Mars and Onward

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CSM: *I'd like to ask about your diverse background. Currently, you're chairman of the Department of Aerospace Engineering and Engineering Mechanics at The University of Texas (UT) at Austin, but your Ph.D. is in electrical engineering. Do you view your interests as multidisciplinary?*

Robert: Yes, I most certainly consider my work to be multidisciplinary. The application of control theory to improving systems and products is an endeavor that spans the gap between engineering, science, and business—and for me that is precisely what makes it such a fascinating subject. Actually, I completed my B.S. and M.S. degree programs in aerospace engineering and then joined the engineering staff at The Charles Stark Draper Laboratory in Cambridge, Massachusetts, where I worked with engineers from other engineering disciplines and even with physicists and mathematicians. As a result of my engineering experience at Draper Labs, I became convinced that systems and control was the area in which I wanted to dedicate my professional life. However, I discovered that, while some of the things I learned in college were actually used in practice, many important elements of a complete engineering education were missing. The mathematical foundations of much of the work in which I was involved was a mystery to me. So, although my personal inclination is to work on applied control problems, I wanted a more rigorous Ph.D. program of study that emphasized systems theory. At the time I decided that a degree in electrical engineering was the optimal approach to combining the mathematics of control systems with engineering applications.

CSM: *What kind of projects were you involved in at Draper Labs prior to joining UT?*

Robert: The Draper Laboratory, which was formerly the MIT Instrumentation Laboratory, had been a primary contributor to the Apollo program. There I worked with many of the original Apollo-era navigation and control system designers that landed humans on the moon. These engineers were my childhood heroes, and I had the good fortune to work with them on the Space Shuttle and eventually, Space Station. While in Cambridge, I was involved in the analysis of the first Space Shuttle rendezvous mission and worked subsequent rendezvous missions until the Space Station Skunk Works started up at NASA Johnson Space Center in Houston. At about that time, I transferred from Cambridge to NASA Johnson as an on-site Draper resident. I participated in the development of the control system for the first Space Station, known as the Power Tower, the baseline design that utilized solar power. The Power Tower design changed many times finally reaching the configuration we see in orbit today. During my years in Cambridge, I was also involved in the analysis of a hypervelocity hit-to-kill interceptor concept.

CSM: *I know you've been involved in guidance projects involving future Mars landings. Can you describe the challenges in such a project?*

Robert: I believe that an actively guided landing on Mars is the next big challenge for control engineers involved in space exploration. Many people don't realize that we have never attempted an actively guided entry, descent, and landing on Mars. The failure of the Beagle2 in December 2003 is a reminder of the perils of free descent. Of course, Viking had a powered descent, which was guided in the terminal phase. But what I am talking about is using lift modulation during the hypersonic upper atmospheric phase to actively maneuver the vehicle, much in the same way that the Apollo spacecraft did during Earth re-entry. The challenges are many. First, the guidance, navigation, and control must be done on board the spacecraft since the communication time delays preclude Earth-based control. Second, there is minimal Mars in-situ navigation infrastructure to support navigation, both during planetary approach and especially during reentry. So what this all means is that during the entry when there are significant aerodynamic lift forces available to maneuver the spacecraft using active guidance, there are essentially no external observations available for improving the state knowledge. This lack of measurements impacts the precision of the landing directly since active guidance depends on having access to an accurate spacecraft state estimate. During the hypersonic phase the spacecraft is using a strapdown inertial measurement unit as the only source of information. Once the supersonic and subsonic parachutes have been deployed and the heat shield is jettisoned, a radar altimeter or other external sensor can be exposed to the environment and used to provide information to the Kalman filter for updating the state estimate. However, by this time in the entry you are only kilometers away from the surface and there isn't much time or fuel to make large trajectory maneuvers.

Another challenge to the GN&C (guidance, navigation, and control) designers is the high variability and uncertainty in the Martian atmosphere. Robustness of the entry, descent, and landing algorithms to environmental uncertainty is essential to overall mission success. There are ways to mitigate many of the difficulties that I just described. However, all of the proposed fixes cost money, and solving the complex guided entry problem within tight budget constraints is, in fact, the principal challenge.

CSM: *You are the "Bishop" in "Dorf and Bishop," earlier known as just "Dorf," my very first controls textbook! Can you describe some of the changes to that text over the years?*

Robert: My first course in controls also used Dorf's *Modern Control Systems*, the second edition! I met Richard Dorf, who is professor of electrical and computer engineering at the University of California, Davis, through a publisher contact, and we originally collaborated on the companion text *Modern Control Systems Analysis and Design Using MATLAB,* which was eventually merged with *Modern Control Systems.* The book is now in its ninth edition, and the tenth edition will appear soon. I have been involved directly as a coauthor since the seventh edition. Initially, my contributions to the book focused on computer-aided design and analysis aspects featuring MATLAB and Simulink. Richard Dorf and I have worked hard to keep an "applied" orientation to the material, while not neglecting the theory. In the tenth edition, I updated the material on state-space design methods and fine-tuned the root locus material. With the advent of effective interactive root locus tools, I think that the level of coverage of hand-sketching root locus can be reduced and replaced with increased emphasis on design and analysis methods. The emphasis on problem solving that has characterized the book since the early days continues in the newest editions. In the tenth edition, I added or changed over 100 problems out of the over 800 problems in the end-of-chapter problem sections. I have always been fascinated with the level of interest that the book generates internationally, having been translated into Chinese, Russian, Portuguese, and Korean, and other international editions as well. I hope to continue to support the international aspects of the book in future editions.

CSM: *At UT you've received several teaching awards. Do you feel you have a special style or approach to teaching that has earned you these awards? Please don't be modest in revealing your teaching secrets!*

Robert: The engineering students who know me will not be surprised when I say that I have no formal teaching philosophy—and no teaching secrets. The simple fact is that I enjoyed being a student, and now I enjoy being with students. The students know and appreciate this. My teaching plan is to be well prepared for each and every lecture, to be accessible to students, and to help guide students along their path of discovery. Accessibility to students is probably the chief contributor to my teaching success. When I was a student, the first day of class each semester was always a joy for me. So when I began teaching I decided that I would try to make the first class day a joy for my students. The goal is to start with good initial conditions! That's how of my semester starts. The rest just follows.

CSM: *Thank you for talking to CSM, and best of luck in your endeavors, here and on Mars!*

Looking Back

Peter H. Meckl, Mechanical Engineering Department, Purdue University, West Lafayette, IN, meckl@purdue.edu.

CSM: *Congratulations on completing an unprecedented nine years as an associate editor of* CSM*! During this time you had the opportunity to work with several editors-in-chief (EICs), including Steve Yurkovich, Tariq Samad, and Dennis Bernstein. How would you characterize their approaches to the magazine?*

Peter: It's hard to believe that so many years have already gone by! It's been a labor of love, and I thoroughly enjoyed my interactions with each of the EICs.

It was Steve Yurkovich who got me involved in the magazine. I first met Steve at the IEEE Robotics and Automation Conference in the late 1980s. At the time, I was presenting some work on designing shaped input commands for robot motors so that the resulting motion would be free of vibration. The control community had been rather skeptical of this approach, since it is inherently an open-loop approach, but Steve immediately took an interest in it. I appreciated having someone of his stature affirming my work and so we struck up a friendship. We met at subsequent conferences and, since we both had young children, we had lots of stories to share. When Steve helped to organize the first IEEE Conference on Control Applications in 1992, he asked me to serve on the Program Committee. In that role, I came to appreciate his style of management. Steve focused on picking the best, most reliable people he could find to do each job. Then, he would ensure that they had the resources and information to do the job right. Since I knew that Steve depended on me, I tried hard to do the best job that I could. So when he asked me to serve as an associate editor for the magazine in 1994, I knew it would be a pleasure to work with him. Steve provided samples of associate editor reports and letters to the reviewers, and helped in providing names of potential reviewers. Each month, I would look forward to his editorials in the magazine, since they often focused on the exploits of his sons BJ and James.

In 1999, Tariq Samad took over as editor-in-chief. I had come to know Tariq from previous discussions at the