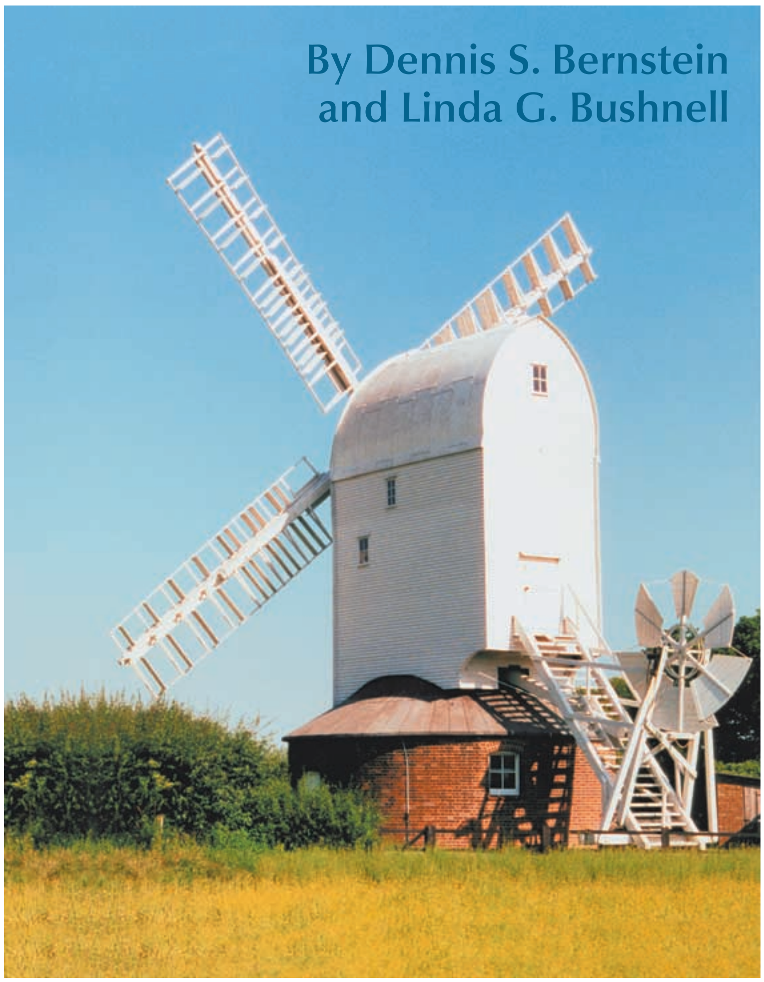
The History of Control: From Idea to Technology



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It has been almost six years since the last special issue of the *Magazine* on the history of control. The June 1996 issue, titled "On the History of Control Research" and organized by guest editor Linda Bushnell, provided an overview of the development of control system technology and highlighted the contributions of individual researchers. We are pleased to present a new collection of articles that significantly expands on the earlier issue.

Before describing the contents of this exciting issue, it is important to acknowledge the ongoing efforts of the IEEE CSS History Committee, chaired by Daniel Abramovitch. He has been active in directing the activities of the commit-

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tee in its efforts to preserve the historical record of control system technology as it unfolds. For more information on the activities of the committee, please see the Web site at http://www.labs.agilent.com/personal/Danny_Abramovitch/css/css_history.html.

History plays a subtle but crucial role in education and research. When a student first encounters the basic concepts of control engineering, there is often little hint of the tremendous human effort that was expended to produce those ideas. The controversy surrounding Heaviside's use of transforms and impulse functions, the discovery by Routh and Hurwitz of linear system stability criteria, and the intricate interplay between state space and input-output ideas are all part of this drama. A neophyte who has the impression that the state of knowledge is static is often surprised to learn of significant gaps in our knowledge, as well as continual changes to what appears to be definitive knowledge. Historical perspective makes all of this clear: Intellectual constructs are in a continual state of flux.

An interesting aspect of the history of technology is the way in which an innovation was developed. In many cases, inventions were the result of numerous people making small advances until a critical point was reached.

Every researcher is an historian. You cannot approach a problem without some idea of what came before you. The goal of research is to build on prior successes, displacing some and strengthening others. So a researcher must understand and acknowledge the history of the subject area, including both successes and failures. All of us have a commitment to the history of our field, since all of us are creating that history.

An interesting aspect of the history of technology is the way in which an innovation was developed. In many cases, inventions were the result of numerous people making small advances until a critical point was reached. As a conspicuous example, we can point to the centrifugal governor, which emerged from the world of windmills to control the steam engine, which thereby made the Industrial Revolution a success.

It is impossible to predict the way technology will develop and what its impact will be. Ideas and technology combine and recombine in subtle ways until success is achieved. The process is slow and tedious, but the outcome is dramatic. Engineering successes create wealth by reducing cost and creating markets. Materials and energy were conquered first; information is now being tamed. At every stage, control technology has played a critical role.

We cannot predict the future, since the signals we have for prediction are noisy. But we don't need much imagination to see significant new opportunities. A panel on future directions in control, dynamics, and systems has put together a report titled "Control in an Information-Rich World," which will be published by SIAM. This panel expanded on an earlier report by Wendell H. Fleming from 1988, also published in book form by SIAM. A draft of the new report, along with more information on the panel, can be found at http://www.cds.caltech.edu/~murray/cdspanel/. We have every reason to believe that the successes achieved in the history of control system technology will prove to be good predictors of future successes.

This issue of the *Magazine* complements and expands on the June 1996 history issue in several ways. Specifically, we take a closer look at the development of technology and its historical context, and we highlight the contributions of individual researchers. To do this, we are fortunate to have collected six articles, written by well-known authors in their field, relating to the history of control technology.

Three of the articles highlight historical contributions from key researchers in the control systems area. The first article, by Fasol, gives a fascinating account of the contributions of Hermann Schmidt, an important early contributor to control and cybernetics in Germany, who viewed feedback and control principles as applicable to a wide range of both man-made and natural systems. This article traces Schmidt's career and gives a broad perspective on his contributions. He is best known for his work on "generalized feedback theory," which encompasses technical as well as nontechnical applications such as physiology and anthropology. The article includes a detailed, annotated bibliography.

The second article, by Bennett, is on the life's work of Otto Mayr, a major contributor to the history of feedback control. Mayr is well known for his classic 1970 book *The Origins of Feedback Control,* which explores the history of ideas and inventions related to feedback control. Many in our community trace their initial enthusiasm to Mayr's book. The author and guest editors had the pleasure of meeting Mayr at the American Control Conference in Arlington, VA, in June 2001. There Bennett conducted a two-hour interview with Mayr (some of the interesting revelations appear in the article). Mayr also gave a talk and answered questions during an evening session organized by the CSS History Committee. It was interesting to learn from talking to Mayr that his all-time favorite controller is the fantail of a windmill, featured on the cover of this issue. [The *Magazine* will publish the text of Mayr's talk in a future issue.—*Ed.*]

The third article, by McClamroch and Pasik-Duncan, gives us a timely profile of women who were early contributors to the control field. These women attained successful careers, a credit to their perseverance and commitment to a field dominated by men. Profiled are Irmgard Flugge-Lotz, who developed the theory of discontinuous or on-off control and was Stanford University's first female professor of engineering; Violet Haas, who contributed to optimal control and estimation theory, as well as to control education; Faina Kirillova, who has made significant contributions to optimal control theory and optimization methods; Makiko Nisio, who is known for her contributions to stochastic control; Huashu Qin, who has contributed to control theory and applications in aeronautics technology; and Jane Cullum, the 1989 CSS President, who is known for her contributions to the development of numerical algorithms.

The next set of articles highlights the development of control system technology. The article by Headrick, an expert horologist, focuses on one of the most critical contributions of control system technology, namely, the clock escapement. This fascinating device, an invention of pure genius dating from the 13th century, is the crucial regulator that made the mechanical clock a success, with enormous impact on technology and society. The escapement is the portion of a clock that regulates speed by using feedback to maintain precise operation in the presence of imperfect components. Headrick's article traces the evolution of the anchor clock escapement, which has undergone centuries of refinement and is without doubt the most ubiquitous of man-made regulators.

The article by Abramovitch and Franklin, which will run in the June issue, takes a detailed look at the history of disk drive control and lists trends to watch in the future. This ubiquitous but hidden device is critical to the modern computer and has had enormous impact on our information society. The focus of the article is on rigid magnetic disks (hard disks). The story starts in the early 1950s with storing data on magnetic drums and quickly arrives at the high-density, small disk drives used in consumer electronics. The article also gives the details and history of the various components in the disk drive control loop. The evolution of the disk drive and associated control problems are also discussed.

The article by Bernstein takes a global view of the history of feedback control through the inventions of the escapement, governor, aileron, gyro, and amplifier, all of which had profound impact on scientific and technological developments in timekeeping, industry, aviation, space, and electronics. The main goal of the article is to connect feedback devices with major advances in science and technology. Viewing feedback control as an "invisible thread" in the history of technology, Bernstein argues that inventions based on feedback control were crucial in the mechanical, scientific, industrial, electrical, aerospace, and information revolutions.

Looking back at the history of control engineering, we see accomplishments that have impacted civilization in almost every way. These successes have improved our standard of living, our health, our ability to enjoy free time, and our opportunities to be creative and productive. These historical accomplishments bode (no pun intended) well for the future of control engineering.

We hope you enjoy reading the articles as much as we did putting this issue together.

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