

## In Memoriam: Professor Avram Bar-Cohen (1946–2020)

*Who Was Instrumental in Laying the Scientific Foundation for the Thermal Management of Electronics*

Professor Avram Bar-Cohen, affectionally known to everyone as Avi, passed away on Oct. 10, 2020. Throughout his life, distressingly cut short while he remained at his peak in every respect, Avi was foremost and supremely devoted to his family, exhibited contagious and indefatigable passion while making academically seminal and industrially paramount contributions to the fields of heat transfer and electronics packaging, and zealously pursued his other diverse interests ranging from economic theory to snowmobiling. We, a small contingent of the innumerable colleagues and, without exception, friends, within Avi's vast technical network are honored and humbled to pen this heartfelt tribute to him. Anyone who has attended a lecture by Avi is familiar with his mantra of "leave the world a better place," *Tikkun Olam* in Hebrew. He was, in so very many ways, profoundly successful in this endeavor. A sampling of them are described here.

**Early Years.** Avi was born Avram Markowitz on Jan. 19, 1946 in Brooklyn, New York, the son of Simon and Dorothy Markowitz. Avi cherished the fact that 1946 was the same year that the world's first programmable electronic computer, the ENIAC, was introduced. Simon was a master plumber and later a technical high school teacher, with whom Avi proudly apprenticed and thereby gained his first exposure to real-world heat transfer operations in the context of, e.g., steam pipes [1]. He was inspired by both of his parents to become a gifted and dedicated educator. Avi has an older sister, Tovah Reis, who lives in Bethesda, MD, and was a senior medical librarian in hospitals and medical schools in the U.S. and Israel. He also has a younger sister, Chani Fedrick, who is a cantor in South Carolina. Their family roots on Simon's side trace back eight generations to what is modern-day Israel. Avi spent his formative years between 1949 and 1957 in Holon, then a small town in Israel and now part of the greater Tel Aviv metropolitan area. He then returned to Brooklyn with his family.

While attending Abraham Lincoln High School, Avi successfully tried out for and excelled on the championship-winning Danish Junior Soccer Team, part of the Empire State League [2]. Fittingly, while playing on the soccer field in 1962 at Camp Habonim in Red Hook, NY, Avi met his soulmate and future wife, Anat, until recently the Executive Director of the Center for Advocacy Training for the National Breast Cancer Coalition. Their 58-year relationship was recently and aptly described by their daughter, Talia, as "the gold standard of love between two individuals."

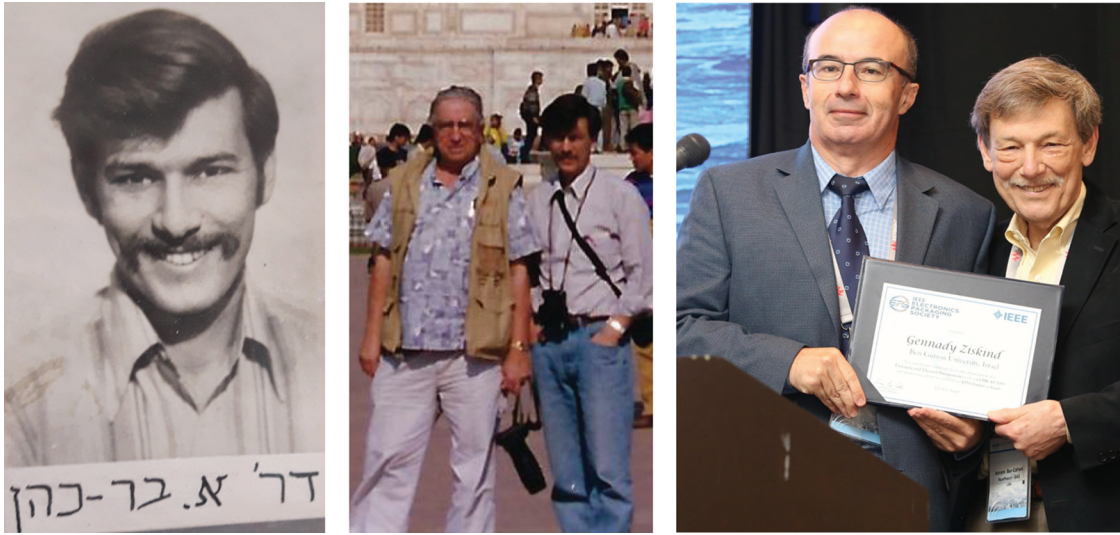
On the academic side, Avi matriculated in the Department of Mechanical Engineering at the Massachusetts Institute of Technology (MIT) in 1963. He completed his joint (honors program) BS and MS degrees in 1968, as a Union Carbide Scholar and, subsequently, Cummins Diesel Fellow, with a minor in Management of Technology, a lifelong interest, under the supervision of the late Professor Arthur (Art) E. Bergles, a dear and enduring friend, mentor and colleague. His MS thesis was on heat transfer in spray towers. Notably, by 1968, Avi had also begun his professional career as an Associate Engineer in the Missile Systems Division of Raytheon Company. Other invaluable mentors and then colleagues of Avi during and subsequent to his years at MIT, where he returned for a sabbatical as a Visiting Associate Professor of Mechanical Engineering in 1977–1978 during which he taught a course on the *Physics of Star Trek* during the Independent Activities Period (IAP), included the late Professors Warren M. Rohsenow and August Ludwig Heselscherwerdt III, and Emeritus Professors Peter Griffith and Borivoje Mikic.

Avi briefly left his studies at the Massachusetts of Technology (MIT), where he was, at 5'7", their All-New England Goalie, to play soccer at the semipro level for the Boston Tigers in the American Soccer League in the late 1960s. Ultimately, rather than try out for a professional soccer team, a viable option, he decided to return to MIT. He described himself in a 2013 interview with Professor Harry Dankowicz, Editor-in-Chief of *Applied Mechanics Reviews*, as a "very springy goalkeeper" [2]. Anat and Avi's first son, Barak, recently the chief operating officer of Bai Brands, was born in 1970. Barak currently directs a number of philanthropic and technical projects in the U.S. and Israel and is based in Princeton, NJ, with his wife and three children. Avi completed his Ph.D. degree at MIT in 1971, also under the supervision of Art Bergles, and his Ph.D. thesis was entitled *Boiling and Condensation in a Liquid-Filled Enclosure* [3]. His first of many publications in this journal was on his Ph.D. research and appeared in 1972 [4]. Even while beginning his professional career at Raytheon and devoting endless hours to soccer, he completed his 3 degrees at MIT in just over 7 years. Avi often quipped that "sleep is overrated."

**Ben Gurion University (BGU).** In 1972, after employment as a Senior Engineer and Section Manager of Advanced Thermophysics, again in the Missile Systems Division of Raytheon Company, Avi returned to Israel. He started his professional academic career at Ben Gurion University (BGU), itself founded in 1969 as the University of the Negev, where he held a succession of appointments from lecturer to Professor until returning to the U.S. full-time in 1988. Avi's belief that human ingenuity was capable, as proved true, of developing the requisite technology to transform the Negev from a relatively barren desert to its modern state and his passion for Israel led him to BGU to be a founder of its engineering program. A photograph of him at BGU in 1974 is shown in Fig. 1 (left). Avi and Anat's second son, Raanan, co-founder of Resolute Ventures, was born in 1975. Raanan, an early dot com innovator, lives in the Bay Area with his wife and two daughters. Early on at BGU, Avi's research interests in engineering applications of thermal science were diverse, but he had a special interest in problems whose solutions could benefit the industrial economy of both the still young State of Israel and that of the USA. In parallel, Avi was already examining the promising future of computerization and realized that its miniaturization required efficient thermal solutions. He began research on this subject and helped to organize the first conferences in the then emerging field of electronics cooling. He was also deeply involved in research concerning heat transfer mechanisms in developing two-phase flow boiling and condensation in tubes (see, e.g., Ref. [5]) and the hydrodynamics of fluidized beds (see, e.g., Ref. [6]). Such activities had direct implications on the U.S. and Israeli power industries. For example, the resolution of the circumferential anisothermality of inclined, diabatic pipes as a function of two-phase flow regimes within them was of practical importance as it had impeded design of reliable industrial steam generators. This research required close cooperation with the steam generating industries in the U.S. and Israel and a collaboration with such well-known colleagues as Professors Peter Griffith at MIT and Yehuda Taitel at Tel-Aviv University. It was funded by the Bi-National U.S./Israel Science Foundation (BSF).

Anat and Avi's daughter Talia Litle, a professional modern dancer, was born in 1981 and currently lives in the Bay Area with her husband and Avi and Anat's sixth and seventh grandchildren. Later in his BGU years, Avi published his seminal work on natural convection heat transfer between vertical plates with the late Warren M. Rohsenow in this journal [7]. Every undergraduate Mechanical Engineering student studies their results during the natural convection portion of their Heat Transfer course. Even more significantly, during this period Avi coauthored with Alan

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**Fig. 1** Left: Avi at BGU, 1974. Middle: Avi and Professor Alan Kraus in India. Right: Avi bestowing an award on Professor Gennady Ziskind, current Head of the Mechanical Engineering Department at BGU, at the IEEE International Conference on Microwave, Communication, Antennas & Electronic Systems (COMCAS) in Tel Aviv, Israel, 2019.

Kraus (pictured with Avi in India in Fig. 1, middle), their seminal book *Thermal Analysis and Control of Electronics Equipment*, published in 1983 [8], a 620 page tome. Nearly 40 years later, it remains a standard reference in the field of thermal management of electronics and, far ahead of its time, contains exhaustive chapters on technologies that only later became commonplace, such as heat pipes and thermoelectric modules.

Avi's deep connections to Israel and BGU (and MIT and Raytheon) were conscientiously maintained for the rest of his life. For example, just a few years ago he was again a co-investigator on a BSF grant, this time as the U.S. partner of the late Professor Gad Hetsroni of the Technion—Israel Institute of Technology. Again, the topic, two-phase cooling for concentrating photovoltaic solar cell arrays, themselves eminently relevant to the modern infrastructure and economy of the Negev, was aligned with current industrial needs. Moreover, Avi was very active in recent IEEE International Conferences on Microwave, Communication, Antennas and Electronic Systems (COMCAS), enormous biannual events held in Tel-Aviv, where he was a plenary speaker. He also conceived and brought to fruition a very successful Packaging and Thermal Management track for this conference. A photograph of Avi bestowing an award on Professor Gennady Ziskind, current Head of Mechanical Engineering at BGU, at this conference is shown in Fig. 1 (right). The organizers of the next COMCAS in November 2021 have already announced their plans to dedicate a memorial session to Avi, a recurring theme at conferences throughout the world. It is also because of Avi that Israeli researchers in heat transfer were allowed to apply for Defense Advanced Research Project Agency (DARPA) funding and complete a number of successful projects. Furthermore, he initiated the formation of the IEEE Electronics Packaging Society Chapter in Israel, formally approved on Oct. 4, 2020, days before his untimely death. Finally, the Project Desert Nova Fund at Ben-Gurion University was created by his children in honor of his countless contributions to technology and the Negev, on the occasion of Avi's seventieth birthday. The goals of the Fund were inspired by Avi's lifelong belief in the power of innovation in solving crucial societal problems.

*Years in Minnesota.* Avi served as General Manager and Executive Consultant for packaging and physical modeling at Control Data Corporation (Minneapolis, MN) from 1984–1989. Early during this period, in 1986, Avi was recruited by and joined such luminaries in the field of heat transfer as Ernst Eckert, Ephraim Sparrow, Richard Goldstein and Suhas Patankar, in the Mechanical Engineering Department at the University of Minnesota and

remained on their faculty until 2001. He taught courses on thermal design, electronics cooling and boiling heat transfer and multiphase flow. From 1988 to 1992, he jointly conducted with Professor Terry Simon and graduate students research on boiling incipience, nucleate boiling, critical heat flux, boiling mechanisms, bubble dynamics, wetting, dissolved gas effects, and fluid selection for electronics cooling. This led to joint publication of 22 conference and journal papers.

Subsequently, in his own Thermal Management of Micro- and Nano-Systems (TherMNs) Laboratory, Avi was the principal investigator for a broad portfolio of fundamental and applied research sponsored by, e.g., 3M, Motorola, Intel, and NSF. Research projects and industry collaborations covered topics such as direct liquid immersion cooling, synthetic jets, gas-assisted evaporative cooling, heat pipes, single- and two-phase heat sinks, integrated circuit thermal characterization and modeling, thermoelectric refrigeration, and packaging adhesive and die-attach fatigue. Representatively, Avi's research with Madhu Iyengar on minimizing the total energy consumed by the fabrication and, in the case of forced convection, fan driving air flow through a heat sink over its lifetime of operation [9] is featured in the standard undergraduate textbook on Heat Transfer by Bergman et al. [10]. This work exemplifies Avi's commitment to *Tikkun Olam* given that, at present, about 1% of the world's energy is used for thermal management of electronics and this number is rising. Avi mentored and graduated 27 Master's students and 10 Ph.D. students at the University of Minnesota.

During his time at the University of Minnesota, Avi published *Design and Analysis of Heat Sinks* [11], again with Professor Alan Kraus. This is the definitive work on the subject. In addition, he edited over a dozen books and authored over 30 book chapters. Overall, during his Minnesota years, Avi published over 60 peer-reviewed journal articles, over 100 conference papers, and gave over 60 invited and keynote lectures. He also pioneered the "classroom of the future" through live/synchronous, internet-delivered Thermal Management courses in collaboration with Professor Sushil Bhavnani at Auburn University and Professor Yogendra Joshi at the University of Maryland.

Avi's guidance to the student researchers was both in presenting his theories on fundamentals and in his discussions of the utility of the research results on the design of cooling solutions for electronic devices. Between 1990 and 2005, Avi participated in the Annual Review of the Heat Transfer Literature with the University of Minnesota Heat Transfer Division faculty. The reviews





**Fig. 2** Minnesota years. Top left: “ABC Group” at Avi and Anat’s house—Mr. and Mrs. Devin Mix and Avi (top row), Evan Graham, Andrew McNeil and Marc Hodes (middle row) and Khadir Mellah and Zane Johnson (bottom row). Top right: Avi with Professor Richard Goldstein at Dick’s retirement celebration. Bottom: An “ABC lunch” at a conference—Maurice Holahan, Avi, Karl Geisler, Madhu Iyengar, Gary Solbrekken, and Zane Johnson from left to right.

were printed in the *International Journal of Heat and Mass Transfer*.

Avi also contributed greatly to the administration of the Department and the College of Science and Engineering at the University of Minnesota as the Director of the Mechanical Engineering Department’s Heat Transfer Division (1998–2001) and Director of the College’s Center for the Development of Technological Leadership (1998–2001). He held the Sweat Chair of Technological Leadership. In 2020, at an event to acknowledge the lifetime contributions of Professor Ephraim Sparrow, the heat transfer faculty of the University of Minnesota chose two highly respected members of the international heat transfer community to speak. Avram was one. Photographs of Avi’s Group in the early and later Minnesota years are shown in Fig. 2 (top left and bottom, respectively). A recent photograph of Avi and Professor Goldstein is also shown in Fig. 2 (top right).

*University of Maryland.* Avi returned to the East Coast to chair the Department of Mechanical Engineering at the University of Maryland (UMD) from 2001 to 2010. He brought unprecedented enthusiasm and energy to this Department, where he made substantial contributions to enhance both undergraduate and graduate studies. Under his leadership, the Department’s national rankings vastly improved, and its research expenditures increased by 63%. Avi was also instrumental in transferring the Reliability Engineering Program to the Mechanical Engineering Department, which helped strengthen their research activities in electronic reliability in the Center for Advanced Life Cycle Engineering (CALCE), one of the five centers currently in the Department, said Professor Balachandran, Minta Martin Professor and Chair of Mechanical Engineering. In the words of Margaret (Peggy) Brumfield, the Executive Director of Administrative Affairs during Avi’s tenure as Chair, “Avi was the exemplary leader who knew how to

motivate the staff and most importantly knew what kind of fiscal analysis he needed. He loved numbers and appreciated their importance as support to making good decisions on utilizing departmental resources.” Avi was named a Distinguished University Professor at Maryland in 2005, the highest honor bestowed on a tenured faculty member. Photographs of Avi in his office at Maryland and with his faculty colleagues are shown in Fig. 3, left and middle, respectively.

At the international level, under Avi’s leadership, in 2002 the Department participated in a sponsored international research and educational collaboration with the United Arab Emirates (UAE). Through this multiyear collaboration, the University of Maryland College of Engineering participated in establishing an engineering institution in the UAE. The institution (known as the Petroleum Institute then and now part of Khalifa University) had six engineering programs, including mechanical engineering, which boasted the highest student enrollment of them. The programs included both undergraduate and graduate programs. In 2012, the institute was granted a six-year ABET accreditation for all of its engineering programs and became the only institution in the UAE at the time to have all of its programs receive such high recognition. Under Avi’s leadership, Mechanical Engineering at UMD played a major role in helping the institute achieve its envisioned goals in instruction, research, and scholarly collaborations. Michael Ohadi, a professor from the Mechanical Engineering Department at UMD, on a professional leave assignment from UMD, served as the founding Chairperson of the Mechanical Engineering Department (2002 to 2006) and later served as the Provost and Acting President of the Institute (2006–2010). A photograph of Avi and Dr. Daniel Mote, former President of the University of Maryland (UMD), College Park, at one of their meetings with a UAE colleague is shown in Fig. 3, right.



**Fig. 3** Left: Avi during his tenure as Department Head at UMD. Middle: Professors Bill Fourney, Avi Bar-Cohen, Art Bergles, and Michael Ohadi at UMD. Right: Avi and Dr. Daniel Mote, former President of UMD, with a colleague from the UAE.

In addition to his research addressing the many practical challenges faced by the electronics industry, Avi was a strong advocate for basic research and realized the importance of a partnership between government and the private sector to support the foundational research needed to address future challenges and, of equal importance, train the next generation of engineers. Shortly after his arrival at the University of Maryland, he began a dialogue with the Office of Naval Research (ONR) regarding cooling challenges the military would face as they moved toward higher power electronic systems. Working with Professors Yogi Joshi and Marty Cerza, Avi organized a workshop in 2003 to identify future thermal challenges and the need for innovative research. As a result of this workshop, ONR started a new program focused on basic research in heat transfer. Many of the concepts developed under that program found their way to Avi's subsequent programs at DARPA.

Avi's administrative duties did not stop him from his active research, collaborative, and scholarly activities. In fact, during his years as Chair, 2001 to 2010, his impressive research and outreach activities included 58 journal articles, 66 peer-reviewed conference papers, 44 invited plenary/keynote/other major lectures, and countless other activities. The Mechanical Engineering faculty, staff, and students will miss Avi's distinguished intellect, engaging presence, momentum-building character, and his affable smile.

*DARPA.* Avi went on assignment from UMD to the Microsystems Technology Office (MTO) at the Defense Advanced Research Projects Agency (DARPA) in the fall of 2010, serving 2 terms through the end of 2015. During his time at DARPA, Avi initiated and led the Intrachip Enhanced Cooling (ICECool) program, whose aim was to enhance the performance of electronic systems through the application of chip-scale heat removal of kW-level heat flux and heat density while simultaneously mitigating local electronic device hot spots. This program engaged both the fundamental research community on microfluidic two-phase cooling in the ICECool Fundamentals thrust and the industrial research community on near-term embedded cooling that would have specific benefits to electronic performance in the ICECool Applications thrust. In addition to ICECool, Avi initiated ICECool's predecessor, the Near Junction Thermal Transport (NJTT) program. He also served as the program manager for several other programs including Thermal Management Technologies (TMT), Semiconductor Technology Advanced Research Network (STAR-Net), and a portfolio of advanced studies in laser diodes, as well as dozens of seedling efforts including topics such as phonon engineering, thermal-electrical-mechanical codesign, liquid metal cooling of electronics and heterogeneous integration. In his 2020 review article in the *Journal of Electronic Packaging* on the advanced power amplifier work funded under ICECool [12], Avi summed up the results of the program in his own words: "the implementation of the embedded cooling thermal paradigm addresses the inherent thermal limitations of wide bandgap materials and enables far greater electrical and RF performance for the coming generation of GaN devices and other compound semiconductor systems than available today."

*Raytheon.* In 2016, Avi returned, after a 48-year hiatus, to Raytheon Corporation, this time as Principal Engineering Fellow in the Space and Airborne Systems Division in Arlington, VA. There, his interests, in addition to the thermal management of electronics, focused heavily on wireless power beaming technology. Avi, as mentioned above, started working for Raytheon as a mechanical engineer in 1968 after completing a combined Bachelor's and Master's degree in Mechanical Engineering from MIT. He was exposed to the challenges and opportunities associated with electronics cooling and Raytheon supported his Ph.D. studies, which turned out to be an excellent investment. Avi's second stint at Raytheon provided an opportunity to continue his efforts in developing defense technologies to support U.S. DoD interests. During this period, he served as a mentor and technical strategist, helping shape Raytheon's next generation of thermal engineers, driving company strategy in thermal management, and increasing the level of engagement between Raytheon engineering and the broader thermal technical community. Avi's work focused on thermal management of high-power density RF devices, high-energy lasers, hypersonics, modeling and simulation, 3D heterogeneous integration, and power beaming technologies. His long-standing relationships within the government and broader thermal technical community gave rise to new collaboration opportunities in thermal storage technologies, phase change heat transfer, high-temperature materials and cooling techniques, and optical power transmission. While at Raytheon, Avi engaged at all levels, from informing senior management to mentoring individual engineers. He increased Raytheon's technical profile by spearheading the generation of books and journal articles that laid out the past, present and future directions of thermal management to influence the industry and inform future research directions. At the time of his passing, Avi was in the midst of fostering international collaboration between U.S. DoD and Israeli Ministry of Defense (IMoD) researchers to advance common goals. Innovation and commitment to helping maximize the potential of every engineer he worked with were the hallmarks of Avi's tenure at Raytheon.

*Publications.* To describe all of Avi's activities on the publications front, especially the tremendous number of highly cited journal papers, along with his own journal and book editing activities, is unrealistic. Here, we mention a few of the book series he was recently editing. They include the well-known, high-impact *Encyclopedia of Thermal Packaging* (ETP, in 4 thematic sets, with 17 volumes in total) [13–16], essentially our community's long-awaited update to and vast expansion of the aforementioned Kraus and Bar-Cohen [8] tome published in 1983. It is unparalleled in the comprehensiveness of its scope. Topics included by Avi in the ETP span the entire spectrum of thermal packaging aspects—from fundamentals to techniques to tools to applications to configurations. One of the volumes is Avi's 3rd book coauthored with Dr. Karl Geisler and entitled *Dielectric Liquid Cooling of Immersed Components* [17].

Avi also began a parallel project—a multiset, multivolume *Encyclopedia of Packaging Materials, Processes and Mechanics*, whose first set *Interconnect and Wafer Bonding Technologies* (in 4 volumes) was just published [18]. In addition to these



gargantuan (in their significance, usefulness, comprehensiveness, details and size) publications, Avi was deeply involved with several flourishing, extremely popular series of individual volumes, i.e., *World Scientific Series in Advanced Integration and Packaging* (a series of individual volumes, co-edited with Profs. Ricky Lee and Bongtae Han) [19]—with a particular focus on 2.5D and 3D form factors—which, according to Avi’s vision, has provided a “technology commons” for the packaging community, a place where ideas can be articulated, examined, and disseminated rapidly and efficiently through both print and electronic media, and *World Scientific Series in Emerging Technologies* [20], in which Avi had aspired to offer readers insightful explorations of the most exciting and compelling emerging technologies with the potential to strongly impact diverse aspects of life on our planet. Finally, true to his commitment to both research and education, just last month Avi decided to branch out this core series of research publications into an educational track as well, thus ensuring that both students and lecturers could benefit from having a forum where they can find lectures and lecture notes for courses on “disruptive new technologies of the future”—and so a separate *World Scientific Series of Lectures in Emerging Technologies* [21] was born.

*Societal Contributions and Awards.* Avi’s contributions in the micro-electronics packaging communities in IEEE and ASME were guided by a well-blended combination of pragmatic, technically deep and aspirational streams of thinking. It is important to understand the evolution of the field to better appreciate his influence. The value of computation in elucidating physical (including heat transfer) phenomena, both through detailed modeling and correlation of theory with experiment, was quite well understood by the sophisticated academics and industrial practitioners of the mid to-late 1980s. However, beginning in the 1990s, personal computing was starting to make its effects felt and Moore’s Law enabled increasingly broader proliferation of computers for more than technical use. This proliferation drove increased focus on semiconductor and packaging technology development and high-volume manufacturing. Thermal management of micro-electronics was one of the greatly challenging aspects of packaging and Avi’s technical contributions in this area are invaluable. What is most impressive about his work is the emphasis on practical implementations of technically sound ideas. There was also a great need to build a strong micro-electronics packaging community and to train next generations of engineers to ensure the continued evolution of packaging. Avi’s academic and industrial background helped him set comprehensive directions and positively influence the growth of the thermal management and packaging communities in IEEE and ASME. In ASME, he helped shape the Electronics and Photonics Division and worked with leaders in industry and academia to develop the InterPACK conference. He, along with Peter Engel, Ephraim Suhir and others, helped InterPACK achieve its current definition and stature. He also established deep connections with industry leaders such as Dr. Nasser Grayeli, and with their help developed the InterPACK industrial advisory board. This board attracted industry sponsorship that was used to greatly enhance student participation. InterPACK has become a primary venue for driving progress in thermal management, reliability, thermo-mechanically robust designs, materials-mechanics interactions and photonics, strengthening links with other ASME communities and tying them with the semiconductor industry.

Avi’s influence in IEEE was similarly powerful in numerous ways. He started the ITherm Conference series in 1988 as a companion conference to the broader ECTC conference. This helped emphasize the need for and value of thermal engineering in micro-electronics packaging and the enduring popularity of this conference is a testament to Avi’s vision. Avi represented the EPS (Electronics Packaging Society) formerly known as the Components Packaging and Manufacturing Technology Society (CPMT) as a Distinguished Lecturer, delivering impactful lectures on thermal management across the globe. He served as Editor-in-Chief

of the IEEE CPMT Transactions (1995–2005), a tenure during which he successfully recruited a number of excellent associate editors. Even after stepping down from this position he continued to take an active interest in the journal and helped shape its strategy. He served on the EPS Board of Governors and was President of the IEEE Electronics Packaging Society. During his tenure, the EPS society continued to grow internationally, developed a strategic Heterogeneous Integration Roadmap, successfully recruited young professionals and developed a more broadly recognizable profile, helped in no small part by Avi’s active and encouraging stewardship. It is to Avi’s tremendous credit that he was able to seamlessly adopt multiple roles, of a highly regarded researcher, an engaged academic, an unassuming mentor, an always available coach and a strategic visionary who could deftly translate vision to action and through engaged encouragement involve and draw out the best from people. He straddled the ASME and IEEE communities (and their respective research in electronics and packaging) creating strong complementary efforts in both societies.

His work was recognized by the community thru multiple awards of increasing levels of importance. He received the InterPACK Achievement Award in 2005. He also received the Luikov Medal from the International Center for Heat and Mass Transfer in Turkey (2008) and ASME’s Heat Transfer Memorial Award (1999), the Edwin F. Church Medal (1994), and the Worcester Reed Warner Medal (1990). He became a member of the European Union Academy of Sciences in 2020. Prior to this, he had been made a Life Fellow of IEEE and ASME. He was awarded the CPMT Society’s Outstanding Sustained Technical Contributions Award (2002), the ITherm Achievement Award (1998), and the THERMI Award (1997). The IEEE EPS community honored him with its highest award, the prestigious CPMT Field Award in 2014.

*Summary.* A recurring theme that emerged during the assembling of this review of Avi’s contributions was that every coauthor and innumerable others were helped on a personal level by Avi. We provide but three examples. First, it was interactions with Avi that ultimately resulted in Professor Portonovo Ayyaswamy conducting workshops on cooling through the sponsorship of the United Nations Industrial Development Organization (UNIDCO) with headquarters in Geneva. Second, it was Avi who enabled Professor Ivan Catton to navigate the intricacies in applying inorganic aqueous solutions (IAS) to phase change heat transfer under DARPA sponsorship. Thirdly, Professor Timothy Fisher recalls meeting Avi at the very first technical conference that he attended, ITherm ’96, and remembers in particular Avi taking the time to have a long and deep technical conversation with him and other students who were just entering the field. There was always a long line of folks wishing to speak with Avi at conferences (even to take photos next to him in the case of younger students) and, always, he made time to reach the end of the line.

As has been made clear, the imprint Avi made on the people with whom he worked and places where he worked will continue in perpetuity. Once Avi engaged with an organization, be it Raytheon, BGU, or a professional society, it became a lifelong contract. The breadth of Avi’s vision, the extent of his grasp of current—and expected future—engineering needs and practical applications was matched by his practical, pragmatic approach. There was no “pipe dreaming” in his truly prophetic vision—his view of the actual needs of the engineering community and of the real capability to deliver, coupled with his excellent understanding of economic viability of innovation, were all based in the reality of engineering research that he knew so well.

May Professor Avram Bar-Cohen, our esteemed colleague and cherished friend who fulfilled his objective of leaving the world a better place, rest in peace.

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Marc Hodes  
Tufts University,  
200 College Avenue,  
Medford, MA 02155  
e-mail: marc.hodes@tufts.edu

Ravi Mahajan  
Intel Corporation,  
5000 West Chandler Blvd,  
Chandler, AZ 85226  
e-mail: ravi.v.mahajan@intel.com

Zvi Ruder  
World Scientific Press,  
9501 Woodington Ct,  
Cary, NC 27518  
e-mail: zviruder@wspc.com

Terry Simon  
University of Minnesota,  
111 Church Street SE,  
Minneapolis, MN 55455  
e-mail: simon002@umn.edu

Karl Geisler  
3M,  
Mail Stop 260-5-B-09,  
St. Paul, MN 55144  
e-mail: kjgeisler@mmm.com

Michael Ohadi  
Department of Mechanical Engineering,  
University of Maryland,  
College Park, MD 20740  
e-mail: ohadi@umd.edu

Joseph Maurer  
MBO Partners,  
2540 South Arlington Mill Dr. Unit B,  
Arlington, VA 22206  
e-mail: jjm9u@virginia.edu

David Altman  
Raytheon,  
528 Boston Post Road,  
Sudbury, MA 01776  
e-mail: david\_h\_altman@raytheon.com

Jim Wilson  
Raytheon,  
13510 N Central Expressway,  
Dallas, TX 75243  
e-mail: jsw@raytheon.com

Gennady Ziskind  
Ben Gurion University,  
P.O.B. 653,  
Beer-Sheva 84105, Israel  
e-mail: gziskind@bgu.ac.il

Mark Spector  
Office of Naval Research,  
875 N. Randolph Street,  
Arlington, VA 22203-1995  
e-mail: mark.spector@navy.mil

Ivan Catton  
University of California,  
Los Angeles,  
420 Westwood Plaza Room 43-132,  
Engineering IV,  
Los Angeles, CA 90095  
e-mail: catton@g.ucla.edu

Vijay Dhir  
University of California,  
Los Angeles,  
7400 Boelter Hall,  
Los Angeles, CA 90095  
e-mail: vdhir@seas.ucla.edu

Timothy Fisher  
Department of Mechanical and Aerospace Engineering,  
University of California, Los Angeles,  
Los Angeles, CA 90095  
e-mail: tsfisher@ucla.edu

Portonovo Ayyaswamy  
University of Pennsylvania,  
Room No. 231, 220 S. 33rd Street,  
Philadelphia, PA 19104  
e-mail: ayya@seas.upenn.edu

Boravoje Mikic  
Massachusetts Institute of Technology,  
Room 5-214, Massachusetts Avenue,  
Cambridge, MA 02139  
e-mail: mikic@mit.edu

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