University of Minnesota Faculty Committee Assessment
of Central Corridor Light Rail Transit Impacts to University of Minnesota Research
Report to President Robert H. Bruininks
July 21, 2009

I. Summary of Charge and Committee Membership

In January 2009, President Bruininks charged a faculty committee chaired by Vice President for Research Tim Mulcahy with assessing the impact of the Central Corridor light rail transit line (CCLRT) on University research and the efficacy of potential mitigations proposed by the CCLRT project office. As part of this effort, the committee reviewed the work completed by the CCLRT project consultants and University consultants, and consulted with potentially impacted faculty researchers, laboratory administrators, and the University CCLRT staff team. The conclusions of the faculty review can be found on pages 9 - 11.

Committee members include:

Tim Mulcahy, Vice President for Research, Chair
Anand Gopinath, Professor, Department of Electrical and Computer Engineering
Bojan Guzina, Professor, Department of Civil Engineering
Caroline Hayes, Professor, Department of Mechanical Engineering
David Thomas, Professor, Department of Biochemistry, Molecular Biology and Biophysics
Kamil Ugurbil, Professor, Departments of Radiology, Neurosciences, and Medicine, and Director of the Center for Magnetic Resonance Research

II. Importance of University of Minnesota Research

The University of Minnesota has more than 80 labs in 17 buildings, along or in close proximity to Washington Avenue, housing highly sensitive, technical research and research equipment that may be adversely impacted by the vibrations and/or electromagnetic interference (EMI) caused by the CCLRT on Washington Avenue, both during construction and when the line is operational.

In these laboratories, cutting-edge research is conducted in the areas of cancer, AIDS, heart disease, high blood pressure, muscular dystrophy, paralysis, diabetes, stroke, infectious disease, drug discovery, bone disease, Alzheimer's, basic chemistry, biodegradable plastics, biofuels, nanotechnology, superconducting plastics, and solar energy. The significance of many of the University's research facilities and the impact of the CCLRT on these facilities extends well beyond the University and its research—it would affect Minnesota businesses, which rely on the University for its research infrastructure.

These laboratories generate hundreds of millions of grant dollars annually for the state economy. These laboratories along Washington Avenue are a substantial component of the University's research productivity and academic reputation. One research facility alone, the nuclear magnetic resonance (NMR) facility in Hasselmo Hall, which will be less than 80 feet from the CCLRT tracks, generates $110 million in grant funding, and supports 160 researchers across 22 University departments, undergraduate and graduate teaching, as well as research by private sector companies. Research conducted by University of Minnesota faculty in all of these labs contributes to economic growth and enhances the health of our community, the state and the world.

The continuity and protection of this research MUST BE a primary concern as the CCLRT is designed, planned, constructed and operated through the campus of one of the nation's top ten public research universities. It must be a priority so as to protect the State of Minnesota's existing, significant investments in the University of Minnesota's research infrastructure, which enable it to conduct research

that is critical to the state and the citizens' wellbeing. Placing this research at risk is tantamount to disregarding Minnesota's economic vitality and the health and wellbeing of its citizens.

III. Summary of the Problem

The University of Minnesota has serious concerns with the CCLRT's impact on its mission-critical research. Without effective mitigations, the vibration and EMI caused by the light rail could have an adverse impact on ongoing research and sensitive research equipment housed in close proximity to the line and could jeopardize federal funds brought into the state. The Metropolitan Council must provide a guaranteed solution for protecting research and the research infrastructure along Washington Avenue, so that conditions along this research corridor do not deteriorate—in other words, existing ambient environmental conditions must be maintained. These labs were built over many decades using millions of taxpayer dollars for the purpose of solving some of the major issues of our time, like diabetes, Alzheimer's, cancer, and renewable fuels. Until appropriate mitigations are found and agreement is reached, we cannot endorse the current plan for the CCLRT. Our analysis has identified multiple concerns for both the operation and the construction of the CCLRT.

The Metropolitan Council's proposed mitigation strategies for vibration and electromagnetic interference have not been shown to be effective under the unique circumstances associated with the proposed siting of the light rail line, that is, within 70 feet of highly sensitive research facilities.

Moreover, impacts to research continuity, research study schedules, construction mitigations, future monitoring, methodology, tracking, and ongoing maintenance of the proposed mitigation measures are inadequately addressed.

IV. Assessment of Vibration Impacts of CCLRT Operations on University Research

A. Summary of the Central Corridor Project Office's (CCPO) methodology, findings, performance criteria, and proposed mitigations

The CCPO completed extensive vibration testing at the University and issued a lengthy report in December 2008 that outlined the predicted vibration levels of the train and the CCPO's proposed mitigation system. In this report, the CCPO proposed the following criteria to determine whether the vibrations caused by light rail operations would negatively impact research at the University:

"1. No impact is predicted if the predicted [light rail vehicle] LRV vibration is less than the ambient vibration. The ambient vibration level exceeded 1% of the time (L1%) is used for this comparison. L1% represents the typical maximum vibration from intermittent events. Because the vibration from each LRV would last for only a few seconds, as long as the LRV vibration is less than the L1%, the future vibration environment would be equivalent to the existing vibration environment.

2. Where the predicted LRV vibration exceeds the ambient vibration but is at least 5 decibels below the VC-E curve, no impact was predicted. [Note: VC curves were developed in the 1980s as a means of defining design standards for environments housing vibration sensitive equipment. Originally defined VC-A through VC-E, with VC-E being the most sensitive, VC-F and VC-G curves recently have been added to address advances in technology.]

3. The vibration levels at frequencies greater than 100 Hz were not considered in the impact assessment. This is because most vibration sensitive equipment is less sensitive at higher

frequencies and many criteria for acceptable vibration environments are undefined above 80 Hz or 100 Hz."

Based upon these criteria, the CCPO concluded that high-resilience track fasteners would suffice as the primary mitigation methodology for managing vibration impacts caused by CCLRT operations on campus. (The CCPO identified a single lab in Amundson Hall that would likely require installation of an additional isolation table to effectively mitigate vibrational impacts.)

In addition to their December 2008 report, the CCPO consultant issued a number of technical memos. They also returned to campus in June 2009 to conduct additional vibration testing using a heavier weight, in order to address coherence issues at the higher frequencies. These additional tests did not validate the adequacy of the high-resilience track fasteners.

B. Summary of U of M consultant findings and recommendations

The University's consultant, Wilson Irhig and Associates, reviewed the technical materials submitted by the CCPO and identified the following issues:

1. Testing methodology
   The vibration propagation field testing employed by the CCPO consultant involved dropping a weight of approximately 45 pounds from a height of approximately four feet. While this methodology is recognized as common practice for characterizing the response of some lightweight structures (e.g. wood framed residential structures), it may not adequately characterize the vibration response of large buildings to a moving train.

   The CCPO consultant then conducted additional testing using the existing Hiawatha line and its impact on the Star Tribune building in downtown Minneapolis and compared this data to what was predicted using the above-described methodology. The University's consultant concluded that the testing did not accomplish its goal of demonstrating that such methodology could reliably predict the response of buildings similar to those at the University to LRT groundborne vibration.

2. Criteria used by the CCPO to assess vibration impacts and the CCPO's resulting mitigation strategy.

   a. Leq vs L1 to define "ambient" conditions.
      The CCPO initially used the time-weighted energy average (Leq) of the ambient vibration as the definition of "ambient" as indicated in their July 29, 2008 report. In this report, the projected LRV vibration level for the CCLRT was compared to the Leq to assess the vibration impacts of LRT operations. The CCPO now proposes to use the weaker standard of L1 as the definition of ambient against which LRV vibration is compared.

      The University's consultant recommends that the Leq is the appropriate measure of ambient vibration for the following reasons:
      - Its use as a criterion is more in line with preserving the existing ambient environment than statistical metrics such as the L1, and
      - As a "weighted average", the Leq is more reliable than an L1 as a basis for design since it is less influenced by transient events, time of day, level of local activity and other factors that are highly variable.

Wilson Irhig and Associates advised the University that using statistical metrics (e.g., L1 or L10) for the ambient condition is not appropriate. Accepting the maximal train vibration (Lmax) to equal the ambient L1 or even L10 would mean that there would be up to twice as many high vibration events as there are now. These additional high vibration events would be an unacceptable deterioration in the existing ambient condition and present significant risks in maintaining the integrity and viability of research. The University's overriding goal should be to preserve the ambient condition. The best way to do that is to limit the "train passby Leq" to the existing ambient hourly Leq during a "quiet hour" of the day when trains are going to be running (after 10pm and before 6am). The reason for the "quiet hour" is that research, if it was necessary that the ambient be at the bare minimum available, could be conducted at that time.

Furthermore, there are improvements that the University (or in some cases a particular researcher) could make to the ambient conditions that they have control over (e.g., isolating local mechanical equipment) but once the trains start running, there are no changes the University can make to reduce what the trains produce. Restricting the train passby Leq to the quiet hour ambient Leq does not mean that there will be no train-induced vibration; only that it is reasonably minimized.

b. Vibration frequencies greater than 80-100 Hz

The CCPO has made the argument that train vibrations at frequencies above 80 or 100 Hz (depending on which conversation, memorandum or report is being considered) are not important. The CCPO bases this argument on the fact that the VC criteria curves only extend to 100 Hz.

These generic VC criteria curves focus primarily on projected impact of vibrations on "process equipment" (i.e., equipment that is highly specialized and therefore carefully designed). The reason the generic VC curves were originally developed was the lack of consistent data and manufacturers' specifications for similar instruments.

To the individuals who proposed the VC curves, there appeared to be decreasing sensitivity to floor vibration at higher frequencies based on the manufacturers' specifications. This is generally recognized to be due to internal isolation built into the equipment by manufacturers. However, the VC criteria were never anticipated to be capable of predicting the future of instrument sensitivity. The University's consultant notes that since the time the VC curves were initially developed, equipment manufacturers have published vibration specification limits for wavelengths up to 300 Hz.

Consequently, limiting the frequency range of consideration for the CCLRT to 80 or even 100 Hz would be extremely short sighted even for manufactured instruments and even more so for custom-built experimental apparatus. According to the University's consultants, the CCPO must address vibration impacts at frequencies up to 200 Hz at a minimum.

In addition, the mitigation strategy proposed by CCPO (high-resilience direct fixation fasteners) is based upon the assumption that vibration at frequencies higher than 80 Hz is not an issue. The December 2008 report includes numerous examples where, at frequencies higher than 80Hz, the predicted vibration with the high-resilience fasteners exceeds even the inflated ambient vibration metric, L1, used by the CCPO.

3. U of M consultant conclusion
   The University's consultant's conclusion regarding vibration is threefold: 1) the testing methodology used by the CCPO is insufficient to demonstrate "no impact," 2) the CCPO chose to use a suboptimal definition of "ambient," and 3) the CCPO made an erroneous assumption that frequencies greater than 100 Hz can be ignored. Any one of these would create a deterioration of the existing conditions along Washington Avenue. Allowing the ambient vibration condition to deteriorate or be degraded due to external circumstances will place significant constraints on University research activities and there will be associated cost implications. The costs can be either immediate or incurred at some time in the future. These costs would be associated with locating vibration sensitive experiments somewhere other than in lab spaces that would be acceptable based on today's existing ambient condition. Other costs would be those associated with purchasing vibration isolation systems or more expensive isolation for individual equipment or experiments, where it otherwise would not be needed. The most costly solution would be the need to construct new buildings for research. Consequently, it is reasonable to expect the CCPO to design mitigation for the CCLRT such that there is no deterioration or degradation in the ambient vibration condition.

C. Faculty assessment and conclusion

The faculty committee has carefully reviewed and discussed the data provided by the CCLRT project office and the University's consultant. As a result of this review, the faculty committee concludes the following:

- The CCLRT project must mitigate vibration impacts of the light rail line to existing ambient conditions. The faculty committee recommends the following conditions:

  - The mitigation requirement must be met in all relevant measures, including L1 and Leq, up to 200Hz.

    The faculty committee agrees with the University consultant's assessment that acceptance of any vibration effects, mitigated or otherwise, that exceed ambient conditions as defined above represents an unacceptable deterioration of the University's existing research environment in the affected laboratories.

  - In addition, the ambient criteria must not be limited to within five decibels below the VC-E curve, as proposed by the CCPO. The University has purposefully constructed exceptionally low vibration environments (such as EECS, MCB, and Shepherd Labs) to allow for extremely sensitive research to be conducted. Ambient conditions in these environments must be met as well.

  Based on the data provided, the faculty committee concludes that the high-resilience track fasteners proposed by the CCPO will not provide adequate mitigation to preserve ambient conditions currently existing at the University's highly sensitive research facilities along the proposed rail line. Accepting the CPPO's assumption of "no impact" (with or without mitigation) in the absence of concrete evidence supporting such an assumption would be irresponsible of the University.

- A low frequency floating slab track could mitigate vibrations caused by the operation of the CCLRT and should be explored as a more viable mitigation strategy. This floating slab track should be installed from the Washington Avenue bridgehead to at least Harvard Street and possibly to Oak Street. Additional analysis is required to determine how the

operation of CCLRT will impact the highly sensitive research facilities in 717 Delaware and would therefore ultimately determine the length of the floating slab.

- The University must also require ongoing, real-time monitoring and controls to identify any degradation of the mitigation system and to prevent trains with wheel flats (and consequently exaggerated vibration profiles) from traversing campus. Such monitoring and controls would use technology similar to that planned for the light rail being built in proximity to the University of Washington in Seattle.

V. Assessment of Electromagnetic Interference Impacts of CCLRT Operations on University Research

A. Summary of CCPO methodology, findings, performance criteria, and proposed mitigations

The CCPO produced an initial report on electromagnetic interference in May 2008. This report recommended that mitigations that limited the impact of electromagnetic interference to 2 milliGauss (mG) at 77 feet – the distance between the track and the 800 MHz magnet in the Hasselmo Hall NMR facility – would be adequate to avoid unacceptable impacts on University research equipment. Following that report, the University did not receive additional information regarding the mitigation of electromagnetic interference until late 2008. Since that time, the CCPO's EMI consultant and the University's EMI consultant have been engaged in follow-on discussions of the mitigation model developed by the CCPO's consultant. This work is ongoing.

In contrast to vibration mitigation, where the CCPO has stated it intends to mitigate to ambient conditions (although the CCPO and University have not yet reached agreement on what constitutes "ambient" as detailed in the previous section), the CCPO has stated its intention to mitigate EMI only to the specifications of existing research equipment.

Because the model employed by the CCPO to estimate EMI impacts of the CCLRT is not complete and validated, the CCPO has produced limited data to estimate the EMI impacts at the University. As of the time of submission of this report, detailed data on these points has not been provided by CCPO or its consultants. However, the CCPO has produced preliminary data regarding ambient electromagnetic fields (EMFs), geomagnetic perturbations caused by the train, and perturbations caused by the propulsion and breaking currents in the overhead catenary wires used to power the train.

B. Summary of U of M consultant findings and recommendations

The University's consultant, Field Management Services (FMS), and its technical team have been working directly with the CCPO consultant to ensure confidence in the predictive qualities of the CCPO's model. This validity of the CCPO predictive modeling is critical, yet unproven. The first review by FMS of the model discovered some obvious errors. Following the initial review, FMS has directed the CCPO consultant to conduct a series of exercises and scenarios with the model in order to validate the predictive value of the model. The CCPO consultant has continued to refine the model.

On June 8, 2009, the University's and CCPO's consultants met to identify any remaining issues with the model. The University's consultant believes the model is nearly complete save for two outstanding issues: 1) the predictive quality of the conditions at the end of the mitigation area (particularly closest to Kolthoff Hall); and 2) the predictive quality of the model as it relates to how the EMFs fluctuate over time. (Various types of equipment in the affected laboratories are sensitive to different levels of EMI over different time periods.)

In addition to working to ensure that the model is able to accurately predict the impacts and the effectiveness of any proposed mitigation strategy, the University's consultant believes that the potential impact of the geomagnetic perturbation caused by the train as a large mass have not been adequately addressed. This issue must be resolved. The ability to accurately predict the cumulative effect of the EMI caused by the electric current associated with the light rail line combined with the EMI effects caused by the geomagnetic perturbation and the existing ambient conditions is essential to defining the full impact of the rail placement and strategies to mitigate them. To date, such effects have not been defined with confidence.

C. Faculty assessment and conclusion

The faculty committee has reviewed and discussed the data provided by the CCLRT project office and the University's consultant. As a result of this review, the faculty committee concludes the following with respect to electromagnetic interference:

- Based upon the data provided to the faculty committee to date, the committee is concerned that the predicted EMFs caused by CCLRT operations will negatively impact the University's ability to conduct research in close proximity to the line. In order to preserve the integrity of University research, the University must hold the Metropolitan Council to the standard of mitigating to existing ambient conditions.

- The faculty committee understands that the University's consultant is continuing to work with the CCLRT project office to ensure the accuracy of the CCLRT EMI mitigation model. The committee expects that the University's consultant will continue to work with the project office until they are satisfied that the model effectively predicts the EMI associated with the trains and demonstrates the effectiveness of the proposed mitigation systems.

- Unlike the situation at other universities near which light rail lines have been or will be constructed, the extremely close proximity of the train to the University of Minnesota's research facilities means that EMI will be caused by both the train's current as well as the geomagnetic perturbation of the train's mass. The decline in the effects of EMI is not a linear function of the distance between the source and a given laboratory, but varies as a function of the square of the distance of the lab from the source (r^2). Therefore, those facilities at distances of 200 - 250 feet or more from a train will likely not experience difficulties related to EMI after installation of mitigation systems similar to those being considered for the CCLRT. However, due to the unprecedentedly close proximity of the University's laboratories (e.g. Kolthoff, Amundson, Hasselmo, Jackson, Weaver-Densford) to the Washington Avenue line, the impact will be far greater, so the implementation of mitigations that will be effective at such close proximities must be validated.

- If, after validation, the model continues to predict EMFs in excess of 2 mG (due to electrical current, geomagnetic perturbations, and existing ambient conditions) in these facilities, despite the proposed mitigation approaches, the Metropolitan Council must provide additional mitigations to reduce the effects to less than 2 mG at each location. Other potential solutions include:
    - Light rail vehicles that could operate on batteries while on campus;
    - Moving the alignment;
    - Relocation of affected laboratories (recognizing that these laboratories would not be able to be used for EMF sensitive research in the future), at a cost allocated to the CCLRT project; or

- Installation of effective active cancellation devices (note: These strategies are still experimental and to our knowledge have not been validated in situations comparable to the current CCLRT project. Furthermore, this strategy would only address existing laboratories, not future laboratory locations, and would be technically challenging, if not infeasible, in multi NMR facilities).

- The University must also require ongoing real-time monitoring of electromagnetic fields to identify any degradation of the mitigation system(s) and to monitor any spikes in the EMF that would negatively impact daily research activities. Such monitoring would use technology similar to that planned for the light rail being built in proximity to the University of Washington in Seattle.

VI. Assessment of Impacts of CCLRT Construction on University Research

A. Summary of CCPO approach to construction mitigations

There has been little to no data provided for the University's review on the subject of CCLRT construction vibration mitigation plans. In preliminary environmental review documents, the project acknowledged that: 1) there will be a vibration impact on sensitive University research facilities; 2) the vibration impact thresholds for University research facilities are "very low;" and 3) "it may not be feasible to achieve these limits during construction." As their proposed solution, the CCPO states in the FEIS, "stakeholders will be consulted and notified of the construction schedule in advance."

The project office has since stated that they are willing to work with faculty to identify slow periods where they could do the majority of the most disruptive demolition. But the type of construction work, the level of disruption, and the timeframe have not been defined.

B. Summary of U of M consultant findings and recommendations

The University's consultant has not addressed this issue because the project office has not presented any information for analysis.

C. Faculty assessment and conclusion

The faculty committee concludes that while vibrational and electromagnetic interference during rail operation along Washington Avenue will have significant impact on the University's research mission, interference during the construction phase of the project will be more intense and therefore represents a very acute issue that will jeopardize research. Furthermore, the committee concludes that the project's proposal to mitigate construction impacts by "scheduling" is woefully inadequate and fails to acknowledge the type and manner of experiments typical of these research facilities. The committee is concerned that the construction would negatively impact research for two years and, in some cases, potentially damage extremely expensive or one-of-a-kind research equipment. Consequently, the committee recommends that the University not agree to any plan that fails to adequately address the acknowledged adverse impacts that will be associated with the construction phase of the project even if the plan includes acceptable mitigations strategies to eliminate adverse impacts of rail operation. The mitigation strategy for construction must be developed in much greater detail and agreed upon in order to not adversely impact ongoing University research.

VII. Faculty Committee Assessment and Conclusions

It is critical that the state protect the existing long-term investment it has made in research infrastructure at the University of Minnesota. Failure to do so will jeopardize the University's ability to conduct research in areas such as medical advances, biofuels, and solar energy, which benefit Minnesota's economy and the people of Minnesota. Consequently, it will also jeopardize the use of the University's existing research infrastructure as a critical component for garnering federal money, providing educational support for students, and creating jobs.

The extremely close proximity of the CCLRT line to the University's research facilities presents challenges that are unique, when compared to any other light rail line that has been constructed or planned for construction in the country. The CCLRT project office has proposed mitigation strategies. However, these strategies are untested, inadequate, or premature as the project office and the University have not yet agreed to the criteria for mitigation.

In summary, this committee concludes the following regarding vibration, EMI, and construction impacts of the CCLRT line on the University:

Vibration

- The CCLRT project must mitigate vibration impacts of the light rail line to existing ambient conditions. The faculty committee recommends the following conditions:

    - The mitigation requirement must be met in all relevant measures, including L1 and Leq, up to 200Hz.

      The faculty committee agrees with the University consultant's assessment that acceptance of any vibration effects, mitigated or otherwise, that exceed ambient conditions as defined above represents an unacceptable deterioration of the University's existing research environment in the affected laboratories.

    - In addition, the ambient criteria must not be limited to within five decibels below the VC-E curve, as proposed by the CCPO. The University has purposefully constructed exceptionally low vibration environments (such as EECS, MCB, and Shepherd Labs) to allow for extremely sensitive research to be conducted. Ambient conditions in these environments must be met as well.

  Based on the data provided, the faculty committee concludes that the high-resilience track fasteners proposed by the CCPO will not provide adequate mitigation to preserve ambient conditions currently existing at the University's highly sensitive research facilities along the proposed rail line. Accepting the CPPO's assumption of "no impact" (with or without mitigation) in the absence of concrete evidence supporting such an assumption would be irresponsible of the University.

- A low frequency floating slab track could mitigate vibrations caused by the operation of the CCLRT and should be explored as a more viable mitigation strategy. This floating slab track should be installed from the Washington Avenue bridgehead to at least Harvard Street and possibly to Oak Street. Additional analysis is required to determine how the operation of CCLRT will impact the highly sensitive research facilities in 717 Delaware and would therefore ultimately determine the length of the floating slab.

- The University must also require ongoing, real-time monitoring and controls to identify any degradation of the mitigation system and to prevent trains with wheel flats (and consequently exaggerated vibration profiles) from traversing campus. Such monitoring and controls would use technology similar to that planned for the light rail being built in proximity to the University of Washington in Seattle.

Electromagnetic Interference

- Based upon the data provided to the faculty committee to date, the committee is concerned that the predicted EMFs caused by CCLRT operations will negatively impact the University's ability to conduct research in close proximity to the line. In order to preserve the integrity of University research, the University must hold the Metropolitan Council to the standard of mitigating to existing ambient conditions.

- The faculty committee understands that the University's consultant is continuing to work with the CCLRT project office to ensure the accuracy of the CCLRT EMI mitigation model. The committee expects that the University's consultant will continue to work with the project office until they are satisfied that the model effectively predicts the EMI associated with the trains and demonstrates the effectiveness of the proposed mitigation systems.

- Unlike the situation at other universities near which light rail lines have been or will be constructed, the extremely close proximity of the train to the University of Minnesota's research facilities means that EMI will be caused by both the train's current as well as the geomagnetic perturbation of the train's mass. The decline in the effects of EMI is not a linear function of the distance between the source and a given laboratory, but varies as a function of the square of the distance of the lab from the source (r^2). Therefore, those facilities at distances of 200 - 250 feet or more from a train will likely not experience difficulties related to EMI after installation of mitigation systems similar to those being considered for the CCLRT. However, due to the unprecedentedly close proximity of the University's laboratories (e.g. Kolthoff, Amundson, Hasselmo, Jackson, Weaver-Densford) to the Washington Avenue line, the impact will be far greater, so the implementation of mitigations that will be effective at such close proximities must be validated.

- If, after validation, the model continues to predict EMFs in excess of 2 mG (due to electrical current, geomagnetic perturbations, and existing ambient conditions) in these facilities, despite the proposed mitigation approaches, the Metropolitan Council must provide additional mitigations to reduce the effects to less than 2 mG at each location. Other potential solutions include:
    - Light rail vehicles that could operate on batteries while on campus;
    - Moving the alignment;
    - Relocation of affected laboratories (recognizing that these laboratories would not be able to be used for EMF sensitive research in the future), at a cost allocated to the CCLRT project; or
    - Installation of effective active cancellation devices (note: These strategies are still experimental and to our knowledge have not been validated in situations comparable to the current CCLRT project. Furthermore, this strategy would only address existing laboratories, not future laboratory locations, and would be technically challenging, if not infeasible, in multi NMR facilities).

- The University must also require ongoing real-time monitoring of electromagnetic fields to identify any degradation of the mitigation system(s) and to monitor any spikes in the EMF

that would negatively impact daily research activities. Such monitoring would use technology similar to that planned for the light rail being built in proximity to the University of Washington in Seattle.

Construction

The faculty committee concludes that while vibrational and electromagnetic interference during rail operation along Washington Avenue will have significant impact on the University's research mission, interference during the construction phase of the project will be more intense and therefore represents a very acute issue that will jeopardize research. Furthermore, the committee concludes that the project's proposal to mitigate construction impacts by "scheduling" is woefully inadequate and fails to acknowledge the type and manner of experiments typical of these research facilities. The committee is concerned that the construction would negatively impact research for two years and, in some cases, potentially damage extremely expensive or one-of-a-kind research equipment. Consequently, the committee recommends that the University not agree to any plan that fails to adequately address the acknowledged adverse impacts that will be associated with the construction phase of the project even if the plan includes acceptable mitigations strategies to eliminate adverse impacts of rail operation. The mitigation strategy for construction must be developed in much greater detail and agreed upon in order to not adversely impact ongoing University research.

Although this report outlines significant challenges that the committee believes must be addressed, based on similar experiences at universities elsewhere we believe reasonable mitigation strategies that will allow operation of the light rail line with minimal impacts on University research do exist. The work between the University of Washington and Sound Transit provides a legitimate model for properly mitigating impacts of LRT on a research university. Rather than starting with a limited budget and asking "What mitigation strategy can be achieved for a particular cost?" the question needs to be: "What mitigation strategy is necessary and sufficient to protect the University's research?" As the University considers its options for moving forward in partnership with the Metropolitan Council on the planning for the CCLRT, the University cannot acquiesce to mitigation strategies that compromise its research mission.