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UNIVERSITY BASED MULTIDISCIPLINARY ORGANIZATIONS - PROMISES AND CHALLENGES

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ABSTRACT

The Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University is a multidisciplinary research organization engaged in developing and applying advanced computer-controlled, optical and laser-based diagnostic instrumentation systems for the characterization of high temperature gas streams. Part of the mission of DIAL is the on-site application of the diagnostic systems to large-scale facilities. The laboratory has approximately 40 professional and support personnel. Twelve faculty members are associated with the laboratory and, because of the multidisciplinary nature of the research program, their disciplines cross college as well as departmental boundaries. This provides for unique graduate research opportunities. Moreover, the laboratory employees 12 full-time research scientists and engineers in addition to a number of technicians and graduate students. The overall program of the laboratory and the rationale for such mission-oriented organizations are presented. In addition, it is pointed out that an organization of this type presents particular administrative problems in universities. While the path from instructor to university president is well laid out in the tenure track system, the administrative path in which the cross-disciplinary researchers find themselves is often unexplored by them or university administrators. Though there are clearly numerous advantages to this kind of organization, there are also disadvantages. Most of these advantages and disadvantages apply to many cross-disciplinary research groups to varying degrees, and these are also discussed in a general way. Recommendations for interfacing cross-disciplinary research groups are also given.

INTRODUCTION

It is well know that American industry's technological edge is continually eroding and the competitive position of U.S. industries will only worsen with time unless a concerted effort is made to improve this situation. Even though there is an ever increasing body of basic knowledge (upwards of a million scientific articles are published each year) with continued and rapid advancement in various technological areas, the implementation and transformation of this knowledge and technology by U.S. companies into industrial improvements is not, at present, very effective.

This problem is due partly to the short-term profit motive approach and to the lack of reward or incentive at any level in taking technical or financial risks. In addition, there are no effective federal or state programs to enable industry to take advantage of the extensive research and development work being carried out by universities and federal laboratories. Looking at the future Japanese challenge and at a unified Europe, the question is whether the U.S. will be a player or an observer in the future technology game. Fortunately, there are strong indications that there is a growing desire on industry's part for government to facilitate university/industry technology transfer solutions (Adam, 1990).

American industry needs a program today for increased productivity and competitiveness like that provided the American farmer by the Morrill Act of 1862. This act, which established the land-grant colleges, brought the many disciplines of the academic community to bear on agricultural problems. The success of this program is unarguable. Today the U.S. is the world leader in agriculture. It is clearly not necessary or feasible to establish new universities to aid industry. Rather, a serious and expanded effort to bring together a variety of disciplines to focus on technological problems and to transfer in a direct way that technology to industry will provide the advantage required to compete globally.

In principle, technology transfer is best accomplished in the context of a university setting with an interdisciplinary, mission-oriented, research group, where the talents and expertise of a number of disciplines can be brought to bear on a particular problem or class of problems. This clearly provides several advantages that are discussed in this paper. Various rationales other than technology transfer have lead many American universities to form cross-disciplinary research groups (CDRG's). Often, however, these groups are composed of only a few professors and possibly some support staff. Many technological problems require the expertise of a large number of individuals from a multitude of disciplines. These disciplines can easily cross college as well as departmental boundaries. The effective pursuit of the research objective requires the formation of these large CDRG's with the appropriate support personnel and equipment. Unfortunately, the goals of such a group are not always consistent with the historical expectations of a university in regard to teaching and research, the latter as judged by refereed publications. These characteristics present special problems and challenes as discussed later in this paper. As we point out, an appropriate organizational structure must be formed to allow these programs to flourish. Unless this is done, universities will not provide the focused research necessary to gain a competitive edge in the global economy for U.S. industry.

ORGANIZATION

The Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University has a new program specifically designed to provide for technology transfer in the area of advanced diagnostics. The major divisions of the laboratory are illustrated in Fig. 1. DIAL is an example of a CDRG being a large, multidisciplinary research organization engaged in developing instrumentation systems for the characterization of high temperature gas streams (Bauman, *et al.* 1989; Cook, 365 *et al.* 1985; Hester, *et al.* 1989; Lindner, *et al.* 1989; Wilson, *et al.* 1988; Yueh, *et al.* 1988). Depending on the physical parameter to be measured, the most applicable diagnostic technique is chosen and the specific hardware is assembled and integrated by DIAL personnel. The measurement system is also interfaced with a computer and software developed for control and data acquisition. Some of the diagnostic systems which are developed, or are being developed, are listed in Table 1. The modeling group is responsible for developing models needed to interpret the optical spectroscopic measurements, and models to describe specific large-scale devices. Prototype diagnostic techniques and instruments are tested on a computer-controlled combustion test stand used to simulate the combustion and thermal parameters present at various locations in a fossil-fueled combustion system. Its versatility allows it to be used to simulate any type of combustion condition and

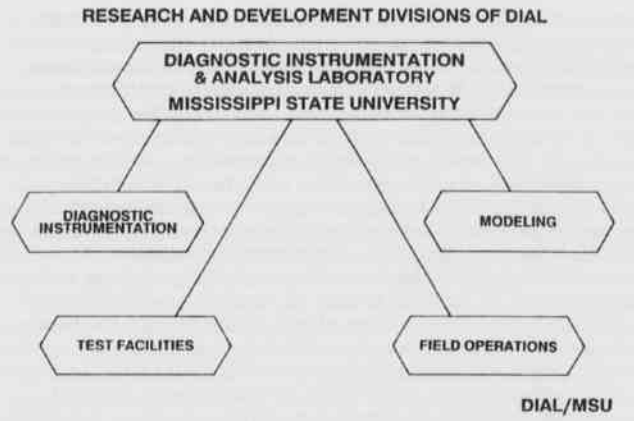

Figure 1. Research and Development Divisions of the Diagnostic Instrumentation and Analysis Laboratory at Mississippi State University.

Table 1. Diagnostic Systems for Characterization of High Temperature Flows

Sodium Line Reversal System (Average Gas Temperature)
Potassium Emission Absorption System (Time Resolved Temperature, K-Atom Density, Electron Density)
Multi-Color Pyrometer System (Wall Temperature and Emissivity)
Two-Color Laser Transmissometer System (Average Particle Size and Particle Number Density)
Laser Doppler Velocimeter System (Local Velocity, Velocity Profile and Turbulence Level)
Gas Analysis System (Gas Composition, e.g., CO, NO, etc.)
Intrusive Multi-Probe System (Optical Temperature Probes -- Wall and Gas Temperature)
Coherent Anti-Stokes Raman Spectroscopy System (Local Gas Temperature and Species Concentration, Temperature and Concentration Profiles)
Particle Size Distribution System (Particle Size Distribution)
Multi-Purpose Imaging System (K-Atom Density, Pressure Profile)
Faraday Rotation System (Electron Density)
Cross Correlation System (Flow Velocity)
Differential Absorption Laser Spectroscopy System (Species Concentration, SO2, NO2, NO, H2O, OH)
Laser Optogalvanic Spectroscopy System (Average Gas Temperature, Qualitative Species Indentification)
Fourier Transform Infrared Gas Analysis System (General Purpose, Rapid, Gas Analysis System)

effluent gas stream. Part of DIAL's program is the application of the diagnostic systems to large-scale facilities. The laboratory staff has, therefore, considerable expertise and experience in using these instruments in the field. DIAL's field team periodically employs the instrumentation systems to measure important combustion parameters in the harsh gas stream environment of magnethohydrodynamic (MHD) test facilities at a number of Department of Energy (DOE) locations around the country. To provide on-site measurements, a large trailer is used to house diagnostic equipment for transportation to, and for use at, a particular facility. Capabilities are provided for use of optical tables for certain laster-based systems. This mobile instrument laboratory has on-board computers for both data acquisition and control of the diagnostic equipment and for on-line data analysis and graphical display of the data in the field.

The development of DIAL's instrumentation systems has not been the work of a single investigator, but a team effort involving engineers from 4 engineering departments, viz., Electrical, Mechanical, Aerospace, Chemical, and scientists from an equal number of science departments, viz., Physics, Chemistry, Computer Science, and Mathematics. The synergistic effect of all team members bringing their expertise to bear on problems has resulted in state-of-the-art instruments that are integrated into a central data acquisition system and are suitable for operation in harsh, real world environments thus extending many diagnostic techniques from the laboratory to the field.

DIAL has approximately 40 professional and support personnel. Twelve faculty members are associated with the laboratory and because of the multidisciplinary nature of the research program, their disciplines cross departmental as well as college boundaries. Moreover, the laboratory employs 12 full-time research scientists and engineers in addition to a number of technicians and graduate students. The breakdown of DIAL's personnel is shown in Fig. 2.

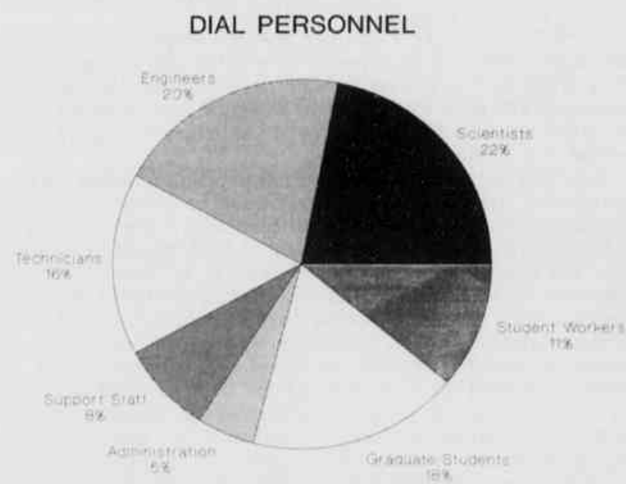

Figure 2. Breakdown of DIAL personnel by category

DIAL PROGRAMS

To provide added insight into a CDRG, we will discuss some of the specific programs of the laboratory. This is necessary to properly understand the advantages and disadvantages of such an organization discussed later, as well as our recommendations for properly interfacing a CDRG with a university. Of course, no single CDRG can possibly include all of the listed advantages or disadvantages. DIAL, however, is a large, diverse CDRG and the authors are experienced with the evolution of this organization over the past decade and hence have an appreciation for the benefits and the problems which can arise.

The overall objectives (see Fig. 3) and approach of the laboratory area as follows:

MISSION - *DIAL's comprehensive mission is to develop and apply advanced optical diagnostic methods to large-scale combustion systems and various manufacturing processes.* Typical industrial applications are found in the chemical, fertilizer, forest products, and oil industries.

GOAL - *DIAL's goal is to improve the effectiveness and competitiveness of U.S. industry through technology transfer of advanced optical diagnostic techniques and thereby impact the understanding, efficiency and environmental safety of industrial processes.* Improving the quality of life and environmental safety through lower emis-

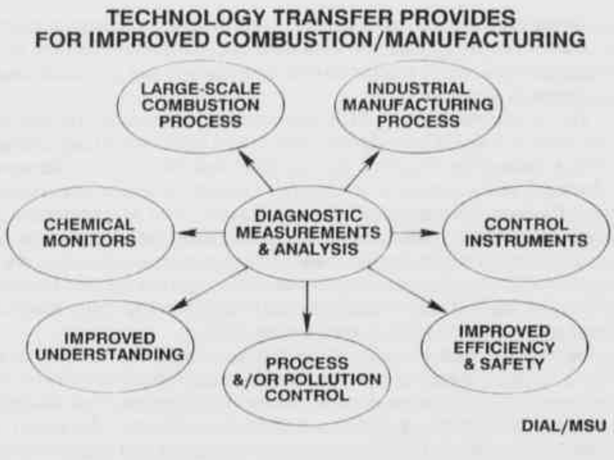

Figure 3. DIAL objectives.

sions of hazardous and toxic waste by developing more efficient chemical reaction processes is particularly important.

APPROACH - *DIAL's approach invoies a unique interdisciplinary laboratory employing the expertise of scientists and engineers with a systems approach to address the many and varied diagnostic problems associated with large-scale industrial processes.* Such problems are not effectively solved with small groups of researchers but require the expertise of a number of disciplines.

Since diagnostic techniques applicable to practical devices are often particularly extensive, it makes considerable economic sense to have a laboratory with state-of-the-art instrumentation prepared to carry out field measurements and to provide data analysis, measurement evaluation and interpretation leading ultimately to an improved process. Moreover, measurements with advanced optical and laser-based techniques prove the applicability of the diagnostic technique, provide data to test combustion models, manufacturing process models, and the information needed to ultimately provide modern industrial sensors. The research effort of this laboratory can lead to increased understanding of the process, reliable models, control strategies, diagnostic and control instrumentation, technology refinements, and hence can have a significant impact on modern energy production processes and the effectiveness and competitiveness of many manufacturing industries. To address the specific problems and needs associated with large-scale industrial processes and to directly affect the engineering science base of such systems, various programs have been formulated by DIAL for technology transfer, diagnostic instrumentation development, analytical model development and validation, and for assistance in defining diagnostic research requirements.

ADVANTAGES

It has become apparent in recent years that the most effective way to approach some of the more challenging research problems is to bring to bear the expertise of 2 or more disciplines. The synergistic effect of the CDRG can lead to not only an efficient solution of the problem under investigation but can sometimes lead to fundamental discoveries as by-products of this work. The record suggests that it will not be necessary to despair for the future of fundamental discovery if a more applied cast is lent to some areas of university research (Allen, *et al.* 1989). It is apparent that there are strong motivations for the formation of CDRG's. In addition, the ability to support teams that include technicians, machinists, draftspersons, technical editors, etc., makes this type of organization attractive to the individual researchers as it relieves them of some of the tedium associated with the traditional approach.

There are a number of benefits to a problem-oriented, multidisciplinary laboratory, particularly if that laboratory has been able to attract federal and/or industrial support, and if the university involved, though emphasizing research, does not have a large research or funding base. With such a CDRG, modern state-of-the-art laboratory equipment is available for instruction and research to departments that do not have comparable equipment. Also, graduate programs are strengthened by providing assistantships for students, research opportunities for both faculty and students, and expertise to develop and teach new specialized courses associated with the CDRG mission. The undergraduate science and engineering programs are strengthened by providing undergraduates the opportunity to work part-time with the CDRG researchers. In addition, permanent professional staff members are available as adjunct faculty with appropriate departments, and joint appointments of teaching faculty via research appointments with a CDRG make possible the hiring of outstanding faculty. Furthermore, departments can gain research overhead through these joint appointments. Finally, national and international visibility of a CDRG can focus on the university and, in particular, the departments involved.

Another important advantage of a CDRG is that it can provide the opportunity to develop a unique interdisciplinary academic program based on the mission of the particular CDRG. This is best accomplished at the graduate level with graduate courses coming from the traditional departmental listings as well as specialized courses developed and taught by the CDRG personnel. Such interdisciplinary degree programs will be more important in the future. The presence of an academic as well as a research mission is also an important plus when the interfacing of such an organization within the university is considered as discussed later.

Many of the benefits mentioned here are quite generic in nature and apply to most CDRG's. Another contribution of CDRG's whose mission aids local and state industries to improve their effectiveness is that direct economic development can ensue. This, in turn, provides an immediate and visible basis for judging the importance and contributions of university-based research. The usual claims that strong university programs lead to economic development are actually long-term expectations, although research monies, of course, do provide immediate effects on the local economy.

DISADVANTAGES

Previously, we have presented the rationale for a mission-oriented laboratory and have pointed out the importance that they can have on technology transfer and economic development. The concept is receiving attention within the federal government, and both universities and industries are starting to appreciate the importance of such an organization. Although the advantages are many, nonetheless, it must be admitted that there are problems with such a laboratory dealing mostly with perceptions, evaluation standards and administrative conflicts. In this section we discuss, in a general way, typical problems which can arise.

Research with a cross-disciplinary, product-driven focus runs counter to the established structure and protocol of universities (Pipes, 1987). The resistance to the CDRG has its roots in this disruption. This resistance can only be overcome by forceful support of the CDRG's by the university administration. The CDRG is often looked on as an intruder in the traditional academic departmental structure. It is seen by some administrators as a competitor for research dollars, talented people, and limited resources (Kash, *et al.* 1988). The fact that it is, for the most part, mission-oriented flies in the face of the conventional research paradigms and thus, the unfair perception of low quality is often held by those not associated with the CDRG. This quality perception can be a very difficult obstacle to overcome. It affects the professional relationships within departments toward those who hold joint appointments in CDRG's and can be disastrous when promotion and tenure decisions are made. This is especially true if those decisions are made external to the CDRG.

Another difficulty is in attracting quality faculty willing to work on applied problem-oriented projects in a traditional university setting. Faculty often would prefer to carry out a more basic line of research. When we refer to faculty here, we mean teaching faculty with a joint appointment to a CDRG. An additional problem deals with the so-called "unfaculty" (Teich, 1979). The unfaculty are members of a CDRG who do not hold an academic department appointment. These unfaculty often possess credentials equivalent to faculty members. Without the faculty appointment, these researchers are often left out of university decisions and given the feeling of being an unwanted step-child. Attempts to solve this problem by giving equivalent rank to full-time researchers is not particularly successful, because this rank usually does not carry conventional benefits given faculty members such as tenure or sabbatical leave. Also, if the CDRG is located in one college, then faculty from a second college who hold academic appointments in their departments are given university input through their departments, but have no input in decision making bodies of the CDRG's college.

Universities, in general, have little experience with this type of organization and are often unable to properly evaluate the performance of faculty members associated with such groups. University promotion standards are usually not directly applicable to faculty members in a mission-oriented program. In addition, "turf battles" can readily arise with regard to the question of who gets the appropriate credit - which department, which college, which dean, which member of the laboratory team, etc.

A number of university administrators would argue that an individual's performance in teaching, research and service is the basis for promotion with perhaps a stated emphasis, whether real or not, on teaching. On the other hand, the attitude on many other campuses is that teaching is not particularly important but rather research is what determines a faculty member's salary and promotion. The reason for this is obvious. A productive researcher who attracts external funding improves the reputation of the department and university while the overhead from such funds enriches the entire university, as well as the local and state economy.

Considering these circumstances, would not the faculty associated with the type of laboratory discussed here be in a good position with regard to promotion and tenure? The answer is — not necessarily. How is research to be judged? Usually, the bottom line is the number of refereed publications and the number of books. On the other hand, a mission-oriented applied group will publish mostly reports, technical summaries, and papers for conferences and proceedings. These do not carry the same weight, and often times there are no refereed publications suitable to the research being performed. One extreme of this situation would be a university group simply carrying out a proprietary research project for some industrial company. Few, if any, publications would result from this situation. However, this is easier for a uniersity to deal with, having made the commitment to perform such a service.

In addition, work done by a CDRG tends to be associated with the group and not with an individual. Publications coming from a CDRG will often have multiple authors. This is as it should be since each individual makes significant contributions but the product is the result of everyone's efforts. The danger with this is that universities tend to place greater emphasis on individual authorship, and on individual work, rather than on group efforts. This can be detrimental to a young faculty member who is trying to establish his research record in order to obtain tenure, and therefore a deterrent for young faculty members to participate in CDRG's. A further discussion of this and other dilemmas may be found elsewhere (Saxberg, *et al.* 1981).

We have noted that refereed papers dealing with more basic studies are harder to come by in a mission-oriented laboratory. This may be illustrated by considering an example in the area of diagnostic development. A typical research project might be to develop and apply an instrument to measure a particular physical property on a large-scale device. The development procedure would involve selection of the appropriate optical technique, selection and acquisition of the required equipment, integration of these components, followed by bench-top experiments to evaluate the method. If this proves successful, then computer interfacing would follow for system control and data collection. This could take upwards of 2 years for a faculty member heading this development and working at 50% time for the laboratory. Application of the system to a practical gas stream, the original goal, could provide the realization that some basic research work is required to properly implement the technique to a large-scale device. Assuming this work is successful, the research and development project could yield a refereed publication, a number of technical reports, and most likely a significant impact on some applied industrial problem. The question is whether an average of one refereed publication over 3 or 4 years is sufficient to warrant promotion and/or tenure. This, however, is often the nature of applied studies. Also, because of priorities, time to pursue avenues of basic research which become apparent cannot always be provided without directly impacting the applied development work. The same effort using the equipment in a laboratory setting could well have yielded two or three publications.

These problems are particularly acute for junior faculty members. One way out of this dilemma is to allow only senior faculty to work with such an organization. This, however, is clearly not a satisfactory solution, and moreover even senior faculty are not immune to publication pressures. From the above discussion it is apparent that the accomplishment of the mission, i.e., successful development of the instrument, must be included in any fair evaluation of the faculty member's performance.

CONCLUSIONS AND RECOMMENDATIONS

We have pointed out the advantages of CDRG's and how they fulfill a necessary role. The interdisciplinary aspect allows for new ideas to be generated by providing ready interaction between different disciplines. The focused approach serves to maximize the research effort and problem solving capabilities of the group. In principle, the advantages far outweight the disadvantages; however, for CDRG's to be successful, a better way to interface these organizations with the university structure must be found. It should be emphasized that these interfacing problems apply to most CDRG's to varying degrees. Here we give a few recommendations and alternative interfacing suggestions for CDRG's.

Clearly, an organization must operate under a set of guidelines relative to promotion, salary, etc. These guidelines need to be set in concert with the university administration, and need to be independent of whether you are faculty or unfaculty. The difficulty arises in trying to employ existing guidelines to evaluate a CDRG member as pointed out previously. If the university organization is such that individual departments effectively set the standards and evaluate its members directly for promotion and/or tenure, and the role of the college or dean is minimal, then the obvious way to interface a CDRG is to raise it to the level of department having all the rights and privileges of any other department in the university. This interfacing mode is particularly easy if a CDRG has its own interdisciplinary graduate program offering an MS or a PhD level degree. Under these conditions, the difference between the CDRG and traditional academic departments is significantly diminished. Unfortunately, all degree programs are usually through traditional departments and the CDRG has no specific academic role.

In most universities, the departments are subject to certain restrictive guidelines imposed by a college; in fact, their decisions are often reviewed by a college committee which reflects the traditional standards imposed on faculty in the areas of teaching, research, and service. Under these circumstances, the above interfacing solution will not work smoothly and perhaps not at all. Clearly, this situation is further complicated by the lack of a traditional academic role. Unless a CDRG is able to adopt rules and regulations for promotion that reflect its mission it cannot readily prosper. Moreover, the rules must apply to both faculty and unfaculty. As far as joint-appointments with teaching faculty from other departments are concerned, it must be understood that their research will be judged by the CDRG. In the setting of faculty salaries and the sharing of overhead, explicit communication between the CDRG and the appropriate department must be part of the interface. The CDRG mission and the difference in its mission must be recognized by all.

Probably the easiest way to interface such an organization effectively in most university frameworks is to put the group under a separate vice president who appreciates the CDRG concept and who will be a forceful leader and spokesperson for the group. The evaluation guidelines for promotion, etc., can then be independent of any particular college or department. Joint appointments are possible only if the department understands that the CDRG will judge the research of the teaching faculty member. Under these circumstances there are still ample reasons, as discussed previously, for a department to cooperate with a CDRG and participate in its program.

Furthermore, it must be noted that if a university accepts the benefits of a CDRG, then it must also accept the responsibility to support it like any other department of the university. It therefore deserves and requires financial support, and moreover, a reasonable number of permanent positions (not necessarily tenure-track positions) need to be associated with the organization.

Finally, we feel that more such organizations will be instituted — their time has come. If universities cannot find a way to effectively and satisfactorily interface these within the university structure then they will be interfaced elsewhere, and this would be a serious loss to the university community. Clearly, many of the problems addressed in this article would not exist if only unfaculty were involved; however, without significant faculty participation the organization would no longer be a true university based multidisciplinary organization.

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