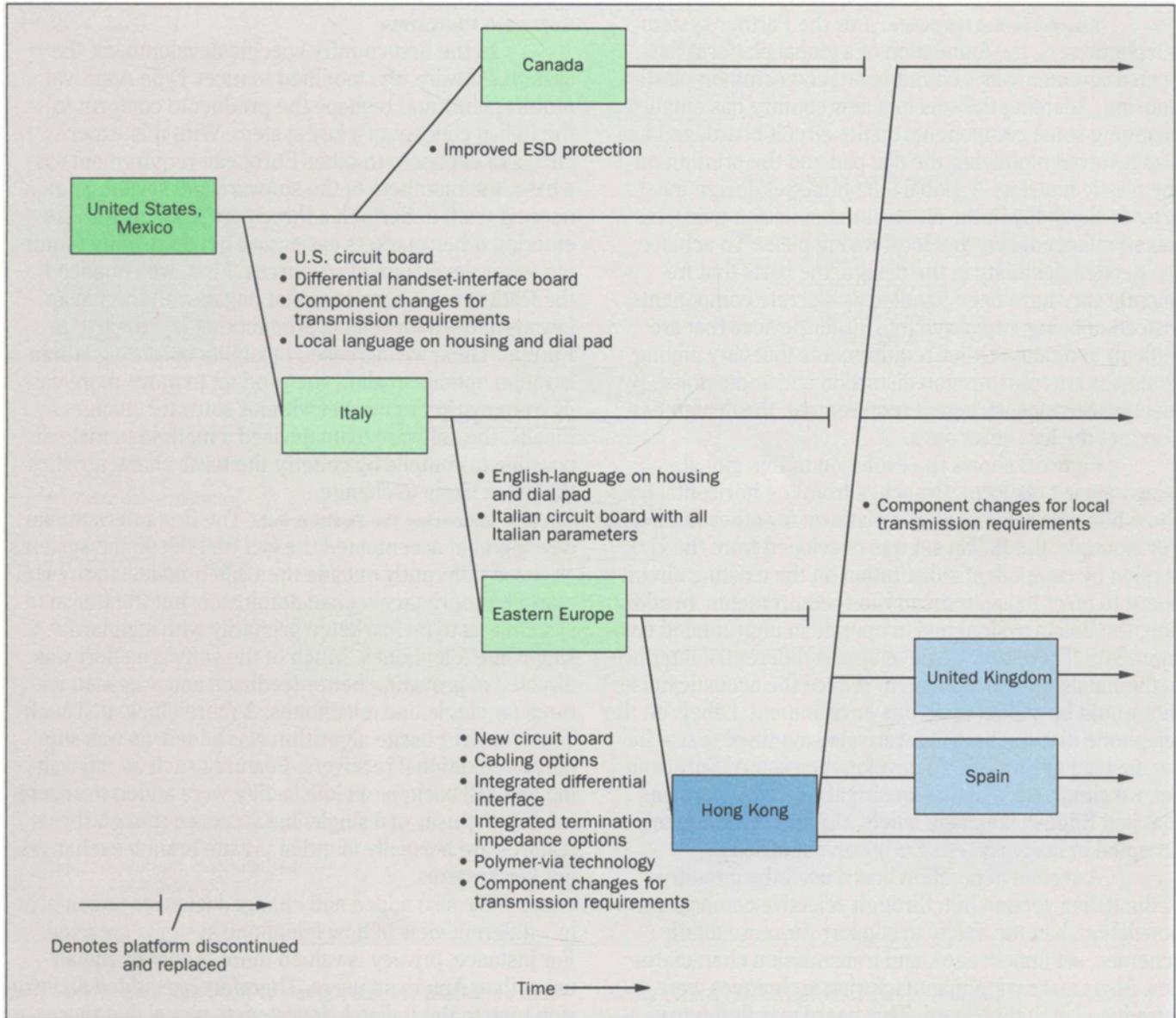


Figure 3. A global telephone-set design must provide flexibility in terms of transmission gains, termination impedance, and local wiring plans. A design that meets the most stringent requirement also meets the less strict ones. In this diagram of the evolution to AT&T's global telephone-set platform, the branches from the horizontal lines show how one set served as a platform for other markets.

permanently embedded in earlier systems. We added programmable lists that allow or block the dialing of prefixes for these types of numbers.

Other examples are the make-to-break ratio for rotary dialing, the insertion of transmission loss to handle a variety of central-office loop lengths, and the timing for dial-tone detection. These features were made programmable, so that the same system can be used in different network environments. (*Make-to-break ratio* is the

ratio of the length of time that a signaling loop is closed to the time that the loop is open. This quantity and the number of pulses per second uniquely define the signaling requirements for rotary dialing.)

Introducing Compilable Options. Once it had a comprehensive feature set, the platform could be customized for different countries by changing basic parameters to meet Type Approval requirements. We identified those parameters and isolated them into country-specific files within the code base. Now, the same code base can be compiled with the characteristics of an individual country just by specifying the country.

With this structure, new countries can be added without disturbing the code for the others. When we update or add new features, we can make the changes once, and then recompile the code base for each country.

One Versus Several Platforms

Because the volume of U.S. Partner systems being shipped today is disproportionately larger than the volume of international systems shipped, a global key-system platform that is flexible enough for all markets has not been an effective solution to achieve manufacturing efficiency. The lowest cost for a high-volume product still can be achieved only by less-flexible customization in the design.

However, if several concurrent platforms are being manufactured at one time, we can simultaneously lower the cost to users for the U.S. market where this cost is critical, yet maintain flexibility for rapid deployment internationally. Having multiple platforms can also be made economical by careful design of subassembly interfaces. For example, power supplies, processors, and telephones can be interchanged with minimal modification, allowing for rapid development of derivative products or models for pretesting in new markets.

Type Approval—Still One Country at a Time

With all the emphasis on understanding global requirements and designing economical and flexible platforms for rapid deployment, the final stage in the successful introduction of a product remains the Type Approval process. As with the technical requirements, this approval process varies among countries, ranging from merely filling out forms to doing six months of extensive, local testing.

Currently, the approval process is still a country-

by-country procedure that requires people who have knowledge of the specific market. In addition, because government agencies are involved, the process sometimes requires more diplomacy than engineering skills. Also, while AT&T is a global corporation, the company still does not have the presence it needs in many countries to introduce or distribute small communications systems successfully. For these reasons, a local expert (either an individual or a company) is essential for timely introduction of a product.

On-site AT&T involvement in the Type Approval testing process has also been useful. This has been especially true when approved test facilities were not available to the designer during the prototype phase, and design adjustments must be made in real time. The need for on-site involvement can be reduced if the approval agency or its authorized representative will accept early models for an unofficial pretest.

Conclusion

The Partner key system has evolved from a single, North American standard product to a collection of control-unit-hardware, telephone-set, and software platforms. The type and number of platforms are a balance between selective platform reuse and custom development. These designs are continually evolving as Global Business Communications Systems' Partner system development team acquires more knowledge about Type Approval and the needs of global customers and applies new technology to minimize development time and the overall manufacturing cost, while maximizing reuse. But given the nature of the Type Approval process, platforms that are developed from a large library of technical requirements still must be flexible enough for rapid modification to accommodate unforeseen needs.

References

1. D. N. Heirman, S. M. Crosby, and D. C. Smith, "International Mandatory Product Standards," *AT&T Technical Journal*, Vol. 72, No. 2, pp. 25-40.
2. H. D. Frisch, B. S. Katz, and J. L. Knight, Jr., "International Considerations in PBX Design," *AT&T Technical Journal*, Vol. 72, No. 2, pp. 17-24.
3. M. R. Berg, N. E. Gallensky, G. D. Hamilton, W. U. Huh, J. L. Knight, Jr., and J. J. Sangerman, "World-Class Hardware and Transmission Design," *AT&T Technical Journal*, Vol. 72, No. 2, pp. 62-73.

(Manuscript received September 21, 1992)

Sandra J. Brown is a member of technical staff in the Small System Design Department with AT&T Global Business Communications Systems in Middletown, New Jersey. The lead systems engineer for international Partner key systems, she is responsible for determining regulatory and customer requirements for international markets and for defining the flexibility needed in the platform products. Ms. Brown joined the company in 1980. She has a B.S. in computer science from Union College in Schenectady, New York; and an M.S. in computer, information, and control engineering from the University of Michigan in Ann Arbor.

Warren B. Houck is a member of technical staff in the Small System Design Department with AT&T Global Business Communications Systems in Middletown, New Jersey. He is responsible for the electrical design of Partner system telephone sets for all countries and for the development of firmware for Partner system adjuncts. Mr. Houck joined the company in 1985. He has a B.S. in electrical engineering from Michigan State University in East Lansing, and an M.S.E.E. from Purdue University in West Lafayette, Indiana.

Giorgio Marinzoli is a member of technical staff in the Small System Design Department with AT&T Global Business Communications Systems in Middletown, New Jersey. He is responsible for functional verification and system testing of Partner system international products with emphasis on the country-specific requirements and features. Mr. Marinzoli joined the company in 1979. He has an accounting degree

from Istituto Tecnico Commerciale in Carrara, Italy; a B.B.A. in international trade from City College of the City University of New York, and an M.S. in computer science from Monmouth College in West Long Branch, New Jersey.

Stacey D. Sern is a member of technical staff in the Small System Design Department with AT&T Global Business Communications Systems in Middletown, New Jersey. The leader of the software-development team for international Partner systems, she is responsible for the design and implementation of the international software platform and features. Ms. Sern joined the company in 1986. She has a B.S.E. in computer science and engineering from the University of Pennsylvania in Philadelphia and an M.S. in computer science from New York University in New York City.

Vincent J. Silverio is a technical manager in the Small System Design Department with AT&T Global Business Communications Systems in Middletown, New Jersey. He is responsible for circuit design of telecommunications solutions for small businesses, and currently is working on the control-unit platform for the Partner system. Mr. Silverio joined the company in 1978. He has a B.S. in electrical engineering from Princeton University in New Jersey and an M.S. in electrical engineering from the State University of New York at Stony Brook.
