LOCKHEED MARTIN

"Perspectives on Scientific Opportunities in Industry"
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Recipient, COSPAR 2022 Space Science Award

For the past 50 years I worked in the Lockheed Martin Advanced Technology Center (ATC), formerly known as the Lockheed Palo Alto Research Laboratory (LPARL). My path to Lockheed Martin started on the traditional academic track to being a university Professor. After high school I attended UCLA where I earned an MA in Mathematics with a minor in Physics. After graduation from UCLA, I became a new graduate student in the Columbia University Physics Department. My goal was to earn a PhD in Theoretical Nuclear Physics. My California lifestyle did not merge well with the Columbia's Physics Department's approach to teaching physics. During my first year I applied and was accepted by the Physics Department of the California Institute of Technology.

The provost at Caltech had led the Bomb Physics Division at Los Alamos and a number of Caltech Professors played key roles in the development of the atomic bomb. Several of their children were fellow grad students. It was clear to me that there were major challenges to being a theoretical nuclear physicist. However, I was lucky to be chosen as teaching assistant in the project for developing a new course for teaching undergraduate physics that was being developed by Richard Feynman and supported by Robert Leighton. As teaching assistants one of our tasks was to create lecture notes for the students. This meant weekly meetings with Leighton to aid in producing weekly summaries for the students. These notes evolved into first volume of "The Feynman Lectures."

I was very impressed by Leighton and asked if I could join his cadre of grad students. He agreed, but while impressed with my mathematical background, he was concerned that I had almost none of the training necessary for an experimental physicist. Caltech had a shop course where students were trained to use machine tools by the professional machinists that built new instruments for members of the Caltech Physics Department. The machinists did not build to design and were an essential part of instrument development process. Senior Professors, including Leighton, were often in the shop building parts.

Leighton was pleased with my progress toward becoming an apprentice machinist and suggested that I design and build a camera that would allow the production of movies of the solar magnetic and velocity fields. Although, it is now hard to believe, the temporal evolution of the Sun's surface flow fields had never been seen. These movies would be projected on the Mt. Wilson Spectroheliograph, built by George Ellery Hale in 1905, at the time the only instrument that could create images in spectral bands sufficiently narrow to make images of the solar velocity and magnetic fields.

I spent the better part of a year designing and building dual 70mm motion picture cameras. Leighton's discoveries using glass plates to measure velocity fields had created a renewed interest in solar physics. The Aerospace Corporation built a new observatory to reproduce the capabilities of the Mount Wilson instrument, but the engineers at Aerospace told the director of the new observatory that it would be impossible to build a movie camera that could be mounted on it. The Director of Aerospace visited Leighton for advice about how to build an instrument that could make velocity movies. Leighton's advice was to build a movie camera system, and "if you come next door with me my grad student will show you a camera and one of the early Doppler movies."

The Doppler movies produced interesting results and upon graduation I was offered positions at several universities in the US and Europe as well as at the Aerospace Corporation. While thinking about where to go, Leo Goldberg, then Director of Harvard College Observatory, visited Leighton to talk about the future direction of Solar Physics. Goldberg had created the Harvard Solar Satellite Project, which was developing new solar instrumentation for use in space. At the end of the meeting Leighton walked over to my office with Goldberg where Goldberg said, "Hello Dr. Title, I'm Leo Goldberg, Bob has said a

lot of nice things about you. How would you like to join my group at Harvard? I can offer you a fellowship now and next year a position as Harvard Research Fellow"!

As a graduate student, Leighton never offered advice, but on occasions he did make suggestions that I was free to take or reject. So, it came as a shock when the next day Leighton made comments on the various job offers I had received. Then, he suggested that it would be a good idea to learn how solar physics could be done from space.

At Harvard I was asked to be responsible for the H Alpha telescopes that the Solar Satellite Project was managing for the NASA Skylab mission. The telescopes were being designed and fabricated at Perkin-Elmer's plant in Norwalk, Connecticut. From my days at Caltech, I was very familiar with the solar telescopes locates at Lockheed Rye Canyon Solar Observatory. I suggested the H Alpha telescopes could be tested using excellent atmospheric seeing almost always available at sunny Southern California sky over Rye Canyon.

Multiple visits to Perkin-Elmer Norwalk to attend reviews of the H Alpha telescope project showed me how many facilities the team building the H alpha telescopes had for design, fabrication, and testing optical instruments. At the same time, I became increasingly aware that the engineering group at Harvard did not have facilities equivalent to those available at Perkin-Elmer. Further, the professors at Harvard regarded the Solar Satellite Engineering team as a drain on the Astronomy Department's available budget for doing important scientific research. It was very clear that in spite of my coveted position, I might never be considered to be a Professor at Harvard.

During one of my visits to Rye Canyon, Martin Walt, a space plasma physicist and the Director of the Lockheed Palo Alto Research Laboratory (LPARL), offered me the leadership of the Rye Canyon Solar Group. A position that then was responsibility of Loren Acton. Because Loren was in Palo Alto and Rye Canyon was near Los Angeles, he was anxious to be relieved of the responsibility of his monthly visits to the Rye Canyon site. He and Martin lobbied and convinced me to leave Harvard and join Lockheed and to eventually bring the Rye Canyon engineers and scientists to Palo Alto.

My experiences as a graduate student at Caltech and as Senior Research Fellow at Harvard taught me that good ideas need strong scientific support, strong engineering support, facilities for testing, as well as the engineers and technicians to support the facilities. Martin and Loren assured LPARL could provide the venue that would allow great progress in optical solar physics both on the ground and in space.

For more than 30 years I have been a Co-Director of the Stanford-Lockheed Institute for Space Research. I also have been a visiting Professor at Tokyo University, a visiting Professor at Max-Planck Institute for Space Research, and a faculty member at Stanford. I have served on the NASA Advisory Committee, as the Chair of the NASA Solar Physics Advisory Committee, the Harvard Observatory Visiting Committee, and Chair of the Directors Advisory Committees of NCAR, NOAO, and NSO. Through my career, COSPAR has provided critical opportunities to advance my research through Scientific Commissions, Panels and serving as author of numerous roadmaps.

I have been elected to the National Academy of Sciences, the National Academy of Engineering, and the Silicon Valley Hall of Fame. I have more than 32,000 thousand citations in refereed publications with an H-Index of 87. The opportunities provided as employees of Lockheed Martin allowed Loren and I to build a staff consisting of world-class scientists and dedicated engineers that is internationally recognized as one of the leading Solar Groups in the world.