EDITORIAL

Historical Snippets from Our Half Century

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One of the proudest technical accomplishments during *Sound & Vibration's* half-century existence was the development of dynamic sound and vibration measurements and their related signal processing, particularly spectral analysis. Analog conditioning and digital sampling hardware and the fast-Fourier transform (FFT) executed on a wide variety of hardware played significant roles in this important evolution. Our first issue (January 1967) was supported by 11 foresighted advertisers: Brüel & Kjær, General Radio, Kistler Instrument, Ling Electronics, Team, IAC, Eckel, St. Joseph Lead, Consolidated Kinetics, Korfund and Photocon. Hewlett Packard and Spectral Dynamics both advertised in later 1967 issues. We appreciated their trust and confidence then, just as we appreciate every advertiser who has made this publication possible for 50 years.

At the time of S&V's birth, three large companies, Hewlett Packard Company, General Radio Company and Brüel & Kjær, dominated the dynamic measurement equipment market. The oldest of these was General Radio, founded in 1915 to serve the then-new radio broadcast industry. The company frequently recruited from nearby MIT and Harvard, aiming to employ the best of the best. Its products were novel and inventive, manufacturing was modern and well inspected, and management was both resourceful and philosophically liberal.

Some of its more diverse products included a range of Strobotac variable-frequency strobe lights for visualizing dynamic motion of machinery, and Herman Hosmer Scott's 1933 Type 559-A Noise Meter, probably the first compact and portable sound level meter. In 1940 the company licensed Scott's patent for a variable-frequency sine-wave oscillator stabilized by negative feedback to a new California startup – Hewlett Packard!

General Radio remained a privately held Massachusetts corporation until 1978, when it went public and modernized its staid old name to GenRad. GenRad purveyed its 2512 single channel FFT analyzer and 2/4 channel FFT systems running GenRad software on DEC PDP-11 minicomputers. It is conjectured that GenRad's refusal to build its own computers led to its eventual demise in the '90s. Herman Scott went on to found the very successful high-fidelity audio equipment company, H. H. Scott (1947-1985).

Hewlett Packard Company was formed in 1939 by William Redington Hewlett and David Packard. Their first commercially successful product was the HP 200A Precision Audio Oscillator that was based on a patent licensed from General Radio. Bill Hewlett's brilliant contribution was to use the instrument's incandescent pilot lamp as a temperature-sensitive, variable resistor in the negative feedback loop that stabilized the Wein bridge oscillator's output amplitude. Despite being built on tube technology, HP 200 series oscillators were sold until 1972! Many laboratories still use them for effective-bits evaluation (per IEEE 1057-1994 and 1241-2000) of ADC systems because of their stability and spectral purity.

By the early 1970s, Hewlett Packard (HP to its friends) had grown to be the largest instrument maker in the world. Every measurement engineer of the era had a copy of their 8-1/2 × 11 × 1+ inch hardbound catalog in his library. HP instruments had an enviable reputation for flawless operation and precise results. HP's Digital Signal Analysis (DSA) division gave us the wonderful (5451 series) FFT analyzers and (5427 series) vibration controllers. Both products were based on the HP-2100 series minicomputers and were followed by a series of more compact FFT instruments.

The DSA division contributions culminated with the 5423A structural dynamics analyzer, a two-channel FFT with built-in modal analysis capability. However, the HP Loveland division, long makers of radio frequency spectrum analyzers, cast a deciding vote in the mechanical testing arena. Their relatively inexpensive HP 3582 2-channel FFT analyzer made such an abrupt change in the cost/performance ratio for such equipment that they virtually killed the business for everyone else in it, including HP's own DSA division. Unlike General Radio, Hewlett Packard dove headlong into the manufacture of computers in the late '70s with good success. This eventually led to a corporate schism in 1999. The computer side of the business (now dominated by personal desktop and laptop computers and office printers) retained the venerable HP name while the instrument business was forced to soldier on under a new banner: Agilent.

Brüel & Kjær (B&K) of Nærum, Denmark, was formed in 1942. From that time until the present, it has been the dominant source of inventive acoustic measurement equipment and a major international player in vibration analysis. In 1943, they introduced the first charge-mode accelerometer, the Type 4301. Their condenser microphones have set the world's performance standards for decades. B&K sound level meters, logarithmic level recorders, *n*th-octave analyzers and FFT analyzers are all first-tier equipment. In 1983 they introduced the Type 2032 dual channel signal analyzer, providing cepstrum analysis and Hilbert transform applications, including demodulation.

B&K's two-channel 2032, with its large display screen, was very popular. It led to the MIMO-capable, 16-channel, Type 3550 of 1991 and today's modular PULSE system. Elsewhere in this issue, Svend Gade has written compellingly about his years introducing, explaining and using these instruments. B&K introduced sound intensity probes and acoustic holography arrays. All of these products were well supported by first-rate technical texts, monographs and application notes; the B&K technical library was legendary. B&K has been a major supporter of this publication from its inception; we have enjoyed at least a page of their advertising in every one of our last 600 issues! Maybe that should be expected. Our publisher worked for B&K before leaving to start *Sound & Vibration* – I think B&K liked his efforts and intent! Jack also coauthored Journey to Greatness – The Story of Brüel & Kjær with Ghita Borring. Copies of this 2012 hardbound book may be ordered at www.SandV.com.

But many of the most important S&V industry contributions were made by younger and smaller companies; consider Time/Data Corporation, founded in 1966 by Ed Sloan, Bob Sackman, Bruce McKeever and Martin Fletcher. They had read the 1965 seminal paper, "An Algorithm for the Machine Calculation of Complex Fourier Series," by James Cooley of IBM and John Tukey of both Bell Laboratories and Princeton University. This paper set forth the details of a fast-Fourier transform (FFT) algorithm and was the impetus that drove Time/Data to build a machine to implement that algorithm on digitally sampled analog measurements. They succeeded and the Time/Data 100 was launched in 1967. Two years later, a faster Time/Data 90 was introduced. Finally, a much-improved Time/Data 1923 based on the popular PDP-11 minicomputer augmented by a bit-reversed counter and other custom transform speed-up hardware was introduced in 1972. These brilliant leading edge offerings were probably a little ahead of their time, and insufficient units were sold to satisfy the company's private investors. Time/Data was sold to the General Radio Company.

Jason Lemon was a professor of mechanical engineering at the University of Cincinnati. In 1967, he left the university and formed Structural Dynamics Research Corporation (SDRC) to provide consulting services regarding vibration and other matters of structural dynamics. SDRC quickly evolved as a software developer with highly successful finite-element and solid modeling codes. Their IDEAS® computer-aided design software became an industry standard.

Albert Klosterman's structural analysis

building block approach (SABBA) software pioneered the use of a minicomputer with swept-sine vibration data from a Spectral Dynamics Co-Quad system to identify modal parameters. The firm was so successful consulting in a narrow subset of vibration analysis that it has inspired two generations of professors to run a similarly focused "business" at the university. David Brown followed by Randall Allemang developed and led a unique learning experience, providing practical "hands-on" experimental work augmented by rigorous theoretical studies. Graduates of their Structural Dynamics Research Laboratory (SDRL) are eagerly sought by industry; they are self-starters and proven problem solvers. SDRC was purchased by Electronic Data Systems in 2001.

Federal Scientific Corporation was formed in 1957 by Henry Bickel and Reinhold Vogel supported by a team of Columbia University researchers. The new company's goal was to commercialize radar signal processing technology developed at Columbia. A device called the coherent memory filter evolved into the time-compression real-time analyzer (RTA), a hybrid audio frequency spectrum analyzer employing an analog-to-digital converter, a recirculating time-history memory, a single detected crystal filter and up/down heterodyning to measure a 500-point digital spectrum.

Their first commercial instrument, the UA-7, was marketed in 1967. Federal went on to develop a series of ever-improving RTAs culminating in the Ubiquitous® UA-500a of 1975, featuring 10-kHz real-time bandwidth and analysis ranges from 10 Hz to 100 kHz. In 1974, we saw the introduction of the company's first FFT analyzer, the Omniferous® OF-400. This was a 120-lb "portable" FFT instrument offering the full gamut of instantaneous spectra, averaged power spectra, FRF, coherence, cross spectrum, auto and cross correlations and impulse response measurements. Three generations of the OF-400 were produced followed by three generations of the smaller but more powerful 660 series. In 1975, Federal was purchased by Nicolet Instrument Corporation (formerly Fabritek) that had previously provided the ensemble averagers (a companion instrument) for the early real-time analyzers. The company name changed to Nicolet Scientific Corporation and we moved from our "nondescript Harlem loft" (as the *New York Times* described it in 1973 when Judge John Sirica empanelled acoustic experts there to analyze the Watergate tapes) to Northvale, NJ.

Spectral Dynamics Corporation was formed by Laurie Burrows and Hugh Ness in 1961. Their first commercial product was the SD101 tracking filter, an all-important element of a swept-sine vibration testing system. The SD101 was based on a Burrows design from his days as test engineer at General Dynamics. He bravely gave up that job, licensed his design back from General Dynamics and started a very successful company whose story is better told by Tony Keller elsewhere in these pages. But I just need to mention that Spectral (including Tony) saw and studied the Federal UA-7 before embarking on the design of their SD301 RTA. I don't want to make a "Federal case" of it, but part of the reason those early black RTAs from San Diego were so good is that they reflected a fair dose of "upper Manhattan" conceptual thought!

PCB Piezotronics was formed by Bob and Jim Lally about a year before *S&V* was born. They began making high-quality quartz pressure and acceleration sensors. Building upon a concept previously patented by David Packard (of HP fame) and things learned while they worked for Kistler Instrument Corporation, they developed and refined their integrated-circuit piezoelectric (ICP®) sensor concept. By building a unity-gain isolation amplifier within each acceleration, force and pressure sensor and powering it from an external, constant-current source, they greatly simplified the use of quartz crystal sensors. ICP transducers eliminate the need for expensive charge amplifiers and cables of known capacitance and they eliminate cable-flex-induced noise.

The company grew from a basement enterprise into a world-wide operation with more than 1000 employees. The external signal conditioning for ICP sensors is so simple that most analyzer vendors now build ICP circuitry into their front ends (under the unpronounceable generic acronym, *IEPE*). The first FFT analyzer to have this feature was Nicolet's 444a and I'm proud to say I'm the guy who got it there and that we labeled it "ICP!"

PCB blessed the modal testing community with their Modally-Tuned® Impact Hammers. These force-instrumented hammers made the measurement of vibration mode shapes far simpler than shaker-excited studies and provided better data for small structures because the boundary conditions of the test item were not affected. PCB joined the MTS Systems Corporation team in 2016. The brothers Lally gave generously to others in our business, providing sensors (including custom prototypes) and business counseling and education to startups and universities. They brought a special kindness and genuine integrity to the noise and vibration control industry.

Mark Richardson headed an application group within HP's DSA division during the 1970s. They focused on modal analysis methods, initially using the HP5451 system. He and colleague Dave Formenti developed a very successful modal "curve-fitter," an algorithm to extract the natural frequency, damping factor and residue (complex amplitude) from a measured motion/force FRF. Their frequency domain rational fraction polynomial algorithm using orthogonal polynomials clearly stood head-and-shoulders above competitive fitters. It was far more precise than simple "co-location methods" such as peak-picking and circle-fitting, because it was a true least-squared-error curve fit. This fitter was clearly superior to time-domain, least-square curve fitters such as the popular Prony algorithm, since it could be controlled to return results solely within a target frequency range.

In 1979 Mark left HP with three old friends of mine from my GM days. He and Dave Formenti, Don Kientzy and Ken Ramsey formed Structural Measurement Systems (SMS) to provide modal software external to an analyzer in an HP desktop computer. Just before leaving HP, Mark and Dave designed and wrote the modal code for the very popular HP5423A structural dynamics analyzer. SMS quickly surprised the industry by offering their structural dynamic modification (SDM) software. SDM utilized eigenvalue modification theory developed by Michigan Technical University's Virgil Snyder and his Ph.D. student John Hallquist. It allowed an engineer to predict the effects of added mass, stiffness or damping on the measured modes of a structure. It was an enormously successful product. SMS went on to develop its very powerful and popular Star Modal and StarStruct packages, the first comprehensive modal software system running in the Windows environment.

In 1984, Paul Mennen, Loren Enochson, George Smith and Richard Bensen left GenRad and formed SIGnology to develop a PC-based analysis solution. Their approach tethered a dedicated instrument box, the SP-20, to a personal computer. The box contained ADCs and a microprocessor communicating with (then brand-new) Texas Instruments TMS-320 digital signal processor (DSP) chips that performed all of the measurement and processing quickly, and then passed results to the PC for display. The PC provided the human interface and translated user entries into processing commands sent back to the microprocessor. This proved to be a very successful system approach. The oscilloscope manufacturing giant, Tektronix, saw the genius in this implementation and bought the company in 1987. The SP-20 was rebranded as the Tektronix 2630.

In 1995, John Van Baren decided to leave Thermotron. He and wife, Val, formed Vibration Research (VR) in the suburbs of Grand Rapids, Michigan. His first product was Windows-based vibration control software focused upon existing Burr-Brown hardware. This was soon replaced by the VR-7500 system, consisting of an in-PC circuit board plus an external hardware box. Van Baren was soon joined by employee number three, his younger brother Philip, who had recently earned his University of Michigan Ph.D. in control theory. They began work on a dedicated hardware shaker-control platform. Brothers Dan and Gerry (and friends at Custom Ideas, Inc.) joined the effort. The outcome of this consortium was the VR-8500 controller; its design was so complete and careful that the first generation (16-layer) PC boards only required a single "cut and jumper" to render them saleable.

That controller is no longer sold today, but its legacy endures through the more

capable VR-9500. VR continues to focus on meticulously designed, reliable hardware in combination with innovative, user-friendly software. John Van Baren may have taken a cue from Per Brüel; he became a multi-engine jet-rated pilot and used those skills to bring VR equipment and people to customers and shows all over the USA. Vibration Research has been very careful not to overstep its area of expertise; they remain strongly focused on single-DOF vibration control and are recognized as the innovators of important new testing methods including field-data replication, patented Kurtosion® (random control with prescribed kurtosis), fatigue damage spectrum control and patented iDOF™, providing protection to valuable test items by controlling accurately at random test initiation and during situations with abruptly changing required RMS level.

The 50 years of *Sound & Vibration's* existence have been filled with unbridled genius and ingenuity. My brief synopsis is merely a light skim from your pot of accomplishments. If I failed to laud your crowning moment or those of your personal hero, it was not by malicious intent. My aging and addled brain simply experienced a "senior moment." I want to personally thank each and every reader for tolerating my thoughts and diatribes in these pages over the years. It has been my joy and an honor to contribute articles and editorials to *Sound & Vibration* since 1976. S&V

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