Sol Golomb — My Friend and Mentor

Alfred W Hales

Solomon W. Golomb, a noted mathematician and a giant in the applications of mathematics to coding and communication theory, passed away on May 1, 2016, at the age of 83. His wife Bo died two weeks later, leaving their two daughters Astrid and Beatrice. He was initially my supervisor and mentor, then colleague and friend.

Sol was born in Baltimore, MD, on May 30, 1932. His father and grandfather were both rabbis, and his father was a linguistics professor at Johns Hopkins – Sol himself was a linguist, speaking seven languages. He attended Baltimore schools for grades K-12 and then went on to Johns Hopkins where he graduated Phi Beta Kappa in mathematics, with an "A" average, in two years, before he turned 19.

Already by this time he had a strong interest in number theory, and in fact his first "publication" was a number theory problem he submitted, while still in high school, to the American Mathematical Monthly.

In 1952 he started graduate work in mathematics at Harvard, eventually receiving his PhD for a thesis in analytic number theory under the direction of David Widder. During this time at Harvard he also worked summers at the Glenn Martin company near Baltimore, on controls and on communications. This combination of "pure" (at Harvard) and "applied" (at Glenn Martin) training turned out to be critical for his future career. As a result of his summer work, his initial results on shift registers appeared in 1955 as a Glenn Martin report. During this period his interest in (mathematical) puzzles and games also began to flourish.

After completing his Harvard work, for the 1955–56 academic year, he went to Norway on a Fulbright Fellowship where he continued his Harvard work on the distribution of prime numbers and also his shift register work. During this year, on a side trip to Denmark, he met Bodil ("Bo") and returned to the US with her as his wife. Upon returning he chose, among several alternatives, to accept a position at Caltech's Jet Propulsion Laboratory (JPL) in California, in their Communications Research Group.

Sol spent seven years (1956–1963) at JPL. During this time he greatly extended his work on shift register sequences, leading to his 1967 magnum opus "Shift Register Sequences" (to be revised and reprinted in 1982 and in 2017). He also made very significant contributions to the JPL mission, such as to orbit determination for the Explorer 1 satellite and also to measuring accurately the distance to Venus. This latter work led to a much improved value for the "astronomical unit" and to a new experimental test of general relativity. He also wrote a number of influential papers in number theory, combinatorics, algebraic coding theory and other areas.

In 1963, Sol decided it was time to move on, to an academic position. He chose USC (over Caltech and UCLA) because it seemed to offer greater opportunities, and took a position in Electrical Engineering with a joint appointment in Mathematics. At USC his career flourished in many respects, enhancing not only his reputation but that of USC as a whole (because of his accomplishments). In fact, he played a major role in bringing to USC other luminaries in his field (EE), quite a few of whom had spent some time with him at JPL. He authored over 200 research papers and seven books, taught and mentored an untold number of students and postdocs, and played an important part as well in USC administration — as Faculty Senate President, Vice Provost for Research, and Annenberg Center Technology Director. He held both the title of Distinguished Professor and of University Professor, and occupied the Viterbi Chair in Communications; and also received the USC Presidential Medallion. At the time of his death, at age (almost) 84, he was still teaching a freshman seminar!

Sol is almost certainly best known for his pioneering work on the mathematical theory and applications of shift register sequences. These are ubiquitous in radar, cryptography, space communications, cell phones, spread-spectrum, wireless communications, etc. Among his other contributions to coding and communication theory are Golomb (entropy) coding, Golomb

rulers, and the Golomb construction for Costas arrays. In this connection he wrote not only the "Shift Register Sequences" book but also (with Guang Gong) the book "Signal Design for Good Correlation". For his exceptional contributions to information sciences and systems the IEEE awarded him both the Shannon Award (1985) and Hamming Medal (2000).

Sol also made many contributions to other fields, with extensive (and seminal) publications in number theory, combinatorics, algebra, and even molecular genetics. In number theory his early work on primes and their distribution played a role in the recent breakthroughs (Zhang, Maynard, etc.) on the twin prime conjecture. He was a noted expert on mathematical puzzles and games — polyominoes were his invention, and he wrote a book about them. And he had a very great influence on future generations due to his generous and insightful mentoring of young people.

In addition to those mentioned above, Sol received many other prestigious awards for his work. He was an elected member of both the US National Academy of Engineering (1976) and of the US National Academy of Sciences (2000), and an elected Fellow of five major scientific/technical organisations. He received the Lomonosov Medal from the Russian Academy of Science and the Kapitsa Medal from the Russian Academy of Natural Sciences. In 2012 he received the William Proctor Award, the highest technical award bestowed by the Sigma Xi honorary society. In 2013 he received the National Medal of Science from President Barack Obama in a White House ceremony. And, only a week before his death, he was awarded the 2016 Benjamin Franklin Medal of the Franklin Institute, for Electrical Engineering.

In conclusion here are three "aphorisms" which can be (and have been) said about Sol's accomplishments:

1) he brought modern combinatorial mathematics to Southern California;
2) he disproved the opinion of G. H. Hardy, and of many of his Harvard teachers, that number theory had no useful applications; and
3) he changed the course of communications from analog to digital.

I first met Sol in 1958 when, as a Caltech student, I started working summers under his supervision at JPL. We wrote three papers together, and I was a (junior) coauthor of his book "Shift Register Sequences". He had a very major positive effect on my career and I owe him a great deal. I last saw him at the Franklin Institute ceremony mentioned above, a week before he died, and we exchanged several e-mails during that last week. (I was helping with the final revisions for the third edition of his book.) The world has lost a uniquely talented individual, and I personally miss him every day.

Alfred W Hales

Alfred W Hales was born in Pasadena, California in 1938. He received his BS degree in mathematics from the California Institute of Technology (Caltech) in Pasadena in 1960, and his PhD in mathematics from Caltech in 1962.

During 1962–1963 he was an NSF Postdoctoral Fellow in Cambridge, England. From 1963–1966 he was a Benjamin Peirce Instructor at Harvard University. In 1966 he joined the Mathematics Department at UCLA, where he was Department Chair (1988–1991) and is now Professor Emeritus. From 1992 to 2003 he was Director of the Institute for Defense Analyses' Center for Communications Research in La Jolla, CA, where he is now a Research Staff Member. He is the author of over 75 research articles and was a (junior) co-author of Golomb's book on Shift Register Sequences (1967, 1982, 2017). His research interests include algebra, number theory and combinatorics.

Prof. Hales is a Fellow of the American Association for the Advancement of Science and an Inaugural Fellow of the American Mathematical Society. From 2010–2017 he was Chair of the Board of Trustees of the NSF Institute for Pure and Applied Mathematics at UCLA. In 1972 he was a co-recipient of the first Polya Prize in Combinatorics, from the Society for Industrial and Applied Mathematics, for his work in Ramsey Theory (the so-called Hales–Jewett Theorem).

Being the granddaughter of a rabbi myself, I appreciate that Dr. Golomb was both the son and grandson of rabbis. A portion of the afternoon's memorial service was given by the campus Hillel rabbi, Hebrew songs were sung by children and Bailey London, Executive Director of USC Hillel also paid tribute to Dr Golomb. The office of the President of USC co-sponsored the afternoon tribute and held a private reception in Dr. Golomb's honour.

UC San Diego's **Information Theory and Applications** (ITA) Center, at its 2017 Workshop in February, devoted an afternoon memorial session to "Remembering Sol Golomb". It was organised by Tuvi Etzion (Israel), with the following speakers:

1) Guang Gong (Canada), "**Golomb's Invariants and Modern Cryptology**";
2) Tor Helleseth (Norway), "**Shift Register Sequences and Golomb's Norwegian Connections**";
3) Hong-Yeop Song (Korea), "**Existence of cyclic Hadamard difference sets and some memories of Prof. SW. Golomb**"; and
4) Andrew Viterbi (USA), "**Celebrating the Life of Solomon Wolf Golomb**".

That evening an interactive puzzle session (with prizes) in Sol's honour was also held, organised by Joe Buhler, Paul Cuff, Al Hales and Richard Stong.

Dr. Golomb will be missed but his legacy lives through his 50 years of teaching at USC, how he revolutionised digital communications with his book on **shift register sequences** and his kindness that touched me deeply after being with him just a handful of times. I was honoured to have been his editor.

Rochelle Kronzek

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