DESIGNING A MICROSCOPY/ ANALYTICAL INSTRUMENTATION FACILITY: STEP BY STEP PROCEDURE

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Designing a microscopy and/or analytical instrumentation facility can be completed in a step by step approach, whether it is a completely new facility or an existing one moving into expanded quarters. The procedure is independent of size. The same basic procedure is required for one room or an entire building. There are several major factors that must be taken into consideration. Check lists can be compiled by the microscopist/analyst. One should easily be able to start at any point along the way. The time and effort initially put into the design will pay for itself many times over in both the convenience and efficiency of the resulting laboratory.

Prior to drawing the actual design of the facility but critical to the design specifics, it is necessary to compile or consider the following information: the size of the facility; general Instrumentation Lab requirements that affect site determination; an activity functional flow diagram; instrumentation and preparation room requirements; a list of all the equipment to be placed in the facility and exact specifications for each; design features not associated with specific equipment; activities requiring space that are not specific to the equipment; general building requirements not specifically related to instrumentation operations; and finally, ergonomic and psychological factors.

Size of Facility

To determine the size of the complex, type and quantity of each piece of equipment, number and size of rooms, and staff needed, the following must be enumerated and justified: facility purpose; functions; application fields; activities; equipment needs and usage; future needs; number and type of users; staff and specific staff requirements.

Equipment List

An equipment list can then be made detailing the available choices and approximate purchasing and operating costs. For pre-existing labs moving to new quarters, the same information should be compiled. In addition, requirements and provisions must be made for moving the existing equipment and/or temporary storage. Equipment manufacturers should be contacted for requirements. Warranties and service contracts may remain valid only if those requirements are met.

Site Determination

This is a function of whether the Microscopy complex is to be put in a new building or a pre-existing building. If a pre-existing building is to be used, current blue prints should be obtained and a meeting arranged between the knowledgeable microscopist, architect and building engineer to discuss building characteristics with respect to the microscopy design requirements. At this time before decisions are made as to room layout, the following should be known to prevent obvious problems and save time spent making room layouts that can't be used because of interferences or logical economic reasons: (1) The environment just outside the building or area that may be a source of stray electrical or magnetic fields or vibration (e.g. loading dock with heavy truck traffic, train or subway nearby, busy roads, heavy machines, large electric motors or transformers, elevators etc.); (2) Area with minimum vibration; (3) Exact location of mechanical chases or utilities, water and drains, building elevators, stairwells, existing entrance(s) to proposed area, building loading dock, building power distribution panel(s) and electrical distribution map; (4) Possible neighboring (next door, overhead, and below) equipment with information on the field and vibration generation of that equipment; (5) Humidity and temperature control; (6) Cleanliness of air supply; (7) Traffic flow patterns to proposed area; and (8) Floor loading capability of area. By examining such information, totally inappropriate areas can be ruled out and more intelligent choices can be made for room layouts based on pre-existing conditions.

Functional Flow Diagram

With the previous listed information in hand, a functional flow chart can be constructed setting out each activity in a logical sequence. The flow diagram should indicate relationships of various activities and those that need to be separated. If the lab is to serve dual training-research functions, then it is suggested that a room be set aside in the complex for a training lab where specimen preparation and other training activities can occur independently of the research or service activities. Beginners are bound to make mistakes, which shouldn't be allowed to influence research or service work. This applies to duplication of instrumentation as well, if extensive training or instrument development is to be done. The goal should be to efficiently place the rooms so that those functions that are closely related are logically and ergonomically placed and appropriate ones separated.

In the simplest case there needs only to be three areas: one for the microscope/analytical instrumentation and utilities; one for specimen preparation, data evaluation, storage and desk space; and the last for computer facilities/digital imaging (or photographic facilities). It is likely that all darkrooms will be replaced with digital imaging facilities, if not already done on the front end, so networking cable raceways should be incorporated initially. There are a minimum of ways in which the three areas can be laid out. This requires careful thought to produce the most appropriate and efficient design with sufficient space and appropriate utilities/services. If there are only a few users, then the digital image processing system can be the one incorporated into the microscope/instrument. If several users are involved however, then a separate workstation might be appropriate to free up the instrumentation.

When a larger complex is designed, however, special thought should be given to the room layouts taking into consideration the need for cleanliness and low air flow (requiring low traffic flow), efficiency of room placement and equipment in the room to compliment functional flow, and other specialized needs. If space allows, an inside corridor in the lab complex is desirable as opposed to entering each room from a main hallway in order to minimize traffic flow and thus maintain a cleaner environment. A central specimen prep room and spokes off that room to all other rooms for the microscope/instrument, imaging facility and office may work in a one-person lab, but not in a larger facility. This means the prep area is usually very dirty because all traffic that must flow through it to get to any of the other rooms. Much needed wall space is lost because it is so broken up by doors. If clean room facilities are needed, then particle size requirements need to be established to determine which class of HEPA filtering is necessary.

Once the functions and necessary activities are listed, the number of necessary rooms generally becomes evident. Even in the simplest case, it is difficult to draw a generic lab unless one has some specific details as to lab activity and specific equipment.

Equipment Installation Information

Pre-installation guides for the electron (EM), focused ion beam (FIB), atomic force (AFM) and confocal microscopes and all other major analytical equipment should be requested from the manufacturers. The manufacturer is responsible for communicating, preferably in written form, what is necessary prior to the installation. Copies should be made of this information for the architect.

General Lab Requirements

There are certain general requirements for the entire microscopy complex that should be taken into consideration during the design. The following must be provided: minimization of vibration, electrical and magnetic interferences, power interruptions, and excessive audible noises; regulated line voltages within a specified percentage; proper grounding; cleanliness; work space with cabinets; appropriately size doors; storage cabinets; proper cooling; filtered air supply; stringent temperature and humidity control; special ventilation for exhausts; proper floor loading; and protection from water damage.

Equipment Listing With Specifications

A listing must be made of all the equipment that is to be placed in the facility and the exact specifications* listed for each. This should include any equipment that requires special consideration for space or services from large analytical equipment to small equipment e.g. pH meters.

Actual Lab Design

Room Sizes. A listing is now made of all the equipment and activities to occur in each room. Once all of the information has been compiled, the room sizes are established by the size of the equipment, work areas necessary for equipment and activities, furniture, clean rooms, and hoods as well as space for traffic flow and psychological considerations. A proportionately reduced drawing should now be made of the outline of the proposed area. The analytical equipment (involving high vacuum systems) room has a certain minimum size based on the equipment specification but if activities such as demonstrations and training on the instrument are to take place, these will generally require a larger room than one used for research only. The same holds true for atomic force and confocal or research-grade light microscope rooms, but room sizes can be smaller since these systems are smaller. For training activities and others requiring discussions, wall space should be made available for plastic coated writing boards (Chalkboards are too dusty.). Always keep in mind the functional flow of the activities, and resulting size required for traffic.

Analytical Equipment Room. The first room generally chosen is the room(s) for the electron or focused ion beam microscope(s), or other analytical instrumentation requiring high vacuum technology (e.g. Auger Spectroscopy, AES; Secondary Ion Mass Spectroscopy, SIMS, ESCA etc.), because of their more stringent requirements. Those systems incorporating imaging have the most stringent requirements. These room should not be near a building power distribution panel or other known electrical or magnetic interferences, or known sources of vibration. It should be located in a relatively dust-free area. Once the proposed location has been determined in a pre-existing building it is important to perform a field check for stray magnetic and electrical fields as well as vibrations. Although new power hasn't yet been installed for the lab, which is being designed, it is important to know what interferences are present in the existing area. Alternating magnetic fields can be detected with a search coil and an oscilloscope or with commercially available gaussmeters. These need to be measured in both horizontal and vertical directions at a specified frequency. Similarly, accelerometer tests can detect vibration problems. These tests should be performed over the entire room area making special note and readings where the electron/ion column is to be positioned. If the equipment or expertise is not available in-house, the equipment manufacturer should be contacted to have a representative do a preliminary on-site check to determine which part of the proposed area would be best for the microscope room(s) based on minimal interferences. These check must be repeated once the renovation of the new area has been completed. For new buildings, assuming the exterior environment is appropriate, these provisions can be built in assuming the microscopist has made the architect and building engineer aware of the needs. To be safe, always have the manufacturer do at least one on-site assessment of the proposed area. In most cases, they insist. If an area does not pass an on-site check, the problems will have to be eliminated, which can be very expensive, or another area chosen that is satisfactory for the manufacturer's warranty and guarantee to be valid. Each microscope/instrument room must meet the specifications listed for that particular model instrument.

If space permits, placing the mechanical pumps, compressor, and water recirculator for the instrument in a close-by-utility closet is desirable to decrease high noise levels and possible vibration interference to the microscope. If it is in the same room, special precautions may have to be taken to prevent these disturbances. Where minimum vibration is crucial especially from walking traffic, isolation pads can be used in addition to vibration tables.

Confocal, Research Grade Light Microscope or Atomic **Force Microscope Rooms.** These systems do not generally require as large an area as high vacuum instrumentation; however they also have stringent vibration requirements, especially the AFM. It is suggested that these types of systems be put on their own vibration table incorporating an appropriate cancellation system.

In addition to meeting instrument manufacturer's specifications, each instrument room should be provided with the following: a table or workbench to fit near the operator for the purpose of loading the sample (room may also be required for a stereo light microscope); a double door storage cabinet approximately 92 cm wide by 183 cm high (36 in x 72 in) for parts; and a pneumatically adjustable padded chair with low magnetic properties. If an energy loss spectrometer (for EELS) is incorporated into the instrument, the chairs must not have any magnetic properties.

Equipment/Furniture/Work Area Placement in Rooms. One must determine that all the equipment and activities fit in the layout space by manually sizing equipment/activities, or utilizing computer aided design programs (CAD). This activity often takes several attempts before a satisfactory initial plan emerges that accounts for all factors. Walk through in your mind the day-to-day activities and be sure the rooms have been located as conveniently as possible for what is being done in the lab, keeping in mind traffic flow requirements. Check also that all physical requirements have been met on the equipment specification list. Draw in all the equipment and workspaces to scale and be sure to indicate where components must be located at a specified distance from each other. Label all equipment and areas and be sure all abbreviations and symbols used are defined. Several good CAD programs exist that make this job easier.

Computer Networking

Once all the data outlets are indicated, then a plan can be designed to provide the most efficient network. It is important to build in cable raceways to accommodate present and future computer needs. Raceways provide the structure for holding computer-networking cables in the appropriate areas. Often, a small room must be dedicated to bring in all the computer cabling necessary into the area and then distributed from that point to other areas in the lab (via switches). There may also be the necessity for a server room if computers are to be networked together using an enterprise system (client-server). In the case of large imaging databases, space must be provided in the server room for RAID arrays for mass image storage. If possible, fiber should be run initially to provide fast transfer speeds, especially for video imaging–the faster the better. A typical 50 min. raw video file is 20 GB. Transferring that file over Ethernet can take up to 1 hr. It is true that there are 1GB copper switches, however that is only true if there is only one distribution off the switch. In addition, copper requires greater maintenance than fiber optics and requires greater care when making connections to minimize the noise. For remote instrument operation, signals must be low noise. Internally this can be provided with fiber optics or in the larger facilities, optical carriers. Externally, data transfer speed is limited by Internet speed.

UPS (uninterrupted power system) can be purchased for individual computers however, these systems generate a considerable field so appropriate care must be taken. Alternately, for a large complex, the UPS system can be built into the building power.

Approval of Draft Plan

It is important at this point to clarify the acceptability of the initial plan (space, room layout and major equipment placement) before the "nitty gritty" of the design is completed. This may involve some compromises, so be prepared with all the facts that justify the layout you have proposed. At this time, the architect should also be sure the design is consistent with state and local safety and ADA codes and suggest any needed changes. After all suggestions are in on the initial plan, make the necessary changes. Be sure that none of the changes compromise the ability of the lab to function properly. The final plan can then be completed.

Completion of Plan

Indicate on the plan the location of all services required, lights, and door swings with abbreviations appropriately defined in a legend e.g. V = vacuum, G = gas, etc. Differentiate phone and data jacks, for non-digital installations. Newer installations will likely utilize digital connections where data and voice go into the same jack. Number the rooms either as they are on the existing blueprint for a pre-existing building or arbitrarily (1,2,3, etc.) in a logical order. Where special instructions are required on the plan, use a symbol that is different looking than any equipment or furniture *e.g.* a triangle with a number in it. After you have completed the design with room layouts and have placed all the equipment, furniture, work areas, hoods, clean rooms, etc., place appropriate power outlets on each wall in each room. Outlets should be liberally available. Consult the architect for suggestions, if necessary.

Listings That Accompany Plan

Finally, make the following listings for the architect and building engineer: (1) General requirements for the Microscopy complex; (2) BTU/hr equipment heat load for each room; (3) Equipment electrical requirements for each room; (4) Type of lighting required, location; (5) Each type of service required, room and quantity (This should include safety, clean room, hood, and special ventilation along with the services); (6) Explanation of all special notes indicated by symbols e.g. triangle.

Presentation of Plan

The microscopist should now meet with their supervisor or with the architect to present the final plan. After they have had time to study the proposed plan there should be another meeting to discuss any questions or new suggestions. There may be changes needed due to previously unknown building, safety, or ADA restrictions or budget limitations. Because all the facts have been compiled in detail however, it should be only a matter of adjusting the plan for the changes. At this point, the architect has blueprints drawn up. These should be carefully checked to be sure that everything was properly transferred to the prints. Final blueprints are then made available and renovation or construction can proceed.

Construction On-Site Visits, Move-In & Set Up

The microscopist should make frequent non-disruptive on-site visits as the construction progresses, regardless how small the facility, and maintain an ongoing dialogue with the architect, building engineer, contracted project engineer and/or construction crew. In this way, questions can easily be answered as they arise and possible mistakes can be detected and/or prevented in cases where the blueprints were not followed. Photography of wiring and plumbing before walls are finished can be helpful in future years. Before photographing, simply place a small sign on the wall with the room number and direction (N,S,E, or W). Design changes at this stage should be absolutely minimal, if necessary at all, as changes after construction has started can have a serious effect on a contractor's legal obligation to complete the project as agreed.

Ongoing Dialogue

Once construction is complete, equipment moved in and the lab in operation, the dialogue established during the design process should continue with the building engineer to ensure that changes in other parts of the building don't negatively affect the Microscopy/Analytical lab operation.

Conclusion

The efficiency and convenience of the resulting Microscopy/Analytical facility is based generally on the active involvement of a knowledgeable microscopist/analyst with the entire lab design process. Although much time, effort and expense is required to create a proper lab design, the rewards are great and readily apparent in the efficient operation of the resulting facility with the possibility of maximum productivity. If the initial design is done well, there should be minimal changes necessary once everything has been moved into the new or renovated facility. The old adage "You get out of it, what you put into it." is definitely true in this case. ■

Endnote:

* Specification and design checklists are available from the author at http://www.deltacollege.org/dept/electmicro/design.html.

Microscopist and Lab Manager for a Centralized Electron Microscope Laboratory Facility at Portland State University

Portland State University seeks an electron microscopist to operate and manage a newly established electron microscopy (EM) facility consisting of a FEI/Philips (Tecnai F-20) 200kV field emission high-resolution transmission electron microscope (TEM) equipped with an embedded digital scanning transmission electron microscopy (STEM) capability, and energy dispersive x-ray spectrometer (EDS), a JEOL 2000FX TEM, and a 611 FEI focused ion beam microscope.

The responsibilities of the position include the management, operation, and maintenance of the microscopes, and training and assisting faculty, student, and outside university users of the microscopes. Candidates preferentially have at least 5-years experience in managing an electron microscopy multi-user facility in an academic or industrial research setting and an outstanding record of team and personal accomplishments. A publication record of EM-related research is expected. Advanced university degree is required as well as a demonstrated experience in either materials science, geological, or biological materials characterizations. The candidate must have experience using the microscopes listed above and be familiar with such operational techniques as digital image acquisition, image processing, structure simulation, and EDS analysis.

The candidates should also have experience performing minor microscope repairs and maintenance. Microscopes will be maintained under service contracts. The successful candidates are expected to be self-motivated and work well with technical staff, faculty, students, and outside users. Candidates will be selected based on their qualifications and accomplishments. Salary will be commensurate with qualifications and experience. Review of applications will begin on November 1, 2002, and continue until the position is filled. Interested candidates should send a letter of interest with a two-page management plan for a multi-user EM facility, plus a full resume and arrange to have five letters of reference sent to the address below.

PSU is an AA/EO institution and, in keeping with the president's diversity initative, welcomes applications from diverse candidates and candidates who support diversity.

Search Committee for EM Manager
Department of Physics
Portland State University
P.O. Box 751
Portland, OR 97207-0751

Microscopy AND Microanalysis

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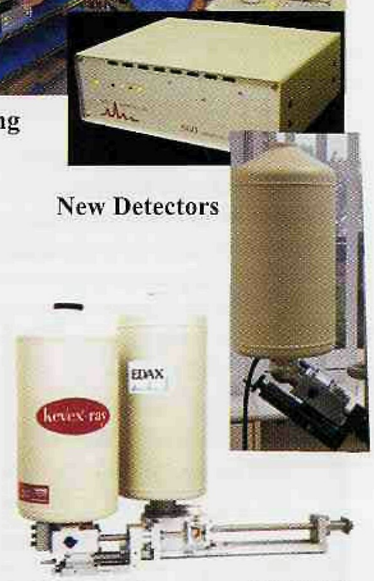
1993: Los Alamos National Lab receives the first IXRF system.
1995: Digital Imaging, Feature analysis, and X-Ray mapping are added into the systems.
1997: IXRF completes the first 100% Integrated EDS Microanalysis system in history developed for LEO Electron Microscopy).
1998: Jetscan Engine Health Monitor wins a millenium award from the British government (developed for LEO Electron Microscopy).
1999: IXRF Completes the "Particle Scan" offering the first truly integrated Particle Analysis inside the operating system of the SEM (developed for LEO Electron Microscopy).
1999: IXRF designs a new hardware interface allowing the use of Oxford PentaFET detectors for upgrading existing customers.
2000: IXRF completes the second fully Integrated EDS system, this time for JEOL Ltd.
2001: IXRF completes Particle Analysis on the Integrated JEOL Ltd product line.
2002: IXRF mounts the first micro x-ray tube on an SEM, to offer the first fully-integrated XRF and EDS microanalysis within the SEM.

Manufacturing



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