

Overview for Reflections and Reviews of Past Predictions

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last 50 years. In 1962, what did they think the future would bring? What were the surprises? What were the big events and discoveries? And if they wished to speculate, what might occur in the next 50 years? The request resulted in several articles, along with notes from e-mails and phone interviews. (Some of these articles will be included in this section and some articles will be presented in our Point of View article series, as we progress through our Centennial Year.) It was a great opportunity for me to talk with people who made tremendous contributions to our field, and who I would not otherwise encounter. There are many different perspectives, some recollections, some philosophy, some commentary, and some predictions. I will begin with an overview of the section from 1962 and note some relationships to the articles in this issue and to comments made in conversations.

When we considered what to do for the 100th anniversary issue, we immediately thought of the predictions that were made in the 50th anniversary issue of May 1962. We thought that we should first review these articles and consider how well they predicted the future. As Yogi Berra is credited with saying, “It is tough to make predictions, especially about the future.” It might be easy to criticize some of these predictions from 50 years ago, but it is really amazing how prescient many of them were. Because of the vulnerability of people making predictions, we opted not to exactly repeat this in this section but you will find predictions (as far as 100 years into the future), perhaps somewhat more conservative in nature, elsewhere in this Centennial Special Issue, contributed by contemporary electrical engineers toiling in their respective fields of endeavor.

Instead, in order to review these earlier predictions, we have sought out IEEE fellows who had been active in 1962 and asked them for their perspectives on the

I. PERSPECTIVES 1962

Many of the papers written in 1962, at the beginning of the race to the moon, predicted that we would be having the 2012 Centennial meeting on the moon. Space exploration was, at that time, more than a near certainty. While the technology was being developed, the political climate was not often taken into account. This aspect was mentioned by John C. Fisher (Research Scientist, G. E. Research Laboratory), who looked forward to space-based telescopes, but commented, “Yet for one reason or another, we may not do so. War or pestilence or economic depression or disillusionment

with a difficult task, or a change of heart with respect to what is felt to be important, may cause the drive toward space to fade away, or be limited to the vicinity of the Earth.” J. H. Dellinger (former President of the IRE in 1925) emphasized the exploration using instruments rather than manned vehicles as safer and less costly. Trying to bring the readers down to earth, he writes, “Just as the earth’s atmosphere distorts a telescopic image, so our space imagining is prone to distortion by the present age when every youngster expects to be promised an excursion ticket to Aldebaran.”

An interesting perspective from 1962 was given by Franz Tank (Professor at Swiss Federal Institute of Technology). He noted, “The five decades from 1862 until 1912 were rich with basic discoveries (from ion, electronic, photoelectric effect, thermoelectric effect, electromagnetic waves [Heinrich Hertz], X-rays, radioactivity, quantum theory, theory of relativity, Rutherford’s model of the atom, etc.). The next five decades from 1912 until 1962 have been used by extension of the gain knowledge and the technical application thereof.” Then, he asks, “Which natural facts, new, and unknown until now, perhaps unpredictable by any theoretical investigation, will be found in the time from 1962 till 2012.” The laser, superconductivity, and semiconductors were known prior to 1962. We have greatly enhanced their utility in the last 50 years. But, I would toss Tank’s question to the reader for thoughts on what was fundamental between 1962 and 2012, and what might be found in the next 50 years.

II. COMMUNICATIONS

The 1962 issue had several sections that ultimately emphasized computers and communication. I have grouped these together for this article. It was clear 50 years ago that communications would be greatly enhanced, that people would be far more connected than they were then. It was also assumed that computing power would increase substantially. In fact, the combination of

advances in computing and communication created the Internet and a world that is far more connected than anyone could have imagined. Today, Andrew Viterbi (Life Fellow 1973) sees a world that is totally transformed from his early days in engineering, mostly the result of increases in computing power and advances in digital connectivity. The computing power available in most homes today exceeds that of the most advanced laboratories in 1962, or even 1982. Furthermore, nanoelectronics and embedded systems make it virtually impossible to find a place in the house or office that is not affected by a computer processor of some sort. Robert Lucky (Life Fellow 1972) and James Flanagan (Life Fellow 1969), both with long experience at Bell Labs, give good perspectives on this subject and we have included both of the articles in the following pages of this section.

Communications was a very active area in 1962, as noted in conversations with Mischa Schwarz (Life Fellow 1966) and John Proakis (Life Fellow 1984). They pointed out the work of the group at Columbia University as being important in laying the foundation for the 50 years after 1962. Schwartz notes the great improvements in the speed and quality of communications over telephone lines and mobile communications, especially the work done at Bell Labs and at universities with the support of ARPA. The current Internet is a direct descendent of the ARPAnet. Research on a worldwide scale led to better connectivity in mobile networks. He foresees a “wireless society” in the next 50 years. Simon Haykin contributes a good historical perspective of adaptive filters and how they fit into communication and other areas, which will be published in this journal as a Point of View article later this year.

Many of the authors in the 1962 special issue foresaw huge increases in communication connectivity and convenience. One noted increased space communications and considered the possibility of communications with extraterrestrials. (See the

latest from SETI, elsewhere in this issue.) Harold Wheeler (President of Wheeler Laboratories, Inc.) predicted in 1962 communication between cars to avoid traffic jams and hazards. He also mentioned biometrics for identification. There was a concern with limited bandwidth. Few foresaw the increase in the usable frequency spectrum that is available today. While optical communication was mentioned, fiber optics was not; it did not seem like a solution to bandwidth problems at that time. Interestingly, E. A. Sack (Westinghouse, Life Fellow 1968), writing in 1962 **with tongue in cheek**, speculated that bandwidth was not the problem. We should limit the amount of communication to that absolutely necessary. He noted that there are only 20 basic television shows with six basic plots. The shortage of spectral space is eventually handled by the government that receives all transmissions and retransmits only those that are worthwhile. Given the hundreds of cable and satellite channels broadcast today, he would have sufficient material for another satire.

Sir Noel Ashbridge (Director of the Marconi Wireless Telegraph, Co., London, U.K.) noted the driving forces for funding communication innovation. “The military needs it, business needs it and the man on the street is always prepared to pay for more entertainment.” His comment, “It is not only the accomplishment but what we do with it that is the exciting prospect” is still true today with another generation of new accomplishments. He noted that for television, fax, and image reproduction, we will discard scanning in favor of a pixel-oriented sensor and screen. His comments on the future of digital imaging and thin-film technologies were right on. While he did not predict the Internet, he did say that “wide-band, wave-guide local services could pump into the home all the information, amusement and propaganda anyone could possibly want.” Peter C. Goldmark (President of CBS Laboratories, a division of Columbia Broadcasting System, Inc.) in 1962

predicted flat screen TVs that would show 3-D color shows, and a small 4" × 3" × 2" box that would hold all the music you'd ever want. Very nice work, Peter!

W. D. Lewis (Executive Director of Research Communications System Division, Bell Telephone Laboratories, Inc.) considered home communications in 1962 and foresaw that most personal correspondence would be electronic. We would have electronic libraries and banking, although he thought these would be facilitated by a central computer system. A worldwide satellite system using microwave systems that would allow navigation, thousands of television channels, and access to an electronic mall was a vision of Henri Busignies (Vice President and General Technical Director of the International Telephone and Telegraph Corp.). He also mentioned the local carrier would be a coherent beam of light. His comment, "The distribution of newspapers and magazines will have been considerably modified by the introduction of electronic transmission . . ." is a considerable understatement. Daniel Noble (Executive Vice President of Motorola Inc.) saw the potential of access to almost unlimited channels, electronic news, and accurate product information as allowing a freedom of choice that would improve programing quality and eliminate advertising. To aid communications in a world community, Yasujiro Niwa (President of the Tokyo Electrical Engineering College, Chiyodaku, Tokyo, Japan), Presper J. Eckert, Jr. (Vice President of Remington Rand Division, Sperry Rand Corporation), and Daniel Noble (Vice President, Motorola Corporation, Fellow 1947) foresaw that almost instantaneous translation of the major languages by computers would enhance our home and professional lives.

III. INFORMATION AND MACHINES

In application areas related to computers, like artificial intelligence and

robotics, several writers had predictions in 1962. George Bekey (Life Fellow 1972), in a personal note to us, recently traced his journey from control, to hybrid analog/digital computers, to robotics, to autonomous robotics and finally to robot ethics. It seems not far from Isaac Asimov's vision of robopsychology. With the data mining abilities of today, our needs and desires can be anticipated by computers. This, obviously, has both made life a bit easier on the one hand and less secure and less private on the other. We are not sure that we want Amazon or Google knowing all of our needs and desires. The evolution of computers has changed the demographics of the global workforce, as was predicted by several authors in 1962. Education in math, science, and engineering is now required at some level for most professional and many nonprofessional jobs.

Writing in 1962, Robert M. Bowie (Vice President of General Telephone and Electronics Laboratories, Inc.) assumed that not only television, but also telephone, newspapers, and personal and financial correspondence would be delivered to the home using high-speed systems. Missing the mark only slightly, he considered the medium of transmission across the country might be "straight gas-filled tubes, operated at optical frequencies." There were few in 1962 who foresaw the revolution created by optical fiber technology. Elsa Garmire (Life Fellow 1981), in her review of lasers, writes of this development in her article to be published as a standalone Point of View article later this year. J. Presper Eckert, Jr., of Maniac fame, noted in 1962 the changing demographics of the workforce that the changes would require. We have seen the need for skilled technical labor increase very much as he and others predicted. Interestingly, Eckert also mentioned that electronic monitoring of patients in both hospitals and homes would be a benefit of the burgeoning computer technology. The article "The doctor is always in" in the IEEE SPECTRUM magazine, October 2011,

details how far we have come toward this goal.

Artificial intelligence was just taking shape in 1962. There was little to indicate where this field would go in the next 50 years. P. M. Lewis II (Research Scientist, G. E. Research Laboratory) predicted that machines in manufacturing would be able to be trained and learn to perform the tasks appropriate for a customer's application. R. M. Page (Director of Research at the U.S. Naval Research Laboratories) considered the interface of machines and humans. He foresaw humans controlling machines directly with the mind. Work on machine interpretation of brainwaves has produced fascinating lab results, but we are just on the verge of seeing this dream fulfilled. Page went a step further to say that machines would be able to interpret human emotions and mental states. The state of emotional interfaces is still in its infancy, but there is currently successful work in the area. Certainly, the data mining of e-mails and credit card transactions has led to interpretations of users' desires and intents.

George L. Haller (Vice President of the General Electric Co.) presented a back-of-the-envelope calculation based on Heisenberg's Uncertainty Principle and reliability theory that showed a limit for physical intelligence. He then considered a more optimistic scenario of computers augmenting the human brain. Jerome B. Wiesner (Special Assistant to the President for Science and Technology, The White House) saw the increasing ability of electronics to extend the capability of humans as part of the natural evolutionary process. He hoped the developments would provide man with the assistance to make "adjustments to the environment which he has created—economic, political and social."

Other aspects of using computers to interact with humans were in control and management. The control applications were somewhat obvious. However, P. M. Lewis II pointed out that the computer would not only

furnish the manager with data with which to make decisions, but would also make decisions. His caveat was that while computers would not make *important* executive decisions, the definition of what constitutes an *important* decision would change.

Latfi A. Zadeh (Life Fellow 1958), in an interview, reviewed the history of fuzzy set theory and fuzzy logic, which was introduced in 1965 with a paper that now has over 33 000 citations in Google Scholar. His efforts to introduce an alternative way to handle uncertainty were somewhat controversial at the time. Despite the fact that there are now 24 journals or transactions that have “fuzzy” in their title (the IEEE TRANSACTIONS ON FUZZY SYSTEMS was started in 1993), there remains some tension between proponents of the fuzzy approach to problems and the more classical probabilistic and statistical approaches. Zadeh points to many applications of the theory that include everything from control of household appliances to automobiles to subway systems. He sees fuzzy systems used to fulfill Lewis’s prediction in the next 50 years with applications to intelligent searches that will include question–answering systems with nontrivial deduction ability that accept speech input.

In 1962, computers were just beginning to be used in the social sciences. Irving Wolff (Vice President of Research at RCA Laboratories) lamented the complexity of the problems with very large numbers of variables and the difficulty of setting up controlled experiments. There has been tremendous growth in numerical and analytical studies due to the increased speed, decreased cost, and general availability of computers. In addition, storage and access to databases has made possible many studies that would have been impossible 50 years ago. The article by Eunice Santos, included in this section, gives a good overview of the accomplishments in the last 50 years and some hints for the future.

Marvin Camras (Senior Engineer at the Armour Research Foundation)

assumed in 1962 that we would have memory packs about the size of a deck of playing cards, very similar to the size of Peter Goldmark’s box, that would hold 100 exabits of data with no moving parts. Entire libraries could be stored in refrigerator-sized boxes. His prediction of animated encyclopedias that would supersede books and the replacement of money by direct bank transfers are only partially fulfilled. These accomplishments have not quite been realized but they are close enough to earn him a gold star. With the advent of faster communication and massive amounts of memory, Vito Cappellini (Life Fellow 1996) recently commented on the role of the European signal processing community in developing greater access to old world art via the Internet. Now art and literature are available for both educational purposes and personal enjoyment.

Simon Ramo (Vice Chairman of the Board of Thompson Ramo Wooldrige, Inc.) considered the extension of people’s intellects by electronics, mainly computers and huge databases. His examples included law, where electronic databases are now indispensable, medicine, engineering, banking, logistics, language translation, education, and voting. Commenting on electronic voting, he emphasized the convenience and not the verification problems. He foresaw that technology would promote a “higher democracy” and efficient, widespread communication would “virtually guarantee” participation and “apathy and ignorance that can destroy democracy is virtually eliminated.”

IV. AUDIO AND SOUND

In 1962, stereo was just becoming commonplace and color television was relatively rare. Benjamin B. Bauer (Vice President of Acoustics and Magnetics, CBS Laboratories) predicted multichannel surround sound that was transmitted in the home via a wireless system. James Flanagan, in his article in this section, notes that

this is now reality, with current technology exceeding predictions. He goes further to comment on what the future might bring in audio, video, and communication between man and machine. Harold Wheeler, in 1962, hoped for a new “efficient” language that would be based on common sounds in languages and optimized for ease of speaking and minimized ambiguity.

V. SOLID STATE

J. A. Morton (Vice President of Bell Telephone Laboratories, Inc.), who was the administrative head of the group at Bell Labs that invented the transistor, predicted a huge impact for the integrated circuit (IC) which was relatively quite new in 1962. This paper had been reviewed in the PROCEEDINGS OF THE IEEE in 1998 because of its historical importance. Harper Q. North (Chairman of the Board of Pacific Semiconductors, Inc.) emphasized that the reliability of the new ICs would make them more important in the next 50 years. Gordon K. Teal (Assistant Vice President of Research and Engineering at Texas Instruments, Inc.) believed electron spin memory would be possible as would precision placement of doping elements. It is noteworthy that the amount of space devoted to what was a very active area and what would become a defining area of electrical engineering was so small.

In a recent conversation, Herman Wieder (Life Fellow 1993), who contributed greatly to the area, noted the growth in solid-state electronics in the past 50 years. He comments that the 2000 Nobel Prize in Physics, given for “basic work on information and communication technology” (Alferon and Kroemer) and “the invention of the integrated circuit” (Kilby), should have been called the Prize in Electrical Engineering. He rightly conjectures, “These devices, coupled with the internet, have generated a world-wide revolution, whose scope may be as large, or larger, than that of the printing press.” Leon Chua (Life

Fellow 1974) sees the memristor as the new device that will profoundly affect the future of electronics. Because of its small dimensions, he believes it “will contribute to further increase in computational power without further scaling down the CMOS transistor, thereby extending the prediction of Moore’s Law for many more years.” Because biological neurons behave like memristors, he foresees building “brain-like machines, endowed with more than 20,000 synapses per neuron.” This can lead to “truly intelligent machines that could outperform the most powerful computers that we know today.”

VI. ELECTRONICS AND SCIENCE

George D. Watkins (Research Scientist, G. E. Research Laboratory) mentions 3-D circuits being constructed from a single crystal. While it did not happen this way, 3-D circuits are becoming a reality. P. M. Lewis II indicated that with the advent of increased component density of ICs, sequential processing would yield to parallel processing, where computers would be connected in large networks. This idea is currently used for several major computational projects where thousands of computers in both labs and homes are linked via the Internet. Ralph Cavin (Life Fellow 1988) recalled how often in his career there was some barrier that was thought to represent a limit and how every time he saw the barrier overcome. He now uses that experience to inspire students to always test the limits.

V. C. Wilson (General Electric Research Laboratory) considered various means of increasing production of power, but noted that energy storage was a key problem. It still is. The power area has been rejuvenated in recent years. There is much activity in alternative energy, power conversion, and efficiency in the form of a smart grid system. There were few predictions of major changes in 1962. In response to my query, Jay Baliga (Fellow 1983), a 2011 recipient of the

National Medal of Technology and Innovation, foresees a complete replacement of fossil-fuel-based transportation and electric power generation in the interest of preserving our environment. He and Alex Huang (Fellow 2006) agree that local energy generation together with enhanced efficiency in lighting, entertainment, food processing, and air-conditioning will create home and offices with near-zero carbon footprints.

Superconductors were known in 1962, but no author commented on their future. Like lasers, they seemed to be an interesting phenomenon but with unknown applications. Theodore Van Duzer (Life Fellow 1977) gives a good historical perspective of the growth of this area and its applications, such as the well-known bullet trains of Asia. The applications to power, electronics, and standards are illuminated in his article which will appear as a standalone Point of View article, later this year. Van Duzer also notes that without government support, the foundational work in superconductors would not have been possible. The history and role of government funding is discussed by Robert J. Trew (Life Fellow 1991), current Editor-in-Chief of the PROCEEDINGS OF THE IEEE, in his article on the role of government in research and development.

VII. ELECTRONICS AND BIOMEDICINE

The areas of artificial intelligence and social sciences deal with the effects of computers, communication, and electronics on human behavior. We have mentioned the recent IEEE SPECTRUM article on patient monitoring, many aspects of which were predicted by V. K. Zworykin (Honorary Vice President, Radio Corporation of America, RCA Laboratories) in 1962. Harold A. Wheeler considered the problem of biological interfacing in his article, where he notes the difficulty of electronic interfaces with nerves, but assumes that the

problem will be solved. Today, there is much work on the physical human–electronic interface from artificial retinas to robot prosthetics. As for medical predictions, Lee B. Lusted (Professor of Bio-Medical Engineering at the University of Rochester) did a remarkable job. He noted that by 2012, nearly all human organs can be replaced. However, we have not fulfilled his prediction that the replacement would be an artificial organ. He hit the mark exactly by noting that surgeons would use fiber optic systems and small tools to repair heart valves. Indeed, laparoscopic surgery shortens the hospital stay for thousands of patients every year. He also indicated that gene therapy would be a reality.

A foundation of electrical engineering is important for those working in the biomedical areas today. In this section, Edwin Lewis recounts a dinner at a conference on hearing research, where a majority of colleagues had degrees in electrical engineering, and the few who did not, collaborated with electrical engineers. The multidisciplinary nature of biomedical research today demands a broad education. As a neurobiologist in an electrical engineering department, he notes examples of the reverse engineering required to model the human systems and to interface with them. He looks forward to “neural enhancement engineering,” where understanding of the brain and neural system will fulfill Francis Bacon’s ideal, “To learn about nature, look to nature itself, and then use what you have learned for the betterment of mankind.”

VIII. EDUCATION

Several perspectives and predictions on education from 1962 present ideas not far from those of today. The outstanding paper predicting the state of education in 2012 is undoubtedly that of W. L. Everitt, Dean of Engineering at the University of Illinois. Everitt’s paper almost could have been written yesterday. This might seem both good and bad. He predicts much

of what might be predicted today, especially with respect to the use of computers in education. The discouraging aspect is to note how little of this promise has been fulfilled. Alan Oppenheim (Life Fellow 1977), an educational leader in signal processing, makes a similar point in his Point of View article to be published later this year predicting the use of computers.

We have more educational technology today than we might have imagined in 1962, but there has been no revolution in the teaching methodologies.

Everitt's distinction between training and education is still a discussion topic today. The use of computers for training, as Everitt and H. A. Zahl (1962 with U.S. Army Signal Research & Development Laboratory, Fort Monmouth, NJ) predicted is still mostly in the future. Maurice Ponte's (President-Directeur Général of the Compagnie Générale de Télégraphie Sans Fil, Paris, France) vision of the classroom of the future includes one of much more freedom, with basic lectures augmented by smaller group tutorials, something that is commonplace now. The trend toward distance education via the Internet was not really foreseen, but then the Internet was not foreseen. Sid Burrus (Life Fellow 1981), whose Point of View article will appear later this year, and Oppenheim point to the current availability of university-level instruction that is available for free via the Internet. Most notable are Stanford University's free online courses with tens of thousands enrolled, MITx, and Kahn Academy. Recently, spin-off companies are being created

to concentrate exclusively on the online market. With the extremely large number of colleges and universities that offer online courses for degree programs, one can only wonder what modality of instruction and certification will dominate in 50 years.

For the practicing engineer, Nathaniel Rochester (Manager of Advanced Computer Utilization, IBM Data Systems Division) envisioned an automatic handbook for design where engineers would have immediate access to data, formulas, standards, etc., and would do the checking calculations for designs. He thought that such a machine would be centrally located to make it accessible to many. This is typical of the visions of computing and communications. The power of local, portable computing today has surpassed the imagination of most of those predicting the future in 1962. Simulation, development, design, and testing software of today far exceeds the expectations of 50 years ago.

IX. ELECTRONICS, SOCIETY, AND PUBLIC POLICY

C. F. Horne (President of General Dynamics/Pomona) considered the public service of the electrical engineer and indicated that in the next 50 years, "the engineer and scientist will be forced to accept more and more responsibility for basic policy decisions in government, business and education." To make this feasible, he required the future engineer to be broadly educated, understanding people and cultures from all over the

world. Sir Robert Watson-Watt (Chairman of the Scientific Advisory Board of Ase Science and Electronics Corp.) presented a historical view that indicated increasing participation of the technical community in the government. He cited the tremendous contribution to the military. He wrote that by 2012, the scientist would be "no longer sentenced to be 'on tap but not on top,' and this is happily because he is both at the top and yet on tap." There have been some gains in involving technical people in government, but it seems doubtful that engineers and scientists have had the impact that Horne and Watkins-Watt hoped for. As James Flanagan recognizes in his current article, we are still working to improve the public perception of engineers and scientists. I suspect that we still will be working to improve our image in 2062 (<http://www.nsf.gov/statistics/seind02/c7/c7s3.htm>).

It is fun to think about the future, about what we might conceive to be 50 years from now. Knowing that some dreams are grandiose and others shortsighted, we will still hope that our technology will create a future that is better in many ways than today. In 1962, Franz Tank concluded his article by saying, "It lies in the nature of every qualified engineer to believe in the future and hope for true and consistent progress in creating a better and happier world. . . . And even if we do not know today the state of the art in 2012 and are only able to presume, we want to believe nevertheless in a better future." I will change 2012 to 2062 and agree with him. ■