# 1

# INTRODUCTION

## Chapter Leaders

**Steven T. Walsh**
***University of New Mexico***
Walsh@unm.edu

**Job Elders**
***Alcatel Optronics Netherlands***
job.elders@kymata.com



## Executive Summary

The purpose of the International Microsystems Roadmap (IMR) is to assist in the development of an industry based on the second micro-manufacturing revolution known alternatively as: Microsystems Technology (MST), MEMS (Micro Electro Mechanical Systems) and Micro-machining. This roadmap in particular aims to "Speed-up" the process of commercialization of products based on microsystems technologies through the pre-competitive sharing of information between over 300 firms that have assisted in this process. The IMR committee, through the thoughtful development of the information provided by its members, seeks to provide value to the entire stakeholder community. Specifically those stakeholders include:

1) MEMS/MST-based product users and potential users (i.e. systems integrators, entrepreneurs, etc.)
2) Suppliers to MEMS/MST manufacturers
3) MST/MEMS manufacturers
4) MST/MEMS researchers and research institutes
5) Policy makers
6) The Angel, Venture, M&A, Investment Banking capital communities
7) Industrial and academic entities seeking to institute facilities

## 1.0 The Nature of Microsystems

Microsystems technologies are an emergent (nascent) disruptive technology base. They form the basis for radical or discontinuous innovations, which if successful, can revolutionize the manufacturing methodology for existing industries or create new ones. This type of commercialization is the cornerstone of the "Winds of Creative Destruction" that is the basis for extreme wealth and job creation. It is also typically an extremely lengthy process. The average time to full commercialization of disruptive technology based products varies by the author doing the study, but has never been reported to be less than 14 years, and is on the average in excess of 17 years. Thus any roadmap that could accelerate the commercialization process would be very valuable.

The emergent microsystems technology-based industry is based on a family of disruptive technologies leading to innovations which are discontinuous in nature rather than evolutionary. However, the family of microsystems technologies is an extreme form of a disruptive technology base. The product technology paradigms that have been derived from this family of technologies are not found in the usual single industry but rather span many industrial settings. These technologies enable product technology paradigms that form the basis for a meta systemic discontinuous innovation platform. The need to accelerate the commercialization process for this extreme form of a disruptive technology is therefore magnified.

## 2.0 Disruptive Technology and Discontinuous Innovations

Microsystems technologies are an emergent or nascent disruptive technology base. Disruptive technologies are scientific discoveries that break through the usual product/technology paradigms creating a new technological competency base. They provide a basis for a new competitive paradigm. Discontinuous innovations are products/processes/services that provide exponential improvements in the value received by the customer. Microsystems-based products are a source of discontinuous innovations.

***Disruptive technologies*** have been referred to as inflection point, earthquake, game-breaking, whirlwind, typhoon or emergent technologies. The nomenclature is not important, but the phenomena have become increasingly important to firms. No longer the domain of

entrepreneurial firms, disruptive technologies change the current product-technology paradigms. These paradigms are replaced by new manufacturing bases with new technological competencies or by new technologies with a new manufacturing base for products and industries that do not yet exist. They initiate the development of new firm-based competencies and are the wellspring of future sustaining technologies.

***Discontinuous innovations*** have been called radical, architectural, generational and revolutionary innovations among many others. They are often based on disruptive technologies but can also be the product of current sustaining technologies that produce higher-value propositions. They provide step-function improvements to current product market paradigms or produce the physical and service products that initiate new industries or markets that define a new and differing product platform from which incremental innovations are generated.

## 3.0 Our Goal

Our goal is to speed up the commercialization process of the emergent microsystems community through the development of an effective roadmap for all stakeholder groups. We will use techniques, whenever possible, developed in other road-mapping efforts, while recognizing the unique nature of microsystems as an emergent disruptive technology base. Specifically, we will try to:

1) Speed up the over 17-year process of disruptive technology innovation by at least 1 standard deviation
2) Provide a common nomenclature
3) Prepare the first ever disruptive technology roadmap
4) Use tolerance as our critical dimension
5) Provide a roadmap that allows companies and individuals to develop a roadmap of their own

## 4.0 The Nature of Roadmaps

Firms routinely perform roadmap processes, so do countries, regions, agencies, national labs, and industries. Yet, almost all of these roadmaps are performed on sustaining albeit

sometimes rapidly changing and even high-technology industries such as semiconductor micro-fabrication. How does one then roadmap effectively for microsystems, a disruptive technology, that although both high tech and fast changing, shares little else with sustaining high technology? The task of road mapping the microsystems technology base is daunting.

Microsystems are a nascent disruptive technology with at least seven competing or perhaps complementary manufacturing technology bases. Further, there are variants of all seven. The emergent microsystems industry is an "Era of Ferment" with new processes heralded routinely. There are few dominant designs or standards and the technology's applications span a plethora of industrial settings. Managers, entrepreneurs and technologists with great microsystems-based ideas are enabling the initiation of companies or redirecting the commercial focus of existing firms. Often, these firms have value propositions that change midstream and the resultant product platforms, microsystems manufacturing base or target industries change radically. Yet as an industry, we seek to provide suppliers a pathway, users an expectation, and microsystems manufacturers with key targets they can obtain. Here we provide a selection process for roadmap development and how stakeholders might effectively use the information provided.

We used the process of roadmap selection to define our task and help others to use information in their efforts. This process originates from the management of technology literature. The process assists us and other nascent road-mappers to get their "Hands Around" the challenges they face when road mapping technologies, especially microsystems technologies.

The roadmap selection process logically follows from the content question of "why roadmap?" The process provides a series of questions and constructs that logically bound and define the task. The roadmap selection process is driven by the nature of the technology under consideration and modified by the strategic nature and scope of the roadmap project. The roadmap selection process defines the parameters for the roadmap effort under question.

The broad nature of a roadmap is defined by the nature of the technology under question. The following sets of constructs help define the nature of the technology under consideration for road mapping:

(1) Potentially disruptive versus sustaining technology

(2) Dominant versus multiple manufacturing technology pathways.

(3) Meta systemic innovation versus singular industry innovation

The terms disruptive and sustaining technologies are ubiquitous in the literature. They have taken on an "all things to everybody" nature and are therefore somewhat ambiguous. Here we provide a definition, an example that emphasizes their utility as a construct central to the issue of microsystems road mapping. Disruptive or potentially disruptive technologies such as microsystems are technologies that set up a new production platform based on new set of technological competencies. They create product technology paradigms that challenge, and if successful, render useless the currently utilized manufacturing competency base or the sustaining technology base. A disruptive technology base usually provides a substantially better (factor improvement or better) value proposition along at least one critical dimension to be considered commercially. As these disruptive technologies become industry standards, they too become sustaining in nature.

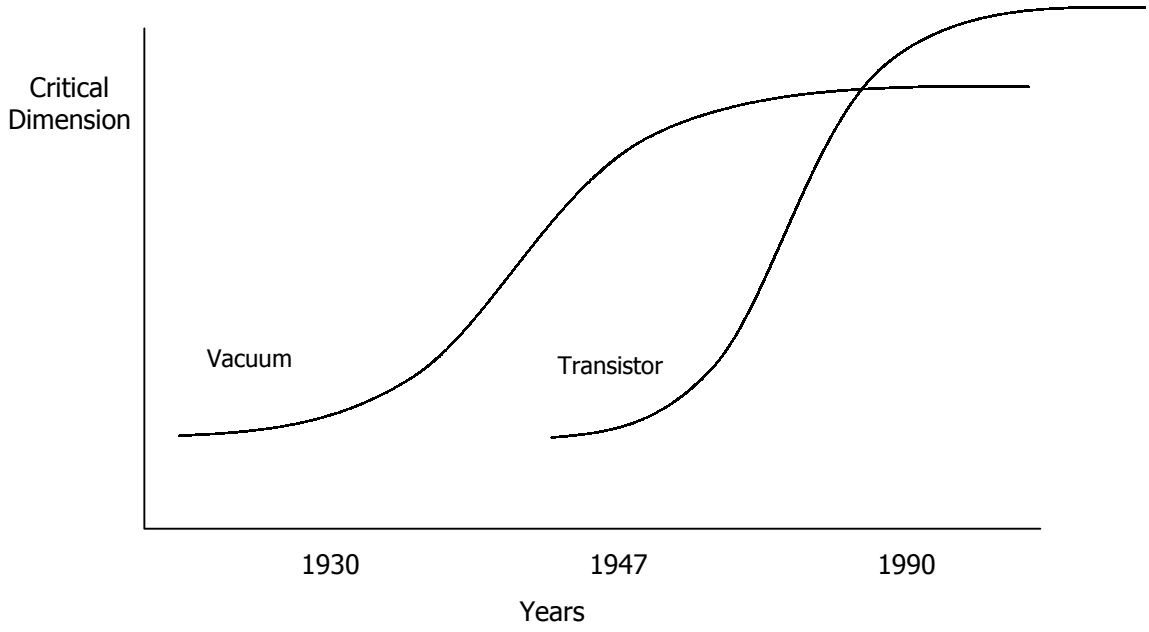


**Figure 1. A Disruptive Technology Displaces a Sustaining Technology.**

Figure 1 demonstrates the successful evolution of a disruptive technology displacing a traditional sustaining technology. In this case, vacuum tubes, the sustaining technology, is

shown being overtaken and displaced by transistors, a disruptive technology enabled by the first semiconductor based micro-manufacturing revolution. Semiconductor-based micro-fabrication, much like other successful disruptive technologies, had at least a factor improvement in both reliability and power consumption relative to vacuum tubes; and for the last 50 years became a dominant sustaining technology.

Microsystems is a disruptive technology and as such is less robust in nature with less of a manufacturing and marketing infrastructure. Microsystems have a broader as well as a less well-developed field of product applications. This suggests an emphasis on the product technology platform rather than the product market paradigm used in sustaining technology based roadmaps. Sustaining technology establishes "Killer Apps" and a dominant technology pathway, allowing for the emphasis on a relatively few product/market paradigms to drive a road-mapping effort.

The second construct (dominant versus multiple manufacturing pathways) provides the roadmap a clearer pathway. Many technologies such as semiconductor micro-fabrication have a single dominant process technology, enabling an easier focus on the product/market paradigm as a driver for the technological roadmap. Microsystems, however, has multiple manufacturing pathways that are effective even for current "killer apps". There are, therefore, few consistent technology product/market paradigms. This again suggests a focus on the product technology paradigm or at least a dismissal of a technological pathway through a Delphi study for particular applications of interest.

Finally, many emergent and sustaining technologies are industry-centric, enabling a single industry focus for the road-mapper and greatly simplifying the road-mapping task. Microsystems technologies are, however, a meta-systemic manufacturing platform, providing a disruptive technological solution to many industrial settings. The multiple industry nature of microsystems suggests either a focus on technology market paradigm or a selected focus on the product/market paradigm.

The nature of a roadmap is further modified and bounded by its strategic purpose. The following sets of constructs help define those bounds. These constructs include the following bifurcations:

1. Corporate versus industrial in nature
2. Market versus technologically concentric
3. Regional versus international in scope.

Perhaps the biggest strategic modifiers of any road-mapping effort are the purpose of the roadmap. Do the strategic focus and stakeholders of the roadmap effort reside in an industry, firm, national labs, agency etc.? A firm-based roadmap, for example, must provide boundaries for the road-mapping effort based on the firm's competency or market interests. National or regional roadmaps for international markets have not had a history of success. However, having boundaries of geographic scope often provides a focus to a dominant technological pathway for that region. Similarly, a concentric market focus or a concentric technological focus either by a firm or an industry provides boundaries.

Here we provide a roadmap that can be used as a starting point by any individual or organization interested in producing a more focused roadmap meeting specific needs.