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SPECIAL FEATURE: TUTORIAL

Organization, management and operation of contemporary academic mass spectrometry service facilities

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The rapid evolution of mass spectrometry in the past 15 years has moved mass spectrometry facilities from the traditional model in which instruments were located in and used for a single department's samples to a distributed model servicing entire universities. In this paper we describe two such shared instrument facilities that have evolved from a base in a single department to facilities that service a broad clientele. The Purdue University Campus-wide Mass Spectrometry Center (CWMSC) is a decentralized facility with multiple sites on campus. The CWMSC is a limited-access facility in which samples are run by service facility personnel in close cooperation with investigators. The Vanderbilt University Mass Spectrometry Research Center (VU-MSRC) is a centralized facility in the medical school that provides services to the university at large. The VU-MSRC is an open-access facility in which users are expected to prepare and analyze their own samples under the guidance of a trained operator. Perhaps the most significant benefit achieved by these models has been the minimization of academic barriers and the resultant intellectual cross-fertilization that has greatly enriched research at institutions where this approach has been adopted. The advantages and limitations of both models are discussed in terms of the traditional academic paradigm of service, research and education.

KEYWORDS: mass spectrometry service facilities; organization; management; operation; academic facilities

INTRODUCTION

Mass spectrometry (MS) fills a unique niche in the rich world of analytical science. Today, mass spectrometry is utilized routinely in all of the basic, engineering and life sciences, more so perhaps than any other analytical technique with the possible exception of chromatography. Indeed, the utility of mass spectrometry today is evident even in history, art and archeology, where MS techniques are used to establish the provenance of art works and historical relics and to study the cultural habits of ancient civilizations. Following the introduction of commercial mass spectrometers in the 1950s, the function of an academic mass spectrometry unit remained little changed for several decades. MS facilities were typically located in a single department, usually the chemistry or biochemistry department, where most of the clientele were located. The home department supplied personnel and operating budgets and instruments were purchased from the department equipment budget. The facilities were meager by today's standards, typically consisting (in the 1970s and early 1980s) of a single high-resolution, double-focusing instrument for exact mass determinations and a low-resolution gas chromatography/mass spectrometry (GC/MS) instrument for mixture analysis. Electron ionization (EI) was used most frequently, followed by chemical ionization (CI) when a molecular mass could not be assigned by EI. The personnel responsible for operation and maintenance typically occupied the lowest rung of the academic ladder, if on it at all, and had narrow prospects for career advancement within the department.

The state of mass spectrometry has changed dramatically in recent years, fueled by the introduction of inexpensive benchtop instruments and even more so by the introduction of advanced techniques to analyze nonvolatile molecules such as complex oligosaccharides, peptides, proteins and nucleic acids. In a very short period the techniques of EI and CI have been augmented with new techniques such as tandem mass spectrometry (MS/MS), fast atom bombardment (FAB), plasma desorption (PD) ionization, electrospray ionization (ESI) and matrix-assisted laser desorption/ionization (MALDI). A recent survey by the Laboratory Manager's Interest Group (LMIG) of the American Society for Mass Spectrometry revealed that electrospray ionization has surpassed EI as the most frequently used technique in service facilities.[1] The newer ionization techniques, in turn, drove instrument developers to expand the range of instrument offerings

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to better address the needs of the biomedical sciences, which demanded instruments with improved sensitivity and a greater mass range. These events pushed personnel at academic MS facilities to purchase new instruments, to learn new techniques and to learn new science in order to support a much more diverse clientele than had been anticipated by the traditional single department management paradigm.

In the late 1960s, a few far-sighted academic research administrators began to place large instruments in National Science Foundation or the National Institutes of Health central service facilities in order to spread the equipment and personnel costs over as many investigators as possible. These facilities were often regional, multi-institutional programs in scope. In addition to amortizing equipment costs over a wider range of users, these facilities were aimed at providing advanced MS to a much wider range of users than could be accommodated by a single departmental instrument facility. Perhaps the most important, but little recognized, advantage of this effort was the lowering of academic barriers and the resultant intellectual cross-fertilization that has greatly enriched research at institutions where this approach has been adopted.

CURRENT STATUS OF ACADEMIC MASS SPECTROMETRY FACILITIES IN NORTH AMERICA

In the spring of 2000, a world-wide survey of academic, industrial and commercial mass spectrometry facilities was conducted by the LMIG on behalf of the American Society for Mass Spectrometry.[1] Excerpted here is a brief glimpse into the functioning of academic MS facilities in the USA and Canada. Preliminary results of the survey were presented at the 48th annual meeting of the society in Long Beach, CA, in June 2000. However, a more thorough analysis of the statistical data collected in the survey will be published elsewhere.

Fifty-six academic facilities (36.1%) in the USA and Canada responded to the questionnaire from a total of 155 replies. Based on the data elicited in the survey, these laboratories are most likely to be managed by a PhD-level scientist (83.6%) with 17 years of professional experience in MS reporting to either the department Chairman (46.3%) or to another senior faculty member (22.2%). Typically, the laboratory is staffed by three scientists including the facility manager. The laboratory is generally the sole or primary MS facility in the organization (78.6%) and is most likely to be affiliated with the department of chemistry (50.9%), biological sciences (30.2%) or pharmaceutical sciences (11.3%). Facility managers are likely to have some teaching commitments, most commonly in the form of instrument training (54.7%), but also formal academic courses (32.1%). Academic MS facilities are least likely to run entirely in an 'open-access' mode (7.4%) or a 'closed-access' mode (29.6%), but rather they operate by employing a combination of the two modes (63.0%). Funding for the facilities generally comes from a blend of departmental support, research grants and service fees. Service fees are generally assessed on a per sample basis (46.4%), on a standard hourly rate (25.0%) or may be individually negotiated (16.1%). Median service fees imposed by MS facilities are \$22 per sample or \$48 per hour for faculty.

THE ORGANIZATIONAL STRUCTURE AND ADMINISTRATION AND SERVICE

The success of an academic MS laboratory depends on a number of factors. The Director must have the ability to evaluate complex instruments, secure funding for them, hire personnel with the skills to operate and maintain complex analytical instruments, acquire the analytical skills to interpret complex data and the intellectual versatility to deal with multiple scientific disciplines. Furthermore, the facility Director must possess the financial and business acumen to create and manage a budget and have the interpersonal skills to solve personnel issues and deal with faculty and administrators at all levels. Success also depends on the support of the research administration in the form of adequate funding and laboratory space, and the ability of the director to communicate the needs of the research faculty back to the academic administration. Indeed, the skills required to manage an academic MS facility are comparable to those required to manage any business. However, the operational model chosen ultimately reflects the culture of the local research community, as illustrated below.

In this paper we compare the organizational and administrative structures of two large campus-wide academic MS service facilities and the impact they have on research and education at their respective institutions. The Purdue University Campus-wide Mass Spectrometry Center (CWMSC) is a closed-access, decentralized MS facility with dedicated instruments and operators in several locales on campus. In contrast, the Vanderbilt University Mass Spectrometry Research Center (VU-MSRC) is an open-access, user-operated centralized facility within the Medical School which serves multiple departments on campus. Both have proven to be effective in delivering quality MS services to their respective organizations. Our aim is to provide research administrators with some guidance as they formulate plans to develop similar campus-wide or regional instrument facilities.

Purdue University

The coupling of the many mass spectrometric techniques with significant research problems requires considerable interaction between a professional mass spectrometrist and users of mass spectrometry. For this reason, Purdue University created the CWMSC in October 1985, with the following goals: (1) to coordinate the operation and maintenance of mass spectrometers which were previously located in different departments, (2) to provide research groups working on significant problems easy access to all of the mass spectrometers on campus, (3) to increase awareness in the University community of the opportunities for problem solving by mass spectrometry and (4) to coordinate the acquisition of new instrumentation as needs evolve. Decentralization, shared resources and economic efficiency are important features of this facility. Key to the success of the facility is the Director, who supervises the staff mass spectrometrists, assists investigators in defining (and recognizing) their needs in mass spectrometry, coordinates access to research mass spectrometers and through clinics, research group seminars, one-on-one meetings and other means, educates the University community in mass spectrometry.

The CWMSC was one of the first, if not the first, interdisciplinary program that crossed school lines at Purdue and as such it continues to provide a model for other programs and centers. A campus-wide NMR facility at Purdue was created in the mid-1990s in part as a result of the success of the CWMSC. The CWMSC utilizes mass spectrometers located in the Departments of Biochemistry (School of Agriculture), Chemistry (School of Science) and Medicinal Chemistry and Molecular Pharmacology (School of Pharmacy). To utilize more efficiently the MS resources on campus and to ensure their use for service and not for specialist MS research, the instruments were located in multiple laboratories on campus to accommodate a large, geographically dispersed faculty. In addition, the CWMSC has pursued a plan that maintains MS expertise in the three departments. This allows close interaction between researcher and analyst even though the specific ionization technique and analyzer needed are not available at each site. This interdisciplinary cooperation insures a high level of quality control for the more routine types of analyses and provides a collaborative analytical MS capability to the Purdue research community with great economic efficiency.

In a typical year between 5000 and 7000 experiments are performed within the CWMSC for between 250 and 300 researchers from over 80 different research groups located in more than 25 departments. This includes supporting research at several Purdue satellite campuses. Most of these samples are individual samples or very small sets of related samples. The Purdue University CWMSC is organized as shown in Fig. 1. The Director and the three staff mass spectrometrists meet on a weekly basis to address instrument concerns, sample updates and specific researcher problems. These meetings are particularly valuable for bringing staff members together to facilitate the flow of information between the three laboratories. The policy committee, consisting of faculty representatives of the three primary departments, meets with the Director on a regular basis. They act as a resource for the Director as well as to provide their input from a departmental perspective for new initiatives in mass spectrometry at Purdue. Each department head is committed to this decentralized, but coordinated concept of MS at Purdue. In addition, the central administration is strongly supportive of MS. Quarterly reports are prepared which highlight the ongoing activities, including fiscal summaries and status of the instruments.

The Director and the staff mass spectrometrists not only obtain data, but also analyze the results, interact with the researchers in interpreting the data and provide preventative maintenance. The special care and commitment with which the instruments are maintained have resulted in only a few service calls, for data system / disk drive problems, in the 15 year lifetime of the CWMSC.

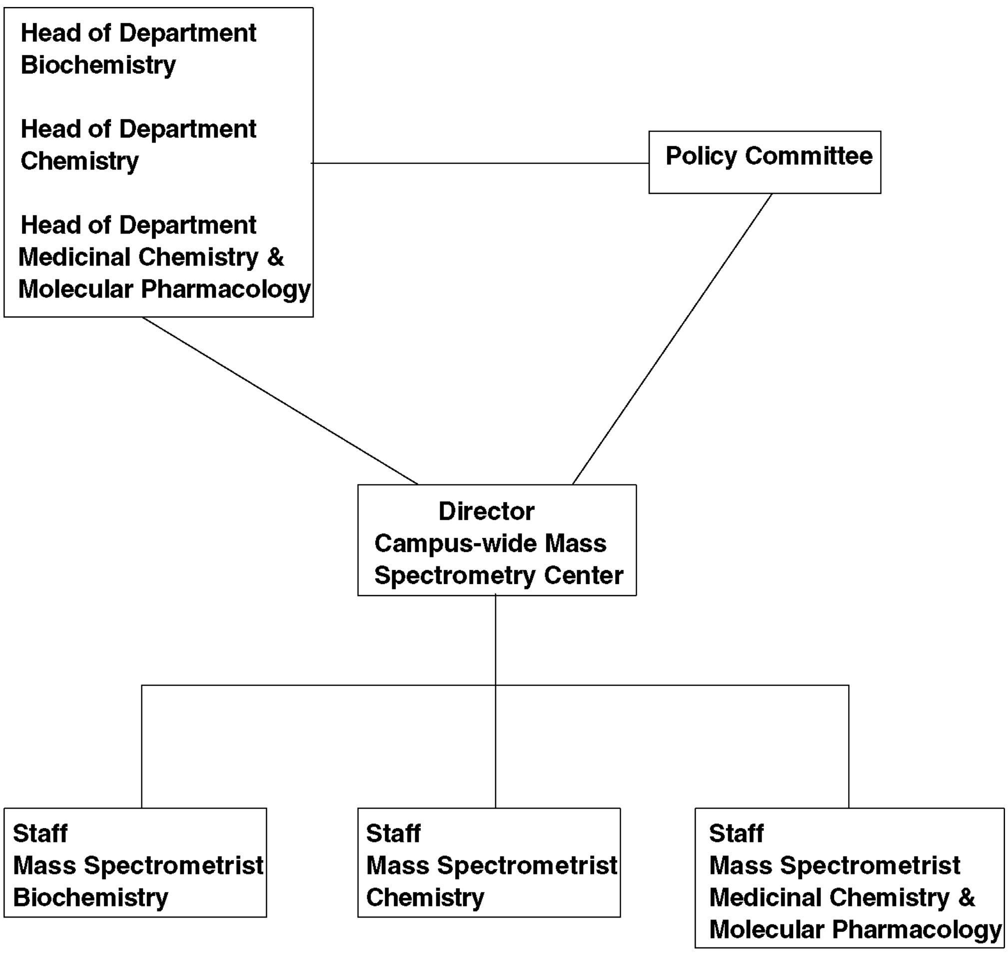

Figure 1. Organization chart of the Purdue University Campus-wide Mass Spectrometry Center (CWMSC).

Table 1. Purdue University CWMSC Service Facility Instruments

Instrument	Age (years)	Use (%)
Finnigan 4000 GC/MS	19.5[a]	29.5[b]
Bioion 20R PDMS	11.0	12.9
PerSeptive Biosystems Voyager MALDI-TOF	5.0	8.6
Hewlett-Packard Engine GC/MS	4.0	8.4
Finnigan MAT 95XL double-focusing instrument	2.5	9.4
Finnigan MAT/Thermoquest LCQ	2.5	9.7
Finnigan MAT/Thermoquest GCQ	4.0	21.5

[a] Average age of two identical instruments.
[b] Total use by both Finnigan 4000 instruments.

Table 2. Ionization techniques most frequently employed (%)

Ionization technique	Purdue CWMSC	Vanderbilt MSRC
EI	44.5	3.0
CI	17.8	43.3
FAB	2.9	—
ESI	12.4	39.7
APCI	—	6.1
MALDI	5.4	7.4
PDMS	9.8	—
High resolution	7.1	—

Table 1 lists a summary of the mass spectrometers that comprise the CWMSC, their location and primary uses. Table 2 summarizes the ionization mode and services most frequently employed by investigators. While it is important that the MS laboratories provide a high sample throughput (ask any of the department heads), one major objective is to provide answers arising from difficult problems. This necessitates not only the appropriate type of sample preparation, mass analyzer and ionization techniques but also the commitment to interacting with the researcher.

Support for the CWMSC comes primarily from fee-for-service charges to individual researchers (40%) and direct institutional support (45%), with a small amount of funds from the Purdue University Cancer Center (15%). An important distinction was made in the beginning that the financial support of the CWMSC would be kept separate from research MS operations.

Vanderbilt University Mass Spectrometry Research Center

The VU-MSRC was formed in 1998 to develop further an existing MS facility and to extend the scope of the resource beyond its traditional department-based inception. The VU-MSRC, which is now an autonomous research center in the Medical School, consists of two principal components, the research facility directed by Dr Richard M. Caprioli and the service facility directed by Dr David L. Hachey (Fig. 2). The purpose of the research facility is to develop novel instrumental and analytical methodologies to solve advanced problems in structural biology and to help solve molecular problems

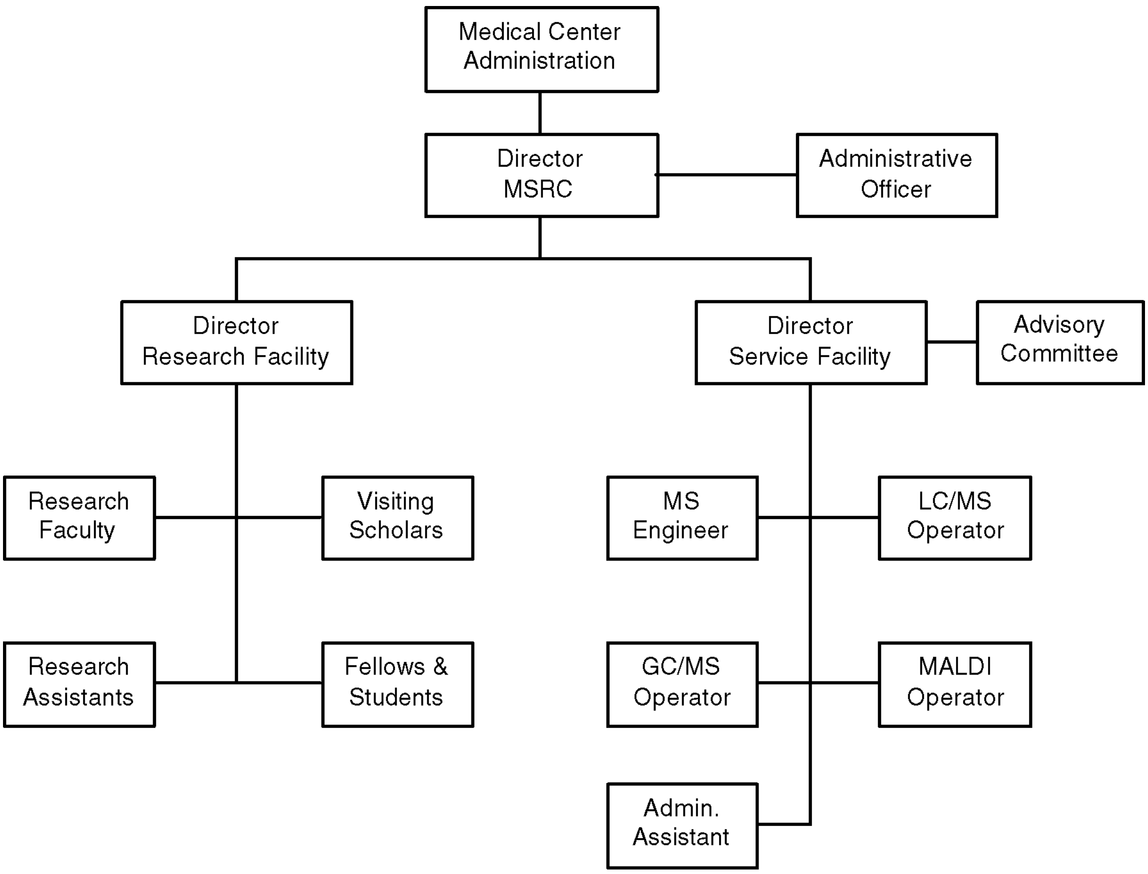

Figure 2. Organization chart of the Vanderbilt University Mass Spectrometry Research Center (VU-MSRC).

using cutting edge mass spectrometric techniques in new areas of biomedical research. An example of this is the technology currently under development for the direct profiling of tumor-specific biomarkers in tissues and imaging of tissues by MALDI.[2,3] On the other hand, the mission of the shared instrument facility is to provide a wide variety of cost-effective, state-of-the-art equipment to investigators for routine quantitation and structural analysis, which tend to require more robust methodologies. The service facility is operated on a user-accessible basis in which users are expected to prepare and analyze their own samples and to manage the quality control aspects of their analytical assays. However, laboratory personnel assist users in developing HPLC and MS methods, develop and document standard instrument operating procedures, maintain quality control (QC) records on instrument performance, help users perform routine assays, perform instrument maintenance and train students and research fellows in the theoretical and practical aspects of MS. Close supervision of users by a trained mass spectrometrist insures that they will learn to acquire and interpret data in an efficient manner and learn to solve analytical and instrument problems that arise.

The MS service facility is managed by a faculty member trained in mass spectrometry and with significant independent research experience in the basic and biomedical sciences. Three instrument operators are responsible for oversight of the LC/MS, GC/MS and MALDI instruments. With a total of nine instruments in the service facility (Table 3), the operators are cross-trained on the different instruments to some degree, but each has a primary responsibility for managing at least three instruments on a daily basis. The primary ionization modes employed most often are summarized in Table 2. Routine instrument maintenance is done by the instrument operators, but major repairs are done by a trained instrument engineer employed by the facility. Finally, monitoring instrument use, purchasing, billing and financial matters are handled by an administrative assistant. In aggregate, the instruments are used 180 h per week which represents the analysis of about 33 000 samples per year. In the first 18 months of full operation the MSRC has provided services to 147 users working for 86 investigators in 24 departments at the university.

A principal goal of the MS facility is to provide high-quality MS services to the Vanderbilt research community. In order to focus on that goal, routine contract work for profit-making organizations is not generally performed in the facility. Support for the facility comes directly from NIH-funded research centers and program project grants (PPGs) (60%), fee-for-service charges to individual grant holders (20%) and direct institutional support (20%). Nearly all of the support for the MS facility comes from federal sources, and so service fees are applied equally to all investigators. Because of the heavy reliance on federal grant support for the MS facility, continuity of funding is an on-going concern. The MS facility provides core analytical services to six PPG and Research Centers with overlapping grant periods, and no single grant source provides the majority of funding. Salary, maintenance and supplies appear as line items in the respective center grant budgets. In order to account for services delivered to the grant, a Center Director generally gives a fixed MS budget to each investigator to which the MS service fees are charged. When the funds are expended, investigators are expected to supply another funding source in order to continue using the facility. The administrative staff monitors the use of the instrument facilities by investigators, deals with financial and business matters and prepares quarterly reports on utilization for investigators and Center Directors. Funding and financial support of the service facility are kept distinct from those of the research facility in accordance with Federal Good Cost Accounting Guidelines. As a consequence of this funding structure, the facility Director is frequently required to assist in the preparation of new proposals and renewal of existing grants. As a service to investigators, the Director also helps with preparation of individual research grants and reviews proposals and budgets for accuracy and appropriateness.

Table 3. Vanderbilt University MSRC Service Facility Instruments

Instrument	Age (years)	Use (%)
Finnigan MAT TSQ-7000 tandem LC/MS	4.6[a]	47.4[b]
PerSeptive Biosystems Mariner TOF-LC/MS	2.0[c]	0.3
PerSeptive Biosystems Voyager MALDI-TOF	2.0	5.5
Hewlett-Packard HP-5989-A GC/MS	6.8	23.2
Finnigan MAT Incos 50B GC/MS	12.0	2.0
Nermag R1010C GC/MS	16.0	5.1
Finnigan MAT Voyager GC/MS	1.5	16.6

[a] Average age of three identical instruments.
[b] Total use by all TSQ-7000 instruments.
[c] Newly acquired service facility instrument.

The interactions between the research facility and the service facility of the MSRC are an important asset of this organizational structure that merits special comment. The majority of users who come into the service facility do not require extraordinary support to acquire data or interpret results. However, when a problem arises that requires more in-depth analysis than appropriate for a service facility that handles hundreds of users a month, that investigator is directed to the research facility whose personnel are more adept at a particular analytical methodology. These interactions inevitably evolve into more thorough collaborative studies between the investigator and the research team member. Conversely, when research techniques such as imaging or tissue profiling become better understood and more robust, users will be able to access this in the service facility. Research personnel also participate in the operator training program of the MSRC, so that students can learn what advanced mass spectrometric techniques are available to them from professionals skilled in a particular technique. The result is a highly interactive and fluid MS facility that satisfies the analytical needs of both novice and experienced investigators and is able to service investigators across a wide range of academic disciplines.

RESEARCH

The opportunity to conduct individual research is necessarily limited in an MS service facility due to the constraints of time and financial resources. The issue of personal research by service facility personnel has been identified as one of the primary factors that affects job satisfaction of facility managers.[1] Most facility managers in an academic institution have an advanced degree and are as motivated by intellectual curiosity as are the research faculty. A certain amount of research is done in most service facilities, usually in the guise of training, when new techniques become available or new instruments are installed so that operators can learn their characteristics.

Purdue University

The Purdue CWMSC places a high priority on coupling the appropriate mass spectrometric capabilities to the research problem. Close interaction between the facility staff and the researcher enhances the overall problem solving capabilities. A maximum synergy is achieved when the research investigator, with his/her knowledge of the experimental system, and the mass spectrometrist, with his/her expertise regarding the instrument capabilities, are allowed to interact to maximize the likelihood of obtaining meaningful results.

One important aspect of the CWMSC is the continued professional growth of the staff mass spectrometrists. This is important not only for their well-being, but also for the continued upgrading of the facilities capabilities as new mass spectrometric techniques evolve. This can occur as a result of collaboration with other researchers to solve a specific problem, as in the determination of the developmental regulation of methyl benzoate biosynthesis and emission in snapdragon flowers.[4] It can also occur as a result of the initiative of the CWMSC staff member whereby an established method used in one area is applied to a related problem in another area, as in the characterization of anthocyanins in wine grape varieties.[5] Similarly, developing the methodology for transferring an analysis from one ionization technique to a newer, more efficient technique has been an important feature over the past 15 years. For example, the analysis of glycine–betaine analogs was initially carried out using FAB. Switching to PDMS in the early 1990's(6) obviated the need for derivatization, thereby simplifying sample preparation. We are now in the process of transferring this analysis from PDMS to ESI (K. V. Wood, C. C. Bonham, D. Miles, A. P. Rothwell, G. Peel, B. C. Wood and D. Rhodes, in preparation).

Vanderbilt University

By design the service and research functions of the VU-MSRC have been separated, even though there is a fluid interaction between the two components. The mission of the service facility is to support and facilitate the individual research of faculty members at the university. However, research collaborations often develop when problem solutions are amenable to using simple modifications to existing instruments. Rather than involve the research facility personnel, it is often more efficient and appropriate to solve the problem using the service facility. As an example, the need arose recently to analyze complex mixtures of highly oxidized cholesterol esters and identify the structures of serial cyclic peroxides present in the reaction products. Atmospheric pressure chemical ionization (APCI) was unable to give a definitive structural assignment. So, following a recent report of the successful analysis of neutral polyunsaturated lipids by 'coordination ionspray' in which silver cations were used to produce charged molecular species in non-polar solvents, a unique solution to the problem was achieved using a standard electrospray ion source.[7,8] Once core personnel had perfected the technique, it was taught to the users who have since put it into routine use. Even though the opportunities for personal research are limited, the diversity of analytical problems that users bring to the facility is enough to satisfy the intellectual curiosity of MSRC personnel because of their close interactions with users.

EDUCATION

A primary difference between the limited-access and the user-accessible models with regard to education is the constantly evolving need to train new users. The limited-access model relies on formal didactic training of users that teaches theory and analysis of data, but does not necessarily impart a practical knowledge of instrument operation. Another difference can be characterized by the centralized/decentralized mode of laboratory operation and the access an individual researcher has to the laboratory personnel. A decentralized MS facility minimizes any researcher / mass spectrometrist barrier that invariably arises due to the distance between the two laboratories. No matter what operational paradigm is employed, the system must prevent users from becoming dissociated from important aspects of the analytical process, including sample preparation, optimization of instrument parameters and analysis of results. Thus, both the CWMSC and the MSRC strongly encourage close cooperation between investigators and service facility personnel. Acquisition of mass spectrometric data is invariably an iterative process in which instrument parameters must be adapted to the sample or the sample prepared in a manner suitable for analysis by MS.

Purdue University

Quality MS necessitates close interaction between instrumentation and problem. This requires the mass spectrometrist to understand not only mass spectrometry, but also how the sample was prepared. Similarly, the researcher must understand the requirements for obtaining mass spectra. Only when both of these criteria have been achieved can the optimum mass spectral results be obtained. This is particularly true at Purdue where only one researcher, in a large user base, submits large batches of samples (~20) to the CWMSC. This emphasizes the individual nature of most samples analyzed and therefore the individual attention needed. The samples submitted address a variety of research interests, with support of synthesis being predominant.

The decentralized setup of the CWMSC enables the researcher to have close interaction with the mass spectrometrist, facilitating the most important aspects of obtaining quality mass spectra, namely sample preparation and the analysis of data. The individual researcher may have obtained some type of formal training in MS, but through individual discussions with the Director or staff mass spectrometrist, or through MS discussions offered to entire research groups, becomes knowledgeable in those aspects of MS having direct relevance. More importantly, the researcher is made aware of the importance of sample preparation. This is particularly true for samples derived from biological material, which can be compromised by the presence of salts, buffers, etc. The researcher does all the method development for samples requiring GC/MS or LC/MS with guidelines from the CWMSC staff. This ensures that the sample being introduced does chromatograph and minimizes potential sample contamination / degradation problems (to the advantage of other users). For first-time users, the interaction with the CWMSC personnel is essential to their understanding both the needs and the pitfalls with regard to coupling a sample to the mass spectrometer through a chromatographic column. This same interaction occurs with all users of the CWMSC to varying degrees, not only to educate, but also to maximize the probability that they will obtain useful results. Although the individual researcher does not operate the instrument, the option is available for him / her to be present during the analysis of their sample, to acquire further appreciation of any aspect of sample loading, instrument tuning, etc. The staff mass spectrometrists make sure that quality data are obtained, but the individual researcher must assess these data to determine how they apply to the problem and, when necessary, to interact with the CWMSC personnel to decide how best to attack a difficult problem.

The quality of data and the knowledge imparted to the research community at Purdue are not hampered by the limited-access format of the CWMSC. The wide range of samples submitted, the large user base and the fact that no one user is overloading the system emphasize the advantages gained in instrument uptime as a result of operation of an instrument by a single operator. Caring for it as well as ensuring timely preventive and corrective maintenance cannot be overstated. This is borne out by the small amount of service that the CWMSC has needed in the past 15 years.

Vanderbilt University

As mentioned above, the MSRC is an open-access, localized user-operated facility. Most of the graduate students and postdoctoral fellows come to the facility with little or no formal training in MS. In order to insure that instruments are used in the most efficient manner, the service facility runs a training program for operators in LC/MS, MALDI and GC/MS. Demand for LC/MS is greatest, followed by MALDI and GC/MS. Training courses are given approximately once a month on an *ad hoc* basis as new students and fellows come to the university. Each course lasts one day and consists first of an overview lecture on the technique covering both theory and operation. The second half is a hands-on tutorial covering instrument setup, operation and shutdown. Each student is then given a one day personal tutorial by facility personnel covering their particular analytical technique in more detail. Novice users are watched closely for several days by service facility personnel to be sure that they are comfortable with the instrument and able to run samples and interpret their data. The service facility Director also reviews the data with them during the early stages so that students become aware of subtle analytical features and how to interpret the data, and perhaps to suggest better ways to conduct their experiments. The overall training experience is highly interactive and users comment frequently on the desirability of having ready access to instrumentation and expertise during their training. The user-accessible mode of operation is intended to promote the research and educational philosophy of Vanderbilt University in which students and fellows take responsibility for their own research. The aim of this program is not to train professional mass spectrometrists, but rather to impart sufficient knowledge that users can speak intelligently on the topic. By requiring students and fellows to run their own samples, their educational experience is enhanced and they are in a stronger position to present and defend their research to the scientific community.

Some aspects of the open access environment deserve comment. Even though the instruments are operated by novice users, no extraordinary instrument maintenance has been required in nearly 2 years of operation as a result of abuse or accidents by operators. No doubt this is a result of the close interaction between facility personnel and users and the effectiveness of the training program. However, novice users generally do not operate as efficiently during the early stages of their training as do the skilled personnel employed by the facility. Casual users with instrument contact less than once a week typically require 1–3 months to become comfortable with instrument setup and operation. The process may take as long as 3–6 months for users to become adept with more advanced features such as tandem MS and the nuances of data analysis. We have noticed recently that more experienced users generally assume a mentoring role within their research group and often work with newer students and fellows on MS techniques that are directly relevant to their projects. As a result, MS expertise is becoming more widely disseminated throughout the university and more research groups are beginning to use the facility as they see the advantages that it brings to their research programs.

CONCLUSIONS

This discussion has compared two successful academic mass spectrometry facilities with different operations, localized / decentralized in terms of location on campus and open / limited in terms of user access, but with the same common goal, i.e. using mass spectrometry to solve difficult and complex analytical problems. The key to providing a quality mass spectrometry facility is (1) providing access to qualified mass spectrometrists who care about finding a solution to a given research problem and (2) having a variety of instruments available with both the mass analyzers and the ionization capabilities for analyzing the most diverse array of samples. Clearly, more than one model is successful in achieving these goals.

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