Tributes to Fusion Minds

Communities form around commitments to shared interests, goals, values, and more. In time, given need and opportunity, they develop institutions to support the community as a whole and to encourage its members to grow and develop. All of this requires significant investments of time and effort by many people from diverse backgrounds, all working together, each doing what they can, when they are able. The International Society of Information Fusion (ISIF) would not have endured for 25 years without their dedication. We stand on their shoulders, and whether they be giants or not, we are bound by a duty to acknowledge their freely given gifts of time and labor, and yes a kind of love, to our field and our community. Some are no longer with us, sadly, and we miss them in many ways. This section of *Perspectives* is intended to be a tribute to, and an acknowledgement of, the contributions they made to the ISIF community.

CHRIS BOWMAN (1948–2023)

Dr. Christopher Bowman unexpectedly passed away on February 11, 2023, due to complications following a medical emergency. We honor his memory and his contributions to the data fusion community.

Chris is survived by his loving wife, Julie Hunter Bowman, and nine children: Aaron, Mark, Sarah, Adam, Laura, Jeff, Quinn, Rebecca, and Bailee. In 1971, Chris joined the Church of Jesus Christ of Latter-Day Saints and served in the church in many different callings. He was an avid racquet sport player, including badminton, tennis, platform or paddle tennis, and pickleball. He loved singing along to old musicals. Despite his many passions and professional dedication, spending time with his family was his greatest joy in life. Chris was wonderfully optimistic. His positive attitude and open-minded appreciation of people and of life were immediately evident to everyone who met him.

Chris Bowman (right) with Alan Steinberg at Workshop on Critical Issues in Information Fusion in Beaver Hollow, NY, 2008 (courtesy of Alan Steinberg).

Chris graduated in 1966 from Garden Grove High School in Garden Grove, CA. In 1970, he completed his bachelor's degree from the University of California, Riverside, with a double major in mathematics and physics. In 1973, he completed his master's degree in mathematics, followed by his Ph.D. in mathematics in 1977 from the University of California, Irvine.

Chris's impact on data fusion, neural networks, and systems engineering has been extensive and profound. As Edward Waltz noted, "Chris Bowman is a legend… truly a pioneer in the fusion field and his depth of understanding (from concept to code) was impressive". Few scientists have such breadth; many can formulate and offer design and algorithmic concepts, and others are strong in implementation, but few have such a breath of skills, vision, and innovation.

Chris was a major pioneer in data fusion, having been the first to define the fundamental functional and architectural design principles of data fusion system engineering. He was first to extend these concepts to resource management processes, thereby enabling the cost-efficient development and operation of responsive information exploitation systems. He is known internationally for his development of the widely used data fusion and resource management dual node network technical architecture that supports affordable system design, development, and comparative analyses.

Chris was more than a theoretician; he had a stellar career applying these theoretical and engineering principles in designing and developing innovative, advanced data fusion and resource management systems for integrated avionics, cooperative tactical operations, missile defense and space situation awareness, and diverse other applications.

From 1978 to 1991, he managed the data fusion and neural networks programs at Verac, Inc., where his team delivered software for multispectral integration, weapon/sensor management, and nonlinear adaptive control with applications in tactical avionics, missile defense, and tactical surveillance. From 1992 to 1995, Chris supported Ball Aerospace in Strategic Defense Initiative efforts.

In 1995, Chris founded and led Data Fusion and Neural Networks, LLC (DF&NN) as president. Prominently, he led DF&NN's ground-breaking development operational software for remote diagnostics of satellite health and operations. He led the Information Fusion Working Group that developed a data fusion and resource management roadmap for the Air Force Research Laboratory. He served on the Signals Intelligence

Science and Technology Advisory Board to oversee development of a large data fusion system, and he was a member of the Hercules Blue Technology Team in support of the Ballistic Missile Defense Organization. Under Project Correlation for the U.S. Air Force Space Warfare Center in the 1990s, Chris was instrumental in developing a set of data fusion engineering guidelines and an evaluation of several major combat information/intelligence correlation systems.

Most recently, he served as cotechnical lead for the U.S. Department of Defense (DoD) high-level data fusion project, developing advanced concepts and methods for exploiting high-level data fusion in a critical tactical application.

In 2018, Chris was honored by the U.S. Military Sensing Symposium Specialty Committee on Sensor and Data Fusion with the prestigious Joseph Mignogna award for his contribution to the development and use of data fusion.

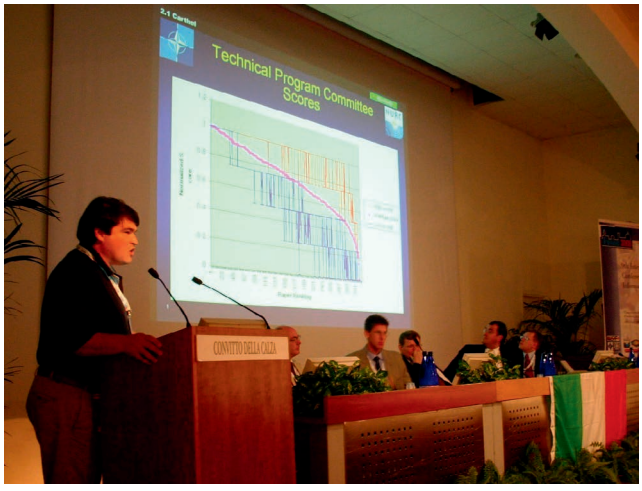
We have lost a great person and a very good one.

—Alan Steinberg and James Llinas

CRAIG CARTHEL (1964–2022)

Craig Carthel, a dear friend and professional colleague, died unexpected in July 2022, shortly before I was to attend FUSION in Linköping. This was a devastating loss, for me as for all of Craig's family and friends. On the professional side, Craig and I collaborated closely in the development of advanced data fusion solutions, with a particular focus on multiple hypothesis tracking (MHT) methods. Our collaboration spanned multiple professional employers and 24 years of joint efforts. He was admired by so many for his technical brilliance (in both mathematics and software solutions), his kindness, and his good humor. In 2006, we hosted FUSION in Florence, where Craig served as technical chair. Beyond his leadership and participation in FUSION, those who supported the ISIF Multistatic Tracking Working Group will remember his contributions and collegiality over many years. In August, during an online tribute that was held in remembrance of Craig, Peter Willett remarked that, when faced with a tough tracking problem, "When all else failed, that was when we turned to Craig". Indeed, how many times I experienced that over the years! I am so fortunate to have had Craig as a friend and colleague for many years.

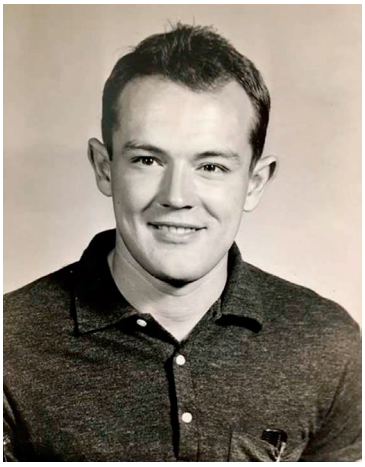
—Stefano Coraluppi



Craig Carthel explaining the paper review and acceptance process during FUSION 2006 in Florence, Italy (courtesy of Stefano Coraluppi).

SAMUEL BLACKMAN (1938–2019)

Sam Blackman is famous for creating industrial strength MHT–interacting multiple model (IMM) software that is used in dozens of important radar, passive optics, and multisensor data fusion systems. It works robustly in the real world and runs in real time on low size, weight, and power computers for stressing multiple target scenarios. It is clearly the algorithm of choice. Sam emphasized how lucky he was to have Bob Dempster help him designing, coding, testing, and tuning the algorithm. What a team! Sam and Bob decided to create this wonderful software all by themselves, on their own time, without any internal or customer research and development support. I vividly recall one big contract that we won specifically because the customer insisted that they wanted Sam's MHT-IMM for data fusion. The customer was thrilled to meet Sam and learn more about his work. Sam was enormously generous with sharing his ideas and time to mentor other engineers. After Sam became too sick to drive into work, many engineers would visit the guru at his house to drink from the fountain of wisdom. Sam loved it. Sam's books and papers are treasured by engineers looking for practical tracking algorithms described clearly by a real expert. But Sam was pretty feisty when he thought that you had grasped for undeserved laurels. This got him in hot water once, but the worldwide tracking community pitched in to help him out.



Sam Blackman, the Wizard of multiple hypothesis tracking dreaming about playing basketball (courtesy of Dale Blair).

—Fred Daum

RUDOLF KALMAN (1930–2016)

"Kalman filter is a beacon in the vastness of non-linear, non-Gaussian phenomena". A historical perspective on the role of the Kalman filter in aerospace is reported in [1]. My appreciation of the contribution given to humanity by Professor Rudolph Emil Kalman's inventions is described in [2]. On 12 September 2016, Professor Sergio Bittanti presented a posthumous

Rudy Kalman (right) with Alfonso Farina in Gainesville, Florida, April 2016 (courtesy of Alfonso Farina).

Ph.D. honoris causa in information technology to Mrs. Dina Kalman in a ceremony held at the Department of Electronics, Information Technology and Bioengineering at the Polytechnic of Milan [3]. I was present at the ceremony together with Professor Luigi Chisci of the University of Florence.

In recent years, I greatly valued my friendship with Rudy and Dina Kalman and our periodic meetings at their residences in Zurich and Gainesville, FL. We used to consult and browse Rudy's extensive library spanning from technical books—in several languages—to his many famous publications. I also had the chance to hear Rudy's explanations of his investigations on long-standing electrical network synthesis and look at his authoritatively handwritten notes.

It was quite an experience to jointly consult on philosophical books like *De Consolatione Philosophiae* by Severino Boezio [4], of which Rudy had a precious English copy together with the original Latin version. He also introduced me to "The Relation of Sense-Data to Physics" by Bertrand Russell, and in particular, he pointed out to me the last paragraph of section 1 at page 114 [5], which I have transcribed: "Thus, if physics is to be verifiable we are faced with the following problem: Physics exhibits sense-data as a functions of physical objects, but verification is only possible if physical objects can be exhibited as functions of sense-data. We have therefore to solve the equations giving sense-data in terms of physical objects, so as to make them instead give physical objects in terms of sense-data".

I keep it in my study room not far from my gaze so that I can ponder it time to time. In the summer, our talks were intertwined with a pleasant lunch or dinner in their garden at the Zurich house or in restaurants in the fresh hills around.

REFERENCES

1. Grewal, M. S., and Andrews, A. P. Applications of Kalman filtering in aerospace 1960 to the present. *IEEE Control Systems Magazine* (June 2010), 69–78.
2. Farina, A. July 27, 2016: Celebrating the professional life of Professor Rudolf Emil Kalman. *IEEE A&E Systems Magazine,* Vol. 31, 12 (December 2016), 47–49.
3. Bittanti, S. Ph.D. honoris causa in information technology to R. E. Kalman. Presented at Department of Electronics, Information Technology and Bioengineering, Politecnico di Milano, Milan, Italy, Sept. 12, 2016. [Online] https://bittanti.faculty.polimi.it/rudolf%20Kalman.html.
4. Boëthius, A. M. T. S. *De Consolatione Philosophiae*. 524 dC, in Latin.
5. Russell, B. The relation of sense-data to physics. *Scientia,* Vol. 16, 16 (1914), 113–141. Available: https://www.princeton.edu/~hhalvors/teaching/phi520_s2015/Russell_SenseDataPhysics.pdf.

—Alfonso Farina

OLIVER DRUMMOND (1928–2016)

Oliver Drummond was a unique character in the target tracking community, which is full of characters (e.g., Dale Blair and Yaakov Bar-Shalom). I had the privilege of knowing Oliver for many years and actually worked for him for a few years. There are a couple of things that stand out in my memories of Oliver. First, he was obsessed with avoiding being constantly connected to the internet. I think he used dial-up internet and would disconnect the phone line from the modem when he wasn't using it. In addition, because he only used dial-up internet, he couldn't download updates the Ballistic Missile Defense Benchmark simulation. So, every couple of months, I would download the updates and mail a CD to him. Second, Oliver was a classic late-night worker. It was best not to call Oliver until after 11 am, California time! On a serious note, Oliver was a very nice person, who always had time to explain something. We all remember some of his famous sayings, and still quote them, and I think all of us truly miss him as a colleague, researcher, and friend.

Oliver Drummond as a young naval officer with a burning ambition to make tracking algorithms work in the real world (courtesy of Dale Blair).

—Darin Dunham

DAVID L. HALL (1946–2015)

Dr. David L. Hall certainly made his mark on the multisensor data fusion and information science community. An Air Force veteran, member of industry, and finally Dean of the College of Information Sciences and Technology at the Pennsylvania State University, where he established the Center for Network Centric Cognition and Information Fusion, Dr. Hall was a teacher and researcher known for integrity and vision. His contributions to information fusion include multiple books, over 200 papers, and key input to the development of the Joint Directors of Laboratories (JDL) Data Fusion Model. His vision for fusion extended beyond defense and intelligence to

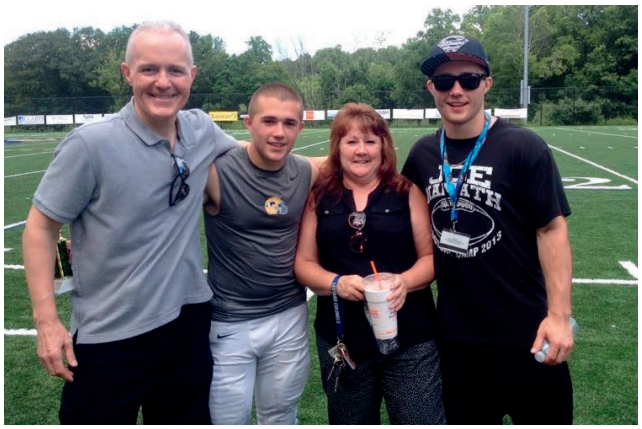
David Hall with his daughters, Dr. Sonya A. Hall McMullen and Dr. Cristin M. Hall (courtesy of Sonya McMullen).

the realm of all things possible, such as applications for smart and safe transportation to health care, to smart homes, and many others. Dr. Hall was quick to address the potential pitfalls of fusion and technology as the coauthor of the publication *Dirty Secrets of Multisensor Data Fusion* that provides enduring guidance for data fusion system development. Dr. Hall was an Institute of Electrical and Electronics Engineers fellow for his contributions to data fusion, and he was awarded the U.S. DoD Joseph Mignogna national data fusion career award for his leadership in data fusion. Although he was a huge proponent of technology, Dr. Hall's philosophy was one of pursuing technology to enhance humanity and human capability for information processing and decision making. Most of all, Dr. Hall would want to be remembered as a son, husband, father, and twin.

—Jim Llinas and Sonya Hall McMullen

ROBERT LYNCH (1960–2015)

Thanks to *Perspectives* for letting me write a few words about Robert S. (Bob) Lynch. Bob worked with me for his Ph.D. (please read his stuff, it's good) while holding down a full-time research job at the Naval Undersea Warfare Center, where he was responsible for all kinds of data fusion products.



Bob Lynch and his family (courtesy of Peter Willett).

Bob loved and lived research. But—second, of course, to his family—his passion was, I think, our ISIF. Bob was always involved in our conferences, and was general chair with Chee-Yee Chong for the successful FUSION 2009 in Seattle. Let's add that our *Journal of Advances in Information Fusion* is now "indexed" (i.e., has an impact factor)—according to my recollection, that can be traced to Bob and his persistence.

Bob was taken from us far too early, in 2015, from a horrible disease that he had been fighting—optimistically and with amazing humor—for more than 5 years. Almost up to the end, Bob was still involved, driving himself (very unwisely) to FUSION in Washington, DC. Bob is survived by his wife Sherry and sons Bobby and Ryan. Bob's memory is honored by our society with the endowed ISIF Robert Lynch Award for Distinguished Service. I miss him.

—Peter Willett

OTTO KESSLER (1942–2015)

Otto Kessler began his career at Naval Air Warfare Center Warminster. He developed advanced radars and sensors for the F14 and the P3. He also sought to fuse output from an aircraft's onboard sensors to improve mission outcome. Frustrated by the lack of investment in fusion, he became a program manager for Office of Naval Research in advanced sensors and fusion. He sponsored a Navy fusion meeting in 1983, and when the JDL was in its infancy in 1985, he became the first additional member (fourth overall) of the JDL Data Fusion Subpanel (DFS). Otto became a vital contributor, and when the DFS decided a symposium was needed, it was his dogged pursuit of funding and support that not only made the first symposium possible but also built it into an annual event.

Otto Kessler (right) and his wife Mary Ann at FUSION 2006 in Florence, Italy (courtesy of Frank White).

Otto was a talented engineer committed to the scientific method. He was a pugnacious believer in making decisions based on facts and careful analysis. Although his intensity could unnerve people, he had a warm, caring, and loyal personality. The JDL DFS was a team, leveraging the talents and vision of all members. Otto, with his brilliant mind and long experience, was an essential member of that team.

—Franklin White

PIERRE VALIN (1949–2014)

When I first met Pierre, he was working for Lockheed Martin Canada in Montreal. Later, he joined as a colleague at Defence Research and Development Canada, Valcartier, and pursued his research on target recognition with evidence theory as the mathematical framework for uncertainty representation. He was a brilliant and unpretentious researcher. Beyond his academic pursuits, Pierre was always eager to connect with others and build relationships. He was dedicated to ISIF, for which he served on the Board of Directors for several years and as President in 2006.

Pierre Valin enjoying a piece of dolce vita in Florence, Italy during FUSION 2006 (courtesy of Jean Dezert).

His contributions to international efforts in information fusion were unparalleled, and he was best known for his role as vice president of membership for ISIF. He established and maintained the society's membership database, analyzed conference participation, and worked tirelessly to manually collect data from past conferences' attendance. The uncounted numbers of hours spent building this colored Excel file provided ISIF with a solid basis of memory that grew and up to now can be queried.

He left too soon, in 2014, before he had the chance to receive in 2015 in Washington, D.C. the *IEEE Aerospace and Electronic Systems Magazine* award for the best paper in 2012.

—Anne-Laure Jousselme

JEAN-PIERRE LE CADRE (1953–2009)

Jean-Pierre Le Cadre was a friend and a brilliant researcher in signal processing and data fusion. He passed away too soon, in July 2009. He was well respected for his high professional standards, integrity, and contributions to the ISIF and the FUSION conferences over many years. Since 2011, the ISIF has recognized his contribution by naming the best paper award after him. Jean-Pierre made significant scientific contributions in the field of antenna signal processing, particularly in the area of passive sensor target tracking. He was a respected and dedicated mentor to his Ph.D. students, always willing to share his knowledge and opinions with a high sense of responsibility toward them. He will be remembered for his passionate interest in the hard mathematical problems of the field and his interest in problems of human society. The writings of Jean-Pierre will continue to live by themselves, and through them Jean-Pierre will remain with us: www.irisa.fr/vista/Publis/Auteur/Jean-Pierre.LeCadre.english.html.

Jean-Pierre Le Cadre in a collegial exchange at FUSION 2000 in Paris, France (courtesy of Claude Jauffrey).

—Claude Jauffrey

PHILIPPE SMETS (1938–2005)

Phillipe Smets was a highly recognised and universally respected scientist who made significant contributions to the field of uncertainty modelling and reasoning under uncertainty. He is best known for the transferrable belief model (TBM), a model for the representation of quantified beliefs, as a subjective and nonprobabilistic interpretation of the Dempster-Shafer theory of evidence. The TBM is based on the assumption that beliefs manifest themselves at two mental levels: the *credal* level, where beliefs are expressed and combined, and the *pignistic* level, where decisions are made. The TBM is equipped with many concepts and tools for handling belief functions, such as the conjunctive combination rule (i.e., the unnormalized Dempster rule), the refinement and specialisation of vacuous and ballooning extensions, the generalised Bayesian theorem, and the pignistic transform. Phillipe was also involved in the development of algorithms for fast computations (the fast Möbius transform, matrix calculus for belief functions, and algorithms for evidential networks), a comparison of TBM to alternative approaches to uncertainty reasoning (such as imprecise probability, random sets, possibility theory, default reasoning, and modal logics), and practical applications of TBM in medicine and engineering.

Philippe Smets, shining under uncertainty (from IEEE).

I had a great pleasure and privilege to be mentored by Phillipe during my study leave at Artificial Intelligence Research Laboratory of the Université Libre de Bruxelles in 2003–2004. He retired in 1999, so we spent many hours working together at his home. Philippe was not only a man of great eminence—he was also a charismatic, visionary, and kind person.

—Branko Ristic

GÜNTER VAN KEUK (1939–2003)

Twenty years ago, on October 17, 2003, the theoretical physicist Dr. Günter van Keuk succumbed to cancer. Since 1965, he had created essential methodological foundations of sensor data fusion and sensor control for the armed forces of the Federal Republic of Germany, the Bundeswehr. His scientific home was the Forschungsinstitut für Funk und Mathematik (FFM, Research Institute for Radio and Mathematics), founded in 1963, whose successor, the Fraunhofer Institute for Information Processing, Communication and Ergonomics (FKIE), can look back on 60 years in 2023. As an outstanding scientist, van Keuk founded the Sensor Data Processing and Control Methods Department in 1975, left his mark on it until 2001, and gave it international recognition. It was the nucleus of the Sensor Data and Information Fusion Department of FKIE.

Günter Karl Friedrich van Keuk as a young theoretical physicist, laying the foundations of data fusion and sensor management in Germany, 1973 (courtesy of Lars van Keuk).

A sense of their own history characterizes mature scientific communities. In this spirit, I dedicated my paper to my esteemed mentor for the special session at FUSION 2018 that recalled 40 years of MHT [1]. Two years after West Germany's entry into the North Atlantic Treaty Organization in 1955, the Society for the Promotion of Astrophysical Research began research in the interest of national defense. In 1963, the FFM became a member of this society, which was renamed Forschungsgesellschaft für Angewandte Naturwissenschaften (Research Society for Applied Natural Science) in 1975 until it was absorbed into the Fraunhofer Society for the Promotion of Applied Research in 2009.

How did an applied data fusion problem lead to the creation of the FFM? On the initiative of physicist Paul Kotowski (1904–1971), Telefunken, a predecessor of today's Hensoldt AG, and of high-frequency engineer Leo Brandt (1908–1971), then state secretary in the North Rhine–Westphalian Ministry of Economics and Transport, mathematician Wolfgang Haack (1902–1994), at the Technical University of Berlin, began an investigation in 1957 of the "use of computers in air traffic control". As early as 1959, Haack and his colleagues presented their first results, which can be seen as the beginning of computer-based, networked information fusion in Germany [2]. van Keuk, then a young physicist from the University of Hamburg, joined FFM in 1965. He was the Ph.D. student of Harry Lehmann (1924–1998), a pioneer of quantum field theory, and of Lothar Collatz (1910–1990), cofounder of numerical mathematics in Germany.

van Keuk was among the first who proposed and demonstrated a sequential track initiation scheme based on an optimal criterion related to state estimates. In this context, he developed a performance prediction model for phased-array radar, which has been called the van Keuk equation in the tracking literature. In Sam Blackman's monumental 1999 handbook *Design and Analysis of Modern Tracking Systems,* many of van Keuk's papers are referenced, indicating his growing international reputation.

REFERENCES

1. Koch, W. On anti-symmetry in multiple target tracking. Presented at the 21st International Conference on Information Fusion (FUSION), Cambridge, United Kingdom, 2018.
2. Haack, W., and Hildebrandt, W. "Die arbeitsvorgänge einer elektronischen rechenanlage für den flugsicherungsdienst, im besonderen die erkennung von kollisionsgefahren. *Telefunkenzeitung,* Vo. 32, 126 (1959), S. 3–10.

—Wolfgang Koch