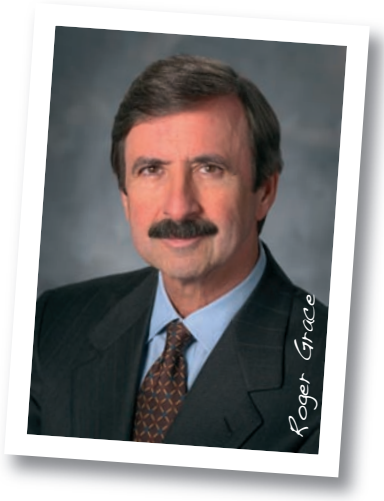


Barriers to the Successful Commercialisation of MEMS: **The 2011 MEMS Industry Commercialization Report Card**

words | Roger H. Grace, Roger Grace Associates

Introduction/Motivation

The MEMS Industry Commercialization Report Card was introduced by me in 1998 as a direct response to a request to participate on a panel of the infamous 'rump session' at the prestigious Solid State Sensors and Actuators Conference a.k.a. 'MEMS Hilton Head Conference' which is held biannually at Hilton Head South Carolina. The topic that I and my fellow panelists were asked to address was "why were there not more MEMS millionaires." Being a marketing research person, I was compelled to conduct an informal study over the several days prior to the session in an attempt to find answers to this question. After numerous interviews with conference attendees, I concluded that there was a high degree of correlation of many of the responses from the interviews as to the key factors that precluded the creation of a successful commercialisation of MEMS, I called these 'critical success factors' and addressed these nine topics during the session. After undertaking additional research on this subject over the next several years, I concluded the enhancing of the Report Card with an additional five topics.

MEMS COMMERCIALIZATION REPORT CARD

SUBJECT	98	99	00	01	02	03	04	05	06	07	08	09	10	11	Δ	S.D.
R&D	A	A	A	A	A	A-	A-	A-	A-	A-	B+	B	B	B+	+1	1.64
Marketing	C-	C	C+	C+	C+	C	C	C+	C+	C+	C+	C	C	C+	+1	2.02
Market Research	C	B-	B-	B-	B	B	B+	B-	B	B	B	B+	A-	B	-2	1.78
Design For Manufacturing	C+	B-	B	B	B	B	B	C+	B-	B	B+	A-	A-	B+	-1	3.03
Established Infrastructure	C+	B	B+	A	A	A	A	A-	A-	A-	B+	B+	A-	A-	0	1.97
Industry Association	INC	INC	INC	B	B+	B+	B+	B	B	B+	B	B	A-	B+	-1	2.54
Standards	INC	INC	INC	INC	C	B-	B-	B-	C+	C	C	C	C+	C	-1	1.56
Management Expertise	C	C	C+	C+	C+	C+	C+	B-	B-	B	B	B	B	B	0	2.98
Venture Capital Attraction	C	B-	B+	A	C	C-	C	C+	C+	C	C-	D	D+	D+	0	2.64
Creation Of Wealth	C	B-	B+	A	C	C-	C-	C-	C-	C	C-	D+	C-	C+	+2	2.70
Industry Roadmap	N/A	B-	B	B+	A-	A	A	B	B-	C+	C-	C-	C	C	0	1.81
Profitability	C-	C-	C-	C-	C-	C-	C-	C	C+	C	C-	D+	D	C-	+2	5.42
Employment	INC	INC	INC	INC	INC	C	C	C+	C+	C+	C	C-	C	C+	+1	2.72
Cluster Development	INC	INC	INC	INC	INC	B	B+	B+	B	B-	C+	C+	C+	C	-1	3.04
Overall Grade							B	B	B-	B-	C+	C+	B-	B-	0	Ave 2.56

ROGER GRACE ASSOCIATES MARKETING COUNSEL

figure 1

The MEMS Commercialization Report Card was created in 1998 as a metric-based vehicle to assess the status of the MEMS industry commercialisation success level based on 14 'critical success factors.' Source: Roger Grace Associates

It is interesting to note that MEMS technology established vis-à-vis the discovery of the piezoresistive effect at Bell Labratories in 1955 by Charles Smith is approximately the same 'age' as Integrated Circuit (IC) technology established vis-à-vis the semiconductor effect that was discovered at the same laboratory by Bardeen et al. only a few years earlier. More importantly however, the total sales of MEMS as reported by numerous groups at the time was approximately 1/25 th. of the sales of ICs in 1998 at the time of the first report card. The MEMS market has been reported by several organisations to be approximately $10 billion in 2011 whereas Gartner has reported that that total IC market was $306.8 billion in 2011 (approximately a 30:1 ratio). The question therefore is: why is there still such a disparity in the market sizes?

The MEMS Industry Commercialization Report Card has been developed not only to help assess the progress of the commercialisation of this technology but more importantly to serve as a vehicle to help guide industry participants overcome the barriers to the successful commercialisation of MEMS. The 14 critical success factors and their grades from 1998 to 2011 for the successful commercialisation of MEMS is given in figure 1. As one can observe, many of the topics addressed here are given in the MEMS commercialisation process presented in figure 2 and explained in detail in reference 1.

Every technology goes through a process of discovery to full commercialisation. Presented in figure 3 is a summary of the commercialisation timetable for a number of popular MEMS devices [3]. As one can see, it took 30 years on average to fully commercialise MEMS devices, from the discovery phase (average of 10 years), through product evolution phase (average of 12 years) and finally through the cost reduction phase (average of 12 years). We believe that future MEMS device commercialisation timetable can be facilitated with close attention to the results and rationale of the MEMS Industry Report Card.

Research Methodology

After the informal market study conducted in June 1998 described above, I was motivated to conduct a more formal approach to determining the status of these factors. I emailed the 1998 study results to my international database of MEMS industry key decision makers in early 1999 and

requested them to 'grade' their opinions of the 'state' of the MEMS industry as well as provide rationale for these grades. These interviewees represented the user, supplier and infrastructure (tool, materials, foundry and software) suppliers, thus closely representing the MEMS industry in general. Every year since 1998, I have conducted this study and have received between 75-120 responses to the study request annually. This market research approach is called 'Delphi', where a limited number of industry experts are queried as to their opinions on a certain subject versus the approach known as statistically significant research which uses large samples to create projectionable results, similar to pollsters to project election outcomes. In the following paragraphs, I will share some of the results of highlights of the 2011 study which resulted from 75 inputs. Presented are grades for seven of the key factors compared to the 2010 grades. I have also provided the standard deviation for each of these grades to provide an indication of the degree of agreement of the participants for each topic.

Results

R&D: 2010 Grade = B, 2011 Grade = B+, Standard Deviation = 1.64

MEMS R&D activities increased in 2011 primarily due to the general revival of the worldwide economy. This subject has historically gained excellent grades in the 'A' level ever since the inception of the study. The industry slowdown of 2008 to 2010 resulted in a reduction of R&D expenditures in the overall tech community. It is my opinion that both R&D and marketing are the first expenses to be cut during economic downturns. There was strong agreement on this grade with the standard deviation coming in at 1.64, which was the second lowest after 'Standards'.

Marketing: 2010 Grade = C, 2011 Grade = C+, Standard Deviation = 2.02

MEMS Marketing has always fared poorly in the past; regrettably it has never emerged from the 'C' level. I concur with the respondents that the primary reason for this is that most MEMS companies are managed by engineers who believe that "if you make a great product, you would be successful and make lots of money" and we all know that, in most cases, this is a fallacy. With my over 30 years' experience in MEMS (and other industries) marketing, I believe that the MEMS industry suffers from a serious technology or product 'push' versus a market or applications 'pull'. Many products that have been introduced have suffered from a lack of adequate up-front market research. Please refer to figure 2 where marketing is the beginning of the commercialisation process. Also, I believe that proper promotion of MEMS has been at an inadequate level. With rare exceptions have MEMS companies done an adequate job in the promotion of their product offerings to establish customer benefits and create differentiation of their offerings. Organisations who I believe have done an exceptional job in the marketing of their goods and services in 2011 include Invensense, ST Microelectronics, MEMSIC and most noteworthy the MEMS Industry Group (MIG). I have addressed this issue in detail in my presentation "MEMS Marketing: Oxymoron or Opportunity" [2].

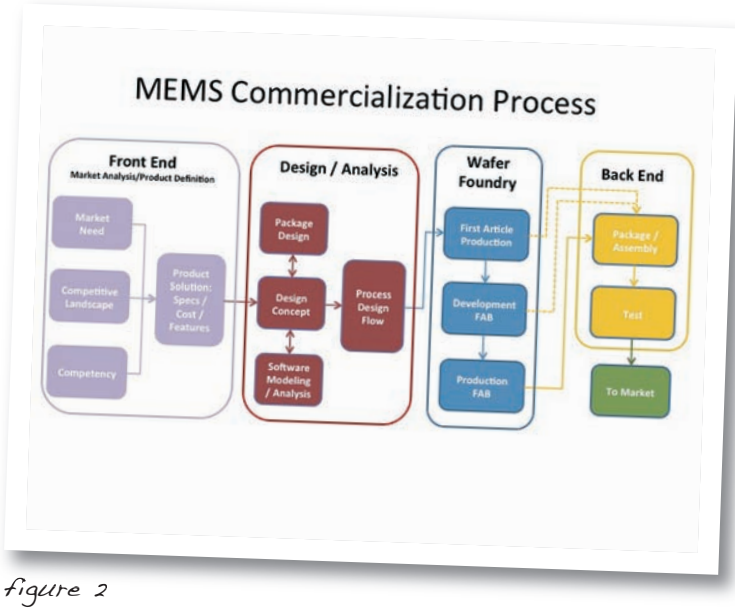


figure 2

The successful MEMS Commercialization process is driven by market research activities to define the product/service continuing to a complex assemblage of design/manufacturing/assembly/packaging and testing infrastructure. It concludes with the 'applications/market pull' of an integrated marketing communications programme and properly established sales distribution vehicles to bring the product/service to market. Source: Roger Grace Associates

Established Infrastructure: 2010 Grade = A-, 2011 Grade = A-, Standard Deviation = 1.97

MEMS Established Infrastructure has received strong grades through the entire report card history. Infrastructure encompasses all of the materials, equipment and services necessary to design and manufacture MEMS devices. Included in this are tools/equipment, materials, design software, packaging/test and silicon wafer foundries. Only a small number of MEMS device suppliers including ST Microelectronics, GE NovaSensor, Analog Devices, Bosch and MEMSIC have their own fabs since there is a proliferation of silicon foundries worldwide that are quite capable of producing silicon MEMS wafers. Referring to figure 2, these foundries primarily exist as development foundries in research universities and institutes including University of Michigan, Stanford and UC Berkeley in the US and Fraunhofer, IMTECH and CEA-Leti in Europe. Many commercial development foundries take the early design and provide design for manufacturing and test functions to support cost-effective and robust medium scale production quantities approximately in the 200-500 wafer-per-month level. Some of these organisations include IMT, Asia Pacific Microsystems, Micralyne and X-Fab. Large scale foundries including TSMC and Global Foundries provide 8" inch Silicon wafer capability for large volume/low cost applications. Many tool and metrology makers support the MEMS R&D as well as production requirements, including SUSS Microtech, EV Group and Polytech. These toolmakers and metrology instrument providers have done an exceptional job to create products specifically suited to MEMS development and production activities. Since MEMS packaging is a key element to its commercialisation, a number of packaging houses currently exist for this, with Amkor being in the high volume area, and a new entrant, Smart Microsystems Center

being a development packaging and reliability assessment house. A recent startup, Acutronic provides inertial MEMS development testing capabilities. Ample MEMS design and analysis software tools exist from companies including SoftMEMS and Coventor.

Standards: 2010 Grade = C+, 2011 Grace = C, Standard Deviation = 1.56

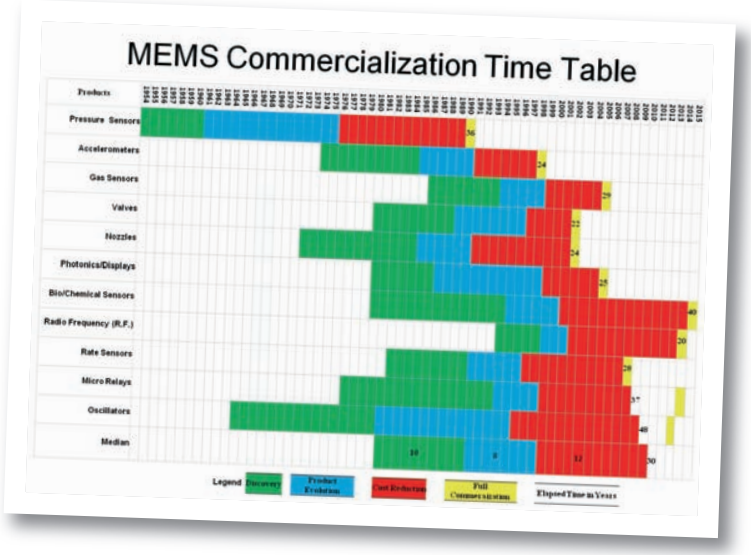
The need for the adoption of MEMS standards has been the topic of many conferences and panel discussions for many years. Numerous attempts have been made by various organisations to develop standards for the MEMS industry. I was personally involved with many of the early MEMS standards meetings in the late 90's sponsored by Semiconductor Equipment and Materials International (SEMI) but with little success. While SEMI boasts over 700 standards for the IC industry, there are less than 10 MEMS standards. Recent activities by the US-based NISTin cooperation with the MEMS Industry Group are revitalising discussion on the topic. There was a general consensus that standards would be beneficial to help facilitate the successful commercialisation of the MEMS industry, the big question is what areas of MEMS manufacturing and testing would benefit most and which standards would have the highest likelihood of being adopted.

Venture Capital Attraction: 2010 Grade = D+, 2011 Grade = D+, Standard Deviation 2.64

The economic downturn of 2008-2010 had significant negative effects on the funding of many startups, especially MEMS. We are just beginning to see the "light at the end of the tunnel" over the past 12 months where money is being made available to continue to support startups. One shining star of the VC funding of MEMS was the New York Stock Exchange initial public offering (IPO) of Invensys, a MEMS gyro company who raised over $65 Million in December 2011. Invensys joins only MEMSIC (MEMS accelerometers, gyros, magnetometers and systems), who was the first to do an IPO in the US, and a French company, MEMSCAP (on the French Exchange) as the only pure-play MEMS device companies to have gone public to date. The recent popularity of MEMS in high volume consumer applications has increased the interest in VCs to support MEMS companies. Biotech, nano technology, green energy and now social media have been vying for the interest and the dollars of the VCs and have been very successful at the expense of MEMS organisations.

Figure 3

The MEMS Commercialization Timetable provides an assessment of the time that has been required to translate various MEMS products from the discovery phase to full commercialisation. Source: Roger Grace Associates/Prof. Steve Walsh, University of New Mexico.



Creation of Wealth: 2010 Grade = C-, 2011 Grace = C+, Standard Deviation = 2.70

2011 was a major year for positive change in the creation of wealth category with a positive change of two grade points. It shared this distinction with the topic profitability. Not since the glory years of 2000/2001 where many MEMS optical telecom component companies received staggering amounts of money to be bought out has the situation been so positive. The major news here was in the acquisition of numerous MEMS companies in inertial sensor and displays by larger firms. Most notable were Pixtronix (MEMS displays in Jan. 2012) by QUALCOMM, Jyve (inertial sensors) by Fairchild, VTI (inertial sensors) by Murata and Sensor Dynamics (inertial sensors) by Maxim. I believe that this aggressive acquisition strategy of MEMS device producers will continue well into 2012 and beyond and has been fuelled by the need of large companies who wish to increase their participation in the mobile phone/tablet market with MEMS products to support their 'bundling' sales strategies. This intense interest has also been a by-product of the reduction of internal R&D investments during the 2008 to 2010 timeframe (see above) as a way to accelerate innovation and make up for lost ground in their product line development by acquiring, rather than attempting to internally develop, critical technology.

Cluster Development: 2010 = C+, 2011 Grade = C, Standard Deviation = 3.04

I have recently written an article in this publication on the topic of cluster development. In the research that I conducted to write the article, it was evident to me that there was a great deal of activity in the continuation of the funding of existing clusters and the demonstrated success of the clusters in facilitating the commercialisation process. However, I believe the reason for the reduction in grade has a great deal to do with the lack of information dissemination of the various clusters worldwide as to their value added to the commercialisation process vis-à-vis success stories. Could it be that the clusters are doing a poor job of marketing (as addressed earlier in this article)? Also, it appears that there have not been many new MEMS clusters recently formed.

Summary and Conclusions

The 2011 MEMS Industry Commercialization Report Card has assessed the grades of 14 of the critical success factors

that I consider to directly govern the successful commercialisation of MEMS. The Delphi market research methodology utilised provided for insightful assessments by some of the world's leading authorities in the MEMS industry from a broad selection of industry perspectives. The 2011 grade remained at a B- from 2010 and the average standard deviation of the 14 topics through the 75 respondent answers was 2.56. From a business perspective the topics of 'Creation of Wealth', 'Profitability' and 'Employment' enjoyed relatively significantly increased grades. This bodes well for investors and participants. Additionally, R&D and Marketing saw single grade improvements. I believe that all of these topics were greatly influenced by the steady improvement of the world economy to fund these activities and the double-digit compounded annual growth rate of the MEMS market sales reported by several market research organisations, most of it coming from the major adoption of MEMS accelerometers, gyros, electronic compasses and microphones into mobile phone and tablet applications. I am hopeful that the results of this Report Card will have value for participants and those interested in the MEMS industry to facilitate the successful commercialisation of MEMS, especially vis-à-vis lessons learned from other industries including the IC industry. Due to the limits of space available for this article, only seven of the 14 topics could be presented. For a more detailed explanation of the report card and the rationale for the grades, please go to my website.

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Roger Grace is President of Roger Grace Associates of Naples, Florida, a marketing consulting firm which he founded in 1982, specialising in the commercialisation of MEMS. His firm provides business development, custom market research, market strategy and integrated marketing communications services to high tech clients worldwide. He has published over 20 articles in industry publications, organised and chaired over 50 MEMS technical sessions and conferences and is frequently quoted in the technical and business press as a MEMS industry guru. He was a visiting lecturer in the School of Engineering at the University of California Berkeley from 1990 to 2003. He holds BSEE and MSEE (as a Raytheon Company Fellow) degrees from Northeastern University where he was awarded the "Engineering Alumni Engineer of the Year Award" in 2004.

rgrace@rgrace.com
www.rgrace.com