Midsize Facilities

The Infrastructure for Materials Research

Final Report of the

NRC Committee on Smaller Facilities

ACS Town Hall Meeting on Facilities
August 30, 2005 • Washington, DC

Bob Sinclair, Stanford University
On behalf of the Committee on Smaller Facilities

Charge before the committee

- NRC's Solid State Sciences Committee identified the issue of midsized facilities in materials research as one that "slips between the cracks"
  - Yet every institution advertises its "research centers, shared facilities, and laboratories" on the home page of its website!

- With support from NSF and DOE, NRC formed the Committee on Smaller Facilities to characterize the current landscape and discuss revenue-neutral strategies for optimizing current investments
  - Provide a definition of small and mid-sized multiuser facilities
  - Collect data on the usage, costs, and structure of smaller facilities
  - Examine the current models of facility operation, assess their effectiveness, and investigate metrics for success
  - Explore the need for long-range support models
  - Assess the effect of the policies and structure of the federal research agencies
  - Discuss observations in an international context

Committee Membership

- The 14 members of the committee are drawn broadly from materials research, physics, and neighboring fields, and from industry, academia, and national laboratories

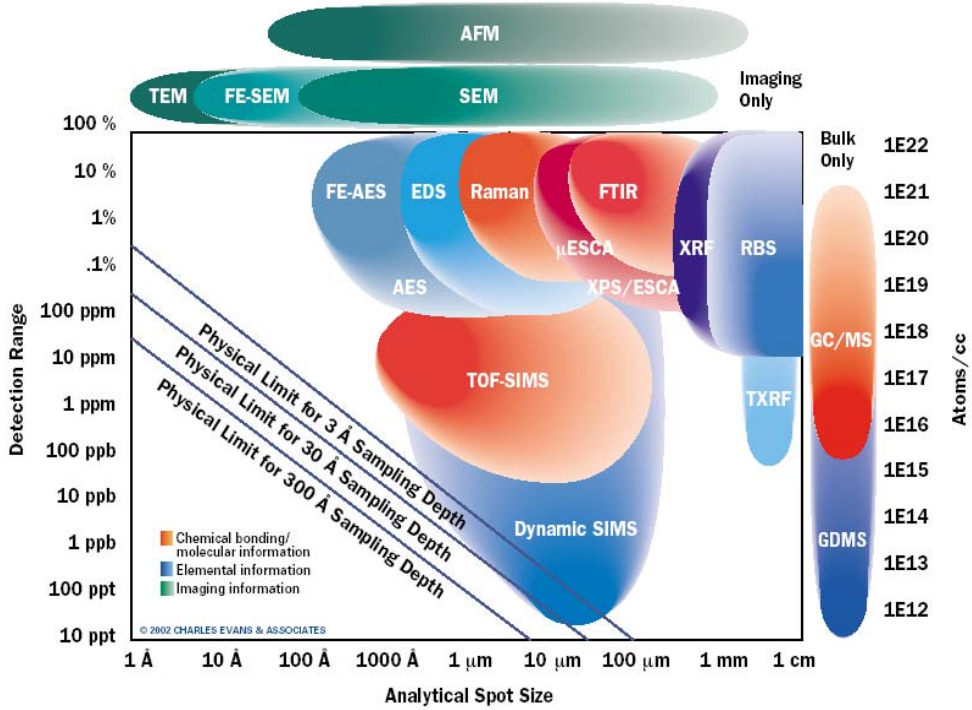
Bob Sinclair, Stanford Univ, *Chair*	**Charles Evans, Jr., Full Wafer Analysis, Inc.**
Ani Aprahamian, Univ of Notre Dame	**Walter Lowe, Howard Univ**
Arthur Bienenstock, Stanford Univ	**Frances Ross, IBM T.J. Watson Research Lab**
John Bradley, Lawrence Livermore Nat'l Lab	**David Smith, Arizona State Univ**
David Clarke, UC Santa Barbara	**John Soures, Univ of Rochester**
James Davenport, Brookhaven Nat'l Lab	**Leonard Spicer, Duke Univ**
Frank DiSalvo, Cornell Univ	**Don Tennant, Lucent Technologies**

Work plan

- Three in-person meetings of the committee
  - May 2003, Washington, DC
  - Oct 2003, Stanford, CA
  - May 2004, Washington, DC
- Data-gathering activities
  - Site visits to facilities around the country (Summer 2003)
  - Questionnaires to facility managers, users
- Discussions with community
  - Interim report to provide point of reference for feedback
  - Town-hall meetings at APS (3/25/04) and MRS (4/15/04) conferences

Escalating capabilities…

- Character of materials research has changed over the past 4 decades
  - No longer a lab-bench-sized science!
- Science and technology breakthroughs have enabled tremendous advances in capabilities
- Today's sophisticated research problems require a host of techniques and approaches, e.g., *synthesis*, *characterization* and *measurement*



- Pooling resources and talents in a centrally maintained facility is a natural way to address these challenges
- These facilities are sufficiently sophisticated in structure and content that a complex support network (both individually and collectively) is required to maximize their effectiveness

…Escalating costs

- Tremendous growth in capabilities and sophistication of techniques comes at a price*, literally*

Modern Instrument	Today's Purchase Price
Electron-beam writer	$2.5–5.0M
Dual-beam FIB	$2.0M
Reactive-ion Etcher	$1.0M
Field-emission gun TEM (fully equipped)	$2.5M
Aberration-corrected TEM	$4.0M
Nano-scale SIMS	$2.0M

Average NSF/MRI award is ~$250k per year; 80% of MRI awards are $500k or less

- Not only is the capital cost of modern advanced instrumentation significant, but also their maintenance & operations!
  - Professional staff, service contracts, specialized environments, suites of tools…all contribute to making midsized facilities more like larger facilities than single-investigator benchtop laboratories
- In today's fiscally constrained environment, revenue-neutral strategies, including reallocation of existing resources, are needed to optimize current (and proposed new) activities

Definition of a midsize facility

- Committee first distinguished between a center and a facility
  - Center = collection of investigators with a particular research focus
  - Facility = collection of instrumentation, equipment, people, or physical resources that enable investigators to conduct certain appropriate activities

- A midsize facility is a facility that owns and operates one or more pieces of equipment at an institution and is characterized by the following criteria
  - Facilitates scientific and/or technological research for multiple users
  - Provides services on local, regional, or national scales
  - Is open to all qualified users subject to general rules of access
  - Resident staff to assist, train, and/or serve users
  - Replacement capitalization cost of between approximately $1 million and $50 million and annual operating budget from about $100,000 up to several million dollars

- Implicit distinction between a facility and its instrumentation
  - Facility includes staff, users, operating funds, specialized environments, and a management plan
  - Facilities are the *interface* between instruments and their users/researchers

The many roles of midsize facilities

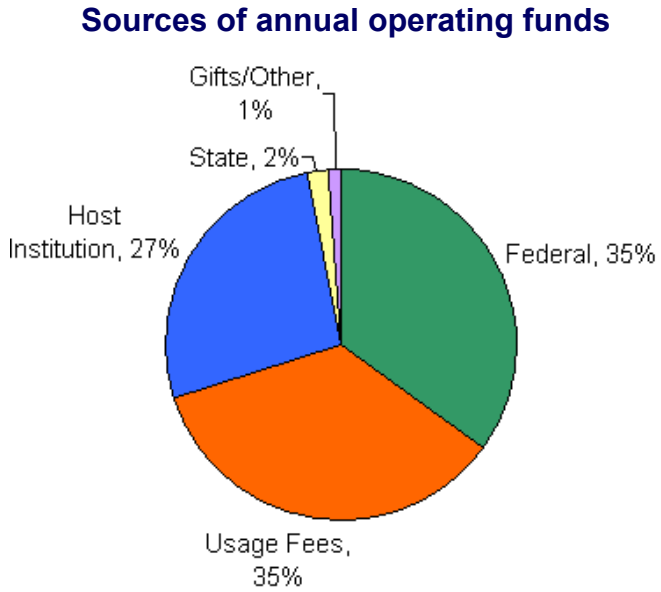
- Enabling research
  - Modern research problems require sophisticated equipment!
- Development of new instrumentation and techniques
  - Responding to the research challenges of users can drive innovation and creativity
- Cross-disciplinary science
  - Meeting ground for researchers with different goals, techniques, and perspectives
- Education and outreach
  - Students are trained on instrumentation, facility staff often play a key role in university teaching activities
- Commercial activities / collaboration with industry
  - Provide key resources of tools and talent for exploratory R&D by fledging or well-established industry – collaborative partnerships
  - Midsize facility capabilities are so essential and widespread that many individuals have been able to create their own businesses based on the concept

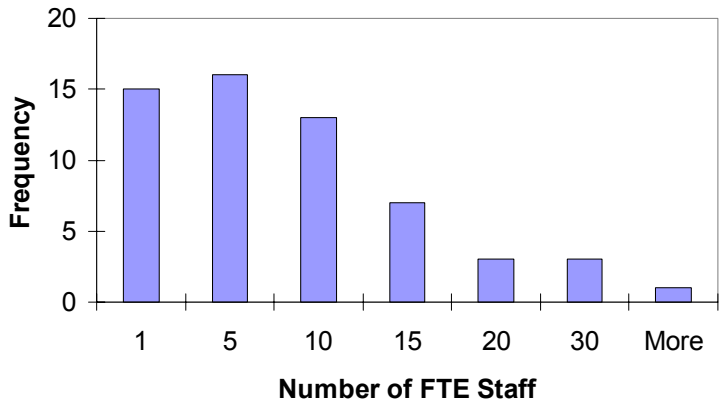
Characterizing midsize facilities (1)

- Committee visited 47 different facilities and contacted more than 220 others to better understand the diverse array of practices
- National population of midsize materials research facilities
  - Estimated to number about 500 facilities
  - Represents perhaps several billion dollars of capital investment and several hundred million dollars of annual operating budgets
- Most impressive observation was that every facility is essentially unique
  - Operating models, research focus, funding sources, relationships with host organizations, etc.
- Spread across many agencies and many programs
  - NSF: NNIN nodes, MRSECs, nanoscience centers, engineering research centers, science and technology centers
  - DOE: e-beam microcharacterization centers, nanoscience research centers, nat'l labs
  - NIH: P-41s (Biomedical Technology Resource Center)
    - An interesting example because of five-pronged approach: technology, collaborative research, service, training, dissemination

Characterizing midsize facilities (2)

- Most facilities not dominated by a single source of operating funds
  - Avg budget ~ $1.1M (median $0.5M)
  - Avg capital ~ $10M (median $7M)
- Wide variety of research activities
  - Synthesis
  - Fabrication
  - Characterization
  - Measurement
  - Computation
- Diverse strategies for managing equipment, working with host institution, balancing competing missions, etc.





Characteristics of success

- Providing a unique or special service that is not generally available at an individual investigator's laboratory
- Fulfilling a particular scientific niche/role in the research enterprise
- Having a clear mission that addresses a well defined or emerging need for a well defined community
- Playing a leading role in education, workforce training, and workforce development
- Facilitating instrument/technology development and/or training
- Promoting synergy and communication among its users and with others
- Fostering cross-disciplinary and cross-sector interactions including scientific, medical, and engineering endeavors
- Representing a means for coordinating scientific endeavors among other facilities or institutions with complementary capabilities

Key challenges

- U.S. situation is unique
- Long-term viability
  - Diverse and stable funding (operations & maint)
  - Stable and secure staffing
  - Visibility to user community
  - Sound management plans & operational practices
  - Maintaining a balanced suite of tools
    - “Racehorse” vs “workhorse” instruments
    - Obtaining highest capability equipment
- Networking with other resources
- Balancing competing purposes
  - e.g., training vs state-of-the-art research
- Cooperation & non-competition with commercial interests

Key findings

- Importance and uniqueness
  - Critical and irreplaceable role in the materials research enterprise
- Need for long-term planning and commitment
  - Instruments are sufficiently expensive that they need stable care, feeding, and continuing support to realize full value
- Need for systematic program planning
  - Facilities & instruments cannot be treated as isolated, atomized units
- Ripe for optimization
  - There is opportunity for greater productivity

Agency strengths

- NSF supports a broad range of materials instrumentation programs that are available to almost any qualified candidates
  - However, support for capital costs over $2M is very rare and there are few formal mechanisms for long-term support (such as needed for a facility)

- DOE supports national labs with powerful equipment and excellent staff
  - However, outside access and availability is limited, and new equipment can generally only be co-located with existing tools (to maximize leveraged infrastructure)
  - The major exception is the university facility (MRL at UIUC) which is widely regarded as a model facility

Recommended strategies (1)

- Realizing economies
  - Collective stewardship
    - Cooperative, responsible planning amongst all stakeholders should be encouraged by the federal agencies to minimize redundancy, coordinate initiatives
    - Explicit and programmatic planning is required for long-term support and oversight, including recognition of user fees
  - Regional networking
    - Incentives: Midsize facilities participating in regional networks should be given priority for expansions of capability or capacity
    - Federal agencies should view proposals for new facilities in regional context
    - Regional and/or national strategies for equipment purchase

Recommended strategies (2)

- Improving effectiveness
  - Long-term infrastructure
    - Optimal utility from existing investments can only be extracted with commensurate commitments to infrastructure from host institutions and federal agencies, including maintenance, user training, education and outreach, instrumentation development
  - Professional staffing
    - Career path for staff should be respected and cultivated; facility operating plans should explicitly address this issue

- Follow-up and Follow-through
  - Federal agencies should periodically review midsize facilities to ensure that primary objectives are being met and that continued operation is viable and appropriate

Regional networking (1)

- Midsize facilities serve regions, typically campuses of national labs or universities
  - Already, some campuses are starting to centralize/consolidate their on-site facilities
  - Often, however, neighboring facilities were not fully aware of one another
- Opportunities for greater synergy amongst facilities
  - Coordination and complementarity of instrumentation and research capabilities
  - Referrals and consultations (regionally and nationally)
- Interconnecting architecture is needed to exploit potential "sum is greater than its parts"

Regional networking (2)

- Teaming of institutions
  - Networking between “large” and “small” schools can allow substantial leveraging and joint research efforts
  - Parallel to activities in small European countries!
- Hub-and-spoke model
  - Hub facility may focus on leading-edge “racehorse” capabilities while spoke facilities might focus on “workhorse” capabilities to even out proposal pressure and lead time
- Largest risk of regional networking is lack of a clear steward
  - If agencies are to reap the economies, they should lead the effort

Take-home message

- Midsize facilities play a key role in the materials research enterprise
  - The provide key advanced equipment enabling modern materials research
  - They are far more than just some tools in a garage: trained staff, operating funds, user community, specialized environments, and management plan are essential ingredients
- To realize certain economies and improve effectiveness, the national collection of midsize facilities needs to be recognized as a coherent system
  - Federal agencies should take the lead in fostering collective stewardship amongst all stakeholders
  - With stewardship, regional networking amongst facilities should be encouraged
- With realized economies, commitment and planning for long-term infrastructure should be enhanced
- Trained, professional staff are essential to facility success
  - Facility operating plans should explicitly address the need for career path and professional development
- Midsize facilities should be reviewed periodically by their sponsors, commensurate with their long-term responsibilities