John R. Pasta, 1918–1981
An Unusual Path Toward Computer Science

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Foreword

The following eloge of John R. Pasta should remind readers that he died before recording his recollections and interpretations of his personal experiences as a contributor to the early development of computing. Sadly, what he might have told us of what he thought when he did it is now lost forever. We will never have his firsthand account to help us learn how to do great things ourselves. I hope potential authors of reminiscences, memoirs, and autobiographies will act now to avoid further losses.

Some of Pasta's early computing activities were shrouded in government secrecy. Some of these restrictions have been removed, but additional areas, deservedly kept secret a generation ago, could surely be made public now. Since there is no incentive for any government functionary to declassify material, it becomes a responsibility of those who know of history kept secret to take the initiative to request its release. I suggest that in addition to asking for the declassification of known documents, computing pioneers can stimulate information release by writing personal accounts of their own experiences in long-ago classified activities and then submitting them to the responsible agency for clearance. —*Eric A. Weiss, Biographies Editor*

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The roots of computer science are many and varied, the roots of computer scientists even more so. John R. Pasta was always proud of being a policeman and said he might have made a career in the New York City police department but for the inspiration and support of his wife. The career he chose instead—physicist, mathematician, computer scientist, and science administrator—was clearly right for him, as his many accomplishments testify, but his early experience walking a beat was a lifetime resource that he valued. From time to time he would draw on it for an analogy, or perhaps mention it to someone who did not know, which always brought a surprised laugh. Finally, at the National Science Foundation, it had direct relevance to his work again when he urged the federal government to become concerned about computer crime and persuaded the foundation to support research on detecting and preventing it. What a remarkable distance had been spanned in 30 years by technology and also by one man's career from a Manhattan "flatfoot" checking doors of stores and banks at night, to a sophisticated cognoscente of people and machines studying how banks and other institutions may be invaded without opening any doors at all.

John was born in New York City in 1918, the eldest of four children, and grew up in Queens. He attended the New York public schools and became interested in physics at an early age when an uncle gave him some of his old college books. After graduating from Townsend Harris High School, he entered City College of New York in 1935 and completed three years. The depression forced him to drop out of college at that stage to take a job as a real estate title examiner for Title Guaranty and Trust Company. In 1941 he took the examinations for the New York City police department, entered the police academy, and became a patrolman in August 1941. In 1942, he was drafted into the U.S. Army, became an officer in the Signal Corps, and took courses on electronics and radar at Harvard and MIT. He married Betty Ann Bentzen at the Little Church Around the Corner in New York City in May 1943. After the war, John and Betty had two children: Diane, now a lawyer in Seattle, and David, completing his doctoral dissertation in statistics at Stanford and president of a statistical computing firm in Palo Alto.

John's tour of duty with the army during World War II was spent in the European theater, mostly as cryptographical security officer and radar officer for the 29th Tactical Air Command, Ninth Air Force, for which he was awarded the Bronze Star and the Belgian Fourragere. During this time he continued to enjoy reading mathematics and physics in books sent to him by Betty. After being discharged from the army in 1946 he took advantage of the GI Bill to finish his undergraduate work at City College that same year and enter graduate school at New York University to study mathematics and physics. Events underneath a

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Kent K. Curtis *studied mathematics, physics, and music at Yale, Dartmouth, and Berkeley. He did scientific programming for the Lawrence Berkeley Laboratory of the University of California, where he was head of the Division of Mathematics and Computing from 1957–1967. He joined the National Science Foundation in 1967 and is head of the Computer Research Section of the Division of Mathematical and Computer Sciences. He has taken leaves at the Atomic Energy Commission and the Courant Institute of Mathematical Sciences at New York University, and has served as a consultant to the Department of Energy, other federal agencies, and the Swedish Technical Development Union. He was one of the founders and first president of VIM, the users group for CDC 6600 computers.*

Nicholas C. Metropolis *received his B.S. in 1937 and his Ph.D. in 1941 from the University of Chicago. He was a staff member on the atomic-bomb project at Columbia University in 1942 and returned to Chicago in 1942–1943 to work on the university's metallurgy project. He was at Los Alamos on the Manhattan Project in 1943 and taught at the Enrico Fermi Institute of Nuclear Studies in Chicago from 1946–1948. He was a group leader at the Los Alamos Scientific Laboratory from 1948 to 1957, directing the construction of the MANIAC during 1949–1952. He was professor of physics at the University of Chicago from 1957–1965 (and was director of the Institute for Computer Research). In 1965 he returned to LASL, where he was appointed a Senior Fellow in 1980.*

William G. Rosen *attended the University of New Hampshire and the University of Illinois, where he received a B.S. in physics in 1943. After serving in the U.S. Army Air Force (including duty as a radar-countermeasures officer), he returned to the University of Illinois, getting an M.S. in physics in 1947 and a Ph.D. in mathematics in 1954. He taught at the University of Maryland from 1954–1961 and then joined the National Science Foundation, where he has held positions in science education, science development ("centers of excellence"), and the director's office. He has been head of the Mathematical Sciences Section since 1979.*

Yoshio Shimamoto *received a B.A. from the University of Hawaii in 1948 and a Ph.D. from the University of Rochester in 1954. He went to Brookhaven National Laboratory in 1954; he was chairman of the Applied Mathematics Department from 1964–1975 and is currently a senior physicist. He has been a visiting professor at the University of Illinois (1964), the Institut für Mathematik of the Universität Hannover (1972), and the Institut für Informatik at the Universität Karlsruhe (1982). In 1972 he received an Alexander von Humboldt-Stiftung Senior Scientist Award.*

James N. Snyder *studied physics at Harvard (B.S. 1946, M.A. 1947, Ph.D. 1949) and then joined the University of Illinois, where he has been head of the Department of Computer Science since 1970. He is on several ACM and IEEE Computer Society committees, as well as the AFIPS Education Committee. He is a Fellow of the American Physical Society and the American Association for the Advancement of Science.*

playing field in Chicago and on a remote mountainside in New Mexico had made it seem that there would be jobs for physicists and had opened an attractive alternative to the police department. It had been a long and unusual path, but by then his direction toward science was firmly established.

As a graduate student he became a research fellow in the Department of Physics at Brookhaven National Laboratory, the beginning of a long and rewarding association with Brookhaven, and completed his thesis on "Limiting Procedures in Quantum Electrodynamics" in 1951 under the guidance of Hartland Snyder. Though computers played no role, it was the kind of work that prepared him to be receptive to computing with all its potential power including its promise for symbolic computation to assist with the immensely complicated and error-prone algebraic reductions required to gain meaning from the perturbation calculations of quantum electrodynamics. All that was still lacking, then, to make the computer scientist he became was the opportunity to discover and become familiar with computers, an opportunity that was soon available when he moved to Los Alamos.

John Pasta at Los Alamos

By one of those curious twists of fate, John had passed up a first opportunity to be at Los Alamos Scientific (now National) Laboratory. During World War II, as a member of the Signal Corps he had been given the choice of being stationed in New Jersey (close to his hometown, New York City) or reporting to an unheard-of activity somewhere in the southwest. Had he decided otherwise, he would have met John G. Kemeny, Peter D. Lax, Paul Stein, and others some seven or eight years earlier; they were part of the so-called SEDs (Special Engineer Detachment). It was only after the war, when he had finished his doctorate, that he became a staff member of LASL in August 1951. The MANIAC was in its final stage of construction and testing, and like many others, John was mesmerized by this marvelous toy that offered so much potential for gaining an insight into nonlinear physics. Trained as a theoretical physicist, he came to grips with "hands-on" computing, dealing directly with all its aspects. In this, he was following in the tradition established at Los Alamos by Enrico Fermi, Edward Teller, and John von Neumann.

His first collaborative effort, with S. M. Ulam, led to an internal report (1953) on some heuristic computer studies in problems of mathematical physics: a similar study in problems of hydrodynamics appeared in *Mathematical Tables and Other Aids to Computation* (1959) (see the Bibliography at the end of this article).

John's most cherished interaction was with Fermi. In the summer of 1953 Fermi raised the question of the nature of approach to equilibrium of a vibrating nonlinear string initially in a single oscillatory mode. Together with Ulam, they formulated some preliminary test problems. As expected, the computations showed that the initial vibrational energy gradually transferred into neighboring modes, and the system seemed to achieve equilibrium—the time taken being the so-called relaxation time. The completely unexpected happened one day when a typical problem was being computed. Owing to a very energetic, distracting discussion, the computations continued beyond the usual cutoff. The results were so strange and mysterious that everyone around was quick to assume that the computer, the traditional whipping boy, had gone awry. The vibrational energy had returned to the initial mode, within a few percent! The rest is history—the stimulation that work provided to soliton theory, the enormous literature that emerged globally. Today it is well known as the FPU (Fermi-Pasta-Ulam) problem.

John took a great interest in the activities of a small group associated with the MANIAC that was preparing the first chess-playing program for a computer. He was impressed by the powerful symbol manipulation, in contradistinction to purely arithmetical operations. As a consequence, he developed what was one of the first uses of graphic display on an interactive basis. The MANIAC had an extra cathode-ray memory tube, identical to the 40 operating as a parallel memory with a 32×32 raster; this was used to monitor, by a 40-way switch, the performance of the others. John devised a clever scheme whereby he could blank out the zeroth stage of the memory and use it to plot any desired function on the monitor as an x versus y graph.

All too soon there was a kind of scientific caesura when John left early in 1956 to accept von Neumann's invitation to go to Washington to set up a mathematics and computer branch in the AEC (Atomic Energy Commission) Division of Research. He always maintained a contact with Los Alamos that was renewed regularly. Despite the press of his many administrative responsibilities, John stabilized his perspective by maintaining a close touch with physics research. There was a special understanding with LASL whereby he could visit whenever the opportunity was available. It was timely, indeed, when John visited Los Alamos in late summer of 1968 just as the conference on numerical simulation of plasma was beginning, and James L. Tuck, who had been honored years earlier by the christening of the controlled thermonuclear effort as Project Sherwood, gave the opening remarks. He took occasion to wax nostalgic: "Some years ago, Fermi, visiting the laboratory here, decided to have some fun in nonlinear mechanics, working with John Pasta (who is here, I see) and Stan Ulam, using Metropolis's fairly new MANIAC computer. The problem they chose was to calculate the configuration of 64 mass points on a Hookian string, restoring force proportional to the extension, with the addition of a small nonlinear force proportional to the extension squared or cubed. As Fermi pointed out, nobody in the world could tell you what the string would be like exactly, after a few thousand oscillations at the fundamental frequency, though statistical mechanics makes general predictions about the equipartition among the modes." There is a certain appropriateness in including these remarks of Tuck, for it was he, in collaboration with Mary Tsingou-Menzel, who established that beyond the first return of the energy to the initial mode, there was a superperiodicity, and perhaps a super-superperiod beyond . . . , thereby expanding the mystery that had been opened by Fermi, Pasta, and Ulam with their numerical experiments in the early 1950s.

Collaboration with Los Alamos continued at a modest and steady level; a manuscript, "Nonlinear Coupled Oscillators: Modal Equation Approach" (with R. L. Bivins and N. Metropolis), appeared in the *Journal of Computational Physics* in 1973. It turned out that this was his last scientific publication. He continued his physics research efforts, however, whenever he could grasp the opportunity. The interest of his last studies was in trying to understand the nature of solitons and their role in natural phenomena. He persisted to the very end.

John R. Pasta with J. Howlett of Oxford University on Thanksgiving Day, 1977, in Washington, D.C.

Computer Research Begins at the AEC

John von Neumann, more than anyone, was the inspiration for the Atomic Energy Commission's interest in computing; he met in John Pasta a kindred spirit and willing ally. They had become good friends in Los Alamos, and von Neumann invited Pasta to spend the summer of 1955 at the Institute for Advanced Study (IAS). It is therefore not surprising that when von Neumann was appointed a member of the Atomic Energy Commission in 1955, he asked Pasta to join the AEC Division of Research in 1956.

To appreciate the role Pasta was to play in Washington, it is useful to review briefly the early history of computers and computing at the AEC. Shortly after it was created in 1946, the AEC, in concert with ONR and other government agencies, had embarked on the construction of an electronic computer at IAS. By 1952 computers based on the institute's design had been constructed at Argonne, Los Alamos, and Oak Ridge. With the emergence of commercial machines in the early 1950s, LASL took delivery of the first customer IBM 701 in March 1953, and Livermore received one of the two UNIVAC I's purchased by the AEC in April 1953 (the second was initially offered to Brookhaven, but eventually went to the AEC Computing Center at New York University), and two IBM 701s in 1954.

By the spring of 1956 the workload of weapons research had escalated to a point where Livermore alone was in the process of taking delivery of four IBM 704s. At the multipurpose national laboratories, on the other hand, decisions were being made to design and build other homemade computers.

Although these decisions were no doubt motivated by the difference in the funding levels of classified versus unclassified research, success of the earlier computer-building ventures had given the laboratories confidence, and they believed they were protecting the AEC's long-term interest in remaining at the forefront of computer technology by undertaking research and development in computer hardware.

This was the environment into which John stepped when he joined the AEC in 1956, and he performed two important functions. The first was to serve as the sole computer expert and advisor at AEC headquarters for unclassified work involving computing. It was his responsibility to be aware of the computer developments both inside and outside the AEC community, to advise on AEC planning for the acquisition and use of computers for unclassified research, and to evaluate the progress of the AEC laboratories in computational science. When computers for and computing done by the unclassified research programs of the AEC had to be justified to Congress, he was frequently asked to testify before the Joint Congressional Committee on Atomic Energy.

John's second task was to institute a contract-research program in mathematics and computers. By 1956 the mechanism for the support of research in the basic sciences, as mandated by the Atomic Energy Act of 1946, was well established, but it was believed that there was no need for a separate and independent program of research in mathematics since relevant mathematics research was implicit in the theoretical physics program. Further, although the AEC was already irrevocably committed to computing in its weapons research, there was little appreciation in Washington of the profound change computers were making in the way fundamental science was done and no interest whatsoever in those areas of research we have come to recognize as computer science. Von Neumann wanted to change this attitude, and Pasta accepted the task of making computers and computer science an explicit factor in the AEC's thinking about its research goals.

The initial emphasis of the computer-research program was on computers, not mathematics. Research at the national laboratories on computer systems design, both hardware and software, found a champion and patron in John Pasta, who helped the laboratories build up staff and expertise in these areas. The wisdom of his decision to support such people eventually paid off, for as the cost of commercial systems came down, the national laboratories were able to purchase and use these systems by making local hardware and software modifications to adapt them for effective use in experimental physics and nuclear chemistry. Thus, before off-the-shelf minicomputer hardware and computer networking became generally available, the national laboratories were routinely using computers as on-line adjuncts to experimental facilities and tying computers of different makes together in a variety of local area networks.

The late 1950s were active and productive years in American science. Federal support of research was increasing, and a spirit of daring was prevalent. An essential ingredient of John's program at the AEC was a strong conviction, which was later shared by his successor, C. V. L. Smith, that good work directed toward the effective and efficient utilization of computers, or devoted to any novel use of computers for the solution of mathematical problems, was in the interest of the AEC and deserved strong support. Those who received support from the AEC's research programs in physics, chemistry, mathematics, and computers were, indeed, participants in the golden age of AEC computing, and they revolutionized science. The effect of their work was felt throughout the world in the natural sciences, although not strongly in academic computer science. The ties of the AEC national laboratories to academic computer science were tenuous, at best, and remain weak even today, a fact that often led the AEC laboratories to develop ad hoc engineering solutions to systems-design problems that were later independently investigated in academic research and solved with greater generality. No publications resulted from the AEC work, and the academic publications were often no longer relevant to current AEC problems. John's AEC research program attempted to breach those barriers but met with limited success.

About the time John arrived in Washington, the need for an exchange of information by those individuals involved in computing at the various AEC laboratories was realized, and an informal meeting was held in Los Alamos. After John's arrival in Washington, these meetings—later called Semi-Annual AEC Computer Information Meetings—were held on a more formal basis until the early 1970s. The first meeting was hosted by the Livermore Radiation Laboratory in the fall of 1956. The main events of that meeting were discussion of the status of the negotiations being conducted by Livermore for a Univac LARC computer and by Los Alamos for an IBM Stretch (7030) computer.

The quality of these meetings clearly varied. Each meeting consisted essentially of an admixture of formal presentations on new numerical techniques and on what was being done at each installation, which included not only the AEC laboratories, but also the major university contractors, to enhance the capabilities of the AEC computing facilities. As the intent and status of new computer systems being developed by the major mainframe builders became known to the potential first users of these systems (i.e., the weapons laboratories), the information meetings served as a suitable forum for the discussion of these systems. On many occasions these discussions were hampered by the reluctance of the speakers to breach the thin line that separated proprietary from nonproprietary information. Whenever such an impasse occurred, it was John who intervened on behalf of full disclosure and he usually prevailed. At an information meeting hosted by Los Alamos in the spring of 1961, he presented one of the more memorable talks on a comparison of the IBM 7030 and the CDC 6600. Even after he left the AEC in 1961, John attended these meetings representing the University of Illinois.

Early in the 1960s, a major concern of the AEC was the availability of computer systems capable of handling the anticipated future loads of the weapons laboratories and, to a lesser extent, the requirements of its reactor and high-energy physics programs. In retrospect, it is somewhat amusing to note that the absence on the horizon of "a machine ten times Stretch" was taken as cause for great concern. In consequence, the major manufacturers were invited to discuss their future plans at a meeting hosted by Oak Ridge National Laboratory in May 1962. Each manufacturer naturally felt reluctant to discuss its future plans in the presence of its competitors, and nothing substantial emerged from the exercise. The representative of one major company even went so far as to devote the entire time allotted him to discussing the sanitary conditions of his company's research facilities.

Shortly after that meeting, with the concurrence of the AEC, a small informal group consisting of Pasta, Nicholas Metropolis, John Richardson, Jerome A. G. Russell, Yoshio Shimamoto, and later Daniel L. Slotnick was organized to discuss and explore some of the newer computer technologies that were beginning to make the news. Since the group initially concerned itself with the usefulness of Content-Addressed Memories (associative memories) to AEC-related problems, the group called itself CAM. In order to ensure freewheeling discussions, no formal record of the meetings was kept, although notes kept by individual members probably still exist. When it became evident that the state of the art in cryogenics gave little hope for the development of large, fast, and cheap associative memories (other implementations, of course, were also discussed), the group's interest in the matter waned. The members felt that the meetings were instructive and worthwhile, however, so they continued to meet at a rate of once every nine to ten months. At one of its meetings, Slotnick was asked to discuss his SOLOMON computer and was invited to become a member of the group shortly thereafter. This association was influential in the subsequent research and development leading to the ILLIAC IV.

Throughout his professional life John maintained close ties with the Applied Mathematics Department of Brookhaven National Laboratory. His first return to BNL was in 1957 when he spent the month of July with the department. Arrangements for that visit were made between T. Johnson, director of research of the AEC, and Leland J. Haworth, director of BNL. Milton E. Rose acted as his official host. The intent of this visit was to have John, who had experience at an AEC weapons laboratory, gain firsthand knowledge of the computational requirements of an AEC multipurpose laboratory. There are indications, however, that what John really wanted to do was to spend some time away from Washington to think about the exploitation of parallelism in numerical computations. This was the first of many visits; from 1961 to 1969, he spent eight of the nine summers at Brookhaven.

With the advent of the bubble chamber as an important detection device in experimental high-energy physics, various computer programs and hardware were developed for automating the processing of bubble-chamber photographs. By the early 1960s, mechanical digitizers of bubble-chamber photographs were being developed, and the automation of bubble-chamber data analysis was virtually complete. These digitizers, however, still required human intervention in the initial scanning phase. In the summer of 1961, John undertook the task of examining the feasibility of automating this initial phase. Robert Marr and George Rabinowitz later joined and completed the project. For various reasons, the system that emerged was not used at Brookhaven, but was used at Columbia University, and some of the new techniques devised were incorporated into systems that were developed in Europe.

Around 1965, John returned to his first love—nonlinear physics—and his time at Brookhaven was devoted to numerical experimentation. The Brookhaven staff also benefited from his managerial talents, for he was constantly drawn into planning and management discussions. When the decision was made to connect minicomputers located at the various experimental facilities to the CDC 6600 of the Central Scientific Computing Facility, John was also involved in the initial planning stage of the project. His accessibility made him an easy target for individuals in need of technical consultation—and more often than not a good devil's advocate.

When John returned to government service in 1970, his formal consulting relationship with Brookhaven had to be terminated. Even then, however, he visited Brookhaven whenever he felt the need to do some physics. His last visit was in August 1979, when he went to Princeton for the wedding of his son and then spent five days at Brookhaven.

The Illinois Years

After spending approximately four years in the Division of Research of the Atomic Energy Commission as head of the Mathematics and Computer Branch, John had developed that branch into a vital part of the Division of Research's programs and had completed the task for which von Neumann had prevailed upon him to come to Washington. He felt ready for a change in career. At the same time, the Digital Computer Laboratory of the University of Illinois at Urbana, which had been supported for several years by the AEC in its research and development of the ILLIAC I and ILLIAC II under the direction of Abraham Taub, was looking for additional scientific and managerial strength. After some discussion, John accepted a position as research professor of physics in the Digital Computer Laboratory, the Graduate College, and the Department of Physics in the College of Engineering at the University of Illinois effective September 1, 1961.

John acclimatized quickly to the academic environment at Illinois and continued some of his original research interests in nonlinear problems on which he had worked with Fermi at Los Alamos. In addition, he became involved with the pattern-recognition and data-analysis problems in the analysis of high-energy-particle events detected in hydrogen bubble chambers used with high-energy accelerators. Another highlight of his early research career at Illinois involved the programming of the ILLIAC II, which became operational in August 1962. As was often the case in those early days, most attention was paid to developing the hardware aspects of a computer system. Only when the machine was near completion was work begun on the operating system and compilers that would be needed before even talented users could exploit the machine. For this work Taub recruited C. W. Gear, who had obtained his doctorate at Illinois several years earlier and was currently with IBM in Great Britain. John joined a group of five staff members Gear had put together, and in two years they produced an operating system and FORTRAN compiler for the ILLIAC II that first ran in August 1964.

While these research activities were going on, some important developments in the administration of the Illinois laboratory were also occurring. Taub spent the academic year of 1962–1963 on sabbatical leave at the University of California at Berkeley. In his absence, he designated Pasta acting head of the laboratory. John did an effective job and impressed both the members of the laboratory and the university administration. Taub, in turn, had made his impression on Berkeley, which was developing an increased interest in computing, as was the case at many schools during the late 1950s and early 1960s. Soon after his return to Illinois, Taub acquiesced to pressure from Berkeley to head a new computer-science program there and resigned from Illinois effective February 1964. John was named head of the Digital Computer Laboratory, and he, in turn, named James N. Snyder associate head.

John's appointment as head of the Digital Computer Laboratory marked the opening of a new era for computers and computer science at the University of Illinois. Previously, the laboratory had concentrated on computers either as interesting devices to be designed and built or as tools to use in order to solve significant problems. Now, for the first time, the laboratory had an administration with a far wider view of computers and the activities and phenomena surrounding them as manifestations of a larger and more basic concept—the emerging new discipline of computer science. The initial step taken toward recognizing this new discipline was the change in name from the Digital Computer Laboratory to the Department of Computer Science.

The first project undertaken by the new department was to build an educational program in computer science. Although a few other universities had set up computer science programs a little before this, the program at Illinois had many distinctive characteristics because the Digital Computer Laboratory (out of which the deparment and the programs evolved) had already been in existence and heavily committed to research and development since its founding 18 years before in 1948. Time has proved that this step was the most important and enduring accomplishment of the Pasta regime. The department had offered some courses prior to the name change in 1964, but these had been carried under either mathematics or electrical engineering; no courses taught by departmental staff could be specifically labeled computer science. A significant number of new courses were introduced in order to cover the discipline broadly. Proposals for a master's degree and a doctorate in computer science were prepared and entered into the long approval process, which required action by eight separate committees or boards. Since the department was at that time a unit of the Graduate College, the master's degree and doctorate presented no problem, but the offering of a baccalaureate also was needed for which no mechanism existed within the Graduate College. Cordial relations with the Department of Mathematics permitted a bachelor's degree called mathematics and computer science to be formulated; it contained a heavy component of mathematics as well as computer science. Although this program was formally housed in the Department of Mathematics, and hence in the College of Liberal Arts and Sciences, the students in it were credited to the Department of Computer Science, and the staff of this department was responsible for all advising and counseling as well as the teaching of the computer-science component. The tedious approval process was carried out in record time; the bachelor's program became official in 1965 and immediately enrolled 41 students. The graduate degrees became available in 1966 and immediately attracted 10 students. By 1970, when Pasta left Illinois, these programs had grown to 302 undergraduates and 141 graduates. At the time this is being written (1982), these figures are 1348 undergraduates and 327 graduate students, respectively. Pasta felt that this facet of his stay at Illinois was personally the most rewarding.

Prior to 1970, the Department of Computer Science and its predecessor, the Digital Computer Laboratory, had also been in charge of the service computing facilities that supported the research and education programs of the entire campus. This service started in 1952 with the ILLIAC I providing the computing power. An IBM 650, added in 1959, was soon replaced by an IBM 7090, which was upgraded to a 7094 in 1962. Upon completion of the operating system for ILLIAC II, it was also utilized to supply a portion of the continuously increasing demand for such service. By the mid-1960s, the 7094 was replaced by an IBM 360 system which grew by steps until, by 1967, it consisted of a large Model 50 connected to a Model 75. In that year, the ILLIAC II was withdrawn from service.

The growth of the department in staff size, research activities, service computational facilities, and computer-construction projects demanded a substantial increase in space, which occurred in three steps. The first quarter of the laboratory was finished in 1956 and the second quarter in 1962. That building was soon outgrown, however, so that another of Pasta's early projects, carried out in parallel with those cited earlier, was the planning and acquisition of funding for the final phase of the laboratory, which more than doubled the space available in the first two phases. This was completed in 1966 and made it possible to draw together in one building all of the staff members, research projects, and service facilities, which had been somewhat dispersed prior to that time.

Another significant development during Pasta's leadership was the consolidation and growth of the ILLIAC III project. In 1960, Bruce McCormick had joined the Department of Computer Science from the Alvarez High Energy Physics Group at the Lawrence Radiation Laboratory, University of California at Berkeley. At Berkeley McCormick was particularly interested in the instrumentation and computer techniques that played a central role in the measurement and analysis of high-energy-particle events detected in hydrogen bubble chambers. After moving to Illinois, he continued to be interested in those problems, but his perspective broadened to encompass the far wider question of the automatic recognition and processing of pictorial information of any type. His consideration of this problem led to the concept of a large and highly parallel computational device whose logic, organization, and command structure would be appropriate to the processing of digitized pictorial information rather than binary numbers. The AEC was, of course, quite interested in problems of this nature, and in 1963 funded a pilot study on the preliminary design of a computer organized along these novel lines. The pilot study yielded promising results, and by 1964–1965 the AEC had agreed to fund the full development of a computer whose cost would be in the order of several million dollars. Naturally, the computer was called the ILLIAC III. Its unusual and novel design is described elsewhere (McCormick 1963). Unfortunately, disaster in the form of a fire struck ILLIAC III before it was completed, and its ideas could not be tested. Nevertheless, it was pioneering work in parallel-computer architectures.

Other research on parallel architectures during Pasta's tenure at Illinois involved the ILLIAC IV project and its originator, Daniel L. Slotnick. Slotnick's initial ideas about parallel computers go back to the mid-1950s. He perfected and developed the concept throughout the next half-dozen years as he moved through several positions. It was at Westinghouse that he developed a large group and a definite proposal to produce a highly parallel machine, called the SOLOMON. (These developments are chronicled in detail in Slotnick 1981 and Slotnick 1982.) During this same period, Pasta and Slotnick had developed a close association as two members of CAM, the small, informal group that met periodically to discuss questions of importance to the AEC in large-scale computation. The SOLOMON project at Westinghouse attracted a considerable amount of favorable interest on the part of several federally supported laboratories that dealt in extremely large numerical problems. Even though there was a clear intent to purchase such machines if Westinghouse would develop them, the corporate decision was made not to undertake the risk. The time was ripe, and Pasta prevailed on Slotnick to join the Department of Computer Science at Illinois in May 1965.

In spite of Westinghouse's refusal to undertake the project, federal agency interest in the parallel computer organization Slotnick had developed continued. Ivan Sutherland, who was in charge of computing activities in the Advanced Research Projects Administration (ARPA) of the Department of Defense, visited Illinois shortly after Slotnick's arrival to discuss building such a machine. This was an important decision which both Pasta and Slotnick considered at great length and with great care since it would mean yet another machine project on top of the AEC's ILLIAC III project, which was ongoing at that time. A positive decision was made, and the ILLIAC IV project was born. Within a very few months, a $10 million contract with ARPA was executed.

By this time, it was clear that the days of actual machine fabrication in a university context were over. The department departed from the approach that had characterized the first three ILLIACs and decided that only the specifications and architectural design of the ILLIAC IV would be carried out at Illinois; the detailed design and fabrication would be carried out as a subcontract to a competent commercial computer company, while, in turn, the systems software and application developments would be produced at Illinois. During the first year of the project, the nucleus of the ILLIAC IV staff was put together, and an initial set of specifications for a two-phase bidding procedure was prepared. In 1966 as a first phase, three 8-month contracts to prepare a detailed final design were let to Burroughs, RCA, and Univac. The proposal from Burroughs was accepted. The ILLIAC IV was to be an array of 256 identical processors operating in perfect lockstep on different data. These were to be organized into four subarrays (quadrants) of 64 processors each. Extremely large and fast disks were to act as the backup storage for primary memory, which turned out to be semiconductor after some experimentation with other alternatives that seemed to be promising at that time. At Illinois, the ILLIAC IV staff expanded rapidly and eventually reached a size of over 100 professionals and research assistants. Approximately six of the professorial staff in the department associated themselves with ILLIAC IV.

At this point, in 1967, John Pasta's association with the department and ILLIAC IV was temporarily interrupted for approximately a year when he spent a sabbatical at the European Center for Nuclear Research (CERN). This was a natural choice because of his research interests in bubble-chamber data processing; his primary intent, however, was to spend the major portion of his time considering the methods and techniques that would have to be developed to apply a computer with ILLIAC IV's novel architecture to the large numerical problems arising in the physical sciences.

During the year John was abroad and during the following year, the ILLIAC IV project, although growing in size, was beginning to have problems; the speed of the individual processors did not live up to the original hopes and expectations; the cost of the machine escalated, reaching $30 million for a single quadrant out of the four originally proposed. In addition, when measured either in terms of personnel size or budget, the ILLIAC IV project was now several times as big as the Department of Computer Science in which it was administratively embedded. It became increasingly difficult and eventually impossible for the department to administer the project. In 1969 the ILLIAC IV was split off from the department and set up as the Center for Advanced Computation, an additional unit in the Graduate College. Thus the era of the ILLIAC IV as a project in the Department of Computer Science came to an end.

For completeness, we will note parenthetically the subsequent history of the ILLIAC IV. The late 1960s were characterized by massive student unrest on many university campuses. The war in Vietnam and the deaths at Kent State University and their consequences are unpleasant reminders to us all. The University of Illinois escaped major violence but did not escape the definite trends of those times. In the face of student unrest and faculty reluctance, the administration of the university seriously questioned whether or not a federally supported computer (possibly tainted by military applications) should be housed on the university campus. Similarly, the federal sponsors seriously questioned the security of such a machine in that type of environment. A mutually agreeable decision to locate the ILLIAC IV elsewhere was taken. Several federal agencies sought to house it; the final site was chosen to be the NASA Ames Research Center at Moffett Field, California, to which the ILLIAC IV was delivered in April 1972.

Another activity that should be mentioned, especially in connection with his Illinois period, is John Pasta's participation in international science. He had always been interested in international science affairs and claimed many European and Japanese scientists among his close friends. He participated in the IFIP conferences beginning in the 1950s and was the American delegate to IFIP in 1965–1966. At that time he was also chairman of the International Relations Committee of AFIPS. It was during his tenure as head of the Department of Computer Science at the University of Illinois that many Japanese students chose Urbana for graduate work in computer science.

Those who had the pleasure of traveling with John always had an unusual bonus because of his keen interest and deep insight in the people and culture around him. One of John's companions recently recalled two memorable trips: to Japan in 1972, on the occasion of the first United States–Japan Computer Conference, and to Russia in 1976. During John's tenure at Illinois, he had developed many friendships with both Japanese graduate students and their derivative faculty, so by the time of the Tokyo meeting in

1972, he was already widely recognized there. Having visited earlier, he was also an excellent guide and advisor to those who were neophytes to the Far East. It was one of the most successful scientific expeditions for his associates. Doors seemed to open easily at the several universities and industrial research installations, the exchange of information was warm and thorough, and, of course, the hosts were most gracious.

The second of the impressive trips, in 1976, was to meetings in Moscow, in Adkademegorodok (Science City) near Novosibirsk, and in Leningrad. In Moscow, academician Andrei Ershov was host. A few months earlier he had been invited to an international conference in Los Alamos but had been unable to attend because of an accident in the family. Primarily because of John's presence at the Moscow meeting, Ershov announced that he would give a second talk—the one he would have given in Los Alamos. It was a warm gesture and much appreciated. Those attending the meeting also discovered that accounts of Russian banquets are not all exaggerated.

John's interest in international science continued throughout his stay at the National Science Foundation and until the end of his life. At NSF he was instrumental in developing international collaboration between Russian and American scientists on computer research and the applications of computers to management sciences. He also participated in several international conferences and warmly supported the International Convocation of Pioneers of Computing organized by N. Metropolis and W. J. Worlton in Los Alamos in 1976 (see Metropolis et al. 1980).

In 1969, Pasta found the situation at Illinois to be similar to that in Washington in 1961. The projects he had undertaken were either well under way or diverted. Also, during Pasta's stay at Illinois, the interest of the National Science Foundation in computers had been developing. In response to the Pierce committee report of 1966, which was strongly influenced by John Kemeny and called for a large national program to enhance computer literacy and education in secondary schools, colleges, and universities, the government had punted by asking NSF to start a pilot program in the summer of 1967 without additional funds. Although this returned the ball to the advocates of computing with only token support, an Office of Computing Activities was established in NSF to combine the already existing university computing-facilities program and a tiny computer-science research program with new activies in education, faculty training, and other areas for developing the application of computers to education and research. In the summer of 1969, Milton Rose, first head of that office, left for an academic position at Colorado State University,

John R. Pasta receiving the Distinguished Service Award in 1979 from George C. Pimental, deputy director of NSF.

and a search was made for a replacement. With his experience, ability, and deep concern for promoting computer research and education, Pasta was interested, and early in January of 1970 he joined NSF to head the Office of Computing Activities. His resignation from the University of Illinois was effective March 31, 1970.

John retained a deep attachment to and a permanent friendship for the Illinois Department of Computer Science during the remaining 11 years of his life. He found the association with students and their education to be the most pleasant and best remembered of his many activities at Illinois. His contributions to the evolution of the department were a significant part of the development of computer science at the University of Illinois.

The NSF Years

If John's personal feelings about his position in Illinois in 1969 were similar to those he had had about his AEC position in Washington in 1961, the situation he met when he returned to Washington was much like the one he had found at the AEC when he first went there in 1956. There was widespread bewilderment, doubt, insecurity, and downright skepticism in government circles about the role of computers in education and research, and computer science as a discipline had almost no recognition at all. His old research-support program at the AEC was weaker than when he had left it nine years earlier; NSF's university computer-facilities program was under attack and being reduced; its computer-research program had never grown; indeed, the only robust computer-research activity in the federal government was that of the Advanced Research Projects Agency of the Department of Defense, which exceeded the sum of all of the others in size. The one major difference he met was in outlook. Sputnik, in 1957, had introduced an expansionary period for government support of science. At the AEC and Illinois, John had enjoyed the advantages of increasing resources. In contrast, Vietnam, in 1967, had introduced a period of consolidation and reduction in support for science, and the computer activities for which John was responsible at NSF in 1970 were fighting for birth and a place in the sun in an environment of stiff competition among mature, aggressive disciplines for diminishing resources. It was a challenge for which he was prepared by background and temperament. His credentials as a physicist often served him well in battles with physicists and other scientists to protect the fledgling computer-research activities, and he always loved the fight. But John's patience, perseverance, keen sense of tactics, and firm conviction of purpose were also needed as well as a refined sense of humor to keep his spirit willing.

Under these circumstances, it is not surprising that John's first few years at NSF were ones of retrenchment and rebuilding. First, the university computer-facilities program was phased out; its mission was declared accomplished. Computing had been stimulated on campuses by the NSF program, and the educational institutions themselves were given full responsibility for determining the nature of the computing services they would provide and the priority to be given to maintaining and expanding them. This was not a position John advocated, because he knew there was much that still needed doing, but resources were such that he accepted it as inevitable in the current climate. He was willing to give on that point to protect the core of computer research and education.

The educational activities of the Office of Computing Activities were the next to go, moved into the foundation's Directorate for Science Education as a more natural organizational home for all of NSF's educational functions. John fought that move bitterly and lost. He was sure that the application of computers to education was a function that needed and deserved special national attention. Nevertheless, neither computing nor education had the "clout" (to use the jargon of the time), and the transfer was made. The Office of Computing Activities was then renamed the Division of Computer Research. In retrospect, considering the history of steadily declining federal support for education during the decade of the 1970s and to the present, that move surely helped protect computer research from too much identification with education, although it just as surely left progress in using computers for education in a weaker state. One can only speculate what difference it might have made to the development of computer research and education in the United States if John had been given resources to pursue the programs he envisioned. Would the United States be in a noticeably stronger position today? Would we be less concerned about losing our competitive edge in technical training? The readers of this article must draw their own conclusions, but it is certain that an opportunity to use John's talents in this direction was not realized.

A final change took place in 1975 when the Division of Computer Research was merged with the Mathematics Section of NSF to form the Division of Mathematical and Computer Sciences, with John as division director and with one section for computer sciences and one for mathematics. It seemed an unnatural marriage to many in both disciplines, but John welcomed this step and was able to convert it into a substantial strengthening of support for computer science and engineering research. Activities of the earlier Division of Computer Research, which addressed applications of computers to research in disciplines other than computer science, were discontinued without loss of budget when the Computer Science Section was formed and placed under the leadership of Kent Curtis. This nearly doubled the effective budget for computer research within a year. Since then, support for computer research by NSF has nearly doubled again, building on the strength John had successfully developed.

In addition to noting John's effective advocacy for computing research and education at NSF, we want to consider some of the special opportunities and problems that arose. First and foremost in any account must be his unwavering support for growth and quality in academic computer science. Computer science, born as a discipline in the 1960s, was growing rapidly throughout the 1970s with all of the problems and anxieties of youth and rapid development. There was little agreement in the community of computer scientists about the appropriate research paradigms for most areas of computer research and much fragmentation of the community into subgroups such as pro- or anti- AI or APL, on or off the ARPANET, and many other distinctions of greater or lesser import. This resulted in disagreement among peer reviewers on the quality of research proposals under their purview, a constant headache for John because his recommendations were further reviewed in the NSF system by higher officials who were chemists and physicists accustomed to consensus in their communities on the value of the proposals in their fields. Nevertheless, John and his staff were able to evaluate the reviews and select proposals for support that consistently reflected his insistence on quality and good taste in science and that contributed greatly to the structure of academic computer research. Gradually, NSF became a serious and widely respected influence in the computer area, as it had long been in other areas of science, and some areas of computer research began to display a measure of consensus about their directions and paradigms for research. This may be the greatest and most lasting contribution John Pasta made through his service at NSF. With his help a new discipline, which is making profound contributions to both intellectual and technical levels of academic life, gained sufficient stature and self-identification to merit respect and permanent recognition by the traditional disciplines.

A second area John worked on steadily from the time he came to NSF was computer networking. He advocated formation of a national computer network among research groups in computer science but was stymied by skepticism at higher levels of NSF and reluctance by the government to take on responsibility for an operation of unknown but possibly frightening magnitude. As a result, he had to remain content to support some small experiments in computer networking while DARPA performed extensive research and developed the technology. Finally, at the end of the decade of the 1970s, the budget for computer research had become sufficiently robust to take a chance on developing the kind of communication he had envisioned from the beginning. Unfortunately, although he lived long enough to see the National Science Board give approval to the Computer Science Network (CSNET) project, he was unable to participate in it or even enjoy the satisfaction of seeing it actually started. There can be no doubt about the correctness of his vision. Time alone will tell whether the projects he saw formulated will bring that vision to fruition.

Throughout his professional life, John was fascinated by the deep impact computer technology was having, first on science and then on the whole fabric of social organization and intercourse. It was natural for him to include in the spectrum of activities supported by his Division of Computer Research at NSF a group of projects performing research on the social impact of computing technology. This led him into several unexpected arenas. One was computer crime, a phenomenon few people were aware of at all when the 1970s began but which was already of such potential magnitude that John believed measures should be taken to study it, understand the kinds of computer crime we may have to combat, and develop means for detecting and preventing it. In addition, he undertook to alert the branches of government that have primary responsibility for law enforcement to the dangers of criminal activity using computer technology. A catalog of computer crime was begun under his sponsorship, and workshops on auditing computer records and computer systems were held. Other research in the area of computer-system security and integrity was supported at a number of locations, including theoretical research on the limits of security attainable in computer systems. Before he died, the task of alerting the law-enforcement agencies of the government to this new form of criminal activity had been accomplished, and they had stepped in to develop countermeasures and support research and development appropriate to their missions. NSF still carries on fundamental research in data and computer-system privacy and security.

This latter research also led to an unexpected turn when Martin Hellman at Stanford discovered the "public-key" cryptology system (Hellman and Diffie 1976), and Rivest, Shamir, and Adleman (1978) at MIT discovered the remarkable prime-factors keys. Suddenly, abstract theoretical computer science and number theory, the most unlikely candidates in the world for attention as applied sciences, were the focus of controversy. NSF was at the center because this was all NSF-supported research. National security, especially the responsibilities of the National Security Agency (NSA), on the one hand, and the needs of science for open communication of ideas, on the other, were the contending forces. Also of great concern to everyone was the rapidly increasing dependence of the nation's economic and financial life on electronic communication. What restraints should NSF accept on its support of research and on the publication of the results of the research it supports in order to protect national security? Where and how should decisions be made on policy and on specific proposals? How should NSF evaluate unsolicited proposals it receives that are relevant to cryptology? What added responsibilities should NSF place on the investigators undertaking such research? These and other questions required a reexamination of NSF policy in consultation with NSA and other branches of the federal government. They also showed the need to develop operating procedures that would satisfy future requirements—procedures that would serve both science and national security if other areas of science touched on security-sensitive subjects.

John was deeply involved in the early stages of these deliberations, and his background as a cryptographic security officer with the army, as a respected and trusted scientist with the AEC (which gave him much experience with issues of classification and security in nuclear science), and as an academic computer scientist gave him a unique perspective for dealing with these questions. There can be no doubt that his influence was critical in setting the initial direction for relations between NSA and NSF, in suggesting appropriate actions by NSF to satisfy NSA's concerns for national security without compromising scientific freedom, and, in general, for setting a course toward stability in what could have become very turbulent waters. Again, he did not live to see these events through, but his steady hand at the tiller, when these issues first arose, was good fortune for the scientific community and the country.

John's interaction with the mathematicians he inherited in 1975 demonstrated his unusual skill and wisdom in dealing with people. The creation of the Division of Mathematical and Computer Sciences, with the mathematical sciences as a section in the division, created an extra layer of administration for the mathematicians, who up to that point had enjoyed equal status with their chemistry and physics colleagues. John sensed their apprehension at dealing with a strange physicist or computer scientist, and he approached them very gently. He cleverly let them learn about him slowly, and they soon discovered that he was wise, observant, understanding, a good listener, and a good leader. One example will have to suffice. Before becoming part of John's division, the section had started plans for establishing a research institute in the mathematical sciences and had run into questions and opposition inside NSF and among academic mathematicians. John willingly stepped in to provide the balanced view that only someone not known principally as a mathematician could provide. He helped in the initial presentation to the National Science Board in March 1978. He presented the case for an institute to the Council of the American Mathematical Society, which was quite hostile at the time. He announced and led a public discussion at the Joint Mathematics Meetings in Biloxi in January 1979. Although he was close to death in May 1981, he was pleased to hear that the National Science Board had approved the establishment of the Mathematical Sciences Research Institute in Berkeley and the Institute for Mathematics and its Applications at the University of Minnesota. His contribution to the institute effort was central, supportive, and vital. To the members of the Mathematical Sciences Section, John was, in every sense, an honorary mathematician.

An article in the *Annals* on John Pasta's contributions at NSF would not be complete without mention of his interest in the history of computing and his concern that we not lose the chance, unique in human history, to benefit from the memories of the pioneers who had shaped the beginning of a revolutionary technology. Although his research funds at NSF were for scientific studies, and another (weakly funded) program in the foundation had responsibility for the history of science, John took the opportunity to work with that program and supplement the resources available for the history of science on several occasions when strong proposals were submitted to NSF. Two examples were the History of Programming Languages Conference in 1978, which Jean Sammet organized (see Wexelblat 1981), and the Convocation of Computer Pioneers, which Metropolis and Worlton organized in Los Alamos in 1976. It gave John great pleasure to be able to attend the latter conference and listen to the papers presented by people from many nations who had been instrumental in one or another key facet of computer technology. Not everything was unclassified, even then, but the World War II mysteries and antagonisms that surrounded some of the origins of computing had dissipated enough so that much new light was shed and new perspectives gained on the relative roles of various contributions from many countries. The publication resulting from that conference, *A History of Computing in the Twentieth Century* (Metropolis et al. 1980), was, appropriately, dedicated to John.

Perhaps the last great contribution Pasta made to computer research, born again from his credentials and standing as a physical scientist as well as a computer scientist, was to persuade William Klemperer, a chemist and assistant director for Mathematical and Physical Sciences at NSF in 1979, that he should give top priority to developing experimental computer research at academic institutions in the United States. The background for this contribution was created by many people, by Jerome Feldman's workshop and the "Feldman Report" (Feldman and Sutherland 1979), by staff studies on the flight of faculty and graduate students from academic to industrial positions, and by numerous other events, but the crucial arguments about the need for experimental research that struck a responsive cord with Klemperer were supplied by John at a retreat of the division directors of Physics, Chemistry, Materials Research, and Mathematical and Computer Sciences with Klemperer and his staff in the fall of 1979. From that time on, Klemperer gave full support to the plans of the Computer Science Section of NSF in developing the Coordinated Experimental Research programs and the Computer Science Network (CSNET). The National Science Foundation is now firmly committed to strengthening academic computer research in the United States. Its success in this endeavor will be a tribute to John Pasta's foresight and persuasiveness.

Personal Notes

John Pasta was a man of many facets—a host of unending surprises when it came to capabilities and experiences, of quiet charm and considerable reserve, but underneath it all, a warm friend of rare trust and reliance. Mary Tsingou-Menzel, a programmer who worked with John in Los Alamos, recently recalled the excitement of that period and remarked that for a long time John seemed to be a stoic of first magnitude. One evening, however, he brought his daughter, Diane, then a toddler, into the computing room. In the course of that session, he would take her in his arms and show her the various components of the MANIAC, and occasionally swing her and toss her gently into the air. It was only then that Mary became aware of John's warm, fatherly characteristics, a surprise not soon forgotten. Another remarkable incident was the time he took Betty to the hospital as his son's arrival was imminent. It turned out that there wasn't time to get her to the delivery room, and John helped the nurse with the actual delivery in the waiting room. His tour of duty as one of New York's finest once again stood him in good stead.

At Brookhaven's Central Scientific Computing Facility, he is remembered by the computer operators as a kind, gentle, and considerate computer user, who never failed to thank them for whatever they did for him. In contrast, he is remembered by a former colleague at NSF as "one of the best street fighters I've ever known—and did we need him!" He was always fair, and when you asked for his opinion, you were able to depend on him for a forthright answer.

John was fascinated by the world around him and never missed the opportunity to better himself. Thus, while he was at Illinois, he availed himself of the facilities provided by the university to resume his childhood piano lessons, which had long been abandoned, and to take flying lessons and qualify for a pilot's license.

Above all, he was a man of considerable courage. He suffered a long, painful illness and had considerable time to contemplate death, yet he maintained the grace to joke on the subject. He served the NSF even after he was no longer able to walk. Until the very end, he was the tough New York City cop whose primary concern was the well-being of science and his country.

John died June 5, 1981. On June 2–4, 1982, a year later, the John Pasta Memorial Conference on Computer Architecture and Computational Mathematics was held at the Institute for Mathematics and its Applications on the University of Minnesota campus in Minneapolis. Kenneth Keller, vice-president of academic affairs, gave the welcoming address. Conference speakers included scientists concerned with the use of computers in the natural sciences and mathematics and scientists and engineers from both industry and academia concerned with computer architecture. Mark Kac of the University of Southern California gave a memorial address in which he reviewed John's contributions to both computer science and mathematical computation and touched his audience with personal anecdotes about John. This conference was the first formal activity of the Institute for Mathematics and its Applications, which made it especially poignant because John had labored hard during the last painful years of his life to gain NSF acceptance and support of the institute. The topic chosen was the central interest of his professional life.

Left to right, in a moment of mutual commiseration, February 1979: William G. Rosen, head of the Mathematics Section of NSF; William H. Pell, former head of the Mathematics Section; John R. Pasta, division director of Mathematical and Computer Sciences. Rosen and Pell soon recovered, but unfortunately Pasta was already ill with cancer.

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REFERENCES

Feldman, J. A., and W. R. Sutherland. 1979. Rejuvenating experimental computer science. *Communications of the ACM 22*, 9, 497–502.

Hellman, N., and W. Diffie. November 1976. New directions in cryptography. *IEEE Trans. Information Theory IT-22*, 6, 644–654.

McCormick, B. 1963. The Illinois Pattern Recognition Computer—ILLIAC III. *IEEE Trans. Electronic Computers EC-12*, 5, 791–813.

Metropolis, N., J. Howlett, and G. C. Rota (eds.). 1980. *A History of Computing in the Twentieth Century.* New York, Academic Press.

Rivest, R. L., A. Shamir, and L. Adleman. 1978. A method for obtaining digital signatures and public-key cryptosystems. *Communications of the ACM 21*, 2, 120–126.

Slotnick, D. L. 1981. Centrally-controlled parallel processors. In *Proc. 1981 International Conference on Parallel Processing*, M. T. Liu and J. Rothstein (eds.), pp. 16–24.

Slotnick, D. L. January 1982. The conception and development of parallel processors—a personal memoir. *Annals of the History of Computing*, Volume 4, Number 1, pp. 20–30.

Wexelblat, R. L. (ed.). 1981. *History of Programming Languages.* ACM Monograph Series. New York, Academic Press.

Bibliography of Works by John R. Pasta

"Limiting Procedures in Quantum Electrodynamics." Ph.D. Thesis, New York University, 1951.

"Heuristic Studies in Problems of Mathematical Physics on High Speed Computing Machines" (with S. M. Ulam). Los Alamos Report LA-1557, June 9, 1953.

"Studies of Nonlinear Problems" (with E. Fermi and S. Ulam). Los Alamos Report LA-1940, May 1955; also in *Collected Works of Enrico Fermi*, Vol. 2, Chicago, University of Chicago Press (1965).

Heuristic numerical work in some problems of hydrodynamics (with S. Ulam). *Mathematical Tables and Other Aids to Computation 13*, 1, January 1959.

"Description of the Electronic Digital Computer at the University of Pisa" (with A. Borsei). Translation, 1959.

"Computer Research in Japan," AEC Division of Research, May 1961.

"A Preliminary Report on Digital Pattern Recognition at BNL" (with R. Marr and G. Rabinowitz). Report BNL 6866, February 1963.

Local equilibrium in lattice thermal conductivity (with E. A. Jackson and J. Waters). Abstract, *Bulletin of the American Physical Society 11* (1966), 413.

Thermal conductivity of one-dimensional lattices (with E. A. Jackson and J. F. Waters). *Journal of Computational Physics 2* (1968), 207.

"The Role of the University in the Computer Age." In *Computers and Their Role in the Physical Sciences*, Fernbach and Taub (eds.), London, Gordon and Breach, 1971.

"Simulation of the SEL-810A Computer on Maniac 2" (with N. Metropolis and M. Fraser). Los Alamos Report, 1971.

"The Heuristic Value of Computers in Physics." In *Computer Physics Communications*, Amsterdam, North-Holland, 1972.

Nonlinear coupled oscillators: model equation approach (with R. L. Bivins and N. Metropolis). *Journal of Computational Physics 12* (1973), 65–87.