
In the April Issue...Guest Editor Thomas W. Eagar, director of MIT's Materials Processing Center, focuses on "Materials Manufacturing" with a series of seven articles on:

New criteria for success in commercializing advanced materials • How Motorola eliminated the need to inspect solder interconnections during electronics manufacturing • Solving GaAs IC manufacturing problems, with examples from Hewlett-Packard • Using mathematical models of the injection molding process to improve quality and design of plastic components • How a team at Owens-Corning Fiberglas successfully used Statistical Quality Control • Using statistical process control and metallurgical theories to achieve higher quality aluminum can stock • How to use "Quality Architecture," a pioneering concept to build quality control into the design of a product from the outset.

POSTERMINARIES

A Postterminaries in Three Movements

A premise: The R&D Enterprise is sick. The symptoms presented by the patient must be examined, a diagnosis must be arrived at, and a treatment must be prescribed before the patient dies. In January, we tackled elucidation of symptoms and their interrelationships. This month we search for root causes. Then, if the patient's insurance coverage is verified, the treatment and prognosis complete our visit to the doctor. We expect those hoping for a miracle cure will be disappointed. Homemade remedies may be sent to the MRS Bulletin as Letters to the Editor.

II. The Disconnect Disorder The Failure of Rational Analysis

R&D now faces a myriad of complex symptoms of trouble that seem out of control. Our anecdotal list in Part I only scratched the surface, but we prescribed a precautionary sanity test to rule out dementia in advance.

Scientists are trained to grapple with sets of complex interacting phenomena. We understand and master them by isolating individual cause-and-effect relationships. Then we distill one or a few underlying processes which succumb to rational explanation. This logical approach, however, has yet to deliver us from our current plight, perhaps because from our frame of reference, only problems we don't own and can't control are identified.

Those arbitrary and capricious, irrational forces with the checkbooks—those non-technical types who wouldn't recognize Nobel-quality research if it fell on them—they are the causal villains who own the problems and we are but the helpless and hapless affected victims. Some have even said something along these lines aloud! If

you take that bellyaching seriously, you have failed the sanity test, and our quick and easy self-diagnosis is delusions of paranoia. This is, of course, too simple. A principal symptom does indeed include our being grossly misunderstood, but not by ignorant persecutors. We are sane and they are sane, albeit in disjointed reference frames.

Changing Ponds

Mindsets from a well-fed past make us slow to notice that our fields' public *maison d'etre* has evolved and catches us acting as if in the throes of an identity crisis. This is not our malady *per se*, just as the frenetic flipping and flopping of a fish out of water is not a disease but an inability to recognize and adapt quickly to a change in environment. Believing we can flop back into the same old pond has hampered our recognition of the true nature of the ailment the providers (we) and the customers (they) share. Simply stated, both suffer from a form of *sensory deprivation*. Inadequate *useful* communication across many important intra- and inter-institutional interfaces has allowed us each to define self-serving versions of the dilemma and its cure without due influence by external context. You see, they see a different pond.

The markedly shifted context and rationale for post-Cold-War support of R&D from national security (which emphasized high technical competence *per se*) to economic development (which focuses on near-term measures of success) has been well described in articles such as that by Michael Schrage some time ago.¹ We are apparently quite hard to convince!

Customer Recognition and Relations

As recently as last October, Congressman George Brown claimed, "Most Members of Congress have sort of a warm and fuzzy feeling that science is good. But when it comes down to the nitty-gritty, they don't know why it's good or what expenditure of funds produces good research or science policy."² Clearly, we remain an enigma to those past, present, and prospective benefactors who dearly want to support us and have been and are themselves terribly misunderstood. Misunderstood by us! By us who now suffer not from *delusions* of grandeur but from *withdrawal* from the grandeur of the research labs of the gone and best forgotten "golden age" of post-World-War-II blindly generous funding.

We and our resource-controlling counterparts talk past each other only partly because our languages differ. Equal blame must be placed on differing perceptions of the nature of our relationship. The technical community has been particularly poor at recognizing its *quid pro quo* basis. All the communication interfaces needing attention fall in one category. They are interfaces between customer and vendor. Rather than being a crass commercial analogy, this is a realistic description of roles. No matter how close to the ivory tower we live, receipt of research support implies delivery of a product or service that the supporter expects has been bought. According to Schrage,¹ "Only the blissfully naive or self-deluded believe that society funds basic science for the sake of pushing back the frontiers of knowledge."

The idea that there is a communications disconnect with the customer is sinking in

in some quarters. The new buzz word "linkage," which leapt from the lexicon of the auto mechanic to the jargon of technology transfer, exemplifies this. It is applied variously to broken links in the innovation chain, differing perceptions of deliverables, and cooperation among government, industry, and academe. It points to untended interfaces where we lack trusted translators, ombudsmen, or facilitators, who are not somehow tainted by a special-interest label. Trust and respect once enjoyed by the research and development community has waned and, as in any other facet of life, once lost, it is extremely hard to recapture.

For all the attempts at bridging some of these interfaces, linkage seems hard to come by. The Carnegie Commission on Science, Technology, and Government points out that "effective communication between Congress and the science and technology community requires more than shared information: it demands shared interpretation as well."³ A point more broadly applicable than just to Congress.

This same report complains of a lack of "generally accepted theories or methods for making predictions about the long-term payoffs from 'Big Science' projects or from small individual investigator grants."³ Indeed, predictability of our enterprise has become the easy alternative focus when denying the messy nature of our pursuits. With a prophetically poor choice of wording, an article in *Washington Technology* on the arrival of "accountability at the DOE labs" notes that "still to be worked out is the potential decreased scientific creativity based on an increased focus on accountability."⁴

How else have we come to this sorry state if not as a result of being *deprived* of a clear *sense* of our role in a changing environment?

Old Essentials - New Styles

There was, of course, a distant time when the research customer was more properly described as a patron and analogies to other human endeavors were more valid. For example, the arts are supported by governments and by private (frequently corporate) foundations. These are creative activities and no one questions the artist's need for freedom from direction, from schedules, or from matters of business and bureaucracy. In fact, the creative genius is flatteringly stereotyped and accepted in our culture as being very clumsy in such practical matters. Enlightened patrons (as distinct from owners) know that the painting, the novel, the concerto, the sculpture are not the prod-

ucts they have financed. They are but the means of delivering the real product, cultural enrichment.

Do we not still see our motives and place in the grand scheme as did James Bryant Conant when he wrote, "...the significance of the fabric of scientific theories that have been produced in the last 350 years is the same as the significance of the works of the musical composers. For most scientists, I think the justification of their work is to be found in the pure joy of its creativeness; the spirit which moves them is closely akin to the imaginative vision which inspires an artist."⁵

Although appreciation for opera, ballet, or fine art is an acquired taste rather than universal, there is little debate over their worth. Science appreciation is also an acquired taste and a respectable number of the public (the ultimate customer) follow our fields through popularized lay-language accounts. Nevertheless, the stereotypical dedicated researcher, sequestered in lab coat among gurgling flasks and flashing lights, pondering the mysteries of the universe, while forgetting to eat or sleep, is becoming ever more mythical. Such luxuries are now few in technical creativity because it is here that the analogy to the arts fails.

"The poet achieves immortality when his poem, the specific artifact, is preserved through generations. The scientist achieves immortality by having his work paraphrased into the textbooks of later generations, with perhaps a biographical footnote thrown in."⁶ That is, our products fit as single and often substitutable pieces into a mosaic which is the only thing of potential commercial value. We have altered our style accordingly by burying the creators under a managerial labyrinth intended to vertically integrate each result into its proper product.

In a news article in *Science* on cluster-beam-induced fusion (not the cold variety), an easily overlooked but telling paragraph at the end reveals: "...most people in the field are pursuing little more than the thrill of basic scientific discovery. But press them a little, and they will admit that somewhere in the back of their minds lurks the possibility that their research could someday harbor payoff to people who have never heard of accelerators, deuterium, and fusion."⁷ We have always circumspectly hoped some eventual good would come of our work. Most are uncomfortable selling the end before the means.

These days, more time can be spent writing proposals and chasing funds in business suits than in lab coats. Unlike the arts, the beauty of our individual discov-

eries and the years of tediously created foundations on which they rest are all too easily forgotten in the rush to capitalize on the end (or more often intermediate) result. The quality of today's high-tech life and many (some legendary) commercial windfalls that have arisen from technological breakthroughs blind many to the indispensable intermediate stages that have brought us here. There is a gestation period for new technologies that cannot be rushed and cannot be skipped, but can be damaged.

We know that an R&D enterprise damaged by impatience will neither be satisfying for us nor satisfy our customers' real long-term needs regardless of how slowly we adjust to life in the new pond.

The Tests Came Back Positive

Where does our diagnosis stand? First, if we let the process of natural selection operate, those who still believe in patrons with deep pockets, research funding as an entitlement, and the tooth fairy will soon be extinct, so we needn't bother with them. For the rest of us, our tests for self-delusion have come back positive. We do know who we are. We do know under what conditions the R&D process works well. What we have not yet learned to do is sense and react to the true nature of our current R&D environment, accept who our customers really are, and see clearly where and how our niche must practically interface to and satisfy the new imperatives.

Sensory deprivation is disorienting but not terminal. If treated early, symptoms can disappear with no permanent damage done. Treatment and prognosis in our case will require another office visit in Part III.

E.N. KAUFMANN

References

1. Michael Schrage, *Washington Post*, October 5, 1990. (Reprinted in FYI circular No. 147, October 5, 1990, American Institute of Physics, Washington, DC).
2. George Brown, as quoted from an article in the *Washington Post* in FYI circular No. 154, November 26, 1991 (American Institute of Physics, Washington, DC).
3. *Science, Technology and Congress: Analysis and Advice from the Congressional Support Agencies*, A Report of the Carnegie Commission on Science, Technology and Government (New York, 1991).
4. *Washington Technology*, September 12, 1991, p. 1.
5. James Bryant Conant in "How Impractical are the Humanities?" by Louis Salomon. In *Mirrors of Man*, edited by Obler (New York, 1962) p. 314.
6. David Hawkins, "The Creativity of Science" in *Science and the Creative Spirit*, compiled by Harcourt Brown (Toronto, 1958) p. 136.
7. *Science* 254 (October 25, 1991) p. 515-517.