Reflections on the early days of the department

by H. H. Goldstine

The paper contains the reminiscences of the founding director of the Mathematical Sciences Department in IBM Research. It is interspersed with a number of anecdotes about his friend and colleague, John von Neumann. It attempts in a short space to recapitulate the history of a distinguished department of mathematics in an industrial environment in an informal and hopefully humorous manner.

It is always nice to be asked to attend an anniversary party but it is awfully hard to be the speaker on such an occasion. All you in the audience can sit in relaxed states and let the poor speaker think of some interesting and not too banal comments. Tonight is for me, however, a particularly happy occasion since I had the good fortune to be here at the parturition of this strong and vital department. In general I have chosen to restrict my remarks and reminiscences about the department primarily to the period prior to 1985, when I stepped down as director.

Fortunately the notion of mathematical sciences is a very old one, so that the founding of this department was really not a daring venture but rather a continuation of a tradition that is at least three millennia old. It is precisely because, in Eugene Wigner's words, mathematics is so unreasonably useful that our subject has existed for so long and been so highly respected.

Further, it was not so daring to sense that the presence of the digital computer would be responsible for a very substantial upheaval in the mathematical sciences and result in the establishment of a whole new discipline: theoretical computer science. This is a subject that was for a short while an object of considerable contempt by our pure mathematical brethren, but is now a virtual *sine qua non* in the modern university or college. Perhaps more importantly it is now an object of great interest to the entire mathematical community. Our colleagues on the other side of the aisle, to use a political idiom, are now very conversant with computers as mathematical tools: for example, at the Institute for Advanced Study in Princeton both Bombieri and Milnor, just to mention two well-known names, are constantly making use of the computer as a tool to gain heuristic insights. It is furthermore of considerable interest to note that some years ago the Hermann Weyl Lecturer at that institution was Dick Karp, an illustrious former member of this department. His subject was computational complexity—and he played to packed houses of mathematicians and computer scientists. And as you all know, computational complexity is a field which Sam Winograd through his personal research and leadership has made a key subject here.

Going back to Wigner's statement, let us look at two early examples of mathematics as a tool of inestimable value to other scientists. One of the earliest instances is that of Ptolemy's invention of trigonometry and the concomitant development of a kinematical astronomy which with modifications survived from about 150 A.D. to the time of Kepler in about 1600. Trigonometry, of course, continues.

What were the choices facing Ptolemy? He made the very cogent decision to develop his model of astronomy using the geometry of his day: Euclidean geometry. This left him with the absolute need to measure the ratio of an arc of a circle to

its chord. A lesser man might conceivably have created a table of these ratios or sines of angles by undertaking a series of careful physical measurements, thereby making theoretical astronomy a branch of physics instead of mathematics. His decision was sound because as we all know it is possible using the theorems of Euclidean geometry to construct by exact mathematical means—apart from the need to extract some square roots—a table of sines and hence to build up the entire edifice of kinematical astronomy, which served very well until the invention of the telescope made possible more accurate observations than could be undertaken in earlier times.

To my mind this construction by Ptolemy of his *Almagest* is one of the greatest achievements of applied mathematics. If anyone doubts this, let him consider that the apparatus set up by that man, even though modified by later figures such as Tycho Brahe and Copernicus, lasted as a useful device for about a millennium and a half. Few of us can expect our achievements to be so important to mankind.

Another obvious father figure for our subject is certainly Isaac Newton, whose accomplishments among other things replaced kinematical astronomy by dynamical astronomy, an achievement that we still live with. We all know of Newton's massive achievements in astronomy, in optics, and in virtually every branch of pure or applied mathematics of his period.

But it is not my aim to catalog nor your desire to sit through a long description of all the great figures in our field. Instead I shall pass quickly on to Richard Courant because he played so important a role in the development of this department, and also by establishing in New York what is so fittingly styled the Courant Institute, in the Goettingen tradition so magnificently begun by Gauss. (Lest I forget, let me mention that the fast Fourier transform of Jim Cooley and John Tukey is an idea that in a very nascent form was conceived of by Gauss and forgotten by the world.)

The other great center for applied mathematics in America in the 1950s was at the Institute for Advanced Study, where such full-time figures as Einstein, Oppenheimer, von Neumann, Weyl, Yang, and Lee as well as such part-time ones as Niels Bohr, Dirac, and Pauli made it preeminent in a golden period from the 1930s through the 1950s. It was also there that one of the very first computers was developed and operated; there also what is now known as theoretical computer science had its modern genesis.

It was very farsighted of Thomas J. Watson, Jr., that he took an extremely active interest in the IAS computer and made von Neumann a consultant to IBM just at the time that the 701 was being developed. Along with this remarkable appointment Watson made another: Mannie Piore to be the first Director of Research for IBM. Mannie had been the Chief Scientist for the most forward-looking of the service R and D establishments: the Office of Naval Research. He was one of the first people to appreciate that IBM's position in the marketplace would in the medium to long term depend heavily upon its establishing a first-class research laboratory. He had another truly great quality: he was able to choose key people and then give them very considerable amounts of authority. This was an exceedingly important quality for the initiator of IBM Research to possess, since it gave the senior staff the freedom and confidence they needed to get this large organization launched.

At about this period—1957 to 1958—I was restless at the Institute for Advanced Study. The initial impetus given to the computer field by the university world had diminished and the time had come for the great industrial organizations to take over and to create the wonderful world that we live in today. It seemed to me that this was the appropriate time to come to IBM and to help in some small way to continue my abiding interest in the computer. Accordingly Mannie Piore brought me on board here, and after a relatively brief time to learn my way around I told him that I felt we needed a mathematical sciences department that was centered around a great computer.

We started the department in the old Ossining Hospital with its magnificent view of the penitentiary yard and little else, but moved from there almost at once to the Lamb Estate. This is now the home of the Hudson Institute and sits on a beautiful bluff overlooking Haverstraw Bay, with a simply marvelous view of New York City to the south and the New Jersey Palisades to the west. There we had a set of assorted but nice buildings in a campus-like setting. It was a great wrench for all of us to leave that site.

In case you don't know about Dr. Lamb, let me tell you a few words. He was what was once known as an alienist and it was his testimony that resulted in the freeing of Harry K. Thaw for the murder of the famous architect Sanford White.

We were very lucky that there were already in IBM a number of very good mathematicians and programmers, including Willard Bouricius and Larry Horwitz, who coalesced around our computer to form a department. At that time our department included the computing center. As a result of the great freedom which Mannie gave me, I was able to retain as consultants a number of eminent mathematical scientists who in my opinion were very helpful or perhaps even essential in making this into the truly fine department that we all know it is. The group of consultants consisted of Courant first and foremost, because he threw himself into helping create this group just as he did with everything he took an interest in. He bore great responsibility for bringing on board here Willy Miranker, as well as Herb Greenberg, Hirsh Cohen, and Bill Dorn. Other consultants were Frank Yang, the Nobel laureate in physics, who was a model for many of us with his brilliance, his expository skill, and his quiet and lovely manner of dealing with people; Will Feller, the great analyst and probabilist,

who was a constant source of mathematical insights and encouragements; and Mark Kac, an inspired and brilliant expositor of the analytical method at its best who warmly encouraged Roy Adler and Alan Konheim. We also were fortunate to have had for long periods of time Juergen Moser, who is as you all know one of the great analysts. He worked closely with Bob Brayton and Willy Miranker on nonlinear stability, a topic that is of considerable interest in all switching devices.

Cal Elgot's group, which contained among others Jim Thatcher, Jesse Wright, Ray Miller, and Eric Wagner, was a first-class center for the study of some of the central logical problems of computer science; in this connection Elgot had the remarkable assistance from time to time of Abraham Robinson and collaborated on some elegant work with Sammy Eilenberg of Columbia. Working closely with Cal's group was Sam Winograd, who had made at MIT a great contribution by extending von Neumann's work on reliable automata. I cannot allude to Sam Winograd's place in this department's history without saying two things: first, that his mathematical accomplishments are marvelous and speak for themselves, and second, that as a wonderful human being he is peerless. The present integrity of this department is a monument to Sam.

Although the change took place after my time, I should like to mention Brad Dunham and his group of logicians, who proceeded in a quite different direction from Cal and his colleagues, and are responsible for some powerful work on chip design. Paul Gilmore was another versatile logician, who made as well significant contributions to combinatorics and operations research.

Among the early groups formed in the department was one whose members were very concerned about numerical mathematics; it contained among others Bob Brayton, Fred Gustavson, Werner Liniger, Willy Miranker, Farouk Odeh, Ted Rivlin, and Ralph Willoughby. As much as I should like to mention the accomplishments of each of them, I shall only remark on the very elegant early studies by Fred, Ralph, and Werner on sparse matrices, because I believe that their interest in the subject and their early appreciation of its importance were instrumental in pushing the field forward. Betty Flehinger's statistical group, then containing Jim Miller, Peter Lewis, and others, was beginning its outstanding consulting, not only within the company but also to medicine and science outside.

One of the people who came from Princeton to this department and became a key figure is Benoit Mandelbrot; we all know how lustrous have been his accomplishments, and that "Fractals" is now almost a household word. Another who has been of very considerable importance to the company, for his work in combinatorics and testing, is Paul Roth. Incidentally, it was Paul who urged on me the hiring of a young Higgins Lecturer in mathematics at Princeton University, Ralph Gomory. Another of the Princetonians who is an active member of the department and has been since very early on is Bryant Tuckerman, who completed here the "Tuckerman tables" of ancient planetary positions that have played a very important role in historical studies. Bryant also was very active in calculating Mersenne primes, and he helped to pioneer the field of computer security. Another early Princetonian was Jim Griesmer, who in the early days worked in error-correcting codes and game theory.

Let me also mention the elegant work undertaken by Dick Toupin on continuum mechanics. He not only played an important role in the department's history by acting as its director but on the technical side made very deep and to my mind significant studies of ink jets in connection with such printers.

Another group that joined us at the Lamb Estate was John Backus's, consisting then of John, David Sayre, Irv Ziller, Lois Haibt, and Bob Nelson, among others.

I have, I am afraid, omitted mentioning the names of many other members of the early department, particularly (but not solely) those such as Fran Allen, Bruce Gilchrist, Dick Kelisky, Lowell Ravesloot, Walt Doherty, Peter Markstein, Herb Serenson, and many others who were part of the Computing Center. Their accomplishments were substantial but my poor memory has unhappily caused me to forget their names. I ask their forgiveness and solicit their sympathy.

I have reserved saying much about Ralph Gomory until now. It took Mannie Piore to get IBM Research started and to ensure that it contained excellent people; it took Ralph Gomory to weave IBM Research into the fabric of the entire company, thereby ensuring it a continuing place, and the company a place of leadership in the world of technology. It was also Ralph who changed the style of operating this department from an autocratic one under me to its present very pleasantly democratic one.

I have been in close contact with Ralph since he and I started negotiating to bring him to IBM Research. This association has been both professional and, perhaps more importantly, personal. I think that every dealing that I have ever had with him has been rich in friendship, warmth, and knowledge. It is difficult for me to say more than that. When Ralph came to the department, he inspired us to form a group around him versed in the sort of finite mathematics made famous by von Neumann's *Theory of Games* and George Dantzig's *Simplex Method.* To this end, we brought here a number of excellent people, most notably Alan Hoffman, Martin Shubik, Gregory Chow, D. K. Ray-Chaudhouri, and T. C. Hu. It was in this era that Ralph and Paul Gilmore were awarded the Lanchester Prize for their beautiful work on stock cutting.

It seems to me that I ought to quit at this point before all your patience is exhausted, and so I shall end by thanking you for inviting me to this lovely occasion.

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