INVERSE TECHNOLOGY TRANSFER: DEVELOPMENT OPPORTUNITIES

DEFINED FROM PRACTICE

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In the world of technology today, scientists and engineers are concerned about having the results of their work proceed through development to application. This concern exists because of a funding-source pressure to be relevant. One response to this pressure is to become a method evangelist and another is to transfer emphasis from research to technology development. However, a way is available to avoid this unfortunate circumstance and that is to focus on appropriate technology.

Appropriate technology is the technology that makes the most efficient use of the resources available. Several measures can be used to gauge what is appropriate technology. One is the best net return for invested money - that is, technology which produces the greatest impact for the smallest amount of investment. This measure fits with the popular business notion of return on investment, and it has been used most recently to justify the large expenditures on the Retirement for Cause Program, established to reduce materials maintenance expense for the F100 engine between now and the end of the century. Another measure is: that technology which has the widest application. Some technologies are desirable because they have impact in many areas and can be used to address multiple problems. Semiconductor technology is probably the most significant example of this type. Without question, it has and will continue to have a major impact across the entire current culture. Other technologies may be appropriate because they solve a given problem by making the best use of people currently at hand.
In the late 60's, a large cadre of trained physicists were available to work on material science problems, propelling this discipline very quickly from the blacksmith era to a technology area critical to many key industries. But regardless of the measure used, the important question is: who determines what the appropriate technologies are?

Appropriate technology is determined by the users and not the researchers. This may appear to be a forward statement to those trying to persuade others to implement the special technology that they have developed. Nevertheless, users are in the best position to judge which technology is appropriate because they understand the needs that must be addressed in implementation more than the researcher does. The user is closer to the problem and can better assess it. He can also best weigh the benefits and more readily predict costs because he understands the true impact of technology on the final results that are desired. Specifically, he can weigh what a new technology will mean to his current business operation. It is trite, but true: it is the bottom line that really counts. In addition to economic questions the user can weigh more thoughtfully the available alternative methods as he is unbiased. Since the user is trying to solve a problem, he does not have a prior commitment to any method like a researcher does. Researchers often seek to justify their work by convincing a user that the developed technology is most appropriate to a particular problem. Because of ownership, a researcher cannot be unbiased in evaluating the appropriateness of a technology for any real application.

Appropriate technology is not necessarily the most advanced technology. External factors can limit the extent to which a technology can be used in a given situation. For example, there are equipment limitations. Theoretical or experimental results often indicate that an approach can have a large potential impact on a specific application. However, in many cases, these ideas cannot be carried forward because of cost or equipment limitations. For example, many of the control approaches now employed that use computer-aided data acquisition systems were not feasible in 1960 because of the limited capability and cost of computers at that time. Similarly, the best idea has often disappeared or been delayed because it simply was too expensive.

Bureaucratic factors can also limit or define what kind of technology is appropriate. A clear example is how quality assurance requirements can increase the cost and effort needed to implement a new system. Those who develop technologies are often unaware of the additional ancillary activities that must be done before implementation is completed. Approaches must be certified, quality assurance procedures must be established, and, in the case of new materials, tremendous amounts of design data must usually be generated. In typical gas turbine applications, for example, the cost of generating such data can be ten times the cost of the initial material development tasks.
Finally--there is risk. Risk by far is the greatest constraint on what technology is appropriate. Practical people like to progress in slow stages, only putting at risk a small portion of their entire system; they rely on well understood approaches to carry the largest part of in-place processes. They are very much aware that establishing completely new systems requires considerable startup time for debugging and smoothing rough edges. Many realize that it takes much more work to make something work than it does to put it together.

An example from another culture may help emphasize the importance of focusing on appropriate technology. Some time ago, the Indian government established the objective of increasing the productive capacity of its people so that it could generate capital and compete effectively in the world market. The approach to meet this objective was to centralize industry, emulating the methods of industrial countries. When implemented, this approach did indeed improve productivity locally, but it had an undesirable effect—employment decreased substantially, especially in primary industries such as dairy processing and shoe making. Unfortunately, the Indian government was focusing on the method of industrialization and not on the problem of productivity. The key to productivity in a large underdeveloped country like India is to deliver domestic goods to the people while employing all of the people so they have the resources to buy these goods. The appropriate technology in this case was one that makes use of the most people. Further, with local cobbler instead of factories providing shoes, little additional burden was placed on the transportation and distribution system—an important concern in an underdeveloped country. Similar types of comments can be made about the dairy industry. Of course, the manufacture of steel is a different matter; and an alternate approach is necessary.

So from these thoughts, the question then comes: what is the point of this for NDE research? It is: that objectives must be problem oriented and that implementation should be done by people with the appropriate talent; i.e., a user.

In support of the first point, being problem oriented has several advantages. One is that problem-oriented people and teams of people have commitment; all effort goes to solve the problem with little chance of becoming side-tracked on items that are not of interest. Sometimes this commitment must be sustained over long periods of time. The development of the single-crystal turbine blade by Pratt & Whitney Aircraft is a typical example. This technology evolved because individuals were interested in increasing the turbine operating temperature. The limitation to be overcome was the removal of the grain boundary from the cast turbine airfoils. A large effort was directed at this problem from the period
The other advantage of being problem oriented is that attention can be directed toward the best methodology, not just toward the favored one. This focus avoids the criticism of being a tempest in a teapot. Opportunities are abundant for observing the technological shooting stars that are popular for a short time and then fade when it is found that the technology does not fulfill a fundamental need. The meteoric size of Si$_3$N$_4$ and SiC as potential structural materials in large gas turbine engines is such an example. Much effort was expended and many papers were given before the ceramists became aware that the material properties of interest to designers of high-temperature turbine components were creep or stress rupture, not strength. Once these material properties were measured at typical engine operating temperatures, it became apparent that these materials were not refractory enough to be used in large engines. Being problem oriented also forces one to establish long-range objectives because it usually takes some time to solve a problem—especially when a significant amount of technology must be developed. Retirement for cause is a modern example of how a long-range plan must be established to accomplish a key technical objective.

Lastly, the greatest advantage in being problem oriented is that it is politically and technically possible to stop when it is clear that practical objectives cannot be met by further development of a particular approach. A great risk may exist for those dealing with funding agencies when they identify inadequacies promptly. Fear naturally arises if one plans to tell an agency that an in-process project will not bear fruit and that either another approach or another task appears to be needed. It takes a reasonable amount of courage and cooperation between investigator and funding agent to give the former the confidence that, by being honest, the funds will not be withdrawn.

Another point about appropriate technology is the importance of having those skilled in implementation doing the implementing. This view, that researchers should not implement the technology they develop is recognized to be contrary to the current trend where researchers are expected to justify their work by carrying it through to application. To follow the popular approach is not to make the most effective use of technical skills. By forcing research people to do development, our investment in the future is diverted: We are no longer exploring new approaches to solve problems. Also, inefficiency of resource utilization results as research people do not usually have a full perspective of the issues that must be addressed in implementation and they usually lack the fiscal and equipment resources necessary to complete an implementation task.

Of course, researchers must be aware of how their technology will be ultimately used. This is part of knowing the problem: The researcher is responsible for establishing which of the methods and
technologies under investigation will be effective so that weak approaches can be culled at the appropriate times.

The art of becoming problem oriented is a difficult assignment because researchers must continually listen to the users that know about the problem. Another difficulty is that the practical person has great difficulty in articulating his problem in the terms associated with the technical area where the solution lies. This is not because he is uninformed; rather, it is because he is not fluent in the language-nomenclature of the technologies available. Nevertheless, the users usually know the value of many approaches and have cursorily identified those technologies with validity for their particular problems. Their method is simple: identify approaches that are rather straightforward and produce the greatest result for the smallest effort. This empirical way is more direct than the contemplative approach of the research and development person.

In summary, this discussion has been concerned with appropriate technology, the technology developed to address problems. Inverse technology transfer refers to the activity whereby the researcher identifies appropriate technology by interacting with the user to isolate problems. The researcher is responsible for this outreach and selection of technologies that address current problems.

Further, the researcher must continually concern himself with the ongoing state-of-the problem as well as with his technological state-of-the-art. If his research misses the mark, if it fails to solve practical problems, it is because his work was not appropriate. Our country's strength has been built on appropriate technology and it is this focus which must be again at the top of the researcher's dedication if our technological leadership is to survive.

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