History and contributions of the IBM Scientific Centers

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The IBM Scientific Centers are celebrating their twenty-fifth anniversary. These worldwide Centers are autonomous organizations that provide IBM with the ability to respond rapidly to the evolution of computer technology for IBM and for its scientific customers. During the past quarter century these Centers have provided technical leadership in almost every branch of computer science. Today, the 17 individual Centers continue to explore new technical areas and provide significant contributions. This paper has three parts: an introduction to the mission, scope, and history of the Centers; a description of each Center's charter, history, and accomplishments; and an extended list of selected publications for each Center.

The IBM Scientific Centers were chartered, and the first four established, in 1964 to provide IBM with the ability to respond rapidly to the scientific marketplace and to changes in technology. From the beginning the primary mode of operation has been establishing long-range contacts with leading scientific customers, understanding their problems, defining solutions, developing prototypes, and ensuring IBM's responsiveness to their needs.

The idea of having a small, entrepreneurial organization within a much larger company has appeared again and again in American industry. "Skunk works," "ad tech groups," and "back room projects" are a part of American corporate folklore. The IBM Scientific Centers were created to fill just such a role for IBM. The emphasis was and is on having an autonomous organization of highly-skilled professionals who can develop scientific solutions and applications at the leading edge of technological change. During the past quarter century there have been many individual accomplishments within the Centers that have had a large impact on IBM, not only in terms of the product line, but also in terms of upgraded scientific and technical quality for other projects within IBM, basic research, market support, and a generally enhanced relationship with scientific customers. Thus, technology transfer remains the Centers' key contribution for IBM.

The approach and initial Centers were so successful that the concept of the centers was adopted on a worldwide basis. There are now 17 operational IBM Scientific Centers. The Centers have contributed in many branches of computer science and especially in computer architecture, personal computing, numerical analysis, algorithms, data structures, operating systems, relational databases, languages, compilers, microcode, networks, artificial intelligence, and knowledge-based systems.

Contributions in science and computer applications developed by the Centers include basic physics, chemistry, mathematics, agriculture, oceanography, surface hydrology, management science, econometrics, operations research, and commercial packages. The Centers have been heavily involved in human issues, such as the medical applications of computers, speech analysis and synthesis, computer vision, and natural-language projects in Spanish, Cat-

alan, Arabic, Italian, French, German, Chinese, and Japanese. On a worldwide basis there has been recurring involvement in addressing problems of national importance to dozens of countries, such as regional planning, food and oil production, pollution studies, mapping the Nile, and protecting Venice from the sea. It is also common for the Centers to have joint studies in progress with many universities and on all aspects of their work. Figure 1 illustrates some of these activities.

The original objective of the Centers was to have each one involved in the professional and academic environment of a nearby university—working with professors, involving students in projects, and contributing to the scientific milieu of the university. In practice each Center has also operated on a national and international basis, participating in projects with governments and remote partners. It was also an objective that the Centers influence IBM's technology direction and product offerings. Both objectives have been consistently achieved over the history of the Centers.

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United States Centers

When the first IBM Scientific Centers were founded 25 years ago in the United States, they were built on already firmly established traditions. The IBM Research Division was well-established, as were several large product development laboratories. The Applied Science Department in New York City under Cuthbert Hurd had been very successful in working with scientific customers during IBM's early expansion into electronic computing in the mid1950s. The key models were the joint IBM and University of California at Los Angeles (UCLA) Western Data Processing Center (WDPC), located on the UCLA campus, and a similar Center near the Massachusetts Institute of Technology (MIT), both of which had been established in 1957. Much of the philosophy and mode of operation for the new Centers came directly from these two prototypes.

The founder of both the earlier centers and the IBM Scientific Centers was C. R. "Charlie" DeCarlo, who was on the staff of IBM senior executive Arthur K. Watson. DeCarlo, with Watson's full support, foresaw a continuing need for an IBM commitment to applied science. The result is the present international network of Centers.

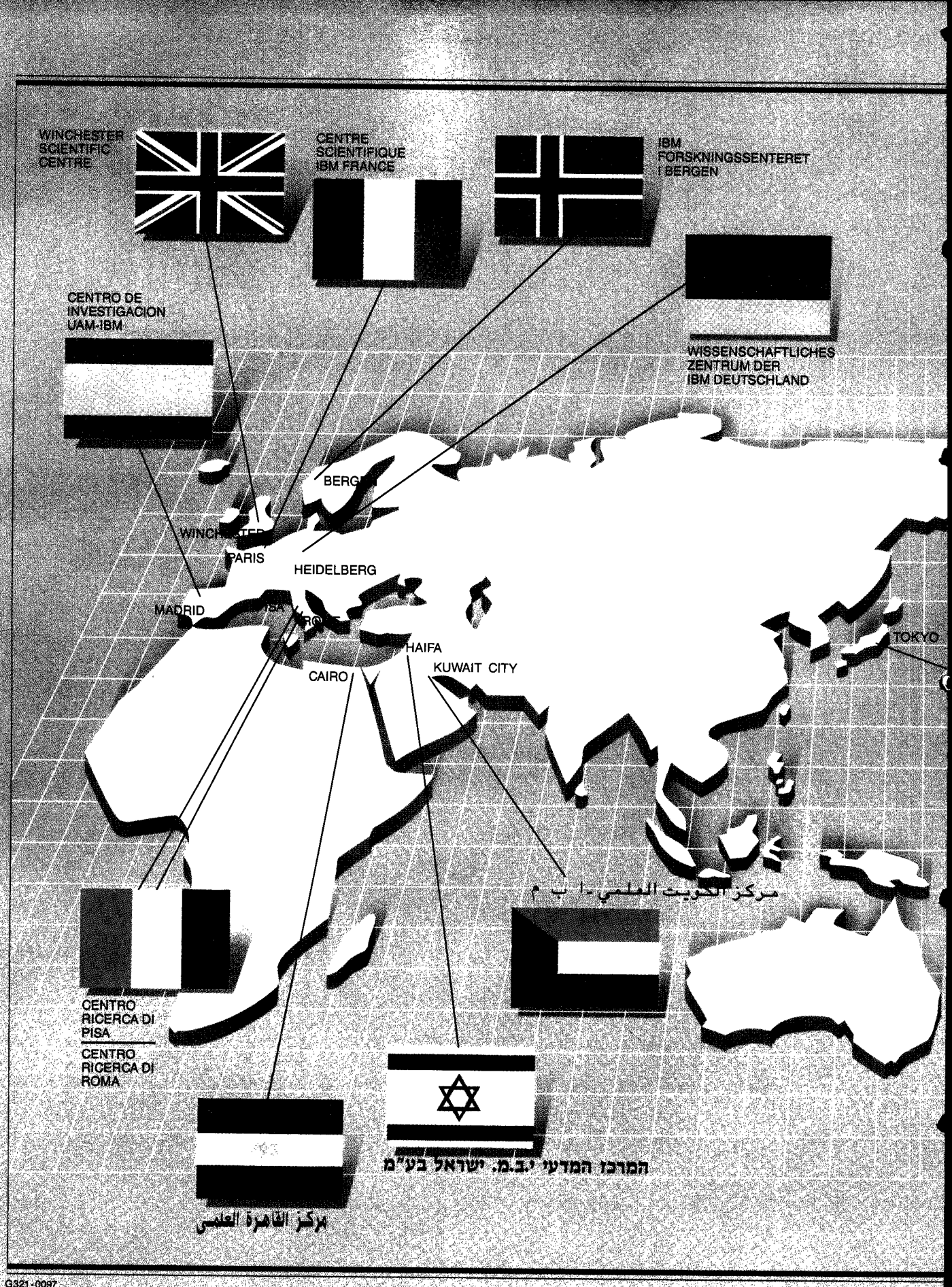
Four Centers were established in the United States in January 1964, with two more planned. The Los Angeles (California), New York City (New York), and Cambridge (Massachusetts) Centers, under the leadership of Homer H. Givin, Theodore I. Peterson, and Norman L. Rasmussen, respectively, were drawn from existing or associated groups. An entirely new Center, headed by John W. Luke, was established at the Los Gatos Laboratory in California and soon moved to Palo Alto, adjacent to Stanford University, in 1965.

After DeCarlo, Herman H. Goldstine was the first director of the new organization. The Centers have had many leaders, but it is Louis Robinson who must be given much of the credit for guiding them during the critical years from 1975 to 1982. Throughout this period he articulately and steadfastly promoted the importance of science and the Centers for IBM and its customers.

World Trade Centers

The IBM World Trade Scientific Centers had their roots in earlier organizations, as did the Centers in the United States. In 1960 a small group of scientists in Paris, headed by Rene Moreau, began projects in scientific development for IBM France. In 1965 a small group of scientists from IBM Italy started working at the University of Pisa. However, it was not until 1967, when the IBM Grenoble Scientific Center opened, that Centers based on the model used in the United States made their appearance.

From 1967 to 1972, twelve new Centers were opened around the world. Around 1980, six more were established, and several earlier ones merged with others and were closed. A number of organizations were also derived from the Centers, such as an IBM-sponsored center at the Asian Institute of Technology in Thailand; the European Center for Scientific and Engineering Computing at the IBM Rome Sci-


WINCHESTER SCIENTIFIC CENTRE
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IBM FORSKNINGSSENTERET I BERGEN
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IBM Scientific Centers
CAMBRIDGE SCIENTIFIC CENTER
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PALO ALTO SCIENTIFIC CENTER
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Figure 1 (A) An original report cover featuring a bubble chamber photograph, emphasizing physics; (B) a report cover from today; (C) announcements of a field-developed program, and (D) an installed user program. The Scientific Centers have generated many such programs.

entific Center in Italy; the Numerically Intensive Computation centers in the United States, Europe, and Japan; and the European Networking Center in West Germany. While they are different organizations, they carry on the same traditions of scientific exploration and service to IBM and its customers.

Contributions

Some further major contributions of the Centers include the virtual machine operating system concept which became Virtual Machine/370 (VM/370), VNET and BITNET, the vector and parallel FORTRAN compilers for the IBM 3090, A Programming Language (APL) and related products, the first IBM Personal Computer (PC) prototype (SCAMP), the Expert Systems Environment (ESE), and the Advanced Interactive Executive/370 (AIX/370) distributed operating system. Two other significant projects are the numerical enhancement of satellite photographs (Figures 2 and 3) and the restoration of famous

Figure 2 LANDSAT Image of San Francisco Bay area

Figure 3 Image of volcano dust cloud, Mt.St.Helens eruption, May 18, 1980. Produced from satellite data at the Palo Alto Scientific Center.

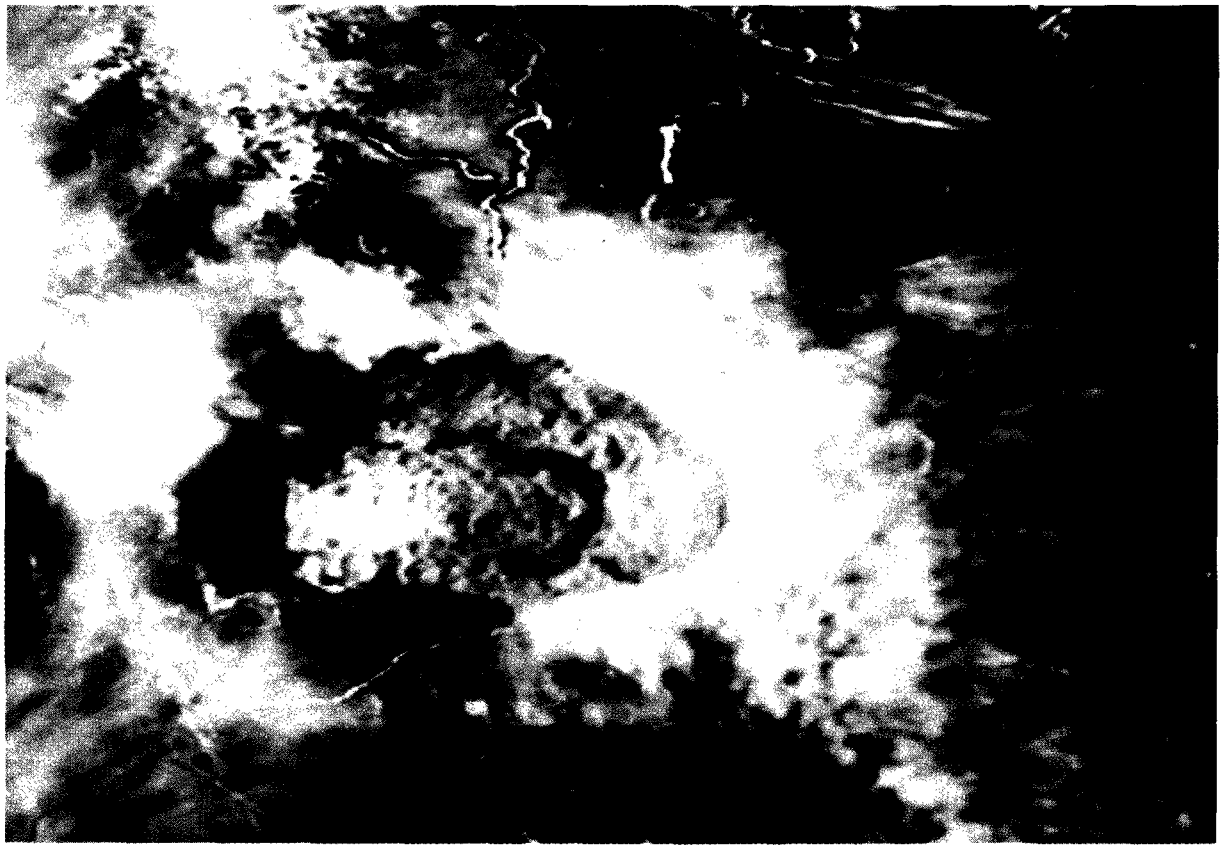
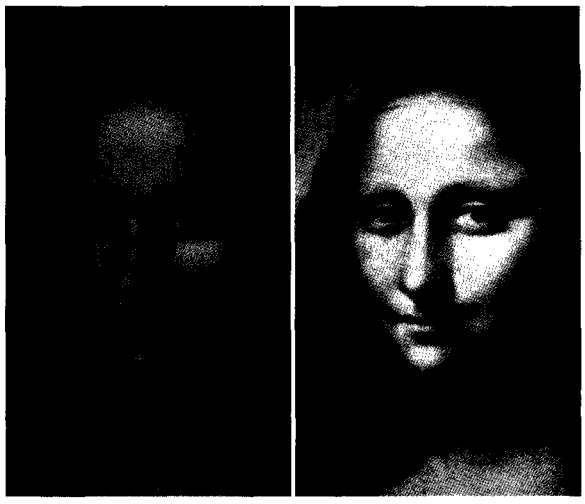


Figure 4 Mona Lisa studied by modern image processing techniques at the Palo Alto Scientific Center.



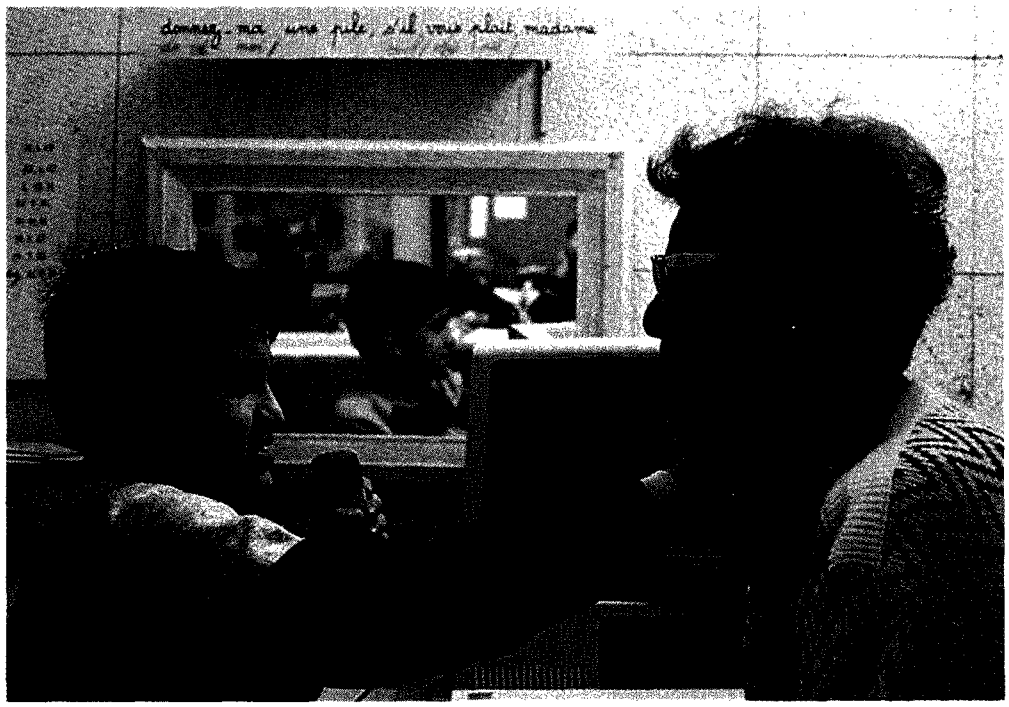
paintings (Figure 4). The Centers have also contributed to solutions for environmental and social problems of their host countries. One example is a computer aid that helps deaf children to speak (Figure 5).

We call special attention to the Hacienda project as an excellent example of cross-center activity and support involving many Centers. The project basis was development, starting in 1978, of an experimental interactive, high-resolution color display and associated software. It led the way for IBM in image processing and resulted in the IBM 7350 Image Processing System, which is still widely used around the world.

Scientific and technical work on the leading edge of change has always been problematical and high risk. The original and continuing mission of the Centers addresses this situation squarely, not only in the choice of problems to be addressed but in an understanding of the special environment within which these problems are best solved. The Centers have been successful in undertaking this work and in transferring technology throughout IBM—frequently into IBM products.

During this first quarter century, there have been over 600 individuals at 26 IBM Scientific Centers worldwide who have been members of the scientific and support staffs. At the same time a greater number of students, temporary assignees, visiting scien-

Figure 5 Deaf child working with a therapist and an IBM Personal Computer. Speech training system developed at the Paris Scientific Center. (From the IBM 1985 Annual Report.)



tists, and joint study partners have also participated. It is clearly impossible for us to properly recognize the work of all these dedicated individuals in this paper. The following section gives a brief statement of the major accomplishments and areas of research and development addressed by the dedicated and diverse groups at each Center. Finally, we include a list of selected publications from each of the Centers. The authors acknowledge their considerable debt to all who contributed to these descriptions and particularly to the Center managers who so willingly contributed materials at our request.

The IBM Scientific Centers can be justifiably proud of their record of a quarter century of service to IBM's customers on a wide range of scientific and technical projects. Perhaps more important than the story of the individual Centers has been their common mission, which allowed them relative freedom within IBM to explore new technical areas, take a broad view of research and applications in science and technology, and make significant contributions in areas of growing importance today.

Major accomplishments and projects

Current IBM Scientific Centers

Bergen, Norway (Established 1986)

In 1986 the newest Center was formed, the IBM Bergen Scientific Center. Its focus has been on project areas of importance to Norway, such as information technology, offshore technology, biotechnology, and fish farming. The resulting technical areas under study are vector multiprocessing, parallel processing for the IBM Advanced Interactive Executive™ (AIX™), workstations, mapping, technical documentation, visualization, and animation. In July 1989 the Center obtained the international mission for environmental sciences within IBM. The Center will be the focal point in IBM for environmental modeling.

Cairo, Egypt (Established 1983)

The IBM Cairo Scientific Center was formed through an agreement with the Egyptian Academy of Scientific Research and Technology and began its work in 1983. The initial projects were directed toward environmental studies with various governmental institutions. These projects included modeling the development of Egypt's "new lands," liquid natural gas spills in the Suez Canal, and employment in Egypt. Two new areas emerged over time: Arabic related research such as natural-language processing and signal processing and pattern recognition, as well as aid for the rehabilitation of people with visual and auditory disabilities. Part of the work on natural-language processing is the subject of a paper in this issue.

25 YEARS
Cambridge, Massachusetts (Established 1964)

The IBM Cambridge Scientific Center (CSC) was founded in 1964 as one of the first four Centers. It evolved from a joint project with the Massachusetts Institute of Technology (MIT), which had produced the Compatible Timesharing System (CTSS) for the IBM 7094. From its start and continuing through today, the CSC has focused on machine architecture, interactive computing, programming languages, networking, and system performance. The major contributions of the Center are summarized below.

Virtual Machine/370 (VM/370): The most widely used System/370 operating system, which grew out of the 1968 development of the Control Program 67/Cambridge Monitor System (CP-67/CMS). VM/370 became a product in 1972. After that announcement, further advanced technological contributions were made in the following areas. Multiprocessor support was added, and major performance and scheduling functions were supplied via the Fair-Share Scheduler, both in 1976. That scheduler quickly became the standard VM scheduler. In 1983 the VM Performance Planning Facility (VMPPF) was added for predicting workload under various system configurations. Between 1979 and 1981, VM was enhanced to allow the Multiple Virtual Storage (MVS) operating system to run under VM as a "preferred guest." This work has been carried on in the Processor Resource/Systems Manager™ (PR/SM™) on the IBM 3090.

Remote Spooling Communications Subsystem (RSCS): A peer-to-peer, store-and-forward network protocol, built using virtual machine principles. It is the major network facility used by IBM for internal communications, connecting over 3400 network computers, and is known informally as VNET.

BITNET: A major university computer network, built using RSCS protocols. It has 441 institutions and 1622 nodes in the United States. Its analogues in other countries (EARN, NETNorth, and other academic networks in the Far East and South America) add an estimated 686 institutions and 1036 nodes.

Yale ASCII terminal system: A collaboration with Yale University to permit full duplex ASCII capability for the System/370 through a Series/1 front end, without changes to host programming. The IBM 7171 and then the IBM 4994 replaced the Series/1 and extended this protocol conversion function.

IBM Personal Computer (PC): A series of projects that resulted in Asynchronous Communication Support, IBM 3101 Emulation Support, PC/370 introduced on the PC/XT, PC/IX, and keyboard standards.

Unattended computer operations: An effort to provide remote and unattended distributed operation for midsize computers. The technologies developed appeared in the IBM 4300, 9370, and Application System/400™ (AS/400™).

Operating systems: Early work on UNIX® implementations for IBM systems including the first VM product, Virtual Machine/Interactive eXecutive (VM/IX).

X-Windows: Two projects to make the X-Window System from the Massachusetts Institute of Technology (MIT) available on VM and MVS.

Text processing: A long-standing involvement in text handling has resulted in products such as SCRIPT, which was the precursor for the later Document Composition Facility (DCF), IBM Usability Aid (QPRINT) for the IBM 6670, and Math Formulator for the IBM PC.

Cambridge Control Unit (CCU) and Continuously Executing Channel Interface (CETI): Two efforts that enhanced the ability to connect IBM System/370 computers directly onto high-speed local area networks.

POLITE: An early effort on WYSIWYG ("What you see is what you get") text systems for the System/370 and IBM PC, which influenced the IBM DisplayWrite/370. This text product pioneered the concept of "UNDO" and "REDO" for backtracking.

Caracas, Venezuela (Established 1983)

In 1983 the IBM Caracas Scientific Center opened its doors, with a focus on remote sensing and image processing. Now the emphasis is on three areas of scientific study: astrophysics and computational chemistry, algorithms and data structures, and software engineering. The first has resulted in new information about electron impact excitation and radiative atomic data. The second has seen improved time and space efficiency for generalized binary search trees, the transforming of multiway trees into practical external data structures, and new methods for collision resolution in hashing algorithms. The third has added a new *in situ* distributive sorting algorithm—EXTQUICK—to the tools available to the software engineer, and currently focuses on programming environments.

Haifa, Israel (Established 1972)

Projects of special interest to the planning, medical, and agricultural concerns of Israel have been the major theme in the work of the IBM Haifa Scientific Center, established in 1972. The positive effect of this work is reflected in the progress cited below. Present advanced technology work is focused on image processing for archival applications, scheduling and routing problems, and natural-language processing in Hebrew.

Regional planning: Efforts have contributed to regional rural development through a computer-aided modeling and planning system based on mathematical models and linear optimization. This work has been used by Rehovot, Israel (for whom it was originally developed), Spain, and Costa Rica.

Medical applications: Projects have made noticeable progress on improved diagnostic capabilities for ultrasound testing using signal and image processing techniques, estimating cardiac output and gas content of blood, specialized interactive systems for diagnosis of endocrine disorders, and the further use of signal processing to appreciably decrease background noise (the "cocktail party" noise problem) in assisting the hearing impaired.

Agriculture: Contributions are most notable in the development of an interactive system for constructing irrigation time tables. This system is now used throughout the country and has an important role in the efficiency of agricultural production in their arid lands.

Mathematics: Theoretical and practical applications of numerical analysis to problems arising in mathematical physics and engineering, such as stiff differential equations and partial differential equations with complex boundary conditions.

Heidelberg, Federal Republic of Germany (Established 1968)

When the IBM Heidelberg Scientific Center (HDSC) first opened in 1968, its projects concerned the physics of bubble chambers and scintigraphic photo analysis. Now the areas of interest are more closely aligned with data processing: natural-language capabilities, knowledge-based querying, relational data models, visual languages for end users, additions to A Programming Language (APL) products, numerically intensive computing (NIC), and immunological information processing for transplant surgery. Each of these subjects is detailed below. HDSC is also part of the European Research Initiative EUREKA.

Natural languages: An early project to permit limited natural-language interaction for database queries, with support for many western languages.

LEX: A project within the Institute for Knowledge Based Systems, that is part of HDSC. It is a German language query system for information on the law.

Advanced Information Management Prototype (AIM-P): A project to add an extended Non First Normal Form (NF^2) to the relational data model in IBM's Structured Query Language (SQL).

Extensions to Query-By-Example (QBE): A long-standing developmental effort to add visual programming for end users to relational database systems. More recently, human factors investigations have led to development of a methodology for solving application problems through graphical manipulation.

APL extensions: As a result of first-hand, concentrated use of APL at the HDSC, additional capabilities were developed for APL and APL2 in support of complementary functions, interlanguage communication, and graphic presentation.

NIC applications: Projects with universities and commercial customers to use NIC for reactive flow; chemical, mechanical, and financial modeling; and simulation, in concert with the European Supercomputing Initiative.

Immunology: An effort to support immunological research in transplant surgery across 300 transplant centers worldwide, using an interactive and distributed information system.

Kuwait City, Kuwait (Established 1980)

The IBM Kuwait Scientific Center operates in cooperation with the Kuwait Institute for Scientific Research (KISR) and has been located on its grounds since opening in 1980. Areas of study at the Center are the environment, Arabic languages, and image processing, as presented below.

Environmental studies: Work has been completed on passive cooling and air pollution, and the focus is now on oil pollution and source identification. Another effort is focused on desalinization by reverse osmosis.

Arabic language processing: Projects are under way in IBM Personal Computer-based speech synthesis, speech and printed character recognition, a recent comprehensive Arabic morphological analyzer and generator, course authoring, and desktop publishing with advanced Arabic printing.

Image processing: Ongoing efforts to map Kuwait using LANDSAT 5 satellite data, to study oil distillation columns using thermal infrared imaging, to model pores in catalysts, and in numerical geophysics.

The IBM Los Angeles Scientific Center (LASC) is one of the first four Centers founded in 1964. It had its beginning in the joint IBM and University of California at Los Angeles (UCLA) Western Data Processing Center (WDPC), a primary education facility for academic computing as well as for IBM. In the early years, projects emphasized management science, education, engineering, and science. In recent years, some of the projects still center on those areas, and new areas have been added, as described below.

Direct numerical control: Projects on remote computer control of machine tools, with software to cut metal according to customer designs.

Computer-aided instruction (CAI): A number of projects in the development and use of CAI were

sponsored, including the development of an interactive supervisor for the System/360.

Oceanography: A joint project with the Scripps Institution to resolve problems in the processing of oceanographic data.

Geophysics: Theoretical studies of earthquake structure using computer simulation and complex models of the earth.

Natural-language processing: Initially a study of applications in medical records, using new syntactic and semantic methods for natural-language information storage and retrieval. Currently, text selection and understanding are being investigated, along with machine translation among many natural languages.

Systems and end users: Projects in operations research (such as a distribution system simulator product), computer-aided design and computer-aided manufacturing (CAD/CAM), application development environments, database security, and distributed computing.

Multidimensional graphics: Joint studies with several universities on the perception of geometric objects in higher dimensions led to advances in computational geometry, displays for exploratory statistical analysis, and algorithms for air traffic and robotics control.

Engineering and scientific systems: Exploration of workstations for use by meteorologists, chemical engineers, and biologists, and for general engineering. Studies in large-scale scientific computing architecture and applications, and in a prototype parallel data store.

Robotics: Projects in vision systems for electronic parts identification and location. Studies are being conducted on artificial intelligence techniques for computer-integrated manufacturing (CIM).

Enterprise and strategic information management: Efforts in improving the effectiveness of business systems planning and integrating it more fully into corporate planning, budgeting, and decision making. A worldwide network of universities and corporations now uses some of the results.

A prototype expert system, called Business Strategy Advisor (BSA), was used by an IBM laboratory to assess competitive software products. Business modeling and a prototype expert system to help identify opportunities for information technologies in enterprises comprise the rest of the work in this area.

Visual programming: Projects to represent programs as forms, with filling-in forms as the way in which a user would see programming. This work is the subject of a paper in this issue.

Security: Studies of tools to enhance the security of IBM's internal computer network and of expert systems for computer security. A prototype system for security audits is now being tested.

Madrid, Spain (Established 1972)

The Autonomous University of Madrid is host to the IBM Madrid Scientific Center, which was chartered in 1972. Major projects at the Center are the automation of the Indies Archive, natural-language processing for Spanish and Catalan, image processing in biology, EXPO'92 visitors information system, 1992 Olympic Games commentators system, and A Programming Language (APL) interpreters.

Image and database processing: The automation of the Indies Archive project is the development and installation of an information system for the management of historical records, integrating a textual database and an archive of pictorial information. A project on image processing in biology, using an IBM PS/2® Model 80, has been carried out in cooperation with the Spanish Molecular Biology Center. Its aim has been to develop algorithms for the filtering, three-dimensional reconstruction, and graphic representation of images of viral particles.

Language processing: The MENTOR (Multitarget ENglish TranslatOR) project is in support of translating IBM manuals from English to Spanish. The approach is valid for other languages, since it relies mainly on a declarative bilingual dictionary that stores most of the information relevant for translation. A lexicon for spelling verification of Spanish and a synonym dictionary have been implemented, together with a morphological analyzer and generator.

EXPO'92 and 1992 Olympic Games information systems: The development of a central information system to provide EXPO'92 visitors with relevant information regarding the fair, events, and activities that will take place in Seville. A 1992 Olympic Games commentators system will provide real time

information related to the sports events and access to the Olympic Games Information Systems database to ratio and television sports commentators, using PS/2s.

APL interpreters: Extensive projects, in cooperation with IBM Japan, that have resulted in several releases of APL and APL2 interpreters for PC APL and APL2, and for IBM 5550 and JX Nihongo (Japanese) APL.

Hacienda (IBM 7350): One of the Center partners in the production of the High Level Image Processing System (HLIPS) for Hacienda.

Mexico City, Mexico (Established 1971)

In 1971 this Center was called the IBM Latin American Scientific Center; in 1973 the name was changed to the IBM Mexico Scientific Center, in keeping with its close ties to Mexican projects. Major project areas include artificial intelligence and expert systems, image processing and remote sensing, geographical information systems, statistics and applied mathematics, and database design. Of special interest is the work on geographical information systems that support decision making concerning natural resources by allowing the mixing of different kinds of mapped data, such as temperature, rainfall, and coastal dune vegetation. A number of programs have also been built for the IBM Personal Computer and Personal System/2® (PS/2) for time series analysis, satellite data processing, and database consistency checking.

25 YEARS
Palo Alto, California (Established 1964)

Founded in 1964 as one of the first four Centers, the IBM Palo Alto Scientific Center (PASC) began its history with three major projects: laboratory automation, nuclear power research, and applied physics in materials science and atmospheric physics. Work has also focused on microcode, image processing, and FORTRAN. Other projects came from Washington in 1969 and Houston in 1974 when those Centers closed. The projects that have been significant through the years are listed below.

Large-scale computing: Areas of study have been high-energy, reactor, atmospheric, and plasma physics; geophysics; and aeronautical, chemical, and power engineering. Commercial data processing problems were also addressed. Notable contributions were the Fast Fourier Transform algorithms for solving partial differential equations, and a number of innovative algorithms for vector and parallel machine architectures. Research has ranged from basic physical processes, through model formulation, simulation, numerical analysis, programming, and graphical display techniques to the verification of models by means of measured data.

FORTRAN: Since 1976, when a project to produce a new optimizer was initiated, FORTRAN projects have provided important contributions to performance, data striping, the influential vectorizing FORTRAN compiler for the IBM 3090 Vector Processor, and, most recently, a parallel FORTRAN compiler prototype for use with multiple IBM 3090s.

Microprogramming: Successful work on implementing large system functions using writable control store was first shown within IBM at PASC. Further projects led to the high-level language machine for A Programming Language (APL), microcode performance assists for Virtual Machine Facility/370 (VM/370) and its Conversational Monitor System (CMS), and APL microcode assists for specific models of the System/370, which became the design for the VSAPL product.

IBM Personal Computer (IBM PC) prototype: An outgrowth of work on microprogramming was SCAMP (Scientific Center APL Machine Prototype), the prototype for the IBM 5100 portable desktop computer and a model for later IBM PCs. SCAMP is now in the collection of the Smithsonian Institution.

Expert Systems Environment (ESE): A development effort that added ease-of-use and new implementation techniques to products based technically on Stanford University's EMYCIN.

Advanced Interactive Executive/370™ (AIX/370™): Efforts that built on earlier university work in distributed operating systems and resulted in the introduction of that technology to IBM.

Image processing: Since 1979 a series of image-based projects with the Hacienda (IBM 7350) and joint studies have resulted in applications such as the DIMAPS imaging system, processing of LANDSAT images, an imaging system for the IBM Personal Computer, computer analysis of the Mona Lisa, and medical imaging.

Laboratory automation: In conjunction with Stanford University and the Stanford Linear Accelerator

Center (SLAC), computers monitored high-energy physics experiments and provided immediate graphic output of the results.

Graphics Program Generator: A development effort that resulted in four products and defined new application areas in geographic information systems for public utilities, manufacturing, and process industries.

Networks and software: Programming projects involved the rework of the APL Departmental Reporting System and improvements in the note handling and cross-system communications of PROFS™. Early work in local area networking led to IBM's first Ethernet™ local area network, contributed significantly to technology used in PCnet, and allowed widely dispersed people to communicate inexpensively with the PSInet computer conferencing system.

Paris, France (Established 1977)

The IBM Paris Scientific Center was chartered in 1977, but it built on a tradition of projects that began in 1960 with the IBM France Scientific Development Department. The main areas of exploration since the Center was founded have been mathematics, linguistics, image processing, and artificial intelligence, as described here.

Mathematics: Early work focused on qualitative statistics for analysis of qualitative variables. More recent projects are on precision in complex and lengthy computations, and in understanding chaos.

Linguistics: The deaf children project resulted in the IBM SpeechViewer™ product in 1988. The stenotypy project produced TASF (*Traduction Automatique de Stenotypes en Francais*), a product for creating natural text out of stenotypy, in French. The French thesaurus project developed lexicographic techniques for multiple native languages, that in turn became part of the IBM DW3700 advanced text processing products. The latest work is on automatic dictation capabilities.

Hacienda (IBM 7350): The first Center partner to receive the hardware prototype and the Basic User Software (HBUS), in 1981. The projects at Paris resulted in the High Level Image Processing System (HLIPS) and APL Image Processing Attachment Support (APLIAS), which both became products.

Artificial intelligence: Very early work resulted in the pioneering expert system *Bateau sans medecin* (ship without a medic). More recent work focuses on theoretical breakthroughs in nonclassical logic through development of a qualitative logic model allowing order-of-magnitude reasoning, and resulting systems for nonshallow reasoning.

Programming in Logic (PROLOG) for VM and MVS: Developed in Paris for using logic programming on IBM machines.

Pisa, Italy (Established 1971)

In 1965 the Centro Studi IBM was established in Pisa and became the basis for the IBM Pisa Scientific Center in 1971. This Center has had major project activity in surface hydrology, computer networks, image processing, and econometric software. A present major concern is with language technology. Projects in these and other areas are described below.

Surface hydrology: Project work was stimulated by serious flooding of the Arno River in 1966 and resulted in a model of the river basin that simulates rainfall and runoff. This work was also used for study of the Nile River and Lake Aswan, in Egypt.

RPCNET: An effort to develop a network for VM-based computing centers. This successful network is still running today.

Econometrics: The design and implementation of a complete set of programs to estimate, validate, analyze, and simulate both linear and nonlinear macroeconometric models.

Hacienda (IBM 7350): Design and implementation of the Host Basic User Subroutines (HBUS), which is the host-resident subroutine library for the IBM 7350 Image Processing System.

Medical imaging: Analysis of radiographs of the internal innervation and blood circulation of the cardiac muscle, with experimental work on two- and three-dimensional object detection and recognition.

Volcanic risk modeling: A project for automatic drawing of volcanic eruption risk maps, which were validated using historic eruptions of Mounts Vesuvius, Etna, and St. Helens.

Language technology: Sistema C product development that performs sophisticated interactive check-

ing and correction of Italian texts. Sistema L prototype for printed document reading by scanner, helped by ad hoc lexical tools: it represents a reference point in the area of the OCR-based reading tools for performance in terms of correctness and usability. Further work, in its early stages, aims at human-aided machine translation of English into Italian.

Rio de Janeiro, Brazil (Established 1986)

The IBM Rio Scientific Center was established in 1986 when the Center in Brasilia moved to Rio de Janeiro and integrated all research and educational activities of the Latin American Systems Research Institute, the Software Technology Center, and the IBM Brazil Sumare Plant. Priorities are now more business oriented, and current research areas are databases, data communications, artificial intelligence, logic programming, microelectronics, software engineering, vector processing, and advanced signal processing.

Significant contributions have been made through development of an accurate model of the borer insect and sugarcane ecosystem for plague control, and through study by remote sensing of the environmental impact of the Tucurui hydroelectric facility. Contributions to computer science include the PACCHIP system, an integrated computer-aided design (CAD) package for very large-scale integrated (VLSI) chip design, the CHRIS software tool for database conceptual design and prototyping, an expert system for heuristic learning of medical diagnoses, data compression algorithms for digital images storage and transmission, and halftoning algorithms for laser printers.

Rome, Italy (Established 1979)

The IBM Rome Scientific Center was chartered in 1979 and absorbed the projects and staffs of the Centers at Bari and Venice. Over time the project focus shifted from that of the former Centers to new areas, as described here.

Distributed processing: The Virtual Machine Distributed Facility (VMDF) was used on XCF (eXtended Communication Facility) to create a single-image VM system that allowed file sharing between remote virtual machines and catalog sharing between VM control programs. It was operational on the network for the Centers in Italy until 1984.

Hacienda (IBM 7350): Implemented the IBM 7350 Image Processing System and, since 1981, has used its special color capabilities, along with the IBM 3838 Array Processor, in numerical modeling projects such as seismic wave migration, fluid dynamics, and meteorology.

Natural-language processing: Among projects with relevance to Italy, one began in 1984 with the goal of understanding the Italian language and in 1987 resulted in the most complete text understanding system presently available in Italy.

Speech synthesis: A text-to-speech synthesizer project for Italian, begun in 1982, further resulted in speech recognition of 20 000 Italian words by 1988.

ECSEC: Projects in numerically intensive computing (NIC) resulted in the establishment of the European Center for Scientific and Engineering Computation (ECSEC) as a department of the IBM Rome Scientific Center in 1984. Since then, the Center has become the European focal point in IBM for NIC.

Tokyo, Japan (Established 1970)

The IBM Tokyo Scientific Center was founded in 1970. Main project areas have been natural-language support, image processing, graphics and displays, scientific and engineering computation, and education, as described below.

Natural languages: Research conducted in machine translation between English and Japanese. Work has also been done on converting Kana to Kanji for a Japanese word processor.

Image processing: Many joint studies with government and university groups emphasized regional and coastal planning. Recent studies included optical character recognition (printed and handwritten) and color image databases.

Graphics and displays: Designed the application programming interface (API) for the IBM 5080 display and its follow-on with Kingston, developed rendering methods including a new texture mapping, and applied them to visual simulation.

Scientific and engineering computation and visualization: Projects included chemical computer-aided design, computational chemistry, and engineering simulation, such as simulating the air flow in a clean

room. New graphics techniques have been applied to the visualization of molecules and air flow.

Education: Having always conducted projects with university partners, recent efforts have involved assistance for the handicapped, mathematical computer-aided instruction, and campus networking.

Winchester, United Kingdom (Established 1979)

In 1979 the IBM United Kingdom Scientific Centre (UKSC) adopted a new charter and a new project focus, and moved from Peterlee to Winchester, England. It remains the only Center with a formal connection to an IBM laboratory—IBM United Kingdom Laboratories Limited, at Hursley Park, England. It also is unusual in its extensive use of visiting professionals, forming roughly half of the staff. The new charter established a new set of project areas for the Center: image processing, graphics systems, and speech processing. The major contributions in these areas are outlined below. In 1988 the Center was a joint winner of the British Computer Society Award for applications of computing.

Interactive Applications eXecutive (IAX): An application of high content, high-resolution image processing capabilities to medical imaging of the heart and neurons, for example.

Graphics: A number of projects surrounding the use of graphical techniques for the presentation of forms and the visualization of large amounts of complex data. Areas for study have been solid geometry, raster display of complex three-dimensional constructions, molecular modeling for the pharmaceutical industry, high-speed imaging using arrays of transputers, automatic interpretation of images, stereoscopic computer vision, fluid flow, astronomy, archaeology, theoretical physics, molecular beam epitaxy, liquid crystal structure, and computer-generated art. The WINchester SOlid Modeling system (WINSOM) and its solid geometry applications are discussed in three other papers in this issue.

Speech processing: Projects focused on English speech synthesis from text and especially automatic phonetic construction from text.

Former IBM Scientific Centers

Bari, Italy (1969–1979)

One of the smallest Centers, the IBM Bari Scientific Center studied the fields of computer-aided instruction and natural-language processing and later relational databases and query languages. It saw the development of the A Query Language (AQL) interpreter as a relational database extension to the A Programming Language (APL) systems. It was consolidated into the new IBM Rome Scientific Center in 1979.

Brasilia, Brazil (1980–1986)

The IBM Brasilia Scientific Center was established in 1980 in the new capital city of Brazil. It's focus was on enhancing the quality of life, the work environment, and the overall community's well-being. In 1984 the Center was honored for this work by receiving the American Chamber of Commerce Award for Corporate Service to the Community. In 1986 the Center merged with other activities in Brazil and moved to Rio de Janeiro.

Grenoble, France (1967–1973)

The first Center outside the United States was the IBM Grenoble Scientific Center. Its efforts were on operating systems and compilers. It played a significant role in the development of CP-67/CMS, in close cooperation with the IBM Cambridge Scientific Center. There was also a project on incremental compilation, the results of which are in use in the FORTRAN Interactive Debug and PL/I Incremental Compiler products. The Center closed in 1973 and much of its work was reassigned to what later became the IBM Paris Scientific Center.

Houston, Texas (1966–1974)

Much of the work at the IBM Houston Scientific Center focused on the use of array processors, such as the IBM 2938 and 3838. These studies included numerical precision, seismic applications, and development of array algorithms. Specific efforts included the array processing language VECTRAN, optical and holographic image processing and display, medical data processing for the heart and X-rays,

chemical engineering real-time process control, and electrical power systems analysis. This Center was merged into the IBM Palo Alto Scientific Center in 1974.

New York City, New York (1964–1972)

Founded in 1964, the IBM New York Scientific Center was one of the first four Centers chartered. It grew out of the prototypical Mathematics and Application Department, originally formed in 1955 in New York City. There were two basic areas of concentration: management science, which included studies of simulation, network analysis, and computational programming; and engineering design, which devised nonstandard data acquisition attachment capabilities for the System/360, graphics facilities for use in textile design, and graphical methods for urban planning. This Center became part of the foundation for the IBM Philadelphia Scientific Center in 1972.

Peterlee, United Kingdom (1969–1979)

This Center was established in 1969 as the IBM United Kingdom Scientific Centre. The major project areas were relational databases and local and regional planning. The relational database work culminated in the early and successful "Peterlee Model" that did much to popularize the concept. The planning work involved a number of projects with governments on using computers for planning. In 1979 the Center altered its focus considerably and moved to Winchester.

Philadelphia, Pennsylvania (1972–1974)

In 1972 the IBM New York Scientific Center and the IBM Research Division group on A Programming Language (APL) joined forces and started the IBM Philadelphia Scientific Center. APL became the major project area for the Center, along with the project areas from New York: simulation, network analysis, and computational programming. The work on APL resulted in the APLNET network, an APL business planning system, a long-standing APL computer center and time-sharing service for other IBM groups, extensions to APL itself, and the groundwork in generalized array theory that became the basis for A Programming Language 2 (APL2). Other projects included airline crew and telephone operator scheduling, cash and asset management, earth resources evaluation, and life insurance budget planning. Most of the Center's work was relocated to the Palo Alto APL development group in 1974, and this Center was closed.

Venice, Italy (1969–1979)

The IBM Venice Scientific Center was located in a thirteenth-century palace—the only Center so honored. A storm surge in 1966, and subsequent efforts to save Venice from the sea, resulted in the creation of this Center. As a result, much of its work centered on hydrology and air pollution. The numerical modeling of combined tidal and meteorological effects in the Venice lagoon, and of the sinking phenomenon in the Venice area due to the pumping of groundwater, remain the major contributions of this Center to basic knowledge in these fields. In 1979 the Center became part of the new IBM Rome Scientific Center.

Wheaton, Maryland (1967–1969)

A Center was established in 1967 in Wheaton, Maryland, to be known as the IBM Washington Scientific Center. Significant areas for this Center were environmental sciences, text processing, cartography, and microcode. The environmental sciences area involved work on mathematical techniques for descriptions and mapping of nature, such as weather prediction and water resources—reservoirs, pollution, and waste treatment automation. The Center's work moved to Palo Alto in 1969.

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