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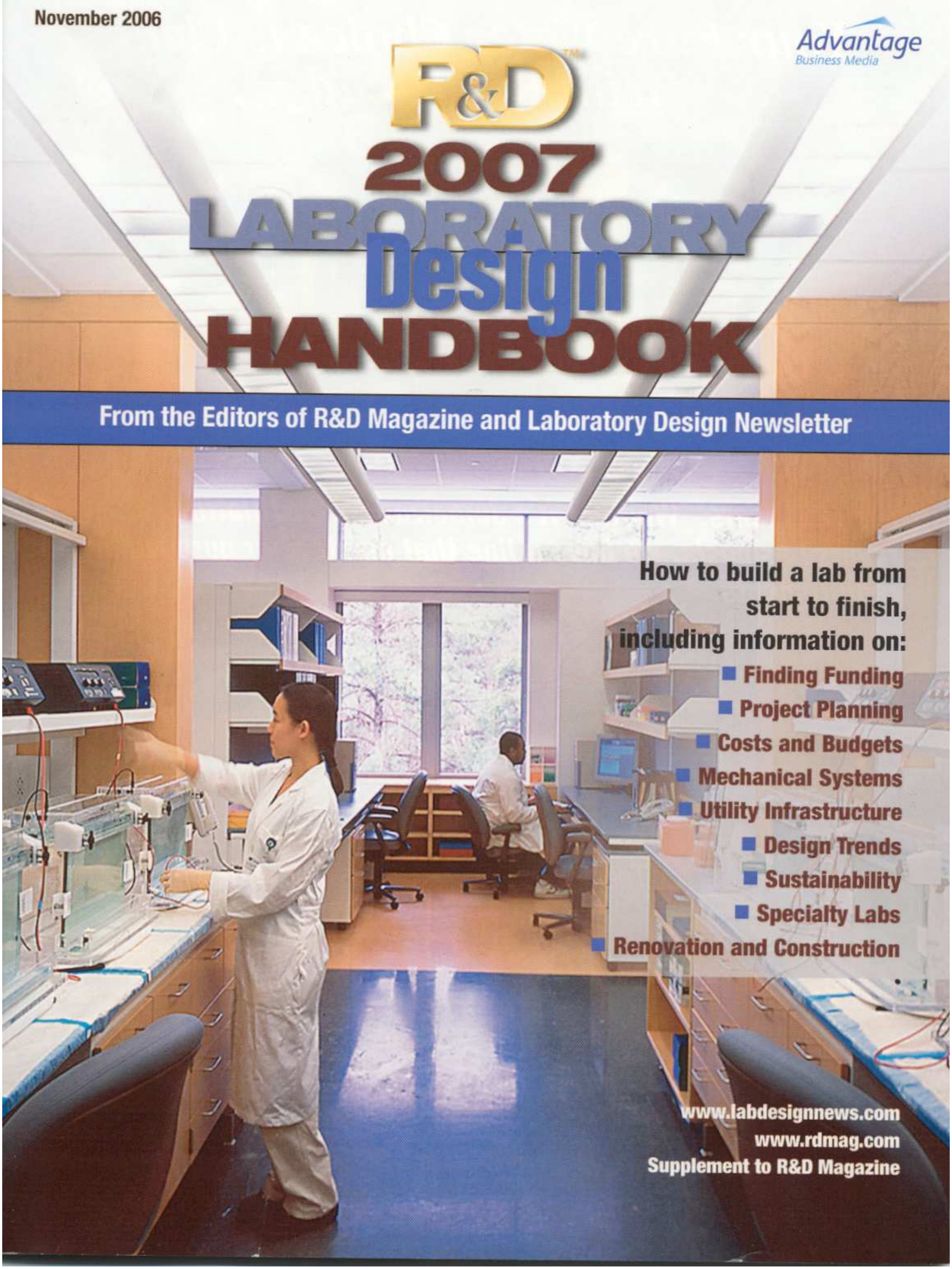

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NANOTECH I: SITE PARAMETERS

Nanotechnology lab planning begins with an investigation of the site's vibration, noise, EMI, and RFI characteristics

By Hal Amick, PE; Lou Vitale; and Bruce M. Haxton, AIA, NCARB, LEED AP

Nanotechnology has been termed the "next industrial revolution." Nanoscience deals with the fundamental principles of molecules and structures between one and 100 nanometers in length. (A human hair is ~10,000 to 50,000 nanometers wide.) World governments are competing to develop expertise in nanotechnology, investing ~$4 billion in 2004. The largest nanotechnology investors are the U.S., Japan, and Western Europe, with China coming up quickly.

The National Science Foundation projects that annual global impact of nanotechnology will exceed $1 trillion by 2015. The first important steps for nanotechnology facilities include site and facility assessments to see if the nanotechnology can be performed on the site. This is the first part of a two-part article, which continues on page 43.

Nanotech sites and facility parameters

Nanotechnology facilities are appearing rapidly at university campuses, government installations, and science parks around the world due to the extensive governmental and institutional competition to exploit the economic development advantages of this relatively new technology. "One site does not fit all" might be a good way to approach planning for nanotechnology. The research carried out in these facilities is highly sensitive to excessive vibration, noise, electromagnetic interference (EMI), and radio frequency interference (RFI), all which vary from site to site, as well as interior "contaminants," including temperature, air quality, and life safety issues. All of these design issues must be identified and quantified as early as possible to minimize cost impact on the project.

Sites have been rejected due to proximity of railroad tracks, traffic, power lines, electrical substations, and large mechanical systems in neighboring buildings. Even the construction of future nearby buildings at the campus or research park may require consideration during planning. The consequences of waiting too long to carry out nanotechnology parameter investigations can be quite dramatic. Many site factors may be accommodated during design, but only if identified early in the design process.

Once an institution, company, or community elects to investigate the potential of nanotechnology, the first step is to analyze the potential sites and their respective critical nanotechnology attributes. It is best to investigate each attribute during periods of greatest impact, such as vibrations due to traffic during rush hour or periods with high truck traffic at high speeds. The objective is to define the magnitude and statistics of the "worst case" performance of each site parameter. Researchers may also need to know how the parameters vary over time.

Not all nanotechnology facilities are equally sensitive to environmental conditions. Work with theoretical or modeling aspects of nanotechnology tends to be insensitive to the environment. The opposite extremes occur with molecular manipulation and certain types of microscopy. In general, the site must be able to meet the most stringent demands within the facility, or else expensive mitigation may be required in the design. (There are also cases in which mitigation simply is not practical.)

Vibration

Potential sources of site vibration include vehicular traffic (both on-site and off-site), railroads and subway systems, construction (especially pile driving and vibratory compaction), and poorly isolated mechanical equipment in neighboring buildings. Some of these vibrations can be accommodated during design; others may rule out a site. (A large earthquake would likely interrupt research, but researchers would also probably have to evacuate in such a situation.) Road maintenance becomes a critical factor, since vehicles crossing speed bumps, potholes, or rough snow-pack can cause some of the worst vibrations.

When the site is an existing building slated for renovation, the above factors must still be considered, but there are several additional ones. Floors suspended over a basement (or crawl space) must be evaluated for vibrations due to personnel activities, particularly walking. The designers may also need measured structural properties, such as stiffness or resonance frequency. Slabs-on-grade need to be evaluated for stiffness and quality of the contact with the sub-grade soil. Existing mechanical equipment that will remain after the renovation will be a source of vibration in the new facility, so it must be evaluated in the new context. (It may have been adequate in the context of the previous building, but not in a nanotechnology facility.)

Electromagnetic interference (EMI)

Nanotechnology equipment is very sensitive to both AC and DC magnetic fields. Direct current (DC) sources include subways and trolleys, as well as moving ferromagnetic masses such as vehicles outside the building—including trains—and elevators, dumb waiters, and steel doors inside the building. These perturb the geomagnetic field of the earth, generating time-varying DC fields that impact nearby scientific instruments such as electron microscopes, electron-beam lithography equipment, and focused ion beam systems.

Alternating current (AC) magnetic fields are associated with the flow of AC electricity. This can be carried by power lines, transformers, switchgear, or the wiring inside a building. Electromagnetic induction occurs when time-varying AC magnetic fields couple with any conductive object, including wires and electronic equipment, inducing circulating currents and voltages. In susceptible electronic equipment and signal cables, electromagnetic induction generates electromagnetic interference (EMI), which is manifested as visible screen jitter in displays, hum in analog telephone/audio equipment, lost sync in video equipment, and data errors in magnetic media or digital signal cables.

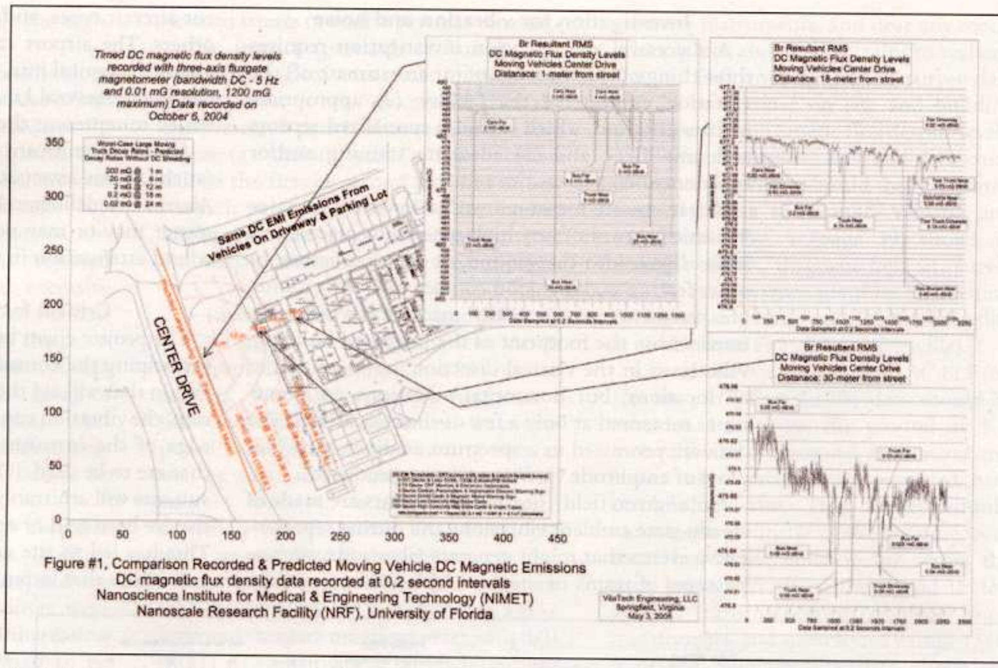

Fig. 1. A DC magnetic field site survey for the Nanoscience Institute for Medical & Engineering Nanoscale Research Facility at the Univ. of Florida, Gainesville.

Colin Gordon/VitaTech/Leo A. Daly

Radio frequency interference (RFI)

Radiofrequency interference (RFI) is EMI for which the frequencies are those associated with radio transmission, generally between 100 kilohertz (KHz) and 50 gigahertz (GHz). One of the most common sources of RFI is the cellular telephone. In the U.S., the Federal Communications Commission (FCC) has legal jurisdiction over RFI. However, at present, there are no mandated RFI susceptibility standards in the U.S. The only standards are those associated with individual items of susceptible equipment.

In Europe, applicable standards such as EN 61000-6-1 exist. EMI/RFI consultants generally base their recommendations on the European standard, but are somewhat more conservative.

Noise interference

A number of processes (often the same ones that are highly sensitive to vibration) are highly sensitive to airborne noise. Some of the instruments are so sensitive that operators cannot even whisper during their use. In all but the most extreme cases, the building shell is adequate to attenuate site noise.

One exception is aircraft noise. If the site is impacted by over-flights by large aircraft (such as beneath takeoff or approach paths for airports), extra measures will be required during the design, but the aircraft noise at the site must be measured so that appropriate designs are used. In the vast majority of situations, sound at audible frequencies is the primary concern.

Airborne contaminants

Most nanotechnology facilities include cleanrooms used for fabrication at the nanometer scale. This environment is inherently sensitive to airborne contamination by particulates or airborne molecular contaminants (AMCs). Generally, the facility's mechanical system will be designed to create an environment with adequate cleanliness, but assumptions are made about the quality of the air entering the building. If the site exhibits unusual airborne particles (such as dust from a cement plant, for example) or chemicals (a refinery, perhaps), the extent and nature of the contaminants must be quantified during the site investigation.

Temperature and humidity parameters

Temperature fluctuation can pose a problem because at the exceedingly small scales of nanotechnology, very slight changes in temperature can lead to relatively large changes in dimensions. If a researcher wants to position a molecule at a particular location, a variation of 1/10 of 1° C between the time the molecule is "grabbed" and the time it is placed will cause it to be placed in the wrong location.

Generally, any building can be designed to withstand very large changes in temperature over a large period of time (such as daytime to nighttime). However, very sophisticated temperature controls are required to maintain the temperature stability needed for some processes. In extreme cases, it may be necessary to control temperatures to within 1/100 of 1° C. Thermal stability is a critical issue during building design, but generally not an issue for site selection.

At this time, the constraints on humidity in a nanotechnology facility are not as stringent, relatively speaking, as those on vibration, noise, EMI/RFI, or temperature stability. This is not an issue of concern for a site study but must be addressed by the mechanical engineer.

Investigation for vibration and noise

A successful site vibration investigation requires three things: (1) knowledge of (or an estimate of) the vibration criteria for the facility; (2) appropriate instrumentation, which includes specialized sensors and amplifiers; and (3) adequate training and/or experience.

Vibrations are measured with a low-frequency (or "seismic") sensor of very high sensitivity, placed on a stake driven into the ground, or on a curbstone or other feature making good contact with the ground. Measurements are generally made at several locations within the footprint of the proposed building. Vibrations in the vertical direction are measured at all locations, but horizontal vibrations are sometimes measured at only a few of these locations. The data are processed in a spectrum analyzer such that plots of amplitude vs. frequency are produced.

On a "green field" site, measurements are made of steady-state ambient vibrations and during representative events that might generate vibrations, such as passages of trains or motor vehicles. When evaluating an existing building, the investigator adds to this list measurement of vibrations due to walking and (perhaps) other personnel activities.

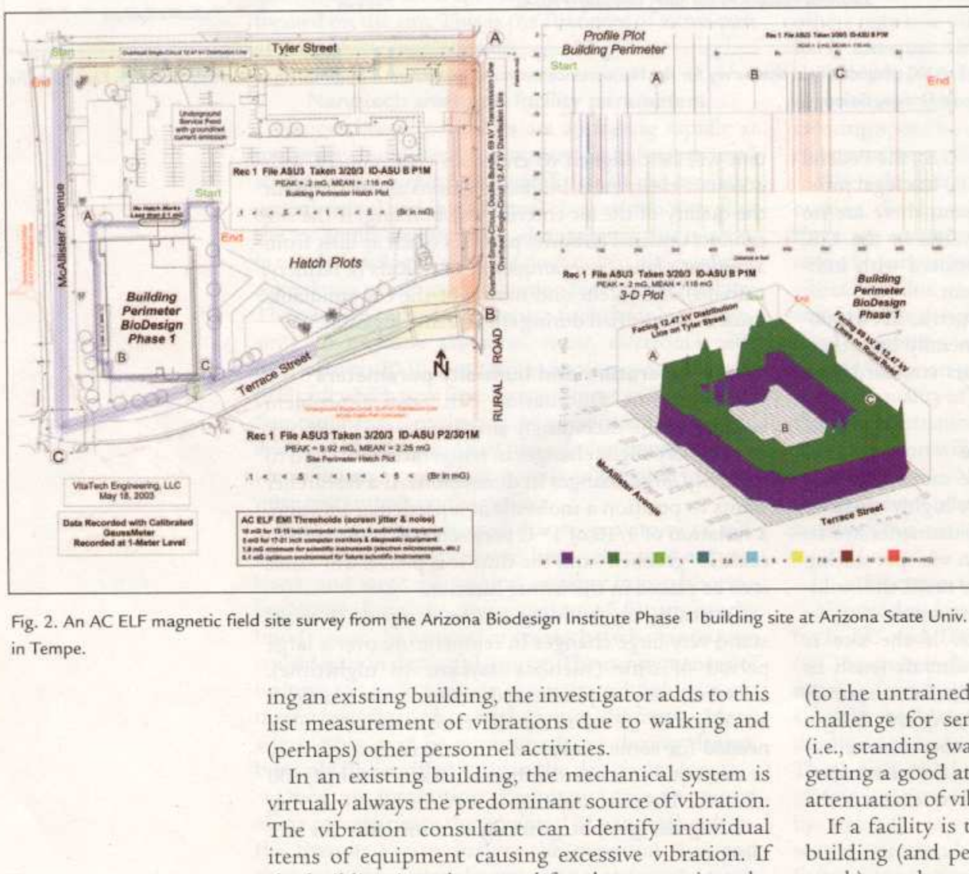

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Fig. 2. An AC ELF magnetic field site survey from the Arizona Biodesign Institute Phase 1 building site at Arizona State Univ. in Tempe.

In an existing building, the mechanical system is virtually always the predominant source of vibration. The vibration consultant can identify individual items of equipment causing excessive vibration. If the building is to be gutted for the renovation, the study should be carried out with the mechanical systems turned off (if possible).

There are two approaches to assessing site noise. Obviously, one can measure it. However, in the case of aircraft noise, the airport may serve many different aircraft types, and some aircraft are noisier than others. The airport can often provide information about the typical mix, and if the noise is measured at the site for several known aircraft, the results can be scaled to represent the other aircraft.

Another significant source of site noise is an alarm (such as an evacuation alarm) being exercised. Alarms are deliberately noisy and intrusive, and an owner may or may not wish to eliminate them via sound attenuation in the building shell.

Critical factors and problems

The project client bears a significant responsibility for helping the consultant conduct a proper investigation that will aid the design team. To assign a criterion, the vibration consultant must have some knowledge of the instruments (or types of instruments) that are to be used. (Occasionally, owners or lab consultants will arbitrarily pick criteria based upon what they've been told or on experience with past projects. This has led to site criteria that were too stringent, and others that weren't stringent enough.)

To approve a site, the consultant must know that the site survey has captured the majority of representative vibration- and noise-generating events. He should be satisfied that the site either meets the most stringent criterion for the facility, or that the planned building can reasonably be expected to attenuate the vibration or noise. The attenuation provided by a building (for either vibration or noise) is a function of frequency, and a certain amount of experience is required to estimate it.

The most challenging measurement problems (other than simple equipment malfunctions) have been weather-related. Rain causes signal connections to short out or generate noise. Temperatures well below freezing cause thermal stresses within the sensors that appear on the analyzer to be vibrations (to the untrained eye). Frozen ground can provide a challenge for sensor placement. High water tables (i.e., standing water) pose two problems: difficulty getting a good attachment to the ground, and poor attenuation of vibrations from a distance.

If a facility is to be successful, the aesthetics of a building (and perhaps its political value as a landmark) may have to be subordinated to the ability to provide a good environment. In several instances, considerable pressure was placed on using a particular site (because it would "make a good architectural statement there") or because it would help facilitate inter-agency cooperation. Generally, if the researchers are allowed to enter the argument, they win.

At least two sites for nanotechnology facilities have been rejected because of rail vibrations. One location was expedient for the internal politics of the institution. The other (at a different institution) was on "neutral" ground that facilitated easier collaboration with researchers outside the organization. Two sites were rejected because on-site traffic caused excessive vibration during certain times of the day. One site was rejected because of the proximity of a building with mechanical equipment causing excessive vibration. In all of these cases, the researchers insisted that environment had to take precedence over everything else, if the building was to be successful in its mission.

At least two nanotechnology facilities are impacted by aircraft noise. In both cases, this was known in advance, and the affected portions of the buildings were built as "shell within a shell," increasing the attenuation. Neither site had to be rejected.

Two facilities have required modifications to streets or traffic patterns to reduce traffic impact (particularly buses). One otherwise-logical site was immediately vetoed when it was discovered that the same research park had an earthquake simulator (a "shaking table"). Two facilities will be the first or second facilities in new research parks, and the owner has had to implement limits on construction activities and setback distances for future buildings.

Investigation for EMI and RFI

VitaTech—located in Springfield, Va.—is a firm specializing in EMI and RFI investigations. VitaTech normally performs a full-spectrum EMF site survey at a proposed nanotechnology building site as well as surrounding areas to identify all sources of DC, alternating current extremely low frequency (AC ELF), and radio frequency (RF) emissions.

Spot and 30-min timed DC magnetic flux density data are sampled with a professional fluxgate magnetometer with 0.01 mG (1 nT) sensitivity at selected locations within the future building site, preferably in future laboratory locations with EMI sensitive instruments, and near any roads, parking lots, and moving trains to evaluate the DC EMI impact. The DC survey data should be overlaid on site and building plans showing magnetic flux density levels, and, where possible, 2-D and 3-D color contour graphics should be generated from the data to simplify viewing and assessment. Fig. 1 (page 39) shows an example of a DC magnetic field site survey (for the Nanoscience Institute for Medical & Engineering Nanoscale Research Facility at the Univ. of Florida in Gainesville).

Lateral and contour mapped AC ELF (60 Hz) magnetic flux density data should be recorded 1-m above the ground at 1-ft intervals with professional gaussmeter and survey wheel around the proposed nanotechnology site. This survey should include the perimeter of the building, contours inside the building (or across the site), laterals to all overhead and underground transmission/distribution lines, transformers, and substations within 1,000 ft of the building. The data should be mathematically interpolated to produce 2-D and 3-D color contour graphics of the power frequency magnetic fields profile. Fig. 2 (page 40) shows an example of an AC ELF magnetic field site survey (from the Biodesign Institute Phase 1 building site at Arizona State Univ. in Tempe).

Wideband timed electric field strength data should be recorded at selected locations around the site to identify potential RFI emission sources, such as antenna farms, commercial TV/FM/AM broadcast emitters, mobile and fixed microwave and cellular towers, and weather radar systems. If the terrain is relatively flat, a single point at the center of the property is the best location for RF data collection.

Timed electric field strength levels should be recorded from 100 kHz to 18 GHz around the site. When detailed RF spectral information is required because the site is in a remote location or exceeds one of the recommended RFI thresholds, it is necessary to use a portable spectrum analyzer with calibrated dipole and microwave horn antennas. Fig. 3 (above) shows an example of a spectrum site survey.

The final EMI/RFI site survey report should present the recorded emission data in 2-D and 3-D graphical format overlaid on the site plan and floor plans. The author should discuss the potential EMI/RFI impact of the ambient data on the new facility and future research tools. A recommended remediation strategy (i.e., magnetic and/or RF shielding, increased separation distance to sources, active-cancellation technology, etc.) should be presented to control the EMI/RFI impact where the thresholds exceed acceptable levels.

Critical factors and problems

One of the most important factors is to correctly decipher the manufacturers' EMI performance requirements. Placement of each scientific tool and instrument depends on the actual EMI susceptibility under defined thresholds, which are often not easy to ascertain from the manufacturer's performance criteria. As with vibration and noise, an experienced consultant will have standard recommended limits based on experience with particular settings which can be used during design, but a space evaluation for a particular instrument should be based upon the requirements of that instrument.

Using the simulated emission profiles and the correct conversion formula, it is possible to identify the appropriate areas for each tool *if the correct EMI susceptibility figure can be ascertained from the manufacturer's specifications.* Therein lies the real EMI challenge.

EMI measurement poses challenges on the consultant side as well. Professional-grade gaussmeters and fluxgate magnetometers have NIST-traceable calibration documents. However, several custom-designed magnetometer systems are based on a fluxgate probe connected to signal processing systems. Unfortunately, such instruments generally do not have NIST-traceable calibration certificates verifying the accuracy of the custom system, especially at the bottom of the dynamic range wherein lies the sensitivity of many instruments for nanotechnology.

Recommendations for expensive mitigation systems (i.e., magnetic shielding, active field cancellation system, etc.) may be presented to the client based on the assumed accuracy of these systems. We recommend that the client always request a NIST-traceable calibration certificate from the EMF survey consultant before deciding to purchase a mitigation solution based on recorded site levels and critical-instrument-specific EMI susceptibility requirements.

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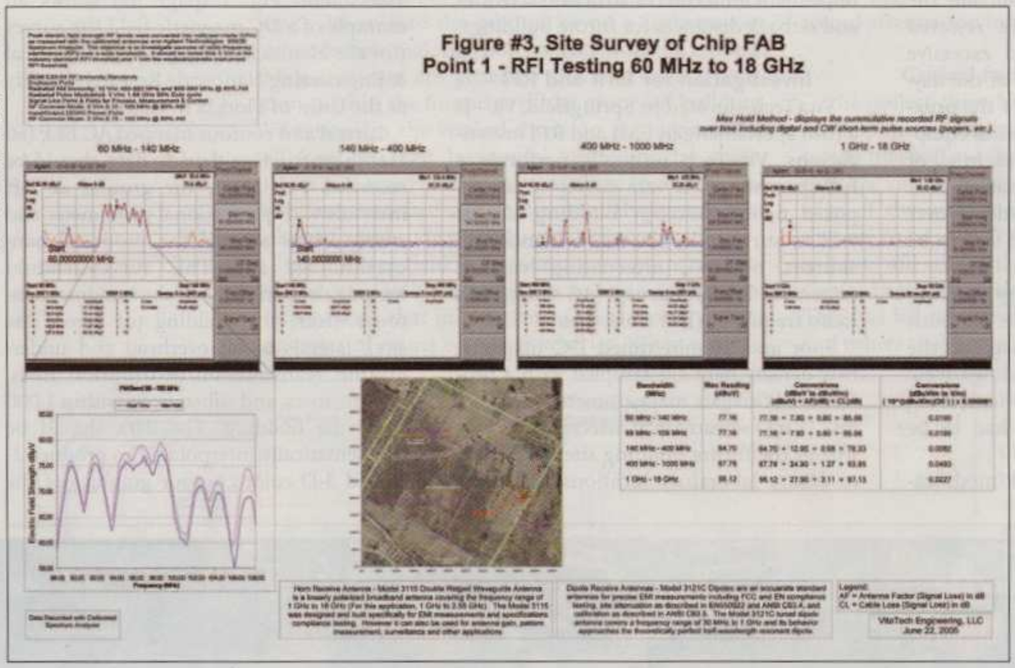

Fig. 3. A detailed RF spectrum site survey.

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NANOTECH II: CASE STUDIES AND TRENDS

Today's new facilities illustrate the state of the art in nanotechnology lab design, and point the way to future trends

By Hal Amick, PE; Lou Vitale; and Bruce M. Haxton, AIA, NCARB, LEED AP

In Part I of this article (page 38), we discussed vibration, electromagnetic interference (EMI), radio frequency interference (RFI), noise interference, airborne contaminants, temperature parameters, and humidity parameters. We also reviewed important site-selection and evaluation strategies, including critical factors regarding measuring and avoiding problems. Samples of EMI and RFI investigations were discussed.

Part II presents some relevant case studies, and makes some predictions regarding tomorrow's design issues for this specialized type of facility.

Case studies

The Advanced Measurement Laboratory at the National Institute of Standards and Technology (NIST) in Gaithersburg, Md., is really a facility for the study of measurement science, but has become the prototype for many nanotechnology facilities. The site vibration and noise survey for this facility was probably the most extensive ever carried out for a technical building.

Measurements were made continuously over 24-hr periods and analyzed for both statistical variation and time variation. Moreover, this was done for two sites, because the initially preferred site had vibrations that were exceeding the requirements part of the time. Ultimately, the scientists were involved in the final selection, basing the decision on a comparison of the statistical variation of a single frequency band.

The 2002 EMI/RFI site survey at the site of the National Institute for Nanotechnology (NINT) at the Univ. of Alberta, Edmonton, Canada, demonstrates how problems can be identified at a site, and the problems themselves mitigated, rather than requiring expensive shielding.

The proposed NINT site had several underground utility tunnels with emissions, as shown in Fig. 4 (below). The perimeter data path had an average level of 0.192 mG and a 1.76 mG maximum peak 1-m above the small north service tunnel (near start point). A second peak of 1.1 mG appears near the parking garage above the east-west utility tunnel, which bisects the proposed site. An unknown ground/net current travels in the north service tunnel meandering southward to the east-west utility tunnel and then west to the parking garage. Two smaller peaks appeared along the perimeter path: 0.5 mG above the east-west utility tunnel at point B, and 0.4 mG above the north-south utility Tunnel at point C. During the east-west utility tunnel inspection, ground currents were traveling on No. 8 stranded bare-copper grounding conductor mounted to the concrete ceiling, creating a ground path with the metal pipes and conduits.

VitaTech recommended using an experienced elec-

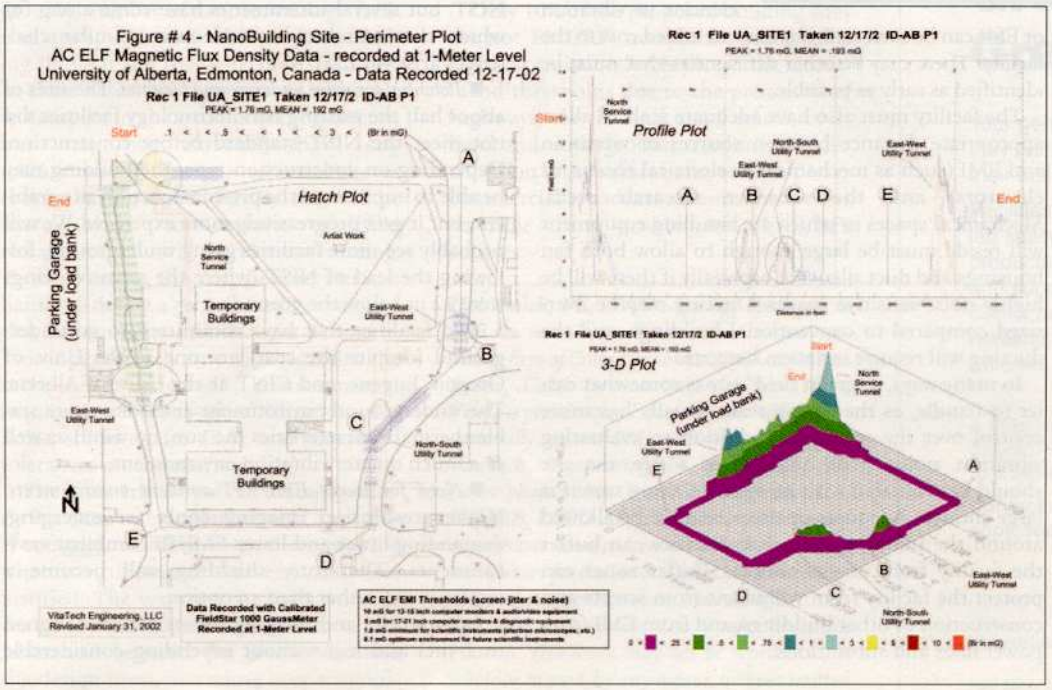

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Fig. 4. Data from an EMI/RFI analysis at the proposed NINT site at the Univ. of Alberta, Edmonton, Canada. The site had several underground utility tunnels with problematic emissions. (See Part 1 for Figs. 1-3.)

trical contractor to measure and trace the ground/net currents at various locations around the loop, isolate the sources/causes, remediate (insert dielectric/isolation couplers in water lines, reroute and/or disconnect redundant grounding conductors, etc.). The work was successful, and the ground/net current emissions are not an EMI threat to the NINT building.

Steve Hall/Hedrich Blessing

At the NIST AML, Gaithersburg, Md., a NIST-developed scanning electron microscope with spin polarization analysis is the highest resolution magnetization imaging instrument in the U.S. It is located in one of the underground metrology wings and encased in a plexiglass enclosure for shielding against acoustic vibration and temperature changes.

Planning issues

Nanotechnology facilities generally place such stringent demands on the building's environment that it is wise to determine feasibility as early as possible, particularly if an existing building is being considered for renovation. Just as an existing building must provide adequate headroom for equipment and HVAC/utility infrastructure, or adequate structural capacity, it must also provide an environment compatible with the environmental requirements. Many deficiencies in vibration or EMI can be corrected, but at some added cost to the facility. There may be other deficiencies that must be identified as early as possible.

The facility must also have adequate scale to allow appropriate distance between sources of vibration and EMI (such as mechanical or electrical rooms, or elevators) and the sensitive research areas. Mechanical spaces in which air handling equipment will reside must be large enough to allow both fan housings and duct silencers, especially if there will be highly noise-sensitive spaces. Ducting may be oversized compared to conventional buildings, and the ducting will require isolation hangers.

In many ways, a "green field" site is somewhat easier to handle, as the design team usually has more control over the setting. In addition to evaluating vibration, noise, EMI, and RFI at a site, the site should be evaluated with an eye to making sure it is large enough. Adequate open space must be allowed around the building such that distance can buffer the facility from on-site sources. Buffer zones can protect the facility from vibrations from streets and construction of other buildings, and from EMI from power lines and substations.

The vibration and EMI/RFI surveys should be carried out as early in the design process as possible. It is not unlikely that a site may be rejected, and this can lead to additional costs if the design effort has progressed to the point of becoming site-specific.

Some consistent EMI/RFI rules are simple to follow: locate all high-current electrical gear (transformers, secondary feeders, switchgears, etc.) and DC EMI sources (such as elevators, parking lots, and roads) at the opposite end of the building from the high-resolution imaging suites and tools. All high-power RF emissions sources within the building must be in an RF-shielded room supplied with EMI/RFI-filtered electrical power to minimize conducted emissions throughout the building.

The complete EMI/RFI rules list is rather long with hundreds of do's and don'ts, but in the end, a low-EMI/RFI environment in the imaging tool areas is achievable when a comprehensive EMI/RFI site survey, electrical power simulations, and detailed mitigation assessment are performed for the site of a new nanotechnology facility.

Future trends

■ *More demanding instruments.* In the semiconductor industry, the demands on a building have reached a point of stability over time, because the environmental requirements are usually accommodated with the production equipment itself. This is not the case with the cutting-edge research instruments used in nanotechnology. There is a growing set of instruments that will function correctly on only a minority of the available sites. The current vibration standard for nanotechnology is that developed for the Advanced Measurement Laboratory at NIST, but several instruments have come along for which that standard is inadequate. Similar challenges arise for EMI/RFI.

■ *Potential for more underground facilities.* The sites of about half the existing nanotechnology facilities did not meet the NIST standard before construction. Depending on construction type, the building may be able to improve on the pre-construction site ambient, but it gets progressively more expensive. We will probably see more facilities going underground, following the lead of NIST (where the sensitive wings were 12 m below the ground).

Two facilities that have committed to go underground (despite the cost) are one at the Univ. of Oregon, Eugene, and CINT at the Univ. of Alberta. The underground environment embodies more stable thermal characteristics (no sun, no wind) as well as a much quieter vibration environment.

■ *Need for lower EMI/RFI ambient environments.* Higher resolution imaging tools are emerging, demanding lower and lower EMI/RFI ambient environments. Therefore, shielding will become a requirement, rather than an option.

Laboratories and imaging rooms can be designed to 1 mG and less without expending considerable resources. Environments under 1 mG to 0.1 mG demand careful planning and expensive EMI control strategies, while achieving 0.01 mG demands a magnetically shielded room to guarantee long-term stability and optimal tool performance. This is true because site conditions (i.e., circulation of ground/net currents, new EMI/RFI sources, etc.) eventually degrade during system-wide maturation.

■ *Need for a universal EMI/RFI testing/susceptibility protocol.* A universal EMI/RFI testing and susceptibility protocol for scientific imaging tools should be implemented by the industry to minimize confusion and ensure optimal performance when a multi-million dollar instrument is to be installed in a nanotechnology research building.

■ *Federal facilities will be followed by industrial leaders.* The federal investment in nanotechnology facilities will probably be limited to the five centers being built by the Dept. of Energy. Many of the "top tier" schools have (or are building) dedicated facilities, and a growing cadre of other institutes are jumping on the bandwagon. Private industry, which has more money to spend, is standing back and letting research happen in the public sector. Once the marketplace gets better defined, then we will see organizations like Intel, IBM, and Motorola taking a more proactive role than they have to date.

■ *"Speculative" nanotechnology facilities.* A growing number of nanotechnology facilities are speculative—what some are calling "build it and they will come" facilities. In these cases, an organization will want to compete in the nanotechnology sector, but may not currently have any researchers. The organization believes that by having a good facility, they will be more likely to attract qualified researchers, who will then attract funding. To some extent, this may be true, but it is harder to define a generic facility than one that has some specific thought behind it. This is particularly true with regard to the more sophisticated environmental requirements (ultra-quiet vibration and noise, shielding for EMI, and very tight tolerances on thermal stability).

The most critical part of defining criteria is a close interaction between a specialty consultant and the researchers, probing what environmental features really are justified. The very best facilities, such as the one at NIST, result from a close collaboration between the researchers and the design team, extending over a significant part of the design process.

Conclusions

Site evaluation of vibration, EMI, and RFI is absolutely essential at all proposed nanotechnology sites, whether green field or existing building. Today's scientific instruments demand very "quiet" environments for maximum resolution and optimal stability during demanding nano- and pico-technology research. Identifying the vibration and EMI/RFI problems before construction will substantially reduce the cost to mitigate, perhaps by a factor of 2 to 3 times.

It is significantly less expense and more effective to move the laboratory during the design phase than to shield the EMI source after the building is operational. In some cases, a vibration or EMI source cannot be modified. When space is at a premium, RF and magnetic shielding are very effective EMI/RFI control methods and are cost-effective when constructed with the building.

Out of 15 nanotechnology facilities we've analyzed, the initial site was rejected for excessive vibration in about 20% of the cases. Several more were marginal, but were used anyway for various reasons. Only about half of them met the NIST criteria, but all met the most stringent vibration criterion used in the semiconductor industry.

By comparison, less than 2% of sites for semiconductor facilities are rejected for these reasons.

Only 10% of the proposed building sites are not EMI/RFI acceptable because the ambient emission levels exceed the recommend thresholds due to the proximity of highways, electric and diesel trains, overhead and underground transmission/distribution lines, substations, or high-power commercial broadcast antennas, as well as invisible but problematic EMI/RFI sources.

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