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Technology Transition-Opportunities and Progress

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Abstract
Don Thompson in his introductory remarks, and many other speakers since then, have talked to the needs for NDE. These fall into three major categories: reliability of the complex constructs that seem increasingly to pervade our civilization; the role of NDE as an important factor in what I might call a rational approach to a "conservation ethic" or a "total life cycle cost" approach to systems;and the use of NDE as a tool for lower cost production. If we accept the validity of these and other needs let us consider the challenge posed by our keynote speaker.

Disciplines
Materials Science and Engineering

TECHNOLOGY TRANSITION-OPPORTUNITIES AND PROGRESS

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Don Thompson in his introductory remarks, and many other speakers since then, have talked to the needs for NDE. These fall into three major categories: reliability of the complex constructs that seem increasingly to pervade our civilization; the role of NDE as an important factor in what I might call a rational approach to a "conservation ethic" or a "total life cycle cost" approach to systems; and the use of NDE as a tool for lower cost production. If we accept the validity of these and other needs let us consider the challenge posed by our keynote speaker.

Our keynote speaker scolded us for our apparent, to him, inability to "get things into the field." Knowledge in reports or even scholarly journals does not necessarily satisfy the needs. This is something that has concerned many of us particularly during the last five years in which there has been a significant increase in the science base underlying NDE (including the work we are reviewing here.) How well, then, is it "getting into the field?" Those of us producing the new knowledge have a normal desire for the satisfaction of seeing it used; those of us who have the practical needs want new approaches to meet them. Are there any ponies in that pile that one of our earlier speakers talked about? Have we found any yet? At the same time, do we have procedures to prevent the oversell in Dr. Sharpe's push-pull slide. Let me briefly review some of the things we've done to try to transition technology intelligently and effectively.

First, of course, is to generate extensive communication between the "scientists" who are generating the possibilities and the "engineers" who will be doing the application engineering or using the new methods. Such "coupling" should be continuous, and include early stages of someone's research to enable the science to vector itself more effectively. Such general communication increases the likelihood that research will not only produce good work, but that it will soon be useful. Beyond this obvious approach, which usually considers generic needs (to an Air Force man an airplane which flies higher, faster and further; to an NDE engineer a more sensitive, more reliable method) we have found it useful to create forums, e.g., a workshop, in which possibilities and needs can be interacted under the stimulus of specific "windows." For example, instead of merely citing the need for more reliable, more sensitive NDE methods for engine components, present a requirement to determine 99.9 percent of 15 mil flaws or larger (99 percent of the time) in the bolt holes or blade slots of nickle base superalloy disks if one is to develop a maintenance philosophy based upon the retirement for cause of engine parts rather than the current retirement after a fixed arbitrary life. This is a window; citing technical goals and specific opportunities for their use. Bringing "possibilities" and "needs" people together in a workshop environment has not only defined approaches towards known windows, it may lead to the definition of unrecognized windows to profitably exploit a new possibility. Workshops like this have been very useful, but remember, they take extensive preparation, and concentrated (to the point of physically exhausting) attention by the participants.

Defining such windows for our possibilities can take a lot of effort, but offers several advantages. First, it obviously gives us a first potential use for our new possibilities. This also helps to sell the effort and get the resources together for an adequate reduction to practice program. Most important, however, it helps us focus our attention. It gives us a baseline against which to measure if we are really doing something useful and effective, and this is important even if the window which provides this baseline is not the specific way in which the new technology is eventually used.

In my experience, one of the keys to accomplishing the coupling I have been talking about is for some of us to become not only horizontally interdisciplinary (able to help combine the classic disciplines such as solid state physics, chemistry, mechanics and metallurgy) but also vertically interdisciplinary. Some of us must be able to understand, effect combinations between, and even contribute to work at the fundamental end, in engineering development, at the initial application stage, and on service engineering problems. Vertical interdisciplinary people are the facilitators who make communication and rapid technology transition work. I have been encouraging some of you to take on this difficult responsibility, and I am pleased at how well some of you have been doing.

Given possibilities, given the knowledge of what we can or cannot do in a specific area of science, given clear-cut windows, given motivated scientists and application engineers with some interdisciplinary facilitators, we should be able to: establish clear cut reduction to practice goals; define program options; select and obtain resources for some of them and get the major reduction to practice programs under way (Fig. 1). The road maps which Don Forney showed you earlier are then a useful tool for outlining what it takes to get from where we are to the eventual objective. They help organize our thinking and allow everybody to be aware of their roles and responsibilities. Equally important, they help other people, not directly involved in the specific efforts on the road map, but who may be working in associated areas, see how they might "plug in" to make a contribution or to derive some benefit. As with any plan, road maps must be subject to change as our knowledge develops. Optimistic and aggressive time lines and predictions are permissable only if we do not let them become straight jackets or delusions.

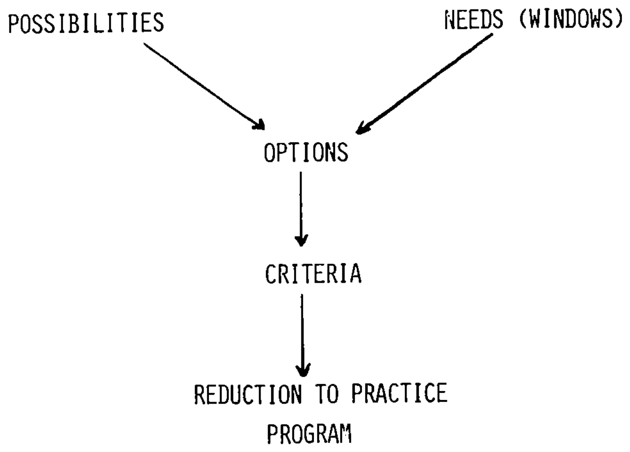

Figure 1. Requirements for technology transition.

Now then, given some tools for stimulating technology transition (communication, windows, roadmaps, workshops, interdisciplinary couplers, etc.), how well have we been doing? The philosophy of the ARPA/AFML program is to work at the fundamental and more speculative end of the R&D spectrum, to identify possibilities for reduction to practice, to spin them off into separately funded efforts (perhaps with some of the same investigators, but with resources from the agencies, etc., which will use the results) while the efforts can be reinvested into the next generation of understanding and new approaches. How many pieces have we been able to spin off, and what are some of the possibilities for the future. I will give you a very brief progress report and I think you will be surprised at how much you have accomplished in a very few years. (We should temper our pride just a little since a few products came early, either because there had already been background work which the ARPA/AFML effort capped off, or there were opportunities to transfer concepts and work from other areas such as medical technology.) You have already heard details of many of these.

In the area of adaptive signal processing the ARPA/AFML program expanded work that had already been underway. Spin-offs now include:

- a small effort in EPRI for corrosion detection
- an AFML activity to develop adaptive signal processing for inspecting adhesive bonds (using separate applied research money)
- plans for separate work to expand the use of adaptive signal processing for inspection of turbine disks

At the same time, there is work going on in the A.F. Avionics Laboratory to provide the chips that will be used in the microprocessers which will be necessary. All of these things, hopefully, can be brought together in manufacturing technology type programs with hardware manufacturers who can produc the complete systems that can, for example, be delivered to our logistics center people at the right point in time to support a new retirement for cause approach to maintenance. In addition, research under the ARPA/AFML program is continuing to provid a new generation of capability: for example, to combine adaptive signal processing with available theoretical models from scattering analysis.

The acoustic imaging work you have heard about is borrowed from medical technology. It has yielde a first generation spin-off which will be pursued i a large manufacturing technology program which will exploit this and other approaches to produce a whol new generation of NDE equipment which we want to provide to Air Force repair and maintenance people over the next five to ten years.

Another example of the equipment the Air Force will try to develop using manufacturing technology funds will be a new generation of advanced pulse echo systems. In addition to a major redesign of the electronics, this program will address the question of the variability of transducers using two "competitive" approaches spun off the fundament program. One will use surface acoustic wave filter to compensate for variability. The other will buil upon some work done under the ARPA/AFML program as well as independent work at places such as G.E. which has resulted in significantly improved transducer performance in terms of reduced ringing and consequently improved signal to noise ratios.

The random signal technique, although explored under a separate ARPA program, provides another example of a spin-off to a reduction to practice program. Here too, it is planned to exploit this approach next year, in a manufacturing technology program to provide an alternative to normal pulse echo methods where much improved sensitivity is needed, such as for thick section titanium.

The electromagnetic transducer work leads even this early in the game, to a wide range of possible applications:

- the American Gas Association for pipeline inspection
- the Army for projectile inspection
- EPRI for reactor steam leaks
- Rockwell International to inspect truck axles.

In most cases, these are funded or "hard planning" spin-off programs.

The early work on measuring moisture content of epoxy matrix resins will also be pursued as a spin-off this year using separate applied research money, permitting the ARPA/AFML program to go back and look into further new possibilities.

The preceding are existing programs or fairly firm plans for spin-offs (although we can expect some change in even "hard" plans) that I am aware of. Some of you may know of others.

Let me now mention two possibilities that appear ready but for which there appear to be no spin-off plans. The first combines our ability to make well defined flaws or discrepancies (for example, by diffusion bonding) with our improved ability to analytically describe scattering from them. It should be possible to use this to provide a wide variety of improved standard defects for calibration. There are no firm funded plans to exploit this, yet. It seems like something some of us should consider doing. The second example involves the recent work which suggests that a real ability to measure surface residual stress in ferrous alloys can be developed. There are other possibilities I'm sure, and perhaps some of you would like to make suggestions.

I would like to encourage all of you to enter into discussions with me, or my colleagues in the Air Force such as Mike Buckley or Don Forney; (and I'm sure my colleagues in the other agencies feel the same) to tell us about additional possibilities which may be ready for transitioning to use. What windows do any of you know about against which we can vector these new possibilities? I'm impressed by what we've done so far, but that's no reason we should rest on our laurels. Are there some particularly pregnant topics where it would be useful to convene a small group of people who know the possibilities, with people who might be possible users, to suggest road maps for spinoff programs?

Finally, let me emphasize the importance of the fundamental scientists who have deep insight into what their work really means (into what we know and what we don't know) keeping some connection with many of these spin-off programs even if they're not a funded, direct part of them, but have gone on to new topics. I'm well aware that subtleties and fine points can be ignored in large, enthusiastic - I think the words often used are "success oriented" - programs. If any of you, particularly in the fundamental community, feel that particular spin-off programs are on thin ice for any reason, I ask you to tell the program monitors about it. If you think they're giving you the idiot treatment, which can happen in a large bureaucracy, come and tell me or some of my senior counterparts in the other agencies about it. After all, the success of technology transition requires that the communication and the cooperation between the fundamental scientists, the application engineers and the eventual users be a total life cycle activity.

DISCUSSION

DR. C. C. MOW (RAND): We have some time to take questions.

DR. BURTE: Or suggestions.

DR. GEORGE MARTIN (UCLA): Your summary and indeed most of the papers here are mainly concerned with finding defects after they have occurred, and sometimes that is necessary. But a thing like weld porosity is something that occurs in the production process. There has been no suggestion so far about bringing the NDT process back to the production stage, using it as a feedback message to control the production process immediately so that you don't make porosity, you don't make the holes in the initial stage.

DR. BURTE: I quite agree with your suggestion. You remember at the beginning I suggested three major categories of need, one of which was for more efficient production. In fact, this whole area of need is going to increase because of increasing activity in computer aided manufacturing. We will need sensors of various sorts to feed into this; it's going to be a big requirement.

DR. DAVID KAELBLE (Science Center): If I can address a point to that comment. Last summer at the ARPA La Jolla meeting there came out identification of a whole class of NDE which is called premanufacturing NDE and that was tied into the very thing that came out here.

DR. BURTE: Some of our more productive windows may well be in that sort of work, but it's going to take some effort on all our part to define these, and then focus work into meeting them.

MR. TOM DeLACY (Ford, Aeronutronics): I guess my remarks would be that I think that in the transfer of the technology we're missing the boat in that we seem to be driven to these boxes. We seem to feel that if you're going to be productive we have to result in a box. I think there should be an office, an area of responsibility within the AFML or ARPA, which guarantees that technology be filtered into the manufacturing community, more particularly into the material sciences community, so that you will eliminate the need for a lot of these boxes. I'll give an example.

I was involved with work in radioactive lighting. The studies were associated with coating development and fused slurry coatings and were especially revealing of problems in the formulations of certain coatings. Techniques such as Mössbauer spectroscopy and otherswhich might evolve from programs such as the ARPA/AFML program would help us to study the oxidation mechanisms in our materials. I think that technology transfer should include as a necessary, important and a very credible product the feeding information into the material sciences community, credible information that will enable us to learn a lot more about the materials and the behavior of materials.

A lot of work that I've seen reported here has been addressing models which I do feel (at least in the short run) will not provide solutions to measure things such as adhesive bond strength. The model will have such limited application (even if we can do it) that it will be impossible to compete with the inconsistency of processing, of variables as they exist and as they will continue to exist. But I think a good part of the technology has applications to the problems of the analysis of fabrication technology that may perhaps eliminate the need for that box. Maybe it will be downstream that we will develop the capability to monitor the adhesive bond strength as well, but in the meantime a good part of the information could serve the material science world and we should accept that charter as credible. However, it seems that at least the general platform here is that if you're not going to generate a black box we're not justified. I think that many of the problems that can be solved are really engineering problems. The problems that have to be solved to eliminate the need for the box, of course, are the materials science problems.

DR. BURTE: Let me comment. I don't disagree with much of what you say. This, remember, is a program to develop inspection capability in areas where it is felt to be needed. However, (and these are words which many of us have said several times) if done well, some of these capabilities can be useful as research tools as well as for actual production line or receiving or maintenance inspection tools. This is well known; it has always been the case for NDE. I don't know if there need be any pressurizing (perhaps I'm wrong) by AFML or ARPA to get the scientific community to pick up the new research tools as they are made aware of them. In addition, I think good NDE research (of the sort we're talking about here which is predicated upon models of what's going on) should have as an "expected byproduct," a considerable amount of feedback to the materials community as to how to make the materials better. For example, some of the work reported by Dave Kaelble has, as a byproduct, directions for how to make less moisture sensitive epoxy resins. In fact, I say an "expected byproduct" because if such information doesn't come out perhaps we have not been doing the research in the right way - perhaps it has been too empirical.

DR. PAUL FLYNN (General Dynamics): I'm rather interested in the technology transfer aspect of this, but in some of the RFPs that have come out in the manufacturing technology area, there are, from the NDE standpoint, demands made to define size, shape and orientation of flaws in structures as complicated as laminar composites and fiber reinforced composites. From the things that were discussed here this is a very tentative ability, even on a laboratory basis--in Dr. Mucciardi's paper, he did reasonably well in looking at size when shape and orientation were constant. I just wonder about the payoff of putting NDE requirements like that in a manufacturing technology program that is supposed to be the application of something that already exists.

DR. BURTE: All I can say is if you think there were unreasonable requirements put in a specific request for proposal, let me know about it or let Don Forney know about it. If the shoe fits, we'll wear it. Tell us about specific cases. That's the request that I made earlier.

DR. FLYNN: Okay, thank you.

MR. PAT RYAN (DOT): There is a funding gap in the intermediate stage of proving feasibility at the lab level and developing for an application. The man who is responsible for solving the practical problem cannot take a risk on something that he can't be pretty sure is going to pay off. There is a need for a venture capital approach in this area, and I wonder if you mean, when you tell us of your windows, that you are in a position to supply some of that venture capital.

DR. BURTE: Yes. Most of the reduction to practice spin-offs I mentioned involve such "venture capital." Even for venture capital areas, though, where you needn't justify the program on the basis of solving the problem involved in a specific window, I believe you need a window so you can measure what you're doing, so you can evaluate your progress.

DR. MOW: I'm sorry I have to cut the discussion off. Don Thompson would like to make a few concluding remarks.

CONCLUSION

DR. DON THOMPSON (Science Center): Thank you very much. That was a very good description of work done to date in this program and by other participants who have attended our meeting.

To conclude the meeting I would like to make only a few comments. As you know, our proceedings have been transcribed by Mr. Voigtsberger. Our procedure after the meeting will be to transmit to the authors the transcripts of their talk for editing and inclusion of the artwork, and then prepare them for publication as the proceedings of the meeting. They will be published as an Air Force Materials Lab report. The attendees at this meeting will receive a copy of the report, and so if there is some reason that that doesn't happen in the future, let me know. This procedure may take on the order of five to six months, depending upon the schedules, times and so forth of both the printing shop and in the workloads of the people who have to edit their work.

I want to thank you all for coming to this meeting; it's been a pleasure to have you here. In concluding, I'd like to make several acknowledgements which I feel are very important. First of all, I wish to acknowledge the support of our ARPA/AFML hosts, Dr. Mike Buckley, Dr. Ed van Reuth, Mr. Don Forney, Dr. Harris Burte; our advisory committee who have always provided guidance for the program; the participants in the program; and our other invited speakers and our session chairmen. Especially, I'd like to thank Roy Sharpe for coming over from England and giving us a very fine summary of the Harwell work and our keynote speaker, the Honorable Harold Brownman. I'd also like to acknowledge with thanks the work of our chief organizer, Mrs. Diane Harris and her staff, Miss Shirley Dutton and Mr. Paul Occor. This group has done an excellent job in organizing and managing so many aspects of this meeting.