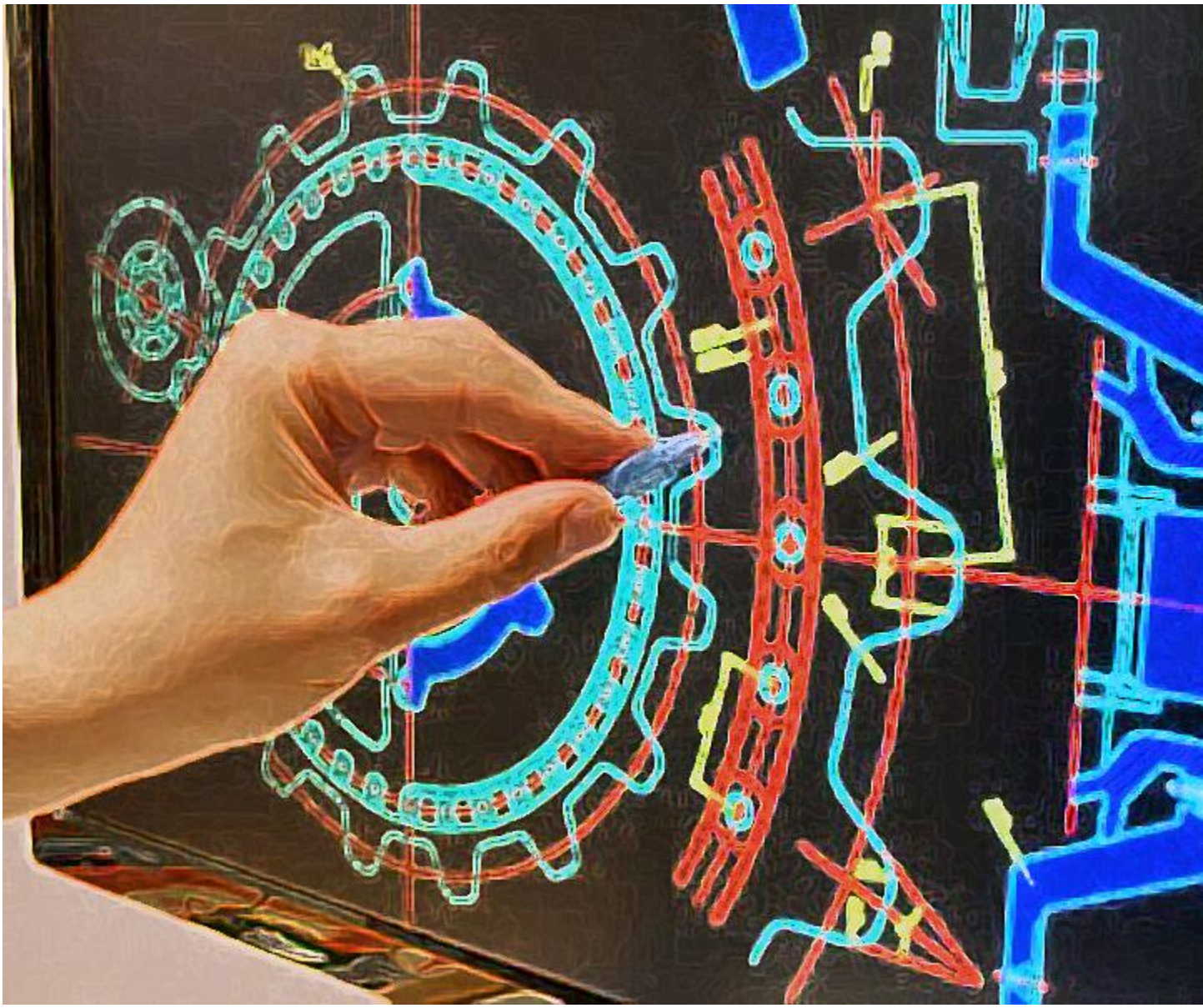


Expert Contributors

MEMS Commercialization Report Card – Part 4: Design For Manufacturing & Test

By Roger H. Grace & David Dipaola

Introduction

Episode 4 will be the first part of a two-part series on the topic of design for manufacturing and test (DM&T), which is one of the most critical of all the 14 commercialization topics, a.k.a., success factors. The 2018 MEMS Industry Commercialization Report Card (Report Card) grade of B+ is one grade lower than that that of the A- grades that it has received in 2015, 2016, and 2017.

Since the inception of the Report Card in 1998, grades for DM&T have risen from the C+ and B- levels prior to 2007 to B+/A- levels. The levels and constancy of these recent high grades supports the author's opinion that MEMS commercialization has reached a mature level in the technology life cycle (see figure 1).

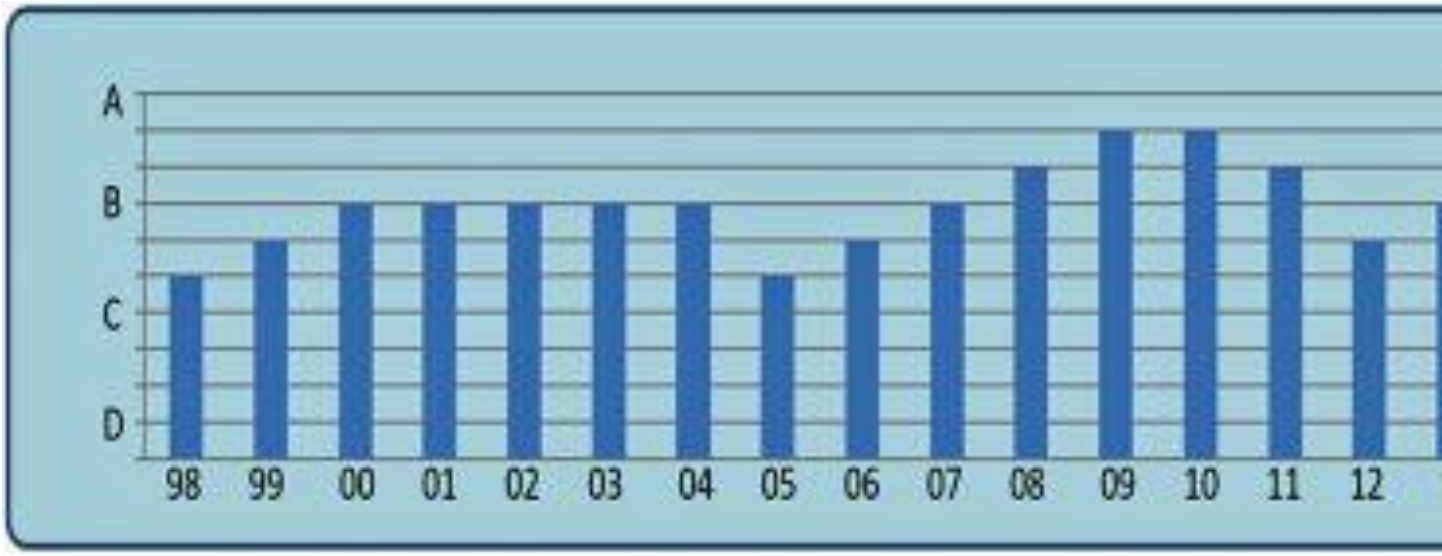


Fig. 1: The Report Card grade for Design for Manufacturing and Test (DfM&T) dropped one grade to B+ in 2018. It had enjoyed A- grades from 2015-2017. DM&T's recent high grades are attributable to the level of maturity in the MEMS product life cycle. Copyright 2019: Roger Grace Associates

In the early days of the commercialization of MEMS circa 1980's, MEMS were considered as stand-alone devices with low-level analog output signals. At Foxboro ICT, a pioneer in the MEMS market and my first position as a MEMS marketing person, they provided customers with discrete carbon resistors specific and calibrated to each sensor and packaged with each sensor and a data sheet to be able to calibrate their piezoresistive pressure sensors.

Users soldered these sensors to the PC board on which the sensor was also mounted with other electronic components including D/A converters, amplifiers, and filters. Over time, sensor producers began to include these electronic functions in what they offered to the market including application specific integrated circuits (ASICS), which provided several of these necessary of functions on one piece of silicon to calibrate and provide high-level digital inputs. We were now on the way to integration.

As these MEMS-based solutions became increasingly more popular, the need to address the entire system became apparent, especially in the manner to which all of the connectivity and integration and was to happen and testing of the approach created. This made the adoption of DM&T critical for the product's success.

It is interesting to note that, as an integral part of DM&T, the concept of packaging and interconnects would play a major role in the ability to provide a low-cost/highly scalable approach that allowed high throughput testing. It is well known that the MEMS package can contribute up to 65% of the total bill of material (BOM) to the cost of the sensor.

This necessitated the need to think about how the MEMS-based solution[1] would need to be manufactured in high volumes to insure their lowest possible cost, highest possible throughput, maximum robustness, and reliability (see figure 2). As a result, it was necessary to create designs that were able to be scalable into high-volume realities at the very early part of the design cycle.

The objective was to no longer make the terrible mistake of creating a suboptimal product that could not be manufactured and tested in high-volume production. Thus, DM&T became most important.

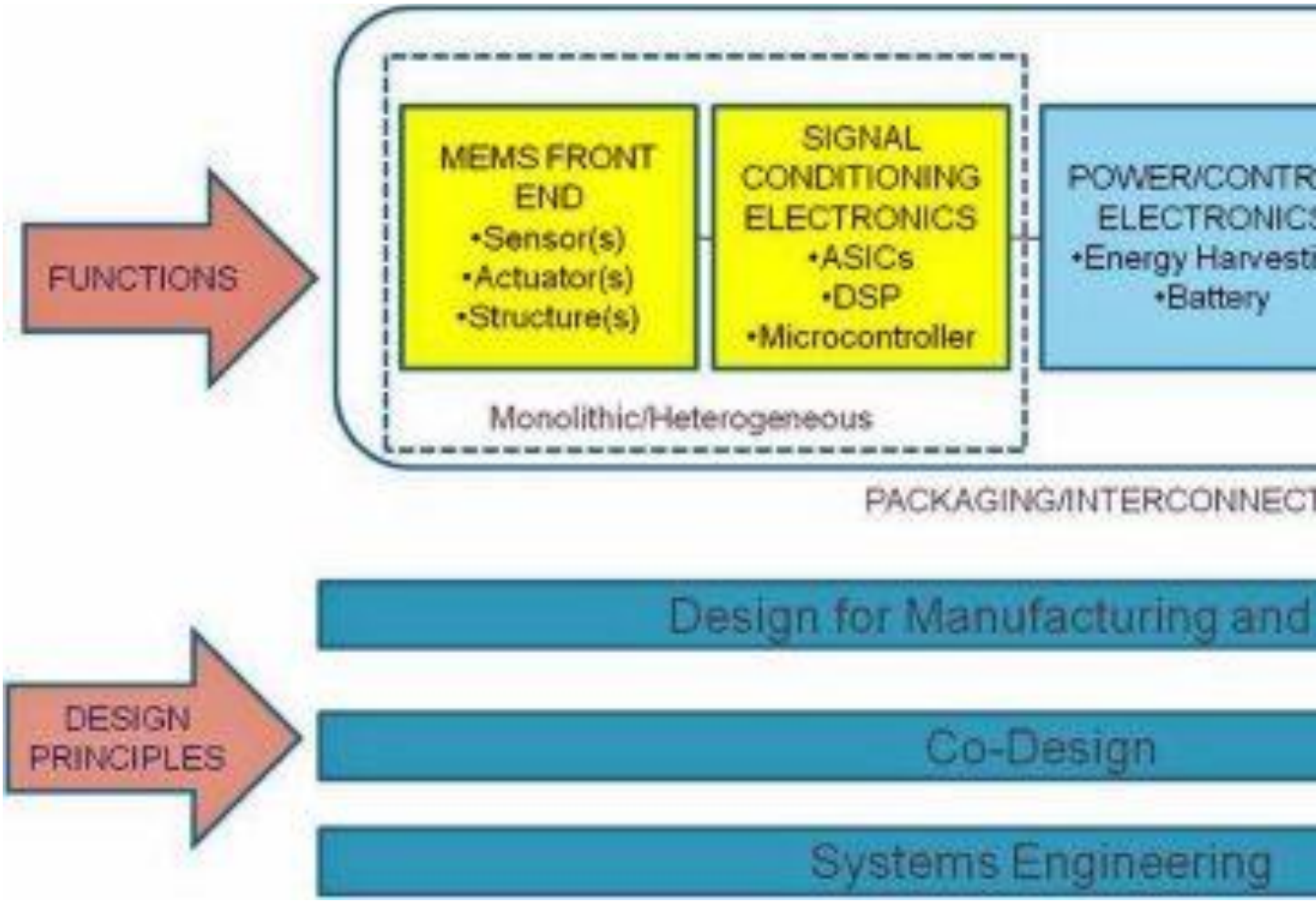


Fig. 2: Sensors are no longer stand-alone components. The majority of sensors are connected to signal conditioning electronics, typically ASICS. Designers of sensors must be aware of all of the possible problems associated with interfaces and packaging in a MEMS-based system solutions approach. Copyright 2019 Roger Grace Associates

The DM&T process needs to be "kicked-off" with what we call the "pizza and Coca-Cola" party. Here, all of the representatives for each element in the commercialization process convene in an open, no-holds-barred brainstorming session discussing each of their requirements, especially from an interface perspective.

The individuals include the system architect, product marketing person or team, device designers, quality control, reliability, procurement, manufacturing engineers, and the packaging and test engineers. The expected outcome of this conclave is to ensure that all elements of the commercialization process are represented from the initial breadboard designs, all the way through high-volume manufacturing and that no critical items are overlooked. I had the pleasure of participating in such events during my days as a marketing consultant with NovaSensor.

Benefits of DM&T

Follow-up interviews with several of the respondents to the report card provided the following comments. They appear in order of importance based on detailed interviews. Benefits of DM&T include:

- **Prevention of costly design changes during production scaling of the product. Instead, do this through an iterative approach off production tools early in the process, which will result in a higher profit margin for the supplier**
- **Reduced time to market. This is especially valid for consumer products that typically have shorter life cycles**
- **Reduction in capital burn during product launch**
- **Improving quality, reliability, robustness, and performance of the product at launch**
- **Streamlining FDA approval (where applicable)**

Many of these attributes are shared by both the supplier and customer.

Use Studies

Several of the respondents to the Report Card were followed-up to provide detailed specific examples of their experiences – both good and bad – in their adoption/or lack thereof of DM&T principles.

Tom Nguyen, Founder and CEO of DunAn Sensing says, "When we initially launched our PNT Series MEMS pressure product line in 2017, we pretty much allowed our engineering team to have carte blanche on creating the design. This was a big mistake. Like most engineers, they wanted to create the very best product on the market for measuring HVAC pressures. They did not look into our internal existing tooling, test fixturing and packaging capabilities and experiences or to look at the availability and suitability of standard "off-the-shelf" components."

"This was a very sophisticated design that regrettably did not meet the market cost requirements or take into consideration the environmental conditions under which the product would be required to operate when using high volume production processes. Conversely, the redesign started by looking at the existing tried and true standard manufacturing processes/tools and then align the design requirements that our product marketing team obtained by "listening to the voice of the customer" in addition to listening to the voices of our manufacturing and test teams."

"As a result of adopting these DM&T principles, we were able to create a design that adapted our exiting test fixturing (see figure 3) and existing mature manufacturing processes thus creating a low-cost solution that met the customers specifications and at a price point that was highly competitive. The resulting product was exceptionally successful in the market…however we wasted a great deal of money and human capital and we lost approximately one year for the redesign process…thus delaying our planned market entry, costing us sales and not being designed into several applications."

Lessons learned:

1. **Bring together all potential contributors to the marketing/sales, design, development, manufacturing and test team for a "pizza and Coca-Cola party" in the early stage of the product development.**
2. **Make a critical assessment of all in-house capabilities and competencies to create the product…make every attempt possible to use what resources you have and/or make modifications to suit the specific design.**

Fig. 3: Proper fixturing is critical for the creation of high reliability and cost-effective products. Shown here (foreground) is a test platform, a.k.a. test tray, which holds 25 sensors. These trays, in turn, are loaded into a cassette (background) with 20 slots resulting in cassette-to-cassette movement of the product through the test process using minimal human handling. Courtesy: DunAn Sensing

Joe Mallon, Co-Founder of NovaSensor and former CEO of Measurement Specialties (now TE Connectivity) reports, "I consider DM&T to go beyond that which happens inside the MEMS supplier's walls. It needs to also consider the critical suppliers to the product and processes."

"I believe that the success of a product is 20% due to its design, 20% to selecting the right technology for the design, and 60% for the infrastructure creation and selection. The infrastructure needs to consider all of the elements from idea conception to delivering the solution to the market. When we created NovaSensor and the industrial MEMS pressure sensor MSP product line at MSI, we virtually designed the company from the inside out; the team of people, the processes, and the equipment."

"Our decision to create this product in 1995 started with considering leveraging our existing high-volume manufacturing capabilities from manufacturing our consumer product line of scales in Shenzhen, China and our silicon processing line for the load sensors, which were critical to the scale's design in Hong Kong. We invited a team of highly experienced sales and marketing people to a meeting in Hong Kong for approximately four days to share their ideas and opinions, vis-à-vis brainstorming sessions of what the product needed to do from a specification and features perspective and who would be our competitors. Once that was done, we aligned the competencies of our Shenzhen manufacturing team with our design team in New Jersey."

"We replicated, to the best of our ability, the rapid prototyping processes and manufacturing tools in the States and transferred them to our Shenzhen facility. Although we were tempted to use highly available low-cost manual labor in the testing of the devices, we decided that we needed to automate this process and created the optimum fixturing to accomplish this in a maximized throughput and minimum cost fashion…we just could not afford to allow failures in the field with improperly tested product, especially since we were the new kids on the block in this application sector. The MSP product line was very successful in the OEM market sector, especially where harsh media interfacing was necessary. We achieved several very high-volume applications including a brake pressure and diesel fuel pressure measurement pressure sensor for out TI Customer."

Lessons learned:

1. **Make a critical assessment of your organization's total existing competencies and capabilities, especially in the manufacturing and test area and maximally leverage to create new products.**
2. **Think "outside the company box" and bring in suppliers/partners/customers into the DM&T process.**

Summary

The 2018 MEMS industry Report Card grade for the topic design for DM&T came in at B+, a grade lower than the previous year of A-. DM&T has maintained strong grade for the past several years primarily from the fact that the MEMS industry is maturing, and based on the several case studies provided above, people are heeding lessons learned.

Infrastructure, as discussed in our previous episode[4], and its judicious application and management is a critical element to a successful DM&T strategy. It should be known that DM&T principles need to reach outside the company as proposed by Joe Mallon and others.

Creating a strong, highly communicative and interactive in-house team coupled with a strong external infrastructure will pave the way to successful MEMS (and other products) commercialization. Part 2 of this most critical-to-successful commercialization topic will appear in the February 19 issue of Sensors Daily. At that time, we will take a deep dive into the concept of DM&T especially as it applies to the medical devices sector.

Learn More

Design for Manufacturing and Test will be one of the many tracks scheduled for the upcoming MANCEF Commercialization of Emerging Technologies Conference (COMS) to be held from October 19-22, 2020 in Rockville, Md. (suburban Washington D.C.). For more information, please visit www.mancef.org/COMS2020

REFERENCES

[1] R. Grace, Thinking Outside the Chip for MEMS Design Success, Electronic Products, February 2010, www.rgrace.com

[2] R. Grace; Barriers to the Successful Commercialization of MEMS Devices, Part 2, Technology Clusters; Sensors Daily; January 8, 2020

[3] R. Grace; Barriers to the Successful Commercialization of MEMS Devices, Part 1, Introduction; Sensors Daily; December 3, 2019

[4] R. Grace; MEMS Commercialization Report Card – Part 3: Infrastructure

About the Authors & Their Companies

David DiPaola

 **David DiPaola is Managing Director of DiPaola Consulting. As an engineer and entrepreneur, David specializes in providing inspiration, design and commercialization for his customers. Through inspiration he provides leadership and business consulting to startups and existing corporations. David also provides design and commercialization services helping customers bring their electromechanical products and sensors from concept to high volume production and all the steps in between.**

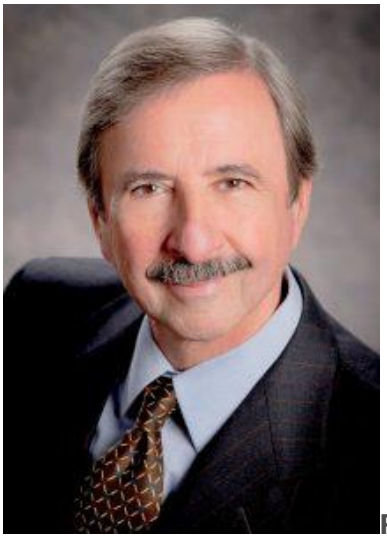
David is also Chairman of the Operations Board at MANCEF specializing in Emerging technology commercialization and is Chairman of the COMS2020 conference in Washington D.C. Capital Region being held Oct 19-22, 2020. Previously, David held technical staff and leadership positions at Texas Instruments and Sensata Technologies and was VP of Global R&D for TT Electronics, PLC. He holds 6 patents and has 3 pending.

About DiPaola Consulting

DiPaola Consulting is located in Rockville, Maryland and provides leadership, business, design and commercialization consulting services for global customers from entrepreneurs and startups to multibillion-dollar corporations. The company's niche is electromechanical products, sensors, micro / nano, wireless, data analysis and software. It also provides complete system design and commercialization of converging technologies. This includes supplier and process development, FDA certification guidance and failure analysis from validations and field returns.

In leadership and business development, DiPaola Consulting helps companies drive new growth and improved margins by building new and derivative products that leverage their core expertise and technologies. This includes developing a company's vision and product roadmaps, intellectual property creation, clean room management, competitive analysis and technical due diligence of mergers and acquisitions. In 2020, the company celebrates nine years of service. For more information, visit www.dceams.com.

Roger H.Grace

 **Roger H. Grace**

Roger H. Grace is president of Roger Grace Associates, a Naples Florida based strategic marketing consulting firm specializing in high technology. His educational background includes a BSEE and MSEE (as a Raytheon Company fellow) from Northeastern University, and the MBA program at Haas Graduate School of Business at U.C. Berkeley. He has specialized in sensors and ICs for over 35 years with a focus on micro electromechanical systems (MEMS). He has authored over 75 technical papers and articles, organized, chaired, and spoken at over 50 international technical conferences.

Roger is frequently quoted as an industry expert in major international technical and business publications on the topic of technology commercialization. He was the co-founder, past president, and currently is the Vice President of the Americas of the Micro, Nano and Emerging Technologies Commercialization Education Foundation (MANCEF), and has served on the Board of Directors of the Florida Manufacturing Extension Partnership from 2008 to 2014. For more details, contact Roger via email at rgrace@rgrace.com.